

NASA-TM-108590



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December 10, 1992

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Enclosed is a copy(ies) of the technical report for the USRA/Goddard Visiting Scientist Program for the period July 1, 1992 through September 30, 1992

If you have any questions, please don't hesitate to contact us.

Sincerely,

Frank J. Kerr  
Program Director

(NASA-TM-108590) GODDARD VISITING  
SCIENTIST PROGRAM FOR THE SPACE AND  
EARTH SCIENCES DIRECTORATE  
Technical Report, 1 Jul. - 30 Sep.  
1992 (USRA) 245 p

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December 10, 1992

Contract No. NAS5-30442  
Technical Reports  
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Subject: Enclosed is the technical report for the period  
July 1, 1992 through September 30, 1992.



Goddard Visiting Scientist Program  
for the Space and Earth Sciences Directorate  
Contract No. NAS5-30442

Technical Report  
for July 1, 1992 through September 30, 1992

Program Director: Dr. Frank Kerr

Submitted to:

NASA/Goddard Space Flight Center  
Contracts Office  
Mail Code 289  
Greenbelt, MD 20771

by

Universities Space Research Association  
Mail Code 610.3  
Building #26, Room 201  
NASA/Goddard Space Flight Center  
Greenbelt, MD 20771



Brief Summary of Task Activities under Contract NAS5-30442  
During the Period July 1, 1992 through September 30,  
1992.

(Individual Project Reports are attached on the indicated  
pages).  
Summary notation and actual reports are sequentially listed  
by Task Assignment number.

**SPACE SCIENCE**

**Task #:**

- 5012 A. Zdziarski visited GSFC in August and continued  
work on fitting the nonthermal pair model. p. 1
- 610-002 R. Lindzen worked with A. Hou on the tropical-high  
latitude transport. p. 2
- 630-001 N. Papitashvili has been working on a task  
formulated from NSSDC to create a set of space  
science data for the CD-ROM. p. 3
- 660-003 T. J. Turner has continued on the ROSAT PSPC  
spectral response. p. 4-6
- 660-004 A. Smale summarizes his accomplishments in working  
on the BBXRT data and the FITS format for  
community release. p. 7-11
- 660-005 L. Jalota describes his research activities  
relating to the spare X-ray mirror and detector at  
the long X-ray beam facility. p. 12
- 660-006 Y. Soong highlights the joint calibration session  
of the 5th mirror and the focal plane CCD  
detector. p. 13
- 660-012 B. Schaefer has been working on the BATSE  
detectors that continue to send down high quality  
data on gamma ray bursts. p. 14
- 660-013 S. Barthelmy has been working on the Gamma Ray  
Imaging Spectrometer (GRIS) and the Rapidly Moving  
Telescope (RMT). p. 15
- 660-018 J. Mitchell describes his activities on the 1992  
IMAX flight, support of the MASS 1992 flight, and  
is writing proposals for two new cosmic ray  
instruments. p. 16-18
- 660-020 A. Rots discusses his efforts in connection with  
the XTE-SOC Preliminary Design Review. p. 19-21





- 660-023 L. Angelini describes her activities on the conversion of the X-ray imaging program XIMAGE from VMS to UNIX. p. 22-23
- 660-024 C. Day has continued his work on the Astro-D Calibration Book and the Astro-D Technical Description. p. 24-25
- K. Ebisawa participated in the Astro-D software meeting at ISAS in Japan. His research includes the application of an accretion disk model to the spectral data of LMC X-3 taken with GINGA. p. 26-27
- K. Mukai gives a general account of his work relating to Astro-D matters. p. 28
- 660-026 M. Loewenstein has completed collaborations on a paper containing the BBXRT analysis and interpretation of the X-ray spectra of the elliptical galaxies NGC 1399 and NGC 4472. p. 29
- 660-027 I. George continues his review of all the calibration data from all the instruments for which scientific data is contained within the HEASARC database. p. 30-33
- 660-028 W. Pence highlights improvements to the FITSIO software package. p. 34
- 660-029 S. Drake highlights his accomplishments and progress with HEASARC. p 35-37
- 660-030 L. Whitlock describes the programs and processes to extract data for source from the Vela 5B data base. p. 38-39
- 660-032 W. Zhang's efforts this quarter went into the following areas, preparing for EDS Testing, Development of Model for PCU, Energy Calibration at Brookhaven, Energy Standards for XTE/PCU and BBXRT Data Analysis. p. 40
- 660-034 H. Cane reports on a study of energetic particle data, obtained from IMP 8, in conjunction with solar wind field and plasma data from magnetic clouds. p. 41-78
- 660-035 B. Dingus reports on her work in developing the drift chamber tracking detector for AGATE. p. 79



- 660-037 D. Kniffen reports on his consulting efforts in supporting the High Energy Gamma-Ray Telescope (EGRET) on the Compton Gamma-Ray Observatory. p. 80-82
- 660-038 M. Corcoran reports on his involvement with the development of the ROSAT public archive. p. 83-85
- 660-040 H. Awaki has been working on the X-ray telescope (XRT) using the a ray tracing program. p. 86
- 660-041 G. Pike highlights the Astronomy from Large Databases II conference held in Strasbourg/Haganeau, France. p. 87
- R. Chandar reports on his programmatic responsibilities in completing the cleaning of the CMA Database. p. 88
- 660-042 R. Nemiroff participated in the investigation of gravitational effects near neutron stars and black holes. p. 89
- 660-043 W. Chen describes his efforts in modeling the secondary maxima in the X-ray and UV light curves of X-ray novae A0620-00, GS2000-25, Nova Muscae 1991, and GRO J0422-32. p. 90
- 660-044 H. Seifert has been working on various aspects of the instrument development for the Transient Gamma-Ray Spectrometer (TGRS). p. 91-92
- 660-046 J. Lochner has spent a considerable amount of time on the Guest Observer Facility (GOF) for the X-ray Timing Explorer (XTE). p. 93-94
- 680-007 I. Hubeny describes his work in developing numerical techniques for calculating model atmospheres of hot stars. p. 95
- 680-009 J. Biggs has been heavily involved in the analysis of Crab pulsar data from the Hubble Space Telescope High Speed Photometer (HSP). p. 96-97
- 680-011 C. Groden has been working on the Cosmology Data Analysis Center (CDAC) Orientation Handbook for the COBE project. p. 98
- 680-021 A. Kogut's major effort has been on the analysis of full-sky maps from the Differential Microwave Radiometers (DMR) experiment aboard the Cosmic Background Explorer (COBE). p. 99



- A. Banday has been providing support for the COBE space project. He has completed his analysis of the eclipse effect. p. 100
- 680-028 D. Cottingham reviews the production of the FIRAS calibration pipeline and new versions of the calibration dataset. p. 101-102
- 680-029 T. Namioka has been working on analytic formulas needed for the design of a deformed ellipsoidal grating. p. 103
- 690-001 S. Ghosh continues his study of the applications using both incompressible and compressible 2-D magnetohydrodynamic (MHD) simulations. p. 104
- 690-007 B. Donn provides consulting support to the Astrochemistry Branch, Code 691. He reports on research on cometary ices and interstellar grains. p. 105
- 690-011 M. Teague is serving as the Solar Terrestrial Energy Program (STEP) Coordinator. His role as coordinator is to provide a variety of coordination services to the U.S. and international STEP scientific communities. No report submitted this quarter.
- V. Papitashvili has been working with Dr. M. Teague as a co-editor of the STEP International Newsletter. He reports on the 1992 STEP Symposium held in August, and Project 6.4, a joint effort between the INTERMAGNET Executive Council and Operations Committee and the STEP Project. p. 106-107
- 690-012 T. Morgan reviews his observations on the emission from Na and K exosphere of Mercury. p. 108
- 690-013 T. Huang is away on business in Japan. His report was not received in time to be included.
- 690-014 S. Hoban continues to work on her project of reduction and analysis of infrared images of Mars and Venus obtained with a 5-18 micron array camera. p. 109
- E. Roettger has been working on the reduction of a survey spectrum of comet Halley taken from the KAO. p. 110-111



- 690-015 M. Goodman updates his accomplishments in installing the SPOF ORACLE database on three of the four SPOF workstations, and installing the PV-Wave graphics language package on the remaining three workstations in the Planetary Magnetospheres Branch (Code 695). p. 112
- 690-018 H. Laakso provides insight on the following subjects, 1) double probe theory, 2) current layers in a cometary environment, and 3) analysis of the CRRES data. p. 113-114
- 690-019 E. Siregar highlights the three main projects he has been involved in. They are developing an analytic study of the parametric instability of large amplitude Alfvén waves, developing a Chebyshev-Fourier spectral algorithm with an infinite computation domain for more realistic solar wind studies in MHD and a vortex street model of fluctuations observed by Voyager 2 in the outer heliosphere. p. 115

#### **EARTH SCIENCE**

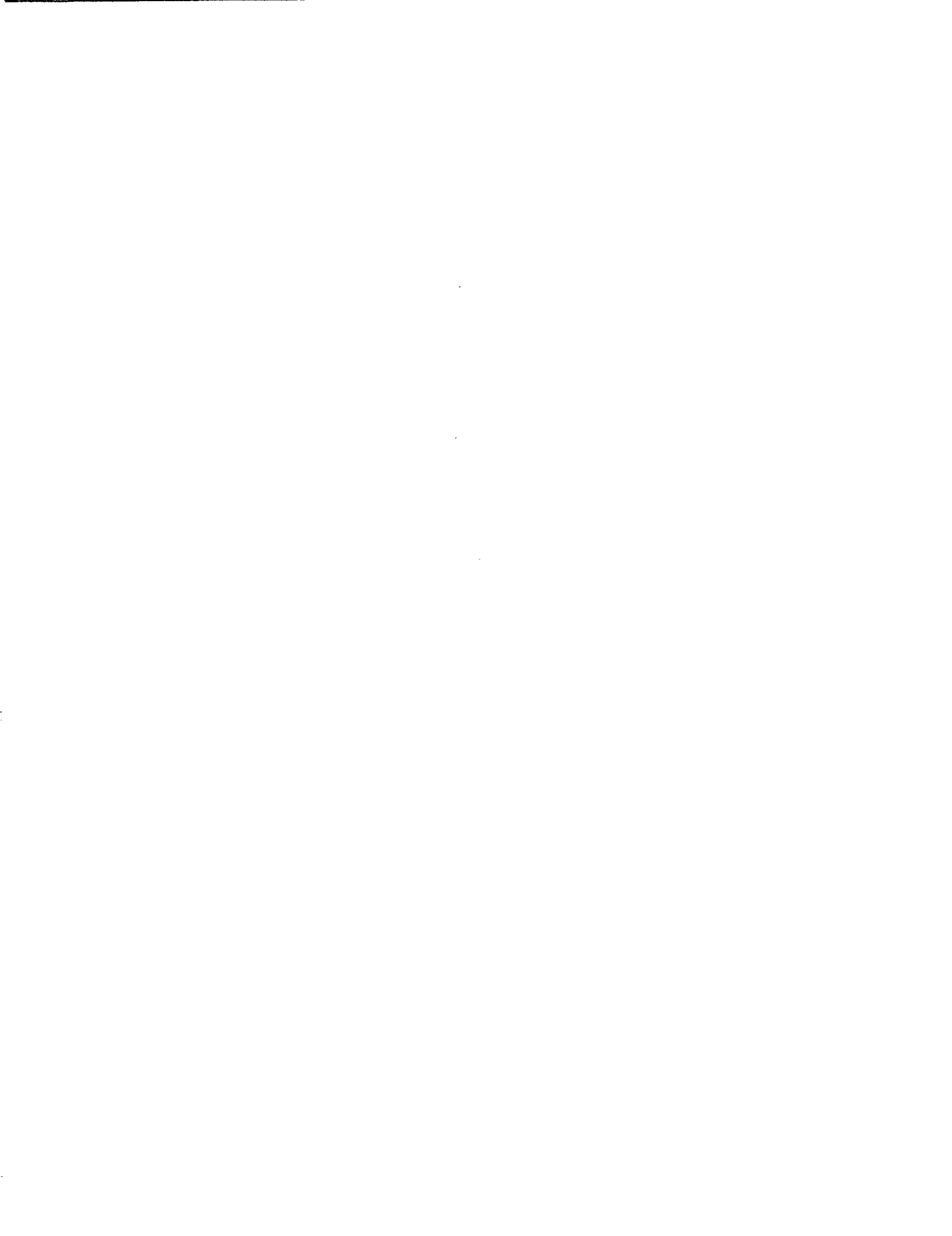
##### **Task #:**

- 900-001 Y. Shimabukuro updates his technical activities in the Biospheric Sciences Branch working with GIMMS (Global Inventory Mapping and Monitoring) Group. The Biospheric Sciences Branch is concerned with terrestrial ecosystem and atmosphere interactions, patterns and processes occurring at several spatial and temporal scales. p. 116-140
- 900-002 J. Dozier reflects on his two years at GSFC as the EOS Project Scientist. p. 141-143
- 900-005 M. Schwaller joined USRA in August and has been assigned to the Code 423 Earth Science Data and Information System Project (ESDISP). p. 144
- 910-002 This task sponsors visitors and lecturers. No reports were received for this quarter.
- 910-003 S. Moorthi has been focussing on the development of the diabatic version of the Semi-Lagrangian (SLSI) GCM. p. 145
- 910-007 V. Mehta reviews the analysis of the global hydrologic cycle in the GFDC GCM. p. 146-147





- 910-008 L. Peng describes his work in progress with the tropical-extratropical interactions. p. 148
- 910-009 J. Rosenfield reviews a paper she completed entitled, "Radiative Feedback of Polar Stratospheric Clouds on Antarctic Temperatures". p. 149-150
- 910-013 R. Gagliardi visited GSFC August through October. During her visits she studied the mode operation of a photon counting system (PC's) which is widely used in the lidar system. p. 151-152
- 910-015 K. Pickering updates his four major research areas: (1) Modeling the effects on free tropospheric ozone production of deep convective events, (2) Modeling the effects on upper tropospheric ozone of deep convective events during STEP, (3) the TRACE-A experiment, and (4) Pre-TRACE-A Ozone/Fires Trajectory Analysis. p. 153-155
- 910-030 This task supports short-term visiting scientists for the purpose of collaboration on research involving clouds, radiation and climate. No reports were received for this quarter.
- 910-032 L. Lait's effort this quarter continued on the constituent reconstructing technique. This technique involves constructing composite constituent fields in space. p. 156-157
- 910-035 S. Tsay visited Colorado State University on multi-dimensional radiative transfer problems. p. 158-159
- 910-036 S. Bloom reviews the development of an improved methodology for simulating observation errors for use in OSSE's results involving LAWS data. p. 160
- 910-037 R. W. Higgins and others have completed the development of the hydrodynamics from the semi-Lagrangian finite difference global multilevel model with the GEOS-1 model. p. 161-163
- 910-038 M. Fox-Rabinovitz updates his activities with the testing of the GLA GCM with three new convection schemes, and the testing of the diabatic dynamical initialization (DDI). p. 164
- 910-042 S. Ravipati has been working to generalize the Principal Component Method (PCM) which describes the probability density function  $p(r,t)$  of rainfall. p. 165



- 910-043 G. Liston has completed a paper entitled, "Evaluating GCM Land Surface Hydrology Parameterizations by Computing River Discharges Using a Runoff Routing Model: Application to the Mississippi Basin". p. 166
- 910-047 J. Joiner has continued on the AIRS/AMSU simulation and retrieval program. p. 167
- 910-049 G. Huffman has been working on the Goddard Scattering Algorithm which focuses on problems estimating precipitation over cold land and ice. p. 168
- 910-050 C. Park updates activities with the heating experiments with Low-Frequency Waves in the Atmosphere, GLA GCM Diagnostic and Seasonal Predictability of Regional Climate. p. 169
- 910-052 H. Chun is working on the long-lasting large amplitude mesoscale wave events. p. 170
- 910-055 J. Scala recently participated in the third International Cloud Modeling Workshop, held in Toronto, Canada. This meeting was held in conjunction with the WMO Workshop on Cloud Microphysics and Applications to Global Change. p. 171-172
- 920-002 R. Myneni reports on several papers recently submitted for publication; 1). Synergistic use of optical and microwave data in agrometeorological applications, 2). Atmospheric effects in the remote sensing of surface albedo and radiation absorption by vegetation canopies, and 3). Radiative Transfer in three Dimensional Atmosphere-vegetation media. p. 173
- 920-004 G. Bluth reports on his involvement in completing the inventory of TOMS data for publication, and finding ways to validate measurements.
- 920-012 C. Russell is involved in several projects relating to the Advanced Solid-state Array Spectroradiometer (ASAS). p. 175-176
- 930-008 M. Satake has been engaged in the development of TRMM Science Data and Information System (TSDIS) and radar rainfall measurements. p. 177-178
- 930-015 K. Olson updates his progress on researching the development of a gravitational N-body code to study the dynamics of galaxy-galaxy interactions. pp. 179-180



B. Fryxell describes his work which involved writing a chapter for a book on computational methods for astrophysics. His chapter will describe the Piecework-Parabolic Method for computational gas dynamics. p. 181-182

930-018 J. Gualtieri gives a research synopsis on inversion algorithms, distance between images, and being a mentor for a VSEP student. p. 183-184

970-002 T. Iguchi highlights a program he wrote that calculates the double scattered radar return from Rayleigh particles. p. 185

970-006 This task supports short-term visitors who come in various guises to collaborate with the Goddard research community.

C. Chen has concentrated his research on the pressure gradient force (PGF) problems over a steeply sloped terrain. p. 186-187

970-007 This task supports visiting scientists and consultants whose efforts are related to the Tropical Rainfall Measurement Mission. Efforts also include mesoscale processes, global-scale processed, and climate.

B. Nolan met with representative of the TOGA-COARE International Project Office (TCIPO) along with NASA field officials to resolve issues relating to the allocation of space in Townsville, Australia. p. 188-189

B. Schardt has been involved with correspondence and records pertaining to the Landsat, Large Format Camera and Shuttle Imaging Radar programs. p. 190-192

W. Vaughan devoted his efforts to background research and information development with NASA Technical Monitors. p. 193-196

970-020 B. Ferrier has spent most of this time in writing the first in a series of two papers on the development of a new ice-phase parameterization and its performance in simulating convective storms in different large-scale environments. p. 197-198



- 970-021 J. Baik has worked on extensive numerical model simulations and discussions on the numerical instability resulting from the liquid-ice phase microphysics. p. 199
- 970-022 N. Chauhan participated in a microwave experiment on the Canadian forest with Canadian Remote Sensing scientists. p. 200-218
- 970-023 S. Bidwell joined USRA in August. He is associated with the Microwave Sensors Branch Code 975 of the Laboratory for Hydrospheric Processes. p. 219-220
- 970-027 A. Kowalski's primary research activity has been concerned with the development of algorithms and corresponding programs for high performance numerical modeling of coupled ocean-atmosphere circulation. p. 221-222
- 970-030 E. Del-Colle's areas of concentration were related to SeaWiFS Data System Management and Design and SeaWiFS/V0 GSFC DAAC Interface. p. 223-224
- 970-031 R. Harrington visited GSFC at the request of Dr. J. Shiue to attend the TRMM Microwave Imager (TMI) Conceptual Design Review (CoDR) data package, and also attend the meeting held at the Hughes Aircraft Company facility in El Segundo, CA. p. 225-234





GAWT  
5012

Andrzej Zdziarski  
Code 666  
NASA/GSFC

Technical Activity Report, 8/27/92-9/4/92

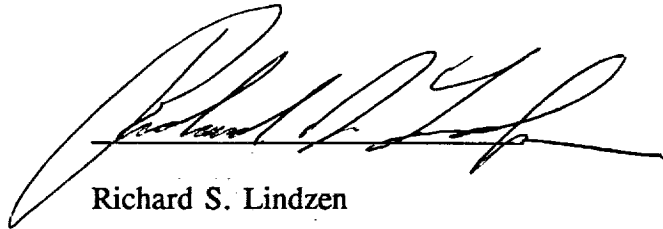
I have continued work on fitting the nonthermal pair model to archive spectra of active galactic nuclei. The modeling is done using the XSPEC package on Sun computers. A paper on observations of Mrk 335 by the instruments BBXRT and Ginga has just been completed. It is shown that the pair model provides an excellent fit and a very likely explanation of the physical processes taking place in the nucleus of Mrk 335.

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**Technical Activity Report**

Richard S. Lindzen  
Contract: NAS5-30442  
Task: 610-002  
Dates: August 31, 1992

I arrived at the NASA/GLA Modelling and Simulation Branch at 8:40 am on August 31. I spent most of the day discussing new work on tropical-high latitude transports with A. Hou. I also had discussions with Michael Fox-Rabinovitz concerning work on normal mode initialization, and with Richard Rood, Ray Bates and Mark Schoeberl. I left Goddard shortly after 4:00 pm on August 31, but continued conversations with Arthur Hou on the way to the airport.



Richard S. Lindzen

August 31, 1992

QUARTERLY TASK REPORT

September 12 - September 30, 1992

Dr. Natalia Papitashvili

Task 630-001

## 1. Current status

The task has been formulated from NSSDC to create a set of space science data for the CD-ROM. Data from OMNI tape (hourly mean values near the Earth's orbit), 5-min IMP-8 data, ISEE-3 data Pioneer's and Helios's data should be collected, loaded in the PC, and re-organized. Data formats have been discussed, OMNI tape has been received.

Due to the office has been provided in the University of Maryland, the personal computer has been delivered from GSFC, and connected with the computer network. Data have been loaded from the VAX computer (Inst. for Physical Sciences and Technology) through the network on the Optical Erasable Disk (provided by NGDC).

The software structure has been discussed and work has began.

## 2. Future plans

During the last quarter of 1992 the global structure of planned CD-ROM should be created. Most of the data should be collected, and part of the should be re-organized and loaded in the PC. A pilot software should be written.

*Natalia Papitashvili*

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## Quarterly Report for July 1st-September 30th 1992

T.J. Turner

TASK # ?

## ROSAT Programmatic Work

Work has continued on the ROSAT PSPC spectral response. Analysis of a high signal-to-noise spectrum (6 million photons!) showed the systematic errors to be 2-2.5% across most of the PSPC bandpass (at the epoch of that observation), but  $\sim 10\%$  at the carbon edge ( $\sim 0.27$  keV) and  $> 10\%$  (rising to higher energies) above 2 keV. Detailed analysis of a large number of spectra taken at different epochs with the PSPC, however, clearly shows that the strength of anomalous residual varies in time (on timescales  $>$  weeks). This means that either there is a large scale calibration problem with a strong dependence on time, or that many sources genuinely have strong but highly variable spectral features. To further pursue this question, we are proceeding to screen the spectral data more carefully. A current idea is that the problem could be related to the production of soft pulses in the contaminated counter gas. This is a time-dependent process, since the counter gas contamination has been (and still is) time variable, and the contamination is higher in some gas tanks than others. The effect is that a small fraction of all events in the counter (i.e. sources, sky background and ionizing particles) produce a small UV-light flash. This in turn is detected as a very soft X-ray event in close proximity in time and detector coordinates to the original event. The net effect is the production of additional soft photons, both in the source and also in the background. Therefore the spectrum is deformed in the soft band. Most of these additional events can be detected by a correlation analysis in time and space, and therefore be removed. We are currently working on software to screen out these UV events, and will then examine the resultant spectra.

I (with Dr. Ian George and Guenther Hasinger of MPE) have also used these high signal to noise data to extract a very accurate set of radial profiles in different energy bands, to examine the accuracy of the model for the PSPC point spread function. The data indeed fit the predicted model very well, we saw very small discrepancies at radii of approximately 2-4 arcminutes. We think these discrepancies may be partly due to residual attitude errors in the in-flight data, and partly due to the fact that a) the geometry of the beam is different in

the finite Panter (ground calibration) facility from a parallel beam in space. Therefore the detailed shape of the penetration term could also be slightly different and b) in the mirror scattering component (Lorentzian) the average grazing angle is slightly larger in the finite beam than in the orbit. A back-of-the-envelope calculation expects therefore about 40% less mirror scattering in orbit than on ground. On the other hand there is always the possibility for additional microroughness on the mirrors due to dust contamination after the Panter tests.

Visiting Guest Observers continue to be an important part of the programmatic responsibility of myself and other ROSAT duty scientists.

#### Astrophysical Research

I have submitted a paper to the Astrophysical Journal during September entitled "ROSAT Observations of Six Seyfert 1 Galaxies". This paper discusses the soft X-ray spectra of a sample of Seyfert 1 galaxies, confirms the presence of spectral features in some sources, and discusses the limitations of PSPC spectral analysis (in the light of the current residual uncertainties in the PSPC calibration). Dr. Paul Nandra, a colleague from the Institute of Astronomy, Cambridge (UK), visited GSFC for several weeks. We worked (with Dr. Ian George) on a number of our collaborative projects, including IUE/X-ray observations of AGN, ROSAT observations of Mkn841 and ROSAT observations of the Piccinotti sample of AGN.

#### Travel

I travelled to the 33rd Herstmonceux Conference on "The Nature of Compact Objects in AGN" July 15-22nd, to present an invited review talk on X-ray Variability in Active Galactic Nuclei. After the meeting I spent a few days working with colleagues at the Institute of Astronomy on ROSAT related calibration issues.

#### Work Planned for the next quarter:

We will write a screening program for the ROSAT PSPC data, and determine whether UV flashing in the detector is the origin of PSPC spectral anomalies.

Nov 4-5th I will attend a ROSAT workshop in Boston. The workshop will focus on calibration issues and data analysis techniques. Nov 6th I will spend at the Center for Astrophysics in discussion with Colleagues from the SAO group (the other part of the U.S. ROSAT Guest Observer Facility).

Assuming the PSPC spectral issue reaches resolution, I will pursue my analysis of six PSPC observations of Seyfert 2 Galaxies. In addition we expect that we (Ian George, Paul Nandra and myself) will soon be able to submit a paper on the analysis of X-ray observations of the Seyfert galaxy NGC3783. This source has a strong absorption edge in the ROSAT data, indicative of highly ionized material, and this feature is the second one ever observed in a Seyfert type AGN. Analysis of Ginga and EXOSAT archival observations of this source strongly support the warm absorber scenario.

9/15/88 100

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October 16, 1992

To: Denise Dunn, USRA.

Re: Quarterly technical report, 7/1/92 - 9/30/92.

**BBXRT matters:** This quarter, a major personal milestone was the release of the Level 2 ("Products") database to the community. If you recall, the conversion and release of the BBXRT data archive is a two-stage process. On September 30th 1992, I was scheduled to release the observation list, spectra, background spectra, response matrices, light curves, and documentation, and I achieved my target date for all products except the response matrices, for which the HEASARC specification changed several times during the last few weeks. The matrices were completed in the first week of October. All products are now available by anonymous FTP from the HEASARC Legacy computer. HEASARC staff now have to complete the interface to the BROWSE facility, at which point I will conduct more testing.

The next stage is the Level 1 ("Photons") release, which requires the conversion of all the raw event, housekeeping and attitude data into FITS format. Prototypes of the code to perform these conversions have been written and now have to be tested and generally massaged to conform to HEASARC/NSSDC standards. The release date for Level 1 is February 1993.

I have completed my first paper based on BBXRT results: "Resolving the Iron K line in Cygnus X-2; an observation with BBXRT" by Smale et al. was submitted to the Astrophysical Journal in September. I enclose a copy of the title page and abstract with this Report. I am also a co-author on five other BBXRT papers that have been submitted to Ap.J. recently: "A new X-ray spectral observation of NGC 1068" by Marshall et al; "BBXRT and Ginga observations of the Seyfert I galaxy Mrk 335" by

Turner et al; "BBXRT observations of NGC4151: I. Iron line diagnostics" by Weaver et al; "A BBXRT spectrum of the massive X-ray binary X Per" by Schlegel et al; and "BBXRT Observations of the Magnetic Cataclysmic Variable H0538+608 = BY Cam" by Kallman et al. My next project will be an analysis of the spectrum of Cygnus X-3.

**Astro-D:** The third and fourth builds of the Astro-D/HEASARC FTOOLS software package have now been completed. As before, I have been closely involved in the design and testing of each FTOOL. I have done some more work on the prototype of the top level shell (XSELECT) which provides the user interface to these tasks in a XANADU-type environment, and will ultimately support a graphical user interface (GUI). My work on XSELECT will "take off" again in a big way in the next quarter, now that the BBXRT first release has taken place.

In July I went to Japan to present and demonstrate our progress to our Japanese co-investigators. I am also a member of the X-ray binaries subgroup for the performance verification phase of the mission; on the same visit I participated in a review of the targets to be observed during the first eight months of the mission to achieve calibration and first-cut science objectives.

**ROSAT:** I have performed more analysis of my ROSAT observation of X1822-371, with two goals. First, I want to examine the spectra during eclipse to search for evidence of temperature stratification in the accretion disk corona. Second, an accurate eclipse timing can be combined with eclipses observed by previous satellites to study the change in the orbital period. Previous work I have done on X1822-371 has indicated that the period is changing on a timescale of about  $10^6$  years, and I should be able to confirm or deny this using the ROSAT data.

**Conferences, travel:** Just the Japan trip referred to above.

**DXS:** I have taken part in several one-day mission simulations for the Diffuse X-ray Spectrometer mission, scheduled for 1992 December - 1993 January. This has involved running software packages and giving suggestions for improvements, and learning more about the DXS instrumentation and operations.

**Other scientific work:** During this quarter, my paper "Long-term variability in low-mass X-ray binaries; a study using data from Vela 5B" appeared in the *Astrophysical Journal*.

**Awards:** In July 1992 I received a Peer Award from the Goddard Space Flight Center Laboratories for High Energy Astrophysics, for my work on the planning, mission operations, software development and other efforts towards the successful flight of BBXRT. The award citation reads: "Peer Award presented to Dr. Alan Smale for innovative solutions to challenging problems on BBXRT; your cheerfulness, understanding and patience are an inspiration to us all."

I have also received three Group Achievement Awards, signed by the Director of GSFC; for the BBXRT Payload Development and Operations Team, for the Astro-1 Investigators Team, and for the Astro-1 Payload Science Team (I'm not sure what the



difference is between the last two ...)

**Next quarter:** In the next quarter I will spend most of my time on software development for Astro-D, particularly my XSELECT package. I will keep working on the changes necessary for the BBXRT Level 1 archiving, and hope to find time to write a paper on the BBXRT observation of Cyg X-3 and contribute to several other BBXRT-related science projects in this group. An unknown variable is how many people from “outside”, in the community, will be attempting archival investigation of BBXRT data – I am the sole member of the “BBXRT Guest Observer Facility” and if substantial interest is shown by the community, tending to questions from archival investigators may take a big chunk out of the time available for other projects.

Please contact me if further  
details are required,

Dr. Alan P. Smale

# Resolving the Iron K line in Cygnus X-2; an observation with BBXRT

A. P. Smale<sup>1</sup>, C. Done, R. F. Mushotzky, K. A. Weaver<sup>2</sup>,  
P. J. Serlemitsos, F. E. Marshall, R. Petre, K. M. Jahoda,  
E. A. Boldt, J. H. Swank, A. E. Szymkowiak, R. L. Kelley & K. Arnaud<sup>2</sup>

Laboratory for High Energy Astrophysics,  
Code 666, NASA/Goddard Space Flight Center,  
Greenbelt, MD 20771

<sup>1</sup> Also Research Scientist, Universities Space Research Association

<sup>2</sup> Also University of Maryland

Submitted to *The Astrophysical Journal*, 9/25/1992

## ABSTRACT

We present the first high-quality, moderate resolution spectroscopy of Cygnus X-2 in the 0.4–12 keV energy range, obtained using the Broad Band X-ray Telescope, part of the Astro-1 shuttle payload. These data enable us to resolve the physical width of the 6.7 keV Fe  $K\alpha$  feature in Cyg X-2 with an energy resolution a factor of 4 better than previous X-ray experiments. The feature is modeled well with a single broad Gaussian line with center energy  $E = 6.71^{+0.23}_{-0.20}$ , full width half maximum  $971^{+505}_{-376}$  eV, and equivalent width 60 eV. There is also tentative evidence for Fe L line emission at 1 keV. A sensitive search for an iron edge feature in the 7-9 keV range results in an upper limit on the absorption depth of  $\tau \leq 0.15$ .

There are three possible sites for the Fe  $K\alpha$  emission: the accretion disk, its corona, or the source itself. The last can be rejected as the continuum spectrum suggests that the central  $kT \sim 1.8$  keV blackbody is Comptonized through  $\tau \sim 20$ . Any line would thus be strongly downscattered, broadened and lost. An origin in a corona covering the source and disk can also be ruled out as the observed broad line can only be produced in material with  $\tau \sim 3$ , far in excess of the limits on the optical depth at the iron edge. A line from an optically thick corona out of the line of sight would only be viewed by reflection rather than transmission, so the photons would travel through  $\tau \sim 1$ , also inconsistent with the lack of an iron edge. Reflection from the accretion disk itself, however, can produce a line of the observed energy, width and equivalent width if the disk surface is highly ionized.

*Subject headings:* stars: individual (Cygnus X-2) – X-rays: stars – binaries: close

SOON E 1 T30

**Report for period 7.1.92 - 9.30.92**

**Lalit Jalota  
Visiting Scientist  
USRA  
Goddard Space Flight Center  
Task Number : 5000-606**

The major event during this period was the calibration of the spare X-ray mirror and detector (from MIT) at the long X-ray beam facility at White Sands Missile Range, NM. The test lasted six weeks, and I spent a total of four weeks there. However, I was also involved in the preparations before the test. This was the first test of the complete system and it served two main purposes, to calibrate the responses of the instruments, and to also familiarize both optic and detector teams with the capabilities of each others instruments and also the problems and limitations. The analysis of the data is continuing.

Other work included some development and testing of a foil mirror using a new technique by Peter Serlemitsos which shows very promising results and finishing off the project with the University of Maryland Graduate Student. The upcoming work will include more research into the latest foil technology, continuing analysis of data from the calibration at White Sands, and two collaborative projects to improve the images from Astro-D and to model the image quality using measurements of surface quality.

To: USRA/Mr. Denise Dunn  
From: Yang Soong, LHEA Code 666, Bldg. 2, Rm 271, X66318  
Date: Oct. 27, 1992  
Subject: Technical Report for 7/1-9/30, 1992

A joint calibration session of the 5th mirror and the focal plane CCD detector provided by MIT, the pre-flight ground calibration was carried out at White Sands Missile Range, New Mexico in mid-August for two months by using its long, 1000 ft, collimated vacuum facility. This experiment provided us the first opportunity under flight configuration to realize the imaging and spectral capability of the telescope and to test the data system.

Current research on new methods for better mirrors is in parallel with the remaining Astro-D instrument calibration. These testings will be carried into the new quarter as well. We would be aiming to have a substantial reduction of the image size by a factor of 2, which would give us 1.0-1.5 arc-minutes in half energy width, where the theoretical limit is 0.5 arc-minute. We are testing replication method for the foil surface finish, which has been proved to greatly reduce the surface roughness for a flat test sample. To replicate from a cylindrical glass mandrel is underway.

Study of the XTE PCA collimator response was carried out into this period. The optical testing of the flight collimator modules is under verification. We are working with the optical labs at Goddard to establish a standard method to test all the flight modules.

Data from the shuttle-borne BBXRT experiment is under study. Vela X-1, an X-ray pulsar, was observed with BBXRT for about a couple of thousand of seconds. An interesting feature, a Fe fluorescence line at 6.4 keV, is studied with the 120 eV resolution five-pixel detectors. A narrow line, i.e. FWHM 150 eV, with a fixed centroid against pulse phase gives clues about the astrophysical conditions of the emission area, which is believed to be in the vicinity of a neutron star. The result will be published in the near future and to be presented in the 181st AAS annual meeting at Phoenix, Arizona. At the same time we are waiting for the X-ray optically BBXRT-alike, Astro-D, on schedule launch in February, 1993.

These activities have been supported by the task - #5000-606.

OC: [unclear]

10 October 1992

## Quarterly technical report of Bradley E. Schaefer

The BATSE detectors continue to send down high quality data on gamma ray bursts. In the last quarter, my activities are the routine work of regular data processing. This includes scientific analysis, data archiving, help for guest investigators, answering questions to nonBATSE team members, refereeing papers, and writing papers. In the last quarter, I have submitted two papers to ApJ(Letters) and had another accepted by ApJ. Starting in June, I worked with a University of Maryland student who is working up a standard analysis routine for gamma ray burst spectra. This work has been expanded to the form of a detailed and complete catalog of all BATSE burst spectra, and will soon be submitted to APJSupp as half of the big BATSE catalogs. I also worked closely for one month with a graduate student from Rice University. He used my software and I had many long discussions with him on the validity of his data reduction methods. During the third quarter of 1992, I attended a COSPAR conference in downtown Washington DC.

Over the next quarter, I will continue working with the BATSE software and continue analyzing BATSE data. I am working on a big catalog paper (to be submitted to ApJSupp) on the first year and a half of BATSE SD results. I will also start on further analysis of cross calibration of CGRO instruments, as provided for by my CGRO Guest Investigator program. I will attend the AAS meeting in Phoenix and the Compton Symposium in St. Louis.

TO: David Holdridge/610.3, USRA  
FROM: Scott Barthelmy/661  
RE: 3rd Quarter 1992 Report

25 OCT 1992

I work on two projects, the Gamma Ray Imaging Spectrometer (GRIS) and the Rapidly Moving Telescope (RMT). My effort was split approximately 90/10 for GRIS/RMT. The activities described below are mine either directly or through the supervision of others. For the GRIS project there are two other scientists whose efforts are in other areas and are not described here. There are no other scientists or support staff contributing on the RMT project.

#### **GRIS project activities:**

We received delivery of the instrument back from the Australia expedition. Minor repairs and improvements to the instrument have begun.

Modifications are being made to the instrument and gondola to include a system being developed in collaboration with Dr. Gerry Skinner at the U. of Birmingham, U.K. This new system is the second in a series of "new Germanium detector technology" developments. It involves a "log cabin" close packing arrangement of Ge detectors. I am lead person in the integration between this new system and our existing GRIS. We expect to fly this on our next expedition in the Fall of 1993 (in New Mexico).

I supervise three people in the above activities.

I have been doing the data analysis on the isotopically enriched Germanium detector that was flown twice this spring in Australia (the first new Ge technology development). The detector is >97% Ge70 (natural abundances are 20% 70, 27% 72, 8% 73, 36% 74, and 8% 76). There is a dramatic decrease in the detector background in the 300 to 1000 keV energy regime with a maximum improvement of 2.1 at 600 keV. This decrease is due to the elimination of the "local" beta decay from neutron activated Ge74. This factor of two improvement is equivalent to a 1.4 improvement in sensitivity (square-root dependence for any background dominated instrument), which is the equivalent of doubling the number or volume of the Ge detectors. The line background is also reduced. The strong instrumental lines at 53, 67, and 140 keV are completely gone. This is important for creating a smooth continuum background in this energy regime where cyclotron lines are likely. I will be presenting these results at the October St. Louis GRO conference and the Jan 93 AAS conference.

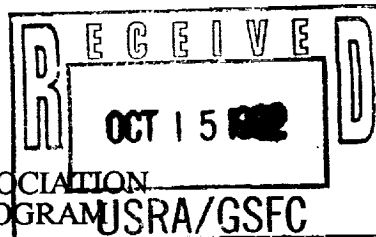
Working with the U. of MD graduate student (Lyle Bartlett), the pulsar analysis for the Spring 90 flight is progressing. The software development necessary for the pulsar analysis is 90% completed.

I refereed the papers for the gamma-ray astrophysics session of the September COSPAR conference.

#### **RMT project activities:**

During this quarter, three trips of approximately one week duration each were made to Kitt Peak to continue the installation and integration. The instrument was made more "automated" and is awaiting a human supervised shakedown period of operation to validate the automation aspects and failure mode fail-safing -- under no circumstances should the instrument be left open to the harsh weather elements.

660-018



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM USRA/GSFC

QUARTERLY TECHNICAL REPORT- Third quarter of 1992 - 10/13/92

Employee Name: John W. Mitchell Task Number: 660-018

During the past quarter my activities have included the 1992 IMAX flight, support of the MASS 1992 flight, and writing proposals for two new cosmic ray instruments. These and other activities are described below.

IMAX (Isotope Matter-Antimatter eXperiment) - This instrument is the product of a NASA/GSFC led collaboration (P.I., Dr. Robert E. Streitmatter), which includes New Mexico State University, the California Institute of Technology, and the University of Siegen (Germany). Among other responsibilities, I acted as the Instrument Manager for this program and had the lead role in carrying out the development of the instrument. During the last quarter, I traveled to Lynn Lake, Manitoba, Canada, (6/22/92-7/22/92) to direct IMAX integration and flight operations.

Final preparations for the IMAX flight were accomplished during June and July, 1992. The instrument was declared ready for flight on 7/13/92, *two days ahead of the nominal schedule*, and launch took place on 7/16/92 at 21:33 CDT. After a long climbout, IMAX reached a float altitude of 119,000 feet at 4:45 CDT on 7/17, and stayed at float for sixteen hours. Landing was just after midnight on 7/18/92, near Peace River, Alberta.

In addition to my general responsibilities, I was directly responsible for several particular aspects of the experiment including: design and construction of the time-of-flight system, design and implementation of the event trigger-logic electronics, and the general experiment electronics.

One of the highest priorities for the IMAX collaboration is the analysis and interpretation of the flight dataset. The initial phases of this effort began during the last quarter, and the analysis is expected to occupy much of my time during the next quarter.

MASS 92- Matter Antimatter Spectrometer System: This is the third in a series of experiments performed by a collaboration led by New Mexico State University and directed toward measurements of the spectrum of cosmic ray antiprotons.

For MASS 92, I also designed and built a new upper TOF array to complement the lower TOF which I built for MASS II (1991). In addition, improvements which I made to the gas Cherenkov system for MASS II were retained for MASS 92. Finally, I was responsible for the design and implementation of the experiment logic.

MASS 92 was prepared in August and September, 1992, for a flight from Ft. Sumner, NM. Unfortunately it had only one real launch opportunity. This was missed because of a balloon failure and no additional launch opportunities presented themselves before weather conditions dictated that the effort should be terminated.

During the past quarter, I prepared the experiment logic and acted as a remote participant and consultant during the pre-flight assembly and checkout. During the next quarter, I expect to begin work on the analysis of the MASS II (1991) flight data, concentrating on the performance of the gas Cherenkov counter.



SMILI (Superconducting Magnet Instrument for Light Isotopes): SMILI was built by a collaboration led by Boston University. The instrument has now been flown twice: in August, 1989, and in August, 1991. My effort on SMILI during the past quarter was the final editing of a paper for the Astrophysical Journal.

E878 (ANTD): This is a new program of experiments at the Brookhaven National Laboratory Alternating Gradient Synchrotron (AGS), which are designed to obtain the heavy ion collision production spectrum of pions, kaons and antiprotons in the energy range from 1.5 GV to 24 GV, as well as to conduct a high statistics search for the production of antideuterons or exotic particles in this range.

For 1992, the E878 program was granted 200 hours of heavy ion beam time (Si beam) and 100 hours of proton beam time by the Brookhaven Program Advisory Council. E878 obtained additional time with a gold beam as apart of an AGS development project.

My primary responsibilities in 1992 were the experiment trigger (with LBL) and the tracking system (with BNL). During the past quarter I acted as a consultant on the data analysis effort.

During the next quarter, I expect to begin studies for a new intermediate index Cherenkov detector to be fabricated for the 1993 running of the E878 experiment.

Experiments E683H and E849H: These experiments were performed in the Beam 40 Zero Degree Spectrometer Facility at the Lawrence Berkeley Laboratory Bevalac heavy ion accelerator, using a solid state detector telescope and a dE vs. total E method of particle mass identification.

The initial E849H analysis has been completed and the results are now being prepared for publication. During the next quarter, I expect to be involved in the final modeling effort.

Experiment E938H: This is a LBL HISS (Heavy Ion Spectrometer System) based experiment, directed toward obtaining information on the energy dependence of the reaction cross sections of a variety of nuclear species of astrophysical importance, incident on a liquid H target (simulating the ISM).

Full analysis of the existing data from E938H will take at least two more years. During the past quarter, I acted as a consultant to the analysis effort as well as participating in collaboration activities. During the next quarter, I will be modelling the instrument acceptance as one of the final steps in preparing for an initial publication.

Cherenkov Detector Development: Under a DDF proposal (on which I am PI), Dr. Louis Barbier and I have been working on the development of new materials based on pressed optical powders. These materials, with optical indices between 1.06 and 1.2, are suitable for use in Cherenkov radiation detectors and may provide improved performance over sintered aerogel radiators in this index range.

During the past quarter, I designed a powder press to be used in fabricating samples. During the next quarter, I will write a year-end report for this effort and will continue the development effort.

### New Proposals:

A Program to Study Beryllium and Other Light Isotopes in the Cosmic Radiation: I am a coinvestigator on this proposal, which was submitted to NASA in August, 1992, in response to NRA-92-OSSA-10 Supporting Research and Technology (SR&T). Under the proposal, a new balloon-borne cosmic ray instrument (named ISOMAX - Isotope Magnet Experiment) will be developed by a collaboration led by GSFC. Initially this program will be directed toward measurements of the isotopic abundances of beryllium and other cosmic ray constituents between lithium and oxygen.

Working on this proposal consumed most of my time during late July and August, 1992. In addition, I spent considerable time during September on internal group deliberations relating to this and other newly proposed or planned work. Initial development work on the ISOMAX instrument will begin during the next quarter.

LArC - A Liquid Argon Calorimeter for Astrophysics: I am the only GSFC coinvestigator on this proposal which was submitted to NASA in response to NRA-92-OSSA-10. Under the proposal, a fully active liquid-argon calorimeter would be developed and tested for balloon flight applications.

During the last quarter I wrote several parts of this proposal. During the next quarter, I expect to participate in a preliminary run of a prototype liquid argon detector at LBL.

Universities Space Research Association  
Goddard Visiting Scientist Program  
Technical Report  
3<sup>rd</sup> Quarter 1992

Arnold H. Rots  
Task number: 660-020

30 October 1992

## 1 XTE-SOC

The first two months of this quarter were completely occupied with efforts in connection with the XTE-SOC Preliminary Design Review which was conducted successfully at the beginning of September. Part of that effort was a preliminary design of the class library for the SOC's software. The SOC is firmly committed now to developing its software following the object-oriented paradigm. This puts us at the cutting edge of software technology which makes the project from that point of view very exciting. It does mean, though, that the design of the class library (the backbone of the software system) is a very labor-intensive and intellectually challenging task. I have pushed this approach along during the past years and spent a great deal of time thinking about that design. I am currently playing the role of chief designer in this effort. The design task should become a little easier, since we acquired a number of new programmers around the time of PDR, some of them with experience in object-oriented programming. Still, the task remains daunting for our relatively small group. On the positive side, though, we expect that the choice of object-oriented methodology will enable us to

produce a software system that will be much easier to extend, to adapt to changes in requirements, and to maintain. The up-front design expense is greater, but the pay-off comes during the implementation phase and extends from then on into maintenance, when traditional approaches usually run into serious overruns due to the fact that that methodology is not very receptive to changes and extensions, and is harder to maintain. I feel I have made a very significant contribution to the project through these efforts.

After the PDR, the first design of the class library has started in earnest. I have managed the design group for the first two months, but this task has now been delegated to one of the technical contractors. During this design period we have monthly meetings with the XTE instrument teams which will contribute to the SOC's software. Personally, I am responsible for the design of the data classes which is the core of the class library, in that it touches on data ingest, database, calibration, monitoring, and analysis subsystems. This is a strongly iterative process. In addition, I am involved in the effort to select a suitable object-oriented database management system.

## **2 Other Activities**

I have started thinking in earnest about time analysis techniques using Bayesian statistics. Some work is going on in the area of algorithm research and I am planning to try applications to X-ray and gamma-ray data that are available in the Laboratory.

## **3 Travel**

I visited the XTE PI team at MIT in August for consultations on software design. I attended the COSPAR meeting in Washington, DC, in August/September. And I was invited to (and attended) the CESDIS workshop on large astronomical databases in September at College Park.

## 4 Next Quarter

In the fourth quarter of 1992 I will continue the design of the class library and perform some research on database issues. The interfaces with the XTE instrument teams will have to be further refined, as well. A start will be made specifying and designing a proto-type pathfinder project.

I intend to continue working on software for the analysis of the BBXRT data and research on the IGM in clusters, as well as time analysis algorithms.

I shall attend the USRA/UMD/GSFC Back to the Galaxy conference at College Park, as well as the second Astronomical Data Analysis Software Systems (ADASS) conference in Boston.

001 10 10

**University Space Research Association  
Goddard Visiting Scientist Program**

**Employee name:** Lorella Angelini **Task Number:** 5000-623

**Period:** 1 July to 30 September 1992

**XIMAGE:** I improved the input/output capability for a number of XIMAGE command, in particular for those directly related to the BROWSE interface. ( eg. the reader for fits and compressed image can now accumulate and image based on the r.a. and dec. value; the output of DETECT, SLICE, PSF contains more informations). The software which allow to extract time selected spectra and light curves has been include to XIMAGE and is currently under test. A REGION command directly interfaced with the display allow to select the special region using circles, boxes, ellipses and rings and instead a WINDOW command operate on time and phase selection. The output format for spectra and light curves is suitable for XSPEC (spectral fitting package) and XRONOS (timing analysis package). I am working on this with Bruce Oneel.

**XRONOS and TIMING:** The timing package XRONOS is ready to be distributed. I am writing a document which describes the new 'standard' format for light curve written in fits. The fits format defined for SSS data has been found not suitable for a number of data set. The new format try to accommodate the information available for old data set, already in the HEASARC on line service (which usually are not complete), and new data set as BBXRT, ROSAT, and ASTRO-D. Photon list and bin data can be written in this new scheme. The new FITS format defined will be implemented in XRONOS, the old format partially inserted has been used as test. I am working on this with Orin Day.

In November both XIMAGE and XRONOS will be presented at the ADASS (Astronomical Data Analysis Software and System) in a session dedicated to the XANADU software.

**EXOSAT Low Energy Catalogues:** The LE database has been finally cleaned and all the entries updated with a quality flag. For the publication of the LE EXOSAT catalogue some work is still needed: manipulate the samples with an algorithm which will calculate and assign a single catalogue position from the positions derived separately from multiple observations, taking into account the errors on the positions themselves.

**Scientific Research:** The paper on 'X-rays From Emission-line Stars in the Herbig-Haro 1 region' studied with the ROSAT HRI data in collaborating with S. Pravdo has been submitted and accepted for publication on AP.J. I am currently working/writing on the time variability of black-hole candidate Cygnus X-1, in which 0.04 Hz QPO were found (1-20 keV). I will present a poster on it at the AAS meeting in January in Phoenix. Other paper in progress: 1) 'The EXOSAT Observations of the LMXRB 4U0614+09', L. Angelini, L. Stella and N. E. White, 2) 'The discovery of the X-ray Transient EXO1847-031', A. Parmar, L. Angelini, N. White, 3) 'QPO and spectral changing behaviour from the

X-ray pulsar OAO1653-40', L. Angelini, L. Stella and A. Parmar, 4) ' An Interactive Deconvolution Technique for Measuring Broad Band Fluctuation Power Density Spectra with Unevenly Sampled Time Series', F. Fiore, C. Done, R. Edelson and L. Angelini.

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read 118  
#118 20-OCT-1992 16:41:57.97 MAIL  
From: HEAGIP::DAY "For Denise Dunn"  
To: NSSDC::USRA  
CC:  
Subj: Quarterly Report

Charles Day 5000-624

REPORT COVERING THE PERIOD 1 JULY TO 30 SEPTEMBER 1992

PROJECT WORK

Continued working on the Astro-D Calibration Book and the Astro-D Technical Description. Continued to define the Astro-D Basic Calibration Files.

Participated in the calibration experiments at White Sands Missile Range, NM. The flight spare Astro-D SIS and XRT were calibrated at the High Energy Laser Systems Test Facility.

Press RETURN for more...

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RESEARCH

Papers published:

Day, C. S. R., Fabian, A. C. & Ross, R. R., 1992. "A search for the iron absorption edge in the tail of an X-ray burst from X1636-53," Mon. Not. R. astr. Soc., 257, 471.

Haberl, F. & Day, C. S. R., 1992. "A GINGA observation of the supergiant X-ray binary system 4U 1700-37/HD 153919," Astron. Astrophys., 263, 319.

Nagase, F., Corbet, R. H. D., Day, C. S. R., Inoue, H., Takeshima, T., Yoshida, K. & Mihara, T., 1992. "Ginga observations of Centaurus X-3," Astrophys. J., 396, 147.

Paper submitted:

Day, C. S. R., Nagase, F. & Asai, K. & Takeshima, T., 1992. "The

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#118 20-OCT-1992 16:41:57.97 MAIL  
discovery of a pulsed iron emission line in Cen X-3," Astrophys. J. (Lett.), submitted 20 Sep 1992.

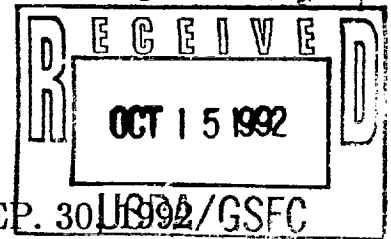


Proposal accepted:

Day, C. S. R., Ross, R. R., Fabian, A. C. & Mitsuda, K., 1992. "The search for the iron absorption edge in the tails of X-ray bursts," submitted to the NASA Ginga Visiting Investigator Program. Accepted at the funding level of \$27,500.

#### WORK PLANNED

Continue working on the Astro-D Calibration Document and the Astro-D Technical Manual. Continue to define the formats of the Basic Calibration Files.



TECHNICAL REPORT FOR JULY 1 TO SEP. 30 1992/GSFC

Ken Ebisawa (USRA Research Scientist )  
task # 666-024

code 668, Astro-D Guest Observer Facility  
Office of Guest Investigator Program

Laboratory for High Energy Astrophysics, NASA/GSFC

PROJECT WORK

- Participated in the Astro-D software meeting in July at ISAS, Japan, and gave a presentation on the Astro-D calibration database system.
- Participated in a board to select targets for pre-verification phase of the Astro-D mission.
- Participated in the calibration of the Astro-D X-ray telescopes and solid-state imaging spectrometer at White Sands Missile Range, NM, in September.
- Fixed the rough format of the GIS calibration files and started to make the preliminary calibration files.
- Preparing texts and figures of the GIS part for the NASA Research Announcement of the Astro-D mission.
- Started developing Astro-D Quick Analysis System and Standard Analysis System.

RESEARCH

- Applying an accretion disk model developed by Dr. L. Titarchuk to the spectral data of LMC X-3 taken with GINGA.
- Applying a reflection model developed by Dr. C. Done for the spectral data of Cyg X-1 taken with GINGA.
- Working on GINGA spectral data of GX339-4 in the low state with M. Ueda.
- Working on combine spectral fitting of GS1124-68 (Nova Muscae 1991) taken with GINGA and ROSAT (collaboration with Dr. J. Greiner [MPE]).
- *Paper Accepted:*
  - Ebisawa, K., Makino, F., Mitsuda, K., Cowley, A., Schmidke, P., Belloni, T. and Treves, A. "Spectral Study of LMC X-3 Observed with GINGA" *Astrophys. J.*, Accepted in July, 1992.
- *Paper in preparation:*

- Ebisawa, K. et al., 1992. "Discovery of Iron Emission Line and Reflection Feature by Optically Thick Matter from GX339-4 Low State", PASJ Lett., to be submitted Oct. 1992
- Ebisawa, K. et al., 1992. "Spectral Variation of GS1124-68 (Nova Muscae 1991) observed with GINGA" Astrophys. J., to be submitted Nov. 1992.
- Ebisawa, K. et al., 1992. "Observation of X1755-338 with GINGA" Astrophys. J., to be submitted Nov. 1992.

- *Proposal Accepted:*

- Ebisawa, K., Gotthelf, E., Titarchuk, L., White, N. & Mitsuda, K., 1992. "Spectral Study of Black Hole Candidates LMC X-3, GS2000+25 and GS1124-68," accepted to the NASA Ginga Visiting Investigator Program, June 1992, for \$21,860.

#### PROJECT WORK PLANNED IN THE NEXT TERM

- Complete and release the Astro-D NASA Research Announcement.
- Complete preliminary GIS calibration files.
- Complete the Astro-D Quick Analysis System and Standard Analysis system.
- Participate software end-to-end test in late November.

#### RESEARCH PLANNED IN THE NEXT TERM

- Complete the analysis of the GX339-4 data taken by GINGA and submit the paper.
- Apply Dr. L. Titarchuk's accretion disk model to the LMC X-3 data.
- Prepare a poster presentation in the AAS meeting in Jan. 1993, with the title "Spectral Study of Accretion Disks around a Black Hole".

**Technical Report July 1-September 30 1992**  
**Koji Mukai (Task number: 660-024)**

**ASTRO-D matters:** I went on two major trips during the last quarter. First was to Japan in mid-July (July 13-17), for a series of meetings at the Institute of Space and Astronautical Sciences (ISAS) near Tokyo, on software status and planning of Performance Verification phase observing program. I presented the status and plans for the data simulator, and gave demonstrations. As of this meeting, I was given the additional responsibility of deputizing for Dr. Petre on proposal preparation software, proposal database and the interface with mission planning software.

The second major trip was to White Sands, New Mexico where a ground calibration experiment of ASTRO-D instruments was carried out over a 6+ week period, using part of the High Energy Laser Systems Test Facility. I spent two weeks there (Sep 7-21), trying to understand what the calibration data are telling us. It was a success for me in terms of obtaining a much deeper understanding of the instruments, although I made no major immediate contributions to the calibration effort.

In between these two trips, I have made some progress in the coding of the data simulator and related matters. Actual release of the software did not occur during the last quarter, however.

**Science:** My major scientific activity of the last quarter was the supervision of Mr. Kazutomi Shiokawa, a Physics graduate student of University of Maryland. Despite his relative lack of astronomical knowledge, he made good progress in analysing archival *EXOSAT ME* data on dwarf novae. In late August, Mr. Shiokawa gave a 30-min presentation to the X-ray group here at Goddard on the results he obtained, which was generally well-received. We are currently working on writing up the results in a form suitable for publication.

A series of paper on "A sixty-night campaign on dwarf novae" have been submitted to *Monthly Notices of the Royal Astronomical Society*, resulting from a major observing campaign on dwarf novae SU UMa and YZ Cnc which took place in Dec '88-Jan '89. I am a co-author on three of the papers, due to my involvement in the observing and in the development of the data reduction software. Although I have not done much work of substance on this in recent years, I'm pleased to see this major project come to a fruitful conclusion.

I have also started a new collaboration with Dr. Jeremy Drake of UC Berkeley, on the possible significance of surface gravity effect on the NaI doublet strengths of cataclysmic variable secondaries. Dr. Drake is an expert in stellar atmosphere, which compliments my knowledge of CV secondaries. Preliminary discussion with Dr. Drake suggests that surface gravity does indeed play a major role; we are currently working on more quantitative assesment of the situation.

**Next quarter:** Our major efforts next quarter will be to prepare for the NASA Research Announcement. This involves programming of the data simulator; writing the technical description of the satellite, to be sent out with the NRA; and completing the proposal preparation/submission software.

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**Technical report for Michael Loewenstein, 7/1/92-9/30/92**

Dr. Serlemitsos, Dr. Mushotzky and I have completed our paper (except for some of the figures) containing the BBXRT analysis and interpretation of the X-ray spectra of the elliptical galaxies NGC 1399 and NGC 4472. Submission is imminent. I presented the results of this work at The Third Teton Summer School on The Evolution of Galaxies and Their Environment (July 5-10).

I have been running numerical hydrodynamic simulations of the evolution of the hot, X-ray emitting gas in NGC 1399 in an effort to better constrain the dark matter and environmental parameters required to explain the BBXRT spectra. Environmental effects (thermal conduction and pressure confinement by the surrounding intracluster medium) seem to be surprisingly important. This may shed some light on the effects of environment in general on the X-ray properties of elliptical galaxies. I hope to start 'production runs' in the coming quarter.

I have been working on the analysis of BBXRT data of the Perseus cluster with Drs. Mushotzky and Arnaud. I have derived the dark matter constraints imposed by the BBXRT high energy data in conjunction with other X-ray and optical data. A mass-to-light ratio greater than 200 is indicated. Using the low energy data we have confirmed the presence and properties of a 'cooling flow' in the center of this cluster. We are planning on doing some more refined analysis of this data as well as other cluster data. Dr. Mushotzky presented some of the preliminary results at the Wyoming meeting.

I have obtained a fraction of the data resulting from my successful Rosat AO-3 proposal, and am about to begin preliminary analysis. This is the first piece in a major project to map (in X-rays) the temperature and density of the nearby Fornax cluster.

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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

QUARTERLY TECHNICAL REPORT  
1992 July 01 - 1992 Sept 30

Employee Name: Ian M George

Task Number: 660-030

Programatic Activities

Work still continues on my review of all the calibration data from all the instruments for which scientific data is (or soon will be) contained within the HEASARC database. The file formats and requirements for associated software are slowly coming together, being circulated, commented upon, fixed and documented. A good example of this is the finalization (in collaboration with Keith Aranaud) of the format required for calibration files required for spectral analysis, which have been distributed to interested parties in the form of OGIP Calibration Memo CAL/GEN/92-002 (below). In collaboration with Alan Smale (of the *BBXRT* GOF), files in the new format have been written for the *BBXRT* mission (for inclusion in the *BBXRT* data archive) and successfully read into the spectral analysis package XSPEC.

In view of the fast approach of the launch of the *Astro-D* mission, the definition, creation & installation of the calibration data for the *Astro-D* XRT, GIS & SIS has now been raised to highest priority. This work is being performed in close collaboration with members of the GSFC *Astro-D* GOF. Second priority status has also now been awarded to the *ROSAT* XRT & PSPC datasets in view of the demands imposed by the soon-to-be-released data archive (in collaboration with the GSFC *ROSAT* GOF).

A major aide to my programmatic responsibilities has been the arrival of programming assistance in the form of Ron Zellar. Together Ron & I have refined my skeleton plans for so-called 'Calibration Index Files' (CIFs) which will provide the primary link between the data analysis software and the calibration files within the database. Good progress has been made with both the detailed CIF format and the development of a variety of software tasks required to construct and manipulate the CIFs. Currently we have an  $\alpha$ -test version of the scheme up and running under the IRAF software environment. In the next two quarters, we plan to install and release the  $\beta$ -test version of the above on all LHEA computer platforms, develop a standalone version of all the tasks (executeable outside the IRAF environment), and start the development of CIF access software. Detailed consideration and instructions will (must) also be provided for the installation & maintenance of the OGIP calibration datasets & software at remote sites. The ultimate time-scale for this activity is provided by the launch of *Astro-D*.

The revision of the VIMAT software package referred to in previous Quarterly Reports has been put temporarily on hold.

Work continues in collaboration with Jane Turner of the *ROSAT* GOF, on assessing the quality of the PSPC detector response matrix. The mis-calibration discovered by us and referred to

in the last Quarterly Report has finally been admitted by MPE. Due to the mounting Guest Observer (GO) disquite, MPE have finally embarked on an appraisal of the situation, the results of which are expected in the near future. Also in collaboration with Jane Turner (and MPE), high signal-to-noise data from an long *ROSAT* PSPC observation of an extremely bright source (the BL Lac Mkn 421) has been analysed in order to test the model of the PSPC point spread function we have previously published in OGIP Calibration Memo CAL/GEN/92-001 (below). It was found that generally the model was a good representation of the data. The source of a number of small discrepancies are currently under investigation both at GSFC and MPE.

In collaboration with Keith Arnaud and other members of the LHEA, the file format for so-called PHA data files (required for the spectral analysis of X-ray data) has been finalized and distributed in the form of OGIP Memo OGIP/92-007 (below). The spectral analysis package XSPEC has been adapted to accept the new format, and  $\beta$ -testing is currently underway.

### Personal Research Activities

My research activities this quarter have been limited due to programmatic demands. The research I have found time for has almost solely centred around the spectral analysis of *ROSAT* PSPC data (in collaboration with Jane Turner). This has been seriously hampered by the PSPC spectral problem mentioned above, and I eagerly await the results of a re-calibration of the detector. Nevertheless a number of datasets have been found to contain scientific results far beyond anything which could be attributed to calibration problems. Thus in collaboration (with Jane Turner) a paper has been submitted discussing the soft X-ray spectra of 6 Seyfert 1 galaxies (below). Also, in collaboration with Dr. K. Nandra (IoA, Cambridge, UK) who visited GSFC for  $\sim 3$  weeks, good progress is being made on a number of additional collaborative projects, and papers should be ready for submission in the near/medium future.

As detailed below, this quarter has seen the acceptance and/or submission for publication of a number of research papers for which I am a co-author. Due to the inevitable time-delay inherent in the publication process some of the work reported within these papers was not conducted this quarter.

### Papers Published/Accepted (in quarter ending 1992 Sept 30)

#### *Refereed Journals:*

- 1. H0414+009 - an X-ray Bright BL Lac with a steep-spectrum radio tail in a distant cluster of galaxies**  
McHardy, I.M., Luppino, G.A., George, I.M., Abraham, R.G. & Cooke, B.A.,  
1992. *Mon. Not. R. astr. Soc.*, **256**, 352.
- 2. The role of Electron-Positron Pairs in Parsec-scale Radio Jets**  
Ghisellini, G., Celotti, A., George, I.M. & Fabian, A.C.,  
1992. *Mon. Not. R. astr. Soc.*, **258**, 776.
- 3. The Broad-Band X-ray Spectral Variability of Mkn 841**  
George, I.M., Nandra, K., Fabian, A.C., Turner, T.J., Done, C. & Day, C.S.R.,  
1992. *Mon. Not. R. astr. Soc.*, in press.

4. **The X-ray Spectral Variability of the BL Lacertae type object PKS 2155-304**  
Sembay, S., Warwick, R.S., Urry, C.M., Sokoloski, J., George, I.M., Makino, F. & Ohasi, T.,  
1992. *Astrophys. J.*, in press.
5. **A ROSAT Observation of NGC 5548**  
Nandra, K., Fabian, A.C., George, I.M., Branduardi-Raymont, G., Lawrence, A., Mason, K.O., McHardy, I.M., Pounds, K.A., Stewart, G.C., Ward, M.J. & Warwick, R.S.,  
1992. *Mon. Not. R. astr. Soc.*, in press.

*Non-Refereed Journals, Conference Proceedings etc:* None

1. **The Dramatic X-ray Spectral Variability of Mkn 841**  
George, I.M., Nandra, K., Fabian, A.C., Turner, T.J., Done, C. & Day, C.S.R.,  
1992. In *The Nature of Compact Objects in AGN*, CUP, in press.

*Other Articles:*

1. **ROSAT PSPC - The On-axis Point Spread Function: In-flight comparison with the PANTER results**  
Hasinger, G.R., Turner, T.J., George, I.M. & Boese, G.  
1992. *Legacy*, 2, in press.  
(CAL/ROS/92-001)
2. **The Calibration Requirements for Spectral Analysis**  
George, I.M., Arnaud, K.A., Pence, W. & Ruamsuwan, L.  
1992. *Legacy*, 2, in press.  
(CAL/GEN/92-002)
3. **The OGIP Spectral File Format**  
Arnaud, K.A., George, I.M. & Tennant, A.F.  
1992. *Legacy*, 2, in press.  
(OGIP/92-007)

Papers Submitted, not yet accepted by Refereed Journals:

1. **ROSAT PSPC Spectra of Six Seyfert 1 Galaxies**  
Turner, T.J., George, I.M. & Mushotzky, R.F.  
1992. *Astrophys. J.*, submitted.



## Non-Local Travel

Cambridge, UK – July 14 – 1992 July 29

The purpose of the trip was two-fold: the attendance of The 33rd Herstmonceux Meeting on "The Nature of Compact Objects in AGN" held at the RGO/IoA in Cambridge (UK); and programmatic & scientific collaboration with members of the IoA X-ray group.

The 33rd Herstmonceux conference centred around discussions of multiwaveband observations and interpretation of Active Galactic Nuclei (AGN). In particular the programme was designed to address whether the fundamental power source in these objects can be explained by the emission from starbursts and/or supernovae in a very dense medium. Such a scenario contrasts dramatically from the 'standard' supermassive black hole paradigm which has been adopted by most workers for the last few decades. I (and most other X-ray astronomers) strongly believe that X- &  $\gamma$ -ray observations play a key role in this debate, and strongly support black hole models. Excellent talks to this effect were given by Turner (USRA), Fabian & Papadakis.

My contribution to the conference was two-fold: the presentation of a poster-paper (above) describing work which has recently been accepted for publication in *Mon. Not. R. astr. Soc.*; and the distribution of copies of the new HEASARC journal *Legacy* and the latest HEASARC CD-ROM containing archival data from the *Einstein* observatory. I believe all were enthusiastically recieved.

During the weekend of July 18/19, and following the conference (*i.e.* on days July 23/24), I collaborated with several members of the IoA (namely Prof. Fabian, Drs Nandra & Johnstone) and Leicester (Prof Pounds & Dr Stewart) X-ray groups. Both these groups have been working with the GSFC *ROSAT* GOF on a spectral problem related to the *ROSAT* PSPC data. The problem is that many datasets show a excess absorption at about 0.27 keV, close to the carbon edge. A number of attempts were made to 'cure' the problem — or at least determine the origin of this effect — but alas without success. We will continue this (programmatic) work now we're back at GSFC as a collaborative effort between the US/UK and German groups.

## Work Planned for the period 1992 Jul 01 – 1992 Sept 30

Projected activities for the next quarter include:

- continued refinement of CIFs and associated software
- continued collaboration with T.Jane Turner and other members of the *ROSAT* GOF continued work on The OGIP *ROSAT* PSPC Calibration Guide.
- continued collaboration with the *ASTRO-D* GOF to finalise and distribute the calibration file formats for this mission.
- continued collaboration with the *ROSAT* GOF to finalise the archival calibration file formats.
- Nov 04 – 06: attendance of the "ROSAT Data Analysis and Science Workshop" at CfA, Boston, Ma, and programmatic collaboration (*ROSAT* and *Einstein*) with colleagues at CfA.

Subject: USRA Quarterly Technical Report - 1 July 1992 to 30 September 1992  
 From: William Pence, Activity 5000-628  
 Date: 25 October 1992

*W/P*

Activities During this Quarter:

I made a number of significant improvements to the FITSIO software package this quarter. Most notably, FITSIO was ported to run within the IRAF software environment using the low-level IRAF subroutines to read and write the FITS files. This version of FITSIO is completely portable and will run without modification on any machine on which IRAF has been installed. This will make the FITSIO package more conveniently available to the various IRAF programming groups around the world. This new version of FITSIO, which also contains a number of other enhancements, will be publicly released on October 28th.

As in previous quarters, most of my time has been devoted to managing the software development project to write programs to analyze FITS format files for the Astro-D project and other missions. I chair a weekly technical meeting with the USRA scientists and STX programmers involved with this project. In September we made the first internal release of this software package, called FTOOLS, for trial use by the other AstroD programming groups. Besides providing the technical leadership of this programming group, I have been heavily involved in testing the FTOOLS tasks and in writing help files and other documentation. Based on the feedback we get from this internal release, and on our own continued testing of the package, we plan to make the first public release of this package in early November. Most of the FTOOLS tasks are very general in nature, therefore we expect that anyone who deals with FITS format data files will find the package useful.

Launch of the AstroD satellite is only 3.5 months away, and most of the planned FTOOLS tasks have been written. We are now devoting more of our resources to working very closely with the AstroD scientists to ensure that the FTOOLS tasks do exactly what is required.

I have also been involved in many other FITS related activities at the HEASARC and have helped to define the particular keywords and formats to be used when converting data from ROSAT, Vela, Ariel V, and the Einstein SSS instruments from their current mission specific formats into FITS format. On a more general note, I have been working with USRA scientist Lorella Angelini to write a definition document for the required formats to be used for the types of data files used for precise timing analysis of the flux from X-ray sources.

Plans for the Next Quarter:

My main activity will be leading the development of the Astro-D software in preparation for launch early next year. This may require travelling to Japan to discuss the status of the project with our Japanese counterparts.

I will be attending the Second annual conference on Astronomical Data Analysis Software and Systems to be held in Boston on November 2-4. I will be presenting a poster paper announcing the first release of the FTOOLS analysis package.

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QUARTERLY TECHNICAL REPORT FROM DR. STEPHEN A. DRAKE  
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CODE 668/LHEA:HEASARC RESEARCH SCIENTIST

1992 July 1st - September 30th

WORK ACCOMPLISHED AND IN PROGRESS

(1) General HEASARC Support

A number of queries from HEASARC users were addressed in this period. Half a dozen requests for the plasma emission codes that I described in the first issue of the new HEASARC journal, LEGACY, were sent to me. Most people wanted copies of the Raymond and Smith code which I e-mailed them or sent by magnetic tape. Those who wanted a copy of the Landini and Monsignori-Fossi code, I referred (as requested by the code's authors) to Brunella Monsignori Fossi so she could supply them with the latest version. Also in response to my article, Dr Jelle Kaastra (SRON/Leiden) has volunteered to visit LHEA in November 1992 and install the latest version of the Mewe and Gronenschild plasma code, as well as a non-equilibrium supernova remnant that he wrote that incorporates the Mewe emissivities. I also dealt with enquiries about emission measure codes (Tom Ayres, U. Colo. and HUG member), ROSAT PSPC effective area (A. Brown, U. Colo), and an SSS spectrum of N158A in the LMC that was not in our SSS database (J. Hughes, SAO: I created the SSS spectra he needed using the IBM SSS software after editing out some bad data that had caused this spectrum to be rejected from our standard reduction of last year, and sent it via e-mail to Dr. Hughes). I also assisted Ms. Kathy Rhode in evaluating a new database, the 3rd Catalog of Nearby Stars (Gliese and Jahreiss), that we had received from U. Leicester, but which contained some erroneous data (contrary to the documentation, no proper motion had been applied to the stars in this database, and all stellar positions were epoch 1950).

I designed and wrote the software to create a new Einstein Monitor Proportional Counter (MPC) database to be incorporated into the HEASARC database and be accessible to the community using the XRAY account and BROWSE. This would be the first time that the MPC data have ever been accessible to most astronomers, without having to laboriously extract the individual data themselves. In the form that we plan to make it available, the MPC data for a given Einstein Sequence Number will be combined into one datum: the lightcurves have been binned into 40.96 second intervals to improve the signal-to-noise and reduce the volume of this database. Tests indicated that the software to extract the spectra and multiband lightcurves using the MPC analysis program pCHIP was working successfully. The completion of this extraction procedure was delayed due to lack of sufficient disk space on the Sun cluster.

I co-ordinated the plan for the transfer of the raw SSS data (in the form of the so-called HME tapes) from the NSSDC IBM computer GIBBS to the NDADS computer, and its translation to FITS format. Prototype FITS structures were to be designed, and the data on these tapes combined with data on an independent set of 9 Einstein Aspect and Spacecraft Ephemeris tapes that Andy Szymkowiak had in his possession. The work on extracting the aspect information on these tapes was commenced by Szymkowiak and Rhode, and continued by myself and Szymkowiak. For 7 of the 9 tapes, we finally located the maps of the tape contents that had been made a number of years previously. For the remaining 2 tapes, this information will have to be recreated.

## (2) Miscellaneous Activities

I visited the NRAO at Charlottesville, Va from August 3rd through 7th 1992, and worked on radio data that had been obtained with the NRAO Very Large Array in the period January to May 1992. I finished reducing 22.5 hours of VLA data that were obtained as part of 2 ongoing VLA programs (a continuing survey of magnetic Bp/Ap stars and a program of near-simultaneous ROSAT and VLA observations of selected Algol binary stars). Highlights of the analysis included the definite and probable detections of 8 more radio-emitting Bp stars, and the detection of a strong extragalactic radio source only 2 arcminutes away from the (radio and X-ray-emitting Algol binary) star delta Lib that implies that Parkes' single-dish claimed detections of this star are contaminated by this nearby source of confusion.

The paper (by myself, Ted Simon (U. Ha), and Alex Brown (U. Co)) reporting the first radio detection of the nearby F star Procyon was accepted by ApJ. on September 23rd, 1992 for publication in March 1993. The paper by myself, Jeff Linsky (U. Co), and Jurgen Schmitt and Christina Rosso (MPE) reporting preliminary results of X-ray (RASS) observations of this same class of stars that was submitted to ApJ (Letts) on May 15th 1992 is currently being revised in the light of the comments received from the referee of this paper.

I continued analyzing the highest signal-to-noise spectra of RS CVn binary stars that the Einstein SSS obtained over the course of its operational life. The deepest exposure of the bright X-ray source Capella had about 25,000 counts and provides a stringent test of the thermal plasma codes that are traditionally used to model the spectra of these stars. Using either a two-component Raymond and Smith plasma model or a two-component Mewe plasma model one finds unacceptably poor fits to the SSS spectrum of this very nearby star. The problem appears to be that the model that best fits the strong lines in this spectrum predicts too much X-ray continuum emission below 1 keV. A BBXRT spectrum of Capella also exhibits this same behaviour when modeled in the same way, indicating that this is not an instrumental effect unique to the SSS. This may indeed indicate that simple optically thin 1 or 2-temperature plasma models are inadequate to represent the actual spectra of coronal stars when obtained with high enough spectral resolution and signal-to-noise. This analysis is continuing and an abstract describing it was submitted to the AAS for presentation at the Phoenix meeting in January 1993.

I finished writing the review paper on the 'Radio emission from Coronal Stars' that I gave orally at the Vaiana Memorial Symposium on Solar and Stellar Coronae that was held in Palermo, Italy from 22nd to the 26th of June 1992. This paper will be published in the proceedings of this conference that will be published in 1993 by Springer-Verlag.

I accepted an invitation to serve on a Peer Review panel judging Guest Investigator proposals submitted for Extreme Ultraviolet Explorer (EUVE) data. I read 30 proposals that were allocated to our panel, evaluated all of the same numerically, and wrote detailed reviews of 9 proposals for which I was primary or secondary reviewer. The EUVE reviews were scheduled to take place in Columbia, Md on October 13th to 14th, 1992.

### NON-LOCAL TRAVEL

None.

WORK PLANNED FOR NEXT QUARTER

I will finish creating a new independent and complete Einstein Monitor Proportional Counter (MPC) database to replace the version presently in the HEASARC database that contains only a small fraction of the available MPC data.

I will visit NRAO at Charlottesville, VA to analyze radio data obtained in February and October 1992 (33 hours of total VLA time) as part of programs to observe magnetic Bp stars and Algol binaries (the latter contemporaneously with ROSAT X-ray observations of these stars), magnetic white dwarfs, and X-ray selected stars that are in many cases suspected to be RS CVn active binary systems.

I will attend the EUVE Reviews, as discussed above from October 13th through 14th.

I will continue overseeing the transfer and FITSification of the SSS database presently resident on the IBM computer to the NDADS computer.

I will reduce ROSAT X-ray data on several magnetic Bp stars that were obtained by myself and Jeff Linsky (U. Colo) as part of AO2 and AO3 Guest Investigator programs.

I will prepare the paper on the analysis of SSS spectra of RS CVN stars that will be given at the Phoenix AAS meeting in January 1993.

OCT 11 1992

Progress Report 1 July - 30 September 1992

Task # 5000 - 630

Laura A. Whitlock, Ph. D.

A standard FITS format was developed for the Ariel 5 light curves for some 90 sources. This conversion (being done with Kathy Rhode/STX) is now underway. The database will be brought online soon --after the addition of the necessary HELP files.

The programs and processes to extract data for sources in uncrowded areas of the X-ray from the Vela 5B data base were completed and tested. Light curves were extracted for 34 sources considered to be uncontaminated by any nearby sources. Two files for each of these sources will be put into the Vela 5B data base - one containing the intrinsic 1-sec observations and another which has been binned into 56-hr averages. These files are now awaiting conversion into FITS format. The wait has been prolonged by the lack of establishment of a FITS standard for such files. However, progress has now been made toward this end and it is expected that conversion of the Vela 5B files will begin in early November. It is expected that the data for these 34 sources will be online by mid- December 1992.

The existing programs for performing the 2-D deconvolution of light curves for sources in crowded areas of the sky were completed and extensively tested to determine their quality and limitations. There are ~65 known sources to be fit using these algorithms. The boundaries for each area to be mapped have been established and execution of this effort will begin in late October.

A paper on the Vela 5B and Ariel 5 all-sky monitor databases was written for the next issue of *Legacy*. Specifically, the paper is "The Ariel 5 and Vela 5B All-Sky Monitor Databases", by L. Whitlock, J. Lochner, and K. Rhode.

Collaborations began with Dr. Jim Lochner (USRA) to analyze the Vela 5B data from sources in the Small Magellanic Cloud and from the Galactic Center. In particular, there are outbursts by several sources in these regions for which Vela 5B has unique data, being the only operational X-ray astronomy detector at the time of the events.

Confirmation was received from Dr. William Wheaton (JPL) that he would honor my request to provide us with a copy of the HEAO 3 gamma-ray spectrometer data base for inclusion into the HEASARC.

Dr. Whitlock attended the SPIE conferences on Optical Contamination and Straylight Rejection held in San Diego, CA in July. There she presented two papers entitled:

- 1.) "4BOUNCE and VBOUNCE: Models for the Study of Contamination Transport and Dynamics", L.A. Whitlock, L.B. Glasgow, and J.L. Jackson.
- 2.) "PEARLSS, A Model for Contamination Effects: Description and Results", L.A. Whitlock and J.L. Jackson.

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## Technical Report for the Third Quarter of 1992

Weiping Zhang

During the period from July 1 through September 30, 1992, Zhang Zhang's time has been devoted to the following areas:

### Preparing for EDS Testing

The Experimental Data System(EDS) for XTE/PCA is being designed and built by MIT. The prototype EDS will come to Goddard for electric interface and some functionality test in March, 1993. Zhang spent time in this quarter specifying and defining the procedures and scopes of the test.

### Development of Model for PCU

To convert the raw data bits from a PCU to useful scientific information, it is necessary to have a good understanding of the responses of each PCU to various inputs. These characteristics will be synthesized into a coherent model. During this quarter Zhang produced the first document that defines the general contents and requirements of the model. This document will be refined and expanded to contain more details in the next few quarters.

### Energy Calibration at Brookhaven

As a part of the PCU calibration, Zhang proposed to use the National Synchrotron Light Source' monochromatic x-ray beam to characterize the energy response of the PCU. The National Synchrotron Light Source is located on the campus of the Brookhaven National Lab in Long Island, NY. He and Dr. Keith Jahoda visited Dr. Peter Siddons at Brookhaven on September 24 to check out the beam environment and to arrange for the calibration run. The breadboard PCU has been scheduled to be calibrated in January , 1993.

### Energy Standards for XTE/PCU

Zhang also has been working to specify the energy calibration standards for XTE/PCA. Each PCU has been designed to be self-calibrated in orbit by am Americium radioactive source. So far the energies of the x-rays lines from Am source have not been well defined. Zhang has searched in the literature and been trying to arrived at the some set of reasonable numbers to use. These numbers will set the energy standards for XTE/PCA.

### BBXRT Data Analysis

Following the public release of the BBXRT data, Zhang with Dr. Jean Swank started analyzing the BBXRT observation of an x-ray transient first discovered by ROSAT and GINGA observations. This work will be carried over to the next quarter. The results are expected to be presented in the June, 1993, meeting of the American Astronomical Society.



## COSMIC RAY DECREASES AND MAGNETIC CLOUDS

H. V. CANE

Laboratory for High Energy Astrophysics, NASA Goddard Space Flight Center, Greenbelt, Maryland and  
Physics Department, University of Tasmania, Hobart, Australia

## Abstract

A study has been made of energetic particle data, obtained from IMP 8, in conjunction with solar wind field and plasma data at the times of reported magnetic clouds. It is shown that magnetic clouds can cause a depression of the cosmic ray flux but high fields are required. A depression of 3% in a neutron monitor requires a field of about 25 nT. Such high fields are found only in a subset of coronal ejecta. The principal cause for Forbush decreases associated with energetic shocks is probably turbulence in the post-shock region although some shocks will be followed by an ejecta with a high field. Each event is different. The lower energy particles can help in identifying the dominant processes in individual events.

## 1. INTRODUCTION

The term 'magnetic cloud' was introduced by Burlaga and co-workers (Burlaga et al., 1981; Burlaga and Behannon, 1982; Klein and Burlaga, 1982 and Zhang and Burlaga, 1988) to describe structures in the solar wind having a magnetic field which changes direction smoothly through a large angle and has an enhanced intensity and a plasma temperature and beta that are of a low value. About a half of such structures were found to follow shocks. It is now commonly accepted that magnetic clouds are a subset of ejecta in the interplanetary medium (e.g. Gosling, 1990).

Recently there have been a number of studies dealing with the role of magnetic clouds in causing decreases in the cosmic ray intensity, with conflicting conclusions. Badruddin et al. (1985), Zhang and Burlaga (1988), Badruddin et al. (1991) and Lockwood and Webber (1991a) attribute the decrease of cosmic rays to turbulent magnetic fields in the sheath between the shock and the associated magnetic cloud. The argument is based on the observation that the decrease commences at the time of shock passage and continues after the cloud has passed by, and that clouds without shocks are associated with small or non-detectable cosmic ray decreases. Lockwood and Webber (1991a) concluded that "the role of magnetic clouds in producing Forbush decreases is relatively unimportant". Note that Lockwood and Webber apply the term 'Forbush decrease' only to those cosmic ray decreases which have an "asymmetric shape" i.e. a rapid decrease followed by a more gradual recovery.

Sanderson et al., (1990a) have approached the problem in the context of the 'two-steps' seen in some cosmic ray decreases. Barnden (1973) first pointed out that some decreases have two steps

and associated the first step with the shock and the second step with the 'driver gas surface'. Sanderson et al. (1990) found that in 18 out of 19 events the second decrease was larger than the first. In another study Sanderson et al. (1991) examined diffusion coefficients in the post-shock regions of shocks associated with 8 decreases and concluded that "the turbulence in the post shock region is not always sufficient to produce a Forbush decrease". In this later paper an alternative location/mechanism for excluding cosmic rays was not proposed. In the earlier paper it was proposed that drifts in the cloud could cause the decrease. Drifts in magnetic 'blobs' as a cause of Forbush decreases was first discussed by Barouch and Burlaga (1975).

It is important to note that Sanderson et al. (1990a, 1991) looked at decreases that occurred at the times of low energy (35-1000 keV) proton bi-directional flows reported by Marsden et al. (1987). These bi-directional flows were interpreted by Marsden et al. (1987) to be another signature of coronal ejecta and in fact approximately a third (12/29) of their shock-related events are also 'magnetic clouds'. From previous work (e.g. Cane, 1988) it is apparent that only one event included in the Sanderson et al. (1990) study was associated with a large, energetic shock. This is the one event for which Sanderson et al. found a large change in the diffusion coefficient at the shock and at which the decrease commenced at shock passage.

There is an important observation that has not been taken into account in recent work on Forbush decreases. Rao et al. (1967) showed that 'energetic storm particles' exist during the onset of Forbush decreases. The rapid increase of low energy particles coincides with the first step and a rapid decrease occurs at the second step. They proposed that the particles are accelerated by the shock. However the idea that the mechanism which accelerates the low energy particles is intimately connected with the mechanism that depletes high energy particles was not explicitly mentioned. In recent work (e.g. Lockwood and Webber, 1991b) the enhanced particle intensities at the onset of Forbush decreases have been treated as 'interference'. Yet scattering in turbulent fields is a favored mechanism for both particle acceleration at shocks (e.g. Jones and Ellison, 1991) and for producing Forbush decreases. It should be possible to use the low energy particles to distinguish which processes are occurring during Forbush decreases and within individual decreases. This has been done in the present paper using data from Goddard Space Flight Center instruments on IMP-8 to address the question of the role of magnetic clouds.

In this study time histories of particles in the energy range 1 MeV to about 5 GeV are examined at the times of the passage of magnetic clouds. It is shown that the high field in magnetic clouds does cause a depression in the cosmic ray intensity.

## 2. RESULTS AND DISCUSSION

The energetic particle data for this study were obtained from the Goddard Space Flight Center experiments on IMP 8 (McGuire et al., 1986). Besides the differential intensities, the rate from the

plastic scintillator anticoincidence guard (G) on the medium energy telescope was also examined. This provides an integral rate for energies greater than about 60 MeV/nuc. This is a very sensitive method for looking at the small decreases in clouds because of a) the lower cut-off rigidity compared with a neutron monitor and b) the absence of diurnal anisotropies which can obscure the onset of the decrease and fine structure within the decrease.

Field and plasma data, obtained from the NSSDC OMNI database, were studied in conjunction with the IMP 8 data for 16 clouds from the Zhang and Burlaga list. From the original list of 19 clouds two events (April 3, 1979 and September 17, 1979) were excluded because of solar particles and another (September 18, 1981) because of an IMP 8 data gap. Only two events (January 4, 1978 and December 19, 1980) can be associated with solar events based on the onset of associated energetic particles (see Cane, 1988).

Figures 1 to 4 show particle and solar wind data (1 hour averages) at the times of four clouds. In addition to the IMP 8 data (30 minute averages) pressure corrected count rates from the Mt. Wellington neutron monitor (1 hour averages) are also shown. Each figure shows from the top to bottom: (a) intensities in the energy ranges 0.9 -1 and 6-11 MeV, (b) and (c) the Mt Wellington neutron monitor and IMP 8 G count rates expressed as a percentage of the pre-event level (d) the field magnitude, (e) the field elevation, and (f) the solar wind speed. Vertical lines indicate the shocks and the boundaries of the clouds.

Figure 1 shows a period in January 1978 when an energetic shock was seen at a number of spacecraft (Burlaga et al., 1981). The cloud following the shock arrived at Earth at 1200 UT on January 4 according to Zhang and Burlaga (1988). However the data in Figure 1 suggest that the cloud may have arrived slightly earlier at 1030 UT. Between the time of shock passage and this time, the low energy ion intensities (illustrated on a log scale) show an enhancement above a long term increase commencing on January 1 and ending after January 7. The G rate, shown on a linear scale, is off-scale during this enhancement. It should be noted that while the G rate has a median response of about 1 GeV, increases in the counting rate are mainly due to particles with energies less than 80 MeV. The G rate shows a minimum level, below pre-event levels, inside the cloud suggesting that cosmic rays are partially excluded from this region. The low energy particles also show evidence of partial exclusion from this region. The neutron monitor data are difficult to interpret in isolation. However, in combination with the lower energy data there is evidence for about a 2% reduction in the cloud preceded by a larger reduction in the post-shock region.

Figure 2 illustrates a different kind of event. The flow and field jumps at the shock are rather small and the field magnitude does not fluctuate very much in the post-shock region. The rms of the magnetic field components is large during the period when the field is fluctuating as can be seen from Figures 6 and 7 of Zhang and Burlaga (1988). For the event in Figure 2 the field reaches a maximum in the cloud. Consistent with the lack of turbulence in the field, and that it is a weak shock, is the absence of any low

energy particles. The minima in the two high energy rates are clearly in the cloud.

Figure 3 shows an event in which the cloud and the post-shock region probably are equally important but the data gaps make it difficult to determine. It is clear that the decrease of high energy particles starts at the shock but that there is a further decrease in the cloud. The field is highest in the post-shock region and is very turbulent. The intensity of the lowest energy particles is high and is off-scale.

Figure 4 illustrates another event in which the field is a maximum in the cloud. The data are consistent with a cloud arrival time slightly earlier than that given by Zhang and Burlaga (1988). An arrival time of 0000 UT on February 12, rather than 0300 UT, was also suggested by Sanderson et al. (1990b). In this event the neutron monitor and G rate decreases do start before the cloud but clearly most of the decrease can be attributed to the cloud. There are some shock accelerated particles superimposed on an increase (partially off-scale) related to a solar event that was not associated with the shock and cloud. Events of Figures 2, 3 and 4 originated in solar ejections that had no obvious electromagnetic signatures.

The remaining 12 events show similar features but with variations. Three events show no decreases in the period before or during the passage of the cloud and these were the ones with the smallest field magnitude in the cloud. It is clear that in the other events the count rate decreases on entry to the cloud but most are preceded by another decrease that starts with the shock. The relative sizes of the decreases seem to correlate well with relative strengths of the field in the post-shock region and the cloud and on the amount of turbulence in the post-shock region.

For those events with a maximum field and a clear depression in the cloud, the depression was estimated based on levels in the G rate just before entering the cloud and the minimum rate in the cloud. By correlating the percentage decrease and the field strength in the cloud (see Figure 5) it can be deduced that a 6% decrease for the IMP-8 G rate requires a field of about 25 nT. From a study of the neutron monitor and G rates a 6% decrease in the latter corresponds to about a 3% in the former. For the 12 events in Figure 5 the depression and the field magnitude are reasonably well correlated with a correlation coefficient of 0.86.

The important result of this study is that high fields and turbulent fields can both cause a depression of cosmic rays. The relative contribution of each process will depend on the particular event. Since one of the criteria Klein and Burlaga (1982) used for defining 'clouds' was a high field strength, (the mean value for the Zhang and Burlaga (1988) clouds is 18 nT), it is the high field strength which is more relevant for the majority of these events. Magnetic clouds are a subset of those ejecta which propagate in the direction of the Earth. The majority of energetic shocks are not followed by high field regions. Perhaps the ejecta in energetic events do not have high fields. Certainly only in some events will the ejecta be intercepted. In other events the turbulence will be more relevant for the depression of cosmic rays. The majority of the shocks studied by Sanderson et al. and Zhang and Burlaga were

not major shocks or major Forbush decreases.

Support for the important role of turbulence in major Forbush decreases can be inferred from the fact that large, energetic shocks responsible for major Forbush decreases also accelerate particles to high intensities and relatively high energies. Furthermore the two events in the Sanderson et al. (1991) study with the greatest change in the diffusion coefficients at the shock are the two with the highest fluxes of low energy particles.

### 3. CONCLUSION

It is concluded that magnetic clouds do play a role in the depression of cosmic rays. The depression is related to the strength of the field with a 3% decrease in a neutron monitor requiring a field of about 25 nT. Generally such high field regions are not observed and so, for the majority of cosmic ray decreases, turbulent fields in post-shock regions are more important. The relative contributions of particular mechanisms will vary from event to event, depending on the maximum field strength in the ejecta, the shock strength and possibly other parameters too.

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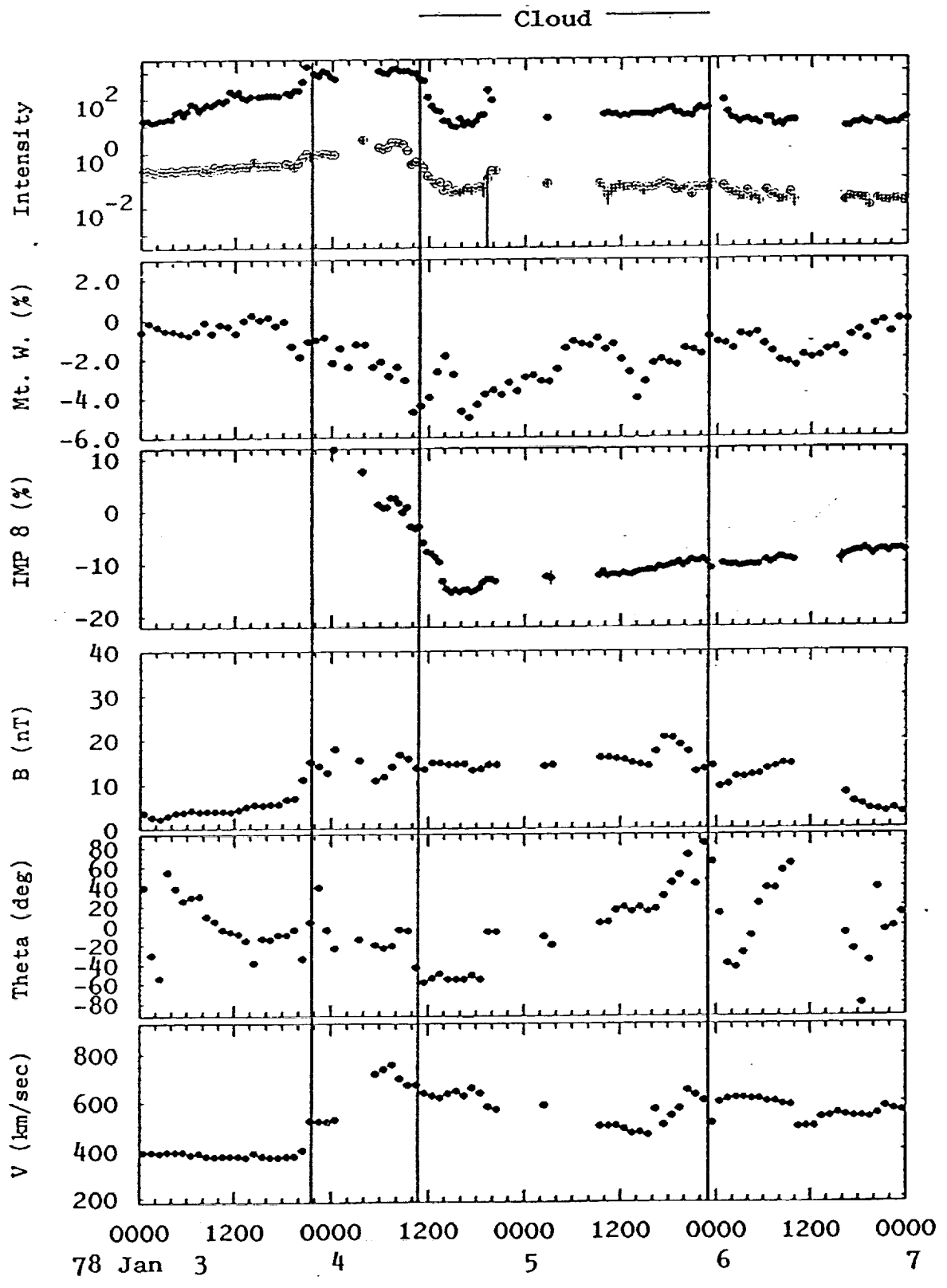
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## FIGURE CAPTIONS

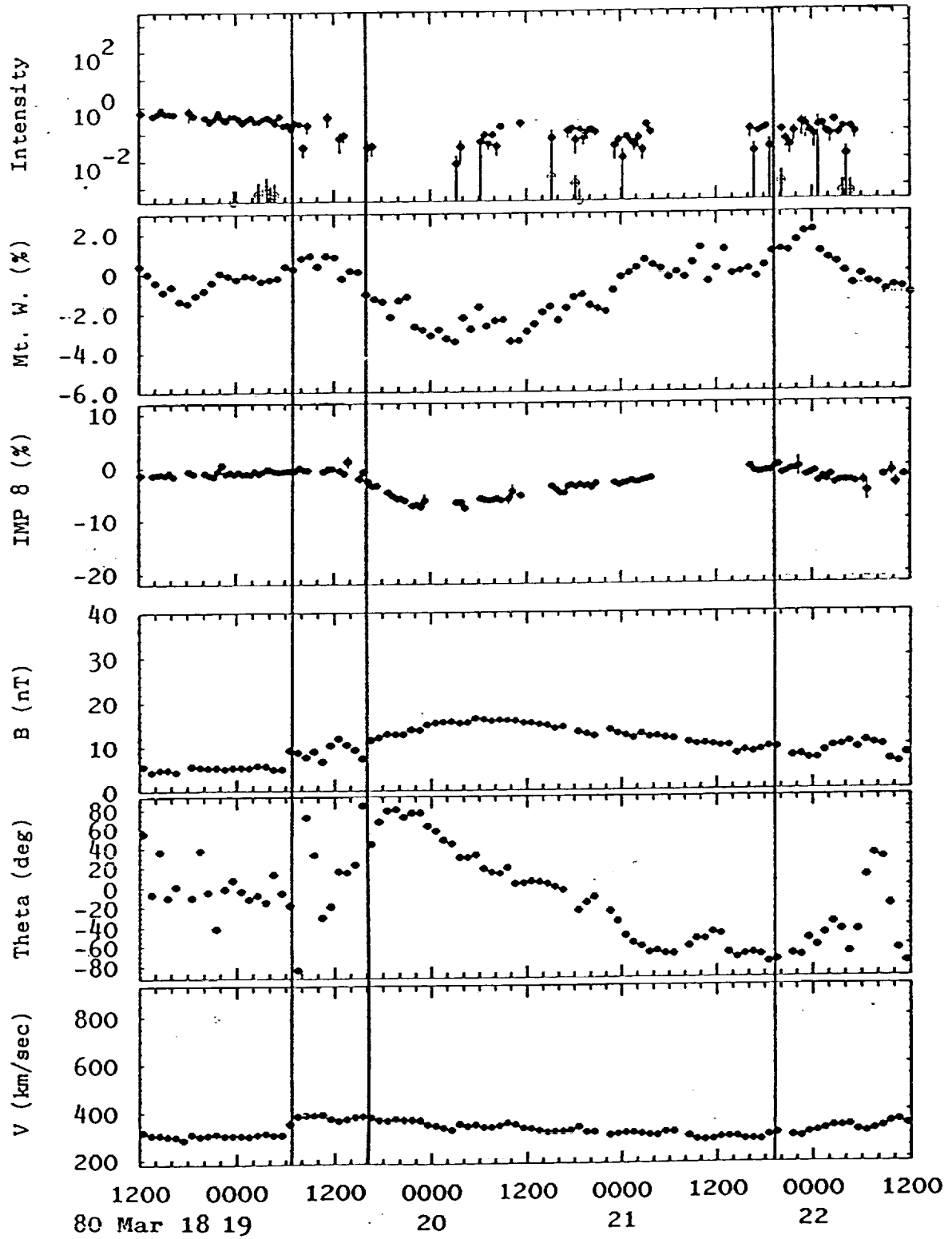
Figures 1-4. Energetic particles recorded at the time of the passage of a shock followed by a magnetic cloud. From top to bottom: (a) intensities (particles/(cm<sup>2</sup> sec ster MeV)<sup>-1</sup> in the energy ranges 0.9-1 and 6-11 MeV, (b) and (c) the Mt Wellington neutron monitor and IMP 8 G count rates expressed as a percentage of the pre-event level (d) the field magnitude, (e) the field elevation, and (f) the solar wind speed. Vertical lines indicate the time of shock passage and the boundaries of the cloud.

Figure 5. Percentage depression of the IMP 8 G rate as a function of the maximum magnetic field measured in associated clouds.

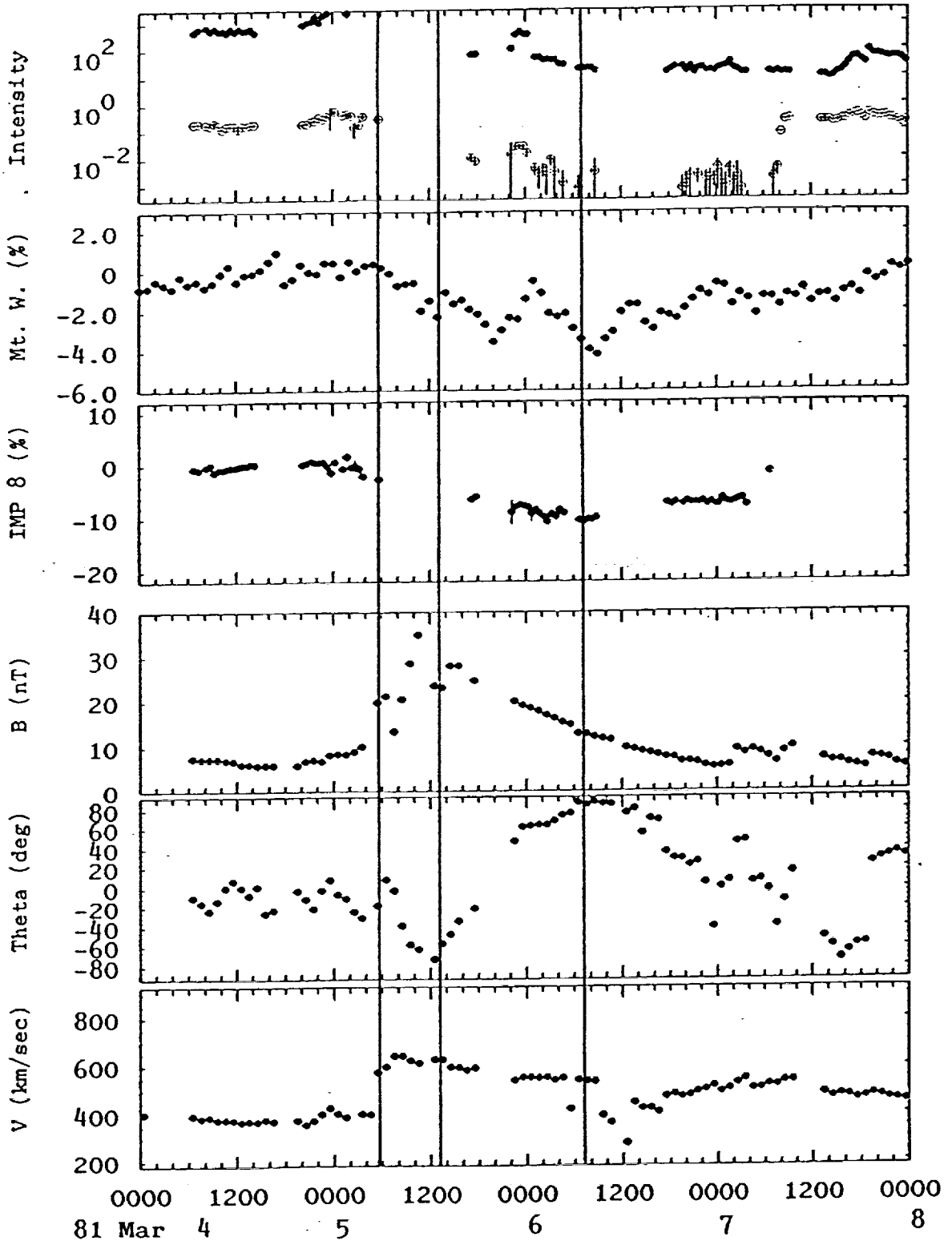




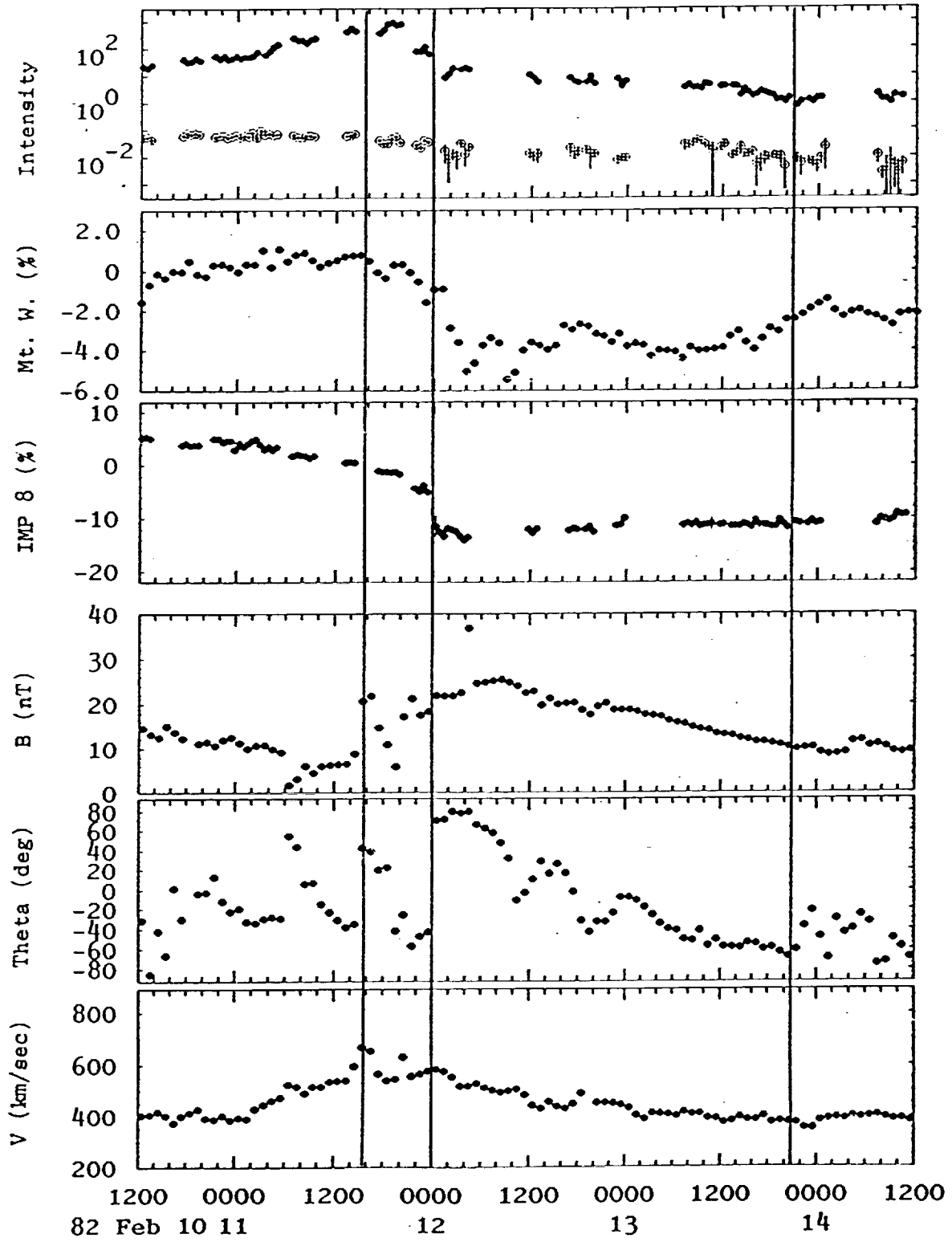
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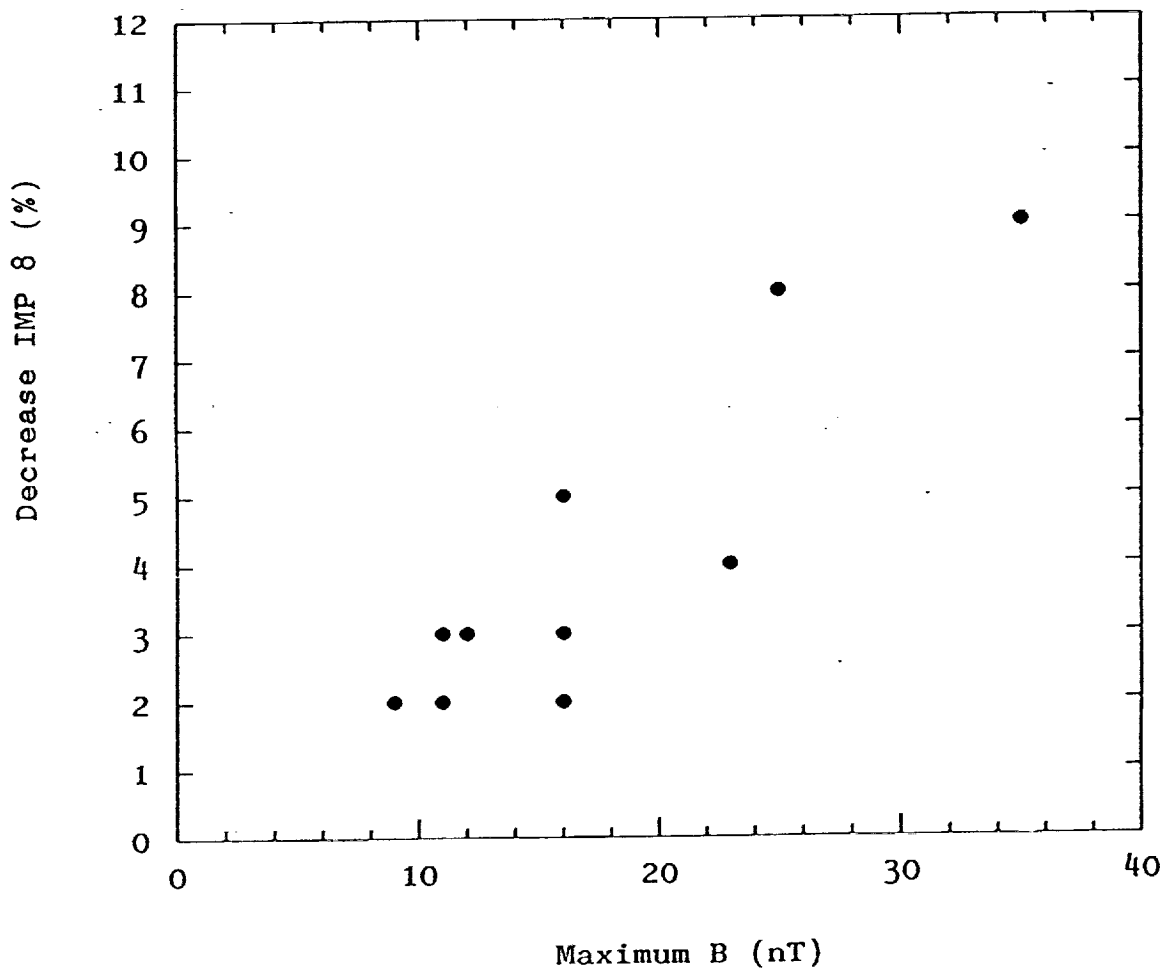


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THE SOLAR WIND STRUCTURES ASSOCIATED WITH COSMIC RAY DECREASES AND  
PARTICLE ACCELERATION IN 1978-1982

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### Abstract

A study has been made of the time histories of particles in the energy range 1 MeV to 1 GeV at times of all >3% cosmic ray decreases in the years 1978 to 1982. Essentially all 59 of the decreases commenced at or before the passages of interplanetary shocks, the majority of which accelerated energetic particles. We use the intensity-time profiles of the energetic particles to separate the cosmic ray decreases into four classes which we subsequently associate with four types of solar wind structures. Decreases in class 1 (15 events) and class 2 (26 events) can be associated with shocks which are driven by energetic coronal mass ejections. For class 1 events the ejecta is detected at 1 AU whereas this is not the case for class 2 events. The shock must therefore play a dominant role in producing the depression of cosmic rays in class 2 events. In all class 1 and class 2 events (which comprise 69% of the total) the departure time of the ejection from the sun (and hence the location) can be determined from the rapid onset of energetic particles several days before the shock passage at Earth. The class 1 events originate from within 50° of central meridian. Class 3 events (10 decreases) can be attributed to less energetic ejections which are directed towards the Earth. In these events the ejecta is more important than the shock in causing a depression in the cosmic ray intensity. The remaining events (14% of the total) can be attributed to co-rotating streams which have ejecta material embedded in them.

## 1. INTRODUCTION

Since the earliest observations (Forbush, 1938) it has been recognized that transient decreases in the cosmic ray intensity occur at the times of sudden commencement geomagnetic storms (SCs). Lockwood (1960) showed that decreases with a rapid onset, Forbush decreases (FDs), generally commence within 3 hours of an SC. Lockwood (1960) also pointed out that most large FDs (magnitudes  $> 5\%$ ) are associated with polar cap absorption events, indicating the presence of high fluxes of protons in the energy range 5-20 MeV. It is now widely accepted that SCs and cosmic ray decreases are caused by interplanetary (IP) shocks and that IP shocks (both transient and co-rotating) accelerate particles, and yet particle acceleration has not been included in attempts to understand the nature and causes of Forbush decreases.

The mechanisms responsible for short term cosmic ray decreases are also responsible for the long term modulation i.e diffusion, convection, adiabatic deceleration and drift. What is not known is the relative contributions of these mechanisms both in general and in specific events. We intend to address this question in two papers. In this paper, the solar wind structure (shock, ejecta, co-rotating stream or combination of these) responsible for every cosmic ray decrease in a specific time period (1978 - 1982) is inferred by examining intensity-time profiles of the cosmic rays and the associated lower energy ( $< 25$  MeV) particle enhancements. The particle enhancements associated with the different solar wind structures have unique signatures allowing them to be

distinguished. With the structures determined it is then possible to identify the predominant mechanism responsible for cosmic ray depressions associated with particular types of structures. For example, drift in smooth, high magnetic fields will dominate in depressions caused by ejecta as discussed in a related study (Cane, submitted to J. Geophys. Res., 1992) where this effect is quantified. In a subsequent paper the relative importance of other mechanisms (including scattering in turbulent fields, and convection) in producing cosmic ray depressions will be quantified using the solar wind plasma and field data. This work (in progress) confirms the associations made in the present paper between cosmic ray decreases and specific types of solar wind structures.

Along with providing a complete list of decreases and their causes, in a 5 year period around solar maximum, we also reconfirm some statistics of cosmic ray decreases obtained in earlier research.

## 2. DATA ANALYSIS

This analysis uses data from the GSFC experiment on IMP 8 (McGuire et al., 1986). In addition to differential proton intensities, data from the plastic scintillator anticoincidence guard (G) on the medium energy telescope are used. These provide an integral rate for ions with energies greater than about 60 MeV/nuc. The time histories of IMP 8  $\sim 1$  MeV to  $\sim 100$  MeV proton intensities and G rate were examined during periods of short term (<20 day duration) cosmic ray decreases >3% recorded by the



University of Tasmania Mt. Wellington neutron monitor in 1978 - 1982. Our list of decreases is slightly different from that of Lockwood (1990). Several of the events listed by Lockwood have been divided into multiple events resulting in 10 additional events. Since we included all decreases  $>3\%$  regardless of their intensity-time profiles, one event on our list (September 15, 1979) was probably excluded from the Lockwood list on the basis of its slow onset and long duration and another event (November 30, 1982) because of the large diurnal variation. Six events on the Lockwood list were too small to be included in the present study. The resulting number of decreases (see Table 1) in the 5 year period was 59. Note that the onset times of the decreases are given to the nearest 3 hour interval. These onset times are only estimates as many decreases do not commence rapidly.

Reports in Solar Geophysical Data of sudden commencement geomagnetic storms (SCs) and lists of shocks detected by near-earth spacecraft (e.g IMP-8, Borrini et al., 1982) have been used to provide the arrival times of the interplanetary (IP) shocks associated with the decreases. In the majority of cases a shock arrived before the depression commenced but for 4 events the ordering was reversed. The time difference between shock arrival and the start of the depression is given in Table 1 and a histogram is shown in figure 1. It was found that 73% (43/59) of the neutron monitor decreases began within 6 hours of the passage of a relatively strong shock. The September 1979 decrease (and possibly the November 30, 1980 decrease), with no shock occurring

within days of its start, may be explained by the presence of a large IP shock moving off the east limb of the Sun (Cane, 1985) because an energetic shock can affect the cosmic ray intensity at Earth, even when the shock itself is not detected (Lockwood, 1971).

The percentage decreases seen by the Mt. Wellington neutron monitor and the IMP 8 G rate are also listed in Table 1. For 25 events the IMP 8 G rate included a particle enhancement, which we attribute to shock acceleration, during some or all of the decrease. In these events the decrease is given as a '-1'. Events listed with a '-2' are those in which there was some other solar event during the decrease. For the other events the IMP 8 decrease was approximately a factor of 2 greater than the neutron monitor decrease.

The events have been divided into 4 classes based on the cosmic ray and IMP 8 proton intensity-time profiles. An example from each class is shown in Figures 2-5. The percentage decreases at Mt. Wellington and in the IMP 8 G rate are shown along with proton intensities in two energy ranges (0.9-1 MeV and 9-23 MeV). The IMP 8 and neutron monitor data are 30 min. and 1 hr averages respectively. The neutron monitor data are pressure corrected. Vertical lines indicate shock passages.

Class 1 events (an example of which is shown in Figure 2) are those in which the G rate and the neutron monitor show a minimum intensity at about the same time and an intense energetic particle enhancement is seen. For most events the enhancement extends above 60 MeV and appears in the G rate but does not extend much beyond

the commencement of the cosmic ray decrease. The low energy particles ( $< \sim 20$  MeV) peak near shock passage and show an abrupt decrease a few hours later. Class 2 events (Figure 3) are associated with intense  $> 60$  MeV ion enhancements seen in the G rate. The G rate stays high beyond the commencement of the cosmic ray decrease, sometimes never showing a decrease as is the case for the event illustrated in Figure 3. For class 2 events the low energy intensities do not exhibit an abrupt fall during the decay following shock passage.

Class 3 and class 4 events (Figures 4 and 5 respectively) are associated with proton enhancements which do not extend above 60 MeV and hence are not seen in the G rate. Consequently the G rate and neutron monitor intensities decrease and reach minimum together. For class 3 events the associated particle enhancement peaks at shock passage at all energies at which it is seen and the intensities drop abruptly during the subsequent decay. These events are similar to class 1 but less energetic. Class 4 cosmic ray decreases are long lived and generally do not have a rapid onset. They also exhibit more structure than the events in the other classes.

Class 1 (15 events) and class 2 (26 events) make up 69% of the total and all can be associated with a specific solar event. The particle events associated with class 1 and class 2 cosmic ray decreases are very energetic. In fact they comprise the majority of all 'solar energetic particle' events observed in the period 1978-1982. The solar source regions of these particle events have

been published previously by a number of authors (e.g. Cliver et al., 1989). The presence of associated energetic particles makes possible the determination of the source locations on the Sun for these cosmic ray decreases. The particle enhancement starts at the same time at all energies at about the time of the associated solar H $\alpha$  event. The longitudes are listed in Table 1.

It is not possible to assign specific source regions for class 3 and 4 decreases because the associated particle enhancements do not have well defined start times and the low energies commence before the higher energies. However there is one exception. The event of November 30, 1980 may have been associated with a relatively energetic IP shock, and associated particle event, originating near the east limb of the Sun, which was not detected at Earth but was detected remotely via the radio emission that it generated (Cane, 1985).

### 3. DISCUSSION

We first consider the size of the neutron monitor decrease as a function of the longitude of the source region for class 1 (open circles) and class 2 (filled circles) events (Figure 6). It can be seen that the events tend to originate in different longitude regimes with class 1 restricted to within 50° of central meridian and the class 2 originating from outside of 20° of central meridian. The distribution of events in figure 6 is similar to those that have been presented previously (e.g. Barnden, 1972a). In particular there are more decreases from eastern regions than

western regions (in our sample 30 vs. 11) and the largest events originate near central meridian. However, by using the source locations based on energetic particles we believe the associations in our distribution are more reliable. We do not find precise agreement with the results of Barnden's study (which included all Forbush decreases  $>3\%$  for the years 1966-1972) since we find 2 decreases from regions beyond  $W60^\circ$  (Barnden found none) and 2 decreases greater than  $7\%$  from  $E90^\circ$  (Barnden's largest was  $5\%$ ).

In a companion paper Barnden (1972b) presented a model for the number density distribution of cosmic ray particles during Forbush decreases based on the large scale structure (proposed originally by Hundhausen [1972]) of interplanetary shocks and their drivers, and on the dependence of a number of characteristics of Forbush decreases on source longitude. The essential features of this model are the presence of ejecta plasma, magnetically isolated from the ambient solar wind, which drives the shock, and the draping of solar wind field lines around the western side of the ejecta. This latter feature means that following passage of a shock originating in eastern regions, the Earth becomes connected to the nose of the shock where it is strongest. This model has also been used to explain the large scale characteristics of energetic particle events invoking IP shock acceleration as the principal source of particles (Cane, Reames and von Roseninge, 1988). It was noted that a sharp drop in particle intensity occurred for central meridian events when the ejecta was intercepted. A similar conclusion was reached by Barnden (1972b). Thus the difference

between our class 1 and class 2 cosmic ray decreases is whether following shock passage the ejecta is intercepted (class 1) or whether the observer continues to be magnetically connected to the shock (class 2).

There has been some recent discussion about the relative roles of the ejecta and the shock in producing cosmic ray decreases (e.g. Sanderson et al., 1990). The existence of decreases in which the ejecta are not intercepted (i.e. class 2) argues that ejecta alone are not responsible for decreases and that shocks must play a role. The close temporal correspondence of the increase in the G rate and the decrease in the neutron monitor for the events like the one illustrated in figure 3 (this event originated on the east limb and other events from the limbs behave similarly) shows the close relationship between the acceleration of low energy particles and the exclusion of high energy particles. Both are presumed to arise from scattering in the turbulent fields in the vicinity of the shock.

The time profiles of the class 3 events suggest that they are similar to the class 1 events but less energetic (based on the absence of particles above 60 MeV). Most have been previously considered in the paper on cosmic ray decreases and magnetic clouds (Cane, submitted J.Geophys. Res., 1992). In these events the ejecta is more important than the shock in producing the cosmic ray decrease. These ejecta are attributed to mass ejections which do not drive strong, extensive shocks and which are detected because they are aimed directly at the Earth. This proposal is supported

by some earlier work relating particle enhancements, shocks and coronal mass ejections (Cane, von Roseninge and McGuire, 1990). Particle enhancements associated with shocks but not showing a prompt onset at all energies were related to slow coronal mass ejections.

The class 4 events are similar to the so-called 'recurrent Fds' discussed by e.g Lockwood (1971) in that they are of long duration and have more symmetrical time profiles. Recurrent events have been associated with co-rotating high speed streams which are prominent at solar minimum and often include low energy particle enhancements peaking within the stream (Richardson et al., 1992 and references therein). However during class 4 events further shocks were detected i.e. in addition to the one usually associated with the onset, consistent with the complex structure of streams around solar maximum. The secondary shocks were associated with further decreases with rapid onsets like class 3 decreases and suggest the presence of ejecta embedded in the streams.

Finally in Figure 7 we shown the distribution of the event sizes and source regions as a function of time. In this figure class 1 and 2 are combined since from a solar point of view they are the same ie. they can be attributed to energetic coronal mass ejections. The implication from Figure 7 is that near solar maximum there were few very energetic coronal mass ejections (a point that has been noted previously e.g. Cane and Stone, 1982). At this time the dominant source of short term modulation of the cosmic ray intensity was a number of co-rotating streams with

embedded ejecta.



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## FIGURE LEGENDS

Figure 1. Distribution of the time delay between shock passage and the start of the cosmic ray decrease for the 55 events associated with shocks at Earth.

Figure 2. Energetic particle observations recorded at the time of a cosmic ray decrease in November 1978. From top to bottom: (a) proton intensities (particles/(cm<sup>2</sup> s sr MeV)<sup>-1</sup> in the energy ranges 0.9-1 and 9-23 MeV, (b) and (c) the Mt Wellington neutron monitor and IMP 8 G count rates expressed as a percentage of the pre-event level. The vertical line indicates the time of shock passage. The event shown in Figure 2 is an example of a class 1 event. The G rate shows an enhancement before the shock passage but the rate drops at about the same time as the neutron monitor rate. The low energy particle enhancement shows an abrupt drop shortly after the shock passage.

Figure 3. The format is the same as in Figure 2. For this class 2 event the intensities stay high for a long time even extending to the range to which the G rate is responsive. The particle enhancement shows a uniform decay without an abrupt fall off.

Figure 4. An example of a class 3 event, which is typified by no enhancement in the G rate and a rapid decrease seen simultaneously in the G rate and the neutron monitor rate.

Figure 5. An example of a Class 4 event which is typified by being gradual in both the onset and recovery. The second more abrupt decrease late on November 11, 1979 looks like a class 3 event.

Figure 6. Size distribution of cosmic ray decreases as a function of source region on the Sun. Filled and open circles represent class 2 and class 1 events respectively.

Figure 7. The variation of sizes and types of cosmic ray decreases during 1978 to 1982. Filled circles represent classes 1 and 2, open circles class 3 and asterisks class 4. The arrow indicates the time of sunspot maximum.

TABLE 1. Cosmic Ray Decreases 1978 - 1982

Event Number	Date	Onset Time, UT	Shock- Onset hrs	Decrease %		Class	Source Longitude
				MTW	IMP8		
1978							
1	Jan. 3	18	3	5	15	1	E06
2	Jan. 25	21	5	5	10	4	...
3	Feb. 15	00	2	17	-1	1	W20
4	Mar. 8	15	0	8	21	2	E20
5	Apr. 10	12	-1	6	17	1	W11
6	Apr. 18	06	6	5	-1	2	...
7	Apr. 30	09	-1	15	-1	2	E38
8	June 2	12	3	7	14	1	W43
9	June 25	12	4	5	-2	1	E16
10	July 13	09	5	8	-1	2	E45
11	Sept. 29	06	3	9	14	3	...
12	Nov. 12	03	2	5	12	1	E01
13	Dec. 19	00	20	6	11	4	...
1979							
14	Feb. 18	09	6	7	-1	2	E59
15	Apr. 5	06	4	7	15	1	W14
16	Apr. 25	03	3	7	11	1	E10
17	June 6	21	2	6	-1	2	E14
18	July 7	06	10	8	-1	2	E36
19	Aug. 19	09	-21	9	-1	2	E90
20	Sept. 15	09	...	10	-1	2	E90
21	Oct. 6	18	7	6	14	4	...
22	Nov. 9	06	4	7	14	4	...
1980							
23	Feb. 6	12	9	7	-2	4	...
24	Apr. 2	21	...	7	18	4	...
25	June 7	15	16	7	19	4	...
26	June 24	06	3	5	11	1	E14
27	July 25	15	4	5	12	1	E17
28	Nov. 25	03	4	4	7	2	W20
29	Nov. 30	00	...	4	10	2	E63?
30	Dec. 19	09	4	6	12	3	W20
1981							
31	Jan. 29	12	5	7	14	4	...
33	Mar. 01	09	1	5	10	3	...
34	Mar. 05	09	3	4	10	3	...
34	Apr. 3	09	5	6	-1	2	W52
35	May 11	03	5	4	-1	2	E42
36	May 18	03	4	8	-1	1	E14
37	July 25	21	16	8	18	3	...
38	Aug. 10	06	2	5	-1	2	E25
39	Oct. 11	06	15	5	-1	2	E83
40	Oct. 14	00	1	8	-1	2	E31
41	Oct. 20	18	...	4	-2	3	...
42	Nov. 11	15	2	8	-2	1	E17
43	Dec. 29	15	10	6	10	1	E16

1982

44	Jan.	31	06	5	8	-1	2	E13
45	Feb.	12	00	9	6	14	3	...
46	Mar.	1	12	0	7	12	3	...
47	Apr.	24	18	-2	4	9	3	...
48	June	9	09	9	6	-1	2	E25
49	June	12	18	3	4	-1	2	...
50	July	11	15	5	6	-1	2	E76
51	July	13	18	2	19	-1	2	E36
52	Aug.	7	00	5	4	13	3	...
53	Sept.	6	03	4	9	18	1	E33
54	Sept.	21	09	5	8	25	1	E06
55	Nov.	24	09	0	7	-1	2	W36
56	Nov.	30	15	3	6	-1	2	W87
57	Dec.	10	09	2	6	-1	2	W86
58	Dec.	17	12	4	5	-1	2	E24
59	Dec.	27	12	5	5	-1	2	E45

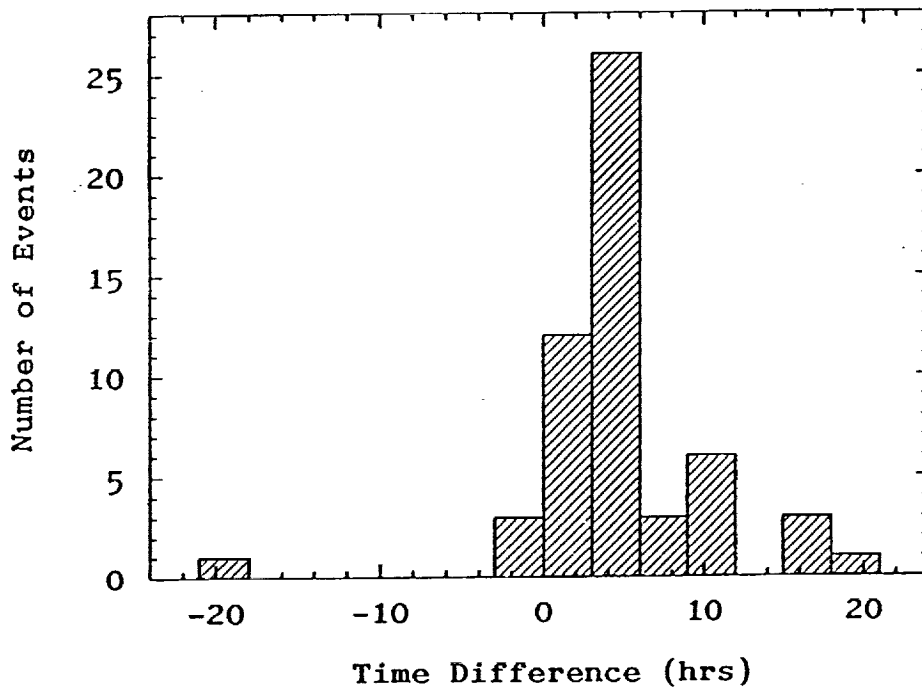


FIGURE 1



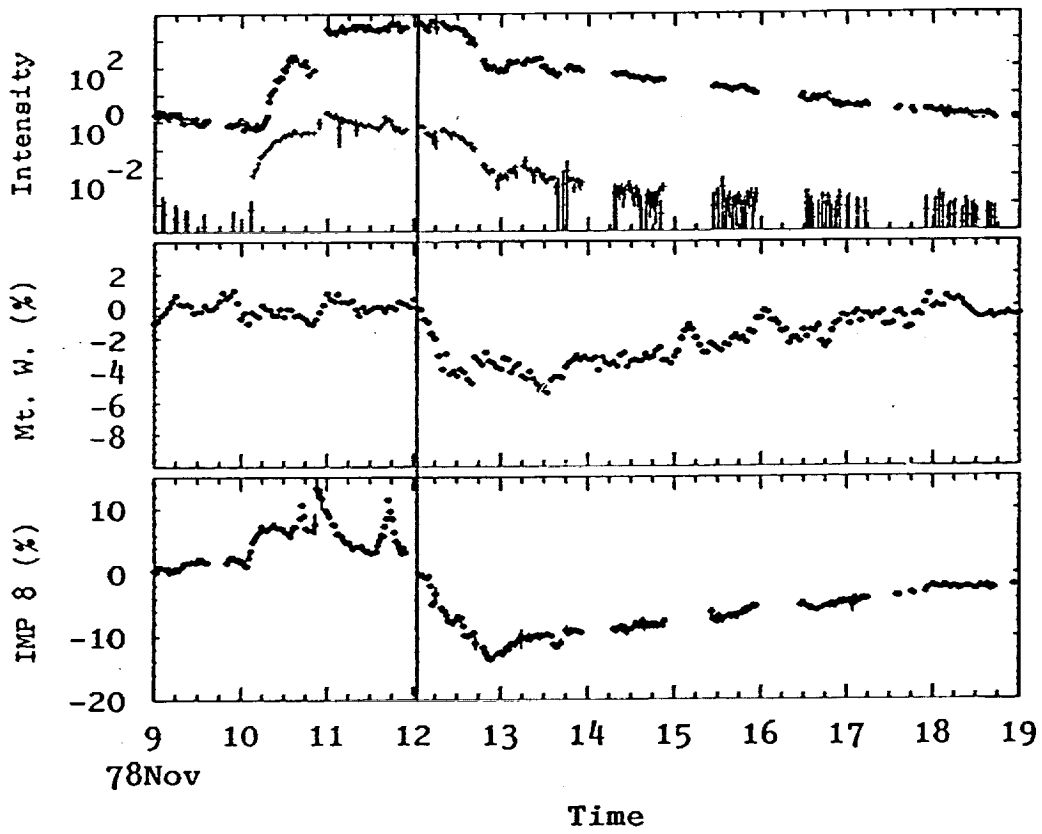


FIGURE 2

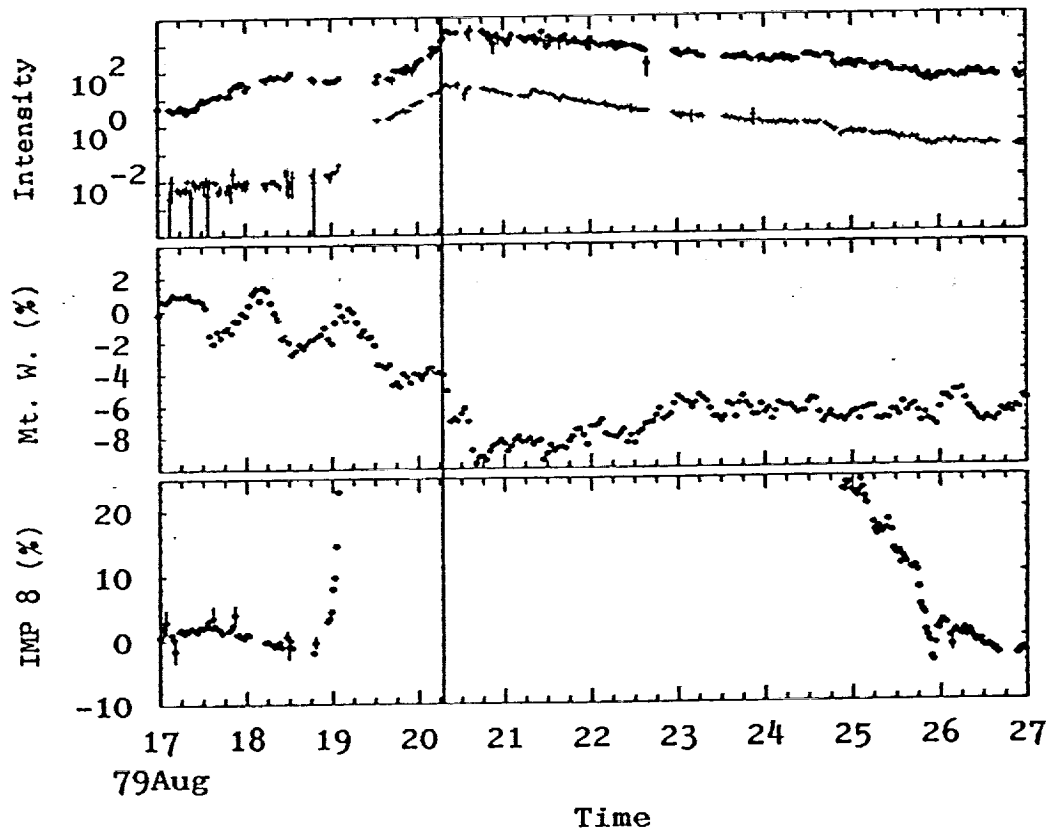


FIGURE 3

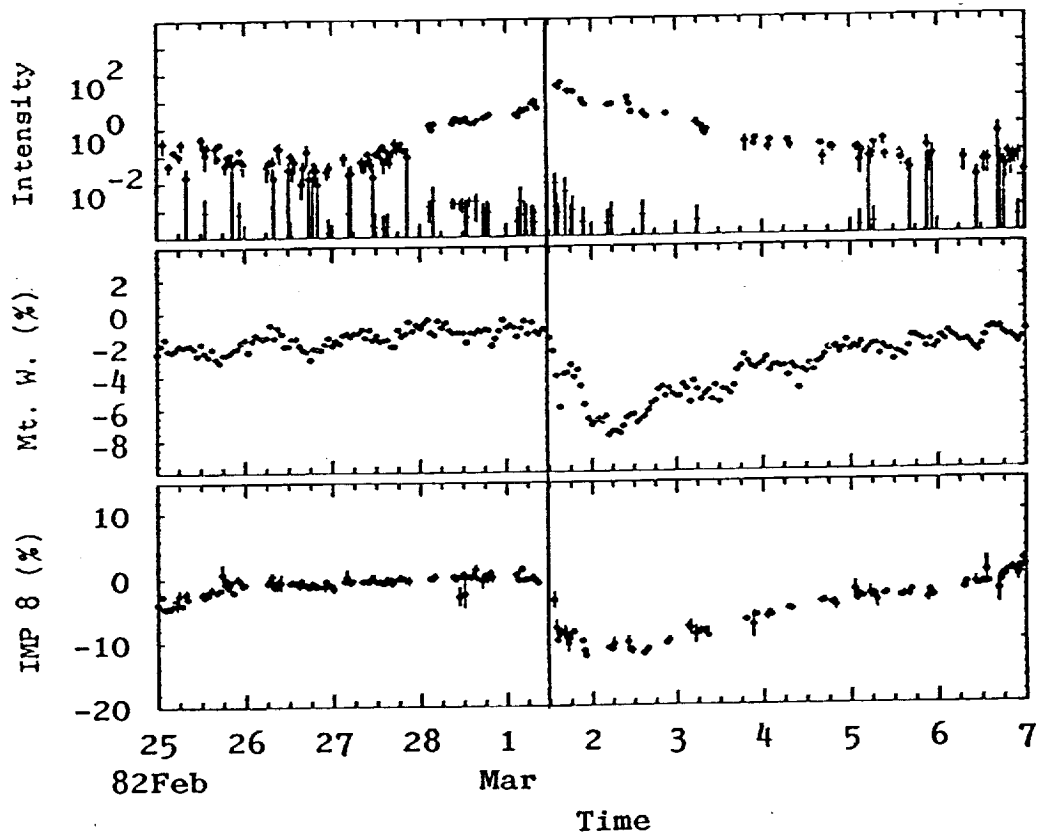


FIGURE 4

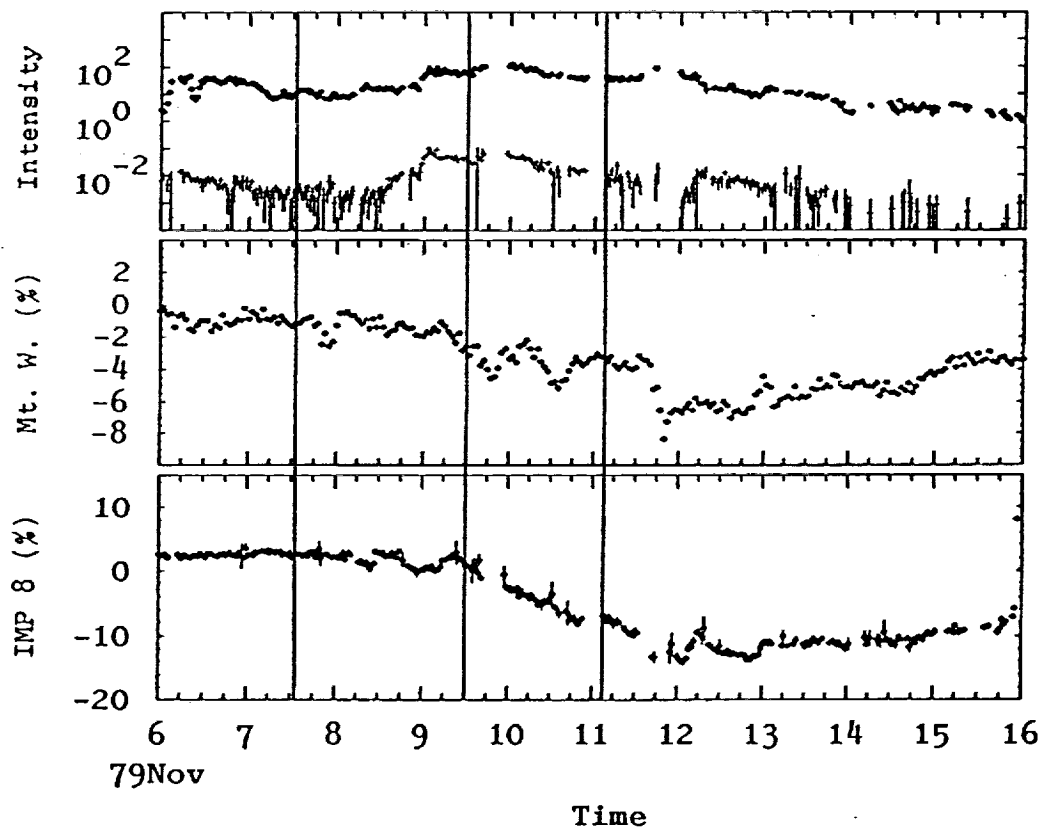


FIGURE 5



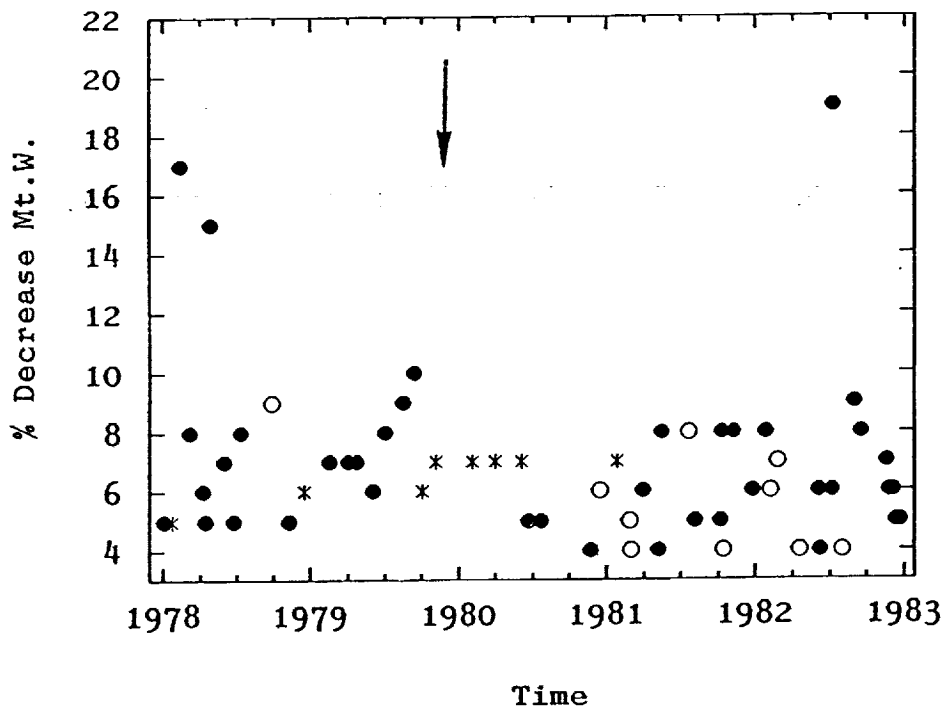


FIGURE 7

Quarterly Technical Report for 1 July to 31 September 1992

Brenda L. Dingus  
Task No. 660-035

I am continuing to develop the drift chamber tracking detector for AGATE. The construction of the 8 - 1/2 by 2 square meter frames has been completed. Four frames have three layers of 2 meter long wires, and the other four frames have only one layer of 1/2 meter long wires. The frames will be placed in a vacuum chamber that we have had built, and amplifiers and discriminators will be installed for each anode wire. The electronics is being tested on the 1/2 by 1/2 square meter frames. An alternative driver for the signals is being considered since the driver causes oscillations on the ground that are then being amplified. We have not yet been able to detect tracks from the 1/2 by 1/2 meter stack of drift chambers due to excessive noise.

The AGATE anticoincidence dome is composed of several very large pieces of plastic scintillator. The baseline readout system uses over 200 photomultiplier tubes. I have recently reviewed a proposal by RMD, Inc. to develop avalanche photodiodes to replace the photomultiplier tubes on the anticoincidence dome. Avalanche photodiodes require less power, are light weight, small, and more stable than photomultiplier tubes.

The results of some of my analysis of EGRET data were presented at the Washington University Compton Observatory Symposium. Godfreid Kanbach gave a paper about the solar flares observed by EGRET during June 1991, and Ping Kwok showed a poster about two gamma-ray bursts which were within the EGRET field of view. I was also a coauthor on several other EGRET talks which were presented. The papers for the symposium will appear in an AIP volume and will be submitted by the end of October.

I have begun writing a paper for Ap. J. on three high galactic latitude sources seen by EGRET which have positions consistent with flat spectrum, radio loud, active galactic nuclei. The 3 sources are 0454-463, 0202+149, and 1606+106. I have examined the data for evidence of time variability and am working on the energy spectrum for each object. The number of gamma-rays observed in all 3 cases is small, so the estimate of the statistical significance is especially relevant. After finishing this paper, I plan to search the EGRET data for evidence of sources which have been detected at energies above EGRET's threshold.

I have also submitted two abstracts for a meeting entitled "Astroparticle Physics and Novel Gamma-Ray Telescopes" which will be held in April 1993 in Orlando, Florida. The abstract titles are "The Advanced Gamma-ray Astronomy Telescope Experiment, AGATE" and "Detectability of Monoenergetic, GeV, Gamma-Rays based on Preliminary EGRET Measurement of the Diffuse Gamma-Ray Spectrum".

The following paper was accepted for publication.

"Observations of the Large Magellanic Cloud in High Energy Gamma Rays", P. Sreekumar, D.L. Bertsch, B.L. Dingus, C.E. Fichtel, R.C. Hartman, S.D. Hunter, G. Kanbach, D.A. Kniffen, Y.C. Lin, J.R. Mattox, H.A. Mayer-Hasselwander, P.F. Michelson, C. von Montigny, P.L. Nolan, K. Pinkau, E.J. Schneid, D.J. Thompson, accepted by Ap. J. Letters.

The following papers were submitted for publication.

"Detection of High Energy Gamma Rays for Quasar PKS0528+134 by the EGRET Telescope on the Compton Gamma Ray Observatory", S.D. Hunter, D.L. Bertsch, B.L. Dingus, C.E. Fichtel, R.C. Hartman, G. Kanbach, D.A. Kniffen, P.W. Kwok, Y.C. Lin, J.R. Mattox, H.A. Mayer-Hasselwander, P.F. Michelson, C. von Montigny, H.I. Nel, P.L. Nolan, K. Pinkau, H. Rothermel, E.J. Schneid, M. Sommer, P. Sreekumar, D.J. Thompson, submitted to Ap. J.

"The EGRET Detection of OVV Quasar 1633+382", J.R. Mattox, D.L. Bertsch, J. Chiang, B.L. Dingus, C.E. Fichtel, R.C. Hartman, S.D. Hunter, G. Kanbach, D.A. Kniffen, P.W. Kwok, Y.C. Lin, H.A. Mayer-Hasselwander, P.F. Michelson, C. von Montigny, P.L. Nolan, K. Pinkau, E.J. Schneid, P. Sreekumar, D.J. Thompson, submitted to Ap. J. Letters

*Brenda L. Dingus*

10/23/92



# HAMPDEN-SYDNEY COLLEGE

Founded 1776

DEPARTMENT OF PHYSICS

October 2, 1992

Dr. Donald A. Kniffen  
P.O. Box 862  
Hampden-Sydney, VA 23943-0862

University Space Research Association  
Visiting Scientist Program  
NASA Goddard Space Flight Center  
Greenbelt, Maryland 20771

Subject: Technical Activity Report

This report accompanies a consulting voucher for services provided under NAS5-30442 in Supporting the High Energy Gamma-Ray Telescope (EGRET) on the Compton Gamma-Ray Observatory, and a travel reimbursement request for a trip to the Goddard Space Flight Center to complete the subject activity. This report covers activities for the month of September 1992.

Activities during this reporting period involved attendance at the EGRET Team meeting held at the Goddard Space Flight Center on September 22-24 and preparations for this meeting on September 21, 1992. The principle activity of this meeting was the preparation of papers for submission in the near future involving Phase I results from the EGRET experiment. The consultant was also responsible for obtaining correction factors for calibration sensitivity values which have been updated using in-flight data.

Sincerely,

Donald A. Kniffen



September 3, 1992

Dr. Donald A. Kniffen  
P.O. Box 862  
Hampden-Sydney, VA 23943-0862

University Space Research Association  
Visiting Scientist Program  
NASA Goddard Space Flight Center  
Greenbelt, Maryland 20771

Subject: Technical Activity Report

This report accompanies a consulting voucher for services provided under NAS5-30442 in Supporting the High Energy Gamma-Ray Telescope (EGRET) on the *Compton* Gamma-Ray Observatory. This report covers activities for the month of August 1992.

Activities during this reporting period involved work accomplished at the Hampden-Sydney College, working remotely via a NASA Internet link. The activities fell into three major categories: (1) scientific data analysis, (2) performance monitoring of the EGRET instrument, and (3) review of the EGRET Guest Investigator involvement in Phase II and Phase III of the *Compton* Observatory Guest Investigator Program.

The data analysis work included development of a correction factor for correcting for an improper exposure in the lowest energies of the EGRET instrument. Upon completion of this work final work will be completed on the time variability in the gamma-ray emission from the source 3C279 discovered by EGRET as a gamma-ray emitter, and the manuscript submitted for publication. This will be followed by papers on EGRET observations of pulsars for the *Compton* Observatory workshop in St. Louis and a paper on gamma-ray emission from the globular cluster 47-Tucanae.

The performance monitoring included the continued supervision of a Hampden-Sydney College student to analyze the housekeeping data from the EGRET instrument. Analysis is done remotely from Hampden-Sydney College, by networking to the computers at the Goddard Space Flight Center.

The analysis of the Guest Investigator involvement consisted of a review of the Guest Investigator proposals to look for

possible conflicts or duplication between the proposed work of the Guest Investigator and work being accomplished by the EGRET team.

Sincerely,



Donald A. Kniffen

Donald A. Kniffen

To: Denise Dunn  
From: Dr. M. Corcoran  
Task No: 660-038  
Subj: 3rd Quarter Technical report, 1 Jul 1992 – 30 Sep 1992  
Date: 23 Oct 1992

ARCHIVE-SPECIFIC TASKS:

My duties as archive scientist involved the development of the ROSAT public archive in anticipation of its opening in October, and development of the new ROSAT Rationalized FITS file format which will be used to distribute/archive data processed by the new software system. My 3rd quarter activities in these areas are described below.

1) Public archive:

a) The data flow pipeline from the USRSDPC to the NSSDC has been implemented and successfully tested. The USRSDPC has successfully sent data to the NDADS staging area, and the NSSDC has successfully copied this data to optical disk. Automatic retrieval of the test data using ARMS was completed successfully .

b) The mechanism by which users can browse the list of distributed ROSAT data sets via use of the Mission Information and Planning System (MIPS) has been implemented. Use of MIPS to request ROSAT public data sets has also been tested successfully.

c) The mechanism by which users can browse the list of distributed ROSAT data sets using BROWSE has been implemented and successfully tested.

d) I've placed lists of public data in an anonymous FTP area for downloading by archive users.

e) I've assisted Peter Damon in writing the "public contents" file which needs to be generated for each data set before the data set can be archived by the NSSDC. Software is now in place to generate this file automatically.

f) I've written a draft of the ROSAT Public Archive User's Manual which will appear as an article in both the ROSAT and HEASARC newsletters.

g) I participated in discussions concerning the overall structure of the archive with representatives of the USRSDPC and MPE in September.

2) Rationalized FITS development:

a) Development of the rationalized FITS files (which will define the format in which data processed by the new processing software will be distributed and archive) is nearing completion. I have now provided file specifications for each of the 4 types of files (BASIC, ANCILLARY, CALIBRATION and DERIVED) associated with HRI and PSPC data.

b) Dave Bouler has written software to generate each of the 4 files for each ROSAT instrument. I am presently engaged in testing these files. Some minor problems have been identified and fixed.

C-2

c) I've re-structured the DERIVED file for both the HRI and PSPC by splitting the file into a number of separate components. Modification of the gatherer routine by Dave Boulder is set to begin.

## USER SUPPORT ACTIVITIES

1) I provided GOF support to the following guest observers in the 3rd quarter

Gayle Rawley  
Tim Heckman  
Lee Armus  
V. Tsikoudi  
Wayne Waldron  
Qingde Wang  
Raymond White  
Richard Pisarski  
Dennis Cioffi

2) I provided archive support to

Richard Thompson  
Stephen Unwin  
Peter Meszaros  
James Rose  
George Pavlov  
Michael Garcia  
Qingde Wang  
Jonghee Rho

in the third quarter.

2) Programming:

Below is a list of IDL programs written or updated in the 3rd quarter:

coverlay.pro - overlays contour map on image  
stretcher.pro - stretches image to specified dimension  
dft.pro - performs discrete fourier transform on time-sorted data  
ring.pro - draws ring at specified location in contoured image  
jd.pro - calculates julian date  
get\_list.pro - modified to read directly from FITS file  
mkatable.pro - outputs spectral table model in XSPEC "atable" format

## SCIENCE ACTIVITIES:

1) I presented a poster of a recent ROSAT observation of the Wolf-Rayet binary V444 Cygni at the COSPAR symposium "Recent Results in X-ray and EUV Astronomy" at the World Space Congress in Washington DC (28 Aug - 5 Sep 1992)

2) I am participating in a collaboration with J. Siah and E. Guinan at Villanova to observe the star HD229041 (which is possibly X-ray bright) with the Automated Photometric Telescope on Mt. Hopkins. Preliminary results suggest the presence of possibly periodic variability.

3) I've completed a draft of analysis of the X-ray spectrum of Zeta Pup obtained with BBXRT.

## PLANNED 4th QUARTER ACTIVITIES

- 1) Supervise opening of ROSAT public archive.
- 2) oversee development/testing of gatherer programs to produce rationalized FITS formatted files
- 3) write up results of ROSAT observations of V444 Cyg.
- 4) Attend "Back to the Galaxy Meeting" at U Md in October.
- 5) Present poster describing the format of the ROSAT Rationalized files at the ADASS conference in Boston in November.
- 6) Discuss ROSAT public archive at ROSAT Workshop in Boston in November.
- 7) Publish paper on BBXRT spectrum of Zeta Pup, and complete analysis of BBXRT spectra of Zeta Ori and EZ CMa.

## Technical Reports for July 1 through September 30, 1992

Hisamitsu Awaki

Code 666

TASK NUMBER : 660-040

In previous period, I tried to figure out the property of the X-ray telescope (hereafter XRT) using the a ray tracing program, and obtained nature of the XRT. In this period; we illuminated the XRT with a parallel X-ray beam at White Sands, New Mexico, and have evaluated the characteristics of the XRT.

First, we prepared the experiment, in particular, I took charge of the preparation of the flow counter monitoring the intensity of X-ray beam. The flow counter was delivered from Japan, and I adjusted it with Dr. Tsunemi who is assistant professor at Osaka University.

We carried out the experiment with MIT and NIST from August 15 through to October 10, and I joined it in twice, from August 15 through to August 22, and September 9 through to September 23. During first two weeks, we set up equipment, and the XRT was calibrated using a monochrometer and an X-ray CCD detector from the beginning of September.

Now, we are analyzing data taken at White Sands. I am interested in the effective area around gold edge. I compared them from the results of a ray tracing, and try to reproduce the data, adjusting the optical constant in the ray tracing.

In addition, I present my paper entitled "Ginga observations of Seyfert Galaxies" at COSPAR Symposium in Washington D.C. in stead of Prof. Koyama. This is a summary of Ginga observation for Seyfert 2 galaxies. We found that in general the observational results are consistent with the prediction of unified Seyfert model proposed by Antonucci and Miller.

In next period, I will evaluate the image quality of the XRT, and would like to investigate how to reproduce real data. Using simulation-data, I would like to study the image restoration technique.

Universities Space Research Association  
Foreign Travel Report - 17 September, 1992

Gregory Pike  
NASA/GSFC  
Code 666  
301-286-3565

During the period September 14-17, 1992 I attended the Astronomy from Large Databases II conference in Strasbourg/Haganeau, France. The conference was designed to allow scientists with large databases to present results and demonstrate the capabilities of their algorithms.

The ALD-II conference allowed me the opportunity to perform a number of tasks. First, I presented the latest results from the IUEAGN database, including our recent BL Lacertae continuum survey and PKS 2155-304 micro-variability study. The database project itself received general exposure to the scientific community. Finally, I was able to update myself on the latest products available to database designers and how these systems have been implemented in other projects such as NED and SIMBAD.

In addition to database design, ALD-II focussed on specific data sets, including *ROSAT*. This was especially informative since I will be developing a database of *ROSAT* spectra in the coming months.

667-246

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
VISITING SCIENTIST PROGRAM  
QUARTERLY TECHNICAL REPORT  
JULY 15, 1992 - AUGUST 14, 1992  
RUPALI CHANDAR

Since arriving here at the end of October 1991 my main programmatic responsibility has been to finish cleaning of the CMA database and produce a catalogue of point sources detected by the 3 - lexan filter of EXOSAT. We have discovered numerous problems with the database and the preliminary catalogue that was created from it. Most of these have been fixed now and we are ready to recreate the database and see what problems still remain to be corrected. All the images included in the preliminary catalogue have been assigned a classification and put into the appropriate sample. There are a total of six classifications:

1. POINT SOURCES - good sources which will go in the catalogue and have correct count rates and position.
2. PSF problem sources - point sources that were detected far out in the detector and have incorrect count rate and position
3. GOOD SOURCES THAT ARE EXTENDED such as supernova remnants, clusters, etc
4. MARGINAL entries - there are 420 of these out of 3956 total entries. These are images where a detection is made, but there is no definite source in the region. These will probably be added on as an appendix to the point source catalogue
5. SPURIOUS detections. These include images that put in unreal sources due to detector problems, such as grating or a pixel stripe, and extra detections of extended emission from a large nearby source
6. CALIBRATION PROBLEMS - this includes the CYGNUSX-2 field (raster scan) and the HZ43 field where the position of the source was not updated, resulting in several entries for a single source.

These different entries will receive classification numbers ranging from 0 to 6 which will make recreation of a cleaned catalogue easier.

The time since July 15th has also been spent writing down exactly what has been done to the database and the catalogue. The above samples have been written down in text files, and we have begun to write a paper of the steps taken to locate the problems and the correction measures applied afterwards. We do plan to continue to work to finish up the catalogue of point sources. Also being continued is work on the images from the aluminum paralene filter.



**Technical Report**  
Robert J. Nemiroff  
1 July 1992 to 31 September 1992

The third quarter of 1992 was one of writing papers, supervising graduate work, and carrying out research. Research topics I participated in included investigation of gravitational effects near neutron stars and black holes, investigation of potential cosmological effects on gamma-ray bursts (GRBs), and searching for possible echoes in GRBs caused by gravitational lensing.

I continued to research how gravitational lens effects distort the appearance of a high gravity environment, such as near a neutron star or black hole. I have now completed a paper on this subject and submitted it to the American Journal of Physics. I also continued to research what visible effects a neutron star would show if it had an ultracompact equation of state. I have been collaborating with Peter Becker and Kent Wood, both of the Naval Research Laboratory on this subject. We have submitted a paper on this subject to The Astrophysical Journal. This paper has been accepted.

I continued a research project of which I was a co-investigator in a Phase 2 *Compton* Gamma Ray Observatory proposal - searching for direct lens echoes in gamma-ray burst data. I spent more time deciding which mathematical tools would best show this and coding these tools onto a VAX computer in FORTRAN and IDL. This research is not yet complete, however some preliminary results are in. All GRBs within 20 degrees of each other that triggered on the *Compton* Gamma Ray Observatory satellite before 21 July 1992 were compared for gravitational lens echoes. No lensing echoes have yet been found, although comparisons are ongoing. Preliminary indications are that a non-detection of echoes inside the first 49 GRB time profiles significantly constrains the type and abundance of dark matter in the universe. Specifically, the non-detection translates into a probability that compact dark matter with mass between  $10^6$  and  $10^7$  solar masses cannot have an abundance of closure density. Research in this area is ongoing and results are being written up into papers.

I continued to help supervise the graduate work of Thulsi Wickramasinghe from the University of Pennsylvania. He has visited NASA/GSFC five times now, twice in this quarter. We continue to discuss how gravitational lensing could be seen in gamma-ray burst data. We also continue to investigate what cosmological redshift distribution is implied by the number counts of gamma-ray bursts of different brightnesses. Thulsi continues to excel in research in this area.

During the fourth quarter of 1992, I plan to continue to fulfill the research objectives outlined in the description of the position that I was hired to fill. This will include studying more about GRBs, gravitational effects detectable in the universe, and detectable gravitational effects on GRBs.

**Quarterly Technical Report**  
(1 July - 30 September 1992)

Name: Wan Chen  
Position: Research Associate  
Task Number: 5000-643  
Date: 25 October 1992

Travel : 10-12 September 1992, Convention center, D.C., COSPAR meeting.

Work accomplished: An Interpretation of the Narrow Positron Annihilation Feature from X-ray Nova Muscae 1991, Wan Chen, Neil Gehrels, and F.H. Cheng, submitted to ApJ, Letters, in 14 August 1992, and the revised version in response to the referee's report in 25 September 1992.

Work in progress and planned:

- (1) Modeling the secondary maximas in the X-ray and UV light curves of X-ray novae A0620-00, GS2000-25, Nova Muscae 1991, and GRO J0422-32. Data show that in these black hole candidates, the normal light curve, an exponential decay of time scale of about 30 days, has always a second maximum around 50-80 days after the outburst. We are trying to model such brightening by increased mass overflow from the secondary due to X-ray heating of the inner Lagrangian point in the late stage of the decay phase when the accretion disk becomes optically thin. This work is in collaboration with Dr. Mario Livio in Space Telescope Science Institute.
- (2) Companion in the Galactic center hard X-ray source 1E1740.7-2942. It has been great difficulty in trying to find the optical counterpart of this source. The IR search in the Galactic center region has always failed to reveal any point source in the radio position or X-ray error circle. We use the reported I-, K-, and L-band upper limits to place a severe limit in the luminosity and spectral type of the possible companion on the HR diagram. The companion has to be a late type dwarf or subgiant. But the X-ray light curve has shown some long-term variability. We are investigating the possibility that binary accretion from a late type dwarf companion to produce such long-term variabilities. A possible explanation is the magnetic solar-cycle type of variability from such stars.
- (3) Instabilities in Bondi-Hoyle type of accretion systems. The long-term variability from the Einstein source 1E1740.7-2942 may also be due to the instabilities in the Bondi-Hoyle accretion if the source is accreting directly from the surrounding molecular cloud. Such an instability may be the result of the X-ray heating of the cloud material near the source. The heating creates a cavity and so turns off the accretion. Low accretion will cause the X-ray radiation drop and the accretion can then restart. We are carrying out theoretical calculations to see if this can work.
- (4) A trip is planned to go to Toulouse, France, to work with SIGMA team on the Nova Muscae black hole mass, 1E1740.7-2942 light curve, GRO J0422-32 possible positron annihilation line data.
- (5) Model the broadband spectrum from stellar black hole accretion disk system X-ray Nova Muscae 1991 and Cen X-4.
- (6) Publish my thesis results.

## USRA Technical Report (3rd Quarter, 1992)

Helmut Seifert (Task Number: 660-044)

### Task Description:

I have been leading the Transient Gamma-Ray Spectrometer (TGRS) data analysis and Ground Support Equipment software development, and am responsible for writing the software requirements/specifications and documentation. I am furthermore designing and testing the algorithms which are being used by the software. Similar work is done by me also for the KONUS instrument. I am taking an active part in the laboratory testing of the TGRS analog/digital flight electronics and software. I am responsible for formulating and conducting all the instrument tests and calibrations during the integration and calibration phase of TGRS.

### Activities:

In July, August, and the first two weeks of September 1992 I was working in the laboratory on the characterization and calibration of the TGRS detector and electronics. For these activities TGRS was in flight configuration, complete with our recently delivered Ge detector (in Al module), front-end, and analog/digital electronics. The detector performs well and we obtain about 4 keV (@1 MeV) resolution.

From 14–16 September 1992 I lead the team which delivered the TGRS electronics to GE Astro in Princeton, NJ. We successfully performed the Bench Acceptance Test and also verified the performance of the GE flight harnesses.

In the time of 17–30 September 1992 I calibrated the detector efficiency using the engineering analog and digital electronics, and in the week of 5–9 October I supervised work on the TGRS Operational Test Fixture (OTF). We installed a fixture which can hold a radioactive calibration source for future use.

From 14–17 October 1992 I attended the Compton Gamma-Ray Observatory Symposium in St. Louis, MO, where I presented a poster paper on the TGRS instrument. During the same time the detector was cooled down again to cryogenic temperatures.

In the week of 19–23 October 1992 more efficiency calibrations were performed in the laboratory. At the same time, I made preparations for various work to be done on the flight radiative cooler after 26 October 1992.

In parallel to all the aforementioned activities, I could complete two software requirements and specifications documents for TGRS and KONUS. The TGRS document deals with software which will generate count time-histories for various data-types. The KONUS document deals with the software which will read/decode the raw telemetry data, extract/sort the data by type, and manage them in a data base.

In the next few weeks there will be more data analysis software development, and on or about 18 November 1992 I will again lead a team which will deliver the TGRS detector/cooler assembly to GE Astro in Princeton, NJ. In the following months I will participate in the various environmental tests at GE.

(U) [unclear]

6660-042  
(6660-030)

**James Lochner**  
**LHEA Office for Guest Investigator Programs**  
**Code 668.0**  
(Activity 5000-646)

**3rd Quarter Report, 1992**

From 1 July through 30 September 1992, Dr. Lochner spent considerable effort on the Guest Observer Facility (GOF) for the X-ray Timing Explorer (XTE). The GOF is part of the Science Operations Center (SOC) managed at Goddard by the X-ray Astrophysics Group (Code 666.0). Having defined the XTE GOF requirements in the previous quarter, Dr. Lochner spent the third quarter collaborating with other SOC members on the development of the SOC software architecture, the construction of a software build plan, and preparing for presentations at the SOC Preliminary Design Review on Sept. 3 - 4.

The software being developed in the SOC for science operations and analysis utilizes an object oriented architecture. Of the many software subsystems being designed, Dr. Lochner has concentrated on the Data Analysis, Calibration and Proposal subsystems. The goal is to achieve completeness in meeting the requirements and allow flexibility as knowledge of the instruments and new analysis techniques develops. During this time, strawman designs were put in place so that a common framework could be developed. By doing this, the design team recognized those subsystems which would entail greater complexity than originally thought. The goal for the next quarter is to put in place realistic designs.

Dr. Lochner also headed up the effort to construct a development plan for the SOC software. Dividing the software into subsystems, each subsystem undergoes a staged development up to and beyond the XTE launch in Aug 1996. This staging puts the fundamental architecture into place early, and successively enhances the capabilities. This approach insures that the software necessary to support operations is in place long before launch.

Considerable effort was spent preparing for the SOC Preliminary Design Review (PDR) on Sept 3 - 4. The month of August was spent participating in reviews and dry runs to prepare for the presentation. At the PDR, Dr. Lochner presented the SOC's design of the Analysis and Calibration software architecture, and of the software build plan. It is anticipated that in the next quarter, Dr. Lochner will formulate appropriate responses to the concerns of the PDR review team.

Dr. Lochner also organized and presided over two of the software interface meetings between the SOC and the instrument teams from MIT, UCSD and GSFC. During the third quarter, these meetings were held at Goddard July 13, Aug 13 - 14, and Sept. 24, with Dr. Lochner presiding

over the latter two. These meetings, which are held regularly, provide opportunities for the SOC and instrument teams to discuss software interfaces and shared responsibilities which must be further delineated. In particular, the meetings during this quarter were important in laying out the framework of the software design, and describing the areas in which the instruments teams are expected to contribute to the software design. We have also discussed common issues such as selection of a data base management system, base class libraries, software development standards and quality assurance standards. Dr. Lochner will continue organizing these meetings into the next quarter.

In other areas, Dr. Lochner has continued to be available to Dr. Laura Whitlock to provide assistance in the HEASARC All Sky Monitor effort. He has continued to share his own plans and ideas which he had developed for the *Vela 5B* and *Ariel 5* data before shifting his effort to XTE. He and Dr. Whitlock wrote an article for the HEASARC journal *Legacy* describing these data and their availability through the HEASARC.

With Dr. Whitlock, Dr. Lochner also continued the investigation of long term trends in galactic X-ray sources using the *Vela 5B* data. They examined the data for the sources in the Small Magellenic Cloud, finding transient events in a HEAO-1 A1 source. They also initiated an investigation into a suspected systematic trend in the *Vela* data due to the satellite's 300 day precessional period. They also continued the routine investigation the *Vela* data for previous outbursts of new transients sources identified in the Circulars of the International Astronomical Union.

Finally, this third quarter saw publication of Dr. Lochner's work with Dr. Alan Smale on a *Vela 5B* study of long term variability in low mass x-ray binaries (Ap.J. 395, 582)

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## Report of activity for the period July - September 1992 - Ivan HUBENY

During this period, I have worked on extending newly developed numerical techniques for calculating very sophisticated model atmospheres of hot stars. Together with Dr. T. Lanz (NRC fellow), we have calculated many non-LTE model stellar atmospheres including effect of tens of thousands spectral lines (the so-called non-LTE line blanketing), using our previously developed concept of non-LTE opacity distribution functions. First results have been presented on the IAU Colloquium No. 138 in Trieste, and several papers are in preparation and are expected to be submitted soon.

I have worked with Dr. D. Mihalas on a third edition of the textbook "Stellar Atmospheres". We have prepared a detailed outline of a completely changed book, taking into account all recent developments.

I have also worked at the NCAR with Drs. B. Lites and P. Judge on radiative transfer with partial frequency redistribution.

I have collaborated with researchers from Space Telescope Science Institute and Johns Hopkins University on model atmospheres for white dwarfs in some cataclysmic binary systems.

### *Trips accomplished:*

1) July 4 - 11, Trieste, Italy - IAU Colloquium No. 138 "Peculiar versus Normal Phenomena in A-type and Related Stars"; presenting two invited papers there.

2) July 24 - August 24, Boulder, CO (HAO NCAR and JILA); collaborating with Dr. D. Mihalas on writing a third edition of the book "Stellar Atmospheres", and collaboration with Drs. B. Lites and P. Judge on radiative transfer with partial frequency redistribution.

### *Papers published:*

1) Hubeny, I., Lanz, T., 1992, "Accelerated Complete Linearization Method for Calculating non-LTE Model Stellar Atmospheres", *Astron. Astrophys.* 262, 501.

### *Papers submitted:*

1) Hubeny, I., Lanz, T., 1992, "Modeling A-type Atmospheres: NLTE Models", in *Peculiar versus Normal Phenomena in A-type and Related Stars*, Ed. by F. Castelli, M.M. Dworetzki, and R. Faraggiana, (in press).

2) Lanz, T., Hubeny, I., 1992, "Spectral Diagnostics of Chromospheres and Winds in A-type Stars", in *Peculiar versus Normal Phenomena in A-type and Related Stars*, Ed. by F. Castelli, M.M. Dworetzki, and R. Faraggiana, (in press).

### My plans for the next three months include

i) I will continue the work on NLTE line blanketed model atmospheres, in collaboration with Dr. T. Lanz. We expect to submit at least one, and hopefully two, papers to *Astronomy and Astrophysics*. Some results will also be presented at the AAS meeting in Phoenix.

ii) I will continue my work in theoretical analysis of hot stars, in collaboration with Drs. Sally Heap and Bruce Altner from the GHRS group in Goddard. In particular, the work will continue on interpreting the HST/GHRS spectra of the hot subdwarf BD+75 325; the first results will be presented at the AAS meeting in Phoenix.

iii) I will continue to work with researchers from Space Telescope Science Institute (groups of Drs. K. Long and K. Horne) on model atmospheres for solar-composition white dwarfs which are found in some cataclysmic variable systems, observed by Hopkins Ultraviolet Telescope and Hubble Space Telescope. Some results will be presented at the AAS meeting in Phoenix.

iv) I will continue to work with Dr. M. Plavec (UCLA) on models of accretion disks and helium-rich stellar atmospheres.

### My travel plans include:

i) December 7 - 17, University of California, Los Angeles: collaboration with Dr. M. Plavec on theoretical modeling of spectra of accretion disks in the Algol and W Serpentis classes of close binary systems, and on helium-rich model stellar atmospheres.

JAMES BIGGS

### QUARTERLY TECHNICAL REPORT

1 July 1992 - 1 September 1992

Hubble Space Telescope High Speed Photometer (HSP) activities have dominated my time in the past quarter. I have been heavily involved in the analysis of Crab pulsar data acquired with the HSP in October 1991 and January

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1992 (see 1/1/92 - 3/31/92 and 4/1/92 - 6/30/92 quarterly reports). One of my main activities was assisting Dr J. F. Dolan (NASA/GSFC) in the analysis and writing up of these observations for publication. The results of our study have been submitted and accepted for publication in the Astrophysical Journal.

Other HSP activities included analysis, on the NCCS CONVEX mini-supercomputer, of approximately 23 million samples of broad-band UV SN1987A data. These data have undergone Fourier analysis, and so far no significant sinusoidal or pulsar-like signal from the proposed remnant pulsar has been found. These observations are far more sensitive than any from the ground, and the upper limit is approximately 31st magnitude. Similar analysis of data collected over 4 months from the eclipsing dwarf nova Z Cha only found periodicities associated with the length of the individual observations, and the time interval between observations. Observations from the high-mass X-ray binary Cyg X-1 were searched for signals from matter infalling onto its proposed black hole. No signals were found, other than that associated with data corruption. The Space Telescope Science Institute (STScI) was notified about this problem. Also, in this quarter I assisted Dr Dolan in the extraction and reduction of polarization calibration observations.

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ROSAT data acquired for two old, but rapidly rotating, pulsars was analysed at the ROSAT data analysis facility at NASA/GSFC. No signals were detected from the pulsars, but useful constraints on their emission were obtained. Other sources, however, were found in the observations, and work is proceeding in order to find more information on them.

In the middle of July 1992, I travelled to the NRAO 140 foot radio telescope at Green Bank, WV, for an observing session in a collaborative project with Dr C. Salter (NRAO) and Dr R. Foster (NRL) in which we are monitoring HI absorption in radio spectra. The observations were a success. So far, we have reduced all the data acquired and have produced absorption spectra for our selection of pulsars of similar, or higher quality, than those



published in the literature. We have also finished a draft of a proposal to observe the HI absorption spectrum of nearby pulsars with the 140 foot telescope at Green Bank.

A paper entitled "PSR 1718-19: A long-period pulsar in an eclipsing binary system" on which I was a co-author with Drs A. Lyne, P. Harrison and M.

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Bailes (University of Manchester) was submitted to Nature. Also, my paper entitled "Analysis of Radio Pulsar Statistics" was published in the August 10, 1992 edition of the Astrophysical Journal. Work on a paper with Drs M. Bailes and A. Lyne (University of Manchester) concerning two radio pulsars I discovered at my previous job is nearing completion.

The Directors Discretionary Proposal (submitted last quarter) to use the HSP to find pulses from the Geminga pulsar was accepted and awarded 1.5 hours observing time by the STScI. Other proposals submitted to STScI on which I was PI were: "A search for optical pulses from globular cluster radio pulsars" with Dr J. Dolan (NASA/GSFC) and Dr W. vanCitters (NSF), and "Phase-resolved UV spectrophotometry of the eclipsing pulsar PSR 1957+20" with Dr S. Shore (CSC). Also, I am a co-I with Drs A Michalitsianos and J. Dolan (NASA/GSFC), and Dr M. Perez (CSC) on a proposal entitled "HSP observations of MWC 560".

James Biggs

10 September 1992

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This quarter, I have been working on documentation for the COBE project. The documents include the Cosmology Data Analysis Center (CDAC) Orientation Handbook, the COBE Guest Investigator System (CGIS) User's Guide, and the Guest Investigator (GI) Handbook. Most of my time has been spent on the CGIS User's Guide. This document is meant to be a tutorial for the CGIS interface, UIDL, and UIMAGE. I was first responsible for writing the section on UIMAGE, the COBE menu-driven software. To do this, I became very familiar with UIMAGE, its capabilities, problems, and areas which may be improved. I report the problems that I find with the new system so that they can be addressed. We are now in the final stages of completing the User's Guide so it can be presented at the October SWG meeting. Once this version is finalized, we will put it on-line so users can access it via the CGIS software. This will involve converting the text and graphics files from WordPerfect to ASCII and then implementing the document into the interface. When the CDAC Handbook is completed, it too will be converted to ASCII and put on-line for access through the CGIS software.

During this quarter, I was also involved in some of the CGIS interface development. I aided in the software conversion from JAM to IDL; this involved changing the menus and text screen files and finally conducting an interface "shakedown" to see that everything was properly installed.

A draft of the Guest Investigator Handbook was partially completed. This will be the visiting scientist's guide to the surrounding area and a brief overview of the CDAC facility.

My non-local travel included travelling to Pittsburgh in order to relocate.

CELINE GRODEN  
NASA/GSFC CODE 6853  
CDAC  
COMMERCE CENTER II

Universities Space Research Association  
Visiting Scientists Program  
Technical Report for Third Quarter 1992

Employee Name: Alan Kogut

Activity: 5000-821

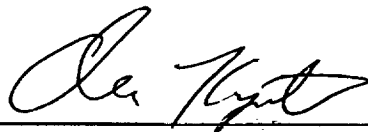
My major effort for the period July 1 -- September 30, 1992 has been analysis of data from the Differential Microwave Radiometers (DMR) experiment aboard the Cosmic Background Explorer (COBE). Sky maps produced from the first year of data show significant structure in the microwave sky at levels consistent with predictions based on structure formation through gravitational collapse. I am a co-author on 3 papers in The Astrophysical Journal describing these results and first author on a fourth paper describing the analysis of systematic artifacts in the first-year maps.

I have continued efforts to quantify the anisotropy in the first-year maps, concentrating on limits to isolated point sources. The number density of such point sources can limit non-Gaussian contributions to the microwave anisotropy, providing a test of various theories predicting anisotropy at roughly the level found in the maps. I am also the first author on a paper describing in detail the DMR observations of the dipole anisotropy and implications for large-scale velocity flows in the Universe.

DMR has continued to take data; there are now nearly three years of data "in the can". The increased sensitivity provided by multiple years requires a more sophisticated understanding of weak instrumental effects in the data stream, while the increase in the size of the data set requires a faster system to make maps in timely fashion. I have assumed a leading role in preparing a new software analysis system to create new sky maps from the 2- and 3- year data set. A major emphasis is the instrument calibration. I have analyzed the multi-year data set for evidence of drifts in the existing calibration and will incorporate the results into a new set of calibration algorithms.

I have continued investigations of the spectrum of the microwave background. I attended the Second School for Astrofundamental Physics in Sicily to present an invited talk reviewing the current status of CMB spectral measurements, including COBE-FIRAS and recent ground-based measurements from the South Pole. I gave a similar talk to the cosmology seminar at Goddard Space Flight Center. I am Principal Investigator on a proposed Small Explorer satellite designed to measure the CMB spectrum to 0.1% precision and the large-scale anisotropy to  $\Delta T/T \sim 10^{-6}$ .

During the next quarter, I plan to complete analysis and implementation of the multi-year DMR calibration. I will submit a paper on the DMR determination of the dipole anisotropy to The Astrophysical Journal, and will continue to investigate point sources and non-Gaussian structure in the one-year DMR maps.



OCTOBER 20 1992

Quarterly Report for A.J. Banday, Activity: 5000-821,  
July 1 - September 30 1992.

Most of my time for the last 3 months has been devoted exclusively to providing support for the COBE space project.

In particular, I have completed my analysis of the eclipse effect and found that a promising means of correction is to use a linear combination of 2 spacecraft housekeeping signals (one corresponding to temperature variations, one to voltage variations during the spacecraft orbit) to remove an apparent baseline variation in the observed differential temperature measurements. This correction applied to the 31 GHz radiometers removes the spurious magnetic coefficients found in the absence of correction to about 70% to be within the month-to-month variations seen in the other channels, and thus the correction may be usable. I continue to monitor the effect, and when time is available try alternative methods of correction.

I have carried a comprehensive comparison between the COBE DMR results and the RELICT1 satellite in the light of their recent claim of detection of cosmic anisotropy in their 37 GHz map after a reanalysis. Having treated the DMR maps in exactly the same fashion as the RELICT1 map, I can confirm that there is no cosmologically significant structure in the COBE maps at the level claimed by the Russian group. This work is intended to be published, and I am currently working on the manuscript.

I have continued to study the effect of incomplete sky coverage and noise on the systematic fitting of quadrupoles to the DMR maps. This may be extended to higher order multipoles in order to check fits to power spectra. This is still in progress.

I have begun to assist Dr Gary Hinshaw in correlating the DMR maps with extragalactic source catalogs at both radio (5 GHz and 1400 MHz) and infra-red frequencies (IRAS point source catalog at 100 microns). It seems that there is little evidence for correlation between the DMR maps and the radio catalogs, which allows a limit to be placed on the contribution of known extragalactic radio sources. Work continues with the IRAS correlation. I have also begun to consider updating the theoretically expected contribution from unresolved discrete radio and IR sources using new deep source counts. I do not expect the limits to change significantly, and the contribution to the DMR maps should be at the 1 - 2  $\mu$ K level.

As my newest DMR project, I have begun to look at the systematic effects which may be present in the maps due to on-board magnetic effects from the spacecraft torquer-bars (used for attitude control). This will be one of my major projects for the next few months.

I continue to collaborate with Dr Bob Nichol of Northwestern University, IL in investigating the Edinburgh/Durham Southern Galaxy and Cluster Catalog.

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#2 26-OCT-1992 18:00:09.11  
From: SMTP%"dc@cobi.gsfc.nasa.gov"  
To: usra@nssdca  
CC:  
Subj: Third quarter progress report

NEWMAIL

Date: Mon, 26 Oct 92 17:58:40 -0500  
From: dc@cobi.gsfc.nasa.gov (Dave Cottingham)  
Message-Id: <9210262258.AA13941@cobi.gsfc.nasa.gov>  
To: usra@nssdca  
Subject: Third quarter progress report  
Cc: dc@cobi.gsfc.nasa.gov

USRA Progress Report  
Third Quarter 1992

David Cottingham

Progress this quarter:

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The FIRAS calibration pipeline has produced numerous new versions of the calibration dataset and I attempted to repeat my earlier analysis on these new datasets. These attempts turned up a variety of defects in the datasets, which led the pipeline maintainers to fix a number of bugs in their software. All of the datasets produced during this quarter proved defective in one way or another. (Since the end of the quarter the pipeline has produced a dataset which appears to be bug-free and we are progressing toward a new set of model solutions.) In addition, Fixsen found and corrected an error in the calculation of the sigmas in the old calibration dataset; in rerunning the fit to the instrument model I found that the reduced chi-squared on this data ranges from 2 to 8, where we previously believed it to be in the range 1 to 4. Thus we find that the previous good fit to this data was an illusion. The badness of fit seems to be due to inadequacies in the bolometer model, which will not affect the calibrated sky signals.

I began extending earlier work by E. Cheng on characterizing the non-linearity of the DIRBE detectors by examining the results of a pre-flight test of the internal reference source (IRS). I have

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repeated this work with newly refined measurements of the channel bandpasses. I have attempted to include the effect of the fused quartz filter which is in front of the IRS, which was ignored in the

earlier work. The data on this filter is unfortunately rather sparse. This work is continuing.

We completed a preliminary analysis of the data from the first flight of the far-IR balloon borne telescope. We have analyzed about 7% of our data and can already place competitive limits on anisotropy in the cosmic microwave background. In this effort I performed the Monte-Carlo statistical analysis for placing bounds on rms fluctuations under various hypotheses about the correlation function of the anisotropy.

Work planned for next quarter:

We are finishing up several papers on the calibration of the FIRAS and on the spectrum of the CBR and dipole anisotropy for submission in January. I am directing the effort to validate these results.

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The development of the FIRAS calibration method will continue. Hopefully we will produce a validated set of calibrated sky maps this quarter.

The analysis of the non-linearity of the DIRBE detectors will be completed next quarter. I will re-analyze the IRS runs under various assumptions about the passband of the Suprasil filter, and, if it seems warranted, will take new measurements of the filter. I will also repeat this analysis with some in-flight IRS data to check that the results are consistent with the pre-flight data.

At present we are planning a new flight of the far-IR balloon borne telescope in the spring of next year. Work will continue on refurbishing this instrument. We hope to complete the analysis of the data from the first flight and begin preparation of a paper on the results.

## RESEARCH ACTIVITIES

(July 1 - September 30, 1992)

Takeshi Namioka

(Task No. 680029)

In the last quarter I derived analytic formulas needed for the design of a deformed ellipsoidal grating. These formulas are capable of minimizing aberration coefficients in the light path function over a given wavelength range. The formulas thus derived are applicable to most design purposes, but they lack the capability of balancing aberrations which is essential to the design of highly sophisticated spectroscopic grating instruments. In order to overcome this shortcoming, I have developed a rigorous third-order aberration theory of the deformed ellipsoidal grating with variable spacing and curved grooves. The theory is based on the exact ray-tracing theory and gives analytical expressions for spectral images formed on a flat or a cylindrical image plane. With the help of a merit function developed for the deformed ellipsoidal grating, the present aberration theory enables one to balance the aberrations as a whole, yielding the truly optimized ruling or holographic recording parameters.

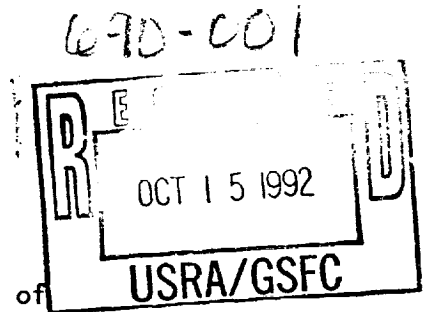
In view of practical difficulties in polishing and testing a deformed ellipsoidal blank to the required accuracy, I have started to investigate the possibility of achieving the required resolution without using deformed ellipsoidal blanks. One approach to the solution is the use of an ellipsoidal holographic grating produced by means of aspheric wavefront recording. The effort, therefore, has been directed toward derivation of an analytic expression for the groove pattern recorded with two aspheric waves generated by reflection of two spherical waves from respective spherical mirrors. The aim of this study is to obtain rigorous fourth-order expressions for the aspheric wavefront recording geometry in the framework of the third-order aberration theory, and such analytic expressions are of pressing need for the phase B study of the FUSE spectrographs.

The work planned for the next quarter includes (1) numerical examinations of the validity of the newly derived analytical formulas of spot diagrams and rms spread of the spots (merit function for grating designs) with reference to those computed by means of rigorous ray tracing, (2) theoretical studies on the aspheric wavefront recording geometry of holographic gratings, and (3) preparation of papers for possible publications.

USRA Quarterly Technical Report: S. Ghosh

Task Number: 690001

period: 1 July 1992 - 30 September 1992



Sanjoy Ghosh has continued studying the properties of magnetohydrodynamic (MHD) turbulence with applications to the solar wind. During this period, S. Ghosh completed a paper on the parametric instabilities of a large amplitude circularly polarized Alfvén wave and submitted the manuscript to a scientific journal. A subsequent paper on the nonlinear phase of these instabilities is under preparation.

In other research, a manuscript on the evolution of magnetic helicity in compressible magnetohydrodynamics with a mean magnetic field was completed and submitted for review by Ghosh. This paper is expected to appear in an AGU Monograph on a recent Chapman Conference on micro- and meso-scale turbulence in space plasmas.

Ghosh participated in the submittal of two proposals. The NASA Space Physics Theory Program proposal under M.L. Goldstein (Code 692) will study the role of turbulence in heliospheric plasmas. This is a renewal of Ghosh's current source of funding. Ghosh is also the consultant for a NASA Small Business Innovative Research proposal by L.W. Klein (ARC). This proposal is for developing three-dimensional, compressible, spectral algorithms for simulating fluid dynamics.

Ghosh's non-local travel during this period include several (bi-weekly) trips to the Bartol Research Institute (Univ. of Delaware, Newark, DE 19716) where he continues his scientific collaboration with Prof. W.H. Matthaeus. In addition, Ghosh attended the Gordon Research Conference on Solar-Terrestrial Modeling (13-17 July, Plymouth State College, Plymouth, NH).



TECHNICAL ACTIVITY REPORT

Bertram Donn

Contract NAS5-30442,

Task 690-007 For the Period March 1 - August 31, 1992

This task provides consulting support to the Astrochemistry Branch, Code 691 for research on cometary ices and interstellar grains. In collaboration with Dr. Reggie Hudson, I critically examined the paper by A. Bar-Nun and associates entitled "Gas Release from Comets" published in Icarus. It was pointed out that those authors did not properly take account of all the parameters associated with their experiments and therefore their conclusions were not justified. This also appeared in Icarus. Discussions were held on the experiments by Moore and Hudson on irradiation of crystalline and amorphous water ice films. Irradiation produced temperature dependent cycling between the two phases. The results have implications for interstellar ice grains and cometary ices.

## QUARTERLY TASK REPORT

July 1 - September 30, 1992

V. Papitashvili

Task 690-011A

Contract NAS5-30442

## 1. The 1992 STEP Symposium

During July and August the preparatory work continued for the 1992 STEP Symposium. Computer equipment for demonstrations during Symposium has been rented, Program Guide has been updated, a lot of organizational work has been done. The Symposium held at August 24-28, 1992, as it was planned. Before Symposium the SCOSTEP General Meeting and STEP SC Meeting took place. During the Symposium about 300 papers have been presented, about 250 people attended the Meeting. A number of demonstrations of communication facilities (on-line data systems, educational software, CD-ROM technology, etc.) was presented, including a direct "dialog-mode" communication with RUSCO via GOLDIS system maintained by WDC-B2 in Moscow. Separate report has been created by Dr. M. Teague with description of all activity for the 1992 STEP Symposium.

## 2. STEP International Newsletters.

Two Newsletters (## 7 and 8) have been generated, printed and mailed in the reporting period. Due to some problems with publication of STEP NL the # 8 has been printed on 20 pages and distribution has been postponed until end of September. Eight articles have been initiated and/or substantially rewritten or translated by the Coordinator and Visiting Scientist. One article has been solicited from Russia, five articles have been written by American scientists, one came from Japan. Newsnotes covered a considerable part of the STEP activity around the World. RUSCO Bulletin Board has been included in the GOLDIS system in the former Soviet Geophysical Committee and regular communications (including "on-line dialog mode") have been pursued between USSCO and RUSCO.

Articles from the leaders of different STEP projects have been solicited during the STEP Symposium and trip of Visiting Scientist. The latter attended the AGU Chapman Conference on VLF/ULF in Williamsburg, VA (Sep 17, 1992) and presented a talk about the current state of STEP Program.

## 3. Project 6.4

Visiting Scientist has been invited also (and partially supported from IAGA) to attend the INTERMAGNET Executive Council and Operatin Committee Meeting in Paris, France (Sep 26 - Oct 1, 1992). In this Meeting the proposal from US STEP Coordinator has been intensively discussed to establish a joint effort with the creation of the INTERMAGNET and STEP Project 6.4 CD-ROMs with worldwide 1-minute geomagnetic data base. The objective of STEP Project 6.4 is to establish an on-line database of ground-based magnetometers in order to provide the STEP Community with a global view of the Earth's magnetic field variations. The invited paper has been presented on the STEP Symposium with identification approximately 100 sites around the World which will accomplish this objective. Part of those sites is located in Russia and FSU states. Four magnetic observatories from Russia (Tixie Bay, Cape Wellen, Dixon, and Ashkhabad) have been digitized by the 1-minute resolution during 1992 in IZMIRAN. Part of these data have been delivered to USSCO, software development has been discussed by the project team.

#### 4. Other Activity

Visiting Scientist received a confirmation from international scientific journals (Journal of Geomagnetism and Geoelectricity, Journal of Planetary and Atmospheric Physics, and Geophysical Journal International) that 3 papers of him have been accepted for publishing in 1992. Two other papers have been accepted for publishing in the Proceedings of Solar-Terrestrial Prediction Workshop. Four papers (invited, solicited and two contributed) have been presented on the STEP Symposium, and will be published in the Proceedings. Visiting Scientist, together with US STEP Coordinator, took a responsibility for editorial work with the STEP Symposium Proceedings for the next few months.

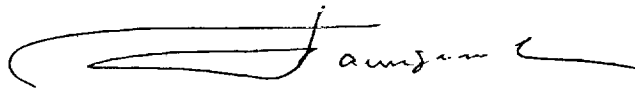
#### 5. Future Plans

A major task for last quarter of 1992 will be a preparation of the STEP Symposium Proceedings (COSPAR Colloquia Series). About 15 papers have been received in the beginning of October, the deadline is October 31. Papers will be forwarded to the Session Chairmen for review, and all volume should be ready for publication at the end of January 1993.

STEP International Newsletter # 9 is under preparation in October. Solicitation of articles will be continued for the following issues.

The process of data collection for the Project 6.4 begins, some data are available in USSCO, software development is in a progress.

Scientific papers for the STEP Symposium Proceedings should be written on the base of presented reports.



10/18-92

### QUARTERLY REPORT

Observations on the emission from Na and K in the exosphere of Mercury obtained in December 1990 during a period of intense solar activity have been reduced. The Na and K emissions do not show a strong spatial correlation. The Na emission shows frequent concentrations towards the polar regions and is time variable. The peak of the potassium emission tends to be fixed from day to day during this period. A simple explanation for this phenomenon is that the surface expression of the relatively incompatible element K is more variable than that of Na. A preliminary report of this work will be given at the Munich meeting of the Division of Planetary Science in October and a publication is being prepared.

There are two broad classes of explanation for the apparent concentrations of Na and K. External ones and internal ones. External ones include photon stimulated desorption and sputtering while internal processes might include diffusion and porous flows (the regolith and megaregolith are highly fractured structures). Both photon simulated desorption and diffusion have been considered this year (see publication list). The conclusion of this work to this point is that diffusion is likely not a major source process for Na and K in the atmosphere of Mercury unless the temperatures at shallow depths are much larger than presently supposed, that the crust of Mercury must be more sodic than previously thought (more like that of the Earth), and that a very likely explanation for the loci of K concentrations is simply that the composition of the crust of Mercury may show regional variations.

*Tom Morgan*

8

690-014

**Quarterly Report: 1 July - 30 September 1992**

Susan Hoban  
Code 693  
301-286-3840      hoban@lep693.gsfc.nasa.gov

Task 5000-714

**Science:**

I have continued a project of reduction and analysis of infrared images of Mars and Venus obtained last year with D. Gezari's (Code 685) 5-18 micron array camera. This work is done in collaboration with M. Mumma, F. Espenak (Code 693), D. Gezari and F. Varosi (Code 685). Preliminary results of this work were presented at the annual meeting of the Division of Planetary Sciences, held in Munich, Germany, Oct 12 - 16, 1992.

My work on the reduction and analysis of narrowband CCD images of comet P/Brorsen-Metcalf continues, in collaboration with M. A'Hearn at the University of Maryland. We are investigating the variations in spatial structure of the OH and CN comae of this comet. We submitted an abstract for the Annual Division of Planetary Sciences meeting on this subject; however, due to illness, I was unable to travel to the meeting to present this paper.

**Proposals:**

I submitted two observing proposals this quarter: 1) I submitted a proposal with M.J. Mumma(NASA/GSFC) and J. Davies (UKIRT) for long-term status for target-of-opportunity observations with the UKIRT to study organic molecules in comets using infrared spectroscopy. Comets come randomly, so such status is needed to have a procedure in place for when a comet does appear. 2) I submitted a proposal with M.J. Mumma and D.C. Reuter (NASA/GSFC) to make infrared spectroscopic measurements of Young Stellar Objects with the IRTF.

**Service:**

*Education:*

E. Roettger (USRA), D.C. Reuter (NASA/GSFC) and I were awarded a small education grant from NASA's Planetary Atmosphere's Program to produce an Astronomy Sourcebook to assist teachers in locating educational resources on astronomy in the Baltimore-Washington Area. We are currently compiling the sourcebook and contacting schools in the area.

*Proposals:*

I am serving on the Hubble Space Telescope Planetary Science review panel. I am currently in the process of reviewing the proposals.

**Programmatic:**

I serve as the IRAF (Image Reduction and Analysis Facility) Systems Manager in our branch. I assist individuals who need help using the IRAF package.

**Plans for the upcoming quarter:**

I plan to continue my work on Mars and on P/Brorsen-Metcalf, continue production of the Sourcebook with Roettger and Reuter, and complete the HST proposal review (scheduled for early November).

692-214

MAIL>  
#6 26-OCT-1992 09:17:56.04 NEWMAIL  
From: LEPVX2::YSEER "E. Roettger 301-286-1528, code 693, T2-  
rm1"  
To: NSSDCA::USRA  
CC: YSEER  
Subj: report

Technical Report, 1 July 1992 - 30 September 1992  
Elizabeth Roettger, GSFC code 693  
Activity 5000-914 lepvax::yseer  
Task number 690-014A Employee number R00903  
Badge number G-115360 Phone number 286-1528

I am reducing a survey spectrum of comet Halley taken from the KAO. This spectrum shows 15 to 20 emission lines of water. I previously developed programs to look for laboratory-detected lines of water, evaluate the intensity, and test for statistical significance. I am learning (and documenting) how to use an available program and computer system to model the EarthUs atmospheric transmission. I am modifying my programs to test, statistically, the results of varying model parameters to match a lunar spectrum, and will apply the answers to the Halley

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spectrum. The line fluxes thus obtained should permit analysis of the excitation state of the water molecules. I expect this to be an iterative process, with more details added each time. The programs can then be used on other spectra from the same observing program. I submitted an abstract of this work for the AAS/DPS meeting in October.

A target-of-opportunity proposal to observe comet Shoemaker-Levy using the CSHELL instrument on the IRTF was granted time; we developed the means for optimizing the search for water emission lines, observed the comet July 21-23, and began reducing the data.

For the 30% of my time earmarked for work with NASA/HQ, I continued coordinating two projects with JPL: the JPL summer school and a related International Conference. I have worked on the announcements and programs, participant lists, invited speakers/lecturers and letters of invitation, protocol, and coordination between JPL and HQ. I organized the Education Research Program reviews (supplemental to Planetary Astronomy/Planetary Atmospheres grants) as well as reviews of the Computational Upgrade Supplements. I was part of the Planetary

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#6 26-OCT-1992 09:17:56.04 NEWMAIL  
Astronomy Review Panel, 4-6 August 1992.

Together with Dr. Susan Hoban, I developed a plan for producing an Astronomy Sourcebook for area elementary school teachers. In cooperation with Dr. Donald Jennings and Dr. Dennis Reuter, we developed and submitted two proposals to allow us to carry out the project. The latter proposal was accepted, and preliminary work commenced.

690-315

Michael L. Goodman  
SPOF/ISTP/GGS  
NASA/Goddard  
Code 695  
Planetary Magnetospheres Branch  
(301)286-3497

10/27/92

USRA NASA Contract Number:NAS 530442

Ms. Denise Dunn  
Administrative Assistant  
USRA Visiting Scientist Program  
Mail Code 610.3  
NASA/Goddard Space Flight Center

Subject: Technical Report for 7/1/92-9/30/92, and  
Planned activities for 10/1/92-12/31/92

Dear Ms. Dunn,

My activities are divided into two categories; operations within the SPOF, and research. My activities within each of these categories are as follows

OPERATIONS:

I have installed the SPOF ORACLE database on three of the four SPOF workstations I am in the process of setting up SQL\*Net TCP/IP to connect the databases on the several workstations. Over the next two months I will begin design and SQL c development for the long term science plan which will be stored in the database.

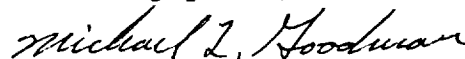
I will be installing the PV-WAVE graphics language package on the remaining three workstations.

RESEARCH:

Alex Klimas, Bill Farrell, Adolfo Vinas, and I have submitted a Director's Discretionary Fund Proposal, "A Faster and More Accurate Plasma Simulation Method to design, develop, test, and apply extensions of our present Vlasov simulation method to include multi-species and higher dimensional electromagnetic phenomena

I have been continuing with the development of an MHD equilibrium model which includes classical resistivity, thermal conductivity, viscosity, and thermoelect effects.

Sincerely yours,



Michael L. Goodman



## Quarterly Technical Report, July 1 – September 30, 1992

### 1 Analysis of work in progress

During the period Dr. Laakso has studied the following subjects:

- Double probe theory
- Current layers in a cometary environment
- Analysis of the CRRES data

#### 1.1 Double probe theory

This work which was started during the previous period has considerably expanded and therefore we have not been able to submit the results during this period as we expected in the previous QTR. However, now the manuscript is almost finished, and we can probably submit it to *Journal of Geophysical Research* at the end of October. The results are not significantly different from those described in the previous QTR. The main difference is a theoretical section in the paper which accurately explains the magnitude of error electric fields in double probe measurements as a function of various parameters such as the electron density, the electron temperature and the floating potential. In addition several applications to the magnetosphere have been added. The current abstract is the following:

"We investigate possible errors in electric field measurements with double probes that are induced by abrupt electron density and temperature gradients. We show that in some occasions such gradients may lead to marked spurious electric fields if the probes are assumed to lie at the same floating potential. Around the space potential, the magnitude of these error signals,  $\delta E$ , vary like  $\delta E \sim T_e (\Delta n_e/n_e)$ , where  $T_e$  is the electron temperature and  $\Delta n_e/n_e$  the relative electron density variation. This not only implies that the error signals will increase linearly with the density variations, but also that such signatures grow with  $T_e$ , i.e., these signals are 10 times larger in a 10 eV plasma than in a 1 eV plasma. We have applied our analysis to various physical situations. For instance, at the plasmopause, error signals can be about  $1 \text{ mV m}^{-1}$ . In double layers the double probe data can easily contain error fields of a few  $\text{mV m}^{-1}$  which, however, point outwards. Thus, these error signals tend to diminish the real dc electric field associated with the double layers. We conclude that although the double probe measurements are often free of these errors, occasionally significant error signals can occur especially at plasma boundaries and during strong transient processes."

#### 1.2 Current layers in a cometary environment

This investigation was presented in the 4th COSPAR Colloquium on *Critical Problems in the Plasma Environments of Comets and Other Non-Magnetized and Weakly Magnetized Bodies*, held in Ann Arbor, Michigan, August 24–27, 1992 (see

Appendix). The studies will be published in a proceedings (deadline: October 31). Our manuscript is almost finished, and the abstract is the following:

"We investigate physical processes in the vicinity of two current layers detected by Vega 1 during its encounter with comet Halley. The  $M_1$  current layer crossed at 360,000 km inbound by Vega 1 coincides with a model enveloping paraboloid of heavy dust grains ( $m > 10^{-8}$  g) which are positively charged at that distance. The dust envelope creates an electrostatic field of a few Volts across the boundary which may produce a hydromagnetic discontinuity. A very strong current layer, also detected during the Vega 1 encounter, appears to have been caused by the stagnation of the solar wind flow in the cometary plasma region. This current layer coincides with a flux enhancement of dust grains ( $m < 10^{-10}$  g) which are negatively charged. We suggest that this solar wind stagnation is at least partially due to an enhanced dust flux."

#### 1.3 Analysis of the CRRES data

We have obtained the first optical disk of CRRES electric and magnetic field data which covers the period of January 6–26, 1991. This period includes several ssc's during which CRRES is located near the plasmopause in the post-midnight sector around 2–3 MLT. Some analysis of these events have been made.

### 2 Work planned for the next quarter (Oct 1 – Dec 31, 1992)

The first two studies (sections 1.1 and 1.2) will be finished during the first month of this quarter. These studies may still take some more time in near future.

There are some interesting common features between comet Giacobini-Zinner and comet Halley. The former was approached by ICE and the latter by several spacecraft. For instance, in the vicinity of both comets drift mirror waves were observed. We have some data available during such events which will be further investigated during this period.

The emphasis during this quarter, however, is to survey research possibilities offered by the first CRRES data disk at GSFC. For instance, some investigations can be made on the electromagnetic waves during ssc's. The possible occurrence of cavity resonances and their coupling to field line resonances is an interesting subject where a lot of progress can be made. Also interesting processes occur in the post-midnight sector during substorms. For substorm studies, all the ASC data from Finland's ground-based stations in 1990/91 are available on a video tape at GSFC.

Harri Laakso  
Harri Laakso

## Appendix: Travel Report

Dr Laakso participated in the 4th COSPAR Colloquium on *Critical Problems in the Plasma Environments of Comets and Other Non-Magnetized and Weakly Magnetized Bodies* which was held in Ann Arbor, Michigan, August 24-27, 1992.

The conference contained a variety of theoretical and observational investigations on the Martian, Venusian, and cometary plasma environments. At this moment there are in-situ observations available in the vicinity of three different comets (Giacobini-Zinner, Halley, Grigg-Skjellerup): although some common features occur among these comets, a number of differences exist. These differences probably hinder that no proper comparison studies between these comets have not been presented so far. This conference did not present anything new in this aspect though a third of the reports considered various problems of cometary plasma environments and their interactions with the solar wind. A number of papers dealt with the dust-plasma coupling which is very important in the vicinity of comets but which may also have some significance in the Martian plasma environment.

Among the speakers were two scientists from the GSFC/Laboratory for Extraterrestrial physics. Dr J. Slavin (Code 696) presented an analysis of Phobos 2 observations of the Mars bow shock taken at unusually distant locations upstream of planet and recent efforts to model flow about the planets under low Alfvén Mach number conditions.

Dr Laakso reported an investigation on the dust-plasma coupling near current layers in the vicinity of comet Halley. A current layer crossing coincides with a model enveloping paraboloid of heavy dust grains ( $m > 10^{-8}$  g). A mechanism was suggested for dust-plasma coupling which can lead into the formation of this current layer. Another current layer appeared to have been caused by the stagnation of the solar wind flow in the cometary plasma region. It was suggested that this stagnation is at least partially due to an enhanced dust flux.

Total attendance at the Colloquium was approximately 80 scientists and graduate students. All the papers will later be published in a proceedings of Pergamon Press (deadline of papers: October 31).

OCT 16 1992

Quarterly Technical Report

Task number: 5000-919

Period: August 10 to September 30, 1992.

October 21, 1992

U.S.R.A.  
Visiting Scientist Program  
NASA-GSFC  
Code 610.3  
Greenbelt, MD 20771.

Since August 10, 1992 I have worked on three main projects: developing an analytic study of the parametric instability of large amplitude Alven waves, developing a Chebyshev-Fourier spectral algorithm with an infinite computation domain for more realistic solar wind studies in MHD and a vortex street model of fluctuations observed by Voyager 2 in the outer heliosphere.

The analytical study uses a time-dependent perturbation approach to extract information on higher-harmonics from a coupled set of amplitude equations for the daughter waves, obtained by linearizing the magnetofluid dynamic equations. Preliminary results indicate that under certain approximations, a closed set of solutions can be obtained for the amplitudes. Part of this study will be shown in a Fall AGU conference paper, San Fransisco, CA, december 1992.

The Chebyshev-Fourier spectral algorithm with an infinite domain is derived from a standard Chebyshev-Fourier compressible MHD code (written by this Author) by including mappings which transform the Chebyshev part of the spatial domain. Two mappings are used (Hyperbolic and Algebraic) as well as a scale factor which determines how large the effective computation domain is compared to the total number of grid points in the computation. This code will have many applications to space physics because it pushes boundary conditions out to infinity.

The final project is a model for the fluctuations observed in the outer heliosphere observed by Voyager and Pioneer spacecrafts (see [1]). The model is made up of two interacting shear layers which create a Karman vortex street. Since August I have finished a paper [2] to be submitted to JGR soon.

For the next quarter (October 1 to December 31 1992) I will continue working on these three projects. Comparison with linear theory will be made with the new approach to the parametric instability of the large amplitude Alfvén wave. Accuracy tests and diagnostics have to be developed for the infinite Chebyshev-Fourier spectral MHD code. A switch will enable the use of either maps in the code. Warp in the current sheet will be tested on the vortex street model for additional realism. A study of flux transport by the vortex street is under way to address the 'flux deficit' problem in the solar wind.

A trip to San Fransisco, CA is planned for the fall AGU meeting in December.

Dr. Edouard Siregar

[1] E. Siregar, E., D.A. Roberts and M.L. Goldstein, 'The Formation of vortex streets through the nonlinear interactions of vortex sheets in a two dimensional compressible flow', Geophys. Res. Let., Vol. 19, NO. 14, p 1427, 1992.

[2] E. Siregar, E., D.A. Roberts and M.L. Goldstein, 'Quasi-Periodic Transverse Plasma Flow Associated with an Evolving MHD Vortex Street in the Outer Heliosphere', submitted to *J.G.R.*, 1992.

## QUARTERLY TECHNICAL REPORT

July 1 to September 30, 1992

Yosio E. Shimabukuro

Task Number: 900-001A

### INTRODUCTION

This is the third report under Universities Space Research Association (USRA) contract as a research scientist at NASA/Goddard Space Flight Center in the Earth Sciences Directorate. During this period, I have attended the regular Branch meetings and technical meetings at Goddard, when I had opportunity to be informed about the on-going researches. I have been working with several remote sensing data over different study sites in collaboration with Biospheric Sciences Branch scientists using the image processing systems located at the Laboratory for Terrestrial Physics Computer Facility and GIMMS Laboratory.

### TECHNICAL ACTIVITIES

During this period, we have been analyzing the effect of scale of measurement on the information content. We finished the preliminary analysis of TM/Landsat and AVHRR/NOAA data acquired on July 29, 1988 over an area in the Central-western region of Brazil. The objective of this work is to present a technique, using coarse resolution AVHRR data in the visible, near-IR, and the reflective part of the 3.75 um band, to generate vegetation, soil, and shade fraction images. These images are formed by the proportion of each component within the AVHRR pixels. The results obtained was submitted to the International Journal of Remote Sensing for publication. ("Linear mixing model applied to coarse resolution satellite data" - copy attached). We continue analyzing TM and AVHRR data over Pacific Northwest and AVIRIS data over Howland Forest in Maine.

The abstract, "Neural network inversion of canopy LAI from high spectral resolution imagery" - J.A. Smith, Y.E. Shimabukuro, and W.T. Lawrence was accepted to be presented in the International Symposium on Spectral Sensing Research (ISSSR) in Maui, Hawaii, 15-20 November, 1992. The inversion of Leaf-Area-Index (LAI) from high spectral resolution imagery is obtained for a northern forest canopy area using a back propagation artificial neural network. The network is trained using input-output

pairs generated by a simple multiple scattering reflectance model. The network was applied to AVIRIS imagery collected from the Howland forest in Maine. General qualitative agreement was obtained with available ground control information and correctly indicated bare soil, road and forest edge boundaries as well as relative LAI density as compared to vegetation fraction images of the same areas computed using the linear mixture model technique.

We have been analyzing the NOAA/AVHRR GAC data from January 1990 to June 1991. The objective of this work is to develop a methodology using NDVI imagery derived from AVHRR and Thematic Mapper (TM) data for monitoring savanna vegetation in Brazil. This work is in collaboration with INPE's investigators. The results are going to be presented to the EMBRAPA (Brazilian Agency for Agricultural Research).

Field work in the Howland forest (Maine) to support the analysis of AVIRIS data (18-23 July, 1992). The study site is located near Howland in east-central Maine (45° 13' N and 68° 43' W) within International Paper Company's Northern Experiment Forest. It consists of small plantations, multi-generation clearings, as well as large natural forest stands. The natural stands in this boreal-northern hardwood transitional forest consist of aspen-birch, hemlock-spruce-fir, and hemlock-hardwood mixtures. Topographically, the region varies from flat to gently rolling, with a maximum elevation change of less than 68 m. There are some bogs and wetlands in the central portion of the forest. The nature of the soil varies from a very well drained to a very poorly drained soil. A 25 m walkup tower supporting meteorological instruments is located within the research forest.

Participation in the XVII International Society for Photogrammetry and Remote Sensing (ISPRS) Congress in Washington D.C. (August 2-14, 1992). The papers: "Use of features derived from proportions of classes in a pixel for the multispectral classification of remote sensing images" - A.P.D. Aguiar, N.D.A. Mascarenhas, and Y.E. Shimabukuro; and "The role of NOAA-AVHRR in vegetation monitoring of Amazonia" - S.C. Chen and Y.E. Shimabukuro, were presented and published in the Congress Proceedings.

Participation in the Payload Panel EOS Investigators' Working Group (IWG) Meeting at Dulles Ramada Renaissance (September 8-10, 1992). The program included the following presentations:

- "Introductory remarks and the issues: Charge to the Payload Panel" - Berrien Moore, University of New Hampshire;
- "EOS Status" - Shelby Tilford, NASA Headquarters;
- "Summary of the Red/Blue Team actions" - Chris Scolese, NASA Goddard Space Flight Center;
- "EOS Data products" - Ghassem Asrar, NASA Headquarters;
- "Update on Landsat-7/8 and their role in EOS" - Darrel Williams, NASA Goddard Space Flight Center and Shelby Tilford, NASA Headquarters;
- "Update on HIRIS-2" - Alex Goetz, University of Colorado; and
- "EOS, Climsat, and EOSDIS" - Lennard Fisk, NASA Headquarters.

Also, it was discussed the Flight of HIRIS-2, Flights of SAGE III / Aero mission, Science goals of WBDCS and plans to fly, MIPAS and SCIAMACHY and their relation to U.S. EOS instruments, POLDER and its relation to MISR/EOSP, MIMR, STIKSCAT on ADEOS-2, MLS/SAFIRE, and EOSDIS.

Participation in the meeting with visitors from the INPE (Brazilian Institute for Space Research) at GSFC and University of Maryland on 21 August, 1992. The visit included the discussion of regional remote sensing with personnel of the Biospheric Sciences Branch and the presentations of GIMMS Laboratory and LTP Computer Facilities.

**WORK PLANNED FOR THE NEXT QUARTER (OCTOBER 1 TO DECEMBER 31, 1992)**

- To analyze the AVHRR GAC data for vegetation phenology studies in Brazil.
- To analyze the AVHRR LAC data for study sites in Brazil (Amazon and Savanna region) and for Pacific Northwest.
- To work with Linear Mixing Model techniques for different remote sensor systems.
- Participation in the MODIS/EOS Science Team Meeting in Santa Barbara, California (27 - 29 October, 1992).
- Participation in the IGBP (AVHRR LAC Data) Meeting in Sioux Falls, South Dakota (9 - 10 November, 1992).
- To work with Forest-BGC Model for Howland forest in Maine.
- To write scientific paper to submit to a remote sensing journal.

LINEAR MIXING MODEL APPLIED TO  
COARSE RESOLUTION SATELLITE DATA

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São José dos Campos, SP, Brazil

## ABSTRACT

A linear mixing model typically applied to high resolution data such as Airborne Visible/Infrared Imaging Spectrometer, Thematic Mapper, and Multispectral Scanner System is applied to the NOAA Advanced Very High Resolution Radiometer coarse resolution satellite data. The reflective portion extracted from the middle IR channel 3 (3.55 - 3.93  $\mu\text{m}$ ) is used with channels 1 (0.58 - 0.68  $\mu\text{m}$ ) and 2 (0.725 - 1.1  $\mu\text{m}$ ) to run the Constrained Least Squares model to generate fraction images for an area in the west central region of Brazil. The derived fraction images are compared with an unsupervised classification and the fraction images derived from Landsat TM data acquired in the same day. In addition, the relationship between these fraction images and the well known NDVI images are presented. The results show the great potential of the unmixing techniques for applying to coarse resolution data for global studies.

## INTRODUCTION

The radiance recorded by the satellite depends basically upon the recording sensor's characteristics and the integrated sum of the radiances



of all surface materials and atmosphere within the instantaneous field of view (IFOV) of the sensor. Thus, the radiation detected will be influenced by a mixture of many different materials (mixed pixels) unless the target is composed of a single material (pure pixel). The spectral characteristics of the resolution elements of the National Oceanic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (AVHRR) (1 km at nadir) are affected by this spatial problem. Several investigators have used the mixed pixel problem of small resolution multispectral satellite data to estimate the probability of its components. We present the following approach for the coarse resolution AVHRR data.

For global change studies, many investigators use the daily global coverage of the coarse resolution AVHRR data for land cover classification. Some workers based on mixture problem have developed a relationship between AVHRR information and high resolution data like TM (Iverson et al. 1990, Cross 1990). Quarmby et al. (1992) presented a linear mixture model for crop area estimation using multitemporal AVHRR channel 1 and 2 data. They assumed that each field within a ground pixel contributes to the signal received at the satellite sensor an amount characteristic of the cover type in that field and proportional to the area of the field. Also, for using multitemporal data, they assumed the proportions do not change between images. Cross et al. (1991) used a linear mixing model in Rondonia, Brazil and Ghana to monitor tropical deforestation. They used the first four channels of AVHRR. Two of the thermal infrared channels (3 and 4) were included because they were considered to contain important information for forest/non-forest discrimination (the forest canopy is relatively cool). This implied that each cover type is thermally distinct and the thermal response is linear. Because the monochromatic thermal

emission is governed by the Planck's equation, a linear model may introduce a significant error into the analysis.

A linear relation is used to represent the spectral mixture of targets within the pixel. The AVHRR has two channels located in the visible and near IR wavelength and one in the middle IR where the spectral responses are influenced by reflected and emitted radiance. In order to more accurately use the information contained in the 3.75  $\mu\text{m}$  channel, the reflective portion of this channel should be extracted. The reflective component should therefore lend itself to a linear model response to the mixed target.

There are several techniques to solve the mixture problem, such as Constrained Least Squares (CLS), Weighted Least Squares (WLS), and Quadratic Programming (QP) presented by Shimabukuro (1987) and the unmixing methods developed at University of Washington (Smith et al. 1985, Adams et al. 1986, Adams et al. 1989). These techniques have been applied for several high resolution data: Adams et al. (1986) applied to Viking images of Mars; Adams and Adams (1984), Shimabukuro (1987), Adams et al. (1990) applied them to MSS and/or TM data, and Gillespie et al. (1990) applied them to AVIRIS data.

The objective of this letter is to present a technique, using coarse resolution AVHRR data in the visible, near-IR and the reflective part of the 3.75  $\mu\text{m}$  band, to generate vegetation, soil, and shade fraction images. These images are formed by the proportion of each component within the AVHRR pixels. The Constrained Least Squares (CLS) method (Shimabukuro and Smith 1991) were applied to one AVHRR image covering an area in the central-western region of Brazil. The validation of the model for this kind

of data will be performed by comparing the resulting fraction images with the classification derived from TM/Landsat and AVHRR NDVI images.

### STUDY SITE

The study site is located between 17° 50' to 18° 20' South latitude and 52° 40' to 53° 20' West longitude on the border of Goiás, Mato Grosso and Mato Grosso do Sul States. The site includes the Emas National Park comprising about 131,000 hectares in which the "cerrado" vegetation is well represented (Redford 1985, IBDF/FBCN 1978, Pinto 1986). Located on the watershed between the La Plata and Amazon River basins, Emas Park is on the western edge of the Central Brazilian Plateau, adjacent to the Pantanal (Redford 1985). It offers a good sample of the Planalto habitats, including a number of small watercourses, the sources of two important rivers, riverine gallery forest and marshes, large areas of grassland (the "campos"), and some open woodland (the "cerrados") consisting of small thinly distributed trees seldom more than three meters high (Erize 1977). The surrounding land of the Park has been used for agricultural and cattle grazing. This Park is commonly affected by uncontrolled fires during the annual dry season (Shimabukuro et al. 1991). Most of these fires are set outside the Park by ranchers to improve grazing quality and to control cattle parasites (Redford 1985). The rest of the study site is covered by "cerrado" vegetation types. The Landsat/TM and NOAA/AVHRR data over this area acquired on July 29, 1988 were available for this study.

## METHOD

### AVHRR 3.75 $\mu\text{m}$ Reflective Component

The AVHRR 3.75  $\mu\text{m}$  band is a mixture of the thermal emitted energy and a reflective energy component. Typically the latter represents less than 10% of the signal for bare soil and urban features and less than 3 percent for green vegetation (Kerber and Schutt 1986; and Schutt and Holben 1991; Remer 1992). The reflective component may be approximated by assuming the emitted energy (brightness temperature) in the adjacent thermal band (10.5 to 11.5  $\mu\text{m}$ ) is related to the emitted energy in the 3.75  $\mu\text{m}$  band at ambient temperature through the Planck Function as follows (Kaufman and Nakajima 1992):

$$L_3 = L_{3\rho} + L_{3\varepsilon} \quad (1)$$

where:

$L_3$  = Total radiant energy measured by the satellite at 3.75 $\mu\text{m}$

$L_{3\rho}$  = The reflective energy at 3.75  $\mu\text{m}$

$L_{3\varepsilon}$  = The emissive energy at 3.75  $\mu\text{m}$

The reflective and emitted components may be expanded according to:

$$L_3 = \rho_3 F_0 \mu_0 / \pi + R_3(T_4) * (1 - \rho) \quad (2)$$

where:

$\rho_3$  = Reflectance in the 3.75  $\mu\text{m}$  band

$F_0$  = 3.75 band solar irradiance at the bottom of the atmosphere

$\mu_0$  = cosine of the solar zenith angle

$R_3(T_4)$  = Emitted radiance at 3.75  $\mu\text{m}$  using the 11.0  $\mu\text{m}$  brightness computed with the Planck Function

Solving for  $\rho_3$ :

$$\rho_3 = (L_3 - R_3(T_4)) / (F_0 \mu_0 / \pi - R_3(T_4)) \quad (3)$$

This formulation ignores the differential atmospheric transmission in both bands and we assume the target surface is flat and the satellite view direction is nadir.

The digital numbers from the satellite data are converted to brightness temperatures using the calibration coefficients and Planck Function coefficients given in the NOAA-9 users Handbook (Kidwell 1988). The parameters and variables used for the computation of the R3 and L3 radiances are given in table 1.

Table 1: The Planck Function parameters and constants for the R3 and L3 radiance computations.

Rad	Temp	$\lambda$	C1	C2	$F_0\mu_0/\pi$
L3	T3	3.75 $\mu\text{m}$	37413	14388	0.0008
R3	T4	3.75 $\mu\text{m}$	37413	14388	0.0008

#### Linear Mixture Model

A linear relation was used to represent the spectral mixture of materials within the resolution element. The response of each pixel in any spectral wavelength was taken as a linear combination of the responses of each component assumed to be in the mixed target. Thus each image pixel, which can assume any value within the image gray scale, contains information about the proportion and the spectral response of each component within the ground resolution unit. Hence, if the proportions of the components are known for any multispectral image, then the spectral responses of these components can be obtained. Similarly, if the spectral response of the components are known, then the proportion of each component in the mixture can be estimated. The basic mixture model may be formulated as:

$$r_i = a_{ij} * x_j + e_i$$

where:

$r_i$  = measured satellite response for a pixel in spectral band  $i$

$a_{ij}$  = spectral response of mixture component,  $j$ , for spectral band  $i$   
 $x_j$  = proportion of mixture component,  $j$ , for a pixel  
 $e_i$  = the error term for spectral band  $i$ .

Subject to:

$$\sum x_j = 1 \quad \text{and} \quad x_j \geq 0 \quad \text{for all.}$$

## Approach

The Constrained Least Squares (CLS) method discussed by Shimabukuro and Smith (1991) was employed for TM and AVHRR data. This technique requires the spectral responses (radiance or reflectance) for the mixture components. We selected the spectral responses for vegetation, soil and shade to run the mixing model for TM data from the imagery by analyzing unsupervised classification results. They were selected choosing the most "pure pixel" inside the corresponding classes. To verify the selection, the error images generated by the model for each TM band were analyzed. This process was iterated until the acceptable error was achieved. Hence, the derived fraction images were considered as ground information for AVHRR imagery. Considering the coarse resolution of AVHRR, it is feasible to accept a "non pure pixel" for these data.

The spectral responses for vegetation, soil, and shade for AVHRR were estimated by using regression techniques (Richardson et al. 1975). A series of corresponding pixels were identified in both images (TM and AVHRR) and each AVHRR channel was regressed against TM fraction images. The spectral responses were derived from the regression coefficients and used as input for the model. The derived fraction images were compared to the ground information and TM results, related to NDVI images for model validation. The model performance can also be evaluated by analyzing the error images.

## RESULTS AND DISCUSSION

The reflective part of the AVHRR channel 3 was extracted using the technique described in the previous section providing the third channel to be used in the mixture model. The vegetation, soil, and shade fraction images were derived from Landsat/TM and NOAA/AVHRR data by applying the CLS method. The component proportions in these images are represented by the variation from dark gray level (small amount of the component) to bright gray level (large amount of the component).

The Landsat/TM data with high spatial resolution (30 meters on the ground) provided ground truth for the AVHRR data. An unsupervised classification of these data showed the complexity within the large scale land cover types. These data may be used to find a most pure pixel (assuming that a pure pixel for TM exists) instead of choosing the pure pixel directly from the image (generally used when this pixel are very distinguishable in the image). The classifier based on K-means identified 13 clusters that were related to possible different land cover types. These clusters were analyzed to identify areas with vegetation, bare soil and water and then compared to the ground truth reported by Shimabukuro et al. (1991). These clusters were rearranged into 7 classes: water and burned areas (blue); "cerrado" (light red); "campo cerrado" (red); "campo limpo" (dark red); bare soil 1 (light green); bare soil 2 (dark green); and cut areas (yellow), (figure 1).

The spectral responses for vegetation, soil and shade for running the mixing model for TM imagery were extracted from the image by analyzing the clusters. The spectral response for shade was searched in water and burned area clusters based on similar low spectral responses (Richardson

et al. 1975; Adams et al. 1986; Shimabukuro 1987; Gillespie et al. 1990). The spectral responses for vegetation and soil were searched inside the "cerrado" and cut area classes, respectively.

The coefficient of determination,  $r^2$ , and the mean spectral responses of vegetation, soil and shade for AVHRR channels were computed by regressing the component proportion derived from TM data against each one of the AVHRR channels (table 2). Vegetation, soil, and shade proportions in red, green and blue, respectively are showed in figure 2. As expected, there are no pure pixels for any one of the components assumed to be in the mixture. Comparing with figure 1 (classification result), the bare soil class has no red pixels, i.e., no vegetation proportion. Yellowish pixels have some amount of vegetation and soil (e.g. cut areas, grassland) and cyan represents pixels containing vegetation and shade amount within the pixel (cerrado class). Some noise is apparent in the picture due to cloudy pixels.

Table 2: Spectral responses for vegetation, soil, and shade for AVHRR channels estimated from TM fraction images utilizing regression model

Channel	$r^2$	DN		
		Vegetation	Soil	Shade
1	78.7	21.8	27.8	11.3
2	93.3	46.5	42.2	10.3
3 Reflective	78.2	5.9	8.4	0.0

Figure 3 shows the NDVI, vegetation, soil and shade images derived from AVHRR data. There is a visual similarity of vegetation fraction and NDVI images. The NDVI values seem to be explained by those fraction images ( $r^2 = 95.2$  and  $90.0$  for TM and AVHRR, respectively). Since we have not done the cloud screening, it is noted the disagreement between



these images for the cloudy pixels. Table 3 shows the mean error for each TM and AVHRR channels. The results show the best fit for the near infrared channel for both sensors.

Table 3: Mean and Standard deviation of the error for TM and AVHRR data

Landsat/TM			NOAA/AVHRR		
Channel	Mean	Stdv	Channel	Mean	Stdv
TM3	3.46	2.68	1	0.29	0.93
TM4	0.22	0.44	2	0.00	0.04
TM5	1.51	1.37	3Reflective	1.13	2.15

Figures 4, 5 and 6 show the NDVI, vegetation and soil fraction images, respectively, derived from AVHRR data over a large area around the study site. The similarity between NDVI and vegetation fraction show the potential of the coarse resolution data for global studies. Again, it is noted the disagreement between these images for the cloudy pixels as mentioned above. In addition, the soil fraction image seems to be useful for deforestation studies since it contains information about soil proportion within the pixels.

### CONCLUSION

In the example cited, the reflective part of channel 3 shows ample sensitivity to various cover types to provide a suitable band for mixture modeling. Further assessment of the influence of the atmospheric transmission in the thermal bands is required to fully benefit from the surface characteristics of the band. This may require incorporation of ancillary data.

As the information contained in the current remote sensing resolution elements are quite often a mixture of several materials, the linear mixing models appear to be a useful tool for image analysis. The approach, analyzing the clusters derived from unsupervised classification and the iterative process analyzing the pixel that violates the constraints, showed to be a useful criteria to choose the "pure component" responses for the model. Also, the error images (for each TM and AVHRR channels) are useful criteria to evaluate the model performance.

The vegetation fraction image was in very good agreement with NDVI image, which shows the amount of green vegetation. Also, the soil fraction image containing information about non vegetation areas, seems to have a great potential for tropical deforestation studies using coarse resolution satellite data. In addition, the shade image contains information that can explain the vegetation index response, especially for the tropical forest which from the multi-layer structure has a high amount of shade.

Finally, the fraction images derived from AVHRR data can be used as additional channels for global studies.

#### ACKNOWLEDGEMENT

We wish to thank Kashka Donaldson and Wayne Newcomb for their assistance at the Global Inventory Mapping and Monitoring (GIMMS) Laboratory. Our thanks to John Schutt and Yoram Kaufman for their useful conversations regarding the 3.75  $\mu\text{m}$  band. During the preparation of this manuscript, the Co-author was serving as a Visiting Scientist at NASA Goddard Space Flight Center under the auspices of the Universities Space Research Association (USRA).

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## Figure Captions

Fig. 1. Land cover classification derived from Landsat TM data using unsupervised classification (K-means).

Fig. 2..Color composite of fraction image (vegetation = red, soil = green, and shade = blue).

Fig. 3..A) NDVI image, B) Vegetation fraction image, C) Soil fraction image, and D) Shade fraction image derived from AVHRR data over the study site.

Fig. 4. NDVI image derived from AVHRR data covering a large area around the study site.

Fig. 5..Vegetation fraction image derived from AVHRR data covering a large area around the study site.

Fig. 6. Soil fraction image derived from AVHRR data covering a large area around the study site.

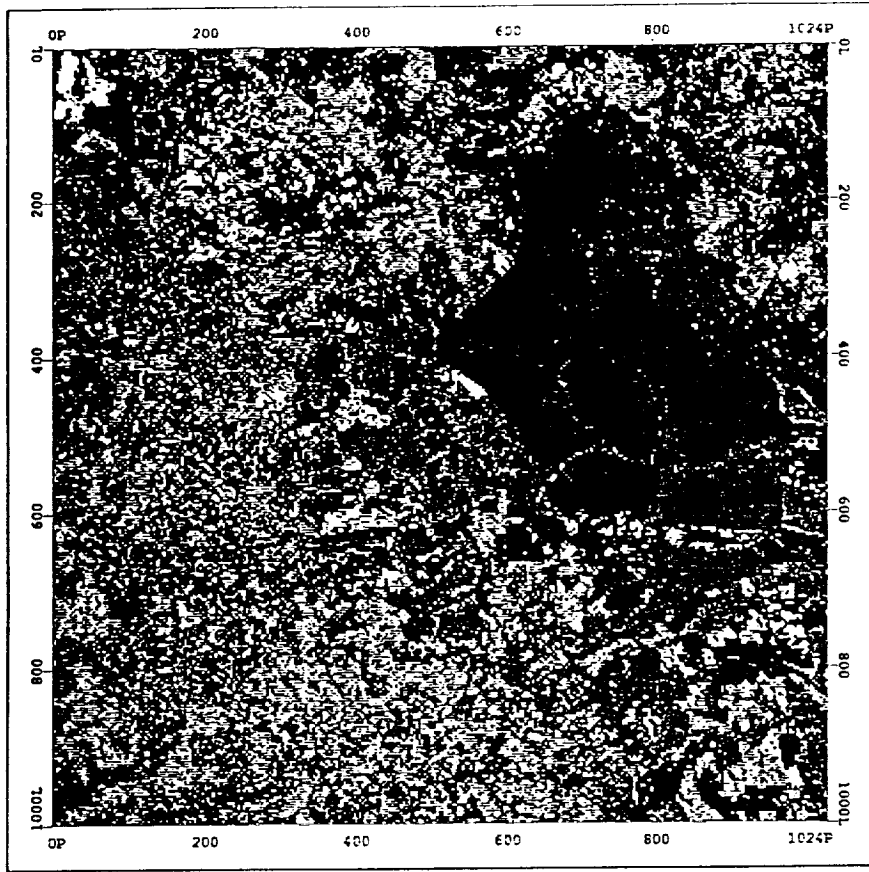


Figure 1

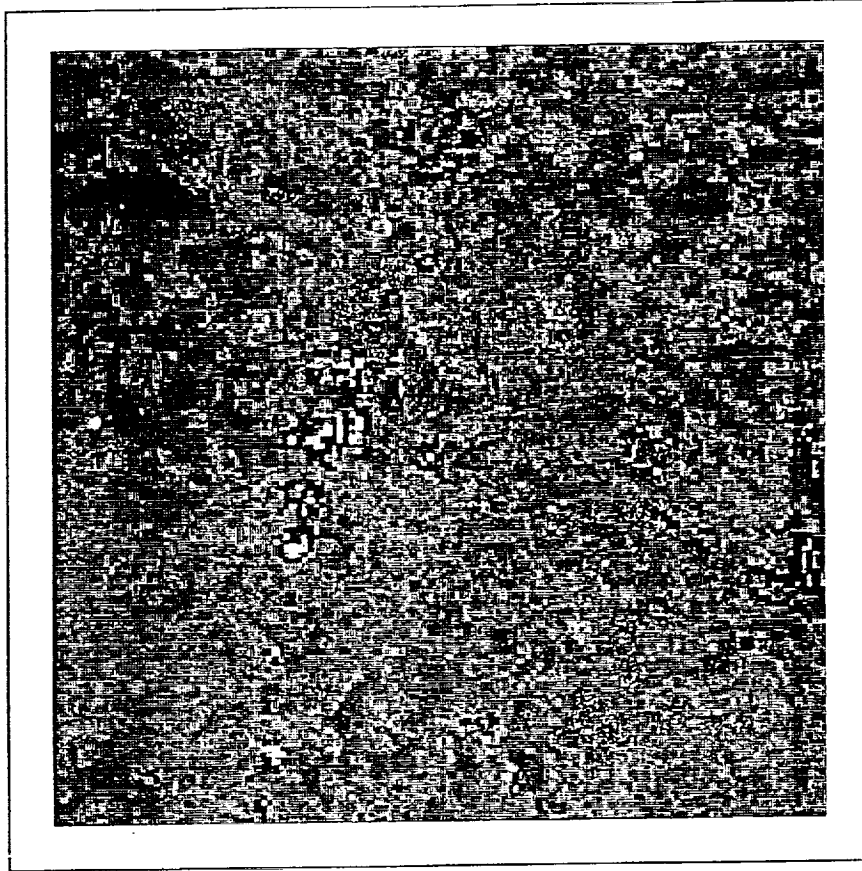
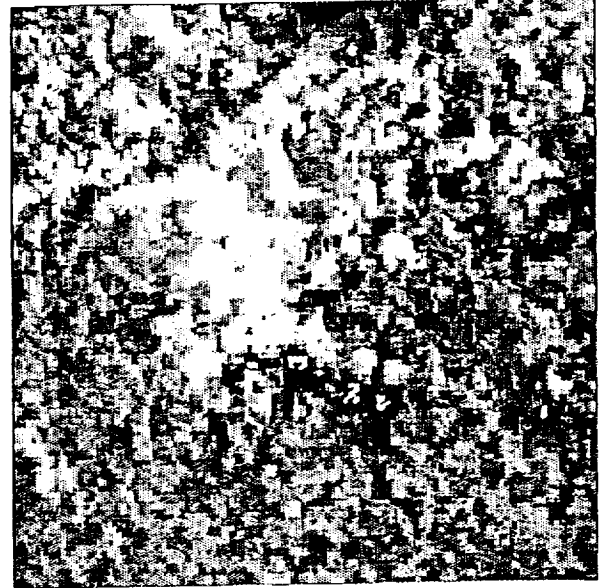


Figure 2





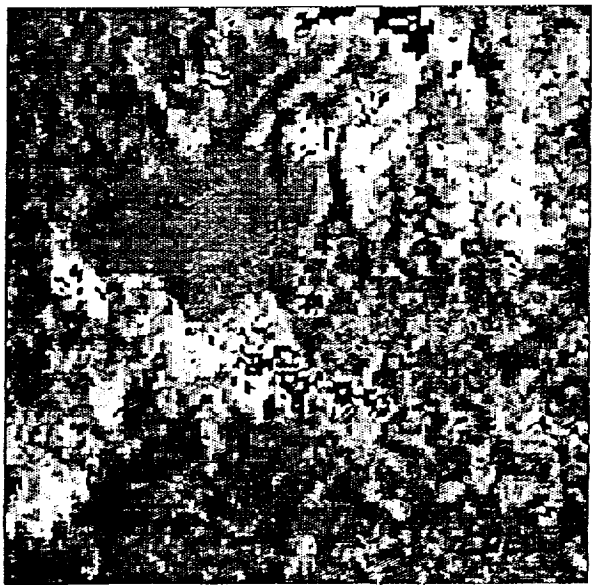
(B)



(D)



(A)



(C)

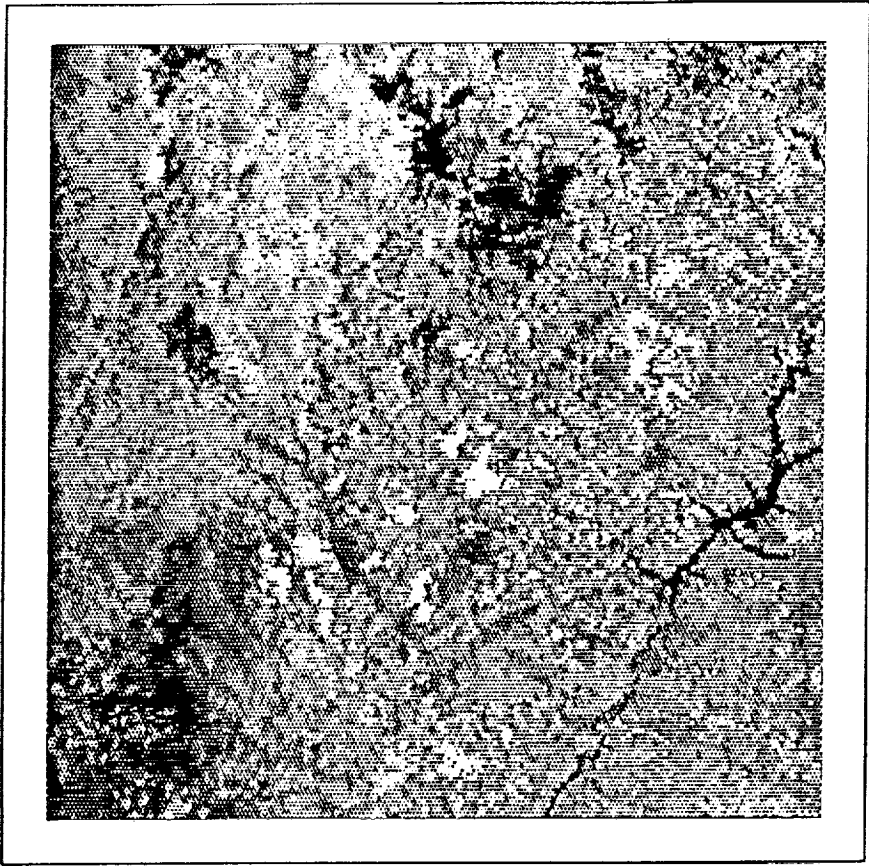


Figure 4

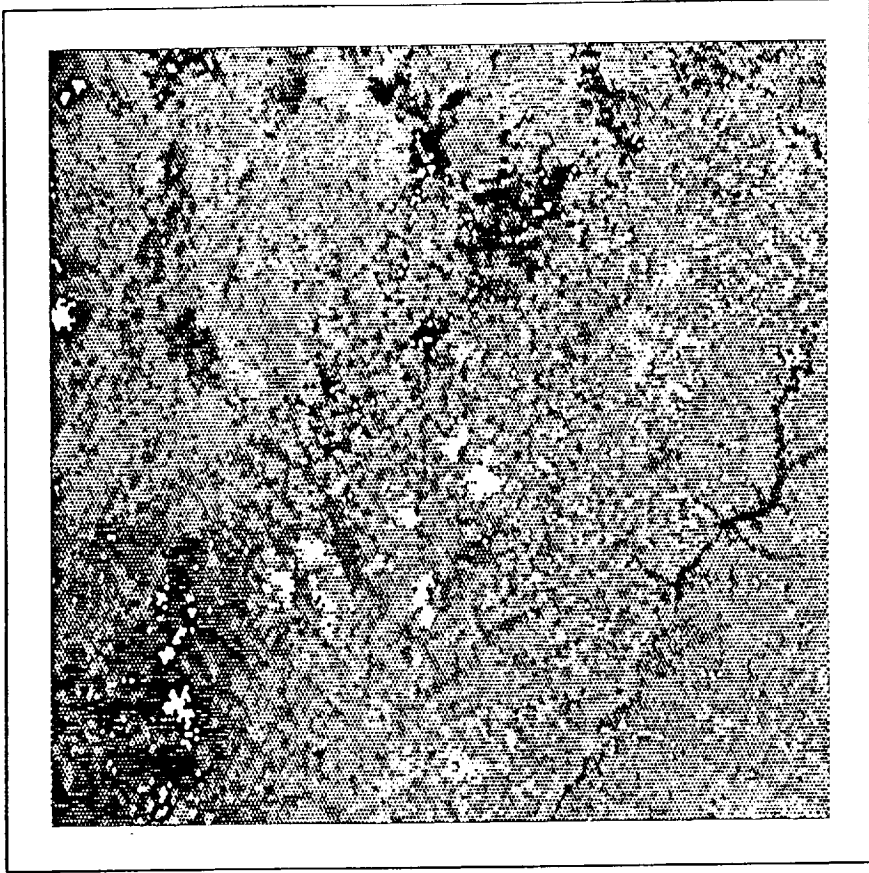


Figure 5

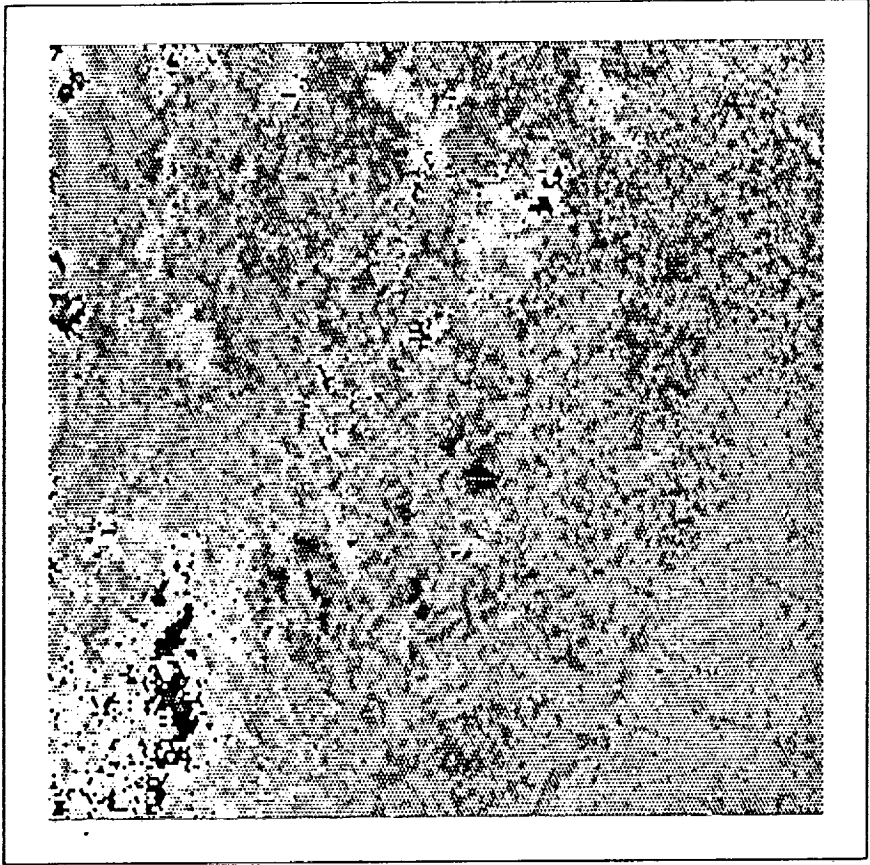


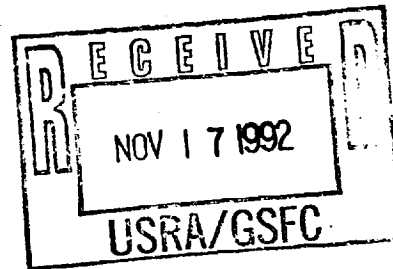
Figure 6



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November 14, 1992

Dr. Frank Kerr  
USRA  
Code 610.3  
NASA Goddard Space Flight Center  
Greenbelt, MD 20771



Dear Frank:

Having been back in the University for six weeks now, I have had some time to reflect on my two years at Goddard as a Visiting Scientist employed by USRA. I found the job of the EOS Project Scientist enjoyable, productive, entertaining, and sometimes frustrating. But I encountered no frustration in dealing with the USRA staff, and I want to thank you for your hospitality, good will, scientific exchange, and excellent service.

For me, personally, and I suspect for almost every academic with a visiting appointment at a NASA lab, USRA offers the ideal vehicle. An appointment through a typical NASA support contractor would have been appropriate and inconvenient for several reasons, and I probably would not have accepted the Project Scientist task had it been available only through a for-profit company.

1. As the EOS Project Scientist, I had to participate in competition-sensitive deliberations. The prime example was the Source Evaluation Board for the EOSDIS Core System contract, but I also helped with the request-for-proposal for the EOSDIS IV&V con-

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tract and participated in discussions about contracting plans for the EOS spacecraft and instruments. Because USRA—a non-profit, academically oriented association—does not compete for these types of contracts, I was able to avoid conflicts-of-interest that surely would have arisen had I worked for a for-profit company. One reason for a scientist to spend a year or two at GSFC is to more fully understand and contribute to the interplay between scientific and technical/engineering issues, and these exchanges and contributions can be more substantial if procurement issues are not excluded.

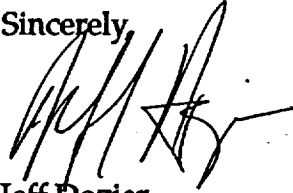
2. As a member of the academic community, I already had a retirement plan through TIAA/CREF, which is open only to non-profit institutions. The ability to continue to contribute to this retirement plan while away from my home university was a major benefit. Otherwise I would have lost two years of service.
3. USRA's other efforts to improve educational offerings in Earth and space sciences are significant, e.g. their consortium of universities working on an improved curriculum for Earth Systems Science. My association with USRA at Goddard has eased my participation in these projects.

I think USRA could help Goddard better address the use of temporary appointments for established academics. When I arrived in May 1990, Gerry Soffen said that he would consider Goddard successful if it could convince me to stay on after my initial two-year hitch. I thought then that he was setting up an unrealistic success criterion, and Goddard cannot be judged to have "failed" because I elected to return to UC Santa Barbara. My two years at Goddard were enormously productive, measured both by service to the scientific community and by personal professional growth, but, as you know, a Full Professor's position in a first-rate university is an awfully nice job, with professional and financial attractions that the government probably cannot match.

However, there is an important part of scientific research that universities are not equipped to handle well. In the Earth sciences, we in academia have few opportunities to work with the people who design and build instruments and spacecraft, bring data to Earth for analysis, and design, develop, operate, and evolve data and information systems. I think Goddard could profitably attract more visitors from the ranks of the senior, established academics, as well as continue to provide opportunities at the postdoctoral level. The scientists will learn more about design and implementation of the large projects that are essential to modern Earth science. The government will benefit from the experience of those of us who carry out small, self-contained projects with a minimum of overhead and paperwork.

Again, thank you for your help during my stay at Goddard.

Sincerely,



Jeff Dozier  
Professor of Geography

cc: John Klineberg  
Vincent V. Salomonson  
Gerald Soffen  
Ghassem Asrar  
Dixon Butler  
Shelby Tilford

Mathew Schwaller  
NASA/GSFC Code 423  
13 October 1992

Quarterly Report to USRA

I joined the staff of USRA on 10 August 1992, assigned to the staff of NASA Code 423, the Earth Science Data and Information System Project (ESDISP). My ESDIP title is Manager of Science Data and External Interfaces. In this regard, I have accomplished the following.

Completed draft report on NASA Requirements for NOAA Data Sets. This report identifies NASA's near- and long-term requirements for NOAA data, and defines a process for implementing solutions to these requirements. I also examined some specific NASA scientific requirements for data from NOAA's National Meteorological Center and recommended a technical solution to these requirements.

Analyzed the compatibility of the Earth Observation System Data and Information System (EOSDIS) with the Department of Defense (DoD) Global Grid System (GGS). This analysis was used as ESDIP input to a briefing to the NASA Administrator.

Attended meeting of the Committee on Earth Observations Satellites (CEOS) Working Group (WGD) on Data in Frascati, Italy. This meeting concerned NASA's use of auxiliary data, i.e., data sets needed for processing satellite data. I gave a presentation on NASA's current use of auxiliary data, and NASA's plans to contribute auxiliary data sets for international users.

Activities ongoing into the next quarter:

I am currently in the process of contributing to the Earth Observations International Coordination Working Group's (EO-ICWG) Implementation Plan. This plan will outline the specific bilateral and multilateral implementations that need to be in place for the data systems associated with the International Earth Observing System.

I am also working on the the distribution policy for data sets provided by the European Center for Medium Range Weather Forecasting (ECMWF). At present, distribution of ECMWF data is relatively restrictive; we are looking for ways to simplify access to the data by NASA researchers.

I also have ongoing responsibility to update NASA's EOSDIS Science Data Plan. A revised version of the Plan is scheduled for the spring of 1993.

SEE 8 1 TJC



SHRINIVAS MOORTHY

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**Activity report for the third quarter of 1992**

During this quarter I focused mainly on further development of a diabatic version of the Semi-Lagrangian Semi-Implicit (SLSI) GCM. Specifically, I have automated the model code with options to have either digital filter initialization, Diabatic Dynamic initialization or combination of both. I also improved the SLSI GCM code and found few bugs. I also found some problems near the poles and designed a filter to eliminate this problem.

Currently, I am planning for extensive evaluation of the GCM both with regard to short range prediction and in climate simulation. The main plan of work for the next quarter is to continue the development of Semi-Lagrangian GCM. Specifically we want to perform a few long simulations as well as some short range forecasts. I also want to get back to do some research on convective parameterization and improve RAS.

I did not perform any local or non-local travel during this period.

Report of Dr. Vikram M. Mehta's scientific activities during  
the last quarter (1 July 1992-30 September 1992)  
Contract number NAS5-30442, task number 910-007

### 1. Variability of global hydrologic cycle in the GFDL GCM

Earlier this year, we acquired a comprehensive data set from a 15-year integration of a high-resolution atmospheric general circulation model (GCM) from NOAA's Geophysical Fluid Dynamics Laboratory (GFDL). Analysis of rainfall in the GFDL GCM shows that the GFDL GCM can simulate seasonal and annual averages and intraseasonal variability of tropical rainfall well. It can also simulate the annual cycle (pattern and amount) of global rainfall quite well. Rainfall in the model's Asian monsoon region appears to undergo interannual variability even though there is no interannual variability in the external forcings of the model. Results of the rainfall analysis suggest that the GFDL GCM is a good tool to study global rainfall variability. Analysis of other components, e.g. evaporation, moisture transport, etc., is in progress. In preparation for Atmospheric Model Intercomparison Program, we are making a detailed comparison of the global hydrologic cycle and its variability in the GFDL GCM developed by Dr. Sud (code 913) at NASA/GSFC.

This work will continue during the current quarter. We expect to learn from this work how the global hydrologic cycle in the earth's atmosphere operates at a variety of time scales from a few days to a few years.

### 2. Coupled ocean-atmosphere variability

I am using my simple coupled ocean-atmosphere models and data from a variety of coupled ocean-atmosphere general circulation models to study variability of Atlantic region climate at time scales of years to decades. During the previous quarter I submitted, in collaboration with Drs. Paul Schopf (code 971), Max Suarez (code 913), and K.-M. Lau (code 913), a proposal to NOAA to study decadal variability of Atlantic region climate with complex models of the coupled ocean-atmosphere system. I have been informed by the program manager at NOAA that the reviews of the proposal are very good and that funding decision is likely to be made before the end of October.

My modelling work on interannual to interdecadal oscillations in the coupled ocean-atmosphere system continues to produce new results. I am preparing a paper titled 'Meridional oscillations in an idealized ocean-atmosphere system, Part II: Coupled ocean-atmosphere modes' for submission to *Journal of Climate*.

### 3. Non-local travel

- a. The Atlantic Climate Panel of the Committee for Climatic Changes in the Ocean invited me to give a seminar to the Panel at its meeting in Moscow (Russia) held from 13 to 17 July. The title of the seminar was **Interdecadal variability of Atlantic Ocean meridional circulations in a linear, coupled ocean-atmosphere model**. The National Science Foundation paid my travel expenses and local hospitality in Moscow was provided by the Russian Oceanography Institute.
- b. I presented two papers at the Second International Conference on Modelling of Global Climate Change and Variability held in Hamburg (Germany) from 7 to 11

September. The titles of the papers were **Interannual to interdecadal variability of meridional circulations in a linear, coupled ocean-atmosphere model** and **Rainfall variability in general circulation models: An inter-comparison study**.

QUARTERLY TECHNICAL REPORT  
(July 1 - September 30, 1992)

by Li Peng

WORK IN PROGRESS

The physical nature of the statistically obtained coupled tropical-extratropical modes was studied by examining the three dimensional structures of the modes which were constructed from the data of wind anomaly based on the time series projected onto the modes. A baroclinic extratropical structure generally suggests that the modes is likely developed outside the tropics, while a barotropic extratropical structure suggests that the mode is likely propagated from the tropics.

Barotropic fluxes of vorticity were computed for each of the significant modes using the wind data. It was found that the characteristics of the fluxes vary greatly with the modes.

It was also found by singular spectral analysis that the low-frequency oscillations have significant effects on intraseasonal oscillations. The coupling in the intraseasonal time scale often varies with the phase of the low-frequency oscillations.

The coding of the model of Lau and Peng (1986) was re-examined for the possibility of optimization and incorporating a simplified boundary layer.

WORK PLANNED FOR THE NEXT QUARTER

To develop a nonlinear atmospheric model with a simplified boundary layer for use in a coupled ocean-atmosphere model.

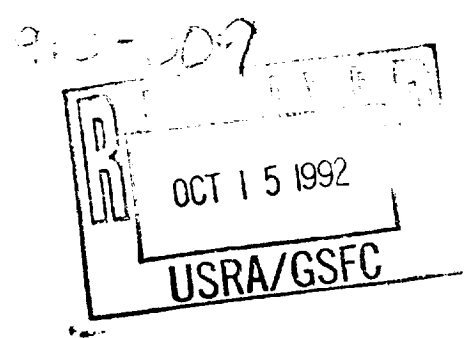
NON-LOCAL TRAVEL

Presented a paper entitled 'Coupled tropical-extratropical modes in East Asia and western Pacific.' at *The Second International Conference on East Asia and Western Pacific Meteorology and Climate*, in Hong Kong, from September 5 to 12, 1992.

USRA QUARTERLY REPORT FOR JULY 1 - SEPTEMBER 30, 1992

Joan E. Rosenfield

Activity: 5000-109



WORK THIS QUARTER:

1. I completed a paper entitled "Radiative Feedback of Polar Stratospheric Clouds on Antarctic Temperatures," and submitted it to Geophysical Research Letters. This paper argues that Antarctic winter and spring temperatures are warmer with the presence of PSCs than they would be without.
2. I finished my writeup on the intercomparison of heating rates and circulations for the Models and Measurements Committee, taking into account the comments made by participants on the draft I had submitted.
3. I did some calculations of the temperature implications of observed long term ozone trends (negative in the stratosphere and positive in the troposphere), using Hohenpeissenberg ozonesonde data supplied to me by Professor Julius London of the University of Colorado. Radiative equilibrium temperatures computed with a decadal trend were at most 1.25 K colder in the stratosphere and 0.1 K warmer in the troposphere, a very small signal.
4. I did some calculations of the radiatively determined temperature changes due to decadal CO<sub>2</sub> increases. The temperature change computed was not enough to explain the lower mesospheric temperature trend of roughly -1.5 K per decade, as analysed by Dr. Arthur Aiken of GSFC.
5. I began work on interpolating the Arctic Airborne Stratospheric Experiment II (AASE II) Northern Hemisphere heating rates onto potential temperature surfaces in order to determine the average heating and rate of descent inside the polar vortex during the time period of this aircraft mission. This is work which will be presented at the American Geophysical Society meeting in December.
6. I worked with Dr. Tina Wang of the Data Assimilation Office, serving as a consultant on the radiative transfer code in the assimilation model.
7. I served as a mentor for a student in the USRA Graduate Student Program.
8. I reviewed 3 papers for the Quadrennial Ozone Symposium, 1 paper for the Journal of Applied Meteorology, 1 proposal from NOAA, and 3 proposals from NASA.

PLANS FOR NEXT QUARTER:

1. Substantially revise the GRL paper in response to the referees' comments.
2. Continue work on AASE II heating rates.

3. Attend the AGU Meeting in San Francisco in December.
4. Compute thermal response to ozone depletions caused by solar proton events.
5. Begin examining the spectral, latitudinal, and altitude dependence of the solar irradiance as computed from the 2D model photolysis rate code, and the solar flux as computed from my heating rate code, in preparation for an intercomparison with observations which should be coming out of the Stratospheric Photochemistry, Aerosols and Dynamics Expedition (SPADE).

ROBERTA GAGLIARDI

## PHOTON COUNTING SYSTEM PROBLEMS

I studied the mode of operation of a photon counting system (PCs), widely used in the lidar system.

An electric signal corresponding to one photon arrives at a pulse height analyzer (P.H.A.). When a signal voltage exceeds a fixed base line voltage, the signal is counted as one pulse. This is the normal case occurring when the photons are individually distinguishable.

The problem encountered with such system is the following: when the signal levels increase, the response of PCs becomes non linear, that is, the output count rate is no longer proportional to the incident light intensity. Non linearity in a PCs' s response is caused by the overlapping of pulses and the finite response time of the electronics. In particular, depending on the pulse height distribution and the discriminator level, the overlapping of pulses (pulse pile-up) can cause count loss or even additional apparent count gain as the signal level increase. In fact, if two or more pulses, that would normally each individually be counted, arrive within too small an interval only one count will be registered. On the other hand, if two or more pulses that normally would not each individually be counted, arrive within too a small interval they may combine together to go over the discriminator level. Thus there are two related but competing processes occurring, one that tends to decrease the observed count rate and one that tends to increase the observed count rate. Therefore it is necessary to explore the extent to which high intensity PC signals can be quantitatively analyzed. Thus, the first data processing that must be done in the lidar system is the application of a correction to the PC data, which, taking into account the count loss and the apparent count gain caused by pulse pile-up, provides an analytical expression between the observed count rate and the true count rate. This correction depending on the kind of PCs.

In practise two fundamentally different types of PCs can be recognized.

Let the input counting rate  $N$  be the counting rate which would be obtained if the dead time were zero, and the output counting rate  $n$  the rate when there is a dead time  $\rho$  after each output count. For non paralyzable system we assume that a new input count occurring during the dead time,  $t \leq \rho$ , after the previous output pulse, will not give an output pulse and also will not extend the dead time. A random input as always assumed. The problem is to find the relation between  $n$  and  $N$ .

The counting loss will be caused by those input counts which arrive during the dead time. Since each output count has a dead time  $\rho$  and there are  $n$  output counts per sec, on the average, the total dead time per sec is  $n\rho$ . The average number of input counts during the interval  $n\rho$  is just  $Nn\rho$ , so the loss is  $(N-n) = nN\rho$  per sec. The solution is:

$$N = n / (1 - n\rho) . \quad (1)$$

For paralyzable system we again assume that a new input count arriving during the dead time will not be counted, but it is assumed that the dead time is extended by the amount  $\rho$  after the (undetected) count arrives. Again the relation between  $N$  and  $n$  is desired. The system will remain blocked if the input counts are always spaced by

less than rho. In general, another output pulse is obtained every time a timing spacing  $\geq$  rho occurs between successive input counts. Thus,  $n = N$  (probability of zero counts during the time rho after a given count). In order to calculate this probability, we have to introduce the Poisson distribution. In fact, for random sequence, the probability of observing x events in any given time interval t is given by the Poisson distribution:

$$P_x(t) = \frac{m^x e^{-m}}{x!} \quad (2)$$

where m is the average number of events occurring in each interval t. For an event to be recorded by a paralyzable counter, we require that no counts be received in a given interval rho, the probability of this occurring is given by:

$$P_0(\rho) = \frac{m^0 e^{-m}}{0!} = e^{-N\rho} \quad (3)$$

where  $N\rho$  is the mean number of input counts expected during the time rho.

Thus

$$n = N e^{-N\rho} \quad (4)$$

This is the general approach to the problem. I studied, in particular, a new method to correct the lidar data for paralyzable system, proposed by Donovan et al. in the Sixteenth International Laser Radar Conference on July 1992. They proposed a new model that describes the non-linear count loss and apparent count gain arising from the overlap of the photomultiplier tube (PMT) pulses, taking into account the distribution in amplitude of the PMT output pulses and the effect of the pulse height discrimination threshold.

The starting point is the eq 4; the problem is that the analyst records the output count rate n and needs to derive the input count rate N with some specified level of accuracy. Usually one can use the series expansion of the exponential in eq 4, followed by dropping of quadratic and higher terms and insertion of the approximation  $N\rho \approx n\rho$ . The idea of Donovan et al. is the following: starting by eq 4, we can write:

$$n = N P_a \exp(-N\rho) + N P_{1b \wedge 2a} (N\rho) \exp(-N\rho) + N P_{2b \wedge 3a} \frac{(N\rho)^2}{2} \exp(-N\rho) + \dots \quad (5)$$

where  $P_a$  is the probability that a individual pulse is above the discriminator threshold,  $P_{1b \wedge 2a}$  is the probability that given two overlapped pulses, that the first pulse's amplitude is below the discriminator threshold while the sum of the second pulse's amplitude plus the amplitude of the first is above the threshold. In general,  $P_{ib \wedge (i+1)a}$  is the probability that given i+1 overlapped pulses that the sum voltage of the first i pulses is below the discriminator level while the addition of the i+1 pulse causes the voltage to go above the discriminator threshold. it easy to see that for the case of uniform pulses which are above the discriminator level will have  $P_a=1$  and  $P_{1b \wedge 2a} = P_{2b \wedge 3a} = \dots = 0$  and thus eq reduces to eq 4. We also can see that the first term in eq 5 take into account the count loss while the remainder terms take into account the apparent count gain. I studied the application of this model to the data and the results obtained by Donovan et al. I also studied the possibility to extend this approach to the real lidar data taken by a Raman lidar placed at the GSFC.



QUARTERLY TECHNICAL REPORT

Kenneth E. Pickering  
Code 916, NASA/GSFC

Progress -- July 1, 1992 - September 30, 1992

Work has been progressing in four main areas:

(1) Modeling the effects on free tropospheric ozone production of deep convective events

This is a joint effort with Code 912 in which selected squall lines are simulated with the 2-D Goddard Cumulus Ensemble Model and the resulting wind fields are used to transport trace gases that are critical for photochemical ozone production. I then use particular profiles from the resulting trace gas distributions in a 1-D photochemical model to estimate the effects of the convection on ozone production during the 24 hours following the convective event.

During this period I was notified that our revised JGR manuscript regarding the effects on ozone production of the entrainment of urban plumes into deep convection was accepted for publication and is now in press.

I met with John Scala (Code 912) and with Russ Dickerson and Olga Poulida from the Univ. of Maryland concerning the June 28, 1989, event from the North Dakota Thunderstorm Project. I have reviewed the meteorological and trace gas data from this event in preparation for model analyses. I have also reviewed initial cloud model results produced by John Scala for this event.

2) Modeling the effects on upper tropospheric ozone of deep convective events during STEP

This is again a joint effort with Code 912, as above. Trace gas data from the NASA ER-2 is being used to compute ozone production rates in the upper troposphere for the 24 hours following the deep convective events that were observed in the Stratosphere-Troposphere Exchange Project (STEP).

During this period I completed the text and figures of a paper entitled, "Upper Tropospheric Ozone Production Following Mesoscale Convection during STEP/EMEX". I submitted the manuscript to JGR.

(3) TRACE-A experiment

Anne Thompson and I have been selected by the NASA HQ Tropospheric Chemistry Program to participate in the next Global Tropospheric Experiment (GTE) field project, Transport and Atmospheric Chemistry near the Equator - Atlantic (TRACE-A), to be conducted in the August-October, 1992 time frame.

During this reporting period all plans for the project were finalized and the Brazilian portion of the experiment was executed. The planning activities included many communications with the GTE meteorological support team at NASA LaRC and the Mission

Meteorologists at Florida State University concerning the available data and facilities in Brasilia for the field project. My activities have also included contacts with the Brazilians regarding soundings to be taken during the experiment. Many discussions were conducted between Anne Thompson, Donna McNamara, Arlin Krueger and myself concerning final plans for sending TOMS total ozone data to the field during the experiment.

I was stationed in Brasilia for two weeks during the initial phase of the field experiment. During this time I assisted in the installation of a temporary satellite data receiving station for geostationary satellite cloud imagery. I actively participated in analysis of synoptic weather conditions, assessment of the possibility of convective activity over the flight region, and in the planning of four specific flights of the NASA DC-8. I rode on the DC-8 for two of these flights, recording significant meteorological and chemical phenomena and photographing biomass fires and convective clouds.

#### (4) Pre-TRACE-A Ozone/Fires Trajectory Analysis

Work has progressed on a project to link TOMS total ozone maxima over the South Atlantic with biomass fire counts for Africa for 1989. I have conceptualized this project and am now supervising and providing guidance to an M.S.-level atmospheric scientist doing the bulk of this work.

We have been using global meteorological data sets with an isentropic trajectory model. Work has proceeded primarily along two lines: (1) examining linkages between specific TOMS maxima and the fire data for specific days and (2) conducting a trajectory intercomparison, using different input data sets.

The proceedings paper for the 1992 Quadrennial Ozone Symposium which describes our results for the first activity was accepted for publication. Minor revisions were made to text and figures and the camera-ready copy was submitted for publication.

I continued the trajectory intercomparison work by computing trajectories over the South Atlantic using two additional input data sets.

#### (5) Miscellaneous activities

a) Participated in initial planning meeting for a future NASA Global Tropospheric Experiment convective transport study. Also contributed to the project "white paper" that was submitted to NASA headquarters.

b) Contributed to Yoram Kaufman's proposal to NASA headquarters concerning urban aerosol fluxes.

#### Planned Activities -- October 1, 1992 - December 30, 1992

(1) Perform further analysis of trace gas measurements from June 26 PRESTORM event. Begin photochemical simulations for this event following receipt of tracer files from Code 912. Coordinate analysis of June 28, 1989, North Dakota event with John Scala (Code

912) and Russ Dickerson and Olga Poulida from Dept. of Meteorology, University of Maryland.

(2) Continue participation in TRACE-A field program by processing real-time TOMS total ozone data and sending it to the field project offices in Johannesburg, Windhoek, and Ascension Island. Begin formulation of plans for analysis of field data and for model simulations.

(4) Continue coordination of ozone/fire trajectory analysis. Perform more case studies using TOMS total ozone and fire count maxima. Complete trajectory intercomparison study. Prepare journal paper.

## USRA Technical Report for Third Quarter 1992

Leslie R. Lait (Task 910-032)

October 23, 1992

During the third quarter of 1992, work continued on the constituent reconstruction technique. This technique, which involves constructing composite constituent fields in (potential vorticity, potential temperature) space, has been applied to data collected during the 1991-1992 AASE-II field experiment as well as ozonesonde data from EASOE, a European campaign from about the same time. In addition, work was begun to apply it to data from the UARS satellite. The UARS research is being done with Gianlucca Redaelli, a graduate student visiting from the University of L'Aquila, Italy.

In preparation for re-analysis of previous field missions' data using the same technique, data from those missions has been installed and integrated into the data analysis system on our computer workstations.

Preparations are also underway for the upcoming Stratospheric Photochemistry, Aerosols, and Dynamics Experiment (SPADE), which will be staged from NASA Ames Research Center in November. New versions of our group's mission plotting and analysis programs are being written, including a complete reworking of our display of meteorological data from radiosondes.

Work continued on a document describing the data format standard created by Eric Nash and myself. This format for electronic exchange of scientific data has generated considerable interest in our branch, and current plans call for this document to be published as a NASA technical report.

Two research proposals from NASA Headquarters were reviewed during this period.

Finally, I gave a talk on the ozone layer to a church group on September 12.

Work planned for the fourth quarter of 1992 includes:

- Participation in the SPADE mission in California.
- Continued analysis of mission constituent data in potential vorticity/potential temperature coordinates, with particular emphasis on UARS data.
- Re-analysis of previous missions' constituent data for comparison with AASE II data

*Leslie Robert Lait*

*11/23/92*

Leslie Robert Lait

# Quarterly Technical Report

To: Universities Space Research Association  
From: Si-Chee Tsay  
Date: 14 October 1992

## A. Travel:

During this quarter I had an invited trip to Colorado State University from September 24-30 to work with Prof. G. Stephens' group on multi-dimensional radiative transfer problems. They have paid all the expenses.

## B. Work in progress or results obtained (1 July - 30 September 1992):

In the past quarter, I have worked on the following research topics:

1. analyzed some interesting radiation measurements (LEADEX) over the arctic environment. In LEADEX, we have gathered the surface bidirectional reflectivity for snow, one-year and multiple-year sea ice, under clear and cloudy sky conditions.
2. completed the setup of running the netCDF formatted data (MODIS selected format) on the Cray-YMP for the first time. An interesting case (cloud microphysics and radiation interaction) on June 17 during ASTEX has been selected for retrieving the effective radius and optical thickness of these clouds. These results have been presented in Japan by Dr. M.D. King and in Colorado State University during my visit (9/24-30) to Prof. G. Stephens' group.
3. conducted the forward simulations of the multiple scattered radiation field at 0.63 and 0.82 microns for water and ice clouds at different values of the effective radius. This project is connected to Dr. Y. Kaufman's study on atmospheric correction.
4. re-composed the microphysics data of Kuwait oil fires to compute their optical properties. The results of simulated radiance field will be compared with the measurements from CAR.
5. completed the computation of spatial distribution of radiative heating rate for two-dimensional media. This project is collaborated with Drs. Stephens and Gabriel in Colorado State University.

## C. Work planned for next quarter (1 September - 31 December 1992):

For the coming quarter, I plan to work mainly on the following research:

1. attending the MODIS Science Team meeting in Santa Barbara (October 27-

- 29) with Dr. M.D. King and attending the FIRE Science Team meeting in Fairfax (November 9-13) to present some results from ASTEX experiment.
2. continue to write up the update paper of DisORT version 2 for submission to Journal of Applied Optics.
  3. continue to analyze the bidirectional reflectivity measurements obtained in LEADDEX and ASTEX experiments. This research will contribute two papers which are tentatively entitled "Observational and theoretical studies to bidirectional reflectivity. Part I. Various types of surface; Part II. Water and ice clouds" by Tsay, S.C. and M.D. King.
  4. continue to analyze the CAR data, generated by Dr. King's instrument in Kuwait oil fires. This case study of scattering pattern by oil drizzle will contribute to a research paper which is tentatively entitled "Simulation of directional and spectral reflectance of the Kuwait oil fire smoke" by Tsay, S.C. and M.D. King.
  5. re-examine more carefully the retrieval of cloud optical and microphysical properties by using data gathered from MAS (MODIS Airborne Simulator) mounted on NASA ER-2 aircraft.

## TECHNICAL REPORT

10/27/92

STEPHEN C. BLOOM

(TASK NUMBER 5000-136)

Work continued on the error simulation project during the last quarter. An extensive series of diagnostic tests have been required to track down various errors in implementing the algorithm. In addition, R. Atlas and I have decided to send a Note to the Monthly Weather Review summarizing the earlier results of this project; namely the difference in correlation structures of O-F between real data assimilations and simulated data assimilations. We feel that this is an important result to communicate to the meteorological community, especially in light of a growing interest in performing OSSE's for upcoming new observing systems (LAWS, EOS, etc.).

Priorities for the upcoming quarter are: (1) OSSE Note; (2) General Balance Method, finish evaluation of this methodology of assigning directions to SSM/I surface wind speeds; (3) work with DAO personnel on publishing IAU results; and (4) assimilation experiment with correlated simulated errors, assess the impact of the approach and determine if further work is warranted. A new area of work is beginning which will involve my continued interaction with DAO. This will be a project to recast and generalize the current OI analysis algorithm into a 3-dimensional variational analysis; an analysis system of this form will have a much greater potential for utility to the research efforts of the Satellite Data Utilization Office. Currently, planning meetings are being held to map out the best strategy to undertake this large task. I anticipate that the 3-d variational system will be a superior framework for the assimilation of LAWS and new types of surface data.

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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

QUARTERLY TECHNICAL REPORT  
(July-September 1992)

Employee Name: Dr. R. Wayne Higgins

Task Number: 910-037

1. Work Completed:

Currently, we (with Ray Bates and Shrinivas Moorthi) are working with the model development group of the DAO (under Larry Takacs) to merge the hydrodynamics from our semi-Lagrangian finite difference global multilevel model with the GEOS-1 model in order to carry out a diagnostic intercomparison of semi-Lagrangian and Eulerian approaches. The code that we provide should be "modular" so that it is easily incorporated (i.e. portable) into the GEOS-1 system. The paper on which this model is based (Bates *et al.*, 1993) and the note which describes the fast solver (Moorthi and Higgins, 1993) used in the code will both appear in the January issue of the Monthly Weather Review. The results of a 1 year integration of this model were discussed at the Second International Conference on Modeling of Global Climate Change and Variability in September in Hamburg, Germany. Our NASA Technical Memorandum based on a more comprehensive summary of the solver (including a copy of the computer code) appeared during this quarter. We continue to work on the second part of our study concerning the semi-Lagrangian model with full physics. This involves further evaluation of the performance of the model, especially near the pole, where some noise in the divergence field still occurs. We plan to carry out an ensemble of 10 day forecasts in order to analyze the predictive capability of our model, and then to write up the results (Moorthi et al, 1993).

Seigfried Schubert and I have begun a series of studies to diagnose the "climate characteristics" of data sets produced in the DAO with particular emphasis on the (physical and dynamical) structure of the synoptic-scale eddies and their connection to the large-scale flow. In this quarter we focused on relationships between the eddies and blocking events. The areas we are investigating include the characteristics of northern hemisphere blocking in GCMs and observations, the "climatological lifecycle" of blocking events (and associated eddy activity) using a zonal index, and the role of the synoptic eddies in directly forcing blocking events. Work in this area will continue. Recently, I was invited to speak on this work (and the work of Higgins and Schubert, 1993) at the Laboratory for Atmospheres Winter-Spring Seminar Series.

In July at the Data Assimilation Offices' annual RTOP Review I discussed recent work (with Siegfried Schubert), on the relationship between boreal winter synoptic-scale transient eddies and low-frequency zonal wind variability (Higgins and Schubert, 1993). Our work will also be discussed at the Seventeenth Annual Climate Diagnostics Workshop in October, 1992 in Norman, Oklahoma.

## II. Papers Published or Accepted for Publication:

Higgins, R.W. and S.D. Schubert, 1993 Low-frequency synoptic-eddy activity in the Pacific storm track, ( to appear in J. Atmos. Sci. in April).

Moorthi S. and R.W. Higgins, 1993: On the direct solution of 2-D separable elliptic equations on the sphere, (to appear in Mon. Wea. Rev. in January).

Bates, J.R., S. Moorthi and R.W. Higgins, 1993: A global multilevel atmospheric model using a vector semi-Lagrangian finite difference scheme. Part I: adiabatic formulation, (to appear in Mon. Wea. Rev. in January).

## III. Technical Memoranda

Moorthi S. and R.W. Higgins, 1992: A fast direct solver for 2D separable elliptic equations on the sphere, NASA Tech. Mem., 104567.

#### IV. Papers Submitted for Publication

Li, Y., I. M. Navon, S. Moorthi, and R.W. Higgins, 1993: The 2-D semi-implicit semi-Lagrangian global model: direct solver and adjoint model development, (submitted to Mon. Wea. Rev.)

#### V. Papers Presented at Scientific Meetings:

Bates J.R., S. Moorthi and R.W. Higgins, 1992: Development of a semi-Lagrangian global atmospheric model. Second International Conference on Modeling of Global Climate Change and Variability, Hamburg, Germany, Sept. 7-11.

Higgins, R.W. and S.D. Schubert, 1992: The interaction between low-frequency synoptic-eddy activity and baroclinic wave packets. Seventeenth Annual Climate Diagnostics Workshop, Norman, Oklahoma, October 19-23.

October 13, 1992

TO: Denise Dunn, 610.3, USRA

FROM: Michael Fox-Rabinovitz (Task Number 910-038)

SUBJECT: Quarterly Technical Report (July 1, 1992 to September 30, 1992)

My activities included the following:

1. Design of the new vector spherical harmonics filter, and continuation of testing the scalar spherical harmonics filter for the 17-layer GLA GCM; completion of the paper on computational dispersion properties of vertical grids for atmospheric and ocean models; participation in testing the frozen version of the GEOS GCM.
2. Continuation of testing diabatic dynamic initialization with the 46-layer stratospheric model.
3. Presentation of the proposal on diabatic dynamic initialization for FY93-95 at the NASA RTOP review meeting.
4. Reviewing NASA and NSF proposals.
5. Participation in organizing committee activities for the Yale Mintz Memorial Symposium.

Work planned for the next quarter will include:

Submitting the paper on computational dispersion properties of vertical grids for atmospheric and ocean models; continuation of testing the scalar and vector spherical harmonics filters for the GLA GCM; continuation of testing diabatic dynamic initialization for the stratospheric domain; participation in activities of the NAS/NRC Board on Atmospheric Sciences and Climate (BASC); presentations on behalf of the BASC to the NRC Board on Mathematical Sciences, and to the Climate Research Committee.

  
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Quarterly Report of Dr. Suhasini Ravipati  
from (July 1 -- Oct. 30 ) 1992

Task Number / NASA5-30442

Task Originator/ Dr. Thomas . L. Bell

I spent lot of my time during these months (as my annual report shows) to generalise the Principal Component Method (PCM) which describes the probability density function  $p(r,t)$  of rainfall 'r' with time 't', in a succinct way as the sum of a few (two or three) functions of the form  $p_{\alpha}(r) \times n_{\alpha}(t)$ .

The PCM including nonlinearity which was tested in August, is working very successfully for two and three modes, and now can be used for any data set of interest. We call this as Nonlinear Principal Component Method (NPCM) .

The  $n_{\alpha}(t)$  as time series has to be studied in order to make an assessment of how best these coefficients show the time scales involved in the data.

I would like to continue these studies in future in INDIA.

USRA Quarterly Technical Report  
July 1 to September 30, 1992

Dr. Glen E. Liston  
Task Number: 910-043

This quarter I completed a paper titled "Evaluating GCM Land Surface Hydrology Parameterizations by Computing River Discharges Using a Runoff Routing Model: Application to the Mississippi Basin", which presents the Runoff Routing Model I developed for use in validating General Circulation Model (GCM) land surface hydrology representations. The model routes GCM produced runoffs through regional and continental-scale basins, and generates river hydrographs throughout the coincident watersheds. This has provided a unique opportunity to compare and relate GCM land surface hydrology with actual hydrologic measurements. As part of this research effort, the paper I authored, "A Runoff Routing Model for Validating General Circulation Model Land Surface Hydrology Parameterizations", for presentation at the Conference on Hydroclimatology: Land-Surface/Atmosphere Interactions on Global and Regional Scales, January 17-22, 1993, was completed and submitted for publication.

In addition to my off-line GCM hydrology research, I have performed an analysis of the hydrologic output from a recent annual Goddard Laboratory for Atmospheres (GLA) GCM integration. Focussing on the Mississippi Basin, this work pointed to possible model incompatibilities with the initial soil moisture data set currently in use. To improve the soil moisture initial conditions used in the GCM, I developed an off-line scheme which computes initial soil moistures which are much more compatible with the current Simple Biosphere-GCM representation of soil hydrology. My GCM research using the Runoff Routing Model has also indicated a strong need for land surface hydrology parameterizations to account for the influence of subgrid-scale soil moisture variability on runoff. I have developed a scheme which accomplishes this, and implemented in the Simple Biosphere version of the GLA GCM.

I have also been working with a computational surface-boundary layer model. In September I presented a paper I authored, called "A Computational Model of Two-Phase, Turbulent Atmospheric Boundary Layers With Blowing Snow", at the International Glaciological Society, International Symposium on Snow and Snow-Related Problems, Nagaoka, Japan, 14-18 September, 1992. A second paper on this subject is called "A Two-Dimensional Computational Model of Turbulent Atmospheric Surface Flows with Drifting Snow", and has been accepted in the journal *Annals of Glaciology*. A third paper I authored titled "Application of the  $E - \epsilon$  Turbulence Closure Model to Separated Atmospheric Surface Layer Flows", was submitted to the journal *Boundary-Layer Meteorology*.

During the following quarter I will continue to explore methods by which to improve the representation of subgrid-scale processes within land surface hydrology parameterizations.

## Quarterly Report Universities Space Research Association

Joanna Joiner Noll  
Goddard Space Flight Center  
Code 910.4  
Greenbelt, MD 20770  
Task # 5000-147

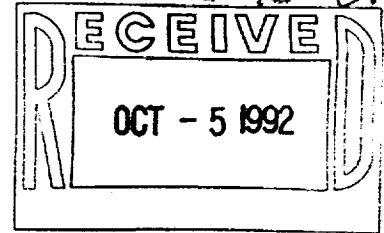
October 16, 1992

This quarter I have continued my work on the AIRS/AMSU simulation and retrieval program. I have been able to show that it is possible to recover the emissivity as a function of frequency. Joel Susskind presented our results at the AIRS team meeting in September. Five teams performed retrievals on a simulated set of radiances known as the "write test". The best results were obtained using the algorithm developed by Joel Susskind and myself. Our collaboration with Frederique Cheruy and Alain Chedin produced the overall best results. Joel Susskind and I are currently revising a paper entitled "Determination of Temperature and Moisture Profiles in a Cloudy Atmosphere Using AIRS/AMSU" which was submitted to the proceedings of the High Spectral Resolution Infrared Remote Sensing for Earth's Weather and Climate Studies following a favorable review.

I have developed a surface temperature retrieval algorithm for the TOVS Pathfinder project. I have begun testing this algorithm using data from June, 1988. The initial results are encouraging. I have also been collaborating with Joe Otterman on several papers including a paper entitled "Surface-PBL Longwave Exchanges: A Comparative Parameterization for Bare and Vegetated Desert-Fringe Regions".

Next quarter, I will continue algorithm development and testing for both AIRS/AMSU and HIRS/MSU (Pathfinder). I will attend the AIRS team meeting in January at JPL in Pasadena. I will also give a seminar entitled "The Millimeter-wave Spectra of Jupiter" at the BIMA seminar series at the University of Maryland.

690-013



To: D. Holdridge  
From: G. Huffman  
Re: Quarterly report  
Date: October 1, 1992

Work on the Goddard Scattering Algorithm (estimation of precipitation from SSM/I microwave) focused on problems estimating precipitation over cold land and ice. Most of the changes I made to the algorithm were in the sense of masking off more areas as "not precipitating." In particular, a "reasonableness test" was imposed at higher latitudes to knock out unphysically high precipitation rates on a pixel-by-pixel basis.

During the quarter, final datasets were submitted to the Wetnet Precipitation Intercomparison Project 1. Also, I assisted Eric Nelkin (USRA summer student) and Andy Negri (912) in generating estimates for the Algorithm Intercomparison Project 2. This international algorithm intercomparison effort focused on data Great Britain in February, 1991, so the cold land problems mentioned above have been acute.

The first version of an oriented, non-symmetric smoother was developed and tested as a side project. It tends to have the desired properties, but generates spurious values in regions where the gradients change direction. Further development will probably start with a better derivative estimator.

The major project in the quarter was preparing for and attending the International Workshop on Analysis Methods of Precipitation on a Global Scale, 14-17 September, Koblenz, Germany, organized by the Global Precipitation Climatology Centre (GPCC). As described more fully in my trip report, the Workshop was intended to review the state of the art in producing global precipitation estimates and help GPCC decide how to merge estimates from different sources (gauges, satellites, and numerical models). Dr. R. Adler (912) was invited, but due to other commitments delegated the trip to me as the prime focus of the global SSM/I-IR combination project. My talk on "Global Precipitation Estimates Using Microwave and IR Data" was the only presentation to discuss the combination of data from different satellite (or any other) sensors, and a diagram developed by Dr. Adler and me formed the basis for the subsequent discussion on data merger.

Finally, we have started conversations with Dr. A. Chang (974) on comparing his SSM/I precipitation estimates with ours. The primary goal is to merge these estimates for GPCC-type activities.

One major issue arising from the GPCC workshop is the need for estimates of uncertainty. Some such estimate will be an important goal in the coming quarter. This effort will likely be associated with a project in our group to generate examples of merged precipitation estimates. We also need to continue examining the behavior of the Goddard Scattering Algorithm under various climatic conditions, as well as the smoothing/combination scheme. Finally, we have enough SSM/I data in a convenient format now that a year of data may be processed to give us a look at the algorithm over a complete annual cycle.

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During the quarter I prepared:

Huffman, G.J., R.F. Adler, P.R. Keehn, A.J. Negri, 1992: Examples of Global Rain Estimates from Combined Low-Orbit Microwave and Geosynchronous IR Data. 4<sup>th</sup> Symposium on Climate Change Studies, 17-22 Jan. 1993, Anaheim, CA.

Huffman, G.J., R.F. Adler, P.R. Keehn, A.J. Negri, 1992: Global Precipitation Estimates Microwave and IR Data. *Proc. of the Internat. Workshop on Analysis Methods of Precip. on a Global Scale*, 14-17 Sept. 1992, Koblenz, Germany, GPCP.

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Chung-Kyu Park  
Task number: 5000-150

October 30, 1992

## Quarterly Technical Report

*Work Period: July 1, 1992 - October 30, 1992*

### 1. Low-Frequency Waves in the Aries GCM

The heating experiments with the Aries GCM have been continued. The model response to the idealized tropical heating appears to be too complicated to identify the extratropical wave sources related to the extratropical forcing due to the nonlinearity of the full model. The model has been linearized to the climatological diabatic heating and tested for the sensitivity to the initial conditions. The integration of the linearized version of the model with different initial conditions raised an interesting question of the model behavior without the transient. The linearized version of the model provided a realistic patterns with the fixed zonal mean temperature. The tropical heating experiments are continued with this linearized model.

### 2. Future Research Plan

The future research plan includes (1) the heating experiments with the linearized version of the Aries GCM to examine the impact of the tropical heating on the extratropical stationary waves and (2) the diagnostics of the multi-year dataset simulated by the frozen version of GEOS-1 GCM.

### 3. Travel

I gave a summer special lecture at Pusan National University, Korea from July 27 to August 22, 1992.

October 20, 1992

To : USRA

From : Hye-Yeong Chun

Subject : USRA Quarterly Technical Report (July 1, 1992 - September 30, 1992)

Task Number : 910052

1. The surface pressure traces of Champaign and nearby area in Illinois for the wave event period of 5-6 January 1989 have been analyzed with an appropriate frequency filter. The detrended surface pressure indicates that the period of sharp pressure drop is about 10-12 minutes. This is consistent with the wavelength calculated from the weakly nonlinear solitary wave theory. Contrary to the other published study (Ramamurthy et al., 1990 *Nature*), using a lower frequency filter, the period of the wave in this case is much smaller than an hour.
2. The 50 MHz ST Doppler radar data observed at the Flatland Atmospheric Observatory located on the flat terrain of east-central Illinois have been analyzed. Again, the horizontal and vertical velocities are quite different based on the filtered frequency range. When we filter out fluctuation with less than 1.5 hr period, the streamline shows a single wave elevation with more than 4 km vertical displacement over 2-3 hrs. This is similar to what Ramamurthy et al had. However, when we use the band filter frequency range from 0.5 cph to 12 cph which corresponds to 2 hr to 5 min, the pattern of the streamlines is quite different. Based on the surface pressure trace, the filter frequency we used is appropriate. However, the large amplitude wave over long period is itself interesting even though this wave is not what is observed in surface pressure trace. Perhaps, the rotational effect should be included in order to consider that large wave.
3. The solitary wave solution is plugged into the 2-dimensional cloud model as the initial condition. Somehow, the simulated surface pressure is well matched with that of the solitary wave solution, except that the magnitude of the pressure perturbation from the numerical simulation is larger than that from the weakly nonlinear solitary wave theory.
4. In the next quarter period, I will include the rotational effect in the weakly nonlinear solitary wave theory. The weakly nonlinear solitary wave solution including rotation can be applied to several wave events observed with a large wavelength ( $> 1000$  km) over long period.

USRA QUARTERLY TECHNICAL REPORT  
JULY 1 - SEPTEMBER 30, 1992

Dr. John R. Scala  
Task # 910-055

I participated in the third International Cloud Modeling Workshop, held in Toronto, Canada, 10-14 August 1992. The meeting was held in conjunction with the WMO Workshop on Cloud Microphysics and Applications to Global Change. I co-chaired the session on mixed-phase Spring/Summer convective clouds. I presented a paper entitled "Two-dimensional simulations of mixed-phase convective clouds: 28 June 1989 NDTP case", and assisted in the coordination of discussions and in the assimilation of results from the session. I presented the group's findings and recommendations for future modeling efforts to the cloud modeling workshop, and to a joint gathering of participants from both workshops on the final day. We found several similarities in the simulations, particularly: 1) a strong relationship between autoconversion and increased hail production, 2) the shedding of hail as the major source of precipitation, 3) a "seeder-feeder" mechanism for hail growth, and 4) strongly overshooting tops associated with peak vertical velocities exceeding  $40 \text{ ms}^{-1}$ . A report of the principle findings of our subgroup is due by 31 October. In addition, I plan to submit a manuscript to the *Journal of Applied Meteorology* that addresses the effect of different initialization schemes on the simulation results of the 28 June NDTP case.

Following the Toronto meeting, I attended the Eleventh International Conference on Clouds and Precipitation, held in Montreal, Canada, 17-21 August 1992. The forum provided an ideal format for the exchange of scientific ideas, and the renewal of professional associations. I discussed last year's CaPE experiment with two of the program's principle investigators: Dr. Barnes of the University of Hawaii, and Dr. Fankhauser of NCAR, and the role of convection in the tropospheric transport of trace gases with Drs. Alheit and Hauf of the Institute of Atmospheric Physics in Germany.

I talked with Dr. Stith of the University of North Dakota and with Dr. Orville of the South Dakota School of Mines and Technology about the upcoming North Dakota Tracer Experiment (NDTE), scheduled for June-July 1993. Both scientists participated in the North Dakota Thunderstorm Project (NDTP), and will be actively involved in next summer's NDTE. Dr. Stith has invited me to come to the University of North Dakota to work with him on several NDTP data sets, and to discuss a strategy for NDTE. I expect to attend a planning meeting early next year to address NDTE field operations.

A preprint paper entitled "Convective transport and mixing of tracers by midlatitude squall-type mesoscale convective systems", authored by J.R. Scala, K.E. Pickering, W.-

K. Tao, J. Simpson, and R.R. Dickerson, was submitted for inclusion in the conference volume of the Special Session on Atmospheric Chemistry at the 73rd Annual Meeting of the AMS. The meeting is scheduled for January 17-22, 1993 in Anaheim, CA. A special issue of the *Journal of Applied Meteorology* is planned for the papers presented in this special session.

The impact of organized mesoscale convection (observed in two recent field programs) on the transport and subsequent photochemical production of ozone is currently under investigation with colleagues in the Atmospheric Chemistry and Dynamics Branch at GSFC, and Prof R. R. Dickerson of the University of Maryland. The study includes storms from OK PRE-STORM (Oklahoma-Kansas Preliminary Regional Experiment for STORM-Central), and the NDTP.

I participated in a workshop held recently at NASA/Goddard Space Flight Center on 30-31 July 1992. The purpose of the meeting was to design a coupled meteorological-chemical experiment to address the convective transport of ozone precursors. I presented my current research to the working group, and assisted in the composition of a "white paper" that will be presented to the GTE Advisory Committee meeting in November. The primary goal is to link the proposed study to a major field program with the most appropriate suite of meteorological and chemical instrumentation. I am completing the animation of several 3-D tracer fields to further emphasize the importance of clouds as deep tropospheric transporting agents. A videotape of the animation will be shown at NASA headquarters during the November meeting.

I performed the following professional duties during the last quarter: 1) selected by the editors of the *Journal of Geophysical Research-Atmospheres* to determine the suitability of a submitted manuscript for publication, and 2) represented the convective-scale modeling group as a member of the GEMPAK committee of the Severe Storms Branch.

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TECHNICAL REPORT: 1st July 1992 – 30th September 1992

Ranga B. Myneni  
Task Number 5000-202

1. A research paper *Synergistic use of optical and microwave data for agrometeorological applications* was submitted for publication in *Advances In Space Research*.
2. A research paper titled *Atmospheric Effects in the Remote Sensing of Surface Albedo and Radiation Absorption by Vegetation Canopies* was submitted to *Remote Sensing Reviews*.
3. A research paper titled *Radiative Transfer in three dimensional atmosphere-vegetation media* was submitted for publication in *Journal of Quantitative Spectroscopy and Radiative Transfer*.
4. I gave an invited talk at the 1992 World Space Congress in Washington, DC, in late August.
5. A research paper titled *Simulation of space measurements of vegetation bidirectional reflectance functions* was accepted for publication in *Remote Sensing Reviews*.
6. I advised this summer a graduate student, Mr. Jeff Privette, and collaborated on research on inverting physically based models through merit function minimization for the estimation of surface state variables. This work will be submitted for publication soon. Mr. Privette is PhD student from the University of Colorado in the department of Aerospace Eng. with Prof. Bill Emery.
7. I am currently working on using artificial neural networks for the inversion of vegetation radiation transport models.

01 July September  
Quarterly Report: 31-March 1992 to 30 June 1992

Gregg Bluth, USRA/Goddard Research Associate

Task # 920-004

My main research goals this past year have been to complete our inventory of TOMS data for publication, and find ways to validate our measurements. With regards to completing the TOMS inventory one of the major obstacles has been overcome: that of standardizing just how we measure and define an eruption cloud. Depending on latitude, season, eruption size, local weather conditions, current instrument conditions, and investigator there were many possible interpretations of the extent and size of an erupted SO<sub>2</sub> cloud, which made it difficult to make intercomparisons of our data. I am now able to use virtually the same method to evaluate each eruption. We are also cataloguing each eruption and storing images and processed data as part of a project with with the Earth Observing System team. With access to National Meteorologic Center wind data, I am also able to estimate SO<sub>2</sub> cloud heights to determine whether they reached stratospheric or tropospheric levels.

On July 23-24, I attended the Earth Observing System (EOS) Plume meeting held at Goddard. I gave a presentation of some recent TOMS results.

From July 6-24 I was mentor to Eleni Roumel under the National Space Club Scholars program. She worked on a project with me using information from Dr. Tom Simkin of the Smithsonian Institution global Volcanism Program. She looked for satellite evidence of a large eruption of Fernandina caldera, Galapagos, discovered by Simkin in the field. The only clues he could give us was that the eruption occurred sometime between late 1980 and early 1982. Eleni and I searched through the TOMS database, and were able to confirm that no large emissions of sulfur dioxide had accompanied the eruption.

The following papers have either been presented or submitted:

- Kump, L.R., G.J.S. Bluth, M. Gibbs, and E.J. Barron (1992) The role of paleogeology in CO<sub>2</sub>-induced climate change. International Geologic Congress August 25-28, 1992, Japan.
- Bluth, G.J.S., A. J. Krueger, C.J. Scott, L.S. Walter, and C.C. Schnetzler (1992) SO<sub>2</sub> Cloud Tracking from the June 27 Eruption of Mount Spurr, Alaska. American Geophysical Union meeting December 7-11, 1992, San Francisco, CA.
- Schnetzler, C.C., G.J.S. Bluth, A. J. Krueger, L.S. Walter, and S.D. Doiron (1992) A sulfur emission index (SEI) for explosive volcanic eruptions. American Geophysical Union meeting December 7-11, 1991, San Francisco, CA.

I submitted a proposal to NASA headquarters in response to a "Dear Colleague" letter. The general topic is understanding and quantifying the role of sulfate and other aerosols in the troposphere:

"Contribution of Volcanic Activity to the Atmospheric Sulfur Dioxide Budget", submitted with Co-Investigators Dr. A.J. Krueger (Code 916) and Dr. L.S. Walter (Code 900).

TO: Denise Dunn, Administrative Assistant  
FROM: Carol A. Russell  
DATE: 10/23/92

SUBJECT: Technical Report for 1 July through 30 September 1992  
Task Number: 920-012

PROJECT REVIEW:

The task I am working on involves a number of projects, all related to the Advanced Solid-state Array Spectroradiometer (ASAS), an airborne imaging sensor operated by the Lab for Terrestrial Physics.

I. FIFE data analysis

ASAS data acquired during FIFE will be used to estimate absorbed photosynthetically active radiation (APAR), hemispherical reflectance (RH), vegetation indices, and other biophysical parameters. Given the ASAS instrument's spectral and bidirectional (off-nadir) capabilities, it is believed the results should improve such estimations.

The above work can only be achieved by using atmospherically corrected radiance values. Atmospheric correction is one of the most important objectives challenging the remote sensing community, and it is critical to the analyses of ASAS data. Consequently, a major part of this work will involve the testing, evaluation, and modification of existing atmospheric correction algorithms on ASAS data. It is hoped that this process will lead to such corrections becoming incorporated feasibly into a routine data processing sequence.

Initial analyses of FIFE data will be limited to homogeneous training areas, and the results will be checked for accuracy using coincident FIFE datasets, available from the FIFE Information System database. Once procedures have been developed and assessed at this level, subsequent work will apply the routines to larger areas, and ultimately include entire images. Variability due to scale differences will be assessed.

A number of procedures for calculating biophysical parameters exist in the literature. These will not be described here, but will be explained in future technical reports as they are used and evaluated.

II. Data Acquisition Missions

The ASAS instrument typically participates in several field campaigns from late spring through early fall each year. I have experience in operating the instrument and locating sites, and may occasionally be required to assist in the collection of ASAS data.

III. Evaluation of Sensor Performance

A new spectral array was just recently installed in the instrument which will be undergoing substantial testing and evaluation. I will be assisting engineers and programmers in these efforts with the objective being to optimize the value of ASAS data for scientific utility.

IV. Interaction with Scientific Community

The ASAS Principal Investigator and I would like to hold a Symposium and workshop dedicated to the use of ASAS data. This would be the first time ASAS users would be assembled together for this purpose. The appropriate forum for these will be determined.

Currently, I also serve as a point of contact for requests of ASAS data that are not accessible through other databases.

#### PROGRESS:

The bulk of work accomplished has been on the Fife Data Analysis topic, since I plan on attending a FIFE workshop in November and will present some results there.

#### I. Fife Data Analysis

Initial inventory and identification of appropriate datasets have been completed. This involved surveying FIS for lightbar data and comparing collection times with archived ASAS data. Eighteen ASAS site passes exist that are sufficiently concurrent with UNL and KSU lightbar measurements for further analysis.

C-130B flight navigation data corresponding to the identified ASAS site passes has been acquired and brought online. Navigation data is essential for establishing correct view and solar geometries relative to a given site.

A meeting was held with several Univ. of Maryland researchers who are collaborating on aspects of the FIFE study and GSFC personnel familiar with the 6S atmospheric correction code, with the goal being to decide upon appropriate input parameters to the correction model.

Mapping of specific training areas onto site photos/overlays has been completed, and selection of these training areas from actual image data has begun.

#### II. Data Acquisition Missions

Not applicable at this time.

#### III. Evaluation of Sensor Performance

Viewed several images produced by the new array to assist in the site identification and discrimination of "slew" data.

#### IV. Interaction with Scientific Community

Provided Dr. Dorothy Hall of GSFC with ASAS data collected over Glacier National Park, Montana.

In addition to the above projects, I submitted an abstract to the Annual Meeting of the Geological Society of America, which was accepted.

#### PLANNED WORK FOR NEXT QUARTER:

Continue selection of small training areas from ASAS images. Atmospherically correct the radiance values obtained from the training areas.

Learn IDL (Interactive Data Language) and create an IDL program to plot 3-D diagrams of radiance values versus spectral band versus view angle.

Compare plotted results with ground and helicopter data.

Attend FIFE workshop and present above plots and comparisons.

Attend Annual GSA meeting in Cincinnati and present talk on dissertation work.



## TECHNICAL REPORT

FOR THE TERM FROM JULY 1 TO SEPTEMBER 30, 1992

MAKOTO SATAKE

TASK NUMBER 930-008  
USRA VISITING SCIENTIST PROGRAM  
CODE 936, NASA / GODDARD SPACE FLIGHT CENTER

OCTOBER 1, 1992

### OVERVIEW

Relating to development of the TRMM -Tropical Rainfall Measuring Mission- Science Data and Information System (TSDIS), topics of my activities in this term include: TRMM related meetings; Input of the airborne radar algorithms into the TSDIS prototype system; and Learning the prototype. As to study on data processing of rain radar data, I have concentrated on study of rain profiling methods. In addition to those two regular activities, I attended a conference on clouds and precipitation held in the August, in Montreal.

### DEVELOPMENT OF TRMM SCIENCE DATA AND INFORMATION SYSTEM (TSDIS)

Along with regular TSDIS meetings, there were some important (non-regular) TRMM related meetings which I attended (in part, some of them), TSDIS Prototype PDR on July 8, TRMM PDR on July 15 to 17, and NASA/NASDA programmatic meeting on July 20 to 22.

I have provided the information, when something in the meetings is considered necessary to them, to my colleagues in CRL, Japan who is engaged in developing the TRMM radar.

Airborne radar algorithms and data provided by Dr.Meneghini (and other TRMM Radar Team members) were inputted to the TSDIS prototype system so as to be used as a model of TRMM radar algorithms and data. Although I wasn't directly involved in this input, I have been concerned with the airborne radar algorithms, as well as TRMM radar algorithms. I am, therefore, very interested in how they work in the prototype system.

I started to learn the TSDIS prototype system, not only its design but how it works (and how to use it). It will hopefully enable me to test connectivity and accessibility of the TSDIS from Japan. That test will be a must before the TSDIS becomes operational.

Since the TSDIS prototype system is under development of its earliest practical version, I have just begun the study by reading a textbook of *unix* on which the system will be operated.

### RAIN RADAR DATA PROCESSING

I have focused on study of rain profiling methods from radar data. There are several methods proposed to retrieve rain rates at each radar range bins from radar signals (backscattering echoes from raindrops) which suffered attenuation during propagating in the rainfall. Among them are methods proposed by Drs.Fujita, Kozu, and Meneghini, each.

My current interest is to examine whether the Fujita's method is applicable to actual airborne radar data and hopefully to space borne radar data. I applied the method to the NASA/CRL T-39 airborne radar data (X- and Ka-band) taken in the CaPE experiment (in Florida, summer 1991), and got the result of retrieved rain rates for a few cases of rainfalls. I talked on the results with Dr.Iguchi who also had been studying rainfall profiling methods.

### ATTENDING ICCP-92

I attended the 11th International Conference on Clouds and Precipitation (ICCP), on August 17 to 21, 1992, at McGill University, Montreal, Canada. ICCP is held every 4 years with a cooperating organization of American Meteorological Society. The 11th ICCP consisted of ~350 papers presented, with ~450 participants from over 30 countries. Its technical areas covered from 'Cloud Microphysics', 'Precipitation Physics', and 'Instrumentation' to 'Remote Sensing of Clouds and Precipitation (including Satellite Observations)'.

Being at the conference, I learned about some of the presented papers - my main interest was on studies and measurements of precipitation - which included several papers relating TRMM presented by the scientists from GSFC and JPL. I could exchange some useful information relating to my task, having discussion with some participants, particularly a person of the McGill Univ. who knew know-how of the Patric Air Force Base (Florida) radar.

### PLAN FOR THE NEXT TERM

In the next term of October to December, respecting the TSDIS prototype development, I am going to learn the prototype system which is to be completed its phase 1 stage by the end of December.

I am planning to finish my rain profiling study, making a report.

## Quarterly Report for Kevin Olson, Task 930-015

### 1 Work in Progress

My research for the period 1 July - 30 September has been focused in several areas. As I described in the last quarterly report, I have written a computer code to do gravitational N-body problems. I also described how I hope to use this code to study problems in the dynamics and star forming properties of interacting/merging galaxies. The code was written in APPL (Applications Portable Parallel Library) to run across our distributed network of workstations and I discussed that I planned to port the code to two available MIMD supercomputers, the Intel DELTA at Caltech and the Intel iPSC/860 at NASA/Ames.

The code was easily ported to both of these machines and APPL worked well on each. Several problems were encountered, however. The code, as originally written, took too much memory per processor to run. Therefore, revisions needed to be made. The code has now been revised and is working on the DELTA. A further problem is that the code is not as efficient as one would like. In fact, the code running across four workstations, executes faster than the same code running across four processors of the DELTA. The problem is the i860 processing chip upon which these machines are based. The i860 has a relatively small memory cache and it is difficult to write code to make efficient use of it. This is compounded by the fact that the fortran compiler does not produce good machine code to take advantage of all the features of the i860 chip. My code is particularly problematic in this regard in that it makes liberal use of pointers. However, the code does scale well with the number of processors and near linear speedups are obtained. Work is continuing in this area to make the code execute as fast as possible for the largest number of bodies possible.

In the past quarter I have also begun to write a similar code to that described above, for the Maspar here at Goddard. The Maspar is a SIMD (single instruction, multiple data) machine with 16,384 processors, and hence has a different architecture than the machines mentioned above. This project has only recently been initiated and a more definitive assessment of the Maspar for this problem is not possible at this time.

In my last report, I also stated that I would write a code to simulate gas dynamics using a technique known as smooth particle hydrodynamics. This is a lagrangian technique and the motions of particles are followed through space. Each particle carries with it local values of the gas pressure, temperature and density, from which the forces on other particles are computed. A one dimensional version of this code has been written and currently runs on my workstation and has been applied to several simple problems (eg. colliding streams of gas). Also, this code has been ported to the Maspar by rewriting the code in Fortran 90.

In the last quarter I also collaborated with Dr. Clark Mobarry in mentoring Ted Yang for the VSEP program. Ted worked on a problem which is of interest to me, namely interacting galaxies. He wrote a code for the Maspar which simulates the interaction of two disk galaxies by using the restricted three body approximation (the mass of each galaxy is assumed to be concentrated at a point in its center and the stars orbiting this mass center are assumed to move as test particles). As result of this, Ted produced a video animation of some of his results which he displayed at his presentation following the completion of the program.

## 2 Work Planned for Next Quarter

1) I plan to continue to work on the N-body code I have written for the Intel machines. The code must be made more efficient (by at least a factor of ten). It is my goal to have the code be able to sum the gravitational forces between 1 million particles in small amount of time (less than 20 seconds). Whether this will be possible remains to be seen. I am confident that performance of this can be achieved, since the major loops in the existing code have not yet been vectorized. Also, several algorithmic changes are presently being investigated for their potential to improve the performance of the code. Also, Caltech will obtain an Intel Paragon computer which will aide in achieving this goal.

This code, once completed and fully optimized, will be applied to problems in the dynamics of interacting galaxies. I hope to address the question of bar formation in a galaxy as a result of its interaction with another galaxy. N-body codes have shown that bars can form as a result of the interaction of two galaxies. However, the number of simulations which addresses this questions is small. With my code I hope to perform a larger search of parameter space (eg. the inclination of the two galaxies, their distance of closest approach, their relative velocity, their internal mass distribution, and their relative mass).

2) I also plan to continue my work on producing a gravitational N-body code for the Maspar in Fortran 90.

3) I hope also to extend the SPH code I have written to multiple dimensions and to test it on some real problems. I also hope to add magnetic effects to the existing code so that problems in MHD can also be studied. Ultimately the SPH code will be combined with the gravitational N-body code described above. If this is accomplished, the code will be used in the study of the dynamics of giant molecular clouds in an effort to understand their structure, their interactions through collisions, and, I hope, to learn something about the processes which lead to star formation.

4) The research projects for the HPCC have now been selected. I anticipate that in the upcoming quarter I will begin to work with these researchers in porting their codes to some of the parallel machines that are available.

7/15/93

**Technical Report for 1 July thru 30 September 1992****Bruce Fryxell**

Much of my work during this quarter has involved writing a chapter for a book on computational methods for astrophysics. My chapter will describe the Piecewise-Parabolic Method for computational gas dynamics. This method has much higher resolution than most numerical schemes in use today, but is very complex and requires a significant effort to program. A floppy disk containing the FORTRAN source code of the program will accompany the book. As a result, this high-resolution method will become easily accessible to a much wider range of researchers, which should significantly improve the quality of research in computational astrophysics.

This algorithm is ideally suited to massively parallel machines and extremely high performance is expected. This, coupled with the high-resolution of the method, should make it possible to solve new classes of problems which are beyond the capabilities of simpler algorithms and serial computers. Work has already begun on adapting the code for use on the Maspar computer at Goddard.

I have also begun work on developing a Magneto-Hydrodynamic code based on the same numerical techniques. Including magnetic fields increases the complexity of the algorithm enormously but is necessary for solving many problems in astrophysics and space physics. There are two separate groups already working on this problem. One is led by Phil Colella at the University of California at Berkeley. I traveled to California to visit him during this quarter and have started a collaborative effort on this project. The other group is led by Paul Woodward at the University of Minnesota. He has also agreed to collaborate with me on this project. I intend to examine these two approaches and combine the best features of each into my code. I expect this to be a long term project which will continue for a year or more.

Another project in which I am involved is the calculation of the supernova mechanism in massive stars. Current one-dimensional models of supernovae fail to explode. Adam Burrows at the University of Arizona and I are calculating multi-dimensional effects which may lead to an explosion. The neutron star formed in the initial collapse of the core of the star is unstable to convective overturn. This will lead to a non-spherical flux of neutrinos being emitted from the young neutron star. Preliminary results have shown that the amount of non-sphericity is much higher than was predicted, and this could have significant consequences. We have written a paper describing these results which is being published in *Science* in October.

During the next quarter I plan to finish the chapter for the computational methods

book which I am writing. The first draft is already complete, and only minor modifications are required. I also expect to finish modifying my code for use on the Maspar computer, and if all goes well, to begin doing some high-resolution simulations on astrophysics problems. Work will also continue on the development of the magneto-hydrodynamic code. A trip to the University of Minnesota is planned to begin working with Paul Woodward on this project.

**QUARTERLY REPORT FOR J. ANTHONY GUALTIERI****July 1, 1992 - September 30, 1992**

Associate Research Scientist, Universities Space Research Association

Computer Systems Research Facility, Code 935

**RESEARCH SYNOPSIS:****Inversion Algorithms:**

**AIRS** A neural network backpropagation code was developed on the Maspar SIMD computer using the the Maspar linear algebra math library. This code will allow very large networks with large training sets appropriate to the AIRS retrieval problem to run at very high speeds. First results show the network running at six million connection updates per second – to be compared to a quarter million connection updates per second on a DEC5000 serial machine. With optimization I believe this speed could be improved by a factor of two to three more.

**GLA** I have continued to attend Joel Susskind's group meetings in Code 911.

**Collaboration with Prof. Howard Motteler** We have worked together to prepare data sets for the HIRS and AIRS instruments using the TIGR data sets from JPL.

**Distance Between Images:**

Together with Jaqueline Le Moigne, NRC Associate of code 936 and Charles Packer of Code 935 some further applications on this algorithm to image registration and fingerprint differentiation were conducted. This work will be included in the presentation at the Frontiers 92 symposium.

**VSEP**

I was mentor for VSEP student Lukasz Zielinski and we studied using formal inversion of feedforward neural networks to solve an inversion problem. He prepared a report that was submitted to VSEP.

**WORK PLANNED FOR NEXT QUARTER:**

**TOVS Pathfinder** Assist Susskind's group in converting their pathfinder products into HDF format for inclusion into the Goddard DAAC. Construct a fast forward code for the SSU instrument for inclusion into Susskind's retrieval algorithm for the TOVS pathfinder.

**Inversion Algorithms:**

Prof. Howard Motteler, NRC RRA, will further adapt the neural network back propagation code I have developed on the Maspar and adapting it to the atmospheric inversion problem.

**PUBLICATIONS**

None this quarter.

**TRAVEL**

None this quarter.



## Quarterly Technical Report of Toshio Iguchi for the period of July-September, 1992

In this quarterly period, I wrote a program that calculates the double scattered radar return from Raleigh particles. The purpose of this calculation is to find out whether the rather high linear depolarization ratios (LDRs) observed at Ka-band in CaPE experiment are due to the multiple scattering effect or not. I think it is a multiple scattering effect and would like to confirm it.

I spent the latter half of the quarter period for the preparation of my talk at TRMM radar team meeting which is to be held on October 5-9. The major part of the work was the review of the existing rain retrieval algorithms for a space-borne radar. I also tested these algorithms with the CaPE data using the program I developed in the previous quarterly period.

In the next quarterly period, I will summarize the results of double scattering calculation and the comparison of rain retrieval algorithms. I also plan to calculate the drop size distribution over a rain storm in the CaPE data and see how the distribution varies. This would be a topic of paper I might submit to the Radar conference next year. I will also continue working with Mr. R. Meneghini on the modification of CRL air-borne radar to a ground-based radar at Wallops island.

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## QUARTERLY TECHNICAL REPORT

1 July to 30 September 1992

by

Chaing Chen

*Universities Space Research Association  
NASA/Goddard Space Flight Center  
Greenbelt, MD 20771*

### Summary of accomplishments

1) During this period, Dr. Chen continued to work on the study of the pressure gradient force (PGF) problems over a steeply sloped terrain. The conventional wisdoms to reduce the PGF error in a hydrostatic model are to limit the slope of the terrain to less than 5% ( $\Delta h/\Delta x < 5\%$ ) or to use larger  $\Delta z$  such that the slope of the grid box is larger than that of the terrain slope ( $\Delta z/\Delta x > \Delta h/\Delta x$ , Mahrer 1984). Numerous experiments were conducted to examine these criteria. It is found the criterion ( $\Delta z/\Delta x > \Delta h/\Delta x$ ) is valid only when the slope of the mountain is greater than 5% and a stably stratified layer is located near the upper part of the mountain. On the other hand, the PGF produces small error when a uniform stratified layer is used in the simulation. The sharp change of stratification near the peak of the mountain is the main contributor of the PGF errors.

2) A major effort devoted during this period is to assist DRS. Koch and Karyampudi to conduct numerical experiments to simulate the generation and the propagation of an undular bore on the lee side of the mountain using Dr. Chen's non-hydrostatic model. We have found that the numerical model is a very useful tool in this research. For instance from the numerical experiments, we learned that the cold pool at the upstream of

the mountain is an essential condition to generate bore at the downstream side. We also learned the curvature effect associated with the low-level easterly jet is very important to maintain the strength of bore while the bore is propagating hundreds of kilometers in the downstream direction.

3) As a part of the effort to develop a future mesoscale nonhydrostatic model, Dr. Chen spent some time to review the unstructured grid method, in which the idea is inspired by the seminar given by Dr. Bacon of SAIC. Dr. Chen feels that the unstructured grid method can be a very powerful tool in the mesoscale research, especially to deal with the scale interaction processes.

SEP

Nolan Associates  
4400 Robertson Blvd.  
Alexandria, VA 22309  
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October 26, 1992

Universities Space Research Association  
Visiting Scientist program  
Mail Code 610.3  
NASA/Goddard Space Flight research Center  
Greenbelt, MD 20771

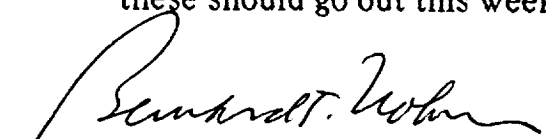
Technical Activities Report No. 9-September 24 thru Octoer 23, 1992

Dates of Effort-September 25,29, October 1,5,7,16,19 and 22, 1992

On September 29 I met with representatives of the TOGA-COARE International Project Office (TCIPO) and members of the NASA field operations team to resolve issues relating to the allocation of space in Townsville and several logistics issues. Originally planned for two days, the meeting with the TCIPO people took half a day. During the afternoon of the 29th I met with the two other NASA operations coordinators (who will be in Townsville sequentially) to work out details for the completion of Section 5.0 of the mission plan dealing with mission operations and coordination. A report covering the outcome of this meeting was prepared and submitted to Dr. Theon on October 5th.

Section 5.0 of the mission plan was completed and incorporated into the document by mid October along with changes to other sections. A fresh copy of the plan was generated and is currently under review by Drs. Kakar and Suttles and myself.

Plans are going forward for a final mission readiness review in mid December. I have prepared an agenda for the review and the cover letter; these should go out this week.

  
Bernard T. Nolan, Consultant

Nolan Associates  
4400 Robertson Blvd.  
Alexandria, VA 22309  
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September 25, 1992

Universities Space Research Association  
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Greenbelt, MD 20771

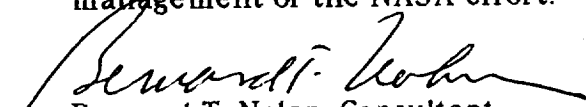
Technical Activites Report-June 29 through July 24, 1992

Dates of Effort-August 28,31, September 3,4,8,9,10,11,14,15,17,21,22, and 24  
1992

Major activity during this period focused on follow up work in connection with the NASA TOGA COARE readiness review conducted August 26 and revisions to the NASA T-C Mission Plan. With regard to the latter, two additional draft revisions have been prepared and edited since the second draft was published and sent out for comment in July. The current version, labeled final draft, is nearing completion and will be distributed to a much smaller contingent of reviewers by mid October. The final draft must be in position before the end of November. I have written several sections of the plan and am collaborating now on a section dealing with field management, operations and logistics. I am also serving as principal editor.

Logistics arrangements for the deployment phase of T-C are entering the final planning stage. I will join a team of NASA operations coordinators in Boulder, CO on September 29 and 30 to work out details with the T-C International Project Office.

On September 3 and 4 I met with Dr. J. T. Suttles, NASA Headquarters, D. McDougal, Langley Research Center and F. Valladares of Science Applications International Corp. in Hampton, VA to discuss support arrangements for publishing the mission plan and also for the January-February 1993 on site management of the NASA effort.

  
Bernard T. Nolan, Consultant

BRUTON B. SCHARDT  
QUARTERLY REPORT  
JULY-SEPTEMBER 1992

Major activity during this quarter involved the sorting of documents and records for the move to the new NASA building. Correspondence and other records pertaining to the Landsat, Large Format Camera and Shuttle Imaging Radar programs as well as miscellaneous documents were either packed for moving, identified for archives or destroyed. The move took place the end of July and the following week the process of unpacking and refileing began. Also involved during this period was the review and selection of LFC 35mm slides with Dr Greer for his presentation to the International Society of Photogrammetry and Remote Sensing Congress. A meeting was also held with Fred Engle and Priscilla Strain of the National Air And Space Museum to review their new publication "Looking At Earth", and to discuss preliminary arrangements for transfer of the LFC from NASA storage to the Air and Space Museum in accordance with recommendations from the General Accounting Office. Another activity in this period was the identification of a piece of LFC support structure hardware that had been discovered at JSC and should have been transported to the Stennis Space Center for storage with the LFC.

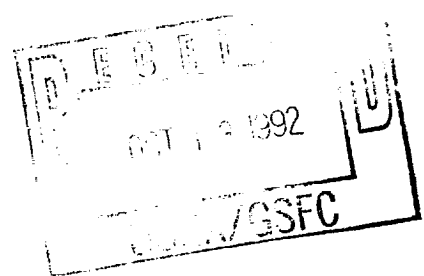
  
BRUTON B. SCHARDT

BRUTON B. SCHARDT  
MONTHLY REPORT  
AUGUST 1992

During this period I was involved in the review and selection of Large Format Camera (LFC) slides with Dr Greer of the Forestry Service for his presentation to the International Society of Photogrammetry and Remote Sensing (ISPRS) Congress. I attended part of this Congress to meet with Eastman Kodak representatives to view their display of a 5 by 14 ft enlargement of a color infrared LFC frame of the Great Barrier Reef. I had assisted Kodak in getting the LFC contact prints for this enlargement and also in getting NASA permission to use the LFC data. Also involved this month was a meeting with Fred Engle and Priscilla Strain of the Air and Space Museum to review their new book "Looking At Earth" which has just been published. This book contains many spectacular photographs including Landsat and LFC imagery. Other activities included making arrangements for reproduction of the slides finally selected for Dr Greer's presentation for use in other presentations on the capabilities of space photography.

*Bruton B. Schardt*  
BRUTON B. SCHARDT

977 007



BRUTON B. SCHARDT  
MONTHLY REPORT  
SEPTEMBER 1992

During the first ten days of this month activities involved identifying the hardware found at JSC that they believed belonged to the Large Format Camera. This was verified by Shuttle cargo bay photographs as being part of the Multi-Purpose Experiment Support Structure designed to support the LFC in flight. It was part of the LFC ancillary equipment that should have been sent to the Stennis Space Center for storage with the LFC. Also involved during this period was an initial quality review of the LFC 35 mm slides that had been reproduced for Dr. Greer of the Forestry Service, and review and comment on a General Accounting Office fact sheet on the Landsat Program. During the latter part of this month I was out of the area on personal travel.

  
BRUTON B. SCHARDT



USRA NAS 5-30442  
Activity # 220-007 Task I

Dr William W. Vaughan

Period 1 June 1982 - 20 August 1982

During this period efforts regarding the statement of work were primarily devoted to the following activities and related services:

- 1) Background research and information development and consultation with NASA Technical Monitor on Technical inputs for accomplishment of activities related to task statement of work.
- 2) Collaboration with Dr John Thoen NASA Hq on preparation of final paper for publication on "The NASA Earth Observation Region: Remote Sensing From Space". This included interaction on development of outline and text including final preparation of graphical and table information and text for completed paper to be published in Rio de Janeiro Global Forum proceedings. The original and copies here

been provided to the NTSR  
Technical Monitor & Theron and are  
available upon request

- 3) The above efforts involved extensive  
interaction and mutual review on development  
of test and associated inputs including  
service necessary to meet schedule. Some  
information developed during the research  
activities was brought to attention  
of Technical Monitor on an ad hoc  
basis for consideration in NTSR  
research program activities related to  
the 50A.

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USRA NAS5-30442  
Activity 970-007

Dr. William W. Vaughan

Period 1 August 1992 - 30 September 1992

During this period principal efforts were devoted to the following activities:

1. Reviews of committee charters and proposed standards task scopes relative to follow-up actions from Standards Technical Council Meeting.
2. Preparations for November Standards Technical Council and Standards Executive Council Meetings relative to agendas and issues for discussion/action.
3. Reviews of technical items relevant to NASA Atmosphere Research Program and interaction with NSA Technical Monitor.
4. Preparation of comments and suggestions on draft documents prior to finalization and approval for standards program publication.

970-007  
Task I

USRA NAS5-30442  
Activity 970-007 Task I

Dr. William W. Vaughan

Period 15 August 1992 - 30 September 1992

During this period efforts regarding the statement of work were devoted to the following activities and related series:

1. Completed follow-up actions on the final publication and distribution of the paper "NASA Earth Observation Program: Remote Sensing from Space" including interactions with the NASA Technical Monitor.
2. Provided detailed reviews and developed inputs relative to presentation of paper entitled "The Tropical Rainfall Measuring Mission" presented at the COSPAR Multi - Sensor Symposium held in Washington, D.C. September 1992. Based on presentation feed backs and inputs from NASA Technical Monitor, accomplished detailed analysis of material and prepared final graphical material, tables and text for publication as part of the proceeding of Symposium. The original and copies are being provided to the NASA Technical Monitor and are available upon request.
3. The above involved extensive interaction with NASA Technical Monitor, reviews and development of material, including supporting services, necessary to meet schedules, etc. Allied topics having potential value to NASA research program activities related to the SOW were brought to the NASA Technical Monitor's attention.

Technical Report of activities  
(1 July to 30 September 1992)

Employee: Brad S. Ferrier  
Date: October 20, 1992

Task Number: 920-005

Over eighty percent of my time during this quarter was devoted to writing the first in a series of two or three papers on the development of a new ice-phase parameterization and its performance in simulating convective storms in different large-scale environments. This first paper is a comprehensive description of the new, four-class ice microphysical scheme (4ICE) that I developed. This was a challenging effort because the parameterization is very mathematical and involves ninety distinct microphysical processes associated with calculating changes in the mixing ratios and number concentrations of four different ice species (cloud ice crystals, snow, graupel and frozen drops/hail), as well as the mixing ratios of liquid water on wet precipitation ice (snow, graupel, frozen drops). Additional improvements to the 4ICE scheme in comparison to other microphysical parameterizations were made in the following areas: (1) representing small ice crystals with non-zero terminal fall velocities and dispersive size distributions, (2) accurate and computationally efficient calculations of precipitation collection processes, (3) reformulating the collection equation to prevent unrealistically large accretion rates, (4) more realistic conversion by riming between different classes of precipitation ice, (5) preventing unrealistically large rates of raindrop freezing and freezing of liquid water on ice, (6) detailed treatment of various rime-splintering ice multiplication mechanisms, (7) a simple scheme for the Hobbs-Rangno ice enhancement process, (8) aggregation of small ice crystals and snow, and (9) allowing explicit competition between cloud water condensation and ice deposition rates rather than using saturation adjustment techniques. A major conclusion of the paper is that it is more important to preserve the spectral widths of the particle distributions rather than conserve particle number concentration when representing changes in ice number concentrations due to melting, vapor transfer processes, and conversion between different hydrometeor species. Large errors in the higher moments of the particle spectra (i.e., radar reflectivity) were shown to occur when conversion processes between hydrometeor classes strictly conserved particle number concentrations. The manuscript includes five appendices (one appendix is a complete list of symbols) that total thirty pages in length. The paper has already been sent for internal Goddard review, and I expect to submit it to the Journal of the Atmospheric Sciences within a week or two. Drs. Joanne Simpson and Wei-Kuo Tao were very kind and positive in their reviews of the manuscript.

Other activities this summer include working with Dr. John Scala on cloud model simulations of the 28 June 1989 North Dakota squall line case discussed at the Cloud Modeling Workshop in Toronto. The birth of my son at the end of July precluded my attending the Workshop. My collaborations continued with Dr. Bob

Pasken on analyzing the single-Doppler radar data from Darwin, Australia. Dr. Pasken will do case studies of a monsoon rainband and a break-period squall line, which I will follow with numerical simulations of these cases (hopefully) next spring. The single Doppler radar study of the evolution and structure of the 22 November 1988 island thunderstorm complex continues with Drs. Keenan and Simpson ; however, Dr. Simpson and I agree that this project requires more work before it can be published. It is likely that a series of sensitivity experiments using my one-dimensional time-dependent cloud model will be incorporated into the paper, as well as comparing these model simulations with convective clouds simulated in other geographical locations. Finally, Dr. Andy Heymsfield provided Dr. Tao and I with his recent analyses of CCOPE airborne microphysical data, as well as composite ice-particle spectra of Kwajalein cirrus at different temperature intervals: Both data sets appear to support several key assumptions I've made in the 4ICE scheme.

Much of my work in the upcoming quarter will concentrate on writing a second paper that compares GCE (Goddard Cumulus Ensemble) model simulations using the 4ICE microphysics of a tropical-maritime (tropical Atlantic) GATE squall line and a midlatitude-continental (southeast U.S.) COHMEX storm with radar observations of both systems. It will be shown that the model performed well in simulating the radar and microphysical structures of both convective systems, even though the observed vertical profiles of radar reflectivity differed substantially. A series of experiments will also assess the sensitivity of the simulated convection to variations in parameterized drop size distributions, fall velocities and aggregation efficiencies of ice, and ice nucleation at cold temperatures. Lastly, preserving the spectral widths of the particle distributions will also be shown to be more important than conserving particle number concentrations when converting between different hydrometeor categories.

I also expect to spend an increasing amount of time on preparing for my participation in TOGA COARE (Tropical Ocean Global Atmosphere Coupled Ocean-Atmosphere Response Experiment) this January, such as making hotel and travel arrangements, getting immunizations against a variety of tropical diseases, taking care of various insurance matters, preparing for five weeks of ship duty, and "brushing up" on several technical manuals that describe the operation of the shipboard radar. I also hope to get a "quick and dirty" version of the GCE model to run on a SUN workstation, so that I can do preliminary model simulations of a few cases while on the PRC ship #5 (soundings will also be taken from the ship). However, this is contingent upon how busy my schedule is at the end of the year.

970-021

21 October 1992

Subject : USRA Quarterly Technical Report

To : USRA

From : Jong-Jin Baik

Task Number : 970 - 021

1. Through extensive numerical model simulations and discussions with our project member, I now expect that numerical instability resulting from the liquid-ice phase microphysics can be removed by using a small time step for the terminal velocity terms for rain water, snow and graupel. This is very important because if it works, numerical simulations afterwards will go very smoothly. After obtaining model results, I will write a paper for journal publication.

2. I gave a seminar at Department of Astronomy and Atmospheric Sciences of Yonsei University, Korea, on 24 September 1992. The title was "Recent Research Trends on Tropical Cyclones".

601 5 1 1870

MEMORANDUM

TO: Denise Dunn, Administrative Assistant  
 From: Narinder Chauhan, Code 974  
 DATE: Oct. 22, 1992  
 SUBJECT: Quarterly Progress Report (July 1 to September 30, 1992)

The data collected during the summer of 1992 experiments conducted at Chickasha, Oklahoma and Boise, Idaho is being processed. The GSFC truck-based radar data has been labelled and arranged in a form that is easily identifiable and therefore easy to use. Though the radar operation was automated to some extent and the data was collected in separate files, but the software to determine the average radar return was not developed at the time of the experiment. This is being done now as an off-line operation and is 80-90 percent complete.

I participated in a microwave experiment on the Canadian forest with the Canadian Remote Sensing scientists from Sept. 21-26, 1992. Scientist had gathered at Petwawa Forest Research Institute, near Ottawa to study the signature of forest on microwaves. Canadian SAR (C and X-band) flew on September 25th and 26th. Multi polarization and multi frequency data was collected. We measured the dielectric constant of different components of the trees in the forest imaged by SAR. Ground truth data related to needle dimensions and their orientations was also collected.

Finally, my publication entitled "A microwave scattering model for layered vegetation" coauthored with Karam, Fung and Lang has been published in IEEE Transactions on Geoscience and Remote Sensing in the July 1992 issue. A copy of the publication is enclosed herewith.



# A Microwave Scattering Model for Layered Vegetation

N93-18074

Mostafa A. Karam, *Senior Member, IEEE*, Adrian K. Fung, *Fellow, IEEE*,  
Roger H. Lang, *Fellow, IEEE*, and Narinder S. Chauhan, *Member, IEEE*

**Abstract**—A microwave scattering model has been developed for layered vegetation based on an iterative solution of the radiative transfer equation up to the second order to account for multiple scattering within the canopy and between the ground and the canopy. The model is designed to operate over a wide frequency range for both deciduous and coniferous forest and to account for the branch size distribution, leaf orientation distribution, and branch orientation distribution for each size. The canopy is modeled as a two-layered medium above a rough interface. The upper layer is the crown containing leaves, stems, and branches. The lower layer is the trunk region modeled as randomly positioned cylinders with a preferred orientation distribution above an irregular soil surface. Comparisons of this model with measurements from deciduous and coniferous forests show good agreements at several frequencies for both like and cross polarizations. Major features of the model needed to realize the agreement include allowance for (1) branch size distribution, (2) second-order effects, and (3) tree component models valid over a wide range of frequencies.

## I. INTRODUCTION

NATURAL phenomena such as the atmospheric carbon dioxide concentration, the hydrologic cycle, and the energy balance in the biosphere are related to the forest. Hence accurate and timely measurements of the forest structure and type through remote sensing are of interest [1]. Of the many ways to measure forest properties, microwave remote sensing is one way which is independent of both weather conditions and the time of day when the measurements can be acquired [2, Chapter 1]. The analysis of these measured data could yield biophysical characteristics of the forest [3]–[5] or its components such as leaves, branches, and trees [6]–[8].

In parallel to the experimental studies, scattering models have been developed to interpret the collected data [9]–[24].

Manuscript received September 19, 1991; revised February 20, 1992.

The work of the first two authors was supported by the National Aeronautics and Space Administration under Grant NAGW-2344 and under NASA's SIR-C data analysis program which is funded through the Jet Propulsion Laboratory.

The work of the last two authors was supported by NASA Grant NAGW-2071 and the NASA EOS Synergism Study organized by JoBea Way of NASA JPL. The numerical evaluations were supported by the Center for High Performance Computing of the University of Texas System.

M. A. Karam and A. K. Fung are with the Wave Scattering Research Center, Electrical Engineering Department, University of Texas at Arlington, Arlington, TX 76019.

R. H. Lang is with the Department of Electrical Engineering and Computer Science, The George Washington University, Washington, DC 20052.

N. S. Chauhan is with the Laboratory for Hydrospheric Processes, Code 974, NASA/Goddard Space Flight Center, Greenbelt, MD 20771.

IEEE Log Number 9200985.

These models may be divided into two categories: i) phenomenological models and ii) physical models.

The phenomenological models are based upon an intuitive understanding of the relative importance of different forest components. Then a scattering model is constructed by summing up the contributions from forest components believed to be important [10]–[12]. The physical models are based upon the interaction of electromagnetic waves with the forest canopy. A canopy can be modeled either as a discrete or a continuous inhomogeneous medium. As a discrete medium the canopy is treated as a collection of randomly distributed discrete scatterers assuming average sizes and shapes of various forest components [13]–[23]. These scatterers may be embedded in one or two layers or a half space medium. For continuous medium modeling, the canopy is treated as a continuous medium with a fluctuating permittivity function [24]. The radiative transfer theory [13]–[20], the distorted Born approximation [21], [22], or the Monte Carlo technique [23] have been used to study electromagnetic interaction with discrete media. The first-order Born and renormalization methods have been applied to study wave scattering from continuous media [24].

Most of the existing scattering models are restricted by assumptions regarding the shape of the scatterers [15]–[21] or the applicable frequency [9], [17]. Some models account only for leaves but not branches or vice versa [16]–[21] and others treat branches and soil surfaces but not leaves [18]. In all these models the scatterers were embedded in one layer above the soil interface or a half space medium.

Recently, a two-layer phenomenological model has been proposed by Richard *et al.* [1987] for a coniferous forested canopy at L-band [11]. In this model the foliage is represented by a cloud of water droplets and the trunk-ground interaction is modeled by dihedral corner reflectors. To avoid issues of tractability and complexity, the individual scattering mechanisms within the forested canopy were modeled separately utilizing empirical or analytical description as appropriate. This model is simple but its domain of applicability is limited. Durden *et al.* [1989] improved this model by replacing the dihedral corner reflector by a finite-length cylinder over a rough interface. The branches are modeled by a layer of randomly oriented cylinders [12]. Several scattering mechanisms are identified and the corresponding Stokes matrices were calculated. The Stokes parameter matrices were then combined to give the total Stokes matrix and resulting polarization signature. The leaf effect was not taken into consideration.

Ulaby *et al.* [1990] proposed a two-layer physical model based on the first-order solution of the radiative transfer theory [13]. This model was used [14], [15] to model multiangle and temporal backscatter from a walnut orchard. It involves the following assumptions:

1. The contribution from trunks in the backscattering direction can be ignored and trunk-ground interaction can be accounted for by considering reflections from the trunks and a flat ground.
2. The cross-polarized term in the trunk phase matrix has been ignored.
3. In the canopy-ground interaction calculation, the ground can be taken to be a specular surface.
4. The forward scattering theorem (optical theorem) can be applied to calculate the extinction coefficient within the canopy. This theorem is accurate to the extent the field scattering amplitude is accurate. Under low frequency approximations this theorem can only provide the loss due to absorption [25]. Hence, scattering loss is not included.
5. The physical optics approach is used to calculate scattering from a leaf. Thus, only leaves larger than a wavelength are considered.

In view of the current status in forest scattering models, there is room for further generalization. The aim of the present study is to develop a scattering model with a wider range of applicability than those available in the literature. In particular, we want to develop a fairly complete but simple physical model which can be applied to both deciduous and coniferous forest over a wide range of frequencies by

1. including coherent and incoherent surface scattering in computation of canopy-soil interactions,
2. using a leaf scattering model which holds for leaves smaller or comparable to the wavelength,
3. accounting for the various branch sizes and their orientation distributions,
4. accounting for cross polarized scattering due to the trunk-ground interactions,
5. using an extinction formulation which accounts for both ohmic and scattering losses where low frequency approximation is made.
6. including the second order radiative transfer solution to account for multiple scattering within the canopy.

A description of the scattering model for a forest canopy is given in Section II. For a linearly polarized incident wave, the explicit expressions for the bistatic scattering coefficient associated with different scattering mechanisms discussed in Section II are given in Section III. In like polarization the second-order volume scattering is generally small compared with the first. However, in cross polarization second-order contribution can be important. Hence, the second-order volume scattering term due to the crown layer is also given.

As a test for the present model comparisons are made between the measured and the predicted values of the backscattering coefficients from both walnut and cypress trees [4], [26]. Two of the authors, Lang and Chauhan have participated in the collection of the walnut tree geometry and ground truth [26].

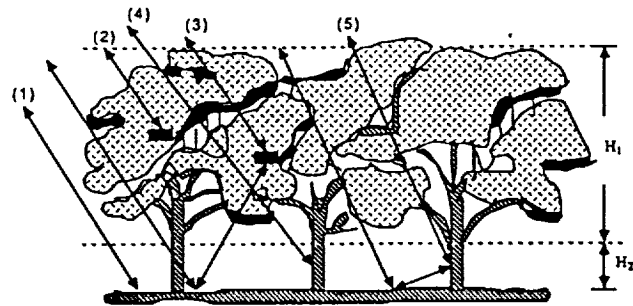


Fig. 1. Geometry of a forest canopy and the backscattering processes for the zero and first-order solutions of the radiative transfer equation: (1) zero order, (2) crown scattering, (3) crown-ground interaction, (4) trunk scattering, (5) trunk-ground interaction.

The cypress tree ground truth is available in the literature [4]. Hence, arbitrary choices of most of the model parameters are avoided.

## II. FOREST SCATTERING MODEL DESCRIPTION

The geometry of the scattering problem is given in Fig. 1. It consists of a crown layer and a trunk layer above an irregular surface. Within the crown layer the branches are grouped into different sizes each with an orientation distribution. They are modeled as randomly oriented finite-length dielectric cylinders. The scattering matrix ( $S$  matrix) for such cylinders can be obtained by estimating the inner field by that of corresponding infinite cylinder [18]. The validity of this approach for calculating the branch scattering matrix was verified experimentally for branches having length to diameter ratio greater than 5 [27], [28]. The extinction coefficient for the branch model is obtained via the forward scattering theorem since the model does not use low frequency approximation [18]. The deciduous leaves are modeled as randomly oriented circular discs. The coniferous leaves and the stems are modeled as randomly oriented needles. The scattering matrix for a needle or a disc is obtained by applying the Generalized Rayleigh-Gans approximation. This approximation holds for thin leaves and for leaf surface dimension smaller or comparable to the wavelength [27]. Thus, for leaves the extinction coefficients are calculated by summing both the absorption and the scattering coefficients [29]. In summary, the crown layer consists of several groups of scatterers, namely, the leaves and a few different sizes of branches. Scatterers belonging to the same group are identical in size.

Each group of scatterers within the crown layer is a collection of identical scatterers with number density  $n_m(m^{-3})$  and a probability density function  $P_m(a, h, \alpha, \beta)$  where " $a$ " and " $2h$ " are the radius and length or thickness of a scatterer within the  $m$ th group. The angles  $\alpha$  and  $\beta$  are the scatterer azimuthal and inclination angles, respectively (Fig. 2). In this study the polar coordinates are used to describe the scatterer orientation with respect to the reference frame and the radial coordinate is parallel to the scatterer axis of symmetry. All the crown constituents are taken to be uniformly oriented in the azimuthal direction. Consequently, the probability density function for the scatterers within the  $m$ th group reduces to

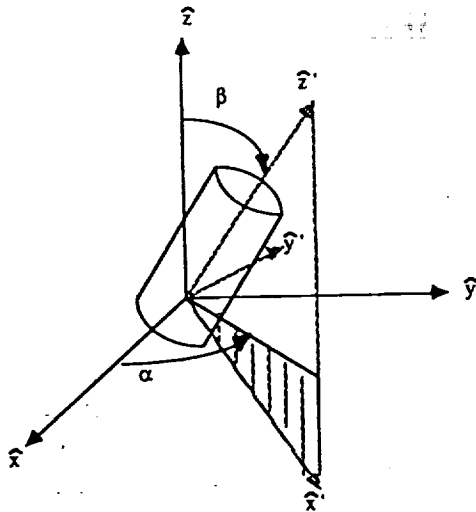


Fig. 2. The polar angles of orientation (defined with respect to the reference frame).

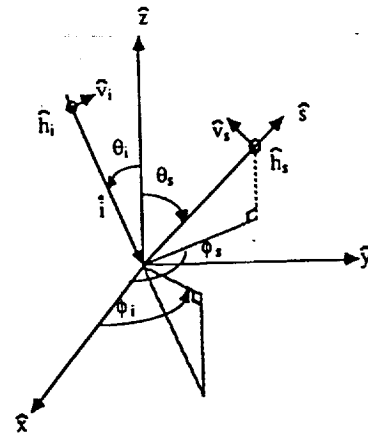


Fig. 3. The polarization vectors of the incident and scattered fields.

the form,

$$P_m(a, h, \alpha, \beta) = \frac{1}{2\pi} P_m(a, h, \beta). \quad (1)$$

Similarly, the trunk layer may also have several groups of scatterers. Each group is modeled by randomly positioned and vertically oriented identical cylinders with number density  $n_m(m^{-3})$ . Each group has its own orientation distribution function. Since a trunk can also be modeled as a dielectric cylinder, the scattering amplitude matrix is the same as the branches [18] and so is the representation for the extinction coefficient.

The Kirchhoff model under the scalar approximation is used to represent the scattering properties of the rough soil surface [2]. The surface correlation function is taken to be a Gaussian function with variance  $\sigma^2$  and correlation length,  $L$ .

### III. THE BISTATIC SCATTERING COEFFICIENTS

Consider a plane wave incident in  $\hat{i}(\pi - \theta_i, \phi_i)$  direction with electric field polarized along  $\hat{q}$  direction,

$$\vec{E}_i(\vec{r}) = \hat{q} E_0 e^{-j\vec{k} \cdot \vec{r}} \quad j = \sqrt{-1} \quad (2)$$

where  $k$  is the background medium wavenumber;  $\hat{q} = \hat{v}_i$  or  $\hat{h}_i$ ; which are the polarization unit vectors (Fig. 3) defined as follows:

$$\begin{aligned} \hat{i} &= \sin \theta_i (\hat{x} \cos \phi_i + \hat{y} \sin \phi_i) - \hat{z} \cos \theta_i \\ \hat{h}_i &= \frac{\hat{z} \times \hat{i}}{|\hat{z} \times \hat{i}|} = \hat{y} \cos \phi_i - \hat{x} \sin \phi_i \\ \hat{v}_i &= \hat{h}_i \times \hat{i} = -\cos \theta_i (\hat{x} \cos \phi_i + \hat{y} \sin \phi_i) - \hat{z} \sin \theta_i. \end{aligned} \quad (3)$$

For the incident field given in (2) and using the albedo as an iteration parameter, the bistatic scattering coefficient from the canopy in  $\hat{s}(\theta_s, \phi_s)$  direction can be written as [Appendix A]

$$\sigma_{pq} = \sum_{v=0}^{\infty} \sigma_{pq}^v. \quad (4)$$

In (4)  $v$  is the order of the iterative solution of the radiative transfer equation. In the following sections we will consider

the zero, the first, and the second-order contribution to the bistatic scattering coefficient.

#### A. The Zero-Order Solution (Ground Scattering)

The zero-order solution of the radiative transfer equation is due to ground scattering as illustrated in the backscattering direction by 1 in Fig. 1. The bistatic scattering coefficient of the ground can be written as

$$\sigma_{pq}^0 = L_{1p}(\theta_s) L_{2p}(\theta_s) \sigma_{pq}^s(\theta_s, \phi_s; \pi - \theta_i, \phi_i) L_{2q}(\theta_i) L_{1q}(\theta_i) \quad (5)$$

where  $\sigma_{pq}^s(\theta_s, \phi_s; \pi - \theta_i, \phi_i)$  is the  $pq$  element of the surface bistatic scattering coefficient matrix given in [2, Chapter 13, pp. 1085–1200]. Its explicit expression depends on the surface parameters and the approximation used to derive it. For a plane interface  $\sigma_{pq}^s(\theta_s, \phi_s; \pi - \theta_i, \phi_i)$  reduces to Fresnel reflectivity [2, Chapter 12].  $L_{1q}(\theta_i)$  and  $L_{2q}(\theta_i)$  are the  $q$  polarized crown and the trunk attenuation factors in the incident direction,

$$L_{tq}(\theta_i) = \exp[-k_{tq}(\theta_i) H_t \sec \theta_i] \quad (t = 1, 2) \quad (6)$$

where  $k_{1q}(\theta_i)$  and  $k_{2q}(\theta_i)$  are the crown and trunk layer extinction coefficients, respectively [18], [29].  $H_1$  and  $H_2$  are the heights of the crown and trunk layers. Similar definitions apply to  $L_{1p}(\theta_s)$  and  $L_{2p}(\theta_s)$  in the scattering direction. The extinction coefficient within the crown region can be written as

$$k_{1p}(\theta_i) = \sum_{m=1}^{N_1} n_m \langle \kappa_{mp}(\theta_i) \rangle \quad (7)$$

where  $N_1$  is the number of groups within the crown layer and  $\kappa_{mp}(\theta_i)$  is the extinction cross section for a scatterer within the  $m$ th group [18], [29]. The ensemble average  $\langle \rangle$  in (7) is taken over the  $m$ th group orientation distribution in the following manner:

$$\langle \kappa_{mp}(\theta_i) \rangle = \frac{1}{2\pi} \int d\beta \int d\alpha P_m(\alpha, \beta) \kappa_{mp}(\theta_i). \quad (8)$$

For a discrete probability density function, the integration in (8) reduces to a summation.

Within the trunk layer the extinction coefficient is

$$k_{2p}(\theta_i) = \sum_{m=1}^{N_2} n_m \langle \kappa_{mp}(\theta_i) \rangle \quad (9)$$

where  $N_2$  is the group number within the trunk layer, and  $\kappa_{mp}(\theta_i)$  is the extinction cross section for a scatterer within the  $m$ th group. The ensemble average in (9) is defined in a way similar to the ensemble average in (8) but with density function describing the trunk orientation distribution.

The backscattering coefficient associated with ground scattering can be obtained from (5) by letting  $\theta_s = \theta_i$  and  $\phi_s = \phi_i + \pi$ , i.e.,  $\hat{s} = -\hat{i}$ .

### B. First-Order Solution (Crown and Trunk Scattering)

The first-order solution of the radiative transfer equation leads to a bistatic scattering coefficient in the form

$$\sigma_{pq}^1 = \sigma_{pq}(c) + \sigma_{pq}(c \leftrightarrow g) + \sigma_{pq}(t) + \sigma_{pq}(t \leftrightarrow g). \quad (10)$$

The first term in (10) accounts for crown scattering, the second term for the crown-ground interaction, and the last two terms for the trunk and the trunk-ground scattering, respectively. In the following subsections explicit expressions for those terms will be given along with the physical meaning of each term.

1) *The Crown Scattering*: The bistatic coefficient of the crown is (illustrated in the backscattering direction by 2 in Fig. 1):

$$\sigma_{pq}(c) = 4\pi Q_{1pq}(\theta_s, \phi_s; \pi - \theta_i, \phi_i) \left\{ \frac{1 - L_{1p}(\theta_s)L_{1q}(\theta_i)}{k_{1p}(\theta_s) \sec \theta_s + k_{1q}(\theta_i) \sec \theta_i} \right\} \quad (11)$$

$$Q_{1pq}(\theta_s, \phi_s; \pi - \theta_i, \phi_i) = \sum_{m=1}^{N_1} n_m \langle |F_{mpq}(\hat{s}, \hat{i})|^2 \rangle$$

where  $F_{mpq}(\hat{s}, \hat{i})$  is the element of the scattering amplitude matrix for a scatterer within the  $m$ th group [18], [29]. The ensemble average  $\langle \rangle$  is taken in a way similar to (8). In (11) the quantity  $Q_{1pq}(\theta_s, \phi_s; \pi - \theta_i, \phi_i)$  represents scattering from a unit volume within the crown region. The quantity within the bracket is the resultant of the integration of the loss factor,  $\exp[(k_{1p}(\theta_i) \sec \theta_i + k_{1q}(\theta_s) \sec \theta_s)z]$ , associated with a unit volume located at  $z$  over the crown depth (note that  $z$  is negative within the crown region).

The backscattering coefficient is a special case of (11) when we let  $\hat{s} = -\hat{i}$ . From (11) it is clear that the crown scattering includes  $N_1$  types of scatterers. They are attenuated by the leaves, the stems and the branches. From (7) and (11) we can see that the interaction between the crown constituents appears only in the loss factors and not in the scattering matrix.

2) *The Crown-Ground Interaction*: The bistatic scattering coefficient due to the crown-ground interaction can be written as a sum of two separate terms:

$$\sigma_{pq}(c \leftrightarrow g) = \sigma_{pq}(c \rightarrow g) + \sigma_{pq}(g \rightarrow c). \quad (12)$$

The first term in (12) represents scattering from the crown followed by scattering from the ground while the second term is associated with scattering from the ground followed by scattering from the crown. The explicit contents of these terms are

$$\sigma_{pq}(c \rightarrow g) =$$

$$L_{1p}(\theta_s)L_{2p}(\theta_s) \int_0^{2\pi} d\phi_t \int_0^{\pi/2} \sin \theta_t d\theta_t \sum_{u=v,h} L_{2u}(\theta_t) \cdot \sigma_{pu}^s(\theta_s, \phi_s; \theta_t, \phi_t) Q_{1uq}(\pi - \theta_t, \phi_t; \pi - \theta_i, \phi_i) \cdot \cos \theta_i \left( \frac{L_{1u}(\theta_t) - L_{1q}(\theta_i)}{k_{1q}(\theta_i) \cos \theta_t - k_{1u}(\theta_t) \cos \theta_i} \right) \quad (13a)$$

$$\sigma_{pq}(g \rightarrow c) =$$

$$L_{1q}(\theta_i)L_{2q}(\theta_i) \int_0^{2\pi} d\phi_t \int_0^{\pi/2} \sin \theta_t d\theta_t \sum_{u=v,h} L_{2u}(\theta_t) \cdot Q_{1pu}(\theta_s, \phi_s; \theta_t, \phi_t) \sigma_{uq}^s(\theta_t, \phi_t; \pi - \theta_i, \phi_i) \cdot \cos \theta_s \left( \frac{L_{1p}(\theta_s) - L_{1u}(\theta_t)}{k_{1u}(\theta_t) \cos \theta_s - k_{1p}(\theta_s) \cos \theta_t} \right). \quad (13b)$$

The physical meaning of (13a) can be explained as follows. The quantity  $Q_{1uq}(\pi - \theta_t, \phi_t; \pi - \theta_i, \phi_i)$  represents the scattered signal from a unit volume located at  $z$  within the crown layer in  $(\pi - \theta_t, \phi_t)$  direction. Such a volume scattering generally causes depolarization. The incident wave on a scatterer at  $z$  is attenuated by a loss factor equal to  $\exp[k_{1q}(\theta_i)z \sec \theta_i]$ . For the scattered signal to reach the crown-trunk interface it is attenuated by a loss factor equal to  $\exp[-k_{1u}(\theta_t)(z + d_1) \sec \theta_t]$ . The integration of these two loss factors over the crown depth gives the quantity in the bracket in (13a). The  $L_{2u}(\theta_t)$  is the loss factor associated with the scattered signal passing through the trunk layer to the soil interface. For this signal to be scattered by the ground and to propagate to the receiver through the trunk and the crown layers, it should be modified by  $L_{1p}(\theta_s)L_{2p}(\theta_s)\sigma_{pu}^s(\theta_s, \phi_s; \theta_t, \phi_t)$ . The integration over  $d\theta_t$  and  $d\phi_t$  accounts for all possible scattering directions through which the signal is scattered from the canopy and propagates toward the ground. The summation over  $u$  in (13a) accounts for the possible polarization combinations. It is clear that in the plane of incidence or for a specular soil surface, there is no cross-polarized scattering from the surface and  $u$  takes on only one value. Similar interpretation is applicable to (13b). The backscattering coefficient corresponding to (13) is found by letting  $\hat{s} = -\hat{i}$ . The integrals in (13) can be evaluated numerically by applying Gaussian quadrature technique [30].

For a slightly rough surface, the coherent field is dominating and it will peak around the specular direction [2]. This allows the following approximation of the surface phase function for the coherent component,

$$\sigma_{qq}^s(\theta_i, \phi_i; \pi - \theta_i, \phi_i) = 4\pi \cos \theta_i R_{qq}(\theta_t) \delta(\cos \theta_t - \cos \theta_i) \cdot \delta(\phi_t - \phi_i) \exp(-4k^2 \sigma^2 \cos^2 \theta_i) \quad (14)$$

where  $R_{qq}(\theta_t)$  is the Fresnel reflectivity. In this case the backscattering coefficients due to the crown-soil interaction reduce to

$$\begin{aligned} \sigma_{pq}(c \rightarrow g) = & 4\pi \cos \theta_i L_{1p}(\theta_i) L_{2p}^2(\theta_i) R_{pp}(\theta_i) \exp(-4k^2 \sigma^2 \cos^2 \theta_i) \\ & \cdot Q_{1pq}(\pi - \theta_i; \pi + \phi_i; \pi - \theta_i, \phi_i) \left( \frac{L_{1p}(\theta_i) - L_{1q}(\theta_i)}{k_{1q}(\theta_i) - k_{1p}(\theta_i)} \right) \end{aligned} \quad (15a)$$

$$\begin{aligned} \sigma_{pq}(g \rightarrow c) = & 4\pi \cos \theta_i L_{1q}(\theta_i) L_{2q}^2(\theta_i) R_{qq}(\theta_i) \exp(-4k^2 \sigma^2 \cos^2 \theta_i) \\ & \cdot Q_{1pq}(\theta_i, \pi + \phi_i; \theta_i, \phi_i) \left( \frac{L_{1p}(\theta_i) - L_{1q}(\theta_i)}{k_{1q}(\theta_i) - k_{1p}(\theta_i)} \right). \end{aligned} \quad (15b)$$

It is clear that (15a) and (15b) satisfy the reciprocity,  $\sigma_{pq}(c \rightarrow g) = \sigma_{qp}(g \rightarrow c)$ . Hence, only one expression in (15) is needed. For like polarization the direct substitution of  $L_{1p}(\theta_i)$  and  $L_{1q}(\theta_i)$  in (15) gives an undetermined value for the backscattering coefficient. To find this value we let

$$\zeta = \left\{ \frac{L_{1p}(\theta_i) - L_{1q}(\theta_i)}{k_{1q}(\theta_i) - k_{1p}(\theta_i)} \right\}. \quad (16)$$

Then, substitution of (6) into (16) yields

$$\zeta = L_{1p}(\theta_i) \left\{ \frac{1 - e^{-(k_{1q}(\theta_i) - k_{1p}(\theta_i)) \cdot H_1 \sec \theta_i}}{k_{1q}(\theta_i) - k_{1p}(\theta_i)} \right\}. \quad (17)$$

By using Taylor expansion for the exponent within the bracket in (17) and keeping the first two terms of the expansion we get

$$\zeta = H_1 \sec \theta_i L_{1p}(\theta_i). \quad (18)$$

From (15) and (18) the like polarized backscattering coefficient for a slightly rough surface due to the crown-ground interaction can be approximated as

$$\begin{aligned} \sigma_{pp}(g \rightarrow c) = & 4\pi H_1 Q_{1pp}(\theta_i, \pi + \phi_i; \theta_i, \phi_i) \\ & \cdot R_{pp}(\theta_i) \exp(-4k^2 \sigma^2 \cos^2 \theta_i) \\ & \cdot [L_{1p}(\theta_i) L_{2p}(\theta_i)]^2. \end{aligned} \quad (19)$$

This above result will also hold for  $\sigma_{pp}^o(c \rightarrow g)$  due to reciprocity.

3) *Trunk Scattering*: The bistatic scattering coefficient of the trunk can be written as (illustrated in the backscattering direction by 3 in Fig. 1);

$$\begin{aligned} \sigma_{pq}(t) = & 4\pi L_{1p}(\theta_s) L_{1q}(\theta_i) Q_{2pq}(\theta_s, \phi_s; \pi - \theta_i, \phi_i) \\ & \cdot \left\{ \frac{1 - L_{2p}(\theta_s) L_{2q}(\theta_i)}{k_{2p}(\theta_s) \sec \theta_s + k_{2q}(\theta_i) \sec \theta_i} \right\} \\ Q_{2pq}(\theta_s, \phi_s; \pi - \theta_i, \phi_i) = & \sum_{m=1}^{N_2} n_m (|F_{mpq}(\hat{s}, \hat{i})|^2) \end{aligned} \quad (20)$$

where  $F_{mpq}(\hat{s}, \hat{i})$  is the element of the scattering amplitude matrix for a scatterer within a trunk group  $m$  ( $m = 1, \dots, t$ ). The scattering mechanism in (20) is similar to that in (11) except the scattered signal from the trunk layer is modified by an attenuation factor  $[L_{1p}(\theta_s) L_{1q}(\theta_i)]$  due to the crown layer.

4) *Trunk-Ground Interaction*: Similar to the crown-ground interaction, the trunk-ground interaction consists of two terms (illustrated in the backscattering direction by 5 in Fig. 1)

$$\sigma_{pq}(t \leftrightarrow g) = \sigma_{pq}(t \rightarrow g) + \sigma_{pq}(g \rightarrow t). \quad (21)$$

The first term in (21) represents scattering from the trunk followed by scattering from the ground. The second term represents scattering from the ground followed by scattering from the trunk. The explicit expressions for these two terms are

$$\begin{aligned} \sigma_{pq}(t \rightarrow g) = & L_{1p}(\theta_s) L_{1q}(\theta_i) L_{2p}(\theta_s) \int_0^{2\pi} d\phi_t \int_0^{\pi/2} \sin \theta_t d\theta_t \\ & \sum_{u=v,h} \sigma_{pu}^s(\theta_s, \phi_s; \theta_t, \phi_t) \cdot Q_{2uq}(\pi - \theta_t, \phi_t; \pi - \theta_i, \phi_i) \\ & \cdot \cos \theta_i \left[ \frac{L_{2u}(\theta_t) - L_{2q}(\theta_i)}{k_{2q}(\theta_i) \cos \theta_t - k_{2u}(\theta_t) \cos \theta_i} \right] \end{aligned} \quad (22a)$$

$$\begin{aligned} \sigma_{pq}(g \rightarrow t) = & L_{1p}(\theta_s) L_{1q}(\theta_i) L_{2q}(\theta_i) \int_0^{2\pi} d\phi_t \int_0^{\pi/2} \sin \theta_t d\theta_t \\ & \sum_{u=v,h} Q_{2pu}(\theta_s, \phi_s; \theta_t, \phi_t) \sigma_{uq}^s(\theta_t, \phi_t; \pi - \theta_i, \phi_i) \\ & \cdot \cos \theta_s \left[ \frac{L_{2p}(\theta_s) - L_{2u}(\theta_t)}{k_{2u}(\theta_t) \cos \theta_s - k_{2p}(\theta_s) \cos \theta_t} \right]. \end{aligned} \quad (22b)$$

The quantity  $Q_{2uq}(\theta_s, \phi_s; \theta_t, \phi_t)$  in (22b) is the scattered intensity per unit volume within the trunk layer. The quantity in bracket is the loss factor for volume scattering in the trunk region. Similar interpretation applies to quantities in (22a).

Similar to the crown-ground interaction (13) the integration over  $\theta_t$  and  $\phi_t$  can be performed by Gaussian quadrature [30]. For a specular or a slightly rough surface and backscattering direction, (22) can be approximated by

$$\begin{aligned} \sigma_{pq}(t \rightarrow g) = & 4\pi \cos \theta_i L_{1p}(\theta_i) \cdot L_{1q}(\theta_i) \cdot R_{pp}(\theta_i) \exp(-4k^2 \sigma^2 \cos^2 \theta_i) \\ & \cdot Q_{2pq}(\pi - \theta_i, \pi + \phi_i; \pi - \theta_i, \phi_i) \cdot \left[ \frac{L_{2p}(\theta_i) - L_{2q}(\theta_i)}{k_{2q}(\theta_i) - k_{2p}(\theta_i)} \right] \cdot L_{2p}(\theta_i) \\ = & \sigma_{qp}(g \rightarrow t). \end{aligned} \quad (23)$$

Following the derivation indicated in (16)–(18) we obtain the like polarized coefficients in the backward direction due to trunk-ground interaction as

$$\begin{aligned} \sigma_{pp}(g \rightarrow t) = & 4\pi H_2 Q_{2pp}(\theta_i, \pi + \phi_i; \theta_i, \phi_i) [L_{1p}(\theta_i) \cdot L_{2p}(\theta_i)]^2 \\ & \cdot R_{pp}(\theta_i) \exp(-4k^2 \sigma^2 \cos^2 \theta_i). \end{aligned} \quad (24)$$

C. *The Second-Order Solution* The second-order solution of the radiative transfer equation with respect to the crown layer albedo is obtained by using the first-order intensity within the canopy as an exciting source. This solution contains many terms, but most of these terms are small compared to the first-order solution. In this study only two dominant terms are kept. These terms are due to scattering within the crown layer. One significant difference between the first- and second-order terms is that the input to the first-order scattering usually involves only one Stokes parameter while the input to the second-order

scattering consists of all four Stokes parameters. The scattering process associated with each term is illustrated in Fig. 4 and their contribution to the bistatic scattering coefficient is given by

$$\sigma_{pq}^2 = \sigma_{pq}(+, +, -) + \sigma_{pq}(+, -, -) \quad (25)$$

where

$$\begin{aligned} \sigma_{pq}(+, +, -) = & 4\pi \int_0^{\pi/2} \sin \theta_t d\theta_t \int_0^{2\pi} d\phi_t \\ & \left[ \sum_{u=v,h} \frac{\cos \theta_i Q_{1pu}(\theta_s, \phi_s; \theta_t, \phi_t)}{k_{1u}(\theta_t) \cos \theta_i + k_{1q}(\theta_i) \cos \theta_t} \right. \\ & \cdot Q_{1uq}(\theta_t, \phi_t; \pi - \theta_i, \phi_i) \left\{ \frac{1 - L_{1p}(\theta_s) L_{1q}(\theta_i)}{k_{1p}(\theta_s) \sec \theta_s + k_{1q}(\theta_i) \sec \theta_i} \right. \\ & \left. + L_{1q}(\theta_i) \frac{L_{1u}(\theta_t) - L_{1p}(\theta_s)}{k_{1u}(\theta_t) \sec \theta_t - k_{1p}(\theta_s) \sec \theta_s} \right\} \\ & + 2\text{Re} \left( \frac{\cos \theta_i Q_{1p3}(\theta_s, \phi_s; \theta_t, \phi_t)}{k_{13}(\theta_t) \cos \theta_i + k_{1q}(\theta_i) \cos \theta_t} \right. \\ & \cdot Q_{13q}(\theta_t, \phi_t; \pi - \theta_i, \phi_i) \left\{ \frac{1 - L_{1p}(\theta_s) L_{1q}(\theta_i)}{k_{1p}(\theta_s) \sec \theta_s + k_{1q}(\theta_i) \sec \theta_i} \right. \\ & \left. + L_{1q}(\theta_i) \frac{L_{13}(\theta_t) - L_{1p}(\theta_s)}{k_{13}(\theta_t) \sec \theta_t - k_{1p}(\theta_s) \sec \theta_s} \right\} \left. \right] \quad (26a) \end{aligned}$$

$$\begin{aligned} \sigma_{pq}(+, -, -) = & 4\pi \int_0^{\pi/2} \sin \theta_t d\theta_t \int_0^{2\pi} d\phi_t \\ & \left[ \sum_{u=v,h} \frac{\cos \theta_s Q_{1pu}(\theta_s, \phi_s; \pi - \theta_t, \phi_t)}{k_{1u}(\theta_t) \cos \theta_s + k_{1p}(\theta_s) \cos \theta_t} \right. \\ & \cdot Q_{1uq}(\pi - \theta_t, \phi_t; \pi - \theta_i, \phi_i) \left\{ \frac{1 - L_{1p}(\theta_s) L_{1q}(\theta_i)}{k_{1p}(\theta_s) \sec \theta_s + k_{1q}(\theta_i) \sec \theta_i} \right. \\ & \left. + L_{1p}(\theta_s) \frac{L_{1u}(\theta_t) - L_{1q}(\theta_i)}{k_{1u}(\theta_t) \sec \theta_t - k_{1q}(\theta_i) \sec \theta_i} \right\} \\ & + 2\text{Re} \left( \frac{\cos \theta_s Q_{1p3}(\theta_s, \phi_s; \pi - \theta_t, \phi_t)}{k_{13}(\theta_t) \cos \theta_s + k_{1p}(\theta_s) \cos \theta_t} \right. \\ & \cdot Q_{13q}(\pi - \theta_t, \phi_t; \pi - \theta_i, \phi_i) \left\{ \frac{1 - L_{1p}(\theta_s) L_{1q}(\theta_i)}{k_{1p}(\theta_s) \sec \theta_s + k_{1q}(\theta_i) \sec \theta_i} \right. \\ & \left. + L_{1p}(\theta_s) \frac{L_{13}(\theta_t) - L_{1q}(\theta_i)}{k_{13}(\theta_t) \sec \theta_t - k_{1q}(\theta_i) \sec \theta_i} \right\} \left. \right] \quad (26b) \end{aligned}$$

where  $\text{Re}(\cdot)$  is the real part operator and,

$$\begin{aligned} Q_{1u3}(\theta_s, \phi_s; \theta_t, \phi_t) &= \sum_{m=1}^{N_1} n_m (F_{muv}(\hat{s}, \hat{i}) F_{m^*vh}(\hat{s}, \hat{t})) \\ Q_{13v}(\theta_s, \phi_s; \theta_t, \phi_t) &= \sum_{m=1}^{N_1} n_m (F_{muv}(\hat{s}, \hat{i}) F_{m^*hv}(\hat{s}, \hat{t})) \\ Q_{13h}(\theta_s, \phi_s; \theta_t, \phi_t) &= \sum_{m=1}^{N_1} n_m (F_{muh}(\hat{s}, \hat{i}) F_{m^*hh}(\hat{s}, \hat{t})) \\ Q_{1h3}(\theta_s, \phi_s; \theta_t, \phi_t) &= \sum_{m=1}^{N_1} n_m (F_{mhu}(\hat{s}, \hat{i}) F_{m^*hh}(\hat{s}, \hat{t})) \end{aligned} \quad (27)$$

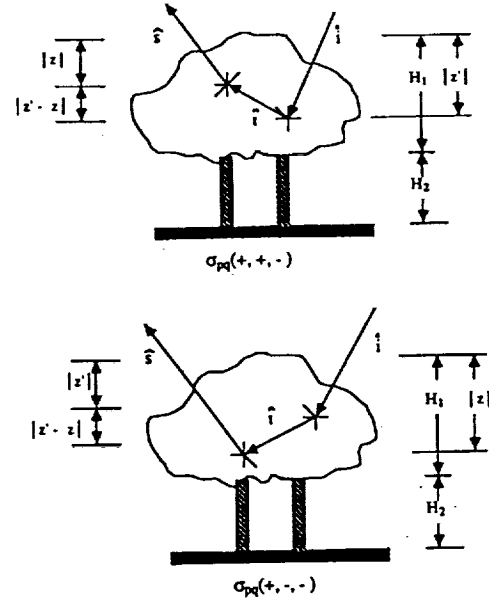


Fig. 4. The scattering processes in (26) associated with the second-order solution of the radiative transfer equation.

with  $*$  is the complex conjugate operator. In addition

$$\begin{aligned} k_{13}(\theta_t) &= \frac{1}{2} [k_{1v}(\theta_t) + k_{1h}(\theta_t)] \\ &+ \frac{2\pi j}{k} \text{Re} \left[ \sum_{m=1}^{N_1} n_m (F_{muv}(\hat{t}, \hat{t}) - F_{mhh}(\hat{t}, \hat{t})) \right] \\ L_{13}(\theta_t) &= \exp[-k_{13}(\theta_t) H_1 \sec \theta_t]. \end{aligned} \quad (28)$$

The processes of scattering in (26a) are illustrated in Fig. 4. From this figure we see that  $\sigma_{pq}(+, +, -)$  represents scattering by a unit volume first from direction  $\hat{i}(\pi - \theta_i, \phi_i)$  to direction  $\hat{i}(\theta_t, \phi_t)$  and then by another unit volume from direction  $\hat{i}(\theta_t, \phi_t)$  to the observation direction  $\hat{s}(\theta_s, \phi_s)$ . These two processes are represented by the quantities  $Q_{1pu}(\theta_s, \phi_s; \theta_t, \phi_t)$   $Q_{1uq}(\theta_t, \phi_t; \pi - \theta_i, \phi_i)$  for the first two Stokes parameters and by  $Q_{1p3}(\theta_s, \phi_s; \theta_t, \phi_t)$   $Q_{13q}(\theta_t, \phi_t; \pi - \theta_i, \phi_i)$  for the last two Stokes parameters. To reach the first scattering volume the incident wave is attenuated by  $e^{k_{1q}(\theta_i) z' \sec \theta_i}$ . In going from the first to the second scattering volume, the wave is further attenuated by  $e^{k_{1u}(\theta_i)(z' - z) \sec \theta_i}$ . After the second scattering the scattered wave with  $p$  polarization is attenuated by  $e^{k_{1p}(\theta_s) z \sec \theta_s}$  before it reaches the canopy-air interface. The integration of the product of these loss factors over  $dz'$  and  $dz$  ( $-H_1 \leq z' \leq z$ , and  $-H_1 \leq z \leq 0$ ) gives the other quantities in (26a). The summation in (26a) accounts for the first and second Stokes' parameters of the scattered wave in  $\hat{i}(\theta_t, \phi_t)$  direction. The  $\text{Re}(\cdot)$  comes from summing the last two Stokes' parameters  $\hat{i}(\theta_t, \phi_t)$ . The integration over  $d\theta_t$  and  $d\phi_t$  accounts for all possible scattering directions through which the signal scattered from location  $z'$  toward location  $z$ . Similar interpretation is applicable to  $\sigma_{pq}(+, -, -)$  in (26b).

From (26)–(28) it is clear that the second-order solution requires all the four Stokes parameters. Also we can see that

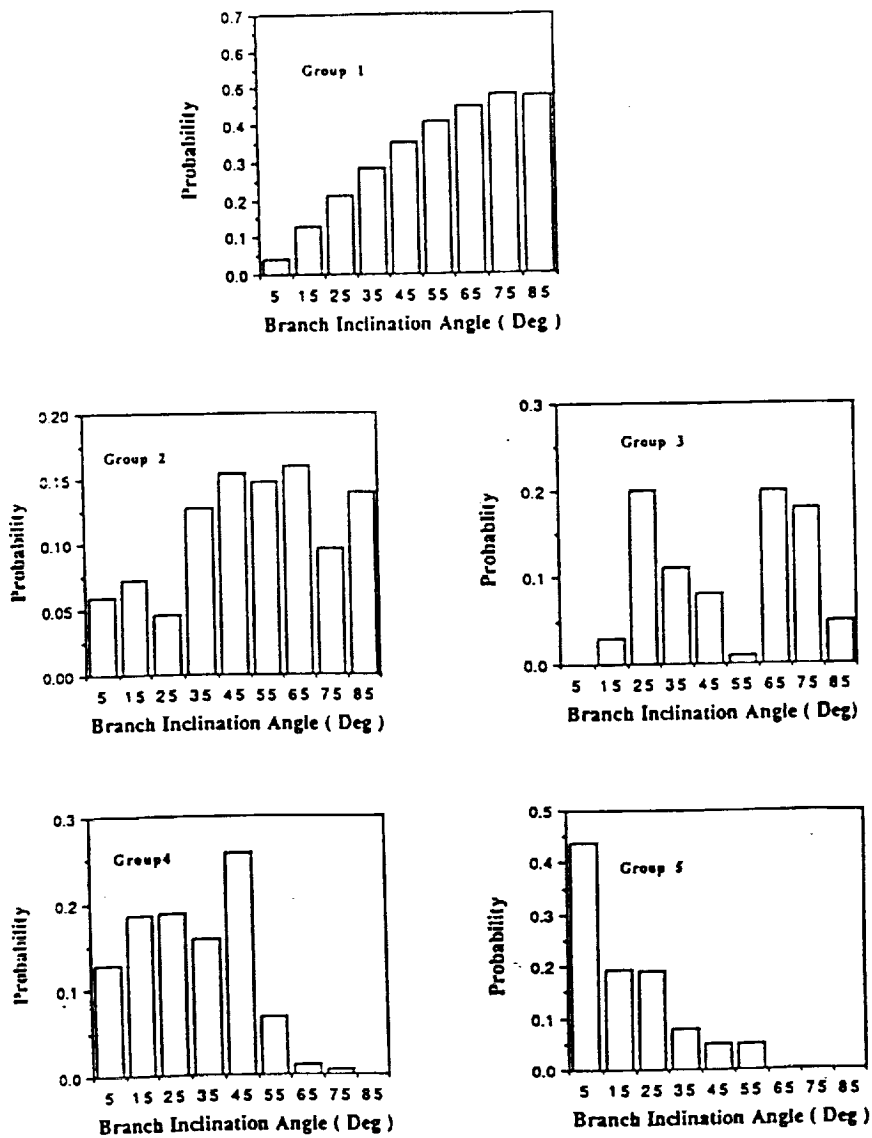


Fig. 5. The probability distributions of the inclination angles for different groups of branches.

TABLE I  
THE PARAMETER FOR EACH BRANCH GROUP

Branch Group	Diameter Range (cm)	Average Diameter (cm)	Average Length (cm)	Number density (m <sup>-3</sup> )
1 /stems	0.0-0.40	0.10	18	250
2	0.5-1.90	1.28	14	11.4
3	2.0-2.90	2.60	32	0.43
4	3.0-6.90	5.00	58	0.33
5 /trunk	7.0-17.1	9.00	76	0.14

the second-order solution includes scattering due to interaction between the forest components.

#### IV. GROUND TRUTH DATA, NUMERICAL RESULTS AND ANALYSIS

In this section comparisons of this model with backscattering measurements from both deciduous and coniferous forest, are carried out to verify the model validity. In addition, the

effects of frequency, second-order interaction, and surface roughness as it impacts tree-ground interaction are illustrated to indicate the model major advantages. Results are organized into three subsections. In the first subsection, the characteristics of a deciduous and a coniferous canopy and the associated ground truth are described. The second subsection shows comparisons between the calculated and measured values of the backscattering coefficients for walnut canopy at *L* and *X* bands and for cypress trees at *S* and *X* bands. Furthermore, illustrations are given showing the contribution of each canopy component to the total backscattering coefficient. The third subsection presents some numerical results to indicate how frequency, second-order interaction, and surface roughness affect the backscattering coefficients.

##### A. Deciduous and Coniferous Canopy Characteristics

In this study the walnut canopy and the cypress trees are taken to represent a deciduous and a coniferous canopy respectively. We shall begin by describing the walnut canopy

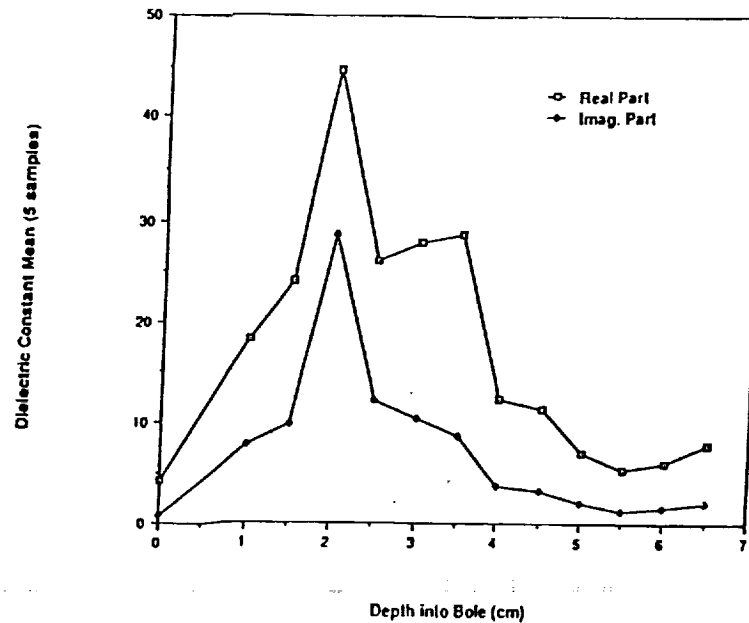


Fig. 6. The relative dielectric constant as a function of depth into walnut bole.

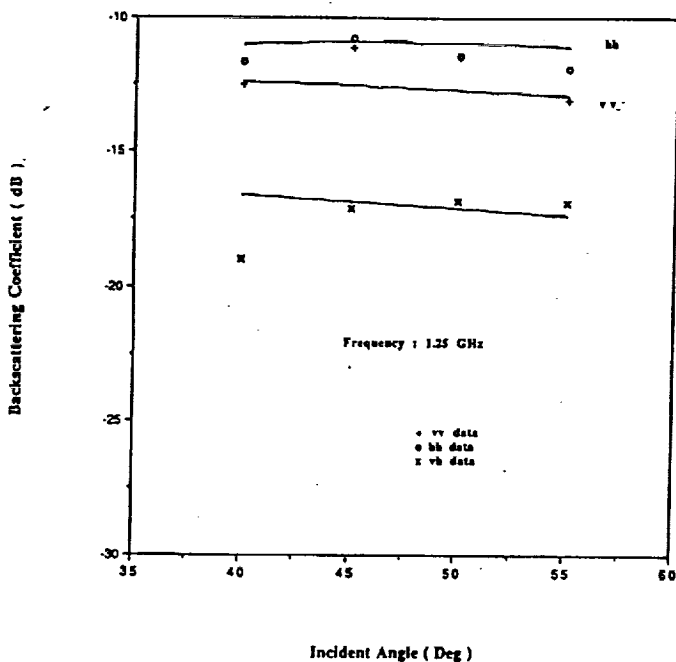


Fig. 7. Comparisons of theoretical and experimental backscattering coefficients for a walnut canopy at  $L$  band as a function of the incident angle.

TABLE II  
DIELECTRIC CONSTANT VALUES

Frequency Band	$L$	$X$
Leaves	19.58-j 5.54	14.9-j 4.9
branch/stems	27.3-j 8.4	20.0-j 9.7
soil	5.00-j 0.7	5.00-j 0.7

and its parameters and then the cypress trees.

#### 1) The Walnut Canopy Characteristics:

The canopy consists of 6-year-old black walnut trees [26, Sec. V, Vol I]. The trees have an average height of 4.8 m.

Their geometry data was collected in two parts. Measurements involving branches with diameter greater than 4 cm were termed skeleton geometry measurements and the rest higher order measurements. A group of 16 walnut trees was chosen for the canopy geometry and ground truth measurements. Their heights, width across the row, and the length down the row were measured. The skeleton branches which terminated into a successively smaller diameter branch were physically sampled for their length, diameter, and inclination angle for all 16 trees. Small branches that grew along the skeleton tend to fill the interior of the canopy. Such branches with diameter less than 4 cm were sampled only for a couple of trees. The thinnest branches with diameter less than 1 cm and length less than 30 cm, were not sampled for their inclination orientations. The branches were grouped into four different groups according to their radius, and for each group an average length of the branch was computed. Beside these four branch groups, there are green stems which have an external covering of green bark and are located just below the juncture with the petioles. For modeling purposes we will consider the stems as a group of branches. The stem group will be labeled as group #1 among the other branch groups. Table I sums up the relevant parameters for each branch group type.

From the inclination angle measurements of the branches, the inclination angle probabilities for all branch groups are calculated. Fig. 5 presents the histograms of the inclination angle probabilities for different radius groups. The data show that as the diameter of the branch increases, it tends to become vertical. The thin branches do not show any preferred inclination.

The leaves were found to be growing only on the branches in groups 1 and 2. The leaves on group 2 branches were determined from the routine sampling of higher order canopy geometry measurements. However, due to the large number of branches in group 1, an exclusive sampling was done to



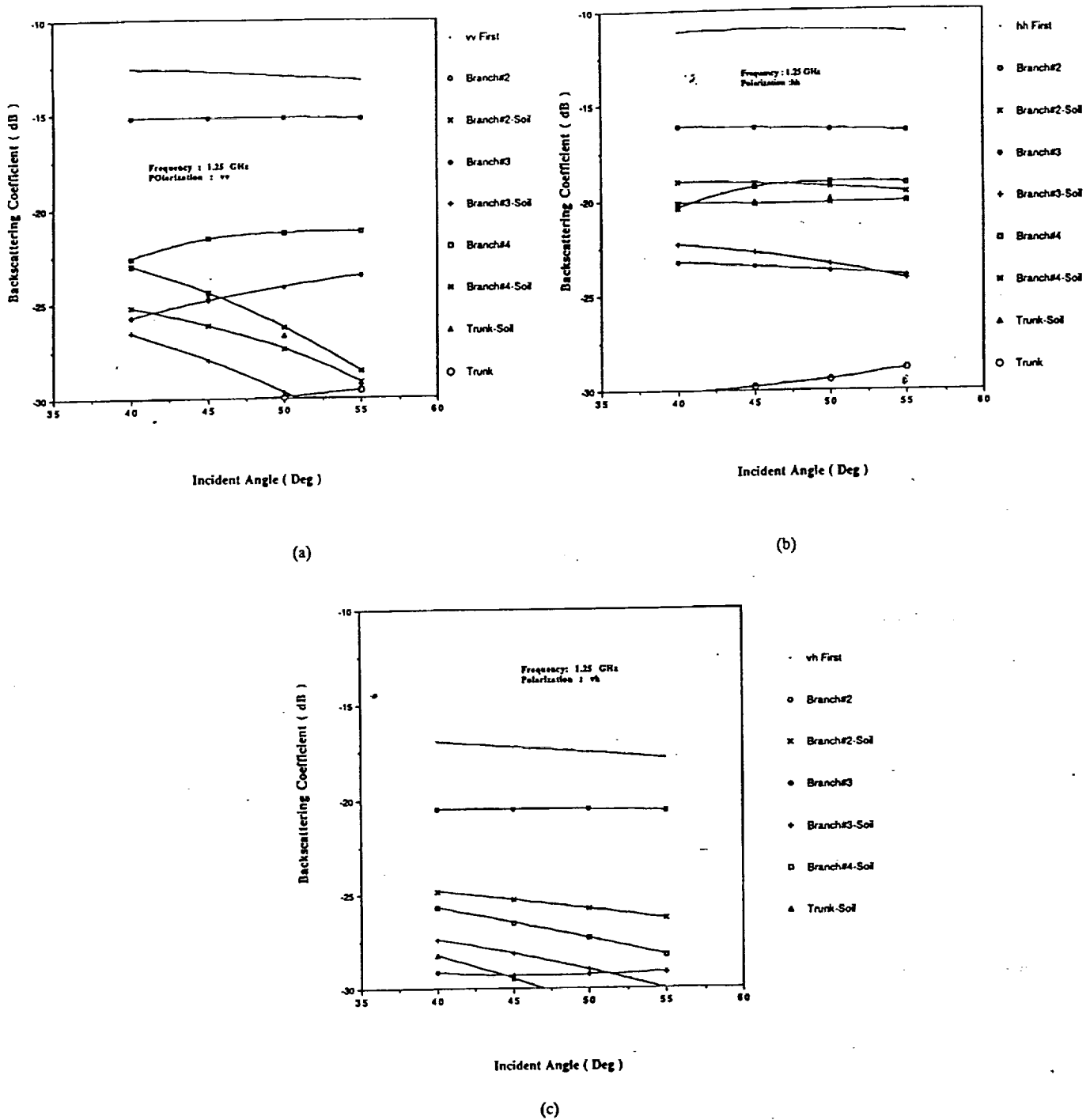


Fig. 8. Illustrations of the contributions by the walnut canopy components in first-order backscattering for (a) VV, (b) HH, and (c) VH polarizations at *L* band.

estimate the number of leaves per branch in the group 1 category. This leaf data was extrapolated to cover the whole canopy. The average density of the leaves was  $250 \text{ m}^{-3}$  [15]. Each leaf had an average leaf area of 254 square cm and on the average there were five leaflets on one leaf. Assuming the leaves to be circular, the leaf area results gave the average disc radius of approximately 3.6 cm and a thickness equal to 0.1 mm. The leaf inclination angle has a probability distribution function equal to  $\sin \beta (0^\circ < \beta < 90^\circ)$ .

*In situ* measurements of dielectric constant of stems, branches, and leaves were made by a team from the University of Michigan at *L* band ( $f = 1.2 \text{ GHz}$ ). An electric probe

was inserted into a hole drilled into a branch to find the dielectric constant [26, Sec. XIII, Vol. II]. The leaves were stacked in layers upon a flat piece of wood. For each stack, the probe reading was noted at three separate locations on the stack. The behavior of the dielectric constant with depth inside a branch or on a stack of leaves was found from probe readings. Fig. 6 shows the relative dielectric constant as a function of depth into walnut bole. It is clear the dielectric constant real part has values between 4 and 45. The imaginary part varies between 1 and 30. For stem dielectric constant a representative value at the *L* band is found to be  $27.3 - j 8.4$ . As this value for the dielectric constant is a mean value for

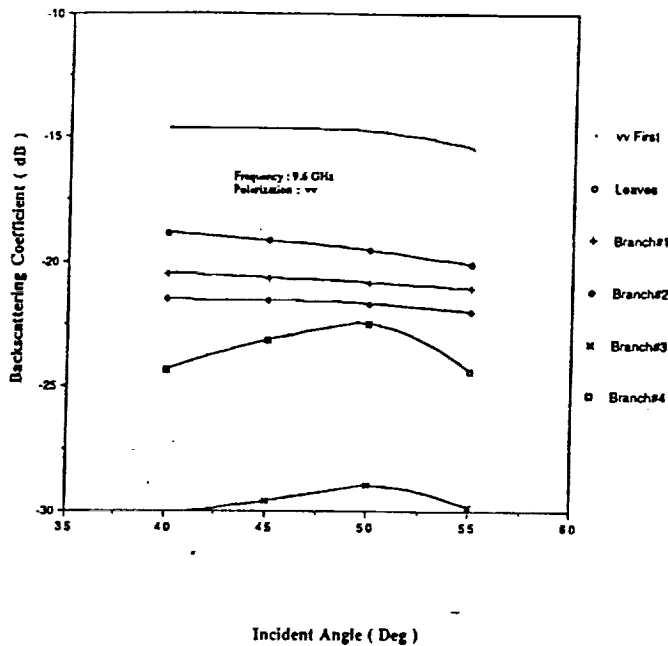


Fig. 9. Comparisons of theoretical and experimental backscattering coefficients for a walnut canopy at X band as a function of the incident angle.

TABLE III  
GROUND TRUTH FOR CYPRESS TREE SCATTERER

	Leaves	Branch#1	Branch#2	Branch#3
Length (cm)	1	13	18	20
Radius (cm)	0.1	0.12	0.3	1
Number	$0.796 \times 10^5$	400	64	10
Density ( $m^{-3}$ )				
$B_m$ ( $^\circ$ )	90	90	90	0.0
$B_0$ ( $^\circ$ )	0.0	0.0	0.0	10
$B_1$ ( $^\circ$ )	0.0	0.0	0.0	0.0
$B_2$ ( $^\circ$ )	90	90	90	60
$n$	2	1	1	6

the bole dielectric constant, it will be taken as representative value for branch dielectric constant. The leaf dielectric value varies from  $8.77 - j 2.88$  to  $19.58 - j 5.54$  according to the number of the leaves stacked in layers upon a flat piece of wood to measure the dielectric constant. Consequently, an average value  $19.58 - j 5.54$  will be used to represent the leaf dielectric constant. There is no independent confirmation of the leaf and branch dielectric constant values as high as used in [14].

The soil relative dielectric constant measurements were repeated on hourly basis. Each observation sequence consisted of three types of data designated: wet, dry, and mix. The wet and dry consisted of separate samples of the soil surface regions which were always wet or always dry, respectively. A transect sampling was used to evaluate the spatial average of the dielectric constant over the three moisture regions. The dielectric transect data consisted of 22 samples spaced 0.3 m apart and extending from center of one row to the center of the next. The location of the transect along a row with respect to the tree and sprinkler location was randomized. The sprinklers were placed along the rows of the trees to irrigate the trees. The water from sprinklers was sprayed in an approximately 3-ft wide strip along the rows of the trees. There was no

sprinkler in between the tree rows. Thus approximately 70% of the area was not irrigated and thus can be classified as "dry soil." It was found that inter-row dielectric constant has values between  $18.48 - j 1.6$  and  $2.79 - j 0.16$ . Furthermore, ten soil samples taken from area partially covered by organic leaf litter showed an average dielectric constant value of  $2.96 - j 0.49$ . In addition, the spatial averaging for backscatter as seen by the radar was done by rotating the boom across the rows in an arc and it was not done along the tree rows. Accordingly, we believe that the ground dielectric constant should have a small average value which is taken to be  $5.0 - j 0.7$ .

To obtain the values of the leaf and branch dielectric constant at X band ( $f = 9.6$  GHz), the corresponding values at L band are incorporated in Ulaby and El Rayes' dielectric constant formula [31] to obtain the leaf and branch gravimetric moisture contents (0.55 for leaves and 0.65 for branches). By substituting these values for the moisture contents along with the X band frequency into Ulaby and El Rayes formula, we obtain the values of the dielectric constant at X band ( $14.9 - j 4.9$  for leaves and  $20. - j 9.7$  for branches). Since the soil effect at X band is unimportant in the backscattering calculation, its dielectric constant is not estimated at X band. Table II sums up the dielectric constant values used for the leaves and stems and branches.

For the purpose of modeling we divide the canopy into two layers above a rough interface. The upper layer with a depth of 3 m is the crown layer and the lower layer with a depth of 1.7 m is for the trunk layer. The crown layer contains leaves and the first four branch groups. The fifth branch group is included in the trunk layer. The soil-canopy interface roughness is represented by a Gaussian correlation function with  $\sigma$  and  $L$  given by 0.021 m and 0.25 m, respectively. In calculating the crown- and trunk-soil interaction terms (13), (22) the soil scattering coefficient  $\sigma_{pu}^s(\theta_s, \phi_s; \theta_t, \phi_t)$  is obtained by summing up the coherent (Eq. 12.52 of [2]) and the noncoherent (Eq. 12.55 of [2]) scattering terms.

2) *The Cypress Tree Characteristics:* The cypress trees with the same height and nearly the same density are considered [4]. They are 3-4 years old. Their trunks are thin, having a diameter of 1-2 cm. The average height of the canopy was about 70 cm. The canopy without leaves is composed of a large number of randomly oriented thin branches and a small number of thin vertical trunks. The leaflets of cypress form a thin rod shape, with length of 1 cm and a diameter of 2 mm, and the whole assembly comprises a relatively flat planer structure. The ground plane is covered with microwave absorbers so that canopy ground interaction effect is unimportant. In this study a one layer model (crown) is used since the trunk height is small. The canopy constituents are grouped into four groups, one group for the leaves; three other groups for the branches. The scatterer inclination angle distribution ( $\beta$ ) is governed by the following probability distribution function

$$P(\beta) = A \cos^n \left[ \frac{\pi}{2} \left( \frac{\beta - \beta_m}{\beta_0 - \beta_m} \right) \right], \quad \beta_1 \leq \beta \leq \beta_2$$

$$= 0 \quad \text{otherwise} \quad (29)$$

where  $A$  is the normalization factor, and  $n$  is the shape factor. The probability density function  $P(\beta)$  has its maximum value at  $\beta_m$ , and is equal to zero at  $\beta$  equal to  $\beta_0$ . By adjusting the values of  $\beta_0, \beta_1, \beta_2, \beta_m$ , and  $n$ , the probability density function  $P(\beta)$  in (29) can include a variety of probability density functions reported in the literature [32].

The dielectric constants of the coniferous scatterers (needle leaves, and branches) are obtained by employing Ulaby and El-Rayes' formula [31] which gives the dielectric constant in terms of the gravimetric moisture content. For cypress trees under consideration, the reported values for the leaf and branch gravimetric moisture contents are around 58.

### B. Comparisons with Backscatter Measurements from Walnut Orchard Canopy

Several sets of microwave data were collected from the walnut canopy [26]. In this study we shall consider two sets of multi-angle data in which the same set of trees were observed at incident angles ranging from  $40^\circ$  to  $55^\circ$  at two different frequencies, 1.25 GHz ( $L$  band) and 9.6 GHz ( $X$  band). The data were collected over a time span of about 2 hours during mid-afternoon, so the variation in the dielectric constant due to the change of environment can be neglected. The model was evaluated as a function of look angle for frequencies 1.25 and 9.6 GHz using the ground truth reported in Tables I and II and Fig. 5. The model output is given in Figs. 7–10. Figs. 7 and 9 show comparisons of measured and calculated scattering coefficients for three different polarizations at  $L$  band and  $X$  band, respectively. Figs. 8 and 10 show the contributions of the individual tree components to the total backscattering coefficients, excluding those more than 15 dB below the total.

At  $L$  band (Fig. 7) there is a good agreement between theory and measurements. The like polarized backscattering coefficients  $\sigma_{vv}$  and  $\sigma_{hh}$  have the same angular trends with  $\sigma_{vv} < \sigma_{hh}$ . The cross polarization  $\sigma_{vh}$  is below the like by about 6 dB. Fig. 8 indicates that the main contribution to the like and cross backscattering coefficients is due to branch group #2. The branches within this group have no preferred orientation and their dimensions are such that their contributions to  $\sigma_{vv}$  and  $\sigma_{hh}$  are approximately the same. Other canopy constituents may be small compared to the wavelength (leaves and branch group #1), or comparable to the wavelength and they are nearly vertically oriented (branch #4 and branch #5). For the small scatterers, their contribution to the like and cross polarization is lower than the noise level. The larger scatterers have radiation pattern with maximum field values confined to the forward direction. Consequently, the scattered field is propagating toward the canopy floor, leading to the soil–canopy interaction terms. Since within the angular range considered in this section, the soil reflectivity is higher for horizontally incident wave than for vertically incident wave, the contribution of the interaction terms are higher for  $\sigma_{hh}$  than  $\sigma_{vv}$ . This is the reason, why  $\sigma_{hh} > \sigma_{vv}$ . Unlike reference [14] we assume the surface to be moderately wet instead of very wet so that this interaction term is not of major importance in  $\sigma_{hh}$ . We made this choice because the surface truth reported in [26] indicates that the very wet condition is a special situation. Also, the  $\sigma_{vv}$  and  $\sigma_{hh}$  returns

are very close to each other. This can be explained if scattering for  $\sigma_{vv}$  and  $\sigma_{hh}$  is dominated by the same branch group as we have found. However, if  $\sigma_{vv}$  is dominated by one branch group and  $\sigma_{hh}$  is dominated by trunk–ground interaction as indicated in [14], then similar level for  $\sigma_{vv}$  and  $\sigma_{hh}$  must be a coincidence.

At  $X$  band, the levels of the backscattering coefficients and the relative levels between polarization components are in agreement with measurements (Fig. 9). An earlier publication [15] did not obtain an agreement at this frequency for cross polarization even though model parameters were readjusted between  $L$  band and  $X$  band. We believe this is due to several factors: (1) enough groups of branches, i.e., an adequate representation of branch size distribution, (2) second-order effects, and (3) validity of model over a wide enough range of frequencies. At  $X$  band the polarized backscattering coefficients have similar angular trends. The cross polarized backscattering coefficient level is below the like polarization by nearly 8 dB. Illustrations of the individual contributors are given in Fig. 10. Here, for like-polarized scattering the leaves and the branch groups #1 and #2 are the most important contributors. At  $X$  band, the dimensions of those scatterers (leaves, branch #1, branch #2) are sensitive to the incident wavelength, and they have no preferred orientation. At this frequency, the interactions with the ground surface are negligible. For cross polarized scattering the major contribution comes from branch group #1 which is the smallest branch group (stems). The cause of depolarization appears to be the small cylindrically shaped stem and its orientation distribution. The leaf area is large at  $X$  band and hence its depolarization is weak. The  $\sin \beta$  function for the leaf orientation distribution also leads to a very small contribution to cross polarization [16], [17], [29].

*Comparisons with Backscattering Measurements from Cypress Trees:* The measurements from a cypress canopy with and without leaves were reported by Hirose *et al.* [4] at  $S$ ,  $C$ , and  $X$  bands for incident angles between  $10^\circ$  and  $40^\circ$ . In this study the  $S$  and  $X$  band data are selected for comparison. The ground truth given in Table III are used in the model to calculate the backscattering coefficients. Figs. 11(a) and (b) show the comparisons with  $S$  band measurements with and without leaves. Results indicate that negligible change takes place due to the presence or absence of leaves at this frequency. The agreement between model and measurements is very good for like and cross polarizations except at  $10^\circ$  incidence in like polarization in Fig. 11(b). This may be due to scattering from the ground which is not well covered with microwave absorber. Similar comparisons at  $X$  band are shown in Figs. 12(a) and (b). Here again the agreement between model and measurements is very good. The presence of leaves leads to a 4-dB and a 2-dB increase in like and cross-polarized scattering, respectively. Thus, leaves are important scatterers at  $X$  band for cypress as well as the walnut trees discussed in the previous section.

### C. Surface Roughness, Frequency and Second-Order Effects

In this section we want to illustrate the effects of soil surface roughness, frequency, and the second-order terms in backscattering.

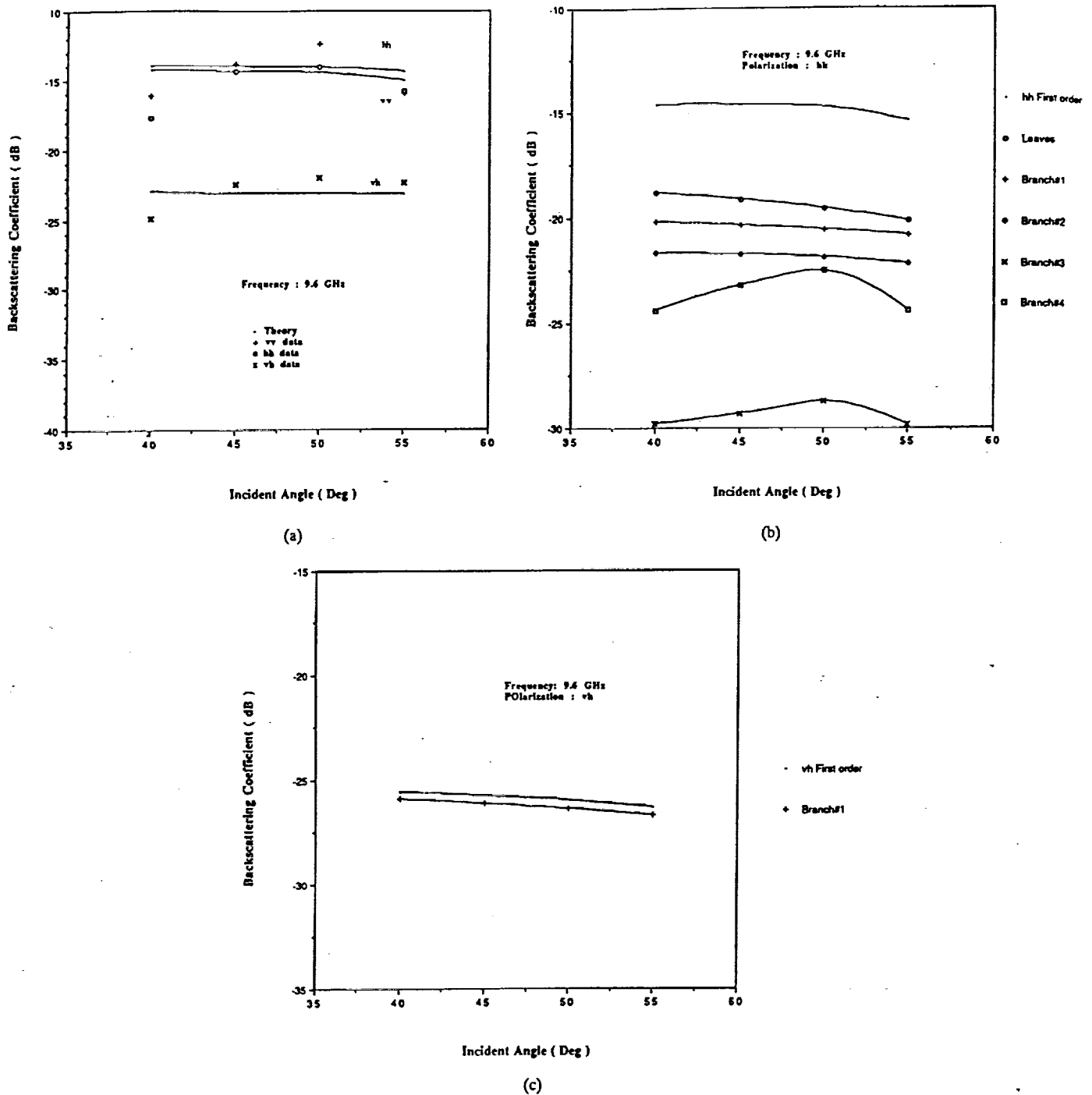
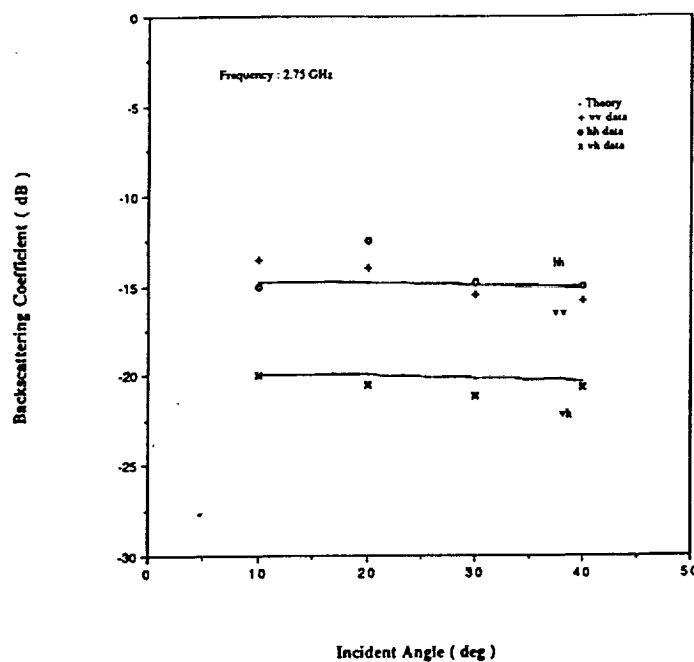


Fig. 10. Illustrations of the contributions by the walnut canopy components in first-order backscattering for (a) VV, (b) HH, and (c) VH polarizations at X band.

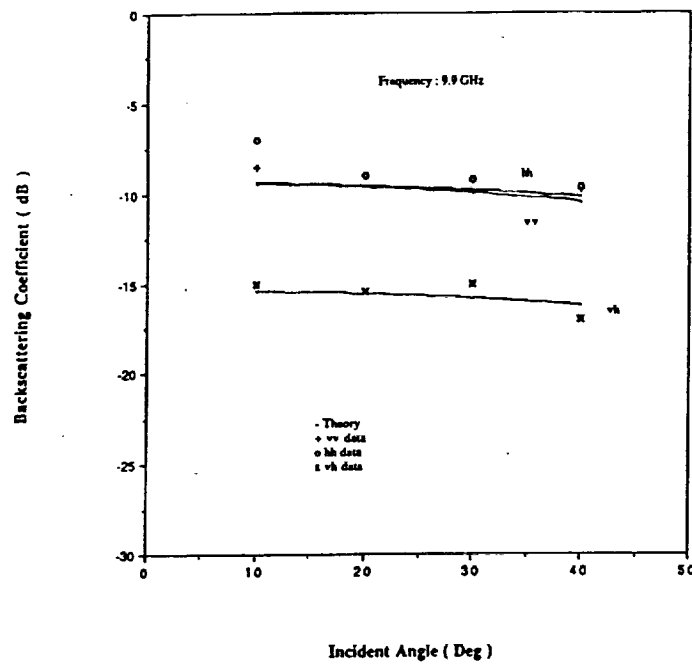
1) *The Role of Surface Roughness on the Interaction Terms:* Scattering due to a rough surface is well known and can be computed easily. Less obvious is how canopy interacts with a plane versus a rough ground surface. More specifically the inclusion of the ground-canopy interaction term is not fully accounted for in the available models [10]–[13] because only a flat ground is considered. To see the difference between the use of a flat versus a rough ground surface we show in Figs. 13(a)–(c) the surface roughness effects on the soil-canopy interaction terms for like and cross polarizations. These figures are generated by using the ground truth reported for walnut

canopy in Tables I and II at L band. For the rough surface the correlation function is taken to be Gaussian and the scattering matrix is obtained by employing the Kirchhoff model along with the scalar approximation [2, Chapter 12].

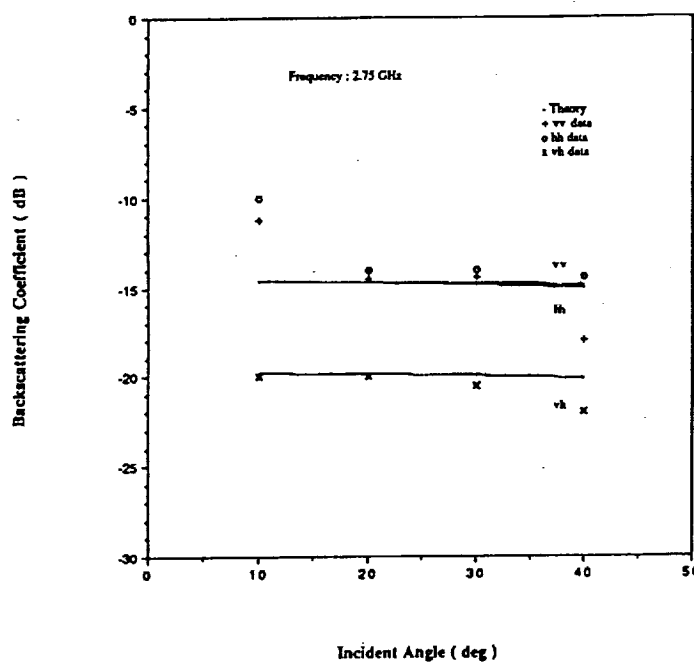
From these figures we see that the inclusion of surface roughness leads to a reduction in the interaction terms for like polarizations (VV, HH) near nadir incidence but an increase in the like and cross polarization terms at higher incidence angles. The angular range within which the interaction terms are higher for the rough than the plane surface varies from one polarization to another and is expected to vary also with



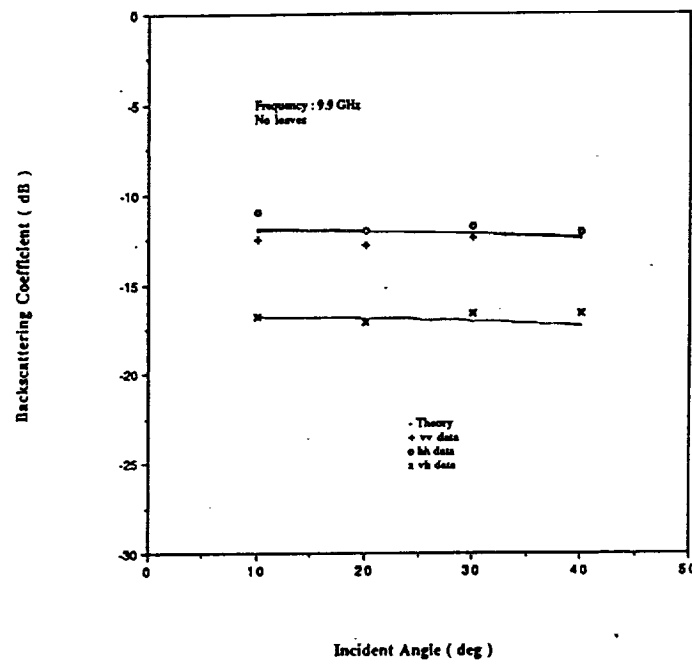
(a)



(a)



(b)



(b)

Fig. 11. Comparisons of theoretical and experimental backscattering coefficients for a cypress canopy at S band as a function of the incident angle: (a) With leaves. (b) Without leaves.

Fig. 12. Comparisons of theoretical and experimental backscattering coefficients for a cypress canopy at X band as a function of the incident angle. (a) With leaves. (b) Without leaves.

a change in the roughness property. While soil roughness is found to be unimportant in the comparisons shown in Section IV.B.1, it is expected to be important when the soil surface is wet.

2) *Second-Order Terms in the Backscattering Coefficients:* The effect of the second-order scattering terms due to branches was not considered in the previous models [11]–[15]. The introduction of the second-order terms in this study is a way to account for the multiple scattering effects within a forested canopy. From the numerical calculations we found that the

second-order terms had little effect on the level and trend of the like polarized signals. Hence, illustrations are limited to cross polarized calculations.

Fig. 14 presents the angular variation of the first- and second-order cross polarized signals ( $\sigma_{vh}$ ) at L and X bands using model parameters for the walnut orchard. It is seen that the second-order term is not important at L band but is significant at X band. Fig. 15 shows the variation of the cross polarized signal from cypress trees as a function of frequency at 40° angle of incidence. From these figures we see that

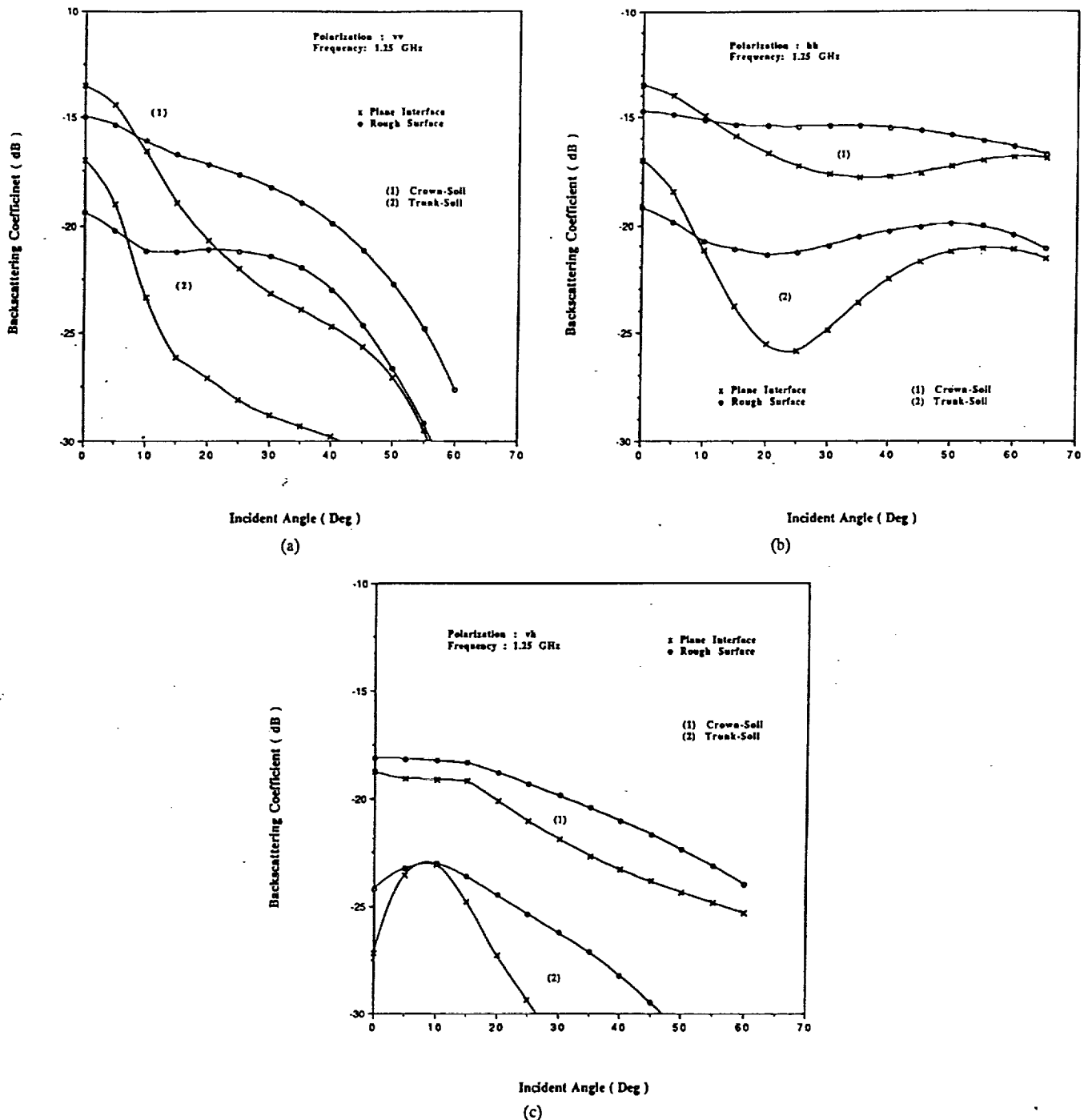


Fig. 13. The effect of including the surface roughness in the canopy-ground interaction on backscattering from a walnut canopy at  $L$  band: (a) VV polarization; (b) HH polarization; (c) VH polarization.

the importance of multiple scattering effects are dependent on frequency and canopy parameters.

3) *Frequency Dependence:* One merit of the current model is that it can be applied over a wide frequency band without changing the forest component modeling or adjusting the forest component phase matrices and extinction cross sections. Fig. 16 shows the variation of the backscattering coefficient for cypress trees as a function of the incident frequency at  $40^\circ$  incidence. From this figure we see that for frequency lower than 4 GHz, the backscattering coefficients increase rather quickly with frequency. This increase indicates a Rayleigh

region for the canopy. In the frequency range, 4–8 GHz, the rate of increase of the backscattering coefficients with frequency is much smaller. This corresponds to the resonance region where significant phase interference takes place. For frequencies higher than 8 GHz, the backscattering coefficients have a higher rate of increase with the frequency. This is not necessary true in general but is due to the specific canopy constituents as illustrated in Fig. 17. Here, the needle-shaped leaves happen to have a dimension that is still in the Rayleigh region and hence its contribution increases fast with frequency. In conclusion, the final frequency behavior of a forest canopy

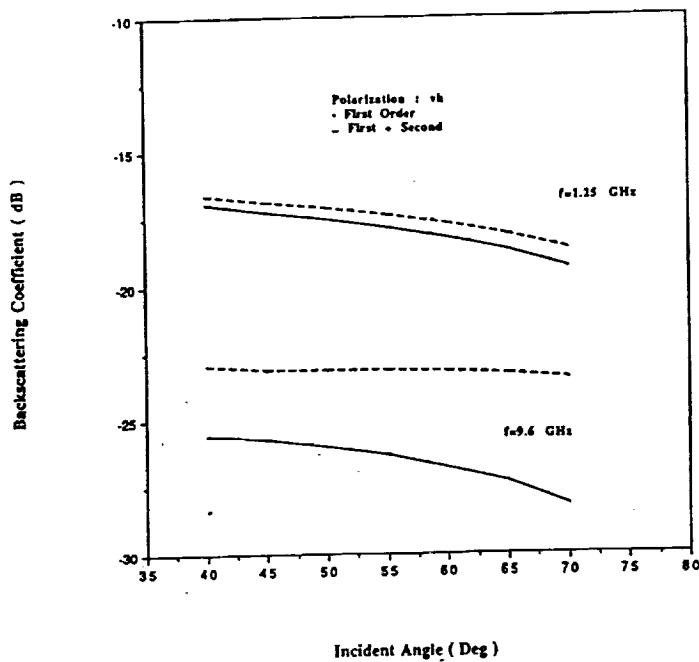


Fig. 14. The angular variation of cross-polarized coefficient for walnut canopy calculated by using the first and second-order solution of the radiative transfer equation at *L* and *X* band (parameters of Figs. 7 and 9).

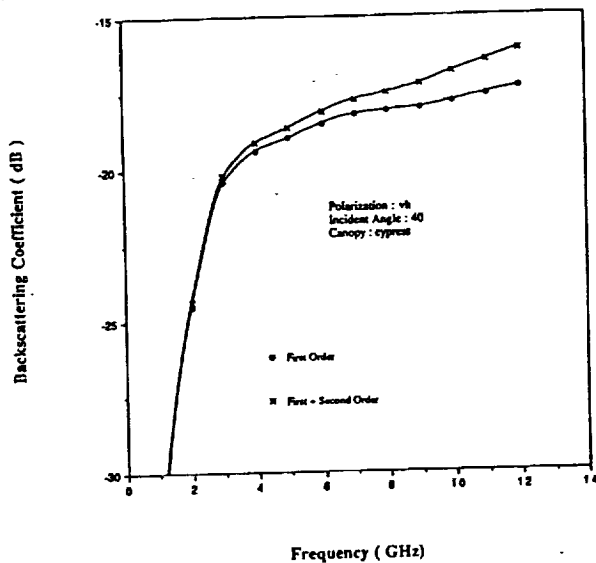


Fig. 15. The variation of the cross-polarized coefficients for cypress trees with the frequency, calculated by using the first and second-order solution of the radiative transfer equation at 40° angle of incidence (parameters as in Figs. 11 and 12).

is dependent on the specific sizes of its components. Hence, it is important to model each canopy component over a wide range of frequency.

### V. DISCUSSION

In this paper a microwave scattering model has been developed for layered vegetation and compared with experimental data from walnut and cypress trees. The major advantages of this model are that, it (1) accounts for first- and second-order scattering within the canopy, (2) fully accounts for the surface

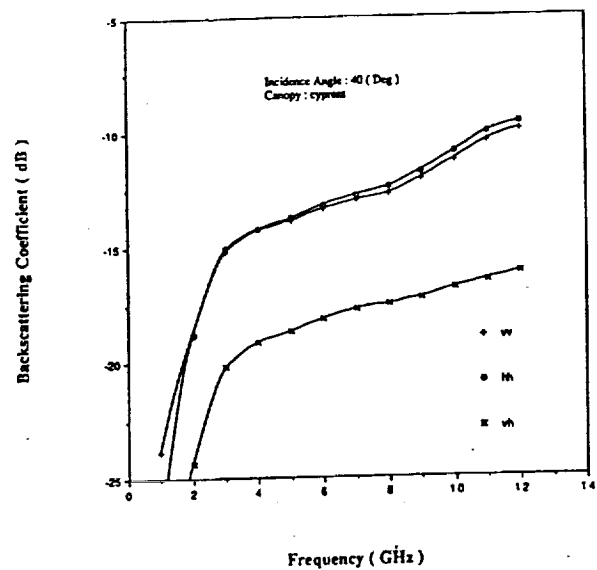


Fig. 16. The variation of the like and cross backscattering coefficients for cypress trees as a function of the incident frequency (parameters as in Figs. 11 and 12).

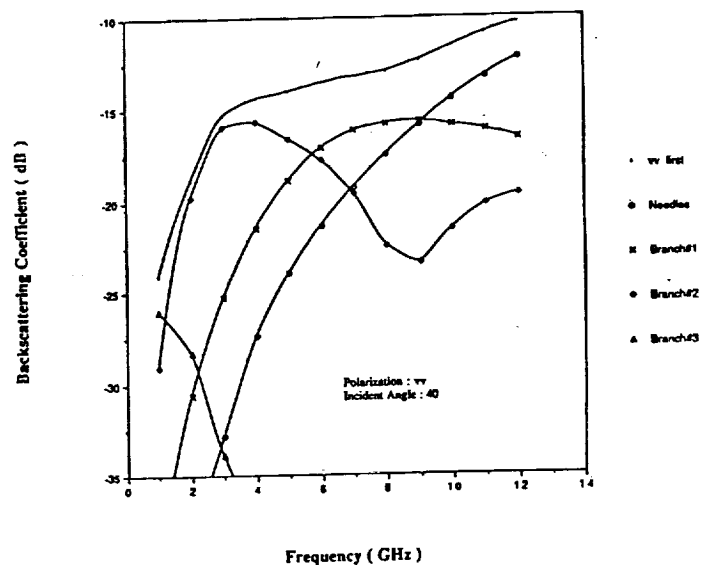


Fig. 17. The components of  $\sigma_{vv}$  for cypress trees as a function of the incident frequency (parameters as in Figs. 11 and 12).

roughness in the canopy-soil interaction terms (3) allows many branch sizes and their orientation distributions and (4) is valid over a wide frequency range for both deciduous and coniferous vegetation.

The application of this model to walnut and cypress trees leads to the following conclusions:

1. To obtain a match between the calculated and measured values of the backscattering coefficients, the branch size distribution is important. In this paper, the branch size distribution has been discretized into four sizes. We expect that the use of only one or two average branch sizes will not be able to explain multifrequency data. This indicates that the structure of a forest is important.
2. Small branches and leaves generally contribute to the backscattering coefficients at *X* band. In particular, cross

polarization at X band is dominated by stems and not leaves in deciduous trees.

- The contribution of the trunk-soil interaction to the backscattering coefficients depends heavily on soil moisture and soil roughness and it is more important for  $\sigma_{hh}$  than  $\sigma_{vv}$  polarization.

## VI. APPENDIX A THE ITERATIVE SOLUTION OF THE RADIATIVE TRANSFER EQUATIONS

**I**N this appendix the radiative transfer equations governing the intensity (Stokes' parameters) within the canopy is presented and the procedures for obtaining their iterative solution is outlined. For simplicity only the radiative transfer equation within the crown layer is considered.

The radiative transfer equations describing the Stokes parameters within the crown layer are [34]:

$$\begin{aligned} \cos \theta \frac{d\bar{I}(\theta, \phi, z)}{dz} &= -\bar{K}(\theta)\bar{I}(\theta, \phi, z) + \bar{S}(\theta, \phi, z) \\ -\cos \theta \frac{d\bar{I}(\pi - \theta, \phi, z)}{dz} &= -\bar{K}(\pi - \theta)\bar{I}(\pi - \theta, \phi, z) \\ &\quad + \bar{S}(\pi - \theta, \phi, z) \end{aligned} \quad (A1)$$

where  $\bar{I}(\theta, \phi, z)$  and  $\bar{I}(\pi - \theta, \phi, z)$  are the upward and downward Stokes parameters at location  $z$  with

$$\bar{I}(\theta, \phi, z) = \begin{bmatrix} I_v(\theta, \phi, z) \\ I_h(\theta, \phi, z) \\ I_3(\theta, \phi, z) \\ I_4(\theta, \phi, z) \end{bmatrix} = \begin{bmatrix} \langle |E_v|^2 \rangle \\ \langle |E_h|^2 \rangle \\ 2\text{Re}(E_v E_h^*) \\ 2\text{Im}(E_v E_h^*) \end{bmatrix}. \quad (A2)$$

$E_v$  and  $E_h$  are the vertically and horizontally polarized components for the electric field vectors. In (A1)  $\bar{S}(\theta, \phi)$  and  $\bar{S}(\pi - \theta, \phi)$  are the upward and downward source functions defined as

$$\begin{aligned} \bar{S}(\theta, \phi, z) &= \int_0^{2\pi} d\phi_t \int_0^{\pi/2} \sin \theta_t d\theta_t \\ &\quad \cdot \sum_{m=1}^{N_1} n_m [\langle \bar{P}_m(\theta, \phi; \theta_t, \phi_t) \rangle \bar{I}(\theta_t, \phi_t, z) \\ &\quad + \langle \bar{P}_m(\theta, \phi; \pi - \theta_t, \phi_t) \rangle \bar{I}(\pi - \theta_t, \phi_t, z)]. \end{aligned} \quad (A3)$$

In (A3)  $\bar{P}_m(\theta, \phi; \theta_t, \phi_t)$  is a  $4 \times 4$  phase matrix of the  $m$ th group of scatterers. This matrix describes the scattering properties from direction  $(\theta_t, \phi_t)$  into direction  $(\theta, \phi)$  [2], [25]. A similar expression can be written for  $\bar{S}(\pi - \theta, \phi)$  by replacing  $\theta$  with  $\pi - \theta$ . Furthermore  $\bar{K}(\theta)$  and  $\bar{K}(\pi - \theta)$

are the upward and downward extinction coefficient matrices. For forest constituents with statistical azimuthal symmetry, the averages of the cross-polarized scattering amplitudes,  $F_{mvh, mhv}$ , vanish and the extinction matrix simplifies to (A4) at the bottom of the page. Where scattering amplitude tensor elements  $F_{mpp}$  (with  $p = v, h$ ) are calculated in the forward direction for an exciting wave in direction  $(\theta, \phi)$ .

An approach to solve (A1) is to diagonalize the extinction matrices and then solve the resulting radiative transfer equations. This can be done using a matrix  $\bar{E}$  constructed from the eigenvectors of the extinction matrix [25]. For the matrix given in (A4) the eigenvector matrix is

$$\bar{E} = \frac{1}{2} \begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 1 & j \\ 0 & 0 & 1 & -j \end{bmatrix}. \quad (A5)$$

Then by multiplying (A1) from the left-hand side by the matrix  $\bar{E}$  we can rearrange (A1) as

$$\begin{aligned} \cos \theta \frac{d\bar{I}(\theta, \phi, z)}{dz} &= -\bar{\kappa}(\theta)\bar{I}(\theta, \phi, z) + \bar{S}(\theta, \phi, z) \\ -\cos \theta \frac{d\bar{I}(\pi - \theta, \phi, z)}{dz} &= -\bar{\kappa}(\pi - \theta)\bar{I}(\pi - \theta, \phi, z) \\ &\quad + \bar{S}(\pi - \theta, \phi, z) \end{aligned} \quad (A6)$$

where

$$\begin{aligned} \bar{I}(\theta, \phi, z) &= \bar{E}\bar{I}(\theta, \phi, z) \\ \bar{\kappa}(\theta) &= \bar{E}\bar{K}(\theta)\bar{E}^{-1} \end{aligned} \quad (A7)$$

and

$$\begin{aligned} \bar{S}(\theta, \phi, z) &= \int_0^{2\pi} d\phi_t \int_0^{\pi/2} \sin \theta_t d\theta_t [\bar{Q}(\theta, \phi; \theta_t, \phi_t)\bar{I}(\theta_t, \phi_t, z) \\ &\quad + \bar{Q}(\theta, \phi; \pi - \theta_t, \phi_t)\bar{I}(\pi - \theta_t, \phi_t, z)] \end{aligned} \quad (A8)$$

$$\bar{Q}(\theta, \phi; \theta_t, \phi_t) = \sum_{m=1}^{N_1} n_m \bar{E} \langle \bar{P}_m(\theta, \phi; \theta_t, \phi_t) \rangle \bar{E}^{-1}. \quad (A9)$$

In (A7)  $\bar{\kappa}(\theta)$  is a diagonalized matrix. Its elements are the eigenvalues of the extinction matrix  $\bar{K}$ . For the eigenvector

$$\bar{K}(\theta) = \frac{2\pi}{k} \sum_{m=1}^{N_1} n_m \begin{bmatrix} 2\text{Im}\langle F_{m vv} \rangle & 0 & 0 & 0 \\ 0 & 2\text{Im}\langle F_{m hh} \rangle & 0 & 0 \\ 0 & 0 & \text{Im}\langle F_{m vv} + F_{m hh} \rangle & \text{Re}\langle F_{m vv} - F_{m hh} \rangle \\ 0 & 0 & \text{Re}\langle F_{m hh} - F_{m vv} \rangle & \text{Im}\langle F_{m vv} + F_{m hh} \rangle \end{bmatrix}. \quad (A4)$$



matrix given in (A5), see (A10) below. In addition,  $\bar{I}(\theta, \phi, z)$  and  $\bar{Q}(\theta, \phi; \theta_t, \phi_t)$  reduce to

$$\bar{I}(\theta, \phi, z) = \begin{bmatrix} I_v(\theta, \phi, z) \\ I_h(\theta, \phi, z) \\ \frac{1}{2}(I_3(\theta, \phi, z) + jI_4(\theta, \phi, z)) \\ \frac{1}{2}(I_3(\theta, \phi, z) - jI_4(\theta, \phi, z)) \end{bmatrix} \quad (\text{A11})$$

and (A12) at the bottom of the page. It is clear that the first two terms of the Stokes parameter vector (A11) do not change with the transformation.

Equations in (A6) are linear differential equations. For the purpose of iteration they can be written as integral equations in the form [34]

$$\begin{aligned} \bar{I}(\theta, \phi, z) &= e^{-\bar{\kappa}(\theta)(z+H_1)\sec\theta} \bar{I}(\theta, \phi, -H_1) \\ &\quad + \int_{-H_1}^z dz' e^{-\bar{\kappa}(\theta)(z-z')\sec\theta} \bar{S}(\theta, \phi, z') \\ \bar{I}(\pi - \theta, \phi, z) &= e^{\bar{\kappa}(\pi-\theta)z\sec\theta} \bar{I}(\pi - \theta, \phi, 0) \\ &\quad + \int_z^0 dz' e^{\bar{\kappa}(\theta)(z-z')\sec\theta} \bar{S}(\pi - \theta, \phi, z'). \end{aligned} \quad (\text{A13})$$

The zero-order solution of (A13) is obtained by setting the source function to zero yielding

$$\begin{aligned} \bar{I}^0(\theta, \phi, z) &= e^{-\bar{\kappa}(\theta)(z+H_1)\sec\theta} \bar{I}^0(\theta, \phi, -H_1) \\ \bar{I}^0(\pi - \theta, \phi, z) &= e^{\bar{\kappa}(\pi-\theta)z\sec\theta} \bar{I}^0(\pi - \theta, \phi, 0) \end{aligned} \quad (\text{A14})$$

where  $\bar{I}^0(\theta, \phi, -H_1)$  and  $\bar{I}^0(\pi - \theta, \phi, 0)$  are to be obtained from the boundary conditions. The  $v$ th order solution ( $v > 1$ ) can be written as

$$\begin{aligned} \bar{I}^v(\theta, \phi, z) &= \int_{-H_1}^z e^{-\bar{\kappa}(\theta)(z-z')\sec\theta} \bar{S}^v(\theta, \phi, z') \\ \bar{I}^v(\pi - \theta, \phi, z) &= \int_z^0 e^{\bar{\kappa}(\theta)(z-z')\sec\theta} \bar{S}^v(\pi - \theta, \phi, z') \end{aligned} \quad (\text{A15})$$

with

$$\begin{aligned} \bar{S}^v(\theta, \phi, z') &= \int_0^{2\pi} d\phi_t \int_0^{\pi/2} \sin\theta_t d\theta_t [\bar{Q}(\theta, \phi; \theta_t, \phi_t) \bar{I}^{v-1}(\theta_t, \phi_t, z') \\ &\quad + \bar{Q}(\theta, \phi; \pi - \theta_t, \phi_t) \bar{I}^{v-1}(\pi - \theta_t, \phi_t, z')]. \end{aligned} \quad (\text{A16})$$

The original Stokes parameters can be recovered from (A14) and (A15) by multiplying them by  $\bar{E}^{-1}$ .

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$$\bar{\kappa}(\theta) = \frac{2\pi}{k} \sum_{m=1}^{N_1} n_m \begin{bmatrix} 2\text{Im}\langle F_{m\nu\nu} \rangle & 0 & 0 & 0 \\ 0 & 2\text{Im}\langle F_{mhh} \rangle & 0 & 0 \\ 0 & 0 & \text{Im}\langle F_{m\nu\nu} + F_{mhh} \rangle & 0 \\ 0 & 0 & +j\text{Re}\langle F_{m\nu\nu} - F_{mhh} \rangle & 0 \\ 0 & 0 & 0 & \text{Im}\langle F_{m\nu\nu} + F_{mhh} \rangle \\ & & & -j\text{Re}\langle F_{m\nu\nu} - F_{mhh} \rangle \end{bmatrix} \quad (\text{A10})$$

$$\bar{Q}(\theta, \phi; \theta_s, \phi_s) = \sum_{m=1}^{N_1} n_m \begin{bmatrix} \langle |F_{m\nu\nu}|^2 \rangle & \langle |F_{m\nu h}|^2 \rangle & \langle F_{m\nu\nu} F_{m\nu h}^* \rangle & \langle F_{m\nu\nu}^* F_{m\nu h} \rangle \\ \langle |F_{m h\nu}|^2 \rangle & \langle |F_{m h h}|^2 \rangle & \langle F_{m h\nu} F_{m h h}^* \rangle & \langle F_{m h\nu}^* F_{m h h} \rangle \\ \langle F_{m\nu\nu} F_{m h\nu}^* \rangle & \langle F_{m\nu h} F_{m h h}^* \rangle & \langle F_{m\nu\nu} F_{m h h}^* \rangle & \langle F_{m\nu h} F_{m h h}^* \rangle \\ \langle F_{m\nu\nu}^* F_{m h\nu} \rangle & \langle F_{m\nu h}^* F_{m h h} \rangle & \langle F_{m\nu h}^* F_{m h\nu} \rangle & \langle F_{m\nu\nu}^* F_{m h h} \rangle \end{bmatrix} \quad (\text{A12})$$

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Dr. Lang is a member of IEEE.



Narinder S. Chauhan (M'87) received the M.Sc. degree in physics, the M.E. degree (Honors) in computer science, and the Ph.D. degree in space physics from Punjabi University, India, in 1972, 1983, and 1979, respectively.

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Dr. Chauhan is a member of IEEE and AGU.

To: Denise Dunn, Administrative Assistant, USRA  
From: Steven W. Bidwell, Task No. 970-023  
Subject: Quarterly Report (July 1, 1992 - September 30, 1992)  
Date: 11/12/92

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August 3, 1992 was the date of my hire in association with the Microwave Sensors Branch (Code 975) of the Laboratory for Hydrospheric Processes. The following is a narrative report on my activities during the past quarter-year presented in chronological order.

Soon after my hiring I made one short overnight 8/5 - 8/6 trip to Wallops Island, VA. During this trip I gained a cursory experience with the millimeter-wave imaging radiometer (MIR) experiment. I became acquainted with the overall system and its integration into the ER-2 aircraft. Paul Racette of Code 975 is the lead engineer on this program and whenever possible I have lent assistance. In this effort I spent about 1.5 weeks working on a gray-scale plotting routine for the MIR data. This routine displays pixel brightness temperature data on a gray-scale hard copy.

The majority of my efforts have been devoted to the EDOP (ER-2 DOPpler radar) experimental radar program. Dr. Gerald Heymsfield of Code 912 (Severe Storms Branch) is the Principal Investigator for this program. There is a critical need for a systems engineer on this program and one of my responsibilities is to fill this role. The EDOP airborne radar system is composed of various subsystems: transmitter, receiver, power distribution, aircraft interface, cabling, waveguide and antennas, and data system. My prior experience in microwave tubes has aided in the troubleshooting of the transmitter and receiver systems. However, numerous problems remain with the data acquisition system and its interface with the radar. My digital electronics experience with regard to the data system is not as comprehensive. It is my goal as the systems engineer to obtain a "jack-of-all-trades" knowledge of the various subsystems.

For a two week period in September 9/15 - 9/26 I was on travel to the Ames Research Center at Moffat Field, CA with Dr. Gerald Heymsfield and the EDOP group. The purpose of this trip

was to fly the Doppler radar system aboard the ER-2 aircraft, gather data, and eliminate remaining problems. Presently the EDOP program is preparing for the ocean and atmospheric experiments in the Southwest Pacific (TOGA-COARE) during January and February 1993. The flights at Ames are intended to ready the EDOP system for this upcoming mission. Largely my time at Ames was spent on troubleshooting the radar and identifying potential failure modes.

In addition to the EDOP activities I have been investigating the possible use of the MIR data from the TOGA-COARE experiments to examine cloud physics. (The MIR is also involved in the TOGA-COARE mission). The MIR device collects brightness temperatures at nine millimeter-wave frequencies. Using data from the 183 GHz and 325 GHz channels one might make some cloud physics observations. Specifically, the two frequencies of interest are water vapor absorption lines and through knowledge of the brightness temperature weighting functions at these frequencies one might estimate the vertical extent of clouds. This would provide an alternative method to a more conventional means using radar.

Finally, in collaboration with Drs. James Weinman and Wei-Kao Tao, I have submitted a Director's Discretionary Fund Proposal to examine processing techniques for a spatial imaging enhancement of radiometric signals. These techniques will be dependent upon over sampling of the desired scene. Such a technique, using a numerical filter, might be used on the TRMM (Tropical Rainfall Measuring and Monitoring) satellite mission. If not applied to this mission, it might be used on the ESTAR (Electronically Scanned Thinned Array Radiometer) satellite. If this proposal is successful I will examine resolution enhancement techniques from data obtained from the MIR experiment. I will intentionally blur the scene and attempt recovery using various numerical techniques. A scene involving a sharp spatial transition such as a coastline might be used in these studies.

For the next quarter year most of my effort will again be concentrated on producing a successful EDOP program. Tests flights at Ames Research Center are planned for mid-November and mid-December. When not working on this program, I will be investigating the scientific programs mentioned above (MIR data for cloud physics and the DDF proposal on resolution enhancement).

**Quarterly Technical Report**  
**July 1, 1992 - September 30, 1992**  
**Dr. A. Daniel Kowalski**  
**Task# 970027**

**1 Introduction**

My primary research activity is concerned with the development of algorithms and corresponding programs for high performance numerical modeling of coupled ocean - atmosphere circulation. These algorithms must be scalable to run on future massively parallel machines containing thousands of processors and capable of teraFLOP performance. This involves spatial and/or functional decomposition of algorithms along with corresponding data dependency analysis.

The research also involves a detailed performance analysis of different parallel machine architectures. Machine details like, for example, the presence of instruction and data cache, vector processing units, pipelined instruction hardware, and interprocessor communication architecture can greatly affect algorithm performance.

**2 Research Activities for the Period**  
**July 1, 1992 to September 30, 1992**

I Co-authored a NASA NRA hpcc proposal with Dr. Max Suarez and Dr. Paul Schopf of NASA/GSFC entitled "Development of Algorithms for Climate Models Scalable to Teraflop Performance". The proposal is still pending. In addition, I composed and submitted a successful mini-proposal for computer time on the INTEL Touchstone DELTA parallel computer at Caltech. I also composed a proposal section for NCCS for a project which would run a coupled atmosphere-ocean model using a distributed system of supercomputers coupled by high speed satellite communications.

Computational work has included conducting single and multiple node performance measurements on the Intel Touchstone Delta and CRAY Y-MP at NASA/GSFC with benchmarks derived from the Goddard coupled ocean/atmosphere model. The benchmarks include the long wave radiation code from the Aries atmospheric model and momentum and continuity hydrodynamics code from the Poseidon ocean model. Current results indicate 2-3 Mflop performance per node on the Touchstone Delta with optimized but untuned benchmark code and 200 Mflop Cray single node performance.

Other activities include the submission of an abstract for the 6th SIAM Conference on Parallel Processing for Scientific Computing and attendance at the Frontiers '92 Conference on Massively Parallel Computation.

### **3 Planned Activities for the 4th Quarter July 1, 1992 to September 30, 1992**

During the next quarter, I plan to continue speedup and efficiency tests on developed benchmarks as well as continue the development and testing of new parallel algorithms for the coupled ocean/atmospheric model. This will begin with the development of a parallel short wave radiation code for the atmospheric model.

I also plan to write a paper for the 6th SIAM Conference on Parallel Processing for Scientific Computing and a workshop on High Performance Computing in the Geosciences.

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of data will be performed by comparing the resulting fraction images with the classification derived from TM/Landsat and AVHRR NDVI images.

### STUDY SITE

The study site is located between 17° 50' to 18° 20' South latitude and 52° 40' to 53° 20' West longitude on the border of Goiás, Mato Grosso and Mato Grosso do Sul States. The site includes the Emas National Park comprising about 131,000 hectares in which the "cerrado" vegetation is well represented (Redford 1985, IBDF/FBCN 1978, Pinto 1986). Located on the watershed between the La Plata and Amazon River basins, Emas Park is on the western edge of the Central Brazilian Plateau, adjacent to the Pantanal (Redford 1985). It offers a good sample of the Planalto habitats, including a number of small watercourses, the sources of two important rivers, riverine gallery forest and marshes, large areas of grassland (the "campos"), and some open woodland (the "cerrados") consisting of small thinly distributed trees seldom more than three meters high (Erize 1977). The surrounding land of the Park has been used for agricultural and cattle grazing. This Park is commonly affected by uncontrolled fires during the annual dry season (Shimabukuro et al. 1991). Most of these fires are set outside the Park by ranchers to improve grazing quality and to control cattle parasites (Redford 1985). The rest of the study site is covered by "cerrado" vegetation types. The Landsat/TM and NOAA/AVHRR data over this area acquired on July 29, 1988 were available for this study.

## METHOD

### AVHRR 3.75 $\mu\text{m}$ Reflective Component

The AVHRR 3.75  $\mu\text{m}$  band is a mixture of the thermal emitted energy and a reflective energy component. Typically the latter represents less than 10% of the signal for bare soil and urban features and less than 3 percent for green vegetation (Kerber and Schutt 1986; and Schutt and Holben 1991; Remer 1992). The reflective component may be approximated by assuming the emitted energy (brightness temperature) in the adjacent thermal band (10.5 to 11.5  $\mu\text{m}$ ) is related to the emitted energy in the 3.75  $\mu\text{m}$  band at ambient temperature through the Planck Function as follows (Kaufman and Nakajima 1992):

$$L_3 = L_{3\rho} + L_{3\varepsilon} \quad (1)$$

where:

$L_3$  = Total radiant energy measured by the satellite at 3.75  $\mu\text{m}$

$L_{3\rho}$  = The reflective energy at 3.75  $\mu\text{m}$

$L_{3\varepsilon}$  = The emissive energy at 3.75  $\mu\text{m}$

The reflective and emitted components may be expanded according to:

$$L_3 = \rho_3 F_0 \mu_0 / \pi + R_3(T_4) * (1 - \rho) \quad (2)$$

where:

$\rho_3$  = Reflectance in the 3.75  $\mu\text{m}$  band

$F_0$  = 3.75 band solar irradiance at the bottom of the atmosphere

$\mu_0$  = cosine of the solar zenith angle

$R_3(T_4)$  = Emitted radiance at 3.75  $\mu\text{m}$  using the 11.0  $\mu\text{m}$  brightness computed with the Planck Function

Solving for  $\rho_3$ :

$$\rho_3 = (L_3 - R_3(T_4)) / (F_0 \mu_0 / \pi - R_3(T_4)) \quad (3)$$

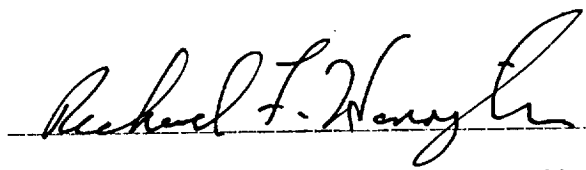
This formulation ignores the differential atmospheric transmission in both bands and we assume the target surface is flat and the satellite view direction is nadir.



August 24, 1992

## MEMORANDUM

TO: Denise Dunn, USRA

FROM: Dr. Richard F. Harrington SUBJECT: Trip Report: Goddard Space Flight Center, Greenbelt Maryland  
August 20 & 21, 1992

Dr. James C. Shiue of GSFC requested that I visit him at GSFC on August 20 & 21, 1992 to review the TRMM Microwave Imager (TMI) Conceptual Design Review (CoDR) data package. This meeting was in preparation for the TMI CoDR to be held at the Hughes facility in Los Angeles on August 26 & 27, 1992. Dr. Shiue had requested on Monday August 17 that I look into two areas of technical concern prior to the GSFC meeting later in the week.

The two areas of concern were:

- (a) Undersampling of the 85.5 GHz channel and the desirability of increasing the TMI scan rate to improve the sampling rate of the scene; and
- (b) the use of a 12 bit A/D converter with AGC in lieu of the specified 14 bit A/D converter without AGC.

The meeting on Tuesday afternoon, August 20th, was held with Dr. Shiue and the above two items were discussed. Also, the TMI CoDR data package was obtained from Dr. Shiue. This was reviewed during that evening in preparation for the discussion on Friday with Dr. Shiue.

The meeting on Friday, August 21st, was held with Dr. Shiue. Detailed discussions on many aspects of the TMI CoDR data package were held. These discussions included, but not limited to the following items:

- (a) The use of integrate and dump techniques as compared to low pass filtering for the integration of the scene in the radiometer design.
- (b) Why is Aerojet using a 14 bit A/D converter in the SSMIS design in lieu of a 12 bit A/D converter with AGC?
- (c) Effect of the A/D converter and low pass filtering on the pixel-to-pixel interference specification.
- (d) Question of possible interference from the precipitation radar (PR) into the TMI's 10.65 GHz channel. Related experience from the Seasat spacecraft and the interference of the SASS into the 6.6 and 10.6 GHz channels of the SMMR.
- (e) Cold sky reflector orientation with respect to the spacecraft.
- (f) Undersampling effects at 85.5 GHz

The meeting was concluded with discussion of the information Dr. Shiue needed prior to the TMI CoDR. Also, Dr. Shiue requested that I take notes during all technical discussions during the CoDR.

MEMORANDUM

August 7, 1992

TO: Dr. James C. Shiue  
Goddard Space Flight Center  
Greenbelt, Md.

FROM: Dr. Richard F. Harrington *RFH*  
Old Dominion University  
Norfolk, VA.

SUBJECT: Potential technical problem for the TRMN Microwave Imager.

STATEMENT OF PROBLEM

The Precipitation Radar (PR) and the TRMN Microwave Imager (TMI) are operating simultaneously during the TRMN mission. The TMI measures the total electromagnetic (EM) energy incident at the input of the radiometer during one integration period. The TMI can not differentiate between the EM energy radiated from the geophysical phenomena such as liquid water in rain which is used to determine rain rate and the coherent EM energy that leaks into the radiometer while the PR is transmitting. Therefore the TRMN system design must insure that the level of PR leakage is sufficiently below the threshold or sensitivity of the TMI to insure minimal error due to the PR leakage radiation.

Microwave radiometers typically use waveguide inputs from the antenna to the low noise amplifier (LNA), if used, or the mixer preamplifier if no LNA is employed. A waveguide is a high-pass filter which only passes EM energy whose frequency is above the cut-off frequency of the waveguide. Therefore spacecraft systems in which the radar operates at a frequency lower than the cut-off frequency of the radiometer input waveguide usually have sufficient isolation within the waveguide structure. This is the case for the 19.35, 22.235, 37 and 85.5 GHz. channels of the TMI. The 13.8 GHz. frequency of the PR is below the 14.09 GHz. cut-off frequency for the 19.35 and 22.235 GHz channels of the TMI. However, the 13.8 GHz frequency of the PR is above the frequency of the 10.65 GHz channel of the TMI. It will be shown later in this memorandum that a total isolation of 165.3 dB is required to insure that the EM radiation from the PR is equal to one-tenth of the EM radiation required for an output of 0.5 Kelvin from the TMI.

POTENTIAL PROBLEM SOLUTIONS

There are two potential solutions to the above problem:

(1) Disable the TMI during the PR transmitting time thru the use of a blanking pulse from the PR.

(2) Provide sufficient isolation by techniques both internal and external to the TMI. A bandstop filter can be added within the RF frontend of the 10.65 GHz channel of TMI. External isolation can be obtained through location of the PR and TMI antennas and detailed analysis of antenna sidelobes.

The first solution is highly desirable since it guarantees a solution to this problem by design. However, it requires an interface between the PR and TMI, a design change in the existing TMI, and potentially an additional output from the PR.

The second solution requires a high level of isolation between the PR and TMI antennas. To insure that the TRMN spacecraft system design provides

(2)

sufficient isolation is a difficult and complicated analytical problem. Testing of the PR antenna and TMI on a spacecraft mockup would be required very early in the program to allow sufficient time for redesign. If sufficient isolation could not be obtained, then a redesign of the PR and TMI could be required.

### ISOLATION REQUIREMENT CALCULATION

- (1) PR Parameters: Frequency: 13.796 and 13.802 GHz.  
Peak Power: 500 Watts  
Pulse Width: 1.67 microseconds  
Pulse Repetition Frequency: 2778.3 pulses per second
- (2) TMI 10.65 GHz Channel Parameters: Frequency: 10.65 GHz.  
RF Bandwidth: 100 MHz.  
Integration Time: 30.67 milliseconds  
Required Radiometer Sensitivity: 0.5 K

Step 1: Determine the increase or delta in the electromagnetic (EM) energy required at the input to the TMI to increase the output by 0.5 K during one integration period.

$$\text{delta energy} = \text{delta power} \times \text{integration time}$$

$$\text{delta power} = k \times \text{sensitivity} \times \text{bandwidth}$$

$$\begin{aligned} \text{where } k &= \text{Boltzman's constant} = 1.38 \times 10^{-23} \text{ Joules/Kelvin} \\ \text{sensitivity} &= 0.5 \text{ Kelvin} \\ \text{bandwidth} &= 100 \text{ MHz} \\ \text{integration time} &= 30.67 \text{ milliseconds} \end{aligned}$$

$$\text{delta energy} = (1.38 \times 10^{-23})(0.5)(1 \times 10^8)(30.67 \times 10^{-3})$$

$$\text{delta energy} = 2.116 \times 10^{-17} \text{ Joules}$$

Step 2: Determine the electromagnetic (EM) energy radiated by the PR during one integration time of the 10.65 GHz channel of TMI.

$$\text{PR energy} = \text{Peak power} \times \text{Pulsewidth} \times \text{PRF} \times \text{Integration time}$$

$$\text{PR energy} = (500)(1.67 \times 10^{-6})(2778.3)(30.67 \times 10^{-3})$$

$$\text{PR energy} = 7.115 \times 10^{-2} \text{ Joules}$$

Step 3: Determine the isolation required.

ASSUMPTION: To prevent the PR energy from increasing the TMI output, the PR energy must be 1/10 of the energy required to give an output of 0.5 Kelvin from the 10.65 GHz channel of the TMI. Therefore:

$$\text{PR energy must be equal to or less than } 2.116 \times 10^{-18} \text{ Joules.}$$

$$\text{ISOLATION} = 10 \log(7.115 \times 10^{-2} / 2.116 \times 10^{-18})$$

$$\text{ISOLATION} = 165.3 \text{ dB}$$

(3)

Since the bandpass filter in the TMI is specified to provide 40 dB of attenuation to out-of-band EM signals, the total required isolation between the PR antenna and the TMI antenna for minimum error due to leakage from the PR is:

ANTENNA ISOLATION = 125.3 dB or greater

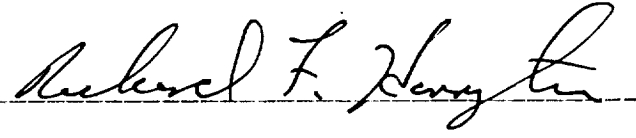
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August 31, 1992

MEMORANDUM

TO: Denise Dunn, USRA

FROM: Dr. Richard F. Harrington



SUBJECT: Trip Report: Hughes Aircraft Company, El Segundo, CA August 25 thru 28, 1992

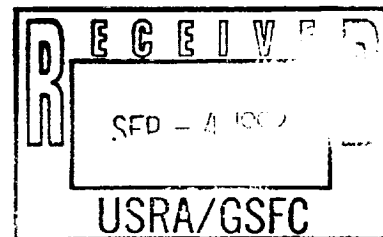
Dr. James C. Shiue of GSFC requested that I attend the TRMM Microwave Imager (TMI) Conceptual Design Review (CoDR) that was held at the Hughes Aircraft Company facility in El Segundo, CA as a member of the TMI Technical Advisory Group. A detailed listing of the discussion items is provided in the attached memorandum to Dr. Shiue dated August 31, 1992. A list of the attendees at the CoDR is also attached. Material obtained at the CoDR included updates to the TMI CoDR data packages and Hughes Interdepartmental Correspondance from Jamie Hilleary, who was unable to attend the CoDR. A tour of the microwave testing laboratory and a demonstration of the two frequency linearity test set-up was conducted Tuesday evening by Dr. Victor Reinhardt of Hughes.

The CoDR was very successful and demonstrates the excellant communications that exists between the GSFC TRMM project office and the TMI contractor, Hughes Aircraft Company.

Members of Dr. Shiue's TMI Technical Advisory Group that attended the TMI CoDR included:

- Dr. James C. Shiue - GSFC TMI Instrument Scientist
- Dr. Wes Lawrence - NASA Langley
- Dr. James Hollinger - Naval Research Laboratory
- Dr. Richard F. Harrington - Old Dominion University

Also in attendance representing the TMI science team was Dr. Tom Wilheit of Texas A & M University.

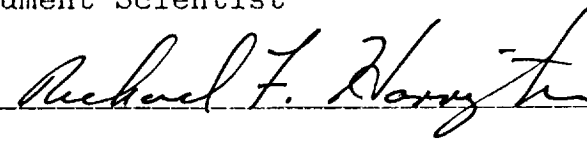


August 31, 1992

MEMORANDUM

TO: Dr. James C Shiue, TMI Instrument Scientist  
GSFC

FROM: Dr. Richard F. Harrington  
Old Dominion University



SUBJECT: TMI CoDR discussion items requiring further study and/or action.

The following is a tabulation of items requiring further study or actions. These items are from my notes taken during the TRMM Microwave Imager (TMI) Conceptual Design Review (CoDR) held at the Hughes Aircraft Company facility in El Segundo, CA on August 26 & 27, 1992.

(1) The linearity specification is very tight and overall system testing can not be accomplished to demonstrate compliance with the specification. Subsystem level testing and analysis will have to be performed to show that the linearity requirement has been met.

(2) Change of polarization at 22.235 GHz from vertical to horizontal.

(3) Change of frequency from 22.235 GHz to 21.3 GHz.

(4) The Mil-Std 1773 bus with the 1553 protocol is new to both Hughes and GSFC. Question of the lack of experience which might result in unforeseen problems in the design phase which only show up in testing. What NASA flight programs have been designed, fabricated, tested and flown using the Mil-Std 1773 bus and 1553 protocol?

(5) Reduction of the 140 degree scan angle to 130 degrees and the resulting impact on the swath width?

(6) Potential of using direct detection at 85.5 GHz. Need to study the maturity of components such as LNA's at this frequency prior to a decision to use direct detection at 85.5 GHz.

(7) PR interference with the 10.65 GHz, 19.35 GHz and 22.235 GHz channels of the TMI. Need to document results of splinter group meeting. Hughes took an action item to solve this problem thru design.

(8) Mechanical interference of TMI during deployment. Further study by Hughes and GSFC is needed to insure that there is not a problem with the recommended deployment option, option C.

(9) Cold sky reflector might see a portion of the spacecraft/solar panels. What is the impact of reducing the scan angle from 140 degrees to 130 degrees? Calculation and/or measurements of potential cold sky calibration error needs to be in the future TMI planning. A 1% spacecraft view of a 300 K spacecraft introduces a 100 % error in the cold sky measurement.

(10) Post detection integration can be achieved either by low-pass filtering or integrate and dump circuits. In the undersampling scheme designed into TMI, which is the correct technique?

- (11) Spin-speed study to improve sampling and provide contiguous coverage at 85.5 GHz. Note: I did not cover this splinter meeting since I was involved in the PR - TMI interference splinter meeting.
- (12) Momentum wheel - questions on:
- (a) physical location
  - (b) input power from raw spacecraft bus
  - (c) design of electronics and control loop
  - (d) when is the BAPTA slaved to the momentum wheel and when is BAPTA slaved to the crystal reference?
  - (e) thermal environment of momentum wheel.
- (13) Atomic oxygen specification, is it excessive?
- (14) Question of the gain drift of the direct detection radiometer receivers as a function of temperature, age and voltage. Is the AGC system dynamic range, resolution and the 12 bit A/D convertor capable of accomodating these expected variations. Note: This is a totally different receiver design from SSM/I.
- (15) Cold sky calibration accuracy of 0.2 K is not achievable. Is this over specified and should it be relaxed?
- (16) How is proper TMI deployment verified from spacecraft telemetry prior to spin-up of the TMI? Is this information needed?
- (17) Data load of 42 Kbps as compared to 37 Kbps due to adding 4 zero bits to 12 bit data to make a 16 bit word required for the Mil-Std 1773 requirement. Should revised data packing and/or data compression be employed to reduce the data load requirement?
- (18) Hughes would like to format 1 scan of data as compared to the GSFC requirement to format 3 scans of data.
- (19) Automatic gain control, questions concerning time period of adjustment, dynamic range and step size using a 4 bit AGC word?
- (20) Torque margin, difference between the Hughes position on acceptable torque margin as compared to the four times worst case required by GSFC.
- (21) Stability of spacecraft supplied clocks and their effect on TMI performance.
- (22) Ephemeris error was missing from pointing error budget.
- (23) Implementation of redundancy in optical transmitters and receivers in the Mil-Std 1773 bus. Use of OR circuit. Is data being sent out simultaneously on both buses? Are both receivers active? Need better definition and understanding on the MIL-Std 1773 bus design.
- (24) Question of SEU performance requirement. How is detection of a single event accomplished? How is the recovery from a single event achieved? Confusion on specification and potential solutions.
- (25) The pointing error of the 10.65 GHz channel beam of 0.2 degrees is relative to the position of the multifrequency SSM/I horn which is 0.2 degrees relative to the 49 degree requirement. This needs a clarification in the specification.

(3)

(26) Spillover effects of the cold sky feed horn on the accuracy of cold sky calibration. Hughes accepted an action item to study this problem.

(27) Hughes requested that the power supply frequencies be increased from the GSFC requirement of 50 KHz maximum to 200 KHz maximum.

(28) Difference in the thermal interface specification:

(a) GSFC: -25 deg C to + 50 deg C

(b) Hughes: 0 deg C to + 30 deg C

Needs to be resolved.



TMI  
 Conceptual Design Review  
 August 25 - 27, 1992

SIGN - IN SHEET

26 AUG 92

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TMI  
 Conceptual Design Review  
 August 25 - 27, 1992

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