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A COMPARISON OF AIRBORNE AND GROUND-BASED RADAR OBSERVATIONS WITH RAIN GAGES DURING THE CaPE EXPERIMENT

Makoto Satake*, David A. Short and Toshio Iguchi*

NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771, USA

ABSTRACT

The vicinity of Kennedy Space Center, Florida, where the primary ground truth site of the TRMM (Tropical Rainfall Measuring Mission) ground truth program is located, was the focal point of the multi-agency CaPE (Convection and Precipitation /Electrification) experiment in July and August, 1991. In addition to several specialized radars, local coverage was provided by the C-band (5 cm) radar at Patrick Air Force Base, Florida. Point measurements of rain rate were provided by tipping bucket rain gage networks. Besides these ground-based activities, airborne radar measurements with X- and Ka-band nadir-looking radars on board an aircraft were also recorded. A unique combination data set of airborne radar observations with ground-based observations was obtained in the summer convective rain regime of central Florida. We present a comparison of these data intending a preliminary validation. A convective rain event was observed simultaneously by all three instrument types on the evening of July 27, 1991. The high resolution aircraft radar was flown over convective cells with tops exceeding 10 km and observed reflectivities of 40 to 50 dBZ at 4 to 5 km altitude, while the low resolution surface radar observed 35 to 55 dBZ echoes and a rain gage indicated maximum surface rain rates exceeding 100 mm/hr. The height profile of reflectivity measured with the airborne radar show an attenuation of 6.5 dB/km (two way) for X-band, corresponding to a rainfall rate of 95 mm/hr.

INTRODUCTION

Future space-borne radars, such as the one to be flown in conjunction with NASA's Tropical Rainfall Measuring Mission (TRMM), are the most promising method to monitor global rainfall. At the present time, prototypes of future space-borne systems are being tested aboard aircraft. At the same time, methods of validating such airborne and space-borne radar observations with ground-based observations are under development.

Ground-based radar and rain gage observations are being collected at numerous tropical sites as part of the TRMM ground truth program [1]. The primary ground truth site, in the vicinity of Kennedy Space Center, was the focal point of the multi-agency sponsored CaPE (Convection and Precipitation/Electrification) experiment in July and August, 1991 [2]. In addition to several specialized radars such as CP-2 radar of NCAR (National Center for Atmospheric Research), local coverage was provided by the C-band (5 cm) radar at Patrick Air Force Base, Florida. Point measurements of rainfall rates were provided by tipping bucket rain gage networks (operated by NASA and several of Florida's Water Management Districts). Besides these ground-based activities, airborne radar measurements with X- and Ka-band nadir-looking radars on board the NASA T-39 aircraft were also collected. A unique combination data set of airborne radar observations with ground-based observations was obtained in the summer convective rain regime of central Florida.

We present a comparison of these data intending a preliminary validation of the airborne radar. Because of the highly variable nature of tropical convection, opportunities for direct comparison of point (rain gage), line (aircraft) and area (surface radar) sensors are rare. In this paper we describe a convective rain event that was observed simultaneously by all three instrument types on the evening of July 27, 1991.

SENSOR DESCRIPTION

SURFACE RADAR

Patrick Air Force Base (PAFB) radar is routinely operated by NASA/Kennedy Space Center, mainly for monitoring hazardous weather for launches and flights. The C-band (5cm) pulse radar with 2.2° beam width was operated in CAPPI scan mode every 5 minutes during the CaPE.

AIRCRAFT RADAR

The airborne radar, which was originally developed at CRL, Japan, is a dual frequency (X- and Ka-band) radar with dual polarization reception capability. It was flown on board the NASA T-39 aircraft over convective cells with tops exceeding 10 km in the CaPE by the NASA/GSFC team.

RAIN GAGES

Rain gage data from a network of tipping bucket type gages, which record the time of each 0.01 inch tip to the nearest second, was provided by the St. John's River Water Management District.

OBSERVATION

In Fig.1, the T-39 flightpath at 22:30 to 22:45 (UTC) of July 27, 1991 is shown with the location of the PAFB radar and its 3km CAPPI image (reflectivity shown in grayscale) at 22:39 (UTC). Three areas of rain cells can be seen westward of the radar from 40 km range and further. Since the PAFB radar is located on the central east coast of the Florida peninsula, all of the rain cells were over land. We concentrated on the southwestern cell which we concluded to be a convective one from observations. The aircraft executed a closed-loop right-hand turn at a roll angle of ~26°, passing over an intense convective cell about 50 km southwest of the radar.

*Visiting Scientists from the Communications Research Laboratory (CRL), Japan through the Universities Space Research Association (USRA).

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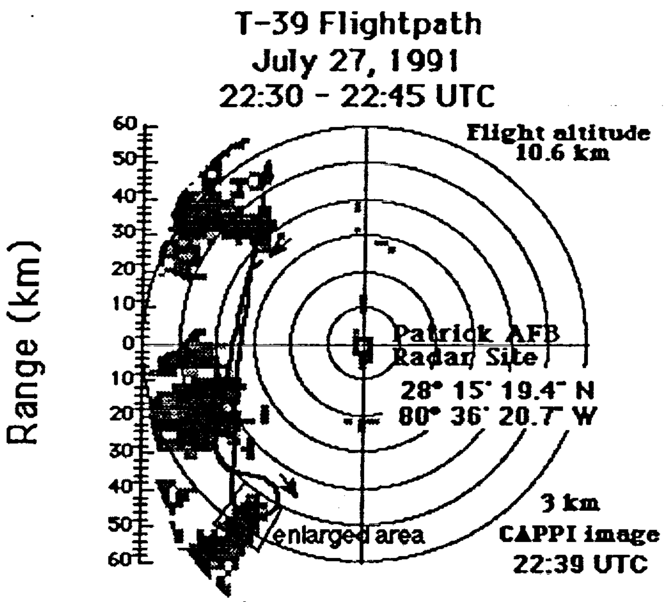

Fig.1 Airborne radar flightpath and PAFB radar CAPPI (3km) image at 22:39 of July 27, 1991.

In Fig. 2 an enlargement of the area over the southwestern cell is depicted in a rectilinear azimuth-range coordinate, overlaid with locations of the rain gage and the T-39 flightpath. The surface radar reflectivities were recorded at 1° azimuth by 2km range resolution using a single pulse measurement. High reflectivities over 50 dBZ can be seen near the flightpath. However, it should be noted that the radar reflectivities, without pulse averaging, might be very noisy and that the radar image and the flight were not exactly concurrent.

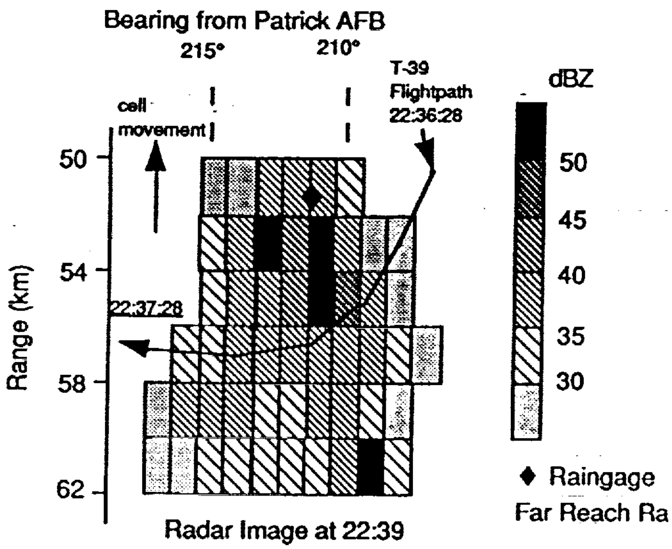

Fig.2 Enlarged surface radar image of a convection rainfall, along with airborne radar flightpath and rain gage location.

Rainfall rates observed with the rain gage at 22:30 to 23:00 (UTC) are shown in Fig.3. The rain started after 22:40 with 40 to 80 mm/hr and rather heavy rain over 100 mm/hr was observed from 22:45 to 22:50.

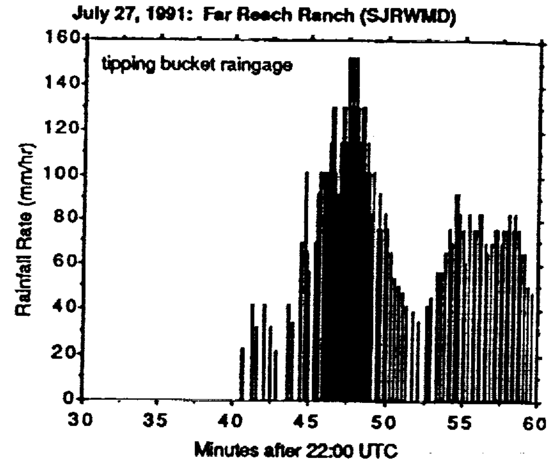

Fig.3 The rain gage rainfall rate, at 211.5° azimuth, 51.5km range from PAFB radar.

Fig.4 shows reflectivities observed by the airborne X-band radar in height-time coordinate. Due to the roll angle of the turning aircraft (~26°), it can be regarded as a tilted vertical cross section in the rain cell (setting the radar altitude to height zero). In the core of the cell at 4 to 5 km altitude, high reflectivities over 50 dBZ can be seen.

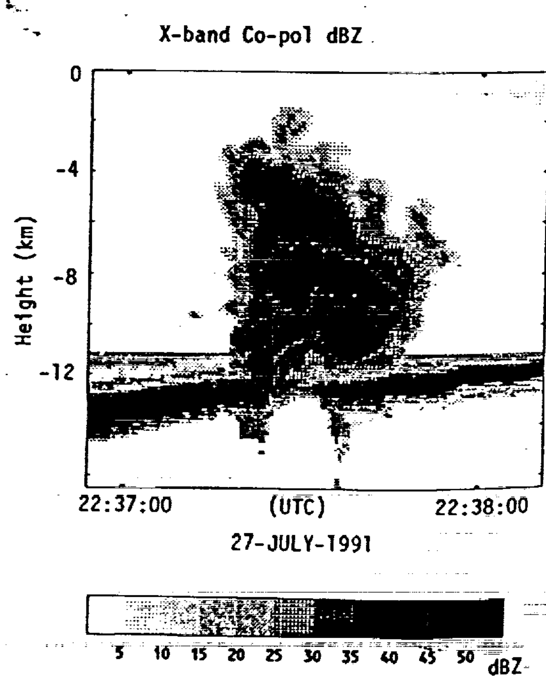

Fig.4 Vertical cross section (tilted) of reflectivities observed with airborne (X-band) radar.

Fig.5 shows altitude profiles of X-band and Ka-band reflectivities, and the linear depolarized ratio (LDR) of X-band, in the middle of the rain cell (setting the land surface to altitude zero).

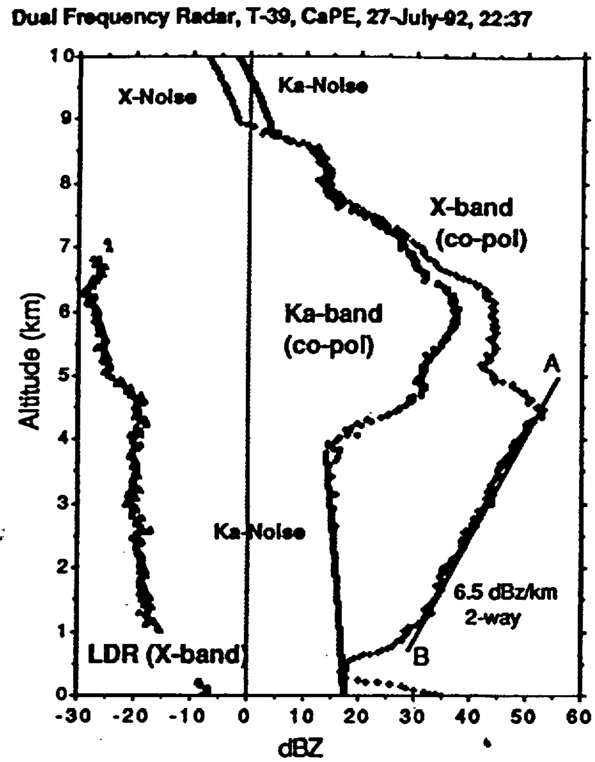

Fig.5 Altitude - reflectivity profiles observed with airborne radar in the middle of the rain cell.

DISCUSSION

Peak reflectivities of the convective cell were around 50 dBZ both in the C-band surface radar (Fig.2) and in the X-band aircraft radar (Fig.4), and peak rainfall rates measured with the rain gage were over 100 mm/hr. These values seem to be reasonable for measurements of a rain cell, considering the differences of observed space (field of view) and observed time period. The sequence of observed time of the peak values from the airborne radar, the surface radar and the rain gage is consistent, assuming movement of the rain cell toward the northeast (shown in Fig.2 as an arrow) which was determined from successive images of the surface radar.

In Fig.5, in the range from 1 to 4 km, a linear slope of X-band reflectivity, 6.5 dBZ/km (two-way) (line A-B) suggests an attenuation due to a layer of constant rainfall rate. As the one-way attenuation coefficient of X-band can be estimated by $0.012\ R^{1.23}$ (dB/km) [3], 3.25 dB/km gives the rainfall rate,

R (X -att, 1-4km) = 95 mm/hr.

Note in Fig. 5 that the Ka-band and X-band reflectivities at the top of the storm are almost equal, consistent with Rayleigh scattering by small particles. After a few km penetration the Ka-band signal begins to decrease rapidly, apparently due to attenuation, falling to the noise level near 4 km. Although the LDR signal shows an increase around 4.5 km, near the 0°C level outside the cloud, the LDR signature does not clearly indicate a concentrated melting level with abundant aspherical particles, as was observed in stratiform precipitation areas [4].

SUMMARY

A preliminary validation of airborne radar observations during the CaPE experiment has shown consistent relations between reflectivities measured by the airborne radar and an operational surface radar. In addition, surface rainfall rates in excess of 100 mm/hr were observed for several minutes by a rain gage, within a convective cell where the airborne radar attenuation inferred a rainfall rate of 95 mm/hr.

Pulse averaged reflectivity data from the operational surface radar will provide better opportunities for general validation. Data from the CP-2 radar (NCAR), a dual frequency dual-polarization surface radar, will soon be available for more detailed case studies.

A more complete examination of the observations needs to examine probability distributions of echo intensities observed by the airborne radar and along flightpaths by the ground-based radars, as well as rain rate distributions observed by rain gages in the vicinity of the flightpaths at the time of the flights. Such statistical comparison methods require a kind of homogeneity assumption that may be satisfied in tropical convection.

ACKNOWLEDGEMENT

Our thanks to O.Thiele, D.Wolff, B.Fisher and D.Makofski of the TRMM Ground Truth Team of NASA/GSFC for processing the surface data. The rain gage data were provided through the good offices of Mr.W.Osburn of the St.John's River Water Management District.

REFERENCES

[1] J.Simpson (edit.), "Report of the science steering group : TRMM (Tropical Rainfall Measuring Mission)," NASA/GSFC, 1988.
[2] G.B.Foote (edit.), "Scientific overview and operations plan for the Convective and Precipitation/Electrification (CaPE) experiment," NCAR, 1991.
[3] F.T.Ulaby, R.K.Moore and A.F.Fung, "MICROWAVE REMOTE SENSING: active and passive," Artech House, MA, 1981, vol.1, p321.
[4] T. Iguchi, R. Meneghini and H. Kumagai, "Radar depolarization signatures of rain in cumulus clouds measured with a dual-frequency air-borne radar," IGARSS'92, this volume.

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D E C E I V E D
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UNIVERSITIES SPACE RESEARCH ASSOCIATION
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS
(for the year ending 9/30/92)

Employee Name: Kevin Olson Task Number: 930-015

General Description of Your Research Activities: (Include a Paragraph on each Activity).

My research is focused on development of a gravitational N-body code to study the dynamics of galaxy-galaxy interactions. To do this, a tree code (Barnes and Hut 1986) is used. In this code the particles are placed in grids of varying size. Each grid has a cell size 1/2 the size of the upper level grid. The total mass and the center of mass of each grid cell at each level are computed and stored. Also, at the lowest grid level a pointer from the grid location to the particles it contains and the number of particles it contains is also stored. To find the force on any one particle, neighboring cells at the lowest level are looked at first. If the quantity (cell size/r) (where r is the distance from the particle to the center of mass to the cell) < 1, the force due to that cell (treating it as a point mass) is added to the force on that particle. If (cell size/r) > 1 the forces due to all particles in that cell are added to the force on the particle under consideration. This is repeated for all particles. Once this is completed, the algorithm goes to the next level (with a cell size twice the size of the previous level) and the nearest cells are searched. The decision to resolve is the same as described above except that a cell is resolved into sub cells rather than into individual particles. In this way a particle sees its nearest neighbors to a high degree of resolution and the mass distribution at larger distances to an increasingly coarse resolution. The scientific question I wish to address by developing the above code is that of the instabilities produced in galaxies when they pass near another galaxy and the effect this has on the interstellar medium of the galaxies. Recent work by other researchers (Noguchi 1988, Gerin, Combes and Anthanassoula 1990) has shown that a bar can be induced to form when galaxies interact. However, the number of simulations carried out to date is small and the available parameter space is sparsely sampled. Also, these simulations are two dimensional. With the code I have developed I hope to run a large number of cases to investigate if bars are indeed a common outcome of galaxy–galaxy interactions and under what conditions they form. The code I have developed is fully three dimensional and things such as inclination of the orbit of the galaxies relative to their disks, mass of the perturber, and mass distribution within the galaxy, will be investigated.

This research has the additional goal of testing out new, parallel programming environments. Toward this end I have developed the above described code using APPL (Application Portable Parallel Library) developed by Angela Quealy at NASA/Lewis and run it across a distributed network of IRIS/Indigo workstations here at Goddard. APPL consists of a set of primitives (callable from either fortran or c codes) for message passing between processes and computing global sums and products across all processes. APPL has been written for a number of different parallel architectures such as Intel iPSC/860, Intel Delta, Alliant FX/80 and distributed networks of IBM RS6000, SUN or IRIS workstations.

Performance of the code is good. Using 6 processors and 16,000 bodies, I have achieved similar performance to that obtained using a Cyber 205 vectorizing supercomputer. Barnes (1988) achieves performance of $\sim$ 35 seconds to do one time step, while my code using APPL achieves $\sim$30 seconds to do one time step with the same number of particles. Through experimentation, it has been found that around 4–5 processors, communications in the network become important and increasing the number of processors doesn't do much good. The developers of APPL have communicated to me similar results.

Among the machines APPL has been developed for are the Intel iPSC/860 (128, 40 Mhz processors, 8 Mbytes of memory each) and the Intel Touchstone Delta (513, 40 Mhz processors, 16 Mbytes each). NASA/Ames has a iPSC/860 and is currently soliciting proposals to use it. I have submitted a proposal for time on this machine and obtained some. Also, I have obtained time to use the Intel Delta machine at Caltech. Experiments in using APPL on these machines is presently in progress. This will be a good test of the portability of APPL codes. Should this prove successful, APPL will provide a convenient way of developing parallel codes, ie. one could develop and debug the code using a distributed network of workstations and then port it to a larger machine with dedicated communications for production runs.

I have also begun preliminary work on developing a Hydrodynamics/Magnetohydrodynamics code known as SPH (smooth particle hydrodynamics). In this algorithm a continuous fluid is modeled as a set of particles. The particles each carry with them average values of the local physical quantities (eg. temperature, pressure, and density). Toward this end I have developed a one dimensional SPH code which models the interaction of two opposing streams of gas as well as the shock tube problem.

Since, in SPH, the gas is modeled as set of particles, it should be relatively easy to combine this with the above mentioned gravitational N–Body code. This has been done by several researchers (Hernquist and Katz 1989). Such codes have been shown to be useful for astrophysical applications where gravity is important (eg. cloud-cloud collisions and galaxy interactions). However, such codes have not been shown to be of good use for a wide array of problems. I plan to investigate this and possibly improve the code by developing it in such a way that it takes advantage of parallel processing. Olson and Kwan (1990) found that a large number of collisions between interstellar clouds are produced by a galaxy–galaxy interaction. They also found that these collisions are of a high relative velocity. They hypothesized that any observed burst of star formation which is triggered by the interaction of two galaxies may be related to these high energy cloud-cloud collisions. By using SPH I hope to model, in greater detail, the collision of two interstellar clouds.

1 References

Barnes, J., 1988, ApJ, 331, 699
Barnes, J., & Hut, P., 1986, Nature, 324, 446
Gerin, M., Combes, F., & Athanassoula, E., 1990, A&A, 230, 37
Hernquist, L. & Katz, N., 1989, ApJS, 70, 419
Noguchi, M., 1988, A&A, 203, 259
Olson, K. M., & Kwan, J., 1990, ApJ, 349, 480

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EMPLOYEE SUMMARY OF ACCOMPLISHMENTS
(for the year ending 9/30/92)

Employee Name: Dr. Anil Deane Task Number:

General Description of Your Research Activities: (Include a Paragraph on each Activity).

General area of research is in turbulence, MHD, magnetoconvection, computational fluid dynamics and parallel supercomputing.

Compressible MHD: Currently an MHD code of S. Zalesak and D. Spicer (Code 930) has been modified to include gravity, viscous and thermal diffusion, and slip-free walls. The code is geared to solve the compressible magneto-convection problem. The presence of boundaries makes the specification of high order "fluxes" (required for the method of FCT) a delicate issue. Even nominally correct procedures can lead to instabilities along the boundaries. Flux forms that are fourth-order accurate that alleviate this problem have been derived[1]. A parallel version of the code has been developed for running on the Intel Delta parallel supercomputer located at Caltech. In this code the domain is decomposed into a number of zones, each of which lays on a single processor of the 520 node machine. The individual zones communicate through message passing routines via a layer of "ghost points" which mark the boundary of each zone. Results of this work are being prepared for publication[2]

1. "High-Order Flux Forms for Boundaries," with S. Zalesak, Internal Report (in preparation).

2. "Compressible Magnetoconvection," with S. Zalesak and D. Spicer (in preparation).

Turbulence Analysis: Newly available techniques such as Karhunen-Loeve analysis and multi-fractal analysis (in which I have made several contributions in the past), and Wavelet analysis (I guided a summer student in this) are being applied to computations of various turbulent flows.

Turbulence Modeling: High Reynolds number flows can require a prescription for the behavior of unresolved scales. Initiating a research effort into models that are applicable to MHD.

Wake Instabilities: The wake of a bluff body provides a laboratory for the study of nonlinear interactions. Work continues (albeit slowly!) on this problem along with collaborators from Princeton University[3]

3. "Flow Past a Circular Cylinder: Dynamics and Symmetry," with I. Kevrekidis, G. Karniadakis and S. Orszag (in preparation).

Parts of the above efforts have been included in two proposals mentioned later.

Other Collaborative Activities: Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborator(s)

1. Contributed to the writing and named 0.2 WY consultant on $2.3 Million Grand Challenge proposal titled "A Grand Challenge Proposal to Develop Accurate, Time-Dependent Simulations of the Coupled Magnetosphere-Solar Wind System," Dr. M. Goldstein, PI, Code 692.

2. Contributed to the writing and named 0.1 WY consultant on $1.2 Million Space Physics Theory Program (SPTP) proposal "The Role of Turbulence in Heliospheric Plasmas," Dr. M. Goldstein, PI, Code 692.

Supply any Additional Information you Feel Would be Useful in evaluating your performance:

1. Direction of VSEP student Christopher Mitchell research on "Wavelet Analysis of Turbulence Data."

2. Attended meeting on Parallel CFD at Rutgers University, April 92.

3. Participated in All-NASA video conference on parallel architectures, March 92.

4. Attended NASA Ames video lecture on Adaptive Grid Refinement, Aug 92.

5. Attendance of two-week lecture series by P. Colella and S. Zalesak on High-Order Godunov schemes and Modern Shock-Capturing methods.

6. Participate in weekly Computational Techniques meetings.

7. Refereed papers for scientific journals (2 for Physics of Fluids A and 1 for Journal of Computational Physics.)

8. Reviewed proposals for NASA SBIR on massively parallel supercomputing.

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UNIVERSITIES SPACE RESEARCH ASSOCIATION
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EMPLOYEE SUMMARY OF ACCOMPLISHMENTS
(for the year ending 9/30/92)

Employee Name: Toshio Iguchi   Task Number: 5000-702

General Description of Your Research Activities: (Include a Paragraph on each Activity).

My activities here are three-fold.

My major research activity is to conduct air-borne radar measurements of rainfall and to analyze the data. The air-borne radar measurements were successfully carried out and many valuable data were collected during the CaPE experiment in Florida in July, 1991. After the experiment, I calibrated the radar and started analyzing the data. Some of the results were presented at IGARSS meeting in Texas in May 1992. The data analysis also includes the comparisons of different algorithms for rain-profile retrievals. This is important for the implementation of the best algorithm for TRMM radar data processing.

We decided that the CRL's (Communications Research Laboratory, my home affiliation), air-borne radar which we used for the measurment of rain from aircraft, for the past 7 years will be reconfigured as a ground based radar and be installed at Wallops Island. Currently, I am collaborating with Mr. Meneghini on this task.

Another research activity on which I am working is the maintainance and calibration of the millimeter-wave (82 and 245 GHz) link system on the Wallops island. The system was damaged (presumably by lightning strike) last fall. The problems were identified and the mixer for 82 GHz channel and the log-amplifier were replaced this spring. The system is now operational and has yielded useful data.

My third activity is to participate in the TRMM science studies. This task includes participating in TRMM meetings, addressing issues concerning TRMM data products, and serving as a liaison between the US and Japanese teams.

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UNIVERSITIES SPACE RESEARCH ASSOCIATION GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS

(for the year ending 9/30/92)

Employee Name: Chaing Chen **Task Number: 5000-706**

General Description of Your Research Activities: (Include a Paragraph on each Activity).

During the past year, efforts had been concentrated on the study of gravity currents propagating in stably stratified shear flows. Originally, this research was motivated by a desire to extend the vorticity matching theory described by Rotunno, Klemp and Weisman (1988) for gravity currents propagating in a neutrally stratified shear flow to an atmosphere with stratification. However, during the course of study we encountered unanticipatedly strange upstream effects, in the form of upstream propagating columnar modes and internal bores, ahead of the gravity current. In order to gain greater insight into the understanding of these effects, numerous sensitivity experiments using Dr. Chen's nonhydrostatic model were conducted with the gravity current replaced by an obstacle to understand what might be the governing parameters for the upstream effects. The writing of a paper regarding this subject was completed and the paper was submitted to the Journal of the Atmospheric Sciences.

At the beginning of the FY92, Dr. Chen has been successfully migrating all the model files from IBM-VM and VAX-MV5 to Silicon Graphics workstations. He also reconfigured the workstations as the front-end computer for the CRAY supercomputer. Therefore, the model can be either integrated at the local workstation or at the remote supercomputer. In addition, in order to digest model data more efficiently Dr. Chen also made arrangements such that all model data are processed at local workstation to produce images and hard copy plots.

Dr. Chen also assisted Dr. Koch to study frontal merging process and hydraulic jumps over Appalachian Mountains using Dr. Chen's nonhydrostatic model. As a result, a paper was written and presented at the Fifth Conference on Mesoscale Processes.

One of the major accomplishments during the past year was the successful development of a hydrostatic model. The purpose is in an attempt to understand the source of errors in the calculation of pressure gradient force over a steeply sloped terrain using hydrostatic equation. The writing of a Note for Monthly Weather Review to address this problem is in progress.

Another major achievement was the adoption of Dr. Tao's cloud microphysical routines into Dr. Chen's model system and the upgrade of the model from a 2D to a 3D model. These modeling activities were a part of efforts to develop a next generation nonhydrostatic mesoscale model to study scale interaction processes occurred in a mesoscale environment.

Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

Chen, CH. and H. D. Orville, 1980: Effects of Mesoscale Convergence on Cloud Convection. *J. Appl. Meteor.*, **19**, 256-274.

HUNG RJ	INT J REMOT	12	831	91
HUNG RJ	INT J REMOT	12	863	91
HUSTON MW	J APPL MET	30	1389	91
MCCUMBER M	J APPL MET	30	985	91
TAO WK	M WEATH RE	119	2699	91

Chen, C. and W. R. Cotton, 1983: A One-Dimensional Simulation of the Stratocumulus-Capped Mixed Layer. *Boundary Layer Meteor.*, **25**, 289-321.

ENGER L	J APPL MET	39	157	91
NICHOLLS ME	M WEATH RE	119	298	91

Chen, C. and W. R. Cotton, 1987: The Physics of the Marine Stratocumulus-Capped Mixed Layer. *J. Atmos. Sci.*, **44**, 2951-2977.

HYMSFIE AJ	J ATMOS SCI	48	493	91
RAUBER RM	J ATMOS SCI	48	1005	91
SLINGO A	J GEO RES-A	96	5341	91
SLINGO JM	Q J R METEO	117	333[illegible]	91

Honors or Awards Received:

Papers Published or Accepted for Publication: (Please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

Chen, C., 1991: A Nested-Grid, Non-Hydrostatic, Elastic Model using a Terrain-Following Coordinate Transformation: The radiative-nesting boundary conditions. Mon. Wea. Rev., 119, 2852-2869.

Keating, G. M., C. Chen, 1993: Extensions to the CIRA Reference Models for Middle Atmosphere Ozone. Adv. Space Res., Vol. 13, No. 1, pp. (1)45-(1)54.

Keating, G. M., C. Chen, 1991: Middle Atmosphere Change through Solar Forcing. Adv. Space Res., Vol. 11, No. 3, pp. (3)9-(3)20.

Papers Submitted but not yet Accepted for Publication: (Please include full title, coauthors [with affiliations], publication, and submission date).

Chen, C., J. W. Rottman, and S. E. Koch, 1992: Numerical Simulations of Gravity Currents in Stably Stratified Shear Flows. Submitted to J. Atmos. Sci. on July 16, 1992.

Papers Presented at Scientific Meetings:

Invited papers: (Include title of talk, meeting name, date, and any special meeting role, e.g. session chair, rapporteur).

Contributed Papers: (Include title, meeting, and date)

Chen, C., J. W. Rottman, and S. E. Koch, 1992: Numerical Simulations of Gravity Currents in Stratified Shear Flows. Preprints, Fifth Conference on Mesoscale Processes (Atlanta, GA), Amer. Meteor. Soc., Boston, 241-245.

Koch, S. E., C. Chen, and P. J. Kocin, 1992: The Role of Scale Contraction Processes in the Formation of a Severe Frontal Rainband. Preprints, Fifth Conference on Mesoscale Processes (Atlanta, GA), Amer. Meteor. Soc., Boston, 186-191.

Chen, C., 1991: A Nested-Grid, Non-Hydrostatic, Elastic Model using a Terrain-Following Coordinate Transformation: The radiative-nesting boundary conditions. Preprints, Ninth Conference on Numerical Weather Prediction (Denver, CO), Amer. Meteor. Soc., Boston, 293-296.

Colloquia, Seminars, and Special Lectures: (Provide title, date, and place)

Community Service: (e.g. Offices in professional societies, lectures to community or educational groups, consultation, etc.)

University Collaborations: Briefly describe activities. Provide name and affiliation of research collaborator(s), courses taught, books written or contributions made to edited books, grant/contract proposals submitted or funded, technical reports prepared, visits made, students mentored, etc. (Co-authored research papers listed above need not be repeated here).

<u>Other Collaborative Activities:</u> Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborator(s)

<u>Supply and Additional Information you Feel Would be Useful in evaluating your performance:</u>

Dr. Chen has taken a lead position to develop a nonhydrostatic mesoscale model. He has for several years been developing a two-dimensional nonhydrostatic, elastic, nested grid model with terrain-following coordinate transformation. Presently, this model has been used to study the propagating of gravity currents in stably stratified shear flow and the merging of gravity currents over the actual Appalachian Mountains. Recently, this model has been upgraded from a 2D to a 3D model. The goal is to evolve the model toward mesoscale regime by integrating modules derived from the existing modeling system, such as GMASS and GCE models.

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EMPLOYEE SUMMARY OF ACCOMPLISHMENTS
(for the year ending 9/30/92)

Employee Name: V. MOHAN KARYAMPUDI Task Number: 610-027

General Description of Your Research Activities: (Include a Paragraph on each Activity).

Dr. Karyampudi performed additional GEMPAK analyses on the observational case study of the 13-14 April 1986 severe weather case and wrote two journal articles (respectively entitled as "The influence of the Rocky Mountains in the 13-14 April 1986 severe weather outbreak. Part I: Formation of a mesoscale tropopause fold and its relationship to severe weather and dust storms" and " The influence of the Rocky Mountains in the 13-14 April 1986 severe weather outbreak. Part II: Generation of an undular bore and its role in triggering a squall line") which were submitted to the *Monthly Weather Review* . This joint work resulted from collobaration with researchers both at Goddard (e.g., Drs. Steven Koch and James Rottman) and at Universities (e.g., Dr. Michael Kaplan at N. C. State University and Dr. Julio Bacmeister at Johns Hopkins University). These papers are presently under revision.

Joint collaborative work with Dr. Michael Kaplan (of N. C. State University) resulted in two other papers (respectively entitled "Meso-beta scale numerical simulations of terrain drag-induced along-stream circulations. Part I: Midtropospheric frontogenesis" and " Meso-beta scale numerical simulations of terrain drag-induced along-stream circulations. Part II: Concentration of potential vorticity within dryline bulges"). These papers were accepted for publication in *Meteorology and Atmospheric Physics* journal.

Dr. Karyampudi participated in the STORM-FEST field experiment (a multi agency field campaign) conducted over the high plains during the period 12-27 February 1992. He assisted the NASA field experiement scientists in the flight planning of the NASA-ER2 aircraft for data collection. Another reason for his participation in this experiment is his interest to closely observe the severe weather events resembling those of the detailed case study (13-14 April 1986) that he analyzed.

Dr. Karyampudi supervised the numerical modeling study of 3-4 January 1989 ERICA case carried out by Dr. John Manobianco as well as the data preparation for the 9-11 September 1988 Hurricane Florence case carried out by Mr. Horn Shin. Dr. Karyampudi also incorporated Kuo et al's technique for enhancing the initial moisture field using the satellite-derived preicipitable water.

Dr. Karyampudi is involved in studying the development of rainbands generated by conditional symmetric instability using 2-D hydostatic and non-hydrostatic model simulations. He not only supervised the overall progress of the project but also contributed to the benchmark simulations of symmetric instability rainbands carried out by Dr. Jong-Jin Baik.

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UNIVERSITIES SPACE RESEARCH ASSOCIATION
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS
(for the year ending 9/30/92)

Employee Name: Brad S. Ferrier **Task Number:** 920-005

General description of your research activities:

During the past year ending on 30 September 1992, the double-moment four-class ice (4ICE) microphysical parameterization that I developed for the Goddard Cumulus Ensemble (GCE) model has been substantially improved by: (1) incorporating two ice multiplication processes and improving the parameterization of ice nucleation; (2) improving the accuracy of rapid accretion processes by reformulating the finite-difference form of the collection kernel; (3) calculating from thermodynamic principles the freezing rates of liquid water collected on ice, rather than assuming instantaneous freezing of the collected water as in other schemes; (4) substantially modifying the method of transferring the number concentrations of particles between hydrometeor classes by preserving the mean spectral properties of the particle distributions rather than maintaining strict conservation of particle number concentrations (especially important in order to simulate accurately the reflectivity structure of convective and stratiform clouds); and (5) constraining the numerical advection in order to prevent decoupling of the different particle moments, such as grid points where there is positive hydrometeor mixing ratios and zero number concentrations (an improved advection scheme will soon be tested that should help solve this decoupling problem). These extensive changes to the 4ICE scheme solved the following problems encountered this past year in simulations of a GATE squall line: (1) modeled radar reflectivities in the convective cores were 10-15 dBZ higher than observed; (2) the reflectivity maxima within the simulated convection were located above the freezing level, whereas the strongest reflectivities were always observed below the freezing level; and (3) the spatial distribution of radar reflectivity in the trailing stratiform precipitation region differed substantially between the simulations and the observations.

I am currently writing a paper describing the 4ICE scheme, and I will soon start on a second paper showing how well his scheme simulates the radar and microphysical structure of an intense midlatitude-continental (COHMEX, COoperative Huntsville Meteorological EXperiment) squall line and a weaker tropical-maritime (GATE, GARP Atlantic Tropical Experiment) squall line. Unlike in any of the other microphysical parameterizations, the radar structures of convective systems in vastly different environments are simulated well using the 4ICE scheme without the need for tuning a variety of adjustable coefficients.

A series of sensitivity simulations of the same TAMEX squall line as studied by Dr. Tao (Tao et al., 1991) were performed using different microphysical schemes , including my 4ICE parameterization. Depending upon the parameterization, the simulated squall line either became upshear-tilted and was long lived or remained downshear-tilted and gradually decayed (this result was also described in the Tao et al. paper). The observed squall line tilted upshear and was long lived. I found that the 4ICE scheme was more sensitive to the initial conditions, such that stronger initial cool-pool forcing produced sustained, upshear systems and weaker cool pools resulted in decaying, downshear storms. Storms tilted upshear rapidly in simulations where large ice fell slowly (e.g., graupel in the Rutledge and Hobbs, 1984 scheme) because of (1) reduced hydrometeor loading and decreased subsidence warming in the downdrafts, (2) more of the ice was advected rearward by the storm-relative winds at mid levels, and (3) less precipitation fell into newly developing updrafts. The upshear tilt of storms either did not occur or was delayed in simulations where higher fallspeeds were assumed for the large ice (e.g., hail in Lin et al., 1983 and frozen drops in 4ICE). In the annual Laboratory review, I had documented a sequence of events associated with the transition from downshear to upshear storm development, in which the rear inflow jet rapidly descended into the leading convective line and the gust front temperatures dropped abruptly as the storm tilted upshear. I plan on writing a short paper describing the results of this work sometime in the fall.

I have also been involved in the following activities this past year: (1) presented a paper and preprint at the 5th Mesoscale Conference; (2) sent a preprint to the 11th Conference on Clouds and Precipitation, and I am working with Dr. John Scala in our cloud modeling group on simulating a North Dakota squall line for the 3rd Cloud Modeling Workshop; (3) collaborated with Dr. Joanne Simpson and Drs. Tom Keenan and Greg Holland on a combined observational and modeling study of island thunderstorms over Northern Australia (mentioned further in the next section), and I am currently working with Drs. Keenan and Simpson on a subsequent study of these interesting convective systems; (4) corresponded and provided guidance to Dr. Robert Pasken, who is visiting our Branch this summer as part of the JOVE program, on analysis of Doppler radar data from the TOGA radar of a monsoon system and a monsoon-break squall line over Darwin; (5) attended a one week workshop to learn the shipborne radar system for the upcoming TOGA COARE (I will be the radar PI on one of the ships); (6) worked closely with Dr. Tao in addressing reviewers' comments of his paper on comparing the water budgets of different convective systems, which has been subsequently approved for publication.

Describe any significant recognition of your work:

The one-dimensional time-dependent cloud model that I developed is currently being used elsewhere at (1) the University of Washington, (2) Colorado State University, (3) the University of Wisconsin, (4) Texas A&M University, and (5) soon will be used at the Bureau of Meteorology Research Centre (BMRC) in Melbourne, Australia. The title of the paper describing the cloud model is "One-dimensional time-dependent modeling of GATE cumulonimbus convection."

I have received very positive comments when my new 4ICE microphysical scheme was presented recently at the 25th International Radar Conference in Paris and at the 5th Mesoscale Conference in Atlanta. Because I am currently writing several articles that describe my scheme and its encouraging performance in being able to simulate accurately vastly different convective storms, I hope to receive more recognition of my recent work in the future.

Papers published or accepted for publication:

Simpson, J.[1], T. D. Keenan[2], B. Ferrier[3], R. H. Simpson[4] and G. Holland[2], 1992: Cumulus mergers in the maritime continent region. Meteorology and Atmospheric Physics, (accepted).

Tao, W.-K.[1], J. Simpson[1], C.-H. Sui[3], B. Ferrier[3], S. Lang[5], J. Scala[3], M.-D. Chou[1] and K. Pickering[3], 1992: Heating, moisture and water budgets of tropical and midlatitude squall lines: Comparisons and sensitivity to longwave radiation. J. Atmos. Sci., (accepted).

1Goddard Space Flight Center, NASA, Greenbelt, MD

2Bureau of Meteorology Research Centre, Melbourne, Australia

3Universities Space Research Association, Goddard Space Flight Center, NASA, Greenbelt, MD

4Simpson Weather Associates, Charlottesville, VA

5Science Systems and Applications Inc.

Simpson et al., 1992

CUMULUS MERGERS
IN THE MARITIME CONTINENT REGION

Joanne Simpson[1], Thomas D. Keenan[2], Brad Ferrier[3], R.H. Simpson[4] and Greg J. Holland[2]

ABSTRACT

We examine a family of tall (up to 20 km) cumulonimbus complexes that develop almost daily over an adjacent pair of flat islands in the Maritime Continent region north of Darwin, Australia and are locally known as "Hectors". Nine cases observed by a rawinsonde network, surface observations (including radiation and soil measurements), the TRMM/TOGA radar, and one day of aircraft photography are used to analyse the development, rainfall, surface energy budgets, and vertical structure of these convective systems.

The systems undergo convective merging which is similar to that observed in previous Florida studies and is multiplicative in terms of rainfall. About 90% of the total rainfall comes from the merged systems , which comprise less than 10% of convective systems, and this has implications for the manner in which tropical rainfall is parameterised in larger-scale numerical models. By comparison to the West Indies, GATE and Florida, the Hector environment contains a weaker basic flow, with less vertical shear. The main thermodynamic difference is that the Darwin area has an unstable upper troposphere and very high tropopause. Numerical modelling results support earlier observations of updrafts in excess of 30 ms^{-1} in this region, but show that only modest convective drafts are experienced below the freezing level (5 km).

The surface fluxes over the islands are estimated from a Monash University study to be mainly in latent form from evapotranspiration, with a Bowen ratio only slightly larger than that commonly observed over oceans. These surface fluxes are crucial to the development of

Tao et al., 1992.

ABSTRACT

A two-dimensional, time-dependent and non-hydrostatic numerical cloud model is used to estimate the heating (Q_1), moisture (Q_2) and water budgets in the convective and stratiform regions for a tropical and a midlatitude squall line (EMEX and PRE-STORM). The model is anelastic and includes a parameterized three-class ice-phase microphysical scheme and longwave radiative transfer processes. A quantitative estimate of the impact of the longwave radiative cooling on the total surface precipitation as well as on the development and structure of these two squall lines is presented.

It was found that the vertical eddy moisture fluxes are a major contribution to the model-derived Q_2 budgets in both squall cases. A distinct mid-level minimum in the Q_2 profile for the EMEX case is due to vertical eddy transport in the convective region. On the other hand, the contribution to the Q_1 budget by the cloud scale fluxes is minor for the EMEX case. In contrast, the vertical eddy heat flux is relatively important for the PRE-STORM case due to the stronger vertical velocities present in the PRE-STORM convective cells. It was found that the convective region plays an important role in the generation of stratiform rainfall in the both cases. Although the EMEX case has more stratiform rainfall than its PRE-STORM counterpart, the relative contribution to the stratiform water budget made by the horizontal transfer of hydrometeors from the convective region is less. But the transfer of condensate from the convective region became relatively less important with time in the stratiform water budget of the PRE-STORM system as it developed from its initial stage, such that the relative contribution to the stratiform water budget made by the horizontal transfer of hydrometeors from the convective region is similar at the mature stages of both systems.

Papers submitted but not yet accepted for publication:

"A double-moment multi-phase four-class ice scheme. Part I: Model Description" to be submitted in September to J. Atmos. Sci. by Brad S. Ferrier (USRA).

"A double-moment multi-phase four-class ice scheme. Part I: Simulations of convective storms in different large-scale environments" to be submitted in October to J. Atmos. Sci. by Brad S. Ferrier (USRA), Wei-Kuo Tao and Joanne Simpson (Severe Storms Branch, Code 912, NASA/GSFC).

"Sensitivity of TAMEX squall simulations to feedbacks between dynamics and microphysics", which is likely to be submitted in November to Atmospheric Research by Brad S. Ferrier (USRA), Wei-Kuo Tao and Joanne Simpson (Severe Storms Branch, Code 912, NASA/GSFC).

Papers presented at scientific meetings:

Contributed papers:

"Sensitivity of TAMEX squall simulations to microphysical schemes and initial conditions" at the 11th Conference on Clouds and Precipitation in August 1992.

"Assessment of the feedback effects between radiation and ice microphysics associated with mesoscale convective systems in different environments" at the 5th Mesoscale Conference in January 1992.

"Radar and microphysical characteristics of convective storms simulated from a numerical model using a new microphysical parameterization" at the 25th International Conference on Radar Meteorology in June 1991.

"Comparison of numerically-simulated microphysical characteristics of convective storms with multiparameter radar observations during COHMEX" at the 25th International Conference on Radar Meteorology in June 1991.

Colloquia, seminars, and special lectures:

"Ice microphysics in the GCE model" presented at the annual Code 910 Laboratory Review in early June.

Community service:

I am a member of the Severe Storms Branch's (code 912) hardware committee, which meets once every two to three months to address issues regarding computer hardware needs of the branch.

University collaborations:

Collaborations continue with all of the institutions summarized in the section regarding significant recognition of work. In addition, a collaborative effort with Prof. Robert Pasken of St. Louis University on analyzing Doppler radar data of different types of Darwin convective storms will continue into fiscal year 1993. Potential collaborations with Dr. Chen at Penn State and/or Dr. Yefim Kogan at Univ. of Oklahoma are planned, where their explicit microphysical parameterizations will be used to improve the 4ICE bulk scheme. Collaborations with Prof. Robert Houze and several of his colleagues at the Univ. of Washington on combined observational and numerical modeling studies of convective systems studied during the 1991 CAPE (Convective and Precipitation Electrification) experiment over Florida are anticipated in the future.

Other collaborative activities:

Close collaboration continues with Dr. Tom Keenan of BMRC on the study of island thunderstorms over northern Australia. In addition, I am involved in plans for an experiment over the islands north of Darwin called MCTEX (Maritime Continent Thunderstorm EXperiment), which is to be carried out in 1994 and 1997. I am also working with Drs. Andy Heymsfield and Wei-Kuo Tao on using aircraft observations of ice in different storms to test and improve the microphysical parameterization in the GCE model. I also supplied model output from simulations using my 4ICE scheme of a midlatitude squall line, a subtropical storm, and a tropical squall line to Dr. Man-Li Wu for testing and development of retrieval algorithms. I have also been working with Dr. John Scala in our cloud modeling group on simulating convective storms from the North Dakota Thunderstorm Project.

Supply any additional information you feel would be useful in evaluating your performance:

I have had to overcome numerous, unforeseen obstacles in improving the 4ICE microphysical parameterization, as described at the beginning of this form. It took me nearly seven months of development of the 4ICE scheme in order to produce a satisfactory parameterization that can simulate convective storms in widely varying conditions. It was also necessary to perform substantial diagnostics and testing of the 4ICE scheme for nearly three months in order to understand the puzzling results of the TAMEX simulations. Although these factors have delayed me from writing the results of my work for almost a year, I am finally in the process of writing several manuscripts which I expect to submit within the next few months. I have also identified areas where bulk microphysical schemes need further improvements. Addressing these issues will require the use of explicit microphysical parameterizations, airborne microphysical observations, conventional and multi-parameter radar data, and multi-frequency passive microwave observations. In my opinion, my understanding of cloud modeling and microphysics, radar and passive-microwave remote sensing, aircraft observational techniques, and mesoscale processes, as well as my experiences in field projects (Pre-STORM, DUNDEE, and in the upcoming TOGA COARE) affords me the opportunity to assist in the development and improvement of the modeling efforts of the Severe Storms Branch's cloud modeling group.

970-021 EV

UNIVERSITIES SPACE RESEARCH ASSOCIATION
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS
(for the year ending 9/30/92)

Employee Name: Jong-Jin Baik Task Number: 970-021

General Description of Your Research Activities: (Include a Paragraph on each Activity).

1. Explicit water-ice phase microphysics has been incorporated in the two dimensional, hydrostatic mesoscale model. The model, called 4.0 version of 2D GMASS, is capable of simulating cold-frontal rainbands, which is initialized with the analytic solutions to the semigeostrophic frontogenesis model. The role of ice-phase microphysics and the impacts of including both cumulus parameterization and explicit microphysics on the simulated cold-frontal rainbands are examined.

2. An axisymmetric tropical cyclone model was used to investigate impacts of including both cumulus parameterization and explicit microphysics on the storm development. Also, the role of inertial stability on the rapid intensification of the storm was studied through numerical model simulation.

3. Observational aspects of tropical cyclone intensity change with special emphasis on upper level eddy angular momentum fluxes were examined using three-year data set over the north Atlantic ocean. The scale-controled objective analysis technique was employed to combine all the available data to give 1° by 1° gridded data set.

4. A weakly nonlinear theory for thermally induced waves is proposed. The theory contains analytic solutions to the weakly nonlinear response of a stably stratified atmosphere to thermal forcing in a uniform basic state wind.

5. The NRL / NCSU model was used to study the rainfall characteristics (orographic-convective nature) during the Indian southwest monsoon. The FGGE data and the nonlinear normal mode initialization technique were employed to provide initial conditions for the model integration.

6. A newly found evidence for sun-climate relation using the satellite and global surface temperature data was proposed. The satellite data consists of the 13-year measurement of solar irradiance and the global surface temperature data come from the data compiled by GISS group.

970-022

UNIVERSITIES SPACE RESEARCH ASSOCIATION
GODDARD VISITING SCIENTIST SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS
(for the year ending 9/30/92)

Employee Name: Narinder Chauhan
Task number: 970-022

General description of Your Research activities:

1. Modeling and its Application : Microwave models are being developed to study the backscatter signatures from vegetation. The models are based on discrete scatter approach and use distorted Born approximation. The procedure for modeling usually involves two steps. The first step is the formulation of a microwave model for a general case of vegetation. Here, the vegetation is treated as a mixture of simple dielectric scatterers and scattering cross-section of each of the dielectric scatterers is computed. The general case can then be specialized for a particular vegetation species and thus, the modeling can be extended to a) natural environment such as grass, bushes, etc. b) agricultural crops such as corn, soybeans, alfa alfa, etc. c) forested areas having hemlock, pine, spruce trees, etc. The active remote sensing models can be extended to obtain brightness temperature (passive case). In either case the models are tested against the experimental data obtained from both active and passive devices.

The multi polarization and multi frequency remotely sensed data in conjunction with microwave models can be used to retrieve ground truth parameters. Development and testing of inversion algorithms is in progress. The estimation of soil water content is one of the most important parameters of interest to hydrology. The modeling process allows the estimation of the above ground vegetation, thus the retrieval of the water contents of soil can be done with a reasonable accuracy. The estimation can be further improved by using both active and passive data in synergism with one another. The passive data show a large dynamic range in brightness temperature to the changes in soil moisture whereas the active data is very sensitive to plant architecture. These properties of active and passive sensors are being used in developing techniques for the retrieval of parameters.

2. Sensor Development: Work is also in progress for redesigning and upgrading the radar system. The L-band antennas are mounted on the boom of a new cherry-picker truck. The old system that powered the antennas has been replaced with HP8719A network analyzer. The L-band radar system was recently used in

experiments at Oklahoma (MACHYDRO II) and Boise. Initial results from the L-band radar show a great promise for retrieving hydrological parameters. Further work to include a C-band along with the existing L-band is continuing on the radar system.

3. SAR Image Processing: A PCI based image processing system on silicon graphic terminals was installed in our branch. This system is being used to develop and implement software for the calibration of AIRSAR data from JPL. During the past few months, a calibration program POLCAL has been tested and implemented on the new system. Some of the old data from MACHYDRO I experiment in Pennsylvania has been externally calibrated by using the corner reflectors and the results were presented at this year International Conference on Geoscience and Remote Sensing.

Papers Published or Accepted for Publication:
"A microwave scattering model for layered vegetation"
M.A. Karam and A.K. Fung (Electrical Engineering Department, University of Texas at Arlington, Arlington, Texas)
R.H Lang (Department of Electrical Engineering and Computer Science, George Washington University, Washington D.C.
N.S. Chauhan (Laboratory for Hydrospheric Processes, Code 974, NASA/Goddard Space Flight Center, Greenbelt, MD.
IEEE Trans. for Geosci. & Remote Sensing, (in press), 1992.

(Please see the abstract attached)

Papers Presented at Scientific Meetings:

Invited Papers, Session Chair, Rapporteur etc.:

I chaired IEEE Session-FP-F, Remote Sensing in Hydrology-SAR, at International Geoscience and Remote Sensing Symposium 1992, Houston , Texas (IGARSS'92).

Contributed papers:

1. "L-band radar scattering from grass", N. Chauhan, P.O'Neill, D. LeVine, R. Lang and N. Khadr, Proceedings of IGARSS'92, Houston, Texas.

2. "Synergistic use of active and passive microwave in soil moisture estimation", P.O'Neill, N.Chauhan, T. Jackson and S.Saatchi, Proceedings of IGARSS'92, Houston, Texas.

3. "Modeling of SAR returns from a red pine stand", R. Lang, O. Kilic, N. Chauhan and J. Ranson, Proceedings of IGARSS'92, Houston, Texas.

4. "An approach to mapping soil moisture with multi frequency polarimetric SAR data", K.S. Rao, N. Chauhan, W.L. Teng, J.R. Wang and E.T. Engman, International Symposium on Photogrametry Remote Sensing, Washington D.C. 1992.

Special Lecture:

A site review by Remote Sensing Program managers from NASA headquarters was held in February, 1992. I shared RTOP talk with P. O'Neill at GSFC/NASA.

University Collaborations:

1. MACHYDRO II experiment at Oklahoma: A two week multisensor experiment was conducted at Chickasha, Oklahoma (June 8-20, 1992). Professor Roger Lang from George Washington University (GWU) Washington D.C. provided the HP8719A network analyzer that was used to drive Goddard's radar system (antennas). Ground truth and canopy geometry measurements were also made jointly by the Goddard teams and members from GWU. Prior to the experiment, Narinder Chauhan made frequent visits to GWU for the development of on-line data acquisition system for the radar.

2. The collaboration on microwave modeling with the George Washington University (Roger Lang and others in his group) and the University of Texas at Arlington has been continuing as evidenced from the published work.

Other Collaborative activities:

1. Jon Ranson, Code 923, GSFC/NASA: Radar modeling of forested areas is progressing well with Jon Ranson's group. A joint proposal on BOREAS project has already been submitted in the spring of 1992. Also a paper entitled "Radar Modeling of Red Pine Trees" written jointly with Jon Ranson is in the process of being submitted.

2. Mark Seyfried, United States Department of Agriculture (USDA), at Boise, Idaho: A joint radar experiment was conducted at Reynolds Creek near Boise to determine the effect of sagebrushes and soil moisture at L-band radar returns. The Goddard radar was taken to Boise for the experiment.

3. Thomas Jackson, United States Department of Agriculture (USDA), Beltsville, MD: The synergistic use of of active and passive sensors for soil moisture estimation is in progress. A paper was presented at the last IGARSS'92 symposium. We also worked with Thomas Jackson during the MACHYDRO II experiment in Oklahoma.

4. David LeVine, Code 975, GSFC/NASA: David LeVine's ESTAR (passive radiometer) flew over the fields where the L-band radar data was being collected in the MACHYDRO II experiment. A joint work involving active and passive sensors will be performed by using modeling and experimental results. Previous work involving PBMR and AIRSAR data from MACHYDRO I (from Pennsylvania) is in the process of submission for publication.

UNIVERSITIES SPACE RESEARCH ASSOCIATION
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS
(for the year ending 9/30/92)

Employee Name: Anthony Daniel Kowalski Task Number:

General Description of Your Research Activities: (Include a Paragraph on each Activity).

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.

My research also requires an in-depth knowledge, and participation in the development of, the analytic physical models and appropriate numerical solution methods. The high performance algorithms must not only be speedy but must also adequately represent the physical processes involved as well as provide accurate numerical solutions to the chosen model.

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.

Since my employment with USRA, I've been working on each of these activities. I've acquired, through a successful mini-proposal, computer time on the Touchstone Delta parallel computer at NASA/JPL and I've been conducting performance and algorithm experiments on that machine and the CRAY Y-MP at NASA/GSFC. In addition, I'm reviewing the current ocean and atmosphere models in preparation for parallel algorithm development.

A Robot System Planner and Automatic Code Generator for Enzyme Kinetics Assays

ABSTRACT

Programs that generate other programs (i.e. code generators) are becoming more prevalent in the software products we use. The most common being any computer language compiler which maps a high level program into a machine level equivalent. The trend is to incorporate more "domain-specific" knowledge into code generators in order to increase the complexity, quality and quantity of code that can be automatically generated. These knowledge-based system techniques were used to develop a code generator at Sterling Winthrop Pharmaceutical Research. The system automatically translates a high level specification of an enzyme kinetics assay into code that directs a laboratory scale robot and its auxiliary devices to perform the assay. It is an integral part of a larger system developed for the purpose of putting into the hands of the bench chemist the capability of developing a completely new automated chemical assay in a matter of minutes.

Other Collaborative Activities: **Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborator(s)**

Dr. Paul Schopf, Dr. Max Suarez
NASA/GSFC
Greenbelt, MD 20771 :
Co-authored a proposal for the development of high performance algorithms for climate models.

Dr. David Rind
NASA/GISS
New York, NY :
Joint supervision of a graduate student working on the development of a turbulence model for the NASA/GISS GCM.

Dr Mark Russo
Scientific Computing Group
Sterling Winthrop, Pharmaceutical Research Division
Malvern, PA 19355 :
Collaboration on the development of a knowledge-based system for automatic code generation for robotic drug analysis.