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An Overview of the Radiation Component of the NASA TOGA-COARE Experiment

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During January and February, 1993, the Physical Climate Branch of NASA sponsored an aircraft program in support of the Tropical Ocean - Global Atmosphere (TOGA) Coupled Ocean-Atmosphere Response Experiment (COARE). The NASA program was integrated with and contributed directly to the COARE objectives, but had as its primary foci measurements of convection and precipitation related to the Tropical Rainfall Measurement Mission (TRMM) and measurements of the physical and radiative properties of tropical cirrus related to the International Satellite Cloud Climatology Project (ISCCP) and the First ISCCP Regional Experiment (FIRE). This brief overview will concentrate on the measurements associated with FIRE and ISCCP.

The NASA program involved two aircraft, the ER-2 used as a remote sensing platform, and the DC-8 used as a combined remote sensing and *in situ* platform. A list of the instrumentation payload for the two aircraft is given in Table 1. The primary instruments for the radiation component were the Radiation Measurement System (RAMS), the two lidar systems (CLS and VIRL), the microphysical measurement system (MMP), and the imaging radiometer (MAS).

The principal objectives of the radiation component of the experiment were to

1. measure the clear sky flux profile in the convective tropics;
2. measure the physical properties and flux divergence of cirriform cloud over a range of optical thicknesses;
3. measure the physical properties and flux divergence of anvil outflow cirrus;
4. overfly the Pilot Radiation Observation Experiment (PROBE) site at Kavieng, Papua New Guinea, with cirrus present; and
5. measure cirrus properties and radiative characteristics coincident with satellite overpasses.

The variety of flight requirements posed by the various components of the experiment and the limitations of the available resources necessitated careful flight planning and optimization of every opportunity to acquire data. Although data collection was essentially continuous on all flights, data of particular utility with regard to the radiation objectives were acquired in three basic modes: (i) dedicated radiation missions, (ii) radiation legs or segments during missions primarily devoted to other experiment components, and (iii) measurements during transit from the aircraft base, located in Townsville, Australia, and the COARE Intensive Flux Array (IFA) centered at about 1.75 °S and 156 °E. A brief summary of the primary radiation flights is given in Table 2. During all these flights the ER-2 and DC-8 were operated in tight coordination in a stacked pattern. Flight 1 was carried out in coordination with a NOAA P3 flying in the boundary layer so a detailed flux profile can be constructed for that mission.

ER-2 INSTRUMENTATION FOR TOGA-COARE		
Instrument	**PI**	**Data Parameters**
Cloud Lidar System	Spinhirne/GSFC	Cloud structure, boundaries and density
MODIS Airborne Simulator (MAS)	King/GSFC	Passive multi-channel radiometric data
Advanced Microwave Precipitation Radiometer (AMPR)	Spencer/MSFC Hood/MSFC	High resolution, multifrequency sampling of tropical rain systems
Millimeter Imaging Radiometer (MIR)	Adler/GSFC Racette/GSFC	Cloud structure, rainfall, water vapor profiling, cirrus cloud ice content and particle size distribution
Radiation Measurement System (RAMS)	Valero/ARC	Radiation fields, infrared fluxes, brightness tempertures
Lightning Instrument Package (LIP)	Blakeslee/MSFC	Components of electrical field and air conductivity

DC-8 INSTRUMENTATION FOR TOGA-COARE		
Instrument	**PI**	**Data Parameters**
Visible and Near IR Lidar (VIRL)	Spinhirne/GSFC	Cirrus radiation characteristics, structure and boundaries
Airborne Rain Mapping Radar (ARMAR)	Li/JPL	Vertical profile of rainfall in convective systems
Microphysical Measurement Package (MMP)	Pueschel/ARC Heymsfield/NCAR Hallett/DRI	Water budget of clouds, portion of condensate transported to anvil
Advanced Microwave Moisture Sounder (AMMS)	Wang/GSFC	Water vapor, retrieval and microwave precipitation signatures
Electronically Scanned Microwave Radiometer (ESMR)	Wang/GSFC Wilheit/Texas A&M	Two dimensional view of rainfall features in conjunction with AMMS/AMMR
Airborne Multichannel Microwave Radiometer (AMMR)	Wang/GSFC	Dual polarized microwave signatures of precipitation
Radiation Measurement System (RAMS)	Valero/ARC	Upward & downward radiative flux, ambient temperature
Dropwinsonde	(Facility)	Temperature, moisture, wind speed, pressure
Lightning Instrument Package (LIP)	Blakeslee/MSFC	Components of electrical field, lightning characteristics and location

Table 1: Instrument payloads for the NASA aircraft.

DATE	FLIGHT No.	DESCRIPTION
Jan. 11-12	1	Clear sky over IFA
Jan. 17-18	2	Thin cirrus in transit to IFA
Jan. 18-19	3	Thin cirrus in transit to IFA
Jan. 25-26	4	Kavieng overflight -- thin to moderate cirrus
Jan. 31-Feb. 1	5	Thin to moderate outflow cirrus to south of the IFA
Feb. 8-9	8	Cirrus outflow from tropical cyclone Oliver
Feb. 20-21	11	Moderate to thick cirrus outflow south of IFA
Feb. 23-24	13	Kavieng overflight -- thick cirrus and convection

Table 2. Summary of radiation-related missions. Dates are UTC.

Flights 4 and 13 were overflights of the PROBE site at Kavieng. The primary purpose for this site, which was sponsored by the DOE Atmospheric Radiation Measurement (ARM) program, was measurement of the surface radiation budget and atmospheric quantities that influence that budget. Surface radiation measurements consisted of broad-band solar and infrared upwelling and downwelling fluxes, total/diffuse/direct spectral solar fluxes, direct/diffuse broad-band fluxes, near-infrared spectral irradiance, thermal infrared (window channel) nadir radiance, and thermal infrared spectral irradiance. Ground-based remote sensing measurements of integrated water vapor and liquid water path, cloud base and cloud structure, and atmospheric optical depth as a function of wavelength were also taken. Meteorological measurements included CLASS radiosondes of temperature, dewpoint, and winds four times a day, wind and virtual temperature profiles acquired with a 915 MHz profiler and radio acoustic sounding system (RASS), and surface temperature, dewpoint, pressure, winds, and precipitation. Whole sky images were acquired with a CCD.

Preliminary analysis of the data is extremely encouraging. The instruments performed reliably and the data quality is very good. These data indicate that most of the experiment objectives were met. At least three complete flux profiles were obtained, one in the clear sky over the IFA and two over the PROBE site. A wide variety of measurements of flux divergence in cirrus of varying optical thicknesses are available. In some of these cases, the cirrus was relatively fresh (i.e., still attached to its convective source), while in others the cirrus was well detached from any convection. Excellent observations of cirrus structure utilizing the lidars are also available. In addition, cloud microphysical measurements were made in conjunction with the radiation measurements in a number of cirrus decks.

To date, data processing has been limited by the participation of several of the investigators in a subsequent campaign and commitments to analysis of the data from previous campaigns such as the FIRE Cirrus II experiment in Kansas. The expectation is that much of the initial data processing will be complete by the end of this year in time for presentations at meetings in the beginning of the 1994.

In summary, the radiation component of the NASA TOGA COARE experiment appears to have been very successful. We anticipate a significant improvement in our quantitative understanding of tropical cirrus to result from these data.

Acknowledgments. A successful field program is always the result of the effort and hard work of a great number of people. I would like to take this opportunity to express my appreciation to the members of the air and ground crews of the NASA ER-2 and DC-8. Without their able participation and co-operation, none of these data would be available. The various staff members of the FIRE Project Office provided invaluable support both prior to and during the deployment, as did the staff of the TOGA COARE Project Office. And last, but certainly not least, the contributions of Drs. John Theon and Ramesh Kakar of NASA headquarters should be recognized. Their continued support of this field program throughout the planning and implementation phases was absolutely vital.