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PROGRESS REPORT: CONTINUED DEVELOPMENT OF AN INTEGRATED SOUNDING SYSTEM IN SUPPORT OF THE DOE/ARM EXPERIMENTAL PROGRAM

Principal Investigators:

Edgeworth R. Westwater	NOAA/ETL
Kenneth S. Gage	NOAA/AL
Yong Han	CIRES/NOAA
Joseph A. Shaw	NOAA/ETL
Jim H. Churnside	NOAA/ETL

ABSTRACT

From January 6 to February 28, 1993, the second phase of the Prototype Radiation OBservation Experiment (PROBE) was conducted in Kavieng, Papua New Guinea. Data taken during PROBE included frequent radiosondes, 915 MHz Wind Profiler/Radio Acoustic Sounding System (RASS) observations of winds and temperatures, and lidar measurements of cloud-base heights. In addition, a dual-channel Microwave Water Substance Radiometer (MWSR) at 23.87 and 31.65 GHz and a Fourier Transform Infrared Radiometer (FTIR) were operated. The FTIR operated between 500 and 2000 cm^{-1} and measured some of the first high spectral resolution (1 cm^{-1}) radiation data taken in the tropics. The microwave radiometer provided continuous measurements with 30-second resolution of precipitable water vapor (PWV) and integrated cloud liquid (ICL), the RASS measured virtual temperature profiles every 30 minutes, and the cloud lidar provided episodic measurements of clouds every minute. The RASS, MWSR, and FTIR data taken during PROBE were compared with radiosonde data. Broadband longwave and shortwave irradiance data and lidar data were used to identify the presence of cirrus clouds and clear conditions. Comparisons were made between measured and calculated radiance during clear conditions, using radiosonde data as input to a Line-By-Line Radiative Transfer Model. Comparisons of RASS-measured virtual temperature with radiosonde data revealed a significant cold bias below 500 m.

In a related effort, ETL will deploy a suite of remote sensors on the NOAA R/V Discoverer and obtain observations in the TWP in 1996. Included in the suite of instruments are a Wind Profiler/RASS, a cloud lidar, a K_a-band radar, a MWSR, and a FTIR. The FTIR is being developed for long term shipboard deployment. The ship time in 1996 will be contributed by NOAA. Crucial to our FTIR development is calibration and operation without the use of liquid nitrogen, as well as to design and construct suitable housing for the shipboard environment. Currently, it is planned to collocate the MWSR and the FTIR in the same seatainer.

PROGRESS

ANALYSIS OF PROBE DATA

We have completely processed all of our MWSR and FTIR data and have sent them to the Penn State archive for TOGA COARE dissemination. We have identified several different meteorological situations including clear, low clouds, high clouds, and precipitation, and have identified the responses of the remote sensor data to these situations. CLASS radiosonde data have been used to calculate radiometric responses and to provide ground-truth for radiometrically- and RASS-derived parameters for the entire data set. However, it has been discovered that the CLASS data were adversely affected by solar heating and consequently, the entire data set is being redone (by NCAR and TOGA COARE). Thus, the final evaluation of the remote sensor data awaits the reprocessed TOGA COARE radiosonde data.

Using a combination of data from the NASA micropulse cloud lidar and broadband shortwave and longwave irradiance data from the Penn State instrument complex, we have been able to identify six clear periods in which our FTIR measured high spectral resolution radiance within one hour of radiosonde launch time. The data have been given to Dr. S. A. Clough (of AER and the ARM science team), who is using them to revise his model of the continuum absorption from water vapor. We show in Figure 1a and 1b comparisons of measurements and calculations using Clough's original Line-By-Line-Radiative Transfer Model (The LBLRTM has since been changed to take into account our data).

An useful quality control technique for PROBE radiosonde data has been identified. Due to a variety of problems associated with solar heating, the CLASS humidity soundings are sometimes in error. By only using CLASS and FTIR data when the CLASS agrees with the very accurate microwave radiometric soundings of precipitable water vapor, suspicious radiosonde data are eliminated.

We have discovered another useful quality control technique using the microwave radiometer data. By identifying periods of moderate to high cloud liquid amount, spurious RASS soundings were identified. Coupled with A. Riddle's subjective quality control, data of high quality were obtained. A comparison of the RASS data with CLASS radiosondes identified a substantial cold bias in the RASS. The correction of these biases and outliers will be very important to both the current and anticipated uses of RASS in the TWP.

We have used lidar data to identify the heights of low-, mid-, and high-level clouds, and to analyze the FTIR data for such cases. We show in Figure 1c, the measured spectra during clear and various cloudy conditions. As a contrast, we show in Figure 1d spectra measured by the same instrument during the

Coffeyville, Kansas FIRE II experiments. The contrast between the humid TWP and dry continental environments is striking.

We developed a profile retrieval method for use with sensors to be deployed as ARCS stations in the TWP. A paper describing the method, using data from RASS, cloud lidar, and microwave radiometers to derive profiles of temperature, water vapor, and cloud liquid, has been accepted by JAOT (Han and Westwater [1]). A second retrieval technique, this time for inferring profiles of cloud liquid using radiometer and wind profiler data, also shows promise (Williams et al., [4]). Finally, we are developing a Kalman filter retrieval technique using both once-a-day or twice-a-day radiosondes as an initial guess. To implement this technique, we will use TOGA COARE CLASS radiosonde data from six ISS sites (as soon as they are available)

We have designed a shipborne FTIR system that will require no liquid nitrogen or other coolants. This system will be optimized for long-term deployment with minimal operator support on a ship in the Tropical Western Pacific.. Progress to date includes system sensitivity analysis, specification of system components, initiation of the procurement process, and initiation of sea-container modifications. The container modifications have been designed to eliminate troublesome thermal gradients within the FTIR beam path and to decrease the amount of required operator attention. Our schedule calls for procurement completion by October 1995, and system integration completion by January 1996. The system will be deployed on the NOAA R/V Discoverer during March 1996.

OTHER ARM ACTIVITIES NOT ASSOCIATED WITH PROBE

We have deployed the ETL dual-channel microwave radiometer on the NOAA P3 as a part of VORTEX and the Wiscombe-Westwater experiment associated with the SGP IOP. This experiment is designed to measure the horizontal variations of cloud liquid water with a radiometer and with high quality *in situ* sensors. We also will be flying over the SGP CART sites in coordination with the Spring IOP. During the CART overflights, we will be focusing on both the horizontal and vertical variations of water vapor during clear conditions. The experiment is still continuing but preliminary data appear to be of high quality.

We have derived a technique to interpolate and to extrapolate 915 MHz and 50 MHz RASS data to altitudes not covered by their measurements. The technique will be evaluated during the SGP spring IOP by comparison with the frequent CLASS radiosonde launches. We are collaborating with several ARM scientists on this evaluation, including R. Coulter, D. Slater and J. Lilyegren.

We have developed a technique to combine Raman lidar soundings of water vapor with data from other CART instruments, including RASS, microwave radiometers, and cloud lidars. This technique may be helpful to extend Raman measurements during the day and during cloudy situations. We are collaborating with the ARM Science Team members Dr. S. H. Melfi (UM/Baltimore) and R. A. Ferrare (NASA/GSFC) on this activity.

PLANS

- Complete development of water vapor, temperature, and cloud liquid profile retrieval algorithms and apply them to the entire Phase II PROBE data set. If successful, supply these algorithms for TWP ARCS implementation.

- Purchase components, integrate with other ETL sensors, and deploy a FTIR on NOAA RV/Discoverer during March 1996.

- Complete the analyses of PROBE data sets and publish the results in the open literature.

- With W. Wiscombe (NASA/GSFC), analyze the aircraft radiometer, cloud liquid, and solar irradiance data that were obtained during the DOE portion of VORTEX.

- Evaluate profile retrieval algorithms on data sets obtained during spring 1995 SGP IOP, and deliver to Drs. J. Liljegren and D. Slater.

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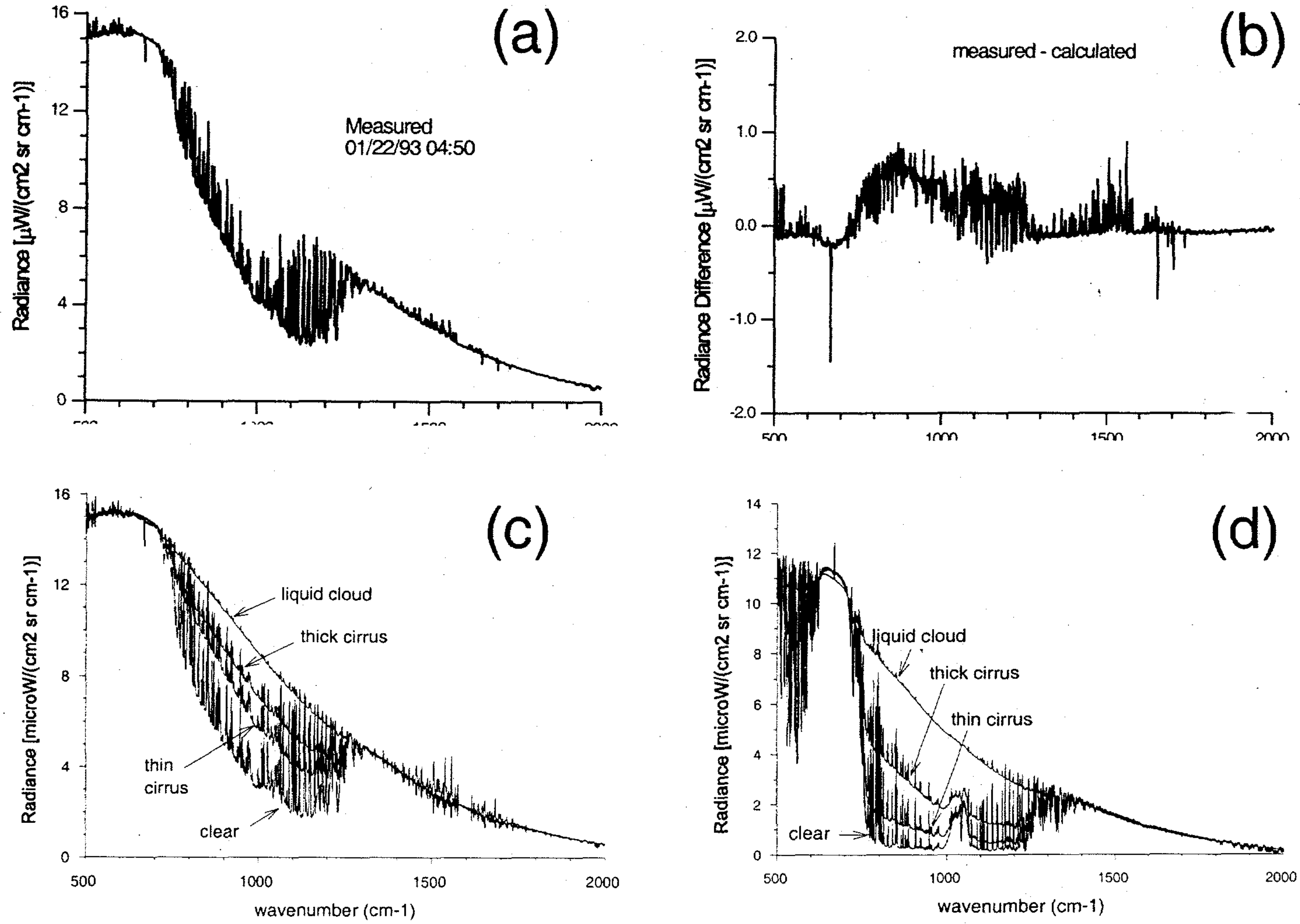

Figure 1. (a) FTIR measurement during clear conditions in Kavieng, Papua New Guinea; (b) difference between measured and calculated radiances; (c) FTIR measurements for various conditions in Kavieng, PNG; (d) FTIR measurements for various mid-latitude atmospheric conditions.