Data from the First Tropical Western Pacific Atmospheric Radiation and Cloud Station

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Introduction

The first Atmospheric Radiation and Cloud Station (ARCS) was installed during September 1996 in Manus Province, Papua New Guinea. The site is located at 2.06 south, 147.42 east in the heart of the Western Pacific warm pool region. This region is characterized by strong solar heating, high water vapor concentrations, and active convection. The sea surface temperature in the Tropical Western Pacific (TWP) is exceptionally high over a very large area. The region undergoes little seasonal variability but it does exhibit fluctuations on a variety of time scales including a strong diurnal cycle, the 40-50 day Madden-Julian Oscillation, and the inter-annual El Niño-Southern Oscillation. While the Madden-Julian Oscillation and El Niño are confined to the tropical Pacific, these cycles have been linked to variability in precipitation around the globe. These links between the tropics and mid-latitudes are not well understood and, consequently, have focused considerable interest on tropical climate variability, particularly in the context of global climate change.

The instruments chosen for the first TWP ARCS were selected to measure the parameters needed to define the surface radiation budget and the properties of the atmosphere that affect that budget. The surface radiation budget is defined by the up- and down-welling broadband shortwave and infrared fluxes. The atmospheric characteristics that most directly affect the surface radiation budget are the atmospheric distribution of water vapor, temperature, aerosol, and clouds. The TWP ARCS includes most of the instruments found at the Southern Great Plains Cloud and Radiation Testbed site. A list of instruments is included in Table 1.

As part of the analysis of the ARCS data, we have been computing the broadband shortwave hemispheric irradiance using a simple clear sky model. The purpose of these calculations is to begin studying the shortwave cloud forcing at the TWP site. The cloud forcing is defined as the difference between the measured irradiance and the model clear sky irradiance. Results from this calculation for the shortwave are shown in the top panel of Figure 1. Perhaps the most striking thing about this graph is how negative the cloud forcing can be. The clear sky irradiances are very high because of the site's proximity to the equator. Meanwhile, deep convective clouds can decrease the midday surface down-welling shortwave irradiance to less than 100 W/m^2. The mean daytime forcing for the first two months of operation was 256 W/m^2. This is the mean shortwave cloud forcing calculated for daylight hours only. Positive cloud forcing occurs when the direct beam is not appreciably attenuated and clouds off

Table 1. Instruments included in the Tropical Western Pacific ARCS. This listing is arranged by the parameters the instruments measure. Together, this set of instruments provides a comprehensive description of the surface radiation balance and the atmospheric properties that affect that balance.

Measurements	Instruments
Surface radiation balance	Up- and down-looking pyranometers and pyrgeometers Sun-shaded pyranometer and pyrgeometer Normal incidence pyrheliometer Up- and down-looking 9-11 μm narrow field of view radiometers UV-B hemispheric radiometer Broad band (solar and infrared) net radiometer
Surface meteorology	Temperature and relative humidity probe; barometer; optical rain gauge; anemometer
Cloud properties	Cloud lidar; ceilometer (7.5 km maximum range); 35 GHz radar[(a)]; whole sky imager[(a)]
Aerosol optical depth	Multi-filter rotating shadow band radiometer (total, direct, and diffuse irradiance in six 10-nm channels)
Column water	Dual channel (23.8 and 31.4 GHz) microwave radiometer
Vertical structure of atmosphere	Rawinsonde; 915-MHZ wind profiler with radio acoustic sounding system (RASS)[(b)]

(a) Not installed
(b) Operated in collaboration with the National Oceanic and Atmospheric Administration Aeronomy Laboratory

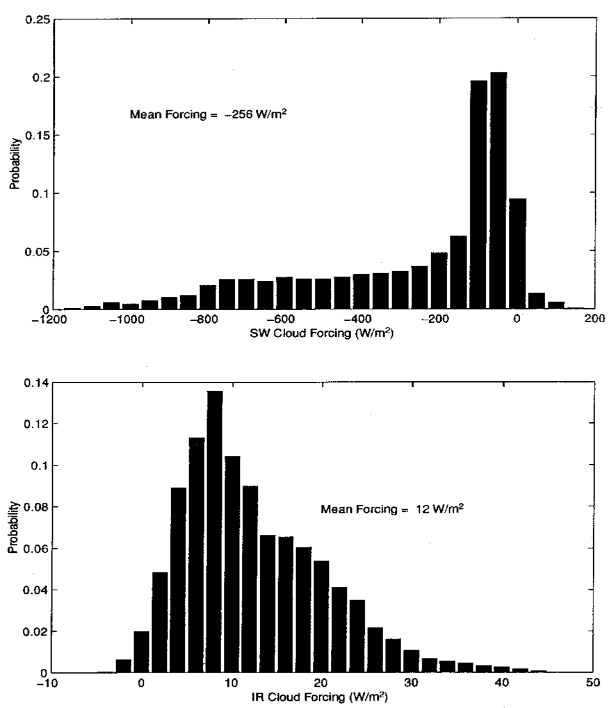

Figure 1. Shortwave and longwave cloud forcing statistics. Cloud forcing here is defined as the measured one-minute average down-welling irradiance at the surface minus the calculated clear sky irradiance.

the axis of the direct beam enhance the diffuse field. As shown in the graph, this enhancement can amount to more than 100 W/m^2.

The bottom panel of Figure 1 shows the cloud forcing statistics for the broadband hemispheric infrared radiometer. Observations from the microwave radiometer and the surface air temperature were used to estimate the clear sky infrared flux because sounding data are not yet available.

These results show that the magnitude of the infrared forcing is quite small, with a maximum enhancement in the irradiance due to clouds of less than 45 W/m^2 and a mean forcing of 12 W/m^2 for the first two months of operation.

In Figure 2, shortwave measurements from November 18, 1996, are compared with calculations from a two-stream model. The period shown appears to be cloud-free based on the broadband shortwave direct and diffuse measurements. Such periods are rare on Manus. The aerosol optical depth was computed using data from the multifilter rotating shadowband radiometer (MFRSR) to be 0.2, and the water vapor column was 4.7 cm. The agreement found between the calculation and the shortwave observation is quite good.

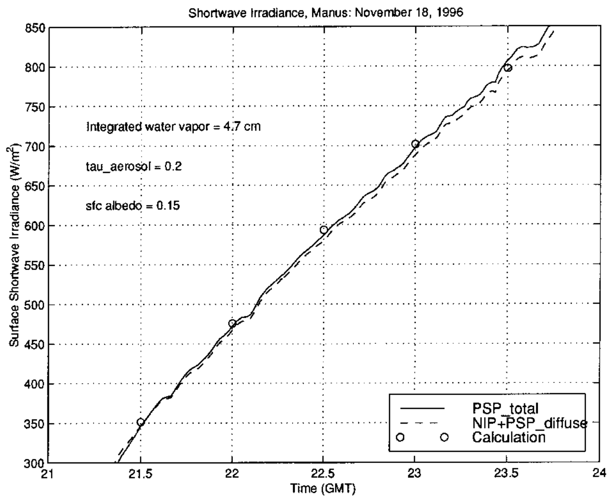

Figure 2. Comparison of shortwave measurements with calculations using a two-stream model for a clear sky case. The model was run using the aerosol optical depth obtained from the MFRSR and the water vapor column from the microwave radiometer.

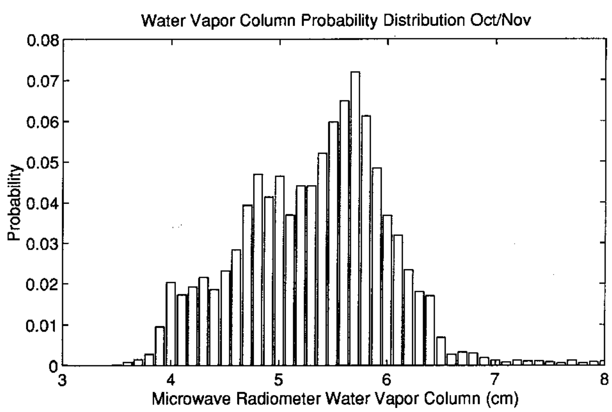

Figure 3. Water vapor column statistics from the microwave radiometer. The mean integrated water vapor column for October and November was 5.4 cm.

As a final illustration of ARCS data, Figure 3 shows the probability distribution of the water vapor column from the microwave radiometer for October and November 1996. The peak in the distribution is at 5.8 cm and the mean is 5.4 cm. Water vapor column abundances of less than 4 cm occur infrequently. The tail of the distribution above 7 cm is due to periods of rain.

During the first few months of operation, there were significant data gaps for the micropulse lidar and the ceilometer. These problems were addressed during a site visit in March 1997, and both instruments are now reporting. Other instruments including the MFRSR and the microwave radiometer have experienced intermittent gaps. On the whole, the system has proved to be very robust.

The combination of instruments at the ARCS site and the anticipated duration of the data record make this a unique data set. We hope that many scientists will make use of these data and provide feedback for which data are most useful and what improvements should be made. As this data set grows and matures, it will become increasingly attractive for collaborative efforts with other tropical climate experiments. Ultimately, these data will allow us to improve our understanding of the tropical climate and the potential for climate change in this important region.