The ARM Program in the Tropical Western Pacific

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The Department of Energy's Atmospheric Radiation Measurement (ARM) program was created in 1989 as part of the U.S. Global Change Research Program. The overall goal of the ARM program is to develop and test parameterizations of important atmospheric processes, particularly cloud and radiative processes, that will be used to improve atmospheric models. This goal is being achieved using a combination of field and modeling studies.

A key ARM precept is that observers and modelers should work together, using field data to develop and validate parameters. ARM's objective is to produce measurements suitable for testing parameters in a sufficiently wide variety of situations so as to span the range of climatologically relevant possibilities. To accomplish this, we need very detailed measurements of radiation and optical properties at the Earth's surface, inside the atmospheric column, and at the top of the atmosphere.

ARM's primary observational methods are remote sensing of clouds, water vapor, and aerosols. It is impossible to meet ARM's objectives, however, without obtaining a large volume of detailed in situ measurements, some of which will have to be acquired from manned or unmanned aircraft. In addition, high-quality satellite observations are needed to measure the top-of-the-atmosphere radiation.

To obtain the required in situ and surface-based remote-sensing data, ARM has been making measurements at three locales using atmospheric radiation and cloud stations (ARCS), as well as acquiring satellite data from other programs. The three locales, shown in Figure 1, are the southern Great Plains of the United States (SGP), the tropical western Pacific (TWP), and the north slope of Alaska and adjacent Arctic Ocean (NSA/AAO). The TWP location, on which we will focus, is managed by the ARM TWP Program Office in EES Division and began phased operations in 1996.

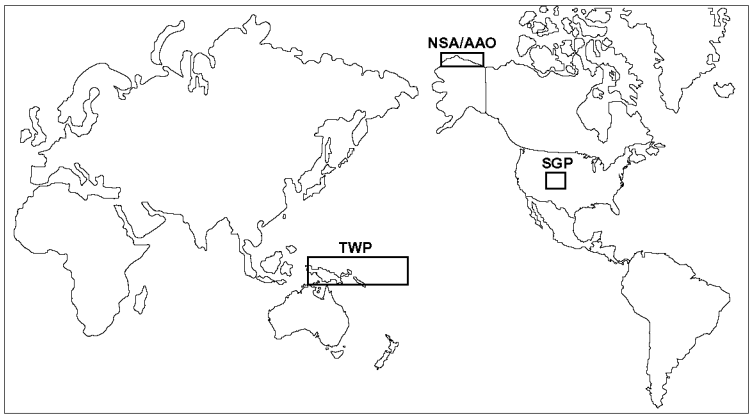

Figure 1. Locations of the three primary ARM locales.

The SGP, which began operating in 1992, covers approximately 55,000 square miles in north central Oklahoma and south central Kansas. The NSA/AAO began in 1997. ARM plans to collect data in each location for at least 10 years.

The TWP Locale

The TWP locale is a large expanse of tropical ocean and maritime continent, lying roughly between 10°S and 10°N latitude and from 135°E to 150°W longitude (Figure 2). The maritime continent area is largely in the southwest, and the open ocean area is in the northeast of the locale. Climatologically, warm sea-surface temperatures, deep and frequent atmospheric convection, high rain rates, strong coupling between the atmosphere and ocean, and substantial variability associated with the El Niño-Southern Oscillation phenomenon characterize the locale. The relationship between climatic variability in this region and variability in other areas of the Earth is well known.

We are addressing three questions in the TWP: radiation budget and cloud forcing, water and energy budgets, and ocean-atmosphere interactions. The large geographic expanse of the TWP, as well as logistical and financial constraints, have influenced our observational strategy, which follows:

(1) Gather a long-time series of basic observations at several locations that will aid in understanding intraannual and interannual variability of surface radiation fluxes and cloud properties.

(2) Conduct intensive field campaigns, which augment radiation and cloud observations, to study the role of deep convection in the tropics on radiative processes.

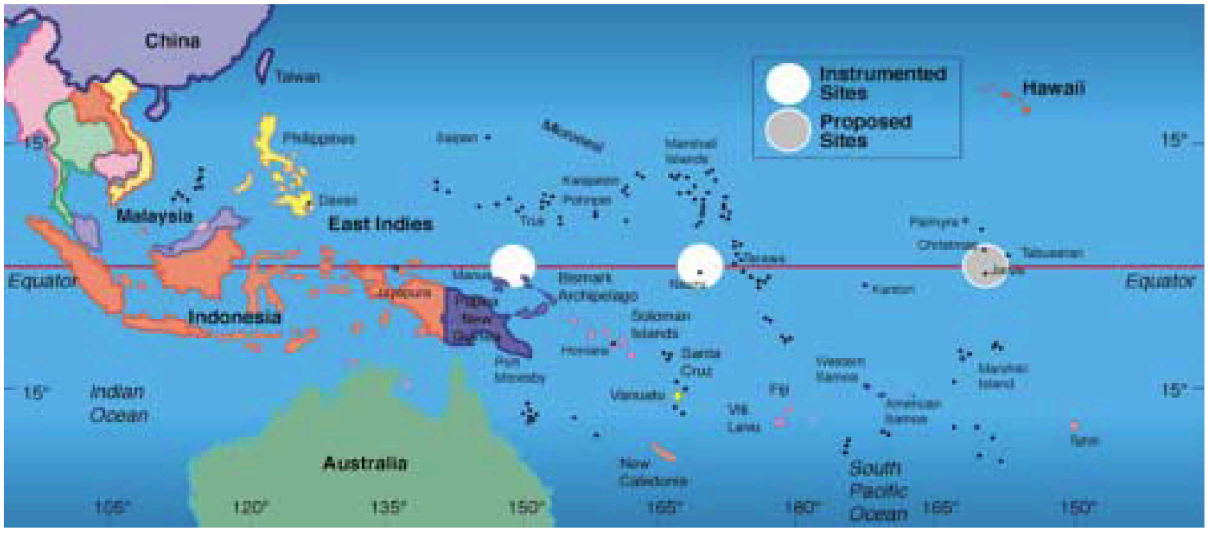

Figure 2. The Tropical Western Pacific Sites.
This map of the equatorial western Pacific region shows the TWP locale and existing and proposed ARCS sites.

(3) Devise and implement a strategy for long-term measurements of ocean-atmosphere properties and fluxes.

The first element of our strategy is most important for two reasons: it relates directly to the primary scientific questions articulated by the ARM Program, and it addresses the lack of data on long-term radiation in the TWP locale.

Atmospheric Radiation and Cloud Stations (ARCS)

To study long-term radiation and cloud properties, ARM uses ARCS, which were designed to collect this type of data. An ARCS system, which is housed in custom modified 20-ft-long sea containers, consists of an integrated instrument set that measures the surface radiation balance, surface meteorology, cloud properties, and some limited atmospheric quantities. In addition to the suite of scientific instruments, a station contains data acquisition systems, monitoring and control systems, satellite communications, a backup electrical generator, a hydrogen generator, and other support equipment. The ARCS system is self-contained and designed to operate semi-autonomously with a minimum of on-site support.

The need to measure the effect of tropical clouds and water vapor on the surface radiation budget is the main scientific driver for the set of observations made by a station. Table 1 summarizes the general measurement categories and the instruments used to obtain them.

Hourly health and status data from the ARCS are transmitted via satellite and are available on the Web. The health and status data provide information on how well the instruments are performing and the condition of support equipment. All of the ARCS data are written to magnetic tapes and periodically shipped back to the United States.

Siting Strategy

An important property of the climate in the tropical Pacific is a strong east-to-west gradient in various climate parameters, including sea-surface temperature, water-vapor column, and frequency of convection. High sea-surface temperatures and frequent deep convection characterize the TWP. Toward the eastern Pacific, there is a steady decline in sea-surface temperature and a corresponding decrease in the frequency of convection. An El Niño is a deviation from these typical east-to-west gradients. Because of this longitudinal structure and its variability, it would be difficult to characterize the climate of the TWP using a single site. ARM plans to deploy ARCS at three sites to sample the structure in this region. Figure 2 shows the existing and proposed locations of the three TWP sites. The third site in the eastern Pacific is currently on hold pending scientific and budgetary considerations.

The Manus Site

The first TWP ARCS site was established in Manus Province, Papua, New Guinea, in 1996 (Figure 2). This was the first site selected because it is within the heart of the Pacific warm pool and is supported by the Papua National Weather Service. The site is located at their weather station at the Momote airport on Los Negros Island at 2.060°S, 147.425°E (Figure 3).

The site is 6 m above mean sea level, and all equipment is located within the weather station compound (Figure 4). Collection of data began in October 1996.

The Manus site has been operating and providing data to the ARM Experiment Center for three years. A global positioning rawinsonde system

Table 1. ARCS Measurements and Instruments.

Measurement	Instrument
Surface Radiation Balance	Up- and down-looking pyranometers and pyrgeometers Sun-shaded pyranometer and pyrgeometer using solar tracker Normal incidence pyrheliometer Up- and down-looking 9–11-mm narrow-field-of-view radiometers UV-B hemispheric radiometer Broadband (solar and infrared) net radiometer
Surface Meteorology	Temperature and relative humidity sensor Barometer Optical rain gauge Propeller vane anemometer Sea-surface temperature measurement[1]
Cloud Properties	Cloud lidar (523 nm) Ceilometer (7.5-km maximum range) 35-GHz cloud radar Whole Sky Imager (WSI)
Aerosol Optical Depth	Multifilter 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 RASS[2]
Atmospheric Emitted Radiation	Atmospheric Emitted Radiance Interferometer (AERI)[1]

[1]Nauru site only
[2]Operated in cooperation with NOAA's Aeronomy Laboratory

was added in August 1997, and a whole-sky imager was installed in August 1998. The instrument suite was completed in early 1999 with the addition of a 35-GHz cloud radar.

The Nauru Site

The second TWP site was established on Nauru Island at 0.521°S, 166.916°E in November 1998. We chose this site because of its location on the eastern edge of the warm pool under La Niña conditions.

The site is located in the Denigomodu (Denig) District on the northwest shore of the island (Figure 5) and is operated in collaboration with the Nauru Department of Island Development and Industry.

Nauru99 Campaign

During June and July of 1999, the Nauru ARM site was host to the Nauru99 Scientific Research Campaign. Nauru99 was an international study of climate in the vicinity of Nauru Island in the TWP. Study participants included the DOE, the National Oceanic and Atmospheric Administration (NOAA), the Japanese Marine Science and Technology Center, Airborne Research Australia, and the Nauruan

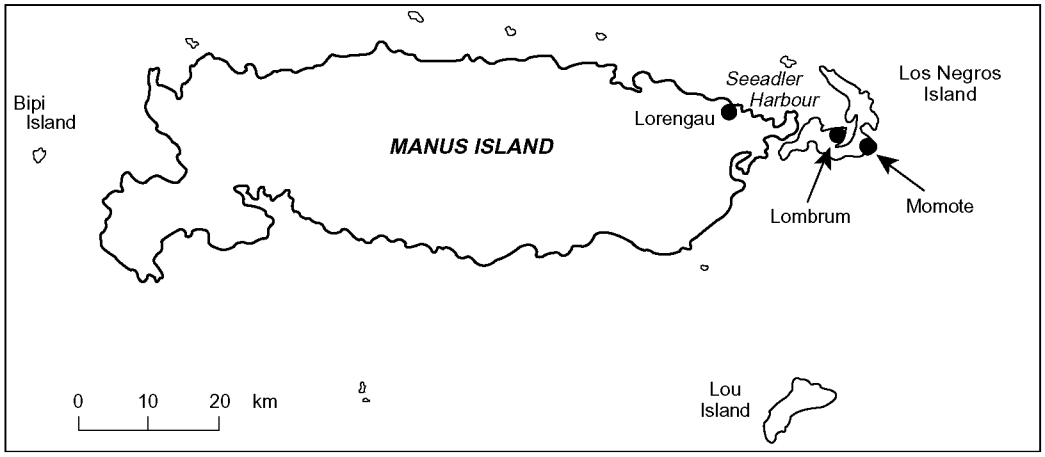

Figure 3. The Manus Site.
The ARCS site is located at the National Weather Service station at the Momote airport on Los Negros Island in Papua, New Guinea.

Figure 4. Manus Weather Station.
The ARCS installation at the National Weather Service station at Momote airport, Manus Province, Papua, New Guinea.

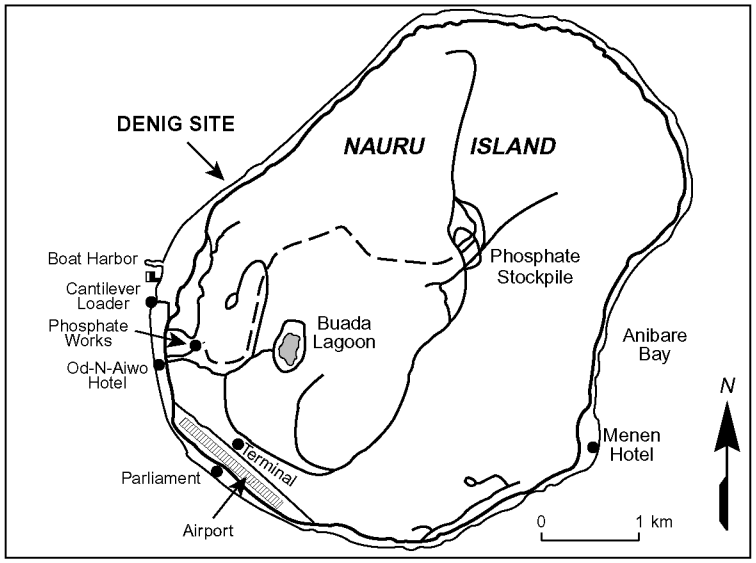

Figure 5. The Nauru Site.
The map shows the Denig Site on the northwest shore of Nauru Island.

Government. The main goal of Nauru99 was to improve our understanding of radiant heat transfer and the effects of clouds on ocean weather processes in the tropics using land-, air-, and ocean-based measurements. Nauru99 also collected data to look at possible island effects on the island-based measurements.

Educational Outreach

ARM also conducts an Education Outreach Program in each locale to complement local and regional education in the areas of basic science, meteorology, and climatology. This program is discussed in the Project Descriptions section of this report. ■

Acknowledgements

The DOE Office of Biological and Environmental Research sponsors the ARM Program. The program draws on the resources of most of the U.S. national laboratories, several universities, and other national and international agencies and contractors. The Manus site operation is a collaborative effort with the Papua, New Guinea, National Weather Service and that of the Nauru site with the Department of Island Development and Industry on Nauru. Operation of the wind profilers at Manus and Nauru is a cooperative effort with NOAA's Aeronomy Lab. The Tropical Western Pacific Program Office works closely with the South Pacific Regional Environment Programme in all aspects of the implementation and operation of the TWP program.

Further Reading

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ARM Web Site: www.arm.gov.