

The Tropical Western Pacific: Status Report

T. Ackerman
Pennsylvania State University
University Park, PA 16802

F. J. Barnes
Los Alamos National Laboratory
Los Alamos, NM 87545

W. Clements
Los Alamos National Laboratory
Los Alamos, NM 87545

D. Renné
National Renewable Energy Laboratory
Golden, CO 80401-3393

E. R. Westwater
National Oceanic and Atmospheric Administration
Wave Propagation Laboratory
Boulder, CO 80303

T. Barnett
Scripps Institute of Oceanography
LaJolla, CA 92093

Introduction

The Atmospheric Radiation Measurement (ARM) Program's Tropical Western Pacific (TWP) locale is the second of the five primary Cloud and Radiation Testbeds (CART) to be established. Phased implementation is currently planned to begin in 1994.

The TWP locale encompasses an immense region of the tropical western Pacific bounded roughly by 10°N to 10°S extending eastward from Indonesia to somewhat east of the international dateline. Climatologically, it is characterized by 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 (ENSO) phenomenon. Any number of diagnostic studies can be cited that show the relationship between climatic variability in this region, particularly ENSO, and variability in other parts of the planet.

Geographically, this locale is characterized by the maritime continent area in the southwest portion and essentially open ocean in the northeast portion. Details on the locale and the scientific challenges are presented in the proceedings of the second ARM Science Team meeting held in Denver in October 1991 (Clements et al. 1992). The purpose of this paper is to report on activities since the 1991 Science Team meeting and discuss future plans.

Overview of Program Activities

In this section, TWP activities since the last Science Team meeting are briefly summarized. Additional information on any activity may be obtained from the Tropical Western Pacific Program Office (Bill Clements: 505-667-2537; Fairley Barnes: 505-667-4933)

Pilot Radiation Observation Experiment

As the ARM Program's first field campaign, we conducted a Pilot Radiation Observation Experiment (PROBE) from November 1992 through February 1993 at a site in Kavieng, New Ireland Province, Papua New Guinea (2°34'S, 150°48'E). PROBE was conducted in collaboration with the Tropical Ocean Global Atmosphere (TOGA) Program's Coupled Ocean Atmosphere Response Experiment (COARE). This ambitious and successful effort consumed much of the TWP team's time during the past two years.

The Experiment

PROBE was conducted to investigate the role of tropical clouds on the solar and terrestrial radiation budgets. A meteorological, solar and infrared radiation, moisture, and cloud monitoring station was set up at the National Weather Service observing station at the airport in Kavieng (2°34'S, 150°48'E), New Ireland Province, Papua New Guinea. The PROBE station consisted of three seacontainers which housed instruments and data-logging equipment.

Data were collected in two phases: November-December 1992 and January-February 1993. The third seacontainer and other instruments were added in Phase II. All data were archived at the site, and some have already been hand-carried back to investigators in the United States. A small sample of the broad-band radiation data was transmitted back daily via the Geostationary Operational Environmental Satellite (GOES) along with the data from the rawinsonde. A paper describing the details of PROBE and presenting some sample data is being prepared for publication.

A Note On Logistics

During Phase II (January 6 to February 28, 1993) of PROBE, the NOAA Wave Propagation Laboratory operated a dual-frequency Microwave Water Substance Radiometer (MWSR) and a Fourier Transform Infrared Radiometer (FTIR). Here, we summarize some of our logistical experiences during PROBE.

The MWSR and FTIR were shipped in a seacontainer from Boulder, Colorado, to Kavieng. Although minor difficulties were encountered in placement of the seacontainer at the PROBE site, all equipment and computers arrived intact.

The only major problem we encountered was obtaining the liquid nitrogen necessary to calibrate the FTIR. Although we started working on this problem six months before the start of the experiment, we experienced numerous unanticipated and frustrating delays in shipping. In addition, a previous shipment of the 1500-liter container for Phase I of PROBE was vandalized enroute with the result that only a small fraction of the original amount reached the field site. However, because of special security precautions arranged by the manufacturer, we were successful in obtaining two complete shipments of liquid nitrogen during Phase II. The MWSR operated continuously through PROBE and, except for periods of rain, the data appear to be good. Because of the problems in obtaining liquid nitrogen, only twenty days of high-quality calibrated spectra were obtained. For more details on this operation in PROBE, see the paper by Westwater et al. in this volume.

Modeling Studies of the Indo-Pacific Warm Pool

Scripps Institute of Oceanography is conducting a variety of modeling studies aimed at understanding the interactions of clouds, radiation, and the ocean in the region of the Indo-Pacific warm pool. (See paper by Barnett et al. in this volume.) These studies are designed to understand the important physical processes operating in the ocean and atmosphere in the region. The modeling studies should help with the design of the ARM CART in this region and also put the eventual measurements from the site into a

large-scale perspective. These tools are available as resources permit to ARM investigators interested in studying the TWP.

TWP Science Workshop

A workshop was held in Santa Fe, New Mexico, on 18-19 May 1992 to better define important science drivers for the TWP. Twenty scientists presented scientific hypotheses that could be tested in the TWP. These hypotheses were discussed and working groups made recommendations following the formal presentations. A report is being prepared.

Ocean Measurements Working Group

An Ocean-based Measurements Working Group (OMWOG) was formed in the spring of 1992 to provide an interface between the ARM functional teams and ocean-based operations. OMWOG will serve all of ARM's ocean operation activities, although it is initially focusing on the TWP project. An ocean platforms catalog that will provide information on platforms for ocean-based operations is being prepared.

Early Awareness and Networking

The importance of making western Pacific nations aware of the ARM Program and its plans for the TWP far in advance of any actual negotiations was identified as a critical task early on. It was also evident that we needed to establish good working relations with regional organizations that might want to collaborate or could be helpful in identifying and obtaining sites. In addition, a number of organizations and programs have conducted scientific research in the TWP area. We have taken every opportunity to interact with as many of these organizations as possible.

The collaboration with TOGA COARE in conducting PROBE was the basis for establishing many of these contacts. The experience gained by the PROBE is a valuable resource to the TWP project. All of the organizations with whom we have interacted, and others, could play a role as we proceed with implementing the TWP. Some of the agencies we have established working relations with are the South Pacific Applied Geosciences Commission (SOPAC); the

South Pacific Regional Environmental Programme (SPREP); the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Office of the South Pacific; the University of the South Pacific; the Australian Bureau of Meteorological Research Center (BMRC); the Division of Atmospheric Research (DAR), within Australia's Commonwealth Scientific and Industrial Research Organization; the New Zealand Meteorological Service; and the New Zealand Institute of Water and Atmospheric Research.

We are continuing to keep our relationships active with these organizations and will be establishing new ones where appropriate. These activities will be critical to implementation of the TWP CART sites and in their continuing operation. There is a genuine potential for cooperation and collaboration within the TWP locale, but we must proceed in an educated and careful manner.

NEPA Activities

We are determining the level of activities required for compliance with the National Environmental Policy Act (NEPA) for the TWP project. The completion of a Los Alamos National Laboratory ES&H questionnaire began this process. A TWP project description, a DOE environmental checklist, and a memo of intent to comply with extra-territorial regulations were prepared and submitted to DOE Albuquerque Operations Office.

Program Office Audits

The Program Office at the Department of Energy and at the Pacific Northwest Laboratory audited the PROBE and TWP projects during May and June 1992, respectively. Past activities, current status, future plans, and anticipated budgets were reviewed. These audits helped to better focus on a science and siting strategy for the TWP program.

JASON Review

In August 1992, the TWP status, its evolving science and siting strategy, and PROBE were presented to the JASON committee as part of their annual review of the ARM Program.

Proposed Science and Siting Strategy

As a result of the TWP Science Workshop, the Program Office Audits, reactions from the JASON committee review, our experience with PROBE, and the anticipated budget situation, we are formulating a new proposed strategic plan for the science and siting of the Tropical Western Pacific.

Scientific Considerations

The overall goal of ARM is to improve cloud and radiation parameterization in general circulation models (GCMs). The components of the current plan that are aimed at achieving this goal include 1) detailed observations of radiation and cloud properties and associated data analysis, 2) studies of relevant atmospheric processes using high-resolution models with explicit physics, and 3) simulations with mesoscale models and single column versions of GCMs. The design and implementation of the Southern Great Plains (SGP) CART has been predicated on these components.

As ARM moves on to the implementation of subsequent sites, the conceptual plan and CART design may need to be modified in order to address the same goal in a different locale. As we move to consider the proposed TWP site, an examination of the principal science issues and relevant logistical considerations is required. Because of the large area, relative inaccessibility, and predominance of ocean, this locale is also characterized by a critical lack of climatological data from the ocean, the atmosphere, and the interface.

The major areas of scientific importance for the TWP locale have been identified as

- radiation budget and cloud forcing
- water and energy budgets
- ocean-atmosphere interactions.

Over the course of the past year, a workshop and several meetings have been held expressly to consider science issues and measurement needs in the TWP. These meetings have provided stimulating discussions and interesting ideas. From these, we have begun to distill an implementation strategy that flows from an amalgam of science issues and logistical and financial considerations.

At a minimum, the TWP science issues require

1. continuous, basic observations of radiation and cloud properties over a broad spatial domain
2. detailed, but not necessarily continuous, observations of atmospheric structure and properties at some location(s)
3. observations of surface fluxes, boundary layer properties, and cloud structure in a purely oceanic environment
4. observations of radiative fluxes at the top of the atmosphere (TOA).

The first requirement comes from the need to establish the magnitudes and variabilities of the surface radiation budget and cloud forcing across the Pacific basin, the second from the need to understand how tropical convection impacts water and energy budgets in the tropics, and the third from the need to understand the coupling of the ocean and atmosphere and how it affects convective organization over the water. The fourth requirement provides the radiation source and sink terms from space.

Other Issues

The logistical and financial constraints include factors such as

1. Infrastructure support throughout much of the area of interest is extremely limited or non-existent.
2. Potential political problems and instabilities mandate against fixed, long-term plans in some areas; funding for capital equipment will be phased over several years.
3. Installing and maintaining instrumentation is so costly that cooperation with other agencies with mutual interests is crucial.
4. The envisaged ocean site has not been tried before and will require considerable development work to draft an acceptable plan.

Our experience gained with PROBE highlights the need to design and build systems that are largely self-contained and can operate with only a minimal amount of attention. The high cost and slowness of shipping replacement parts requires that systems be rugged, reliable, and redundant.

Standardization of instrument and computer parts, whenever possible, is highly desirable, and some inventory of spare parts will have to be kept on site or at a central location.

The financial issues are driven by the amount of money available to the ARM Program and the need to continue instrumenting the SGP site. It is unlikely that the ARM budget can support the combined development of two major sites simultaneously. Thus, a siting strategy for the TWP that can begin with modest expenditures and expand to fit yearly funding profiles is highly desirable.

Also, the ARM Program extends beyond the first two sites to include the North Slope of Alaska, Eastern Ocean Margins, and the Gulf Stream locales. The siting strategy for the TWP should provide for common design and development of instruments and a common deployment scheme which could be used at these future sites. Thus, a strategy that is flexible and, to some extent, portable from one remote locale to another is highly desirable. This strategy is particularly important for the ocean-based component of the program, which is likely to be quite expensive. Fashioning a common and economical design for ocean-based instrumentation will take considerable time and effort.

Given the high cost of operating in a remote environment and the current funding situation, it is critical that ARM management seize every opportunity for collaboration with appropriate existing scientific programs and multi-national organizations in the region. A few installations are being operated in the islands, but these are rather modest in scope and instrumentation. The most active site in the area is maintained by the Australian research community in Darwin. This site has state-of-the-art instrumentation such as Doppler radar and wind profilers and is currently being upgraded to support TRMM validation research. Collocation and cooperation with this activity should be a high priority for ARM.

Evolving Science and Siting Plan

The combination of science issues with logistical and financial considerations has led to the proposal of a phased, flexible deployment scheme. The scheme is designed to begin the acquisition of data in the TWP soon (currently summer 1994), augment that acquisition consistently over the next few years, and culminate with

the deployment of an oceanic facility. The proposed scheme has four distinct components:

1. deploying three to five Atmospheric Radiation and Cloud Stations (ARCS) across the western Pacific
2. adding an augmented ARCS to the Australian Bureau of Meteorology research facilities in Darwin
3. developing and deploying an enhanced oceanic facility incorporating some combination of moorings, ocean platforms, and island-based remote sensors
4. deploying upward-looking solar radiometers on a number of the 65 to 70 established ATLAS moorings in the TOGA TAO array, which extends across the Pacific basin from 10°N to 10°S.

Details of this science and siting strategy are given in evolving document "Science and Siting Strategy for the Tropical Western Pacific CART Locale," which is available from the TWP Program Office (Ackerman et al. 1993).

This strategy will rely on the use of satellite data, and unmanned aerospace vehicles (UAVs) when they become available. ARM has been exploring the possible use of UAVs in support of the CART. The development of simple sounding packages that could be flown on small UAVs would be immensely valuable to this oceanic site. It would provide the means to do atmospheric sampling over a broad spatial area, a capability that is currently missing. The additional development of simple radiation and cloud sampling packages would also be of great utility to this site. Close coordination between the TWP program planning and ARM's UAV and satellite programs will be maintained.

Meetings

We participated in the following professional meetings:

Twenty-First Annual Session of the South Pacific Applied Geoscience Commission, 26-29 September 1992, Nuku'alofa, Tongatapu, Tonga. Peter Lunn and Clements made joint presentations on the ARM Program and the TWP Project.

1992 Western Pacific Geophysics Meeting of the American Geophysical Union, 17-21 1992, Hong Kong. Clements presented a paper entitled "The USDOE ARM Program: Tropical Western Pacific and Southern Great Plains CART Projects."

73rd Annual Meeting of the American Meteorological Society, 17-22 January 1993, Anaheim, California. Ackerman's paper was presented; Barnes held a poster session; Clements and Renné also participated.

GOALS (Global Ocean Atmosphere Land System) Conference/Workshop, 1-2 March 1992, Honolulu, Hawaii. Clements presented ARM/TWP overview.

References

Ackerman, T., W. Clements, and D. Renné. 1993. *Science and Siting Strategy for the ARM CART Locale*. Working

report, available from the Tropical Western Pacific Program Office, P.O. Box 1663, MS F665, Los Alamos National Laboratory, Los Alamos, NM 87545, or from the Tropical Western Pacific Site Scientist Office, Department of Meteorology, Pennsylvania State University, 503 Walker Bldg., University Park, PA 16802-5013.

Clements, W., T. Ackerman, and D. Renné. 1992. Tropical Western Pacific Project: Status. *Proceedings of the Second Atmospheric Radiation Measurement (ARM) Science Team Meeting*, October 26-20, 1991, Denver, Colorado. CONF-9110336, U.S. Department of Energy, Washington, D.C.