Tropical Western Pacific Project: Status

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The Tropical Western Pacific Locale

The Atmospheric Radiation Measurement (ARM) Program's Tropical Western Pacific (TWP) locale will be the location of the second of five primary Cloud and Radiation Testbed (CART) sites. Figure 1 shows the TWP locale in relation to the other primary CART locales. The locale lies in the tropical warm pool region roughly between 10° S to 10° N of the equator and from 130° E to the dateline. Phased implementation is scheduled to begin in late 1993.

The main activity of the TWP project in the next year is to define the particular science to be conducted and to select an appropriate site or sites to make the required measurements. These activities will be led by the current TWP team:

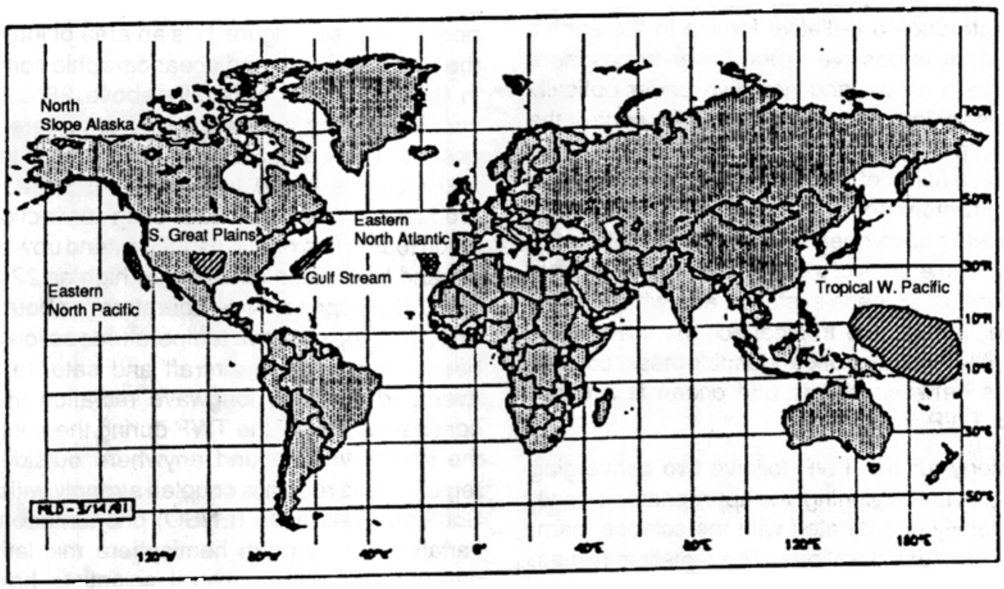

Figure 1. Primary CART Locales

- Site Program Manager: Bill Clements, Los Alamos National Laboratory
- Site Scientist: Tom Ackerman, The Pennsylvania State University
- Pilot Radiation Observation Experiment (PROBE) Coordinator: Dave Renné, National Renewable Energy Laboratory
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The TWP locale encompasses a region where the average annual sea surface temperature is greater than 28° C. This region, known as the "warm pool," provides a significant source of latent and sensible energy to the earth's general circulation. The region is characterized by deep convective systems, sometimes organized into mesoscale supercluster circulations. Through scale interaction processes these mesoscale systems influence large-scale atmospheric circulation patterns (such as the zonal Walker circulation and the Hadley cell) and oceanic circulations. Thus, the warm pool influences the climate of other tropical regions and that of the mid-latitudes. The strong coupling between the ocean surface and the atmosphere is such that changes in the circulation of one influences the circulation of the other.

One coupling mechanism is the production of large-scale cirroform and stratiform clouds from the deep convection. These clouds introduce a radiative forcing to the earth's energy budget that is positive in the lower troposphere under optically thin cirrus, and negative under optically thick cirrus. This radiative forcing will, in turn, control the sea surface temperature (SST). Changes in SST can influence the intensity of convection, representing a feedback mechanism to the atmosphere. Although mesoscale systems have been studied extensively in the tropics, the radiative effects of extensive stratus and cirrus clouds which form from these systems, and which cover, on the average, 70% of the tropical oceans, have been given relatively little attention. Understanding these radiative coupling effects between clouds and ocean is a major objective of the TWP site.

Our siting strategy for the TWP follows two converging paths (Figure 2). In the beginning, the appropriate science, which will be closely coordinated with the science team, will drive the siting considerations. The logistical issues, which are not mutually exclusive, also will be examined. Although initially the science will have the larger influence on our siting strategy, at some point scientific and logistical issues must be balanced to determine what we can realistically accomplish under logistical and budget constraints. Siting in the TWP presents some interesting challenges, and we must sustain a creative, flexible, and coordinated approach if we are to meet them successfully.

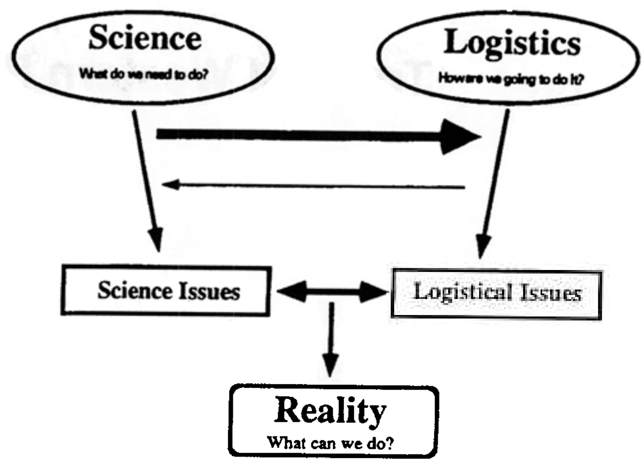

Figure 2. General TWP Siting Strategy

Scientific Challenges

The TWP region (also commonly referred to as the warm pool region; see Figure 1) is an area of intense interest to the meteorological and oceanographic community. SSTs in this region are generally above 28°C, making them consistently the warmest found anywhere in the world's oceans. The warm SSTs result in a large transfer of heat and moisture to the tropical atmosphere, which in turn produces extensive areas of deep convection. Convective cloud tops in this region usually extend upwards of 15 or 16 km and have been detected as high as 22 km in isolated cells. The tropopause temperature is about 195 to 200 K, and cloud-top radiative temperatures as low as 185 K have been detected from aircraft and satellite. The monthly averaged outgoing longwave radiation in the maritime continent sector of the TWP during the austral summer is the lowest value found anywhere outside of the polar regions. This region is coupled strongly with the El Niño—Southern Oscillation (ENSO) phenomenon, and thus to variations in northern hemisphere mid-latitude weather patterns. Recently, several scientists have postulated feedback mechanisms related to climate change that are tightly related to features of the TWP circulation.

As a result of these interlocking features of ocean and atmosphere, the TWP has been selected as the location of the second CART site. Because of the complexity of ocean-atmosphere-land interactions in this region, and the general paucity of data, there are an enormous number of unanswered scientific questions that can be addressed by a CART site in the TWP.

The science questions of interest to ARM can be collected under five general headings: 1) cloud-radiation interactions, 2) vertical transports of mass and energy, 3) air-sea interaction, 4) initiation of convection, and 5) the coupling of the tropics to the mid-latitude. These headings are broad and collectively span a tremendous diversity of atmospheric and oceanic processes. It is uncertain whether all of these areas can be addressed using data collected at the TWP CART site. Thus, one of the high priorities over the next year will be to define science issues and prioritize the issues with regard to data collection and use of ARM resources.

A variety of science questions can be identified under each of these general headings. In the context of clear-sky radiation, one of the crucial areas of uncertainty is the nature of water vapor continuum absorption under conditions of high water vapor paths. Because integrated water paths in excess of 5 percepitable cm are often found in the TWP, this is an ideal region to study this particular problem. Satellite measurements have identified this region as an area of large infrared and solar cloud forcing, and have also suggested that these two large forcings are opposite in sign and nearly cancel each other. Thus, an important question to be answered by the TWP CART site is the impact of clouds on the surface radiation budget and the cloud forcing of the atmosphere and surface. The limited data currently available suggest that tropical convective clouds can have a dramatic effect on the solar flux at the surface, but have a relatively modest effect on the infrared flux. One might expect the converse to be true for atmospheric heating. Thus another question of considerable interest is the radiative heating profiles produced by tropical cirrus.

Convective systems not only generate clouds, they are also responsible for much of the vertical transport of energy and mass in the tropics. Evaluating these transports is important not only in order to understand the physical processes involved in convection, but also to construct sound convective parameterization schemes for numerical models. One of the central questions under this heading involves the moisture budget of tropical cloud systems, including such issues as the precipitation efficiency of tropical clouds, water vapor transport and injection into the upper troposphere, the latent heating profile in convective cells, and the nature of the circulation and precipitation in the stratiform and cirriform regions associated with convection. Vertical momentum and energy transport by convective systems is also of considerable interest.

Understanding the interaction between air and sea in the TWP is crucial to understanding cloud formation. Several questions might be raised under this general heading. Those most important to ARM are probably those that affect the surface energy budget, such as the radiation budget at the ocean surface, and the latent and sensible heat fluxes. The latter are influenced by the precipitation rate and the effect of fresh water on temperature and salinity. A strongly related issue is the reliability and accuracy of satellite estimates of surface fluxes. Quite clearly, surface fluxes over the ocean cannot be monitored adequately at the surface. The only possible approach is to use satellite remote sensing. However, the satellite techniques must be validated and continuously verified.

The initiation of convection in the TWP is not adequately understood. Much of the time the atmosphere in the TWP is near neutral stability. This feature has led to some contrasting hypotheses about the nature of convection and convective initiation. Land-ocean contrast clearly plays a role in initiating convection. Thus, there is a need to assess the role of islands, both small and large. Obviously, convection also occurs over the oceanic areas. Large convective systems in this area show a marked diurnal cycle suggesting that radiation plays an important role. Significant differences between monsoonal convection and convective complexes also need to be addressed.

Apart from the direct science questions, some very interesting observational issues will need to be addressed in the context of the TWP site. One is the large spatial scale of the region and the required observations. It can be easily argued that observations are needed on the scale of thousands of kilometers to understand the radiative implications of, for example, ENSO. How are these observations to be carried out, given the limited number of usable islands and the available resources? Much of the area under consideration is remote, lacks the typical technical support infrastructure found in the United States, and is hot and humid. These characteristics will present numerous challenges for many of the instruments commonly used in mid latitudes. The instruments will have to be made more rugged and reliable, and perhaps be modified to operate in high water vapor environments.

Another major challenge will be the definition of the environment in which the observations are made. Given the paucity of routine observations available in the TWP, it will be difficult to define the dynamic and thermodynamic fields in the vicinity of the CART site(s). The solution to this problem appears to be some judicious combination of model simulations, routine observations, and satellite observations.

Finally, the scope of the problem that we face in the TWP will strain the fiscal and personnel resources of the ARM program. Therefore, it will be necessary to investigate carefully observations currently being made in the area and try to integrate ARM with these other programs. Such integration will be to the benefit of both ARM and the other programs in the TWP.

In short, the ARM TWP site offers a unique opportunity to the atmospheric community. However, the extremely broad scope of the questions that might be addressed and the difficulty of the logistics in the area present an enormous challenge to the ARM science team and the management team. Resolution of these issues will require careful planning and hard work. The TWP team looks forward to leading that effort and solicits your contributions.

The May 1991 Locale Visit

During May 1991, Dave Renné and Bill Clements made the first ARM visit to the TWP locale. They first visited the Federated States of Micronesia (FSM) and then joined members of a Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Response Experiment (TOGA COARE) (described in the following section) site survey team to Papua New Guinea (PNG) and Australia. The purpose of this trip was to obtain initial information relevant to ARM on the locale, identify logistical issues ARM might be facing, and establish some contacts in the area. The trip provided an excellent opportunity to share the experience of the TOGA COARE team with which we will be working in the ARM PROBE activity (described in the following section). An informal trip report is available.

In FSM, Renné and Clements visited the islands of Pohnpei and Chuuk (formerly Truk). Their main contacts were National Weather Service officials who were extremely helpful and gracious hosts. On Pohnpei and Chuuk they discussed ARM activities with NWS personnel, met with the Commissioner of Land, explored the island for sites suitable to establish a CART central facility (CF), and toured the National Oceanic and Atmospheric Administration (NOAA) 50-MHz wind profiler in Kolonia. On Chuuk they had a very interesting visit to the Xavier High School located on a small hill in Moen.

After the Chuuk visit, they joined a TOGA COARE site survey team (Dave Carlson, Karyn Sawyer, Hal Cole, Warner Ecklund, and Jim Moore) in Port Moresby, PNG. There they met with officials of the PNG Weather Services and the head of the Physics Department at the University. They were then accompanied by Ken Zorika of the Weather Services Office on visits to Kavieng (New Ireland) and Manus Island. Both of these locations are sites for Integrated Sounding Systems during TOGA COARE. In both Kavieng and Manus they again met with Weather Service and government officials and explored logistical and operational matters.

Some of the observations from the FSM and PNG visits were the following:

- The Weather Services' personnel are essential contacts.
- Officials are interested in the ARM Program and are willing to cooperate.
- There are relatively few potential CART central facility sites, primarily because the land is heavily vegetated and/or its ownership is unclear.
- Political protocol is extremely important.
- The two islands provide the basic necessities in the way of food, services, and general merchandise, but specialized goods and services are generally not available.
- General telephone availability is poor.
- Commercial water and electricity are generally unreliable for scientific purposes.
- Ship docking facilities and the ability to handle sea containers vary.
- Commercial airline service to most islands is on a flight circuit that provides service once a day going opposite directions on alternate days.

An ARM Pilot Study During TOGA COARE

The ARM Program plans to conduct a major field campaign in the TWP in conjunction with TOGA COARE. TOGA COARE is a multinational ocean-flux study conducted under the auspices of the World Climate Research Program.

From November 1992 through February 1993, when ARM will be actively planning for the implementation of the CART facility in the TWP, an Intensive Operation Phase (IOP) of TOGA COARE will be conducted near the Solomon Islands and eastern Papua New Guinea. The IOP will focus on air-sea interface processes in the warm pool region to better understand the coupling mechanisms between the ocean and atmosphere. TOGA COARE is an ideal opportunity for ARM to conduct the PROBE and to learn about the performance of key instrumentation systems in the tropics.

PROBE is expected to provide an important contribution to TOGA COARE as well as toward the planning for CART in the TWP by addressing the following objectives:

- study the coupling between large-scale cirroform and stratiform clouds associated with deep tropical convection and the surface radiative energy budget
- gain knowledge and experience toward operating a CART facility and learn about the performance of key instrumentation systems in the TWP.

PROBE Experiment Design

The basic approach for PROBE will be to install a surface radiative measurement and cloud imaging station at Kavieng, Papua New Guinea, (2° 34' S, 150° 48' E). Continuous measurements will be obtained from this station to relate cloud conditions with surface and tropospheric radiative flux. In addition, high-altitude aircraft from the National Aeronautics and Space Administration (NASA) with specially equipped radiometer and in-situ cloud measurement capability will periodically fly over the site during their operations to and from TOGA COARE's Intensive Flux Array (IFA) (Kavieng is one of the closest locations to the IFA that has regular air service and a reasonable size community which can provide some logistical support).

The PROBE surface station will be designed around the Integrated Sounding System (ISS) being installed at Kavieng for TOGA COARE by NOAA's Aeronomy Laboratory and the National Center for Atmospheric Research (NCAR). The radiometric sensors normally associated with the ISS will be enhanced for PROBE to provide complete radiative flux measurements spectrally and over broad wavelengths. The sounding data will be used to model radiative flux divergence through the troposphere. The cloud imaging component of the surface station will consist of a variety of remote sensors such as those developed by NOAA and university organizations. These sensors might include an interferometer, a microwave radiometer, a window radiometer, a cloud base lidar, and an all-sky camera. This array of equipment can provide information on cloud structure, particle characteristics, and radiative properties.

The NASA DC-8 and ER-2 research aircraft will make in-situ cloud and above-cloud radiation measurements in the mid- and upper-troposphere over the site. There will also be efforts to coordinate these aircraft flights with over-passes of key satellite instruments, such as the NOAA AVHRR. These data will be combined with the surface data in the form of an "instantaneous radiative flux experiment" to examine the radiative effects of stratiform and cirroform clouds on SST, the formation of deep convection, and the consequential redistribution of water vapor in the troposphere and lower stratosphere.

Data management for PROBE includes data interfaces with the ISS; transfer of ARM-related data to TOGA COARE; and receipt and incorporation of NASA aircraft, ISS, and TOGA COARE data into the ARM data management system. Since the normal procedure for the ISS is to transmit its data via GOES satellite to Boulder, Colorado, some of the PROBE data can be transmitted in this way as well. The operators of this equipment will archive the data from the remote sensing instruments on site.

Programmatic Coordination and Schedule

PROBE represents significant collaboration between ARM and other federal programs. The experiment will provide an important contribution to TOGA COARE by addressing one of the key energy pathways (radiation flux) between clouds and ocean surface. PROBE's surface radiation facility will support and be supported by NASA's airborne Clouds and Radiation Experiment, which represents the next major NASA FIRE (First ISCCP Regional Experiment) activity following CIRRUS and ASTEX. PROBE represents collaboration with NOAA and NCAR for the ISS to be installed on Kavieng for TOGA COARE, and a potential collaboration with NOAA and other organizations for acquiring cloud imaging and remote sensing equipment.

Implementation of PROBE will be a major activity for ARM's TWP team. The basic experiment design was finalized in time for the International TOGA COARE Workshop, which was held in Townsville, Australia, March 8-13, 1992. Any special equipment configuration and software development was completed by mid-summer. The equipment was shipped to Kavieng in early August and will be installed in October in time for TOGA COARE. Although continuous measurements from all sensors associated with the ISS are planned for the entire IOP as basic support to TOGA COARE, PROBE activities will concentrate on two six-week phases:

- Phase I (approximately November 1 - December 15, 1992) - a complete checkout and test of all equipment
- Phase II (January 10 - February 28, 1993) - a joint activity with NASA's airborne Clouds and Radiation Experiment.