TOGA-COARE

Coupled Ocean-Atmosphere Response Experiment in the Western Equatorial Pacific

The Problem

Our planet's climate varies in many ways that are well recognized but poorly understood. A striking example is El Nino, a warming of the surface layer of the Pacific Ocean along the west coast of South America. El Nino events, which occur about every four to five years, appear to disrupt climate in distant places. They are accompanied by droughts in South Pacific, Australia, Indonesia, India and Africa; floods in South America; hurricanes in French Polynesia; and severe winter storms in the United States. Climate variations such as El Nino have serious impacts on human affairs, including loss of life, crop failures and depletion of fisheries. However, they cannot be predicted far enough ahead to allow government officials and other decision-makers to take effective actions to mitigate their impacts.

The scientific and human issues that surround such regional climate variations dramatically illustrate the importance of three central questions in ocean/atmosphere research:

* How do the ocean and atmosphere interact in a global system to produce climate variations on time scales of seasons to years?

* Can we understand this coupled system well enough to predict regional climate variations such as droughts, flooding or stormy periods months to years in advance?

* Once we understand climate variation, can we then assess long-term climate change?

To answer these questions, mathematical models that express ocean/atmosphere processes as equations are run on computers to simulate the behavior of the coupled system. The models can be tested against historical observations to identify additional data required to depict global ocean/atmosphere coupling more realistically. If the models improve sufficiently to reproduce (and perhaps predict) seasonal and interannual climate variations, climate researchers can then address the larger challenge of long-term climate change.

A Critical Region

Energy from the sun drives large-scale atmospheric motions that determine global and regional climate. Because solar radiation strikes the earth most directly near the equator, the equatorial oceans absorb most of this energy. The oceans release much of the energy to the atmosphere as heat or moisture, primarily from tropical "warm pool" regions. In the atmosphere, the upward movement of warm, moist air transports large amounts of energy, releasing it when water vapor condenses into cloud droplets and raindrops. Present climate models lack realism because they do not accurately represent complex mechanisms that transfer energy between warm pools and the atmosphere. Very few weather reports come from the vast tropical warm pool regions, and scientific research has been severely limited by lack of adequate regional oceanographic and atmospheric data.

Computer models and historical data indicate that a particularly important region is the western Pacific warm pool northeast of Australia. With water temperatures generally higher than 29°C (Figure 1), this warm pool is the largest single expanse of warm water on the planet. The region receives nearly 5 meters of rainfall annually as part of an intense convective process that releases great amounts of heat to the upper atmosphere and produces clouds that block some incoming energy but trap outgoing energy. Fresh rain-water falling on the sea surface affects the ocean's ability to absorb and mix heat, which in turn influences the transfer of heat and moisture back to the atmosphere. Variations in the extent and duration of this intense exchange of energy between the warm pool and the overlying atmosphere appear to induce climate variations over the entire Pacific basin and beyond.

The Experiment

The Coupled Ocean-Atmosphere Response Experiment (COARE) is providing data on ocean/atmosphere interactions in the western Pacific warm pool region. COARE was designed by an international group of scientists (Lukas et al., 1991; TOGA-COARE Panel, 1990; Picaut et al., 1989) as an integral part of the Tropical Ocean Global Atmosphere (TOGA) Program. This program is an international scientific effort to describe, model and predict variability of the coupled ocean/atmosphere system on time scales of months to years. As a component of the World Climate Research Program, TOGA is jointly sponsored by the World Meteorological Organization, the International Council of Scientific Unions (ICSU), the UNESCO Intergovernmental Oceanographic Commission and the ICSU Scientific Committee on Oceanic Research. The TOGA-COARE International Project Office in Boulder, Colorado, U.S.A., oversees COARE planning, field operations and data management (TCIPO, 1991), and the COARE Panel is charged with the scientific oversight of the experiment.

COARE has three components: one focused on the atmosphere, one on the ocean and one on the interface between these two systems. Each component of COARE possesses a number of elements (Figure 2). These are:

* pilot studies of subjects such as ocean mixing

* a two year-long period of enhanced monitoring of the ocean and atmosphere over the entire western Pacific warm pool region

* a four-month Intensive Observing Period (IOP) focused on energy exchange and mixing in the center of the region

* a continuing modeling effort

* a data-analysis phase

COARE will provide a comprehensive set of accurate scientific data from the western Pacific warm pool to allow climate modelers to quantify more realistically several aspects of coupled ocean/atmosphere processes. The experiment focus on energy exchange between ocean and atmosphere over an area of nearly 7.5 million square kilometers. Extending from 10°N to 10°S latitude and 140°E to 180° longitude, the COARE domain covers the warmest part of the warm pool region (Figure 3). The domain covers mainly open ocean with scattered islands and atolls.

Enhanced monitoring of the ocean and atmosphere over the western Pacific warm pool region, using ground-based weather stations, weather balloons, research vessel surveys, volunteer observing ships, moored buoys, surface drifters, and meteorological and oceanographic satellites, has begun in September 1991 and will continue up to December 1993. During the four-month IOP, from November 1992 through February 1993, COARE scientists will determine how moisture, momentum and heat are transfered between the ocean and the atmosphere during fair and stormy conditions. In addition to island-based surface observing stations equipped with radar and other atmospheric sounding and profiling devices, researchers are using the basic observational platforms of oceanographic and atmospheric research: ships, buoys, aircraft, balloons and satellites. These platforms carry advanced direct and remote sensors carefully calibrated to measure energy exchanges accurately.

A Multinational Effort

The COARE field experiment, coordinated from an operation and communication center in Townsville, Australia, requires a truly multinational research effort. More than 700 scientists, students, technical and logistical specialists and ship and aircraft crew members from at least 15 nations participate directly in the field research. During the IOP, more than a dozen ships, from Australia, France, Japan, the People's Republic of China and the United States, will deploy instrumented buoys and measure temperature, salinity, current and mixing in the upper ocean. Seven aircraft from Australia, the United Kingdom and the United States will measure temperature, moisture, precipitation and mixing in the atmosphere, operating from Townsville and Honiara in the Solomon Islands. The ship and aircraft data will be combined with measurements from special observing facilities, weather stations, balloons and satellites operated by many nations, including Australia, the Federated States of Micronesia, France, Germany, Indonesia, Japan, Nauru, New Zealand, Papua New Guinea, the People's Republic of China, Russia, the Solomon Islands, South Korea, Taiwan, the United Kingdom and the United States. Many governments will provide invaluable logistical support and assistance with transportation, housing, import and export regulations, customs clearances, and other administrative and diplomatic matters associated with a large-scale international scientific field experiment.

The Future

With COARE, as with any large field project in oceanographic and atmospheric research, a major part of the scientific work begins after the data-gathering phase is finished. Analysis and reanalysis of the COARE data to reach scientific conclusions about ocean/atmosphere interactions will start immediately after the IOP. This process can begin promptly because a system for data management (organizing the immense amounts of data collected in the field so they will be available to researchers as soon as possible in useful form) was developed as part of the overall experiment plan. The task of representing the scientific conclusions mathematically in coupled ocean/atmosphere models can proceed rapidly because pilot modeling studies before the field experiment helped define the kinds of data to be collected and the observing and measuring techniques needed to collect them. Weather forecasting and analysis centers of several nations will provide standard and special services to COARE during the course of operations. These centers will in turn use the COARE data set to improve models of ocean/atmosphere interaction and tropical and global forecasts. Although analysis of the COARE data set will continue for many years the ability of climate researchers to understand and predict present climate variability and possible future climate change should improve very quickly.

Note: This summary of the TOGA-COARE Program was originally prepared by the TOGA-COARE International Project Office and then amended by J. Picaut.

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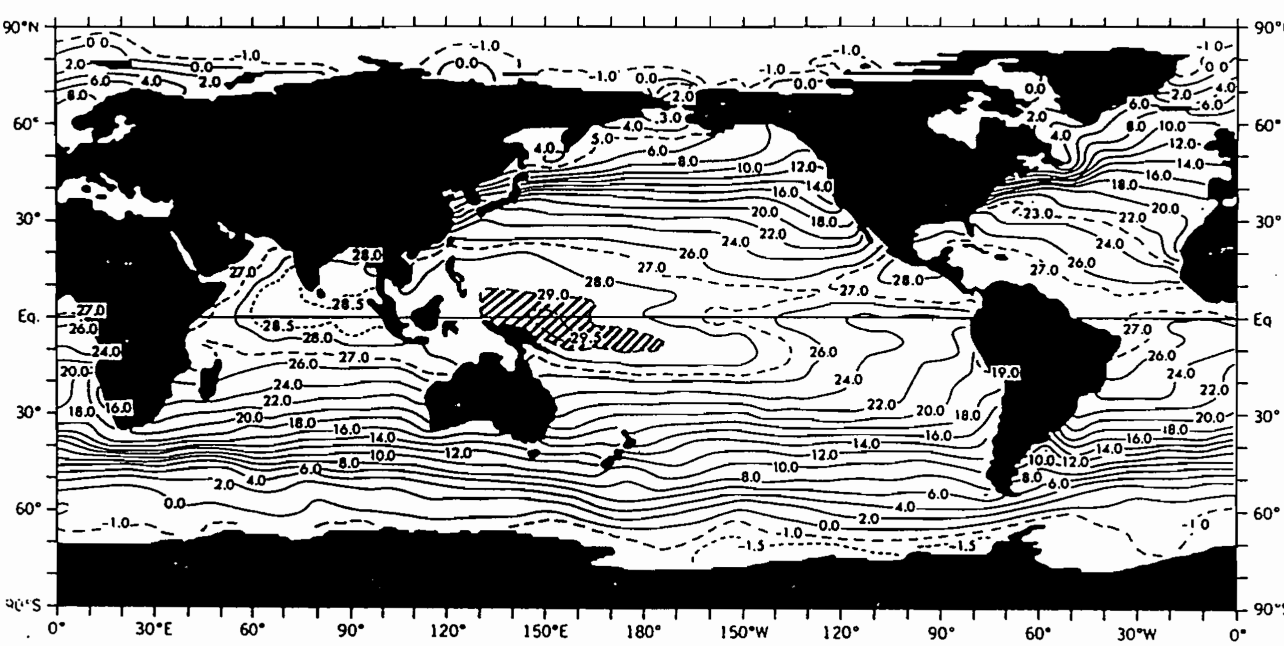

Figure 1

Mean sea surface temperature. Hashed area denotes temperature higher than 29°C (from Levitus, 1982)

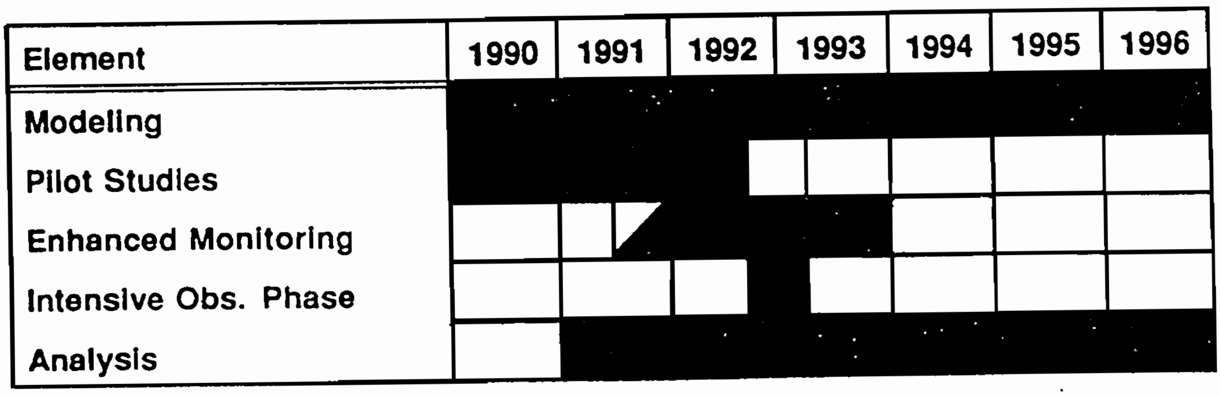

Figure 2

TOGA-COARE schedule of activities

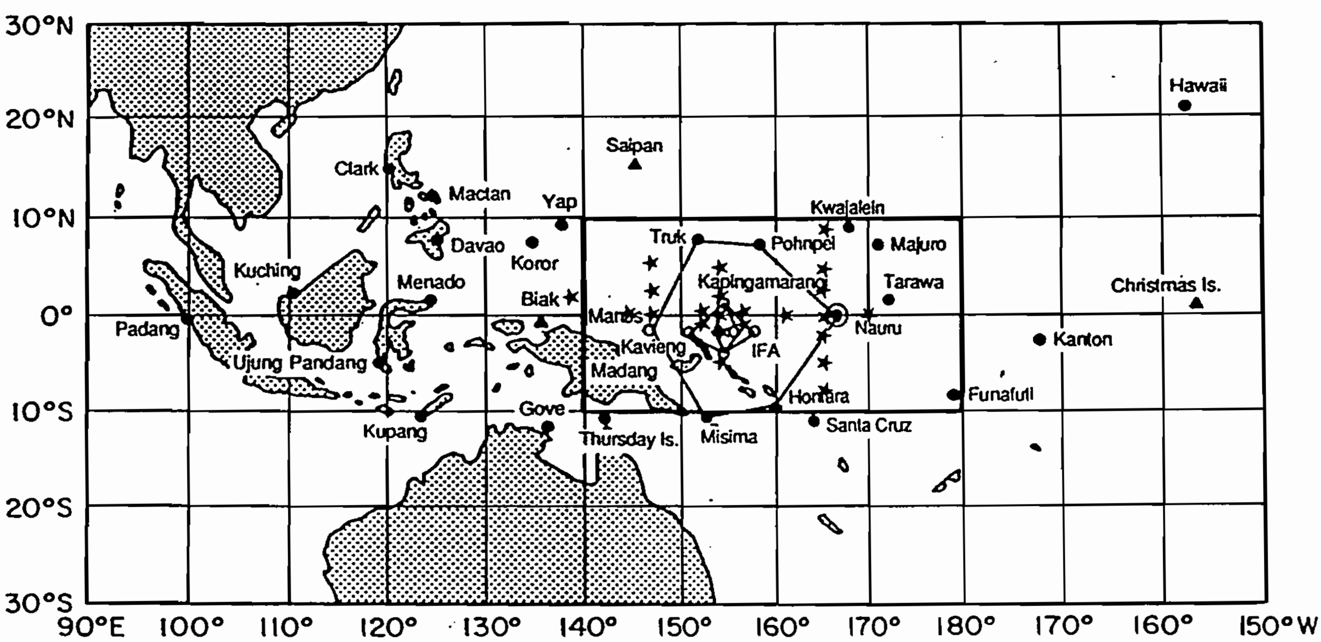

Figure 3

The TOGA-COARE region (10°N-10°S, 140°E-180°) showing the Intensive Flux Area (IFA) centered at 2°S-156°E, and the locations of lower-atmosphere profilers (solid triangles), proposed integrated sounding systems (open circles), rawinsonde stations (solid circles) and oceanographic moorings (stars)

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