Special Working Session on the Role of Buoy Observations in the Tropical Western Pacific Measurement Scheme

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Attending

W. Clements (TWPPO)
F. Barnes (TWPPO)
T. Ackerman (TWP Site Scientist)
M. Ivey (ARCS Manager)

H. Church	J. Curry
J. del Corral	B. DeRoos
S. Kinne	J. Mather
J. Michalsky	M. Miller
P. Minnett	B. Porch
J. Sheaffer	P. Webster
M. Wesely	K. Zorika
G. Zhang	

Focus of Discussion

The session convened on March 2, with brief introductions by Bill Clements. The purpose of the session was to discuss the scientific merits of retrofitting TOGA/TAO buoys with shortwave radiometers. Three questions were posed at the outset of the session to focus the discussion. These questions, followed by a summary of the general response (in italics) are as follows:

1. Does the Atmospheric Radiation Measurement (ARM) Program need widespread radiometric measurements in the Tropical Western Pacific (TWP) locale to augment the five Atmosphere Radiation and Cloud Stations (ARCS) and future ocean sites already planned?

   There was general agreement on and enthusiasm about the need for buoy-based radiation measurements in the TWP locale as well as across the equatorial Pacific. There was a consensus that ARM should take advantage of the TAO program to meet these needs.

2. If there is a need for these measurements, can buoy-based radiometers with satellites and other measurement platforms provide useful data?

   There was general agreement that instrumenting TAO buoys would provide essential scientific information.

3. If buoy-based radiometric measurements were made, who would use them?

   At least eight present at the session, as well as Tim Barnett in absentia, indicated they would use buoy-based radiation data if it were obtained.

Michael Reynolds explained what the Tropical Atmosphere Ocean (TAO) array is and summarized some of the measurement problems associated with buoy-based radiometry. A more detailed discussion of the problems was provided in a document prepared and distributed by Reynolds prior to the session; a copy is appended to this report.

Limited tests on the roof of a building at Woods Hole Oceanographic Institution (WHOI) indicate that mean tilt is the largest potential source of error in buoy-based shortwave radiometry using the Eppley precision spectral pyranometer (PSP). Limited data from the

First Air-Sea Interaction Experiment (FASINEX) indicate mean tilt is typically a few degrees. For the TAO array, tilt and buoy azimuth tend to vary slowly (order 1 cycle per day). The errors caused by wave-induced buoy motions are thought to be small (a few % of the total uncertainty). The time constant of the PSP (a few seconds) attenuates the effects of wave-induced buoy motion substantially.

The costs to instrument about ten TAO buoys (including radiation and tilt sensors, loggers, battery pack, and ARGOS transmitters) would be about $10K per buoy. The annual maintenance costs, including ARGOS data-link fees ($1K to $1.5K per year), would likely be less than $5K per buoy per year. Whether DOE would have to pay the annual maintenance costs is uncertain.

Accuracy

There was considerable discussion, and confusion, about the accuracy and precision implications of the WHOI and Pacific Marine Environmental Laboratory (PMEL) evaluations and what ARM might expect to achieve from PSPs on TAO buoys. Although we did not reach a consensus on this matter, some accuracy values mentioned included the following: we must do better than ~30 W m^{-2}; 10 W m^{-2} would be all right; and 3-4 W m^{-2} is the best that can be done at land sites. Chris Fairall's (National Oceanic and Atmospheric Administration [NOAA]) intercomparison with a high-quality gimballed ship system and a TAO buoy showed mean differences in daily averages of about 10 W m^{-2} and a mean difference over 30 days of about 7 W m^{-2}. Multi-year data from the TAO array show that El Niño-Southern Oscillation (ENSO) signals of about 50 W m^2 can be well resolved.

It appears that 10 W m^{-2} could be achieved with the currently available sensors; however, some doubt it (Joe Michalsky, for instance). John Sheaffer recommended that a careful study of the actual accuracy, using buoys, be completed before the TAO array is instrumented. He also suggested that the radiometers be calibrated aboard ship during routine maintenance cruises. Others thought that the PSPs should be sent to the National Renewable Energy Laboratory (NREL) for several weeks to be properly calibrated.

The calibration method would therefore be a big factor in the ultimate cost to maintain the array. The calibration issue was tabled until other operational parameters for the array are resolved.

Scientific Objectives

Several questions were asked concerning the objectives for instrumenting the TAO buoys. The responses were in four broad categories: 1) buoys could serve as extended facilities à la the Southern Great Plains (SGP) Site, 2) they could validate satellite observations, 3) they could populate a general circulation model (GCM) grid cell, 4) they provide information about ENSO-scale processes.

One objective would be to use the buoys to validate satellite observations. Several thought this to be a good idea. A second objective would be to monitor open-water conditions, primarily sea-surface temperature (SST) and the surface radiation fluxes, around ARCS(s) in a way analogous to extended facilities. A third objective would be to provide information about the east-west gradient in the surface conditions across the equatorial Pacific.

We discussed at length which objective might be met with the TAO array and how a subset of the buoys could be selected to optimize the value of the measurements in each case. As a result of the discussion, two general concepts for the array design emerged:

- the sparse, large-scale array
- the dense, or cluster, array.

One cluster design to satisfy the needs for satellite intercomparisons would be about 500-km square. A third design would be to design a cluster to characterize a GCM grid square. Another recommended approach was to cluster the instruments around ARCS and perhaps add other sensors to provide more complete information (infrared [IR]) thermometers, in situ SST sensors, and down-welling IR meters were among them). There was no agreement on how big a cluster surrounding an ARCS should be. The fourth design was a broad east-west array that could resolve ENSO-scale processes. This approach could focus on dynamic aspects in the equatorial wave guide or thermodynamic and radiative ones away from the equator.

Other Suggestions and Opinions

1. It would be very useful to get subsurface information to understand preconditioning of the upper water column by precipitation. Water temperature and salinity in the upper few meters would be good to have to test the Ramanathan thermostat and other hypotheses.
2. The TAO array is a high-priority item in the post-TOGA era (e.g., the Climate Variability and Predictability program). ARM should take advantage of it.
3. Do a GCM study (observation simulation system experiment) to optimize the array design.
4. Move the instruments during the TWP study to respond to changes in science priorities and the evolution of the ARCS deployments.
5. Look at satellite data to get a handle on the scale of the island effects around an ARCS.
6. Dr. Ramanathan (via John del Corral) suggested one buoy-based radiometer be placed between each island ARCS site. In a prior communication, he states:

   ". . .instrumenting TOGA-TAO arrays with solar pyranometers (if it can be routinely calibrated) is very critical and a must. Maybe, we do not need all of the moorings, but a small subset (say about 6 total) spaced between the ARCS site(s) would be adequate. But, we need some simulation studies to help design this subset. . . .the next important question concerns the importance of boundary layer and convection in regulating radiative and evaporative fluxes. It is unclear, how ARCS can address this issue. Again, TOGA-TAO arrays may be critical. . . ."
7. Dr. Barnett (verbally before the meeting and subsequently by EMAIL on March 17th) strongly endorsed the cross-Pacific "sparse array" for the study of climate connections. His EMAIL states:

   "mounting the radiometers on the TAO buoys immediately will have several benefits:

   a. The data can be used rather quickly to determine an optimum deployment of the ARCS. This would be done by looking at the spatial correlation function between the sensors. Given the likely cost of the ARCS it will be mandatory to justify their number. With no other adequate measurements of radiation currently available, the buoys are our only hope. They should be highly cost effective.

   b. The data will also help define the temporal sampling from the ARCS. . . .continuously, every 5 minutes or daily averages, etc. So we will quickly see if the MJOs (Madden-Julian Oscillation) are the dominate signal in the radiation field as they are in the latent heat flux field.

   c. We can begin doing science with the radiation data. . . .e.g., use it to validate the space/time structure of the radiation field as produced by the AGCMs.

   I am guessing that one could begin the above studies with maybe 6-12 months of data so the payoff will be quick.

   All the above is predicated on the fact that the sensors work, are reliable, maintain calibration, etc. This is mandatory! Since the TAO array is already in place, the ARM Program would incur cost only for mounting the radiometers. . . ."
8. Joe Michalsky suggested using 3 buoys on the equator at the east end of the TAO array, in addition to a cluster around the ARCS.

Next Steps

1. Write a specification for an ARM radiometer data logger which could be used on the TAO buoys and at other ARM sites such as the NAS.
2. Determine actual one-time and per unit costs for hardware. Determine operation costs per platform per year.

NOAA Collaboration

1. Re-visit the NOAA/PMEL prospectus. Establish a reasonable time schedule and data specification.
2. Negotiate a best cost for instrumenting a subset of the array.

Scientific

1. Coordinate a plan for progressive implementation of the array in a manner than optimally fulfills TWP scientific goals.

ARM Program

1. Coordinate all above activities with ARM management. By iteration between program resources, scientific goals, and instrumentation development, it is hoped some portion of the array can be instrumented in parallel with the ARCS deployment.

As noted, before the meeting, a more detailed discussion of the buoy array question was distributed. The text of that paper by R. M. Reynolds and the ARM-TWP Implementation Team follows.