DOE/SC-ARM-0505

Nauru Island Effect Study (NIES)
IOP Science Plan

June 2001

Chuck Long
Pacific Northwest National Laboratory
ARM TWP Site Scientist, NIES IOP Lead Scientist
Richland, Washington

Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Contents

Figures

Nauru Island Effect Study (NIES) IOP

Science Plan

1. Background

During June and July of 1999, the Nauru99 Experiment occurred. This experiment included participation by the Japanese Marine Science and Technology Center (JAMSTEC) research vessel Mirai, and the National Oceanic and Atmospheric Administration (NOAA) research vessel Ronald H. Brown, and a Flinders University of Australia Cessna aircraft. In addition, two simple instrument packages (hereafter referred to as "top side met") were deployed as shown in Figure 1 that included temperature, relative humidity, pressure, wind speed and direction, downwelling shortwave (SW) and upwelling longwave (LW) sensors. For Atmospheric Radiation Measurement (ARM) Program, the primary purpose of the experiment was to investigate if there are any island influences affecting the measurements recorded from the Atmospheric Radiation and Cloud Station (ARCS) located on the western side of the island.

Figure 1. Nauru island showing the location of the ARCS, and the two top side met instrument packages deployed during the Nauru99 Experiment. (J. Cole, PSU).

During the recent Department of Energy/ARM Nauru99 Workshop held at Pacific Northwest National Laboratory (PNNL), various results were presented that indicated there indeed is an island effect on the measurements being made at the Nauru ARCS2 site. Detection of an island effect was shown in many ways, including comparisons between ship and ARCS data, comparison of top side met and ARCS measurements, and even satellite images. The cause of this "island effect" is due to the ARCS2 site being located on the leeward side of the island, a siting that proved necessary given the limited available choices on Nauru. Of the results presented at the Workshop, Figure 2 shows a statistical comparison (provided by Jason Cole of Penn State University) of downwelling SW irradiance. On average, the downwelling SW measured at the ARCS site is significantly less than that measured at the two top side sites from about 10 a.m. local until about an hour before sunset. In addition, the ARCS SW measurements exhibit more minute-to-minute variability than the top side measurements. These effects are attributable to low level, small clouds being produced at time by the island. Figure 3 shows a comparison of top side and ARCS 1-minute SW measurements for July 12. As is shown, there is much more variability in the ARCS SW measurements on this day than those measurements taken top side. This island effect on the downwelling SW was also confirmed by the Ron Brown measurements. At the end of the Nauru99 Experiment the NOAA Ron Brown took measurements close to Nauru Island. Figure 4 shows a comparison of the ratio of Ron Brown over ARCS measured downwelling SW during the times when the Ron Brown was stationed just off shore, downwind of the ARCS site and on the opposite side of the island, upwind of the ARCS site. As Figure 4 shows, there is on average a 10% difference between when the Ron Brown is upwind of the island compared to downwind of the ARCS on these days. Certainly, this is compelling evidence that the leeward side location of the ARCS has resulted in an island effect on at least the SW ARCS measurements.

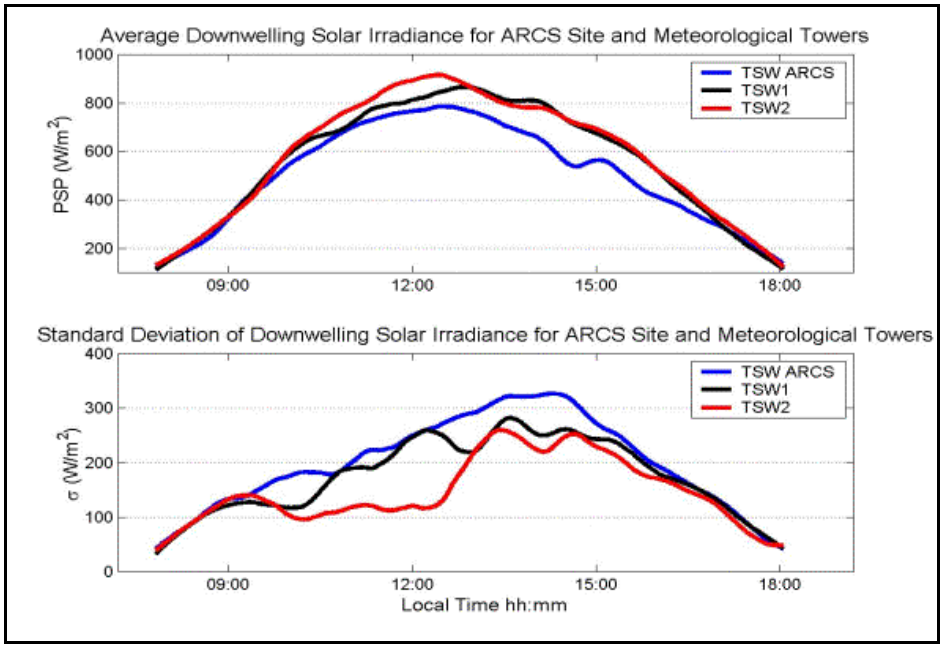

Figure 2. Comparison of average (top) and standard deviation (bottom) of measured downwelling SW irradiance at the Nauru ARCS (blue), and the two top side met packages (black and red) shown in Figure 1. (J. Cole, PSU).

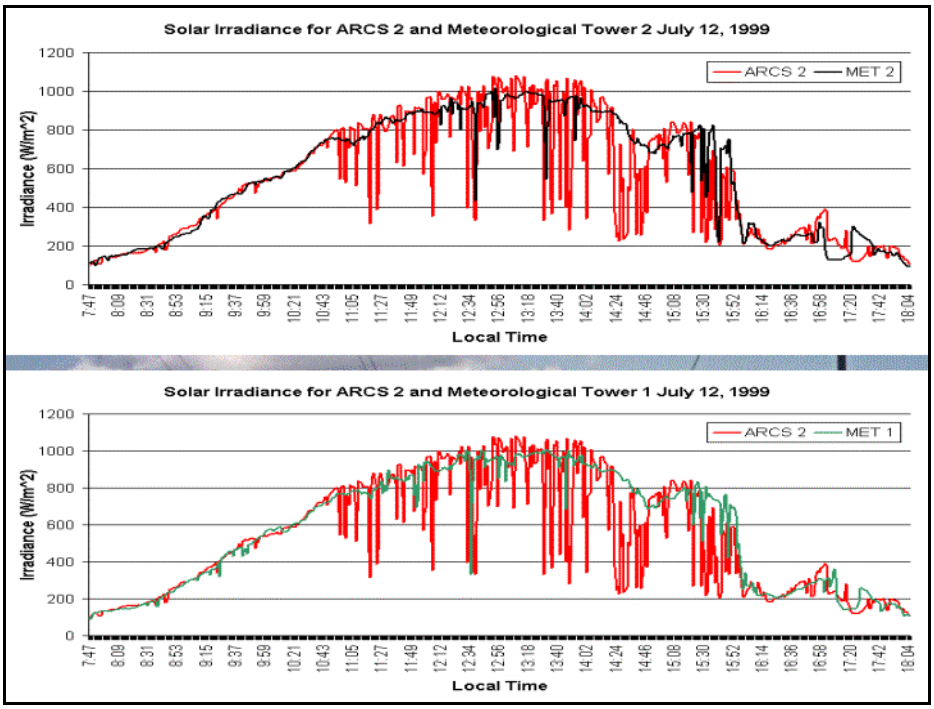

Figure 3. Comparison of 1-minute measured downwelling SW irradiance at the Nauru ARCS (red), and the two top side met packages (black and green) shown in Figure 1. (J. Cole, PSU).

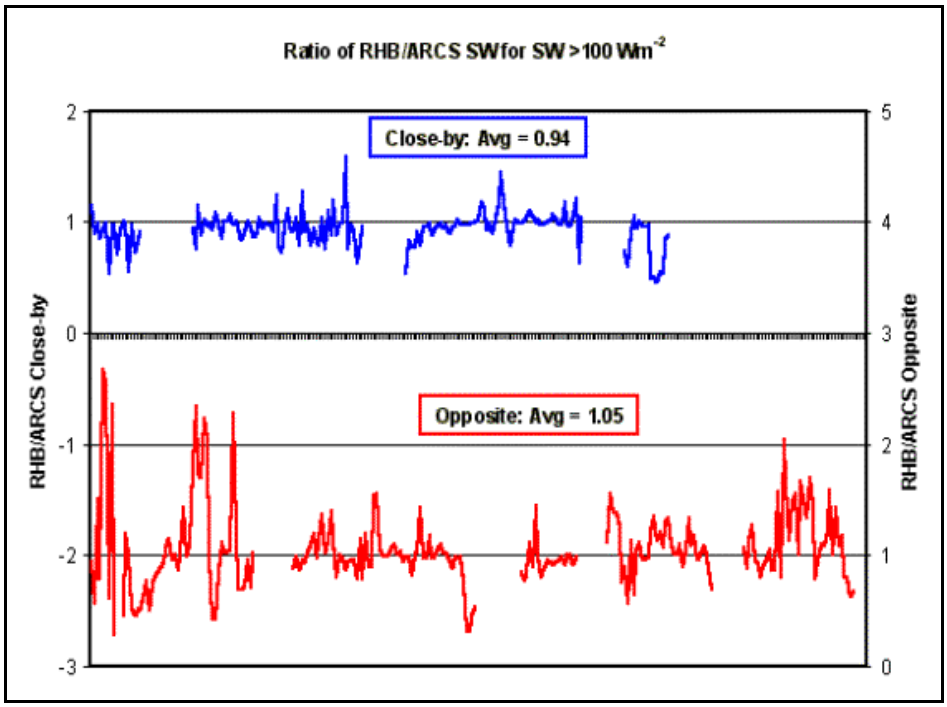

Figure 4. Comparison of the ratio of Ron Brown over ARCS measured downwelling SW irradiance at the Nauru while the Ron Brown was stationed just off shore, downwind of the ARCS site (top) on the opposite side of the island, upwind of the ARCS site (bottom).

Figure 5 shows a comparison, similar to Figure 2 top panel, but for the upwelling LW. In this case, the ARCS upwelling LW measurements are significantly lower than those top side. This is likely due to the mining that has occurred over the past few decades in the center of Nauru island, and is a contributing factor to the production of the low level cloudiness by raising the profile of the island via a "heat dome" effect. A summary of the major results presented by Jason Cole is given in Figure 6. Altogether, some measurements, such as moisture amounts and wind speeds, do not appear to be significantly affected by the island. Some measurements, such as wind direction (slightly) and downwelling longwave, appear to be consistently affected. Other measurements, such as downwelling shortwave, cloud base height statistics, and cloud amounts (not shown here) appear to be significantly, though only periodically, affected.

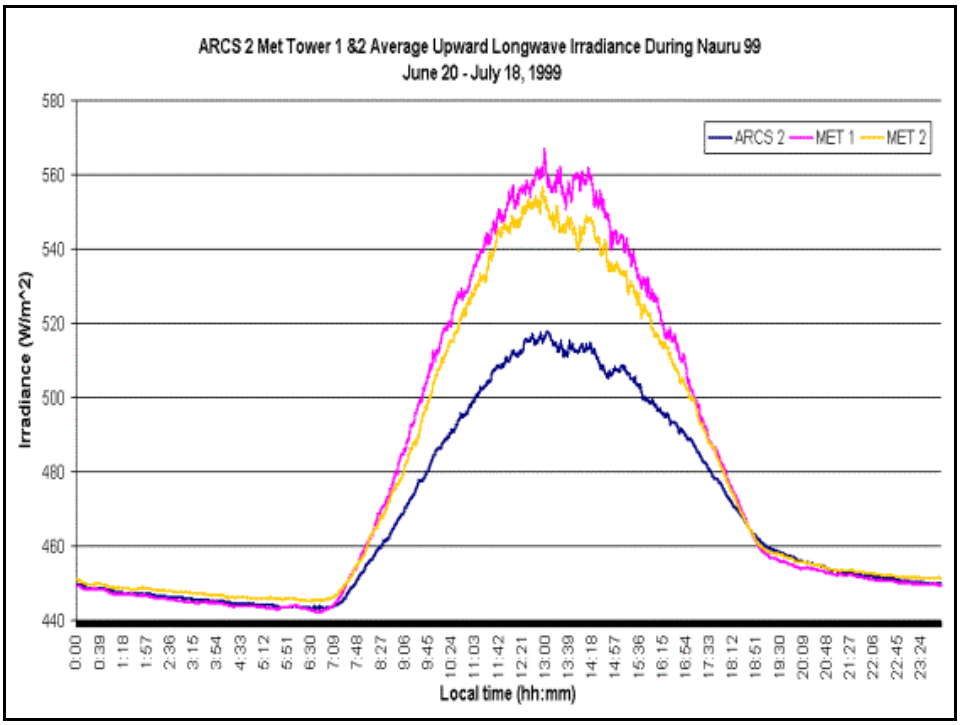

Figure 5. Comparison, similar to Figure 2 top panel, of the upwelling LW irradiance measured at the ARCS (blue) and two top side sites (pink and yellow) as shown in Figure 1. (J. Cole, PSU).

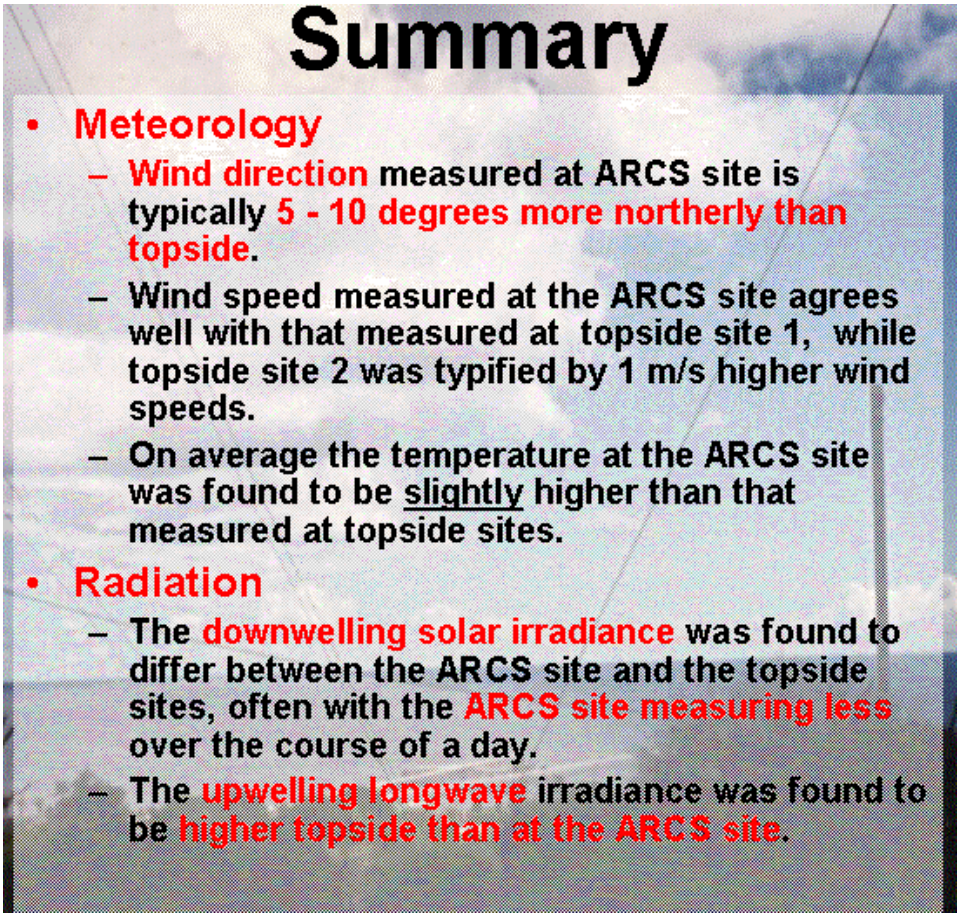

Figure 6. Summary of major findings by J. Cole, PSU, in comparison of Nauru99 top side data with corresponding ARCS2 data.

2. Scientific Requirement

An Island Effects Workgroup convened during the Nauru99 Workshop to discuss the Nauru99 results and propose strategies to address the island effect issue. Our discussion approach was based on two questions:

1. Is it enough to identify the occurrence?
2. Or must we "correct" for the effect using statistical and/or modeling approaches?

The results from the comparisons of ARCS measurements with those of the top side sites and the Ron Brown show that the occurrence of significant island effect can be detected by comparison of ARCS2 site measurements with corresponding measurements made on the windward side of the island. Windward measurements are also needed to further study and quantify the island effect as it relates to specific measurements. To this end, the Island Effect Workgroup produced two initial recommendations that were presented during the summary session of the Nauru99 Workshop:

1. Install the rough equivalent of a permanent "top side met stand" on the windward side of the island.

2. Propose an extended Intensive Operational Pertiod ("IOP") of more sophisticated instruments on the windward side of the island.

The first recommendation addresses the detection of significant occurrences of an island effect, and will allow the long-term study of effects on basic measurements. The permanent installation would be a rather simple collection of instrumentation including standard met measurements, downwelling shortwave irradiance (from perhaps a Licor pyranometer), and possibly a few others depending on initial results of the second recommendation. The idea is to have a self-contained, low maintenance package that uses radio broadcast of the collected data to the ARCS2 site.

The second recommendation, a call for a more temporary installation of more sophisticated instrumentation, is necessary to quantify the more important island effects shown so far on cloud amount, cloud base height frequency distributions, and surface radiation. In addition, these measurements can be used to relate these effects to the more simple measurements made by the permanent instrument package with an aim of possibly "correcting," or at least actively quantifying, what the island effects are in the data record on a continuing basis. The "IOP" instrumentation would include a ceilometer, since the island effect on clouds is restricted to the lower atmosphere given the distance from the windward shore and the ARCS site. Other suggested instruments include a Total Sky Imager, an Infrared Thermometer, and quality broadband shortwave and longwave instruments.

This Science Plan addresses primarily the second recommendation of the Nauru99 Island Effects Workgroup, a 1-year deployment of instruments on the windward side of Nauru island. This Nauru Island Effect Study (NIES) is proposed for the period early September 2001 through roughly end of August 2002. Significant preliminary work has already been accomplished related to this effort, such as contacting the Nauruan government to determine feasibility and degree of acceptance and cooperation. So far, all indications are that NIES is not only feasible, but welcomed.

3. Experimental Approach

In specific, what is proposed is a 1-year deployment of a moderately sophisticated instrument package on the windward side of the island, with the expectation that there will thereafter be a permanent installation of a far less sophisticated and low-maintenance set of instrumentation. The specific instruments for the NIES 1-year deployment are:

1. Upward facing broadband radiometers
   - shaded, ventilated B&W pyranometer
   - unshaded, ventilated precision spectral pyranometer
   - shaded, ventilated precision infrared radiometer
   - normal incidence pyrheliometer
   - solar tracker
   - unshaded Licor pyranometer

2. Upward facing infrared thermometer

3. Met package (T, P, relative humidity, wind speed, wind direction)

4. Ceilometer

5. ea. – Total sky imager (TSI)-880 sky imagers, one in the windward package, one at the ARCS2 site

6. Mult-filter rotating shadowband radiometer (MFRSR)

It is expected that it will be possible to relate the wind direction with the occurrence of an island effect on the ARCS2 measurements, since if the ARCS2 is not down wind of the island then there likely is not an island influence on the ARCS measurements. In addition, we expect to be able to at least identify when a significant an island effect occurs through comparison of the NIES and ARCS downwelling SW shortwave irradiance measurements. This detection is likely possible through comparison of the temporal variability, as much as through comparison of magnitude, of the downwelling SW. Thus, we will study the relationship between the fielded Licor and tracker-mounted instruments in the hope that for the longer term the Licor will be sufficient for this purpose.

The other focus of NIES data analysis is to relate the meteorological and downwelling SW measurements to the comparative differences in low cloud base heights and frequency of occurrence, cloud base temperature statistics, cloud amounts, and aerosol optical depths. This analysis is intended to address the questions posed by the Nauru99 Island Effects Workgroup regarding whether it is enough to merely identify the occurrence of an island effect on the ARCS2 measurements, whether it is possible and/or feasible to try to quantify the island effect on shorter time scales (rather than just quantify the long-term statistics of the island effect), or is it feasible to remove the island effect from the ARCS2 data. The feasibility here is related not only to the certainty with which the NIES measurements can be used to identify and quantify the island effect, but the determination of the instrumentation and operational cost needed for permanent measurements to do so. These issues will be addressed as part of the NIES analysis.

Related to the possible instrumentation that could be cost-effectively installed on a permanent basis, the SW Flux Analysis code (Long and Ackerman 2000; Long 2001; Long et al. 1999) has been adapted to the MFRSR data stream. Since the MFRSR includes a broadband SW channel, it is likely that the MFRSR can be used to infer sky cover. (For the Tropical Western Pacific [TWP], the SW Flux Analysis code must be run to fit clear sky data over periods much longer than a day, since the occurrence of “clear enough” days as defined in Long and Ackerman [2000] are rare. This mode of running the code works well for determining total SW cloud effect, but is less accurate in determining daily clear-sky estimates of diffuse SW, which in turn are used to infer sky cover. Thus, there is some research still needed to better adapt the SW Flux Analysis code to infer sky cover when run in this mode.) Given this, the primarily “hands-off” operational capability of the MFRSR, and the likely affect of the top side phosphate mining on aerosol amounts downwind of the island, it may be prudent to consider leaving the MFRSR as an addition to the permanent instrument package. This last will also be determined as part of the NIES analysis.

For the permanent installation, it is anticipated that a minimum of the NIES Met package and the upward facing Licor pyranometer will be needed. This, however, depends on the exact results derived from the 1-year study. We expect that after about 6 months of data, the TWP Site Scientist Office personnel will be able to determine the specific instrumental needs and costs for various levels of island effect detection, quantification, etc. These results will then be presented for discussion so that we can adjust our planning accordingly for the permanent installation.

The location of the NIES instruments will be on the windward side of Nauru, near the Menen Hotel. The Menen hotel is located on the eastern side of Nauru, just to the south of Anibare Bay (Figure 7). The plan is to set up a 1-year lease of one of the end hotel rooms to house the data acquisition and logging computers, as well as the system power converters and uninterruptable power supply. This will also supply the power needed for the instrument platform, and some security. Our first choice is to locate the instruments in a fairly cleared, level area on the north end of the hotel Figure 8 (circled in red). This north end of the hotel has a sufficient field of view (FOV) generally free of significant obstructions, and requires minimal site preparation. Should the area on the north end of the hotel prove unavailable, the NIES platform could possibly be located at the south end of the hotel. This site, however, has more obstructions to the FOV such as a few palm trees along the shoreline and a large cage for housing birds.

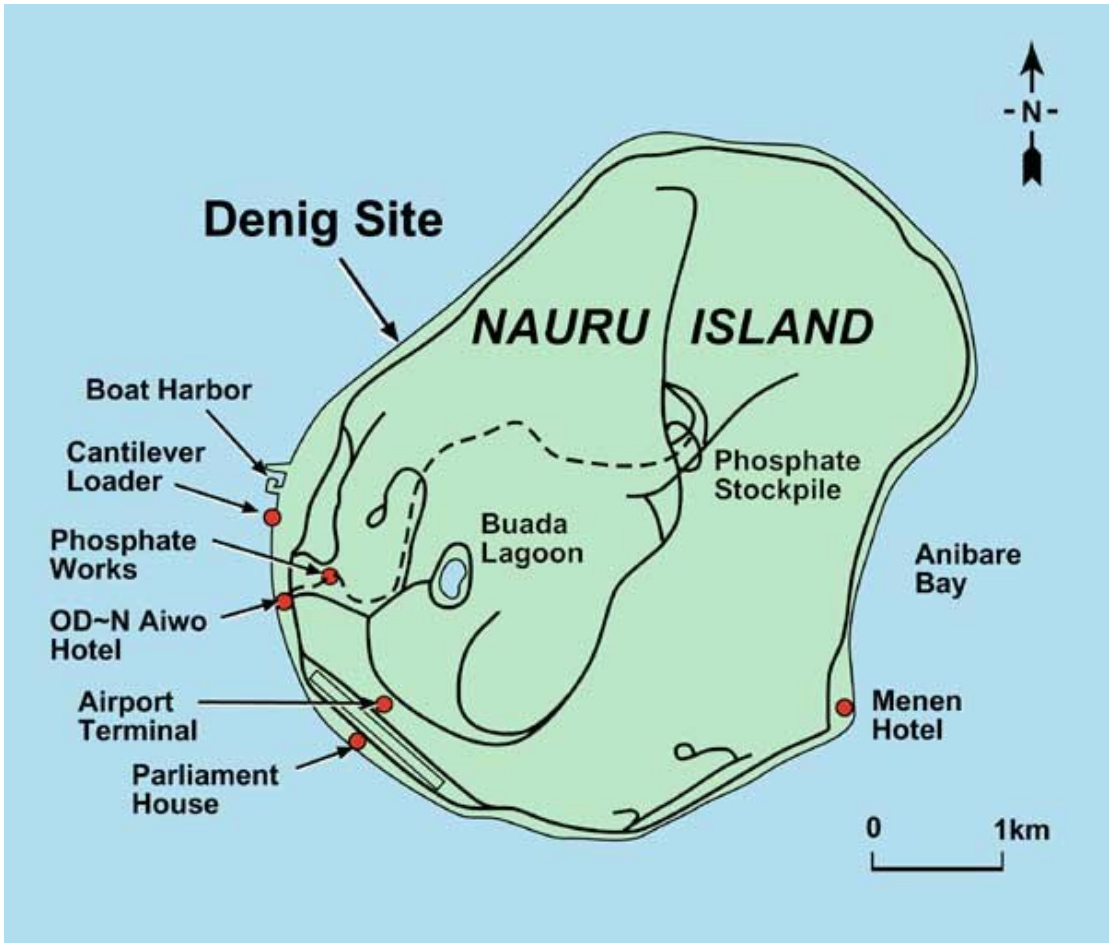

Figure 7. Map of Nauru showing the location of the Menen Hotel, proposed location of the NIES windward instrument site.

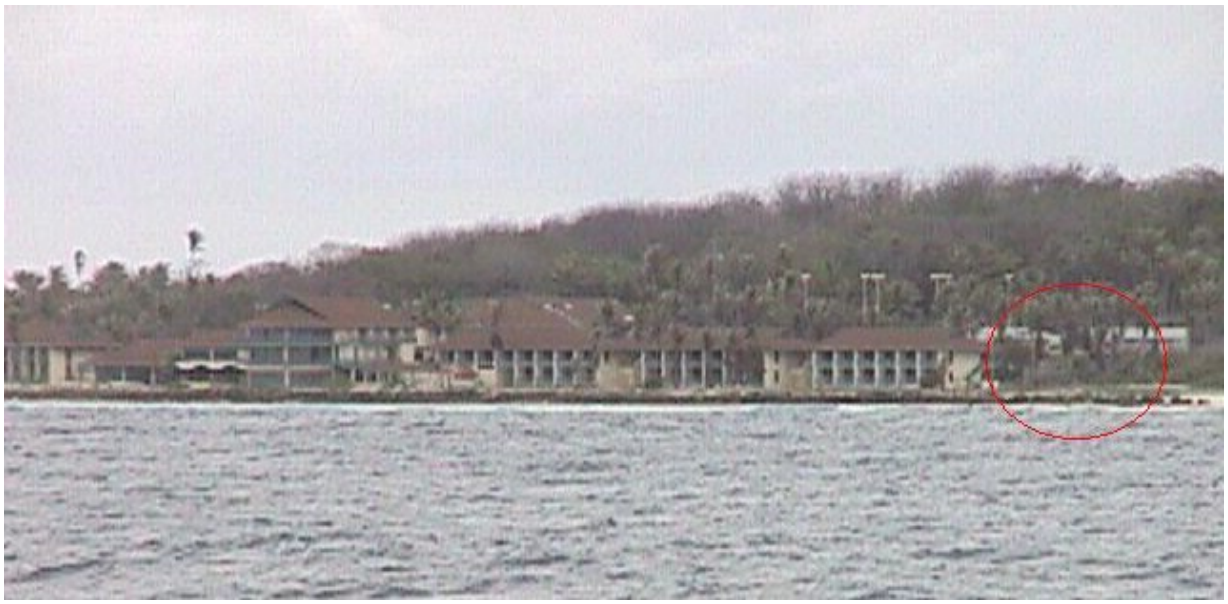

Figure 8. Photo of the Menen Hotel showing the proposed location of the NIES windward instrument site (red circle).

Contacts by Bill Clements and Larry Jones of the TWP Program Office have garnered support for the NIES from the current President of Nauru. The NIES Proposal included in Appendix A was forwarded to Andrew Kaierua and Joseph Cain of the Republic of Nauru Department of Industry and Economic Development in order for them to pursue the required arrangements and permissions needed. To date, all indications are that the locating the site at the north end of the hotel and a 1-year lease of the north corner ground floor room are achievable.

4. Special Issues Affecting Implementation

For the IOP deployment it is important to note that the intent of the NIES 1-year study is to quantify the island effect in our ARCS2 measurements. As such, it is imperative that the same instruments (make and model) be deployed to windward as we have at the ARCS2 to eliminate instrument-type differences and record only island effect differences in the measurements. This naturally includes the need that the same instrument maintenance practices be performed as well (i.e. daily dome cleaning, etc.). The one exception to this is for the Licor pyranometer and Met instruments. Since these instruments are the minimum required for the permanent installation, and it would be most cost-effective if they could be run primarily in a “hands-off” mode for the long term, they need to be run in the same “hands-off” mode (at least initially) during NIES. These Met and Licor data will need to be analyzed for the extent of the detrimental effect of not being attended to on a daily basis, and for determination of the type and periodicity of attention needed for the long-term deployment. This determination of needed attention is also related to the determination of certainty needed, given the results of the discussion on what should be included in a permanent installation noted in the previous section.

5. Proposed Timeline for IOP

Assembly and testing of NIES instruments and data acquisition system
– in progress.
– complete by end of July

pursue the required arrangements and permissions needed on Nauru
– in progress
– include necessary arrangements for site permission and preparation
– complete by end of August

Install NIES site
– beginning of September,
– anticipate 1 week, Kevin Widener, Chuck Long, 1 Aus BOM RESET Tech
– Include installation of TSI and SciTech tracker at ARCS2

6-month mark of NIES
– Site Scientist office provides summary of analysis to date
– discussion of permanent instrument system
– design and necessary arrangements for permanent instruments
– most likely at the Menen hotel, flat roof between north and south sections
– of the hotel previously identified

End of NIES, 1-year after data collection start
– pack up NIES temporary instruments
– anticipate 1 week, 3 people
– Include installation of permanent instrument system

6. Proposed Participation in IOP

This IOP is sponsored by the TWP Site Scientist Office, and at present includes only TWP PO and TWP SSO participation. During the 1-year of the study, there is a possibility of some participation by the JAMSTEC R/V Mirai, but at no cost to ARM should this occur.

7. Anticipated Data Processing and Delivery

The data collected for NIES will be stored on portable media and shipped to PNNL along with the regular monthly data shipments from the Nauru ARCS2. The TWP Site Scientist Office will monitor and process the NIES data, including quality assessment, and make it available as IOP data. It is anticipated that the NIES data can be archived within 4-6 weeks after arrival at PNNL on a continuing basis. In order to promote and encourage ARM Science Team participation in analysis of these data, the TWP Site Scientist Office recommends no further access restrictions for these data other than the time necessary for quality assessment and release to the IOP archive.

8. References

Long, CN, and TP Ackerman. 2000. "Identification of clear skies from broadband pyranometer measurements and calculation of downwelling shortwave cloud effects." *Journal of Geophysical Research* 105(D12):15609-15626.

Long, CN. 2001. The Shortwave (SW) Clear-Sky Detection and Fitting Algorithm: Algorithm Operational Details and Explanations, Atmospheric Radiation Measurement Program Technical Report, ARM TR-004, Available via http://www.arm.gov/docs/documents/tech_reports/index.html.

Long, CN, TP Ackerman, JJ DeLuisi, and J Augustine. 1999. "Estimation of Fractional Sky Cover from Broadband SW Radiometer Measurements." In Proceedings of the Tenth Conference on Atmospheric Radiation, June 28-July 2, Madison, Wisconsin.

Appendix A

NIES Proposal sent to Nauru Department of Industry and Economic Development

Appendix A