SCIENCE AND OPERATIONS PLAN (DRAFT)

Nauru99

An International Study of Tropical Climate in the Vicinity of Nauru Island in the Tropical Western Pacific Ocean

Fri, Apr 23, 1999 - Current Draft

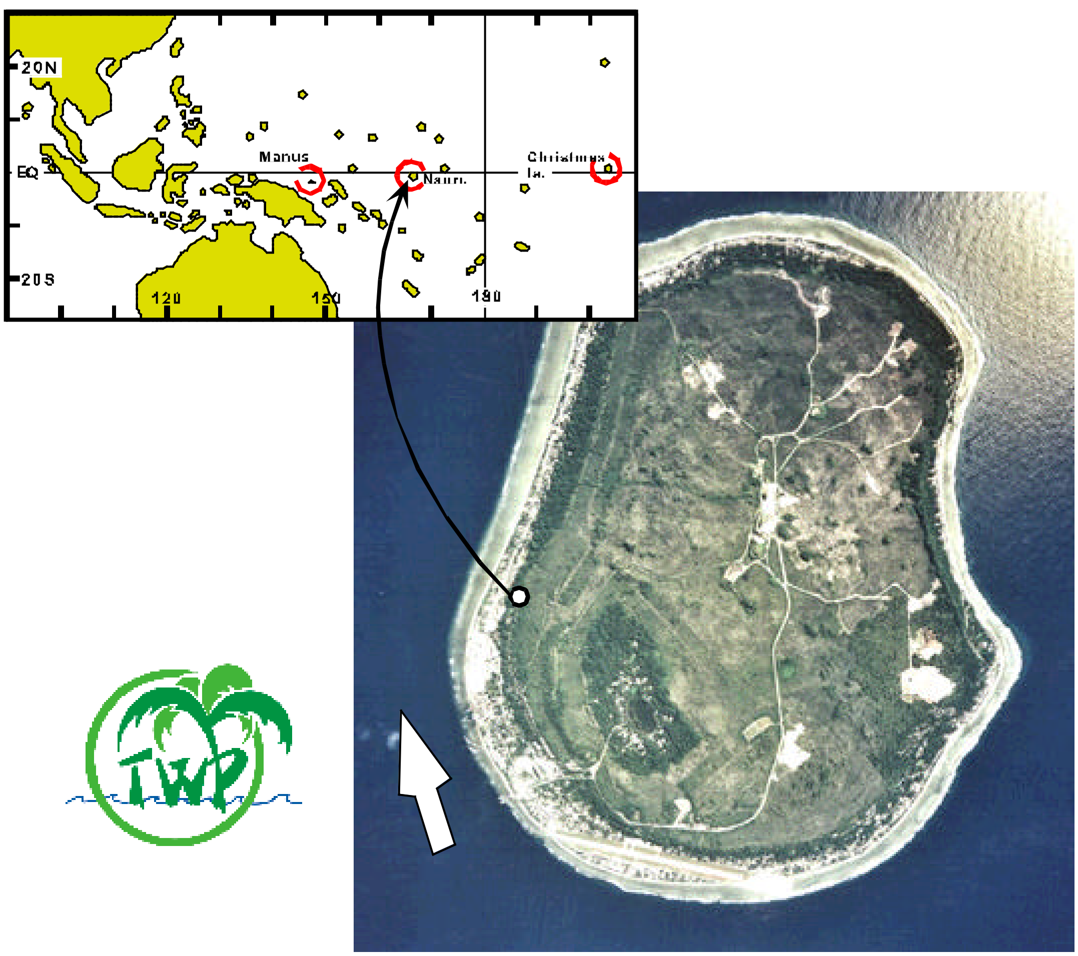

Figure 1 (Cover). Shows a map of the ARM TWP locale and the location of current and intended ARCS sites. An aerial photograph of Nauru Island shows the effects of phosphate mining. The airport on the south side of the island gives some idea of the small size of the island. Logos across the top of the page represent JAMSTEC, DOE/ARM, and NOAA.

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WEB ADDRESSES

www.arm.gov	D.O.E. ARM home page
www.armocean.bnl.gov/nauru99	BNL Nauru99 home page
www.arm.gov/sites/TWP/twp.html/	TWP ARCS home page
www.lanl.gov/staff/clements/nauru99/	Nauru Island Nauru99 information
www.etl.noaa.gov/nauru99/	NOAA ETL Nauru99 home page
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Contents

1 Summary

The tropical western Pacific Ocean (TWP) is considered to be a fundamental driver of climate variations over the entire globe. The U.S. Department of Energy's (DOE's) Atmospheric Radiation Measurement (ARM) program in the TWP seeks to better understand the processes which effect this region and also the mechanisms by which the TWP effects world climate. The ARM Science Plan emphasizes three elements: long time series of basic observations at several locations, intensive field campaigns, and long-term measurements of properties and fluxes over the ocean.

A major element of the TWP program is installation of Atmospheric Radiation and Cloud Stations (ARCS) on islands along the equator. The first installation was on Manus Island, Papua New Guinea in October 1997 (Mather *et al.*, 1997). The second station was installed on Nauru Island in September 1999. The ARCS stations supply measurements of the surface radiation budget and radiatively important atmospheric properties at single points. But questions on the ability of island measurements to properly represent conditions in this oceanic regime are of paramount importance for the interpretation of measurements. Consequently, the ARM program must make a concerted effort to determine the extent to which those observations represent the oceanic environment around the islands. This requires making similar measurements on the open ocean near the islands. Also, there are a variety of atmospheric processes, for example, the vertical transport of water and energy by tropical convection, that cannot be addressed within normal operating conditions in the TWP due to logistical and cost constraints.

Nauru99, the second intensive operation related to the TWP program, was conceived to address several hypotheses: (a) We believe that island effects are minimal during periods of active convection, the Madden-Julian Oscillation (MJO) effects and during the night. (b) There may be some island effects during the day. (c) Small islands do not effect isolated cirrus clouds. and (d) Island effects will be noticable in cloud fraction and liquid water content, but the impact of the small islands on overall downwelling radiation relative to the open ocean is small.

The Nauru99 operation will commence on 17 June with the arrival of the Japanese ship *MIRAI* to the Nauru vicinity. The NOAA ship *RON BROWN* will arrive a few days later (June 23) and these two heavily instrumented research vessels will occupy stations in two different patterns designed to study different mesoscale processes. In the large triangle pattern, each ship will take position near NOAA TAO buoys at 165W longitude, equator and 2°S, forming, with the ARCS site, a triangle with sides of approximately 200 km. The small triangle will have sides of 25, 41, and 50 km. Concentrated platform intercomparisons will be made near the island. The MIRAI departs from the area on July 5 and the RON BROWN will remain to make close-in comparisons with the island site until it departs on July 17, 1999.

The instrumentation on the *MIRAI* and the *RON BROWN* is considerable. Both ships will have almost redundant instrumentation to that on the island, including Lidars, S-band radars, radiosondes, and radiometers. Each ship will be operating 5-cm Doppler weather radars and dual-Doppler studies of clouds are expected. Each ship will be fully equiped to make direct measurements of all components of the air-sea energy flux, both by direct eddy-correlation and by bulk transfer methods. Aerosols will be collected and analysed.

Research aircraft will be deployed throughout the operation with the goal of providing coverage between the vertices of the triangles. A suite of aerosondes will be deployed by the Australian Bureau of Meteorology. Sets of aerosondes fly will in various combinations along the legs of the triangles. A Cessna research aircraft from Flinders University, Adelaide, Australia, will concentrate on covering the boundary-layer structure along the legs and in the center of the triangles.

2 Background

There is a strong relationship between climatic variability in the tropical western Pacific (TWP) and variability in other regions of the globe. These connections are well documented in the meteorological and oceanographic literature (c.f., reports by the United States CLIVAR Implementation Planning Report (CLIVAR, 1996) and the World Climate Research Programme (CLIVAR, 1997)).

The ARM Science Plan (DOE, 1996) lists three primary research objectives for the TWP:

1. Surface radiation budget and cloud forcing.
2. Water and energy budgets of clouds and cloud systems.
3. Ocean-atmosphere interactions.

The Science Plan also gives three critical elements for the TWP observing strategy:

A. A long time series of basic observations at several locations.
B. Intensive field campaigns to augment the long-term measurement sets.
C. Long-term measurements of properties and fluxes at the ocean-atmosphere interface.

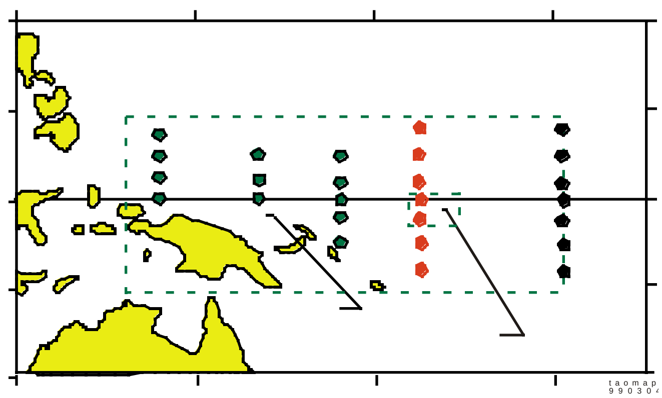

Figure 2: A map of the TWP locale showing locations of the two ARM Atmospheric Radiation and Cloud Station, ARCS, sites on Manus and Nauru Islands, the locations of TAO buoys (circles), and the area of interest for the Nauru99 campaign. Three colors are used for buoy locations: **green** designates the locations for the TRITON buoys which will replace the current NOAA TAO Atlas buoys in the next few years, **red** marks the next-generation NOAA Atlas buoys with advanced radiometers, and **black** marks the conventional Atlas buoys which have no radiation measurement.

The installation of the Atmospheric and Cloud Radiation Stations (ARCS) at Manus Island, Papua New Guinea (Mather *et al.*, 1997) and at Nauru Island (Figure 2), begins to address the first observational element. Other ARCS are planned for additional tropical sites in the future (cover figure). The ARCS will provide measurements of the surface radiation budget and radiatively important atmospheric properties across the expanse of the TWP. It is well known that the radiation budgets at the two island sites are highly variable, both in space and in time (Figure 3) and the ARCS are located to best monitor these variations. Manus Island is roughly 75 km in length and 50 km in width. The ARCS site is located on the southeastern extremity of the island on flat, uniform terrain. Nauru is a very small island, approximately circular with a 5 km diameter, and the ARCS site is immediately adjacent to the shore on the southwest side.

The need for the latter two elements of the observing strategy is quite clear. First of all, the ARCS measurements are all being made on small islands. Consequently, the ARM program must make a concerted effort to determine the extent to which those observations represent the oceanic environment around the islands. This requires making similar measurements on the open ocean near the islands. Secondly, the ARCS are located on land surfaces, but the surface of interest is the adjacent ocean. Thus, ARM must support periodic efforts to measure the radiation and heat fluxes at the ocean surface. Thirdly, there are a variety of atmospheric processes, for example, the vertical transport of water and energy by tropical convection, that cannot be addressed within normal operating conditions in the TWP due to logistical and cost constraints.

The ARM program has already begun to work towards testing these observational strategies through participation in joint tropical experiments and ship cruises. Participation in TOGA COARE and MCTEX proved valuable both in terms of the scientific return and the experience gained for instrument deployment and operation in the tropics. Recent ship cruises—CSP cruise (Post *et al.*, 1997) and TOCS-JUSTOS (Reynolds and Smith, 1997)—have provided valuable data sets. Analysis of the CSP cruise data taken in the vicinity of Manus has provided some very interesting insights, although the data are insufficient to provide definitive answers. The indication from the cloud data is that low cloud heights are much the same on the island as over the ocean, but there is greater fractional coverage over the island by low clouds. (Due to the lack of an MPL during the CSP visit, no assessment of high clouds could be made.) A diurnal cycle in the circulation was identified on the island but, interestingly, the same cycle appears over the ocean. The working hypothesis is that the entire oceanic area around Manus experiences a diurnal circulation driven by the influence of the high mountains on the island of New Guinea, as well as the mountains on New Britain and New Ireland. Confirmation of this awaits further study.

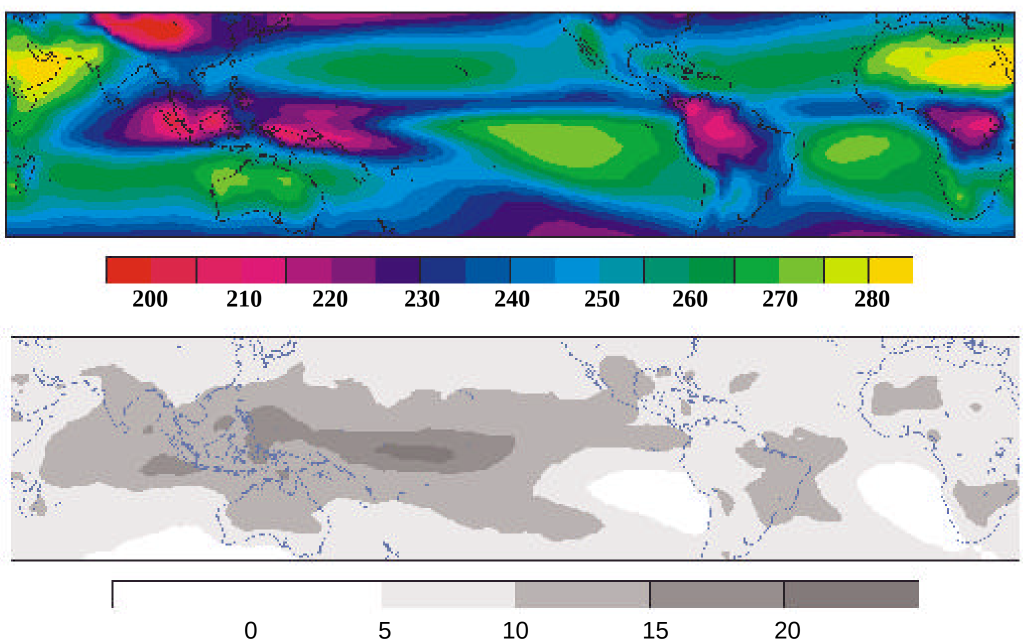

Figure 3: The outgoing longwave radiation (OLR) from the tropical pacific as measured from space. OLR, a surrogate for cloud-top height, is quite low in over the TWP, an indication of the high cumulus convective clouds there. The lower panel shows the standard deviation in OLR over the climatic averaging period. Nauru Island is located in the region of highest variability.

As a first step toward the third element, the NOAA Pacific Marine Environmental Laboratory (PMEL), with support from ARM, has developed new data loggers and shortwave radiometers that will substantially upgrade insolation measurements in the tropical Pacific. Eight TOA buoys along the 165°E meridian (Figure 2) have been instrumented with the new packages. Buoys at 8N, 5N, 2S, and 8S were instrumented with the new packages in June 1997. The line was fully instrumented in January 1998. These solar measurements will provide a limited but continuous data set to compare to the measurements made on Nauru. Questions regarding the accuracy and utility of these buoy measurements need to be addressed as part of the Nauru99 operation.

Nauru99 was conceived in order to continue implementing observational objectives B) and C) as they relate to island effects. A primary scientific goal of this campaign is to document the local influence of the island and thereby to assess how representative the Nauru ARCS measurements are of the surrounding oceanic environment. A secondary scientific goal is to determine the surface radiative budget of the ocean environment around Nauru, and obtain a data set that can be used to relate TAO buoy measurements to this radiative budget. An additional programmatic objective is to learn how to carry out campaigns with multiple platforms (Figure 4) in the TWP locale given the logistical difficulties.

The project is fortunate to have two participating ships. Two triangular configurations have been devised so as to take full advantage of the extended coverage. From a large triangle configuration, data sufficient to run and confirm a 200-km scale single column model will be taken. The small triangle configuration will be designed so that a dual Doppler radar investigation of cloud systems is possible.

The scientific questions that are addressed by ARCS measurements at Nauru (and other sites) basically fall into two categories. The first category is climatological, e.g. What is the monthly-mean downwelling solar irradiance at the site? The second is process oriented, e.g., What is the impact of the ubiquitous cirrus cloud (see figure 3) with a given optical depth on the downwelling solar irradiance at the surface? One of our working hypotheses for island sites is that the second category of observations is essentially unaffected by an island. This means that the microphysical properties of clouds over the island site are the same as those of similar cloud types over the ocean. A second working hypothesis is that the first category of observations is weakly influenced by the island, and that we can identify those periods and cloud types that are most likely to be influenced by the island. More specifically, we think that

1. Island effects (Figure 5) are minimal during periods of active convection (the active phase of the Madden-Julian oscillation) and at night.
2. Island effects may be detectable during the day during periods of suppressed convection.
3. Island effects are not important for isolated cirrus clouds.
4. Island effects are most likely to be detectable in the measurements of cloud fraction and perhaps liquid water content; however, the impact of these differences on the overall downwelling radiation budget over the island, relative to the open ocean, is likely to be small compared to the overall impact of clouds on the radiation budget.

These hypotheses are the result of our analysis of COARE data collected at island sites and over the ocean (Long, 1996), as well as satellite data analysis (Reynolds, personal communication and Barr *et al.*, 1997). In addition, based on our COARE data analysis, we think that solar irradiance measurements made either on the island or on a buoy and averaged over periods on the order of a month are representative of relatively large spatial areas on the order of hundreds of kilometers. Finally, we think that surface flux measurements made from buoys near the island can be used to characterize the oceanic environment around the island. The Nauru99 field campaign is being designed to address these issues.

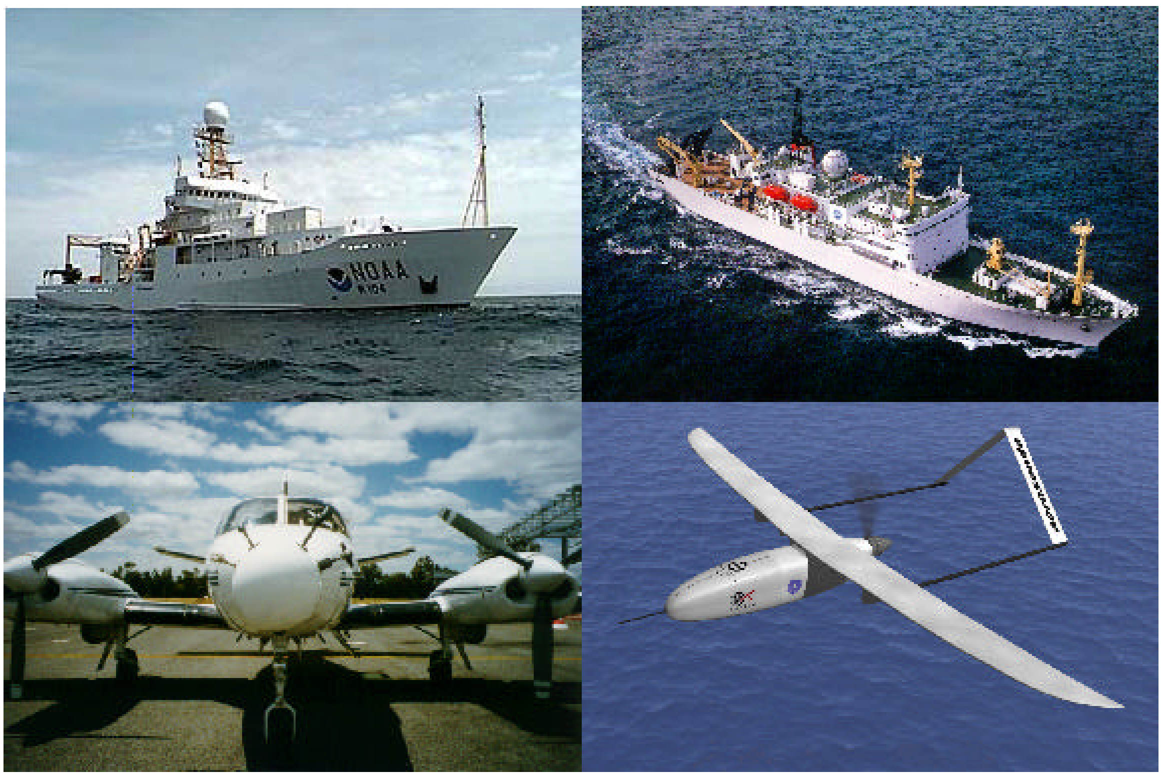

Figure 4: Instrument platforms that will be used during Nauru99. From the top left and clockwise: the NOAA ship R/V *RON BROWN* , the Japan Marine Science and Technology Center (JAMSTEC) ship R/V *MIRAI*, the un-manned aircraft Aerosonde, and the Cessna 404 boundary-layer research aircraft. Both ships carry 5-cm Doppler weather radars.

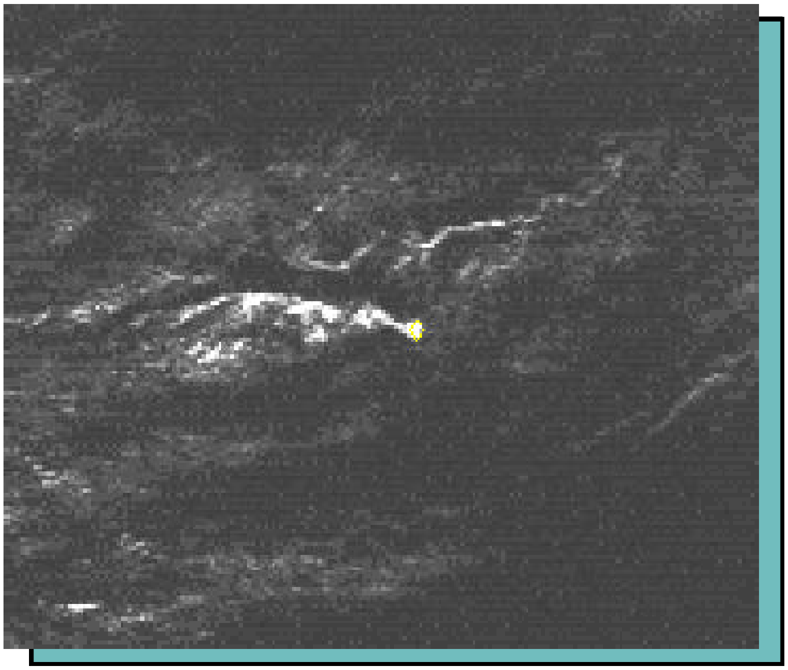

Figure 5: A striking example of convective cloud formation being triggered by Nauru I. The island is in the center of the image, and the island-induced clouds form a plume to the west. The presence of clouds eleswhere indicates that the conditions were conducive to cloud formation and Nauru provided the trigger for localized cloud formation. The image is from the visible channel of the Japanese GMS satellite and was acquired on 10 April 1996 at 01:42 UTC. Courtesy of Peter Minnett, Univ. of Miami.

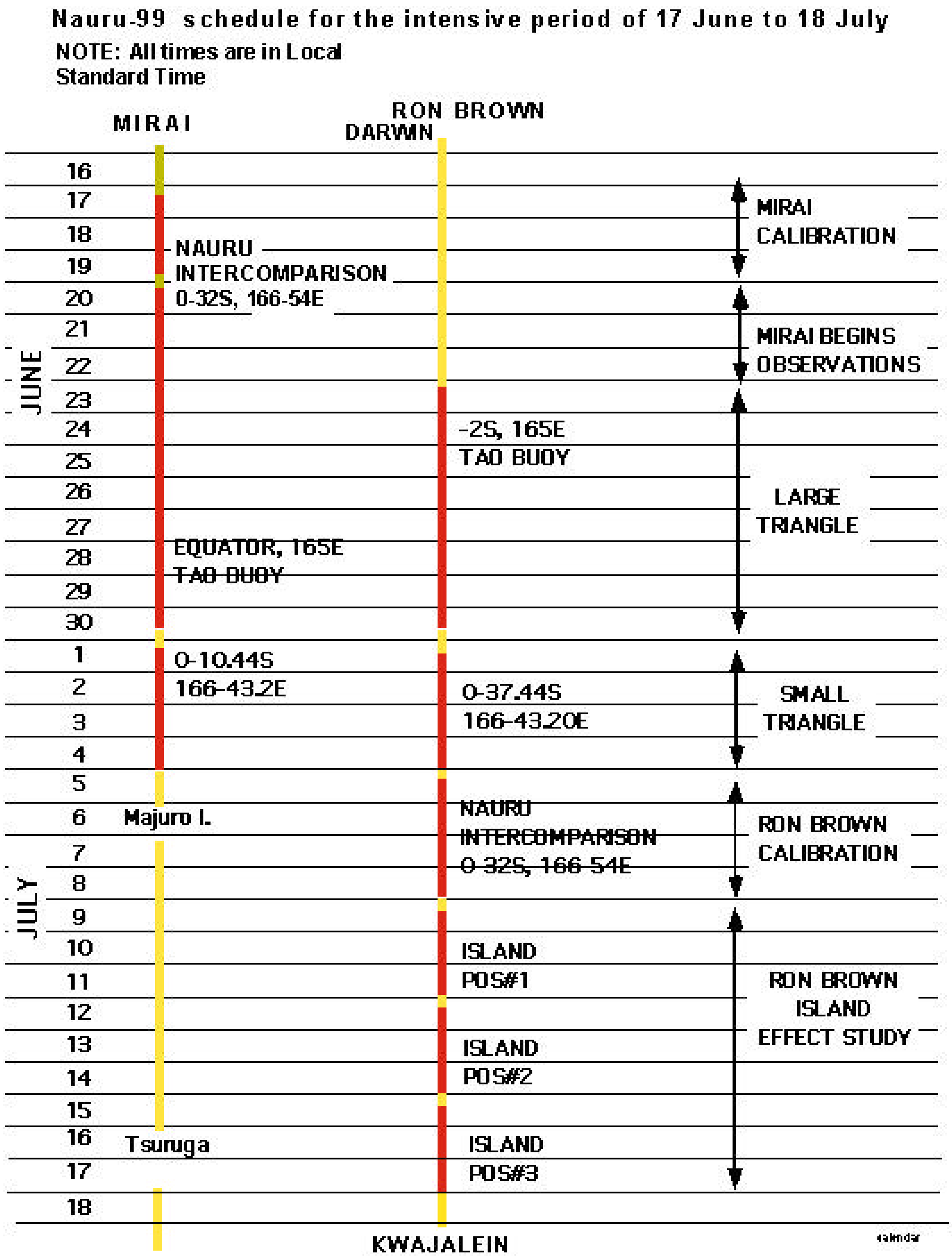

Figure 6: Calendar of events during Nauru99. Note, all times here are in local time.

3 Observation Strategy

This section provides a basic overview of the different operational modes during Nauru99. More detail for each of the island and the four major platforms is given in later sections. Finally, one can consult the ship cruise plans for maximum detail on ship operations. Cruise plans are available at web sites listed on page 2. An overall calendar of the Nauru99 experiment is shown in Figure 6.

Two research ships are participating in Nauru99, the NOAA R/V *RONALD H. BROWN* and the R/V *MIRAI* from the Japan Marine Science and Technology Center (JAMSTEC) (Figure 4). The ship(s) will carry a complement of instruments that basically matches the instrumentation on the island, including lidar and mm cloud radar. Eight-per-day radiosonde soundings also will need to be acquired from the ships during intensive measurement periods. The final component of the field campaign is the solar radiation observations on the TAO buoys.

Both the *RON BROWN* and the *MIRAI* (Figure 4) carry steerable Doppler weather radars with approximatey 200 km ranges for echos and 100 km ranges for Doppler velocities. The *BROWN* carries a C-band (6 GHz) weather surveillance radar system that has been Dopplerized to map precipitation velocity and intensity. The *MIRAI* has a C-band Doppler system of equivalent power and range that can be steered over an elevation range of -17 to 85°.

3.1 Mirai-Island Intercomparison Period and Time Series

On June 17 the *MIRAI* will arrive and proceed directly to Nauru for at least 2.5 days of intercomparison. The ship will position herself as close as possible to the ARCS. During June 17–19, scientific personnel can make visits between the island and the ship. Also, during the intercomparison period, a HF radio set will be established on the island and communications to the ship established (see Section 4.5 for more discussion of communications.).

After three days of intercomparison with island sensors, *MIRAI* will take a position at the equator TAO buoy (0°N, 165°E). It will hold station there, *positioned with the buoy to starboard when facing the mean wind.* In this position, neither ship or buoy will be blocked. *MIRAI* will hold this position for 11 days, from the morning of 20 June until after sunset of 30 June. Ship drift should be checked so the ship-buoy distance never exceeds 5 km. Note: the holding pattern that is described here is desirable for maintaining the best exposure for comparisons of meteorological and radiation measurements. It is expected that in normal operations and to support the different programs, that the ship might need to vary from this pattern.

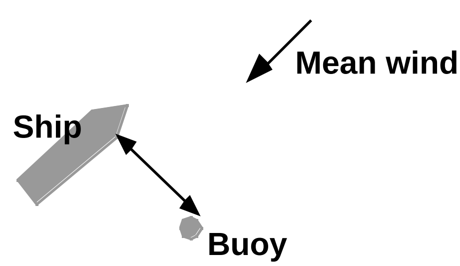

Figure 7: During periods when ships operate near to the TAO buoys, they should aligh themselves with the buoys on their starboard side, *when facing the wind.*

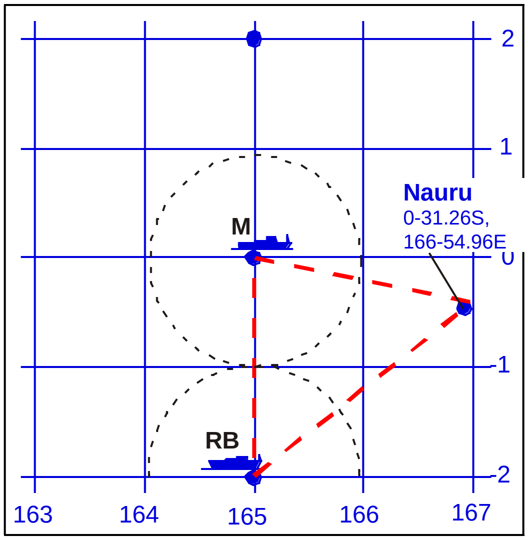

Figure 8: LARGE TRIANGLE CONFIGURATION: This pattern supports a single-column model study and provides an intercomparison calibration of two fo the TAO radiation buoys. The *RON BROWN* holds position at the 2°S TAO buoy and the *MIRAI* holds position at the equator buoy. The approximate length of each leg is 200 km. Station time approximately 7 days. TAO buoys are shown as solid circles and the range of the Doppler radar in intensity mode is shown as the dashed line.

3.2 Large-triangle Configuration

On or before 23 June, the *RON BROWN* arrives from Darwin and takes a position at the TAO buoy at 2°S, 165°E. This marks the start of the **large triangle** configuration (Figure 8). As for the *MIRAI*, the *RON BROWN* will position itself with the buoy on its starboard when facing the wind. The large triangle pattern is designed to (a) provide a solid intercomparison with two critical TAO buoys and (b) to provide a data set that can be used for single-column modeling of the region. The large triangle pattern will be held for one full week.

During the large triangle period, the Cessna 404 aircraft will make near-daily circuits around the triangle with occasional grids in the interior of the triangle (Section 9). Also, three aerosondes will be directed around the triangle in a chain (Section 10).

The Cessna flights will include low-level passes over the island so the local flux distributions can be mapped. Communication from the Nauru Island operations center to the Cessna will be by VHF (airband radio) and, if the link is lost due to the distance, by HF (2–12 MHz) radio (see Section 4.5).

The aerosondes will fly around the perimeter of the triangle in a vertical saw-tooth pattern so vertical sections through the boundary layer around the triangle will be mapped. Aerosondes travel at approximately 100 km/hr and each leg of the triangle is of order 200 km, so a circuit around will take six hours. Three aerosondes will be deployed at approximately one hour increments.

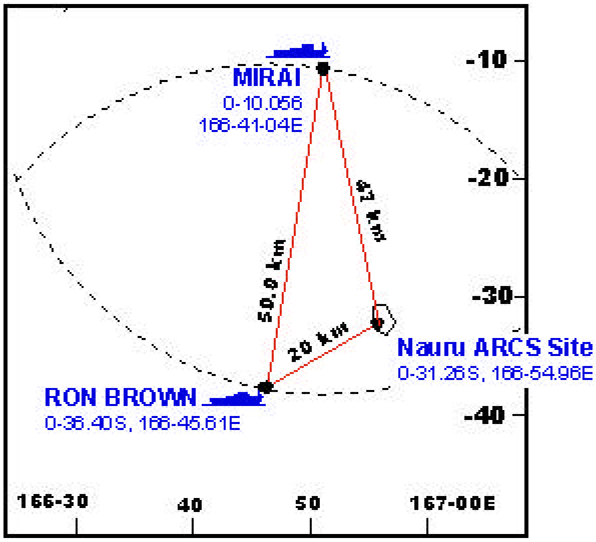

Figure 9: SMALL TRIANGLE: *MIRAI* moves to latitude -0.1676 and longitude 166.6840, approximately 47 km and at an azimuth of 340° from the ARCS site. *RON BROWN* moves to -0.610 latitude and 166.760 longitude, 20 km and at an azimuth of 240° from the ARCS site. Station time is approximately 4 days. The Nauru ARCS site position is latitude -0.521° and longitude 166.916°.

3.3 Small Triangle Configuration

On the night of 30 June, the two ships will move to a position near the island in a **small triangle** configuration (Figure 9). This pattern will (a) provide detail on the spatial variability of mesoscale features around the island, and (b) be optimum for dual-Doppler studies of cloud features and precipitation.

During the small triangle period, if the weather conditions are such that Doppler radar studies are poor, then the ships will move together for a ship-ship intercomparison for at least one day. The Nauru operations center will make this decision and inform both ships the previous evening. In this case the *RON BROWN* will move to the location of the *MIRAI*and the intercomparison will take place over the next day.

Cessna and aerosonde operations during the small triangle period will be dictated by weather conditions and will focus on understanding details of the boundary layer in the vicinity of the island. Heat island effects, lee modifications, and upstream conditions will be explored.

3.4 BROWN-Island Intercomparison

At 00 local standard time on 5 July the *MIRAI* will depart from the Nauru area and return to japan via Majuro Island. The *RON BROWN* will move to a position as close to the ARCS site as possible and begin a four-day intercomparison period, 5–8 July.

Conditions permitting, personnel will be exchanged at this time. In addition, the Portable Radiation Packages on the island and the ship will be exchanged so that systematic differences can be evaluated.

3.5 Island Effect Survey

From July 9 until the time it departs for Kwajalein Island at 00 LST, 18 July, the *RON BROWN* will occupy various sites around the perimeter of the island. Three different sites will be occupied, each for approximately three days. Durations of station holding at the sites will be determined by a priority of remaining scientific goals to be obtained, as determined by the Nauru Operations Center after consultation with the ship's party.

Cessna and Aerosonde operations will continue as for the small triangle pattern with emphasis on the mesoscale meteorology in the vicinity of the island.

4 Operational Details

This section lays out several conventions for unified operation during the various segments of the experiment.

4.1 Operations Center

Overall operations will be directed from Nauru Island. The island scientist (Charles Long) will be responsible for coordinating efforts between the ship, airplanes, and island activities. Every effort will be made to have a daily radio conference between all participating platforms (ships, island, and aircraft) (see Communications, Section 4.5 below).

4.2 Time Keeping

Basic time keeping will be UTC (Universal Coordinated Time). The goal is to maintain time accuracy between all platforms to better that ±1 second. Daily checks for each platform will be used to coordinate this time. The following steps are suggested:

- Time checks will be a regular part of the daily radio conferences.
- Real-time clocks on isolated instruments will be checked routinely and set as required.
- Time marks in the data, such as holding one's hand over a radiometer, will be recorded where possible.
- Chief scientists will ensure good timekeeping is maintained by all participants.

The *RON BROWN* and the *MIRAI* central clocks will be integral to the shipboard computer system data logging. All independent instruments must have their clocks checked and routinely synchronized with the ship's clock.

4.3 Radiosonde Operations

Coordination of radiosonde launches is essential for success of the program. The following guidelines will be followed:

- Balloons will be released 1/2 hour before the nominal ascent time.
- Sonde frequencies will be adjusted to the following:
  MIRAI – 401 MHz
  Nauru Island – 403 MHz
  RON BROWN – 405 MHz
  The Aerosonde will reduce its operating frequency to 398 MHz.
- All sondes *from ships* will be operated in the "research mode." Because Nauru99 is meant to be a comparison to the island site in normal operation, the island site will operate in its normal operational mode.
- Launch schedule will be coordinated by the Nauru chief scientist and will be eight per day during the large and small triangle periods. It is essential that all sondes be released at common times. The *MIRAI* intends to launch eight (8) times per day throughout the experiment.
- It is important to have a high-quality temperature and RH measurements at the time of the launch.
- If a launch fails within 30 minutes of launch time, a second launch can be released at the discretion of the operator.
- Optimum ascent rate is 3.5 ± 0.5 m s^{-1}.

4.4 Public Relations

It is desirable that all contact with the news media is coordinated with either the ARM-appointed media persons or the JAMSTEC public relations person. The primary contact in the U.S.A. will be **Kathryn Lang** and for Japan will be **Yasushi Taya**. See the participant list in section 11. Additionally, the Chief Scientists listed on page 2 can be consulted.

4.5 Communications

HF radios: Both ships have HF radios that operate in the range of 2–12 MHz. The radio connection will be simplex, i.e. single frequency for receive and transmit. NOAA's Pacific Marine Center will lend a radio to the Nauru99 project for installation on the island. The radio will be set up and tested at BNL, then shipped to the ARCS Integration Center for shipment to Nauru.

Nauru99 HF Frequencies

2182.0 KHz	Emergency and hailing
6203.0 KHz	Nauru99 primary frequency
8225.0 KHz	Nauru99 upper frequency
4083.0 KHz	Nauru99 lower frequency

Station Call ID

MIRAI	JNSR
RON BROWN	WTEC
Nauru Island	"OPS CENTER"
Cessna	"Investigator"
Aerosonde	"Aerosonde Gound Control‡"

Note (‡): In Aerosonde operations, the ground station will usually be identified as "Aerosonde Ground Control" and will reference "Aerosonde Unmanned Aircraft" or "Aerosonde Robot Aircraft" when one is in flight. Where more than one aircraft is in flight at the same time, these will be identified by "Number 1," "NUmber 2," etc. Aerosonde ground control can be contacted on the local tower and/or area frequency.

Marineband VHF Radio: When the ships and airplanes are within approximately 5–10 km of the island, an ordinary VHF marine band radio (156–162.5 MHz) will provide simple, line-of-sight communication. Hand-held VHF radio units are available from each ship and can be provided to the island personnel if needed. The ships routinely monitor 122.8 MHz.

Airband VHF: The Cessna 404 can operate with HF (as above) or an airband VHF radio (118–136.9 MHz). Airband radios will be provided from NOAA and NCAR for both ships and the island.

INMARSAT: Both ships have INMARSAT A/B/C. The *RON BROWN* has INMARSAT M as well. Nauru has INMARSAT-B. Efforts are being made to provide the island with an INMARSAT-M set which provides excellent voice, slow fax, and 2400 bps digital operation. Costs of M are reasonable at approximately $4.33 per minute. INMARSAT-M will provide a good backup to the radio links.

Telephone: Nauru has a reasonably good telephone service and a phone call to either ship via Inmarsat-M is a reliable (though not cheap) means of communicating.

Internet: Nauru Island has an internet service provider. The ships have regular links to internet via their Inmarsat-B radio links. Thus email and modest data sets can be sent using email protocols.

COMMUNICATION SUMMARY

DEVICE	FREQUENCIES	comments
HF Radio	2000–8000 KHz	Selected 2182.0, 6203.0, 8226.0, and 4084.0 KHz for Nauru99
Airband VHF	118–136.9 MHz	Monitor 122.8 Mhz, Select channels on site.
Marine band VHF	156–162.5 MHz	Standard marine band channel selections.
Aerosonde	398 MHz	Unmanned aircraft operates up to three aircraft from a single frequency.
Vaisala radiosonde	400–406 MHz	RON BROWN = 405; Nauru = 403; MIRAI = 401; 8 launches per day, 2 huors per launch
CIMEL	401.76 MHz	Sun photometer. Transmits 2 min per hour
Cell phones	896–912 MHz	Available on the island
Cordless phones	43.7–49.9 MHz	basic phone
900 MHz cordless	902–928 MHz	Also present

5 Data Policy

Approved version: 15 April 1999

The Atmospheric Radiation Measurement (ARM) program, funded by the U.S. Department of Energy (DOE) of the United States of America, and the Ocean Research Department of the Japan Marine Science and Technology Center (JAMSTEC) of Japan are interested in the effective use of data obtained during the intensive field experiment called Nauru99.

It is recognized that the development and maintenance of a Comprehensive and accurate data archive is a critical step in meeting the goals of Nauru99. The overall data management philosophy is to make the completed data set available to the world research community as soon as possible in order to better incorporate the information into world climate modeling efforts.

This data policy has been developed jointly by ARM and JAMSTEC with input from the participants of the Nauru99 campaign.

1. General guidelines:
   a. ARM-sponsored data will be shared in accordance with the basic tenets of the ARM Program:
      1). “Free and open” sharing of data.
      2). Immediate processing and sharing of data by DOE supported Principal Investigators, in the field when and where feasible.
      3). Timely release of data to the ARM Science Team and the general scientific community through ARM data system.

   b. All ARM and JAMSTEC collaborating scientists are encouraged to follow the ARM data protocols of timely release and “free and open” sharing.

2. Details:
   a. Nauru Site Health-of-status Data: ARM site Health-of- Station data (typically hourly) from Nauru will be made openly available through the ARM web site. These data are preliminary (see below) and should not be used for any purposes other than qualitative.

   b. Preliminary Data: “Preliminary data” are defined as data that have not necessarily been subjected to review, quality control and/or documentation by the responsible investigator. “Preliminary Data” are not considered publishable without the coordination and concurrence of the responsible investigator. During, and immediately after, the Nauru99 campaign, all participants will have free and open access to all preliminary data, where feasible, given the limitations of ship-to-ship or ship-to-island transfers, and bearing in mind that some instruments require extensive post analysis before usable data emerge.

      At the latest, preliminary data should be available to participating scientists within three months of the end of the experiment (by 1 Nov 1999). ARM and ETL have agreed to maintain restricted repositories for preliminary data sets.

   c. Quality Assured Data: “Quality-assured data” are fully calibrated and come with full documentation (metadata). All participating scientists will strive to prepare complete quality-assured data sets within one year of the end of the experiment (1 Aug 2000). It is recognized that for some instruments data processing can be lengthy, and the one-year schedule is not feasible. However, recognizing the open-data philosophy, investigators who cannot meet the deadline are requested to post a timetable by which they can submit the quality-assured sets.

   d. ETL will act to ensure collection and timely submittal of quality assurance data sets from the *RON BROWN*.

   e. JAMSTEC will act to ensure collection and timely submittal of quality data sets from the MIRAI.

   f. ETL and JAMSTEC will forward quality-controlled data sets to the ARM Archive as soon as they are available. They will coordinate data submittal to the ARM database including timetables for data submittals that extend beyond the one-year schedule.

g. A Nauru99 data workshop will be scheduled for approximately December 1999, in advance of the March 2000 ARM Science Team Meeting. There are some data sets that are crucial to most participants for data analysis—e.g. navigation, radiosondes, mean meteorology, aircraft mean trackline data— ETL, ARM, and JAMSTEC are encouraged to make these data sets available in a quality or near quality form as soon as possible.

h. The ARM Archive will track data versions and ensure latest data versions are made available to data recipients.

i. Nauru99 participants may release their own preliminary data to whomever they wish and the preliminary data of other investigators with the consent of the data's originator.

j. Non-participants who wish to use Nauru99 data sets are encouraged to enlist the collaboration of the investigator for those data.

3. Data Attribution and Publication

Early publication of research and analysis results is a key objective of the ARM Program. The following principles are established to encourage or facilitate early publication.

a. All ARM routine data are freely publishable upon receipt.

b. Data shared in the field are to be considered preliminary data; these data will not be considered publishable.

c. Data originating from ARM-funded Nauru99 participants will be quality controlled and initially released to the ARM Archive for distribution to Nauru99 participants as soon as possible after collection, but no later than 1 August 2000. All data entered into the shared data archive for Nauru99 will be restricted to access by Nauru99 participants until 1 August 2000, when data will be moved to an archive accessible by the general scientific community. Until 1 August 2000, Nauru99 data users will not publish analytical results without the collaboration of the investigator responsible for the data.

d. A final, quality controlled data set will be released to the ARM Archive as soon as possible, but no earlier than 1 August 2000. This data set will include all necessary quality assessments and documentation. At this time, the data will be considered openly publishable. Data users are cautioned to confirm data versions with the originator prior to publication.

e. The ARM Nauru99 web page will list points of contact and versions for each data set.

f. The automatic inclusion of a data originator as a co-author is not insisted upon in the ARM program. For Nauru99, until the general release of data on 31 March 2000, the investigator responsible for a data set will be given the opportunity to choose being listed as a co-author, or being acknowledged as the source of the data. After 3 March 2000, the source of any data can be recognized either through co-authorship or through an appropriate acknowledgement.

g. The lead scientists, Dr. Tom Ackerman and Dr. Chris Fairall will prepare a summary of the Nauru99 campaign, for posting on the ARM web site. This summary will ultimately include a listing of available data and URLs as appropriate. An initial summary report will be posted within two weeks of the completion of the field effort and will be updated on a timely basis as data are made available.

The ARM Program and, where appropriate, the researcher responsible for a specific measurement should be acknowledged in publications. ARM should be acknowledged as the programmatic origin of the field program. ARM-funded investigators will use the following acknowledgement: "This research was supported by the Office of Biological and Environment Research of the U.S. Department of Energy (under grant or contract number - if you want or need to include it) as part of the Atmospheric Radiation Measurement Program." ARM collaborators are encouraged to appropriately acknowledge the cooperation or collaboration of the " U.S. Department of Energy through its Atmospheric Radiation Measurement Program."

When any data publications include the JAMSTEC, then proper acknowledgement will be given to the JAMSTEC, to the R/V MIRAI, and to the researcher responsible for the measurements.

Figure 10: Panoramic view of the ARCS site on Nauru island.

6 Nauru Island Operations

6.1 ARCS Site

The ARCS site on Nauru (Figure 10) is located on the coastline of the western shore. The table below lists the instruments that are operated continually as part of the site.

ARCS INSTRUMENTS

WSI	Whole-Sky Imager
MPL	Micro-Pulse Lidar, High resolution
MMCR	Millimeter Cloud Radar
CEIL	Ceilometer
AERI	Atmospheric Emitted Radiance Interferometer
MWR	Microwave Radiometer
BBSS	Balloon Borne Sounding System
PROF	Profiler, 915 MHz †
SKYRAD – Sky Radiometer Stand	
PSP	Precision Spectral Pyranometer
PIR	Precision Infrared Radiometer
PSP-S	Shaded Precision Spectral Pyranometer
PIR-S	Shaded Precision Infrared Radiometer
NIP	Normal Incidence Pyrheliometer
IRT	Infrared Thermometer
UVB	Ultra-violet-B Radiometer
MFRSR	Multi-frequency Rotating Shadowband Radiometer
GNDRAD – Ground Stand Radiometer	
PSP	Precision Spectral Pyranometer, downward looking
PIR	Precision Infrared Radiometer, downward looking
IRT	Infrared Thermometer, downward looking
NETRAD	Net Radiometer
SMET – Surface Meteorological Tower	
ORG	Optical Rain Gauge
WND	Anemometer (two units for redundancy)
T/RH	Temperature and Relative Humidity
BAR	Barometer

† Operated on the island topside by NOAA Aeronomy Lab

Additional "guest instruments" will be deployed during the Nauru99 operation. These are listed in the table below:

Guest Instruments

NICKNAME	NAME	INSTITUTION	DESCRIPTION
PRP	Portable Radiation Package	BNL	Incorporates a PSP, PIR, and Fast-rotating shadowband radiometer (FRSR) into a single package. Both ships and island will have PRP units as transfer standards.
	Cavity Radiometer	ARM	Calibrated measurement of direct-normal solar irradiance.
TSI	Total Sky Imager	YES	Simplified version of the WSI. Both ships will also have TSI units.
RSR	Rotating Shadowband Radiometer	PSU	Eppley PSP with shading arm for direct-diffuse separation of solar insolation
	Disdrometer	NASA	Measures rainfall size distributions. Will be deployed in association with the 915 MHz system operated by NOAA. (Tokay *et al.*, 1999)
CIMEL	Sun Photometer	ARM	Direct-pointing tracking sun photometer.
TEBS	Topside Energy Balance Stations	PSU	Total energy balance portable data system that will be placed at remote sites on the island.
	Aerosonde	BOM	Unmanned aircraft (see Section 10)
	Cessna 404	Flinders U.	Instrumented boundary-layer aircraft (see Section 9)

6.2 Nauru Island Operations Center

The Nauru99 **Operations Center** will be established on Nauru Island prior to the arrival of the *MIRAI*. The island chief scientist, Dr. Charles Long, will serve also as coordinator of all campaign operations, including ship and airplane activities; he will also act as a focal point for information on the progress of the experiment.

6.3 Customs and Island Government

All contact or negotiation with the Nauru government must be coordinated with the TWP project Office (see page 2). The goodwill and support of the government has been carefully cultivated and should not be jeopardized.

For ships coming to Nauru waters:

- Ships must notify the island government when they are with in the Exclusive Economic Zone (200 miles) and state their intent.
- Ships must also notify the island when they are entering Sovereign Waters (12 miles). When the Ship gets in to the Sovereign Waters, they must radio in and wait for the following: Harbour Master, Quarantine Officer, Customs and Immigration Officer. These three Officials will go out to the ship and meet with the Captain on Nauru Requirements and check their paperwork/passports/etc.

7 *RON BROWN* Operations

The *RON BROWN* cruise plan is available as a PDF document on the web address given on page 2. Much of the information given for the MIRAI in the next section can be found there for the R/V RON BROWN.

Scientists and other Nauru99 participants should check with the Atlantic Marine Center (AMC) in Norfolk, VA (http://www.pmc.noaa.gov/amc.htm, Tel. 757-441-6208) or the ship's homepage (http://www.pmc.noaa.gov/rb/in updates on planned arrival and departure times of RONALD H. BROWN at Darwin, Australia, and Kwajalein Island. Travelers should allow for possible flight delays due to weather, holidays, or other considerations.

Participating Institutions:

NOAA Environmental Technology Laboratory
NOAA Aeronomy Laboratory
NOAA Pacific Marine Environmental Laboratory
NOAA Atlantic Oceanographic and Meteorological Laboratory
NOAA National Environmental Satellite Data and Information Service
National Center for Atmospheric Research
Pennsylvania State University
Brookhaven National Laboratory
Max Planck Institute (Germany)
Le Vai Moana Marine Center (Samoa)

The following instruments are planned for the *RON BROWN*.

Surface meteorology	(T, P, ρ, and V), 0.01 to 10 min averages
Cloud presence	Vaisala Ceilometer, 7.6 km altitude
Vertical soundings	Radiosondes, 2–8 daily, 20 mb max altitude
Wind fields	Radar wind profiler, 10 km altitude
Surface Fluxes	heat, momentum, moisture, CO_2
Sea surface temperature	below, surface, and skin
Cloud structure	Cloud radar, 35 GHz, 20 km max altitude
Liquid water structure	S-band precip radar, 20 km max altitude
Cloud distributions	All-sky camera, day and night operation
Cloud distributions	Total sky camera owned by ARM TWP
Infrared spectrum	Fourier Transform Interferometric Radiometer (FTIR)
Column water liquid and vapor	Microwave radiometer, 10, 15, 24, 32, 37, 90 GHz
BL temperature profiles	S-band (60 GHz) radiometer
Aerosols	Aerosol lidar (0.532 μm)
Vertical structure	Doppler scanning lidar (2 μm)
Water vapor/aerosol	DIAL lidar (0.73 μm)
Satellite information	SeaSpace satellite receiver
Aerosol *in situ* sampling	PMEL (Bates) aerosol system, 0.05–5.0 μm, complete chemistry
Short/long wave radiation	Portable Radiation Package, broadband SW and LW, sun photometer 0.4–1 μm
Misc radiation	Visible, IR, direct and diffuse components
Precipitation	Integrating and optical rain gauges
waves	wave spectra and glint sensors
CO_2	*in situ* CO_2 sensors
Basic navigation	all ship nav data with shipboard computer system recording
chlorophyll	*in situ* sensors
aerosols	backscatter profiles (various lidars)
aerosols	sun photometers

Officers:

CO (Captain)	CMD Roger Parsons
FOO (Field Ops Off.):	LT Alan Hilton
XO (Exec Off.)	LCDR Fred Rosman
Navigation Off.	LT Mark Boland
Chief Survey Tech	John Shannahoff

Onboard Participants:

Name	Affiliation	Nationality	Gender
Heather Zorn	NOAA/ETL	USA	F
Jeff Hare	NOAA/ETL	USA	M
Duane Hazen	NOAA/ETL	USA	M
Brad Orr	NOAA/ETL	USA	M
Madison Post	NOAA/ETL	USA	M
Scott Sandberg/Rob Newsome	NOAA/ETL	USA	M
Andrey Grachev	NOAA/ETL	USA	M
Jeff Otten	NOAA/ETL	USA	M
Boba Stankov	NOAA/ETL	USA	F
Derek Coffman	NOAA/PMEL	USA	M
Drew Hamilton	NOAA/PMEL	USA	M
Paulette Murphy	NOAA/PMEL	USA	F
Tony Reale	NOAA/NESDIS	USA	M
Volker Matthias	Max Planck Inst.	Germany	M
Klaus Ertel	Max Planck Inst.	Germany	M
Friedhelm Jansen	Max Planck Inst.	Germany	M
Volker Wulfmeyer	NCAR	Germany	M
Scott Smith	DOE/BNL	USA	M
Chuck Pavloski	Penn. State Univ.	USA	M
Hans Verlinde	Penn. State Univ.	USA	M
Jennifer Aicher	LVMMC	USA	F
Tepora Toliniu	LVMMC	USA	F
Steve Piotrowicz	NOAA/OAR	USA	M

TOTAL: 23

8 *MIRAI* Operations

Draft Cruise Instructions for the R/V *MIRAI* MR-99-K03 Cruise
Feb 1999
Ocean Research Department, JAMSTEC

8.1 Objectives

The cruise will be carried out with co-operative research in the Tropical Western Pacific area with the following objectives:

(1) Characterization of the interaction between the ocean and the atmosphere, especially on the convective systems (cloud cluster, etc.)
(2) Evaluation of effects of diurnal cycle on theinteraction between ocean and the atmosphere.
(3) Evaluation of solar irradiance and intervening aerosol on the energy budget in the boundary layer
(4) Evaluation of vertical transport of energy and greenhouse gases
(5) Characterization of the planetary boundary layer structure over the warm water pool
(6) Characterization of the ocean surface structure

8.2 Ship for Mission

R/V MIRAI

Ship	Phone	+81-90-3022-5636
	FAX	+81-90-3023-0780
IMMARSAT	Phone	+872-120-6371
	FAX	+872-81-120-6371
E-mail	`mail@mirai.jamstec.go.jp`	
Mother port	JAMSTEC Mutsu Branch 690 Kita-Sekine, Sekine, Mutsu-city, Aomori Pref. 035-0022, JAPAN	
	Phone	+81-175-25-3811
	FAX	+81-175-25-3029

8.3 Ports of Call

Hachinohe (Japan)
Chuuk (the Federated States of Micronesia)
Majuro (the Republic of the Marshall Islands)
Tsuruga (Japan)

8.4 Logistics

Headquarter	Ocean Research Department, JAMSTEC 2-15 Natsushima-cho, Yokosuka, Kanagawa 237-0061 JAPAN phone: +81-468-66-3811 FAX: +81-468-65-3202
General Manager of the cruise	Masahiro Endoh (Director of the Ocean Research Department)
Chief Scientist	Kunio Yoneyama `yoneyamak@jamstec.go.jp`
Co-chief Scientist	Masaki Katsumata `katsu@jamstec.go.jp`

MIRAI INSTRUMENTS FOR NAURU99

INSTRUMENT	TYPE	PARAMETER	OPERATION	REMARKS
C-band Doppler Radar	Mitsubishi Electric with Sigmet RVP-6	Reflectivity Radial Velocity	Continuous 360° full volume scan 1 sequence = 7.5 min; 3 rpm Intensity mode = 0.7° Doppler mode = 0.0, 0.7, 1.4, 2.1, 3.6, 4.6, 5.8, 7.2, 8.8, 10.6, 12.6, 14.8, 18.0, 22.0, 27.0, 32.0, 40.0°	Range: intensity Mode = 200 km Doppler Mode = 100 km
Radiosonde	Vaisala, RS80-15GH (H-humicap)	Pressure, temperature, humidity, wind	8 times per day (00, 03, 06, 09, 12, 15, 18, 21 UTC) Period: 15 June – 6 July	Lower band: 401 MHz (400-406 span) Calibrate using humidity calibrator VAPORPAK H-31 (Digital Inst.) Well ventilated container Launch if $\mid T_{sonde} - T_{outside} \mid < 0.5^{\circ}$C and $\mid \mathrm{RH}_{sonde} - \mathrm{RH}_{outside} \mid < 5\%$
Ceilometer	Vaisala, CT25K	Cloud height and visibility	Continuous, 1-min	Instrument (starboard side of compass deck) computer (control room)
Total Sky Imager	YES Inc. TSI-440A	sky images, cloud fraction	Continuous, 1-min	Instrument on starboard side of roof of anti-rolling device room Computer in the control room
Portable Disdrometer	Yamaguchi Univ.	Drop size distribution	Continuous, saved on video tape	Under development Instrument (starboard side roof of anti-rolling device room)
Sun photometer Pyroheliometer Spectroradiometer Microwave radiometer		spectral radiation precipitable water vapor	Set out during day time	
Supersonic Thermoanemometer Infrared Hygrometer	Kaijo, DAT-300 Kaijo, AH-300	turbulent fluxes of momentum, heat, and water vapor	Ship moves dead slow toward the wind about 1 hour every three hours.	Instrument (foremast upper platform) Computer (control room)
Mie scattering LIDAR Sky radiometer	NIES		Continuous Continuous	Stored in container at the stern/starboard of upper deck
Sfc Met Station Anemometer Thermometer Dew-point meter Barometer Rain gauge Radiometer	 Koshin Electric, KE-500 Koshin, FT Koshin, DW-1 Yokogawa, F-451 R.M. Young 50202 STI, ORG-115DR Eiko Seiki, MS-801 MS-201	 wind speed/dir temperature dew point pressure rain rate rain rate shortwave radiation longwave radiation	Continuous, one-sec samples, 1-hour averages	 foremast (30.16 m) both sides of compass deck (24.85 m) both sides of compass deck (24.85 m) outside of met room (19.5 m) compass deck (24.7 m) compass deck (25.35 m) foreboom for up radiation (14.86) radar mast for downward radiation (34.70)
Water Monitoring Thermosalinograph DO sensor Flourimeter Particle size sensor	 SBE SeaCat SBE-21SST Oubisufair Lab 2127 Turner Designs 10AU005 Nippon KAIYO, P-05	 SST(bulk), Salinity Dissolved Oxygen Flourescence Plankton size	Continuous, 1-min	Intake at -2.4 m
CTD/RMS	CTD: SBE Inc. SBE-9Plus RMS: Gen Oceanics, 1016	temperature, salinity, depth, water samples	Every three hours to 200 m with CTD at 03, 06, 09, 12, 15, 18, 21 UTC. To 1000 m with CTD/RMS at 00 UTC.	
ADCP	RDI Inc., VM-75	current profiles	Continuous, 5-min average	Depth cell = 16 m, No. cells = 40 layers. First cell depth = 32.6 m, Last cell depth = 672 m

Visiting Scientists

Profiler RASS	Radian, LAP-3000	wind virtual temperature	Continuous, 30 minutes	NCAR: antenna (upper deck) Computer (dry lab)
MAPR	NCAR	wind	Continuous	NCAR: antenna (upper deck), Computer (dry lab)
Microwave radiometer		Precipitable water	Continuous	NCAR
Meteor. Station		temperature, humidity, wind, pressure	Continuous	NCAR
S-band radar	ETL, 3-GHz radar	precipitation	Continuous	ETL: antenna (top of Seatainer) Computer (dry lab)
Portable Radiation Package (PRP)	Eppley PSP, PIR FRSR (YES Inc. Head) Tilt/compass	shortwave and longwave insolation optical depth pitch, roll, azimuth	Continuous, 2-min averages	BNL: instrument (foremast upper platform) computer (control room)
Meteor. Package wind temperature humidity barometer rain rate rate accum SST	 R.M. Young wind monitor Vaisala PRT Vaisala Humicap R.M. Young STI ORG R.M. Young BNL PRT and 4-20 mA	 relative speed and direction air temperature humidity pressure mm/hr accum mm water temperature	Continuous, 1 sec samples	BNL: instrument (foremast upper platform) computer (control room)
M-AERI	RSMAS	Upward and downward IR spectrum. Skin SST	Continuous	RSMAS: instrument (foremast, lower platform) Computer (control room)
SiSTeR	RAL	Skin SST	Continuous	RAL: instrument (foremast, lower platform) Computer (control room)

8.5 MR-99-K03 Nauru-99 Cruise Schedule

Date	Day	LST	Activity	Position
June 1	(Mon)		MIRAI returns to Sekinehama from a prior cruise	
June 2	(Tue)		Leave Sekinehama for Yokohama	
June 4	(Thu)		Arrive in Yokohama	
June 8	(Tue)		Depart Yokohama	
June 14	(Mon)	08:00	Arrive Chuuk, F.S.M.	0728N, 15151E
		14:00	Leave Chuuk	
June 17	(Thu)	03:00	Arrive Nauru-99 Area	0000, 16500E
			Nauru-99 Observation	
			Move to near the Nauru	0030S, 16700E
July 05	(Mon)	00:00	Leave Nauru-99 Area	
July 06	(Tue)	12:00	Arrive Majuro, Marshall Islands	0707N, 17110E
			Unload US group instruments	
			(Disembark / Fueling)	
July 07	(Wed)	12:00	Leave Majuro	
July 14	(Wed)	18:00	Off Kagoshima (X-Baiu 99, if possible)	
July 17	(Sat)	08:00	Arrive Tsuruga, Japan	3540N, 13604E
			Immigration/Customs	
July 18	(Sun)	09:00	Open House	
		18:00	Leave Tsuruga	
July 20	(Tue)	08:00	Arrive Sekinehama	4122N, 14113E
			Unload instruments / Disembark	

Participating Institutions	
BNL	Brookhaven National Laboratory
GODI	Global Ocean Development Inc.
JAMSTEC	Japan Marine Science and Technology Center
KUMM	Kobe University of Mercantile Marine
KU	Kyoto University
MRI	Meteorological Research Institute
MWJ	Marine Works Japan Ltd.
NCAR	National Center for Atmospheric Research
NIES	National Institute for Environmental Studies
OU	Okayama University
OUS	Okayama University of Science
OPU	Osaka Prefecture University
RSMAS	Rosenstiel School of Marine and Atmospheric Science
RAL	Rutherford Appleton Laboratory
TOHIT	Tohoku Institute of Technology
TNCMT	Toba National College of Maritime Technology
UT	University of Tokyo
YU	Yamaguchi University

8.6 Participants List

Table 1: Mirai MR99-K03 Cruise Participants List

	Name	Organization	On Board			
			Sekinehama →Chuuk	Chuuk → Majuro	Majuro →Tsuruga	Tsuruga →Sekinehama
1	Kunio Yoneyama	JAMSTEC	•	•	•	•
2	Masaki Katsumata	JAMSTEC	•	•	•	•
3	Kenji Suzuki	YU	•	•	•	•
4	R. Michael Reynolds	BNL	•	•	•	•
5	Ray Edwards	BNL	•	•	•	
6	Michael Susedik	NCAR	•	•		
7	Louis Verstraete	NCAR			•	
8	William Brown	NCAR	•	•		
9	Jennifer Hanafin	RSMAS	•	•	•	•
10	Tim Nightingale	RAL	•	•	•	•
11	Hiroshi Ishida	KUMM		•	•	
12	Katsutoshi Kozai	KUMM		•	•	
13	Mitsuru Hayashi	KUMM	•	•	•	
14	Tomoko Iwamoto	KUMM	•	•	•	
15	Masanao Kusakari	KUMM	•	•	•	
16	Masayuki Sasaki	MRI	•	•		
17	Tetsuya Takemi	OSU	•	•	•	
18	Kazuyoshi Kikuchi	UT	•	•	•	
19	Naoki Nakatani	OPU	•	•	•	
20	Osamu Tsukamoto	OU	•			
21	Toru Iwata	OU	•	•	•	
22	Takehiko Kono	OU	•	•	•	
23	Satoshi Takahashi	OU	•	•	•	
24	Eiji Yamashita	OUS	•	•	•	
25	Kunimitsu Ishida	TNCMT	•	•	•	
26	Ichiro Matsui	NIES	•	•	•	•
27	Masaki Hanyu	GODI	•	•	•	•
28	Fumitaka Yoshiura	GODI	•	•	•	•
29	Satoshi Okumura	GODI	•	•	•	•
30	Koyotake Kouzuma	GODI	•	•	•	•
31	Satoshi Ozawa	MWJ	•	•	•	
32	Shinichiro Yokogawa	MWJ	•	•	•	
33	Katsunori Sagishima	MWJ	•	•	•	•
34	Mikio Kitada	MWJ	•	•	•	•
35	Mizue Hirano	MWJ	•	•	•	
36	Ai Yasuda	MWJ	•	•	•	
37	Keisuke Wataki	MWJ	•	•	•	

8.7 Miscellaneous

Safety Measures

1) All must obey the JAMSTEC regulation "Guideline for the safety maritime work".
2) According to the sea traffic law regulating the prevention against collision(Article 27 Clause 4), light(or designated shape) must be turned on(or hoisted).
3) Especially during the stationary observation, special attention should be paid to other ships around.
4) As facing trouble or accident, meet with obey the guideline of JAMSTEC Accident/Trouble Measures.

5) Every observational work must be abided by each regulated manuals.
6) During Doppler radar observation, going up to the outer deck of radome, rooftom of the stern pilothouse, and the rooftop of radiosonde container is prohibited.

Permissions and Registrations

1) We will take nothing to be limited by the Foreign Exchange and Foreign Trade Control Law (Article 48 Clause 1).
2) We will not act as that is necessary to adjust the conflict on the fishing right.
3) Requests for research clearance in foreign waters (Nauru, Marshall Islands and the Federated States of Micronesia) have been submitted by JAMSTEC to the Ministry of Foreign Affairs through the Science and Technology Agency, based on the United Nations Treaty (Article 13) related to the Law of Sea.
4) JAMSTEC will submit the application for the warning on the international radio navigation, which is provided by the order from the Ministry of Transport.
5) Doppler radar operation is abided by the condition on the certification (No. Toujitsu-17) from the Ministry of Posts and Telecommunication, which allows the radar operation at the place where is farther than 220km from the Japanese main lands.
6) The notation about the radiosonde flying will be submitted to the Minister of Transport obeying A Civil Aeronautics Law (Article 99-2).

8.8 Instruments and Data

For the objectives described above, the scientific instruments will be equipped on the R/V *MIRAI* by participating researchers in addition to the permanent *MIRAI* instruments. Main targets to measure are a) Precipitaion, b) Atmospheric Sounding focussing on boundary layer structure, c) Solar Radiation, d) Turbulent Flux, e) Aerosols, f) Greenhouse Effect Gases, and g) Sea Surface Structure. See Figure **??** for details.

8.9 Mirai Communication

The *MIRAI* has an extensive set of communication options:

- GMDSS communication sets (typical) MHF or HF
- Marine VHF is used to communicate with other vessels according to distance. (Note: Marine VHF cannot communicate with aircraft VHF)
- Inmarsat A/B/C/M

Regular Inmarsat-B connections to the Internet are expected (four-times daily nominal).

8.10 Mirai Ship information system

The *MIRAI* information system is available via TCP/IP connection, no spare RS232 ports are available. The computer system updates a 256 byte navigation data file once each second. Only the most recent record is in the file. Data include time, lat, long, HDG, SPD, CSE, TAIR, TDEW, WND, BATHY, and a variety of quality indicators.

The BNL shipboard computer system (SCS) will access the information file each second and log it into the SCS data stream. The SCS computer will use TCP/IP protocol to maintain its clock the same as the ship.

9 Cessna 404 Titan Aircraft (VH-EOS)

The C404 is the successor of the FIAMS Cessna 340B which was used during TOGA-COARE. It had been funded, together with its standard set of instrumentation, by a join grant from the Australian Research Council (ARC) and the Sir Ross and Sir Keith Smith Fund (SRSKSF) in Adelaide.

The C404 is an all-metal, low-wing, un-pressurised commuter-type aircraft, powered by two 375HP geared turbo-charged piston engines. It features a large cabin which can be configured for up to 12 passengers in its commuter role. For research purposes, it is planned to carry no more than four system operators/scientists and normally one pilot. Access to the cabin is through a wide cargo door.

Depending on the mission profile and the required load, the C404 can stay airborne for up to 10 hours in its most economical configuration. Its maximum range is 3,000km and its normal cruising speed 165kts with slower speed possible if required by the particular task. Operating altitudes are from a few meters above the Earth's surface to about 10km with breathing oxygen required above 10,000ft (approx. 3km). The aircraft can carry up to 1,000kg of useful load, depending on its configuration.

The aircraft's scientific instrumentation is similar to that of the former FIAMS Cessna 340A. As with all other ARa aircraft, the C404 is equipped with the latest version of the standard DAMS data acquisition and real-time monitoring system. Many of the basic sensors (air temperature, humidity, wind, turbulence, etc.) are located around a scientific nose cone. Differential pressure ports at the hemispheric front section of the nose cone measure the incidence angles of the airflow, while atmospheric state sensors are mounted around the cylindrical section of the nose cone. A weather radar (with PPI and RHI scanning capabilities) is mounted inside the nose cone. There are a number of air intakes for air chemistry measurements using optional instrumentation within the cabin of the aircraft. Fuselage stations for user instrumentation can be made available. A platform for small radiometric sensors is located on the cabin roof. An under-fuselage pod is available for down-ward looking radiometric or scanner instrumentation. For the measurement of aircraft parameters (pitch and roll angle, heading, accelerations and angular rates), the aircraft carries a Honeywell LaserNav Inertial Navigation System in the front luggage compartment and also a four antenna array Trimble TANS Vector GPS unit. Navigation parameters are also derived from these units. The standard and optional instrumentation of the C404 is listed in the table below.

As the aircraft is unpressurised, breathing oxygen is required for the occupants for operations above 10,000ft (approx. 3km). A modern oxygen system is fitted to the aircraft for this purpose. The scientific equipment is normally powered from a dedicated scientific electrical bus, which is isolated from the aircraft's normal power circuitry. Scientific power can also be supplied from an external unit while on the ground.

Cessna C404

Altitude range	15 - 8,000m
Typical endurance	7hrs
Typical range	3,000km
Typical scientific payload (excluding crew)	750kg
Approximate cabin dimensions available for instrumentation	1.3m (w) 5.0m (l) 1.3m (h)
Special features	Scientific nose cone under-belly pod
Flight procedures	VFR, IFR, in cloud
Engines	2 piston engines

INSTRUMENTATION AND SYSTEMS
OF CESSNA C404 'VH-EOS'
(Nauru99 Complement)

PARAMETER	SENSOR(S)	COMMENTS
position, time, attitude, accelerations	Honeywell LaserNav Inertial Navigation System Trimble TANS Vector GPS Attitude System NovAtel differential GPS receiver (together with base station)	
turbulence, turbulent fluxes of sensible heat, water vapour, momentum, CO2, O3, Nox	nose cone pressure port system with two Rosemount 1221VL differential pressure sensors for air angles	25 Hz
air temperature	modified NCAR k-probe (Pt100 sensor) FIAMS reverse flow probe (Pt100 sensor) modified Meteolab TP4S (thermocouple)	on nose cone on nose cone on nose cone
humidity (absolute humidity, dew point)	A.I.R. LA-1 Lyman-Alpha hygrometer modified Meteolab TP4S dewpoint system NOAA/ATD Infrared open-path gas analyser	on nose cone on nose cone underneath nose cone
static and dynamic pressure	Rosemount 1281 pressure transducer	in aircraft pitot-static system
height above ground or water	King KRA-10A radar altimeter	0-800 m
surface temperature	Heimann KT-15 infrared radiometer	4° viewing angle, 8-14 m
global radiation (up- and down-welling)	2 Eppley PIR pyrgeometers 2 Eppley PSP pyranometers	
spectral radiometers	FIAMS VEG-1 (down-welling, 2 wavelengths) FIAMS VEG-2 (up-welling, 3 wavelengths)	630, 780,830 nm 1° viewing angle
CO2 concentration	LiCor 6251 Infrared closed-path gas analyser	on top of aircraft nose
NO, NO2, NOx concentration	Monitor Labs 8840 NO Analyser FIAMS fast chemi-luminescence NO sensors	slow response
particles, CCN	Laser particle counter Condensation nucleus counter	
video	NDVI/color video scanner	Over the island
weather radar	Bendix/King RD-81VP, PPI and RHI scans, 2 displays	
data system	data logging, real-time processing, 64 analogue channels (up to 100Hz, 16 bit A/Ds), RS232/422, ARINC419/429 I/O DAMS II	
navigation and flight guidance	Garmin GPS155 navigation computer	
power	12VDC, 24/28VDC, 115VAC, 240VAC	28V/100A total maximum

10 Aerosonde Operations

Taken from the Aerosonde Web page `http://www.aerosonde.com`

The Aerosonde (McGreer and Holland, 1993) is a miniature robotic aircraft for long-range environmental monitoring. It has been developed specifically for meteorological and environmental reconnaissance over oceanic and remote areas, for which its economy will allow routine operations on a much wider scale than has been affordable in the past. It has the potential to fill chronic gaps in the global upper-air sounding network, and to conduct systematic surveillance of tropical cylones and other severe weather. It can also be adapted to other applications requiring lightweight payloads; one example is geomagnetic survey.

Miniaturisation is a key factor. It is now possible for aircraft weighing less than 15 kg to undertake autonomous missions of several thousand kilometres and several days duration, with precision navigation anywhere on the globe, timely communication back to a monitoring site, and instrumentation appropriate for a variety of missions in earth and atmospheric science. The Aerosonde will combine high performance with the benefits of small size, including low costs of manufacture and use; opportunistic basing; and independence of elaborate facilities. They promise to make previously impractical missions economical on a wide scale.

Aerosonde development has been underway since 1992. To date we have built and demonstrated the components necessary for long-range autonomous operations. Phase I Aerosondes were given their full operational trial by the Bureau of Meteorology in early 1998 and passed all objectives. In addition, we have conducted several missions in Australia, Taiwan, Canada and the United States, including flights of over 30 hours and 5 km altitude, and completely autonomous missions including takeoff and landing. The development target is for the Aerosonde to extend this range to 7000km, up to 5 days and 14 km altitude (Phase II Aerosonde).

The Aerosonde is developed jointly by Environmental Systems and Services in Melbourne, The Insitu Group in Washington State and the Australian Bureau of Meteorology. Its sponsors include the US Office of Naval Research, National Oceanic and Atmospheric Administration, and Department of Energy, and the Taiwan Central Weather Bureau.

The Phase I Operational Aerosonde

Wingspan	3 metres
Weight	15 kg
Engine	26 cc Petrol (LL Avgas)
Performance	Cruise: 20-30 $\mathrm{m\,s^{-1}}$ Range: $>$ 3000 km Endurance: $>$ 30 hrs Surface to 4800 m
Payload	1–2 kg
Operation	Autonomous
Observations	Wind, Pressure, Height, Temperature, Moisture
Navigation	GPS
Communication	UHF Radio, Satellite

11 Participants List

Nauru99 Participant List

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DOE	U.S. Department of Energy
GODI	Global Ocean Development, Inc.
JAMSTEC	Japan Marine and Science Technology Center
KU	Kyoto University
KUMM	Kobe Univ. of Mercantile Marine
LANL	Los Alamos National Laboratory
MPI	Max-Planck-Institut fuer Meteorologie
MRI	Meteorological Research Institute
MWJ	Marine Works Japan Co., Ltd.
NCAR	National Center for Atmospheric Research
NIES	National Inst. for Environmental Studies
NOAA	National Oceanic and Atmospheric Administration
ORNL	Oak Ridge National Laboratory
OU	Okayama University
PNNL	Pacific Northwest National Laboratory
PSU	Pennsylvania State University
RSMAS	Rosential School of Marine and Atmospheric Sciences
SNL	Sandia National Labs
TIOT	Touhoku Inst. of Technology
TNCMT	Toba Natl. College of Maritime Tech.
YU	Yamaguchi University

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