CRUISE REPORT

**Tropical Ocean Climate Study (TOCS)
and
Japan-United States Tropical Ocean Study (JUSTOS)
On the R/V KAIYO, 25 Jan to 2 March 1997, to the
Tropical Western Pacific Ocean
BNL COMPONENT[†]**

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11 April 1997

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The R/V KAIYO

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Summary

The Japanese U.S. Tropical Ocean Study (JUSTOS) cruise on the R/V KAIYO in the Tropical Western Pacific Ocean was a collaborative effort with participants from the Japanese Marine Science and Technology Center (JAMSTEC), the National Center for Atmospheric Research (NCAR), and Brookhaven National Laboratory (BNL).

The ship departed from Majuro in the Marshall Islands on 25 Jan 1997, stopped at Truk Is., Micronesia from 10-13 Feb 1997, and the cruise terminated in Palau on 2 March 1997. The primary activity of the KAIYO was repair and maintenance of several of the TAO buoys in the TWP. The TOCS/JUSTOS work, continued as a background activity, included:

JAMSTEC: Provided the ship, flew radiosondes approximately every three hours over much of the cruise, made CTD and water sample casts at regular intervals, and collected underway ADCP current measurements.

NCAR: Provided a wind profiler radar and radio-acoustic sounding system (RASS), operated the SABL lidar profiler, made kite and balloon measurements in the lower boundary layer, and assisted with balloon work.

BNL: Installed and operated a shipboard flux measurement system consisting of true winds, long and short wave downward radiation flux, temperature and relative humidity, rainfall, and a fast rotating shadowband radiometer that measures both direct and diffuse components of broadband radiation.

This report is a summary of the instruments, measurements, and initial analysis of the BNL portion of the cruise only. It includes a brief description of the instrument system, calibration procedures, problems and resolutions, data collection, processing and data file descriptions. This is a working document, which is meant to provide both a good description of the work and as much information as possible in one place for future analysis.

Acknowledgements

This work has been possible thanks to the gracious support of JAMSTEC and the Japanese government who provided the ship and some funding. The NCAR and BNL costs were largely provided as part of the ARM Infrastructure activities under the Ocean Site Management program. Thanks go to Ted Cress (PNNL) and Peter Lunn (DOE) for their interest and support. The BNL equipment was fabricated and calibrated by Ray Edwards, Bill Behrens, and Steve Boose of BNL.

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1 Introduction

The ARM Ocean Program is necessary as a supplement to the island-based ARCS (Atmospheric Radiation and Cloud Station) installations. Measurements from ships and buoys, by necessity, require simpler instruments that are heavily modified for the marine environment. Logistical costs are high. Thus, the challenge is to focus on the most effective means of producing required data sets. Synergistic associations with other climate programs such as the U.S. Ocean CLIVAR and the Japanese Tropical Ocean Climate Study (TOCS) are an important consideration.

Figure 1: Location of current and proposed ARCS sites in the Tropical Western Pacific Ocean. ARCS sites are shown as red circles. Manus I. site was installed in 10/96 and Nauru I. installation is planned for mid 1998.

The importance of the ARM Ocean Program is manifest in the ARM Science Plan (DOE, 1996). The Ocean Program is viewed as a crucial supplement to the island-based Atmospheric Radiation and Cloud Station (ARCS) deployments at up to five island sites across the western Pacific (TWP, 1994). The first island site, Manus Island, Papua New Guinea, was installed in October 1996. The second is due to be installed in 1998 on the island of Nauru.

The scientific focus of this cruise was influenced by a number of factors including the extensive experience of JAMSTEC in the Tropical Western Pacific (TWP), the ongoing research by these investigators on the TOGA COARE data set, the highlighting of outstanding scientific problems over the TWP by participants at the recent meeting of the ARM Ocean Working Group and the session at the recent TOGA COARE air-sea flux workshop that outlined serious errors in the rawinsonde measured low-level humidity.

Figure 2: Map of the TAO buoy locations in the Pacific Ocean.

During the cruise, the winter 1997 TOCS cruise by the JAMSTEC R/V *KAIYO* the basic upper air sounding and oceanographic experiments conducted by JAMSTEC during these cruises were supplemented by contributions from NCAR and BNL. Of great importance, this experiment is also meant to serve as a test of a possible long-term collaboration between JAMSTEC and U.S. scientists interested in future field studies into ocean-atmosphere interactions. A complete description of the cruise and its research goals is available on the world-wide web¹, as well as the ARM Ocean program Implementation Plan (1997).

1.1 Cruise Description

The ship departed from Marjuro, Marshall Islands on 25 January 1997. Table 1 (below) summarizes events that relate to the BNL operations. The cruise trackline (Fig. 3) shows the main effort of the ship.

This report is meant to describe all aspects of the cruise. Specifically, it provides information related to the interpretation of the BNL mean flux measurement instrumentation. Appendices provide additional information related to the cruise. The lists of souls on the two legs are given in Appendix A. The Scanning Aerosol Backscatter Lidar (SABL) is described in Appendix B. Information on JAMSTEC, the R/V *MIRAI*, and the new Triton buoy that will replace the NOAA Atlas buoys in the western Pacific is contained in Appendix C. Appendix D and E list radiosonde and CTD operation information, respectively.

¹<http://www.oasd.bnl.gov/oasd/mike/armocean/ifo/justos.html>

Figure 3: The JUSTOS cruise trackline.

Table 1: Time table of Events Relating to BNL Instrumentation

DATE	J-DAY	TIME†	DESCRIPTION
22 Jan	022	—	KAIYO in port, Majuro. BNL arrives.
26 Jan	026	1700	KAIYO Departs Majuro - 422 switch box fails.
27 Jan	027	0350	Changed SST probe to #3
28 Jan	028	2244	Clean all wiring, restart system.
30 Jan	030	0530	PIR Cal coefficient set to from 200000 to 245700.
31 Jan	031	0100	Start Zeno calibration
		1732	Restart Zeno, configuration file v205
1 Feb	032	0213	Re-install RH sensor, leak fixed.
		2200	Investigate SST noise, bad cable discovered.
2 Feb	033	0700	SST cable temporary repair. Deploy SST.
3 Feb	034	0903	Reprogram Met/Nav system for $\pm$ latitude.
		2315	Put a rain cover on back of T/RH probe, rain spikes?
4 Feb	035	0444	SST probe cable repair, probe #1 back in the water.
		2146	Turn on GOES DCP, test transmissions
6 Feb	037	0200	Wind calibration maneuver.
		0700	Move wind sensor to rear upper deck, starboard side.
10 Feb	041	0000	Enter Truk lagoon.
13 Feb	044	0448	Ship departs Truk harbor.
		0515	Start wind collection from mast top.
14 Feb	045	0530	SST probe repaired, #3 probe deployed.
18 Feb	049	0-12	Operations near Manus Island
18 Feb	049		FRSR fails, motor burn out, down for remainder.
19 Feb	050	09	Onset westerly wind burst
20 Feb	051	17	PIR out of cal-possible dampness in case
21 Feb	052	23	Begin Zeno calibration and maintenance
22 Feb	053	03	Enf Zeno cal and maintenance - PIR operational
27 Feb	057	01	End of scientific measurements

† All times are in UTC (Greenwich).

1.2 R/V KAIYO and Instrument Locations

The *KAIYO* (Fig. 4) is a "Small Water Area Twin Hull" (SWATH) design catamaran ship with length overall (LOA) of 68 m and width at the stern of 28 m (Fig. 5). The crew numbered approximately 28, and there were 18 scientists from Japan, the U.S., and Indonesia. A roster for the two legs can be found in Appendix A.

The SWATH design provides excellent stability in moderate seas. Four lateral thrusters, stabilizer fins, and propellers in each of the hulls are all controlled by a dynamic positioning system so that the mean tilt is much less than one degree with standard deviations of about $\pm 2^\circ$. Such performance makes this vessel excellent for radiation measurements.

Figure 4: A photograph of the R/V *KAIYO* showing position of the BNL instrumentation.

Stability degrades rapidly as seas exceed 3 to 3.5 m. When this occurs, the strain on the stabilizer fin is great and water begins to strike the underside of the vessel. We encountered foul weather on departing from Truk and the ship had to hove to into the wind for about half a day. Bad weather continued, with the onset of a strong westerly wind burst on 19 Feb that persisted until the cruise terminated on the 28th.

- (2) Wide work:
Provides a wide working area and can mount more research and observation equipment on board.
- (3) Minimized underwater noise:
To get the maximum possible effect from various acoustic equipment, underwater noises emitted from the vessel are minimized by the following systems and methods:

- (5) Positioning system:
Depending on the kind of experiment, it is necessary to keep the ship's position within a certain area for certain period. KAIYO is equipped with four-point mooring system which fixes the ship position by four anchors (100m depth max.). Another equipment, Dynamic Positioning System, keeps the ship position automatically by two main propellers and eight thrusters. These devices enable the ship to keep its position within a certain area on the sea, whether shallow or deep.

Fig. 2

Figure 5: A layout drawing of the KAIYO. The BNL PRP was located at position #4, at the top of the bow and about 24.3m above the surface. The wind sensor was deployed at positions #1, on the port flying bridge, and position #2, the rear of the upper deck, before finalizing on position #3 at the top of the mast and 29m above the sea surface.

1.3 Flux Instrumentation – Ship Installation

Figure 6: Photograph of the Portable Radiation Sensor and supporting meteorological sensors with the Zeno data logger on the upper deck of the *KAIYO*.

The BNL instruments were placed in various places on the ship (Figs. 4 and 5) in hopes of having the best exposed position. The portable radiation sensor (PSP, PIR, temperature, relative humidity, pitch, roll, fast rotating shadowband radiometer, and barometer) were located on a mast at the front of the upper deck well in front of the main mast and so removed from any major shadowing structures.

HEIGHTS OF INSTRUMENTS (M)	
Radiation sensors	24.3
Pitch and Roll	24.3
Temperature/RH	23.0
Barometer	20.0
SST probe	-0.2
Wind/GPS/Compass	
Pos. 1	16.6
Pos. 2	22.0
Pos. 3	29.0

The wind and navigation system was placed in three different locations during the cruise. From 27 Jan to 9 Feb it was located on a pole extending out from the port-side flying bridge, about 16.6 m above the water. This location was expected to provide good exposure for oncoming winds, and also allowed access to the electronics. This was the first time the electronics were deployed and it was felt that access was an important consideration. The flying bridge location was not good because the sensor was in the lee of the ship too much of the time.

On 9 Feb the wind sensor was moved to the upper deck (position 2, Fig. 5, photo in Fig. 1.3), about 23 m above the water and 3 m above the upper deck. This position was an improvement (See Fig. 9 for a wind tunnel study of wind flow around an oil platform of comparable size), but barely, so, with improved confidence in the reliability of the electronics, during the port call at Truk Is. we decided to move the wind sensor to the top of the main mast (position 3 in Fig. 5), about 30 m above the sea surface and almost level with the ship's wind sensor. The installation was complete on 14 Feb, minutes before the ship departed for Leg 2.

Figure 7: Photograph of the wind sensor on the top mast of the *KAIYO*. This location provides optimum exposure. By visual observation and inspection of the data it appears that the Inmarsat-A radome does not affect the accuracy in direction or speed. The wind monitor is shown at the top of the mast. Just below is the Navico compass. The waterproof box houses the GPS electronics and micro-computer that processes the wind and navigation data. For this cruise the computer collected one-second samples of compass readings, position, ship speed and course, magnetic variation, UTC time, and apparent wind speed and direction and sent them as a single ASCII line each second. The next generation wind sensor will make one-second measurements, convert to true wind vectors, and average for one minute (typical).

The sea-surface temperature (SST) sensor, called the "sea snake," was hung from the bow of the ship (position 5 in Fig. 5, photo in Fig. 8). The height of the bow railing was 9 m and so a heavy shackle was needed to keep the line near vertical into the water. The probe remained at the

sea surface just below the surface in clear water ahead of the wake. The catamaran design was optimum for SST measurements like this.

Figure 8: A photograph of the Sea Snake sea-surface temperature sensor. (snakephoto)

Figure 9: A wind tunnel study result of the flow distortion around an oil platform of approximately the same size as the *KAIYO* main superstructure. The flow pattern shows reduced wind speeds (30% of true) near the roof, but increased wind speeds at 3-14 m above the roof. (platdistortion)

2 BNL Instrumentation

2.1 System Overview

A system overview of the instrumentation (Fig. 10) shows three major sensor groups all connecting to a central processing site in the ship laboratory. The three main components to the system are (a) wind and navigation subsystem, (b) radiation and meteorology subsystem, and (c) fast-rotating shadowband radiometer subsystem. A fourth subsystem is the GOES telemetry data collection package (DCP). The subsystems all communicate with the central computer over EIA422 serial lines. Power and serial lines are run separately (Fig. 11). A considerable effort was made to ensure solid grounding and no ground loops. Each remote computer system was grounded directly to the ship structure.

In the laboratory, the data logging PC operates an eight-channel serial switch with EIA422-to-EIA232 conversion. Any of the inputs can be selected for data collection. A universal power supply (UPS), power distribution box, and mass storage device (ZIP drive) complete the arrangement. Data analysis and processing was accomplished with a separate Macintosh computer, zip drive, and color printer.

The system shown in figures 10 and 11 changed soon after the beginning of the cruise when the ship's powerful radar apparently disabled the eight-channel serial switch. (Grounding and surge protection are art forms and not totally predictable!) As a result, two small Soltec 422/232 converter boxes were adapted, and data were collected by manually plugging in different subsystems.

2.2 Portable Radiation Package

The Portable Radiation Package (PRP) (see photo in Fig. 6) is comprised of an **Eppley PSP sensor** for global shortwave insolation, an **Eppley PIR sensor** for downwelling longwave radiation, and a fast-rotating, shadowband radiometer of special design for making direct/diffuse broadband shortwave radiation measurements from moving platforms.

All sensor outputs are recorded by a Zeno Model 3200 data logger (Fig. 12). The data logger samples all input analog variables at a one-sec rate, then computes one-minute averages. A large capacity memory allows the logger to collect up to several weeks of data.

In addition to the radiation sensors, the following meteorological sensors were sampled: **temperature, relative humidity, and barometer**. The pitch and roll of the ship was recorded with two **x-y tilt sensors** mounted on the radiation sensor plate.

The Fast-Rotating shadowband radiometer (FRSR) is a stand-alone subsystem that has its own computer, serial interface, and power connections (Fig.13). The principle of the FRSR is described in several places (Reynolds, 1996; Reynolds and Smith, 1996). In short, the RSR arm rotates in a full circle with a period of approximately five seconds. By combining a fast silicon-cell detector, 20

Hz sampling, and special shadow-detecting software, the arm shadow can be detected regardless of the azimuth or tilt of the device.

This version of the FRSR used a Si sensor from International Light, the SED033/F/W sensor. This is a great improvement over the LiCor sensor used in previous excursions. The IL sensor passband is flat over the 400-1000 nm short-wave band (Fig. 14) and compares nicely with the Eppley PSP. Note the LiCor sensor is strongly attenuated in the blue (400 nm) and hence the diffuse measurements from the LiCor are much harder to interpret. After calibration (Sec. 4) the FRSR compares extremely well with the PSP.

2.3 Wind-Navigation System

The wind and navigation subsystem (Fig. 7 and 15) was a separate subsystem so it could be placed in an exposed place on the ship. The computer interfaced with a Navico flux-gate compass with serial output, a Trimble Model Lassen-SK8 miniature OEM GPS receiver, and an R.M. Young marine-grade wind monitor.

The wind monitor was oriented on the ship with its south lubber line facing the bow. The reason for this was that the direction-measuring potentiometer has a dead zone directly at the north position on the wind monitor. If it were deployed in the logical way, facing the bow, the sensor would spend much of its time in the dead zone. We add 180° to the measurements during processing.

2.4 GOES Platform

The GOES platform shown in figure 10 was included to evaluate the performance of the unit operating from a ship in the far west Pacific where the satellite elevation is extremely small, almost at the horizon. No data was transmitted over this unit. The data collection platform (DCP) sent only its default "No Data" message on an hourly basis. These transmissions were monitored at BNL for accuracy and reliability.

The GOES platform configuration (Fig. 16) had both a +12 vdc power input and a serial EIA422 connection. The plan was to send occasional messages over GOES (GOES-grams), but this was abandoned after the loss of the serial-switch. All available hardware was tied up in data collection.

Figure 10: Sketch of the complete JUSTOS mean meteorology flux system.

Figure 11: Sketch of the cable interconnection for the flux package.

Figure 12: Block diagram for the Portable Radiation Package and Zeno data logger.

Figure 13: Block diagram for the Fast Rotating Shadowband Radiometer.

Figure 14: Frequency response of several short-wave radiation measurement devices.

Figure 15: Block diagram for the Wind and Navigation Data Unit.

Figure 16: Block diagram for the GOES Data Collection Platform (DCP) system.

3 Data Collection and On-board Processing

3.1 Zeno Data Processing

The ZENO data logger was downloaded once each day just at the beginning of the next julian day (local time 9–11 am, depending on time zone). The output format is shown in figure 17 below. The basic sample time was once per second, and most variables were averaged over a basic one-minute period. The one-minute records with mean, standard deviation, minimum and maximum for each variable were stored in a large volatile memory. Because of the volatility of the memory, a battery-backed, un-interruptable power supply was used.

The ASCII data files were processed on a Macintosh computer using Matlab routines for data processing, plotting, and storage. Daily plots were printed each day.

3.2 FRSR Data Processing

The FRSR scans were compiled as one-minute averages in the FRSR computer, which had a 460KB RAM memory and could store about 1.5 days of data. Like the ZENO, the FRSR data were downloaded as a binary file at the end of each julian day. The binary files are processed into ASCII files with a special C decode application on the Macintosh computer.

An example of the FRSR ".dat" file is shown in figure 18. Each minute of data was given as header line and a table of 60 columns for each of the analog-to-digital measurements as the arm swings over the upper hemisphere. The header line includes the global flux value (the "nadir" reading when the arm is at its bottom), the standard deviation of the global value, the average shadow value, and the mean dip value (ratio of global minus shadow over the standard deviation for the sweep). More information about the data treatment is given in the figure.

3.3 Wind-Navigation Data Processing

The wind-navigation subsystem sampled the winds, compass, and GPS at a one-second rate and sent an ASCII record (Fig. 19) over its EIA422 serial line. It is normal practice to allow the computer to compute one-minute vector averages from the one-second data, and then store and send one-minute samples. However, it was decided to collect one-second samples on this first voyage on the KAIYO because the compass corrections were not known. The ship's magnetism can have a strong effect on the compass reading and it must be known in order to remove it. (See the discussion of compass corrections below.)

The one-second data lines were collected by a PC and stored on disk. One day of data resulted in an ASCII file of about 7.2MB. A C program was used to (a) remove bad values, (b) correct the compass according to an empirical calibration equation, (c) convert from apparent winds to relative winds using the compass reading and variation, (d) convert from relative winds to true

winds using the GPS ship speed and course, and finally (e) compute one-minute vector averages. A one-minute file with format shown in the figure is produced.

THE ZENO OUTPUT RECORD FOR THE JUSTOS EXPERIMENT																			
		PSP				PIR													
DATE	TIME	av	min	max	stdev	av	pile	Rcase	Rdome										
97/02/07	23:13:59	643.3	571.7	28.54	0.418	4.7	8289.0	8098.9											
		AIR TEMP				RH				BAROMETER									
Rcase	Rdome	av	min	max	stdev	av	min	max	stdev	av	min	max							
29.68	30.35	28.10	28.1	28.2	0.01	77.7	77.79	0.4	1007.08	1006.9	1007.3								
		PITCH				ROLL				RAIN				SST					
stdev	av	mn	mx	std	av	mn	mx	std	av	mn	mx	std	av	min	max	stdev	Tint	Vext	Vint
0.09	3.7	2.8	7.1	1.3	2.6	8.5	0.1	0.0	0.0	28.78	28.8	28.8	0.01	25.8	14.6	12.5			

The ZENO saved data record for each minute. Generally the average (av), minimum (mn), maximum (mx) and standard deviation (std or st dev) are computed for each minute. The date and time are recorded at the end of the minute average. For the PIR, the mean LW radiation is computed from the ARCS standard calibration equation. The pile value, and case and dome thermistor resistances and computed temperatures are given so newer calibration equations can be compared.

zenoformat

Figure 17: The ZENO output record format.

FAST ROTATING SHADOWBAND RADIOMETER DATA FILE FORMAT

	Julian day	internal counts		No. samps in scan	Nadir (mvolts)	No. Scans in this avg.	Nadir std dev (mvolts)	Shadow (mvolts)	Mean dip value
	38.0013889	1	1	60	1279	10	42.4	206	4.46
0	10	1278	50						
1	10	1278	50						
2	10	1278	50						
3	10	1277	50						
	• • •								
25	10	1238	53						
26	10	1225	55						
27	10	1205	57						
28	10	987	155						
29	10	303	129						
30	10	206	7						
31	10	317	86						
32	10	1006	166						
33	10	1215	49						
34	10	1239	51						
35	10	1254	51						
36	10	1262	52						
	• • •								
57	0	-99	-99						
58	0	-99	-99						
59	0	-99	-99						

Edge1

Shadow (mvolts)

Edge2

Composite Scan Sample

No. samples in the composite avg.

Composite mean (mvolts)

Standard Deviation for samples

The FRSR data file format name has the form "R97jjj.dat" where jjj is the utc julian day. One record as above is generated each minute. The first line is the summary line and has basic information on this minute's sample. The table below is a composite of the 10 swings of the RSR arm. On each swing the 60 analog-to-digital samples are aligned into a composite where the minimum value, the shadow, is positioned at index 30. A "nadir" sample is taken when the arm is at its bottom position, this is also called the global reading. For each rotation a "dip ratio," the ratio of (global - minimum) to the standard deviation of all samples in the rotation (samples are taken only when the arm is above the horizon), is computed. On sunny days the dip ratio is > 4. When the dip is less than 1.3 (adjustable) the composite is not updated.

rsformat.csv

Figure 18: The FRSR output record format.

Figure 19: The wind-navigation subsystem output record format.

4 Calibration and Data Quality

Shortwave Global Radiometer: The Eppley PSP sensor was calibrated at the factory before being shipped to BNL. This was the first deployment of the sensor. A post calibration will be performed upon its return to New York. The sensor was cleaned at regular intervals although, owing to the considerable rain, it was never in need of cleaning. The ZENO data logger was calibrated at 1, 5, 10, and 15 mv.

Longwave Radiometer: The Eppley PIR was cleaned as frequently intervals as the PSP sensor. It was factory calibrated and will be post-calibrated at the end of this cruise. The ZENO data logger was calibrated for inputs of .1, .5, 1, and 1.5 mv.

Temperature and Relative Humidity: The temperature probe is a precision PRT and the relative humidity probe is a capacitance type identical to that used for the ARM/ARCS sites. The ZENO channels were calibrated over the input voltage ranges. During the cruise an aspirated Assman psychrometer was used to verify the sensors. Relative humidity agreed to within 1% usually, and temperatures to about 0.5°C.

Barometer: The R.M. Young barometer is calibrated and guaranteed to be within 0.2 mbar at 20-30°C. Comparisons with the ship barometer were routinely made and agreed to about 0.1 mbar.

Pitch and Roll Sensors: These sensors were added at the last moment for obtaining qualitative information on the mean and standard deviations of the tilt components during the voyage. Assembly and calibration were done by the following steps: (1) level the top plate with all components on it; (2) level the PSP and PIR radiometers on the plate; (3) measure the output of the tilt sensors in volts; (4) record the tilt readings measured by the data logger and use these as offset values in the data logger scaling equation.

Wind Monitor: The wind monitor requires no direct calibration. The propellor determines the calibration, and as a result, unit-to-unit variability is better than a few ms^{-1} and less than 1-2°. A special test stand was used to verify the direction and a synchronous motor was used to validate the wind speed measurement.

The wind sensor was aligned on the ship by eye; there was no real way at sea to do better. The wind monitor was aligned with its north mark toward the stern for reasons described in section 2.3. The apparent wind speed and direction were compared with the ship's unit and agreed to better than 1 ms^{-1} and 5°.

Compass: The fluxgate compass was mounted on the aluminum pole directly beneath the wind monitor and aligned to it. The compass needed to be corrected for the hard and soft magnetism on the ship and this procedure required that the ship be pointed in many directions around the compass and a table of compass deviation vs. measured direction. For any direction this was done over a period of time by making simultaneous readings of the ship's gyroscope heading and the compass. An example of the error curve for when the compass was positioned off the flying bridge is given in figure 20. A calibration correction equation in the form

$$C_0 + C_1 \sin 2\theta + C_2 \cos 2\theta + C_3 \sin 2\theta + C_4 \cos 2\theta$$

where C_0 - C_4 are derived correction coefficients and θ is the measured angle was derived. The corrected curve indicates that for this calibration errors of -18 to +26° were reduced to about $\pm 5^\circ$. At position 3, at the top of the mast the compass agrees with the gyro heading to better than 5° for all directions and thus no correction was applied during the cruise. A final correction can be applied during post analysis if that is necessary.

Global Positioning System: The GPS receiver required no calibration. Position, speed, and course were compared routinely with the ship and were correct. The course and compass agreed very well.

Fast-Rotating Shadowband Radiometer: The new radiometer head for the FRSR arrived too late for making an exhaustive intercomparison at any calibration site. However, it was sent to NOAA in Boulder (Dr. Charles Long, personal communications) and was tested for approximately one week, several days as a global device and several under a tracker. For both configurations it was inter-compared with several "standard" Eppley PSP sensors. The results from this short inter-comparison test were as follows:

direct beam: A calibration multiplier of 1.13 was required and a significant zenith angle error for lower sun angles, $\cos z_e < .7$, was observed.

diffuse irradiance: A good comparison was made after a calibration of 1.13 was applied.

During the cruise the possibility of making an in-field correction using the PSP sensor was explored. This technique showed great promise and will be reviewed here. The julian day 034 is chosen as it was about the clearest day observed. Figure 21 is a daily plot for that day. The correction from local time to UTC is -10 hours, thus the graphs show part of two solar days. We see relatively clear conditions in the evening and morning, and partly cloudy conditions through the day. The top graph shows the measured global and shadow irradiance using the factory calibration value.

Figure 22 is a scatter plot of the global measurements made by the PSP and the FRSR for julian day 034. The graph plainly shows both the calibration error and the zenith angle error seen by NOAA. The slope of the background error indicated a multiplier of 1.1372 was required to rotate the curve into the 45° line.

Based on the NOAA measurements, the diffuse components of the FRSR and PSP compared extremely well. This information was used to perform a zenith correction. The FRSR-derived diffuse and direct beam components were derived from the following equations:

The shadow-band values at the edges of the solar disk are computed as

$$F_{arm} = F'_g - \frac{1}{2}(F_1 + F_2)$$

where F'_g is the global (nadir) measurement; F_{arm} is the "arm" correction term; and F_1 and F_2 are the measurements for sample indices 25-26 and 35-36 (see Fig. 18).

The arm correction and calibration correction are used to produce the diffuse component:

$$F_{diffuse} = C(F_{shadow} + F_{arm})$$

where C is the correction term ($= 1.14$); and F_{shadow} is the measured shadow irradiance.

The diffuse term is removed from the PSP global value to yield a best guess of a direct beam irradiance with no zenith angle error:

$$F'_{direct} = F_{psp} - F_{diffuse}$$

where F'_{direct} is the direct beam value from the PSP sensor; and F_{psp} is the PSP global irradiance. The prime signifies a component derived from the PSP.

Figure 23 is a plot of the difference between the FRSR and PSP direct-beam values, ($F_{direct} - F'_{direct}$), and the cosine of the zenith angle, $\cos \theta_z$. The plot is somewhat noisy owing to the partly cloudy, mixed conditions. However, the zenith angle error is clearly distinguishable for cosine values less than 0.7. A fourth-order polynomial fit to this curve yielded an excellent match to the curve.

When the calibration multiplier correction and the zenith angle correction were made to the FRSR data, the fit, Figure 24, was significantly improved. The standard error is less than about 5 W m^{-2} for the one-minute samples. This exercise gives confidence that the FRSR can be calibrated to agree near-perfectly to the PSP and that meaningful direct and diffuse beam components can be estimated with high accuracy.

$$F_{direct} = mboxcorrect(F'_{direct}, \theta_z)$$

$$F_g = F_{direct} + F_{diffuse}$$

Figure 20: The compass calibration for compass position 1, just outside the port flying bridge. The error curve (o) was derived from comparisons with the ship's gyroscope heading. Using the assumption that the error curve is composed of effects from hard and soft iron, which induce first and second harmonic components in the error, the correction curve is derived in the form $C_0 + C_1 \sin 2\theta + C_2 \cos 2\theta + C_3 \sin 2\theta + C_4 \cos 2\theta$ where θ is the measurement angle.

Figure 21: Fast RSR plot for Day 034. The top graph compares the global and shadow measurements using the factory calibrations. The lower graph shows the direct beam and diffuse components of the total irradiance. Low diffuse radiation indicates clear to partly cloudy conditions.

Figure 22: FRSR comparison to PSP. Both the calibration error and the zenith angle error are evident.

Figure 23: FRSR zenith error, plot of $F_{direct} - F'_{direct}$ versus cosine of the zenith angle. Note the zenith angle error occurs for $\cos\theta_e < 0.7$. A fourth order polynomial fit to this error curve was used to remove the zenith angle error.

Figure 24: Comparison of corrected FRSR and PSP global values. The FRSR global value combines corrected diffuse and direct components for its global value. The direct beam component was corrected for calibration error and zenith angle error. The diffuse component was corrected only for calibration error.

5 Data Summary

Performance Summary: This section presents an overview of the data collected during the cruise. The table in figure 25 shows a time line for each sensor. The Zeno data logger required a program change and calibration on day 031. There was a period when the RH sensor stopped because water got into the sensor housing. The sensor was opened and dried and began operating properly for the rest of the trip. Assman psychrometer comparisons agreed to this sensor, generally to better than 1%.

The SST probe was a continual problem during the first part of the cruise. Turbulent motion of the cable at the underwater connector quickly destroyed the cable. A spare cable was spliced onto the probe, but it too failed in short order. When spare cables arrived in Truk, the probe connection was re-built with a modified design to protect the cable connector. After day 44 the SST measurement fared better. Each morning and evening the probe was brought on board and examined. Tape was added as needed to maintain the probe condition. Plainly, the probe design was not up to the constant erosion and turbulence involved in towing and it must be revised.

The FRSR operated very reliably until day 49 at which time the computer began to fail. The prototype computer used had volatile RAM, and thus a reboot caused all data to be lost. The next design will need to incorporate static RAM and regular data downloads to prevent lost data.

The wind/navigation system operated exceptionally well during the entire cruise. The only down periods were planned times for shifting the position of the wind monitor and once to change modify the program to properly handle southern latitudes.

Insolation Measurements: Plot summaries for shortwave radiation on all days are presented in Figures 26 and 27. The time base for these plots is shifted so a particular solar day fills each plot. The average solar insolation for the day is written in the upper right-hand corner of the plot.

A wide variety of daily insolutions is seen, from a low of 80 W m^{-2} to a high of 271 W m^{-2} . The high value was on day 034, and this day was selected as the best one to verify the calibration of the FRSR sensor (Section 4).

For comparison, the FRSR direct and diffuse component estimates are presented in Figure 28. These curves were corrected for the calibration error by a multiplication of 1.14, but no zenith correction was made. Thus we expect the direct-beam values to be slightly small. The daily average direct beam and diffuse insolation components are written in the upper right-hand corner of the plots for each day. The sum of these components should agree with the PSP total insolation reading, and in general it does very well. A formal comparison will be done during later analysis when the zenith errors can be fully extracted.

Meteorological Summary: A summary of meteorological conditions is presented in figures 29 and 30. We see the winds during the first part of the cruise were weak and northeasterly and

during the later part of the cruise, in the far western Pacific, they switched to the northwest and generally increased. The western Pacific became much more rainy.

Figure 25. Summary table of all PRP sensors deployed for JUSTOS.

Figure 25:

Figure 26: Graphs of shortwave irradiance for days 30 to 45. The computed top-of-the-atmosphere solar irradiance times 0.8 is shown as the smooth bell curve. Times are in UTC.

Figure 27: Same as Figure 26 for days 46 to 57.

Figure 28: Direct (solid line) and diffuse (dashed line) solar irradiance measured by the Fast Rotating Shadowband Radiometer. The daily mean direct and diffuse insolation is listed in the upper right corner of each plot.

Figure 29: Summary of meteorological data for days 29 through 43.

Figure 30: Summary of meteorological data for days 43 through 57.

A Station Bill for legs I and II.

STATION BILL

R/V KAIYO TOCS(MAJURO-CHUUK) 1997 1/4~1/25

NO.1 LIFE BOAT(RIGHT) 50 PERSONS		NO.2 LIFE BOAT(LEFT) 50 PERSONS	
C R E W			
POSITION	NAME	POSITION	NAME
Captain	Hiroshi Hyoudou	Chief officer	Hajime Oda
2nd officer	Yosiyuki Mizui	3rd officer	Masakatu Yamada
Chief engineer	Toshihiro Kimura	1st engineer	Youichi Kikuchi
2nd engineer	Mituhiko Ueki	3rd engineer	Kazuto Yosiura
Chief radio officer	Hideyuki Akama	2nd radio officer	Satosi Watase
Boatswain	Norio Nagatani	Able seaman(A)	Yoshimasa Azechi
Able seaman(B)	Yosiaki Sirai	Able seaman(C)	Yasuyosi Kyuuki
Able seaman(D)	Kazumi Ogasawara	Sailer(E)	Yousuke Chida
Sailer(F)	Takasi Kiyohara	No.1 oiler	Akira Kajitani
Oiler(A)	Kouichi Kobori	Oiler(B)	Kiyosi Yahata
Oiler(C)	Jyunji Mouri	Assistant oiler(D)	Yosinori Kawai
Chief steward	Kiyotosi Teranisi	Steward(A)	Isao Kasima
Steward(B)	Yoshitarou Tamiya	Steward(C)	Jihei Nakatuka
Steward(D)	Isao Matsumoto	Jr.2nd officer	Isao Maeda
P a s s e n g e r s			
JAMSTEC	Kentarou Andou	JAMSTEC	Kunio Yoneyama
NME	Ken Katayama	NME	Satoru Kanda
NME	Mituru Hayashi	NME	Hiroshi Yamamoto
NME	Masayuki Hujisaki	NME	Nobuharu Komai
SANYO	Keiko Komine	NME	Hiroaki Sakou
KEEC	Yasuo Ishida	SANYO	Masashi Aihara
PMEL	David Zimmerman	PMEL	Stephen Smith
NCAR	Scott Smith	NCAR	Charles Martine
NCAR	Jeseph R. Vinson	NCAR	R.Michael Reynolds
Total 23persons		Total 23persons	

STATION BILL

R/V KAIYO

TOCS(CHUUK-PALAU)

1997 2/13~3/2

NO.1 LIFE BOAT(RIGHT) 50 PERSONS		NO.2 LIFE BOAT(LEFT) 50 PERSONS	
C R E W			
POSITION	NAME	POSITION	NAME
Captain	Hiroshi Hyoudou	Chief officer	Hajime Oda
2nd officer	Yoshiyuki Mizui	3rd officer	Masakatsu Yamada
Chief engineer	Toshihiro Kimura	1st engineer	Youichi Kikuchi
2nd engineer	Mitsuhiro Ueki	3rd engineer	Kazuto Yoshiura
Chief radio officer	Hideyuki Akama	2nd radio officer	Satoshi Watase
Boatswain	Norio Nagatani	Able seaman(A)	Yoshimasa Azechi
Able seaman(B)	Yoshiaki Sirai	Able seaman(C)	Yasuyoshi Kyuuki
Able seaman(D)	Syuji Takuno	Able seaman(E)	Kazumi Ogasawara
Sailer(F)	Takashi Kiyohara	No.1 oiler	Akira Kajitani
Oiler(A)	Kouichi Kobori	Oiler(B)	Kiyoshi Yahata
Oiler(C)	Jyunji Mouri	Assistant oiler(D)	Yosinori Kawai
Chief steward	Kiyotoshi Teranishi	Steward(A)	Isao Kasima
Steward(B)	Yoshitarou Tamiya	Steward(C)	Jihei Nakatuka
Steward(D)	Isao Matsumoto	Jr.2nd officer	Isao Maeda
P a s s e n g e r s			
JAMSTEC	Kentarou Andou	JAMSTEC	Kunio Yoneyama
NME	Ken Katayama	NME	Satoru Kanda
NME	Mituru Hayashi	NME	Hiroshi Yamamoto
NME	Masayuki Hujisaki	SANYO	Masashi Aihara
SANYO	Keiko Komine	PMEL	Stephen Smith
KEEC	Yasuo Ishida	NCAR	Eric R.Miller
PMEL	David Zimmerman	BNL	R.Michael Reynolds
BNL	Scott Smith	BPPT	Ali Alkatiri
NCAR	Jeseph R. Vinson	Security officer	Isbandi Andriyanto
BPPT	Djoko Hartoyo		

Total 24persons

Total 23persons

B INFORMATION ON THE NCAR SABL LIDAR SYSTEM

SABL Performance Goals

- Qualitative measurements available in real time out to 10 km at 7.5 m resolution.
- Quantitative information from the troposphere and lower stratosphere available with post processing of the data at a range up to 5 km.
- Lidar backscatter data available in real time to assist scientists with the direction of the experiment.
- Capable of high resolution measurements of the earth's "clear air" boundary layer, wet cloud edges, ice clouds and aerosol plumes.
- Some ability to perform aerosol size and/or type discrimination.

SABL Design Features

- Small, Compact, Rugged
 - Telescope is constructed from invar for thermal stability.
 - Size of telescope and receiver is only 15" x 15" x 32".
 - Telescope and receiver are mounted on same plate.
 - The received signals are linear and digitized at 12 bits eliminating the need for logarithmic amplifiers commonly used in similar lidars.
 - Nd:YAG laser with frequency doubling for operations at 1064 and 532 nm.
- High Resolution Data
 - Digitizer capable of sampling both channels at 40 MHz (3.75 m gates) simultaneously.
- High Signal to Noise Ratio
 - Telescope is 14" in diameter.
 - Narrow band filters (< 10 angstroms) are placed in front of the detectors.
 - Laser energy of approximately 75 mjoules at 1064 nm and 50 mjoules at 532 nm.
- Quantitative Measurements
 - Detectors are thermally stabilized with thermoelectric coolers.
 - Peak transmitted power is monitored on each pulse.

SABL Design Features Continued

- Remote Operation
 - Convergence of the laser beam with the receiver's field of view is done electronically with computer controlled adjusting screws.
- Real Time Displays
 - Both wavelengths can be displayed simultaneously.
 - Data can be displayed in relative dB with the contribution due to molecular backscatter removed .
 - Remote display for use by the mission scientist can be implemented.
- Scanning Capabilities
 - Are planned but are currently not implemented.

SABL

SABL Data System

SABL Transmitter Specifications

Wavelengths	1064 nm (Infrared) 532 nm (Green)
Pulse Energy	75 mJ at 1064 nm 50 mJ at 532 nm
Pulse Length	15 ns (2.25 meters)
Polarization	Linear (1000:1)
Pulse Rate	Up to 60 per Second
Beam Divergence (adjustable)	1 mrad to 4 mrad (0.06 deg to .24 deg)
Beam Diameter (at the telescope)	25 mm

SABL Receiver Specifications

Telescope Diameter	35.5 cm (14 inches)
Telescope Speed	f/5.0
Telescope Field-of-View (adjustable)	1 mrad to 5 mrad
Background Filter Bandwidths	0.92 nm at 1064 nm 0.16 nm at 532 nm
Detectors	Avalanche Photodiode at 1064 nm Photomultiplier Tube at 532 nm
Digitizer	12 Bits at up to 40 MHz (3.75 meter gate spacing)

SABL Data System Specifications

Maximum Number of Gates (Depends somewhat on pulse rate)	2500
Maximum Recording Bandwidth	430 KBytes / Second (2500 gates at PRF of 40)
Tape Format	Field Version of DORADE
Computers/Operating Systems	VMEBus Based / VxWorks (For Real Time Acquisition) Sun Sparc-5 / Unix (Display and Control)
Typical Length of Data Display	10 to 15 Minutes
X-Windows Interface Control Of:	Sample Rate (Gate Spacing) Total Number of Gates APD Bias Voltage PMT Bias Voltage Pulse Repetition Rate * Scanning Parameters * PMT & APD Temperatures * Data Recording On-Line Logbook Operator Event Logging All Display Parameters

C INFORMATION ON JAMSTEC, R/V MIRAI, AND THE TRITON BUOYS

Chairman

President

Hiroshi Ohba

Mitsugu Ishizuka

LOOKING AHEAD TO 21ST CENTURY

The vast dimensions of the sea contain not only abundant biological and mineral resources which are useful for human living, but unlimited and clean energy such as tidal power and wave power. For continued prosperity of human beings which population is increasing rapidly, they will have to seek increased portion of natural resources, including food, in ocean, and the need on research and development of science and technology for such purposes will be ever more stronger.

Another important aspect of the ocean is its close relationship with global environmental issues such as warming climate and abnormal meteorology. In order to predict the global environment in the 21st century under expanding social and economic development of human beings and to make remedial actions, it is essential to clarify the functions of the ocean in global environment under international cooperation by observing marine phenomena, including those in deep seas, in a global scale.

Japan Marine Science and Technology Center, being the core research and development organization for marine science and technology in Japan, is implementing aggressive research and development programs based on the recognition of its mission, commitment, role and responsibility.

JAMSTEC LOCATION MAP

RESEARCH SUPPORT ORGANIZATIONS

INFORMATION ACTIVITIES

Function as Information Center of Marine Science and Technology

As the international cooperation in marine science and technology research and development is enhanced, it is required to acquire accurate information on the international trend of marine science and technology and related activities in each nation.

In order to meet such needs on information, JAMSTEC surveys the new developments and literatures concerning marine science and technology in Japan and abroad, classifies the information thereby collected, organizes data base from which the information can be systematically supplied, and engaged in variety of information services.

Such services include publication of JAMSTEC's research achievements and consultation services concerning general marine science and technology topics.

Diffusion of Results

Publications

1. Research Report of JAMSTEC :	Semiannually
2. Collected Abstracts for Research Report of JAMSTEC :	Every 2 years
3. Technical Report Symposium on Deep Sea Research (Using "SHINKAI 2000/6500") :	Annually
4. Journal, "JAMSTEC" :	Quarterly
5. Various Research Reports :	Irregularly
6. JAMSTEC's News, "Natsushima" :	Every two months
7. Annual Report :	Annually
Symposiums	
1. JAMSTEC Research Meeting :	Annually
2. Symposium on Deep Sea Research Using the Submersible "SHINKAI 2000/6500" :	Annually
3. Ocean Wave Energy Utilization Symposium :	Irregularly

VESSEL & MAIN RESEARCH FACILITIES

RESEARCH VESSEL "KAIYO"

Length : 61.6m
Breadth : 28.0m
Depth : 10.6m
Gross Tonnage : 2,849 tons
Cruising Speed : approx. 13 knots
Cruising Range : approx. 5,100 miles
Accommodation : 69 persons

MANNED RESEARCH SUBMERSIBLE "SHINKAI 2000"

Length : 9.3m
Breadth : 3.0m
Height : 2.9m
Depth capability : 2,000m (max.)
Dry Weight : 23.2 tons
Speed : 3 knots (max.)
Crew Complement : 3 persons

SUPPORT VESSEL "NATSUSHIMA"

Length : 67.4m
Breadth : 13.0m
Depth : 6.3m
Gross Tonnage : 1,553 tons
Cruising Speed : approx. 12 knots
Cruising Range : approx. 10,800 miles
Accommodation : 55 persons

UNMANNED VEHICLE "DOLPHIN 3K"

Length : 2.9m Depth capability : 3,300m (max.)
Breadth : 1.9m Dry Weight : approx. 3.7 tons
Height : 1.9m Speed : 3 knots (max.)

10,000m class deep sea ROV "KAIKO"

Depth capability : 11,000m (max.)
Speed : 2 knots (max.)

	(Launcher)	(Vehicle)
Length :	5.2m	3.1m
Breadth :	2.6m	2.0m
Height :	3.2m	2.3m
Dry weight :	5.1 tons	5.4 tons

TECHNICAL INFORMATION SERVICE, SPECIFICATION OF RESEARCH/SUPPORT VESSELS AND TABLE OF RESEARCH FACILITIES

TRAINING AND EDUCATION SHIP OPERATION

In implementing researches on marine development in future, special skills and knowledges are required in order to conduct sophisticated observation and research activities such as long-term, continuous observation on research vessels and simultaneous survey of wide areas from aircraft and artificial satellites. JAMSTEC operates training courses for ocean observation technique, acoustic technique and diving technique to have researchers and engineers engaged in ocean researches acquire new technique. In addition, skilled man power is fostered by seminars and training schools operated on ships.

JAMSTEC operates manned research submersible "Shinkai 2000", "Shinkai 6500", and research vessel "Kaiyo" for various experiments, tests and researches. These ships are not only engaged in the implementation of research and development works promoted by JAMSTEC, but it is operated effectively under cooperation with universities and research institutions both in Japan and abroad as coordinated by the governmental ministries and agencies, in order that the research and development of marine science will be implemented in a comprehensive manner. International cooperative research operations have been conducted with American and French researchers boarding the

manned research submersible vessels, etc.

"Shinkai 2000" performs 75 dives a year, and Shinkai 6500 performs 60 dives a year, while support ship "Yokosuka" stays at sea more than 250 days in a year for surveys and researches.

FACILITY/EQUIPMENT

JAMSTEC constructs and operates large experiment and research facilities commonly used for various research and development of marine science, and provides them for public use to private corporations, universities and national research institutions.

SUPPORT VESSEL "YOKOSUKA"

Length : 105.2m
Breadth : 16.0m
Depth : 7.3m
Gross Tonnage : 4,439 tons
Cruising Speed : approx. 16 knots
Cruising Range : approx. 9,000 miles
Accommodation : 57 persons

(Note : 1 mile = 1,852m)

MANNED RESEARCH SUBMERSIBLE "SHINKAI 6500"

Length : 9.5m
Breadth : 2.7m
Height : 3.2m
Depth capability : 6,500m (max.)
Dry Weight : 25.8 tons
Speed : 2.5 knots (max.)
Crew Complement : 3 persons

Equipment/Facility Name	Specifications	Equipment/Facility Name	Specifications
High Pressure Test Vessel	Maximum pressure : 1,560kg/cm ²	Diving Training Pool	Depth : 3m
Medium Size High Pressure Test Tank	Maximum pressure : 1,580kg/cm ²	Open Tank	Depth : 3m, 4 observation ports.
Small Size High Pressure Test Tank	Maximum pressure : 700kg/cm ²	Underwater Anechoic Tank	Length : 9m, width : 9m, depth : 9m.
Underwater Simulation and Training Facility	Maximum pressure : 50kg/cm ² (consisting of wet, dry and sub chambers)	Water Tank with Wave Generator	Length : 40m, width : 4m, maximum wave height : 0.2m
Emergency Repression System	Operating Pressure : 5kg/cm ²	Circulating Water Tunnel	Flow speed : 0.5 - 5.0m/sec.
Diving Apparatus Test Chamber	Maximum pressure : 50kg/cm ²		

History of the Japan Marine Science and Technology Center (JAMSTEC)

The Japan Marine Science and Technology Center (JAMSTEC) is a general oceanographic research institution established in October 1971 based on the "Establishment of the Japan Marine Science and Technology Center Act" approved at the 65th Diet session (1971). It is an entity embodied in a joint effort of government and industry, and comes under direct supervision of the Science and Technology Agency (STA).

1970
December The Japan Federation of Economic Organizations requested the establishment of JAMSTEC to the Government.

1971
May The establishment of JAMSTEC Act was approved by the Diet.
October JAMSTEC was established.

1971
August The "SEATOPIA" Project-experiment on habitat 30m under the sea. (Tago Port, Shizuoka Pref.)

1973
December Underwater monitoring ocean floor survey experiment 100m under the sea. (Off Atagawa, Shizuoka Pref.)

1975
March Completion of the building for joint research, and training (Currently used as the main office building).

1976
March Sea experiment with an ocean the towing type (Sagami Bay, Kanagawa Pref.)
June Completion of a high pressure test facility.

1977
February Ocean remote sensing system experiment. (Tokyo Bay)
June The Crown Prince visited JAMSTEC.

1978
July Completion of animal simulator facility for hyperbaric diving research.
August Experiment with "Kaimai", an experimental wave power generation system. (Off Yura, Tsuruoka-shi, Yamagata Pref.)

1979
November Ocean experiments with a deep-sea camera system of the free-fall and self-surfacing type and with a deep towed ocean floor survey system.

1980
August Launching of the "Natsushima", a support ship for the 2,000m class manned submersible "Shinkai 2000".

1981
October Completion of the "Shinkai 2000" system.
November Introduction of the "Shinkai 2000" and the "Natsushima", attended by Prince Hironomiya. (Harumi, Tokyo)

1982
February Air-launched, expendable micro sensor experiment. (Sagami Bay, Kanagawa Pref.)

1983
June Ocean experiment with an advanced oceanic observation system. (Sagami Bay, Kanagawa Pref.)
July "Shinkai 2000" started Japan's first manned deep sea research. (Toyama Bay)
September Started experiment with a shore fixed wave power generation system.

1984
August Opened the Hatsushima Island Marine Museum.
November Started research and development on microwave remote sensing technology.

1985
May Reclamation work completed for JAMSTEC facility additions.
May Completion of catamaran "Kaiyo", for oceanic research and experiment for underwater diver work.

1986
July "Shinkai 2000" discovered hydrothermal vents (Okinawa Trough).
September Started Japan-China joint research of the Kuroshio.

1987
January Started observation of El Nino event.

December Started Japan-France joint program to survey the North Fuji Basin life system.

1988
January Completion of "Dolphin 3K", (3,300m depth capability), an unmanned deep-sea research vehicle.
March Built a meteorology/oceanography observation facility on Okinotorishima Island.
July Carried out 300m-depth saturation dive experiments using "KAIYO". (Off Hatsushima Island, Sagami Bay)
July Launching of the "Yokosuka", a support ship for the 6500m-class manned submersible "Shinkai 6500".

1989
January Launching of the manned deep research submersible "Shinkai 6500".
June "Shinkai 2000" discovered black smokers in the Okinawa Trough.
August "Shinkai 6500" succeeded in reaching 6,527m below sea level in its final sea test series.

1990
April Completion of the "Shinkai 6500" system.
April Introduction of the "Shinkai 6500" and the "Yokosuka", attended by the Crown Prince. (Harumi, Tokyo)
October Establishment of the "Deep-Sea Environment Program".
November Started international joint research in the Arctic Region.

1991
April Started experiment with "Marine Aya No.1" an artificial sea bed, of the submerging surfacing type. (Ayasato, Iwate Pref.)
May Commissioned the "Shinkai 6500" system to regular underwater research service.
July "Shinkai 6500" discovered the world's deepest colony of calyptogena and fissures on the Pacific plate, caused by plate distortion.
November Held "The 20th Anniversary International Symposium", inviting heads of world's leading oceanographic institution as speakers.
November Concluded research cooperation agreements with WHOI and SIO.

1992
August Prince and Princess Hitachinomiya visited the "Deep-Sea Water Research Center".
August Started multi-parameter observation of the North Pacific and the Arctic Region, Japan's first of its kind.
September Held "The First International Workshops Undersea Research and Ocean Research".

1993
June Concluded a research cooperation agreement with NOAA/PMEL.
July Completion of the Deep-Sea Research General Building.
August Investigated the sea floor around Okushiri Island soon after the "Hokkaido Nansei Oki (Off Southwest Hokkaido) Earthquake".
August Completion of the Deep-Sea Environment Experiment Systems.
September Built the Deep-Sea Long Term Observation Station off Hatsushima Island, Shizuoka Pref.
December Completion of the seminar and training building.

1994
April Deployed an ice ocean environment buoy (IOEB) station on an ice chunk of the North sea.
June "Shinkai 6500" started an investigation under the sea around the Central Ridge. (MODE '94)

1995
March 10,000m class deep sea ROV "KAIKO" succeeded in reaching 10,911m below sea level in its final sea trial. (Mariana Trench)
July Concluded a research cooperation agreement with AWI. (Germany)

FUNCTION AND ORGANIZATION OF JAMSTEC

Support Association

JAMSTEC was established in October, 1971, and in the beginning, the Japan Federation of Economic Organizations functioned as the channel for conveying the needs for JAMSTEC's activity and requesting the funding cooperation. However, as the initial funding program was successfully completed in fiscal 1975, it became desirable to establish an organization through which more support from the private sector can be provided. JAMSTEC consulted with Science and Technology Agency, Japan Federation of Economic Organizations and private corporations, and it was decided to establish the system of "Support Association", which was inaugurated in fiscal 1976. As the end of 1990, approximately 180 industrial organizations and individual corporations, including those in shipbuilding, electric utilities, financial, steel, machinery, electrical and construction business, take part in this Support Association.

JAMSTEC identifies the needs of private sector corporation which will play important role in the marine industry of future through this Support Association, and implements its activities based on this information.

OCEANOGRAPHIC RESEARCH VESSEL " MIRAI "

General Arrangement

Principal Particulars

1. Particulars	Dimension (L × B × D × d)	abt. 130m × 19.0m × 13.2m × 6.9m
	Gross tonnage	abt. 8,600 tons
	Researcher / Observer / Crew	28 / 18 / 34 persons (Grand Total 80 persons)
	Service speed	abt. 16 knots
	Endurance	abt. 12,000 sea miles
	Propulsion system	Diesel-electro hybrid propulsion
2. Delivery		Autumn in 1997

Configuration of the low latitude buoy

Configuration of float

Sensor specifications

SENSOR	RANGE	RESOLUTION	ACCURACY
Wind speed	0~60m/s	0.1m/s	0.3m/s
Wind direction	0~360°	0.7°	5°
Short wave radiation	0~1400W/m ²	0.1W/m ²	0.5%
Relative humidity	0~100%RH	0.1%RH	1%RH
Air temperature	-20~+55°C	0.01°C	0.1°C
Precipitation gauge	0~500mm/h	0.001mm	5%
Barometric pressure	800~1100hPa	0.0038%	0.01%
CTD	Conductivity	0~70ms/cm	0.001ms/cm
	Temperature	-3~+33°C	0.0006°C
	Depth	0~1000psia	0.003% F.S.
Current speed	0~1000cm/s	0.1cm/s	1%, 0.5cm/s

Data sampling and real time data transmission

Under water data transmission:

Inductive coupling data communication method

Satellite data transmission:

ARGOS system.

The minimum sampling rate for all sensors will be every 10 minutes, and hourly averaged data be transmitted in real time.

Relationship to International Programmes

The TRITON plan will be discussed at international forums and implemented by JAMSTEC with the cooperation of interested countries. The scientific goals of the TRITON project address the observational requirements of international research programme of CLIVAR (Climate Variability and Predictability), a major component of the World Climate Research Programme sponsored by the World Meteorological Organization, the International Council of Scientific Unions, and the Intergovernmental Oceanographic Commission of UNESCO. TRITON project will be a component of

the CLIVAR observing system and also contribute to the development of the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS). TRITON implementation will begin in the western equatorial Pacific where it will be integrated with the existing TAO (Tropical Atmosphere Ocean) Array, which is presently maintained by the Pacific Marine Environmental Laboratory / National Oceanic and Atmospheric Administration of the United States, in cooperation with France, Chinese Taipei, Korea and Japan.

TRITON Development Schedule

FY1994: Conceptual buoy design.

FY1995: Basic buoy design and construction of the prototype buoy. Open sea trial of the low-latitude prototype buoy.

FY1996: "International Workshop on Ocean Climate Variations from Seasons to Decades with Special Emphasis on Pacific Ocean Buoy Network", in May 1996 at Mutsu. Continuation of the open sea trial of the low-latitude prototype buoy. Construction of the buoy maintenance building at the mother port of R/V "Mirai" at Mutsu.

FY1997: Launching R/V "Mirai".

Open sea trial of mid- and high-latitude prototype buoy.

Deployment schedule

Region A: Begin deployment in FY1997 (Mar 1998) harmonized with TAO array and completed in FY1999.

TRITON buoys will enhance the capability of TAO buoys in the warm pool region by carrying salinity sensors down to 750m and full meteorological sensors, and be deployed in order to obtain long-term data for process studies

on ENSO.

Region B: Begin deployment in FY2000.

TRITON buoys focusing on oceanic change and air-sea interaction associated with Asian monsoon in the far western Pacific Ocean and the eastern Indian Ocean.

Region C: Begin deployment in FY1999.

TRITON buoys focusing on intermediate water formation and air-sea interaction in the frontal region between the subtropical gyre and the subpolar gyre.

Proposed buoy array

D BALLOON LAUNCH LOG

LEG ONE BALLOON LAUNCH SURFACE INFORMATION

Date	Time	Press	Temp	Td	RH%	uwind	vwind	wspd	wdir
970128	00Z:	1009.6	28.0	23.8	78.0	-0.6	2.4	2.5	167.0
970128	12Z:	1009.3	28.3	24.9	82.0	-2.8	-3.3	4.3	40.0
970128	18Z:	1006.4	28.4	23.8	76.0	0.0	-6.5	6.5	0.0
970129	00Z:	1008.4	30.8	23.5	65.0	-0.7	-8.5	8.5	5.0
970129	06Z:	1004.5	28.8	23.9	75.0	0.0	-5.0	5.0	0.0
970129	12Z:	1006.8	25.3	23.9	92.0	-2.6	-1.5	3.0	60.0
970129	18Z:	1004.4	27.5	23.3	78.0	-4.9	-0.9	5.0	80.0
970130	00Z:	1006.5	28.3	23.7	76.0	-8.5	-3.1	9.0	70.0
970130	03Z:	1004.5	28.3	25.7	86.0	-9.5	1.3	9.6	98.0
970130	06Z:	1004.2	27.4	23.4	79.0	-3.3	4.0	5.2	140.0
970130	09Z:	1005.5	27.4	23.7	80.0	1.3	4.9	5.1	195.0
970130	12Z:	1006.6	27.9	24.8	83.0	2.1	4.4	4.9	205.0
970130	15Z:	1005.3	27.8	24.0	80.0	2.6	7.2	7.7	200.0
970130	18Z:	1006.7	24.7	22.0	85.0	-2.0	-0.3	2.0	80.0
970130	21Z:	1006.9	26.8	21.1	71.0	-0.6	3.4	3.5	170.0
970131	00Z:	1008.5	27.4	23.9	81.0	1.0	1.1	1.5	220.0
970131	03Z:	1006.0	31.8	22.0	56.0	1.3	1.9	2.3	213.0
970131	06Z:	1005.7	28.2	22.9	73.0	1.8	-1.1	2.1	300.0
970131	09Z:	1008.7	24.8	20.9	79.0	-5.0	-0.0	5.0	90.0
970131	12Z:	1009.3	26.4	23.5	84.0	-5.6	-2.1	6.0	70.0
970131	15Z:	1006.2	26.8	22.7	78.0	0.4	5.0	5.0	185.0
970131	18Z:	1005.7	27.2	24.5	85.0	1.7	6.3	6.5	195.0
970131	21Z:	1007.0	27.7	22.9	75.0	-4.2	3.5	5.5	130.0
970201	00Z:	1007.7	29.5	24.4	74.0	-6.5	-0.0	6.5	90.0
970201	03Z:	1005.3	31.0	24.4	68.0	-6.8	1.2	6.9	100.0
970201	06Z:	1005.5	29.1	24.2	75.0	-5.5	-0.0	5.5	90.0
970201	09Z:	1006.2	28.2	25.0	83.0	-4.7	1.7	5.0	110.0
970201	12Z:	1008.0	28.7	24.1	76.0	-7.4	1.3	7.5	100.0
970201	15Z:	1006.7	28.8	23.9	75.0	-5.7	1.0	5.8	100.0
970201	18Z:	1006.0	28.8	23.7	74.0	-7.0	1.9	7.2	105.0
970201	21Z:	1007.0	29.1	24.7	77.0	-4.8	2.7	5.5	120.0
970202	00Z:	1007.9	29.8	22.5	65.0	-4.9	-0.9	5.0	80.0
970202	03Z:	1005.3	29.6	23.6	70.0	-6.1	-1.1	6.2	80.0
970202	06Z:	1005.0	29.1	22.4	67.0	-3.0	1.4	3.3	115.0
970202	09Z:	1006.5	29.6	22.6	66.0	-2.1	-2.1	3.0	45.0
970202	12Z:	1007.8	29.5	22.5	66.0	-2.5	-5.4	6.0	25.0
970202	15Z:	1005.7	29.3	24.2	74.0	-2.0	-5.5	5.8	20.0

970202	18Z:	1005.3	29.0	24.1	75.0	0.0	-5.0	5.0	0.0
970202	21Z:	1006.0	29.2	23.9	73.0	-1.9	-5.2	5.5	20.0
970203	00Z:	1007.9	28.7	24.5	78.0	-2.1	-5.6	6.0	20.0
970203	03Z:	1005.2	31.4	24.8	68.0	-4.1	0.8	4.2	101.0
970203	06Z:	1004.2	29.2	23.7	72.0	-1.5	-5.7	5.9	15.0
970203	09Z:	1006.0	29.4	23.8	72.0	-0.8	-4.5	4.6	10.0
970203	12Z:	1007.9	29.1	24.0	74.0	-2.5	-4.3	5.0	30.0
970203	15Z:	1005.7	29.1	24.9	78.0	-3.4	-2.4	4.2	55.0
970203	18Z:	1005.0	29.2	24.8	77.0	-1.6	-2.9	3.3	30.0
970203	21Z:	1006.0	29.3	23.5	71.0	-4.9	-2.9	5.7	60.0
970204	03Z:	1004.5	30.6	23.5	66.0	-4.0	-1.5	4.3	70.0
970204	06Z:	1003.7	30.6	23.8	67.0	-3.1	-1.1	3.3	70.0
970204	09Z:	1006.2	30.0	25.1	75.0	-2.8	-0.0	2.8	90.0
970204	12Z:	1009.1	28.8	24.6	78.0	-3.5	2.0	4.0	120.0
970204	15Z:	1005.7	28.4	23.8	76.0	2.4	-2.4	3.4	315.0
970204	18Z:	1004.9	28.1	25.7	87.0	3.4	-0.6	3.5	280.0
970204	21Z:	1005.9	28.3	24.1	78.0	0.4	-2.2	2.2	350.0
970205	00Z:	1006.9	29.0	23.9	74.0	4.0	0.3	4.0	265.0
970205	03Z:	1005.4	30.0	24.0	70.0	0.9	-2.3	2.5	340.0
970205	06Z:	1004.2	30.1	24.0	70.0	1.3	-0.9	1.6	305.0
970205	09Z:	1006.2	29.2	23.4	71.0	0.7	-3.9	4.0	350.0
970205	12Z:	1008.3	29.1	23.3	71.0	-1.5	-4.2	4.5	20.0
970205	15Z:	1006.8	26.7	23.4	82.0	-0.7	8.3	8.3	175.0
970205	18Z:	1005.5	27.9	23.7	78.0	1.5	-4.0	4.3	340.0
970205	21Z:	1007.0	28.0	24.0	79.0	-2.5	-0.0	2.5	90.0
970206	00Z:	1008.2	27.2	24.7	86.0	-0.0	4.5	4.5	180.0
970206	03Z:	1005.2	27.7	23.7	79.0	3.6	1.0	3.7	255.0
970206	06Z:	1004.2	28.6	24.2	77.0	1.7	-1.0	2.0	300.0
970206	09Z:	1005.5	28.2	24.4	80.0	2.3	0.9	2.5	250.0
970206	12Z:	1009.0	27.9	25.0	84.0	-0.4	-4.5	4.5	5.0
970206	15Z:	1006.4	27.9	23.7	78.0	-2.4	-3.4	4.1	35.0
970206	18Z:	1004.7	27.4	24.1	82.0	-3.8	-1.4	4.0	70.0
970206	21Z:	1007.2	27.5	24.4	83.0	-2.2	1.2	2.5	120.0
970207	00Z:	1008.4	29.4	24.3	74.0	-2.6	1.5	3.0	120.0
970207	03Z:	1005.7	24.6	19.2	72.0	-1.9	5.4	5.7	160.0
970207	06Z:	1005.0	29.8	22.8	66.0	0.7	3.7	3.8	190.0
970207	09Z:	1006.3	25.5	22.8	85.0	1.7	9.7	9.8	190.0
970207	12Z:	1008.1	26.7	23.6	83.0	-4.5	-0.0	4.5	90.0
970207	15Z:	1006.6	27.5	22.7	75.0	-3.7	4.4	5.7	140.0
970207	18Z:	1004.5	27.5	23.5	79.0	-3.9	1.8	4.3	115.0
970207	21Z:	1005.6	27.7	23.5	78.0	-1.5	0.5	1.6	110.0
970208	00Z:	1006.9	27.9	23.5	77.0	-2.3	-1.9	3.0	50.0
970208	03Z:	1005.7	27.5	16.8	52.0	-0.9	-5.2	5.3	10.0
970208	06Z:	1003.9	28.1	23.9	78.0	-2.1	-3.6	4.2	30.0

970208	09Z:	1005.3	28.0	24.0	79.0	-5.3	-3.7	6.5	55.0
970208	12Z:	1007.2	26.9	23.4	81.0	-7.8	-4.5	9.0	60.0
970208	15Z:	1006.5	27.0	23.5	81.0	-6.2	-3.6	7.2	60.0
970208	18Z:	1004.4	27.6	23.9	80.0	-6.4	-7.7	10.0	40.0
970208	21Z:	1005.2	27.8	22.8	74.0	-10.4	-6.0	12.0	60.0
970209	00Z:	1007.2	28.3	22.6	71.0	-8.5	-8.5	12.0	45.0
970209	03Z:	1005.3	28.2	22.5	71.0	-9.9	-9.9	14.0	45.0
970209	06Z:	1006.6	28.4	23.3	74.0	-8.2	-6.9	10.7	50.0

LEG TWO BALLOON LAUNCH SURFACE INFORMATION

Date	Time	Press	Temp	Td	RH%	uwind	vwind	wspd	wdir	Tpsy	Tw	RHpsy
970214	00Z:	1006.3	28.8	22.6	69.0	-11.7	-6.8	13.5	60.0			
970214	06Z:	1003.5	28.7	23.8	75.0	-8.8	-2.7	9.2	73.0	28.3	25.5	79.9
970214	12Z:	1005.4	29.3	24.6	76.0	-11.1	-3.0	11.5	75.0			
970214	18Z:	1003.2	28.3	23.7	76.0	-10.5	-5.8	12.0	61.0			
970215	00Z:	1006.2	25.5	23.6	89.0	-6.9	-1.2	7.0	80.0			
970215	03Z:	1003.5	27.1	23.4	80.0	-9.0	-10.7	14.0	40.0			
970215	06Z:	1002.0	28.7	24.7	79.0	-9.2	-7.7	12.0	50.0	29.2	25.5	74.3
970215	09Z:	1003.9	28.4	24.4	79.0	-9.4	-5.5	10.9	60.0			
970215	12Z:	1005.2	26.6	24.5	88.0	-11.5	-0.0	11.5	90.0			
970215	15Z:	1005.0	28.5	24.5	79.0	-8.8	-3.2	9.4	70.0			
970215	18Z:	1003.4	24.9	23.3	91.0	-4.5	-2.6	5.2	60.0			
970215	21Z:	1004.0	27.2	24.9	87.0	-6.5	-3.8	7.5	60.0			
970216	00Z:	1005.8	27.4	24.7	85.0	-2.5	-0.4	2.5	80.0	28.0	25.7	83.2
970216	03Z:	1003.6	27.8	24.9	84.0	-0.7	-1.9	2.0	20.0	28.0	25.7	83.2
970216	06Z:	1002.1	26.3	24.5	90.0	5.4	0.7	5.4	263.0			
970216	09Z:	1003.0	26.9	24.8	88.0	-1.3	-4.8	5.0	15.0			
970216	12Z:	1004.8	26.7	24.9	90.0	-7.3	-6.1	9.5	50.0			
970216	15Z:	1004.7	26.9	23.8	83.0	-0.0	-0.5	0.5	5.0			
970216	18Z:	1002.9	25.0	24.3	96.0	-2.2	2.7	3.5	140.0			
970216	21Z:	1003.9	26.3	24.3	89.0	1.0	-1.7	2.0	330.0			
970217	00Z:	1006.2	27.2	24.3	84.0	-0.3	-1.0	1.0	15.0	27.9	25.2	80.4
970217	03Z:	1004.0	27.8	24.0	80.0	0.8	-0.6	1.0	310.0	29.0	25.5	75.5 ???
970217	06Z:	1002.0	27.4	24.3	83.0	1.3	-1.5	2.0	320.0			
970217	09Z:	1003.5	27.2	24.7	86.0	-1.3	-1.5	2.0	40.0	27.8	25.5	83.2
970217	12Z:	1004.9	27.5	24.6	84.0	0.0	-0.0	0.0	0.0			
970217	15Z:	1004.1	26.9	24.8	88.0	3.5	2.0	4.0	240.0			
970217	18Z:	1002.1	26.1	23.8	87.0	2.2	-0.4	2.2	280.0			
970217	21Z:	1003.0	27.0	23.7	82.0	2.0	-3.5	4.0	330.0			
970218	00Z:	1005.3	27.9	24.1	80.0	3.1	-2.6	4.0	310.0			

970218	03Z:	1003.8	27.3	24.0	82.0	1.4	-7.7	7.8	350.0	27.5	24.6	78.9
970218	06Z:	1002.1	25.9	23.8	88.0	7.9	1.4	8.0	260.0			
970218	09Z:	1003.3	26.7	23.6	83.0	11.0	0.0	11.0	270.0			
970218	12Z:	1004.9	27.0	23.7	82.0	5.6	-3.3	6.5	300.0			
970218	15Z:	1004.5	26.7	24.4	87.0	5.2	-2.4	5.7	295.0			
970218	18Z:	1002.1	26.7	24.4	87.0	0.9	-4.9	5.0	350.0			
970218	21Z:	1003.1	27.2	24.3	84.0	0.9	-4.9	5.0	350.0			
970219	00Z:	1005.0	27.3	24.4	84.0	-1.9	-5.2	5.5	20.0	27.5	25.2	83.0
970219	03Z:	1003.4	24.6	23.7	95.0	-5.0	-5.0	7.1	45.0			
970219	06Z:	1002.4	25.3	19.5	70.0	-0.6	-6.2	6.2	6.0			
970219	09Z:	1004.8	25.9	23.8	88.0	-6.1	-3.5	7.0	60.0			
970219	12Z:	1006.2	25.0	23.1	89.0	4.5	0.0	4.5	270.0			
970219	15Z:	1006.0	26.1	23.2	84.0	2.1	-2.5	3.2	320.0			
970219	18Z:	1004.2	26.2	23.5	85.0	10.0	-4.0	10.8	292.0			
970219	21Z:	1004.4	26.3	24.0	87.0	12.7	-5.9	14.0	295.0			
970220	00Z:	1006.1	27.9	24.1	80.0	8.0	-2.9	8.5	290.0	28.3	25.7	81.2
970220	03Z:	1005.0	28.5	23.9	76.0	29.9	-2.6	30.0	275.0	28.8	25.7	78.1
970220	06Z:	1002.8	28.3	23.9	77.0	14.9	-1.3	15.0	275.0	28.3	25.4	79.2
970220	09Z:	1003.9	28.2	24.4	80.0	10.4	-3.8	11.1	290.0	28.2	25.5	80.5
970220	12Z:	1005.8	28.2	24.8	82.0	4.2	-7.4	8.5	330.0			
970220	15Z:	1005.9	28.3	24.1	78.0	10.9	-5.3	12.1	296.0			
970220	18Z:	1003.4	28.2	24.6	81.0	8.5	-8.5	12.0	315.0			
970220	21Z:	1004.1	26.3	23.8	86.0	7.4	-7.4	10.5	315.0			
970221	00Z:	1006.6	26.6	24.3	87.0	8.0	-2.9	8.5	290.0	26.4	24.7	87.3
970221	03Z:	1003.6	26.8	24.5	87.0	8.1	-5.9	10.0	306.0	26.4	25.0	89.3
970221	06Z:	1000.8	27.8	25.6	81.0	12.5	-2.7	12.8	282.0	26.8	25.0	86.4
970221	09Z:	1002.6	27.9	24.1	80.0	8.0	-6.7	10.5	310.0			
970221	12Z:	1004.4	28.4	24.4	79.0	7.8	-7.8	11.0	315.0			
970221	15Z:	1004.4	28.2	24.6	81.0	5.5	-7.5	9.3	324.0			
970221	18Z:	1002.4	28.0	24.9	83.0	-1.7	-7.8	8.0	12.0			
970221	21Z:	1003.2	28.0	24.4	81.0	-1.2	-6.9	7.0	10.0			
970222	00Z:	1005.4	28.2	24.4	80.0	-1.5	-4.2	4.5	20.0	28.9	25.7	77.4
970222	03Z:	1002.8	28.2	24.8	82.0	-2.7	-4.7	5.4	30.0	30.0	26.1	73.0 ???
970222	06Z:	1001.4	29.5	25.5	79.0	0.3	0.0	0.3	270.0	29.8	26.2	75.2
970222	09Z:	1002.2	26.8	24.5	87.0	5.4	1.0	5.5	260.0			
970222	12Z:	1003.3	27.5	24.0	81.0	-1.7	-3.0	3.5	30.0			
970222	15Z:	1003.3	26.0	25.0	94.0	-5.3	-6.5	8.4	39.0			
970222	18Z:	1001.7	25.7	25.0	96.0	2.9	-3.2	4.3	318.0			
970222	21Z:	1002.0	27.2	25.0	88.0	8.5	3.1	9.0	250.0			
970223	00Z:	1003.7	23.0	20.0	83.0	8.6	4.0	9.5	245.0			
970223	03Z:	1003.1	27.0	25.0	89.0	11.4	4.1	12.1	250.0	26.7	25.2	88.6
970223	06Z:	1001.5	27.7	24.4	82.0	12.8	-2.3	13.0	280.0	28.0	25.0	78.4
970223	09Z:	1001.8	27.2	23.0	78.0	9.8	-0.9	9.8	275.0			
970223	12Z:	1003.0	27.4	24.5	84.0	9.4	-1.6	9.5	280.0			

970223	15Z:	1004.0	27.2	24.5	85.0	2.4	-8.9	9.2	345.0				
970223	18Z:	1002.6	26.8	24.7	88.0	2.4	-7.7	8.1	343.0				
970223	21Z:	1003.2	26.1	24.5	91.0	0.0	-7.5	7.5	0.0				
970224	00Z:	1005.8	27.0	23.1	79.0	0.0	-5.0	5.0	0.0				
970224	03Z:	1005.1	25.4	23.1	87.0	1.9	-0.7	2.0	290.0				
970224	09Z:	1003.0	26.0	23.9	88.0	6.3	-10.0	11.8	328.0				
970224	12Z:	1004.9	26.8	24.5	87.0	6.1	-5.1	8.0	310.0				
970224	15Z:	1005.7	27.1	24.2	84.0	8.9	-1.6	9.0	280.0				
970224	18Z:	1004.3	27.2	23.3	79.0	-3.8	-7.1	8.0	28.0				
970224	21Z:	1004.7	27.5	24.0	81.0	-8.5	0.4	8.5	93.0				
970225	00Z:	1005.9	27.7	23.7	79.0	11.0	1.0	11.0	265.0	28.5	24.7	73.3	??

SITE: fixed, kal TIME: 19-FEB-1997, 23:21:00 (1) TEMP/WINDS DEWPOINT

PLOT GENERATED: 20-FEB-1997, 23:49:24

WINDS PROFILE
One barb = 10.0 m/s

E CRUISE OPERATIONS LOG

Date	Time	Cast #	Latitude	Longitude	SST	Salinity
970127	2012	1	0801.459	16500.844	28.9	
970128	0249	2	0700.018	16500.007	29.9	
970128	0923	3	0600.062	16500.080	29.7	
970128	1503	4	0503.987	16459.920	29.6	
970128	2252	5	0400.002	16459.903	29.7	
970129	0448	6	0259.959	16500.129	29.7	
970130	0238	7	0158.819	16457.854	29.8	
970130	0840	8	0100.177	16500.039	29.7	
970201	0645	9	-0001.002	16501.050	29.7	
970202	0144	10	-0259.930	16500.062	30.4	
970202	0809	11	-0359.941	16459.996	30.3	
970203	0216	12	-0458.832	16511.712	30	
970204	2105	13	-0227.709	15723.284	29.5	
970205	0553	14	-0201.371	15600.011	30.6	
970205	0924	15	-0130.007	15559.966	30	
970205	1246	16	-0100.027	15600.083	29.8	
970205	1619	17	-0029.948	15600.038	29.3	
970205	2212	18	-0001.037	15608.554	29.3	
970206	0317	19	0030.025	15559.905	29.8	
970206	0732	20	0100.046	15559.929	29.8	
970206	1051	21	0130.011	15559.990	29.6	
970206	2143	22	0202.691	15600.401	29.2	
970207	0703	23	0300.015	15559.950	29.7	
970207	1245	24	0359.970	15559.990	29.4	
970207	1832	25	0500.049	15600.039	29	
970208	0006	26	0600.014	15559.977	29.5	
970208	0621	27	0700.018	15600.001	29.3	
970209	0201	28	0800.489	15559.933	28.8	
970215	0254	29	0458.134	14702.195	29.1	
970215	1725	30	0300.026	14700.002	29.7	
970216	0310	31	0159.785	14659.965	29.7	
970216	0635	32	0130.024	14659.999	29.3	
970216	0952	33	0059.992	14659.942	29.9	
970217	0354	34	0000.994	14659.328	30.2	
970217	0752	35	0030.022	14659.949	29.6	
970217	1419	36	-0030.029	14700.050	29.9	
970217	1750	37	-0059.884	14759.891	29.5	
970217	2121	38	-0129.925	14659.888	29.5	
970217	2306	39	-0139.993	14659.941	29.6	
970219	0658	40	-0000.070	14600.158	28.8	
970219	1230	41	-0000.001	14500.155	28.9	
970219	1950	42	-0000.038	14400.119	28.8	
970220	0220	43	0000.030	14300.063	29	
970220	0959	44	-0029.930	14200.422	28.7	
970220	1326	45	0100.057	14200.325	28.7	
970220	1701	46	-0130.001	14200.030	28.8	
970220	1957	47	-0155.008	14200.104	28.6	
970220	2351	48	-0230.774	14200.032	28.3	
970221	0130	49	-0239.801	14200.020	27.7	
970222	0032	50	0000.667	14158.486	29.1	

970222	0637	51	-0000.042	14100.076	28.7	
970222	1314	52	0000.006	14000.144	28.7	
970222	2000	53	0000.002	13900.099	28.5	
970223	0509	54	-0059.948	13800.211	28.9	
970223	0849	55	-0030.151	13800.117	28.7	
970223	1229	56	-0000.295	13800.094	28.7	
970223	1607	57	0030.010	13759.938	28.4	
970223	1947	58	0059.911	13759.970	28.5	
970223	2316	59	0130.040	13759.965	28.3	
970224	0250	60	0159.957	13800.012	28.7	
970225	0045	61	0227.397	13725.010	29.3	

F ZENO CONFIGURATION PROGRAM

```
* Zeno 3200 System Setup File
* Program Version And Date: Zeno 3200 V1.60-768-4, Jun  3 1995
* Copyright (C) Coastal Environmental Systems, 1995.
* Setup File Date And Time: 97/01/31 04:03:13
*
PARAM1 60 0 60 2 110 4 203 203 19200 19200
PARAM2 19200 0 0 0 0 2 1 0 0 0
PARAM3 16777 1 60 18 0 0 0 0 2 2
PARAM4 2 2 0 0 0 3276800
PARAM5 NONE NONE
* 1. GLOBAL PSP gain = 100/
*     v205 -- offset = -60 w/m^2 from zeno adc probs
* 2. GLOBAL PIR
*     v205 -- offset = -132 w/m^2 due to zeno offset
* 3. CASE THERMISTOR
* 4. DOME THERMISTOR
* 5. TEMPERATURE - PRT voltage gain = 10/2 = 5
*     no power, 1.25 vdc excitation, no warmup time,
*     v205 -- offset .000540 v zeno adc offset
* 6. TEMPERATURE REF - Ref resistor voltage (1.5K). gain = 1/4
*     v205 -- offset .000540 v zeno adc offset
* 7. RH -- in the 12-bit analog chan 10
*     gain = 1/2, no sw pwr, no excit pwr,
* 8. TILT-X [-2 to 2 vdc] <--> [-20 to 20 deg]
* 9. TILT-Y, [-2 to 2vdc] <--> [-20 to 20 deg]
* 10. ORG, [0-5 vdc] <--> [0.05 -- 2000 mm/hr]
*     v205 -- set offset to -.1 due to 95mv noise from org
* 11. IRT [-60 to 40] C, 0-5 vdc
* 12. External voltage input
* 13. Internal regulated voltage
* 14. Internal temperature
* 15 BAROMETER - R.M. YOUNG analog
*     0-5 vdc output for 800 to 1100 mbar. Thus attenuate by 4
*     Resolution with 11 bits = 300/2048 = 0.15 mb.
*
* 16 SST SENSOR -- 4-20 ma x 25 ohm = [0.1 -- 0.5] vdc
*     The calibration curve is linear between -4 to 40 C
*     Attenuate by a factor of 2.
*     Resolution for 11 bits = 44/2048 = 0.02 C/bit.
*     Calibration equation: T = 110V - 15 , for v = [0.1--0.5]
*     v205 -- probe#3 cal terms [2.3981, 111.81, -16.130]
```

```
*      v205 -- correct cal for .00054v adc offset = [2.3981, 111.81, -16.19] -> +.06 C corre
SENSOR 3 "PspG" 3 2 2 0 0 0 0 1 0 2 0 117371 -60 0
SENSOR 3 "PirG" 1 2 0 0 0 0 0 1 0 2 0 245700 -132 0
SENSOR 1 "Rcase" 8 0 0 0 2 1 0 1 0 1 0 -0.4 1 0
SENSOR 1 "Rdome" 9 0 0 0 2 1 0 1 0 2 0 -0.4 1 0
SENSOR 3 "Tpvt" 6 1 2 0 1 0 0 1 0 2 0 1 -.00054 0
SENSOR 3 "Tref" 5 0 2 0 1 0 0 1 0 2 0 1 -.00054 0
SENSOR 1 "RH" 10 0 1 0 0 0 0 1 0 2 0 100 0 0
SENSOR 1 "TiltX" 13 0 1 1 0 0 0 1 0 2 0 10 0 0
SENSOR 1 "TiltY" 14 0 1 1 0 0 0 1 0 2 0 10 0 0
SENSOR 3 "ORG" 7 0 3 6 0 0 180 1 0 2 20 0 -0.1 0
SENSOR 1 "IRT" 12 0 1 6 0 0 60 1 0 2 0 95 -60 0
SENSOR 1 "Vext" 1 0 2 0 0 0 0 1 1 3 0 10.27 0 0
SENSOR 1 "Vint" 2 0 0 0 0 0 0 1 1 3 0 1 0 0
SENSOR 1 "Tint" 3 0 0 0 0 0 0 1 0 3 0 1 0 0
SENSOR 3 "Baro" 2 0 3 0 0 0 0 1 0 2 0 60 800 0
SENSOR 3 "SST" 4 0 0 0 0 0 0 1 0 2 2.3981 111.81 -16.19 0
* PROCESSES -----
* 1. PspG - average samples
* 2. Pir E - average samples
* 3. Case resistor => 1/S3
* 4. Case resistor => Rcase in ohms
* 5. Average Rcase over the minute
* 6. Case temperature - Steinhart-Hart Eqn. -- average and instantaneous
* 7. Dome resistor 1/S4
* 8. Dome Resistor => Rdome in ohms
* 9. Average Rdome over the minute
* 10. Tdome using Steinhart-hart equation
* 11. Compute Longwave irradiance from E, Tcase, Tdome
* 12. Average LW irradiance
* 13. TEMPERATURE -- divide Vpvt/Vref
* 14 TEMPERATURE -- mult by const.
* 15. TEMPERATURE -- quadratic equation
* 16. TEMPERATURE -- average values
* 17. RH - avg
* 18 TILT X
* 19. TILT Y
* 20 ORG
* 21 IRT
* 22 VOLTAGE EXTERNAL INTERNAL, POWER MANAGEMENT
* 23 TEMPERATURE INTERNAL
* 24 BAROMETER
* 25. SST temperature, avg,
PROCESS 1 2 S1.1
```

PROCESS 1 2 S2.1
PROCESS 5 9 S3.1
PROCESS 5 8 P3.1 0 0 0 0 0 9925 -9925
PROCESS 1 2 P4.1
PROCESS 4 1 S3.1 0.00103085 0.000238918 1.57464e-07 9925
PROCESS 5 9 S4.1
PROCESS 5 8 P7.1 0 0 0 0 0 9935 -9935
PROCESS 1 2 P8.1
PROCESS 4 1 S4.1 0.00103085 0.000238918 1.57464e-07 9935
PROCESS 4 5 P10.2 P6.2 S2.1 1 4
PROCESS 1 2 P11.2
PROCESS 5 7 S5.1 S6.1
PROCESS 5 5 P13.1 15
PROCESS 5 8 P14.1 0 0 0 0 10.04 235.79 -245.83
PROCESS 1 2 P15.1
PROCESS 1 2 S7.1
PROCESS 1 2 S8.1
PROCESS 1 2 S9.1
PROCESS 1 2 S10.1
PROCESS 1 2 S6.1
PROCESS 4 4 S12.1 S13.1
PROCESS 1 1 S14.1
PROCESS 1 2 S15.1
PROCESS 1 2 S16.1

* ----- DATA LINES -----
* CONFIGURATON PART NUMBER
* DATE AND TIME
* PSP avg, std dev, min, max
* PIR - LWavg, Eavg, Rc,Rd,Tc,Td
* TEMPERATURE
* RH
* BAROMETER
* TILT-X
* TILT-Y
* OPTICAL RAIN GAUGE
* IRT
* VOLTAGES AND INTERNAL TEMPERATURE
* END OF LINE
DATA 6 1,2 "v205, " 1.1 0 0 1
DATA 3 1,2 "" 1.1 0 0 1
DATA 9 1,2 "Pspav" 1.1 1 6 8
DATA 8 2 "Pspmn" 1.5 0 4 8
DATA 8 2 "Pspmx" 1.4 0 4 8
DATA 8 2 "Ppspd" 1.3 1 5 8

DATA 9 1,2 "Lwav" 12.1 1 5 8
DATA 8 2 "PirE" 2.1 1 5 8
DATA 8 2 "RcAv" 4.1 1 6 8
DATA 8 2 "RdAv" 8.1 1 6 8
DATA 8 2 "Tcase" 6.1 2 5 8
DATA 8 2 "Tdome" 10.1 2 5 8
DATA 9 1,2 "Tav" 16.1 2 5 8
DATA 8 2 "Tmn" 16.5 1 4 8
DATA 8 2 "Tmx" 16.4 1 4 8
DATA 8 2 "Tsd" 16.3 2 5 8
DATA 9 1,2 "RHav" 17.1 1 4 8
DATA 8 2 "RHmn" 17.5 0 3 8
DATA 8 2 "RHmx" 17.4 0 3 8
DATA 8 2 "RHsd" 17.3 1 4 8
DATA 9 1,2 "Bpav" 24.1 2 5 8
DATA 8 2 "Bpmn" 24.5 1 4 8
DATA 8 2 "Bpmx" 24.4 1 4 8
DATA 8 2 "Bpsd" 24.3 2 5 8
DATA 9 1,2 "Txav" 18.1 1 4 8
DATA 8 2 "Txmn" 18.5 0 3 8
DATA 8 2 "Txmx" 18.4 0 3 8
DATA 8 2 "Txsd" 18.3 1 4 8
DATA 9 1,2 "Tyav" 19.1 1 4 8
DATA 8 2 "Tymn" 19.5 0 3 8
DATA 8 2 "Tymx" 19.4 0 3 8
DATA 8 2 "Tysd" 19.3 1 4 8
DATA 9 1,2 "Orgav" 20.1 1 5 8
DATA 8 2 "Orgmn" 20.5 0 3 8
DATA 8 2 "Orgmx" 20.4 0 3 8
DATA 8 2 "Orgsd" 20.3 1 4 8
DATA 9 1,2 "Sstav" 25.1 2 5 8
DATA 8 2 "Sstmn" 25.5 1 4 8
DATA 8 2 "Sstmx" 25.4 1 4 8
DATA 8 2 "Sstsd" 25.3 2 5 8
DATA 8 1,2 "Tint" 23.1 1 4 8
DATA 8 1,2 "Vext" 22.1 1 4 8
DATA 8 2 "Vint" 22.2 1 4 8
DATA 6 1,2 "<OD><OA>" 1.1 0 0 1
EOF

G Policy of Data Utility of TOCS K9702 Cruise

- (1) Every dataset is available among every K9702 cruise passengers freely.
- (2) Above "passengers" indicates PMEL, BPPT, NCAR, BNL, NME, and JAMSTEC.
- (3) Whenever you use and write and/or present, you must notice "These datasets are obtained in the R/V KAIYO cruise as TOCS project of JAMSTEC. This cruise is also under incorporated with BPPT Indonesia."

* When you use JAMSTEC's datasets, you must include Ando or Yoneyama's name in the first two years in addition to above mentioned (3).
If someone else request you the permission to use JAMSTEC dataset, you must also notice to JAMSTEC(Ando or Yoneyama).

H Serial Numbers of BNL Equipment

The following ARM equipment was used during this cruise:

PART	SERIAL NUMBER
Zeno	298 - WD24829
PSP	31282F3
PIR	30169F3
WND	18428
Aspirator	-
T/RH	693978
GOES DCP	PA95041128
ORG	03318-C7