R.V. FRANKLIN

NATIONAL FACILITY
OCEANOGRAPHIC RESEARCH VESSEL

RESEARCH SUMMARY

R.V. 'FRANKLIN'

FR05/88

Principal Investigators:

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AUSTRALIA

R.V. FRANKLIN IS OWNED AND OPERATED BY CSIRO

REPORT ON THE FRANKLIN CRUISE FR05/88

1. ITINERARY

Depart: Townsville, 2030 - 21 June, 1988
Arrive: Port Moresby, 0800 - 1 July, 1988

Depart: Port Moresby, 0800 - 2 July, 1988
Arrive: Cairns, 1700 - 18 July, 1988

2. SCIENTIFIC PROGRAMS

Within the context of a multi-disciplinary study of physical, biological and chemical oceanographic processes in the oceanic boundary zone bordering the Australian and Papuan Barrier Reef systems, this cruise had several related objectives.

a. To map 3-dimensional mesoscale motion in the East Australian Current between 14° and 15°S with CTD/XBT sections, ADVP sections and radio-tracked drifters.

b. To survey hydrographic, current, nutrient and chlorophyll fields in the oceanic boundary along the Papuan Barrier Reef in a wind regime conducive to Ekman-forced upwelling.

c. To obtain cross-basin hydrographic sections of thermal and density structure on transit legs between Australia and Papua New Guinea.

d. To measure primary production and nitrogen utilization rates of size fractionated phytoplankton populations in the ocean boundary zone along the Australian and Papuan Barrier Reefs.

e. To collect quantitative benthic infauna samples for community structure and biomass analyses from the continental slope adjoining the Papuan Barrier Reef.

f. Measure sediment bacterial production rates on the continental slope adjoining the Papuan Barrier Reef.

3. PRINCIPLE INVESTIGATORS

Miles Furnas (Chief Scientist)
Australian Institute of Marine Science
Sub-objectives: b and d above

Derek Burrage
Australian Institute of Marine Science
Sub-objectives: a,b and c above

Daniel Alongi
Australian Institute of Marine Science
Sub-objectives: e and f above

Collaborating Investigator

Masamichi Inoue
Coastal Studies Institute, Louisiana State Univ.
Sub-objective: c above

4. RESULTS

a. Three (3) CTD, five (5) ADVP and five (5) XBT sections were run across and through the East Australian Current and the northward flowing boundary current between 14° and 19°S. Two VHF- tracked drifters were released in the boundary current and tracked for four days, verifying the surface flow inferred from the ADCP data. One drifter was recovered. The other, unrecovered, drifter finally came ashore near the tip of Cape York after nearly four weeks adrift.

b. Nine (9) CTD and eight (8) ADVP sections, supplemented with XBT's were run seaward normal to the Papuan Barrier Reef. Six cross-shelf CTD sections were occupied in the northern Coral Sea, two in the Solomon Sea and one southward from Tagula Island into the central Coral Sea. These sections show evidence of surface and deep boundary currents flowing around the southern end of the Louisiade Archipelago, with leakage of surface water from the Coral Sea through the Louisiade Archipelago. Along the southwestern coast of Papua New Guinea and around the southwestern margin of the Papuan Barrier Reef, the surface current flows directly against the wind and appears to suppress large-scale, Ekman-forced coastal upwelling, although the wind stress regime was highly favorable to upwelling. Some slight upwelling along the continental slope was observed, but this upwelling was limited to a very narrow boundary layer along the PBR.

c. Eighteen (18) ^{14}C primary production and seven (7) ^{15}N nitrogen uptake experiments were carried out. Size fractionation of particulate matter in the primary production experiments was carried out to estimate the contributions of net- (>10 μm), nano- (2-10 μm) and pico-phytoplankton (<2 μm) to community primary production. Preliminary analysis of samples on board indicates higher phytoplankton biomass and production within the Louisiade Archipelago and Solomon Sea than in the Coral Sea, despite upwelling favorable winds in the Coral Sea. Chlorophyll and nutrient samples were routinely collected at all hydrographic stations. Water samples for chlorophyll analyses were also size fractionated to determine standing crop and the depth distribution of net-, nano- and pico-phytoplankton.

d. Replicate. relatively undisturbed samples of the benthos were obtained with a Smith-MacIntyre grab at four sites down the continental slope of PNG (700-4350 m) on the Coral Sea side and at three sites (2300-2800 m) in the Solomon Sea. Quantitative subsamples were collected and processed aboard for determining sediment grain size, macrofaunal taxonomic composition, meiofaunal abundances, bacterial standing crop and bacterial production (using ^{3}H thymidine uptake). Attempts to grab in the central Coral Sea Basin were unsuccessful.

e. Hydrographic sections and XBT drops were made during the two crossings of the Coral Sea Basin to resolve basin scale thermohaline structure. Two ADVP transects were obtained during this crossing and an ARGOS drifter was deployed on the run from Jomard Entrance to Cairns.

5. CRUISE NARRATIVE

The cruise began inauspiciously with the non-appearance of a seamen and adjustment troubles with the main engine governor. In all, an effective start was delayed by 26 hours. One additional day of cruise time was granted to compensate for the loss of time.

After clearing Palm Passage. the first CTD station was occupied seaward of Myrmidon reef and scientific operations got underway.

East Australian Current Operations 22 - 29 June

Our initial hope to use satellite imagery for guiding operations in this area was frustrated by cloud cover. Only one image was received, which failed to show any significant surface temperature structure in slope waters. In the fall-back mode, four CTD/XBT sections were run across the EAC [Myrmidon Reef - Flinders Reef; Trinity Opening - Bouganville Reef; Ribbon Reefs - Osprey Reef; Jewell Reef - seaward]. Four ADVP sections across the EAC were also run at ca. 14°S which showed a strong northward flowing boundary current. An attempt to calibrate the ADVP near Flora Reef was only partially successful due to rough weather conditions. Rough seas and high winds were a constant problem at this stage. Several CTD stations were abandoned due to high winds. Two VHF-tracked drifters were deployed on 26 June at 14°58'S 146°25'E to observe surface and near-surface (20 m) Lagrangian flow. Radio contact was maintained with the drifters on a daily basis until 28 June, when one drifter was recovered at 14°08'S 145°49'E. minus the drogue element which had broken from its tether. The other drifter was followed for an additional day, but could not be recovered due to time constraints. The drifters proved moderately easy to find with the RDF gear, but difficult to see under the prevailing weather conditions, due to their minimal surface profile and lack of visual strobe. The unrecovered drifter finally came ashore near the Escape River, near the tip of Cape York.

On 29 June, Franklin left the EAC area and proceeded toward Port Moresby on a cross-basin hydrographic section, arriving on the morning of 1 July.

PNG - Papuan Barrier Reef Operations 2 - 13 July

Once we cleared PNG harbor, the winds reasserted themselves (ie. > 30 kts). Four CTD sections normal to the coast and two along-shore sections were carried out heading toward Jomard Entrance. Moderately green water was observed just south of Cape Rodney. but strong upwelling was not observed despite the strong equator-ward winds parallelling the coast. A strong south-eastward flowing boundary current was observed in the ADVP data.

On the third transect normal to the coast (6-8 July), grabbing for benthic samples was carried out at four stations:

Position	Depth(m)	Location
11°06'S 150°52'E	700	Moresby Trough
11°20'S 150°50'E	2400	Moresby Trough
11°34'D 150°45'E	3250	Moresby Trough
12°03'S 150°35'E	4350	Coral Sea Basin

Use of the AIMS box-corer was precluded by the sea state and because electronics from the trawl winch controls had been cannibalized to repair the the CTD winch controls. A Smith-McIntyre grab (0.25 m^2) was deployed successfully from the starboard A-frame using the hydro winch.

Following the fourth transect normal to the coast, Franklin passed through the Jomard Entrance and commenced stations within the Louisiade Archipelago. Chlorophyll concentrations measured within the archipelago were the highest observed during the cruise and the water transparency, the least (euphotic zone ca. 45 m). Based on quick visual scans, zooplankton abundance and species composition were also noticeably different than observed in the Coral Sea. The weather, finally, was calm though cloudy.

After passing through the Lousiade Archipelago, Franklin entered the Solomon Sea and began a CTD/ADVP section and commenced benthic grabbing at selected stations.

Position	Depth(m)	Location
10°10'S 151°57'E	2400	Solomon Sea
10°03'S 152°13'E	2775	Woodlark Basin
9°55'S 152°30'E	2850	Woodlark Basin

CTD stations in the Solomon Sea went well, though at times under rough conditions. Chlorophyll concentrations east of the Louisiade Archipelago remained higher than measured in the Coral Sea. Grabbing went fitfully. A number of grab mis-fires occurred at the first station, due in part to the steep slope at that station and possible damage to the grab, which was dropped approximately two meters onto the deck. Running repairs were made by the engineers. After three stations, grabbing was terminated to conserve time for a series of grabs in the central Coral Sea. On the night of 8 July, a second series of calibration runs for the ADVP were successfully carried out.

Following two more transects normal to the PBR off Tagula Island and a run up to Jomard Entrance, course was set for Cairns. A final line of closely spaced CTD and XBT stations was run away from the reef. Evidence for upwelling in this section was restricted to a narrow (ca. 30 nm) band adjoining the reef and extended to a maximum depth of 500 m. A third GPS/ADVP calibration run was held on the night of 15-16 July, though weather conditions were marginal. A final deepwater grabbing station in the central Coral Sea Basin was occupied for 2 grabs. Both were unsuccessful. Some mud was collected in the first. but the second mis-fired completely. Further grabbing was abandoned.

Position	Depth(m)	Location
13°08'S 150°20'E	4300	Coral Sea Basin

A CSIRO Argos-tracked drifter buoy. provided by Dr. G. Creswell, was deployed. northward of the supposed South Equatorial Current inflow region. XBT's were dropped at regular intervals between CTD stations on the run to Grafton Passage. At approximately 2030 on 17 July, the second engineer began bleeding from an ulcer on his foot. The bleeding was quickly controlled, but on medical advice, the ship proceeded to Cairns to transfer the engineer to hospital and scientific sampling was terminated.

Franklin arrived at Grafton Passage at 0130 hrs on 18 July. After transferring the engineer to the pilot boat off Cairns, the ship proceeded northward for a speed test run and ADVP gyro calibration. The pilot was picked up at 1600 on the afternoon of 18 July and the ship docked at approx. 1700 hrs.

6. SUMMARY

In most respects, the cruise was an operational success. Despite inclement weather and rough sea conditions throughout the cruise. virtually all planned hydrographic stations were occupied successfully. The final series of CTD stations across the East Australian

Current were abandoned due to the prevailing medical emergency. Replicate benthic samples were collected at seven of ten sites.

The few unsuccessful operations were 1) the attempt to use satellite imagery to guide sampling strategy, foiled by the almost constant cloud cover throughout the trip, 2) the attempt to obtain sea-surface temperatures with the CSIRO-Aspendale IR radiometer which was unsuccessful due to an electronic malfunction in the radiometer and cloud cover and 3) the inability to use the boxcorer due to sea state and cannibalization of the towing winch controls.

Overall, 104 CTD stations were occupied and 160 XBT's dropped. Subsamples for dissolved nutrient analyses (NH_4, NO_2, NO_3, PO_4, $Si(OH)_4$) were taken from all discrete water samples collected (approx. 1200). Discrete dissolved oxygen samples for calibrating the oxygen sensor on the CTD were also collected at virtually all stations. For productivity studies, 18 production experiments were conducted. Seven subsurface light penetration profiles were measured when cloud-free weather conditions permitted and 17 vertical zooplankton net tows to 150 m (replicated X 2) were made at production stations when wind and sea-state conditions permitted.

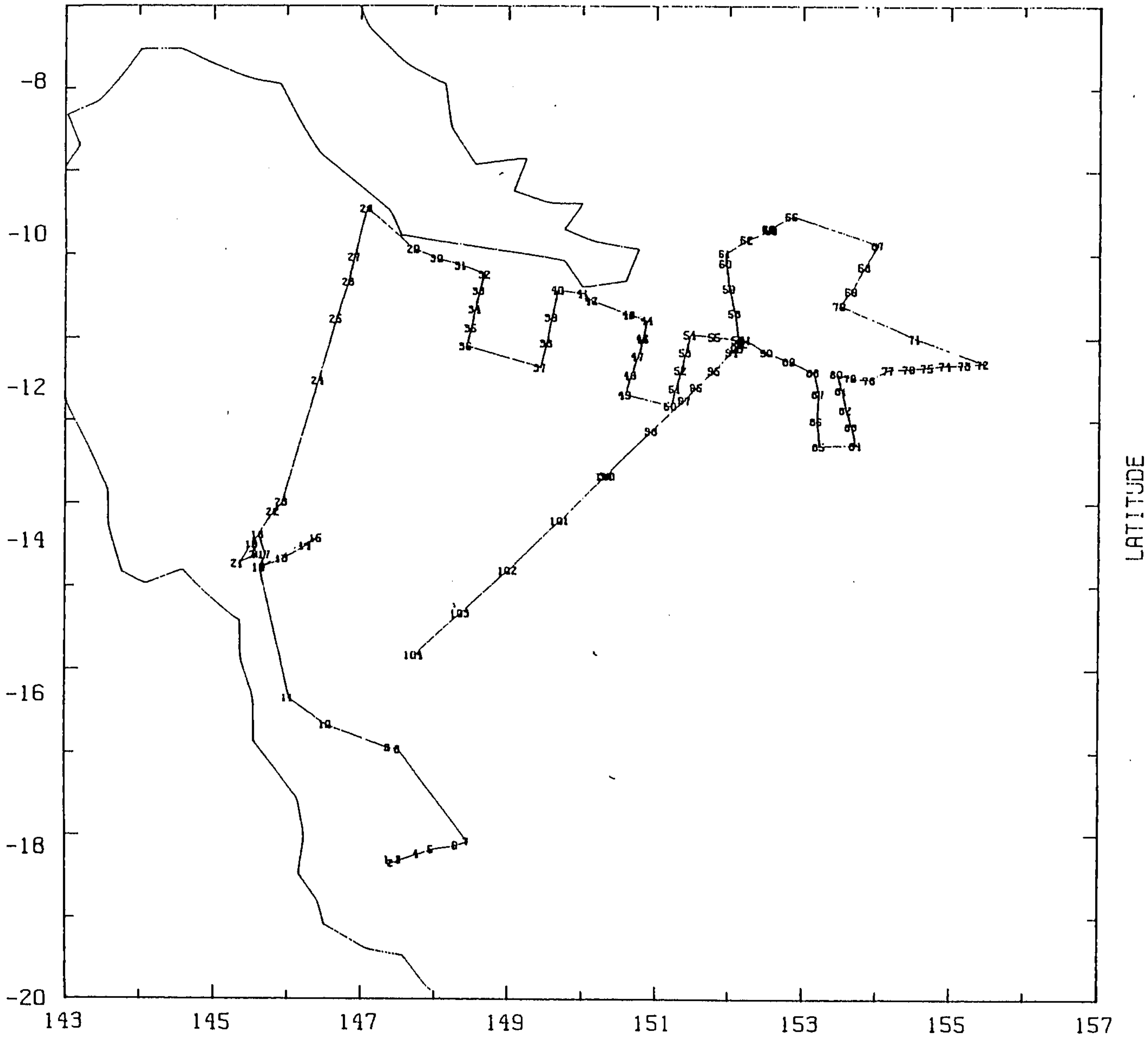
The chief scientist, in particular, and the AIMS scientific party in general, wish to thank the CSIRO National Facility support staff and ship's crew for their diligent and enthusiastic performance throughout the cruise in enabling us to meet the many and varied objectives of the scientific program.

7. PERSONNEL

Australian Institute of Marine Science

Miles Furnas (Chief Scientist)
Derek Burrage (co-Principle Investigator)
Daniel Alongi (co-Principle Investigator)

Alan Mitchell
Peter Liston
Craig Steinberg
Otto Dalhous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LATITUDE

CSIRO Division of Oceanography (National Facility Support)

Robert Beattie (Cruise Manager)
Paul Boult
Philip Adams
Ron Pleshke
Mark Rayner

8. APPENDICES

Some suggestions:

Despite the impressive level and sophistication of instrumentation and software development aboard Franklin. I still feel that the present procedures for dropping XBT's remain clumsy and potentially dangerous, with considerable running back and forth needed to go through the checkout steps for the XBT system and for a "launcher" to remain on deck in rough weather with the hand-held unit during a drop. Re-drops, when required by probe failures, are very time consuming.

Two suggestions to streamline this procedure might be made 1) installation of two "old" type of deck launchers with their reliable, weatherproof breeches on the stern quarters and the construction of signalling lights operated from the operations room to indicate to the person outside when to close the breech, pull the pin and return inside, leaving the XBT to do its own thing or 2) for using the hand-held launcher, modification of the ship's computer software to use the underutilized waterproof terminal in the wet lab to set up the XBT drop by carrying the launcher into the wet lab through either the wet lab double doors or the side hatch aft of the engine room escape trunk.

The autoanalyzer and nutrient analysis procedures, while excellent for deep water mass nutrient analyses, are unsuitable for mixed- layer and upper-thermocline nutrient measurements where the bulk of biological uptake and recycling are taking place. This is especially the case for tropical and sub-tropical waters. Many nutrient processes of recent interest occur within the 0-1 uM range of concentrations and in many cases, within the gradient between 0 and 0.2 μM. The most difficult nutrient to store and analyze is ammonium. yet this species is often the most abundant inorganic N species in the mixed layer and is the preferred nitrogen source for phytoplankton. If ammonium can be analyzed reliably in the above concentration ranges. the other nutrients are relatively easy. If the Franklin is to achieve her potential as a platform for chemical, productivity and mixed layer dynamics studies. a serious rework and rethinking of nutrient analysis procedures is needed. It should be explicitly stated that the chemistry technicians worked diligently throughout to achieve the maximum performance available from the system set up on the Franklin.

Several suggestions for improving procedures for nutrient analyses can be made.

1. The best and most convenient wash solution for low nutrient concentration analyses is tropical or sub-tropical surface seawater. Low-nutrient (including ammonium) seawater can reliably be stored for several weeks in a clean, dark, cool place in acid-cleaned polyethylene carboys. The wash solution can readily and should be standardized at periodic intervals (daily during use) by manual methods. When used, it should be pumped through the sampler in a one-pass basis, rather than recycled as currently done.

2. There was some suggestion that frozen samples were getting contaminated with ammonium. even in the -40C freezer. For best results, the delay between sampling and analysis should be as short as possible. The hold is a poor place for storing low-nutrient samples. Replacement of the currently unused dumb-waiter and instrument rack in the chem lab with a dedicated -40C freezer or an appliance "tucker-box" type of freezer would provide a better and much cleaner environment for nutrient sample storage than the present arrangement.

3. The snap-cap vials currently in use have been checked at AIMS and shown to be replicably ammonia-free when new and will remain that way in storage when stored properly. However, the caps are difficult to remove cleanly, avoiding touching of the rims with wet, rusty or greasy fingers. Vials are also stored for months in the dubious atmosphere of the hold. Screw cap vials for low nutrient samples are strongly recommended.

4. Chemistry procedures on the autoanalyzer should be implemented to allow routine analyses of samples in a 0-1 μM full-scale range. Such procedures are available from a range of sources. If the autoanalyzer works well in this range, as it should, higher concentrations can easily be run at lower colorimeter gain settings or with dilution.

Surface solar irradiance should be made an essential and ongoing part of the meteorology package, with intensity resolution of 1 ppt and temporal resolution of 1 min. This is an essential parameter for many biological and chemical studies as well as physical modelling of air-sea interaction and mixed layer dynamics. Humidity sensors would also be an important addition to this instrument package for use in estimating air-sea heat fluxes.

A water-resistant, non-skid floor in the biological trailer would improve safety and productivity within during rough or wet weather. Considerable amounts of water entered during wet or rough weather periods when the door had to be kept open or when the air conditioner was not coping. A detachable awning for the door to keep rain out would also be useful. The drain for the air conditioner condensate failed to drain properly, making the aft end of the trailer difficult to work in at times. There is a lack of tie down points in the foreward end, particularly for securing items on the plastic bench.

The seawater lines leading to the fluorometer in the GP laboratory were filled with some sort of colored slime which may have compromised the calibration of this data set. The plumbing leading to the fluorometer cannot be cleaned. The fluorometer should be disconnected after cruises, cleaned and stored dry unless absolutely needed. A redesign of the plumbing to allow complete cleaning is also needed.

We were unable to use the main towing winch throughout the cruise after cannibalization of controls early in the cruise to keep the CTD/hydrographic winch going. Additional spares should be procured to make sure that both winches can be fixed during a cruise when both are needed.

Additional general purpose computer terminals are needed to do work on the VAX while underway. For greater flexibility, provision of ship-attached PC's (IBM AND MacIntosh) to allow users to use their own software and readily interface with the shipboard system as well as act as terminals using emulation software should be strongly considered. For report writing or general work between stations, the word-processing software on the shipboard VAX is very clumsy compared to PC-based software.

The new seawater lines provided on the after deck are now more than sufficient for most uses. A good job!

The new location of the VAX and enlargement of the operations room is well done and contributed greatly to efficiency underway. Another worthwhile and greatly appreciated change!

COMMENTS ON ADVP OPERATIONS:

The acoustic doppler profiler (ADVP) is a valuable facility and in spite of its complexity is relatively easy to operate. We obtained and processed GPS transects daily and will utilize NAVSAT data for large scale absolute currents retrospectively.

The ADVP functioned in a reliable fashion and produced good data throughout the cruise. The documentation in the manuals provided by Jan Peterson and the older document by Len Zedel were useful and informative.

The procedures for calibration are OK in theory and should work well in good weather, but require refinement for adverse conditions. The need to obtain data at different speeds, since misalignment error is a linear function of ship speed, needs more emphasis. The confounding effects of differences in heading on backgracks and wind and wave-induced drift need to be taken into account in analysis, and it is not clear that data obtained in the standard calibration procedure is adequate to account for these effects.

The major difficulty experienced was finding the right combination of location, time and weather conditions for calibration runs and main gyro (absolute direction) tests. In spite of bad weather, three ADVP calibration tests were performed. An auxiliary ADVP gyro swing (direction relative to main gyro) was performed at the end of the cruise in protected waters. However, the main gyro correction was never obtained during the cruise due to bad weather. It was, requested on entry into port, but was not reported to the scientific party and due to other priorities, may never have been performed.

Although the present software and procedures are adequate, they are far from optimal and further thought and effort in program development would be beneficial for the productivity of this system, particularly where rapid feedback and adaptive sampling is a project requirement.

Some aspects of the operation, data logging and screen presentation were tedious or time consuming and not particularly informative. On the other hand, preliminary Vax-based software provided by Jan Peterson was very useful for monitoring system performance and obtaining preliminary results. This system should be further developed and refined. Some problems with the VAX system which needed system manager intervention included data file recovery or retrospective transfer to VAX after system crashes. This procedure also results in ping data being in reverse order.

The comments which follow are not intended as criticisms of the existing system, so much as suggestions for enhancing its productivity.

The main issues concern data presentation and 'on-board' processing as follows:-

a) The tabulated screen data and manual logging procedures are not immediately useful. They give an incomplete picture of system operation and performance and do not provide the scientist with feedback in a form which is easily and quickly evaluated.

b) Programs for doing preliminary calibration while at sea would be invaluable. Contingency procedures (allowing for restrictions on ship heading and speed due to wind, wave conditions) for calibration under difficult conditions are also highly desirable. In this way the quality of calibration and velocity data collected can be evaluated during the cruise (and repeated if necessary).

Specific suggestions for improvement are:

1. Where GPS is up give velocity profiles on screen and on the Plotwriter in absolute, not relative vectors. The Plotwriter was very useful as a record of vertical velocity structure and data quality, but not meaningful for current direction or speed (without looking at the source code there was no indication of the reference frame used or of the method for computing shear).

2. Eliminate screen scrolling and instead update a stationary screen in the manner of DELP. Ensure vital messages are not lost from the screen especially if unattended, e.g. tape change operations, no. of GPS fixes.

3. Provide clear and easily read indicators of ADVP, weather and navigation status on the ADVP screen. E.g. indicate whether GPS or SATNAV nav is up, or whether bottom tracking is on, ship water speed and heading, on station or not, current gyro correction, and when last updated, present ADVP parameters (especially bin geometry), and present micro and VAX filename. Display a velocity profile plot to one side with different colours for different components to save space, and allow plotting to full depth. The tabular presentation is practically limited to bin 12 if GPS data is not to be scrolled off, so deeper current cannot be monitored.

4. Consider providing better visualization of the velocity field, navigation, wind and ship velocity, and pdr depth using on screen diagrams and/or graphics plots along the lines of modem aircraft navigation screens. Such enhanced real-time graphics may require additional computing power. Perhaps an IBM AT clone could be used for this purpose. The present tabular screen output is difficult to read, and tedious to reproduce in a manual log and with the exception of performance indicators like GPS error or 95 % velocity error, the data are not very useful.

5. Consider reinstating an option to give velocities relative to ship-based coordinates for special purposes, especially for calibration.

6. Integrate SATNAV fixes as well as GPS into the data base together with indicators of fix quality. Provide programs for processing SATNAV ADVP data to produce preliminary large scale circulation results while at sea.

7. A more subtle problem is whether to use successive GPS fixes or GPS velocity for calculating absolute currents. The latter is usually considered relatively noisy and is derived from GPS using an entirely different technique (? doppler shift for velocity, compared with time ranging for fixes). Some GPS navigation computers (e.g. Magnovox) Kalman filter the fixes to reduce noise.

8. Investigate whether alternative 'dockside' or 'in- well' type operations can be used to check probe alignment. This would be particularly useful when field calibration is hindered by bad weather. For example, could alignment be monitored using a specialised light source and sensor in the instrument well with the source rigidly attached to the top of the transducer assembly?

9. Press for RD to fix or upgrade hardware bottom tracking capabilities.

10. If manual logging of data is to continue the emphasis should be on conditions which affect current measurements, either as forcings e.g. wind and sea state, sources of error, particularly in navigation and ship motion, such as ship maneuvers, SATNAV and GPS fix quality and Satellites visible, maneuvers, and indicators of data quality, i.e. absolute current when available, percent good returns, 95% error velocity. Less emphasis should be placed on hand-copying tabulated data. The present log sheets are too small for hand writing at sea and there are no columns for several parameters which affect current. The outputs for relevant data e.g. wind, pdr, GPS status are scattered around the ops room and would be better located on one ADVP screen.

11. Annoying bugs in the present system are in erroneous displays of echo amplitude and GPS fixes scrolling off screen. Tedious aspects are the involved way in which the system menu must be accessed to change turn default screening off and on, before resetting parameters and the dangers of the operator forgetting to reset an important menu parameter like sending files to the VAX after a system crash. The present default menu parameters are inappropriate so why not change them?

12. A more subtle, but pervasive difficulty is that an inexperienced operator could set up the machine inappropriately without any indication of a potential problem. The 'standard' configurations for different depth ranges could be programmed as high menu level choices invoking appropriate parameter settings.

COMMENTS ON PDR:

The Precision Depth Recorder suffered operational problems continually during the cruise, though careful attention by CSIRO support staff kept it functional. The lack of any indication of false readings such as when on station resulted in erroneous depths being recorded in the ADVP log early in the cruise. This requires attention.

COMMENTS ON CTD AND XBT PROCESSING:

The CRUISUTIL directory is a useful VAX feature for obtaining contour sections for CTD transects. We improvised XBT plotting in the same manner, but this should be added to the system properly. The utilities could be further refined and their use by project scientists could be encouraged. Particular suggestions for enhancements are:

1. Add a capability to do Geostrophic velocity and perhaps transport sections. This requires a change in program SECT.FOR structure or a new version to allow access to successive profiles for computing the horizontal density gradient.

2. Rationalise the production of contoured sections from XBT, CTD, and ADVP systems so that these data can be merged or overlaid at the same scales. This would greatly enhance the combined value of geostrophic and doppler velocities.

3. Store the raw XBT data (time and resistance) at full resolution (10 Hz). Because probe acceleration formulae and resistance - voltage - temperature conversions can change or be improved, it is desirable to be able to return to raw data should reprocessing be necessary.

4. Allow production of full resolution XBT and CTD data, rather than 2 m averages to retain information useful for fine structure studies.

5. Make explicit the method of reducing CTD and XBT data to 2 m cell sizes. Simple cell averaging may perform poorly in high gradient areas. Make explicit any corrections which might be done for salinity spikes due to probe response mismatch when correcting raw CTD data. Again, this is important for fine structure studies.

Miles J. Furnas
Chief Scientist

FURNAS:CruiseRep-P