FRANKLIN

National Facility
Oceanographic Research Vessel

RESEARCH SUMMARY

CRUISE FR 7/91

Sailed Townsville	0001	Saturday	31 August 1991
Arrived Townsville	1400	Thursday	12 September 1991
Sailed Townsville	1000	Friday	13 September 1991
Arrived Cairns	0900	Monday	23 September 1991

Drs Derek Burrage and David Williams
Australian Institute of Marine Science

Dr Lance Bode
James Cook University

BOUNDARY FLOWS AND FRONTAL CONVERGENCE IN THE CORAL SEA

-oOo-

Drs Ian Barton & Fred Prata
CSIRO Division of Atmospheric Research

VALIDATION OF ERS-1 SCANNING RADIOMETER

-oOo-

Thierre Correge
Australian National University

GEOCHEMISTRY OF OSTRACODS

For further information contact:

ORV Operations Manager
CSIRO Division of Oceanography
GPO Box 1538, Hobart, Tasmania 7001

8 November 1991

Phone (002) 206 222
Fax (002) 240 530
Telex AA 57182

FRANKLIN is owned and operated by CSIRO

FRANKLIN

Research Summary FR7/91

Itinerary:

Sailed Townsville 0000 31 Aug, 1991
Called Townsville 1400 12 Sept., 1991
Departed Towsville 1000 13 Sept., 1991
Arrived Cairns 0900 23 Sept., 1991

Principal Investigators:

Dr. Derek Burrage - Australian Institute of Marine Science (AIMS)
Dr. David Williams - AIMS
Dr. Lance Bode - Dept. of Civil and Systems Engineering, James Cook University of North Queensland (JCU)
Dr. Ian Barton and Dr. Fred Prata - CSIRO, Division of Atmospheric Research (DAR)
Mr. Thierry Correge - Dept. of Geology, Australian National University (ANU)

Co-Investigators:

Dr. Carl Nilsson - CSIRO, Division of Oceanography (DOC)
Mr. Rowan Hughes - AIMS/JCU
Mr. William Skirving - AIMS/JCU and Dr. Mike Bonnell -JCU
Mr. Stephen Blake - JCU

Scientific Program

Boundary Flows and Frontal Convergence in the Coral Sea. D. Burrage, D. Williams (AIMS), L. Bode (JCU)

NOAA Satellite ground-truthing and infra-red radiometer inter-comparison. W. Skirving (AIMS/JCU)

Numerical Circulation models of the Coral Sea. R. Hughes (AIMS/JCU)

Primary Productivity of the Surface Layer (S. Blake, JCU)

Validation of ERS-1 Scanning Radiometer (I. Barton, F. Prata, DAR) - Piggyback project

Geochemistry of Ostracods (T. Correge, ANU) - Piggyback project

BOUNDARY FLOWS AND FRONTAL CONVERGENCE IN THE CORAL SEA

Objectives:

1. To observe the volumetric transport from surface to bottom of the SEC inflow in the Coral Sea and to map its subsequent trajectory and bifurcation.

2. To define the hydrographic and current structure of the Frontal Convergence zone of the EAC seaward of the southern GBR and to investigate associated mesoscale fronts and interactions with the topography of the southern GBR, prior to its exit from the Southern Coral Sea into the Tasman.

3. To measure the surface currents associated with the Coral Sea current system using hydrographic and Acoustic Doppler current data and Lagrangian satellite-tracked buoys deployed in the bifurcaton and frontal convergence region and conincident radar altimeter data.

4. To correlate the physical properties of the large-scale and meso-scale circulation features in the SEC bifurcation and its southern branch, the EAC, with the distribution of major fisheries and associated fishing effort.

5. To acquire ground-truth data to validate the recently launched ERS-1 satellite remote sensing systems using ship-board data acquisition systems and to measure sea surface temperatures along-track using ship-mounted infra-red radiometers.

Results:

Selected results of scientific studies relevant to particular cruise objectives and investigators are described below.

A. Circulation and Hydrography of the Southern GBR, EAC and Frontal Convergence Zones (D. Burrage and D. Williams).

The cruise track for parts 1 and 2 are shown in Figure 1. Part 1 was executed primarally south of 20S while part 2 was executed principally to the north of that latitude.

After completing CTD and ADVP transects within a SAR swath and around Percy Islands, a CTD transect was run through the southern end of the GBR lagoon, along the axis of the Capricorn channel and extending to and over the Recorder seamount. During this transect eastward flows of cold shelf water were detected in ADVP Thermo-salinograph and CTD data south of Pt. Clinton within a zone were persistent upwelling and ultimate entrainment into the EAC has been observed in previous NOAA AVHRR imagery. While this upwelling feature appeared more extensive than usual, there was little evidence of a cyclonic gyre which has been observed seaward of the Capricorn Bunker group and trapped between the EAC and the shelf edge on previous occasions (Griffin Middleton and Bode (1987); Kleypas and Burrage(1991). Throughout part 1 of the cruise both ADVP transects and AVHRR imagery showed that the EAC flowed strongly southward from Swain reef and impinged on the shelf south of Fraser Island. The relatively southerly position for the impingement point and the unusually strong upwelling in comparison with previous AVHRR observations may explain the lack of evidence for a cyclonic gyre at this time. Two CTD/XBT/ADVP transects run later in part 1 from Saumarez Reef and from the Fraser Seamount which intersected off

Lady Elliot Island confirmed the observations described above.

An unusual feature of the EAC detected both in AVHRR imagery and in ADVP and XBT data which has not been previously described in this area was also observed. This was an extension of the main stream of the EAC which forked and retroflected off Fraser Island in the form of a warm north-eastward trending surface jet. When this jet was first observed in AVHRR imagery acquired on 2 Sept., its structure resembled that of mushroom vortices or hammer head jets which have been described elsewhere. By the 8 Sept., newly acquired imagery and ADVP data from the Fraser seamount transect revealed that the jet had developed in strength and then extended from 154 to 157 E, a distance of some 165 nautical miles. This was accompanied to the south by a cyclonic circulation of cold, saline water probably derived from the Tasman Sea. The cold current was evidently advecting the buoyant EAC water eastward while shear waves were evident on the interface between the warmer and colder streams.

One of the primary objectives for the first part of the cruise was to study a large-scale sea surface temperature front separating warm Coral Sea waters to the north and cooler waters to the south This front typically extends several 100's km east of Fraser Island. The front has been observed in previous AVHRR imagery analyzed at AIMS and is mentioned in the Japanese fisheries literature. In september, 1990 it was a focus for Japanese long-line fishing activities.

The location of the front was established early in the cruise using AVHRR images acquired via INMARSAT and was found to intersect meridion 158 E at 23 S with a generally NW to SE trend. A large cold water body lay to the SW between this location and the EAC main stream. This body was evidently intruding in a NW direction and was partly cut off to the south by the eastward EAC retroflection described above. The Argo Bank CTD transect (stations A1-A6) was run across the front along 158 15' E from approximately 24 S to 22 S. The resulting CTD temperature section (Figure 2a) shows the SST front with a temperature of 22 C located between stations A3 and A4, with its subsurface extension trending northward to station A6. Colder upwelled water appears at station A3, while further south the influence of the EAC retroflection is evident at stations A1 and A2. ADVP velocity vectors (Figure 2b) were consistently westward at A2 and eastward at A5 at the time the stations were occupied. A preliminary assessment of T/S plots from stations on either side of the front suggest that the colder water to the south originates in the Tasman Sea, while the warmer water to the north is derived either from the EAC itself or from Coral Sea surface waters.

Two Argos drifters were deployed at stations A2 and A5 on 9th. Sept. drogued to 100 m on either side of the front and separated by about 65 miles. The initial motion of these drifters was consistent with thermal wind balance across the front (eastward to the north, westward to the south) and with the ADVP data. The southern drifter headed westward and then north-west following the bottom countours on the eastern flank of the Cato

trough. By the 18 th. Sept. it had crossed the trough near Bird Island and looked set for entrainment into the EAC. (Figure 2c). However, by 25 Sept., it had diverted NE and performed a sub-mesoscale cyclonic loop. The northern drifter followed an anti-clockwise track of approximately 50 miles radius following the topographic contours of Nova Bank and the Bellona Plateau and by 18 th. Sept. had slowed almost to a standstill as it crossed the CTD transect about 70 miles north of its deployment location. By 25 Sept., this drifter had almost completed an anti-cyclonic circuit suggesting entrapment in a mesoscale warm-cored eddy.

Careful correlation of the hydrographic, ADCP and ARGOS data with that from the AVHRR sensors will be needed to interpret the details of the various interacting flows and water bodies. However, we may draw the preliminary conclusion that within the Frontal Convergence zone, near the latitudes of Fraser Island and Swain Reef, and seaward of the EAC main stream, jet-like extensions of eastward-flowing EAC waters and south-eastward moving warm Coral Sea waters override and inter-penetrate northward and westward flowing cold waters probably of Tasman sea origin.

B. Fisheries and relationship with topography and fronts (D. Williams)

Aims:

The aims of the fisheries research was to determine possible relationships between Japanese long-line fishing activities, the "Frontal Convergence Zone" off the southern GBR and bottom topography.

Background:

In Aug. - Sept. each year, the Japanese longline fleet which fishes for tuna and bill fish concentrates its activities in the Australian Fishing Zone (AFS) between latitudes 20S and 30S. Early in the season, activity is concentrated in the southern part of the region and boats tend to move north as the season progresses. The fishing boats are obliged under their Bilateral Access Agreement to radio their positions every day and their catch every 2 days to thje Australian Fisheries Service (AFS) in Canberra.

Details of the movements and catches of the fleet were provided by AFS during the cruise. Trained observers were placed on Fishing boats in support of the project to obtain detailed information on composition of the catch by depth and location and the results of operational XBT casts, if possible.

Results:

Mapping of the positions of boats at the beginning of the cruise indicated a close link of fishing activity with the line of seamounts running approximately N-S along 155E from 24S to 29S and with the western edge of the Dampier Ridge running parallel

to the line of seamounts ar approximately 157 E from 28S to 25 30'S then north westward to 24S. Fishing activity and the swimming depth of most species targetted is largely restricted to the surface 200m yet even the small seamount peaks are more than 400m below surface and the bulk of the mounts are deeper than 1000m. The side of the Dampier Ridge where activity is concentrated is deeper than 3000m.

These observations suggest an hypothesis that despite its depth, the bathymetry has a major effect on the distribution and catchability of fish in the surface 200m. A CTD and ADVP transect (C) was modified to cross the Recorder Seamount at 25S, 155 E which is one of the centres of fishing activity, to determine whether the seamount was affecting physical processes near the surface. The results (Figure 3a) indicate upwelling of waters surrounding the seamount. Satellite images received via INMARSAT during the cruise show a distinct patch of cold water near the seamount, which lends support to the inferred upwelling. The section also suggests the presence of an anti-cyclonic (warm-core) eddy in the near-surface layer above the seamount. The ADVP data (not plotted) shows evidence of anti-cyclonic veering of the ambient flow at the sea mount, consistent with the presence of such an eddy.

A similar, XBT, transect M (Figure 3b) was run across another seamount (Fraser seamount) to the north-east of Recorder with similar results. This transect was continued eastward to determine whether the 3,000m deep Dampier Ridge might also be having a significant effect on the surface waters above it. Five CTD casts were made moving up the western flank of the Ridge. Interpretation of the results will be complicated by the presence of warm surface waters possibly associated with the retroflecting jet drawn from the EAC.

Earlier work suggested that there might be a relationship between the fishing activities of the longline fleet and the location of the the "Frontal Convergence" zone of the EAC seaward off the southern GBR. At the time of the cruise most of the fishing activity was to the south of this front. A CTD transect across the front, however, revealed major doming of the thermocline which may significantly enhance biological productivity in the vicinity of the front. Hydrological samples from the casts remain to be analysed.

C. Circulation and Hydrography of the Western Coral Sea (L. Bode, D. Burrage).

The main purpose of circulation and hydrographic studies during the second part of the cruise was to map the large-scale features including the SEC inflow and its bifurcation and to investigate the presence of cyclonic gyre observed during previous cruises by AIMS aboard FRANKLIN. The transects during this part consisted essentially of a closed anti-clockwise circuit of the western Coral Sea. The cruise track for Part 2 is shown in Figure 1 for transects north of 20S; ADVP vectors are

given in Figure 4b. This differs from the cruise track which was originally planned because higher priority was given to identifying the mesoscale processes associated with the SEC inflow while lower priority was assigned to the second (shorter) Radar Altimeter track. Also, since a decision was made to deploy the remaining pair of drifters simultaneously within the EAC along the principlal radar altimeter track this obviated the need to reoccupy location DD which has been used in previous deployments.

The eastern leg (Frederick Reef transect - stations F11 (CTD #86) to F28 (#103) traversed the main SEC inflow region. As seen from Figures 1 and 4b, currents flowed basically westward from stations F17(#92) to F24(#99), often with speeds in excess of 0.5 m/s. A rough estimate of volume transport across this section gives 20 Sv. An extremely sharp front was encountered at station F16(#91), with surface temperatures rising abruptly by approximately 2.5 C. The hydrographic contours (Fig. 4a) show this feature clearly, in Temperature and Salinity. An upwelled body of high Temperature and low Salinity water was encountered around station F18(#93); the near surface ADVP currents show a pattern which appears to be related to that of the hydrography. There is also a reasonably strong correlation between the salinity and dissolved oxygen (not shown), although the dissolved oxygen also shows a pronounced minimum, centred on 600 m. Two Argos drifters were deployed on this transect spanning the main stream of the inflowing SEC at stations F20(#95) and F23(#98). The latter (MRT 112 ID # 7585) appears to have failed only one day after deployment, but the other is is presently returning positions via Systeme Argos.

Other features noted include the following:

* A persistent N-NW flow of cool water, extending over roughly 130 km, and with speeds in excess of 0.5 m/s, between stations H5(#85) and H6(#86). This northward flow observed between H5 and H6 was consistent with a northward flow encountered between stations F11(H6) and S4 during part 1 (not shown). Strong south easward flow associated with presence of the EAC flowing over the Marion Plateau was observed in the western portion of this transect (H1 - H5).

* As discussed in relation to SAR studies, flow through the passage between Tregrosse and Lihou Reefs was to the north.

* Flow adjacent to the continental shelf of PNG (within approximately 100 km) was eastward following the PNG slope and hence away from the Gulf of Papua. Continuing south, along the North Reef transect from the Louisiade Archipelago of PNG to North Reef near Flinders Reef, the currents turned to the west, as an apparent continuation of the SEC inflow observed along the Frederick Reef transect. Further south, there was considerable variation in direction of the surface currents along this leg. However, currents were large, being consistently over 0.75 m/s. Along the entire transect there was considerable structure in the hydrography which may indicate some interleaving of water masses.

Unambiguous interpretation of the current structure may be difficult, given the wide variation in directions along this lengthy transect. However, it is hoped that satellite images, more detailed analysis of the hydrographic data, as well as further numerical modelling by Rowan Hughes, will aid interpretation.

NUMERICAL MODELLING OF THE CIRCULATION OF SOUTH-WESTERN PACIFIC AND CORAL SEA (R. D. Hughes)

This research involves the development of an Ocean General Circulation Model (OGCM), using the Cox-Bryan code, of the Coral Sea and adjacent Eqautorial waters. A bifurcation is evident in the model at approximately 15 degrees South, off the shelf edge at Princess Charlotte Bay.

Cruise Objectives:

a. Establish the possible existance and position of a bifurcation between Tasman and SEC waters on the Northern Queensland coast, as reported by Andrews & Clegg (1986), and Church (1987).

b. Obtain more CTD and ADCP data relevant to a possible strong clockwise recirculation (approx 15 Sverdrups) south-west of the Louisiade archipelago (PNG).

This has been found in dynamic height calculations from earlier AIMS cruises on Franklin in 1985 and 1990 in that vicinity. The OGCM shows a clockwise turning in this area, but it is much weaker (less than 3 Sv.) and does not recirculate.

c. Obtain further deep cast CTD data (3000m and deeper) from the western Coral Sea area which will allow more reliable dynamic height calculations. The OGCM shows abyssal (greater than 1300m) water moving southwards along the Queensland coast, originating from Vitiaz and the New Britain straits; no bifucation in deeper waters is predicted.

The second part of the cruise (13 to 22 Sep 1991) was intended to provide most of the data needed to meet these objectives. However, due to time limitations most of the CTD casts were limited to 1500m, so that only a very limited amount of data was useful for objective (c). FR0690 provided more deep cast data, but there is still insufficient information to provide reliable dynamic height calculations of abyssal water. The 1500m casts were sufficient for surface dynamic height calculations, and the data will be combined with that of FR0690, to be used for dynamic height calculations referenced to 1500m.

The Franklin ADCP collected in 1988 and in 1990 showed strong evidence of a continous cyclonic boundary current circulation around the Gulf of Papua. ADCP data from the present cruise has also shown a strong clockwise circulation near PNG, as mentioned in objective (b); however, since only two transects were done during this cruise it is not clear how much of this water is recirculating, and how much is flowing outwards, to the

East, along the coast near Tagula Island.

Objective (a) could have been best realized by several south-south transects, off the shelf between latitudes 18 and 11 degrees South, using the ship's ADCP. Time permitted only one transect from 17.5 to 16 S, and the ADCP data showed strong (0.8m/s) south-east flow along this run. This indicates that any possible bifurcation point was above 16 S at the time of the cruise.

PRIMARY PRODUCTIVITY OF THE SURFACE LAYER (S. Blake)

The aims of this exploratory study was to investigate whether the SEC bifurcation zone is associated with enhanced primary productivity. It is continuation of work commenced during FR05/90.

The location of the "bifurcation zone" of the EAC at the western boundary of the Coral Sea shows considerable variability in both time and space, but is roughly centered off the Cairns/ Port Douglas/ Cooktown part of the N. Queensland coast. This area is thought to be characterised by increased radiances using the visible channel on board the NOAA-11 satellite (Blake, unpublished data). Whilst the spectral and spatial resolution of the AVHRR instrument is generally too limited to be routinely used detect local upwelling, and frontal effects, it is ideal for the delineation of larger regional-scale processes.

To test for enhancement of primary productivity within the bifurcation zone, the ship's underway Turner Fluorometer system was run in conjunction with the thermosalinograph, CTD and other satellite sea truthing experiments (see also Fr 05/90). Phytoplankton (measured as chlorophyll-a concentrations), and their derivatives and break-down products (the phaeopigments), control the spectral as well as spatial distribution of light within the euphotic zone. This technique compares the natural red fluorescence of the living plankton cells with the phytoplankton productivity in the upper layer, and is an invaluable semi-quantitative tool for measuring the surface concentration of phytoplankton over large spatial scales in oligotrophic waters in a research vessel underway.

The fluorometer was initially calibrated at 1600 on the 18th Sept. during the northwards transect to PNG, and again at 0130 on 22nd to recalibrate prior to approaching the approximate region of bifurcation. Fluorescence measurements were logged continually until 23rd Sept. (Green Island). The background Coral Sea chlorophyll concentrations remained consistent indicating low ambient primary productivity and no instrumental drift error. Exceptions included:

1) A 70km wide zone of high chlorophyll, high temperature, low salinity signature water 135 km south of PNG on 19th Sep.

2) High chlorophyll, low temperature, high salinity water adjacent to the Louisiade Archipelago (19 Sep). This is explained

as a forced marginal upwelling in 300m of water.

3) A 60km wide zone with identical characteristics to 1. above (20 Sep).

4) High chlorophyll associated with the bifurcation area.

5) High chlorophyll associated with Grafton Passage

Combining the fluorescence data with the ADCP, CTD (especially NO_3) and the ATSR & AVHRR SST imagery will provide more information on the origin and development of these remote, high productivity areas within the Coral Sea.

ERS-1 Ground-truthing Studies (Burrage, Barton, Prata, Nilsson and Skirving)

One of the major goals of the cruise and of both the AIMS and CSIRO P.I.s was to obtain shipboard data coincident with that from sensors flown on the ERS-1, NOAA and MOS-1 satellites with the primary emphasis on ERS-1. This data collection activity has provided ground-truth data for a number of the Australian ESA-approved ERS-1 projects including those of Burrage (RA,SAR and ATSR), Barton (ATSR) and Nilsson (SAR). With its comprehensive range of instrumentation (RA, AMI SAR, ATSR and AMI Wind/Wave Scatterometer) and a 3-day repeat cycle, ERS-1 overpasses were a primary cruise track determinant. Since the ERS1 RA track lies at the centre of the 500 km wide ATSR swath, while the 100 km wide SAR swath lies outside of the ATSR swath, and to the right of the flight path, a flexible planning approach was required to optimize the various opportunities for ground-truthing. The temporal and spatial scales of the phenomena being observed by the various sensors and the degree of coincidence required for ground-truthing each instrument essentially set the planning priorities for the remote sensing ground-tracks.

ERS-1 Radar Altimeter (D. Burrage)

Three hydrographic transects (Legs S and F and G) were aligned along ERS-1 nadir tracks in order to acquire CTD, XBT and ADVP data for verification of the ERS-1 Radar Altimeter (RA). This work is a field component of the European Space Agency (ESA)-approved project entitled "North Australian Tropical Seas Circulation Study" (designated AUS 6-14 by ESA). The goals of this study are consistent with Cruise objective 1) in that the RA can be used to map surface geostrophic currents, validated against ADVP data. The resulting surface currents will be combined with geostrophic currents computed from the hydrographic data to yield volume transport estimates for the inflow of the SEC into the Coral Sea and the outflow of the EAC into the Tasman. By its nature the Radar Altimeter is best suited to large-scale surface current studies but may also detect mesoscale processes. A maximum coincidence error of 3 days for RA ground-truthing was considered adequate, while spatial departures of CTD transects along RA tracks was minimized. The northward half of transect F through the SEC began and ended at the time of ERS-1

overpasses and spanned the intervening period.

ERS-1 Synthetic Aperture Radar (D. Burrage and C. Nilsson)

Two regions lying within FRS-1 SAR swaths were selected for intensive field investigation during the first part of the cruise. These were the Percy Islands located off Broad Sound in the southern portion of the GBR (Overpasses were 2/9 1000 EST and subsequently at 3-day intervals) and the Frontal region which crosses the Australian Fishing Zone Boundary east of Fraser Island (Overpasses at 3/9 0930 EST and 3/9 2230 EST and subsequently at 3-day intervals). A fourth overpass over Flinders passage on 1/9 at 2300 was ignored at the commencement of the cruise because it was found just prior to departure that the Alice Springs receiving station was not scheduling night-time (ascending) passes for reception. This constraint may have been removed, subsequently, to allow further ground-truthing.

Percy Isles:

Based on the available ERS-1 scheduling information a hydrographic and acoustic doppler survey consisting of a 'box' centred on the Percy Isles (21 45S,150 20'E) and falling within the expected SAR overpass was commenced with a station off Broad Sound at 0635 EST on 1/9/91. 7 CTD casts were made along a 36 Mile across-shelf transect with an additional station seaward of the islands and one in the channel between them. ADVP data were acquired on a 13 by 9 Mile rectangular course centred on the islands and executed clockwise during an ebbing tide. Two ADVP runs were done through the channel, one during the ebb, and one during the subsequent flood tide.

Surface thermosalinograph data revealed a frontal drop in temperature of approximately 0.6 degree as the channel was entred from the NE end. A subsequent NOAA 11 satellite image acquired the same day and transmitted to the ship from Hobart revealed a large-scale across-shelf temperature gradient with a front located just seaward of the islands. A subsequent image obtained on 9 Sept., revealed that the front persisted. New information received during the operations revealed that the SAR overpass for this date had not, in fact, been scheduled by ESA for acquisition, so field operations were scaled down to allow time to meet the next scheduled ATSR overpass further south. Although not coincident with a satellite overpass, the data if coupled with a numerical tidal circulation model, should allow interpretation of subsequent SAR passes over this area.

Diamond Islets and Lihou Reef:

Since Lihou Reef which is located on the Queensland Plateau lies wholly within the same SAR swath which passes over the Percy Islands and close to the CTD transect between Flinders Reef and way point W3, the opportunity was taken for a detailed CTD and ADVP transect across the passage between Tregrosse and Lihou Reefs.

On the 15 Sept. an XBT/ADVP transect was done along the south side of Tregrosse Reef and 4 CTD stations (D1-D4) were done spanning the passage separating the two reefs. Originally, southward flows through passage were expected, consistent with an inflowing SEC. However, flows proved to be weak and variable on the run between Flinders and Tregrosse Reef and, while the flow adjoining (and perhaps through) Tregrosse Rf was southward, that through the passage between Tregrosse and Lihou was moderately strong (0.3 m/s) and to the north! It remains to be seen whether flows of this magnitude are sufficiently strong to generate sub-mesoscale features downstream which may be detectable in the SAR imagery.

By its nature SAR is sensitive to local wind and wave fields and to sub-mesoscale (10 km scale) processes in which interaction between wind and current or current and topography predominate. Hence it is potentially well suited to the study of wakes and eddies around reefs and shear waves associated with oceanic and shelfbreak fronts.

ERS-1 ATSR, NOAA and MOS-1 Ground-Truthing

AIMS INFRARED RADIOMETRY PROJECT:

Conducted by William Skirving (AIMS/JCU) and Stephen Blake (JCU) with Mike Bonell (JCU) and Derek Burrage (AIMS).

Aims:

There were three main aims of this project:

a) To monitor the sea surface temperature (SST). This data base will be used as a supplement to the other oceanographic data collected during the cruise (eg. CTD, XBT, etc.). It will also be used as ground-truthing data for SST retrieval from NOAA AVHRR data.

b) To conduct inter-comparisons between narrow and wide-band radiometers.

c) To determine the extent of the SST skin effect.

Instrumentation:

Two radiometer systems were used in this project. The AIMS radiometer system consists of four commercially available 8-14 micron radiometers, two with a 4 degree field of view (deg.FoV) and the other two with a 15 deg. FoV. They were made by everest Inc., California. The other radiometer was designed and built by C.S.I.R.O. Division of Atmospheric Research. This radiometer is capable of sensing in five different windows ranging from 8.6 to 12 microns.

Implementation:

Two Everest radiometers (one 15 and one 4 deg. FoV) were

mounted in PVC tubes on the starboard side of the monkey island, along side the DAR radiometer. They were each equipped with an airpurge as protection from sea spray. The compressed air was supplied to the radiometer by a portable compressor, which was positioned inside the portable lab on the aft deck. The regulator and filters were positioned near the radiometers for ease of use.

Data Collection:

Part 1 (31st Aug - 12 Sep, W. Skirving)

Throughout the first leg of the cruise, the two protected Everest radiometers were used to monitor SST almost continuously, so as to provide transect and ground-truthed data. These radiometers consisted of a 4 deg FoV radiometer pointing at the sea at an angle of -45 deg. relative to horizontal, and a 15 deg FoV radiometer monitoring sky radiation at an angle of +45 deg. relative to horizontal. These data will also be used to determine the extent of the SST skin effect (a cooling of the sea surface skin due to latent heat loss). The other two unprotected radiometers (4 and 15 deg. FoV) were used to obtain an intercalibrataion with the DAR radiometer, which was operated by Dr Fred Prata. These Everest radiometers were kept inside except during intercalibrations to minimise the effects of the marine environment. Throughout most of the first leg of the cruise these calibrations were performed on an opportunistic basis, however on the second last day Dr Prata was kind enough to devote some time specifically for intercalibrations.

During the second half of the cruise Stephen Blake took over the operation of the Everest radiometers from William Skirving. Only the two protected radiometers were used on that leg. The data from part 2 of the cruise will be used for transect, ground-truthing and SST skin analysis. Stephen's report follows:

Part 2 (13th Sep - 23 Sep, S. Blake)

The two Everest radiometers mounted on the starboard side of the monkey island were monitored continuously from 13th - 22nd September, whilst set to record approximately 1000 bytes of data per minute in a burst sampling mode. The aim of these continuous deployments was to monitor SST between Townsville, Marion Reef, PNG and Cairns to obtain a regional perspective on ambient SST variability, and to sea truth the ATSR aboard the ERS-1 satellite (as a direct comparison to the more routinely available NOAA AVHRR imagery). One of the radiometers was set at a 45° upward angle to record sky radiances, whilst the other was left pointing at the sea surface at a 45° downward angle.

The DAR AVADS Radiometer operated by Dr Fred Prata was also in operation episodically during the second leg of the cruise. Together, the two data sets provide both continual and high resolution radiance data sets to analyse for sea-surface skin effects; ATSR (ERS-1) & NOAA AVHRR sea truthing; and ambient background SST levels associated with Coral Sea meso- and macro-scale hydrodynamic features (surface currents, fronts, eddies, gyres and shears).

Calibrations between the Everest and AVADS Radiometers were undertaken on the first leg of the cruise. Radiosonde launches were undertaken in conjunction with Dr Prata at times of satellite overpasses. 7 ERS-1, 7 NOAA-11 and 7 NOAA-12 images were captured (pending suitable cloud-free images). Another DAR radiometer (Barton Radiometer), was operational in the shelfal waters coincident with our deployments until 18th September aboard the R.V. Lady Basten operated by AIMS. During the 30 CTD stations monitored, the following atmospheric ground-truth data were also collected: Wind direction, wind speed, pressure, SST, salinity, dry & wet bulb temperatures, humidity, air temperature (digital), and % cloud cover. A Rotronic humidity error curve has been constructed with the aid of Eric Masden from the wet/dry calculated humidity readings. The DELP pressure reading was found to consistently read 3 hP too low compared with the aneroid barometer. Temperature and humidity error plots were found to be highly correlated but in opposite directions. All 14 Mb of analog radiometer, and their corresponding time values have been compressed and archived as 15 separate "ARCHIVE.ZIP" files. The very calm sea-states during this leg of the cruise are worthy of special mention, however extremely high humidity levels (<92%) were encountered north of approximately 14° S on the PNG transect.

Acknowledgements:

I would especially like to thank Stephen Blake for running the AIMS radiometers during part 2 and Dr Fred Prata for sharing data from the AVADS. I would also like to thank the entire O.R.V. Franklin crew and the CSIRO technicians for invaluable assistance. Lastly I thank Drs Nilsson Burrage for their suggestions and comments.

Piggy Back Projects:

1. VALIDATION OF ERS-1 SCANNING RADIOMETER

I. Barton, F. Prata, CSIRO Division of Atmospheric Research, Private Bag No. 1, Mordiallic, Vic, 3195 (03) 586 7666.

The Radiometer (AVADS)

An accurate, calibrated chopper radiometer was mounted on the starboard side rails of the Monkey Island. The radiometer could be moved in elevation to view the sea at zenith angles ranging from 75 deg to horizontal, and to view the sky up to 90 deg. An optimum zenith angle of 40 deg was determined for viewing the sea after consideration of wake effects and angular emissivity dependence. Data from the radiometer was logged on a computer (maintained in the bridge). The computer also controlled the duty cycle of the radiometer, sampling times, channel selection, calibration intervals and repetition rates which are selectable using a computer program.

The radiometer was operated at satellite overpass times and, when clear skies prevailed, some 60 minutes prior to the overpass

to obtain data on sky radiation. The radiometer was also used to intercompare results with the AIMS radiometer (operated by W. Skirving) and to investigate angular effects.

Satellite data

The radiometer was primarily used to validate measurements made by the ERS-1 ATSR and the NOAA-11 and NOAA-12 AVHRRs. During the first part of the cruise many opportunities arose to collect simultaneous radiometer and satellite data. Table 1 lists many of the satellite orbits and overpass times targetted during the cruise. This list will be completed when the full extent of acquisitions to date is assessed.

Radiosonde data

A Vaisalla receiver and processor, installed on FRANKLIN were used to acquire data from radiosondes launched from the after deck. A specialised radiosonde launching platform was used. Radiosondes were launched within 1 hour of the satellite overpass. A total of 23 successful launches were made (see Table 1).

Preliminary results

Part 1 31 Aug - 23 Sep 1991

The ideal conditions (few clouds) have contributed to a highly successful data gathering cruise. The radiometer performed well; the measurement error on all channels was below 0.1K. Satellite data have not been processed yet but all of the NOAA data will be archived at CSIRO Division of Atmospheric Research, Division of Oceanography and NASIS and will be processed in due course. The ATSR data is expected to be delivered to DAR within a few weeks. Analysis of the radiosonde data indicate that precipitable water amounts varied between 1 and 2 g cm^{-2} (Table 3). These data will be used with an atmospheric transmission model to evaluate the atmospheric correction due to water vapour on the 11 and 12 micron channels of the ATSR and AVHRR. An angular effect was noticed when viewing the sea surface at zenith angles greater than 50 degrees. This effect was noticeable on all five channels of the AVADS radiometer (see Table 3 for an example).

On several balloon ascents, altitudes of 18 km or more were achieved. The temperature profile showed an anomalous warming of 1-3 deg around 18-19 km. Presumably was due to the Pinatubo volcanic aerosol (mostly H2SO4 droplets) present in the tropical lower stratosphere.

Part 2 13 Sep - 23 Sep 1991

During part 2 there was to be increased emphasis on collection of coincident data in humid atmospheres. It was essential to remain within the ATSR swath (approx. 500 km) and obtain radiometer, radiosonde and satellite data. Due to the

excellent weather conditions experienced throughout the cruise the goal was achieved on 6 out of 8 opportunities. Unfortunately of the two humid opportunities, one occurred in very cloudy conditions, while the other was missed due to higher priority project considerations. Nevertheless, the cruise has provided some excellent data and enough coincidences to produce a valuable validation data set.

Between ATSR passes, data was also collected for NOAA-11 and NOAA-12 coincidences. In total the ship was under 7 ERS-1 orbits, 7 NOAA-11 orbits and 7 NOAA-12 orbits. Ten radiosondes were launched, one reached 28 km, a record for the whole cruise. The radiometer was used to obtain a series of multiple wavelength and multiple view angle sea surface radiance measurements. These will be used to validate ATSR SST algorithms.

Clear atmosphere and calm seas prevailed on a number of occasions while CTD's were being done and the radiometer was used to estimate the 'skin' temperature while the 'bulk' temperature was measured by the CTD. Sky measurements were also made at most CTD stations.

The radiosonde data for the second leg yielded precipitable water vapour amounts of around 1.5 g cm^{-2} with one occurrence of 2.5 g cm^{-2} and one high value of 4.7 g cm^{-2}. These data will be used in atmospheric transmittance models to study the effects of water vapour absorption on measurements on the 10-12 micron window.

2. GEOCHEMISTRY OF LIVING OSTRACODS

Thierry Correge and Patrick De Deckker, Dept.of Geology, ANU
PO Box 4 Canberra ACT 2600 Telephone (06) 2494303

Objectives:

To collect living benthic ostracods from different water depths, with different bottom temperatures.

This work is a continuation of that carried out during cruise FR06/90 and is primarily designed to enlarge the database we already have concerning the relationship between the temperature of the water and the Mg content of ostracod shells. We also want to test an hypothesis concerning the link between O2 content of the water and the morphology of the carapace of the ostracod genus Krithe.

The goals in part 2 of cruise FR07/91 (13-23 September 1991) were to collect deep-sea sediments using a Smith-McIntyre Grab, as well as water samples and physico-chemical properties of the water. A total of 6 grab samples were collected in temperatures ranging from 16 to 2.25 degree. In these samples, the ostracods, and possibly pteropods when present, will be used for geochemistry work. Analysis on material from FR06/90 showed that a direct relationship exists between the temperature of the water and the Mg content of the ostracod shells. Samples collected

during cruise FR07/91 will allow us to verify our first results, and to extend our database to higher temperatures (last years' highest temperature was 6 degree). Some additional work will also be carried out on the use of the ostracod genus Krithe as tracer of the dissolved oxygen in sea water. The samplings were done at the stations shown in Table 5. In addition, 6 water samples were taken at CTD #93 to see if the distribution of Sr in the water column is affected by the oxygen.

Acknowledgements:

It is a pleasure to thank once again Derek Burrage for allowing me to participate in this cruise and for all the very informative discussions we had on the oceanography of the Western Coral Sea. I thank AIMS and the Dept. of Marine Biology, JCU, for the loan of the Grab. Very special thanks go to the captain and crew of the R.V. Franklin, to the people from CSIRO Oceanography, and to all the scientists who made this cruise a most enjoyable one. And, of course, thanks to Neptune/Poseidon for keeping his sea so calm!

Scientific Activities:

The cruise was divided into two parts. C. Nilsson was involved in the first part, while, Mr. T. Correge's Ostracod sampling was confined to the second part. L. Bode joined the cruise in Townsville for the second part, replacing D. Williams as Co-Chief Scientist. CTD, XBT and ADCP observations spanned both parts.

A total of 115 CTD Stations were completed along 16 transects spanning the western Coral Sea to within 15 m of the bottom or to maximum depths of 4000 m (Deep), alternating with shallow casts to 1000 or 1500 m, where appropriate to save time, while maintaining high spatial resolution in the more variable upper layers. See cruise track (Fig 1) for locations of CTD transects.

Water Sampling for Nutrients, (Reversing Thermometer) Temperature and Salinity sampling were carried out at all stations. Salinity, temperature and nutrient data were analysed on board.

Acoustic Doppler and Thermosalinograph data were recorded continuously, while underway. Almost 24 hr coverage of GPS fixes were available and were fully exploited to obtain precise navigation data for Acoustic Doppler Velocity Profiles. Bottom tracking runs concurrent with GPS were done in the central and southern GBR and while crossing the shelf at Townsville and Cairns. Preliminary corrections were calculated and applied to ADVP vector plots.

A total of 132 XBT drops (mostly of type T7 Blue label, i.e. to 750 m, with some T4s (450m), in shallower areas) were made along selected transects, also half way between stations on most CTD transects.

Four ARGOS Satellite tracked drifters were deployed and tracked via Systeme Argos, two in the frontal convergence zone and two in the central Coral Sea within the South Equatorial Current.

Six days of Sea Surface and Sky temperature data were acquired simultaneously with the AIMS and CSIRO infra-red radiometers. Concurrent cloud and relevant weather observations were also made.

Seven Benthic Samplings were made using the Smith/McIntyre Grab loaned by JCU through AIMS to Mr. Correge. All grabs except one were successful. The failure was due to the cable becoming caught in the 'bite' so that most of the sample was lost.

Major Events:

Since the goals of the cruise were strongly supported by an integrated program of shipboard and remote sensing data acquisition, major events associated with both data types are documented below.

Hydrography and Remote Sensing:

CTD and XBT transects (distinguised by C and X, respectively) were named for geographical landmarks and designated by an alphabetic letter to denote station numbers. Hydrographic transects completed are given in Table 1a and b including cast numbers, starting and ending date/time, and position. Times given are at the beginning of the first or last cast for the transect. Positions are repeated where transects were contiguous. Satellite overpass times and air-sonde deployment activity are shown in Tables 2 and 3.

ARGOS Drifter Deployments:

During part 1 two ARGOS drifters were deployed on either side an oceanographic front:

ARGOS buoy # 7584 was deployed at 0000Z on 9 Sept., 1991, drogued to 100 m at position A2 (CTD # 48). This position coincided with the colder southern side of a major oceanographic front separating the warmer waters of the Coral Sea from those of the Tasman. This was an older MRT 101 PVC tube type buoy used in a temporary deployment during FR9006 and was considered expendable.

ARGOS buoy # 7587 was deployed on the warmer side of the front at position A5 (CTD # 51) at 0911Z 9 Sept., 1991, also drogued to 100m. This buoy was of the newer MRT 112 type with a alloy body and subsurface float to support the 'holey sock' drogue element. The VHF transmitter assembly was not deployed because subsequent recovery was not considered feasible for this position.

During part 2 two ARGOS drifters were deployed along the Frederick Reef Transect (N) while crossing the South Equatorial

Current (SEC):

ARGOS # 7586 drogued to 100m was deployed at 1456Z on 18/9/91 within the core of the SEC (as defined by the hydrography), but in the slower flowing southern side of the main stream at station F20(#95).

ARGOS # 7585 also drogued to 100 m was deployed at 0414Z on 19/9/91 on the northern margin of the SEC (as defined by the hydrography) just north of the maximum flow streamline as indicated by ADVP measurements and at station F23(#98).

Early tracking results indicate that the drifters are functioning and continuing to follow the course of the SEC. Both these drifters were of the later MRT 112 alloy-bodied type and were fitted with tethered surface radar marks equipped with VHF transmitters to facilitate possible recovery by RDF at a later date.

CTD Preparation:

An initial mid-shelf station CTD #1 was undertaken near the Percy Islands with the dual purpose of providing a practice cast for the scientists and crew and giving an indication of hydrographic conditions on the shelf.

The first CTD (#54) obtained during part II was done in slope water near the site of AIMS long-term current meter mooring (C5) near Myrmidon Reef to enable an intercomparison between the ADVP vectors and conventinal Aanderaa current meter measurements.

RDF Calibration:

This was done off Townsville at 0100 on 31 Aug.,, 1991. The antenna radiation pattern showed a single distinct Null in the forward direction with broad maxima on either side, as desired. This system was intended for use in ARGOS drifter recovery operations if appropriate but was not used since subsequent changes to cruise track precluded recovery during this cruise.

Unscheduled events:

Upon departure from Townsville at 0000 on 31 Aug., the bow thruster was found to be inoperative. The ship was set hove to for approx 6 hrs in a position NW of Broad Sound while the fault was diagnosed and corrected.

Science Team:

Twelve hour watches were maintained as in the following table with the exception that Skirving, Blake, Nilsson and Prata followed rotating watches to facilitate ground-truth radiometry and air sonde launches coincident with ERS-1 ATSR and NOAA AVHRR overpasses.

Watches (L <=> 1300-0100, E <=> 0100-1300)

Cabins (A-F)

	Part I			Part II	
A	Jeff Dunn	(CSIRO)	E	Jeff Dunn	(CSIRO)
	Erik Madsen	(CSIRO)	L	Erik Madsen	(CSIRO)
B	Gary Critchley	(CSIRO)	L	Gary Critchley	(CSIRO)
	Dave Williams	(AIMS)	E	Lance Bode	(JCU)
C	Rowan Hughes	(JCU)	L	Rowan Hughes	(JCU)
	Craig Steinberg	(AIMS)	E	Craig Steinberg	(AIMS)
D	Fred Prata	(DAR)	E	Fred Prata	(DAR)
	Carl Nilsson	(DOC)	L	Steve Blake	(JCU)
E	Val Latham	(CSIRO)	E	Val Latham	(CSIRO)
F	William Skirving	(AIMS)	L	Thierry Correge	(ANU)
CS	Derek Burrage	(AIMS)	L	Derek Burrage	(AIMS)

Ship's Officers and Crew:

Master Don Gordon, 1st Mate Dick Dougal, 2nd Mate Paul Toussaint-Jackson, Chief Engineer Peter Noble, 2nd Engineer Ron Parrott, Electrical Engineer Ron Boult, Bosun Jannick Hansen, AB Bluey Hughes, AB Chris Hallen, AB Norm Marsh, Greaser Philip French, Ch Steward Steve Corridon, Ch Cook Gary Hall, 2nd Cook Bob Clayton.

Difficulties and Suggestions:

Due to an oceanographic winch cable fault, which also existed during FR0690, CTD casts were limited to a maximum depth of 4700m so that total geostrophic transport of the Coral Sea could not be calculated. I have since been informed that a replacement cable is available. As suggested previously, it is vital that the chief scientist be fully informed of equipment problems which could be cruise determining, prior to the cruise, so that remedial steps can be taken or alternative observational strategies considered.

Conclusion and Acknowledgements:

The research conducted during this cruise involved close collaboration and cooperation among cruise participants and remote sensing support staff from AIMS, JCU, CSIRO Divisions of Atmospheric Research, Oceanography and Fisheries, NASIS and CSIDA, particularly in respect to the the fisheries research and all remote sensing activities. Particular thanks are extended to Carl Nilsson for his efforts in coordinating satellite data acquisition and transfer of reconnaissance AVHRR imagery to the ship and to Paul Tildesley and John Parslow for image preparation. As such all participants hope that the spirit of this cooperation can be continued and expanded in future field experiments and remote sensing endeavours. Thanks are also due to Nick Harcock and Malcolm McKenzie of AIMS Computer Services who supplied timely updates of ARGOS drifter positions via

INMARSAT and to the personnel from the Australian Fisheries Service who facsed regular updates on Japanese fishing fleet activities.

Since all the major cruise objectives were met, while in addition smaller scale studies such as around Percy Islands and two seamounts were also achieved, I consider this a very successful cruise and wish to thank the Captain and crew and all the ORV Personnel for their dedication and cheerful and willing response to all requests for assistance. The ship-board systems functioned reliably and data logging proceeded efficiently and effectively. Special thanks to Jeff Dunn and his team for helping make the cruise both successful, scientifically and very enjoyable.

References

Griffin, D. A., Middleton, J. H. and Bode, L. (1987) The tidal and longer-period circulation of Capricornia, Southern Great Barrier Reef. Aust. J. Mar. Freshw. Res., **38**, pp 461-474.

Kleypas, J. A. and D. M. Burrage (1990) First satellite observations of surface circulation patterns in the southern Great Barrier Reef, Australia. (to be submitted).

Tables

Figures

Table 1a. Hydrographic Surveys (Part 1)

Letter C denotes transects comprising CTDs (often with XBTs interspersed), while X denotes transects comprising XBT drops.

Stns	Cast	#	Lat(S)	Lon(E)	Time	Date	Significance
P1	C	1	21 49.9	149 58.6	2035	31/8	Percy Islands:
P9	C	9	21 42.3	150 19.6	0756	1/9	ERS1 SAR swath.
C1	C	10	22 35.9	152 13.8	0023	2/9	Capricorn Channel: SGBR
C16	C	24	25 33.6	155 49.8	0022	4/9	Gyre, EAC, Recorder Guyot
F1	C	24	25 33.6	155 49.8	0022	4/9	Frederick Reef (South):
F11	C	34	19 48.7	154 25.9	0241	5/9	ERS1 RA, ATSR Nadir track
S4	C	35	20 19.6	153 40.1	0637	4/9	Saumarez Reef:
S10	C	41	23 51.5	152 49.3	1038	7/9	ERS1 RA, ATSR Nadir track
E2	X	34	23 59.2	153 16.3	1353	7/9	Lady Elliot Island:
E6	X	39	24 27.3	154 55.6	2239	7/9	EAC & Retroflection.
M1	X	39	24 27.3	154 55.6	2239	7/9	Fraser Seamount:
M6	X	46	24 27.3	154 29.9	0112	8/9	Tuna Fishery
R2	C	42	24 27.5	155 53.1	0301	8/9	Dampier Ridge Transect:
R6	C	46	24 16.8	156 21.3	0939	8/9	Tuna fishery
K1	X	48	24 14.4	156 28.0	1114	8/9	Kelso Bank Transect:
K4	X	51	24 07.6	157 48.4	1725	8/9	Cold Intrusion
A1	C	47	24 4.9	158 14.9	1937	8/9	Argo Bank: Frontal Zone:
A7	C	53	21 45.4	158 14.9	1410	9/9	ARGOS deployment.
B2	X	58	21 49.0	157 47.5	1712	9/9	Bird Island Transect:
B14	X	77	22 35.4	152 12.5	1949	10/9	Wreck Rf. EAC. Cap Ch.

Table 1b. Hydrographic Surveys (Part 2)

Stns	Cast	#	Lat(S)	Lon(E)	Time	Date	Significance
Q1	C	54	18 13.5	147 20.4	0617	13/9	Queensland Trough:
Q6	C	59	17 48.6	148 15.3	1818	13/9	EAC & under current.
T1	C	60	17 57.4	148 25.3	2037	13/9	Tregrosse Reefs: SEC
T6	C	65	18 00.0	150 19.9	1120	14/9	Bifurcation & Qld Plateau
D1	C	66	17 41.2	150 58.9	1605	14/9	Diamond Islands: Passage
D4	C	69	17 41.3	151 18.9	2100	14/9	Tregrosse - Lihou Reefs.
U1	C	69	17 41.3	151 18.9	2100	14/9	Lihou Reef - Hydrog. Pass
U14	C	82	19 47.0	150 31.2	2256	15/9	Townsville Trough and EAC
H1	C	82	19 47.0	150 31.2	2256	15/9	Hydrographer's Passage
H5	C	86	19 48.7	154 25.8	2039	16/9	EAC and Northern extension
F11	C	86	19 48.7	154 25.8	2039	16/9	ERS1 RA, ATSR Nadir track
F28	C	103	11 20.8	152 27.4	2001	19/9	SEC inflow, PNG outflow
N1	C	103	11 20.8	152 27.4	2001	19/9	North Reef: SEC
N7	C	109	17 30.0	148 2.0	1830	20/9	Coral Sea Gyre
I1	C	109	17 30.0	148 2.0	1830	20/9	Innisfail Transect:
I3	C	111	15 48.0	146 27.7	0907	22/9	EAC, SEC bifurcation
G1	C	111	15 48.0	146 27.7	0907	22/9	Grafton Transect:
G5	C	115	16 36.7	146 16.2	1806	22/9	EAC, SEC bifurcation

Table 2. Summary of Satellite Overpasses and Ground-truthing Activities

Satellite	Dates of Overpass	Type of Remote Sensing Event
NOAA 11 & 12	Various 31/8-23/9	AVHRR Visible and Infrared data. Acquired by DAR,DO,NASIS
Mos1	10-15/9,Paths 3,7,8	Acquired by ACRES
ERS-1 SAR	# 715 5/9/1991	Descending pass over Lihou Rf. and Percy Islands. Acq. ACRES
ERS-1 RA	17, 20/9	Desc. passes along Transect F and crossing SEC. Acq. ESA
ERS-1 ATSR	31/8-12/9 13-23/9	All overpasses ground-truthed Several overpasses, 3 d cycle

Table 3. Radiosonde Data Collection (Part 1)

Date	Time EST	Max Height km	PW g cm^{-2}
31-8	1900	19.1	2.27
1-9	1453	19.0	1.06
2-9	0224	19.3	1.11
2-9	1014	18.2	0.99
2-9	1457	16.0	1.05
2-9	1935	16.6	1.10
2-9	2212	21.1	1.57
3-9	1448	15.0	1.42
3-9	1959	18.0	1.04
4-9	1906	16.7	1.40
5-9	0148	15.0	1.35
5-9	0628	20.4	1.48
5-9	0947	20.6	1.56
5-9	1415	19.8	1.24
5-9	1908	17.3	1.06
5-9	2203	17.6	1.74
7-9	0711	17.3	1.51
7-9	1445	20.2	1.43
8-9	0813	21.3	0.80
8-9	1453	19.0	0.81
8-9	1900	20.3	1.01
8-9	2315	19.2	1.24

Table 4 Temperature Variation with Zenith Angles

Zenith Angle (deg)	Brightness Temp (at 11 microns, deg)
20	20.31
30	20.25
45	19.73
60	18.54
75	16.27

Table 5. Grab Sample Stations

CTD	Date	Lat(S)	Lon(E)	Grab	Depth(m)	Tb(C)
#56	13/9	18 04.55	147 39.53	#1	1076	4.33
#63	14/9	17 58.69	149 34.54	#2	494	11.2
#72	15/9	18 18.91	151 19.09	#3	1600	2.64
#84	16/9	19 48.08	151 56.87	#4	370	16.03
#102	20/9	11 24.51	152 28.00	#5	562	8.7
#107	21/9	14 53.57	149 44.18	#6	2038	2.25

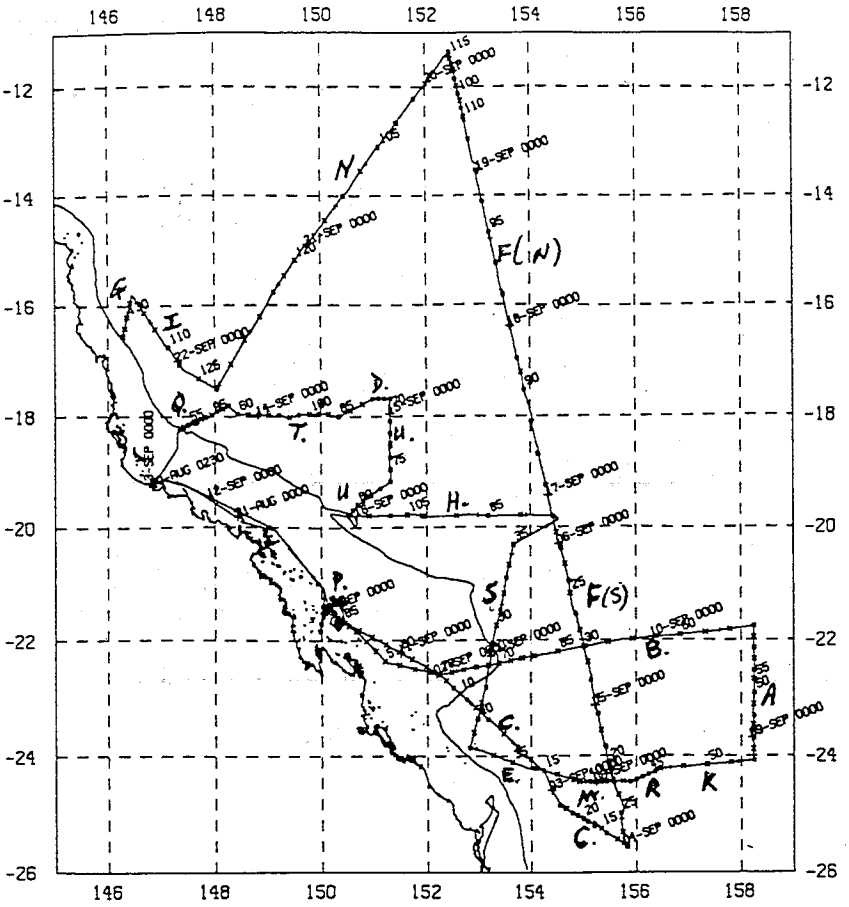

FIG 1
(see TABLE 1 for Transect details)

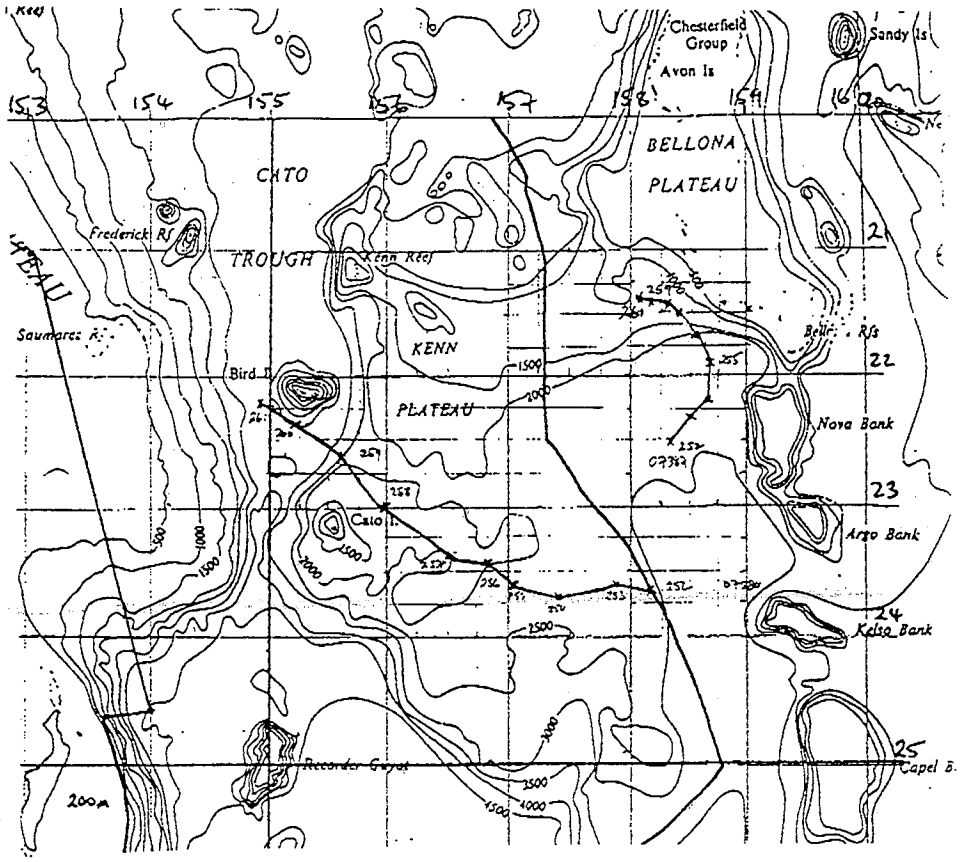

FIG 2c

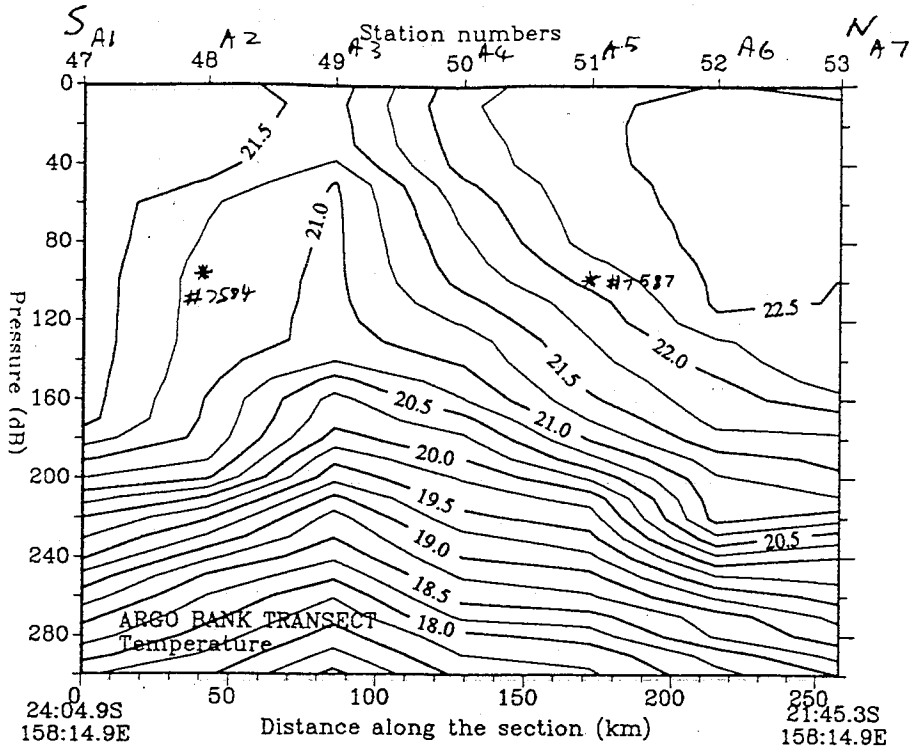

FIG 2a.

* ARGOS DEPLOYMENT DROGUED TO 100 M

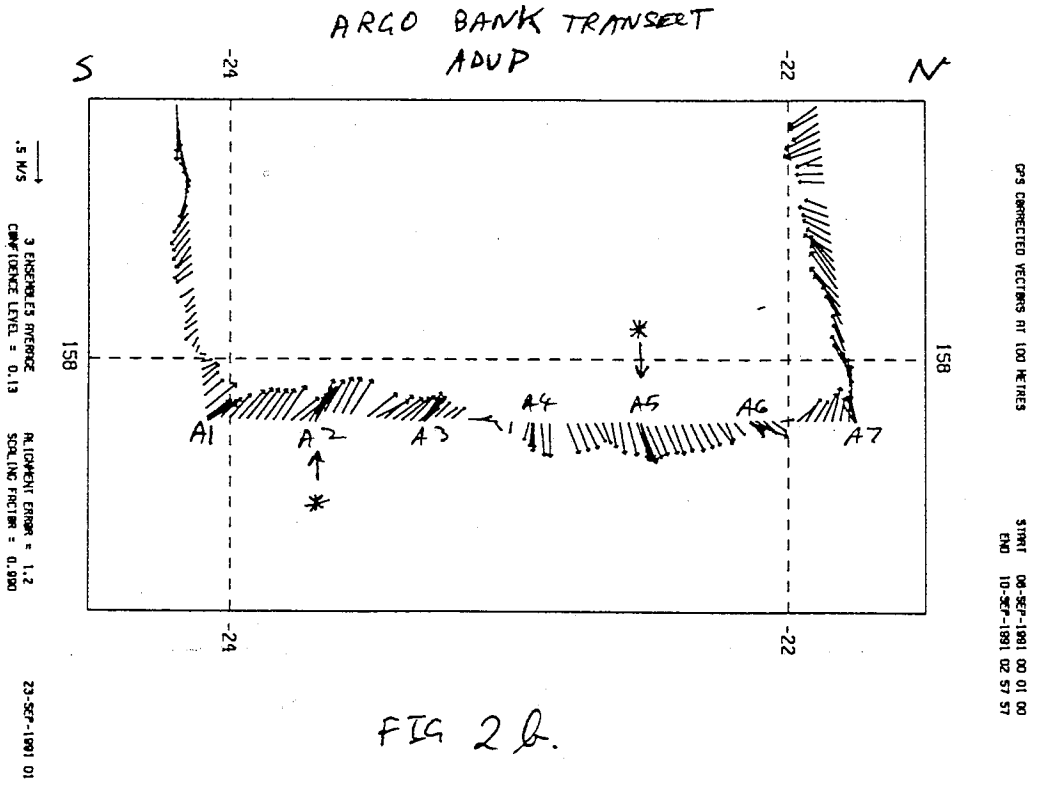

FIG 2b.

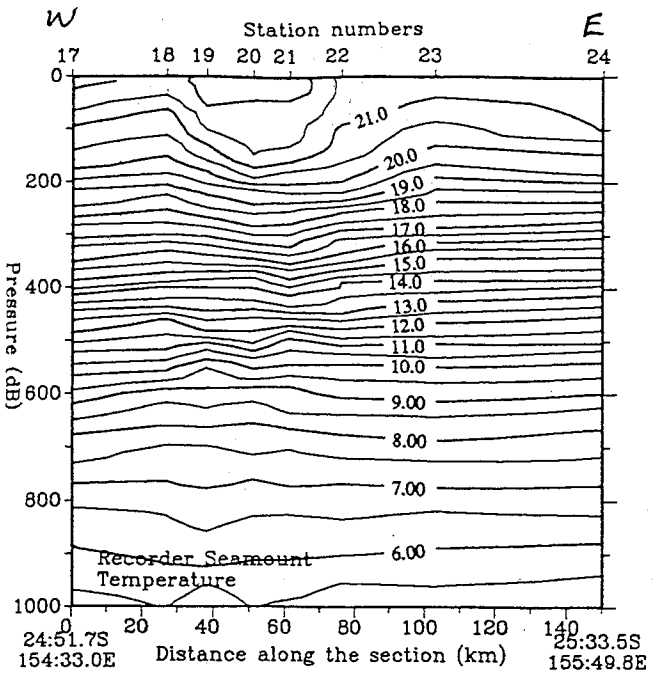

FIG 3 a.

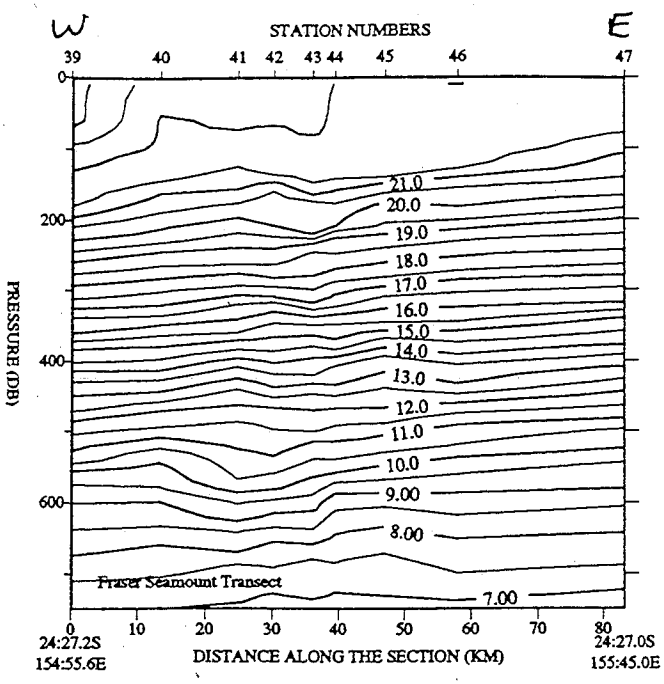

FIG 3 b.

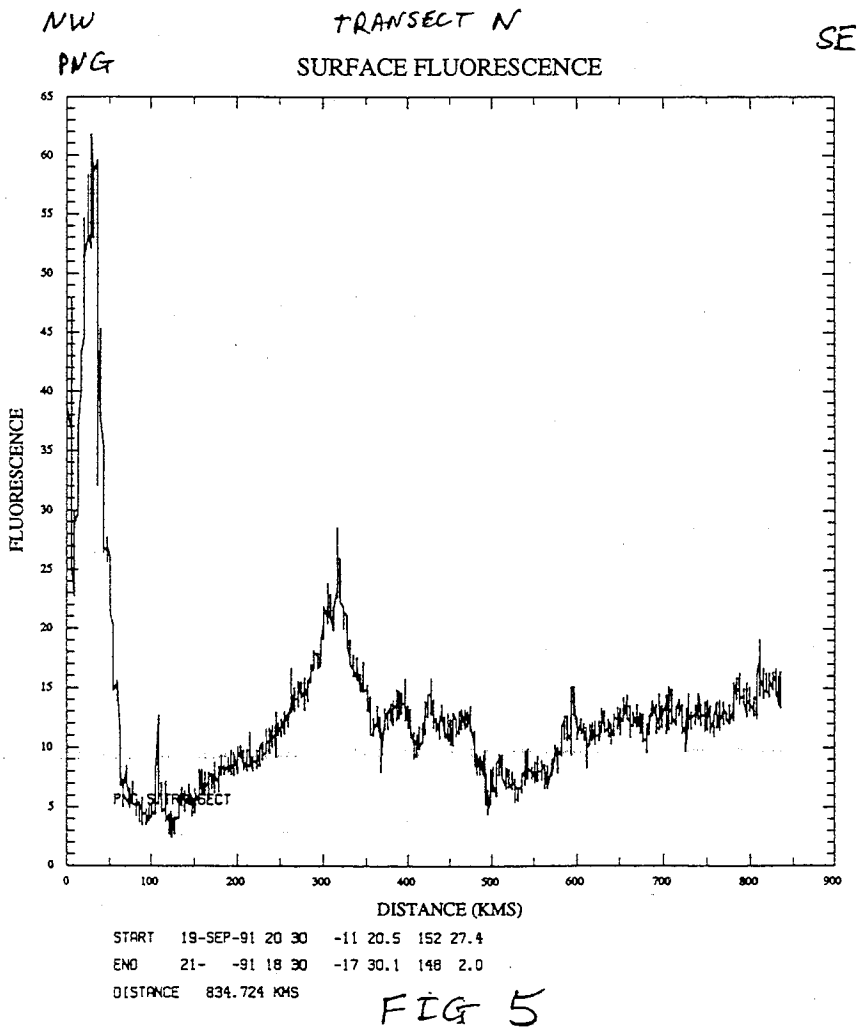

FIG 5

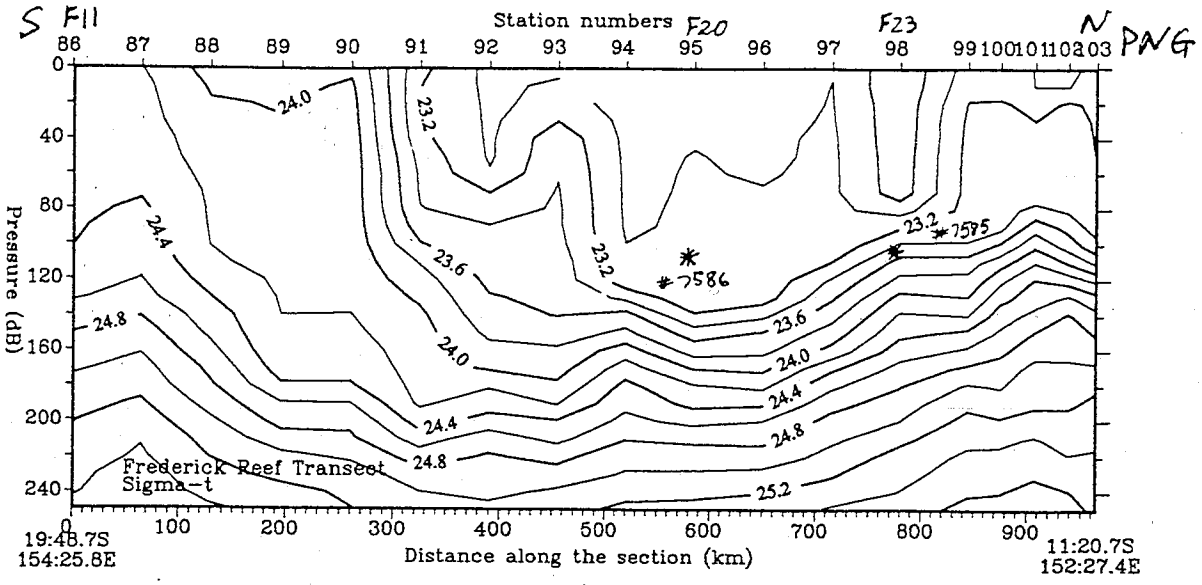

FIG 4a

* ARGOS DEPLOYMENT DROGUED TO 100 M

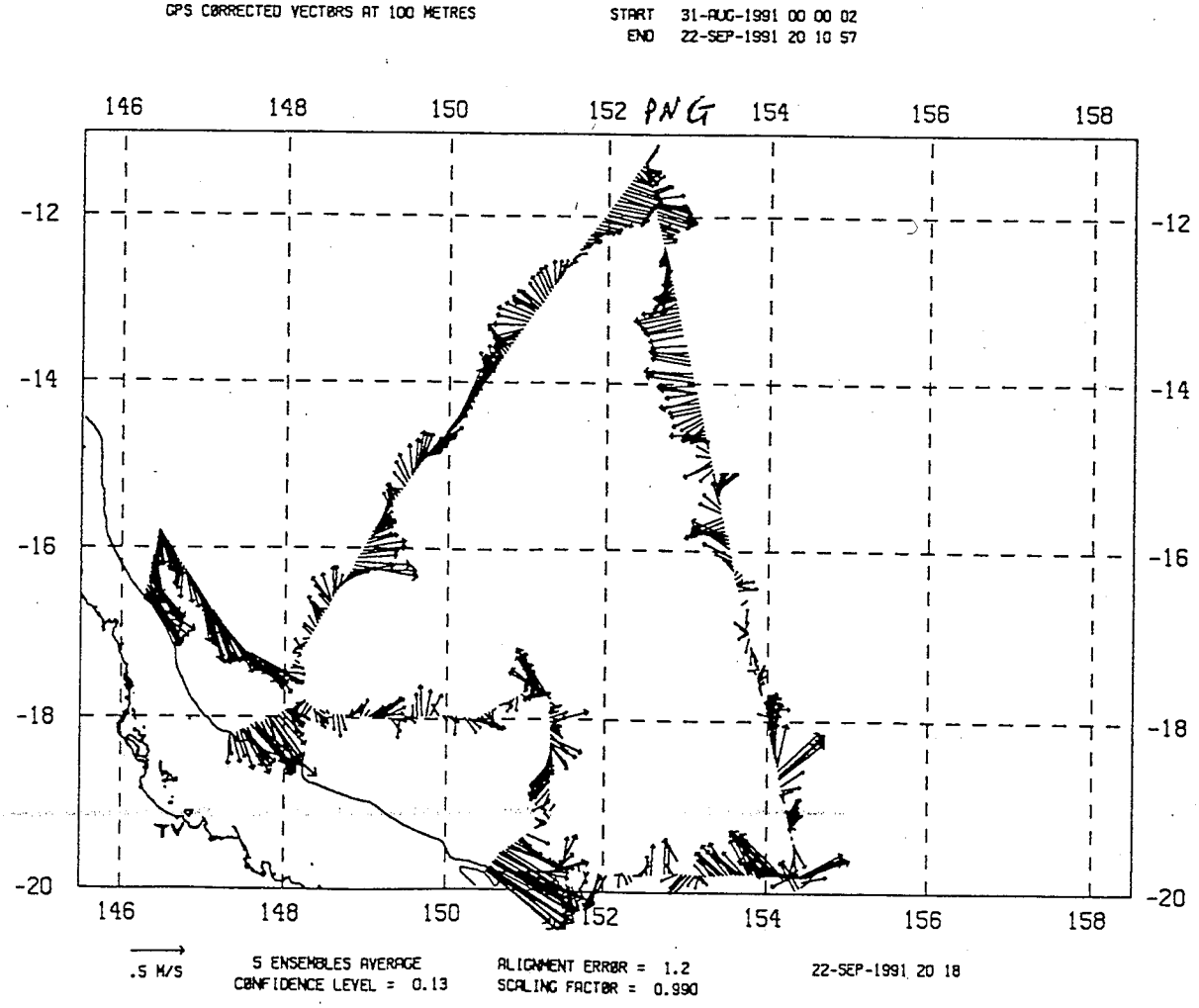

FIG 4b.