FRANKLIN

National Facility
Oceanographic Research Vessel

Tasman-Coral Sea mass and heat transport / Regional Ocean Observing Network design – Part 1.

CRUISE SUMMARY

RV FRANKLIN

FR 04/01

Depart Hobart 1000hrs, Friday 11 May 2001
Arrive Wellington 1000hrs, Wednesday 23 May 2001

Principal Investigators

Dr Ken Ridgway (Chief Scientist)
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Dr Rick Bailey, CSIRO Marine Research
Dr Ian Barton, CSIRO Marine Research
Dr Richard Coleman, CSIRO Marine Research/University of Tasmania
Dr Phil Sutton, New Zealand Institute of Water and Atmosphere (NIWA)

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Principal Investigators

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Phil Sutton, New Zealand Institute of Water and Atmosphere (NIWA)

Scientific Objectives

This cruise is the first component of a multi-cruise experiment to enclose the Coral-Tasman Sea. The two following cruises (FR05/2001 & FR06/2001) and a section east of New Zealand to be performed by colleagues at NIWA will complete the box around the region. We note that FR04/2001 also involves a high degree of collaboration between CMR and colleagues from NIWA.

The following objectives relate to both the individual leg (FR04/2001) and the combined set of cruises:

- to measure the seasonal, interannual and decadal fluctuations in the transport of mass, heat and freshwater into the Tasman Basin,
- to survey the East Australian Current and associated eddies and fronts using in-situ and satellite data,
- to investigate the relationship between oceanic heat transport into the Tasman Sea, SST anomalies and regional climate fluctuation,
- to provide appropriate in-situ data for testing and validation of remote sensing techniques as well as ocean only and coupled ocean-atmosphere models,
- to develop and validate multidisciplinary elements of a Regional Ocean Observing Network (ROONet) in support of an Australian Ocean Observing System (AOOS),
- to contribute to the development of an operational marine monitoring and nowcast system for Australian waters which also forms part of the Australian Ocean Observing System (AOOS),
- to gain an understanding of the basin-scale ocean variability within the Tasman and Coral Seas as part of the GOALS objective of the international Climate Variability program (CLIVAR).

Cruise Objectives

To occupy the PX34 section (Sydney – Wellington) as part of the long-term monitoring of the mass and heat transport in the Tasman Sea.

To "value add" to the 10 years of high density XBT data (1991-2001) collected along this route from merchant vessels by achieving the following:

- assess the errors involved in obtaining dynamic height from XBT temperature profiles along the section,
- quantify the contributions to the baroclinic flow below 800m along the section,
- assess the validity of steric height and temperature extrapolation schemes along this section,
- determine a revised sampling strategy to enable the section to be maintained in the long term with a combination of satellite and in-situ data collection,
- assess the validity of inferred subsurface temperatures from surface satellite altimeter/SST observations and improve existing vertical projection schemes,
- assess the capabilities and utility of a real-time oceanographic analysis system under operational conditions,
- assess a range of data collection methods for application to 'Ship of Opportunity ' programs,
- acoustically map and monitor at suitable and spatial scales the critical water column plankton/nekton and seabed habitats of the region,
- obtain validation data for sea surface temperature (SST) for MODIS, ATSR-2 and AVHRR satellite instruments,
- collect data to assist with the development of ocean colour algorithms using SeaWiFS, MODIS, and other ocean colour data,
- calibrate and evaluate XBT and XCTD instrumentation against the CTD.

Cruise track

The cruise track is shown in Fig. 1. The first section was essentially a steaming leg from Hobart to Brisbane. This followed an ascending TOPEX/Poseidon track which paralleled the southeast Australian coast north from Bicheno (BC). The track then turned northwestward along a descending altimeter track toward the NSW coast (CD). The main section of the cruise then followed the typical route of the XBT high-density merchant vessels between Sydney and Wellington (EF, PX34).

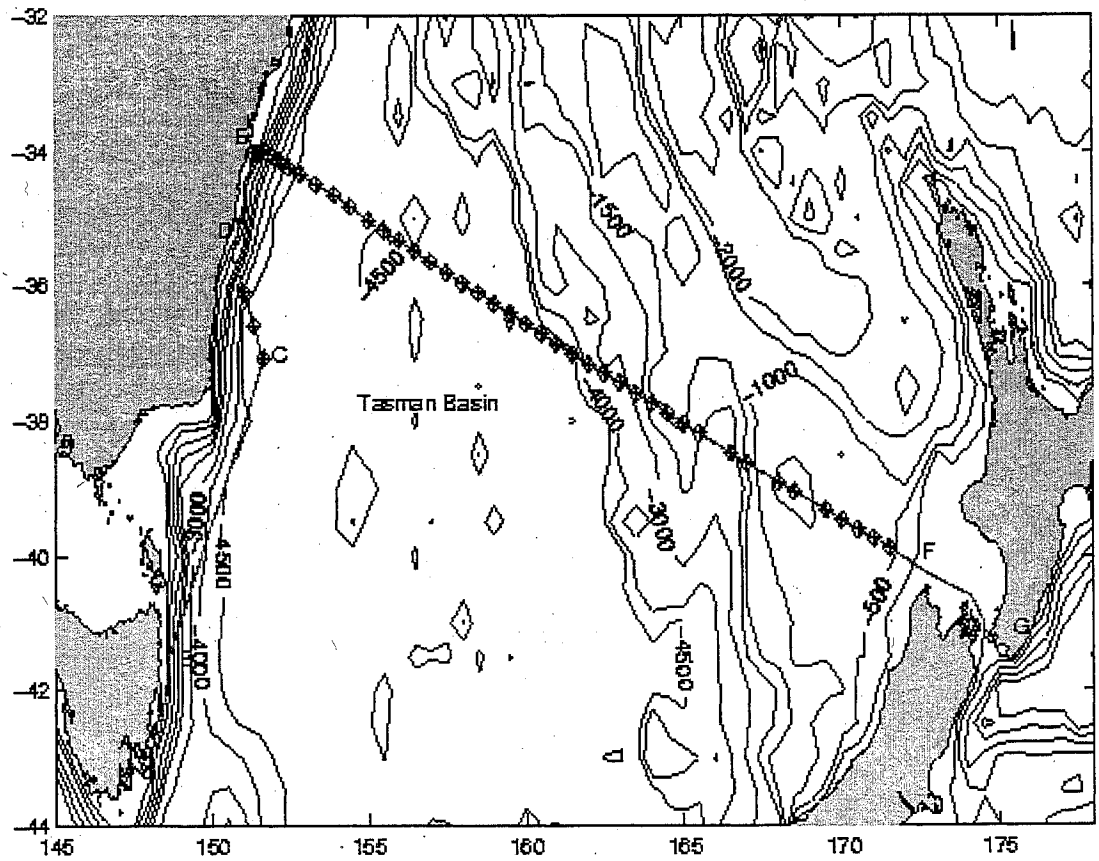

Figure 1. The red line shows the cruise track for FR04/2001. CTD stations are indicated by blue diamonds.

Results

Data collected during the cruise should enable the objectives (outlined above) to be achieved satisfactorily. The Sydney-Wellington CTD section is particularly valuable, as it both provides a 'benchmark' for the 10 years of XBT transects and also the section itself may be understood in the context of this XBT time series. We note that the processing procedures for Franklin data have been streamlined, so that much of the data is now readily available either during or soon after a cruise. For example, the CTD data is now processed during the cruise and the calibration with bottle samples is now completed by the end of the cruise.

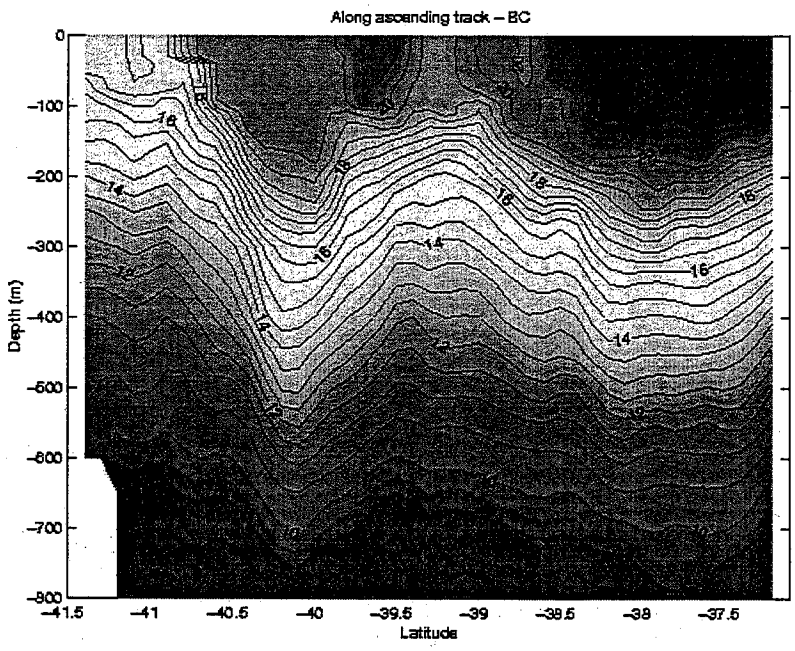

Figure 2. Temperature along section BC from XBT data.

The temperature section along an ascending Topex/Poseidon altimeter track (Eastern Tasmania to point C) obtained from the XBT data is shown in Figure 2. We observe that the section bisects two anticyclonic eddies, one just east of Bass Strait (~40°S) and the other offshore from Eden (151°E, 38°S). This result confirms the picture provided by the real-time altimeter maps that were routinely received during the cruise. For example, in Figure 3 the surface topography early in the cruise (May 14) we see the same two eddies. The ability to receive such real-time surface height images is very useful for interpreting the in-situ data that is collected during the cruise as well as providing a valuable management tool. This facility could easily be made available routinely to all cruises. The cruise track than diverged northwestward towards the coast (CD), along a descending altimeter track and crossed a cyclonic feature. This was clearly visible in both the surface height field (Figure 3) and in the AVHRR SST map (Figure 4). Three CTD stations down to 2000m were supplemented with regular XBTs, which provide a comprehensive description of the section.

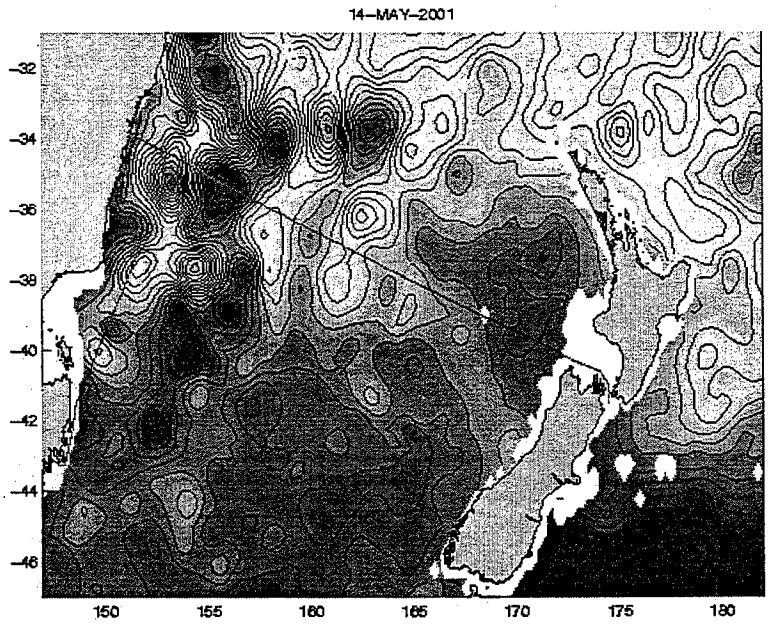

Figure 3. Surface height field from real-time TOPEX/POSEIDON anomalies added to mean height field from CARS climatology.

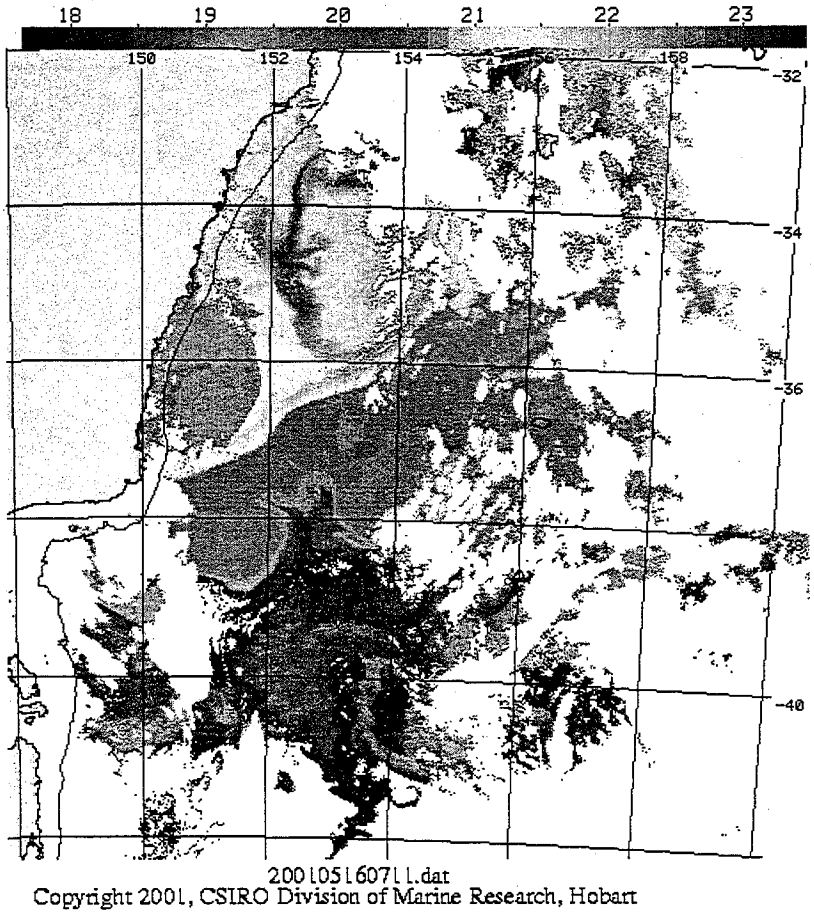

Figure 4. SST map from AVHRR satellite data for 16-MAY-2001.

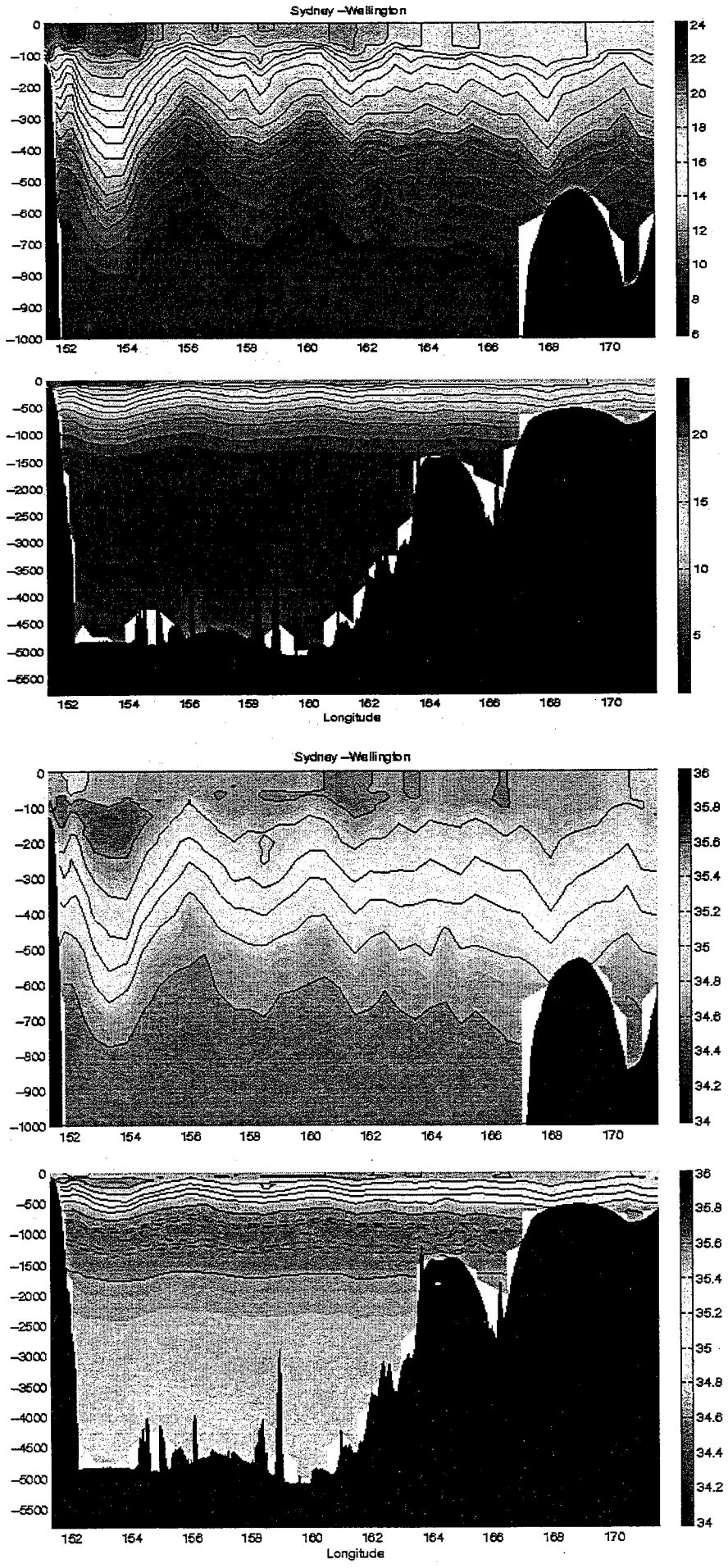

Figure 5. Temperature and Salinity along section from CTD.

The main purpose of the cruise was to obtain a full-depth CTD transect between Sydney and Wellington. This was successfully achieved and the temperature and salinity sections are presented in Figure 5. The most obvious feature is an energetic warm core eddy adjacent to the NSW coast at about 153°E. Figure 3 shows that the cruise track actually cut through the northern half of the eddy with southward currents of up to 1.0 ms^{-1} observed on the inshore edge (see ADCP currents in Figure 6). A filament of warm, fresh water of northern origin wrapped around the eddy (see Figure 4) and is observed as a surface tongue in both Figures 5a and b at 152.5°E. We note that the return flow on the eastern flank of the eddy is still evident in the temperature field but its salinity signature has been lost. The saline feature observed inside the eddy between 100-200m is associated with Subtropical Lower Water which has been advected southward within the eddy. Further eastward the transect crossed a quite intense cyclonic eddy – the eddy pair actually are seen to have a distinctive dipole structure (Figure 3). Large northward currents (> 0.8 ms^{-1}) were observed between 154°-156°E (Figure 6).

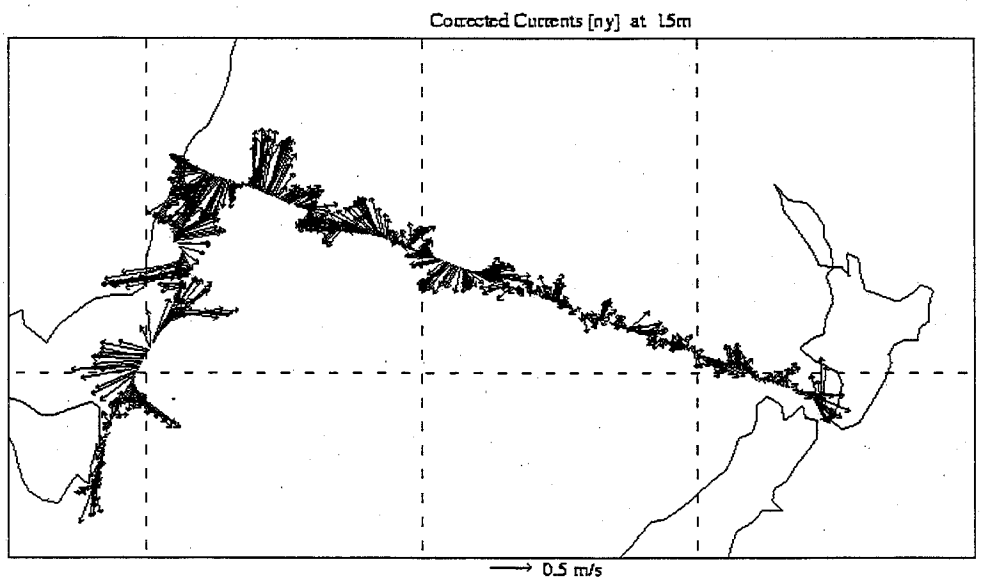

Figure 6 Current vectors at 15-m depth from the ADCP

In addition to the CTD's a completely independent temperature section was obtained from XBT data. When compared with CTD full-depth sections these data enable several uncertain aspects of the results gained from the previous time series of XBT sections to be assessed. In particular, we are able to determine the accuracy of the T-S method for calculating steric height (and transport) directly from XBT temperature profiles and to quantify the extent of sub-800-m baroclinic flow and the validity of vertical extrapolation schemes.

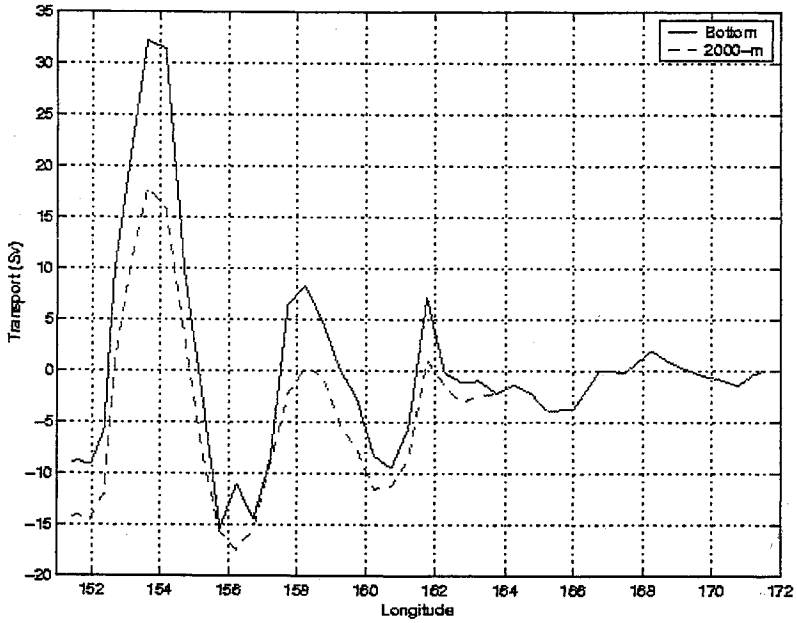

Figure 7. The cumulative geostrophic transport across the section EF.

The accumulated volume transport relative to the New Zealand endpoint and referenced to the bottom is presented in Figure 7. Once again it is clear that the most energetic region is confined to the abyssal depths west of Lord Howe Rise. There is a strong southward flow with a magnitude of more than 40 Sv, on the western flank of the eddy off Sydney. The return flow to the north is even stronger – some 48 Sv. The net transport through the section is only about 8 Sv due to the cancellation that occurs. We observe that if the geostrophic calculation is referenced to 2000m as is common for this region, the individual flows associated with each eddy are reduced and the net transport actually increases to 14 Sv.

The cruise also obtained 'ground truth' data to be used for the validation of remote sensing instruments. Two infrared radiometers (TASCO) were operated almost continuously during the voyage. A downward looking instrument which was mounted on the bridge deck to view a patch of water just outside the wake on the starboard side of the vessel and an upward looking radiometer to observe the reflected sky component. These instruments are of a relatively simple and low cost design, suitable for routine deployment on merchant vessels. The plan at the moment is to only use a downward-looking radiometer on such volunteer ships, since it would be impractical to deploy a sky-viewing radiometer due to the degradation of the lens from rain and spray.

The measurements from the radiometer will be compared with those from the thermosalinograph and CTD. This will allow the "skin effect" on SST to be determined. The output (raw and corrected) from the downward radiometer is plotted in Figure 8a and the reflected sky radiance is presented in Figure 8b. The lower plot is really the "apparent temperature" of the sky, from which the radiance is calculated using Planck's equation. This is then used to correct the inferred radiance from the sea surface, and the corrected SST is calculated from the corrected radiance. There were several periods

when the cover was installed on the sky-viewing radiometer, which shows up as warmer measurements, at about the ambient air temperature.

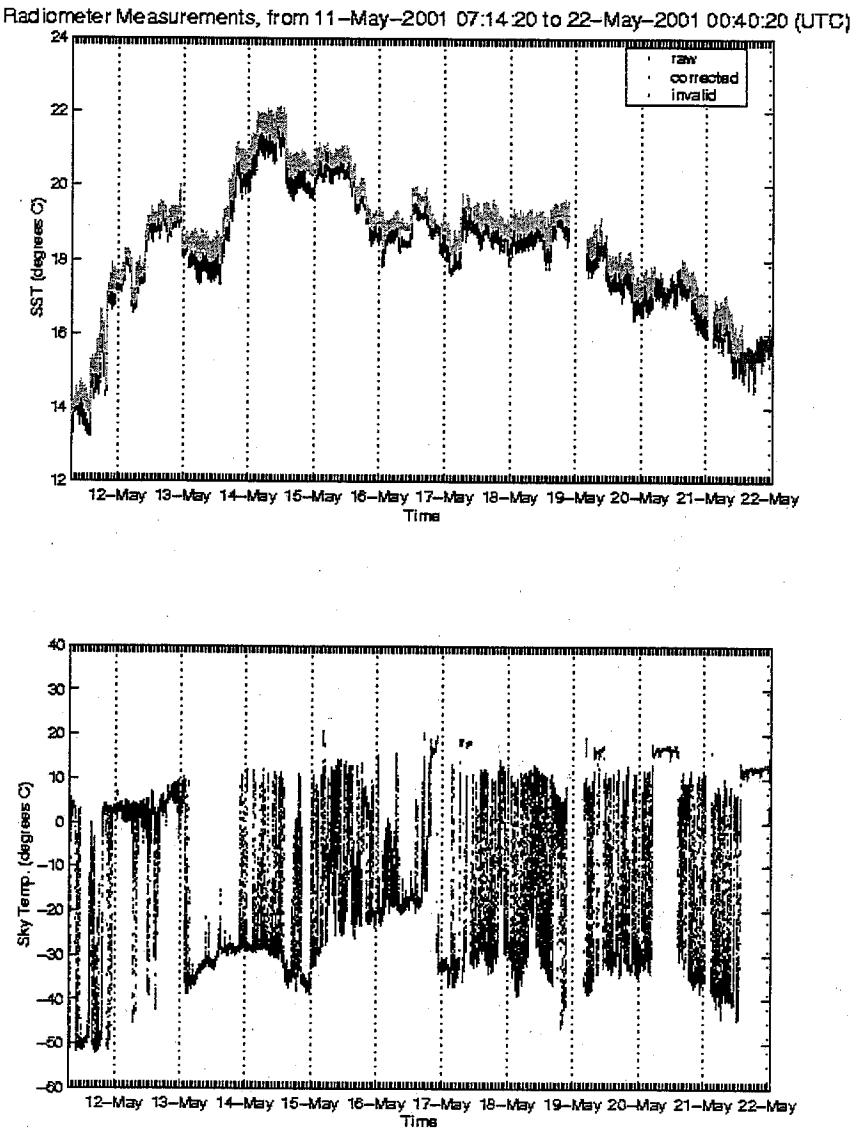

Figure 8. Radiometer measurements collected during FR04/2001.

During the cruise a 'piggy-back' experiment was conducted by Ian Helmond. He performed sea-going tests of an aquashuttle. This is a small towed body which samples temperature, salinity and several biological properties in the top 50m. The instrument was deployed five times between CTD casts to test its stability (a new type of stabilizer has been installed) and hence refine the existing design. The tests involved several deployments with Franklin proceeding at a range of speeds.

Summary of Data Collected

CTD profiles
A total of 46 full-depth CTD profiles were obtained using 12 bottle rosettes. Samples of oxygen, salinity, NO_3+NO_2, SiO_2 and PO_4 were obtained.

XBT's
A total of 120 XBTs were dropped along the entire cruise track. These consisted of 50 T7s, and 70 deep blue.

Underway
Observations were collected from the ADCP, GPS (ASHTEC), thermosalinograph, and a suite of meteorological sensors for the duration of the cruise.

SST
Two infrared radiometers were operated almost continuously during the voyage and five radiosonde balloons were launched when crossing ERS2 satellite tracks.

Cruise Narrative

We departed Hobart at 1000 on Friday May 11th. Since this was one of the rare recent departures of Franklin from Hobart quite a large crowd gave us a rousing send-off on a very still and crisp autumn morning. The rather weak sunlight filtered through low cloud provided a spectacular backdrop of mountain and city as we proceeded southwards down the Derwent River.

The test launch of the CTD was performed at 1600. We used the new Seabird instrument with the large frame although only twelve 5 litre Niskin bottles were used. The start of an ascending TOPEX/POSEIDON track off Bicheno was reached at about 0130 and we commenced dropping XBTs. The standard XBT system used for VOS deployments was used with the probes (T7) launched from an appropriate point on the aft deck. An initial problem with the earth connection of the system was soon solved and the sampling then began in earnest. In order to resolve the fine-scale structure along the track probes were dropped hourly and we were fortunate to slice through two warm core eddies, which were further south than often observed. The location of these eddies confirmed the picture shown in the surface height field obtained from the real-time altimetry product provided by the Regional Oceans Group.

As we steamed northward along the track the weather steadily improved although a cloud cover remained. The already light winds of 10-15 Knots dropped to below 10 knots. At 0500 on Sunday the 13th we reached the next way-point which was also the first station (37° 4.8'S, 151° 39'E). Since the schedule was tight the CTD was only sampled down to 2000-m. A total of 3 CTDs (all to 2000-m) and further closely spaced XBTs were completed along the section which followed a northwestward path along a descending altimeter track toward the NSW coast. The ship then proceeded on a path parallel to the coast to pick up the start of the main cruise section just off Sydney. Due to the very settled conditions the ADCP was collecting good data to maximum depth. The transect crossed over a cyclonic, cold–core eddy which was pushed up against the coast somewhere near Jervis Bay.

The start of the Sydney – Wellington section was reached at 0600 on Monday 14th. By this time the sky had cleared and the seas moderated even further. Sunshine, blue skies and glassy seas contributed greatly to a relaxed happy atmosphere on board ship. A slight delay at a station was experienced when one of the acquisition computers went down unexpectedly. The stations over the slope region were soon completed and then at CTD 10 we reached the abyssal waters of the Tasman Basin and eastward progress slowed considerably. Following this station the first deployment of the aquashuttle was completed successfully. This involved a series of test 'flights' at speeds ranging from 4-11 knots. An independent set of XBT data were collected along the section. This included probes launched at the CTD stations as well as between stations. To be consistent with the routine high-density sections, 'deep blue' probes were used.

Since the Tasman Basin is quite wide along this section (600-nm) we completed twenty stations at greater than 4000-m depth. We encountered strong southwestward currents of up to 1.8 knots which was evidence of an anticyclonic eddy. The altimeter map clearly showed that we were crossing over the northern flank of this eddy and so the currents changed to a northward direction (~1 knot) when we reached its eastern side. We received regular up-dates of the real-time altimeter maps which helped to place our results into a wider context of the basin circulation.

An important component of the cruise was the SST validation exercise. This involved continuous monitoring of the sea surface temperature (SST) for MODIS, ATSR-2 and AVHRR satellite instruments. An infrared radiometer measured the surface skin temperature while another radiometer assessed the surface heat and radiation budget. Several weather balloons (with standard radio-sonde attached) were deployed at satellite crossing points.

As we proceeded eastward the weather conditions reverted to a more normal pattern. The high which had been stationary over the Tasman finally moved on an we were subject to consistent north-easterlies of 20-25 knots. This wind pattern was associated with the northern edge of a following low. This system was maintained then for the rest of the voyage.

Reaching the edge of the Lord Howe rise signaled the end of the deep stations and that the cruise was coming to an end. The wind and seas had built up to some extent although not quite enough to stop us working. The load cell on the CTD was carefully monitored and we noted consistent zero load as the ship rolled. The speed of the winch was restricted to as low as 40m/min to reduce the severity and occurrence of these events. On Monday 21st the ship lost all power due to a failure in the 24 volt circuit. The heavy swell meant that the ship rolled considerably. Fortunately, power and steerage was restored after about an hour and no other problems were encountered. Fortunately no data were lost during this incident. The build-up of wind and seas continued and combined with the tightness of our schedule the CTD sampling was reduced slightly. The range of ADCP collected deteriorated in concert with the change in weather conditions

This cruise was the last for two stalwarts of marine science research in Australia. George Cresswell has spent the past 30 years undertaking many cruises, countless stations in a range of vessels. We recognize his fundamental contribution to the understanding of the East Australian Current (and its eddies), the Leeuwin Current and many other oceanic phenomena around Australia. We celebrated his last CTD and salinity sample by 'anointing' him with a few Niskin bottles of water (T = ~ 20°C, S = 35). Ian Helmond has also been with CSIRO for over 30 years – the past 20 with the

Marine Laboratories in Hobart. His creativity and ingenuity have been behind much of the ocean moorings deployed and instrumentation developed in that period.

We arrived in Wellington on schedule at 1000 on May 23.

Summary

The cruise was very successful and a high quality data-set was obtained which met all our initial objectives. All instruments performed well with no obvious problems. The CTD functioned very well and the CTD vs. sample comparisons indicated that the data were of the highest quality. The full depth CTD section will provide a very valuable complement to understanding and interpreting the 10-year time series of high-density XBT sections. We note that the electrical black-out and subsequent loss of engine power and steerage appears to underline a worrying vulnerability of the vessel. Although in this case no harm was done in other circumstances the results may have been far more serious.

Personnel

Scientific Participants

Ken Ridgway	CMR	Chief Scientist, CTD watch A leader
Phil Sutton	NIWA	CTD watch B leader
Phil Wiles	NIWA	CTD watch B
Mat Walkington	NIWA	CTD watch A
Ken Suber	CMR	CTD watch B
Ian Helmond	CMR	Aquashuttle testing
Bernadette Heaney	CMR	Computing
Mark Underwood	CMR	Electronics
David Terhell	CMR	Hydrochemistry
Gary Critchley	CMR	Hydrochemistry
Neale Johnston	CMR	Hydrochemistry

Franklin Crew

Neil Cheshire	Master
Arthur Staron	First Officer
John Boyes	Second Officer
John Morton	Chief Engineer
Dave Jonker	First Engineer
John Hinchliffe	Electrical Engineer
Rod Willis	Bosun
Norman Irvine	IR
Malcolm McDougall	IR
Simon Smeaton	IR
Howard Davies	Greaser
Shaun McQuaid	Chief Steward
Paul Brown	Chief Cook
Mark Wheeler	Second Cook

Data Distribution

Following a reasonable period for data processing and reporting of results, the data collected from this cruise will be made freely available to international scientific programs (e.g. CLIVAR), national and international data archives, including those of New Zealand.

Acknowledgments

I would like to acknowledge the professionalism of the ORV staff. I was impressed with their competence and general ability to get things done in all circumstances. I would also like to thank all members of the scientific staff who worked so very well as a team, obtaining data of the highest quality. Thanks particularly to our colleagues from NIWA for there contribution to the success of the cruise. The assistance provided by the ship's officers and crew was of a very high standard and contributed greatly to the smooth operation of all aspects of the cruise. In general, the cruise was a most satisfying experience both on a scientific and a personal level.

We gratefully acknowledge the support provided by the CSIRO Earth Observation Centre which has been central to the success of this cruise in collecting such a valuable set of simultaneous satellite and in-situ data.

Ken Ridgway
Chief Scientist