2009 program

RV *Southern Surveyor*

MARINE NATIONAL FACILITY

CSIRO

voyage summary SS06/2009

SS06/2009

Perturbation flow processes over seamounts in the East Australia Current Outflow in the Tasman Sea

Itinerary

Depart Sydney 9:00am, Thursday 29th October, 2009
Arrive Sydney 9:00am, Monday 9th November, 2009

Principal Investigators

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Scientific Objectives

The aim of this project is to investigate flow perturbations over and around seamounts in stratified waters. The moderate currents of the East Australia Current outflow impinging on seamounts in the Tasman Sea provide a unique laboratory for the study of oceanic stratified flows over and around topographic features. This study is significant as a study in fundamental physical oceanography in its own right because of the complexity of stratified rotating flows over topography, the need to accurately encapsulate such effects in regional and larger scale models, and because of the implications of nutrient uplift to biological productivity. This work will build substantially on that undertaken during Voyage SS09/2006 where we studied flow perturbations around reefs and islands of the Lord Howe Rise. In this project, we utilise both modelling and field work approaches. The modelling work is being undertaken using the state of the art model ROMS (Wilkin and Zhang, 2006). Observational work is undertaken in the present Voyage aboard RV *Southern Surveyor*, using ADCP, CTD, Seasoar and moored current meters. We plan to deploy instrumentation on the top of Taupo Seamount, and to measure comprehensively the current and hydrographic structure of the ocean around that seamount and Barcoo Seamount depending on flow conditions. These are steep-sided seamounts lying along the 156°E meridian. Model output is used to plan our experimental array, and later the experimental results will be compared to model output, and the model further developed to more accurately predict topographic flow perturbations in regional scale ocean models.

In summary, the combination of currents and seamounts around 33°S, 156°E comprises an ideal natural laboratory to:

a) observe flow perturbation processes in deep stratified ocean flows (Middleton and Robertson),

b) utilise an improved ROMS model (presently the most innovative of regional ocean models) to facilitate interpretation and understanding (Wilkin, Roughan and Middleton), and

c) determine likely effects of climate change on physical processes, and on nutrient supply from the deeper ocean (Roughan, Middleton and Wilkin).

Voyage Objectives

The Barcoo and Taupo Seamounts lie along the 156°E meridian, usually impacted by the flow of the East Australia Current. The plan is to undertake transects using ship- board equipment, including the National Facility Conductivity-Temperature-Depth (CTD) system and associated water samples, a Lowered Acoustic Doppler Current Profiler (LADCP) suspended on the CTD, the ship's hull mounted ADCP, and the towed vehicle known as the Seasoar to investigate the interactions of the EAC with the topographic features. The precise locations of the transects will depend on Sea Surface Temperature (SST) images obtained close to and during the voyage, however generally the transects will be 30-60 km long across the width of the seamounts, (6-8 hrs, towing the Seasoar). The transects will lie in regions where steep topography (0- 4000 m) is associated with strong currents.

Ship-board Observational Program

It was planned that CTD casts would be undertaken at stations along transects of the Tasman Front, normal to the current, as it approaches and crosses the seamount chains. The CTD on the *Southern Surveyor* is equipped with a full rosette, optode oxygen sensor, par transmissivity and fluorescence. We planned to take standard nutrient samples at some stations, and to make CTD transects up to 1000 m deep.

ADCP transects were planned to provide current velocities in the upper 400-600 m of the water column. Concurrently with the ADCP transects it was planned to use the Seasoar to profile the upper 200 m of the water column, enabling a fine scale view of the stratification (temperature, salinity, fluorescence, oxygen) as observing how the currents interact with the topography.

Satellite imagery of ocean colour and sea surface temperature are an essential part of the field component, and are used to ensure transects are suitably related to current and topography interactions.

Moored Observational Program

We proposed to deploy one mooring on the Taupo Seamount for the duration of the voyage to identify tidal currents. Taupo Seamount is an ideal location as it extends from the seafloor (~4000 m depth) to within 130 m of the sea surface and is flat on the top. The mooring will be comprised of one single point current meter and one Seacat moored CTD system on a single mooring with acoustic release. A string of thermistors 5 m apart will be placed on the mooring line.

Results

The voyage track is shown in Figure 1, in which the Research Vessel *Southern Surveyor* is seen to be working intensively around the Taupo and Barcoo Seamounts.

A single current meter, with moored CTD and a string of temperature sensors was deployed for 8 days on the top of Taupo Seamount to measure the currents while we were in the area. All instruments were seen to be working on retrieval, except for one Tidbit temperature sensor which had suffered from fish bite. Tidal range was approximately 1.7 m on Tuesday 3rd November (Full Moon), and associated maximum tidal currents ~ 0.4 m s-1. Only weak mean currents were observed (not shown here).

Preliminary CTD and Seasoar sections taken along east-west parallels at Taupo Seamount showed small currents, by contrast to those we had observed three years previously on Voyage SS09/2006.

Reference to Sea Surface Temperature (SST) images (see Figure 2) indicated that stronger currents could be expected at Barcoo seamount, which at the time was just south of a temperature front resulting from the East Australia Current outflow, and aligned in the east-west direction with warmer waters to the south.

After undertaking a Seasoar section, crossing both Taupo and Barcoo seamounts, we initiated a comprehensive CTD section running south-south-east to north-north-west. The locations of the stations, and all other stations undertaken with the CTD on this Voyage, are shown in Figure 3. One section is shown in Figure 4, in which a number of features are evident. Firstly the temperature contours are essentially level around

Taupo Seamount, indicating weak geostrophic currents. By contrast Barcoo Seamount is embedded in strongly sloping isotherms, indicating a strong current to the west. The sloping isotherms extend to at least 1000 m depth, indicating the existence of strong currents to at least that depth. At the sea surface north of Barcoo is a strong surface temperature front. At that stage we resolved to undertake the majority of our observations with reference to flows incident to, and in the wake of, Barcoo Seamount.

A Seasoar section was taken along the same section at the CTD section just described, and this is shown in Figure 5. The Seasoar profiles up and down while the towing vessel is underway at ~ 8 kt describing a zig-zag in the section along the ships's track. Notable in the northern sector of the temperature section are the sloping isotherms being the surface expression of the front evident in the CTD section. The dissolved oxygen section shows a marked filament of low oxygen associated with the front uplifted into the surface layers. This filament is associated with a pulse of high fluorescence which appears at ~40 m depth, above the uplifted water masses, and is indicative of plankton growth and nutrient upwelling at the frontal zone.

With a strong current impinging on Barcoo Seamount, we elected to conduct a CTD section along the inferred axis of the flow, showing both the upstream and downstream affects of the wake. This is shown in Figure 6. In the surface 300 m and upstream of the seamount the flow is seen to be uplifted as it approaches the seamount through the doming of isotherms just over the upstream sill. Over the Seamount the isotherms drop, and then rebound vertically rising again in the lee of the Seamount. Below 300 m depth the isotherms are contorted as a result of wake flow processes.

Some idea of the wake can be gained from the shipboard ADCP data, which were taken at a number of sections downstream of the seamount. The locations of some of these sections are shown in Figure 7, with reference to the Barcoo topography and the incident current.

Some ADCP data is shown in Figure 8, in which the four sections are shown one above the other. Evident features in all sections include the strong flow to the west in the surface layers, and the persistent return flow at depths below 300 m towards the left of the figures. This return flow is possibly a consequence of wake eddies, which are attached to the Seamount, or at least which have not separated during our period of observations.

A Lowered Acoustic Doppler Current Profiler (LADCP) was deployed to extend velocity observations deeper in the water column than provided by the shipboard ADCP, typically ~600 m. Velocity profiles were not collected for every Conductivity Temperature Depth (CTD) cast, and specifically not for shallow casts or the yo-yo casts. A total of 39 LADCP profiles were collected to 1000 m as noted with the asterisk in Table 2.

The LADCP has two 250 kHz Sontek units, one upward looking (SN C245) and one downward looking (SN C366). They observe the water column above and below the CTD, respectively, as the LADCP is lowered through the water column. The LADCP units were attached to the CTD rosette by Drew Mills. The system was started and stopped for each cast and the battery recharged. The LADCP operates in a similar manner as an ADCP, only from a platform rotating and moving in 3-D, which requires additional processing.

The data was processed by Robin Robertson using software provided by Sergei Sokolov (CSIRO), which is based on the commonly used Visbeck/Krahmann LADCP processing software for RDI instruments. Some modification of the software was necessary, primarily for input of the CTD data, shipboard ADCP data, and navigation data from *Southern Surveyor*. During processing, it was determined that beam 4 on the upward looking unit was unserviceable for all casts. Additionally, some casts had a warning message about a weak downward looking beam. Target strength was good for all casts and typical beam extents were ~50 m in the upper 200-300 m and ~100 m below that depth in each direction. Profiles were divided into 8 m bins. A typical plot is shown in Figure 9.

An important feature of the data acquisition during this Voyage was the operation of the multibeam echo sounder which produces swath data of bottom depth. The data were collected using the Kongsberg Simrad EM 300, and the nominal sonar frequency is 30 kHz. For data accuracy, sound velocity and sound absorption profiles were produced from XBT and CTD data as available, and loaded into the acquisition system. In total, 2353 linear kilometres of swath data in the Barcoo/Taupo seamount areas were acquired, and the resulting colour-coded contour plot shown in Figure 10.

At the end of this report, and before the Figures, a number of logged details are presented, these being

- A list of the CTD sections occupied during the Voyage,
- A list of the CTD stations occupied during the Voyage,
- A list of the XBT stations occupied during the Voyage, and
- A list of the Seasoar sections occupied during the Voyage.

Voyage Narrative

All times listed in this narrative are given in Eastern Standard Time (EST).

Thursday 29th October
At 9:00 am RV *Southern Surveyor* departed from White Bay, Sydney Harbour. We left the Heads at 10:30 am, undertook an Emergency Muster Drill, then proceeded on a north-easterly heading toward Taupo Seamount after dropping the Pilot. At 33º 52'S, 152º 19'E we undertook the first CTD station at 4:30 pm, deploying the CTD to 1000m in over 3000 m of water depth. We then continued on toward Taupo Seamount.

Friday 30th October
On arrival at Taupo Seamount we proceeded to investigate an area to determine its suitability for our mooring. Comprised of a midwater InterOcean S4 current meter, a moored CTD system and an acoustic release, the mooring was streamed in 130m of water at 11:02 am and deployed at 11:08am at 33º 13.06'S, 156º 13.18'E.

The ship then moved northward, and began the first Seasoar/ADCP Survey at latitude 33º 11.5'S, from east to west across the top of the Seamount, finishing that day at 6:50pm (Leg 1). Low current velocities were evident everywhere.

We proceeded to conduct a CTD section (Stations 2 to 11) at the same latitude (33º 10'S), so gaining an appreciation of the general hydrography. The first station was begun at 8:00 pm and the last completed the next morning at 6:00 am. The water column was characterised by surface temperatures of approximately 22.5º C dropping to ~20º C at 120 m, the depth of the Seamount top. In deeper waters, values of temperature were usually < 7o C at 1000 m.

Saturday 31st October

Following the completion of CTD Station 11, the *Southern Surveyor* moved to begin the second Seasoar/ADCP survey leg, beginning at 09:45 am and finishing at 8:15pm. The objective here was to investigate the entire cross-section of the Taupo – Barcoo Seamounts, so that the survey was begun at latitude 33° 36'S, 156° 04'E and completed at 32° 18'S, 156° 20'E.

Immediately on completion at 8:30 pm a CTD survey was begun on the reverse track to the Seasoar leg. This comprised stations 12 to 28. Station 12 was to the north and Station 28 at the southern end. This section was completed the following day at 2:30 pm.

Sunday 1st November

The morning was taken completing the CTD line begun the previous day. On completion the ship was positioned at 33o 05'S, 156 o 28'E, and another Seasoar/ADCP survey undertaken tracking westward across Taupo Seamount (Leg 4) to 155° 54'E. This was completed at 10:00 pm, but unfortunately only small currents were again observed.

As a strong east- west SST front was observed only 10 nm north of the Barcoo Seamount it was decided to investigate flows around the Barcoo Seamount area which might result from the north-south temperature and density gradients. Strong currents had been seen in the previous CTD and ADCP surveys in the area the previous Saturday. The vessel therefore relocated to 32° 45'S, 156° 10'E, with the Seasoar/ADCP operating as Leg 5.

Monday 2nd November

With strong currents flowing westward in the general Barcoo area, the first Seasoar/ADCP survey in the Barcoo wake was completed along the 156° 10'E meridian from 32° 45'S to 32° 20'S. This leg was denoted Leg 6. Following this leg the vessel was positioned 7 km west and another leg (Leg 7) undertaken along the 156° 05'E meridian.

Each of these legs showed extremely strong westward flowing currents in the top 250m of the water column, with significant flow disturbance including recirculation cells below 270 m which is the approximate depth of the top of the Seamount. These features were exactly what we had been searching for, so it was decided to concentrate observations around the Barcoo seamount.

Further wake Seasoar/ADCP legs were undertaken in the north-south direction between the same latitudes as for Legs 6 and 7, at longitudes 156° 05'E (Leg 8) and 156° 05'E (Leg 9).

Following Leg 9 the ship repositioned at 32° 40'S, 155° 54'E and conducted a Seasoar/ADCP Survey (Leg 10) eastwards up the axis of the wake and across the top of Barcoo to the upstream side at 32° 33'S, 156° 30'E.

On completion a set of CTD stations (Stations 29 to 41) was undertaken at 32° 36'S back west over the seamount and into the wake. The water column structure had large steps of size up to ~100 m below the level of the sill, and large undulations were seen in the wake structure along the axis.

Tuesday 3rd November

On completion of the set of stations along the axis of the Barcoo wake, it was decided to run a long CTD section across the far wake at longitude 155o 50'E, and the near wake at 155º 50'E. This began at CTD station 42 at 32º 20'S with stations being occupied as the ship moved southward to 32º 48'S, ending at Station 49.

A further section was begun eastward at 32º 48'S (CTD 49 to 54) to join this section with the near wake section, which was necessary to ensure that the mean flow wake, now tending to flow toward direction south of west, was captured by the CTD section.

Wednesday 4th November

Overnight the CTD stations were continued, with the aim of identifying the structure of the wake to 1000 m depth. CTD stations were occupied travelling northward on 156º 10'E in the immediate wake of the Seamount (CTD 54 to 61).

Following this the *Southern Surveyor* steamed east to begin a Seasoar/ADCP survey upstream. This was begun at 32º 20'S, 156º 35'E and proceeded southward along that meridian (Leg 11).

This was followed by a Seasoar/ADCP survey on the 156º 30'E meridian (Leg 12), followed by a Seasoar/ADCP survey on the 156º 25'E meridian (Leg 13).

Thursday 5th November

The day began with a Seasoar/ADCP survey on the 156º 20'E meridian (Leg 14), followed by a Seasoar/ADCP survey on the 156º 15'E meridian (Leg 15).

At 10:07 am, in 1500 m of water, and at position 32º 3.380'S, 156º 14.00'E the Seasoar display showed erratic signs in depth and roll, then an absence of electronic data returned from the vehicle. On cable retrieval the Seasoar was missing.

We continued Leg 15 monitoring only the ADCP, followed by Legs 16, 17, 18 and 19 along the 156º 10'E, 156º 05'E, 156º 00'E and 155º 55'E meridian.

Friday 6th November

We began Leg 19 along the 155º 55'E meridian, but cut short the Leg early at 32º 29'S, in order to conduct an ADCP/XBT survey along what appeared to be the axis of the wake, from downstream to upstream. This survey began at 3:00 am, at 32º 29'S, 155º 55'E, and ended at 7:00 am at 32º 38'S, 156º 30'E.

A CTD survey was then begun on the reciprocal track beginning with Stations 62, 63 and 64 upstream of Barcoo Seamount, and 65 on top of the Seamount. Stations 66 to 71 were then taken toward the north-north-west in the wake of the flow which had now changed to flow towards that direction.

Following that survey the ship moved to the location of Station 67 in the wake, this location (32º 30.5'S, 156º 13.6'E) being notable as one with substantial mixed layers, particularly between ~350 m and 500 m depth. It was decided to run a sequence of CTD casts at hourly intervals to create a time series of "yo-yo" profiles. The first was undertaken at 7:30 pm, and the last at 3:30 am Saturday, giving a total of 9 casts.

These were labelled CTD 72 to CTD 81.

Saturday 7th November
At ~4:00 am, on completion of the CTD time series, the Surveyor tracked to the location of the mooring on top of Taupo Reef (33º 13.1'S, 156º 13.2'E). After manoevering, the ship was positioned with the mooring ~190 m off the starboard beam, the distance was corroborated by the acoustic release transponder, and the release activated on the first trigger signal. The mooring was immediately evident floating ~200 m off the ship's beam and was brought aboard by 10:15am

The *Southern Surveyor* then tracked back to Barcoo to complete the swath mapping, undertaking this throughout the afternoon and evening.

Sunday 8th November
Throughout the day we steamed toward Sydney.

Monday 9th November
The *Southern Surveyor* entered Sydney Harbour at 7:30am and tied up at White Bay at 9:00am.

Summary

We are pleased to report that we met all voyage objectives, notwithstanding the disturbing loss of the Seasoar and attached Ecopuck.

In particular we have thoroughly documented observations of the flow properties incident to, over, around, and in the wake of a large seamount embedded in a strong baroclinic oceanic flow. While we have not yet had time to digest all of the implications of the salient features it is clear that the presence of the large seamount in the strong current induces processes including:

- upwelling in the incident flow upstream of the seamount,
- a depression of isotherms in the flow over the seamount top,
- a further raising of isotherms downstream of the seamount top,
- recirculating wake flows downstream of the seamount at depth,
- strong vertical shear in horizontal velocity just below the level of the seamount top,
- constant temperature layers in the wake probably due to vertical and horizontal
- mixing due to shear instabilities, and
- internal waves and internal tides emanating from the Seamount sides.

Stratified flow over topography in the earth's rotating frame of reference clearly remains a fascinating concept, with a large number of associated complex physical processes. In time, the data set obtained will hopefully go some way toward a further explanation of these processes.

Scientific Personnel

Jason Middleton (UNSW) Chief Scientist
Ryan Mccabe (UNSW)
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MNF Support Staff

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Ships Crew

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Rob Ferries (Second Mate)
John Morton (Chief Engineer)
Dave Jonker (First Engineer)
Aminul Haque (Second Engineer)
Tony Hearn (Boatswain)
Graham McDougall (IR) Peter Ives (IR)
Chris Softley (IR)
Ken Rawson (Chief Cook)
Geoff Coulson (Second Cook)
Andrea Henderson (Steward)

Acknowledgements

We would like to express our heartfelt thanks and appreciation to those most directly involved in ensuring the success of our Voyage, being the MNF support staff and the Ship's crew of the *Southern Surveyor*. At all times, with some adversity, the MNF support staff provided capable and professional support in a friendly and helpful fashion. Ship's crew were similarly obliging, responding to our adaptive sampling strategy with helpful suggestions, and capable articulation of the vessel and its equipment. Though faced with a variety of operations, and following job hazard analyses, all tasks were performed safely with never a risk to personnel.

This project is supported by an ARC grant to Jason Middleton,
and by the Marine National Facility Steering Committee.

Jason Middleton
November, 2009

CTD Section list SS 06/2009

CTD Station Numbers	Description of Section
1	Test
2 to 11	East west section across Taupo at 33o 10'S
12 to 28	NNE -SSW Section across both Seamounts 33° 36'S, 156° 04'E to 32° 18'S, 156° 20'E
29 to 41	East-West section across Barcoo, upstream to down stream
42 to 49	Section crossing wake far downstream at Barcoo at 155° 50'E
49 to 53	Joining Section
53 to 61	Section crossing wake near downstream at Barcoo at 156° 10'E
61 to 71	Section from upstream to downstream, SE to NW
72 to 80	Time Series in wake at (32° 30.5'S, 156° 13.6'E)

CTD LOG

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CTD No	Date (Z)	Time (Z)	Seabed depth	Cast depth	Latitude	Longitude
1	29-Oct	0530	>2000	1000	33 52	152 19
Taupo East-West						
2	30-Oct	0906	>2000	1008	33 10	156 30
3	30-Oct	1050	1010	950	33 10	156 18
4	30-Oct	1205	600	500	33 10	156 17.8
5	30-Oct	1255	336	254	33 10	156 17.3
6	30-Oct	1350	150	127	33 10	156 13.4
7	30-Oct	1455	149	127	33 10	156 06
8	30-Oct	1545	323	225	33 10	156 02.5
9	30-Oct	1625	516	482	33 10	156 02
10	30-Oct	1745	1100	1000	33 10	156 01
11	30-Oct	1850	>2000	1000	33 10	155 55
Taupo-Barcoo SSW-NNE						
12*	31-Oct	0940	>2000	1000	32 12	156 22
13*	31-Oct	1105	>2000	1000	32 20	156 20
14*	31-Oct	1250	1515	1000	32 32	156 17
15	31-Oct	1350	305	250	32 33.7	156 16
16	31-Oct	1420	275	257	32 35	156 16
17	31-Oct	1510	310	222	32 38	156.16
18*	31-Oct	1543	1460	1000	32 39.7	156 16
19*	31-Oct	1726	1500	1000	32 47	156 14
20*	31-Oct	1908	1800	1000	32 55.6	156 12
21	31-Oct	2032	720	632	32 58	156 12
22	31-Oct	2130	257	235	33 02	156 11
23	31-Oct	2230	138	122	33 08	156 09
24	31-Oct	2325	135	121	33 15	156 08
25	1-Nov	0025	524	524	33 21	156 07
26*	1-Nov	0105	1033	1000	33 22	156 07
27*	1-Nov	0215	>2000	1000	33 25	156 06
28*	1-Nov	0345	>2000	1000	33 30	156 05
Barcoo wake axis						
29*	2-Nov	1045	>2000	1000	32 36	156 29
30*	2-Nov	1155	>2000	1000	32 36	156 24
31*	2-Nov	1310	1400	1000	32 36	156 23
32	2-Nov	1410	300	280	32 36	155 20
33	2-Nov	1450	260	250	32 36	155 16
34	2-Nov	1530	300	290	32 36	156 12
35	2-Nov	1605	715	700	32 36	156 11
36*	2-Nov	1700	1150	1000	32 36	156 10
37*	2-Nov	1805	>2000	1000	32 36	156 08
38*	2-Nov	1915	>2000	1000	32 36	156 05
39*	2-Nov	2100	>2000	1000	32 36	156 00
40*	2-Nov	2215	>2000	1000	32 36	155 55
41*	2-Nov	2325	>2000	1000	32 36	155 50

CTD No	Date (Z)	Time (Z)	Seabed depth	Cast depth	Latitude	Longitude
Barcoo far-field wake						
42*	3-Nov	0215	>2000	1000	32 20	155 50
43*	3-Nov	0345	>2000	1000	32 24	155 50
44*	3-Nov	0455	>2000	1000	32 28	155 50
45*	3-Nov	0615	>2000	1000	32 32	155 50
46*	3-Nov	0725	>2000	1000	32 36	155 50
47*	3-Nov	0836	>2000	1000	32 40	155 50
48*	3-Nov	0947	>2000	1000	32 44	155 50
49*	3-Nov	1059	>2000	1000	32 48	155 50
50*	3-Nov	1218	>2000	1000	32 48	155 57
51*	3-Nov	1345	>2000	1000	32 48	156 03
52*	3-Nov	1508	>2000	1000	32 48	156 10
53*	3-Nov	1640	>2000	1000	32 48	156 17
54*	3-Nov	1805	>2000	1000	32 44	156 14
55*	3-Nov	1930	>2000	1000	32 42	156 10
56*	3-Nov	2035	>2000	1000	32 39	156 10
57	3-Nov	2144	1350	1000	32 36	156 10
58	3-Nov	2250	690	600	32 33	156 10
59*	3-Nov	2340	>2000	1000	32 30	156 10
60*	4-Nov	0135	>2000	1000	32 27	156 10
61*	4-Nov	0230	>2000	1000	32 24	156 10
Barcoo Axis SE to NW						
62*	5-Nov	2007	>2000m	1000	32 37.6,	156 29.3
63*	5-Nov	2130	>2000m	1000	32 36	156 24.6
64	5-Nov	2250	>2000m	1000	32 35.7	156 21.6
65	5-Nov	2340	>2000m	1000	32 34.5	156 17.6
66	6-Nov	0020	>2000m	1000	32 32.5	156 14.3
67	6-Nov	0127	>2000m	1000	32 30.5	156 13.6
68	6-Nov	0231	>2000m	1000	32 28.5	156 12.9
69	6-Nov	0335	>2000m	1000	32 26.5	15612.4
70	6-Nov	0433	>2000m	1000	32 24.5	156 11.9
71	6-Nov	0534	>2000m	1000	32 22.5	156 11.4
Barcoo wake time series						
72	6-Nov	0825	>2000m	1000	32 30.5	156 13.6
73	6-Nov	0925	>2000m	1000	32 30.5	156 13.6
74	6-Nov	1025	>2000m	1000	32 30.5	156 13.6
75	6-Nov	1125	>2000m	1000	32 30.5	156 13.6
76	6-Nov	1225	>2000m	1000	32 30.5	156 13.6
77	6-Nov	1325	>2000m	1000	32 30.5	156 13.6
78	6-Nov	1425	>2000m	1000	32 30.5	156 13.6
79	6-Nov	1525	>2000m	1000	32 30.5	156 13.6
80	6-Nov	1625	>2000m	1000	32 30.5	156 13.6

Note * next to CTD Station number indicates a Lowered ADCP (LADCP) cast was undertaken.

XBT LOG

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XBT No	Date (Z)	Time (Z)	Seabed depth	Cast depth	Latitude	Longitude
1	29-Oct	2120	>2000	750	33.35	155 .73
2	29-Oct	2310	>2000	750	33.26	156.17
3	30-Oct	2230	>2000	750	33.57	156.06
4	5-Nov	1548	>2000	750	32 29.5	155 55.7
5	5-Nov	1603	>2000	750	32 29.5	155 57.4
6	5-Nov	1609	>2000	750	32 30.1	155 59.3
7	5-Nov	1624	>2000	750	32 30.3	156 00.7
8	5-Nov	1638	>2000	750	32 30.9	156 02.5
9	5-Nov	1649	>2000	750	32 31.2	156 03.8
10	5-Nov	1659	>2000	750	32 31.5	156 05.2
11	5-Nov	1709	>2000	750	32 31.9	156 06.9
12	5-Nov	1719	>2000	750	32 32.3	156 08.2
13	5-Nov	1729	>2000	750	32 32.7	156 09.5
14	5-Nov	1739	>2000	750	32 32.8	156 10.8
15	5-Nov	1750	>2000	750	32 33.3	156 12.2
16	5-Nov	1826	>2000	750	32 34.5	156 17.1
17	5-Nov	1856	>2000	750	32 35.7	156 21.6
18	5-Nov	1918	>2000	750	32 36.5	156 24.5
19	7-Nov	1951	>2000	750	32 37.6	156 29.3
20	7-Nov	0036	>2000	750	32 51.9	156 18.9
21	7-Nov	0156	>2000	750	32 39	156 22.2

SEASOAR LOG

Leg	Raw Files	Start Time (UTC)	End Time (UTC)	Start Latitude	End Latitude	Start Longitude	End Longitude
1	001	30-Oct 1:52	30-Oct 04:26	33 11.455S	33 12.400S	156 16.663E	155 53.169E
2	002	30-Oct 4:26	30-Oct 08:19	33 12.400S	33 09.986S	155 53.168E	156 29.043E
3	003-006	30-Oct 22:46	31-Oct 02:13	33 36.262S	33 09.779S	156 03.707E	156 09.499E
	004	31-Oct 2:13	31-Oct 06:08	33 09.779S	32 38.691S	156 09.499E	156 16.003E
	005	31-Oct 6:09	31-Oct 06:56	32 38.690S	32 32.923S	156 16.003E	156 17.212E
	006	31-Oct 6:56	31-Oct 09:04	32 32.912S	32 16.355S	156 17.213E	156 20.820E
	007	31-Oct 10:27	31-Oct 10:40	32 13.819S	32 16.423S	156 21.843E	156 20.991E
	008	01-Nov 7:14	01-Nov 10:56	33 05.009S	33 04.965S	156 27.267E	155 51.879E
4	009	01-Nov 11:44	01-Nov 14:58	33 04.996S	32 45.111S	155 50.065E	156 09.836E
5	010	01-Nov 14:58	01-Nov 18:16	32 45.110S	32 19.732S	156 09.836E	156 08.867E
6	011	01-Nov 18:16	01-Nov 22:06	32 19.732S	32 45.190S	156 08.871E	156 03.525E
7	012	01-Nov 22:06	02-Nov 01:47	32 45.190S	32 19.826S	156 03.525E	155 58.449E
8	013	02-Nov 1:47	02-Nov 05:22	32 19.827S	32 45.098S	155 58.447E	155 53.864E
9	014	02-Nov 5:22	02-Nov 05:22	32 45.098S	32 45.096S	155 53.863E	155 53.862E
	015	02-Nov 5:22	02-Nov 06:09	32 45.096S	32 39.284S	155 53.861E	155 53.979E
10	016-017	02-Nov 6:09	02-Nov 08:32	32 39.283S	32 35.673S	155 53.979E	156 13.983E
	017	02-Nov 8:32	02-Nov 10:22	32 35.673S	32 33.217S	156 13.985E	156 30.542E

Leg	Comments
1	East over Taupo Bank and east slope
2	West, back over east slope and Taupo Bank – one mile north of last transect
3	Transect south of Taupo to North slope of Barcoo (heading 337)
	East to west over Taupo Bank
4	heading NE from west of Taupo to west Barcoo Saddle
5	heading north on west Barcoo slope
6	heading south on west Barcoo slope, 5' west of Leg 6
7	heading north on west Barcoo slope, 10' west of Leg 6
8	heading south on west Barcoo slope, 15' west of Leg 6
9	??
	transit to start of leg 10
10	Heading east north east across Barcoo Bank

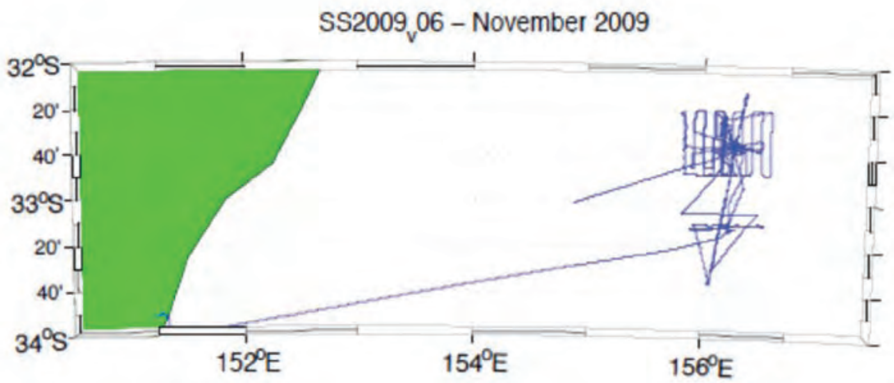

Figure 1. Voyage track for Voyage SS06/2009, showing activities centred at the Taupo and Barcoo Seamounts (32-33ºS, 156ºE).

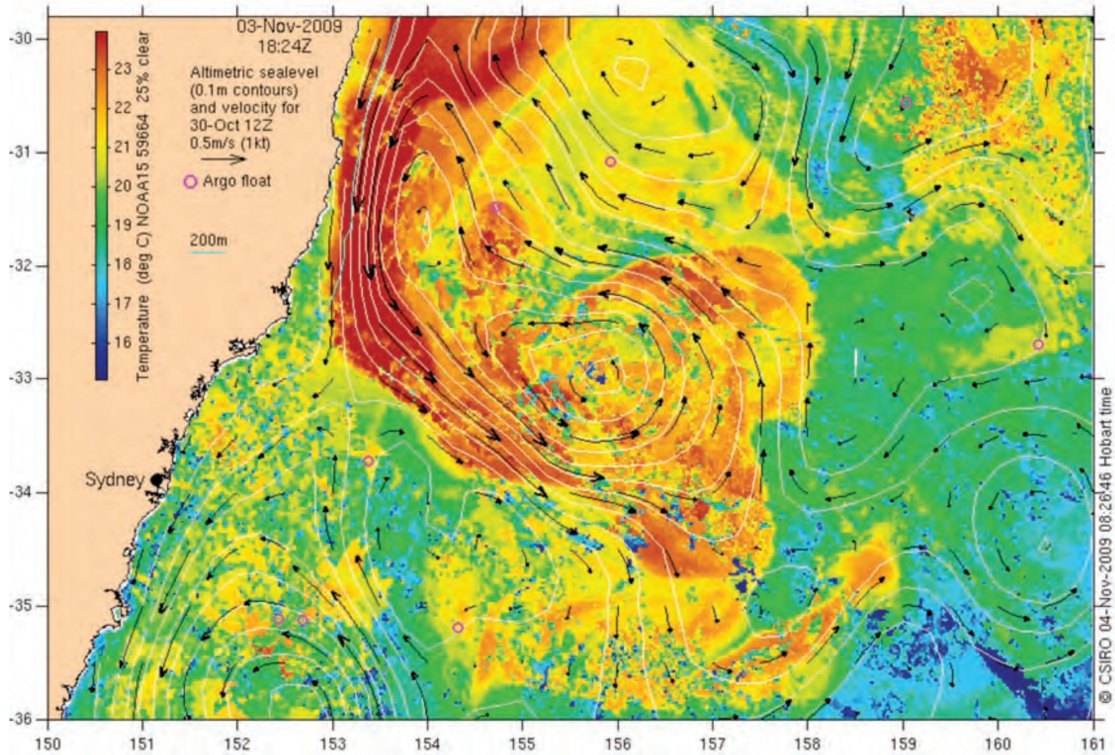

Figure 2. The Sea Surface Temperature image and estimated altimetric surface currents from 3rd November, 2009. Note the front at 32º S, 156º E which is directing currents to flow to the west in the warmer waters.

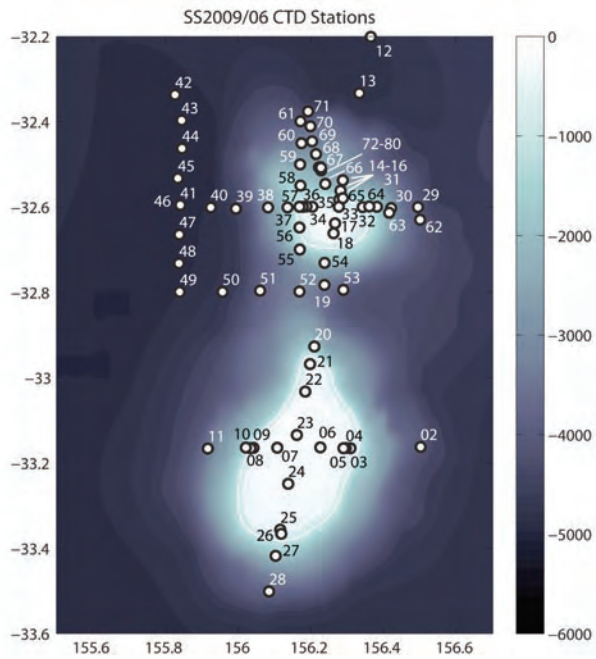

Figure 3. Showing the locations of all CTD stations occupied during this Voyage. The lighter shading centred at about 33.2º S latitude indicates the Taupo Seamount, while the lighter shading centred at 32.6º S latitude indicates the Barcoo Seamount.

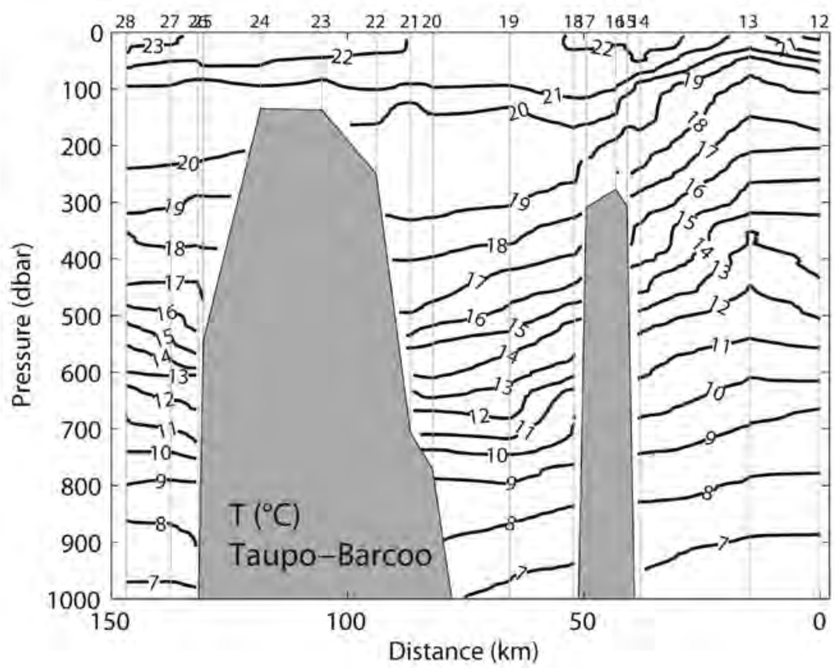

Figure 4. Plot of the CTD section taken from the south-south-west of Taupo Seamount (left of diagram) to the north-north-west of Barcoo Seamount (right of diagram). Note the sloping isotherms surrounding Barcoo, indicative of a strong background current flowing to the west. Note also the surface temperature front north of Barcoo Seamount at Station 13.

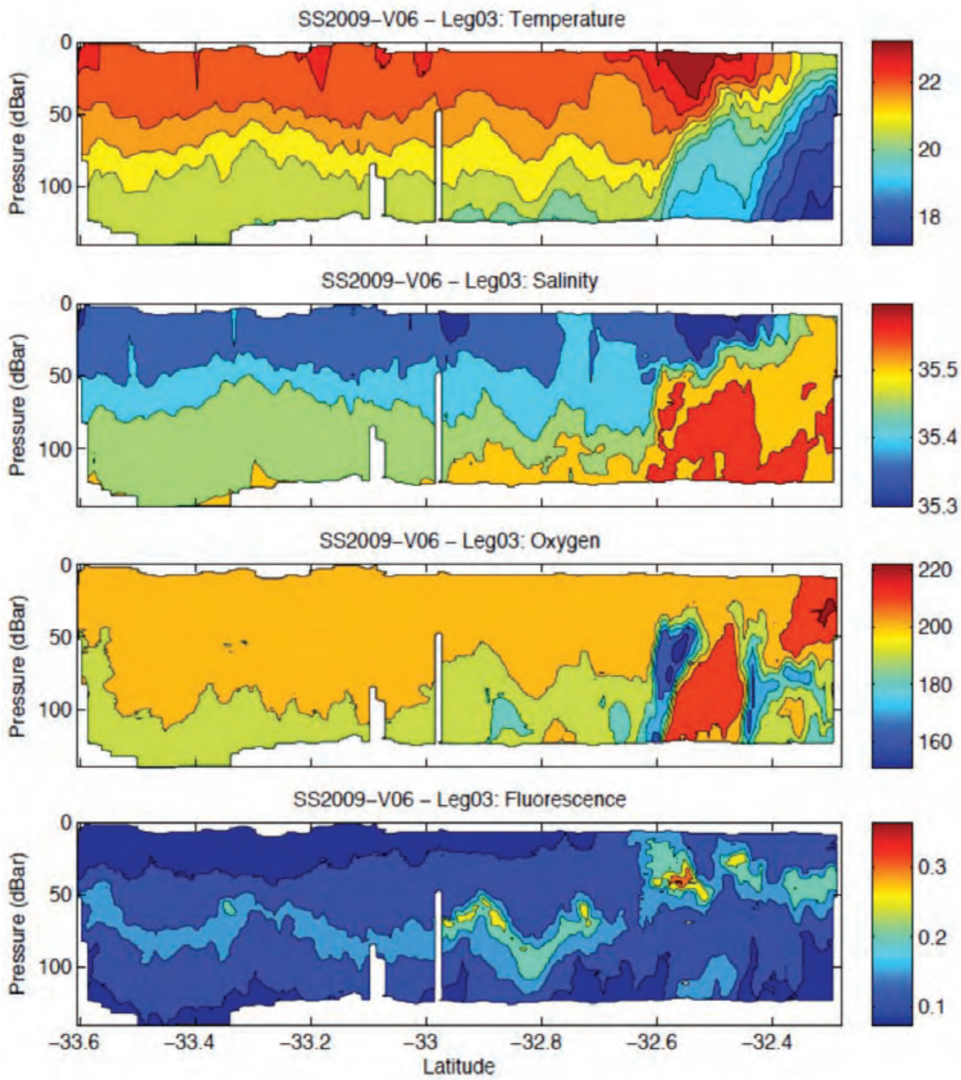

Figure 5. A Seasoar section of the surface 150 m taken over the same section as undertaken with the CTD. Evident are the sloping isotherms to the north associated with the surface front. At the front there is also evidence of a low oxygen filament, this being indicative of a frontal upwelling process. Confirmation of this is given by the fluorescence data which show a patch of strong concentration of plankton overlying the upwelled filament.

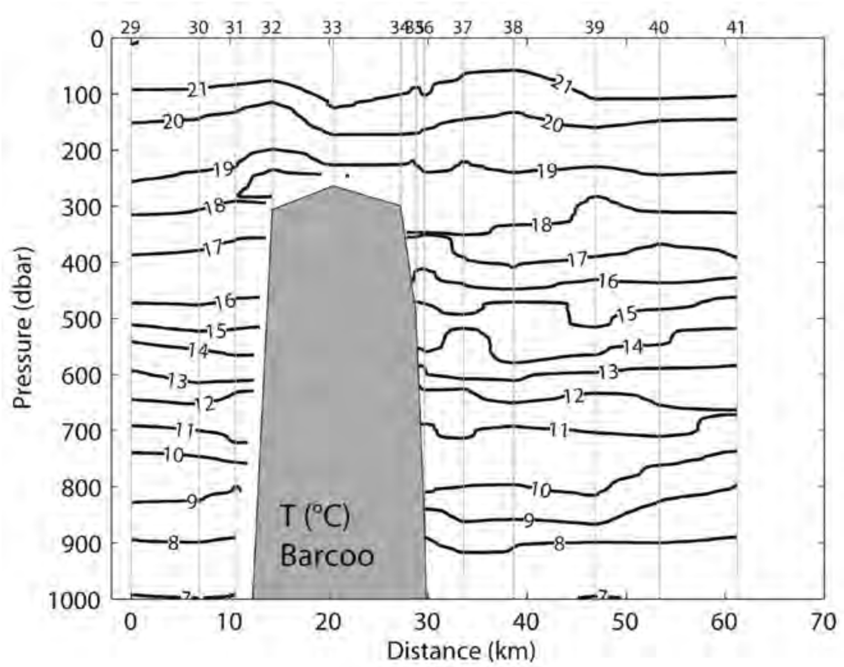

Figure 6. A CTD transect along the axis of the wake from upstream (left) to downstream (right). In the upper 300 m the uplift at the up-current edge of the Seamount is evident, as is the lowering of isotherms over the Seamount, and the rebound raising of isotherms in the lee of the Seamount. Below 300m the isotherm contours are heavily disturbed by wake related processes.

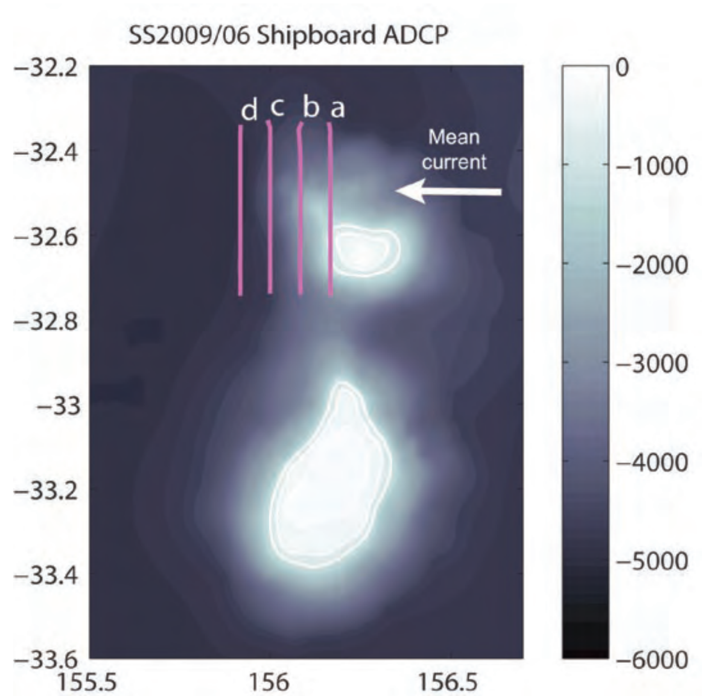

Figure 7. Locations of successive shipboard ADCP sections in the lee of Barcoo Seamount.

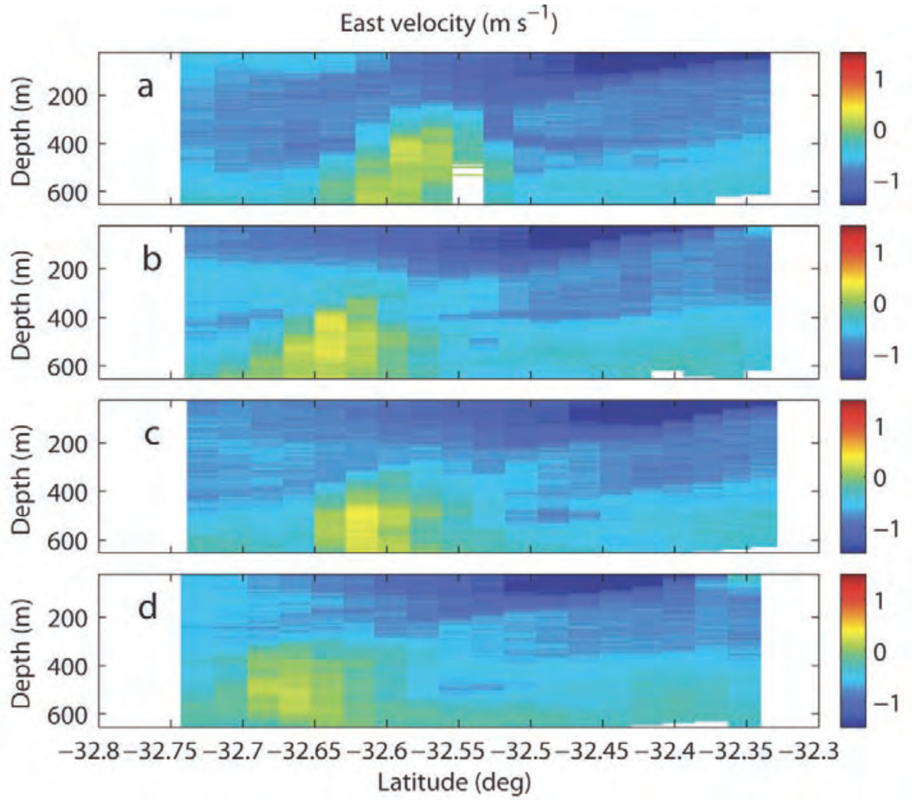

Figure 8. Successive shipboard ADCP sections in the wake downstream from Barcoo, showing strong surface flows to the west especially in the north, and return flows to the east at depths below 350 m directly in the lee of the Seamount.

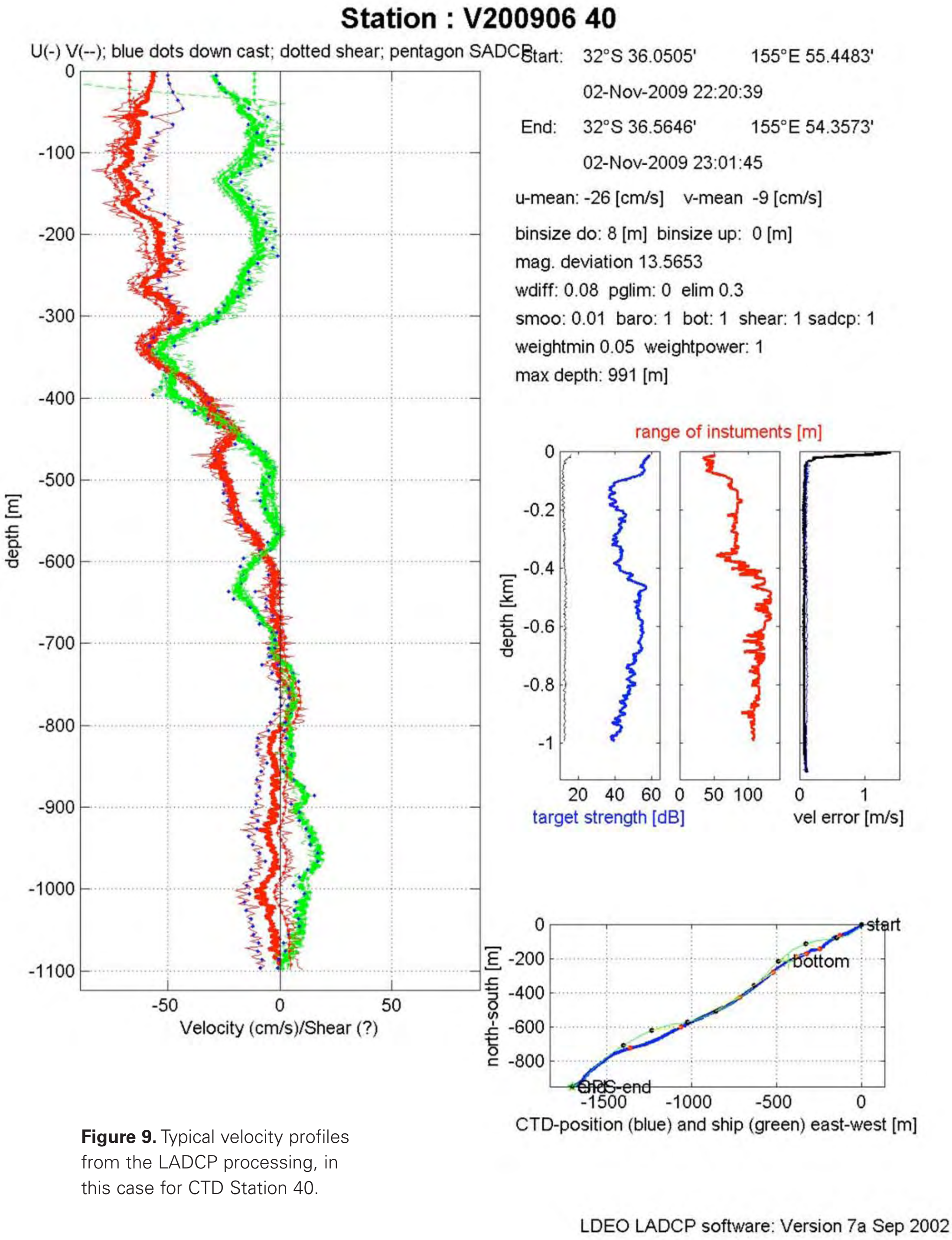

Figure 9. Typical velocity profiles from the LADCP processing, in this case for CTD Station 40.

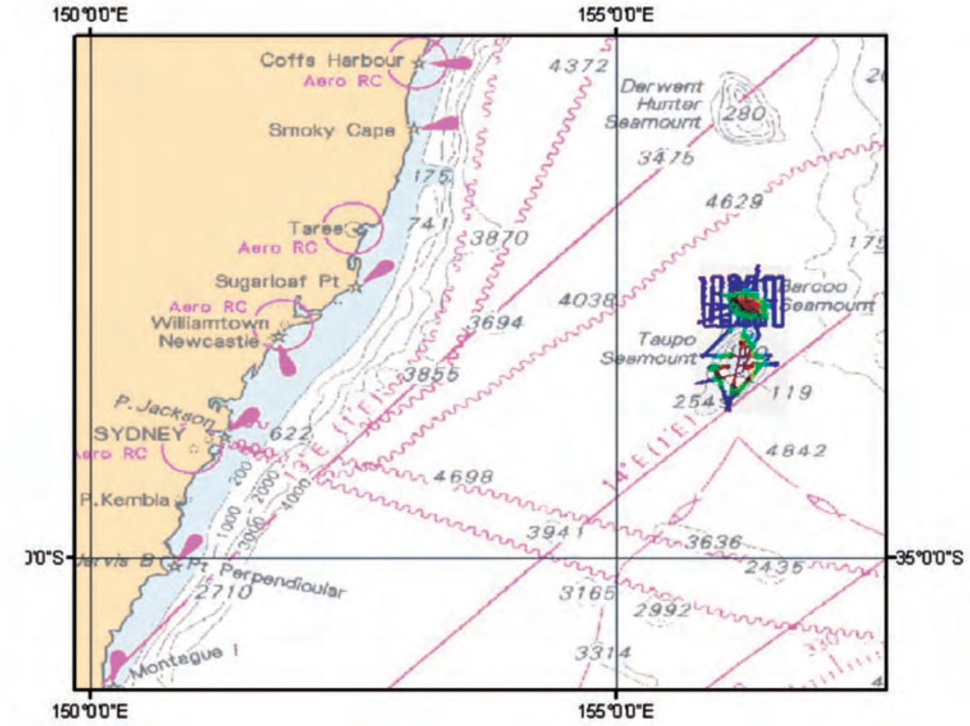

Figure 10a. The locations of the ship's track relative to the Taupo and Barcoo Seamounts, and the general positioning relative to the Australian coastline.

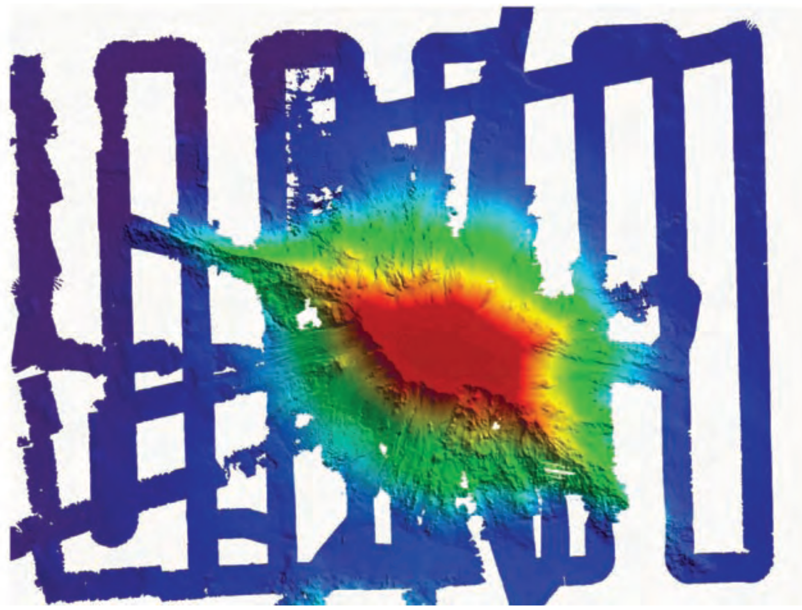

Figure 10b. Te topography of Barcoo Seamount as depicted in colour and shading by the Kongsberg Simrad EM 300 multibeam echo sounder. The nominal sonar frequency is 30 kHz.