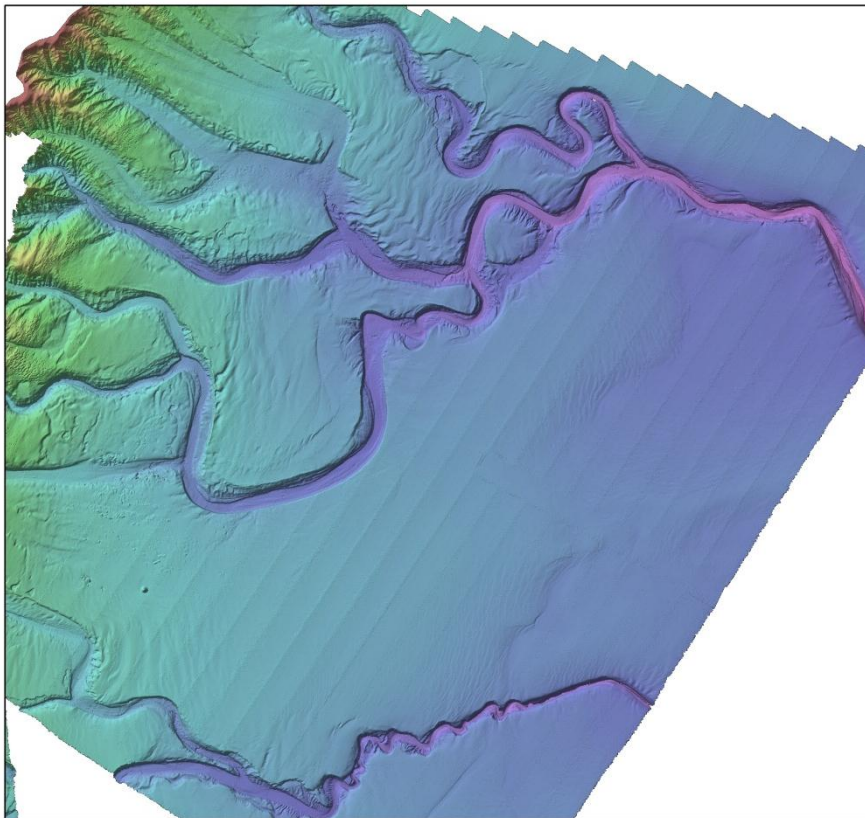


OS20/20 Canterbury - Great South Basin
TAN1209 Voyage Report

Prepared for Land Information New Zealand

September 2012



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Cover Image: Sun-illuminated DEM of the parts of the Otago Fan Complex and Northern and Central Channels of the Bounty system.

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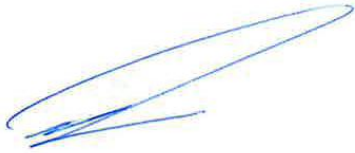
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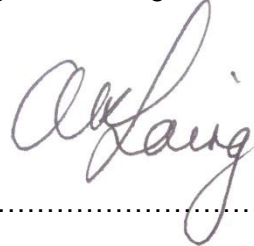
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General Manager Marine Business Services



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Executive summary

This survey was undertaken with the intention of collecting data across the head of the Bounty Trough and Otago Canyons to act as a base survey for future voyages to determine the biodiversity of the area and to analyse the detailed geomorphic expression of tectonic and sedimentary processes.

Funding for the *Tangaroa* sea days for this project were allocated out of the 2012/13 OS20/20 program. The funds for the science personnel, equipment and data processing were made available out of NIWA's core science funds and from a separate contract with Shell GSB Ltd.

The initial plans for the project were to survey approximately 21,000 km² of seafloor. At the completion of the survey new data had been acquired over the planned area plus an additional area to the north resulting in ~23,000 km² of new data.

The multi-beam data collected document the seafloor including portions of the Otago Fan Complex, and North, Centre and South Channels - tributaries associated with the Bounty Channel and Fan System, and associated levee structures. This network of canyon-fed channels has been previously documented, but the detail afforded by multi-beam coverage was hitherto unknown.

The survey documents:

- the narrow v-shaped canyon heads of the Otago Fan complex progressing into broad U-shaped canyons,
- the entrenched (250 m) sinuous North, Centre and South Channels with asymmetrical convex levees and associated sediment wave fields, low relief mounds or terraces, outer bank and point bars, and gully erosion features,
- the occurrence of cut-off or abandoned meanders suggesting that when active the channel-levee system is evolving through time,
- pockmarks predominately on the northern levees up to 200 m across and exhibiting 20 m relief.

1 Introduction

In November 2004, Cabinet agreed to establish Oceans 20/20 as a 15 year project with the following vision:

“Complete by 2020 an ocean survey that will provide New Zealand with the knowledge of its ocean territory to:

- *demonstrate our stewardship and exercise our sovereign rights;*
- *conserve, protect, manage and sustainably utilise our ocean resources; and*
- *facilitate safe navigation and enjoyment of the oceans around New Zealand.”*

It was also agreed that the scope of the OS20/20 project would cover:

- *Geographic area: the exclusive economic zone, the continental shelf, the Ross Sea region; and (as a secondary focus) South Pacific islands within the realm of New Zealand;*
- *Physical zones: subsurface, sea-floor, water column and atmosphere; and*
- *Information and Inventory Supporting: minerals exploration, fisheries, maritime safety, oceanographic science (incl geological hazards), protection, conservation, resource management and where appropriate recreation and tourism;*

Projects and objectives were developed with input from multiple agencies, research providers, and other relevant parties under the following themes:

1. sovereignty, stewardship, security and management;
2. maritime safety;
3. natural hazards and risk management;
4. fishing and aquaculture;
5. biodiversity and ecosystems;
6. minerals, hydrocarbons and other physical resources; and
7. climate.

In terms of these original themes this project covers aspects of 3, 4, 5 and 6. Numerous science disciplines including marine biodiversity, marine geology processes, and physical oceanography will benefit from these datasets. The dataset will cover areas of interest to the petroleum industry and so will contribute to petroleum exploration and gas hydrate research.

Funding for the *Tangaroa* sea days for this project were allocated out of the 2012/13 OS20/20 program. The funds for the science personnel, equipment and data processing were made available out of NIWA's core science funds and from a separate contract with Shell GSB Ltd. Four days out of a total of 18 were allocated to the survey of the Shell 3D box.

2 Voyage Plan

2.1 Background

The proposal was to conduct a multi-beam survey of parts of the Canterbury and Great South Basins (head of Bounty Trough), as shown on the map below (Figure 1).

The current government is keen to encourage oil exploration and production, and has already invested a significant amount of money to support seismic surveys of this area for hydrocarbons. Four blocks have been permitted for exploration in the area; 38264 and 38262 in the Canterbury Basin, and 50120 and 50119 in the Great South Basin.

The area has not been extensively surveyed using modern multi-beam technology, with only a few transit lines and an opportunistic survey of the shallower portions of some canyons. The seafloor in the area has very rarely been directly (using corers, sleds, dredges etc.) or indirectly sampled (using drop or towed cameras). The vast majority of sampling has occurred on the nearby shelf and the heads of canyons, with only the occasional sampling station located on the slope and trough (Figure 2). Very little to nothing is known about the biodiversity of the area or the physical characteristics of the predominant deep-sea habitat (canyon-incised slope at the head of a large ocean trough).

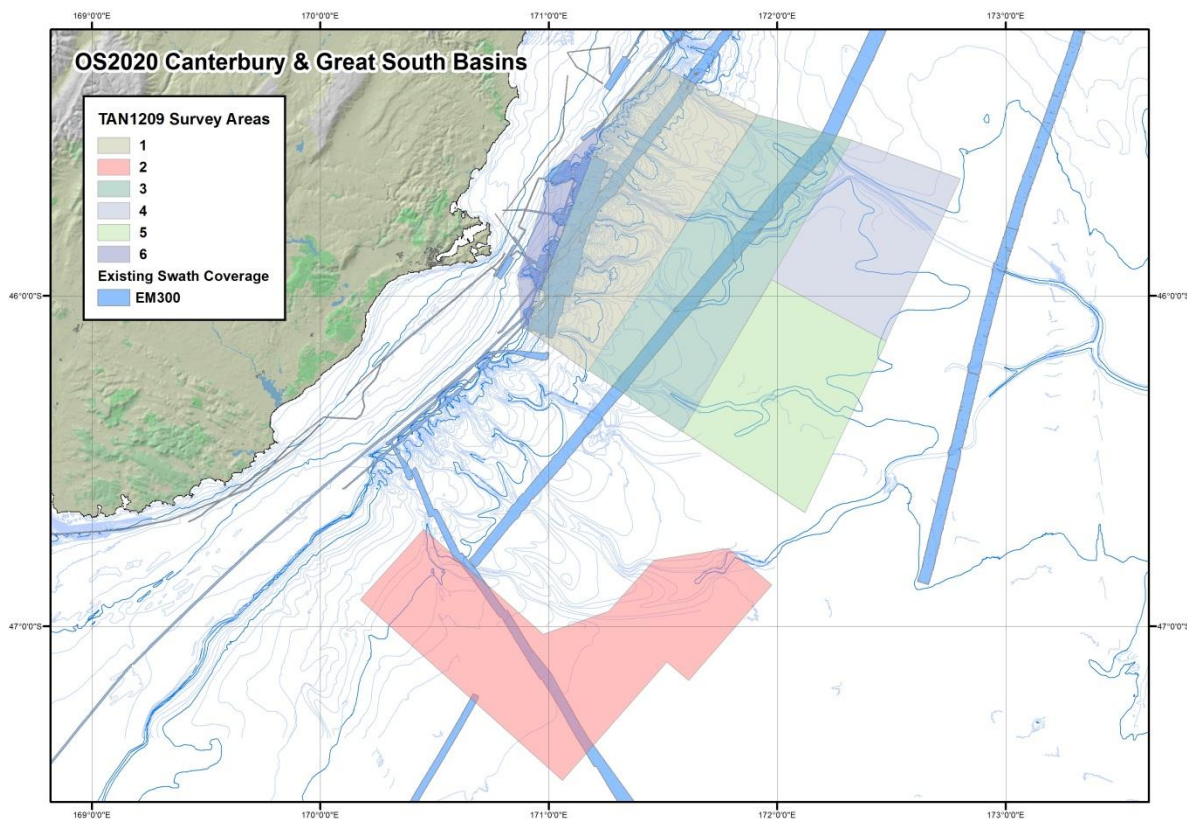


Figure 1: Proposed survey extent and priority areas for OS20/20 Canterbury - Great South Basin Mapping.

The completed survey, mapping the area using multi-beam provides a physical context for any planned exploratory oil drilling in the future, and the planning of any future oil platform installations.

Data from the multi-beam survey will also provide morphologic data (bathymetry which can be used to describe seafloor topography and backscatter which is indicative of sediment type) which can be used to generate a classification of the seafloor environment.

The logical next stage of the project will involve the collection of samples for a biodiversity assessment to be used to establish an environmental baseline, evaluate the potential environmental effects of any oil drilling, and to draw up monitoring or spatial management guidelines specific to the area.

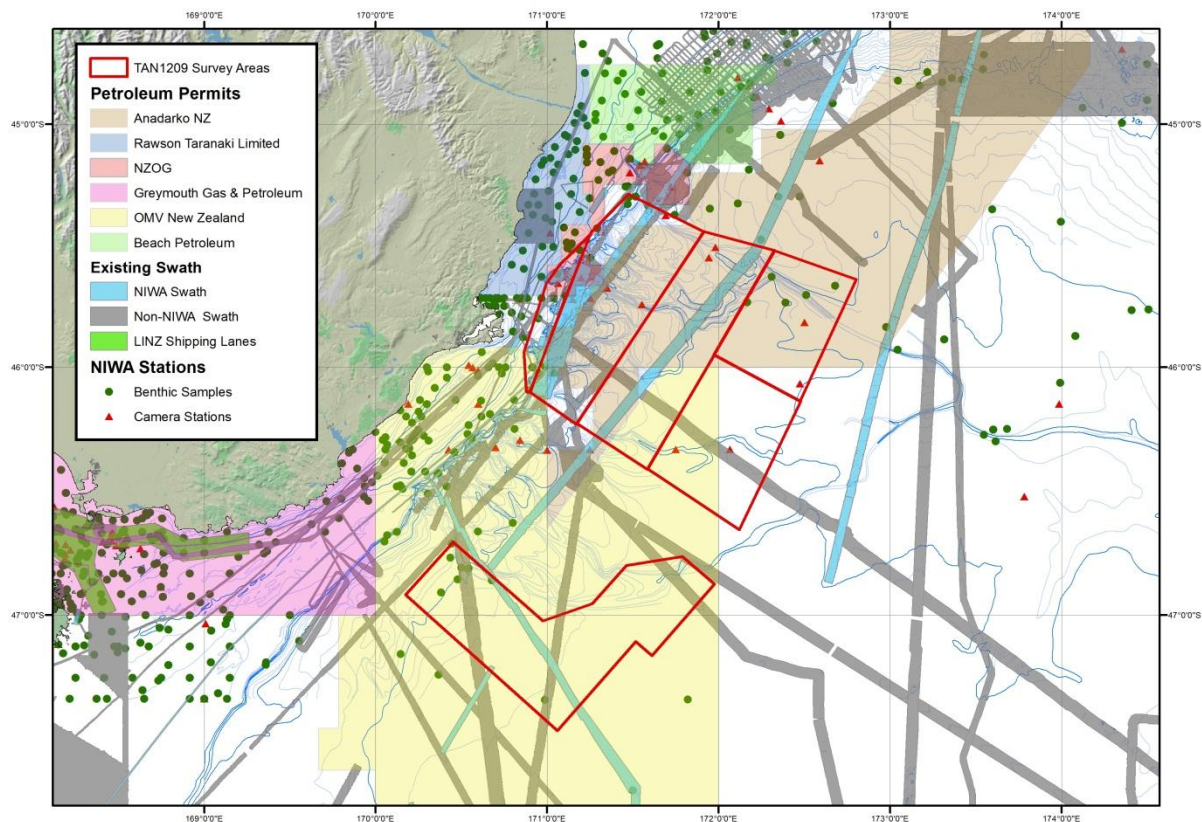


Figure 2: Petroleum permit areas, NIWA stations (camera & bottom samples) and existing multi-beam coverages prior to the survey (high resolution 30 kHz (EM300/302), low resolution 12 kHz and LINZ shipping lane swath), overlain by survey areas.

2.2 Objectives

The overall purpose of the Canterbury and Great South Basins voyage was to complete high resolution multi-beam mapping of the head of the Bounty Trough and the Otago Canyons to act as a base survey for a future voyage to determine the biodiversity of the area and to analyse the detailed geomorphic expression of tectonic and sedimentary processes.

These objectives included

- obtain a full coverage, high resolution, multibeam bathymetric map of parts of the Canterbury – Great South Basin area and combine it with existing high resolution 30kHz multi-beam data into a single coverage.
- process new multibeam backscatter data and combine it with existing high resolution 30kHz multi-beam data into a single coverage.
- collect 3.5 kHz seismic reflection data on all ship tracks.

2.3 Voyage Schedule

The OS20/20 vessel days for 2012/13 were divided amongst two programs, with the Canterbury – Great South Basin voyage allocation being 18 days

Voyage Number	TAN1209	
Vessel	<i>RV Tangaroa</i>	
Duration	18 days	
Departure	30 June 2012	1800
Return	18 July 2012	1300
Personnel	John Mitchell (Voyage Leader)	NIWA
	Peter Gerring	NIWA
	Alan Orpin	NIWA

2.4 Voyage Narrative

Tangaroa departed for the survey area at 1800 Saturday 30th June 2012 arriving at 2130 1st July. After the completion of an initial sound velocity profile (SVP) surveying commenced. Survey speed is normally held to 8 knots but due to the calm weather experience during most of the survey period this was increased to 10knots (Figure 3).

After completion of an initial line along the seaward end of Area 1 at 0100 2nd July the vessel transited to the southern Area 2 box arriving at 0845. Surveying commenced with the collection of an SVP. Additional SVPs were collected as changes in water properties (mainly temperature) effected the data quality (Figure 4). This area was surveyed in 3 discrete blocks. This staged approach ensured each block was completed before moving on to the next in case bad weather forced abandonment of the area before the work could be completed. The data collection continued in good weather with calm seas until completed and the vessel returned to the northern OS2020 survey area arriving 0300 6th July.

The survey work in the northern block commenced with the areas completed in the order of Area 1, Area 3, Area 4 and Area 5. SVPs were collected as on an irregular basis as changes

in water properties indicated they were required. Once the main survey blocks were completed the vessel moved inshore to Area 6 to complete the survey of the canyon heads in areas partly covered by earlier NIWA voyages. The collection of canyon head data was stopped once evidence of canyon structures ended on the shelf in 80-150m of water. The good weather experienced throughout the survey resulted in the planned areas being completed by 0300 16th July leaving approximately 30 hours of survey time remaining.

It was decided to utilise the remaining hours to complete the survey of the upper sections of the Waitaki Canyon. This survey was completed by 0900 17th July and the *Tangaroa* departed for Wellington.

An additional short line (<1 hour) was collected near to Wellington in the southern Cook Strait to fill a small gap left in the data coverage during the previous year's OS2020 Southern Hikurangi survey. The vessel arrived alongside Aotea Quay at 1300 on 18th July 2012. Demobilising was completed and the vessel cleared by 1600 the same day.

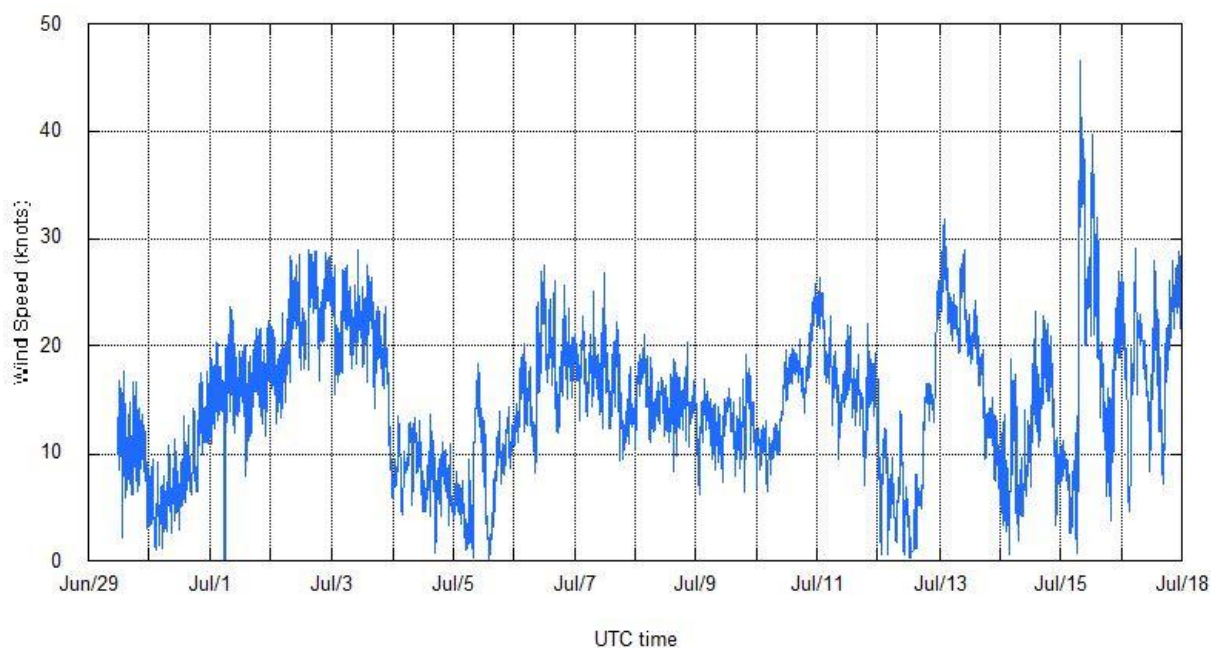


Figure 3: Wind speed (2 min average) experienced during the survey. Average wind speed less than 15 knots.

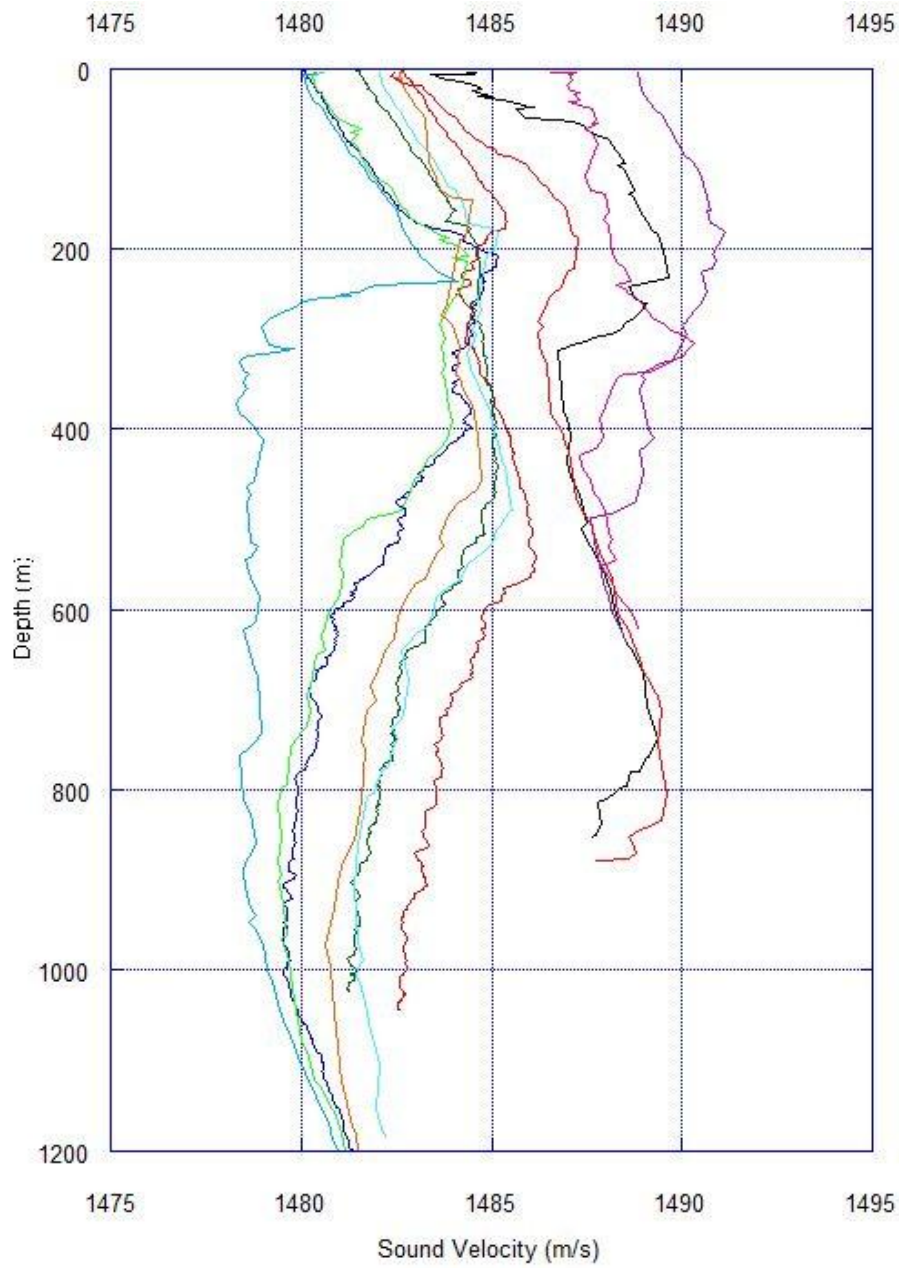


Figure 4: Representative Sound Velocity Profiles collected across the survey area.

3 Equipment

3.1 Navigation

The primary positioning system used was the position derived from the forward Applanix POS/MV GPS Antenna, differentially corrected by the Fugro SeaStar XP Wide Area Differential GPS (WADGPS) service.

The differential corrections consist of pseudo-range corrections generated by the Fugro SeaStar XP WADGPS system. These corrections were uplinked through a Fugro monitoring station and received on board the vessel via the Pacific Ocean Region (POR) satellite.

Analysis of the system accuracies and survey conditions indicate the positioning accuracy of Order 1 horizontal accuracy standards were met or exceeded (Appendix 1).

3.2 Kongsberg EM302 Multi-beam

The Kongsberg EM302 multi-beam echo sounder, centred on 30 kHz was used throughout the survey. The multi-beam was operated to obtain the maximum swath width with a maximum beam angle of 65°/65° apart from a few periods in shallow water where the beam angle was further widened. The Kongsberg EA600 single-beam sounder operating on 12 kHz was run throughout the survey.

The Kongsberg EM302 multi-beam echo sounder and Seafloor Information System (SIS) software were used for data acquisition.

The EM302 multi-beam worked well in all depths experienced during the survey from the shallow part of the survey in 100m to the maximum depth of around 2000m. Swath widths of up to 4.5km were accomplished.

Error sources for the multi-beam bathymetry are summarized in Appendix 1. Most errors are predictable and easily corrected for with the exception of sound speed. The predictable errors are normally accounted for by a patch test of the system prior to the start of surveying. *Tangaroa* was fitted with a new EM302 in August 2010 and a full patch test completed in December 2010. A further patch test was completed on 2nd – 3rd July 2011 prior to the vessel's departure for a Papua New Guinea survey with a partial test in tropical waters 1st August 2011 (Appendix 2).

The unmeasured change in sound speed through the water column is unpredictable and can potentially result in significant depth and positioning errors. This error source is mitigated through continually monitoring the bathymetry data for evidence of sound speed artefacts during sounding operations. The surface sound speed is continuously measured and used to calculate departure angles at the transducer and are also used as an indicator of sound speed changes throughout the water column.

SVP profiles were planned to be collected whenever a change in velocity was observed. The nature of the water masses in the survey area were such that relatively large scale variations in water temperature were observed both alongshore and offshore. SVP profiles were required to adjust for velocity errors caused by these changes. Despite this there is still some evidence of velocity error in the outer sectors of the data especially over areas of very flat seabed.

Heave and attitude were provided by an Applanix POS/MV 320 motion sensor on *Tangaroa*. The POS/MV generates attitude data in three axes. Measurements of roll, pitch, and heading are accurate to 0.02° or better (manufacturer's specifications) regardless of the vessel's latitude. Heave measurements supplied by POS/MV maintain an accuracy of 5% of the measured vertical displacement or ±5cm (whichever is the larger) for movements that have a period up to 20 seconds (manufacturer's specifications). No significant heave artifacts were observed in the processed data helped by the good weather experienced for most of the time.

Analysis of the system accuracies and survey conditions indicate the multi-beam accuracy of LINZ MB-1 accuracy standards were met with the caveat of the non-application of tidal reductions (Appendix 1).

3.3 3.5 kHz Sub-bottom Profiler

The 3.5 kHz system is a hull-mounted system on *Tangaroa* controlled by a Knudsen Chirp 3260 sub-bottom profiler. It consists of the Knudsen transceiver and 16 transducers in a 4x4 array, mounted inside a sea-chest, pinging directly through the hull. The 3.5 kHz system was run during the full voyage in conjunction with the swath system. The system is heave-compensated in real-time to improve data quality. All data were recorded to disk in proprietary *.keb format.

The resulting 3.5 kHz data showed varying degrees of sub-bottom structure up to 50m below the seafloor depending on seabed conditions and slope. The data collected can be viewed using Knudsen PostSurvey software.

4 Survey Data

4.1 Multi-beam Data

The Kongsberg EM302 multi-beam echo sounder and SIS software were used for data acquisition. SIS was used to display the previous sounding coverage as well as the current sounding coverage and was used to provide planning and navigation for the data acquisition and bridge personnel. Raw data files were then exported into CARIS for processing and cleaning.

To ensure the intended survey area was completed in the available time, overlap between lines was kept to a minimum and vessel speed as close to 10 knots as possible. As a result the vessel's acoustic noise was greater and the outer beams noisier which had an impact on the visual appearance of the bathymetry coverage and accuracy of the depth data in the outer beams.

Water column data were collected on all lines concurrently with the bathymetry. These data were logged to a separate file for later examination in CARIS HIPS &/or Fledermaus Midwater.

All data collected by *Tangaroa* were backed up at the end of each line to an external on-board mass storage device and then transferred to NIWA Greta Point on the vessel's return.

Survey datum for the bathymetry data is Mean Sea Level (MSL).

4.1.1 On-board Processing

The raw Kongsberg EM302 data were imported into CARIS HIPS V7.1 software for initial processing.

Two field-sheets were created, one for the northern survey area and the other for the southern area.

The bathymetry data were examined and cleaned in CARIS HIPS initially with the swath editor, then gridded using the CUBE surfacing tool and final cleaning completed using the CARIS subset editor. Minimal cleaning of the data was required due to the good weather and calm seas experienced during acquisition. CUBE process was then rerun to produce a digital terrain model of the survey area gridded at 20m. A 5x5 nearest neighbour interpolation was then run to fill in any insignificant holes in the resulting DTM (Figure 5).

The backscatter data (strength of return signal) was extracted from the raw data using CARIS HIPS Mosaic editor producing a simple GeoBar for each line with a 10m grid resolution. Imagery data processed in Mosaic Editor is stored as **Georeferenced, Backscatter Rasters**, or GeoBaRs. These images were then mosaicked using an Auto-Seam method. This method determines which pixels have higher significance when there is overlap. A backscatter mosaic with 20m resolution was produced. A 5x5 nearest neighbour interpolation was then run to fill in any insignificant holes in the resulting mosaic (Figure 6).

The surfaces images were then exported to ESRI ArcMap v10 GIS for plot production.

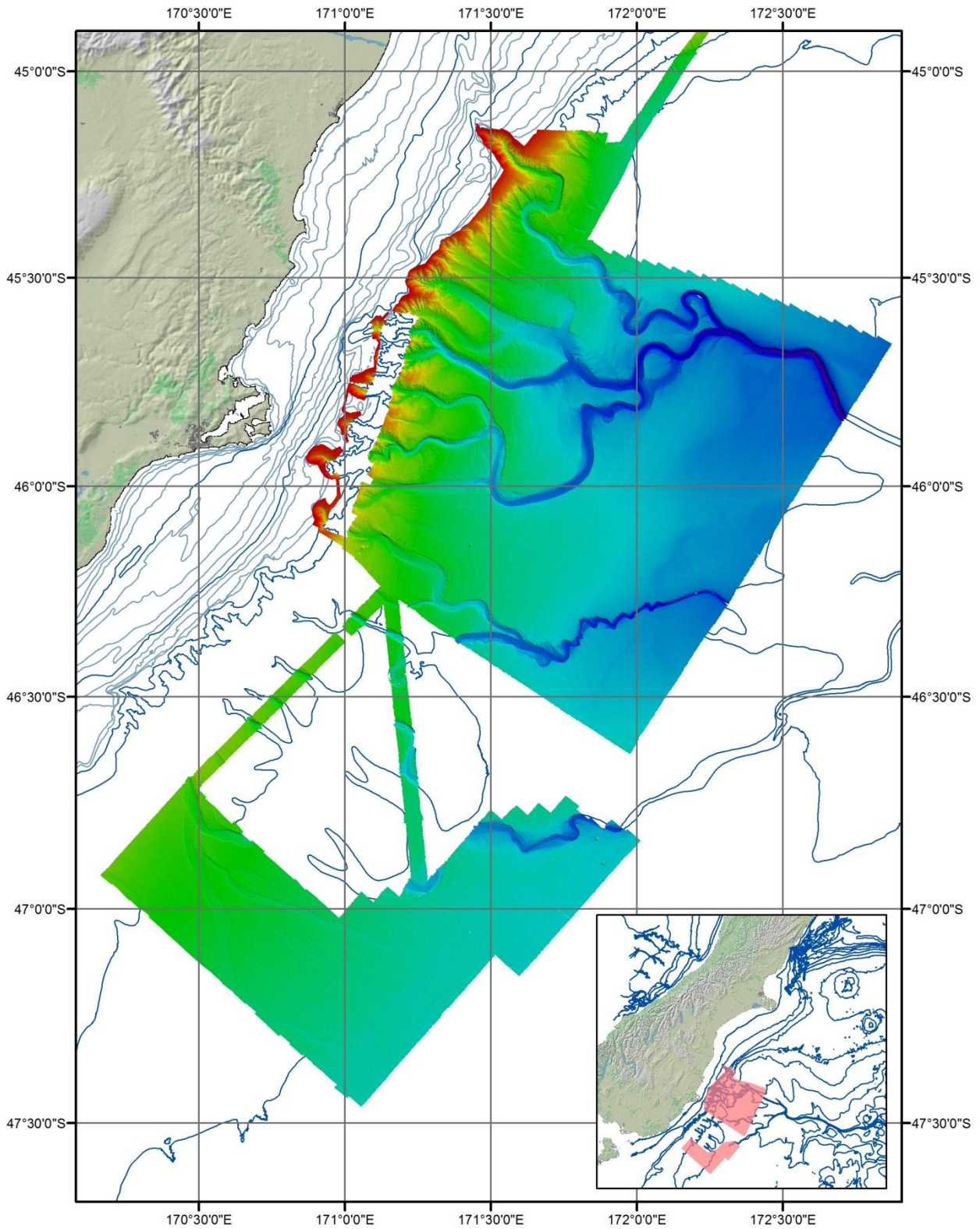


Figure 5: Ship-board processed bathymetry data.

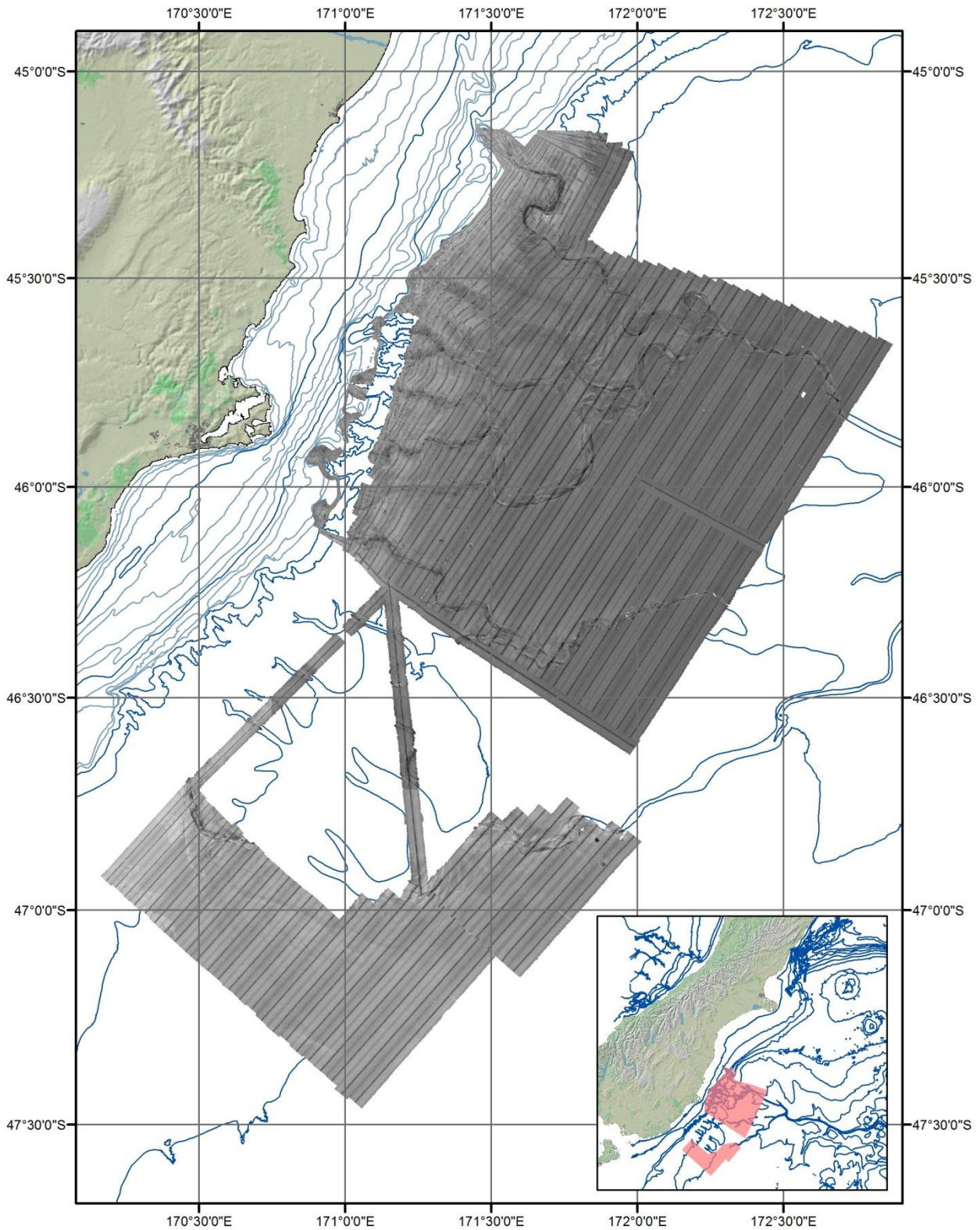


Figure 6: Ship-board processed backscatter data showing a very strong specular return at nadir.

4.1.2 On-shore Processing

Multi-beam

No further cleaning of the bathymetry data was required on-shore.

In ArcMap a NIWA tool was run to convert the ascii xyz grid into ESRI grid and from that various end products were produced. These include DTM, hillshade, sun illuminated tiff (Figures 7 & 8), and 50m contour coverages (Figure 9). Additional data from several earlier *Tangaroa* science voyages were included in the final grid to complete the multi-beam mapping of the survey area (Figure 10).

These data have been processed following recognised hydrographic methodology to enable the provision of this report.

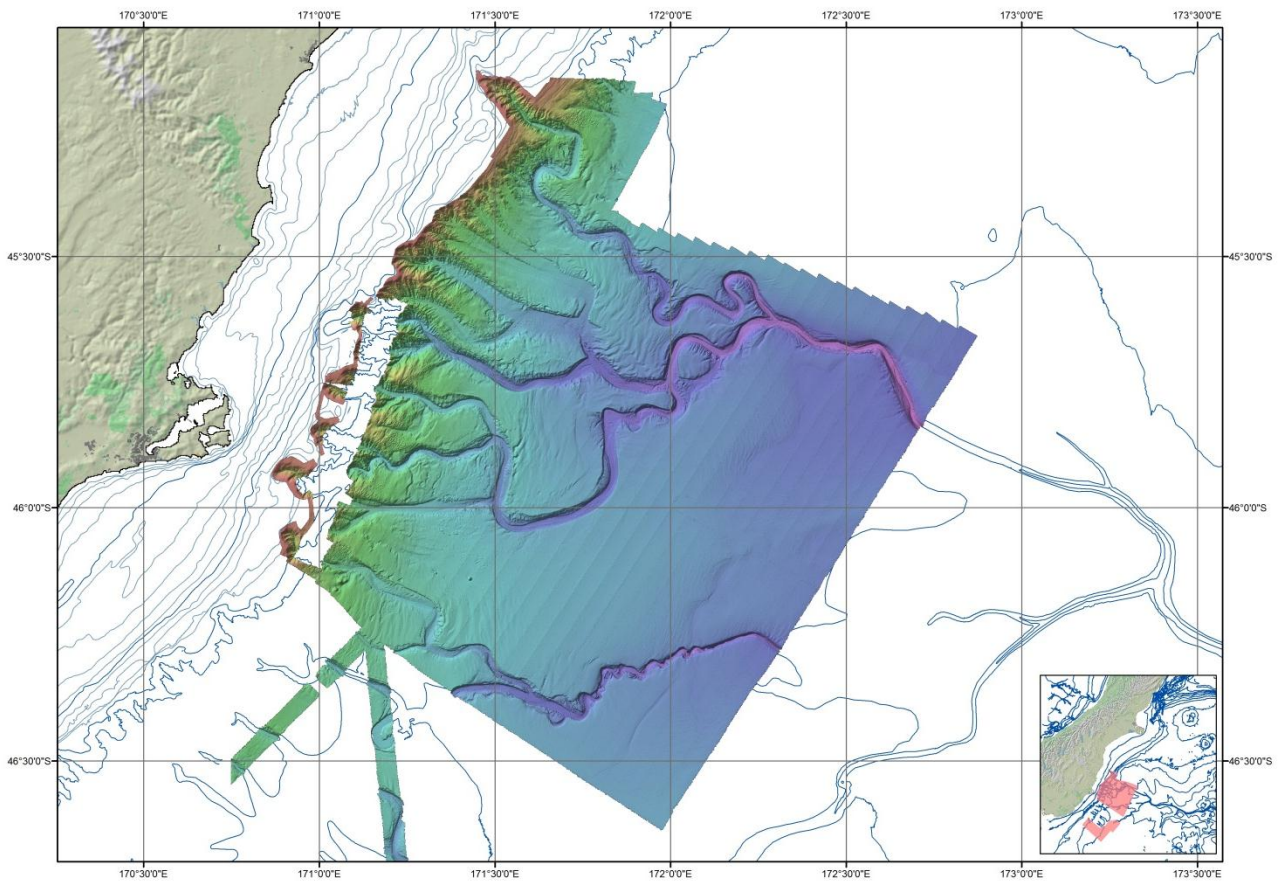


Figure 7: Sun illuminated tiff of the northern survey area. 5x vertical exaggeration. Local colour ramp 100-1950m.

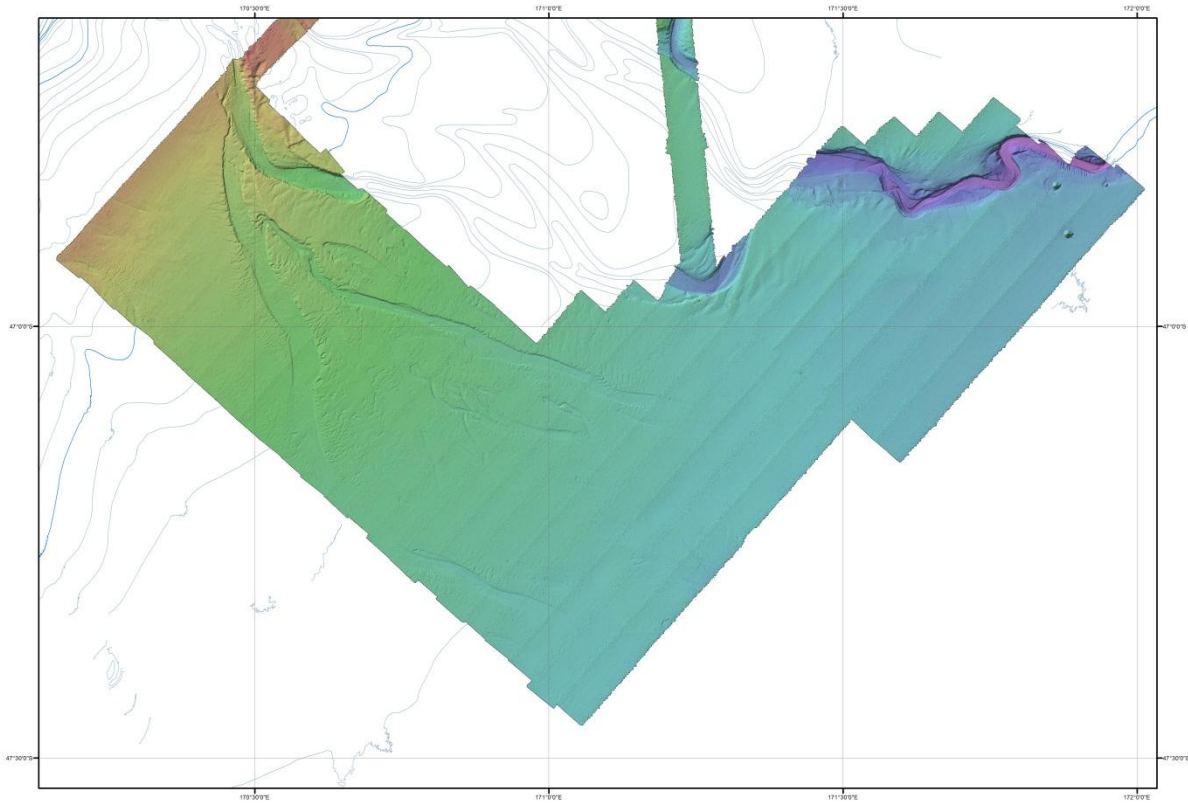


Figure 8: Sun illuminated tiff of the southern survey area. 5x vertical exaggeration. Local colour ramp 750-1650m.

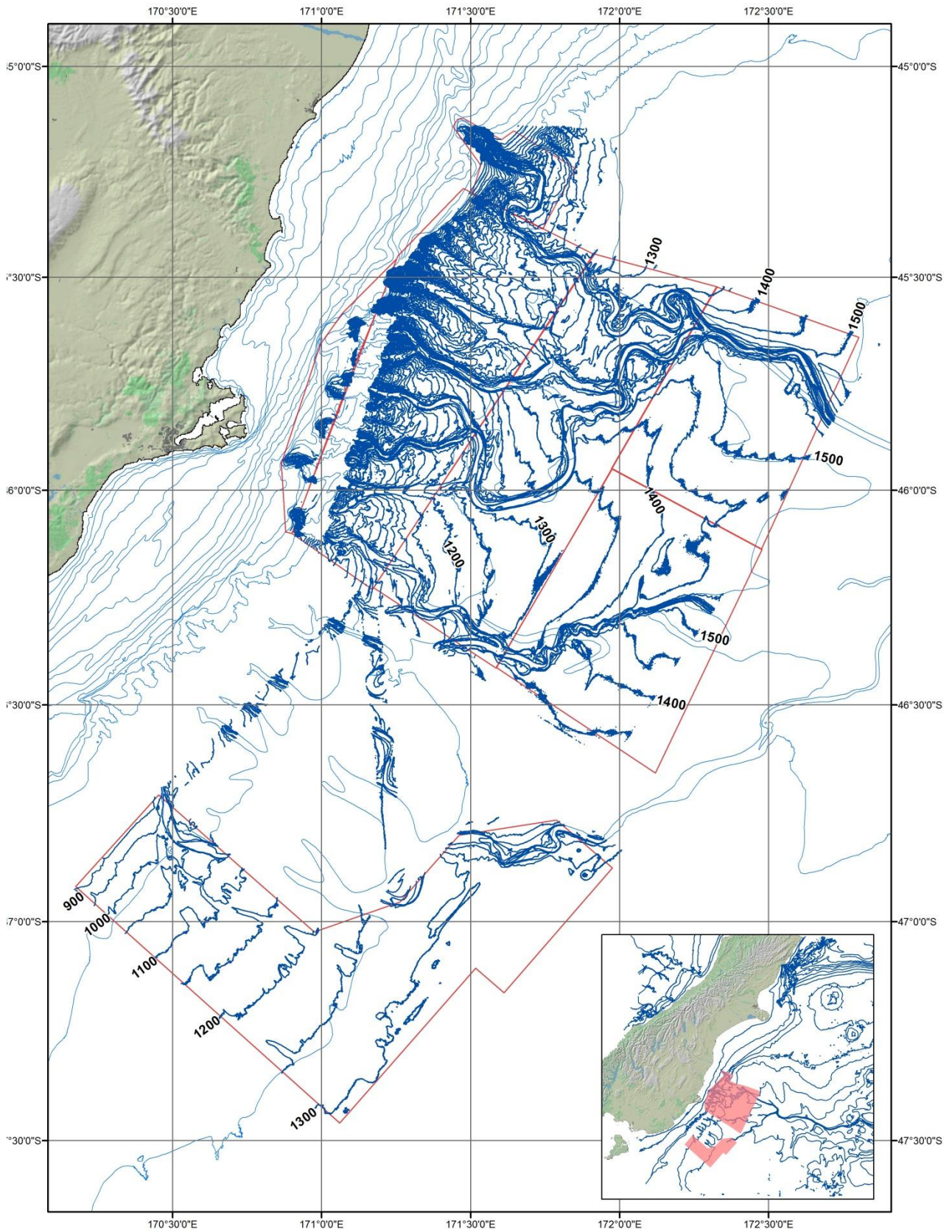


Figure 9: 50m contours derived from new multi-beam data. Underlying contours are those from existing data prior to this survey.

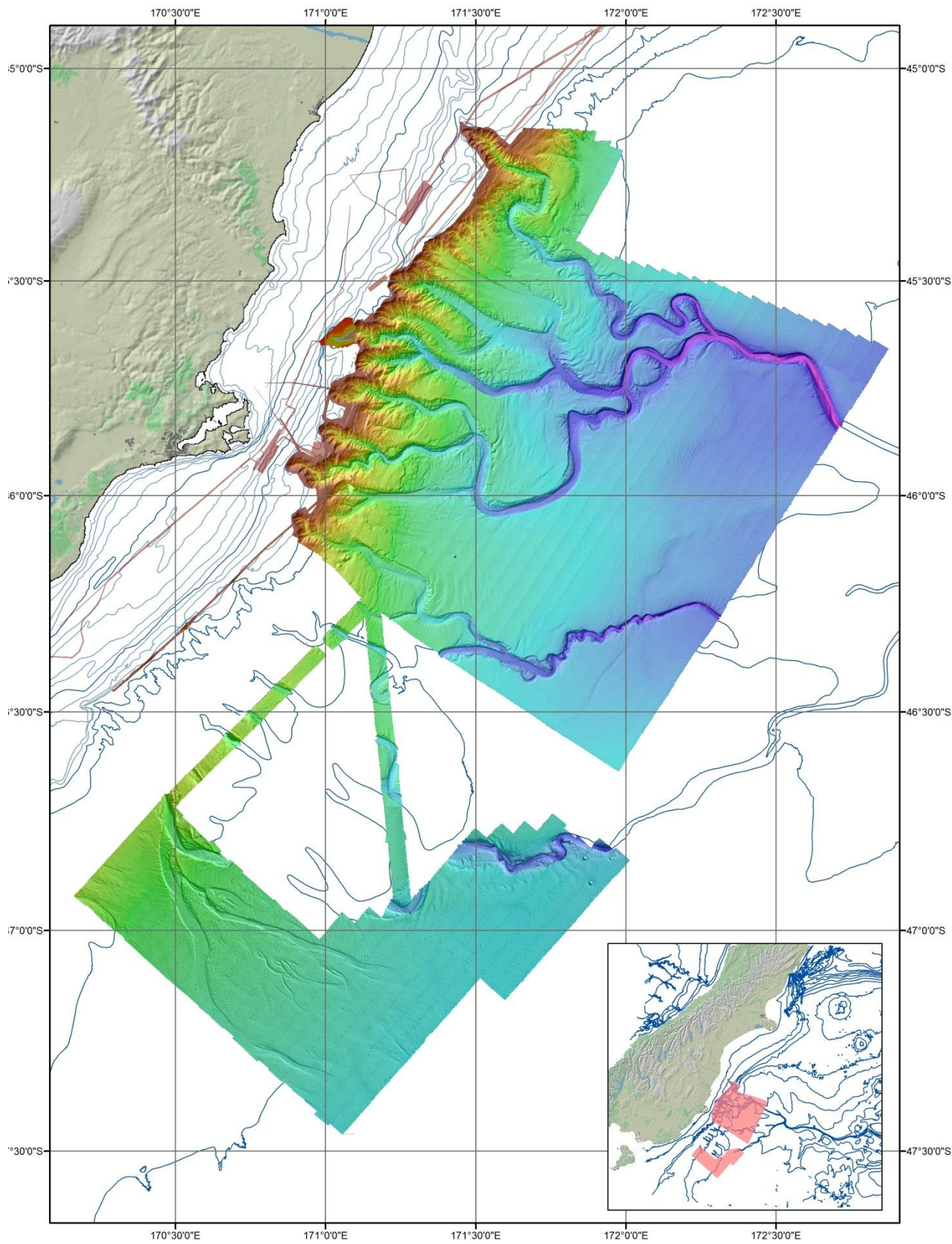


Figure 10: Sun illuminated tiff of the entire survey, with additional science voyages included. 5x vertical exaggeration.

4.2 3.5kHz Sub-bottom Data

The sub-bottom data obtained by the 3.5 kHz system is logged on board in proprietary Knudsen (*.keb) format. These files can be viewed (Figures 11, 12 & 13) using Knudsen PostSurvey software Version 2.70 which can be downloaded from <http://www.knudsenengineering.com/html/software/postsurvey.html>

Preliminary processing of this data involved the conversion of the keb files to a Seg-Y format using the Knudsen Seg-Y conversion program. The resulting Seg-Y files were then run through a software suite produced by Geological Survey of Canada, Atlantic Geoscience Centre (GSC, Atlantic), (Figures 12 & 13).

The three stage process is

- Combine_SegY to merge Seg-Y files into 12 or 24 hour data blocks
- SegyJp2 program convert the combines files into jpeg 2000 format. This also adjusts for phase window shifts in the raw data.
- SegyJp2Viewer to view the resulting jpeg 2000 and commence horizon interpretation the results of which can then be exported as shape files into ArcGIS.

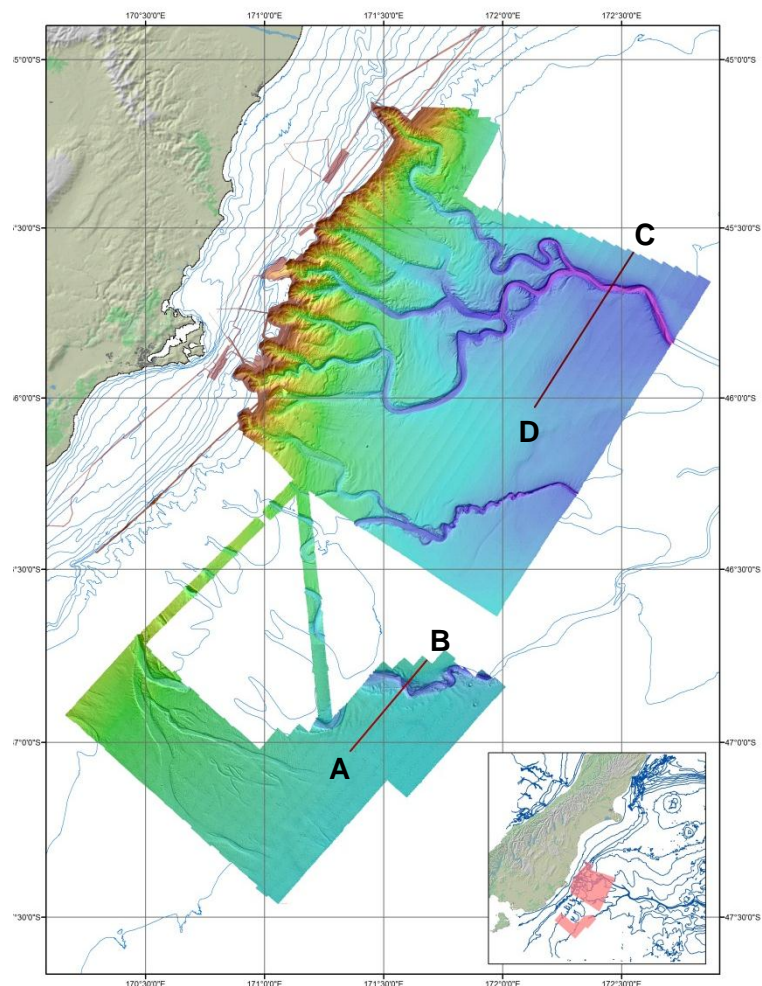


Figure 11: Location of example 3.5 kHz lines.

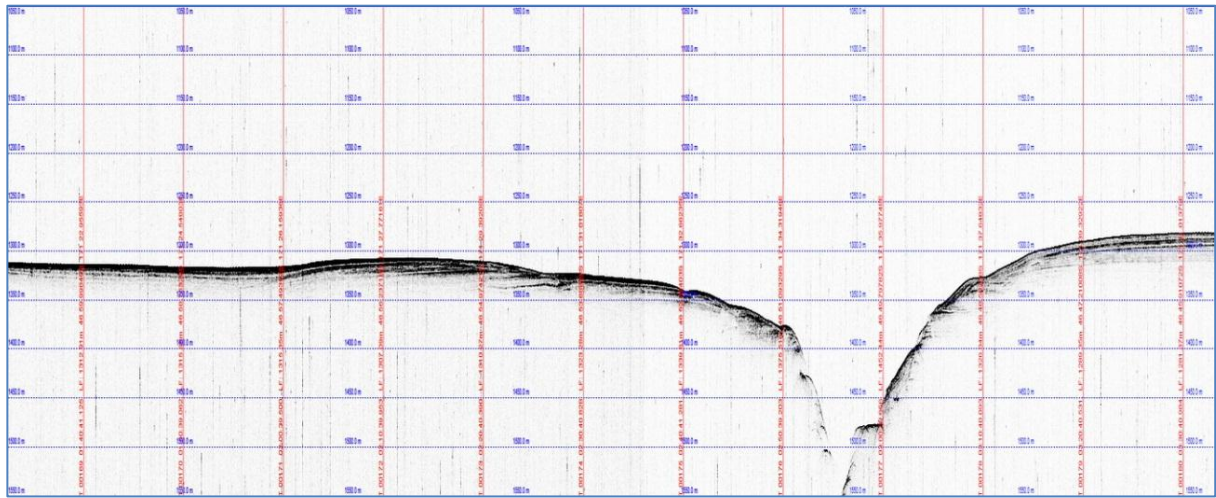
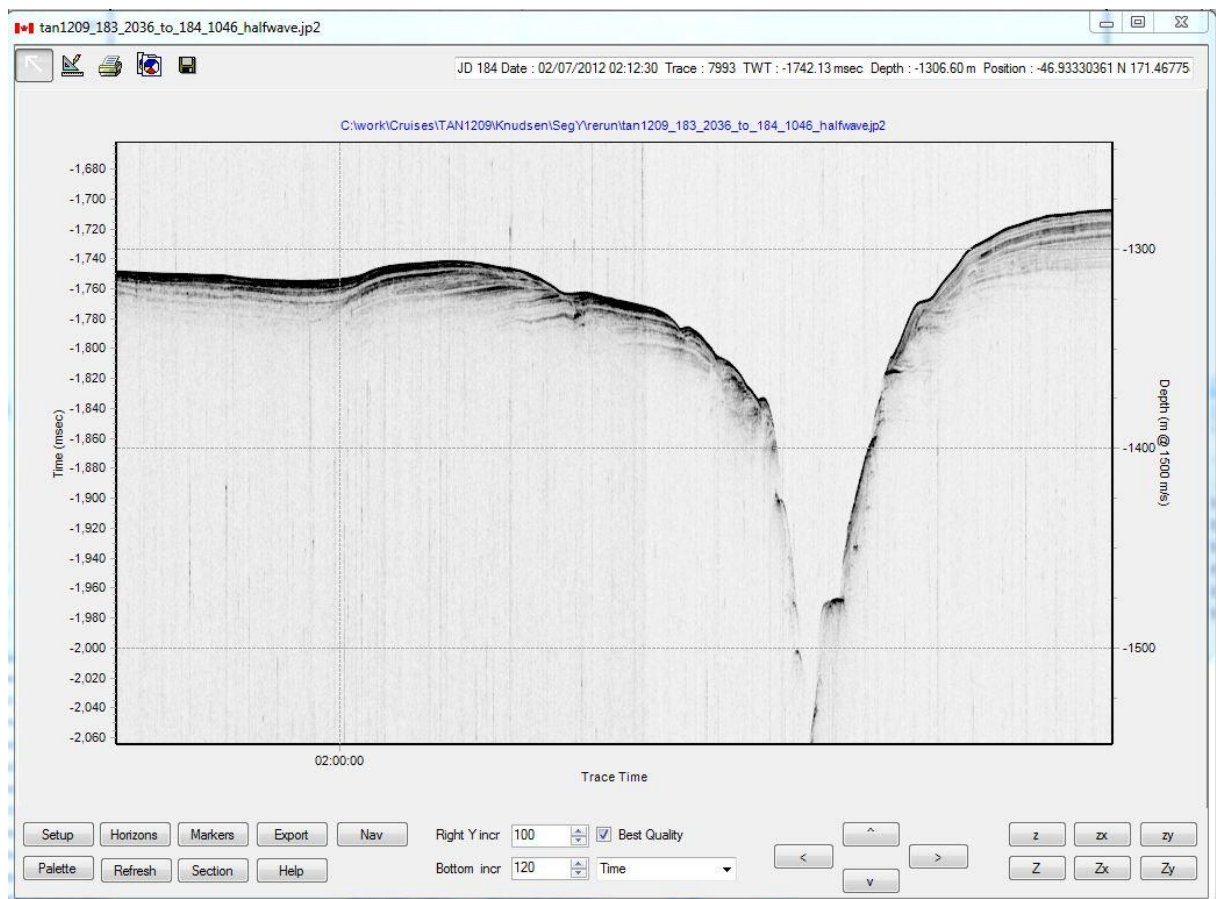
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Figure 12: Example 3.5 kHz data from southern block. Top panel raw keb file format viewed in Knudsen software, bottom panel same data after preliminary processing in GSC software.

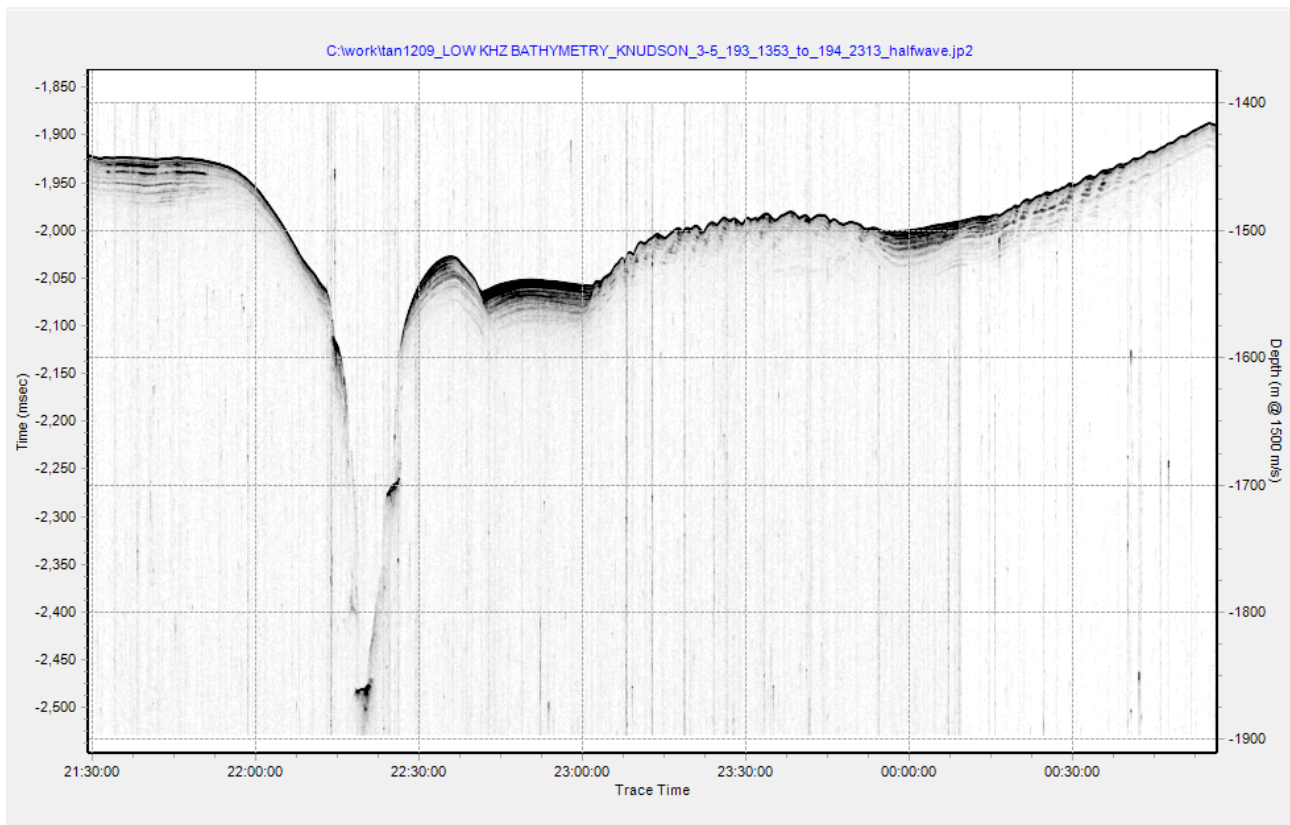
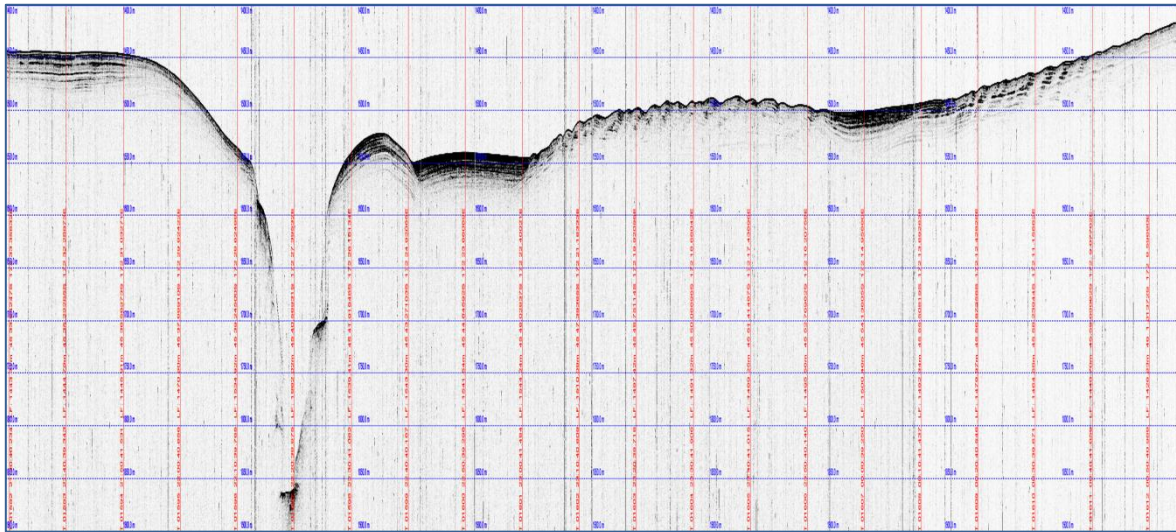
C**D**

Figure 13: Example 3.5 kHz data from northern block. Top panel raw kebf file format viewed in Knudsen software, bottom panel same data after preliminary processing in GSC software.

5 Preliminary Results

This survey was undertaken with the intention of collecting data across the head of the Bounty Trough and Otago Canyons to act as a base survey for future voyages to determine the biodiversity of the area and to analyse the detailed geomorphic expression of tectonic and sedimentary processes.

The initial plans for the project were to survey approximately 21,000 km² of seafloor. At the completion of the survey new data had been acquired over the planned area plus an additional area to the north resulting in ~23,000 km² of new data.

The multi-beam data collected document the seafloor including portions of the Otago Fan Complex, and North, Centre and South Channels - tributaries associated with the Bounty Channel and Fan System, and associated levee structures (Figure 14). This network of canyon-fed channels has been previously documented, but the detail afforded by multi-beam coverage was hitherto unknown.

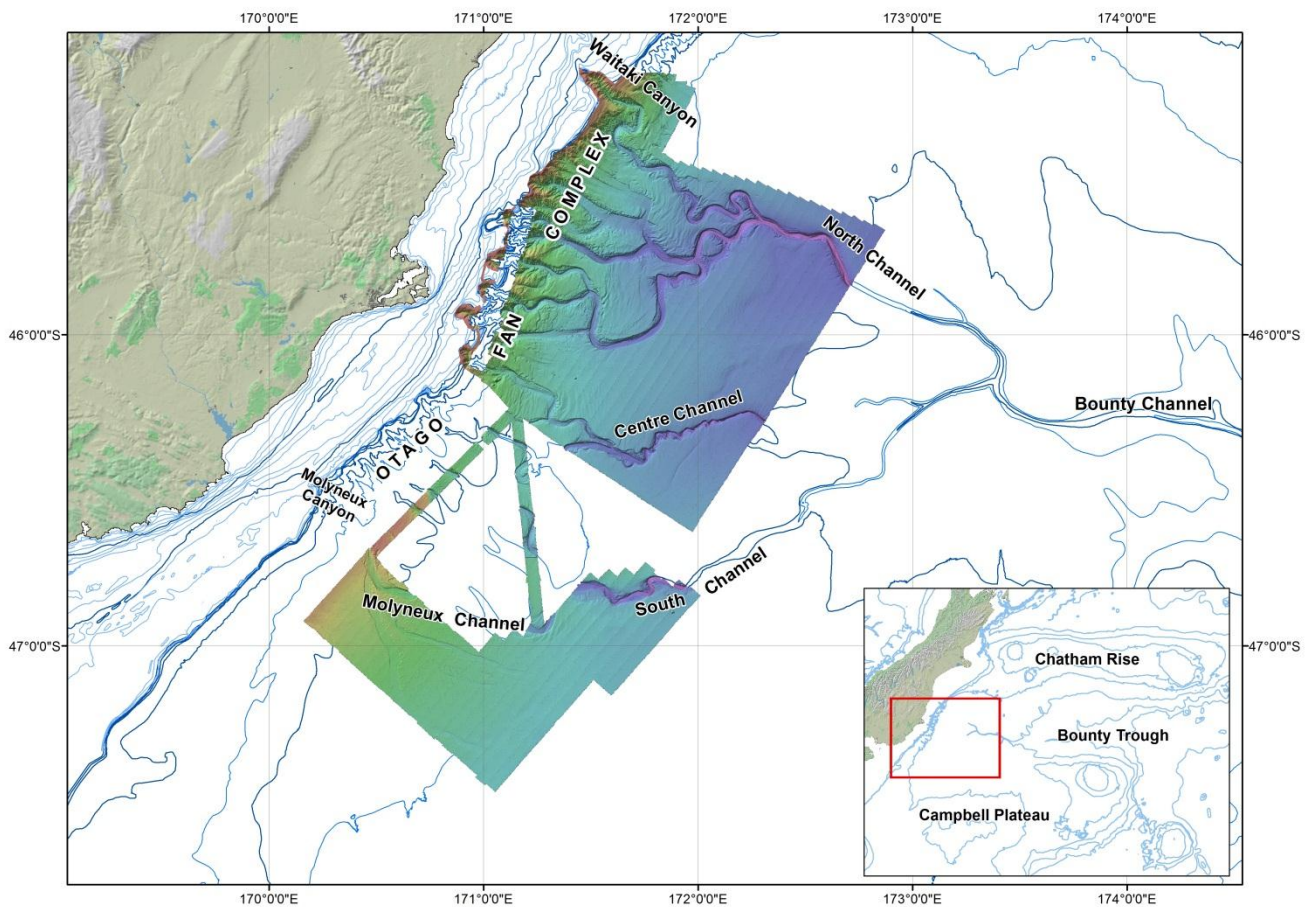


Figure 14: Location of the survey area within the wider Bounty Trough region.

5.1 Submarine canyon system – Bounty Trough

The larger Bounty Channel and Fan System is located within the Bounty Trough and comprises the Otago Fan Complex, which feeds the axial Bounty Channel, which in turn flows onto the abyssal depth Bounty Fan (Figure 14). The Bounty Trough is a failed rift in the eastern New Zealand continental margin, incepted in the late Cretaceous (Carter et al. 1994) and bounded to north by Chatham Rise and the south by the Campbell Plateau. The Bounty Channel and Fan System is an extremely long lived sediment transport system, with the eastern margin of NZ being characterised since the Paleocene (55my) by a marine channel (Carter and Carter, 1987).

Primary controls on the Bounty Channel and Fan system are tectonism, sea level, and sediment supply. Tectonism controls the form of the Bounty Channel and Fan system by controlling basin shape, and to a degree the longevity of the system related to subsidence following rifting. Tectonism also controls the rate at which sediment is supplied to the Bounty Trough, supply rates greatly increased following the inception of the Alpine fault/Southern Alps, part of the Pacific/Indo-Australian plate margin. The type and amount of sediment supplied controls the deposits formed, with sea level primarily controlling whether available sediment enters the Bounty Channel and Fan system. Both sediment supply and sea level are influenced by climatic conditions.

Today sediment is shed from the Southern Alps, sediment not trapped in onshore lakes is river-borne to the coast, and passes east across the adjacent shelf. Sediment is transported either directly, or reworked from the shelf, into the Otago Fan complex at the head of the Bounty Trough (Carter and Carter, 1996) or diverted alongshore away from Bounty Trough. Hence, the Bounty Trough is characterised by predominantly pelagic sedimentation represented by a drape of foraminiferal-nannoplankton ooze over channels and levees alike. However, levees on the Otago Fan Complex still receive terrigenous sediment presumably reworked from the adjacent continental shelf. During glacial periods, terrigenous sediment from the Southern Alps was discharged from rivers directly and distributed throughout the Bounty Trough as hemipelagic and turbiditic sediment facies. Turbidity currents travelled and overspilled the entire length of the Bounty channels thereby producing asymmetric levee growth and terrigenous deposition (Carter and Carter, 1988).

Otago Fan Complex is a series of nearshore canyons that bisect the continental shelf, hence a group of coalescing fans fed by ~ nine major and many minor submarine canyons along a 200km long section of the eastern South Island continental slope. Canyons reach maximum depths of ~750m some 5-15 km down canyon from their headwall and extend into the North, Central and South channels, which ultimately merge to form Bounty Channel 200km seaward of the shelf edge. The canyons form a set of tributaries, rather than acting as distributaries. Channels are bordered by prominent levees which, on the steep Otago fans, are mainly narrow sandy ridges (Carter and Carter, 1988).

The axial Bounty Trough, a 700km long zone between the Otago Fan Complex and a distinct sill at 3250m depth, is by comparison a gently sloping floor along which the Bounty Channel runs, following the coalescence of the North, Central and South Channels. For most of its length the Bounty Channel maintains a uniform incision depth of 350-380m relative to the north wall and is flanked by broad, low relief, muddy levees. In most cases, levees display

preferential development on the left side of the channel (facing down-channel) (Carter and Carter, 1988). The channels receive tributaries from the flanking slopes of Chatham Rise and Campbell Plateau.

5.2 Incised Channels

The multibeam data reveal the entrenched and sinuous nature of the channels comprising the Bounty Channel system (Figures 14 and 15). Sections of the North, Centre and South Channels range between ~250-350 m of relief as measured against the north bank. A thalweg is commonly evident on the floor of the channel, switching location with channel curvature. Bedforms within the channels comprise outer-bank bars associated with tight meander loops at outer corners of bend apices and point bars associated with inner bends. A broader morphology of low relief terraces also occurs. These terraces are likely due to slumping and/or are eroded ledges formed during channel entrenchment. Gully erosion is also evident, often associated with outer bend corners.

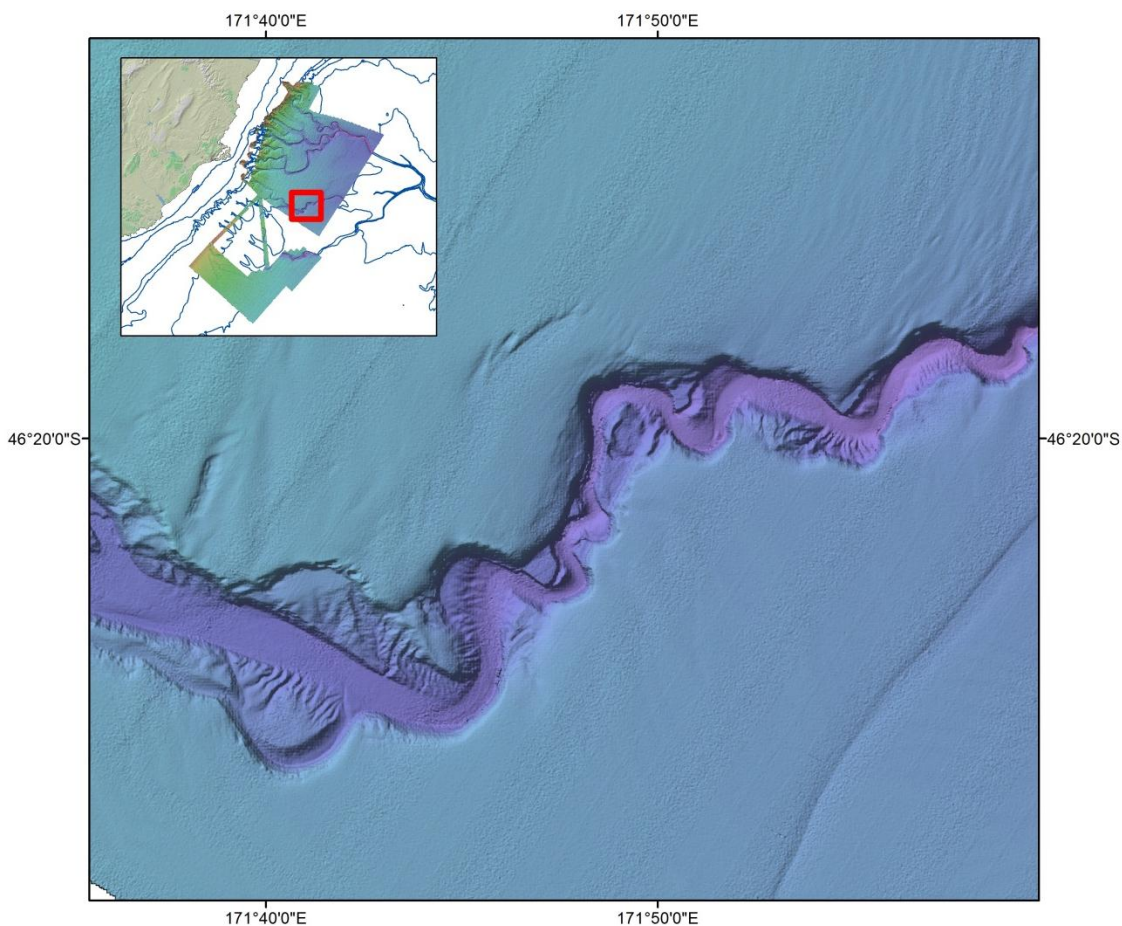


Figure 15: Sun-illuminated DEM of Centre Channel illustrating entrenched and sinuous nature of channels, thalweg, channel bars, terraces and erosion.

5.3 Canyon and Channel Levees

Canyons and channels within the Bounty system are commonly flanked by broad, low relief, muddy levees. In most cases, levees display preferential development on the northern levee (left side of the channel, facing down-channel) (Carter and Carter, 1988) i.e. the bank and levee are higher than the southern bank and levee. This is due to the Coriolis force and influenced by channel curvature, basement relief, sediment supply and bottom currents (Carter and Carter, 1986; Carter et al., 1990). The head of the Molyneux Channel, at the base of the Otago Fan Complex, is shown in Figure 16. Preferred levee development of the left or northern wall of Molyneux Channel is exhibited, with levees forming as narrow ridges (~500 m wide), 10-12 m high. The channel tilts to the south on this left (north)-turning bend. Molyneux Channel is at this location a broad U-shaped channel ~5 km wide and entrenched ~150 m into the surrounding seafloor.

The levees bounding the North and Centre and South Bounty Channels, in the main, exhibit a convex profile that thins away from the channel to merge with the surrounding seafloor/interlevee region. Thick sequences of sediments are evident within the 3.5 kHz profiles and previous studies of the Bounty Channel region indicate levee thicknesses, and associated sediment wave fields, of up to 400 m down channel (Carter et al., 1990). An example of the bounding levee of North Channel is shown here in Figure 16. Sediment waves are illustrated in Figure 13. These bedforms were formed by channel overspill of coarse sand to silt turbidity currents (episodic high density flows that leave distinct sedimentary deposits and erosional features in their wake) during glacial periods of wave growth, interrupted by interglacial quiescence when the seafloor was draped mainly by pelagic calcareous ooze (Carter et al., 1990).

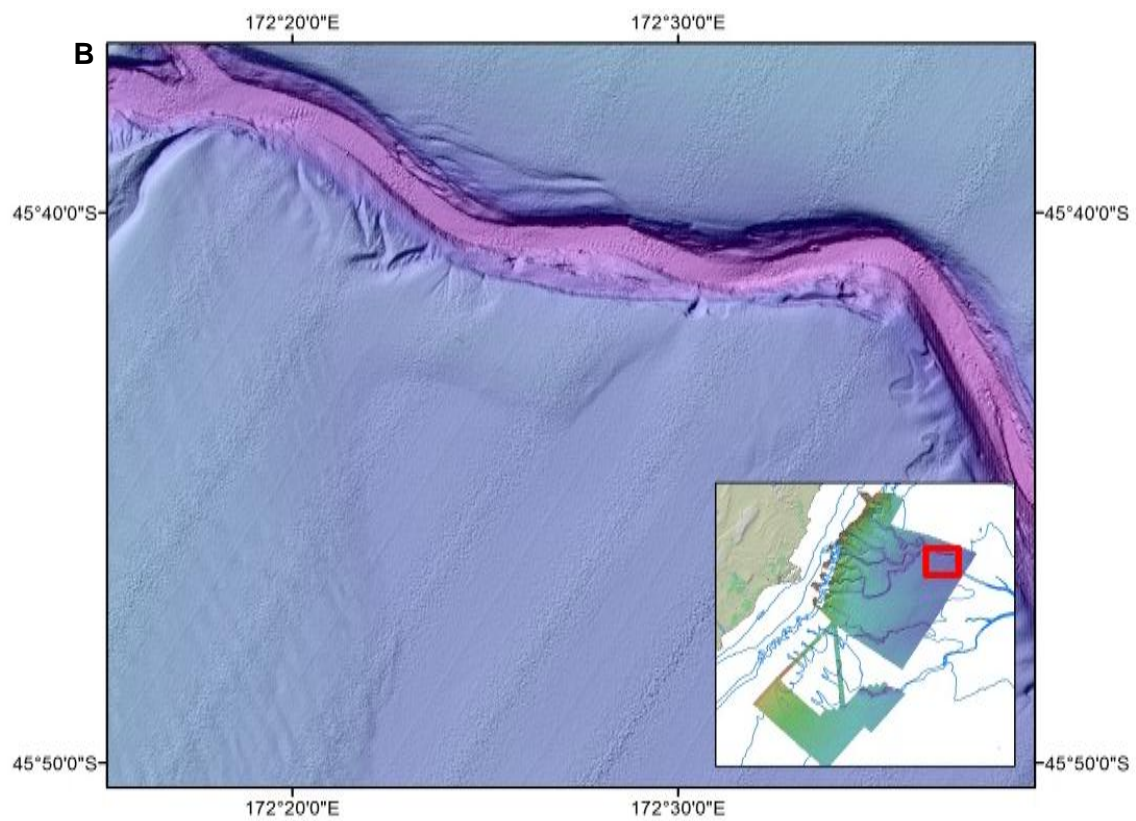
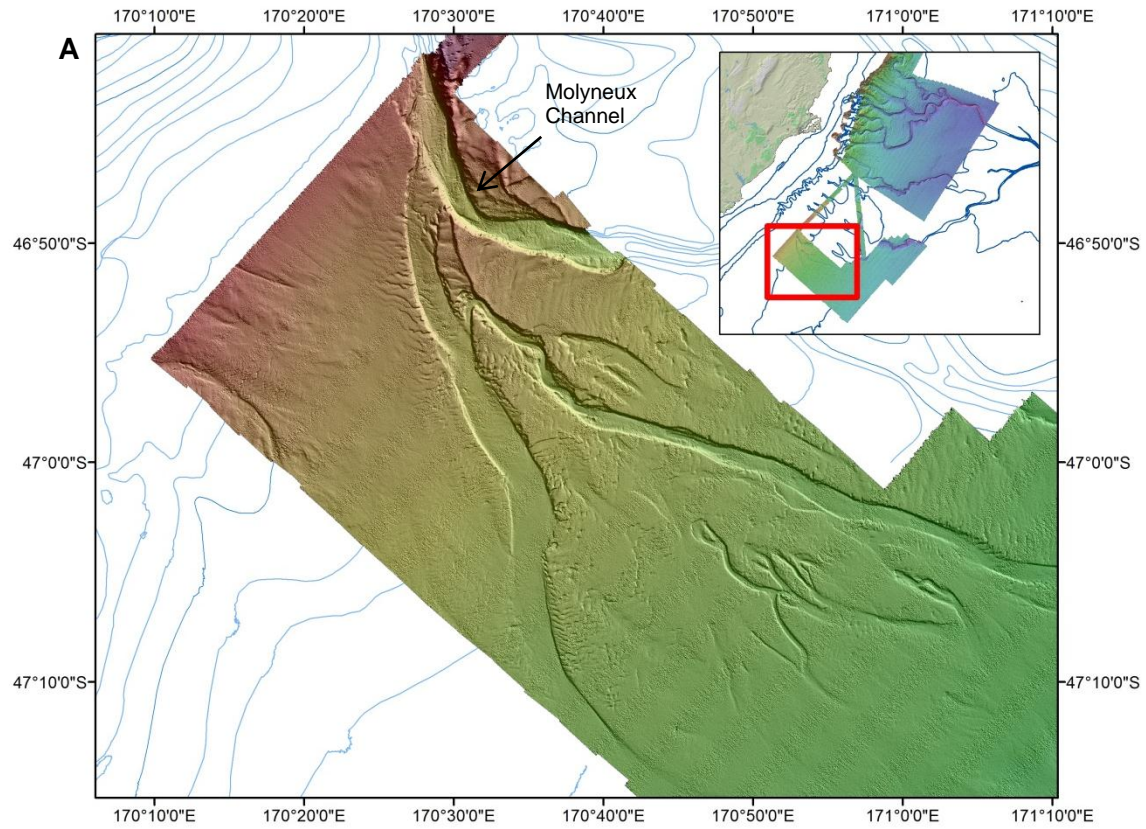


Figure 16: Sun-illuminated DEM of a) the southern swath sector of the survey showing Molyneux channel, associated distributary channels, and interlevee regions; b) North Channel and the bounding levees.

5.4 Meander Loops

Characteristic of sinuous submarine channels, the channels surveyed here are well developed, with recurring meanders, and in this case, higher sinuosity evident between ~1300 and 1500 metres water depth (Figures 14 and 17). The occurrence of cut-off or abandoned meanders suggests that through time, when active, the channel-levee system is evolving, such that meanders form, grow and are eventually cut-off or abandoned. In some instances this can lead to lateral migration and/or channel avulsion.

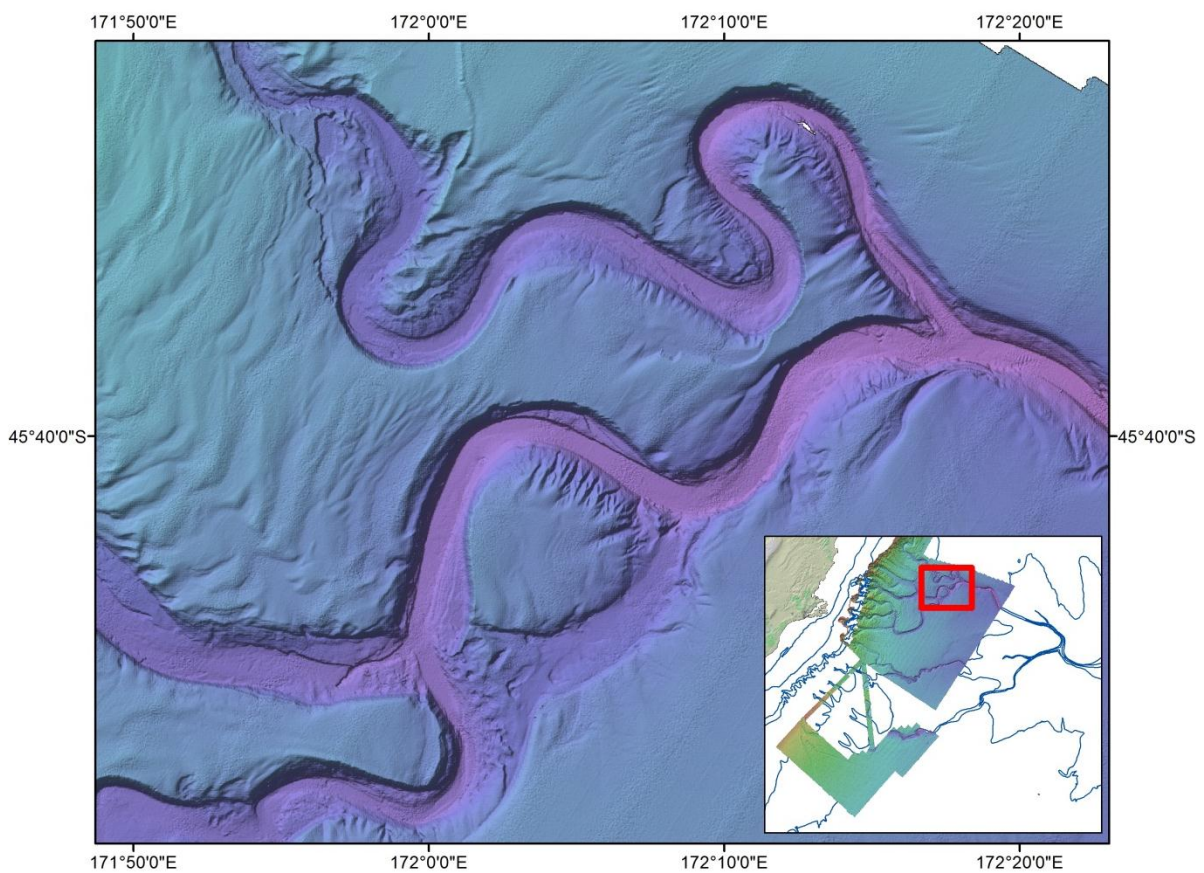


Figure 17: Sun-illuminated DEM of tributaries to North Channel exhibiting meander loops and a cut-off or abandoned meander.

5.5 Canyons - Otago Fan Complex

The nearshore canyons of the Otago Fan Complex bisect an ~200km long section of the eastern South Island continental shelf (Figure 14) and act as sediment conduits between the near-shore sediment transport system and the deep Bounty Channel. Canyons exhibit low sinuosity, reach maximum depths of ~750m some 5-15 km down canyon from their headwall and form a set of tributaries to the Bounty Channel system. Canyons heads are commonly narrow, steep-sided, V-profiles and exhibit prominent gully erosion (Figure 18), progressing downslope into broader U-shaped canyons.

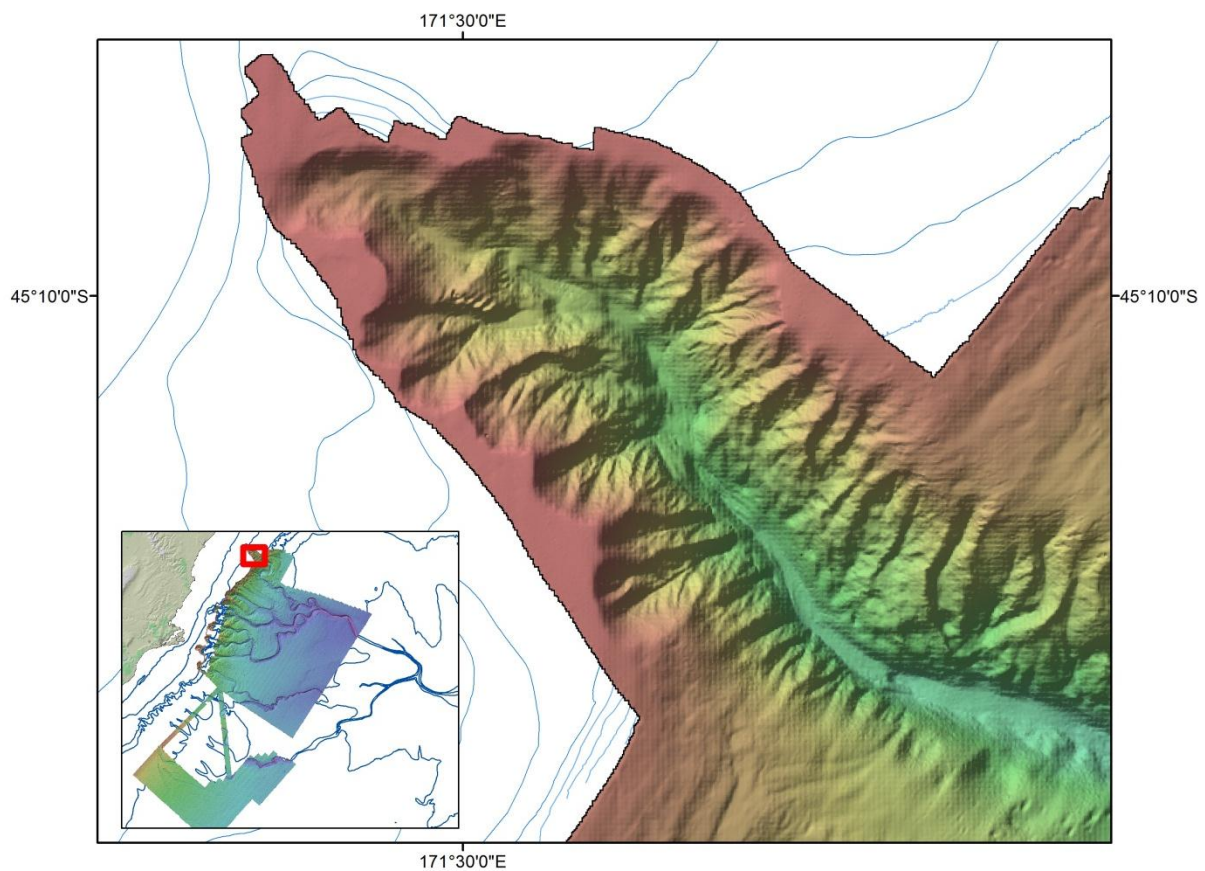


Figure 18: Sun-illuminated DEM of incised canyon head gully, Waitaki Canyon.

5.6 Pock marks

Pockmarks occur over large areas of the seafloor around the continental slope of New Zealand and are at times coincident with the location of concentrated slope failure. These features are likely to be related to fluid expulsion at the seabed, possibly gas or ground water. It is possible that such fluid systems play a role in destabilising slopes. Pockmarks occur predominately between 500 and 850 metres water depth, often in greater abundance on the northern levees, and are up to ~200 m across and exhibit ~20 m relief.

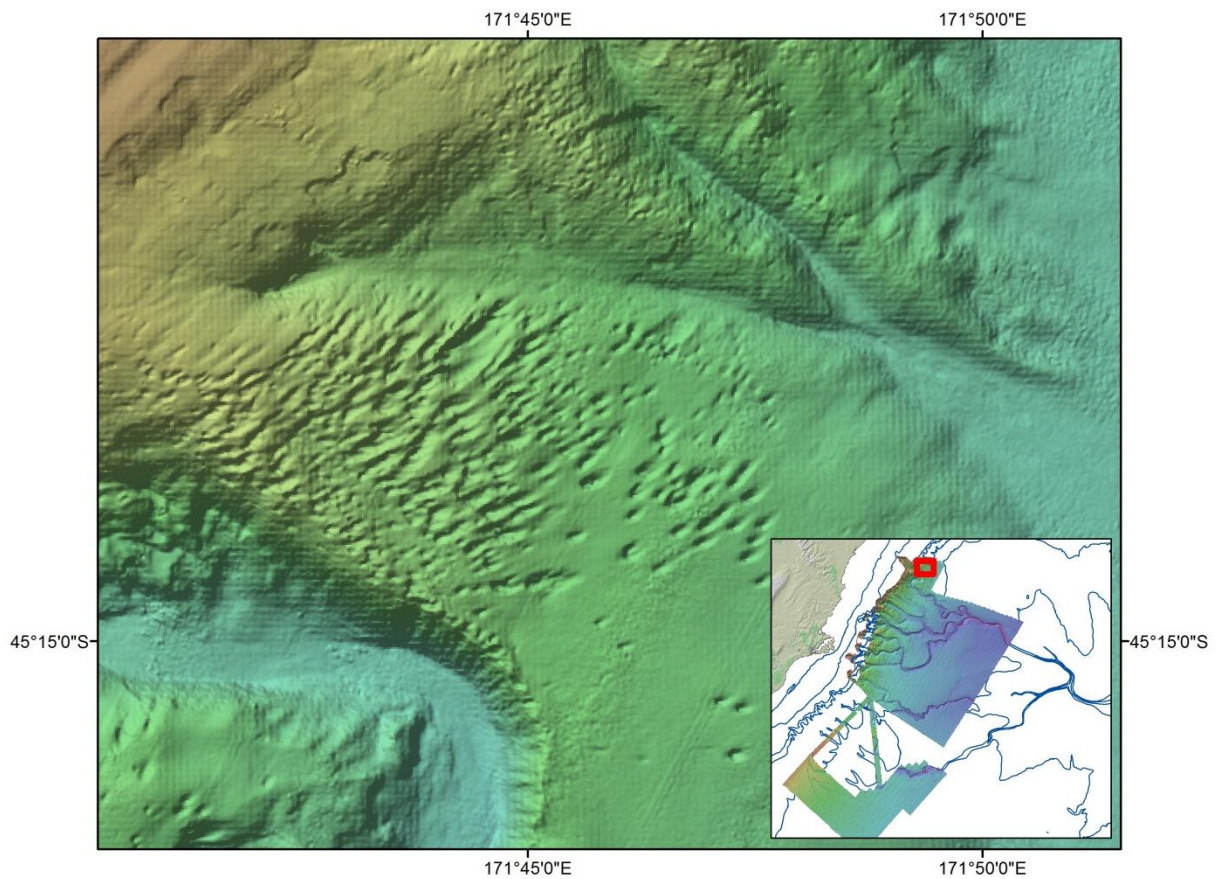


Figure 19: Sun-illuminated DEM of widespread pockmarks on the slopes, predominately on the northern levees, adjacent to the incised canyons.

5.7 Summary

This survey was undertaken with the intention of collecting data across the head of the Bounty Trough and Otago Canyons to act as a base survey for future voyages to determine the biodiversity of the area and to analyse the detailed geomorphic expression of tectonic and sedimentary processes.

The multi-beam data collected document the seafloor including portions of the Otago Fan Complex, and North, Centre and South Channels - tributaries associated with the Bounty Channel and Fan System, and associated levee structures (Figure 14). This network of canyon-fed channels has been previously documented, but the detail afforded by multi-beam coverage was hitherto unknown

The survey documents:

- the narrow v-shaped canyon heads of the Otago Fan complex progressing into broad U-shaped canyons,
- the entrenched (250 m) sinuous North, Centre and South Channels with asymmetrical convex levees and associated sediment wave fields, low relief mounds or terraces, outer bank and point bars, and gully erosion features,
- the occurrence of cut-off or abandoned meanders suggesting that when active the channel-levee system is evolving through time,
- pockmarks predominately on the northern levees up to 200 m across and exhibiting 20 m relief.

6 Acknowledgements

All aspects of the survey were successful thanks to the hard work of all involved.

Pre-voyage efforts of all the OS20/20 participating organisations including LINZ, have ensured the success of the project.

The survey could not have been successfully completed without the professional efforts of all involved. We would like to acknowledge the efforts of the master and crew of *Tangaroa* and NIWA Vessels Company. The crew of *Tangaroa* were, as always, helpful and professional and all work was carried out efficiently. The small but dedicated survey party also performed up to high expectations as attested to by the quality of the data obtained.

7 References

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Appendix 1. Accuracy of Soundings & Positions

Estimate of the sounding error budget for the Kongsberg EM302 multi-beam are listed in Table 1. These values are an estimate based on the survey practices utilised during the sounding survey.

For the EM302 the estimates provided are for soundings gathered at seven depth values and are developed for a swath width of 4 x water depth (WD). The EM302 was operated at port/stbd angles of up to 65°/65° which is equivalent to 4 x WD.

Sounding accuracy has been assessed in accordance with Land Information New Zealand (LINZ) standards for hydrographic surveying.

Table 1: Error Table for Depths collected with EM302.

EM302 *Tangaroa*

Vertical Accuracy									
Source of Error		Depth in Metres							
		100	500	1000	2000	3000	4000	5000	
		Note							
a.	Draught Setting	1	0.20	0.20	0.20	0.20	0.20	0.20	0.20
b.	Variation in Draught	2	0.15	0.15	0.15	0.15	0.15	0.15	0.15
c.	Velocity of Sound	3	0.29	1.25	2.45	4.85	7.25	9.65	12.05
d.	Spatial Variation in SV	4	0.34	2.44	0.73	0.53	0.00	0.00	0.00
e.	Temporal Variation in SV	5	0.05	0.05	0.05	0.05	0.05	0.05	0.05
f.	Application of Measured SV	6	0.05	0.05	0.05	0.05	0.05	0.05	0.05
g.	Depth Measurement	7	1.00	3.75	7.50	15.00	22.50	30.00	37.50
h.	Heave	8	0.05	0.05	0.05	0.05	0.05	0.05	0.05
i.	Settlement and Squat	9	0.15	0.15	0.15	0.15	0.15	0.15	0.15
j.	Roll, Pitch and Seabed Slope	10	0.10	0.20	0.25	0.30	0.35	0.40	0.45
k.	Co-tidal Readings	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
l.	Tide Corrections	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Standard Error: $\sqrt{(a^2 + b^2 + \dots)}$			1.14	4.66	7.93	15.78	23.64	31.52	39.39
Required accuracy:									
IAW TH Standard 31 for MB-1			1.19	5.64	11.26	22.50	33.75	45.00	56.25
IAW TH Standard 31 for MB-2			1.58	7.52	15.01	30.00	45.00	60.00	75.00
IAW TH Standard 31 for MB-3			1.98	9.40	18.76	37.51	56.25	75.00	93.75

Notes

1	Based primarily on ships' drawings and draught readings at W/L
2	Very little change throughout survey
3	Based on SV Plus accuracy. acc+0.0024WD where acc=0.05m/s
4/5	Spatial Variation could be significant
6	Used during data acquisition
7	Estimates from MBES trials and rated accuracy of system. If WD <150m then 1m. If WD >150m then 0.75% WD
8	POS/MV manufacturers specifications apply
9	Based on squat trials
10	Errors minimised through patch testing
11	Not Applied.
12	Not Applied.

Table 2: Horizontal position accuracies for beams 45° from nadir for EM302.

Horizontal Accuracy									
Source of Error		Depth in Metres							
		100	500	1000	2000	3000	4000	5000	
		Note	Metres						
a.	DGPS Position at Transducer	1	3.00	3.00	3.00	3.00	3.00	3.00	3.00
b.	MBES/Positioning latency (100ms)	2	0.40	0.40	0.40	0.40	0.40	0.40	0.40
c.	Range measurement accuracy	3	0.14	0.14	0.14	0.14	0.14	0.14	0.14
d.	Gyro Error 0.05° (Uncoupled to roll, pitch)	4	0.09	0.44	0.87	1.75	2.62	3.49	4.36
e.	Roll Error 0.05° (Uncoupled to gyro, pitch)	5	0.12	0.62	1.24	2.47	3.71	4.94	6.18
f.	Pitch Error 0.05° (Uncoupled to gyro, roll)	6	0.09	0.44	0.87	1.75	2.62	3.49	4.36
g.	Gyro, Roll and Pitch errors coupled in 3D	7	0.20	0.98	N/A	N/A	N/A	N/A	N/A
Approximate (errors treated as linear)									
Total Standard Error: $\sqrt{a^2 + b^2 + c^2 + d^2 + e^2 + f^2}$			3.03	3.15	3.50	4.62	6.05	7.61	9.24
Accurate (errors coupled in 3D)									
Total Standard Error: $\sqrt{a^2 + b^2 + c^2 + g^2}$			3.04	3.18	N/A	N/A	N/A	N/A	N/A
Required accuracy:									
IAW TH Standard 31 for Order-1			10.0	30.0	55.0	105.0	155.0	205.0	255.0
IAW TH Standard 31 for Order-2			15.0	35.0	60.0	110.0	160.0	210.0	260.0

Notes

1	As realised during survey
2	Latency test cannot detect timing biases less than 100 milliseconds.
3	Maximum value taken from MBES operators' manual
4/5/6	Accuracy of POS/MV motion sensor. Errors treated as if in a linear system. Roll, pitch and gyro errors are coupled to each other and can act synergistically in 3D space.
7	The three motion errors are coupled to one another and computed using a Tate-Bryant rotation sequence.
	Although the two methods of computing the TSE yield very similar values, this similarity may not be valid for larger angular errors and beam angles.
	It would require a rigorous and complex model to give mathematically accurate horizontal accuracies across the full swath width and such an undertaking is beyond the scope of this ROS.

Estimates from the above tables indicate that MB-1 standards have been achieved by the EM302 for all depths. This may not be the case for all depths if tidal corrections are applied. For the majority of work conducted during this survey lines were run such that the vessel ran in the outer beams of the preceding line; therefore these would have not complied with the target detection criteria for MB-1.

Appendix 2. EM302 Calibration Report

TAN1110

RV Tangaroa

EM302 Multibeam Calibration Report

July, 3. 2011

TAN1110

RV Tangaroa
EM302 Multibeam Calibration Report

Anne-Laure Verdier
John Mitchell

Prepared for

NIWA

July, 3. 2011

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Introduction

Calibration of the Kongsberg EM302 multibeam echo-sounder installed on *R. V. Tangaroa* was undertaken in Cook Strait on Saturday 2nd of July 2011. The system was calibrated after modifying the lever arm values of the GPS antennas. Weather conditions during the calibration were favourable with 10 knots of wind and less than 1m swell. Calibration tests were conducted by Anne-Laure Verdier and John Mitchell.

Offset measurements

All offsets are in terms of the “NIWA frame” defined and measured at installation of the EM302 multibeam. The origin of the NIWA frame or “reference point” is the centre of the face of the EA600 12 kHz transducer, located 0.20m forward of frame 63, 1.1 metres to starboard of the centre line and 0.23 metres below the baseline. The X, Y plane of the NIWA frame is parallel to the design baseline of the vessel. The NIWA frame is square with but offset from the builders design frame. The builders design frame has its origin at the intersection of the rudder shaft and the baseline. .

Offsets between the *Tx* and *Rx* transducer arrays of the EM302 multibeam and the reference point are applied in the SIS acquisition software (figure 1 “Sensor setup”).

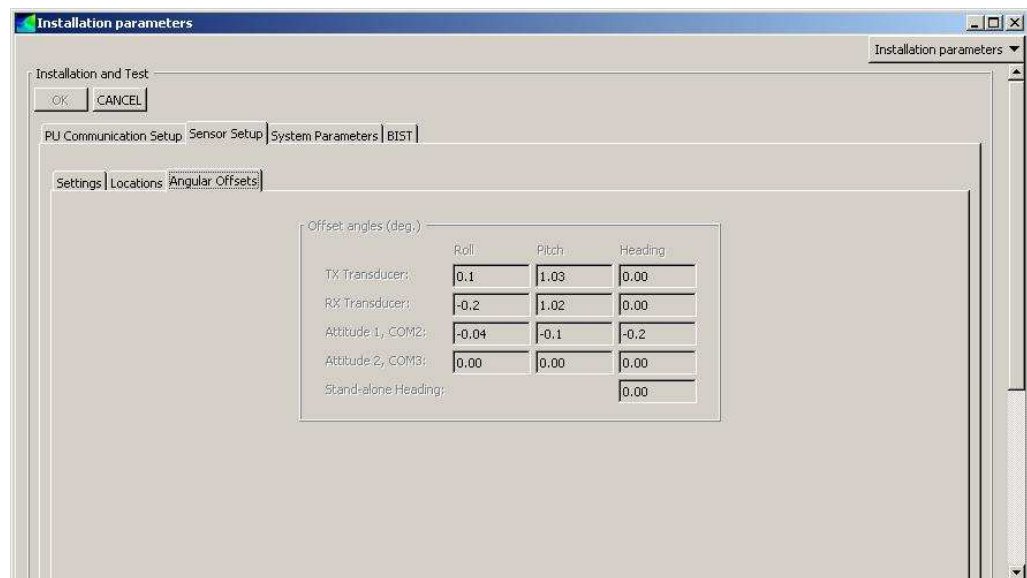


Figure 1: Sensor setup of the EM302 multibeam echo-sounder from the Installation menu in SIS prior to Patch Test calibration.

The offsets between the positioning antenna and the reference point are applied in the POS-MV. The POS-MV outputs position and attitude at the reference.

Sound Velocity measurement

Sound Velocity for the EM302 transducer face is measured using an Applied Microsystems Smart SV&P probe housed in a water tank in the bow thruster room. Additionally, Applied Microsystems a SVPlus probe are used to collect sound velocity profiles of the water column.

Patch Test

Calibration was carried out over a significant features in Cook Strait: Holmes Rock (41° 27.48'S - 174° 51.622'E), Canyon slope (41° 48.50'S - 175° 07.00'E), Hikurangi Trough (41° 53.25'S - 175° 15.25'E). This was the second calibration of the EM302 multibeam since its installation on board *R. V. Tangaroa*.

Diary of events

All dates and times are in UTC.

02/07/11	0615	SVP Measurement
	0721	Begin Latency calibration.
	0757	End Latency calibration.
	1252	SVP Measurement
	1526	Begin Pitch calibration.
	1555	End Pitch calibration
	1642	Begin Roll calibration.
	1759	End Roll Calibration
	1814	Begin Heading Calibration
	2015	End Heading Calibration

Latency

Two survey lines were run over Holmes Rock. Lines in same direction at different speeds (9.5 knots and 4.5 knots) were used to confirm there was no latency offset in the EM302 using the SIS calibration tools (Figure 3).

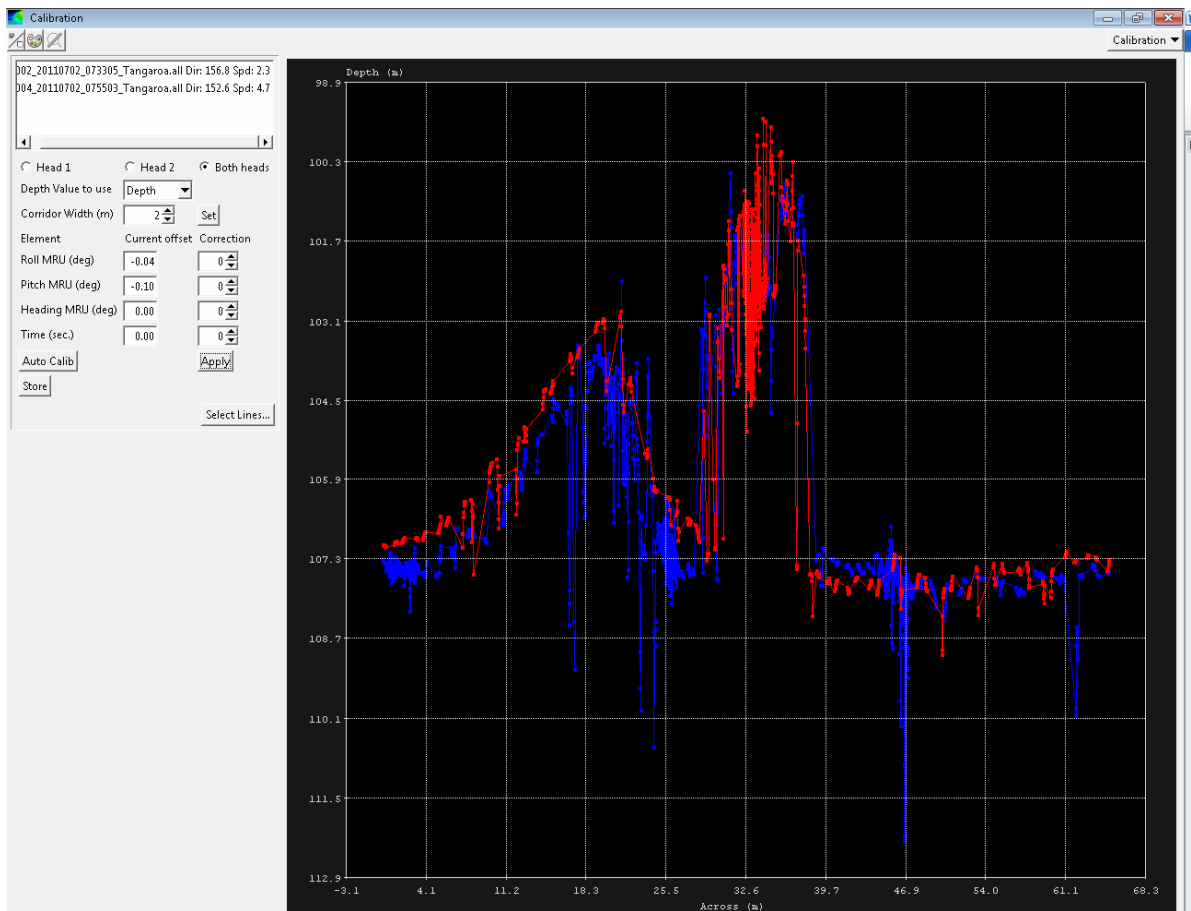


Figure 3. Latency test showing time delay of 0 sec.

Pitch

Pitch tests were undertaken over a canyon slope. Two reciprocal collinear lines were surveyed over the edges of the feature. The lines were analysed in the SIS calibration module. There was no pitch offset in the EM302 (Fig. 4).

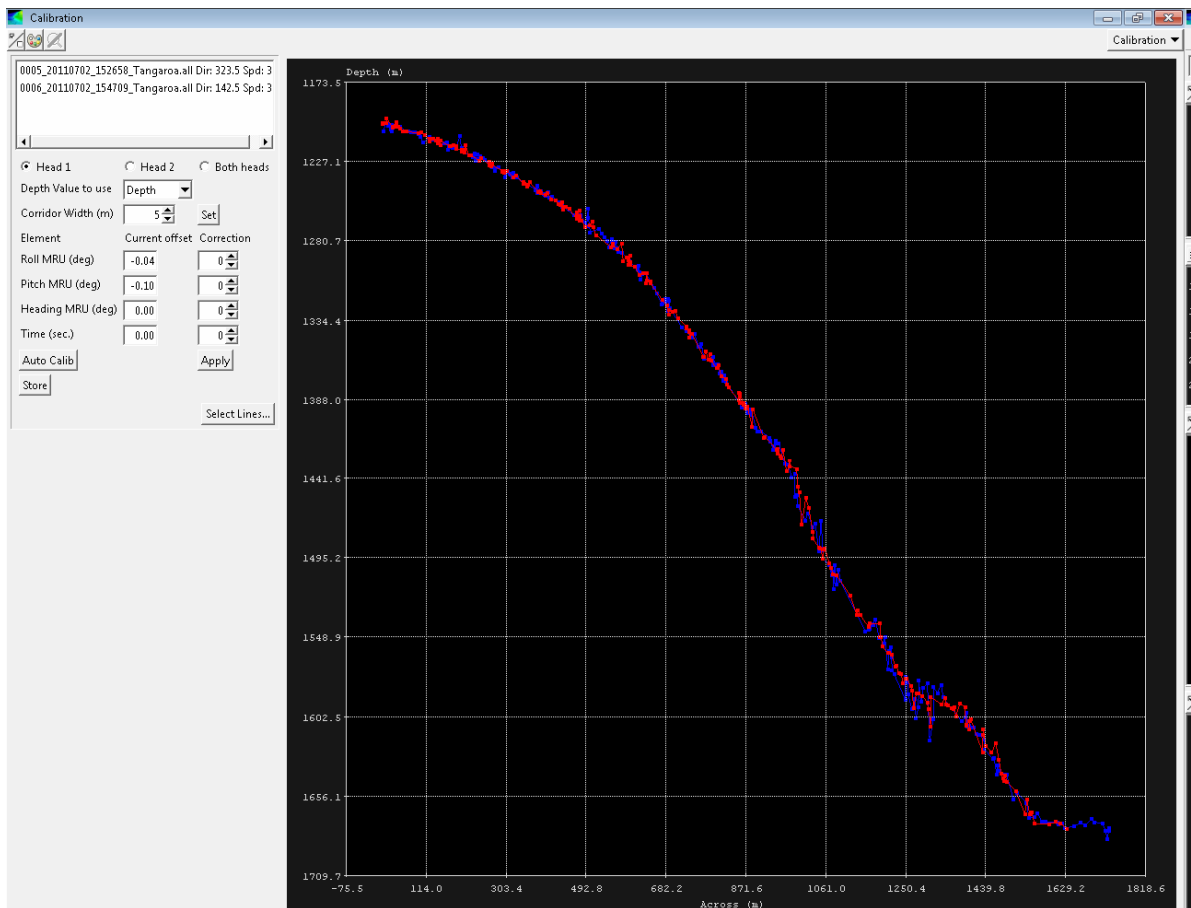


Figure 4. Pitch test showing no offset.

Roll

Roll tests were undertaken over a flat area. Two collinear lines were run over a flat seabed. The lines were analysed in the SIS calibration module and an offset of 0.1° was found and applied to the system (Figs. 5a, 5b and 5c).

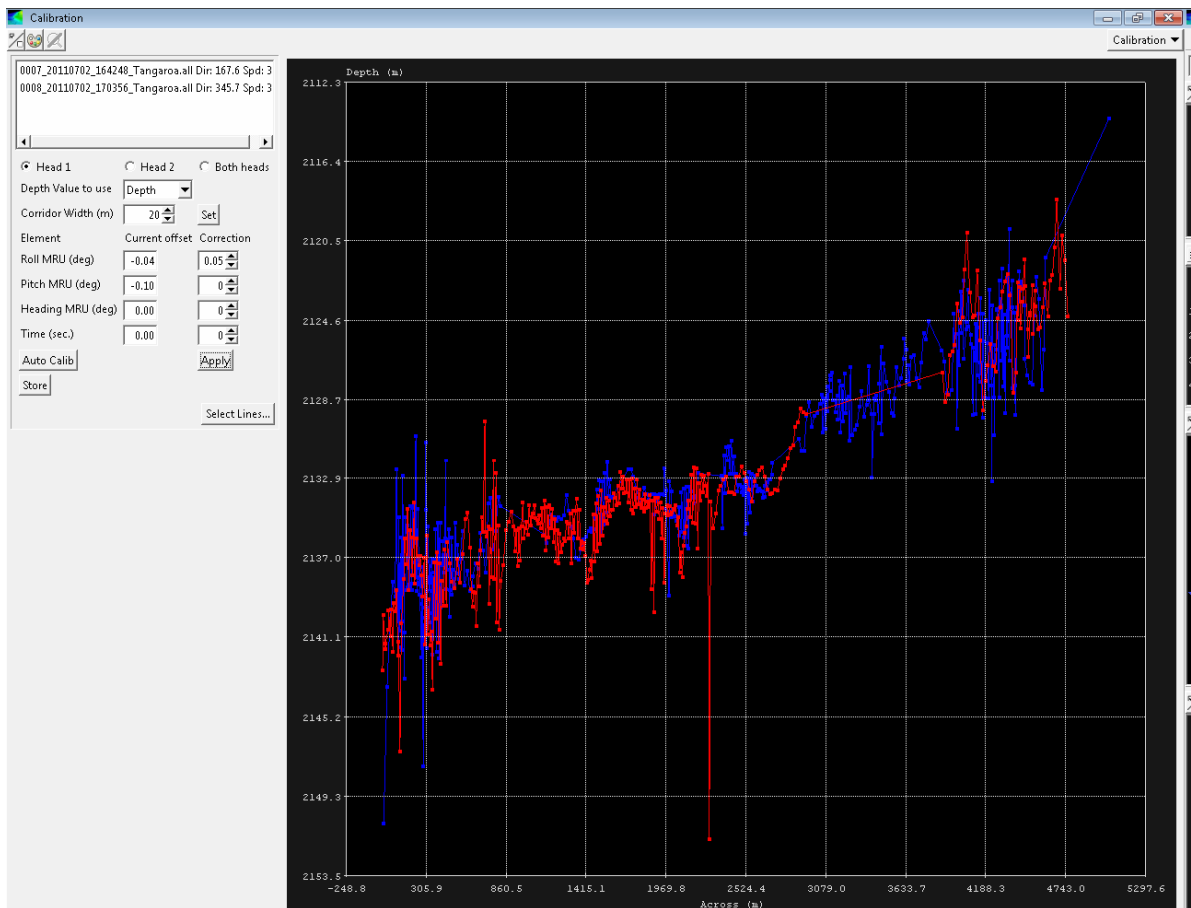


Figure 5a. Roll test showing an error of 0.05° .

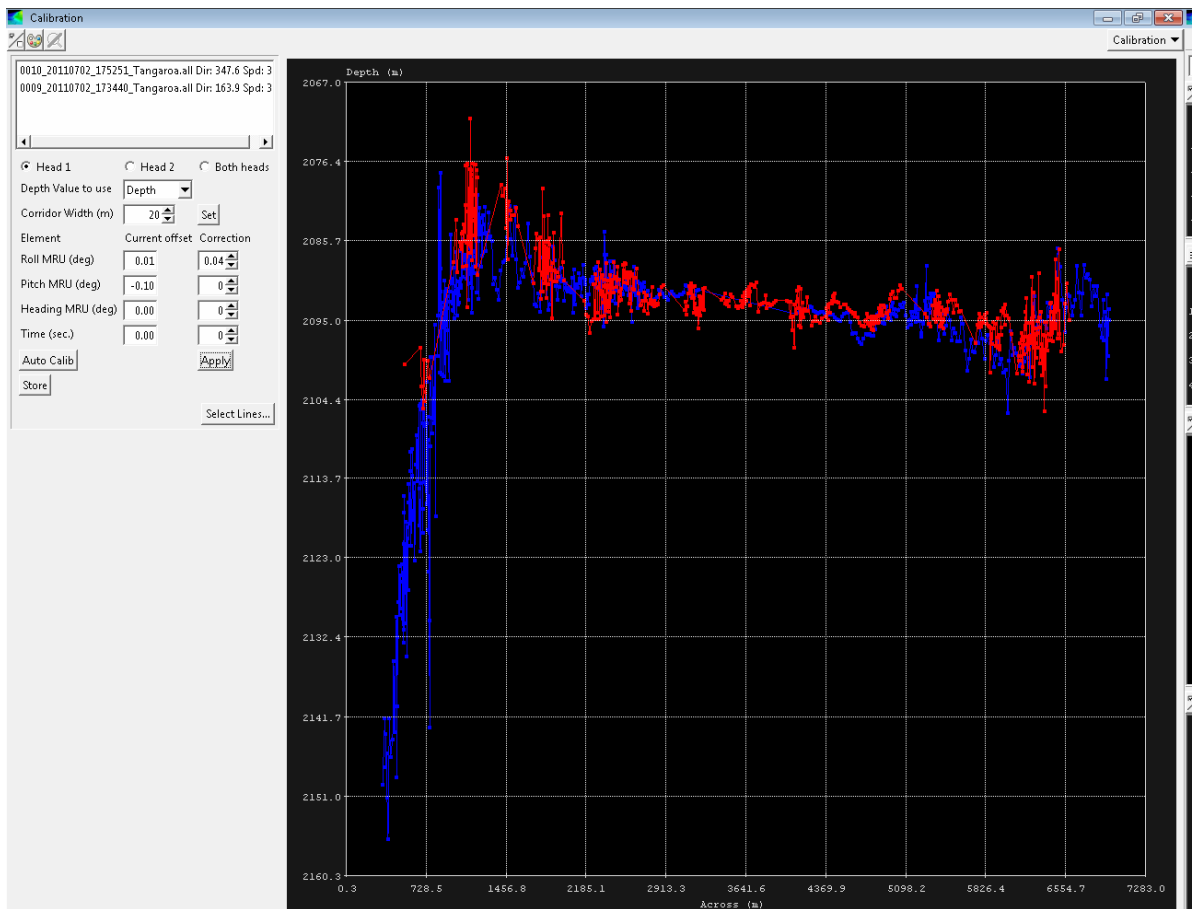


Figure 5b. Roll test after correction showing an error of 0.05°.

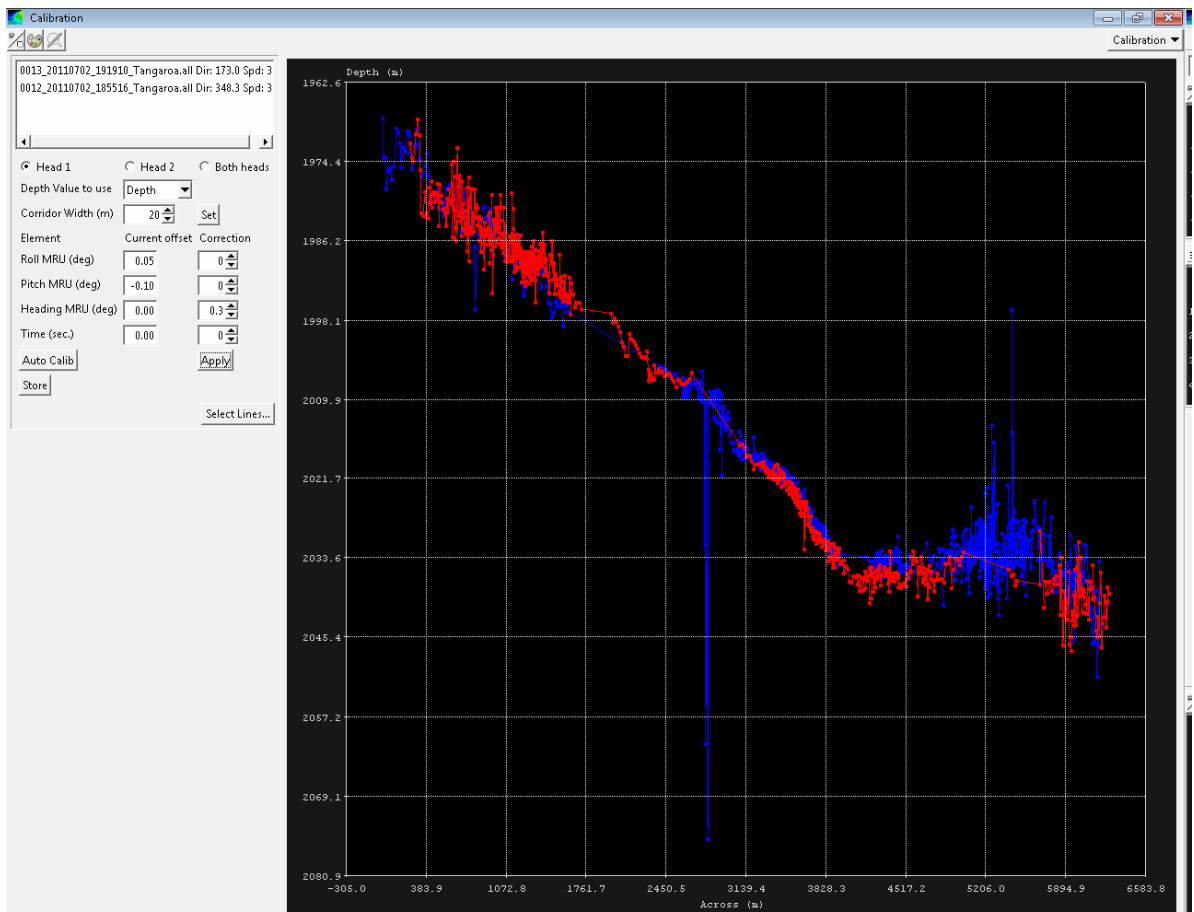


Figure 5c. Roll test after correction showing no more error.

Heading

Heading tests were conducted over a canyon slope. Two parallel lines were surveyed in same direction. The target was analysed in the region of overlap between the two lines using the SIS calibration module and an offset of 0.3° was found and applied to the system (Figs. 6a and 6b).

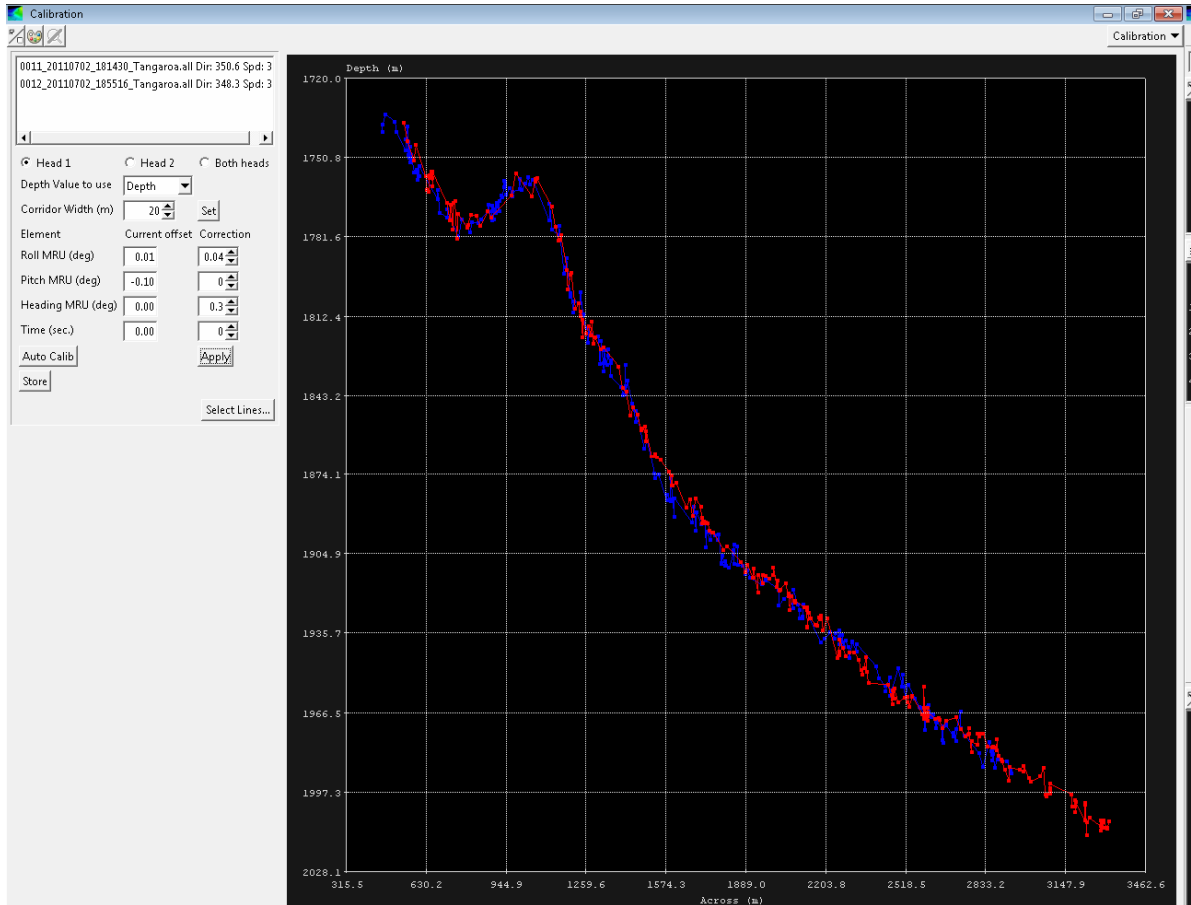


Figure 6a. Heading test showing an error of 0.3° .

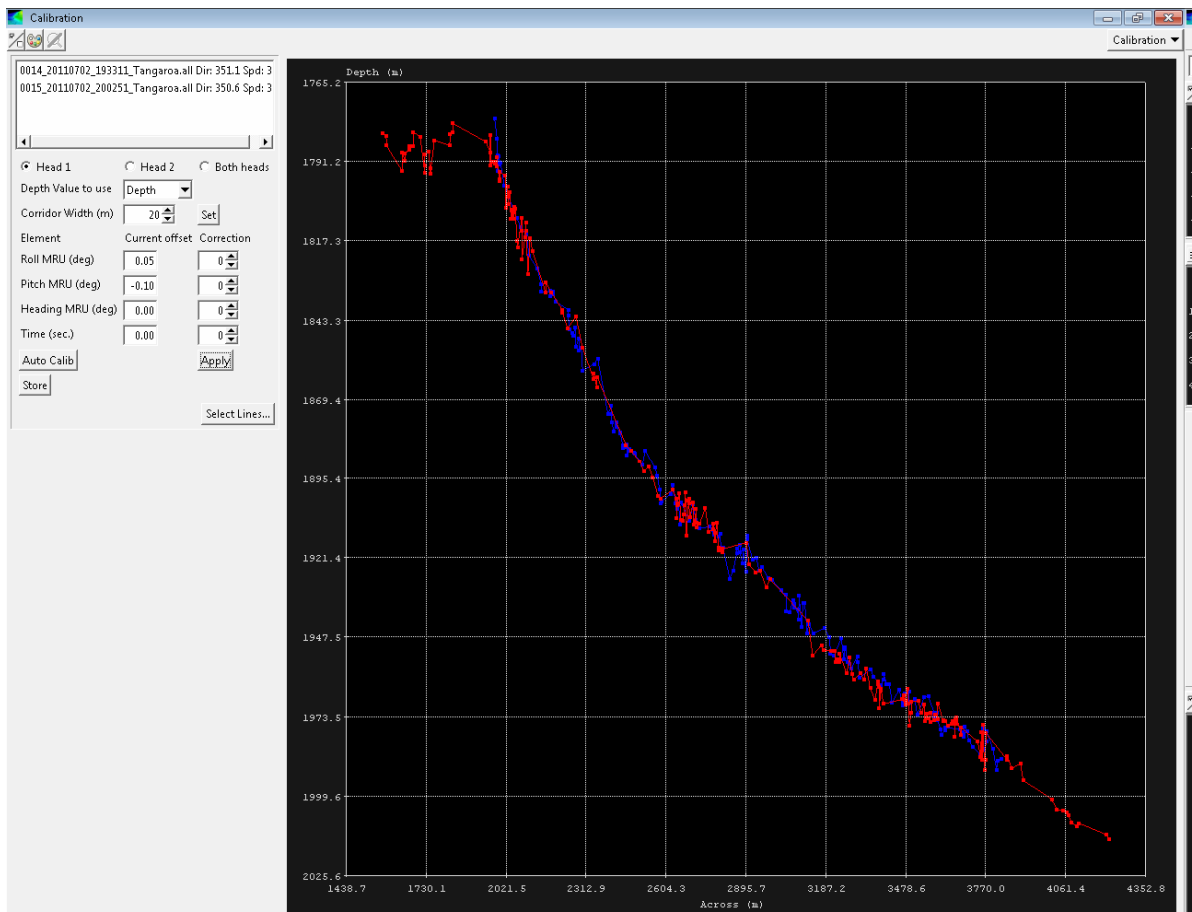


Figure 6b. Heading test after correction showing no more error.

Calibration results

On completion of the calibration some adjustments were required for the EM302 (Figure 7).

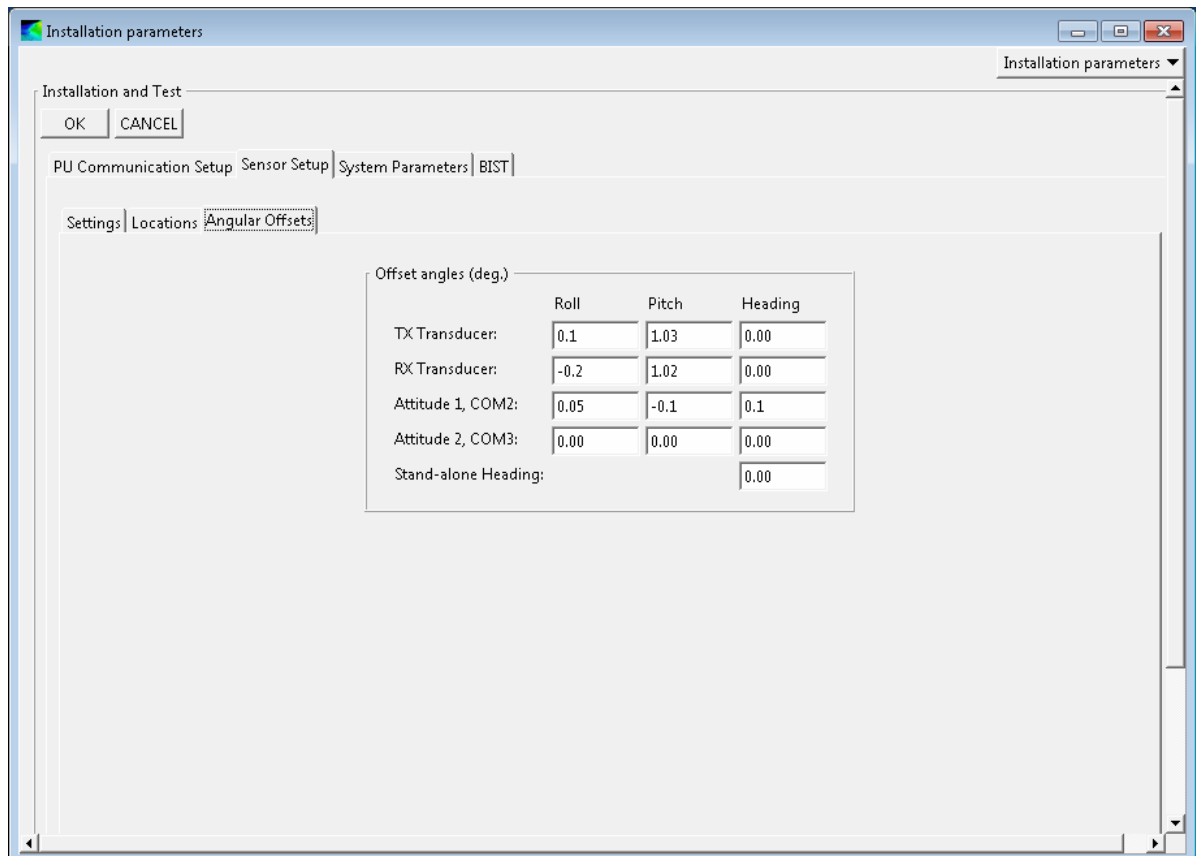


Figure 7. Final settings on Installation menu of EM302 multibeam following calibration.

Appendix A: EM302 Multibeam maintenance history.

Date	Description
August-November 2010	Installation of Multibeam in Drydock, Singapore. Installed under supervision of Kongsberg.
November 2010	Harbour Acceptance Trials. RX32 board 2 was changed to spare board.

TAN1110

RV Tangaroa
EM302 Multibeam Calibration Report
Addendum

August, 1. 2011

TAN1012

RV Tangaroa
EM302 Multibeam Calibration Report
Addendum

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Introduction

Full calibration of the Kongsberg EM302 multi-beam echosounder installed on *R. V. Tangaroa* was undertaken in Cook Strait on Saturday 2nd July 2011. As a check of the system's calibration in tropical waters a partial calibration was conducted during the transit between Madang, PNG and the survey site off Wuvulu Island. Calibration tests were conducted by Anne-Laure Verdier and John Mitchell.

Sound Velocity measurement

Sound Velocity for the EM302 transducer face is measured using an Applied Microsystems Smart SV&P probe housed in a water tank in the bow thruster room. Additionally, Applied Microsystems a SVPlus probe are used to collect sound velocity profiles of the water column.

Calibration Checks

Calibration checks were carried out over suitable features between Madang and Wuvulu Island.

Diary of events

All dates and times are in UTC.

20/07/11	0729	SVP Measurement (05° 10.29'S - 145° 52.05'E)
	0825	Begin Pitch calibration.
	0857	End Pitch calibration
21/07/11	0602	SVP Measurement (02° 45.24'S - 143° 52.01'E)
	0941	Begin Roll calibration.
	1045	End Roll Calibration

Pitch

Pitch tests were undertaken over a sloping seafloor. Two reciprocal collinear lines were surveyed over the feature. The lines were analysed in the SIS calibration module and no offset was found in the data (Figure 1).

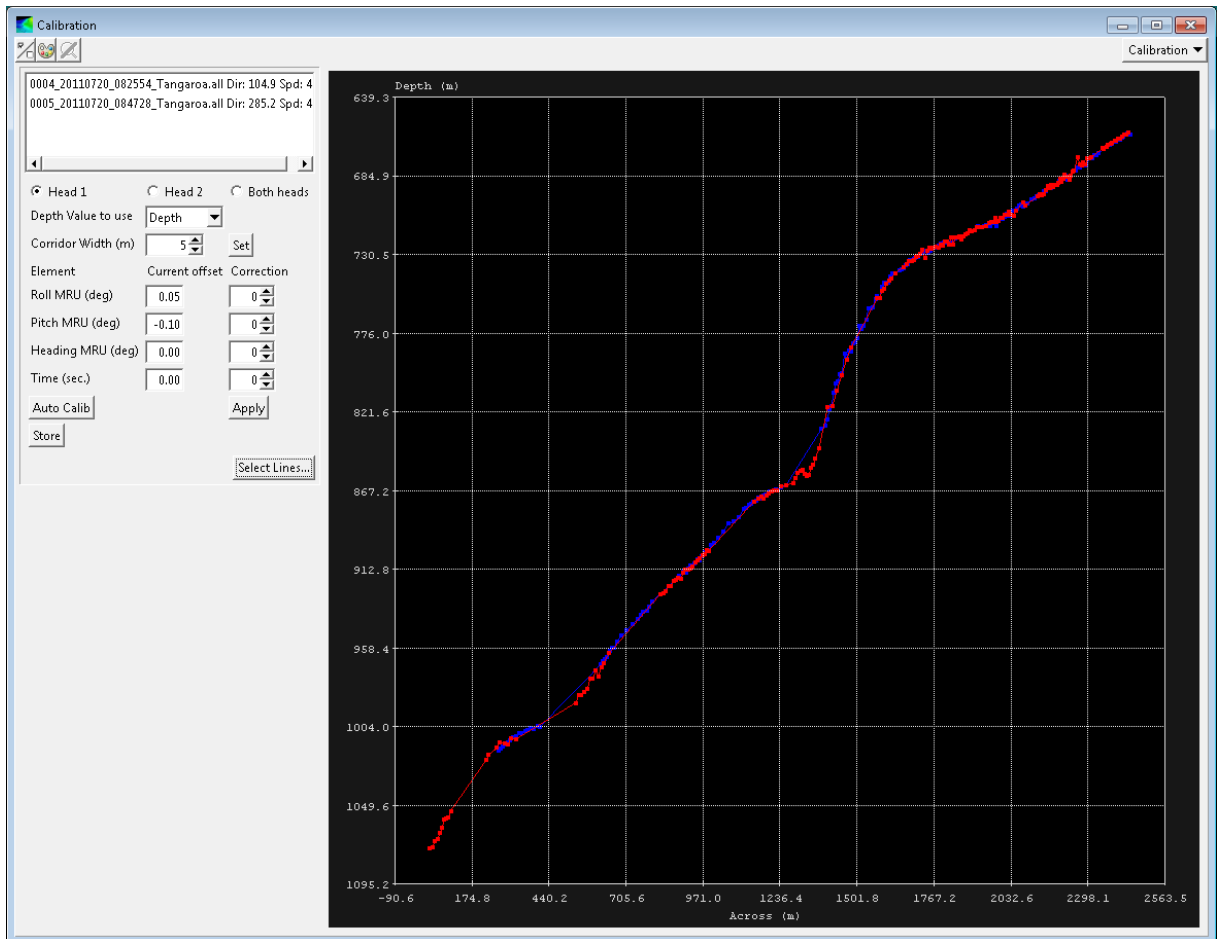


Figure 1. Pitch test showing no error.

Roll

Roll tests were undertaken over a relatively flat seabed. Two collinear lines were run over the seabed. The lines were analysed in the SIS calibration module and no offset was found (Figure 2).

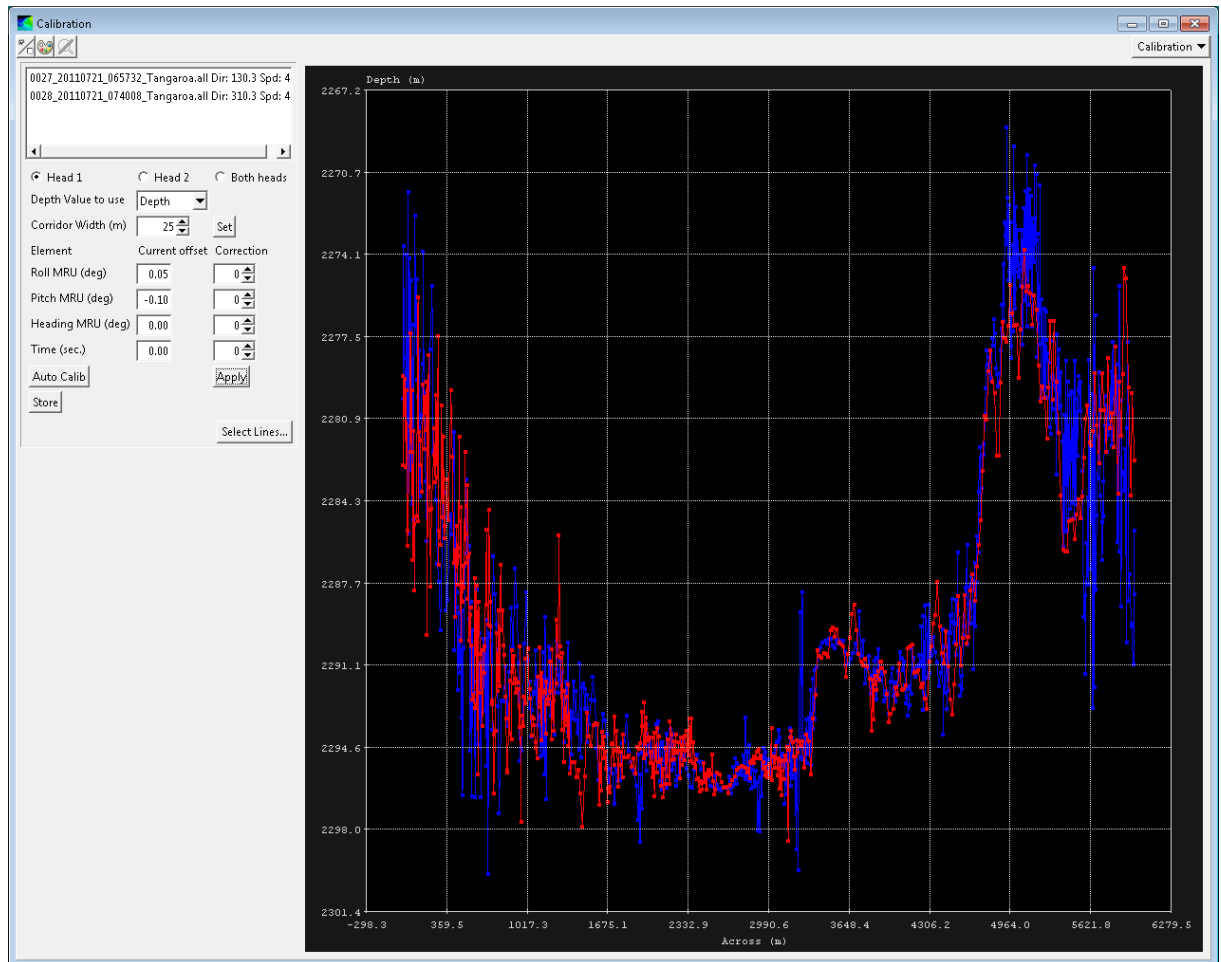


Figure 2. Roll test showing no error (large vertical exaggeration).

Calibration results

On completion of the calibration checks no adjustments were required to the installation angles. This shows that the patch test completed in Cook Strait, Wellington, was still relevant for data to be collected in the tropical waters north of Papua New Guinea.