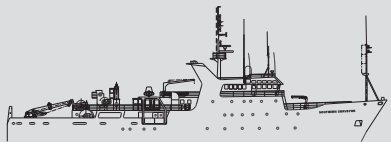

MARINE
NATIONAL FACILITY

RV *Southern Surveyor*

2009 program

CSIRO

voyage summary SS01/2010

SS01/2010

PINTS – primary Productivity induced by Nitrogen and Iron in the Tasman Sea.

Role of iron and other micronutrients in controlling primary productivity in the Tasman Sea: bioavailability, biogeochemical cycling and sources

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Voyage period

Start: 1600hr, 23/01/2010

End: 1800hr, 15/02/2010

Port of departure: Sydney, New South Wales, Australia

Port of return: Hobart, Tasmania, Australia

Responsible laboratory

CSIRO Marine and Atmospheric Research

Castray Esplanade, 7001 Hobart, TAS Australia

Chief Scientist(s)

Dr. Christel Hassler, University of Technology Sydney and
CSIRO Marine and Atmospheric Research

Alternate Chief Scientist – Dr. Michael Ellwood, Australian National University

Objectives and brief narrative of voyage

Macro- and micronutrients, mainly iron and nitrate, control oceanic primary productivity, phytoplankton community composition and subsequently carbon uptake and generation of radiatively important gases for climate. Assessing key underlying processes that control primary productivity and carbon export to the ocean's interior such as micro and macro-nutrient bioavailability is required to fully understand the ocean role in controlling climate change and improve modelling approaches. Indeed, data allowing an accurate modelling of iron bioavailability in the oceans is sparse. Although large dust deposition from eastern Australia to the ocean may occur, the Tasman Sea presents a region of great contrast: northern waters are nutrient poor while southern waters are nutrient rich, but low in iron. Consequently, the input of iron via dust to the northern and southern regions may influence nutrient uptake, primary production and nitrogen fixation.

The proposed research voyage studied iron bioavailability, sources and its biogeochemical cycling in the surface waters of the Tasman Sea. For this purpose samples for iron chemical speciation as well as dissolved and particulate concentrations were taken.

Other trace metals can act as co-limiting factors on primary productivity. Therefore, samples were taken to analyse several other trace elements that are essential for phytoplankton growth such as Zn, Cu, Mo and Co. Other parameters that inform on biogeochemical processes and the sources at play, such as dissolved Cd and Pb, and Fe and Cu isotopic signatures were also studied. In addition to trace elements, macronutrients and especially nitrogen can limit primary productivity in the Tasman Sea. For this purpose samples were taken to determine the concentration of dissolved and particulate (organic) nitrogen, bacterial nitrogen recycling and the rate at which phytoplankton are able to fix atmospheric nitrogen. All these results on nutrients potentially limiting marine phytoplankton are being compared with phytoplankton biomass, biodiversity, productivity and physiological parameters to gain further insight on their control in the biology of the Tasman Sea. Data were gathered using a mapping approach (CTD, trace-metal-clean rosette and McLane pumps) along a voyage track designed to provide measurements on the effect of variable resources of iron (Australian continental dust, shelf sediments) on iron biogeochemistry as well as nitrogen sources. In addition on-deck incubations performed at process stations (at which the ship remained stationary) were used to determine how phytoplankton respond to variable perturbations relevant to nutrient limitation and climate change scenarios. The effect of variable sources of organic iron and Australian desert dust, variable levels of pCO2 and increasing temperature were investigated.

Results from this voyage will thus improve our understanding on the parameters controlling primary productivity in the Tasman Sea and the biological response to relevant climate change scenarios. A refined understanding of the dynamics of the Tasman Sea is required to improve existing models. During this voyage, samples were also taken to validate a new method for measuring iron bioavailability (e.g. iron dependent bioreporter) and limitation (e.g. photophysiological parameters) in the ocean, with potentially wide application to the growth of Australian and international marine research.

Scientific Objectives

The main hypothesis of this project is that iron and other micronutrients are critical drivers of primary production in the Tasman Sea. In turn, the scale of primary production is instrumental in determining the biological uptake of CO_2 and fixation of carbon in surface waters.

Specific objectives with name of PIs involved in brackets:

1. Conduct zonal and meridional transects traversing the Tasman Sea to gain an understanding of the transport mechanisms influencing dust supply and its importance: a) as a source of iron and b) to link iron supply to nitrogen cycling in northern and southern waters (Bowie, Butler, Law, Ellwood);

2. Test iron-dependent bioreporter(s) as tools to measure iron bioavailability in the Tasman Sea (Hassler);

3. Characterise the iron biogeochemical cycling, chemical speciation, sources and potential control on primary productivity in the Tasman Sea (Law, Ellwood, Hassler, Doblin, Bowie);

4. Evaluate macronutrient limitation (e.g., nitrogen) of primary production and strategies to circumvent it (e.g., nitrogen fixation) (Law, Ellwood);

5. Investigate the role of other micronutrients in primary production and species composition. For example, the effect molybdenum and copper availability has on nitrogen-fixation by investigating the distribution of molybdenum and copper isotopes in the natural plankton community north and south of the Tasman Front (Butler, Ellwood, Bowie, Hassler, Doblin);

6. Undertake plankton incubation experiments to look at the influence of pCO2 or sources (e.g. Dust and organic matter) on nutrient uptake (Law, Ellwood, Hassler).

Voyage Objectives

This voyage proposes two set of activities: transect stations and process stations (see Figure 1).

The transects conducted during this project will allow mapping of important biogeochemical parameters, whereas process stations will provide information about (i) the main factors controlling biological stocks and activities and (ii) the vertical distribution of the parameters measured during the transects in the whole water column. The information gathered at the process stations will be critical to identifying key parameters and processes driving the control of primary productivity by macro- and micro-nutrients, as well as pointing the sources and cycling of iron.

The following activities will be conducted onboard the *Southern Surveyor* to meet our scientific objectives:

(1) Regular CTD profiles down to 1000 m at each station to characterise physical oceanography (temperature, salinity, dissolved O2, transmissivity and fluorescence). In addition water will be sampled for macro-nutrient analysis (MNF Hydrochemist), Particulate organic carbon (POC) and nitrate (PON), and phytoplankton characterisation. Phytoplankton characterisation includes:

a) floristic information: measured mainly back in the laboratory using microscopy, high-performance liquid chromatography and flow cytometry. Samples will be fixed or stored in liquid nitrogen until analysis.

b) physiological information such as primary productivity and photosynthetic health, measured onboard using FRRF, PhytoPAM, spectroscopic analysis and 14C incubations as well as with an in-situ submersible PAM (profiles in the upper 100 m).

At process stations (See Figure 1) deep CTD casts to the bottom (> 3000-4000 m) will be done to gain more information on the physical oceanography.

(2) Trace metal sampling using a) a aluminium rosette equipped with 12x 10L Niskin-X bottles at each station and b) hose deployed overboard (see Figure 1, voyage track).

The water collected will be manipulated in a clean environment either under laminar flow or in one of the two clean room vans set up on board.

Using the trace metal (TM) rosette water was sampled to 1000 m all stations. In addition, deep casts will be done at process stations (down to 3000 – 4000 m). Water was collected for the following parameters:

– Dissolved trace elements (Fe using Flow injection and others such as Cd, Zn, Co, Mn, Pb, etc using ICP-MS techniques).

– Iron chemical speciation using electrochemical approach

– Iron bioavailability using iron-dependent cyanobacterial bioreporter

– Large sample volumes (10L) for iron and copper isotopes and isolation of natural organic matter

– Set up incubation at depth of Chlorophyll maximum to determine iron bioavailability, dust impact and primary productivity for natural phytoplankton community

– Nutrients at the nanomolar levels

At various stations a weighted hose was deployed over the side of the vessel to collect large volumes of surface water, mainly to measure underway parameters, set up on-deck incubation at process stations and collect water for further culturing work.

(3) Deployment of McLane pumps: McLane pumps were deployed at most transect stations (at 4 depths) to collect particulate matter for trace metal, carbon, nitrogen and biogenic silicate analysis.

(4) Dust was collected using a high-volume sampler set up on the monkey island. Filters are to be analysed by ICP-MS to assess metal solubility and fluxes associated with dust deposition.

Results

Deployment of the trace-metal-clean rosette, the McLane pumps and the hose pumping were all successful. According to measurements of chemically labile zinc (electrochemistry, Ellwood) made on board, water sampling was achieved without bringing artefact contamination. Therefore sampling for analysis of trace elements using the trace-metal-clean rosette system from ANU and the clean container from CSIRO were successful in maintaining a non-contaminating environment.

All measurements done on board (primary productivity, photo-physiology, nitrogen fixation, iron bioavailability went according to plan. Results will attest if they were successful but based on preliminary results it seems to be the case.

During this voyage three process stations were occupied and their location was refined using satellite images sent daily while at sea (from Mark Baird and Ken Ridgeway).

Therefore all voyage objectives were fulfilled.

Samples were collected to address scientific goal 1-4. However, these require additional analysis in the laboratory and results are not available yet.

The on-deck incubations (objective 5) went well and samples were collected to address scientific objective 5.

The only preliminary data available so far are macronutrients measured by MNF Hydrochemists (Alicia Navidad and Sue Reynolds), primary productivity estimates (Doblin) and iron bioavailability and iron-to-carbon ratios of the phytoplankton found at the three process stations (Hassler) and Fv/Fm (van Hale and Doblin).

The nutrients analysis revealed concentration of nitrate and nitrite to below normal detection limits down to depth of 60 m in the northern region compared with shallower depths in subantarctic waters (where Process station 3 is located, see voyage track). In the subantarctic region, satellite images showed a massive phytoplankton bloom (possibly coccoliths based on calcite estimates) extending from Tasmania to New Zealand (sea images attached, courtesy of Dr. Mark Baird), Si was depleted to level below Hydrochemists' detection limit. This suggested contrasting macronutrients concentrations in the surface water of the Tasman Sea and provided us with an exciting opportunity to test our scientific objectives.

The results obtained for 14C incubations are good and will provide a good estimate of primary productivity. Primary productivity was lower at process station 1 and higher at process station 3. However, these results need to be normalised against phytoplankton biomass which requires further analysis. Based on fluorometric measurements made at sea and satellite images, the biomass of phytoplankton (Chlorophyll a) was lower at process station 1 as compared to process station 3. At most of the stations visited, the maximum quantum yield, often used to infer nutrient limitation, was high, attesting to a healthy phytoplankton community.

The analysis of iron bioavailability (incubation with 55Fe) demonstrated the role of saccharides and natural exoploymeric substances in promoting iron bioavailability. Interestingly, these organic substances also release some NOx, and can potentially relieve nitrogen limitation. Iron bound to the two atmospheric dust samples (provided by Prof. Grant McTainsh, UG) showed an interesting effect on iron bioavailability. Iron bound to 0.5 mg /L of atmospheric dust (pre-equilibrated for 24 h) did not decrease iron bioavailability as much as fulvic acid (100 µg/L), a compound associated with continental shelf input.

Voyage Narrative

Except when we left Garden Island (Sydney) on the 23rd of January, the weather was exceptionally calm for the Tasman Sea. This allowed us to successfully deploy light equipment (trace-metal-clean rosette from the ANU and McLane pumps from NIWA and UTAS) required for the collection of dissolved and particulate trace metal samples. During this voyage, we carried out two sets of activities: transect stations (marked with a yellow symbol in the voyage track) and process station (marked in red in the voyage track), where the vessel remained stationary for 2-4 days. At each transect station, the water was sampled down to 1000 m and trace-metal-clean sampling was undertaken at most stations (Stns marked in white in the voyage track). Deep-water sampling (3000-4500 m) was also undertaken at the three process stations, along with perturbation experiments in order to evaluate what parameters control phytoplankton abundances, diversity and productivity. Experiments investigated the response of phytoplankton to climate change scenarios (i.e. increase of Australian dust deposition, increased level of atmospheric pCO2 and sea-surface temperature).

Our first transect was Sydney – Process station 1, during which four stations were sampled. Our first station was on the 23rd of January and this station was use as a toolbox station to check operations associated with the deployment of the CTD and the trace-metal-clean rosettes. It was also used to check all equipment and procedure used to sample and process the water on board. The Niskin bottles from the trace-metal-clean rosette were filled with acidified seawater to ensure that the bottles would not contribute to a background contamination of trace metals. Absence of contamination was regularly verified using the electrochemical measurement of labile zinc at sea. We arrived at Station 2 on the 25th January and did an extensive rinsing of the trace metal rosette followed by sampling (abbreviated as TM cast below), CTD cast and toolbox on the deployment of the McLane pumps (30-240 m). At Station 2 a large volume of seawater was sampled at 20-25m depth using a clean line deployed overboard and water was pumped directly in the CSIRO clean van using a Teflon pump (this sampling is hereafter referred to as hose pumping). This water was used to start the first incubation experiment investigating the effect of pCO2 levels and atmospheric dust deposition on the phytoplankton. Station 3 was visited on the 26th of January and CTD and TM casts were done. Similar operations and McLane pumps deployment were done at station 4 on the 27th of January.

At process station 1 – the ship remained on location for four days and numerous activities were carried out as follows:

– Two sets of incubations were started using water collected with hose pumping- investigating Cu isotopic signatures, phytoplankton response to different levels of pCO2 and Australian desert dust enrichment.

– One set of incubations using water collected at the depth of Chl a max (90 m) was started to investigate the phytoplankton response to iron enrichment (inorganic, organic and associated with Australian desert dust).

– Eight McLane pump deployments from 30 to 1000 m.

– Seven TM casts to cover the whole water column from surface to 3000 m.

– Four CTD casts (one daily) down to 1000m

– One deep CTD cast down to 3000m

– Internal-tide casts (0-500 m minimum) every 6-8h to investigate the variability of the depth of the deep Chl a max.

– Five shallow CTD casts to 95m to measure in-situ fluorescence and photosynthetic efficiency of the phytoplankton.

– Finally we performed short-term incubation using radiotracers (55Fe and 14C) to measure iron bioavailability, Fe:C ratio and primary productivity.

The first half of our second transect was from Process station 1 to Process station 2. We left Process station 1 on the 31st January and arrived at Station 6 on the same day. At this station we did a CTD and TM cast. Due to a CTDF cable retermination we could not use the CTD and therefore to head off to Station 7 and do Station 8. At this station we did a CTD cast on the 2nd of February and then reached Process station 2 on the 3rd of February. The location of Process station 2 was changed to capture an increase in surface Chl a as seen in transmitted satellite images.

At Process station 2 – the ship remained on location for three days. The duration of this process station was shortened as fewer incubation experiments were scheduled and we needed to catch up on the original schedule (owing to late departure from Sydney). The following operations were performed:

– One set of incubations using water collected with hose pumping, investigating the phytoplankton response to different levels of pCO2 and Australian desert dust enrichment.

– Four TM casts to cover the whole water column down to 3500 m

– Three CTD casts down to 1000 m

– Six McLane pump deployments from 30 to 2000 m.

– Two deep CTD casts down to 4500 m, (due to problem of communication with the instruments of the CTD below 2800 m we decided to avoid any further deep CTD casts during the voyage.

– Interdial cast (0-500 m minimum) every 10-12h to investigate the variability of the depth of the deep Chl a max.

– Two shallow CTD casts to 95m to measure in-situ fluorescence and photosynthetic efficiency of the phytoplankton.

– Finally we performed short-term incubations using radiotracers (55Fe and 14C) to measure iron bioavailability, Fe:C ratio and primary productivity.

The second half of our second transect was from Process station 2 to Process station 3. We left Process station 2 late on the 4th of February and we sampled water at Station 10 (6th February) and 11 (7th February). According to satellite imagery station 9 was just out of a bloom of coccolithophores and station 11 marked the beginning of the bloom. CTD casts were done at both stations and TM cast and McLane deployment were done only at Station 10. We arrived at Process station 3 on the 7th of February. This process station was located in the bloom of coccolithophores captured by satellite imagery. The location of Process station 3 was also relocated in order to be as far south as possible and fully in the Sub-Antarctic region – a region known to be prone to iron limitation – a focus of this research voyage.

At Process station 3 – the ship remained on location for 3 days and the following operations were completed:

– Two sets of incubations were started using water collected with hose pumping- investigating Si uptake kinetics, phytoplankton response to different levels of pCO2, temperatures and Australian desert dust enrichment.

– One set of incubation using water collected at the depth of Chl a max (90 m) was started to investigate the phytoplankton response to iron enrichment (inorganic, organic and associated with Australian desert dust).

– Five TM casts to cover the whole water column from surface to 3500 m.

– Four CTD casts down to 1000m

– Six McLane pump deployments from 30 to 2000 m.

– Three shallow CTD casts to 95m to measure in-situ fluorescence and photosynthetic efficiency of the phytoplankton.

– Finally we performed short-term incubations using radiotracers (55Fe and 14C) to measure iron bioavailability, Fe:C ratio and primary productivity.

Our third transect was from Process station 3 to Hobart and was mainly within contrasted surface Chl a levels, associated with the bloom and the heterogeneous surface Chl a typically associated with this area (see work associated with SAZ-SENSE voyage in 2007). One of our aims was to identify whether iron and particularly its input from the continental shelf were responsible for such heterogeneity,

and thus, we did 6 stations in the transect. TM and CTD casts were done at all stations. McLane pumps were used to collect samples at stns SAZ-14, 16 and 18. Station SAZ-14 was the reoccupation of the Process station 3 from the SAZ-SENSE voyage (Aurora Australis, Jan-Feb 2007). We remained 36 h at this station to allow give better micronutrient characterisation using TM casts and the McLane pumps, experiencing some rougher weather condition prevented us deploying this equipment for 12 hours. At this station, the following operations were undertaken:

– Two TM casts to cover the whole water column from surface to 3750 m.

– One CTD casts down to 1000m

– Three McLane pump deployments from 30 to 2000 m.

– Two shallow CTD casts to 95m to measure in-situ fluorescence and photosynthetic efficiency of the phytoplankton.

Our last Station was just 44 nautical miles out of Hobart on the shelf and maximum depth sampled was 800 m for the CTD and 750 m for the TM casts. The voyage on time on the 15th of February around 17:30.

Summary

Overall the PINTS voyage was very successful; we benefited from very calm sea conditions and were, thus, able to deploy our equipments to sample for trace-metal work/analysis. The voyage clearly benefited from the inter-disciplinary background of the PIs and participants and much collaborative work was done at sea. Subsequent laboratory analyses are required to define whether we were successful in addressing our scientific objectives but so far preliminary results are promising.

GEOTRACES Process study

Project name:
PINTS – primary Productivity induced by Nitrogen and Iron in the Tasman Sea.

Coordinating body:
GEOTRACES (www.geotraces .org). Dr. Andrew Bowie is the GEOTRACES representative for Australia.

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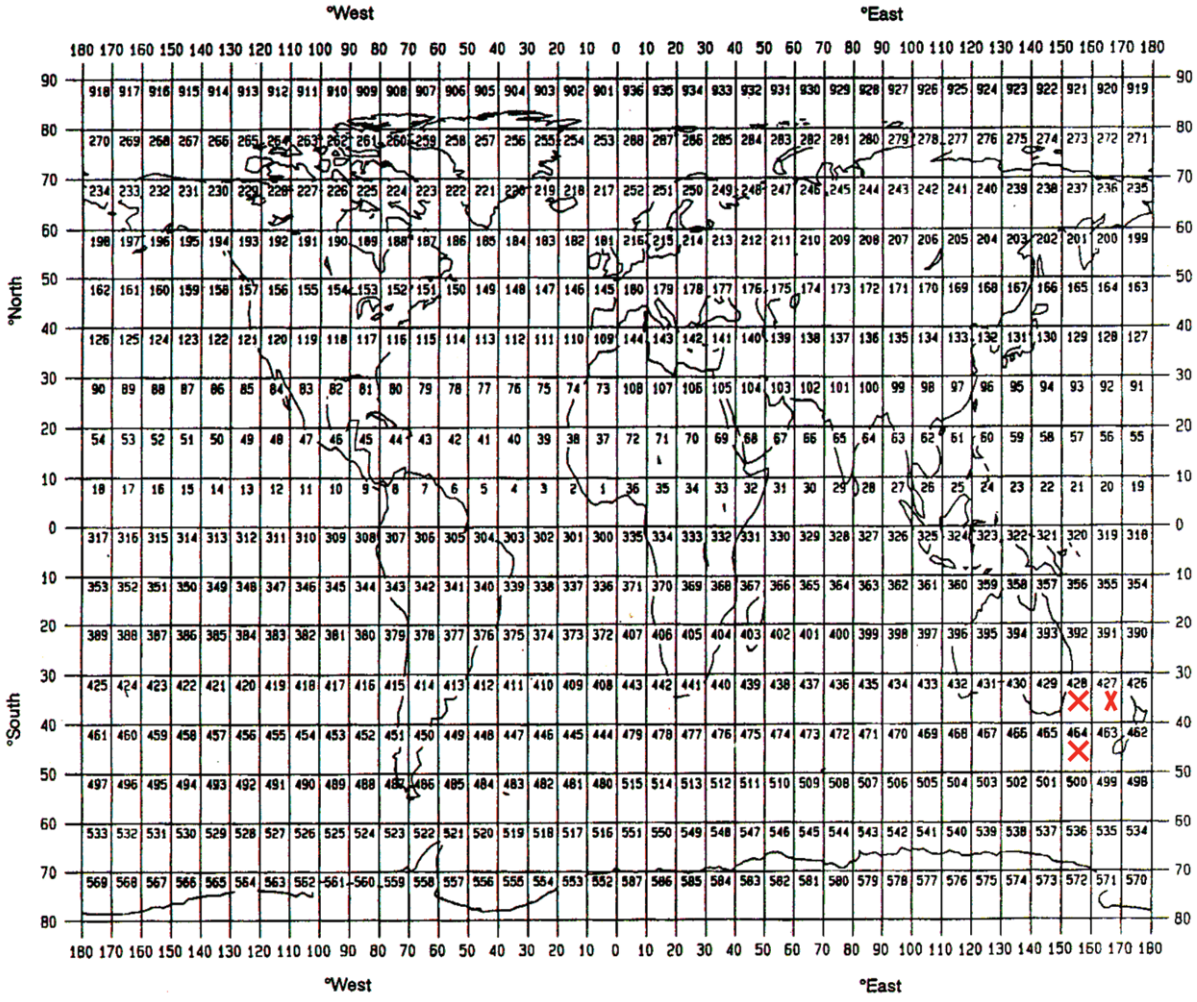
GEOGRAPHIC COVERAGE - INSERT 'X' IN EACH SQUARE IN WHICH DATA WERE COLLECTED



SUMMARY OF MEASUREMENTS AND SAMPLES TAKEN					
Item No.	**PI** see page above	**NO** see above	**UNITS** see above	**DATA TYPE**	**Description**
1	MNF	110	C		Temperature, measurement at the top and bottom of each CTD
2	MNF	115			Salinity and dissolved oxygen done to calibrate the sensor of the seabird 911, 2-3 sample per cast (depending on depth of CTD)
3	MNF	900	µg/L		Nutrients (NOx, Si and PO4) associated with CTD deployment and incubation experiments done at Process stations.
4	D	100	nmol/l/d		Biological nitrogen fixation rate in surface water sampled with CTD (top 75m), and in incubation experiments at Process stations. Measured by incorporation of isotopically-labelled dinitrogen into particulate organic nitrogen. Samples collected for land-based Mass Spectrometry analysis further.
5	D	30	N/A		Presence of nifh, a gene that controls the expression of nitrogenase, the primary enzyme used during nitrogen fixation. Samples collected from upper 75m from CTD, and in incubation experiments at Process stations. Analysis at IFM-GEOMAR, Kiel, Germany.
6	D	300	nM & µM		Nutrients (NO3, NO2, NH4) at low level from CTD (upper 75m from Stn 1 to Stn13) and incubation experiments done at Process stations. These need further analysis by flow injection and will complement analysis that were below detection limit from the MNF Hydrochemists
7	D	20	No. per ml		Identification, counts and morphological measurement of coccolithophores present in the top 30 m from CTD deployment. Analysis by Scanning Electron Microscope
8	D	20	µM		Particulate carbon and nitrate present at a depth of 15m from the CTD deployment and incubation experiments done at Process stations. Samples collected for land-based Mass Spectrometry analysis.
9	D	150	µM		Exo-enzymes associated with bacterial degradation of organic matter. Samples collected from CTD deployment from upper 75m and incubation experiments done at Process stations. Samples analysed using fluorescence techniques.
10	D & E	400	Relative units		Measurement done at sea from the top 100 m for each CTD and for incubation experiments done at Process stations. These relate to photosynthetic health of the phytoplankton community and are used to infer nutrient limitation. These samples were analysed with the FRRF and the Water-PAM on board.
11	E & A	350	Cell/mL		Sample for the determination of picoplankton abundance using flow cytometry. These samples require further analysis. Sample were taken from the top 100m at CTD deployment and from incubation experiments done at Process stations.
12	E	20	µg C/ Chla d		Measurement of primary productivity using 14C incorporation at 18 different light levels, done at sea. Primary productivity was measured at the process stations (full water column P vs I) and in association with incubation experiments done at process station (pCO2 and dust experiments). These would require further analysis: the analysis of pigments (see below) and dissolved inorganic carbon concentration.
13	E	100	Relative units		Measurement of photo-physiological parameters done at sea using a Water-PAM (Walz GmBH). These measurements will help to understand the acclimation of phytoplankton to different light levels and assess any potential nutrient stresss.

14	E	20	m^2 / mg		Measurement of particulate absorption (chlorophyll a specific optical absorption coefficient) and a*PSII (fraction of light absorbed by PSII) using spectrophotometric approach. Pigment analyses and in-situ PAR estimates will be required to derive carbon flux. The measurements were done to compare primary productivity using the conventional 14 C approach (see above).
15	C & F	40	µg/L or µg/ Chl a		Measurement of particulate organic carbon and nitrogen. These will require further analysis. These samples were collected from the CTD at a depth of 15 m and Chl a max.
16	A and C and E	400	µg/L		Measurement of pigments and Chl a using HPLC technique back in the laboratory. These will be use to infer the biomass and the composition of the phytoplankton community. These samples were collected from the CTD deployment (top 100m) and incubation experiments done at process stations.
17	F	300	nM		Samples collected for total dissolved iron from the trace metal rosette. These samples will be analysed in the lab using flow injection technique.
18	C and B	300	nM		Samples collected for total dissolved trace metals (Co, Ni, Cu, Zn, Cd, Pb) from the trace-metal-clean rosette. Sample will be analysed using ICP-MS.
19	B	220	nM		Samples collected using the trace-metal-clean rosette for Zn and Cu chemical speciation. Samples will be analysed using electrochemical techniques.
20	A	150	nM		Samples collected from the trace-metal-clean rosette and incubation experiments done at process stations for Fe chemical speciation. Samples will be analysed using electrochemical techniques.
21	A	50	nM Fe/ Chl a		Samples collected from the trace-metal-clean rosette for Fe bioavailability measurement using either phytoplankton culture representative of the Tasman Sea or the iron-bioreporter. These analyses will require further work in the lab.
22	C and A and F	80	nM		Samples collected from the trace-metal-clean rosette for dissolved Zn and Zn chemical speciation. These samples will require further analysis using flow injection and electrochemical techniques.
23	F	48	nM		Samples collected from the trace-metal-clean rosette- for a GEOTRACES intercalibration exercise in the determination of trace elements using various techniques.
24	B and F	40	nM		Samples collected from the McLane pumps for the determination of particulate metals, carbon, nitrogen and biogenic silicate. These samples will require further analysis using ICP-MS techniques
25	B	10	nM		Samples collected with the trace-metal-clean rosette for Fe and Cu isotopic signature. Samples will require further analysis using MC-ICP-MS technique.
26	A	200	nM Fe/ Chla h		Measurement of the effect of organic ligands, atmospheric dust and Cu and Zn on iron bioavailability to natural phytoplankton. Measurement of the Fe internalisation rate constant for natural phytoplankton using 55Fe incubation on-board. These measurements required further analysis (pigments and dissolved iron).
27	A	100	nM		Measurement of iron size fractionation (soluble and colloidal) using 55 Fe incubation at process stations.

28	D	3			Incubation experiments investigating the effect of atmospheric dust, variable pCO2 and increase temperature (4oC) on phytoplankton biomass, productivity, Fe: C ratio, Fe chemistry and nitrogen fixation.
29	A	2			Incubation experiments investigating the effect of inorganic and organic iron enrichment (incl. atmospheric dust) on phytoplankton, biomass, biodiversity, productivity and iron chemistry.
30	A	15			Fe:C ratio at process stations and associated with incubation experiments listed on 28.
31	E	150			Samples were collected from CTD deployments and fixed in alkaline Lugols solution to determine dominant phytoplankton groups using microscope enumeration. These samples will serve to complement pigment data.
32	A	300			N isotopic composition. These samples will require further analysis.
33	MNF	30			LADCP deployment to measure in-situ currents.
34	C				Atmospheric dust collection. These samples will require further analysis involving ICP-MS technique.
35	E	10	Relative units		In situ measurement at each process station of dark adapted fluorescence yield. Dual measurements using blue and red excitation will yield an estimate of the cyanobacterial photosynthetic efficiency as well as the photosynthetic efficiency of the total phytoplankton community.

CURATION REPORT

Item No.	DESCRIPTION
1	The organisational unit is the Marine National Facility. Data will also be made available (after the 2-year delay) on the GDAC Meta-database as this voyage is a GEOTRACES Process study.
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3	The organisational unit is the Marine National Facility. Data will also be made available (after the 2-year delay) on the GDAC Meta-database as this voyage is a GEOTRACES Process study.
4	The organisational unit is the NIWA. Data will be made available to international meta-database (GDAC). A timeframe of 2 years is expected to analyse the samples and publish the results.
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9	The organisational unit is the NIWA. Data will be made available to international meta-database (GDAC). A timeframe of 2 years is expected to analyse the samples and publish the results.
10	The organisational unit are the University of Technology Sydney and the University of Otago. Data will be made available on national meta-database (MarLIN) as well as international meta-database (GDAC). A timeframe of 2 years is expected to analyse the samples and publish the results.
11	The organisational unit is the University of Technology Sydney. Data will be made available on national meta-database (MarLIN) as well as international meta-database (GDAC). A timeframe of 3 years is expected to analyse the samples and publish the results.
12	The organisational unit is the University of Technology Sydney. Data will be made available on national meta-database (MarLIN) as well as international meta-database (GDAC). A timeframe of 3 years is expected to analyse the samples and publish the results.
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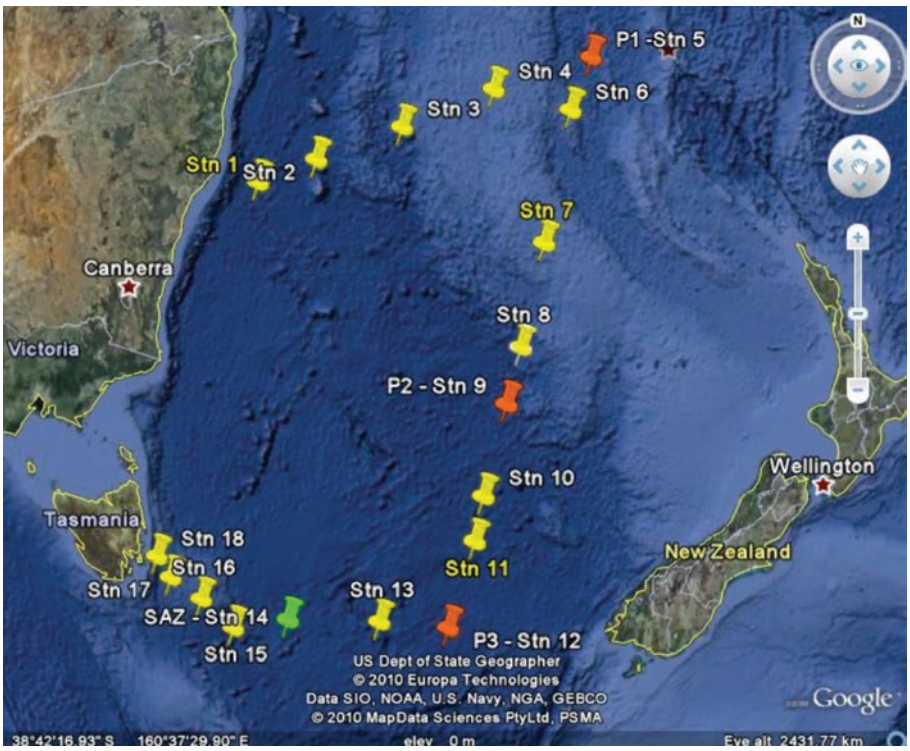
14	The organisational unit is the University of Technology Sydney. Data will be made available on national meta-database (MarLIN) as well as international meta-database (GDAC). A timeframe of 3 years is expected to analyse the samples and publish the results.
15	The organisational unit are CSIRO Marine and Atmospheric Reasearch and ACE-CRC. Data will be made available on international meta-database. A timeframe of 2 years is expected to analyse the samples and publish the results.
16	The organisational unit is CSIRO Marine and Atmospheric Reasearch. Data will be made available on national meta-database (MarLIN) as well as international meta-database. A timeframe of 2 years is expected to analyse the samples and publish the results.
17	The organisational unit is the University of Tasmania. Data will be made available on international meta-database. A timeframe of 2 years is expected to analyse the samples and publish the results.
18	The organisational unit are the Australian National University and CSIRO Marine and Atmospheric Research. Data will be made available on national meta-database (MarLIN) as well as international meta-database. A timeframe of 3 years is expected to analyse the samples and publish the results.

19	The organisational unit is the Australian National University. Data will be made available on national meta-database (MarLIN) as well as international meta-database. A timeframe of 3 years is expected to analyse the samples and publish the results.
20	The organisational units are the University of Technology Sydney and the University of Otago (NZ, Eike Breitbarth). Data will be made available on national meta-database (MarLIN) as well as international meta-database (GDAC). A timeframe of 3 years is expected to analyse the samples and publish results.
21	The organisational units is the University of Technology Sydney. Data will be made available on national meta-database (MarLIN) as well as international meta-database (GDAC). A timeframe of 3 years is expected to analyse the samples and publish the results.
22	The organisational unit is the Australian National University. Data will be made available on national meta-database (MarLIN) as well as international meta-database. A timeframe of 3 years is expected to analyse the samples and publish the results.
23	The organisational units are the University of Tasmania, the Australian National University, CSIRO Marine and Atmospheric Research, University of Technology Sydney. Data will be made available on international meta-database (GDAC). A timeframe of 2 years is expected to analyse the samples and publish the results.
24	The organisational unit are the Australian National University and the University of Tasmania. Data will be made available on national meta-database (MarLIN) as well as international meta-database. A timeframe of 2-3 years is expected to analyse the samples and publish the results.
25	The organisational unit is the Australian National University. Data will be made available on national meta-database (MarLIN) as well as international meta-database. A timeframe of 3 years is expected to analyse the samples and publish the results.
26	The organisational units is the University of Technology Sydney. Data will be made available on national meta-database (MarLIN) as well as international meta-database (GDAC). A timeframe of 2 years is expected to analyse the samples and publish the results.
27	The organisational units is the University of Technology Sydney. Data will be made available on national meta-database (MarLIN) as well as international meta-database (GDAC). A timeframe of 2 years is expected to analyse the samples and publish the results.
28	The organisational unit is the NIWA. Data will be made available to international meta-database (GDAC). A timeframe of 2 years is expected to analyse the samples and publish the results.
29	The organisational units is the University of Technology Sydney. Data will be made available on national meta-database (MarLIN) as well as international meta-database (GDAC). A timeframe of 2-3 years is expected to analyse the samples and publish the results.
30	The organisational units is the University of Technology Sydney. Data will be made available on national meta-database (MarLIN) as well as international meta-database (GDAC). A timeframe of 2 years is expected to analyse the samples and publish the results.
31	The organisational unit is the University of Technology Sydney. Data will be made available on national meta-database (MarLIN) as well as international meta-database (GDAC). A timeframe of 3 years is expected to analyse the samples and publish the results.
32	The organisational unit is Princeton University (USA, Patrick Rafter).
33	The organisational unit is the Marine National Facility. Data will also be made available (after the 2-year delay) on the GDAC Meta-database as this voyage is a GEOTRACES Process study.
34	The organisational unit is the CSIRO Marine and Atmospheric Research. Data will be made available (after 2-years) on national meta-database (MarLIN) as well as on the GDAC Meta-database as this voyage is a GEOTRACES Process study.
35	The organisational unit is the University of Technology Sydney. Data will be made available on national meta-database (MarLIN) as well as international meta-database (GDAC). A timeframe of 2 years is expected to analyse the samples and publish the results.

Voyage track

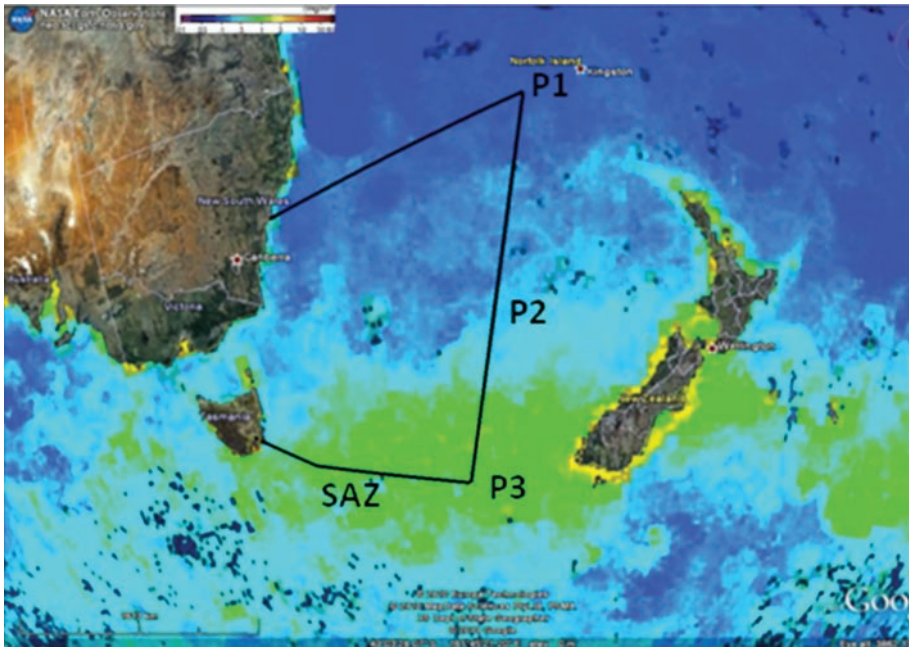


Transect stations are shown in yellow, process stations in red and reoccupation of the process station 3 from the SAZ-SENSE voyage (*Aurora Australis*, Jan-Feb 2007) in green.

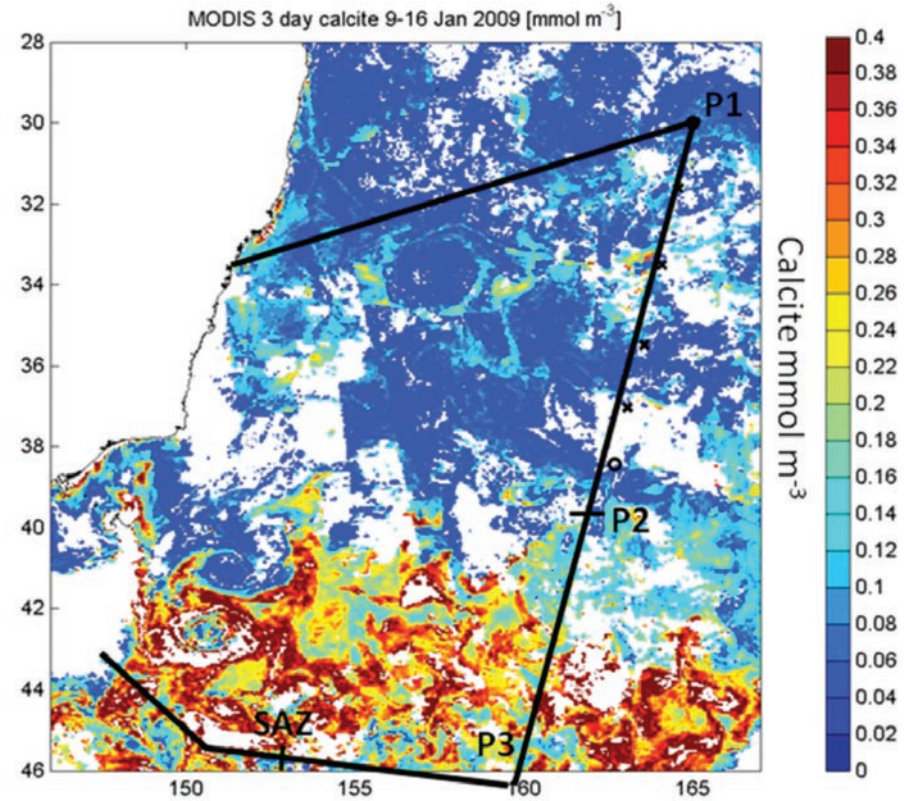
All the station where samples were taken for trace metal analysis (trace metal rosette, McLane pumps) are labelled in white, all other stations are labelled in yellow.

GENERAL OCEAN AREA:

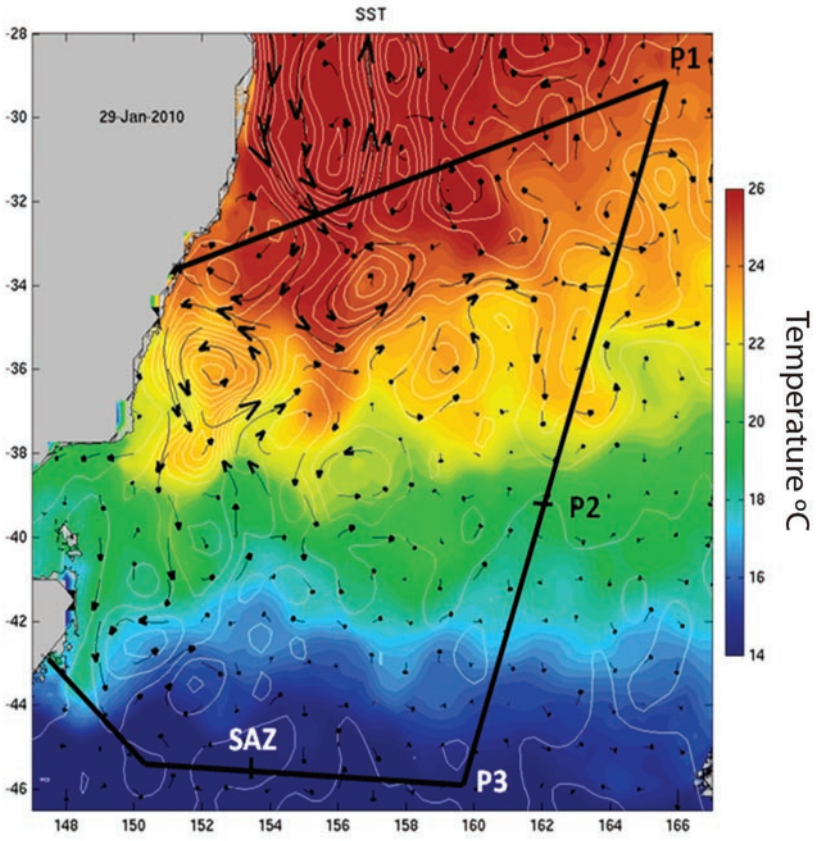
Tasman Sea



Composite chlorophyll a image for January to February 2010 with the voyage track overlaid.



Calcite- 8 day average from MODIS. Similar image was obtained from the 17-24 January 2010. Image is a courtesy of Dr. Mark Baird.



Sea Surface temperature map of the study area.
Image is a courtesy of Dr. Ken Ridgway.

SPECIFIC AREAS:

North and South of Tasman front and the northern part of the Subantarctic zone.

PERSONNEL LIST

Scientific Participants

Name	Affiliation	Role
Christel Hassler	UTS	Chief Scientist – Biological and Chemical Oceanographer
Michael Ellwood	ANU	Alternate Chief Scientist – Chemical Oceanographer
Claire Thompson	ANU	Chemical Oceanographer – PhD student
Edward Butler	CSIRO	PI – Chemical Oceanographer
Eike Breitbarth	UOtago	Chemical Oceanographer
Ros Watson	CSIRO	Chemical Oceanographer
Cliff Law	NIWA	PI – Biological Oceanographer
Robert van Hale	NIWA/UOtago	Chemical Oceanographer
Martina Doblin	UTS	PI – Biological Oceanographer
Gabriel Shaw	UTS	Biological Oceanographer – Honours student
Karl Forcey	CMAR	MNF Electronic support
Alicia Navidad	CMAR	MNF Hydrochemistry support
Sue Reynolds	CMAR	MNF Hydrochemistry support
Hiski Kippo	CMAR	MNF Computing support
Don McKenzie	CMAR	MNF Voyage Manager

Marine Crew

Name	Role	Name	Role
Les Morrow	Master	Gareth Gunn	IR
John Barr	Chief Mate	Matt Barrett	IR
Rob Ferries	Second Mate	Jonathan Lumb	IR
Nick Fleming	Chief Engineer	Peter Ives	IR
Dave Jonker	First Engineer	Jason Wall	Chief Cook
Seamus Elder	Second Engineer	Robert Dittko	Second Cook
Tony Hearne	Bosun CIR	Cassandra Rowse	Chief Steward

Acknowledgements

I wish to acknowledge ANU, NIWA, UTAS, ACE-CRC and CSIRO support for sharing important equipment essential to sample water for trace metal work and perform incubation experiments. I thank ANU, NIWA, UOtago, UTAS, CSIRO, UTS and ARC Discovery Project scheme (DP 1092892) for financial support for post-voyage analysis. I also thank Tom Trull, Lesley Clementson and Andrew Bowie who were essential for the preparation of this voyage and contributed to post-voyage analysis; Mark Baird and Ken Ridgway for their insightful satellite images. I would like to give special thanks to Ed Butler who encouraged me in the early stages and throughout the accomplishment of this research project.

I also would like to warmly thank the MNF and CSIRO-CMAR for their financial support on this research voyage. Finally, I would like to thank all the Marine National Facility and their staff as well as the crew of the RV *Southern Surveyor* as without them this voyage would not have been possible.

Christel Hassler
Chief Scientist

CSR/ROSCOP PARAMETER CODES

METEOROLOGY

M01 Upper air observations
M02 Incident radiation
M05 Occasional standard measurements
M06 Routine standard measurements
M71 Atmospheric chemistry
M90 Other meteorological measurements

PHYSICAL OCEANOGRAPHY

H71 Surface measurements underway (T,S)
H13 Bathythermograph
H09 Water bottle stations
H10 CTD stations
H11 Subsurface measurements underway (T,S)
H72 Thermistor chain
H16 Transparency (eg transmissometer)
H17 Optics (eg underwater light levels)
H73 Geochemical tracers (eg freons)
D01 Current meters
D71 Current profiler (eg ADCP)
D03 Currents measured from ship drift
D04 GEK
D05 Surface drifters/drifting buoys
D06 Neutrally buoyant floats
D09 Sea level (incl. Bottom pressure & inverted echosounder)
D72 Instrumented wave measurements
D90 Other physical oceanographic measurements

CHEMICAL OCEANOGRAPHY

H21 Oxygen
H74 Carbon dioxide
H33 Other dissolved gases
H22 Phosphate
H23 Total – P
H24 Nitrate
H25 Nitrite
H75 Total – N
H76 Ammonia
H26 Silicate
H27 Alkalinity
H28 PH
H30 Trace elements
H31 Radioactivity
H32 Isotopes
H90 Other chemical oceanographic measurements

MARINE CONTAMINANTS/POLLUTION

P01 Suspended matter
P02 Trace metals
P03 Petroleum residues
P04 Chlorinated hydrocarbons
P05 Other dissolved substances
P12 Bottom deposits
P13 Contaminants in organisms
P90 Other contaminant measurements

MARINE BIOLOGY/FISHERIES

B01 Primary productivity
B02 Phytoplankton pigments (eg chlorophyll, fluorescence)
B71 Particulate organic matter (inc POC, PON)
B06 Dissolved organic matter (inc DOC)
B72 Biochemical measurements (eg lipids, amino acids)
B73 Sediment traps
B08 Phytoplankton
B09 Zooplankton
B03 Seston
B10 Neuston
B11 Nekton
B13 Eggs & larvae
B07 Pelagic bacteria/micro-organisms
B16 Benthic bacteria/micro-organisms
B17 Phytobenthos
B18 Zoobenthos
B25 Birds
B26 Mammals & reptiles
B14 Pelagic fish
B19 Demersal fish
B20 Molluscs
B21 Crustaceans
B28 Acoustic reflection on marine organisms
B37 Taggings
B64 Gear research
B65 Exploratory fishing
B90 Other biological/fisheries measurements

MARINE GEOLOGY/GEOPHYSICS

G01 Dredge
G02 Grab
G03 Core – rock
G04 Core – soft bottom
G08 Bottom photography
G71 In-situ seafloor measurement/sampling
G72 Geophysical measurements made at depth
G73 Single-beam echosounding
G74 Multi-beam echosounding
G24 Long/short range side scan sonar
G75 Single channel seismic reflection
G76 Multichannel seismic reflection
G26 Seismic refraction
G27 Gravity measurements
G28 Magnetic measurements
G90 Other geological/geophysical measurements