SANAE 55 Cruise Report

Compiled by

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3. Cruise Research projects:

1. Southern Ocean Seasonal Cycle Experiment III summer cruise (SOSCEx III) - led by CSIR with Dr Pedro Monteiro

- Scale Sensitivities of CO_2 Fluxes in the Southern Ocean - **SNA14072378878** – led by Dr Pedro Monteiro
- Surface ocean physical dynamics of the Southern Ocean –**SNA14071475720** – led by Dr Sebastian Swart
- Understanding the biogeochemical response to physical drivers in the Southern Ocean using bio-optics - **SNA14073184298 –** led by Dr Sandy Thomalla
- Bioactive trace elements in Southern Ocean – **SNA2011110100001 –** led by Prof Alakendra Roychoudhury
- Southern Ocean Phytoplankton Adaption to mimicked future changes in light and iron availability - Molecular bases and modelling (SOPA) – **SANCOOP 234229** – led by Dr Susanne Fietz

2. South Atlantic Meridional Overturning Circulation SA (SAMOC-SA) - **SNA14071275358** - led by Prof Isabelle Ansorge.
3. Vibration Responses of the SA Agulhas II Polar Supply and Research Vessel – led by Dr Anriette Bekker
4. Ross Seal Foraging Ecology, Mammal Research Institute – led by Prof Marthan Bester
5. The Continuous Plankton Recorder (CPR) for basin scale mapping of plankton – led by DEA under Dr Sir Hans Verheye.
6. Bird life SA – At sea top predator observations – led by Dr Azwianewi Makhado

4. Cruise participants (ship based scientists)

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PI = Principal Investigator; GL = Group Leader

5. Introduction

5.1. Bonus Good Hope line (BGH)

Interocean exchanges play an important role in global climate in response to variations of local or remote heat and freshwater fluxes via the global ocean circulation. Pathways and mechanisms of oceanic heat fluxes and fresh water transports are critical issues in the comprehension of the present climate and its stability. This global ocean transport is coupled to convective overturning, happening essentially in the North Atlantic and in the Southern Ocean, which links the full ocean volume to the climate at decade-to-century time-scales. In the following we will refer to this global circulation with the term of "Meridional Overturning Circulation" (MOC) (**Figure 1**). But what is the MOC structure, and how does it feed back into convective processes and their associated climate phenomena? Because observations are sparse, the detailed global structure of the MOC remains poorly understood.

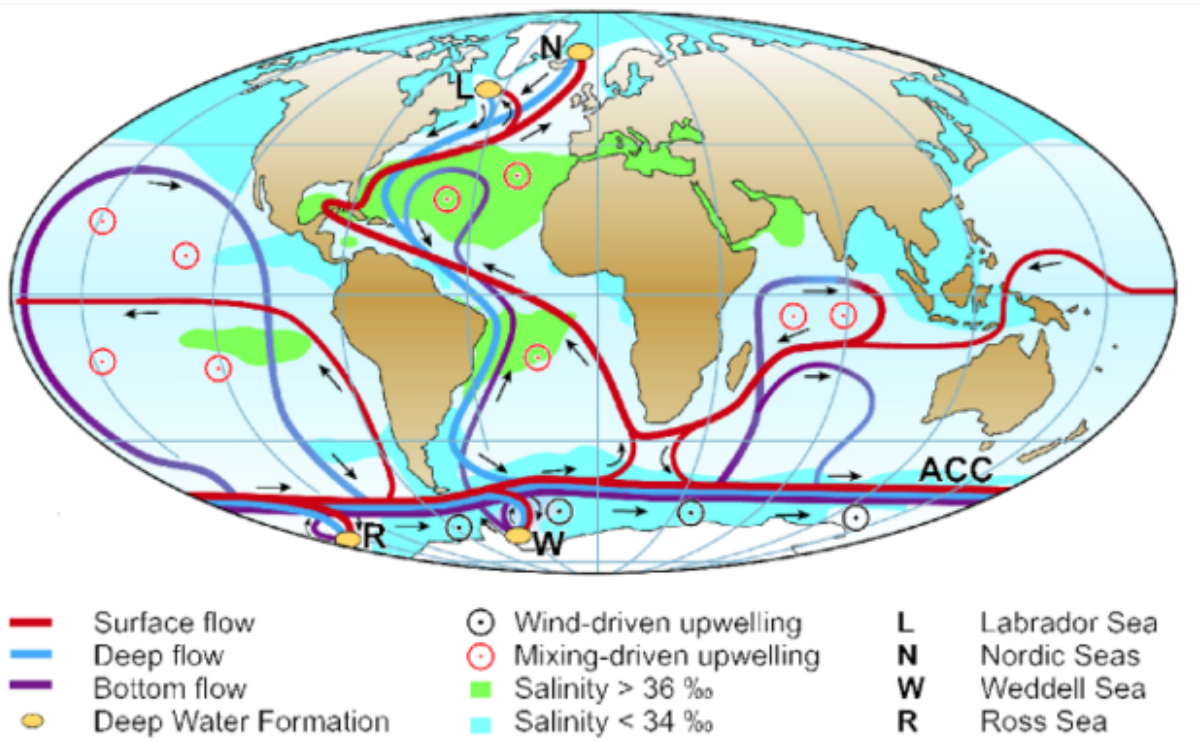

Figure 1. Schematic of the ocean circulation (from Kuhlbrodt et al., 2007) associated with the global Meridional Overturning Circulation (MOC), with special focus on the Atlantic section of the flow (AMOC). The red curves in the Atlantic indicate the northward flow of water in the upper layers. The filled orange circles in the Nordic and Labrador Seas indicate regions where near-surface water cools and becomes denser, causing the water to sink to deeper layers of the Atlantic. This process is referred to as "water mass transformation," or "deep water formation." In this process heat is released to

the atmosphere. The light blue curve denotes the southward flow of cold water at depth. At the southern end of the Atlantic, the AMOC connects with the Antarctic Circumpolar Current (ACC). Deep water formation sites in the high latitudes of the Southern Ocean are also indicated with filled orange circles. These contribute to the production of Antarctic Bottom Water (AABW), which flows northward near the bottom of the Atlantic (indicated by dark blue lines in the Atlantic). The circles with interior dots indicate regions where water upwells from deeper layers to the upper ocean.

The Southern Ocean is a critical crossroad for this process as it provides an interocean communication route for heat and freshwater (climate) anomalies, as well as anthropogenic tracers (Sloyan & Rintoul, 2001; Sarmiento et al., 2004). The polar-extrapolar communication of heat and freshwater helps to close the hydrological cycle through the production of Antarctic Intermediate Water and Subantarctic Mode Water (AAIW and SAMW). The Southern Ocean plays also a key role in the global carbon cycle due to unique features involving both dynamical and biological processes (Sabine et al. 2004). In particular, the outcropping of deep-waters as well as formation of AAIW, SAMW and Antarctic Bottom Water provide an important mean of gases such as CO_2, to be exchanged between the deep sea and the atmosphere (**Figure 2**). Also, AAIW and SAMW transfer nutrients northward within the thermocline. Recent hypotheses suggest that this transfer could sustain a large part of the primary and export productions of the world ocean (up to 75%, Sarmiento et al., 2004).

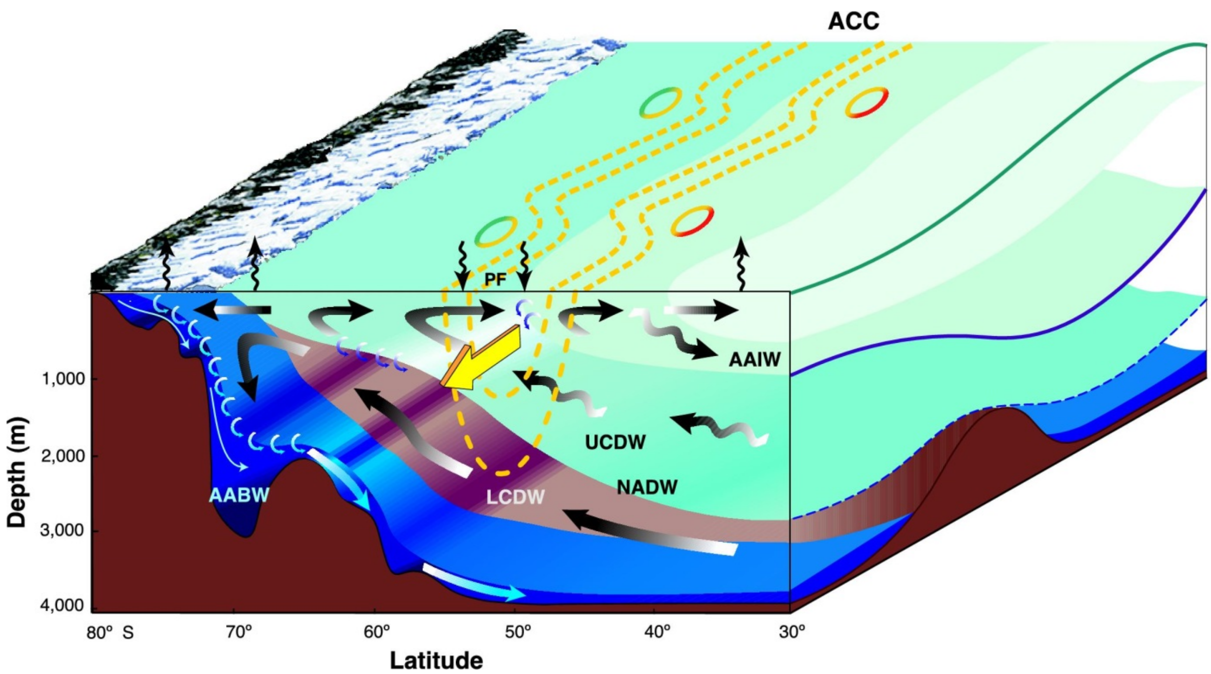

Figure 2: Schematic representation of Southern Ocean meridional overturning circulation. (From http://dimes.ucsd.edu)

The Antarctic Circumpolar Current (ACC) is by far the largest conduit for interbasin exchanges. Very recent analyses of satellite and in situ observations have uncovered that the Southern Ocean is a very turbulent region (Sokolov and Rintoul, 2007a; 2007b; Sallée et al. 2007). This is particular true for the ACC. Indeed, this current that is the most intense of the world ocean is not flowing eastward as an homogeneous wide flow but it is concentrated on a number of quasi-permanent circumpolar jets (**Figure 3**). These jets are limited by fronts that dynamically separate water masses. Their positions are determined by topographic steering (Gordon et al., 1978; Rintoul et al., 2001) and by the wind stress curl (Nowlin and Klinck, 1986). These frontal systems are thought to be the sites of formation of SAMW and AAIW

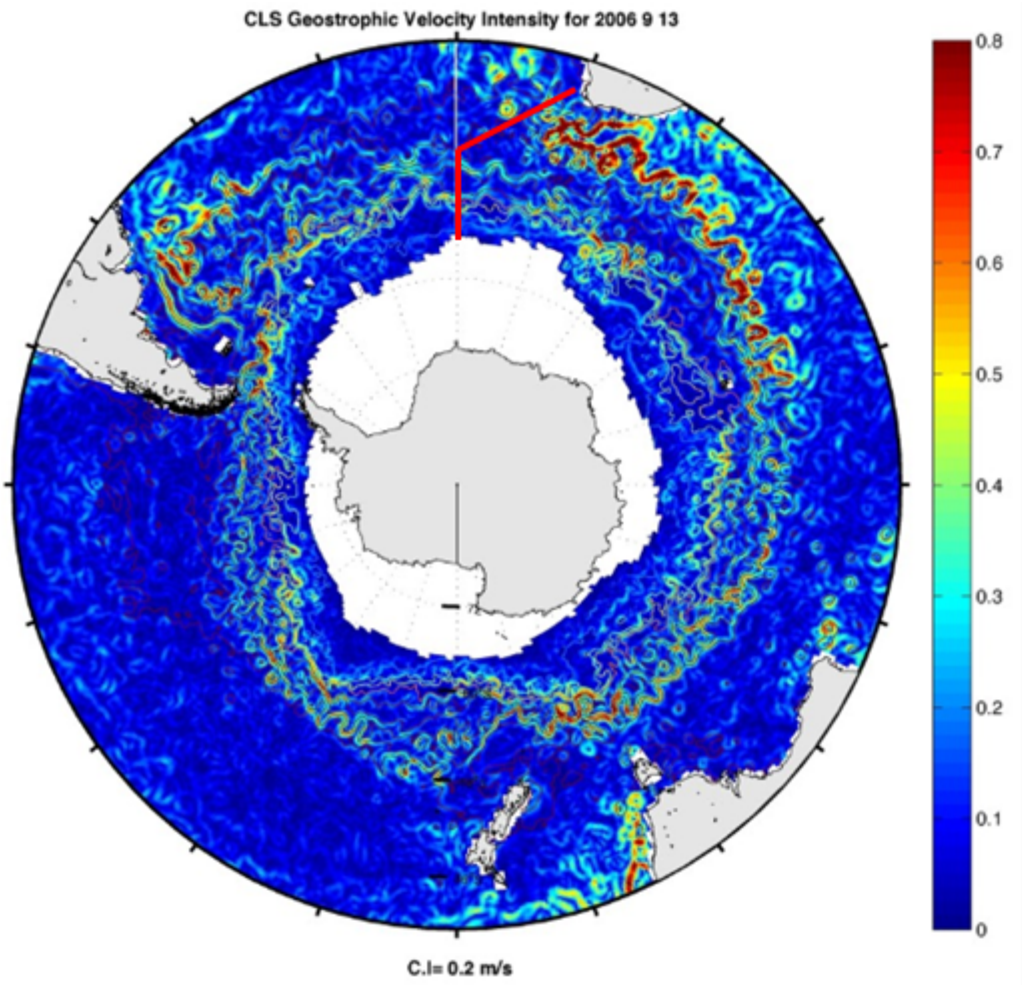

Figure 3: Intensity of the Southern Ocean geostrophic velocity computed from the CLS altimetry derived Absolute Dynamical Topography for November 11, 2006. The figure shows the existence of multiple intense jets that compose the Antarctic Circumpolar Current (colours are function of the intensity of the velocity. These jets materialize the limit of multiple circumpolar fronts (contours).

The Bonus Good Hope line (BGHL) transect is a monitoring platform that provided detailed information on the physical, biological and chemical structure of ocean water mass south of South Africa, where two ocean basins (Atlantic and Indian) exchanges. This transect has been achieved through a multi-national collaboration between the UK, USA, France, Netherlands and Russia with South Africa having completed 18 of the 23 crossings. The initial heat flux focus of XBT observations has been extended to include CO_2 observations and underway ocean biogeochemistry sampling and now counts the strongest demonstration of South Africa's steward-ship activity in the Southern Ocean. The aim of the BGHL programme is to establish an intensive monitoring platform that provides detailed information on the physical structure and volume flux of water south of South Africa, where inter-ocean basin (Indian and Atlantic oceans) exchanges occur. Sustained observations such as repeat transects provide the only means to monitor the vertical structure and to investigate the variability of the fronts in this region. The BGHL programme investigates year to year and longer period variability in the fluxes, such as those related to the Antarctic Circumpolar Wave. The objectives of the Good Hope line are to continue the repeat high density physical and biogeochemical data collection along the Good Hope cruise track.

5.2. Cruise track

SANAE 55 cruise undertook a transect along the Bonus Good Hope line from the 5th December 2015 to 12th February 2016 (34.02°S; 14.64°E - 51.43°S; 0.00°E – 70.00°S; 02.00°W). The cruise crossed important Southern Ocean fronts, Sub-Antarctic Zone (SAZ), Polar Front (PF) and Antarctic Circumpolar Current (ACC). The Buoy run transect was also conducted that crossed the Weddell Sea to South Georgia island (70.16°S; 08.40°W – 54.11°S; 36.00°W) (**Figure 1**).

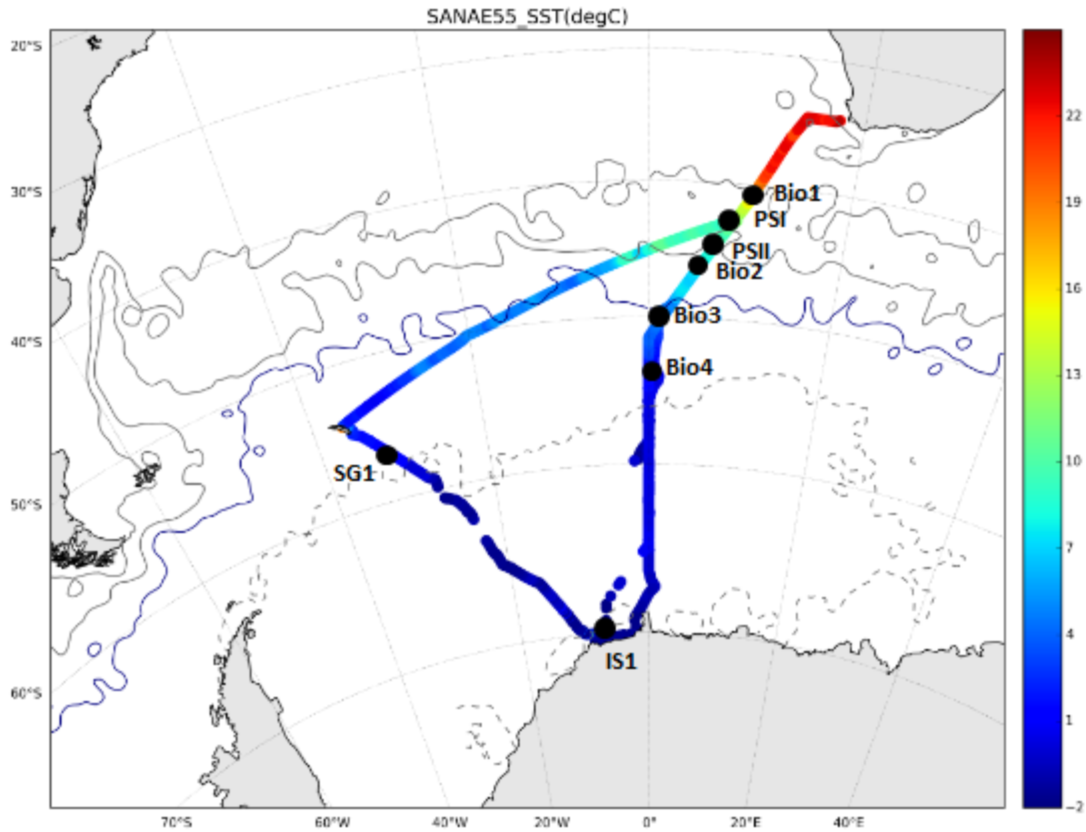

Figure 4: SANAE 55 cruise track map of sea surface temperature (SST) along the Bonus Good Hope Line and Buoy run. Black dots represents the CTD sampling stations: Bio1 (37°24.487'S; 12°31.127'E), PSI (42°41.579'S; 08°44.271'E), PSII (45°00.683'S; 06°33.759'E), Bio2 (45°59.918'S; 05°55.559'E), Bio3 (50°27.091'S; 01°02.574'E), Bio4 (55°41.979'S; 00°00.002'W) IS1 (70°26.551; 07°49.456'W), SG1 (55°41.349'S; 33°58.768'W)

5.3. Cruise highlights

For the first time, the Bonus Good Hope line transect was sampled and crossed three times during austral spring season (early summer 5th – 16th December 2015; mid-summer 5th – 11th January 2016; late-summer 31st January – 11th February 2016). This high sampling resolution using a combination of underway and continuous sampling, on-board ship incubation experiments, robotics (buoyancy and wave gliders, bio-optics, Argo floats), high resolution models and Satellite observations, will cover the full seasonal cycle in the Southern Ocean. Deep CTD cast for CPIE calibration were conducted as well as the underway XBT deployments to measure the heat flux along the BGH line. A continuous underway ship's sound, slamming and vibration were investigated in order to understand the effects on human comfort (motion sickness) as well as the Antarctic sea ice measurements to understand its impact on the structural dynamics of the ship. Underway sea-birds observation as top predators was also conducted. For the first time, Ross seal foraging ecology project was conducted and about 11 seals were tagged with

Satellite Relay Data (Position, time, Depth and Temperature) loggers and a total of 22 Ross seals samples for scats, vomitus, blood fur and whiskers were collected.

5.4. Cruise General Objectives

The general cruise objectives for each project are:

1. **Objective 1**: *SOSCEx III* – to conduct high resolution seasonal sampling (early-, mid- and late summer) using a combination of ship-based experiments (**ocean productivity**: Biological Carbon Pump, Bio-optics, **CO2**: Solubility Pump, **Trace Metals**: Iron (Fe) Biogeochemistry), robotics (**Gliders**: Buoyancy and Wave gliders, Argo floats), high resolution **models** and satellite observations in order to understand how ocean regulates and influenced by climate change. The SANAE 55 summer cruise complete the SOSCEx III project and this will aid us in understand the Southern Ocean seasonal cycle (winter vs summer).
2. **Objective 2**: *SAMOC-SA* – to conduct deep CTD cast in order to calibrate 4 CPIES that were deployed during winter cruise (22 July – 15 August 2015) and to continue with long term heat flux monitoring transect using XBT's along the Bonus Good Hope line. To gain a better understanding of Indo-Atlantic inter-ocean exchanges and their impact on the global thermohaline circulation and thus on global climate change; To understand in more detail the impact these exchanges have on the climate variability of the southern African subcontinent; To monitor the variability of the main Southern Ocean frontal systems associated with the Antarctic Circumpolar Current; To study air-sea exchanges and their role on the global heat budget, with particular emphasis on the intense exchanges occurring within the Agulhas Retroflection region south of South Africa, and to examine the role of major frontal systems as areas of elevated biological activity and as biogeographic barriers to the distribution of plankton.
3. **Objective 3**: *Ship's sound and vibration* – to determine the effects of the Southern Ocean and Antarctic waves and ice forces on the ship's hull, propeller and equipments on board in terms of structural fatigue life for the expected 30 years of operation.
4. **Objective 4**: *At sea-birds observation* – to collect and identify sea-birds abundance, distribution and diversity data for the classification of ocean "hotspots" which can therefore be used for seabirds conservation.
5. **Objective 5**: *Ross Seal foraging and ecology* – to improve our knowledge of the way oceanographic conditions affect the rarest of the four true Antarctic species of seal breeding off the Princess Martha Coast, Antarctica, with a view to using them as bio-indicators of apparent environmental change due to global climate change.

5.5. Cruise Activities (specific objectives) on RV SA Agulhas II

As indicated/shown above (**Figure 1**), the cruise track was divided into three Legs in order to cover the summer seasonal cycle along the BGH line. The activities conducted during each Leg are indicated below.

Leg 1: Undertook transect from 05th to 15th December 2015 along the Good Hope line (GH) from Cape Town to Antarctica. Cruise track and CTD stations are shown below in **Figure 5**.

The following activities were conducted:

1. CTD1, 3 and 4 stations: deep (>4000m) GEOTRACES Niskin CTD casts were conducted for CPIEs calibration.
2. Underway XBT deployment every 90 minutes
3. Human comfort response to sound, vibration and slamming questioneers were handed to passengers to complete
4. Underway surface ocean biogeochemistry sampling for Chl-a every 4 hours, nutrients, POC, HPLC, proteins every 2 hours.
5. Continuous underway pCO_2 and TCO_2 measurements
6. Underway sea-birds observations
7. *Bio1 station*: 1 x shallow (1000m) GEOTRACES GoFlo Fe pool and other trace elements, 1 x shallow (1000m) GEOTRACES Niskin biology casts
8. *PS1 station*: 1 x shallow (100m) GEOTRACES GoFlo cast Fe/light and P vs E bioassay experiments; 1 x shallow (1000m) GEOTRACES GoFlo Fe pool and other trace metals cast; 1 x shallow (1000m) GEOTRACES Niskin biology/glider calibration cast; retrieval and deployments of buoyancy glider and deployment of wave glider.
9. *PS2 station*: 1 x shallow (1000m) GEOTRACES GoFlo Fe pool and other trace metals cast; 1 x shallow (1000m) GEOTRACES Niskin biology cast; retrieval and deployment of buoyancy glider.
10. Pack ice thickness daily measurements, shaft line vibration and ship's structural vibration
11. Ross seals census

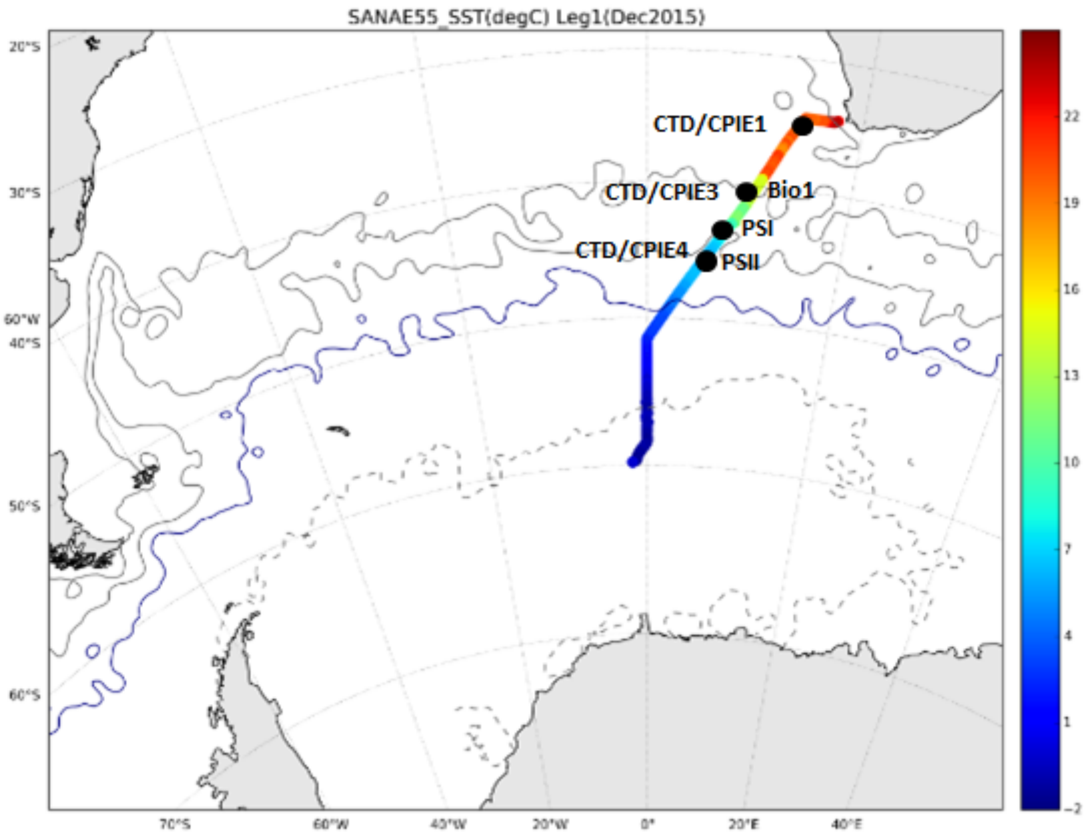

Figure 5: Plot of SST along the GH. Black dots indicate the CTD 1, 3 and 4 stations conducted for CPIE calibrations. Gliders were deployed at PSI and II as part of the SOSCEx III and GEOTRACES CTD profiles.

Leg 2: Undertook transect from 24th December 2015 to 12th January 2016. Leg 2 transect crossed the Weddell Sea to South Georgia (70.482°S; 8.31°W – 54.82°S; 35.55°W**)**, then across the Sub-Antarctic Zone (SAZ) and connected the BGH line at 42°41.5'S; 08°44.1'E (PS1 station). Then, from BGH line to ice shelf (70.14°S; 02.14°W).

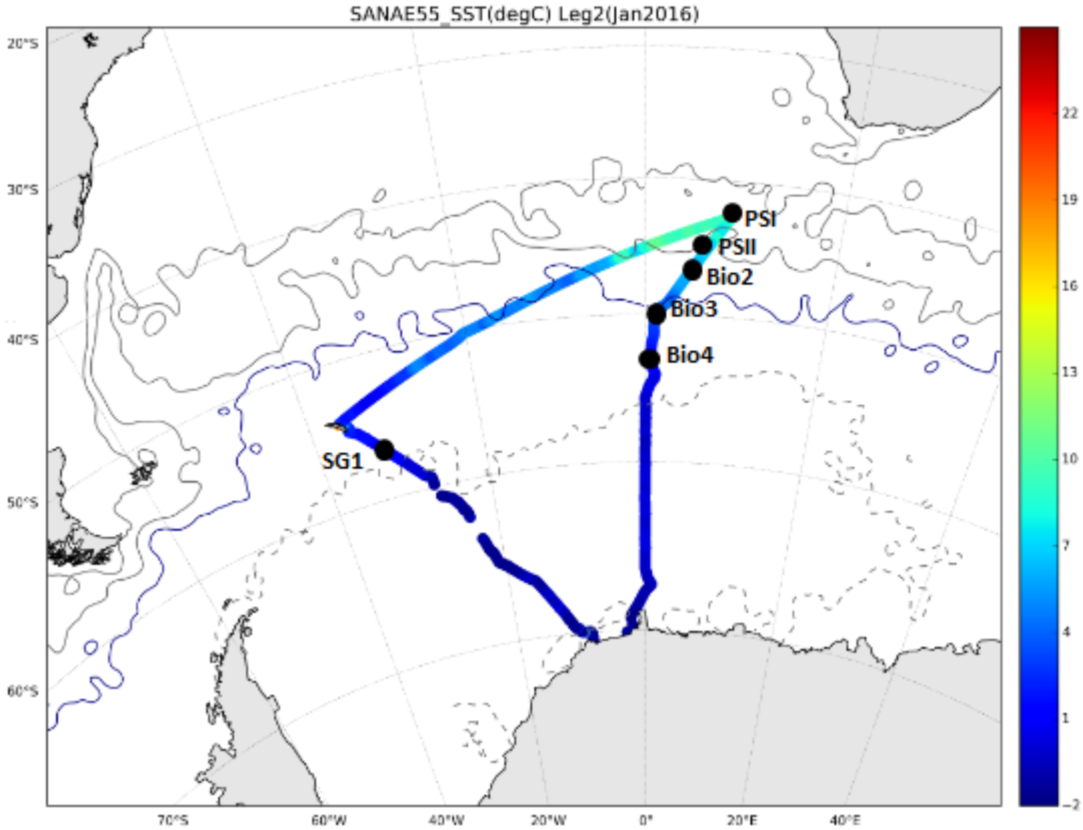

Figure 6: Plot of SST along the cruise track. Black dots indicate the SG1, PSI and II, Bio2/DTM2, Bio3/TM1 and Bio4/DTM3 stations.

The following activities were conducted:

1. Pack ice thickness daily measurements, shaft line vibration and ship's structural vibration
2. Underway surface ocean biogeochemistry sampling for Chl-a every 4 hours, nutrients, POC, HPLC, proteins every 2 hours.
3. Continuous underway PCO2 and TCO2 measurements
4. Underway at sea-birds observations
5. Human comfort response to sound, vibration and slamming
6. Ross Seals census
7. Retrieval and deployment of SAWS buoy at South Thuli
8. Dropped 6 SAWS buoys at South Georgia
9. Deployment of 5 SAWS buoys en-route to PS1 station
10. *PS1 station*: 1 x shallow (100m) GEOTRACES GoFlo CTD cast for Fe/light and P vs E bioassay experiments, 1 x shallow (1000m) GEOTRACES Niskin CTD cats and 1 x deep (2000m) GEOTRACES GoFlo Fe pool and other trace elements cast.
11. *PS2 station*: 1 x deep (2000m) GEOTRACES GoFlo Fe pool and other trace metals cast; 1 x deep (4500m) GEOTRACES Niskin biology and CPIE calibration cast.

12. *Bio2/DTM2 station*: 1 x deep (4500m) GEOTRACES GoFlo Fe pool. Other trace metals cast including P vs. E bioassay experiment; 1 x shallow (1000m) GEOTRACES Niskin biology.
13. *Bio3/TM1 station*: 1 x shallow (4500m) GEOTRACES GoFlo Fe pool, other trace metals cast including P vs. E bioassay experiment; 1 x shallow (1000m) GEOTRACES Niskin biology.
14. *Bio4/DTM3 station*: 1 x deep (4500m) GEOTRACES GoFlo Fe pool, other trace metal cast including P vs. E bioassay experiment; 1 x shallow (1000m) GEOTRACES Niskin biology.

Leg 3: Undertook transect on the 31st January to 11th February 2016 along the Zero Meridian to GH line (70.25°S; 02.83°W to 51.43°S; 00.00°W/E) from Antarctica to Cape Town (34.500°S, 17.259°E) (**Figure 7**).

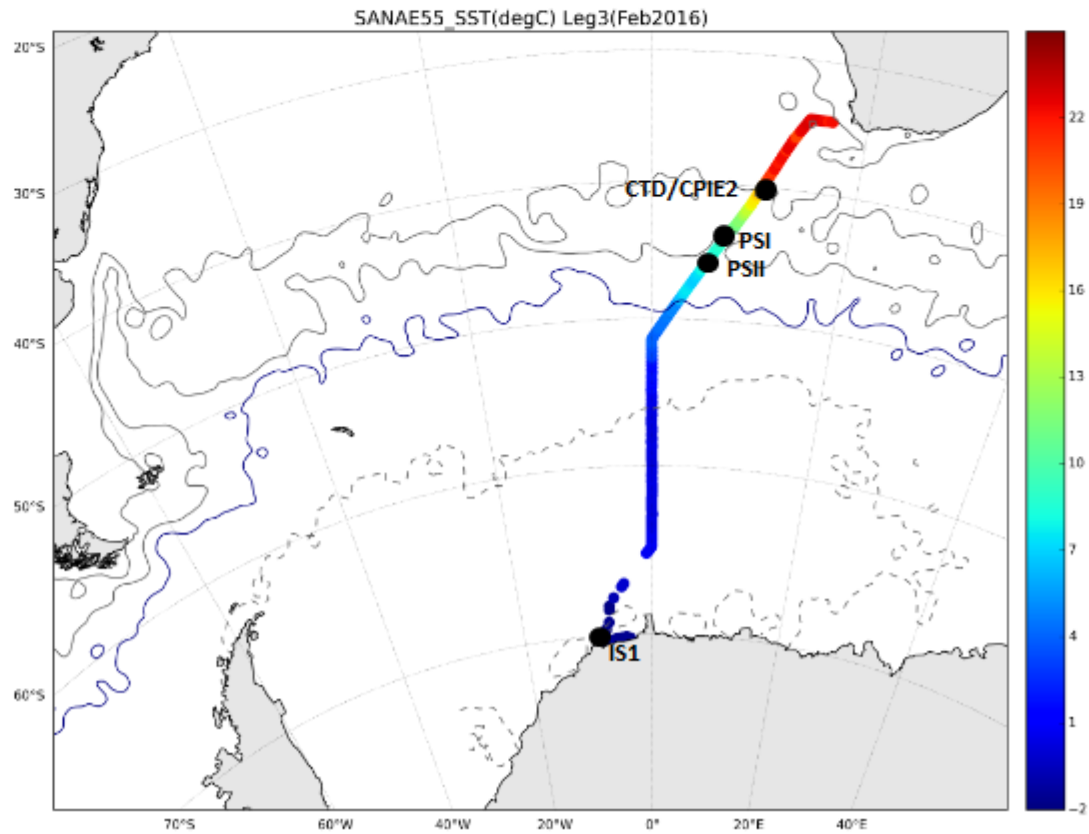

Figure 7: Plot of SST along the cruise track. Orange dots represent the Argo floats deployments, Black dots indicate Ice shefl (IS1), PS1 and 2 and CTD/CPIE2.

The following activities were conducted:

1. Underway Continuous Phytoplankton Recorder (CPR)
2. Underway surface ocean biogeochemistry sampling for Chl-a every 4 hours, nutrients, POC, HPLC, proteins every 2 hours.

3. 5 x Argo floats deployments
4. Underway XBT deployment every 90 minutes
5. At-sea bird observations
6. Human comfort response to sound, vibration and slamming
7. *PS2 station*: 1 x deep (2000m) GEOTRACES GoFlo Fe pool and other trace metal cast; 1 x shallow (1000m) GEOTRACES Niskin biology cast; Retrieval of a buoyancy gliders retrievals, deployment of Argo float.
8. *PS1 station*: 1 x shallow (100m) GEOTRACES GoFlo Fe/light and P vs E bioassay experiments; 1 x deep (2000m) GEOTRACES Fe pool and other trace metals cast; retrieval of wave and buoyancy gliders; 1 x shallow (1000m) GEOTRACES Niskin biology cast.
9. *CTD2 station*: 1 x deep (4500m) GEOTRACES Niskin for CPIE calibration.

6. Southern Ocean Seasonal Cycle Experiment III (SOSCEx III)

Rationale

The Southern Ocean is a key component of the earth system through its regulation of atmospheric CO_2 (50% of ocean CO_2 uptake; 30% of carbo export flux) and the global heat balance through the closure of the global meridional ocean circulation and its seasonal sea ice dynamics (Schlitzer et al., 2002; Marinov et al., 2006; Marinov et al., 2008; Sallée et al., 2010; Marshall and Speer, 2012; Gille, 2014; Waugh, 2014). It also plays a pivotal ecosystem role through both ocean primary production as well as in regulating the supply of nutrients, to the lower latitudes which supports 85% of ocean production (Marinov et al., 2008; Sarmiento et al., 2004). Changes to the Southern Ocean carbon cycle and its impact on 21st century atmospheric CO_2 depend critically on the climate sensitivity of these large-scale characteristics (Watson et al., 2014; Le Queré et al., 2007, 2013; Roy et al., 2011; Raupach et al., 2014). Based on recent preliminary findings we propose that the seasonal cycle is a key mode to both diagnose these sensitivities and evaluate earth systems models.

The mean decadal global anthropogenic carbon budget and ocean uptake (1.8 – 2.2$PgCy^{-1}$) are now well established, with the Southern Ocean accounting for about 40-50% of the total ocean uptake (Takahashi et al., 2009; LeQueré et al., 2014). The ocean mediation of atmospheric CO_2 has two components: the uptake of anthropogenic CO_2 and variability in the exchange of natural CO_2 (McNeil, and Matear, 2013; Bernadello et al., 2014). While the magnitude of the steady state ocean CO_2 uptake, linked to the increasing CO_2 emissions, is now robustly constrained (Le Queré et al., 2013) the major challenge to the ocean carbon community is to understand the drivers, magnitudes and trends of the non-steady state driven changes in the ocean carbon fluxes (Monteiro et al., 2010; Lenton et al., 2013; Wanninkhof et al., 2013; McNeil and Matear, 2013).

The challenge lies in both resolving the interannual variability and trends as well as understanding the dynamics that play a critical role in seasonal and intraseasonal dynamics. These may make a significant contribution to reducing the uncertainty and improving our understanding of the climate sensitivities of ocean carbon cycle models. While the former challenge will be addressed mainly using observations and empirical models, the latter will be achieved by using ocean and earth systems models and large scale seasonal cycle experiments (Swart et al., 2012; 2014; Majkut et al., 2014). The Southern Ocean mediates both the magnitude of the ocean uptake of anthropogenic CO_2 as well as the variability of the larger net exchange of natural CO_2 (Majkut et al., 2014; LeQueré et al., 2013). In this way it plays a critical role in both the uncertainties of Global ocean–atmosphere CO_2 fluxes as well as the modelled climate sensitivities of the Carbon cycle. Although there is increasingly strong evidence for large scale changes in the atmospheric forcing and Southern Ocean to global warming (Hall and Visbeck, 2001; LeQueré et al., 2007; Bönning et al., 2008; Gille, 2014), there is also evidence that while Global biogeochemical ocean models are able to get close agreement on the mean annual flux of CO_2, they are not able to reflect the seasonal and intra-seasonal modes correctly (Lenton et al., 2013). This point to an important gap in reflecting changes in the forcing that will impact the coupled carbon–climate systems which determine the non-steady state part of the ocean atmosphere CO_2 exchange in the 21st century. Recent work has strengthened the need for such an approach by highlighting the role of sub-seasonal modes in modulating the seasonal characteristics of ocean physics and primary production responses in the Sub-Antarctic Zone south of Africa (Thomalla et al., 2011; Swart et al., 2012; Swart et al., 2014; Joubert et al., 2014).

We hypothesize that an important part of the climate sensitivity of these processes which regulate the carbon, heat and productivity fluxes are linked to fine-scale ocean dynamics, which are not adequately understood and reflected in coupled climate and earth systems models (see **Figure 1**). SOSCEx III aims to explore the nature of this scale sensitivity with a particular focus on the seasonal cycle mode (Monteiro at al., 2011) as a test for the climate sensitivity of earth systems models in respect of the evolution of both atmospheric CO_2 and ocean ecosystems in the 21st Century.

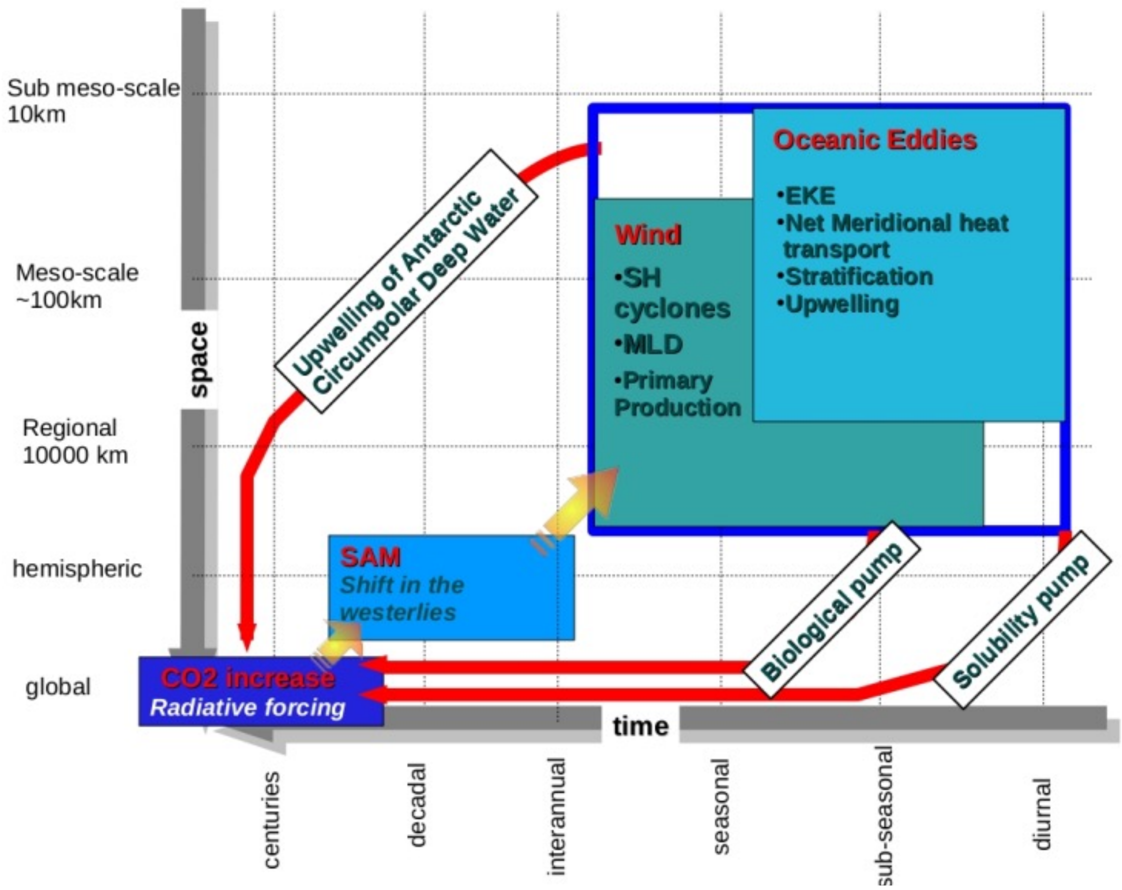

Figure 1: A space –time plot that summarizes the core scale sensitivity hypothesis of the SOCCO programme: That meso- & sub-mesoscale ocean dynamics interact with seasonal and sub-seasonal modes of forcing to mediate the role of the Southern Ocean on the non-steady state behaviour of atmospheric CO2, which in turn drives trends in large scale atmospheric systems such as the Southern Annual Mode (SAM).

There have been extensive advances on the role of meso- and sub-mesoscale ocean dynamics in explaining the spatial variability and phasing of biogeochemical properties (Lévy et al., 2012). We build on this knowledge to understand how seasonal and sub-seasonal dynamics interact with meso- and sub-meso scales to modulate the seasonality of carbon fluxes and primary production (Swart et al., 2014). In this way we aim to investigate the role of fine scale dynamics on long-term carbon-climate sensitivities. This approach is summarized in **Figure 1**: whereby the role of the Southern Ocean in the long term evolution of the radiative forcing effect of atmospheric CO_2 (lower left portion of Figure), which drives large scale atmospheric systems such as the Southern Annular Mode (SAM), depends on the sensitivity of the carbon flux drivers (upwelling of Circumpolar Deep Water (CDW), biological and solubility pumps) to fine scale surface boundary layer dynamics.

A closer examination of the seasonal and intra-seasonal modes of variability may not

Only help to diagnose critical dynamics, which explain inter-annual variability, but also climate sensitivities which may improve century scale climate predictions as well as explain large scale paleo-climate-biogeochemical adjustments in the ocean and atmosphere (Martinez-Garcia et al., 2014; Sigman et al., 2000; 2010). The importance of seasonal cycle dynamics in understanding the climate sensitivity of ocean carbon fluxes has been highlighted by Rogers, 2008; Monteiro et al., 2010; Monteiro et al., 2011; Lenton et al., 2013). However, Seasonal Cycle experiments have been hard to undertake because of platform limitations, until recently limited to ships and moorings and their space–time scale limitations (**Figure 1**).

The proposed high-resolution seasonal cycle approach extends its contribution to advancing the understanding of climate sensitivities beyond carbon to ecosystem dynamics (Smetacek et al., 2004). One of the key drivers of the carbon flux in the Southern Ocean is the biological pump mediated by primary productivity in the upper ocean boundary layer (Marinov et al., 2008; Arrigo et al., 2008; Cassar et al., 2011). Primary productivity which accounts for an estimate annual carbon export flux of $3PgCy^{-1}$ (Schlitzer Et al., 2002) also supports energy supply into the austral polar and Sub-polar ecosystems (Smetacek et al., Sarmiento et al., 2004). Core to our thinking is that the Seasonal Cycle is the mode of variability that couples the physical mechanisms of climate forcing to ecosystem response in production, diversity and carbon export. This is highlighted in the spatial variability of contrasting seasonal modes, which contribute to elevated regions of primary productivity in the Southern Ocean (Boyd et al., 2002; Thomalla et al., 2011). More recently, a link has been made between the seasonal iron supply driven by convective winter entrainment and the phasing and magnitude of the spring bloom in the austral polar and sub-polar regions (Tagliabue et al., 2014). However, notwithstanding the key role of winter mixing, recent data obtained using ocean robotics indicate that storm driven entrainment during the summer may play a critical role in extending the duration of seasonal primary production (Swart et al., 2014) through their impact on Iron fluxes (Joubert et al., 2014). Collectively these studies indicate that there are important gaps in our understanding of the role of fine scale dynamics, which may advance the understanding of climate sensitivities not yet fully reflected in climate models.

On this basis we propose a year long high resolution (space and time) seasonal cycle experiment as an interdisciplinary platform to address the required understanding of the role of fine scale dynamics in driving large scale responses of the coupled ocean–atmosphere systems in the Southern Ocean.

Aims and Objectives

The challenge in predicting long term trends in the Southern Ocean carbon cycle lies in our ability to resolve interannual variability and the link between seasonal and Intraseasonal dynamics in physical drivers and biogeochemical responses. Despite their importance, surface ocean processes at these scales are poorly understood and quantified due to operational limitations of ships and moorings. This has necessitated the use of autonomous, remotely sensed and modeling platforms that are able to address the temporal and spatial scale gaps in our knowledge of a hitherto under sampled ocean.

Building for the SOSCEx III winter cruise, the investigation of the seasonal cycle was completed during this summer cruise (SANAE 55). During this cruise, two processed stations (PSI and II) were repeated and sampled at different time austral spring (early-, mid- and late summer). More specific aims were:

- To re-deploy the robotics platform (buoyancy and wave gliders) at these two process stations to complete the high-resolution sampling of a full seasonal cycle in the SAZ.
- To provide high-resolution dissolved Fe profiles coverage in the upper mixed layer during austral spring to understand how the dFe (reservoir) is used to sustain spring bloom during the growing season.
- To collect high resolution underway bio-optics measurements that characterise the phytoplankton community and contribute towards improved ocean colour algorithm development specific to the Southern Ocean.
- To improve our understanding of winter versus summer phytoplankton productivity and physiology through a combination of primary production and P vs I, Fe/light incubation experiments and photo-physiology estimates of photosynthetic efficiency
- To characterise the CO_2 flux in austral spring

6.1. CO2 observations – solubility pump

PI: Pedro Monteiro

Team: P. Moteiro and N. Van Horsten

Funding: Scale Sensitivities of CO_2 Fluxes in the Southern Ocean - **SNA14072378878**

6.1.1. Rationale / Motivation

The gradient between the atmosphere and ocean represents the thermodynamic potential for gas exchange of CO_2 across the air-sea interface. When the concentration is higher in the ocean, gas would tend to reach equilibrium by efflux to the atmosphere and vice versa.

6.1.2. Aims and Objectives

- To observe and analyze the scale sensitivities of CO_2 fluxes in the Southern Ocean and how they influence the characteristics of the seasonal cycle. The hypothesis is that the biological pump dominates the CO_2 flux characteristics in the Sub-Antarctic Zone (SAZ) and ocean physics does so south of the Polar Front Zone (PFZ).
- What is the seasonal cycle of the flux of CO_2 (FCO_2) in the Sub-Antarctic Zone and the Polar Ocean Zone (55.0 – 60.0°S)?

- How do scales of variability of FCO_2 compare between the SAZ and the PFZ?

6.1.3. Methods

pCO

Partial pressure of CO_2 (pCO_2) in the atmosphere and ocean were measured using an infrared gas analyser (manufactured by General Oceanics), as described in Pierrot et al., 2009. The instrument was calibrated using 4 reference gases, certified against reference standards traceable to National Oceanic and Atmospheric Administration (NOAA) internal standards. The instrument was sequenced to change between reference standards, atmospheric air, and seawater roughly every 4 hours. Data was logged through a computer interfaced through LABVIEW which also controlled the operation of the instrumentation. The instrument was monitored regularly to ensure water flow, gas flow and equilibrator levels (and pressure) were in an appropriate range.

Dissolved Inorganic Carbon (DIC) and Total Alkalinity

Total dissolved inorganic carbon and total alkalinity samples were collected from the wet biology lab, from the same underway water supply where the TSG water is sampled. Intake temperature was recorded at each point where underway samples were collected. After the buoy run (**Leg 2**) it was discovered that salinity should have been recorded. The salinity was later extracted from the TSG output. High resolution CTD samples were collected from approximately fifteen depths with increased resolution in shallower depths (**see Appendix A**). Samples collected for ship-based analysis were stored in 500mL bottles (identical to CRM bottles as supplied by A Dickson) and were spiked with 400µL of concentrated Mercuric Chloride ($HgCl_2$) to terminate any biological activity in the sample. The 500mL samples were analysed on board using Marianda's VINDTA 3C (Versatile Instrument for the Determination of Titration Alkalinity). The VINDTA determines total alkalinity by potentiometric titration and by use of Coulometry measures CO_2 from the same sample. Accuracy of the VINDTA was determined by running Dickson's CRM's before and after each sample batch. Consistency in reproducibility of CRM's was not always achievable for entire batches. The precision of the analysis was tested by replicating a composite seawater test sample as well as replicate samples collected from the underway seawater supply and CTD samples.

6.1.4. Preliminary results.

Data delivery – Data validation and processing of DIC, Alkalinity and CO_2 will take less than 1 month, allowing on time data base delivery. Presented below is the raw dataset from samples analysis done on the ship during different legs.

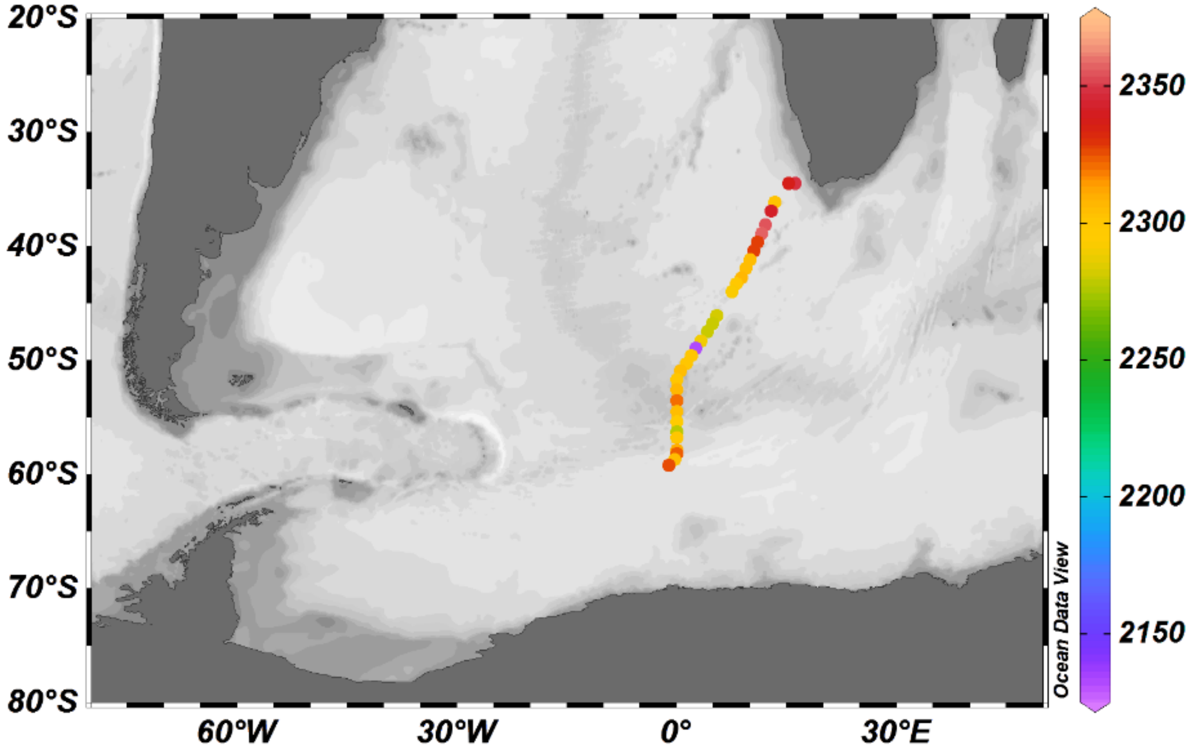

Figure 1: Underway alkalinity ([μmol/kg]) measurements for samples collected during Leg 1.

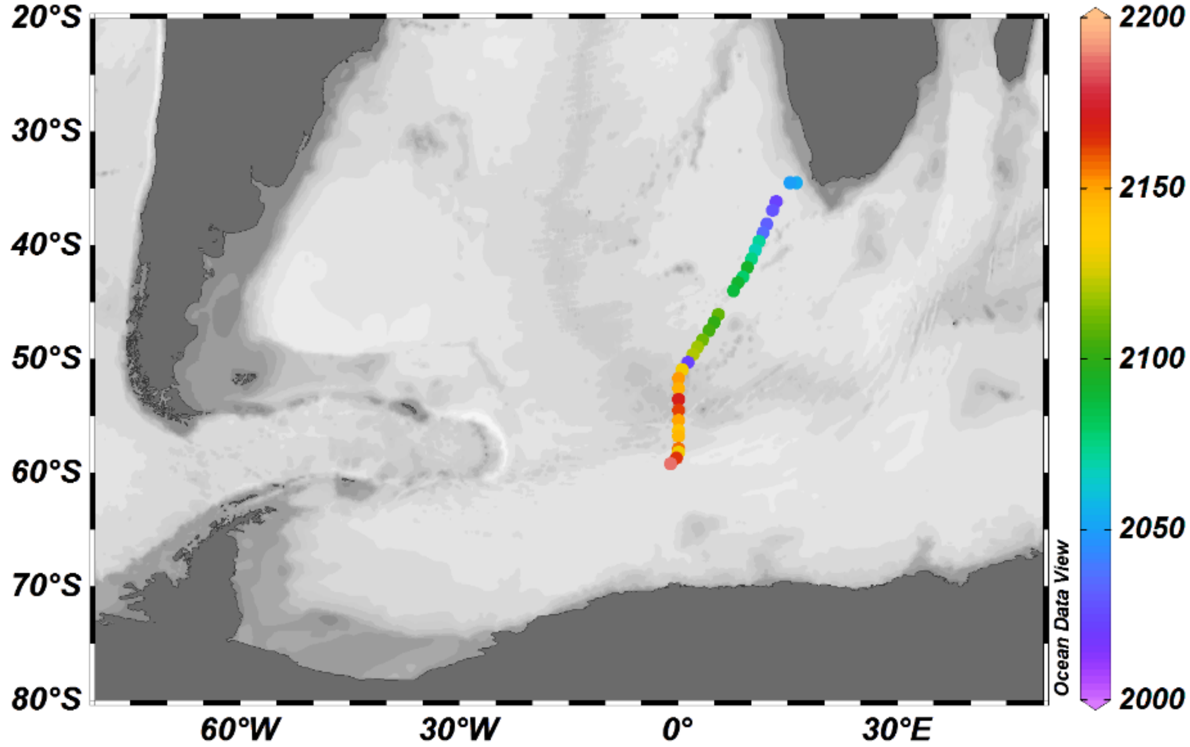

Figure 2: Underway dissolved Inorganic Carbon (DIC [μmol/kg]) measurements for samples collected on Leg 1.

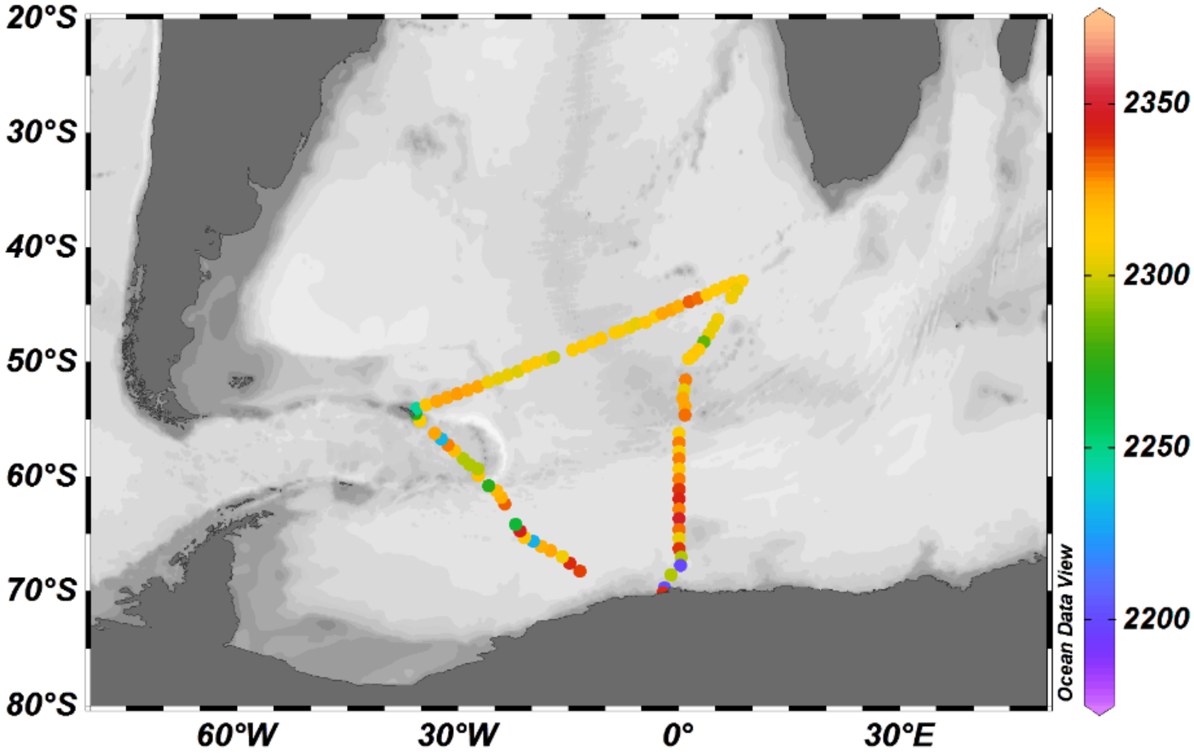

Figure 3: Underway alkalinity measurements ([μmol/kg]) for samples collected on Leg 2 (buoy run).

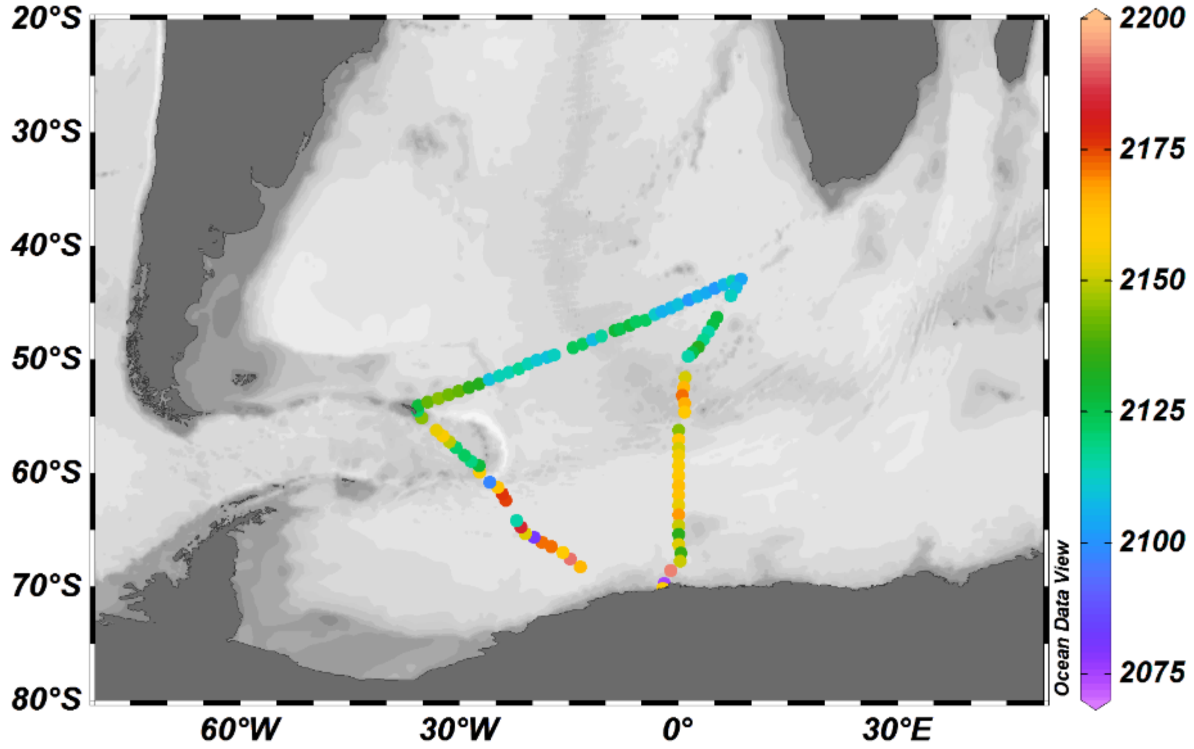

Figure 4: Underway dissolved Inorganic carbon (DIC [μmol/kg]) measurements collected on leg 2 (buoy run).

6.1.5. Issues and recommendations

- Spare quartz cuvettes are needed for the underway fluorometer which is attached to the pCO_2 instruments.
- New metal clamps of various sizes are needed for the pCO_2.
- Lens wipes and stationary stock needed to be made available in larger quantities for all CO_2 analyses.
- More DIC sampling bottles are needed for the high resolution sampling intended, specifically in case the VINDTA instrument is not functioning optimally.
- The numbering of DIC sampling bottles should be sorted out prior to the cruise to prevent any confusion with samples collected.
- All chemicals such as NaCl and H_3PO_4 and CRM's, to be used for DIC and TA analysis should be stocked in surplus for the cruise.
- A complete set of functioning spares for the VINDTA should be loaded on the ship for the cruise.
- The reference electrode used for the potentiometric titration for TA analysis was found to be very sensitive to vibration and slamming, causing reproducibility for TA difficult to achieve.
- Numerous issues were experienced with both the VINDTA and pCO_2 instrument computers. New computers or servicing of the current computers are needed.
- Oxygen optode attached to the pCO_2 instrument did not have waterproof cabling and this caused rust in the cable connection due to the optode having to be submersed in seawater. The rust caused a break in communication of the optode to the computer. A new cable, preferably a marine cable, should be bought for future cruises.
- The atmospheric inlet for the pCO_2 measurements had a significantly decreased flow and a leak is suspected in the tubing causing incorrect values for this measurement.
- Underway water supply was erratic and had to be adjusted regularly. A constant water supply pressure is needed.
- Underway water supply does not work in areas of sea-ice.
- Gas flow rates on the pCO_2 instrument were found to not be stable and would change without adjustment.

6.2. Ocean productivity – biological carbon pump

PI: Sandy Thomalla

Team: Hazel Little, Sandy Thomalla, Mhlangabezi Mdutyana, Surina sinhg, Estee Vermuelen, Ryan Miltz

6.2.1. Chlorophyl-a: Rationale / Motivation

Phytoplankton plays an important role in sequestering atmospheric CO_2 into the deep ocean through photosynthesis. Through photosynthesis, phytoplankton converts CO_2, water and light energy into sugar (organic carbon), water and oxygen. Photosynthesis takes place within a phytoplankton organelle called the chloroplast. Within the chloroplast, photosynthetic pigments, of which chlorophyll-a (Chl-a) is the most important, absorb light energy transported by photons. By measuring changes in Chl-a concentration, an estimate of phytoplankton abundance, distribution and the rate of primary production can be determined, and from this the biogenic flux of CO_2 into the ocean.

6.2.1.1. Aims and Objectives

- Chl-a samples were collect to calibrate the underway fluorometer, the flourometer sensors on both the GEOTRACES and Niskin CTD's as well as the fluorescence sensors on both buoyancy gliders.

6.2.1.2. Methods

Chl-a samples were collected every 4 hours from the scientific underway seawater supply and from certain depths from the CTD Niskin biology casts (generally 6 depths).

Chlorophyll

250 ml of seawater was filtered through 25 mm Whatmann GF/F filters. The filters were placed in glass vials with 8 ml of 90% acetone and kept in a -20°C freezer for 24 hours. After 24 hours the samples were removed from the freezer, and stored in the dark for 10-15 min to equilibrate to room temperature. Samples were inverted three times before the fluorescence was measured by the fluorometer. The raw fluorescence units were recorded and converted to chlorophyll concentration using a standard calibration curve created on 14 July 2015 using raw chlorophyll (Sigma C6144 Anacystis nidulans).

6.2.1.3. Preliminary results

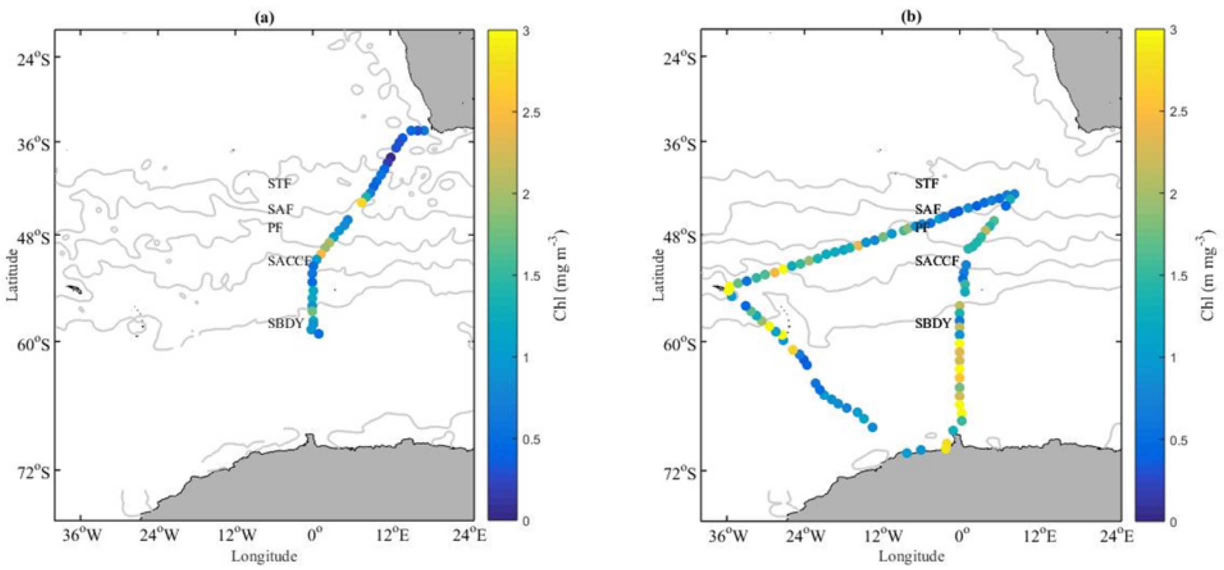

Figure 1. Surface Chl-a concentrations (mg m^{-3}) from underway samples for (a) Leg 1 (5 December 2015 – 12 December 2015) and (b) Leg 2, buoy run, (25 December 2015 – 13 January 2016). The mean December front location, as defined using satellite altimetry, are plotted (grey line):

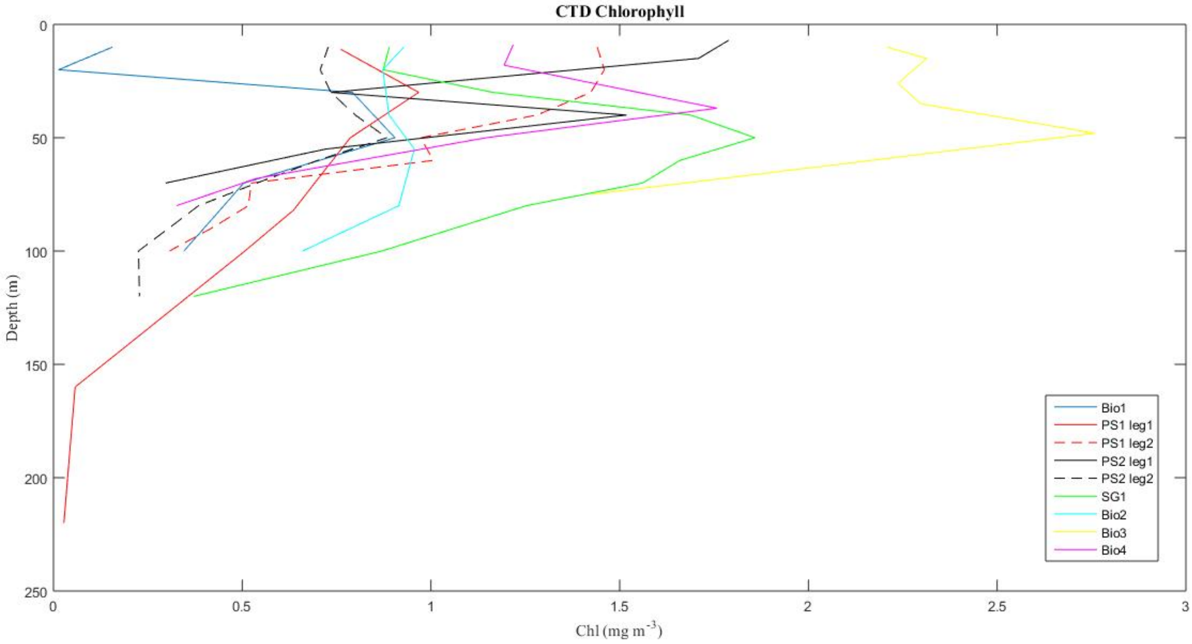

Figure 2. Chlorophyll-a concentration (mg m^{-3}) profiles from the nine biology Niskin CTDs cast between 5 December 2015 and 13 January 2016.

6.2.2. Particulate Organic Carbon (POC): Rationale

Particulate Organic Carbon (POC) is another biomass indicator for phytoplankton. POC measures the amount of organic carbon that is used by phytoplankton. Unlike chlorophyll, POC is not affected by the changing physiology of phytoplankton nor the quenching of fluorescence.

6.2.2.1. Aims and Objectives

- POC samples were collected to be used as an indicator of phytoplankton biomass.

6.2.2.2. Methods

POC samples were collected every 4 hours from the scientific underway seawater supply and from CTD Niskin biology casts (generally 3 depths, surface, MLD and midway between surface and MLD).

<u>*POC*</u>

Two litres of seawater was filtered onto 25 mm ashed (pre-combusted) Glass Fibre Filters (GFF). The ashed filters were combusted overnight (5 pm – 8 am) in a muffle furnace at 400 °C prior to the cruise. After filtration, the filters were placed in a petri dish and dried in an oven at 60°C for 24 hours. Following drying the filters were acid fumed for 24 hours to remove particulate inorganic carbon by placing the filters in a desiccation chamber that contained a beaker of concentrated HCL in the fume hood. After the filters had undergone this cycle, they were punched using a size 13 punch, before being folded into foil cups in a labelled 96 well plate. A blank ashed GF/F, in a foil cup, was placed intermittently in each row in the 96-well plate. Further processing will continue on the CHN analyser on land.

6.2.3. High Performance Liquid Chromatography (HPLC): Rationale

High Performance Liquid Chromatography (HPLC) is a method used for separating different pigments present in phytoplankton. This involves the chromatographic separation, identification of components in given solution allowing for identification of the dominant phytoplankton species present in the water column in terms of their taxonomic identification and photo-physiological characterization.

6.2.3.1. Aims and Objectives

HPLC samples were to determine the dominant phytoplankton species present in the water column.

6.2.3.2. Methods

HPLC samples were collected every 4 hours from the scientific underway seawater supply and from selected depths from CTD Niskin biology casts (generally 6 depths).

HPLC

Two litres were filtered through 25 mm Whatmann GF/F filter. The filters were collected in cryovials and stored in the -80°C freezer. Further processing will continue on land.

6.3. 15N Primary Production and Nitrification

PI: Sarrah Fawcett and Sandy Thomalla
Team: Mhlangabezi Mdutyana and Sandy Thomalla

6.3.1. Rationale / Motivation

The worlds' ocean take-up about 30% of anthropogenic atmospheric carbon dioxide, as such are known as the biggest carbon sink and store this carbon dioxide in the oceans' sediments as Dissolved Inorganic Carbon (DIC). Phytoplankton enables the ocean to sink carbon to the sediments through the process of photosynthesis. This drawdown of carbon is made possible through two processes which are biological loop and solubility loop; biological loop through the process of photosynthesis by phytoplankton take-up nutrients like nitrate, ammonium, urea and silica from the euphotic zone (sunlit surface oceanic waters). Phytoplankton after having assimilated the nutrients, die and are grazed upon by zooplankton, and eventually sink out of the euphotic zone as particulate organic matter (POM).

Our oceans' understanding between the ocean interactions with carbon dioxide is vital because carbon dioxide is a greenhouse gas and the ocean is a carbon dioxide sink. Southern Ocean is known as the largest ocean carbon sink and this is credited to its high rate of primary production; there are two types of primary production 1) new and 2) regenerated production. New production is primary production based on nitrate, as this form of nitrogen is new to the euphotic zone i.e. it has been upwelled into the surface waters. Regenerated production is primary production based on non-nitrate nitrogen sources i.e. forms of nitrogen excreted or re-cycled within the euphotic layer.

The *f*-ratio is used to quantify the biological pump's efficiency in carbon export. The amount of primary production fuelled by new nitrogen (Nitrate) over total primary production is called the f-ratio. This relies on the assumption that nitrate is only supplied to the euphotic zone from Deep Ocean through upwelling and that ammonium (regenerated) is recycled within the euphotic zone therefore becomes regenerated nitrogen.

However, recent evidence has shown that nitrification, the biological oxidation of ammonium to nitrate, can be quite significant within the euphotic zone. As a result, production from nitrate cannot be simply classified as new production. This undermines the usefulness of the f-ratio as a proxy for carbon export. However, despite the persistent debate about the biological pump in the Southern Ocean, there have been very few measurements of euphotic nitrification in the Southern Ocean.

This summer cruise represents an opportunity to enhance the understanding of the nitrogen cycle in the Southern Ocean and its links to the carbon cycle. For this reason, a complete set of nitrogen uptake and regeneration measurements is needed especially during winter as there's little information regarding data collected during winter seasons, as winter data set has been collected already in winter, the summer experiments are performed to compare seasonal differences in phytoplankton's nitrogen uptake. Nitrate and ammonium uptake are measures of primary productivity. On the other hand, the regeneration measurements allow for corrections to the isotopic dilution of the 15-N tracers and better constraints to carbon export models.

6.3.2. Aims and Objectives

- To determine of Nitrogen (NO_3, NO_2 and NH_4) uptake and regeneration.
- To determine of Carbon uptake.

6.3.3. Methods

Primary production and nitrogen cycle experiments were carried out in three legs at 8 stations during summer cruise (SANAE 55 Voyage).

Table1: Primary production and nitrogen cycling stations during SANAE 55 (Summer 2015/16 Cruise)

Leg	Station	Date	Latitude	Longitude
Leg 1	PS1 CTD 04	08-12-2015	42°41.600 S	08°44.198 E
Leg 2	SG 1 CTD 08	29-12-2015	55°41.542' S	33°59.121'W
	PS1 CTD 11	05-01-2016	42°41.600' S	08°44.198' E
	BIO2 CTD 16	07-01-2016	45°59.920' S	05°35.559' E
	BIO3 CTD 18	08-01-2016	50°27.091' S	01°02.575' E
	BIO4 CTD 20	09-01-2016	55°42.020' S	00°00.000' E
Leg 3	PS1 CTD 26	08-02-2016	42°41.600' S	08°44.198' E
	Ice Shelf Station CTD 22	26-01-2016	70°26.550' S	07°49.498' E

Nitrogen uptake and regeneration

Water from five light depths was sampled using GEOTRACES Niskin CTD. Selected depths were 55%, 30%, 10%, 1% of surface irradiance, and one depth in 200 meters (dark matter). Water was sampled at these depths, filtered to remove zooplankton and placed in 1.0 L and 2.0 L polycarbonate Nalgene bottles.

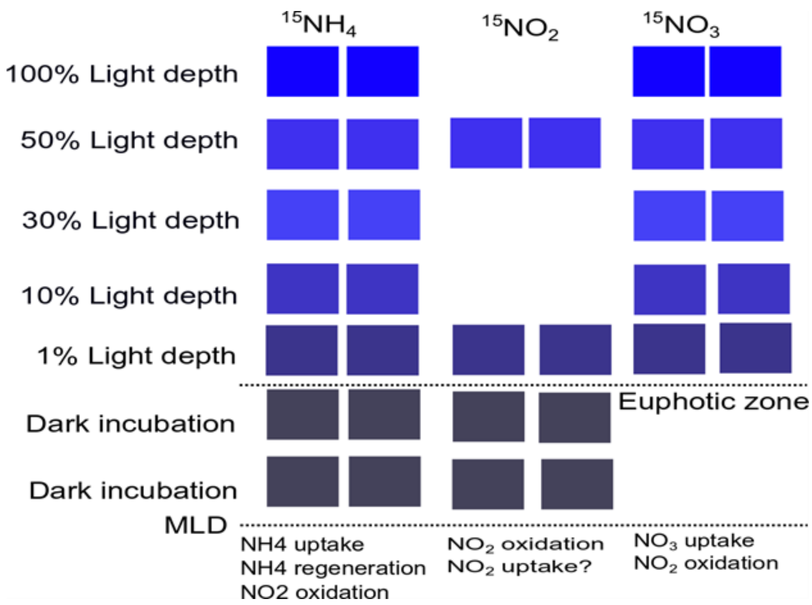

Figure 1: Sampling depths for primary production and nitrogen cycling experiments. Each square represents a replicate. The ^{15}N tracer added is shown in the top row and the measured process in each bottle is shown in the bottom row.

Two 1L (A and B) bottles from four light depths (55%, 30%, 10%, 1% and (Dark) 200 meters) were spiked with ^{15}N (1 μmol $^{15}NO_3$ / 1 ml) to investigate the uptake of nitrate. Spikes were adjusted to achieve $^{15}N\text{-}NO_3$ ambient enrichments of ~10%. Two 1L (A and B) bottles from five light depths (55%, 30%, 10%, 1% and Dark) were spiked with $^{15}NH_4$ (0.05 µmol $^{15}NH_4Cl$ / 100 µl) to achieve 50 nmol/L as ammonium concentrations were often below the detection limit. Two 1L bottles from two light depths (1% and Dark) were also spiked with $^{14}NO_2$ (200 nmol/L above ambient concentration) as a carrier.

Two 1L bottles from four light depths (55%, 10%, 1% and Dark) were spiked with $^{15}NO_2$ to achieve a concentration of 20 nmol/L. Prior to ^{15}N tracer inoculation of the bottles and after zooplankton was removed from the water samples, five 50ml water samples were taken and frozen in the -20°C for ammonium determination ashore. Prior incubation two 50ml inoculated water sample from each 1L NH_4 bottles was taken for both oxidation and regeneration, and stored in -20°C fridge to be analysed ashore. A 50ml inoculated water sample from 1L NO_3 bottles was taken before incubation and stored in -20°C fridge to be analysed ashore. A 50ml inoculated water sample from each 1L NO_2 was taken before incubation and stored in -20°C fridge to be analysed ashore.

The inoculated samples from each light depth were incubated in tubes covered in neutral density filters that simulated the various light depths. Incubators were cooled with a constant flow of surface seawater to further simulate *in situ* conditions. The samples were incubated for 24 hours, following which the samples were filtered through pre-combusted 25mm Whatmann GF/F filters and placed into a petri dish and placed in an oven for 24 hours, after they are placed in a desiccator with hydrochloric acid and fumed for 24 hours and after they are punched for POC analysis ashore. Before filtration after incubation 50ml was taken from all three (NH_4, NO_3 and NO_2) sealed with parafilm and stored in -20°C fridge to be analysed ashore.
Primary production profiles

In addition to the ^{15}N tracer, in addition to ^{15}N tracer ^{13}C tracer (in the form of Sodium Bicarbonate Salts) was added to all the bottles in order to measure carbon uptake at the same time as nitrogen uptake.

NH_4
For most of the stations ammonium concentrations were determined for each of the sampled depths. This was done using the fluorometric method for ammonium concentrations. Most NH_4 concentrations showed low levels which were below detection limit of 0.07 µmol/L and as a result will be re-measured ashore using back-up samples.

6.3.4. Experiment issues and recommendations

- The water supply used from the underway for incubators had a very low pressure and as a result at times the incubators had low water and rarely was completely not flowing to the helideck. Water supply with high enough pressure is essential as this will totally eliminate significant leaking of the incubators.

- Ship-based ammonium determination had a number of complications and was eventually ceased for the last two stations, it is assumed that the problem was with UV-NH_4 Modulator. Ashore analysis will be conducted to further investigate the problem.
- Replacement of the old neutral light filters (especially for 55% light depth) as they are shabby and peeling off the incubators.
- A third incubator needs to be built as this will increase the space which is currently a challenge.

6.4. Fe biogeochemistry and other Trace elements

PI: Dr Thato Mtshali and Prof Alakendra Roychoudhury

Ship based Team: Thato Mtshali (group leader), Natasha van Horsten, Ryan Cloete, Ryan Miltz,

Funding: Roychoudhury, A (SANAP, NRF): Bioactive trace elements in Southern Ocean – **SNA2011110100001**

6.4.1. Rationale / Motivation

The Southern Ocean is one of the largest High-Nutrient, Low-Chlorophyll (HNLC) region and an example of the modern marine environment where Iron (Fe), next to light and grazing, is strongly limiting primary productivity (Boyd, 2007). This effectively controls the strength of net primary productivity (NPP) and the efficiency of the 'biological carbon pump (BCP)', which exports fixed carbon into the deep ocean and so influences atmospheric CO_2 concentration (e.g., Kwon et al., 2009) and climate. Its limiting factor/behaviour is due to its low level (<1.0nM), low solubility in oxygenated ocean and low supply. Synthesis studies has shown that Fe can be supplied to the surface-dwelling phytoplankton from above via Iron bearing dust (Jickells et al., 2005), melting sea-ice and icebergs (Lannuzel et al., 2008; Lancelot et al., 2009) although these acts as capacitors for Iron or from below by vertical mixing or upwelling of subsurface dFe (Tagliabue et al., 2014) and hydrothermal inputs (Nishioka et al., 2013) or by physical processes (so-called new Iron) such as vertical diffusive flux (Boyd et al., 2005), horizontal advection (Bowie et al., 2009), interaction between bathymetry and currents (Blain et al., 2007), convection winter mixing or entrainment (Tagliabue et al., 2014) or storm driven entrainment during summer (Joubert et al., 2014, Swart et al., 2014, Thomalla et al., 2015). During this cruise, a high resolution seasonal sampling of dFe profiles were conducted in order to characterize the depth of the “ferricline”. Dataset obtained from this cruise will be compare to winter cruise in order to characterise and understand seasonal entratinment of dFe in the Southern Ocean.

Other trace elements, such as Cu, Zn, Cd, Co and Mn, will also be investigated as they play important role in phytoplankton metabolic processes. The data which is produced as a result of this cruise will aid in increasing the scarce number of trace element datasets in the Southern Ocean. This will be the first step in better understanding the biogeochemical cycling of these elements and, on a larger scale, the global carbon cycle.

6.4.2. Aims and Objectives

- To conduct a seasonal high depth resolution for dFe profiles (early-, mid- and late-summer) in order to characterize the depth of the 'ferricline'. Dataset collected on this cruise will be compare to winter cruise data as part of the SOSCEx III project.
- Other trace metals will also be measured to understand the processes and distributions in the Southern Ocean, as part of the GEOTRACES programme.

6.4.3. Methods

GCTD deployment and retrieval

Seawater samples were collected using a trace metal GEOTRACES CTD rosette equipped with clean 24 x 12L GoFlo bottloes and deployed on a conducting Kevlar cable (General Oceanics, USA). The GoFlo bottles were washed according to literature method described by Gregory et al., 2012. The acid washed GoFlo bottles covered with shower caps, ziplog bags and PVC lining were stored inside a trace metal clean class-10 laboratory container on ship's deck. Care was taken during transportation and deployment of bottles to avoid contamination from the ship and operating personnel. Once the rosette was on-board, new zip-lock bags were placed on the sampling spigot and the top and bottom of the GoFlo bottles were coved with new shower caps. During the transportation to and from the rosette, the whole GoFlo bottle was covered with a new PVC lining. Subsampling and sample acidification were conducted inside a trace metal clean class-10 container.

Sub-sampling for nutrients, Fe pool and other trace metals

125ml LDPE sampling bottles were washed according to the literature method described on GEOTRACES Cookbook 2010 (Cutter et al., 2010). Befoe GoFlo bottles are stored on its rags inside the container, bottles are flushed outside with MilliQ-H2O to remove sea-salts. Nutrients were collected first straight from the GoFlo bottles sampling spigot and then filtered through a 0.2μm pore size Anatop syringe filters (as per GEOTRACES recommendations). Seawater samples for total dissolved Iron (TdFe) were collected by connecting an acid washed polytetrafluoroethylene (PTFE) tubing onto the sampling spigot and filled in acid-cleaned 125 ml LDPE bottles. Seawater samples for dissolved Iron (dFe) were collected as filtrate of seawater passing through an online 0.2μm pore size Acropak capsule filter. The GoFlo bottles were pressurised with N2 gas (99.99% N2) at 2 bar to increase the flow rate through the filter. All sampling bottles were filled to the same level in order to achieve equal pH of ~1.7. Samples were acidified with 250μl 30% HCl (ultrapure, Merck Millipore) under the HEPA filtered laminar flow hood. All samples were double zip-lock bagged and stored at room temperature for further analysis on land at SUN. A detailed sampling positions is shown below (**Table 1**)

Table 1: Detailed record of sampling station, date, longitude, latitude and parameter sampled.

legs	Date	Station	Latitude	Longitude	Parameters
1	05/12/2015	Soak	34°29.997'S	14°38.349'E	GoFlo soak
	06/12/2015	Bio1	37°24.480'S	12°21.090'E	dFe, Nutri
	08/12/2015	PS1	42°41.500'S	08°44.240'E	dFe, TdFe, Nutri
	09/12/2015	PS2	45°00.100'S	06°33.690'E	dFe, TdFe, Nutri
2	29/12/2015	SG1	55°41.901'S	34°00.012'W	dFe, Nutri
	03/01/2016	Test	46°46.956'S	06°10.121'W	GoFlo test
	05/01/2016	PS1	42°41.604'S	08°44.216'E	dFe, TdFe, Nutri
	06/01/2016	PS2	44°59.894'S	06°34.641'E	dFe, TdFe, Nutri
	06/01/2016	Bio2/DTM2	45°59.930'S	05°35.500'E	dFe, TdFe, Nutri
	08/01/2016	Bio3/TM1	50°27.106'S	01°02.667'E	dFe, TdFe, Nutri
	09/01/2016	Bio4/DTM3	55°41.977'S	00°00.116'E	dFe, TdFe, Nutri
3	27/01/2016	Ice shelf	70°26.550'S	07°49.438'W	dFe, Nutri
	07/02/2016	PS2	45°00.000'S	06°30.000'E	dFe, TdFe, Nutri
	08/02/2016	PS1	43°00.000'S	08°30.000'E	dFe, TdFe, Nutri

6.4.4. Preliminary results

Data delivery – Deployment of GEOTRACES CTD rosette and sampling for Fe-pool at all stations was successful. A total of 852 Fe-pool and other trace metal samples were collected and will be analysed at Stellenbosch University using ICP-MS and at UniBREST in France using a Flow Injection Analyser (FIA). Trace metal analysis will take 4 – 12 months. Data validation and processing of nutrients will take less than 1 month, allowing on time data base delivery.

6.4.5. Issues and recommendations

Issues

- Milli-Q- The milli-Q machine in the FIA container was out of order therefore an alternative MilliQ-H2O machine in the wet lab was being used. In order to prevent contamination and particles entering the carboy, black plastic bags were rigged into a roof like structure above the milli-Q machine. In addition, acid cleaned PTFE tubing was used to connect the MilliQ filter to the carboy. Parafilm plasic was used to cover the opening of the carboy with a small hole punctured through for the PTFE tubing to fit through.
- Air conditioning unit – It was suspected the filter in the AC unit was not effective in blocking outside particles from entering the sampling container. A very thin mesh was placed around the AC unit. Small particles were seen caught in the mesh confirming our suspicions. It was decided to switch the AC unit off.
- GOFLO bottle number 20 repeatedly did not trigger during the casts on leg 3.
- Need to buy a 50L LDPE carboy with tap for sub-sampling

Recommendations

- Address the problematic Milli-Q systems in the FIA container by either replacing spare parts or calling in a technician.
- Replace filters in AC unit. As an extra precaution erect a more permanent mesh around the AC outflow.
- Replace all lanyards on GOFLO bottles as this may be causing triggering issues. Also a lanyard from another bottle broke during a cast indicating replacements are necessary.
- By attaching taps to the 50L bioassay carboys, sub sampling for the bioassays will be much more time efficient as opposed to using funnels which often result in spillage and water waste during rough seas.

6.5. Bio-optics – Ocean colour

PI: Sandy Thomalla

Team Members: Sandy Thomalla, Thomas Ryan-Keogh, Hazel Little, Mhlangabezi Mdutyana, Surina Singh, Estee Vermeulen, Ryan Meltz

Funding: Understanding the biogeochemical response to physical drivers in the Southern Ocean using bio-optics - **SNA14073184298**

6.5.1. Rationale / Motivation

The Southern Ocean is a well-established carbon dioxide sink and plays an essential role in the global carbon cycle. The in situ examination of the influence of seasonal cycles and physical drivers on biological production is often spatially and temporally limited. Remote sensing has allowed for regional characterisation by providing routine, synoptic and cost-effective observations at a high frequency and over decadal time scales. Most often remotely sensed data are the only systematic observations available for chronically under-sampled marine environments (e.g. the polar oceans), and there is thus a need to maximise the value of these observations by developing ecosystem-appropriate, well-characterised products.

The capacity of the Southern Ocean to act as a long term carbon dioxide sink will only be revealed upon a better understanding of the impacts of various forcing mechanisms on phytoplankton physiology and community structure. By examining a large variety of in situ bio-optical and physiological parameters we hope to develop and validate appropriate regional ocean colour algorithms. Our bio-optics suite includes instruments to measure the inherent optical properties (IOPs- scattering, attenuation and absorption), as well as the fluorescence signal, used to illustrate the photosynthetic efficiency of phytoplankton populations. These data are complemented with a range of biogeochemical measurements, linking the optical properties to carbon content, size distribution and taxonomic composition of algal communities.

The above listed bio-optical, biogeochemical and photo-physiological data will be used to parameterise the particle field (dominated by the phytoplankton community) through empirical relationships between IOPs and size, pigment and carbon content. This information in conjunction with radiative transfer models and reflectance inversion algorithms will allow us to use satellite derived ocean colour data to investigate biological responses (through changes in biomass, community structure and physiology) to event, seasonal and inter-annual variability in ecosystem physical drivers at the required spatial and temporal scales.

6.5.2. Aims and Objectives

- A comprehensive dataset of optical and biogeochemical variables for the Southern Ocean
- Regionally specific relationships between water optical properties and biogeochemistry for the Southern Ocean
- A quantification of the current bias in satellite ocean colour observations
- Improved ocean colour algorithms for phytoplankton biomass, particulate organic and inorganic carbon content.
- A better estimation of phytoplankton functional types from marine reflectance
- An understanding of the response in the phytoplankton community (biomass, carbon content, community structure) to event, seasonal and inter-annual variability in ecosystem physical drivers
- An improved understanding of the interconnectedness between phytoplankton biomass, production, community structure, export potential and CO2 fluxes
- An improved ability to predict the long term responses of the Southern ocean biological carbon pump to global warming and climate change

6.5.3. Methods

6.5.3.1. Absorption and Attenuation – WetLabs AC-S

Underway sampling

The WETLabs Spectral Absorption and Attenuation Meter (ac-s) performs concurrent measurements of the water's absorption (a) and attenuation (c) characteristics through incorporation of a dual path optical configuration in a single instrument. The spectral range is between 400-730nm. The ac-s was set up to measure continuously flow-through chamber, receiving seawater from the ship's scientific seawater supply. The set-up ensured a continuous stream of seawater flowed into the bottom of the 'a' tube and out the top, leading into the bottom of the 'c' tube, before flowing out of the top of the 'c' tube and into the custom perspex container that housed the ac-s. The ac-s was constantly kept seawater temperature due to the continuous overflow. The ac-s measures unfiltered seawater to determine the total absorbance and attenuation, and filtered seawater to measure the absorbance and attenuation of dissolved substances. The difference between the two measurements provides the absorption and attenuation spectra of the particle field which in the Southern Ocean is dominated by the phytoplankton community.

To start up the instrument, the ac-s, 'valve - underway' and ', 'flow' python scripts were selected. Before each cruise the scripts need to be adjusted to save the data in a new folder relative to the cruise. Constant issues occurred with the flow rate. Either being too high >0.53 which causes turbulence and bubbles that contaminate the absorption and attenuation signal or too low <0.2 which can result in zero flow during filtered modes that sometimes does not recover to suitable flow during unfiltered modes. A new system needs to be designed that maintains constant flow to the ac-s that cannot be affected by filtered / unfiltered switches or by diverting to paths of less resistance to other instruments (or out the debubbler).

CTD sampling

At all Niskin biology CTD's 3 x 12 Litre water samples (designated Niskin) were collected, one from the surface, one from the base of the mixed layer and one from the middle of the mixed layer for bio-optical analysis. The sample was pumped under positive pressure through the ac-s to measure total absorption and beam attenuation.

Calibration

At the beginning of the cruise 03/12/2015 an air calibration was carried out as per the instructions in the manual whereby the ac-s was dismantled, including all O-rings, and washed thoroughly in warm soapy water. The individual parts of the 'a' and 'c' tube were dried thoroughly in the drying cupboard for a few hours. Ethanol was used to clean the optical windows on the instrument, as well as the inner surfaces of the 'a' and 'c' tubes. The instrument was re-assembled, and an air calibration was performed. Following the air calibration, a clean water calibration was performed whereby milli-q water was pumped (using pressurised 10L carboy) into the a and c tubes. This step was repeated 3-4 times. It is unclear why there is such drift in the readings, in particular the c channel. Wondering if it is related to flow rate?

Following leg 1, after my arrival at the ice and before the buoy run a dirty water calibration was performed 26/12/2015, where milli-q water was passed through the ac-s and data recorded. This dirty water cal should have been done immediately after the scientific sea water pumps and optics were switched of when stuck in the ice before arrival in Antarctica and not many days / week later before buoy run departure. It is anticipated that the biofouling in the stagnant tubes will have increased during this time thus overestimating the befouling term needed for correcting the data. This needs to be bourne in mind when processing the data. Following dirty calibration the instrument was dismantled and cleaned with warm soapy water and ethanol soaked lens cleaners for optical windows and flow tubes. Following cleaning, the instrument was re assembled and milli-q run through the system several times in an attempt to get a good clean calibration data file.

After the Buoy run another dirty cal clean cal was performed on 14/01/2016. This time immediately after water was switched off when ice was too thick for pumps to work.

At the end of the cruise 11/02/2016 a dirty calibration, clean calibration and air calibration were repeated as above.

6.5.3.2. Backscattering - WetLabs BB9

The WETLabs Scattering Meter (ECO BB9) contains three BB3 instruments, each providing a backscatter measurement for 3 different wavelengths (collectively 412nm, 440nm, 488nm, 510nm, 532nm, 595nm, 650nm, 676nm and 715nm), as well as one data multiplexer, which functions to power the BB3 instruments, to start each data sample, to read all data and to re-format and output the data from all BB3s in a synchronized manner. Scattering and back-scattering are very useful IOPs in terms of describing particle size and composition in ocean environments.

Underway sampling

The BB9 was set up in a continuous flow-through chamber, receiving seawater from the scientific underway ship's supply. When the instrument is started, profiles are checked using ECOView120 software, however the data is saved through the python file 'bb9'.

CTD Sampling

At each of the Niskin biology CTD's three samples from within the mixed layer were analysed for their bio-optical characterization. The BB9 was drained and filled up from the bottom by pumping the sample into the BB9 using positive pressure. Once full the pump was switched off and the Ecoview software was used to record several minutes of data for each sample.

PIC Sampling

For leg 3, we (Pedro Monteiro) managed to get the PH sensor working. The new one was broken, the old one re wired into the system and corrected for offset and temperature allowing it to be properly calibrated. Every 4 hours the BB9 python script was stopped. The acid pump turned on (speed between 10 and 20) pumping 5% glacial acetic acid into the flow to the BB9. When the PH of seawater (~7.8-8) had been reduced to the low 5's (4.8 – 5.5) suitable for dissolving PIC, the BB9 was drained and filled with low PH sample. The Ecoview software was used to record several minutes of data for each sample. The time, coordinates and PH for each sample were recorded in the optics logbook. A co incidental PIC filtered sample was carried out simultaneously at each 4 hourly station.

Cleaning

On 03/12/2015, 26/12/2015, 14/01/2016 and 11/02/2016 06/08/2015 the BB9 was drained and cleaned with warm soapy water and ethanol soaked lens cleaners wiped the optical windows.

6.5.3.3. Size Distribution (Coulter Counter)

Suspended particles are a ubiquitous component of natural waters, and play an important role in the biogeochemical cycling of elements and in the structure and functioning of marine ecosystems. Examining light scattering and absorption within the ocean, and attempts to partition optical contributions among different constituents of seawater reply implicitly on some parameterisation of the particle size distribution. An instrument, such as the Beckman Coulter-Multisizer, is used to analyse particle size distribution and has sufficient resolution in size to resolve distinct populations within mixed assemblages of particles (Reynolds, R.A. et al. 2010). In brief, the Coulter counter has a microchannel that separates two chambers containing electrolyte solution (0.2µm filtered seawater). As seawater containing particles is drawn through the microchannel each particle cause a brief change to the electrical resistance of the seawater. The counter detects these changes in electrical resistance and infers particle size.

The instrument was set up as per standard protocol. Electrolyte was generated by first filtering seawater through a 25mm Whatman GF/F (0.7µm) and subsequently through a 0.2µm isopore polycarbonate filter. The 100µm aperture tube was inserted and calibrated using 14 drops of 20µm beads. A specific SOP was created for the SOSCEx III summer cruise, which standardly made use of the 100µm aperture, sampling 20 runs at 2ml per run.

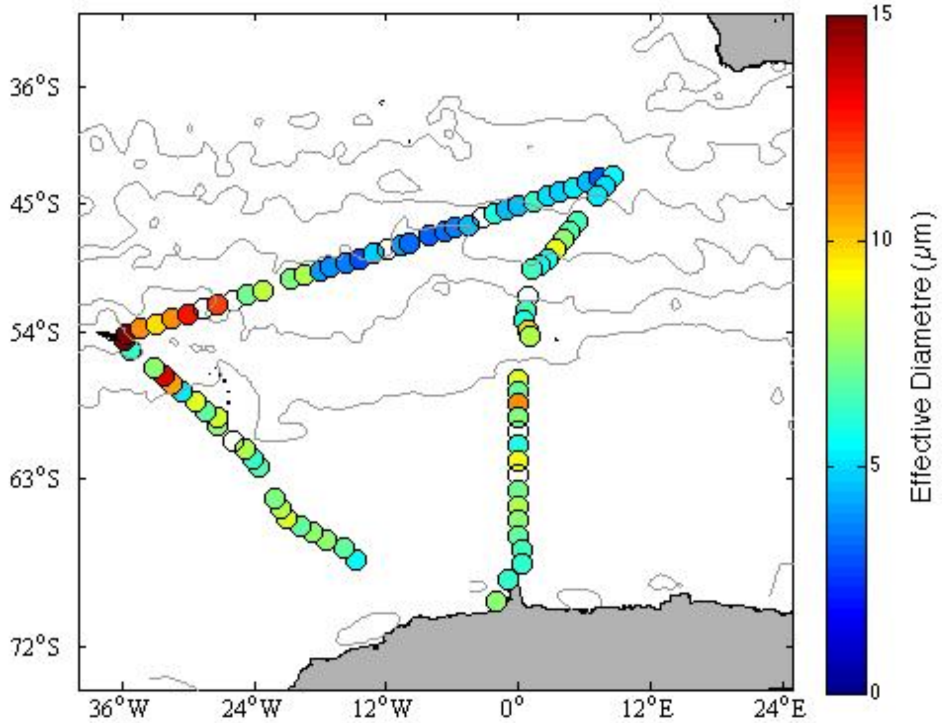

Figure 1. Plot of phytoplankton size distribution along the cruise track (leg 1 and 2)

Underway samples were collected from the ships uncontaminated seawater supply every 4h and all Niskin biology CTDs were sampled at three designated biology depths (typically surface, bottom of mixed layer ad mid-way between surface and mixed layer).

In between stations the sample beaker was filled with clean electrolyte and the system was drained and filled. All samples were sufficiently inverted before being analysed and the system was flushed once prior to every sample.
Blanks (0.2µm filtered sea water) were run once per day.

References

Reynolds, R.A., Stramski, D., Wright, V.M. and Wozniak, S.B. (2010) Measurements and characterization of particle size distributions in coastal waters. J. Geophys. Res., 115 (C08024): 1-19

6.6. Nutrient Addition Incubation Experiments

PI: Thomas Ryan-Koegh and Sandy Thomalla
Team: Thomas Ryan-Koegh, Hazel Little, Sandy Thomalla, Ryan Cloete, Ryan Miltz and Thato Mtshali

6.6.1. Rationale

Nutrient addition bioassay experiments were performed using a highly replicated design to investigate the effect of iron (Fe) availability on phytoplankton physiology, growth and nutrient drawdown and the photosynthetic molecular composition of the microbial communities, over different timescales.

6.6.2. Aims and Objectives

Two different experimental designs were run simultaneously: 24 hr incubations, and 6/7-day incubations; with the short-term bioassays primary function to analyse the rapid changes in physiology upon Fe addition while the long-term bioassays were to assess changes in community physiology, structure and photosynthetic molecular composition in response to Fe.

6.6.3. Methods

Strict controls were required to avoid the contamination of incubation containers and sampled water. Incubations for the 24 hr bioassays were performed in 1 L acid washed polycarbonate (PC) bottles and the incubations for the 6/7-day bioassays were performed in 2.4 L PC bottles. All PC bottles used in incubations were passed through a rigorous cleaning process (Eva et al., 2011) involving a Decon wash (Merck Millipore) for 1 week, soaked in 3.0M 32% HCl (analytical grade, Merck Millipore) for 1 week, filled with 1.0M 30% HCl (suprapur; Merck Millipore) for three weeks followed by 3 x rinsing with MilliQ-H2O (18.2MΩ, Q-Pod element) then stored with acidifies MilliQ-H2O of ~0.01M 30% HCl (suprapur, Merck Millipore) until experimental set-up. Prior to experimental set-up, storage acid was discarded and the bottles were rinsed 2 to 3 times with seawater. Bottle filling and all manipulation steps including spiking and sub-sampling were performed within the dedicated Class-100 air filtered clean container.

Seawater for incubation experiments were collected using the trace metal clean GEOTRACES CTD (GCTD) rosette system equipped with 24 x 12L GoFlo bottles. In order to ensure there was no contamination of water, the Go-Flo bottles were washed and handled as discussed in the Iron Biogeochemistry section of this report (**section 7.3**). The PC bottles were filled to the same level (~ 2L or 1L mark, respectively) and little space was left at the bottle neck to ensure some gas exchange occurs. Following filling, bottles were spiked with micro- (FeCl3) and macro-nutrients (NO3 and 13C), sealed with parafilm, then double bagged before being incubated in light and temperature controlled incubators. Light levels were set correspondent to the in-situ percentage light depth that the water was collected, at ~30-35%. The diurnal cycle of the light was set to switch on and off to mimic in-situ local sunrise and sunset of the sampling location.

The experimental design of the long-term bioassays (6/7 days) involved the incubation of 32 x 2.4L PC bottles, in 2 sets of 16: one set for the Iron addition at a concentration of 2.0 nM and one for controls. Samples were taken for chlorophyll, nutrients, POC/PON, HPLC, FRRf, microscopy and photosynthetic protein concentrations. A complete list of sampling locations and initial chlorophyll is provided in **Table 1**.

The experimental design of the 24 hr bioassays involved the incubation of 6 bottles, in 2 sets of 3 bottles; one set for Iron addition at a concentration of 2.0 nM and one for controls. Samples were taken for chlorophyll and FRRf; measured on both a Chelsea FAST*track*™ FRRf and a FAST*act*™ FRRf laboratory system. A complete list of sampling locations and initial chlorophyll is provided in **Table 2**.

Table 1: Sampling locations, start and end times and initial conditions for the long-term nutrient addition incubation experiments.

	PS1: Expt 1	**PS1: Expt 2**	**PS1: Expt 3**
Lat/Long	-42°41.579'S 08°44.271'E	-42°41.606'S 08°44.217'E	-43°00.008'S 08°30.013'E
Sampling method	GCTD	GCTD	GCTD
Start Point	08/12/2015	05/01/2016	09/02/2016
End Point	15/12/2015	12/01/2016	14/02/2016
Initial Chlorophyll (μg.L^{-1})	0.979±0.063	0.845±0.042	0.903±0.075

Table 2: Sampling locations, start and end times and initial conditions for the short-term nutrient addition incubation experiments.

	Expt 1 SG1	**Expt 2 BIO2**	**Expt 3 BIO3**
Lat/Long	-55°41.349'S -33°58.768'E	-45°59.918'S 05°55.559'E	-50°27.091'S 01°02.574'E
Sampling method	GCTD	GCTD	GCTD
Start Point	29/12/2015	07/01/2016	08/01/2016
End Point	30/12/2015	08/01/2016	09/01/2016
Initial Chlorophyll (μg.L^{-1})	0.735	0.889	2.297
	Expt 4 BIO4	**Expt 5 Ice Shelf**	
Sampling location	-55°41.979'S -00°00.002'E	-70°26.551'S -07°49.456'W	
Sampling method	GCTD	GCTD	
Start Point	09/01/2016	26/01/2016	
End Point	10/01/2016	27/01/2016	
Initial Chlorophyll (μg.L^{-1})	1.757	1.485	

6.6.4. Preliminary Results

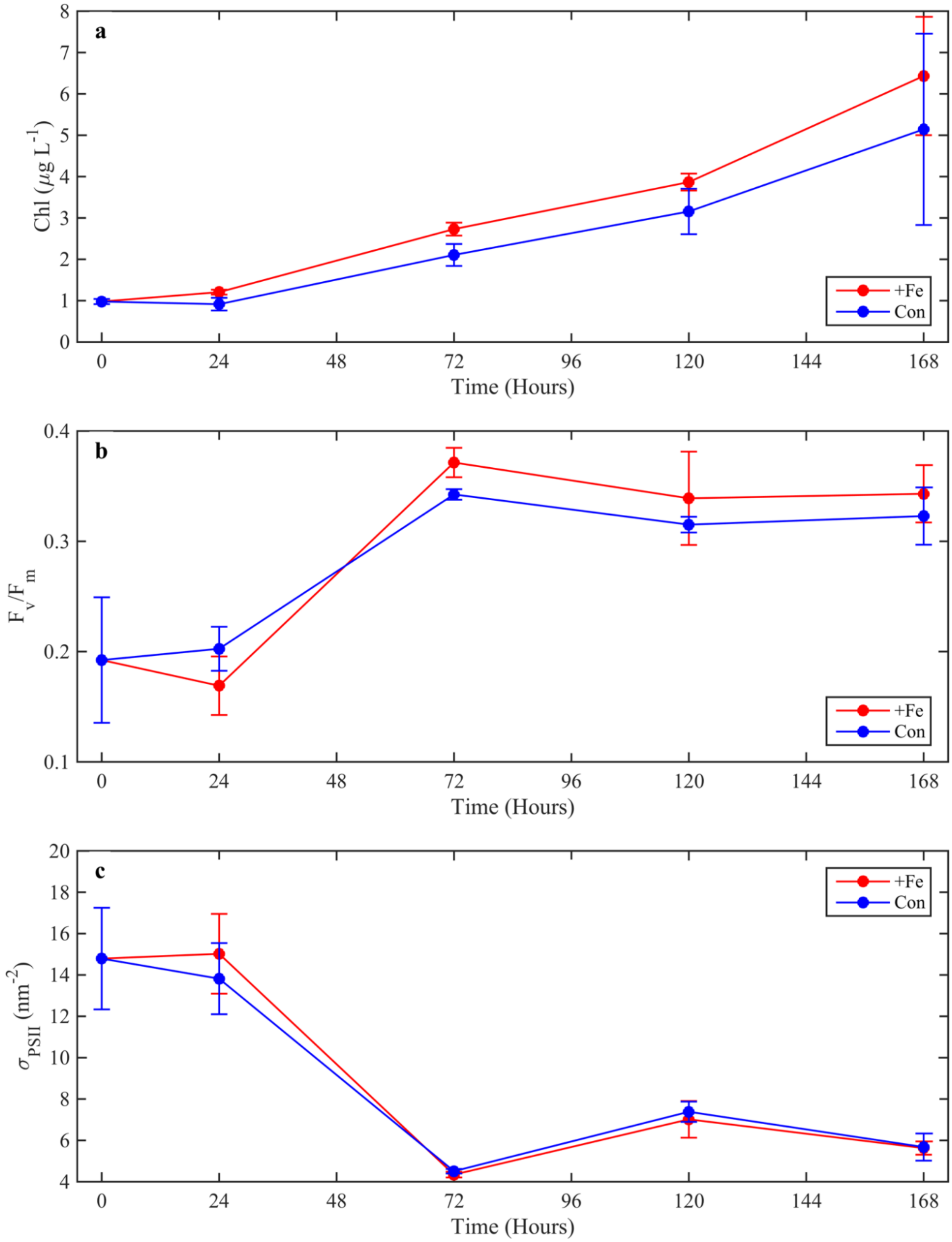

Figure 1: Initial results from long-term incubation experiment 1. a) Chl-a concentrations (μg L^{-1}). b) F_v/F_m. c) σ_{PSII} (nm^{-2}).

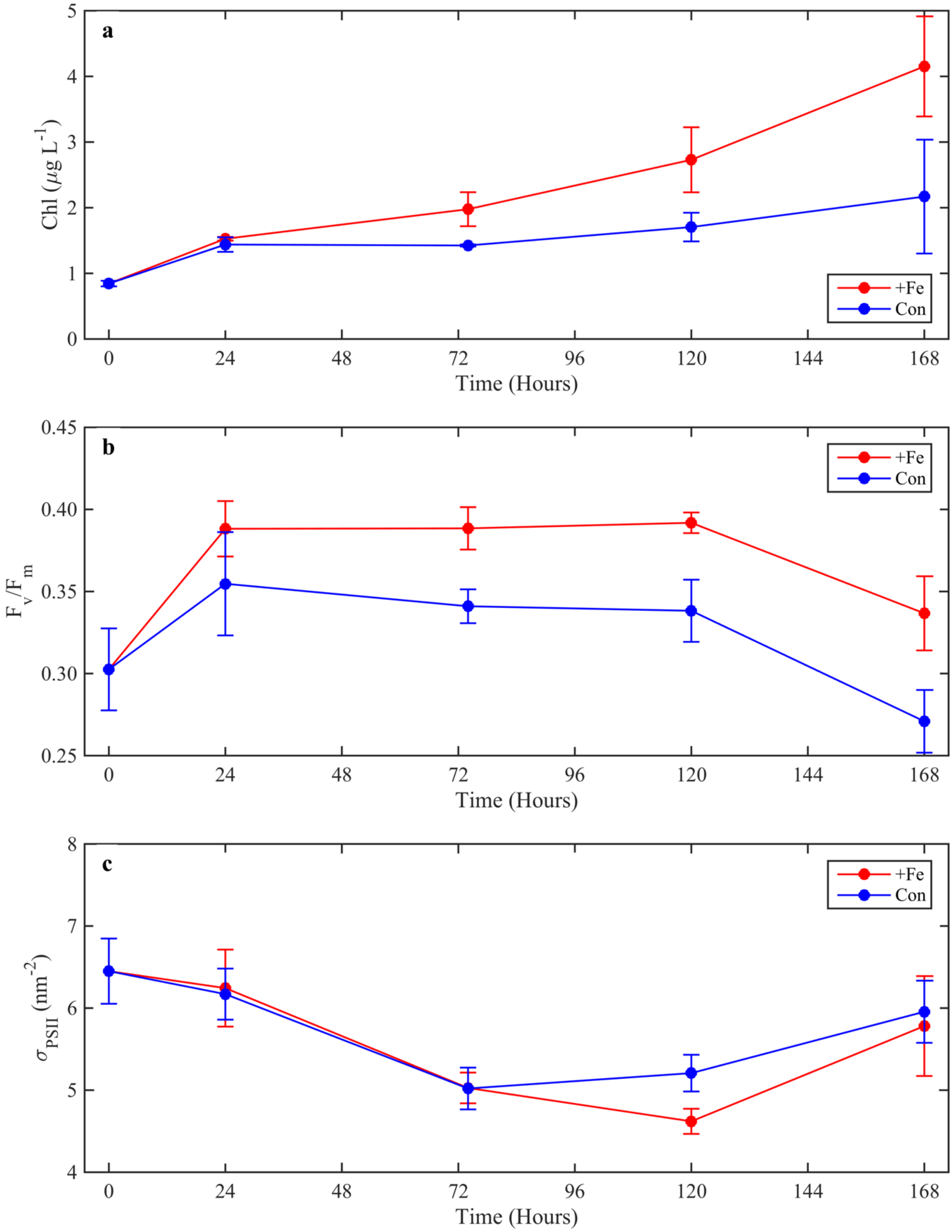

Figure 2: Initial results from long-term incubation experiment 2. a) Chl-a concentrations (µg L^{-1}). b) F_v/F_m. c) σ_{PSII} (nm^{-2}).

Figure 1 and 2 shows the results from long term Fe/light bioassay incubation experiments 1 and 2. On a general basis however, it was seen that Fe addition enhanced Chlorophyll level and relief of Fe stressed phytoplankton cell as compared to the control. A significant difference in Chlorophyll and Fv/Fm between Fe addition and control was observed in experiment 2 that was conducted later in summer season (see **Table 1**). More parameters will be analysed to support these observations.

6.7. Phytoplankton Photophysiology

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Team: T. Ryan-Keogh, S. Thomalla, H. Little, R. Miltz, E. Veermeulen, M. Mdutyana

6.7.1. Methods

Underway Measurements

A Satlantic FIRe (Fast Induction Relaxation fluorometer) was connected to the ship's non-toxic underway water supply within the wet biology laboratory in order to assess and monitor the photophysiology of the Photosystem II within the surface phytoplankton population. The FIRe had the following parameters:

STF: 100
STRP: 60
STRI: 60
MTF: 600
MTRP: 60
MTRI: 100
Sample Delay: 300 ms
No. of Samples: 12

Blank samples were collected from the seawater filtered through a 0.2μm pore size GF/F and then again through 0.2 μm polycarbonate filter to perform FRRF and FIRe blank corrections.

CTD Sampling

Water samples for Fast Repetition Rate Fluorometry (FRRF) were collected from each GCTD Niskin rosette casts at 6 depths located in the mixed layer. Dark bottles were used for sub-sampling before dark acclimation for 30-40 minutes. Photophysiological parameters were performed/measured using a Chelsea Technology FastOcean™ and FastAct system™. The following protocol was used:

Sat Flashlets: 100
Pitch (μs): 2
Rel Flashlets: 25
Pitch (μs): 84
Sequence interval (ms): 100
Sequence Reps: 32

The PMT was adjusted according to the *in situ* biomass, with modifications made to the LED settings in order to achieve a measurement within a range of $R\sigma_{PSII}$ of ~0.04, as prescribed by the manufacturer.

Fluorescence Light Curves (FLC)

Samples for FLC measurements were collected every 4 hours while underway and from the surface bottle of each GCTD Niskin casts. Measurements were performed using a Chelsea Technology FastOcean™ and FastAct system™. The following protocol was used:

PAR (µmol photons m^{-2} s^{-1})	**No. of replicates**
0	12
10	24
30	12
51	12
72	12
92	12
113	12
134	12
154	12
175	12
216	12
335	12
446	12
650	12
839	12
900	12
1049	12
1260	12
1500	12
1865	12

Light Delay (s): 1
Light loop pitch (s): 10
Dark Delay (s): 1
Dark loop pitch (s): 10
Water jacket pump: On – level 1

As recommended by the manufacturer the number of replicate measurements at the first light step was doubled to allow the sample to acclimatize appropriately to ensure a successful a fluorescence light curve. The total time for the light curve was 42:31.

6.7.2. Problems encountered

- Due to the variations in biomass there were issues with obtaining valid measurements at some UW stations
- Maintaining the water jacket temperature to the *in situ* temperature of collected samples – no water bath was loaded onto the ship so the milli-q bottle was stored under running seawater whilst not being used. The water may have heated up to room temperature during FLC runs.
- The 0.2 µm filters were initially used to collect blanks but a signal was still present. GF/F filtrate was passed through a 0.2 µm polycarbonate filter to remove the signal.
- There was inconsistency across shifts with the dark acclimation time, particularly important for samples collected during daylight hours.

6.8. Key metabolic proteins in marine microbial communities

PI: Thomas Ryan-Keogh and Sandy Thomalla

Team: Thomas Ryan-Keogh, Sandy Thomalla, Hazel Little, Ryan Miltz, Estee Veermeulen and Mhlanga Mdutyana

6.8.1. Rationale

The diversity of marine microbial communities is poorly understood, however, microbial processes catalyse biochemical cycles on global scales. Despite this diversity the protein catalysts that perform the chemistry of these reactions are highly conserved. Iron (Fe) is a fundamental requirement for high rates of production due to the abundance of Fe-containing protein catalysts in the photosynthetic apparatus of photosynthetic cells (Shi et al. 2007). Thus Fe availability has the potential to limit the abundance of these proteins and set a limit on metabolic activity and hence primary production within the ocean. Primary production in the ocean is usually quantified through basic methods in oceanography (e.g. chlorophyll content, photosynthetic efficiency (F_v/F_m), remote sensing).

6.8.2. Aims and Objectives

Using this novel quantitative technique, our aim was to investigate the photosynthetic process at a molecular level in order to better understand the role of Fe availability on photosynthetic activity. Samples were collected for metabolic protein analysis across the STZ, SAZ, PFZ and AZ.

6.8.3. Methods

Water samples were collected from the GCTD Niskin casts and the ships non-toxic supply (**Table 1**) and from nutrient addition experiments. From the GCTD, samples were collected from the surface (10-15m). Samples were collected in polyethylene carboys and volumes ranging from 0.58L to 2.00L (depending on biomass in seawater) were filtered for 1-2 hours onto 4 × GF/F filters (0.7 µm pore size, 25mm, Whatman) and stored at -80°C freezer. Filters will be used for protein extractions to target key photosynthetic proteins including components of photosystem I & II and Rubisco.

Table 1: Sample location, Temperature, chlorophyll concentration and the volume of seawater filtered through GFF.

Sample ID	Date	Time (GMT)	Lat	Lon	Temp	Chl (ug.L-1)	vial 1 (vol)	vial 2 (vol)	vial 3 (vol)	vial 4 (vol)
U009	06/12/15	09:59	-36.115	13.384	19.47	0.319	1.88	1.86	1.84	1.72
CTD03	06/12/15	19:25	-37.408	12.519	16.02	0.156	1.705	1.88	1.91	1.805
U018	07/12/15	09:58	-39.631	11.043	14.73	0.425	2	1.96	2	1.95
U024	07/12/15	21:59	-41.938	9.380	11.01	0.395	2	2	1.95	1.81
CTD04	08/12/15	03:23	-42.693	8.738	11.60	0.761	2	2	2	2
CTD06	09/12/15	03:50	-45.011	6.563	6.45	1.440	2	2	2	2
U031	09/12/15	11:00	-46.110	5.487	6.04	0.791	2	2	2	2
U037	10/12/15	00:00	-48.305	3.293	5.22	0.984	2	2	2	2
U049	11/12/15	00:01	-52.598	0.000	1.74	0.587	2	2	2	2
U061	12/12/15	00:00	-57.546	0.004	-0.82	1.229	2	2	1.74	1.69
U067	12/12/15	12:00	-59.229	-1.072	-1.33	0.534	2	2	2	1.95
U072	25/12/15	10:59	-68.266	-13.494	0.93	0.838	1.36	1.37	1.31	1.41
U078	26/12/15	00:00	-66.478	-17.481	-0.64	0.791	2	2	1.935	2
U084	26/12/15	13:00	-65.313	-20.982	-1.62	1.006	2	2	1.75	1.9
U091	27/12/15	12:59	-61.830	-24.176	-1.31	0.369	2	2	2	2
U098	28/12/15	12:59	-59.334	-27.375	-1.42	7.089	2	2	2	2
U104	29/12/15	00:00	-57.764	-30.539	-0.07	1.931	1.62	1.8	1.58	1.6
U110	29/12/15	13:59	-56.211	-33.155	1.26	0.431	2	2	2	2
CTD08	29/12/15	19:42	-55.685	-33.971	1.51	1.789	1.5	1.58	1.22	1.17
U117	31/12/15	01:57	-53.735	-34.326	1.98	1.733	2	2	2	2
U125	31/12/15	13:59	-52.750	-30.079	2.15	2.434	1.875	1.805	1.905	1.88
U129	01/01/16	02:08	-51.766	-25.919	4.88	1.226	2	2	2	2
U140	02/01/16	01:59	-49.792	-18.045	3.86	1.168	1.98	1.91	2	2
U146	02/01/16	12:55	-48.933	-14.435	4.71	0.895	1.735	2	2	1.9
U152	02/01/16	00:59	-47.941	-10.572	4.90	1.002	1.68	1.4	1.7	1.62
U157	03/01/16	12:59	-46.947	-6.722	5.64	0.862	1.79	2	2	2
U163	04/01/16	00:59	-46.007	-3.244	6.66	1.035	1.52	1.48	1.56	1.6
U169	04/01/16	12:00	-45.096	-0.119	8.41	0.385	2	2	2	2
U175	05/01/16	00:00	-44.080	3.804	8.92	0.558	2	2	2	2
U181	05/01/16	11:57	-43.095	7.320	9.78	0.674	1.99	2	1.99	1.75
CTD11	05/01/16	17:46	-42.693	8.737	10.50	0.728	2	2	2	2
U183	06/01/16	00:02	-42.929	8.519	10.25	0.714	1.47	1.45	1.4	1.42
CTD14	06/01/16	13:24	-44.989	6.798	7.09	0.890	2	2	2	2
CTD16	07/01/16	00:55	-44.999	5.926	6.72	0.928	2	2	2	2
U195	07/01/16	16:00	-48.240	3.351	5.65	1.480	2	2	2	2
U199	08/01/16	00:00	-49.375	1.940	4.78	1.401	2	2	2	2
CTD18	08/01/16	10:08	-50.452	1.043	3.20	2.208	2	2	2	2
U208	09/01/16	00:01	-53.135	0.526	1.62	0.525	2	2	2	2

CTD20	09/01/16	16:36	-55.700	0.000	0.05	1.218	2	2	2	2
U216	10/01/16	00:00	-57.027	0.024	0.01	1.362	2	2	2	2
U222	10/01/16	12:03	-59.332	0.001	-0.26	0.918	2	2	2	2
U228	11/01/16	00:00	-61.973	0.000	-0.02	2.271	2	2	2	2
U234	11/01/16	11:59	-64.593	0.000	0.42	1.751	1.28	1.28	1.12	1.18
U240	12/01/16	00:00	-67.040	0.318	-0.58	4.739	0.64	0.72	0.68	0.58
U249	12/01/16	21:59	-70.138	-2.138	-1.65	4.184	2	2	2	2
U252	26/01/16	00:00	-70.274	-6.069	-1.58	0.902	2	2	2	1.98
CTD22	26/01/16	19:17	-70.443	-7.824	-1.41	1.129	2	2	2	2
U258	02/02/16	04:00	-68.211	-6.313	-1.82	3.579	0.84	1	0.94	0.92
U262	02/02/16	12:00	-66.747	-3.332	0.65	2.436	1.73	1.39	1.4	1.49
U268	03/02/16	00:00	-64.562	0.000	0.90		1.93	1.4	1.88	1.77
U274	03/02/16	12:00	-61.961	0.004	0.32		1.74	1.53	1.5	1.85

6.8.4. Problems encountered:

1. Liquid nitrogen was unavailable for the cruise so filters could not be flash frozen. There is a potential that some of the sample may degrade during the freezing process within the -80°C freezer.

References

1. Shi T., Sun Y., Falkowski P.G. (2007) Effects of iron limitation on the expression of metabolic genes in the marine cyanobacterium *Trichodesmium erythraeum* IMS101. Environmental Microbiology 9: 2945-2956

7. South Atlantic Meridional Overturning Circulation (SAMOC)

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Team: Tahlia Henry, Kate Brink, Yuri Contronoe and Tobin Davenport
Funding: NRF

7.1. Rationale / Motivation

The global oceanic thermohaline circulation, often referred to as the Meridional Overturning Circulation (MOC), is a vital link in the global transport of mass and heat across ocean basins particularly between the tropics to higher latitudes. The physical structure of this circulation belt and its efficiency in regulating climate is substantially influenced by the nature of water mass exchange between ocean basins (Gordon, 1986). The Antarctic Circumpolar Current (ACC) is by far the largest conduit for such exchange. Extending unbroken around Antarctica it is the primary means by which water, heat and salt are redistributed between different ocean basins. Interpreting the causes of temperature and salinity variability observed in the ocean interior requires an understanding of the formation of Southern Ocean water masses and the circulation paths they follow. Changes in heat supplied by the deep ocean may influence the atmosphere directly or through changes in sea ice. Furthermore, water masses formed in the Southern Ocean have been shown to ventilate the intermediate and abyssal depths of much of the world's oceans. As these exchanges play an important role in regulating mean global climate, sustained hydrographic observations are crucial in order to describe and better understand the physical and dynamic processes, which are responsible for the variability of the ACC. The major part of the flow associated with the ACC is concentrated at a number of circumpolar fronts, which act as boundaries separating zones of uniform water masses (Gordon, 1986) (**Figure 1**). The zones of uniform water properties between the fronts are commonly referred to as the Subantarctic Zone (SAZ) between the STF and the SAF, the Polar Front Zone (PFZ) between the SAF and the APF, and the Antarctic Zone (AAZ) between the APF and the Antarctic continent (Gordon, 1986).

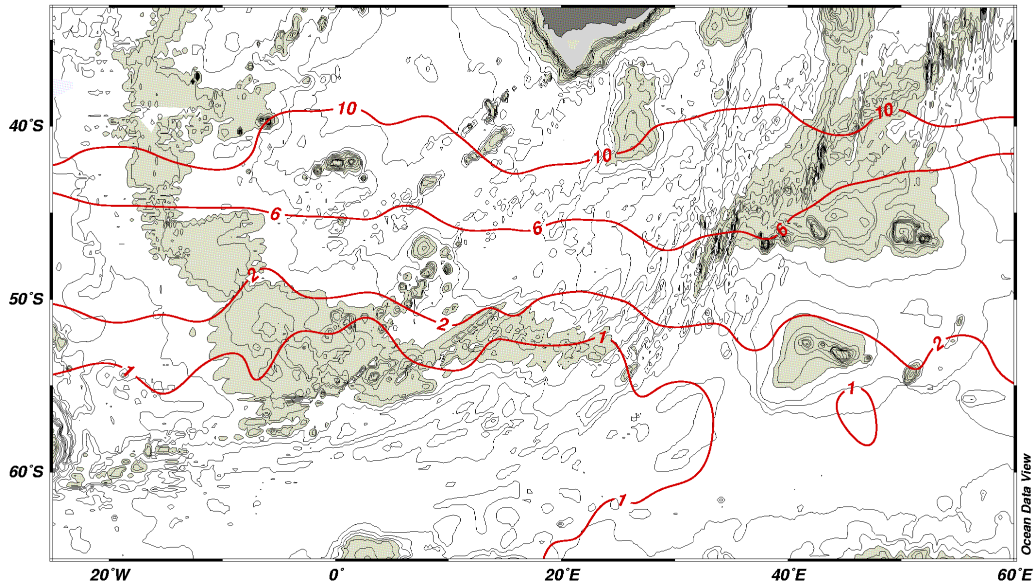

Figure 1: Schematic diagram showing the average position of the subsurface temperature expressions of the STF (10˚C), SAF (6˚C) and APF (2˚C) south of South Africa. The SACCF is represented by the 1˚C isotherm, which lies below the Tmin.

South of Africa, the Southern Ocean plays a unique role in providing a source for the equatorward flux of heat into the South Atlantic. Recent modelling studies on the global ocean circulation suggest that Indo-Atlantic interocean exchanges through the Agulhas Current system are far more important for the thermohaline circulation than the direct input of water from the Drake Passage (Speich et al., 2001; 2002). Estimates of the percentage of mode and intermediate waters entering the Atlantic via the Agulhas region is highly variable ranging from 0% (Rintoul, 1991) to 50% (Gordon et al., 1992). Therefore, in order to understand the role of this key component of the MOC on the global ocean circulation and its possible role in climate it is critical that the inflow of Indian waters into the Atlantic Ocean be properly quantified and monitored through sustainable hydrographic observations.

The state of long-term observations and modelling of the Southern Ocean south of Africa is not as developed as it is in other regions of the ocean and atmosphere.

Oceanographic observations in the Southern Ocean are sparse due to its remote location, with only the ships supplying Antarctic scientific bases providing an opportunity to sample repeatedly along well-defined cruise tracks. The limited opportunity for data collection is further accentuated during the winter months when sea ice and hostile weather conditions present additional logistic challenges. While major achievements have been made in the last eighteen years during the WOCE/JGOFs era and more recently since the start of the GoodHope monitoring line in 2004 (Ansorge et al., 2004) we are only now beginning to understand the mean state and variability of the Southern Ocean (Swart et al., 2008; 2009); its coupling with the atmosphere and cryosphere, and of the zonal and meridional fluxes – but for summer months only. In addition, the Southern Ocean Seasonal Cycle Experiment (SOSEx), a combined observational and modelling programme run parallel to GoodHope, aims to predict the response of the carbon cycle to climate change through an improved sensitivity to seasonal, sub-seasonal and mesoscale forcing scales. This combined high-resolution approach to both long-term observations and modelling experiments will address key questions relating to the physical nature of the Southern Ocean and its carbon cycle. Furthermore, the Southern Ocean upper water column processes, which are important to seasonal productivity and carbon fluxes, undergo an annual "reset" during winter months when net heat losses, elevated wind stress and sea ice formation lead to an increase in the mixed layer depth (MLD). This winter "reset" is a critical process in the seasonal cycle, ensuring the regeneration in iron and nitrate concentrations during summer months when the MLD shallows. Current logistic constraints have restricted observations to December-January and as a consequence our ocean and climate numerical models are unable to accurately simulate seasonal ventilation processes, nor can they address impacts, changes in the biogeochemical pump through seasonal shifts in the MLD, will have on the annual carbon flux. A knock on effect to the absence of any long-term real time data is the inability for local scientists to provide a complete picture of the Southern Ocean's impact on climate.

A key component of this programme is the implementation of the high density XBT transect between Cape Town to Antarctica and the deployment of a 7-PIES array between 35˚S and 43°S (Tables 3 and 4). The Good Hope programme commenced in 2004 and has to date provided upper thermal (0 – 1000m) data on over 26 transects (Swart et al., 2008; 2009), however the transects have been restricted to summer months only and our knowledge on the impact seasonality has in this belt is limited. In order to monitor the variability in volume transports brought on by the leakage of Agulhas water into the South Atlantic through ring-shedding events, the new SAMOC-SA programme deployed an array of PIES moorings (beneath the Good Hope transect) spanning south-westwards from the South African continental shelf (Ansorge et al., 2014).

Sustained observations such as repeat transects along GoodHope currently provide the only means to monitor the vertical structure and to investigate the variability of the fronts in this region. This programme investigates year-to-year variability in the physical fluxes, such as those related to the Antarctic Circumpolar Wave. Such intense and periodic monitoring has been underway in the Drake Passage and south of Tasmania (Sokolov and Rintoul, 2002) since the 1970s. In this study, we describe the frontal structure in the upper ocean as determined from underway surface, XBT and stationary CTD measurements.

As a component of the Meridional Overturning Circulation (MOC), the Southern Ocean plays a major role in the global ocean circulation and it is hypothesised that it has an important impact on present day climate. However, our understanding of its complex three-dimensional dynamics and the impact of its variability on the climate system and affect of seasonality remain to this day rudimentary. The international Good Hope research venture aims to address this knowledge gap by establishing a programme of regular observations across the Southern Ocean between the African and Antarctic continents.

7.2. Aims and Objectives

- To gain a better understanding of Indo-Atlantic inter-ocean exchanges and their impact on the global thermohaline circulation and thus on global climate change;
- To understand in more detail the impact these exchanges have on the climate variability of the southern African subcontinent;
- To monitor the variability of the main Southern Ocean frontal systems associated with the Antarctic Circumpolar Current;
- To study air-sea exchanges and their role on the global heat budget, with particular emphasis on the intense exchanges occurring within the Agulhas Retroflection region south of South Africa, and
- To examine the role of major frontal systems as areas of elevated biological activity and as biogeographic barriers to the distribution of plankton.

7.3. Methods

XBT

To effectively measure oceanic changes of heat fluxes, in particular across regions of inter-basin exchange, high-density observations need to be undertaken. Repeat XBT sections across “chokepoint” sections provide measurements of changes in upper ocean heat content and SST on both seasonal and inter-annual time scales. In addition, by exploiting the relationship between upper ocean temperature and dynamic height, XBTs can be used to infer velocities even in the Southern Ocean where salinity changes are important (Rintoul and Sokolov, 2001). In this way, XBT sections serve as a useful tool in measuring changes in the interocean exchange of heat.

In the framework of Good-Hope, XBTs were funded by the NOAA's Office of Global Programs as part of their High Density XBT project at NOAA/AOML. The southbound

Good-Hope transect was conducted on-board the SA Agulhas II as Leg 1 between the 5 to 15th December 2015. A total of 97 Sippican Deep Blue XBTs were deployed between 33˚59'S, 17˚50'E and 65˚50'S, 00˚00'E enroute to the ice edge at 66˚S. A total of 4 CTD stations were deployed as part of the PIES calibration programme. Salinity samples from 4000, 2000 and 200m were processed with a Guide-line model 8410A portasal according to the manual in order to confirm the recent calibration of the salinity sensor.

Table 1: Definition of the fronts bordering the Antarctic Circumpolar Current adapted from Belkin and Gordon (1996).

FRONT	SURFACE RANGE	SUBSURFACE (200 m) RANGE
STF	10.6 – 17.9˚C: 34.3 – 35.5	8.0 – 11.3˚C: 34.42 – 35.18 Axial value: 10˚C, 34.8
SAF	6.8 – 10.3˚C: 33.88 – 34.36	4.8 – 8.4˚C: 34.11 – 34.47 Axial value: 6˚C, 34.3
APF	2.5 – 4.1˚C	Axial value: 2˚C

Table 2: Highlighting the positions and times of all hydrographic stations (XBT) occupied along the 2015 southbound and northbound GoodHope transect

STATION	LONGITUDE	LATITUDE	GMT	DATE	COMMENTS
XBT 1	34 29.990 S	16 23.120 E	13:20	05/12/2015	
XBT 2	34 29.990 S	16 02.00 E	14:50	05/12/2015	
XBT 3	34 29.990 S	15 38.50 E	16:20	05/12/2015	
XBT 4	34 29.990 S	15 17.50 E	17:50	05/12/2015	
XBT 5	34 29.990 S	14 54.28 E	19:20	05/12/2015	
XBT 6	34 29.990 S	14 38.35 E	20:50	05/12/2015	
XBT 7	34 29.990 S	14 38.35 E	22:20	05/12/2015	Operator recorded the same co-ordinates as XBT6?
XBT 8	34 29.997 S	14 38.34 E	23:50	05/12/2015	
XBT 9	34 35.449 S	14 34.13 E	01:20	06/12/2015	
XBT 10	34 53.313 S	14 20.34 E	02:50	06/12/2015	
XBT 11	35 09.714 S	14 07.65 E	04:20	06/12/2015	
XBT 12	35 26.968 S	13 54.24 E	05:50	06/12/2015	
XBT 13	35 39.99 S	13 44.07 E	07:20	06/12/2015	
XBT 14	35 54.047 S	13 33.11 E	08:50	06/12/2015	

XBT 15	36 16.026 S	13 16.23 E	10:50	06/12/2015	
XBT 16	36 27.508 S	13 08.71 E	11:58	06/12/2015	Two probes dropped on this deployment
XBT 17	36 44.414 S	12 57.58 E	13:20	06/12/2015	
XBT 18	37 02.95 S	12 45.46 E	14:50	06/12/2015	
XBT 19	37 21.05 S	12 33.36 E	16:20	06/12/2015	
XBT 20	37 24.48 S	12 31.12 E	17:50	06/12/2015	CTD station
XBT 21	37 38.55 S	12 22.35 E	23:50	06/12/2015	Drop made 1hr 30mins after CTD station
XBT 22	37 55.82 S	12 11.60 E	01:20	07/12/2015	
XBT 23	38 15.79 S	11 59.11 E	02:50	07/12/2015	
XBT 24	38 34.08 S	11 47.60 E	04:20	07/12/2015	
XBT 25	38 50.44 S	11 36.26 E	05:50	07/12/2015	
XBT 26	39 06.82 S	11 24.65 E	07:20	07/12/2015	
XBT 27	39 24.31 S	11 12.20 E	08:50	07/12/2015	
XBT 28	39 41.18 S	11 00.14 E	10:20	07/12/2015	
XBT 29	39 57.42 S	10 48.53 E	11:50	07/12/2015	
XBT 30	40 15.06 S	10 36.76 E	13:20	07/12/2015	
XBT 31	40 32.85 S	10 24.90 E	14:50	07/12/2015	
XBT 32	40 50.46 S	10 13.15 E	16:20	07/12/2015	
XBT 33	41 08.76 S	10 00.85 E	17:50	07/12/2015	
XBT 34	41 26.40 S	09 48.00 E	19:20	07/12/2015	
XBT 35	41 42.97 S	09 34.06 E	20:50	07/12/2015	
XBT 36	41 59.31 S	09 20.23 E	22:20	07/12/2015	
XBT 37	42 15.79 S	09 06.25 E	23:50	07/12/2015	
XBT 38	42 32.39 S	08 52.05 E	01:20	08/12/2015	CTD Station
XBT 39	42 41.59 S	08 44.13 E	04:20	08/12/2015	Still on station…attempted drop?!
XBT 40	42 44.76 S	08 47.48 E	10:15	08/12/2015	
XBT 41	42 50.09 S	08 43.55 E	11:45	08/12/2015	Rough seas, double drop to get a clean cast
XBT 42	43 01.28 S	08 25.92 E	13:15	08/12/2015	
XBT 43	43 14.90 S	08 13.26 E	14:45	08/12/2015	
XBT 44	43 30.07 S	07 59.08 E	16:15	08/12/2015	
XBT 45	43 45.76 S	07 44.36 E	17:45	08/12/2015	
XBT 46	44 01.97 S	07 29.04 E	19:15	08/12/2015	

XBT 47	44 17.72 S	07 14.11 E	20:45	08/12/2015	
XBT 48	44 39.86 S	06 53.05 E	22:15	08/12/2015	
XBT 49	44 49.42 S	06 43.88 E	23:45	08/12/2015	
XBT 50	45 00.10 S	06 33.73 E	01:15	09/12/2015	CTD station
XBT 51	44 58.58 S	06 33.90 E	04:15	09/12/2015	
XBT 52	45 07.48 S	06 26.33 E	05:45	09/12/2015	
XBT 53	45 23.54	06 11.09 E	07:15	09/12/2015	
XBT 54	45 40.30 S	05 54.85 E	08:45	09/12/2015	
XBT 55	45 57.47 S	05 38.13 E	10:15	09/12/2015	
XBT 56	46 14.43 S	05 22.48 E	11:45	09/12/2015	
XBT 57	46 29.25 S	05 06.95 E	13:15	09/12/2015	
XBT 58	46 44.08 S	04 52.30 E	14:45	09/12/2015	
XBT 59	46 59.22 S	04 37.26 E	16:15	09/12/2015	
XBT 60	47 14.69 S	04 21.84 E	17:45	09/12/2015	
XBT 61	47 29.70 S	04 06.77 E	19:15	09/12/2015	
XBT 62	47 45.18 S	03 51.20 E	20:45	09/12/2015	
XBT 63	48 00.28 S	03 35.96 E	22:15	09/12/2015	
XBT 64	48 00.27 S	03 35.96 E	23:45	09/12/2015	SDS went down
XBT 65	49 44.74 S	01 48.06 E	09:00	10/12/2015	
XBT 66	49 59.25 S	01 52.78 E	10:30	10/12/2015	
XBT 67	50 15.56 S	01 15.39 E	12:00	10/12/2015	
XBT 68	50 30.51 S	00 59.59 E	13:30	10/12/2015	
XBT 69	50 45.92 S	00 43.10 E	15:00	10/12/2015	
XBT 70	51 00.86 S	00 27.83 E	16:30	10/12/2015	
XBT 71	51 15.99 S	00 10.63 E	18:00	10/12/2015	
XBT 72	51 34.09 S	00 00.00 E	19:30	10/12/2015	
XBT 73	51 54.09 S	00 00.18 E	21:00	10/12/2015	
XBT 74	52 14.19 S	00 00.08 E	22:30	10/12/2015	
XBT 75	55 33.48 S	00 00.19 E	00:30	11/12/2015	Start of scatter ice, XBTs stopped
XBT 76	60 45.32 S	01 27.88 E	23:00	12/12/2015	Clear patch, no ice XBT resumed
XBT 77	61 03.81 S	01 14.23 W	00:30	13/12/2015	Hit ice, XBTs stopped
XBT 78	65 48.33 S	00 56.96 W	12:15	14/12/2015	Ice cleared, Last XBT for Leg 1
XBT 79	66 45. 57 S	03 21.49 W	12:00	02/02/2016	Leg 3 Ice shelf to Cape Town
XBT 80	66 27.61 S	02 46.08 W	13:30	02/02/2016	
XBT 81	66 12.50 S	02 17.29 W	15:00	02/02/2016	

XBT 82	65 56.04 S	01 45.15 W	16:30	02/02/2016	
XBT 83	65 40.24 S	01 15.11 W	18:00	02/02/2016	
XBT 84	65 24.21 S	00 46.19 W	19:30	02/02/2016	
XBT 85	65 09.30 S	00 17.13 W	21:00	02/02/2016	
XBT 86	64 52.05 S	00 01.15 W	22:30	02/02/2016	
XBT 87	64 55.44 S	00 00.10 E	00:00	03/02/2016	
XBT 88	64 16.14 S	00 00.01 E	01:30	03/02/2016	
XBT 89	63 58.65 E	00 00.01 E	03:00	03/02/2016	
XBT 90	63 38.80 S	00 00.02 E	04:30	03/02/2016	
XBT 91	63 18.99 S	00 00.01 E	06:00	03/02/2016	
XBT 92	62 51.45 S	00 00.19 E	07:30	03/02/2016	
XBT 93	62 38.95 S	00 00.00 E	09:00	03/02/2016	
XBT 94	62 18.70 S	00 00.01 E	10:30	03/02/2016	
XBT 95	61 56.72 S	00 00.42 E	12:00	03/02/2015	
XBT 96	61 37.44 S	00 00.48 E	13:30	03/02/2016	
XBT 97	61 20.59 S	00 00.05 E	15:00	03/02/2016	
XBT 98	61 00.31 S	00 00.46 E	16:30	03/02/2016	
XBT 99	60 40. 62 S	00 00.42 E	18:00	03/02/2016	
XBT 100	60 20.43 S	00 00.28 E	19:30	03/02/2016	
XBT 101	60 00.54 S	00 01.24 E	21:00	03/02/2016	
XBT 102	59 41.87 S	00 00.01 E	22:30	03/02/2016	
XBT 103	59 24.10 S	00 00.69 W	00:00	04/02/2016	
XBT 104	59 04.68 S	00 00.08 E	01:30	04/02/2016	
XBT 105	58 47.79 S	00 00.71 E	03:00	04/02/2016	
XBT 106	58 28.54 S	00 02.17 W	04:30	04/02/2016	
XBT 107	58 11.80 S	00 00.41 W	06:00	04/02/2016	
XBT 108	57 52.84 S	00 00.38 W	07:30	04/02/2016	
XBT 109	57 33.87 S	00 00.62 E	09:00	04/02/2016	
XBT 110	57 13.86 S	00 00.29 E	10:30	04/02/2016	
XBT 111	56 54.23 S	00 02.95 W	12:00	04/02/2016	
XBT 112	56 36.74 S	00 00.70 E	13:30	04/02/2016	
XBT 113	56 17.92 S	00 00.48 E	15:00	04/02/2016	
XBT 114	56 00.06 S	00 00.81 W	16:30	04/02/2016	
XBT 115	55 42.06 S	00 00.22 W	18:00	04/02/2016	
XBT 116	55 23.03 S	00 00.46 E	19:30	04/02/2016	
XBT 117	55 04.59 S	00 00.88 W	21:00	04/02/2016	
XBT 118	54 46.52 S	00 00.19 W	22:30	04/02/2016	
XBT 119	54 27.96 S	00 00.79 E	00:00	05/02/2016	

XBT 120	54 11.57 S	00 00.14 E	01:30	05/02/2016	
XBT 121	53 49.02 S	00 00.50 E	03:00	05/02/2016	
XBT 122	53 19.59 S	00 00.61 E	04:30	05/02/2016	
XBT 123	53 19.71 S	00 00.21 E	06:00	05/02/2016	
XBT 124	53 03.07 S	00 00.35 W	07:30	05/02/2016	
XBT 125			09:00	05/02/2016	Operator failed to write down the co-ordinates!
XBT 126	52 25.60 S	00 00.78 W	10:30	05/02/2016	
XBT 127	52 08.56 S	00 00.00 E	12:00	05/02/2016	
XBT 128	51 57.36 S	00 00.04 E	13:30	05/02/2016	
XBT 128	51 32.34 S	00 00.02 E	15:00	05/02/2016	
XBT 129			16:30	05/02/2016	Operator failed to write down the co-ordinates!
XBT 130	50 59.81 S	00 28.24 E	18:00	05/02/2016	
XBT 131	50 59.81 S	00 28.24 E	19:30	05/02/2016	Frozen SDS system
XBT 132	50 27.44 S	01 02.95 E	21:00	05/02/2016	
XBT 133	50 06.37 S	01 25.33 E	22:30	05/02/2016	
XBT 134	49 55.01 S	01 37.32 E	00:00	06/02/2016	
XBT 135	49 27.44 S	01 01.95 E	01:30	06/02/2016	
XBT 136	49 24.01 S	02 09.84 E	03:00	06/02/2016	
XBT 137	49 07.85 S	02 26.64 E	04:30	06/02/2016	
XBT 138	48 53.13 S	02 91.87 E	06:00	06/02/2016	
XBT 139	48 37.77 S	02 57.72 E	07:30	06/02/2016	
XBT 140	48 11.40 S	03 24.65 E	10:00	06/02/2016	XBT got wet, previous 2 drops missed
XBT 141	47 20.08 S	04 16.46 E	15:00	06/02/2016	Previous drops missed as computer crashed
XBT 142	47 05.09 S	04 31.47 E	16:30	06/20/2016	
XBT 143	46 49.60 S	04 46.87 E	18:00	06/02/2016	
XBT 144	46 34.78 S	05 01.53 E	19:30	06/02/2016	
XBT 145	46 20.31 S	05 15.81 E	21:00	06/02/2016	
XBT 146	46 06.32 S	05 29.53 E	22:30	06/02/2016	
XBT 147	45 53.06 S	05 42.54 E	00:00	07/02/2016	
XBT 148	45 38.96 S	05 56.22 E	01:30	07/02/2016	

XBT 149	45 24.58 S	06 10.17 E	03:00	07/02/2016	
XBT 150	45 10.78 S	06 23.48 E	04:30	07/02/2016	
XBT 151	44 58.87 S	06 32.26 E	06:00	07/02/2016	
XBT 152	44 52.52 S	06 39.84 E	10:30	07/02/2016	
XBT 153	44 58.87 S	06 32.26 E	12:00	07/02/2016	
XBT 154	44 27.62 S	07 04.79 E	13:30	07/02/2016	
XBT 155	44 15.07 S	07 16.71 E	15:00	07/02/2016	
XBT 156	44 02.62 S	07 28.57 E	16:30	07/02/2016	
XBT 157	43 49.26 S	07 41.12 E	18:00	07/02/2016	
XBT 158	43 37.07 S	07 52.57 E	19:30	07/02/2016	
XBT 159	43 24.43 S	08 09.42 E	22:00	07/02/2016	
XBT 160	43 11.91 S	08 16.10 E	22:30	07/02/2016	
XBT 161	43 00.27 S	08 28.44 E	00:00	08/02/2016	CTD station
XBT 162	42 17.30 S	08 35.31 E	09:00	08/02/2016	
XBT 163	42 23.20 S	08 50.56 E	10:30	08/02/2016	
XBT 164	42 17.54 S	09 04.83 E	12:00	08/02/2016	
XBT 165	42 01.39 S	09 18.56 E	13:30	08/02/2016	
XBT 166	41 47.13 S	09 30.65 E	15:00	08/02/2016	
XBT 167	41 29.28 S	09 45.69 E	16:30	08/02/2016	
XBT 168	41 12.84 S	09 58.17 E	18:00	08/02/2016	
XBT 169	40 56.28 S	10 09.31 E	19:30	08/02/2016	
XBT 170	40 39.63 S	10 20.46 E	21:00	08/02/2016	
XBT 171	40 24.57 S	10 30.52 E	22:30	08/02/2016	
XBT 172	40 06.91 S	10 42.26 E	00:00	09/02/2016	
XBT 173	39 32.45 S	11 06.45 E	03:00	09/02/2016	No fire on the previous XBT (1:30)
XBT 174			04:30	09/02/2016	Operator failed to write down the co-ordinates!
XBT 175	39 01.18 S	11 28.73 E	06:00	09/02/2016	
XBT 176	38 45.51 S	11 00.90 E	07:30	09/02/2016	
XBT 177	38 29.45 S	11 50.59 E	09:00	09/02/2016	
XBT 178	38 13.96 S	12 00.93 E	10:30	09/02/2016	
XBT 179	39 01.18 S	11 28.73 E	12:00	09/02/2016	
XBT 180	37 40.65 S	12 21.11 E	13:30	09/02/2016	
XBT 181	37 24.18 S	12 31.33 E	15:00	09/02/2016	
XBT 182	37 07.88 S	12 42.15 E	16:30	09/02/2016	
XBT 183	36 51.78 S	12 52.81 E	18:00	09/02/2016	
XBT 184	36 38.52 S	13 01.50 E	19:30	09/02/2016	

XBT 185	36 21.24 S	13 12.87 E	21:00	09/02/2016	CTD station
XBT 186	35 39.85 S	13 44.27 E	04:30	10/02/2016	
XBT 187	35 24.69 S	13 56.10 E	06:00	10/02/2016	
XBT 189	35 09.66 S	13 07.36 E	07:30	10/02/2016	
XBT 190	35 54.77 S	14 19.27 E	09:00	10/02/2016	
XBT 191	34 39.03 S	14 31.42 E	10:30	10/02/2016	
XBT 192	34 30.01 S	14 46.96 E	12:00	10/02/2016	
XBT 193	34 30.00 S	15 05.90 S	13:30	10/02/2016	
XBT 194	34.30 00 S	15 23.06 E	15:00	10/02/2016	
XBT 195	34 30.01 S	15 50.10 E	16:30	10/02/2016	
XBT 196	34 30.00 S	16 16.52 E	18:30	10/02/2016	
XBT 197	34 30.58 S	16 39.23 E	20:00	10/02/2016	
XBT 198	34 30.61 S	16 50.36 E	21:30	10/02/2016	
XBT 199	34 30.00 S	17 13.64 E	23:00	10/02/2016	
XBT 200	34 24.18 S	17 34.20 E	00:30	11/02/2016	

Frontal Locations

The Southern Ocean is characterised by the strong zonal nature of its main frontal bands, and its spatial structure is strongly determined by the position and flow regime of a number of frontal system separating different ACC zones (Belkin and Gordon, 1996). Extensive measurements have been made in the South Atlantic and South Indian sectors of the Southern Ocean over the past 3 decades (Ansorge et al., 2004). Full depth CTD measurements have been made during AJAX SR2 WOCE and on an opportunistic basis enroute to the ice edge. Unlike other regions of the Southern Ocean, where frontal systems display high bands of variability with enhanced eddy activity such as at the Drake Passage and South Georgia, at the South-West Indian Ridge (Ansorge and Lutjeharms, 2003) and south of Australia (Sokolov and Rintoul, 2002), the frontal characteristics in the region of the Greenwich Meridian line are less intense and variable, as can be inferred from altimetry and from historic hydrographic data. In addition, investigations by Billany et al., (2010) into the seasonality of these frontal locations at the Greenwich Meridian have shown that the STF has the most pronounced annual cycle, whereas the SAF, and particularly the APF, show smaller seasonal shifts. A rapid change in the STF position occurs from May to August when this front moves northwards.

Identification of the main ACC fronts is essential in order to trace the upper level circulation associated with the baroclinic shear. However, accurate identification of the fronts is not always simple, especially in regions where they remain merged. One major difficulty is the various definitions that have been given for the characterisation of the fronts bordering the Antarctic Circumpolar Current. Depending on authors, these definitions are based on either surface or subsurface property values, whereas others have used phenomenological definitions. Definitions for both surface and subsurface ranges are given above in Table 1, however, in order to unambiguously place the fronts before describing the frontal features observed along the southbound GoodHope transect, each front will be defined using their representative subsurface axial values at 200m, where generally each front is marked best.

Subtropical convergence

The Subtropical Convergence (STC) marks the boundary between warm, salty subtropical surface water and cooler, fresher Subantarctic Surface Water to the south. It is the most northerly front associated with the ACC (Figure 1) and the most prominent surface thermal front. XBT data collected from over 70 crossings of the STC have shown that in the South Atlantic the STCs mean position lies at 41º40'S (Lutjeharms, 1985). The surface expression during GoodHope 2014 southbound transect of the STC was found between 39º39' – 40º54'S and the subsurface core, identified by the 10ºC isotherm at 200m, at 40º42'S (Figure 3). Previous studies in the South-east Atlantic sector of the Southern Ocean (Smythe-Wright et al., 1998) have identified two separate fronts associated with the Northern (NSTC) and Southern boundaries (SSTC) of the STC. These observations have been made from over 10 datasets extending across the South Atlantic from the Brazil Current at 42ºW to the Agulhas - Benguela region at 11ºE. Surface temperature and salinity definitions given by Belkin and Gordon (1996) cover the range 14.0 –16.9ºC, 34.87 – 35.58 for the NSTC and 10.3 – 15.1ºC, 34.30 – 35.18 for the SSTC. Examination of the thermosalinograph data collected during this leg (Figure 2) reveal two distinct surface frontal features between 39º49'S- 40º06'S and between 40º20'S – 41º15'S where surface temperatures drop from 18.83º - 15.16ºC, 35.49 – 34.02 and 16.13º – 11.13ºC and 34.665 – 34.045 respectively. Providing further support in the belief that in the SE Atlantic the STC may exist as two separate bands (Belkin and Gordon, 1996).

The altimeter-derived geostrophic currents in the region show that lying to the north of the STC two domings of the isotherms south of 40ºS correspond to two meanders of a large Agulhas ring and suggest that a ring was crossed during the GoodHope 2014 southbound transect. Surface temperatures and salinities across this feature range from 20 - 22ºC and >35.50 and are thus indicative of Agulhas Water, which has become entrained within this ring.

Sub-Antarctic front

The Sub-Antarctic Front (SAF) marks the northern boundary of the Polar Frontal Zone (PFZ), which is a transitional zone between SASW and AASW. In comparison to the STC, which is clearly characterised by a sharp and consistent gradient in both surface and subsurface expressions, making identification extremely easy (Lutjeharms and Valentine, 1984; Lutjeharms, 1985), the SAF is less clear in its surface expression. The exact boundaries of the PFZ can therefore be difficult to identify due to the weak nature of this front. The SAF is predominantly a subsurface front and can be defined by the most vertically orientated isotherm within a temperature gradient lying between 3ºC and 5ºC, while it's surface expression extends between 8ºC and 4ºC (Lutjeharms, 1985). Lutjeharms and Valentine (1984) have identified the SAF as having a mean position of 46º23'S south of Africa. Using the criteria described by Belkin and Gordon (1996) in which the subsurface temperature range between 4.8 - 8.4°C and 34.11 - 34.47 at 200m, with axial values of 6°C and 34.3, we observed the subsurface axis of the SAF at 44º07'S during GoodHope 2014 southbound transect (Figure 3). Thermosalinograph data places the surface expression of the SAF between 44º05'S – 49º16'S (8.51 - 4.24ºC, 34.031 – 33.618) (Figure 2). This appears to be considerably wider than in other studies in this region of the Southern Ocean (Belkin and Gordon, 1996). However, recent investigations (Smythe-Wright, 1998) have shown that in the South Atlantic, the SAF is often found as a broad frontal band extending over 250km (45º54'S - 48º42'S). Closer examination of the SST and in particular the SSS (sea surface salinity) data reveal a number of narrow reversals between 44º43'S (33.854 – 33.7) and 46º38'S (33.666 – 33.598) (Figure 3). This observation is in agreement with Holliday and Read (1998) who have identified a number of surface steps related to both temperature and salinity inversions. The exact cause of these inversions is not known, however Lutjeharms and Valentine (1984) and Wexler (1959) have ascribed these inversions to either wind-induced upwelling or the poleward shedding of eddies.

Antarctic Polar front (APF)

The APF marks the northern limit of the Antarctic zone and the subsurface expression of the APF is historically identified by the northern limit of the 2ºC temperature minimum at a depth of 200m (Whitworth, 1980; Belkin and Gordon, 1996). In some instances this is not coincident with the surface expression of the APF (Lutjeharms and Valentine, 1984) and instead the surface expression can be identified by the maximum temperature gradient between 6ºC and 2ºC. The APF is characterised by a shallow temperature minimum associated with the remnants of Winter Water, which lies at depths between 50 – 150m. It is seasonally variable; in winter it is nearly homogenous extending to 250m, while in summer the mixed layer extends only to between 50 - 100m. Temperature for this water mass range from -1.8 – 6°C at the APF and salinity from 33.4 - 34.2. During the GoodHope 2014 southbound transect the subsurface expression of the APF was found to lie at 50º22'S. The surface expression, identified from the thermosalinograph lay between 50º14'S – 52º51'S (4.7 – 1.46ºC, 33.796-33.894).

Southern Antarctic Circumpolar Front (SAACF)

Orsi et al. (1995) have identified an additional ACC front, which they have termed the Southern ACC Front (SACCF) and described as a circumpolar, deep reaching front lying south of the APF. The position of this front corresponds to the position of the atmospheric low-pressure belt Antarctic trough, which separates the easterly and westerly wind belts at ~65ºS. In contrast to the other fronts associated with the ACC, the SACCF does not separate distinct surface water masses, instead it is defined by the temperature and salinity characteristics of the Upper Circumpolar Deep Water (UCDW). Two branches of the SACCF, marked by a high salinity gradient 33.80 – 33.63 at 63.4ºS and 33.78 - 33.09 at 64.7ºS between 0.9 –0.7ºC, were observed by Holliday and Read (1998) in the SE Atlantic from their RRS Discovery dataset. South of Australia (Budillon and Rintoul, 2003) the SACCF has been identified by the location of the 0ºC isotherm along the T_{min}, which places the front at a mean position of 63º48'S. Increase in air temperatures between December – February results in the warming of the surface mixed layer and the northern extent of the TML cooler than 0ºC forming a reliable indicator of the position of the SACCF (Orsi et al., 1995). Using this definition, places the SACCF during GoodHope 2015 southbound transect between 53ºS and 55º44'S. In this region the T_{min} formed by the presence of the remnants of Winter Water average 80m in thickness and centred at 150m.

ADCP

ADCP data was collected underway until sea ice was encountered at 59°48.679'S. The ADCP onboard is a 75 kHz Teledyne RD Instruments Ocean Surveyor capable of reaching depths of up to 700m. Surface temperature and salinity data were recorded continuously by the shipboard thermosalinograph (TSG). This dataset was averaged into 20 minute intervals in order to reduce noise levels but to retain adequate information to identify the main frontal characteristics (Figure 1). The exact clarification of surface fronts based on exact temperature and salinity definitions is difficult because of the variable nature of surface waters and the influence of precipitation, especially at mid latitudes (Holliday and Read, 1997). We use here the surface definitions provided by Belkin and Gordon (Table 1) as a guide in determining the surface expressions of each frontal band.

Profiling Argo Floats

In the remote regions of the Southern Ocean, the monitoring of changes in upper ocean temperature and salinity structure is only possible using drifting platforms due to the lack of routes of merchant ships. For example, profiling floats containing temperature and salinity sensors provide a cost-effective means of monitoring such regions. Along the first transect, 10 ARVOR floats were deployed at selected intervals. Each float descended to a "parking depth" of 1900m before profiling the upper 2000m, a cycle that is repeated every 10 days. Data can be obtained from http://www.ifremer.fr/coriolis.

Table 3: Design specifics for the ARVOR floats.

Number of cycle	255
Cycle period	10
Reference day (Julian day)	59
Ascent time at surface for each cycle	20.00 GMT
Drift sampling period (hrs)	24
Ascent sampling period (seconds)	10

Drift depth (dbar)	1900
Descent speed	3 cm/s
Ascent speed	9 cm/s
Profile depth	2000

ARVOR measure at a resolution of 1 dbar during their ascent period and have an accuracy of 0.001PSU, 0.001ºC and +/- 10 dbar. The range at which these sensors are able to measure are from 0 - 42 Psu, -3 – 32ºC and 0 - 2500 dbar.

Underway SDS

Sea surface salinity is very poorly known over most of the Southern Ocean, yet it is the primary controller of surface density south of 60°S. Surface salinity is vital in determining the water mass characteristics and the location of deep/bottom water formation. High-resolution surface salinity data is an essential component for accurate analysis in global ocean models. At present, climate models indicate that the dominant global warming signal south of 60°S is not as a result of SST increase, but due to the decrease in surface salinities. Freshening of the upper layers is a critical force in reducing convection and maintaining cool surface conditions and sea ice cover in these models. Surface temperature and salinity data were recorded continuously by the shipboard thermosalinograph. These data were averaged into 20 minute intervals in order to reduce noise levels but to retain adequate information to identify the main frontal characteristics (Figure 4). The exact clarification of surface fronts based on exact temperature and salinity definitions is difficult because of the variable nature of surface waters and the influence of precipitation, especially at mid latitudes (Holliday and Read, 1998). We use here the surface definitions provided by Belkin and Gordon (1996) (Table 4) as a guide in determining the surface expression of the main fronts.

Leg 2 - Buoy Run

Date: 29/12/2015 – 09/01/2016

General operation:

- CTD (Conductivity, Temperature, Depth) and Kevlar winch
- Bottles Used: Niskin Bottles (Biology traces) and GoFlo Bottles (Bioassay cast and DFe casts)
- No salinity samples were taken for calibration purposes
- Message in a bottle deployments

Table 4: Leg 2 Buoy run transect

Station ID	Station Activity	Latitude	Longitude	Depth	Date	Start Time	End Time	Operator
(SG1)	GCTD – GoFlo	55°41.349'S	33°58.768'E	1500m	29/12/15	17:50	18:20	Tahlia and Clinton
	GCTD – Niskin	55°41.349'S	33°58.768'E	1500m	29/12/15	19:42	20:58	Tahlia and Clinton

(SG2)	GCTD – GoFlo	**Cancelled**						
	GCTD – Niskin							
Test Station	GCTD – GoFlo	46°46.950'S	06°10.146'W	500m	03/01/16	14:55	15:30	Kate and Tobin
PS1	GCTD – GoFlo	42°41.586'S	08°44.214'E	100m	05/01/16	16:55	17:05	Kate and Tobin
	GCTD - Niskin	42°41.586'S	08°44.214'E	1000m	05/01/16	17:46	18:34	Kate and Tobin
	GCTD – GoFlo	42°41.586'S	08°44.214'E	2000m	05/01/2016	23:41	01:15	Tahlia and Clint
PS2	GCTD – GoFlo	44°59.894'S	06°34.641'E	2000m	06/01/2016	11:15	12:49	Kate and Tobin
	GCTD - Niskin	44°59.894'S	06°34.641'E	1000m	06/01/2016	13:24	14:11	Kate and Tobin
Bio 2	Geotrace - GoFlo	45°59.918'S	05°35.559'E	3500m	06/01/2016	21:21	00:15	Tahlia and Clint
	GCTD - Niskin	45°59.918'S	05°35.559'E	1000m	07/01/2016	00:43	01:30	Tahlia and Clint
Bio 3	Geotrace - GoFlo	50°27.106'S	01°02.667'E	1500m	08/01/2016	08:20	09:45	Kate and Tobin
	GCTD - Niskin	50°27.106'S	01°02.667'E	1000m	08/01/2016	10:05	11:00	Kate and Tobin
Bio 4	Geotrace - GoFlo	55°42.021'S	00°00.002'W	3000m	09/01/2016	16:35	18:15	Tahlia and Clint
	GCTD-Niskin	55°42.021'S	00°00.002'W	1000m	09/01/2016	18:35	19:05	Tahlia and Clinton

Message in a bottle:
ACC project run by Dr Alan M. Schwartz (United States – xenophage@gmail.com)
All bottles were deployed on 10/01/2016 at 5 – 10 min intervals between 58° S - 60° S. Deployments were successful and in accordance with the instructions set by Dr Schwartz.

Leg 3 – Return journey from the Ice Shelf to Cape Town
Date: 01/02/2016 – 11/02/2016
Hydrographic Schedule:

- CTDs (repeat of PS 1, PS 2 and recovered CPIE 2 calibration CTD28)
- Processing of underway and CTD salinity samples with the Portsal

Salinometer

- XBT of the GoodHope line
- Argo Float deployment
- CPR (Continuous Plankton Recorder) changeover of 5 cassettes

CTD
The CTD stations conducted during leg 3 was a repeat of stations conducted along Leg 1 i.e. Process Station I and II. CPIE 2 calibration CTD was recovered on Leg 3 as it was cancelled on Leg 1. All calibration results are pending and will be

conducted for the oxygen, salinity and fluorescence sensors in order to validate the data collected.

Note: Minor malfunction of the CTD winch was experienced on CTD 27, the system was rebooted as the winch controls were unresponsive.

Table 5: Schedule of CTD stations for Leg 3

Station ID	Station Activity	Latitude	Longitude	Depth	Date	Start Time	End Time	Operator
Process Station II	GCTD - GoFlo	44°58.788'S	06°32.300'E	2000m	07/02/16	06:10	07:37	Tahlia and Tobin
	GCTD - Niskin	44°58.788'S	06°32.300'E	1000m	07/02/16	08:40	09:40	Sandy and Kate
Process Station I	Geosoak	43°00.008'S	08°30.014'E	100m	08/02/16	02:25	02:40	Tahlia and Tobin
	GCTD - Niskin	43°00.008'S	08°30.014'E	1000m	08/02/16	02:20	03:30	Kate and Tobin
	GCTD – GoFlo	43°00.008'S	08°30.014'E	2000m	08/02/16	06:33	07:15	Tahlia and Tobin
CPIE 2 Calibration	GCTD - Niskin	36°13.431'S	13°17.651'E	4500m	09/02/16	21:54	02:30	Tahlia and Clint

XBT

The XBT hand launcher was used to deploy all XBTs along the GoodHope line in order to obtain temperature data. However, the system crossed on the 08/02/2016. The XBT computer was rebooted and trouble shooting of the program allowed for further XBT observations, the hand launcher was replaced and operations continued until the deployments were terminated before reaching the continental shelf.

Argo Floats

In the framework of the cooperation between the Oceanography Department of UCT and the University of Naples "Parthenope" (Italy), 5 floats were deployed along the GoodHope Line.

Four NOVA floats were deploted at 58°S, 55°S, 49°S and 45°S, while a single DOVA float was located at 51.5°S. Float release positions were defined on the basis of the climatological position of ACC fronts south of Africa, in order to deploy one float for each inter-frontal zone aiming at monitoring the properties of water masses inside the ACC and the associated variability.

Float and drifter related research activities are conducted in the framework of the Italian PNRA (programma Nazionale di Ricerche in Antartide) MORSea project and realized through the collaboration of the Italian INOGS (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale) and University of Naples "Parthenope" in the framework of the ARGO-Italy project

During the XXXI Italian Expedition in Antarctica (Austral Summer 2015/16) the MORSea project lead to the quasi-synoptic release of floats and drifters along two main chokepoints of the ACC, south of Africa and south of New Zealand. Field activities were conducted by scientists from the University of Naples “Parthenope” that joined the Antarctic voyages of the S/A Agulhas II and of the R/V Italica during January and February 2016.

CPR – Continuous Plankton Recorder
All deployments of the CPR and changeover of cassettes were successful. The cassettes were stored in the appropriate hard cases with formaldehyde and all deployment sheets filled in and signed by the Master of SA Agulhas II.

7.4. Preliminary results
Data delivery – XBT data validation and processing will take less than 1 month, allowing on time data base delivery.

Acknowledgements

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7.5. Issues and recommendations
- There continue to be suggestions to improve the SDS system, and a letter listing these has been sent to Andre Hoek of Sea Technology following previous voyages. Problems encountered with the SDS system during this southbound leg included; regular freezing of the data-stream and during the first 4 casts station number/grid reference could not be listed.
- Hooks to keep the computer cupboards housing the CTD deck unit are required.
- Scuppers/Drainage holes required on all steel benches in the wet Bio lab.

- More efficient numbering system for the amber bottles provided for salinity samples
- It must be noted that during the southbound and northbound transect no problems were experienced with the winch system. However software issues regarding the CTD computer/sea-save program was experienced but later rectified. It did however result in the loss of a CPIE calibration CTD station 2 on Leg1, the station was recovered on the return leg home (09/02/2016). The NMEA display settings on the CTD program was not recovered therefore the data was manually logged from the header file. I firmly believe that correct handling and maintenance of the entire CTD system (hard/software) prior to and following all deployments will prevent any problems developing with the CTD profiler. Each CTD cast was lowered to within 15 m from the sea-floor and in all cases both the altimeter and pressure read-outs were closely observed to avoid any damage caused by the instrument landing on the seafloor. The CTD should not be lowered at speeds exceeding 1 m/s and given over the side activities, especially in the top 30 m, weights >100 kg are crucial – this is a cause for concern with the GEOTRACE system, which appears to be under-weight.

Conclusion

The Antarctic Circumpolar Current forms an important link in the global thermohaline overturning circulation. Modifications in the saline characteristic of water masses associated with the ACC play a vital role in maintaining both global heat and salt budgets. Determining the transport flux of the ACC south of Africa has been an observational goal for many years. Such observations have been conducted during the World Ocean Circulation Experiment (WOCE) during the 1990s in which repeat transects across the ACC were restricted to 3 chokepoints. Intense and periodic monitoring of both the Drake Passage and south of Tasmania have continued since WOCE, however a regular monitoring line between South Africa and Antarctica commenced only in 2004. Despite a large number of publications (Ansorge et al., 2004, Swart et al., 2008, 2009 and Billany et al., 2010) our understanding of the impact seasonality has on the physical, biological and biogeochemical characteristic of the ACC remains limited.

Our understanding of how and why this transport varies with time and season remains incomplete due to the severe lack of observations. The sources, pathways and characteristics of these exchanges are not well-enough established to allow their influence on the climate system south of South Africa, to be quantified. The aim of GoodHope is therefore to establish an intensive monitoring line that will provide new information on the volume flux of the region south of South Africa, in particular the Indo-Atlantic exchange. An investigation studying the empirical relationship between upper ocean temperature and the baroclinic transport stream from repeat hydrographic sections across the ACC, south of South Africa is now currently underway. Application of this empirical relationship to all the past and future observations will be necessary to monitor the variations and variability of the ACC south of South Africa (Swart et al., 2009). By further defining a second empirical relationship between surface dynamic height and cumulative transport and validating these findings with in-situ hydrographic data it will be possible in future to accurately extrapolate the ACC behaviour, in particular its seasonality and inter-annual variability, through satellite altimetry.

This is the continuation of a new and exciting multi-national and inter-disciplinary endeavour aimed at integrating high-resolution physical, biological and atmospheric observations with along-track satellite and model data. Since the start of the GoodHope project in early 2004 a total of 26 transects have now been completed and this cruise represented the first PIES deployment along the northern sector of the GoodHope line. It is hoped that data emanating from the long-term monitoring of the GoodHope project will result in a clearer understanding of the Indo-Atlantic inter-ocean exchange in this region of the Southern Ocean, whether climatic changes are having an impact on volume transports as well as salt and heat fluxes between ocean basins and how these changes could impact on both regional and global present day climate changes.

8. Vibration response of the SA Agulhas II Polar supply and Research vessel

PI: Annier Bakker
Team: Keith Soal (team leader), Rosca de Waal, Clinton Saunders,
Funding: NRF

8.1. Rationale / Motivation

Polar research vessels operating in ice and open water are relied upon by research institutes and their scientists to re-supply bases as well as to serve as floating laboratories. Increasing interest in the Arctic's Northern Sea Route (Roughead, 2015; Masters, 2013) as well as in Antarctica have resulted in countries such as Germany, China, the USA, Australia and Russia investigating options for new polar vessels (COMNAP, 2014).

In 2012 STX Finland recognized the sparse high resolution full-scale data spanning across disciplines, and formed an international consortium of research institutions and universities. The aim of the consortium is to create a scientific basis for the design of ice going ships in terms of ship hull, propulsion, power requirements and comfort for passengers and crew on board. The consortium members included Aker Arctic, STX Finland, DNV, Rolls-Royce, Wärtsilä, The Department of Environmental Affairs (South Africa), Smit Vessel Management Services, Aalto University, the University of Oulu and the University of Stellenbosch.

8.2. Aims and Objectives

- The aim of this research is to investigate the effect of dynamic ship responses on human comfort, shaft line fatigue and structural fatigue. This is extremely valuable information for vessel owners and operators in order to operate the ship safely and efficiently with a known Antarctic loading profile for the planned 30 year lifetime. The insight will also be valuable in designing optimal future vessels, with the focus on knowledge and skill transfer to the South African ship building market.
- The current slamming investigation is aimed at determining the mechanisms responsible for the undesired impulsive stern phenomenon as well its impact on human comfort, equipment damage and structural integrity.
- The shaft line investigations are aimed at determining ice induced torque loads on the propeller, which will be used to predict the fatigue life of the propeller.
- The current structural dynamic investigation will look at estimating ice loads using a novel technique which incorporates rigid body and elastic motion using operational modal analysis. The goal of this work is to develop a structural health monitoring system which can be used via an interactive monitor in the bridge to provide extra information on current vessel loads to the captain and his navigating officers.

8.3. Methods

The SA Agulhas II was instrumented in Cape Town harbour during November 2015 with 42 accelerometers and 18 strain gauges. These are high precision ICP and DC sensors capable of measuring vibration at their respective measurement points and are connected to a central measurement computer in the vessels engine store room where all channels are recorded synchronously. Measurements are recorded at 2048 Hz continuously throughout the voyage. Ice observations were conducted continuously during ice navigation from the bridge of the vessel. Members conducted 2.5 hour shifts during which time estimations of ice thickness, ice concentration, floe size and snow thickness were made. These observations will be used to correlate to ice induced shaft line and structural vibration events. A questionnaire was also issued to all passengers and crew. This captured daily information regarding motion sickness as well as the influence of slamming on human comfort activities and equipment usage while in open sea. Information regarding vessel loads and operating regimes have also been recorded together with video footage and ship log book information.

8.4. Preliminary results

Data processing is currently under way and the main findings of the voyage will be published as part of articles, conference proceedings and master and doctoral theses. The preliminary findings are the following and include:

8.4.1. Ice impact case study

A case study was performed during a significantly large ram while carving ice at Neumayer. The angular acceleration of the impact at the stern, CMU and cargo hold are shown in **Figure 1** and the angular displacements in **Figure 3**. It can be seen that the ship rolled by 4 degrees after impact, but that a numerical integration error causes a drift as the data sequence becomes longer. This will be used together with pitch, yaw and linear accelerations, velocities and displacements to calculate the forces experienced during heavy ice ramming on the hull. Modal analysis was also conducted to determine the structural parameters during this heavy ice ramming case. **Figure 3** shows the singular value decomposition (SVD) of the data. From this it can be seen that significant structural responses, shown as peaks in the figure, are present in the frequency range 0 – 8 Hz. Three bending modes are identified at 2.06 Hz. 3.88 Hz 5.81 Hz and a torsional mode is identified at 6.5 Hz. The mode shape associated with the first bending mode as well as the MAC matrix are shown in **Figure 4**, confirming unique and orthogonal mode shapes. This data will be used together with the 6 degree of freedom motion to back calculate the ice impact forces.

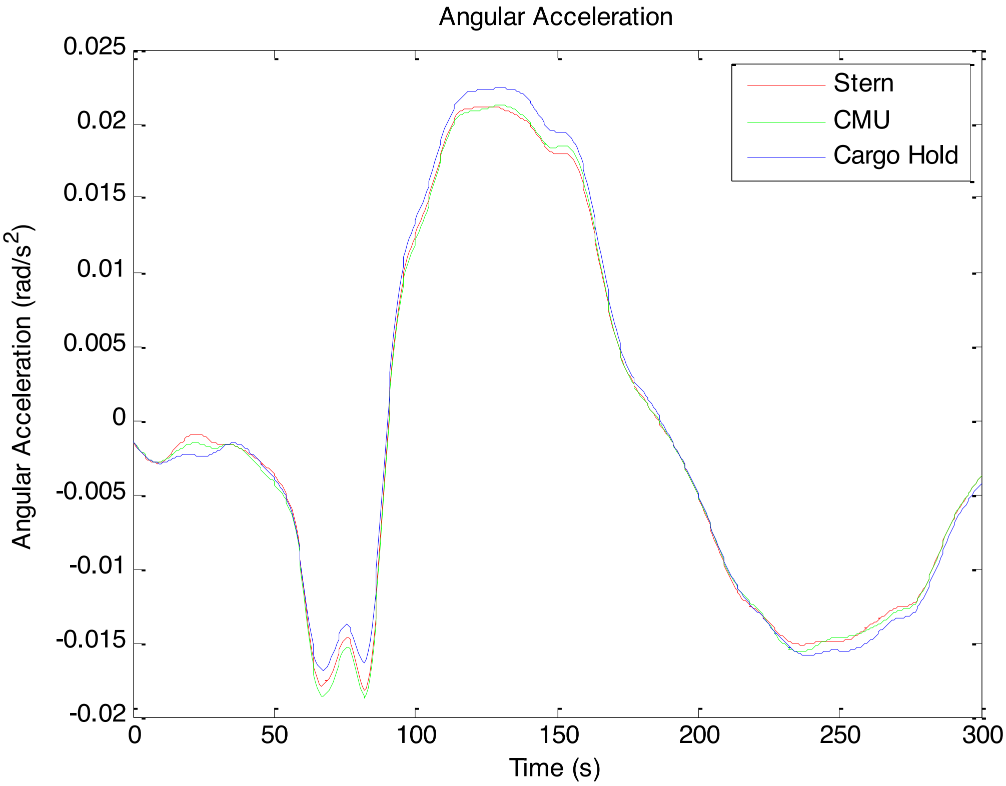


Figure 1 - Angular Acceleration

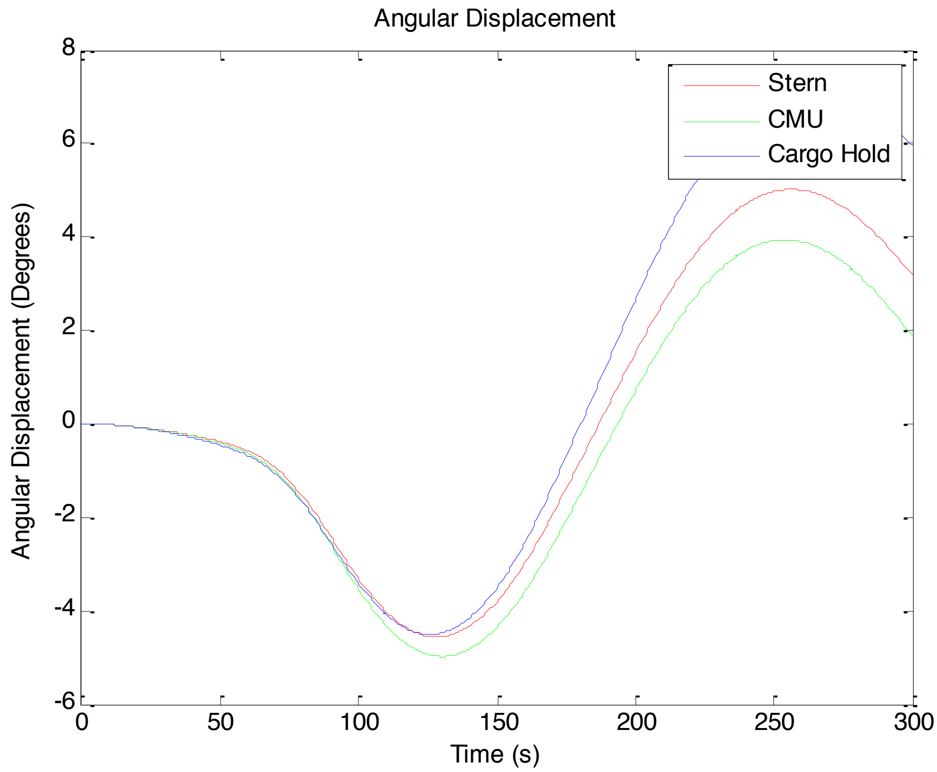


Figure 2 - Angular Displacement

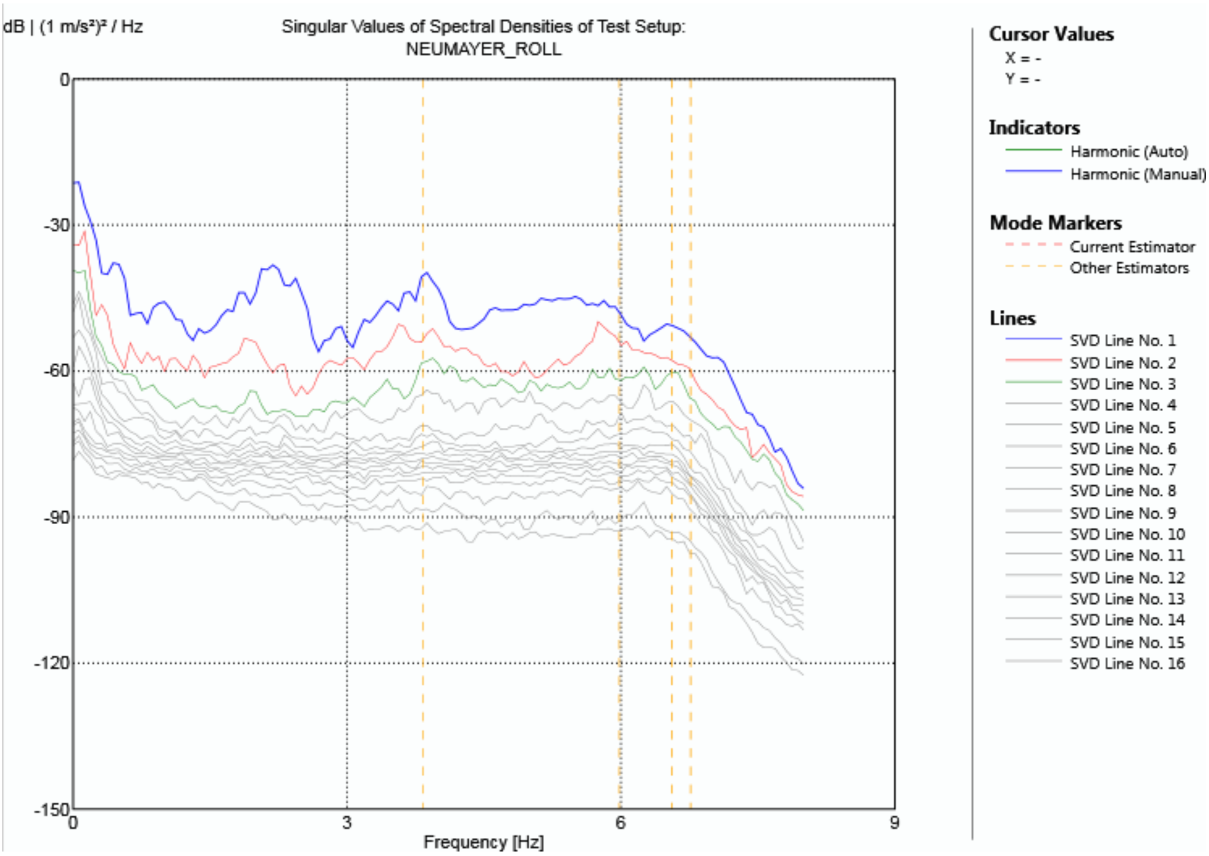


Figure 3 - Singular Value Decomposition

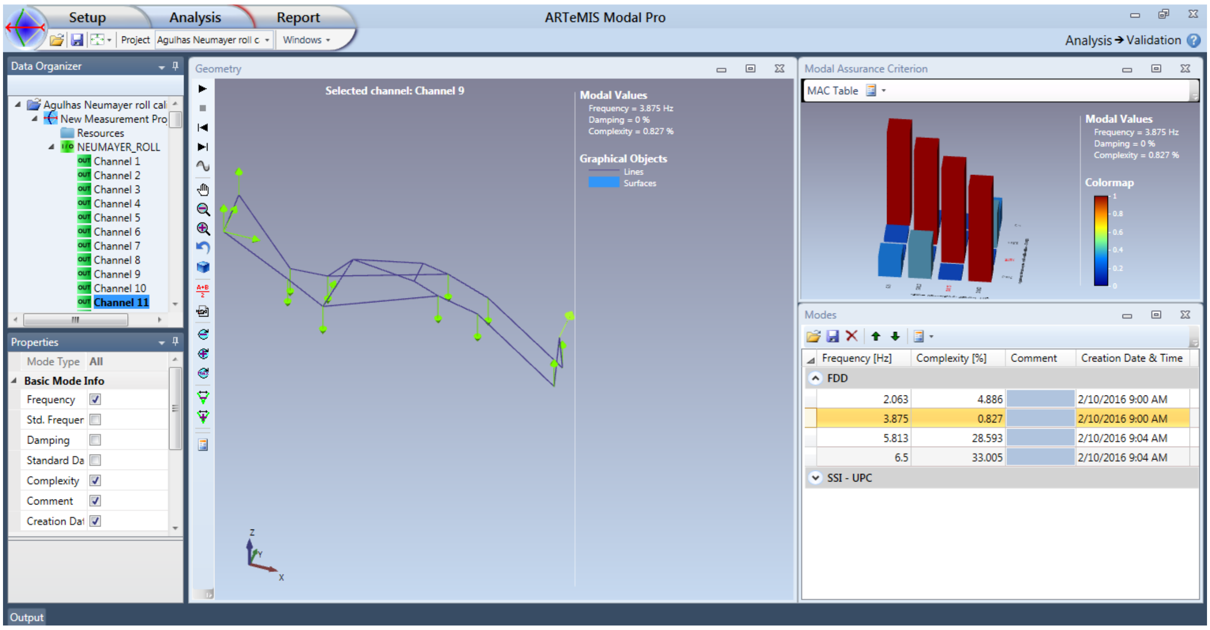


Figure 4 - Mode shape and MAC matrix and Natural Frequencies

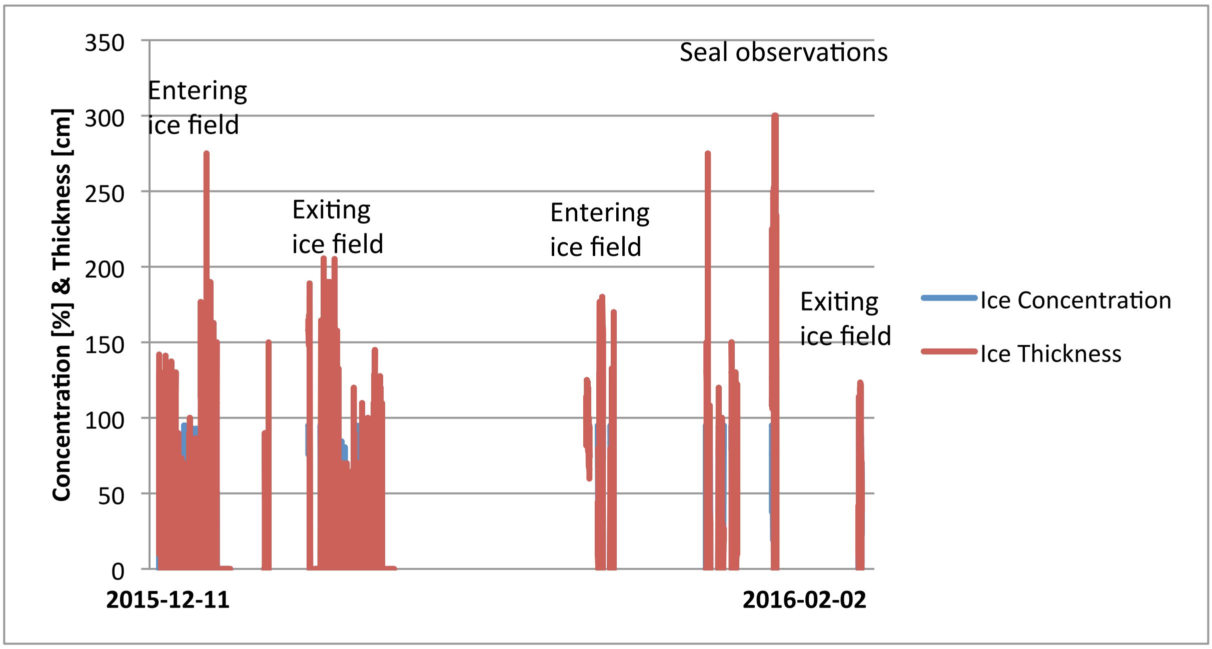


Figure 5: Ice observations

8.4.2. Ice Observations

Ice observations were conducted continuously during ice navigation. Ice thickness, ice concentration and floe size are presented in **Figure 5**, where it can be seen that the thickest ice was 280 cm. This data will be used to correlate to vibration levels measured on board.

8.4.3. Shaft line investigation

Torque and thrust data was recorded on the shaft line in order to determine ice loads on the propeller. This data was then analyzed through rain flow counting and compared to previous voyage data in order to get an ice loading profile that the vessel is exposed to during an Antarctic voyage. **Figure 6** presents the loading the propulsion system is exposed to during the 2016 voyage and compared to data recorded by DNV on the 2013 voyage.

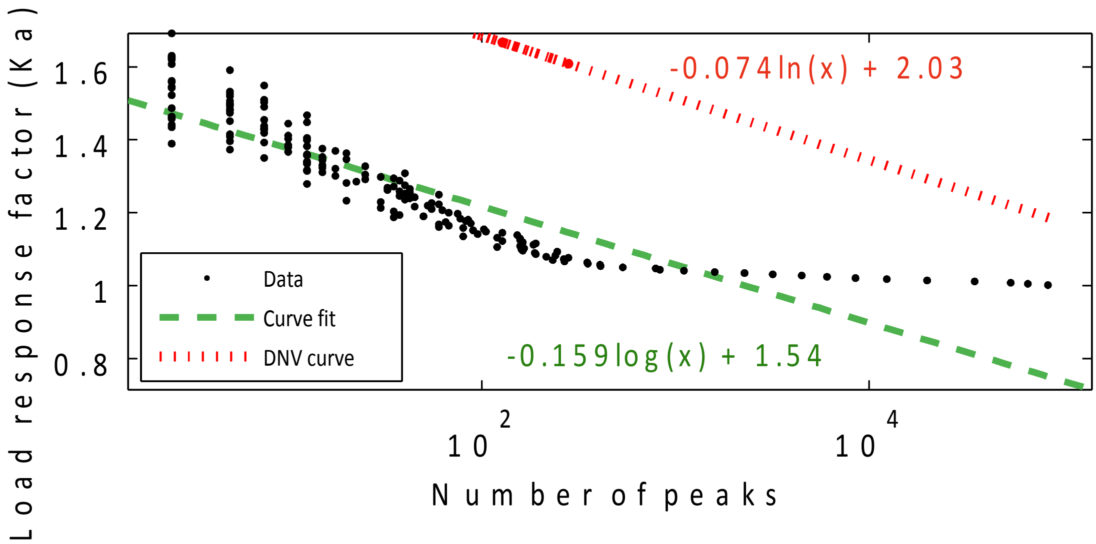


Figure 6: Rainflow counting 2016

A single ice impact was recorded in **Figure 7**, denoted by 1. This data is very useful for interpreting and investigating the effects of ice impacts on the blades of the propeller. The single ice impact is followed by a shear wave that propagates through the shaft line (2) and dies out (3) due to water damping.

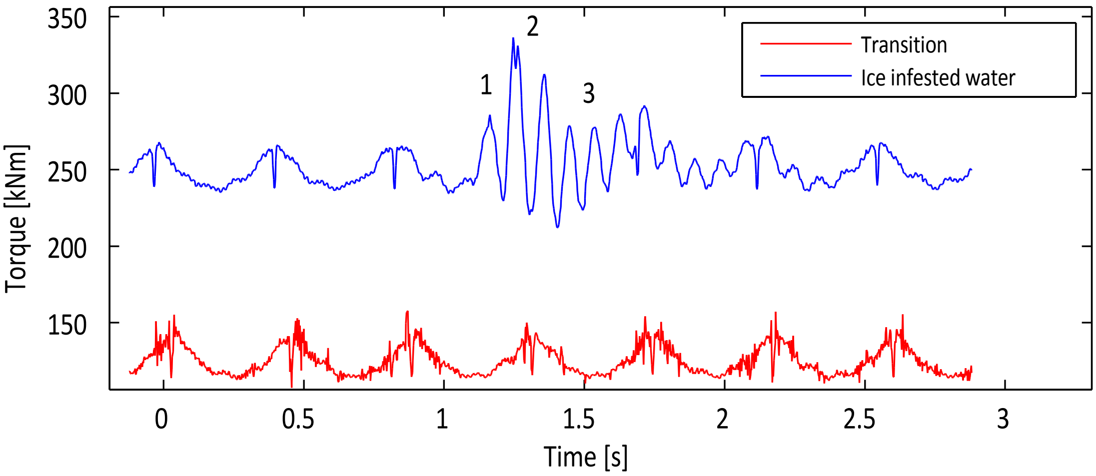


Figure 7: Ice impact

8.4.4. *Slamming Investigations*

A subjective measure for human response to motion sickness and slamming during the 2015/2016 Antarctic Summer Cruise was conducted by means of distributing a questionnaire to the passengers and crew on board the SA Agulhas II. This questionnaire is an updated version of a similar questionnaire distributed on previous cruises. An example of the questionnaire to be filled out daily is shown in **Figure 8**. The information gathered from these questions will be used to find a correlation between the human subjective response and the structural objective (measurements) response.

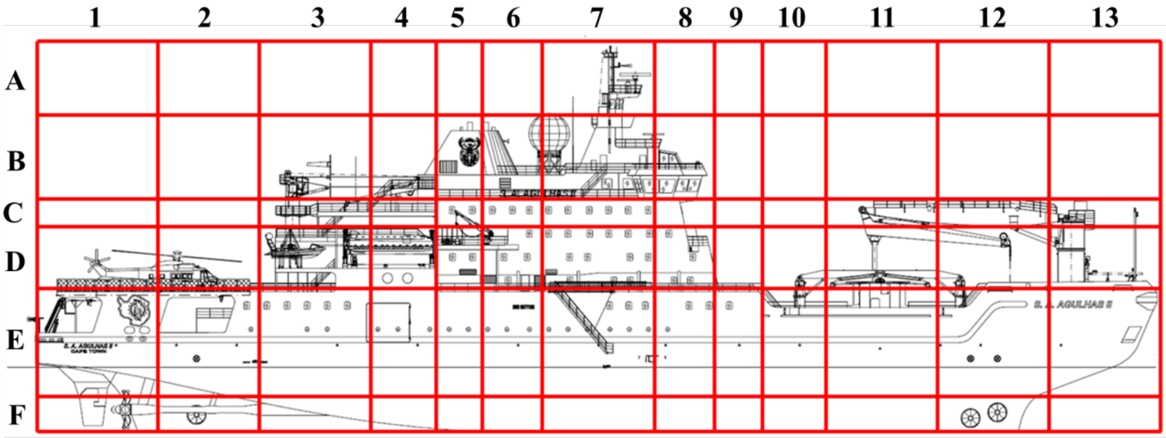
The questionnaires form part of the ongoing slamming investigation on board the SA Agulhas II. Previous investigations, on this vessel, relating to slamming have revealed the captain and crew reporting sleep interruptions as well as it negatively effecting finer work that needs to be carried out on board. Various reports of slamming knocking out ship communications and other computerized equipment were also logged by the crew of the vessel. During the Marion 2015 voyage the captain subjectively stated that the slamming felt was “as bad as they have ever had”; while the chief engineer stated “he has felt worse” on board the vessel. Nonetheless slamming is proving to be a persistent problem and requires further study. Unfortunately, during the 2015/2016 Antarctic Summer Cruise the swell conditions did not provide for consistent slamming measurements. Ideally more opportunities would be favourable in order to capture better measurements of slamming events on the vessel. The 2017 Marion Cruise would be ideal for measurements as passengers and crew from the Marion cruises have consistently reported rough swell conditions.

Daily questionnaire: Day 1, Friday 03/12/2015

1. **Motion sickness**

Did you get motion sick?		*Did you vomit?*		*What is your illness rating on a scale of 0-3? (0 = nothing, 1 = slight, 2 = moderate, 3 = dreadful)*			
Yes	No	Yes	No	0	1	2	3
Do you take motion sickness tablets?		*Do you use any other means to prevent motion sickness?*		*What medication or means to you use to combat motion sickness?*			
Yes	No	Yes	No				

2. **Top three locations where you spent the most time today**



	Zone	*Hours spent*
1		
2		
3		

3. Slamming

Encountered slamming	No	Occasionally	Regularly
Worst slamming incident rating (1= nothing, 3 = slight, 10 = severe)	1 2 3 4 5 6 7 8 9 10		
Activity/equipment affected by slamming (tick the appropriate boxes)	No	Typing/writing	Visual tasks (reading/TV)
	Equipment use	Equip. damage	Sleeping
Did you find slamming to be uncomfortable?	Yes	No	
Comments:			

Figure 8: Motion sickness and slamming questionnaire

8.5. Issues and recommendations.

A short constructive critique: The 2015/2016 Antarctic voyage has shown good scientific progress with projects starting to yield significant research outputs in terms of papers, articles and higher degrees. The leadership shown by Thato has been a major factor and is highly appreciated. Captain Gavin and his crew have remained as professional as ever and their support and interest in the research aims are much appreciated. To this end the Chief engineering, Alan Paterson provided significant insight into many aspects of the vessels performance. The competition between science and logistics, as well as the continual scientific sacrifice, often due to miscommunication and the lack of planning are however still hindering the ability of the SANAP program to move from a good science platform to a world leading space for scientific innovation. To this end the participation and involvement of the current DCO Shiraan Watson has been a positive step in the right direction, however more needs to be done to plan earlier, and more thoroughly, as is the custom of other world leading Antarctic research institutes.

9. Ross Seal Foraging Ecology

PI: Prof Marthan N Bester
Team: M.N. Bester (PI and team leader), Martin Postma, Nico Lubcker, Mia Wege
Funding: NRF

9.1. Rationale / Motivation

Several studies demonstrated the usefulness of marine top predators, including seals and seabirds, as monitors of global change. Obtaining a comprehensive picture of the Ross seal foraging activity in a three-dimensional environment and gain an understanding of seal behaviour in the context of both biological and physical parameters of the marine ecosystem in the Eastern Weddell Sea off the Princess Martha Coast, East Antarctica, is especially relevant in view of the proposed development of a CCAMLR Marine Protected Area (MPA) in the Weddell Sea (Teschke et al. 2013).

9.2. Aims and Objectives

This study proposed to:

- Investigate the at-sea foraging behaviour (i.e. ranging and diving behaviour) of Ross seals Ommatophoca rossii in an area of high relative abundance off SANAE III/Neumayer Station, Princess Martha Coast,
- Research their diet through direct (vomitus and scat collecting) and indirect (dive behaviour and stable isotope analyses) means, and
- Compare their (and the other ice-breeding seal species') distribution and abundance on the cruise track of the SA Agulhas II with earlier ship-board surveys.

All of the above are done to improve our knowledge of the way oceanographic conditions affect the rarest of the four true Antarctic species of seal breeding off the Princess Martha Coast, Antarctica, with a view to using them as bio-indicators of apparent environmental change (van Franeker 1992; Reid & Croxall 2001; Weimerskirch et al. 2003), perhaps due to global climate change.

9.3. Methods

The following two methods we applied:

- Shipboard surveys were conducted from the bridge (at an elevation of 23 m) of the MV SA Agulhas II as the vessel transited the pack ice to Penguin Bukta (70°15.77'S, 02°42.88'W) off SANAE IV (Table 1). Censuses were taken, while the ship was moving, between 10h00 and 15h00 local apparent time (LAT). This covers the peak haulout period of both crabeater seals (Lobodon carcinophaga) (Erickson et al.1989) and Ross seals (Blix and Nordoy 2007). The strip widths were 200m to either side of the ship track (400m total width). Strip boundaries were determined using sighting boards (Siniff et al. 1970), and it was assumed that no undercounting occurred. The counts were undertaken by two observers at a time (out of four observers) standing in the wings of the ship's bridge, rotating on 2-3 h schedules, with ship's position recorded every 15 min from the ship's GPS navigational system, and a hand-held Garmin GPSMap64. Seals were identified to species and recorded by group size following Laws (1993). Ice coverage was classified (in tenths) following Erickson et al. (1993). A constant vigil by one observer, rotating with the 3 others in 3-4 hour shifts, was also maintained outside of the survey period of Leg 1 (see Results), to identify any seals within sight of the ship, in particular Ross seals, to service aims (a) and (b) above.

- Ross seals were physically restrained, by enveloping the animal with a nylon fishing net with a rope threaded through the leading portion, followed by roping the front flippers against the seal's body. One person then restrained the animal's head by hand while straddling the forequarters of the animal, and another restraining the hindquarters by hand and body weight while straddling the animal. Each animal's pulse, muscle tone and breathing were monitored throughout the period of restraint. After covering the animal's eyes with a towel, an action that deprived them from optical stimuli which usually settled them down, biopsy samples (whiskers, blood & hair) were variously taken, and one of two different model types of Wildlife Computers satellite linked data recorders (SLDRs), the MK10 Splash tag (86 x 55 x 26 mm; 130 g) or Spot6 tag (72 x 54 x 24 mm; 119 g) was deployed on the heads of restrained animals using a two-component epoxy resin.

9.4. Preliminary results

(a) The ship first encountered the northern edge of the open ice pack on 11 December 2015, at 56°15.6'S, 00°014W, on its way to the ice shelf on the Princess Martha Coast, Antarctica. Three days after the arrival at Penguin Bukta on 16 December, the ship departed westward to Atka Bay (70°30.54'S, 08°10.93'W), remained for two days, and then headed for Southern Thule, South Sandwich Islands on 22 December, arriving 28 December. At the time, the northern boundary of the pack ice in the vicinity of Southern Thule was at 59°11.73'S, 27°51.89'W. Vigil for pack ice seals was terminated the previous evening at 60°44.51'S, 26°12.28'W. At the time of the start of the shipboard survey (**Leg 1**) on 12 December 2015, the N-S ice extent included in the surveyed area was estimated to be circa 842 nm (1558 km), or about 21 times the extent (~40 nm) at the start of **Leg 2** one month later on 12 January 2016 (Table 1).

Table 1: Seal numbers recorded during ship-based strip transect surveys in the pack ice of the eastern Weddell Sea during the 2015/16 austral summer.

Leg	Census	Date	Time	Duration	Lat.Start	Lat.End	Lon.Start	Lon.End	Crabeater	Ross	Weddell	Leopard	Total	Distance
1	1_1	2015/12/12	10:00-15:00	5	-58.95	-59.67	-0.72667	-1.46933	5	0	0	0	5	90.41514
1	1_2	2015/12/13	10:00-15:00	5	-62.9367	-63.9622	-0.89617	-0.94033	5	0	0	0	5	113.9747
1	1_3	2015/12/14	10:00-13:15	3.25	-67.253	-67.666	-4.248	-5.02685	8	0	0	0	8	56.62758
1	1_4	2015/12/15	11:15-15:00	4.75	-69.4082	-69.4268	-4.67283	-4.19717	1	0	0	0	1	18.69722
1	1_5	2015/12/19	13:00-15:00	2	-70.2509	-70.2349	-2.72725	-3.99315	1	0	0	0	1	47.58227
1	1_6	2015/12/24	09:00-15:00	6	-70.3003	-70.081	-8.32067	-8.43567	14	0	0	0	14	24.74495
1	1_7	2015/12/25	10:00-11:00;	4	-68.2555	-67.523	-13.5217	-14.8345	6	0	0	0	6	73.98201
1	1_8	2015/12/26	10:00-10:35;	4.5	-65.4946	-64.8353	-20.5214	-21.3742	8	0	0	0	8	82.32446
1	1_9	2015/12/27	10:00-15:00	5	-61.9235	-61.2612	-23.9282	-24.78	2	0	0	0	2	86.28131
2	2_1	2015/01/12	11:30-15:00	3.5	-69.1954	-69.5965	-2.13672	-2.12845	30	4	0	1	35	44.57696

A total of 594.63 linear km (321 nm) of transect was surveyed during the nine shipboard censuses on **Leg 1** (Table 1), during which only 50 crabeater seals were observed (100%) at a mean density of 1.03 nm-2. Outside of the strip transect and/or during off-peak hours, apart from additional crabeater seals, a Weddell seal Leptonychotes weddellii (15 Dec, 69°28.2'S, 04°03.1'W), leopard seal Hydrurga leptonyx (27 Dec, 61°46.8S, 24°16.9'W), southern elephant seal Mirounga leonina (27 Dec, 62°22.8'S, 23°53.6'W) and two single Ross seals (24 & 27 Dec; 69°58.60S, 9°38.6'W & 61°58.6'S, 3°53.6'W) were sighted. After the survey of Leg 1 was terminated on 27 December at 60°44.51' S, 26°12.28'W, two further southern elephant seals and a leopard seal were sighted the following day on different ice floes in the immediate vicinity of Southern Thule. The ship then remained in open water for the following two weeks, before re-entering the pack ice on 12 January 2016 for **Leg 2**.

The only census of **Leg 2** on 12 January was taken in the contiguous pack ice located immediately off the Princess Martha Coast in the same, but much reduced, ice mass where the shipboard censuses of Leg 1 were conducted earlier. Within transect during survey hours, pack ice seals were encountered in a ratio of 85.7% crabeater seals, 11.4% Ross seals, 2.9% leopard seals and 0.0% Weddell seals. Although only a relatively small area (5.19 nm^{-2}) was censused, the high Ross seal density (0.78 nm-2) was similar to shipboard surveys in late summer during the 1970s (0.45 to 0.84 nm-2) by Hall-Martin (1974) and Condy (1976 & 1977), lower that the 2.91 nm-2 of Wilson (1975), but considerably higher than the aerial surveys in the late 1980s (Erickson & Hanson 1990) and 1990s (Bester et al. 1995; Bester & Odendaal 2000) in a broadly comparable area (9oW - 9oE).

Outside of the censusing periods on **Leg 2**, crabeater seals and Ross seals were also encountered on 13 and 14 January, and again from 21-27 January, when actively searching for Ross seals to satisfy aims (a) and (b) above (no transect censusing conducted at these times). A few Weddell seals and two leopard seals were also sighted then. A lone Ross seal (no other seals) was seen (69o40.9'S, 07o06.2'W) in the early evening (19:30) near the cruise track of the ship, after departure from Atka Bay (70°30.54'S, 08°10.93'W) at 15:00 LAT on 01 February. Another was sighted at 23:24 just inside (69°14.3'S, 06°37.7'W) the outer limit of the pack ice which was reached shortly after midnight.

(b) We restrained ten seals (one of which died unexpectedly – see the incident report [Bester 2016] and Ross006 in **Table 2**), and deployed four SLDRs before upgrading the restraining equipment to stabilise the head and body of the captured animal more securely. This was done by introducing an A-frame of light-weight aluminium poles into the netting. We then restrained a further twelve Ross seals with little trouble, biopsy sampled eleven of these, and deployed the remaining seven SLDRs. Poor weather and SANAP operational requirements prevented us from biopsy sampling the remaining eight seals that we were permitted to restrain and sample (n = 30). All eleven instrumented animals (see details of deployments in Table 2) were alive and well, providing successful uplinks to the Argos satellite system to the start of February (**Figure 1**).

Table 2: Details of the deployment of SLDRs on, and sampling of Ross seals off the Princess Martha Coast, eastern Weddell Sea, in January 2016.

ID	Date	Time (Local apparent)	Sex	Device type	PTT	Device number	LAT	LON
Ross002	2016/01/13	13:30	F	Splash	152416	10L0076	-70.11166667	-3.073333333
Ross005	2016/01/14	08:00	M	Spot	152420	15U2314	-70.09185	-2.786333333
Ross008	2016/01/21	11:00	M	Splash	152417	10L0079	-70.2505	-2.832
Ross011	2016/01/22	10:30	F	Spot	152418	15U2312	-69.88296667	-2.0094
Ross012	2016/01/22	12:40	F	Splash	152414	15A0561	-69.8922	-2.0409
Ross014	2016/01/22	15:20	F	Splash	152415	15A0532	-69.90401667	-2.0791
Ross015	2016/01/22	16:30	F	Spot	152419	15U2313	-69.92278333	-2.092916667
Ross017	2016/01/23	10:00	F	Spot	152421	15U2316	-70.0143	-2.157366667
Ross018	2016/01/23	12:36	F	Splash	152413	15A0560	-70.03531667	-2.150933333
Ross019	2016/01/23	16:00	F	Spot	152423	15U2319	-70.07856667	-2.226483333
Ross021	2016/01/27	10:30	M	Spot	152422	15U2318	-70.51588333	-8.108483333
Sampling only animals								
Ross001	2016/01/13	11:00	U	None	None	None	-70.12333333	-2.846666667
Ross003	2016/01/13	15:00	M	None	None	None	-70.03	-3.03
Ross004	2016/01/13	16:30	M	None	None	None	-70.01833333	-3.096666667
Ross006	2016/01/14	10:30	M	None	None	None	-70.08506667	-2.847283333
Ross007	2016/01/14	12:15	F	None	None	None	-70.08855	-2.837316667
Ross009	2016/01/21	14:00	M	None	None	None	-70.11811667	-2.989983333
Ross010	2016/01/21	16:00	M	None	None	None	-70.0959	-3.058316667
Ross013	2016/01/22	14:30	F	None	None	None	-69.8974	-2.0658
Ross016	2016/01/23	09:23	F	None	None	None	-70.0143	-2.157366667
Ross020	2016/01/25	15:00	F	None	None	None	-70.26051667	-2.7765

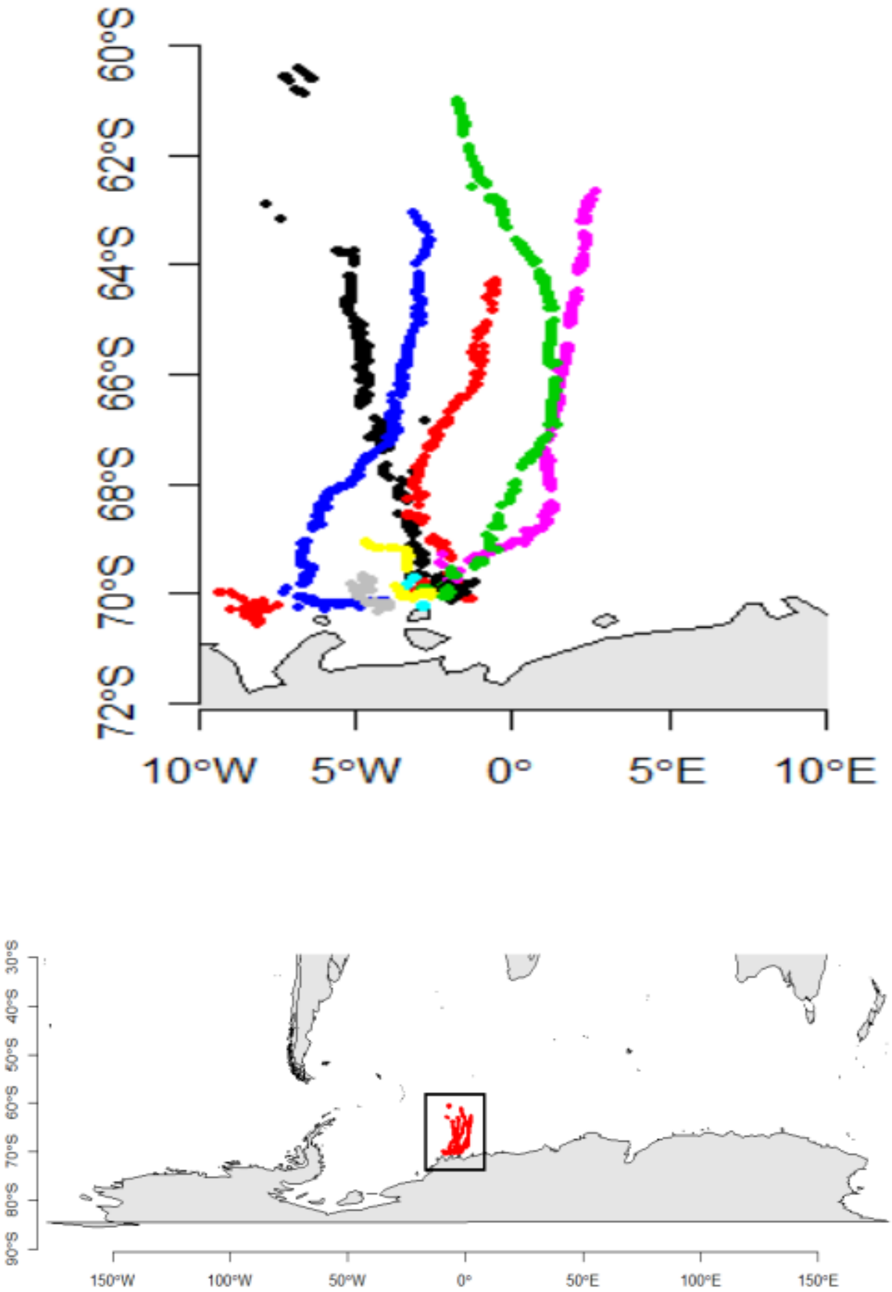


Figure 1: At-sea locations for the eleven satellite-tracked Ross seals (Ommatophoca rossii) between 16 January 2016 and 5 February 2016 (top image). Tracks are colour coded to distinguish amongst individual seals. The geographical area of deployments, in relation to the rest of the Southern Ocean, is shown in the bottom image.

(c) Time line for the fieldwork: In ice working = 17 days (24.3%); in ice waiting to work = 18 days (25.7%); at sea unable to work = 35 days (50%).

(d) **Summary**: Ross seal surveys in early summer are futile as the animals only start returning from late December (Bester et al. 1995; this study) after their post-breeding pelagic period at sea (Blix & Nordoy 2007). By mid-January numbers of moulting adults increased (Arcalis-Planas et al. 2015; this study) to high densities concomitant with the decrease in the extent of the pack ice (Bester et al. 1995; Bester & Odendaal 2000; this study). Although fully moulted animals are usually found only towards the end of January/early February (Blix & Nordoy 2007), SLDRs can be deployed earlier when animals completed the moulting of the head pelage (Arcalis-Planas et al. 2015; this study). The seasonal differences in density of Ross seals in the pack ice and between the years can probably be ascribed to differences in pack ice density and extent, timing of censuses, the survey methods (aerial versus shipboard, line versus strip transects), and placing of track lines (inner pack, outer pack, across a bathymetric gradient or not) through the pack ice (Eklund & Atwood 1962; Bester et al. 1995, 2002; Bester & Odendaal 2000). It is, however, clear that:

- A relatively large population of Ross seals can predictably be found in the eastern Weddell Sea off Princess Martha Coast in mid-January, at a density similar to what was considered to be high in the 1970s.
- Suitable methodology has been developed for ship-board searching, accessing, catching and restraining of Ross seals on ice floes in the pack ice, that allowed the largest (n = 11) seasonal deployment of SLDRs on Ross seals ever (this study).

9.5. Issues and recommendations

- I never received the minutes of the Voyage 18 planning meeting.
- I received the Sailing Instructions a day before the ship was due to sail.
- The seal group did not receive proper protective clothing across the board, as particular sizes of boots and inners were not available in the DEA clothing store.
- The ship sailed two days late, due to cargo issues, and as a result we were all trapped onboard due to passport control constraints.
- I received my Decision on IEE file (14/12/16/5/1) after the work was done (30.01.2016).
- I received my permit (04/2015-16) to work with and biopsy sample Ross seals after the work was done (02.02.2016).
- The time line indicates that 75% of ship's time over a period of 70 days was spent waiting for, or unable to do fieldwork (unavoidably so, by the nature of the cruise).
- To execute the project, we undoubtedly need 4 researchers in the field, as was evident during this Voyage 18.
- Given the results of this research project, we need to be in the field from mid-January to early February 2017 during the next summer of fieldwork, to use our time optimally.

- Given our current understanding of what we need for our research to be successful, we only require two weeks of research/ship's time during the latter half of the cruise. We cannot afford to spend 2.5 months on the ship for only two weeks' worth of research. Therefore we suggest alternatives (below) to DEA to better accommodate us and the other projects aboard the ship.
- One solution to the problem is to fly in to join the ship at Penguin Bukta/Neumayer around 15 – 18 January 2017, and return with the ship early February 2017. Currently there is no funding for the 'flying in' option.
- The other solution is two cruises, one centred on December 2016/early January 2017, the other centred on January/early February 2017. We join the ship in Cape Town for the second cruise.
- Due to the deteriorating Rand/Euro/Dollar exchange rate, the funding for the tracking of the current batch of instrumented Ross seals is unlikely to be adequate. As a result, we cannot purchase the ten SLDRs for next season, never mind paying for the tracking costs of any new deployments in 2016/2017. This will require a considerable adjustment (increase) to our funding.
- We acknowledge the improvements of the internet on the ship in comparison to previous voyages. We would like to thank the responsible parties for this upgrade.

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Acknowledgements: The 'Sealers' (Martin, Mia and Nico) for their unstinting support, dogged determination, and innovativeness. Captain Syndercombe and the Officers and Crew of the SA Agulhas II extended every possible courtesy to us in support of our research objectives. They were the main reasons for our success, in particular the Captain's determination to locate Ross seals in the pack ice. Without such logistical support, this project would have failed in many respects. As it is, it led to a worldwide unprecedented seasonal deployment of satellite-linked data recorders on Ross seals. The science groups onboard are acknowledged for their encouragement and positive attitude towards our endeavour, especially when we suffered the seal fatality. Chief Scientist, Dr Thato Mtshali, is thanked for his support, and the DCO & Deputy DCO for facilitation. DEA for logistical support within SANAP, and the DST, through the NRF, for funding this project.

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10. The Seabird Atlas at sea (AS@S) Survey

PI: Tyron
Team: Alta Zietsman and Mia Cerfonteyn
Funding: NRF

10.1. Rationale / Motivation

In this survey we collected data of the distribution and abundance of seabirds and other marine megafauna for the Seabird Atlas @ Sea (SA@S) project. This project is collaborative between the South African National Biodiversity Institute (SANBI), the Animal Demography Unit (ADU) at the University of Cape Town and BirdLife South Africa.

Data from the SA@S project will ultimately be used to assist institutions in defining 'ocean hotspots', where visible marine life (such as seabirds or cetaceans) congregate in relative abundance and with some degree of consistency. It also aims to identify important areas for highly threatened species. These areas might become marine Important Bird Areas for BirdLife International, or contribute to the designation of Marine Protected Areas, special nature reserves on the high seas, no-take zones to protect sensitive species from commercial fishing, etc.

10.2. Aims and Objectives

Collect data for SA@S to identify possible ocean hotspots, which might qualify as future marine protected areas, as well as analyse long-term seabird population trends

10.3. Methods

Flying and sitting birds were identified within 10 minute-length transects from the monkey-island, only while the vessel was in consistent, linear motion. Date, time, weather conditions and beginning and end GPS points were recorded. The count area was determined using the angles of observation (either 90° or 180°) and distance from the ship (between 50-300m) for each transect. Each bird encountered, excluding "ship-followers" or birds that appeared attracted to the vessel, was identified and counted. If no birds were encountered within consecutive transects, those empty transects were combined to form one longer transect. This was done to simplify the data-capturing process

10.4. Preliminary results

We have completed 1510 transects, varying in length from 10 minutes to two hours. Bird observations were always done during daylight hours when the ship was in consistent, linear movement over a total of 45 days. This includes the voyage to and around the ice shelf, the buoy run and the return voyage. At the Antarctic coast bird observations were done over an 24-hour period due to constant daylight in the summer. However, observations were halted when the vessel was ice-breaking, off-loading at the ice-shelf, not moving in a linear fashion or whilst she was restricted to a small area surveying for Ross seals. From personal communication with BirdLife South Africa it does seem as if less birds were present than in previous surveys, but the data will need to be analysed to confirm this.

The following bird species were identified

Storm-petrel (unidentified)
White-bellied Storm-petrel
Wilson's Storm-petrel
White-chinned Petrel
Diving-petrel (unidentified)
Common Diving-petrel
Terns (unidentified)
Common Tern
Antarctic Tern
Shearwaters (unidentified)
Sooty Shearwater
Great Shearwater
Prions (unidentified)
Antarctic Prion
Broad-billed Prion
Albatross (unidentified)
Grey-headed Albatross
Sooty Albatross
Light-mantled Albatross
Wandering Albatross
Black-browed Albatross
Yellow-nosed Albatross
Shy Albatross
Subantarctic Skua
Pintado (Cape) Petrel
Soft-plumaged Petrel
Great-winged Petrel
Antarctic Petrel
Northern Giant Petrel
Southern Giant Petrel

White-headed Petrel
Blue Petrel
Snow Petrel
Kerguelen Petrel
Antarctic Fulmar
Chinstrap Penguin
Adelie Penguin
Emperor Penguin

10.5. Issues and recommendations

11.5.1. OBSERVATION BOX:

Temperature: The observation box can get extremely cold in the Antarctic region. We would like to thank the Captain and the crew of the SA Agulhas 2 for making improvements on the observation box: a heater was added and a gap was closed above the door to block out wind which improved conditions considerably. We would suggest another heater to increase the temperature and decrease humidity which fogs up the glass.

Windscreen wipers: It is very difficult to do accurate observations during rain or snow, as we are unable to see through the glass or to stand outside to do observations due to the weather conditions. Windscreen wipers would be a massive and much appreciated improvement.

Fresh water supply: We would like to thank the crew for their constant efforts in keeping the windows of the observation box clean, which is an endless task. However, the salt spray can sometimes dirty the glass again within a few hours, which can be easily solved by rinsing the windows with fresh water. The lack of access to fresh water on the Monkey Deck was probably our biggest problem as it prevented us from cleaning the windows ourselves after a large salt spray or a period of salt build up. Of all our recommendations, this is the most important one as we believe it would make the biggest improvement for observers.

Leaks: There are leaks in the ceiling of the observation box which can cause problems when using electronic equipment and books. We would also recommend putting a large chest in the observation box for weather gear and equipment as we would like to keep the area tidy, but also do not want to carry everything up and down the stairs when we finish for the day. A chest will also protect our equipment from the water.

Noise: We were warned at the beginning of the trip that noise travels easily from the Monkey Deck to the Bridge and luckily this never became a major issue during our trip. We would just like to reiterate that all passengers be warned of this at the start of the trip as many visit the observation deck for recreational purposes. A large sign might also be helpful to increase awareness.

Clothing: Observers often have to wear full cold weather gear for observations and sometimes snow boots. We would recommend that they get an allocated area to leave their snow boots upon entering the ship so as to not spoil the carpets. We would also recommend that they get informed about the Duty Mess Room so that they can eat in their weather gear if they have no time to change for dinner. Changing for meal times can become a problem if you have a tight schedule or if you share a cabin with someone who works night shifts and is sleeping during the day.

11.5.2. COMMUNICATION

Prior to voyage: We understand that the time before a voyage is extremely busy for the DEA, but the lack of communication and information to passengers can be very stressful before a voyage. We struggled to get information directly from the DEA regarding our medicals and voyage information and we often had to depend on second-hand information from other passengers. Please ensure that the mailing lists are updated as new passengers are added to the voyage and that updates about the voyage are regularly sent to prevent misunderstandings and confusion.

During the voyage: Communication via email or Whatsapp during the voyage was not always sufficient. We would recommend choosing one form of communication which is not dependent on internet access, such as a notice board or the information screen in Lounge 6 and sticking to that. We would also recommend giving at least 12 hours' notice before a meeting, so that we can plan our days around it and not lose out on too much observation time. Also, please ensure that all ship-based scientists are not called for meetings that primarily revolve around oceanography-related activities.

Acknowledgements

We give our sincere thanks to the Department of Environmental Affairs, Shiraan Watson, Dr. Thato Mtshali and the Captain and crew of the SA Agulhas 2 for making this voyage successful and enjoyable. We understand that it is no easy feat to safely transport such a large and diverse group of people to one of the most remote locations on the planet and we commend you for doing it successfully and always keeping our comfort in mind. The massive amount of effort that went into this project is acknowledged and very much appreciated. We hope that the data we collected will in some way contribute to the future success of the South African National Antarctic Program.

SANAE 55:
Issues and recommendation, feedback from the wash-up meeting that was held on the 23rd February 2016 from 10:15 – 11:30am at the ship RV SA Agulhas II.

Compiled by
Dr. Thato Nicholas Mtshali

Present: Captain Craig (Ship's Captain), Thato Mtshali (CSIR/SANAE 55 Chief scientist), Sinekhaya Bilana (CSIR/STS), Warren Joubert (CSIR), Andre Hoek (CSIR/STS), Marcel van den Berg (DEA), Sandy Thomalla (CSIR), Tahlia Henry (UCT), Bigboy Joseph (DEA), Jeremy Peterson (DEA)

Abbreviations:
POA = Plan of Action
PI = Principal Investigator
RGL = Research Group Leader
DEA = Department of Environmental Affairs
NRF = National Research Foundation
SDS = Scientific data System

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1. Project: CO2 and underway Biogeochemistry and Bio-optics

- Underway water supply was erratic and had to be adjusted regularly. A constant water supply pressure is needed.

POA: The plan is to put 6-way manifold that can be controlled separately (pressure) for water supply. This will be fixed before Marion cruise (responsible person: Ships engineer, Marcell in agreement with DEA).

- Underway water supply does not work in areas of sea-ice.

POA: Polyurethane coating did work. The plan is to coat the other side of the water supply pump before Marion cruise. If not possible, this will be done/addressed when the ship goes to dry dock.

- Problems encountered with the SDS system during this southbound leg included; regular freezing of the data-stream and during the first 4 casts station number/grid reference could not be listed.

POA: Andre and Sinekhaya will address this before Marion cruise. Data availability to the community will be requested from Ashley and Marcell will try and send it to Sandy.

2. **Project: Fe biogeochemistry and other trace elements**

- GEOTRACES CTD cable was damaged and we did cut about 3m – need to buy deadend for the conducting Kevlar cable.

POA: need to check the deadend inlets. Sinekhaya will prepare a spare deadend before Marion cruise.

- CTD control programme – configurations kept on missing. Software issues regarding the CTD computer/seasave program. CTD console kept on freezing

POA: Andre and Sinekhaya will address this before Marion cruise and Marcell will install antivirus.

- GCTD Oxygen and Salinity sensors - need to be checked as it was showing some spiked on the profile.

POA: The GEOTRACES CTD sensors need to be serviced (Sinekhaya will address this)

- GCTD frame – polyurethane coating chipped off where GoFlo's are attached.

POA: The plan is to put nylon plastic clamps/hooks and this will be discussed with Mike Peterson (Sinekhaya will address this).

3. Project: South Atlantic Meridional Circulation – SA (SAMOC-SA)

- Hooks to keep the computer cupboards housing the CTD deck unit are required.

POA: This will be addressed before Marion cruise (Marcel and Tahlia)

- More efficient numbering system for the amber bottles provided for salinity samples

POA: This will be addressed by PIs or RGLs who are responsible for collecting salinity samples on any cruises.

4. Project: Sound and vibration (Stellenbosch University)

- The competition between science and logistics, as well as the continual scientific sacrifice, often due to miscommunication and the lack of planning are however still hindering the ability of the SANAP program to move from a good science platform to a world leading space for scientific innovation

POA: This will be addressed by science community representative and DEA (Nishedra)

5. Project: Ross seals Foraging and ecology (Prof Marthan Bester, UP)

- I never received the minutes of the Voyage 18 planning meeting.

POA: point taken by DEA

- I received the Sailing Instructions a day before the ship was due to sail.

POA: Point taken and will be addressed with the cruise DCO

- The seal group did not receive proper protective clothing across the board, as particular sizes of boots and inners were not available in the DEA clothing store.

POA: This will be addressed by science community representative with DEA (Nishedra). There is a need to start planning for summer cruise now, if there will be a need to procure sea-going clothing gear for appropriate sizes. We have been completing protective clothing gear forms every year and this should serve as a reference on what sizes of clothing is required for cruises (more or less).

- The ship sailed two days late, due to cargo issues, and as a result we were all trapped onboard due to passport control constraints.
- I received my Decision on IEE file (14/12/16/5/1) after the work was done (30.01.2016).
- I received my permit (04/2015-16) to work with and biopsy sample Ross seals after the work was done (02.02.2016).

POA: This will be addressed by DEA (Nishedra)

- The time line indicates that 75% of ship's time over a period of 70 days was spent waiting for, or unable to do fieldwork (unavoidably so, by the nature of the cruise).
- To execute the project, we undoubtedly need 4 researchers in the field, as was evident during this Voyage 18.
- Given the results of this research project, we need to be in the field from mid-January to early February 2017 during the next summer of fieldwork, to use our time optimally.
- Given our current understanding of what we need for our research to be successful, we only require two weeks of research/ship's time during the latter half of the cruise. We cannot afford to spend 2.5 months on the ship for only two weeks' worth of research. Therefore we suggest alternatives (below) to DEA to better accommodate us and the other projects aboard the ship.
- One solution to the problem is to fly in to join the ship at Penguin Bukta/Neumayer around 15 – 18 January 2017, and return with the ship early February 2017. Currently there is no funding for the 'flying in' option.
- The other solution is two cruises, one centred on December 2016/early January 2017, the other centred on January/early February 2017. We join the ship in Cape Town for the second cruise.
- Due to the deteriorating Rand/Euro/Dollar exchange rate, the funding for the tracking of the current batch of instrumented Ross seals is unlikely to be adequate. As a result, we cannot purchase the ten SLDRs for next season, never mind paying for the tracking costs of any new deployments in 2016/2017. This will require a considerable adjustment (increase) to our funding.

POA: These will be addressed by science community representative with DEA (Nishedra)

- We acknowledge the improvements of the internet on the ship in comparison to previous voyages. We would like to thank the responsible parties for this upgrade.

6. Project: At sea bird observations

Temperature:

- The observation box can get extremely cold in the Antarctic region. We would like to thank the Captain and the crew of the SA Agulhas 2 for making improvements on the observation box: a heater was added and a gap was closed above the door to block out wind which improved conditions considerably. We would suggest another heater to increase the temperature and decrease humidity which fogs up the glass.

POA: An extra heater will be installed to address this issue (Responsible person: Ship's captain and engineers)

Windscreen wipers:

- It is very difficult to do accurate observations during rain or snow, as we are unable to see through the glass or to stand outside to do observations due to the weather conditions. Windscreen wipers would be a massive and much appreciated improvement.

POA: this won't be possible due to logistical issues.

Fresh water supply:

- We would like to thank the crew for their constant efforts in keeping the windows of the observation box clean, which is an endless task. However, the salt spray can sometimes dirty the glass again within a few hours, which can be easily solved by rinsing the windows with fresh water. The lack of access to fresh water on the Monkey Deck was probably our biggest problem as it prevented us from cleaning the windows ourselves after a large salt spray or a period of salt build up. Of all our recommendations, this is the most important one as we believe it would make the biggest improvement for observers.

POA: The project's PI need to submit a proposal to DEA and ship's Captain for installation of water supply on the monkey-island deck.

Leaks:

- There are leaks in the ceiling of the observation box which can cause problems when using electronic equipment and books. We would also recommend putting a large chest in the observation box for weather gear and equipment as we would like to keep the area tidy, but also do not want to carry everything up and down the stairs when we finish for the day. A chest will also protect our equipment from the water.

POA: A plastic box chest to put clothes and other working materials will be installed before Marion cruise (responsible person: Ship's captain and engineers)

Noise:

- We were warned at the beginning of the trip that noise travels easily from the Monkey Deck to the Bridge and luckily this never became a major issue during our trip. We would just like to reiterate that all passengers be warned of this at the start of the trip as many visit the observation deck for recreational purposes. A large sign might also be helpful to increase awareness.

POA: RGL and scientists working at this area need to inform everyone who visits the monkey deck not to make noise.

Clothing:

- Observers often have to wear full cold weather gear for observations and sometimes snow boots. We would recommend that they get an allocated area to leave their snow boots upon entering the ship so as to not spoil the carpets. We would also recommend that they get informed about the Duty Mess Room so that they can eat in their weather gear if they have no time to change for dinner. Changing for meal times can become a problem if you have a tight schedule or if you share a cabin with someone who works night shifts and is sleeping during the day.

POA: Every passenger is informed at the beginning of the cruise about not walking inside the ship with their snow boots. These are taken out just before entering the ship's corridors.

Communication

- Prior to voyage: We understand that the time before a voyage is extremely busy for the DEA, but the lack of communication and information to passengers can be very stressful before a voyage. We struggled to get information directly from the DEA regarding our medicals and voyage information and we often had to depend on second-hand information from other passengers. Please ensure that the mailing lists are updated as new passengers are added to the voyage and that updates about the voyage are regularly sent to prevent misunderstandings and confusion.

POA: This can be avoided if the chief scientist can be appointed early so that he or she can be a link between DEA/DCO and the science community.

During the voyage:

- Communication via email or Whatsapp during the voyage was not always sufficient. We would recommend choosing one form of communication which is not dependent on internet access, such as a notice board or the information screen in Lounge 6 and sticking to that. We would also recommend giving at least 12 hours' notice before a meeting, so that we can plan our days around it and not lose out on too much observation time. Also, please ensure that all ship-based scientists are not called for meetings that primarily revolve around oceanography-related activities.

POA: This will be addressed by the cruise's chief scientist or DCO. However, the internet and Wi-Fi communication was much better on SNAE 55 voyage and we would like to thank DEA and the ship's management.

Other issues arise at the meeting:

1. A request for Wi-Fi installation in the labs (Wet, Geo and general laboratories). This is very important for as it will help scientists when they have to communicate with land based technicians/engineers or PI about fixing

equipments also when they need to download manuals. **This will be addressed before Marion cruise.**

2. There is a need to have a -80°C freezer to store samples. The one on the ship got broken and need to be **serviced before Marion cruise** (**responsible person: DEA**)
3. Need to fix atmospheric CO2 tubing inlet. This will be addressed **before Marion cruise** (**responsible person: Warren, Marcel – AI company**)
4. Heat flux equipment situated above the monkey island need to be removed and it is too heavy to be installed there and it broke during SANAE 55 voyage (**responsible person: Sandy will communicate with Steve**). There was also a request from the captain that any heavy equipment to be installed up there should be communicated with DEA and the Captain before.