ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

EXPEDITION PROGRAMME PS97

Polarstern

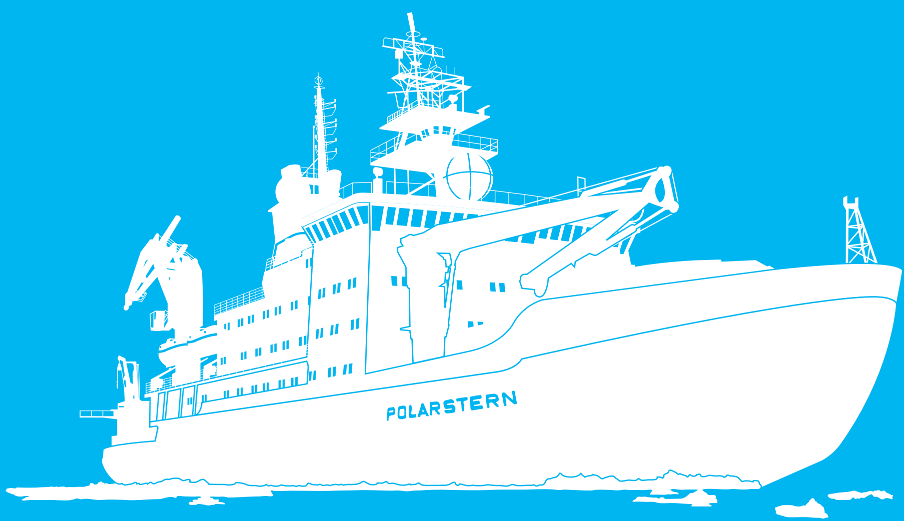
PS97

Punta Arenas - Punta Arenas

16 February 2016 - 8 April 2016

Coordinator: Rainer Knust

Chief Scientist: Frank Lamy



Bremerhaven, Oktober 2015

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Contents

1. ÜBERBLICK UND FAHRTVERLAUF

F. Lamy (AWI)

Die Drake Passage ist die wichtigste geographische Engstelle für den Antarktischen Zirkumpolarstrom und spielt eine herausragende Rolle für die heutige Ozeanzirkulation und das globale Klima. Trotz ihrer Wichtigkeit für unser heutiges und wahrscheinlich auch zukünftiges Klima, ist bisher wenig über klimatische und ozeanographische Veränderungen auf längerfristigen, geologischen Zeitskalen bekannt. Schwerpunkt der *Polarstern* Expedition PS97 (ANT-XXXI/3) sind marin-geologische Arbeiten in verschiedenen Arbeitsgebieten entlang des südamerikanischen Kontinentalrandes, des Südrandes des Falkland Plateaus, zentralen Nord-Scotia-Rückens und des Nordrandes der Antarktischen Halbinsel im Bereich der Südshetland Inseln. Hinzu treten Nord-Süd Profile über die westliche und zentrale Drake Passage. Das wichtigste wissenschaftliche Ziel der geologischen Arbeiten ist unser Wissen über die paläozeanographische Rolle der Drake Passage bei globalen Klimaänderungen im Quartär auf orbitalen und sub-orbitalen Zeitskalen zu verbessern. Weitere Themen beinhalten die Erkundung von höchstauflösenden Paläoklima-Archiven vor Südchile und den Südshetland Inseln, die Weiterentwicklung von Meereisrekonstruktionen mit Biomarkern sowie die Erforschung der glazialen Ausdehnung der pazifischen Seite des Patagonischen Eisschildes und dessen Rückzugsgeschichte. Dafür planen wir außerdem Arbeiten auf dem chilenischen Festland vorgelagerten Inseln. Neben der Gewinnung von langen Kolbenlotkernen und Oberflächensedimenten, ist eine geophysikalischen Vorerkundung von potentiellen IODP Kernlokationen am chilenischen Kontinentalhang geplant. Die Sedimentbeprobung wird von bathymetrischen, sediment-echographischen und ozeanographischen Arbeiten begleitet. Die ozeanographischen Arbeiten sollen den bisher wenig bekannten Cape Horn Strom und die westliche Drake Passage besser abbilden. Dabei geht es insbesondere um Strömungsmessungen. Darüber hinaus sollen Wasserproben und Planktonfänge für die Verbesserung, Kalibrierung und Validierung mehrerer Mikrofossil-basierter Proxymethoden gewonnen werden.

Neben paläozeanographischen und paläoklimatische Fragestellungen, sollen physiko-chemische und biologisch-ozeanographische Untersuchungen durchgeführt werden. Ein Schwerpunkt liegt hierbei auf der Untersuchung, wie die Limitierung von Spurenmetallen und deren Recycling funktioniert und wie sich der globale Klimawandel auf antarktische Mikroalgengemeinschaften auswirken wird. Die Verfügbarkeit von Spurenmetallen, insbesondere Eisen, wird als der wichtigste Umweltfaktor angesehen, der sich maßgeblich auf die Produktivität und die Artenzusammensetzung von Phytoplanktern des Südpolarmeeres auswirkt. Da zudem der Anstieg des atmosphärischen CO_2 bereits zu signifikant höheren CO_2-Konzentrationen des Meerwassers und daraus resultierenden geringeren pH-Werten (‚Ozeanversauerung') im Vergleich zu vorindustriellen Werten geführt hat, die auch zu Veränderungen in der Zusammensetzung von Phytoplanktongemeinschaften sowie der Eisenchemie zur Folge hat, wird dieses Projekt auch die Sensitivität von Phytoplanktern unterschiedlicher Regionen in Hinblick auf Spurenmetallverfügbarkeit und Klimawandelszenarien untersuchen, um deren Auswirkungen auf zukünftige Veränderungen besser einschätzen zu können.

Die paläoklimatischen Landarbeiten werden durch weitere geologische und geodätische Arbeiten im Bereich des chilenischen Kontinentalrandes und der nördlichen Antarktischen Halbinsel (Südshetland Inseln ergänzt). Neben glazial-geologischen Fragestellungen, steht hierbei auch die Erforschung der längerfristigen tektonischen Entwicklung des Scotia Meer Raumes im Fokus. Dabei sollen vorwiegend Gesteinsproben für die thermochronologische Datierung gewonnen werden. Die geodätische Arbeitsgruppe erforscht rezente Krustenbewegungen im Bereich der Antarktischen Halbinsel und des chilenischen Kontinentalrandes. Dabei geht es z.B. um Daten zum glazial-isostatischen Ausgleich, die Modelle sowohl der Glazialgeschichte als auch der viskoelastischen Reaktion der Erde verbessern sollen. Im Gebiet der Antarktischen Halbinsel sind GNSS-Messungen an Lokationen geplant, die 1995 vermarkt und zum ersten Mal vermessen wurden. Eine Zweitmessung erfolgte 1996 bzw. 1998. Eine dritte Beobachtungsepoche ermöglicht die Bestimmung von Koordinatenänderungen über eine Zeitspanne von 20 Jahren und auf einem Genauigkeitsniveau, das sonst bei permanenten GNSS-Messungen erreicht wird. Im chilenischen Bereich sollen neue GPS-Stationen errichtet werden, mit dem Ziel rezente Deformationen im Bereich der tektonischen Plattengrenzen zwischen der Antarktis, Scotia und südamerikanischen Platten zu dokumentieren.

Die *Polarstern* Expedition PS97 (ANT XXXI/3) beginnt am 16. Februar 2016 in Punta Arenas und endet am 8. April 2016 wieder in Punta Arenas.

Der geplante Fahrtverlauf findet sich auf Abb. 1.1. Eine wichtige Voraussetzung für die physiko-chemischen und biologisch-ozeanographische Untersuchungen ist die Einhaltung von Mindestzeitabständen vor, zwischen und nach den drei Hauptstationen (Bio-1 bis Bio-3; Abb. 1.1). Aus einer Kombination der Anforderungen der an der *Polarstern* Expedition PS97 (ANT-XXXI/3) beteiligten Arbeitsgruppen ergibt sich die vorläufige Fahrtroute, von der es aufgrund der zu erwartenden schwierigen Wetter- und Seeverhältnisse in der Drake Passage natürlich signifikante Abweichungen geben kann. Die vorläufige Fahrtroute führt von Punta Arenas durch die Magellanstraße an den chilenischen Kontinentalhang. Dort sind drei vorwiegend marin-geologische und ozeanographische Arbeitsgebiete geplant (SCM I bis SCM III; Abb. 1.1). Parallel werden die ersten Landarbeiten durchgeführt. Im Anschluss beginnen wir ein erstes Nord-Süd Transekt über die westliche Drake Passage (DP West; Abb. 1.1), in dessen zentralen Bereich sich die erste biologische Hauptstation befindet (Bio-1; Abb. 1.1). Im Anschluss erfolgen die marin-geologischen, geologischen und geodätischen Arbeiten im Bereich der nördlichen Antarktischen Halbinsel, östlich etwa bis in den Bereich der Elefanteninsel. Von dort beginnen wir dann das Süd-Nord Transekt in der zentralen Drake Passage bis in den Bereich des West-Scotia-Rückens. In diesem Gebiet befindet sich die zweite biologische Hauptstation (Bio-2; Abb. 1.1). Im Anschluss folgen marin-geologische Arbeiten im Bereich des Nord-Scotia-Rückens, gefolgt von einem Transit nach Süden, wo die letzte biologische Hauptstation lokalisiert ist (Bio-3; Abb. 1.1). In diesem Bereich sind darüber hinaus noch weitere Wassersäulen- und Sedimentarbeiten geplant, bevor wir erneut in Richtung Kap Horn dampfen, um das zentrale Drake Passagen Profil zu vervollständigen. Die verbleibende Expeditionszeit ist für den Kontinentalrand-Bereich um die Südspitze von Südamerika vorgesehen, mit vorwiegend marin-geologischen Arbeiten. Zum Abschluss planen wir seismische Arbeiten zur Erkundung von Bohrlokationen zur Ergänzung des International Ocean Discovery Program (IODP) Antrages „SUBANTPAC“.

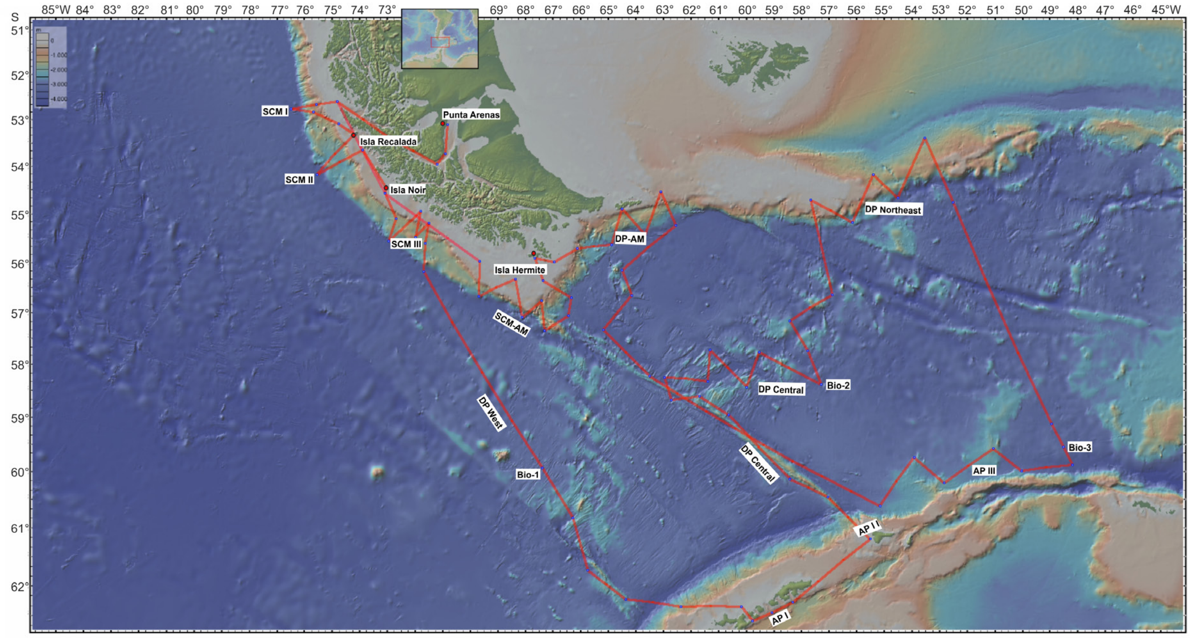

Abb. 1.1: Fahrtroute des FS POLARSTERN während der Expedition PS97 von Punta Arenas entlang des südamerikanischen Kontinentalrandes, im Bereich der Drake Passage und des Nordrandes der Antarktischen Halbinsel. Die Abkürzungen auf der Karte beziehen sich auf Namen der Transekte und Arbeitsgebiete, die im Text erwähnt werden.

Fig. 1.1: Planned track of RV POLARSTERN during expedition PS97 from Punta Arenas along the South American continental margin, the Drake Passage, and the northern rim of the Antarctic Peninsula. Abbreviations on the map refer to names transects and working areas mentioned in the text.

SUMMARY AND ITINERARY

The Drake Passage forms the major geographical constraint for the flow of the Antarctic Circumpolar Current and plays an essential role in the modern ocean circulation patterns and global climate. Despite its importance for modern and likely also future climate, little is known about past climatic and oceanographic changes on longer, geological time-scales in this region. During *Polarstern* expedition PS97 (ANT-XXXI/3), we plan to focus on marine geological work in different working areas along the southern Chilean continental margin, the southern rim of the Falkland Plateau, the central North Scotia Ridge, and the northern margin of the Antarctic Peninsula in the area of the South Shetland Islands. In addition, we plan for two North-South transects across the western and central Drake Passage. The principle scientific goal is to enhance understanding of the paleoceanographic role of the Drake Passage during Quaternary global climate variations at orbital and sub-orbital time-scales. Further research conducted during the expedition will cover the exploration of ultra-high resolution paleoclimate archives off southern Chile and the South Shetland Islands, development of biomarker-based sea-ice reconstructions, and unravelling the glacial extent of the Pacific margin of the Patagonian ice-sheet and its deglaciation history. For this purpose we also plan to work on offshore islands at the southern Chilean continental margin.

Besides obtaining long piston cores and surface sediments, we plan to perform geophysical surveys at suitable locations (primarily along the Chilean margin) for planned IODP proposals. Sediment sampling will be accompanied by bathymetric, sediment echo-sounding, and oceanographic surveys. The oceanographic work will improve our understanding of the understudied Cape Horn Current and the westernmost Drake Passage. One focus will lie on obtaining current speed measurements. Furthermore, we plan to obtain water, plankton, and surface sediment samples for the improvement, calibration, and validation of different microfossil-based proxy methods.

In addition to paleooceanographic and paleoclimatic research questions, it is planned to carry out physico-chemical and biological-oceanographical investigations. A major focus of the planned expedition is to understand how trace metal limitation and cycling operates and how global change will impact the Southern Ocean ecosystem. The availability of trace metals, in particular iron, is considered the key factor in controlling Southern Ocean phytoplankton productivity and community structure. As the increase in atmospheric CO_2 has already caused significantly higher aquatic CO_2 concentrations and lower pH values ('ocean acidification') compared to pre-industrial times potentially affecting plankton community structure as well as iron chemistry this project will also evaluate the sensitivity of phytoplankton of different regions to trace metal input and climate change scenarios in order to predict their response to future changes.

The paleoclimatic work on land will be complemented by geological and geodetic investigations at the Chilean continental margin and the northern Antarctic Peninsula (South Shetland Islands). Besides glacial-geological questions, work will focus on the investigation of the long-term tectonic reconstruction of the Scotia Sea area. For this purpose, we will collect rock samples for thermochronological analyses. The geodetic working group will investigate recent crustal motion patterns at the Antarctic Peninsula and along the southern Chilean margin. One focus is, for example, to obtain glacial isostatic adjustment measurements in order to improve models of glacier loading and the viscoelastic response of the Earth's crust. In the region of the Antarctic Peninsula, we plan to take vertical GNSS measurements at sites we set-up in 1995, with a second measurement phase in 1996 and 1998. A third measurement phase during PS97 (ANT-XXXI/3) will allow to infer coordinate changes over a time span of about 20 years whereby the same level of accuracy can be reached as for permanent GNSS observations. Additionally, we will set up new GPS stations in Chilean Patagonia (Magellan Strait region, Cordillera Darwin) in order to extend observations on recent deformations in the region along the tectonic plate boundary between the Antarctic, Scotia and South American plates.

Polarstern expedition PS97 (ANT XXXI/3) will start on 16t^{h} February 2016 in Punta Arenas und will end on 8th of April 2016 again in Punta Arenas. Fig. 1.1 shows the planned track of *Polarstern* during expedition PS97 (ANT-XXXI/3). A principal requirement for the physical-chemical and biological-oceanographic investigations is the compliance of minimum time intervals between the three main station (Bio-1 to Bio-3; Fig. 1.1). The preliminary cruise track is based on the requirements of the different PS97 (ANT-XXXI/3) groups and may change depending on weather and sea conditions, which are expected to be difficult in the Drake Passage region. The planned cruise track follows the Strait of Magellan from Punta Arenas to the Chilean continental margin. In this region, we plan for three, primarily marine geological and oceanographic working areas (SCM I to SCM III; Fig. 1.1). This marine work will be complemented by parallel land work. Thereafter, we will begin the first North-South transect across the western Drake Passage (DP West, Fig. 1.1), in the central part of which, the first biological sampling will take place (Bio-1, Fig. 1.1). Following this transect marine geological, geological, and geodetic work in the region of the northern Antarctic Peninsula, eastward to the Elephant Islands will take place. From there, we will start a South-North transect across the central Drake Passage up to the area of the West Scotia Ridge. In this region, the second phase of biological sampling will be conducted (Bio-2, Fig. 1.1). Thereafter, we will perform marine geological work along the North Scotia Ridge, followed by another transit southward, where the final biological work is located (Bio-3; Fig. 1.1). In this area, we plan to perform additional water column and sediment work, before continuing towards Cape Horn, in order to complete the central Drake Passage profile. The remaining expedition time will focus on the southern tip of South America with primarily marine geological sampling. At the end of the expedition, we plan for the seismic work in order to survey potential drilling locations in order to complement the International Ocean Discovery Program (IODP) proposal “SUBANTPAC”.

2. MARINE GEOLOGY AND PALEOCEANOGRAPHY

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Background and objectives

The Antarctic Circumpolar Current (ACC) is the world’s largest current system. Through inducing pronounced upwelling and formation of new water masses, the ACC fundamentally affects the global meridional overturning circulation (Marshall and Speer, 2012), atmospheric CO_2 content (e.g. Toggweiler et al., 2006), and the stability of Antarctica´s ice sheets. The ACC physically and chemically homogenizes the circumpolar ocean while thermally isolating Antarctica by limiting poleward meridional heat transport. The bulk of the geostrophic transport in the ACC is associated with the Polar and Subantarctic Fronts (PF and SAF) whose positions are determined by the location of the maximum westerly wind stress and bottom topography (e.g., Orsi et al., 1995).

The flow of the ACC is constricted to its narrowest extent in the Drake Passage (DP). This so-called “cold water route” through the DP is one important pathway for the return of fresh and cold waters to the Atlantic, which strongly affects the strength of the Atlantic meridional overturning circulation, in concert with the “warm water route” inflow of warm and salty Indian Ocean water masses through the Agulhas Current system (Beal et al., 2011; Gordon, 1986). Modelling studies suggest that abrupt climate changes and the stability of the Atlantic meridional overturning circulation (Knorr and Lohmann, 2007) strongly depend on the interplay of the cold and warm water route, the latter of which transports relatively warm and salty water from the Indian ocean into the Atlantic (Knorr and Lohmann, 2007). Paleoceanographic reconstructions suggest that in many regions, the PF and SAF, which today delimit the bulk of the ACC transport, may have moved northward during the last glaciation. These inferences have been made from a number of sediment records in the Atlantic sector of the Southern Ocean (e.g., Gersonde et al., 2003; Diekmann et al., 2000; Walter et al., 2000; Asmus et al., 1999), whereas the few published studies from the Pacific Southern Ocean suggest a limited movement of the sea-ice margin and oceanic fronts during the last glacial maximum (LGM) (e.g., Gersonde et al., 2005). These results are in contrast to high resolution sediment records from cores along the southern Chilean margin that suggest a more substantial movement of the northern margin of the ACC (Lamy et al., 2004, 2007; Kaiser et al., 2005) and the SAF (Caniupan et al., 2011; Verleye et al., 2010). New sediment cores have been recently retrieved from the Pacific Southern Ocean during cruises with RV *Polarstern* (ANT-XXVI/2) and RV *Sonne* (SO-213; SOPATRA). First unpublished, preliminary data suggest that also in this sector regionally varying but generally more substantial northward shifts of the fronts occurred during glacials (Gersonde et al., unpublished data). Yet little is known about the movement of these fronts relative to the Drake Passage, the region most likely to control changes in ACC transport, Antarctic Intermediate Water (AAIW) production, and interbasin mixing. Antarctic Intermediate Water (AAIW), characterized by a salinity minimum and high oxygen content, occupies the 600-1,100 m layer of the water column in the oceans of the Southern Hemisphere (Hanawa & Talley, 2001). It is generally agreed that this water mass is formed at the ocean's surface in the high latitudes of the Southern Ocean east and west of the Drake Passage (e.g., Hanawa & Talley, 2001; Piola & Georgi, 1982; England et al., 1993). The subduction and the spreading of this global water mass contributes to the ventilation of the permanent thermocline and of the Oxygen Minimum Zone (OMZ) along the Eastern South Pacific, the removal of atmospheric CO_2, and to the regulation of temperature anomalies.

Satellite tracked surface drifters reveal that today Subantarctic surface water of the ACC is transported northeastward across the Southeast Pacific from ~53°S/100°W towards the Chilean coast at ~40°S/75°W (Chaigneau and Pizarro, 2005) where surface waters bifurcate northward into the Humboldt current system (HCS) and southward into the Cape Horn Current (CHC) flowing towards the Drake Passage (e.g., Strub et al., 1998). The northward deflection of ACC water into the HCS presently only comprises a small fraction of the total ACC flow. In contrast, the CHC and the underlying Southeast Pacific Slope Water provide a major fraction of the present Drake Passage throughflow reaching locally more than 50 % of the total throughflow in the northern part of the Drake Pasage (Well et al., 2003). Grain-size and geochemical studies on a high resolution sediment core (MD07/3128), located at the southern Chilean margin off the mouth of the Magellan Strait, suggest important changes in the strength of the CHC over the past 60 kyr BP (Lamy et al., 2015). These changes can be interpreted in terms of strongly reduced contributions of northern ACC water to the Drake Passage throughflow during the last glacial in general, and particularly during millennial-scale cold phases as known from e.g. Antarctic ice-cores. At the same time, advection of northern ACC water into the HCS was likely enhanced (Lamy et al., 2015). This northward supply of cold waters into the HCS in the surface and below at intermediate water levels provides an important linkage between high and low latitudes affecting e.g. the tropical eastern Pacific (e.g., Rincon-Martinez et al., 2010) and beyond (Euler & Ninnemann, 2010). In contrast, preliminary studies from the Scotia Sea suggest constant flow speed through the Drake Passage between the LGM and the Holocene (McCave et al., 2012). The present Chilean margin results are so far only based on one single core. Therefore, more high resolution records on the CHC contribution to the Drake Passage throughflow including records of multiple glacial/interglacial cycles are required. High-resolution sediment archives are expected further southwest along the Chilean margin as indicated by seismic data (Polonia et al., 2007).

The strength and position of the southern westerly wind belt (SWW) plays a crucial role for the Drake Passage throughflow and the ACC in general (e.g. Marshall and Speer, 2012). Furthermore, the wind belt is very important for global climate including the forcing of atmospheric CO_2 variations (Anderson et al., 2009, Denton et al, 2010; Lamy et al., 2007). Proxy reconstructions of SWW changes during the last glacial in the Southeast Pacific sector suggested a northward shift or extension forced by shifts of sea surface temperature (SST), gradients and oceanic fronts (e.g., Lamy et al., 1999; 2007; Moreno et al., 1999). These northward shifts are largely consistent with results from the South Atlantic sector (e.g., Barker et al., 2009; Stuut & Lamy, 2004) and the Southwest Pacific/Indian Ocean region (e.g., De Deckker et al., 2012; Lorrey et al., 2012). However, all these studies have so-far been based on records from the northern SWW margin and little is known from the present core of the westerlies, with even less understanding of the southern margin towards Antarctica, an area covered by this *Polarstern* expedition. Though a number of modelling studies have targeted changes in the position and strength of the SWW during the LGM, results are inconclusive (e.g., Rojas et al., 2009). Regarding the role of the Drake passage some modelling studies suggest that the volume transport through the passage has been reduced during glacial stages and subsequently increased across the last glacial termination (Knorr et al., 2003; 2007) accompanied by a southward shift of the Antarctic Circumpolar Current and the associated fronts.

An additional major target of PS97 is to retrieve high resolution Holocene sediment records from southernmost Patagonia and South Shetland Islands, located north and south of the Drake Passage, respectively (Fig. 1.1). Instrumental climate time-series from this region including the western Antarctic Peninsula (AP) only cover the past few decades (e.g., Garreaud et al., 2007, Schneider et al., 2003, Gille et al, 2002). These data suggest that rapid regional warming of air temperatures on the AP and adjacent islands observed over the last 50 years is exceptional. Ice core data from the AP suggest that this warming is unprecedented within the past 500 years (Vaughan et al. 2001). The long-term perspective from ice-cores, marine and terrestrial sediment archives is crucial for distinguishing natural and anthropogenic climate changes as the baseline for accurate future projections. This is particularly true for reconstructions of the SWW, which have intensified at its southern margin over the past 40 years and are expected to do so over the next centuries. This may provide a positive feedback on global warming through reducing the uptake of anthropogenic CO_2 or even promoting outgassing of old naturally stored CO_2 through upwelling (e.g., Russel et al., 2006). Global warming at an increasing pace ever since the end of the Little Ice Age (c. AD 1350-1900) causes significant change in the coastal marine environments of the West Antarctic Peninsula (WAP) and beyond. High-resolution sediment cores from Maxwell Bay (MB, King George Island, South Shetland Islands) provide crucial information on the impact of climate change as well as they provide the means for the reconstruction of the climate fluctuations themselves (Hass et al., 2010, Monien et al., 2011). The vertical sediment flux in Maxwell Bay is controlled by summer melting processes that cause sediment-laden meltwater plumes to form in the tributary fjords. These leave a characteristic signature in the sediments downstream which can be used to distinguish summer and winter-dominated periods through the past two millennia. Considering that the WAP is located in today's warmest part of the AP, the records provide insights into the climate factors affecting the Antarctic Peninsula Ice Sheets and potentially also the whole West Antarctic Ice Sheet with possible consequences on a global scale (Bamber et al. 2007).

Paleo sea-ice reconstructions based on biomarkers are successfully performed in the Arctic realm (Müller et al., 2011). In the Southern Ocean, however, they remain a major challenge. So far, biomarker-based sea ice reconstructions in the Southern Ocean are mainly based on the identification of this C_{25}-HBI diene and related C_{25}-HBI trienes, which serve as indicators of phytoplankton productivity. The applicability of these compounds to qualitatively reconstruct past sea ice conditions has been demonstrated by a limited number of studies in the Scotia Sea (Collins et al., 2013) and along the Antarctic Peninsula (e.g. Barbara et al., 2013). Investigations into the potential use of these HBIs to also estimate past SSTs, however, are still pending. Organic geochemical bulk (TOC, CNS) and biomarker (HBIs, *n*-alkanes, sterols, alkenones etc.) analyses of surface sediments and longer sediment cores from the Drake Passage (i.e. along a transect from ice-free into ice-covered areas) that cover Holocene and Pleistocene time intervals will contribute to paleoenvironmental reconstructions in the Southern Ocean. Further, the biomarker data will be compared to microfossil data and sea ice estimates based on diatom assemblages. Analyses of long sediment cores basically target the assessment of past changes in sea ice, SST, and paleoproductivity conditions associated with climate shifts. In particular, in areas and time intervals, where diatom assemblages are affected by silica dissolution, biomarker-based sea ice reconstructions may provide important information on ice-ocean-atmosphere interactions and CO_2 ventilation changes associated with glacial-interglacial climate transitions.

The main scientific questions and objectives addressed by our coring program include:

1. How has the SWW varied with climate and impacted ACC transport through the Drake Passage? The northern part of the Drake Passage is presently located in the centre of the westerlies. Available westerly wind strength records from adjacent southern Patagonia only cover the Holocene. Though these are discussed controversially, there is some evidence that winds increased during the early Holocene warm interval, whereas wind speeds were reduced further in the northern part of the SWW. The reverse pattern seems to apply for the relatively cold late Holocene. Do these patterns likewise extend to glacial/interglacial changes with thus reduced wind speeds and throughflow in the Drake Passage during colder glacials?
2. How did the latitudinal positions of the PF and SAF as well as the winter and summer sea-ice margins in the Drake Passage change across the past glacial/interglacials and at millennial time-scales, e.g. during MIS 2-4? The location of the fronts is crucial for the ACC flow through the Drake Passage. Therefore, we plan to perform several coring transects spanning the ACC frontal systems starting north at the Pacific entrance of the Magellan Strait, along the southernmost Chilean margin, and across the Drake Passage. The records are expected to provide constraints on the history of ACC transport and surface water gradients to infer frontal movements in the vicinity of Drake Passage
3. What is the role of the Cape Horn Current in contributing to Drake Passage throughflow? Data from core MD07/3128 (Lamy et al., 2015), suggest strongly varying flow speeds of the CHC from the Holocene to the last glacial including the well-known Antarctic-type millennial-scale variations. Are these changes extending into the previous glacials and interglacials?
4. How has deep and intermediate water circulation changed over time in the Drake Passage region? The SE Pacific off southernmost Chile is presently the major formation area of Antarctic Intermediate Water (AAIW). Depth transect across the continental margin covering deep (SE Pacific Slope Water; Circumpolar Deep Water), intermediate, and mode water levels are needed to reconstruct these circulation changes at glacial/interglacial and during millennial time-scales.
5. Is there a consistent pattern of short term climate and ocean variability during the Holocene and what is the amplitude and timing in the present centre of the westerlies over southernmost South America and at the southernmost margin of the westerlies over the northernmost WAP? Can warm phases of the early Holocene and the past millennium (in particular the Medieval Warm Period) serve as analogues for future warmer conditions?

Work at sea

There are three major working areas for our marine geological work: (1) the *Southern Chilean Margin* (SCM; Fig. 1.1). Here we plan for three coring transects from the shelf across the entire continental margin. These transects will cross the Cape Horn Current (see 5.) and will allow to reconstruct past variations in this current together with the different deep and intermediate water masses. This work will include extensive mapping of the continental slope region in order to find suitable sedimentary sequences with high sedimentation-rates. (2) the *Drake Passage and Argentinian Margin* (DP/AM; Fig. 1.1). The major goal here is to obtain systematic coring transects across the Drake Passage. Due to the strong currents, it will be difficult to locate sediment basins with comparatively high resolution sediment archives. However, "sediment pockets" are most likely present in vicinity of bathymetric morphology in small depressions or basins (Maldonado et al., 2006). We therefore focus on a transect at the western (Pacific) entrance from the SCM along the Phoenix-Antarctic-Ridge to the continental margin of the Antarctic Peninsula with the South Shetland Trench (transect DP West, Fig. 1.1). A second N-S transect is planned in the central Drake Passage from the Antarctic Peninsula Margin along the Shackleton Fracture Zone and West Scotia Ridge. In the Subantarctic Drake Passage this work will be completed by extensive coring along the southernmost Chilean Margin (SCM-AM; Fig. 1.1), the Argentinian Margin (DP-AM) and eastward to the central North Scotia Ridge (DP Northeast; Fig. 1.1). (3) In the vicinity of the *South Shetland Islands* (AP I; Fig. 1.1) we plan to primarily investigate the Nelson, English and McFarlane straits. Moreover, we plan to revisit selected core location in Maxwell Bay.

The standard work-plan for all sites includes (1) extensive survey with hydroacoustic measurements (HYDROSWEEP and PARASOUND) in order to locate potential locations with undisturbed sediment sequences (see 5.). (2) Sediment sampling with multi-corer and box-corer for surface sediments, followed by piston-corer and gravity-corer to obtain long sediment cores. The kasten-corer for high-volume sediment cores will be applied at a few selected locations (e.g. Maxwell Bay). On board laboratory work includes measurement of physical properties on sediment cores with a Multi-Sensor-Core-Logger, the establishment of preliminary stratigraphies based on diatoms, foraminifera, and nanofossils as well as core description and sampling (only selected cores).

Data management

All data will be uploaded to the PANGAEA database. Unrestricted access to the data will be granted after about three years, pending analysis and publication.

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3. GEOSCIENTIFIC WORK ON LAND

3. 1. Paleoenvironmental records from Chilean islands

R. Kilian (U. Trier), F. Lamy (AWI), H.W. Arz (IOW), M. Arevalo (Punta Arenas). A. Geiger (U Glasgow)

Background and objectives

Reconstructions of Holocene changes in the behaviour of the southern westerly wind belt (SWW) based on paleoclimate records from terrestrial and marine archives in southern Patagonia provide partly inconsistent and controversially discussed trends (Kilian & Lamy, 2012). While records from the hyperhumid side point to a stronger and/or southward displaced SWW core during the Early Holocene thermal maximum (Lamy et al., 2010), records from the lee-side of the Andes show either no long term trend or the opposite, suggesting enhanced westerlies during the late Holocene "Neoglacial" (e.g., Fletcher & Moreno, 2011). Likewise, centennial-scale global or hemispheric cold intervals, such as the Little Ice Age, have been interpreted in terms of enhanced and reduced SWW strength. Some SWW variations can be linked to changes in the El Niño-Southern Oscillation (ENSO) consistent with instrumental climate data-sets (Schneider & Gies, 2004) and might be ultimately forced by solar variability. Resolving these inconsistencies in southernmost Patagonian SWW records is a prerequisite for improving hemispheric comparisons and links to atmospheric CO_2 changes.

Relatively far offshore located islands have probably been reached by the LGM glaciers and may thus potentially contain terrestrial paleoclimate archives reaching beyond the LGM or even into the last interglacial. We plan land expeditions by helicopter during our *Polarstern* cruise in order to obtain longer records from two different Islands including Isla Recalada, Isla Noir, and Islas Hermite. Despite commonly applied sedimentological, biological, and geochemical proxies, the islands are well suited for investigating new proxies such as changes sea spray-related halogenides. These sea spray proxies potentially provide direct indicators for changes of the westerly winds.

Work at sea

Satellite images and aerial photographs show numerous small lake and ponds suitable for drilling. We plan to disembark a group of scientists and coring devices either by helicopter or Zodiac. The group will stay on the islands for 2-3 days. During this time work with *Polarstern* can continue within the reach of the helicopter. The land group will be led by R. Kilian and M. Arevalo, who have both long-standing experience with lake coring and expeditions in remote and harsh environments. Short, up to ca. 1-m-long sediment cores will be recovered with a gravity corer from rubber boats. Longer piston-cores will be retrieved at selected locations likewise from rubber boats using an aluminum tripod mast.

Data management

All data will be uploaded to the PANGAEA database. Unrestricted access to the data will be granted after about three years, pending analysis and publication.

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3. 2. Patagonian ice sheet dynamics

A. Geiger (GU), R. Kilian (U. Trier), F. Lamy (AWI), H.W. Arz (IOW)

Background and objectives

During the last glacial cycle (11.7-115 kyrs) the Patagonian Ice Sheet stretched about 2,000 kilometres along the Patagonian Andes (38-55°S), recorded by an extensive network of glacial moraines east of the Andean divide. Incidentally the majority of studies providing geochronological constraints of glacier extent are located here, due to the favourable preservation potential of glacial landforms and relative ease of access (Fig. 3.2.1). At only two sites west of the Andean divide are constraints of glacier extent available (Fig. 3.2.1). Though numerical modelling exercises have been utilized to understand Patagonian Ice Sheet dimensions and dynamics from the Last Glacial Maximum (LGM: 19-23 cal kyrs; Hulton *et al.* 2002) empirical data of ice thickness, extent and rate of recession from the western portions of the Patagonian Ice Sheet are lacking between 43-54°S. This substantially hinders our understanding of Patagonian Ice Sheet dynamics toward the west, broader internal glaciological feedbacks as well as the interaction between the Patagonian Ice Sheet and the local to global climatic forcings during the late Quaternary.

Frontal moraines produced by the Patagonian Ice Sheet in the Patagonian West Fjords are presently below sea-level making access problematic and establishing dating control of glacier extent difficult. In addition dense forest cover precludes reliable remote mapping of the geomorphology marking glacier extent and dynamics on land. To address these issues, this work will focus on assessing and mapping the glacial geomorphology at pre-selected field sites in addition to obtaining geochronological control of Patagonian Ice Sheet dimensions in the Patagonian West Fjords between 53-55°S. The latter will be established by utilizing *in-situ* produced terrestrial cosmogenic nuclide dating of bedrock and erratic boulders abandoned by the disintegrating western portions of the Patagonian Ice Sheet. Horizontal west-east transects will establish the timing of glacier extent and retreat, whilst vertical transects will provide constraints of ice-thickness and palaeo-ice surface elevations. The horizontal and vertical exposure ages will be used to reconstruct glacier surface profiles, retreat rates and shed light onto the palaeo-glaciology and climatic dynamics during the last glacial cycle.

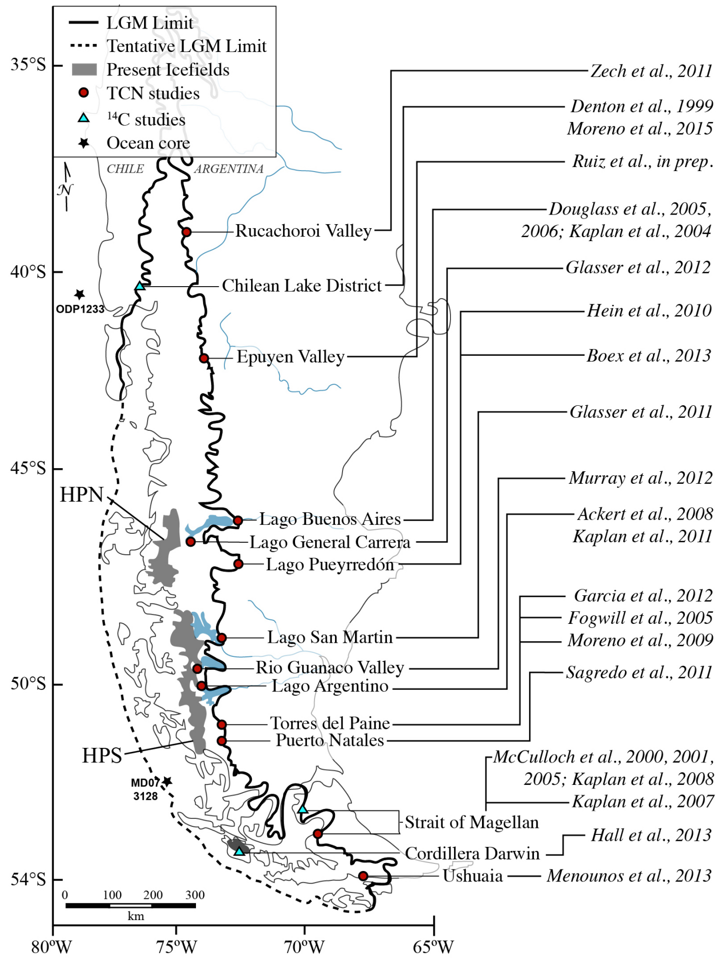

Fig. 3.2.1: Compilation of geochronological studies utilizing terrestrial cosmogenic nuclide (TCN) and radiocarbon dating to constrain Patagonian Ice Sheet extent/thickness. Note stippled western Ice Sheet margin indicative of tentative glacier extent. Adapted from Geiger, 2015.

Work at sea

The *Polarstern* helicopter will be used to access land sample sites in the Patagonian West Fjords between 53-55°S. Surficial bedrock and erratic boulder samples will be collected for surface exposure dating along vertical mountain transects east of Isla Recalada (53°S/72-73°W) and Noir (54°S/72°W) and on Isla Hermite and surrounding islands (55°S/67°W). Promising sample sites have been pre-selected via remote sensing. Individual erratic boulders could not be identified from the imagery, hence actual sample site verification and selection will occur once in the field from the Helicopter using binoculars. Individual rock samples will be selected following reconnaissance once on land.

Where possible, quartz-rich rock samples will be obtained in order to utilize *in-situ* cosmogenic ^{10}Be, ^{26}Al and ^{14}C dating (see Briner *et al.* 2014). Where quartz-rich rock is absent, sample collection for *in-situ* cosmogenic ^{36}Cl will occur. Ideally bedrock-erratic pairs will be collected at each elevational increment (limited by suitable sample availability). The vertical difference between bedrock-erratic sample pairs will be between 100-200 meters. This methodological approach has been utilized successfully in other formerly glaciated terrain (e.g. Brook, *et al.* 1996).

The upper five centimetres of the samples' rock surface, perpendicular to incoming secondary cosmic ray trajectories will be sampled, obtaining a maximum of 1 kg (lithology dependent). A battery driven circular handsaw, chisel and hammer will be used to obtain the samples. Each sample will be stored in labelled fabric bags to avoid cross-contamination. Field data and observations relevant for exposure age calculations will be noted: a hand-held GPS will be used to obtain geographical coordinate and altitude information, topographic shielding of the sample sites will be established using a compass and clinometer, observations of differential weathering patterns will be noted down for both bedrock and erratics. The overall geomorphological context of the sample sites and its surrounding, will be mapped to aid in further interpretations of former Patagonian Ice Sheet dynamics. Photographs of the samples, sample sites and broader context will be taken for reference. Following each sampling day, the data collected will be digitised and backed up.

Preliminary (expected) results

To present empirical data on Patagonian Ice Sheet extent and thickness is unavailable for the proposed study sites in the Patagonian West Fjords. Due to the presence of submarine moraines west of Isla Recalada, glacier coverage was extensive in the past. Based on extent studies at similar latitudes toward the east, glacier maxima/retreat are/is recorded from ca. 45-17 kyrs (e.g. McCulloch, *et al.* 2005; Darvill, 2015 personal communication). It is therefore likely that geochronological constraints obtained for this study will fall into MIS3-2. To present it has been debated whether the Patagonian Ice Sheet extended as far south as Isla Hermite during the last glacial cycle. Hence exposure ages obtained from this location will provide further insight.

Data management

Sample processing will be carried out at a laboratory suitable for terrestrial *in-situ* produced cosmogenic nuclide analysis (^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl). Once sample processing has started, the typical time-period to obtain exposure age results is between 9-15 months, depending on laboratory and AMS priorities and availability. The results from this work will be published in peer-reviewed journal articles where all the relevant sample and target processing information will provided for wider community access (see Dunai & Stuart, 2009).

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3. 3 Thermotectonic & glacial evolution of crustal fragments around the Scotia Sea

M. Zundel (U Bremen); C. Spiegel (U Bremen, not on board)

Background and objectives

The tectonic evolution of the Scotia Sea is a long-standing problem in Geoscientific research. It is of particular interest for understanding post-Gondwana plate tectonic evolution of Antarctica, but it is also of significance for oceanographic, climatic, and biological research: prior to the – presumably Eocene / early Oligocene – opening, the area of the Scotia Sea was clogged by numerous crustal fragments which formed barriers blocking deep-water circulation. Opening of the Scotia Sea led to the formation of the Antarctic Circumpolar Current, the largest ocean current on earth, which may have resulted in continental glaciation of Antarctica and a sharp decrease of global temperatures. It also allowed high-latitude fauna and flora exchange between the Atlantic and Pacific oceans, and put an end to biota migration between Antarctica and South America (e.g., Dalziel et al., 2013, Eagles & Jokat, 2014). Today, various crustal fragments surround the Scotia Sea are separated by different basins. The largest continental blocks involved in the opening of the Scotia Sea are South America and the Antarctic Peninsula. This project pursues two superimposed goals of reconstructing: (I) the long-term tectonic history of the Scotia Sea area and (II) a regional shorter-term glacial record.

(I) For deriving the thermotectonic evolution, we will use thermochronological dating methods on samples from (i) the southern Patagonian Andes, including the Magallanes fault zone, (ii) the South Shetland Islands, including the island group around Elephant Island, and (iii) if possible with respect to the cruise schedule, the South Orkney Microcontinent. Comparing the tectonic evolutions of these crustal blocks gives evidence about common or differential movements and thus allows inferences about the timing of their separation and the opening of oceanic basins between these blocks (see, e.g., Carter et al., 2014). Regarding southern Patagonia, a wealth of data already exist in the literature, which will be compiled for this study, so that it is planned to add only sample points from key location such as Isla de los Estados located at the transition between Patagonia and the north Scotia Ridge. The Magallanes Fault zone was presumably connected to the lateral shear zone along the North Scotia Ridge, thus better constraining the time of its activity is of great interest, which is why we plan to sample rocks from both sides of the fault zone. For the Antarctic Peninsula, the present-day hard rock exposures mostly monitor the young tectonic history related to recent subduction processes. The older history reflecting the tectonic evolution during the Eocene / Oligocene, i.e., coeval with the main opening period of the Scotia Sea, is stored in the sedimentary strata deposited at that time. This is the reason why for sampling the Antarctic Peninsula (King George Island), we mostly focus on sedimentary rocks. The geology of the Elephant Island Group (South Shetland Islands) is very similar to that of the formerly adjacent South Orkney Microcontinent. Comparing their tectonic histories may give evidence on the timing of separation of both blocks and thus on the opening history of the Powell Basin.

(II) In addition to the tectonic evolution of that area (that potentially initiated southern hemisphere glaciation), we are also interested in the younger deglaciation history. While a wealth of data already exists for the Antarctic continent, information on the Antarctic and Sub-Antarctica islands is limited. The area at the northern rim of Antarctica is particularly vulnerable to climatically-driven environmental change, and has experienced higher than

Antarctic-average warming during the last decades (Vaughan et al., 2003; Meredith & King, 2005), with strong impact on marine wildlife (Trivelpiece et al., 2011). We are particularly interested in a high-resolution reconstruction of post LGM (last glacial maximum) glacial thinning and retreat rates, for testing how rapidly local glaciers have reacted to changed global climate conditions in a pre-anthropogenic age. For this, we plan to apply cosmogenic exposure dating to glacially eroded bedrocks and erratics from King George Island, the Elephant Island Group and, if possible, the South Orkney Islands.

Work at sea

Supported by the helicopters on board of *Polarstern* we plan to take basement samples along the Strait of Magellan, i.e., to both sides of the Magallanes Fault Zone. This part of the sampling will be carried out in close contact with the Geodesy working group around Mirko Scheinert. Furthermore, we will collect rock samples for thermochronological analyses from several islands off western Chile, namely Isla Recalada, Isla Noir, and Isla Hermite, in cooperation with the Paleoclimatology working group around Rolf Kilian, and also from Isla de los Estados. Sampling for thermochronology and for cosmogenic nuclide analysis will take place on several of the South Shetland Islands (presumably King George, Nelson, Robert, Greenwich and Livingston Islands) and around Elephant Island (Elephant, Clarence, Seal, Cornwallis, Gibbs Islands).

To obtain additional information on the erosion history of other continental fragments of the Scotia Sea, we also plan to analyse coarse clastic detritus retrieved from box corers (or, alternatively, Piston or Gravity corers) along Burdwood and Davis Bank, and close to the Malvinas Plateau and the Patagonia and Antarctic Peninsula margins.

Preliminary (expected) results

Measurements for topographic shielding required for correcting exposure ages will be performed directly in the field. Sample processing, thermochronologic analysis (apatite fission track and (U-Th-Sm)/He dating), as well as cosmogenic nuclide analysis (^{10}Be exposure dating) will be performed after the cruise in the frame of the PhD project of Max Zundel. The new data will provide key information on the tectonic evolution of the crustal fragments surrounding the Scotia Sea, and on the post-LGM deglaciation history of Antarctic and Subantarctic Islands, thus in turn providing benchmarks for future climate models.

Data management

All data will be uploaded to the PANGAEA database. Unrestricted access to the data will be granted after about three years, pending analysis and publication.

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3. 4 Repeated GNSS measurements in the region of the Antarctic Peninsula to investigate neotectonics

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Background and objectives

The determination of the recent crustal motion pattern of Antarctica forms an important precondition for the investigation of its glacial history and of the tectonic situation. Changing ice-mass loads can be found in glacial history but also in recent times. The magnitude of these vertical deformations can be predicted on the basis of models which combine the glacial history with the viscoelastic reaction of the Earth. For West Antarctica these predictions cover a wide range, from 5 to more than 10 mm/yr, thus being much larger than predictions for East Antarctica. Different groups have made attempts to measure the vertical deformation by GNSS. Within the German Antarctic Project (GAP95 and GAP98) GPS stations were established, among others, in the region of the Antarctic Peninsula. A consistent homogeneous reanalysis has been performed recently by Rülke et al (2015).

Now, we plan to carry out GNSS measurements at seven locations in the region of the Antarctic Peninsula, which were set up during GAP and observed for the first time in 1995 and for a second time in 1996 or 1998. The anticipated third observation epoch aims to infer coordinate changes over a time span of about 20 years whereby the same level of accuracy can be reached as for permanent GNSS observations. These coordinate changes will be interpreted in terms of horizontal and vertical crustal deformations. For the horizontal component, the deformation will be analyzed primarily in terms of plate tectonics. The residual horizontal deformationhas to be tested for significance before allowing to discuss its consequence for further tectonic interpretation. For the vertical, we will get *in-situ* data to investigate the glacial isostatic adjustment (GIA). The vertical deformation rates will help to constrain GIA model predictions, which still vary considerably across different models. Hence, the results will enhance the vertical deformation pattern yielded by observations in the Antarctic Peninsula region, and thus will allow to improve both the models on glacial history and on the viscoelastic response of the Earth. Finally, an improved and more reliable determination of the GIA effect will have a positive feedback on estimates of the Antarctic ice-mass balance and of the respective sea-level change.

Additionally, we will set up new GPS stations in Chilean Patagonia (Magellan Strait region, Cordillera Darwin) in order extend observations on recent deformations in the region along the tectonic plate boundary between the Antarctic, Scotia and South American plates.

Work at sea

All locations will be reached by helicopter. Out of the seven sites in the Antarctic Peninsula region we plan to occupy four to five sites (Fig. 3.4.1 and Table 3.4.1), while the sites ESP1 and MAR1 are out of reach within this cruise.

In Chile, one site (BFIT) will be re-observed and up to seven new stations shall be set up. They will be chosen in such a way to find an optimum position due to geological conditions and free visibility over the horizon.

The GPS equipment will be set up and remain at each location to observe permanently for 3 days at least. A close coordination with the activities of the other groups operating on land is anticipated in order to realize the works in an economic way. The geodetic group will consist of two scientists based at TU Dresden.

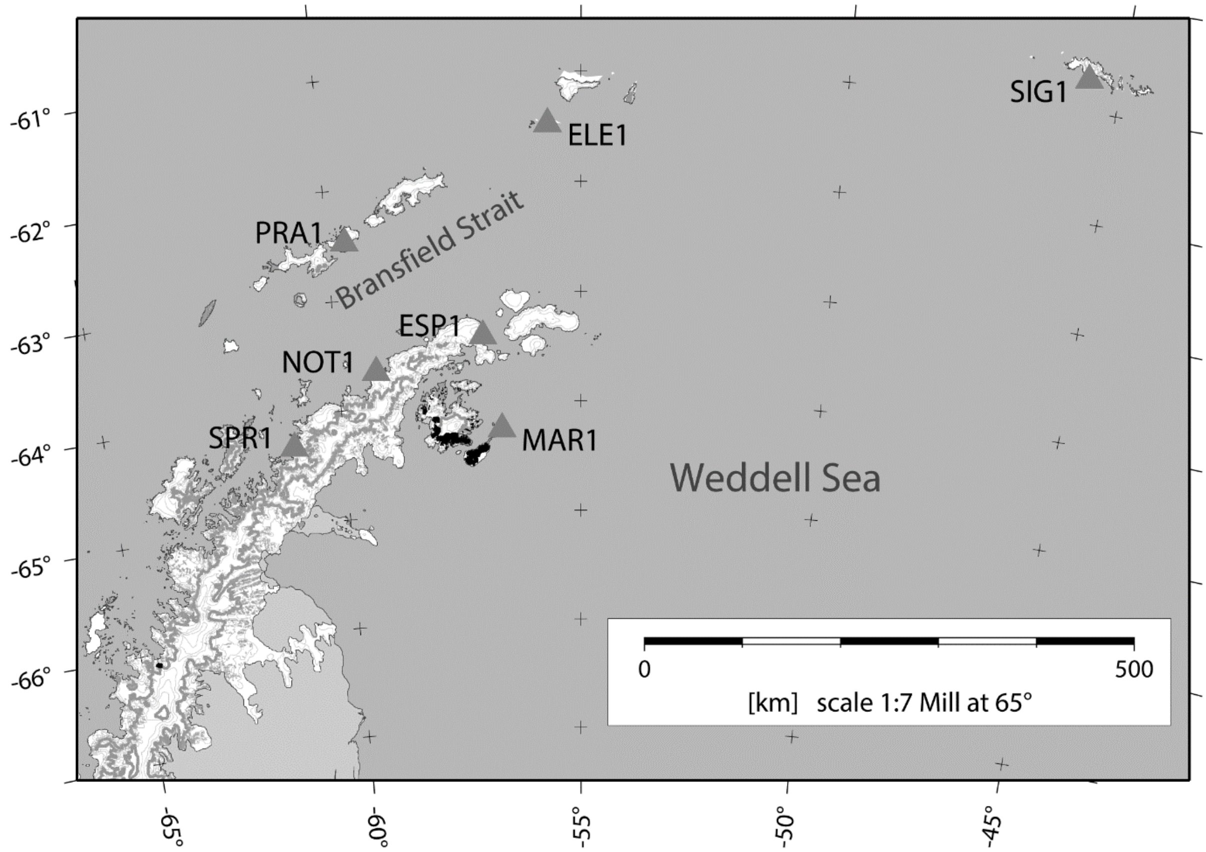

Fig. 3.4.1: Overview map of the northern Antarctic Peninsula and South Shetland Islands

Tab. 3.4.1: Approximate coordinates of GPS stations. The stations ESP1 and MAR1 will not be occupied during this cruise. The occupation of SIG1 depends on the final cruise plan.

Station	Location	Longitude	Latitude	Previous observations
ELE1	Gibbs Island	-55.6314	-61.4807	1995, 1998
NOT1	Notter Point	-59.2082	-63.6742	1995, 1998
PRA1	Arturo Pratt	-59.6503	-62.4776	1995, 1996, 1998
SPR1	Punta Spring	-61.0519	-64.2953	1995, 1998
SIG1	Signy	-45.5927	-60.7077	1995, 1998
ESP1	Esperanza	-56.9961	-63.3951	1995, 1996, 1998
MAR1	Marambio	-56.6570	-64.2449	1995, 1996, 1998

Data management

All data will be uploaded to the PANGAEA database. Unrestricted access to the data will be granted after about three years, pending analysis and publication.

4. GEOCHEMISTRY

S. Henkel (AWI), S. Kasten (AWI, not on board)

Objectives

The main objective of the geochemical sampling on board is to acquire high-resolution profiles of pore-water and sediment geochemistry to investigate early diagenetic processes. The mayor aims are (1) to study the distribution of easily reducing Fe oxides in near-shore sediments of Antarctic Islands, (2) to investigate the post-depositional redistribution of iron and related stable iron isotopic fractionation during continual burial and varying redox conditions, and (3) to assess the potential diagenetic overprint of proxy parameters that are used to reconstruct paleoceanography and paleoclimate.

Iron is supplied to the Antarctic shelf and the Southern Ocean via meltwater streams and icebergs. For the past decades, due to ongoing glacier retreat, Fe fluxes seem to have increased (e.g. Raiswell et al. 2008, Monien et al. 2011, Majewski et al. 2012, Monien et al. 2014), which has implications for post-depositional biogeochemical processes and Fe fertilization. A recent study by Monien et al. (2014) indicates that the increased supply with Fe(III) into Potter Cove, a shallow bay of the King George Island, stimulates dissimilatory iron reduction (DIR) and benthic fluxes of bioavailable Fe back into the water column. Studies on reducible Fe fractions in Antarctic sediments in combination with pore-water data are, however, scarce. Therefore, overall trends and the importance of Fe(III) supply for DIR in Antarctic sediments are hard to assess. Geochemical sampling and analyses conducted in Potter Cove by Henkel et al. (2013) and Monien et al. (2014) were restricted to water depths of a few tens of meters. The existing datasets from Potter Cove are ought to be complemented by sampling sediment cores from Maxwell Bay (water depths up to 600 m). As benthic Fe fluxes are supposed to show negative δ^{56}Fe values, the isotopic composition of Fe in the water column can be used to evaluate the contribution of this Fe source (Staubwasser et al 2006, Severmann et al. 2010). Sediment sampling is therefore planned to be complemented by water column sampling for Fe concentrations, δ^{56}Fe, and suspended particles.

Furthermore, a focus of the geochemical work on board *Polarstern* will be the deep Fe reduction below the sulfate-methane transition (SMT). More and more studies hint to an important role of Fe(III) regarding the stimulation of the anaerobic oxidation of methane (AOM) and the biogeochemical cycling of other elements, such as P, in shelf and ocean margin sediments (e.g. Sivan et al. 2011, Riedinger et al. 2014, Egger et al. 2015). The processes taking place below the SMT are, however, not well understood. Recently, Oni et al. (2015) showed that deep Fe reduction in North Sea sediments is associated with increased occurrences of JS1 bacteria and ANME-3-related archaea. These results hint to a microbial mediation of deep Fe reduction rather than a solely abiotic process (Fe reduction by reaction with hydrogen sulfide). The specific mechanism of the interplay between these microorganisms and their importance in other environmental settings, is, however, unknown. At selected sites, where a shallow SMT is indicated (e.g. by sulphide smell and CH_4 bubbling), sediment samples will be taken for a thorough analysis of Fe phases and their stable Fe isotopic fingerprint. Furthermore, pore water aliquots for δ^{56}Fe analyses will be conserved and part of the sediment will be used for molecular analyses.

Post-depositional biogeochemical processes may alter the distribution of elements and overprint so-called proxy parameters (e.g. Ba_{excess} and magnetic susceptibility). Where important for the reconstruction of paleoenvironmental conditions, geochemical sampling and analyses will be performed to enable an identification of redox zones and to draw conclusions about the potential corroboration or primary records.

Work at sea

Gravity (GC) and multicorer (MUC) cores will be sampled in 25 cm-intervals and 1-2 cm intervals, respectively. For the investigation of iron cycling and the distribution of reducible Fe(III) oxides, three combined deployments of the MUC and GC within Maxwell Bay are targeted. The three sediment stations are planned be complemented by 3-4 water column profiles, where at each profile, 5 depths are sampled using 5L GoFlo-bottles. The GoFlo bottles will be emptied inside the clean container within approx. 20 min. Subsequent filtration (max. 24 h after sampling) will be performed in a clean bench. Suspended matter collected on the filters will be used for automated SEM analysis. GC and MUC samples will additionally be gained where high terrestrial inputs cause a rather rapid burial of Fe(III) into the methanic zone (shelf regions). Geochemical sampling will furthermore be performed "on-demand", where dating and paleoproxy studies depend on the identification of early diagenetic features (e.g. secondary barite fronts or alteration of susceptibility).

Methane samples will be taken immediately when gravity cores are cut into segments. Pore-water sampling on multicorer and gravity cores will subsequently be performed by use of rhizons (Seeberg-Elverfeldt 2005, Dickens et al. 2007). For sampling the gravity cores, small windows will need to be cut into the liners. Pore-water analyses on board of *Polarstern* comprise the photospectrometric Fe(II) measurement after Stookey (1970) and HPO_4^- determination. Additional pore-water aliquots will be conserved for sulfide, sulfate, chloride, cation, and δ^{56}Fe analyses. Sediment samples will be taken rapidly to avoid oxidation. They will be stored frozen under anoxic conditions for later geochemical and microbial analyses. Multicores may additionally be sampled for ^{210}Pb dating. As pore-water sampling is time-consuming and has to be done immediately after core retrieval, a maximum of two cores (no matter if GC or MUC) can be processed per day.

Data management

All data will be uploaded to the PANGAEA database. Unrestricted access to the data will be granted after about three years, pending analysis and publication.

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5. PHYSICAL OCEANOGRAPHY

W. Schneider (COPAS/IMO), H. Fenco (INIDEP), C. Lange (COPAS/IDEAL), F. Lamy (AWI), L. Lembke-Jene (AWI), A. Piola (not on board, HIDRO).

Objectives

The purpose of the hydrographic survey in the northwest Drake Passage is to evaluate the water mass characteristics and velocity structure of the Cape Horn Current. The Cape Horn Current is thought to be the main pathway of low salinity near-coastal waters in the SE Pacific feeding into the SW Atlantic (Hart, 1946). Observations and models suggest that these diluted waters flow into the southwest Atlantic shelf primarily via Le Maire Strait and also east of Isla de los Estados (Matano et al., 2010). However, there are no modern observations designed to determining the water properties or to quantify this flow. The survey in the northern Drake Passage will also allow sampling the inflow of deep waters, including the Southeast Pacific Deep Water (e.g. Naveira Garabato et al., 2002) with unprecedented resolution.

Likewise, a hydrographic transect will be conducted covering the western part of Drake Passage from the South American continent to the Antarctic Peninsula in order to estimate the volume transport through this passage and the water mass structure, however with a reduced sampling rate. This transect will be used together with existing historical transects for variability studies regarding the upper items.

Work at sea

The work at sea will consist in the occupation of four full-depth, high-resolution hydrographic (CTD/LADCP) sections. The CTD will be fitted with a dissolved oxygen sensor. The oxygen data will be used in combination with the potential temperature and salinity to more clearly characterize the water masses within the Cape Horn Current and also the eastward flowing deep waters derived from the SE Pacific. The CTD will be fitted with one or two lowered

Acoustic Doppler Current profilers (LADCPs). CTD profiles will reach the near bottom layer (within 10 m of the bottom) to assure sampling of the densest waters flowing along the margin into Drake Passage. Water samples for the determination of salinity and dissolved oxygen will be collected at selected levels primarily for CTD sensor calibrations. Water samples will be analyzed on board. The same sampling strategy will be applied to the Drake Passage transect.

Preliminary (expected) results

We expect to produce the first modern description of the Cape Horn Current, its water mass structure and transport, as well as indications of the downstream modifications as the waters from the SE Pacific first interact with the swift flows associated with the Subantarctic Front in the northern Antarctic Circumpolar Current.

Data management

The CTD and LADCP data will be processed on board after the Cape Horn Current and the Drake Passage are completed. Data will be made available to the scientific party and associated investigators.

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6. HYDRO-ACOUSTICS

6.1 Bathymetry

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Objectives

Accurate knowledge of the seafloor topography, hence high resolution multibeam swath bathymetry data, is key information necessary to understand marine processes and the glacial history of polar continental margins. It is of particular importance for the interpretation of oceanographic, geological and biological data in a spatial context. For geological studies, bathymetry data can moreover provide valuable information on the glacial history of an area by revealing the geomorphology of the seafloor, i.e. sub- and proglacial bedforms. Potential sediment depo-centres and areas of erosion can be identified by combining data on seafloor topography collected with swath bathymetry systems with information about sub-seafloor composition and stratigraphy derived from acoustic sub-bottom profiling. Seafloor depressions, for example, may act as sediment traps, whereas steep slopes and escarpments are often affected by erosion, thereby exposing old, hard and laterally variable substrate. Furthermore, seabed topography and seafloor substrate are key environmental parameters for benthic ecosystems, and consequently their characterisation will allow for habitat classifications.

Although repeatedly visited by research vessels, large parts of the Drake Passage have not been mapped with multibeam echosounder and thus lack high resolution multibeam swath bathymetry. The same holds true for the proposed study areas offshore Chile and the

Antarctic Peninsula. The bathymetric models for these areas are mainly derived from satellite altimetry, which is heavily affected by persistent sea-ice cover, with only limited direct sounding measurements. For detailed survey planning, the satellite altimetry derived bathymetry often lacks the resolution necessary to identify small- to meso-scale topographic features. This is especially true for glacial-geomorphological seabed features, such as mega-scale glacial lineation, moraines, and drumlins. Also sedimentological features related to bottom currents, such as scours and sediment waves, cannot be resolved from satellite altimetry data. Therefore, ship-borne high resolution bathymetry surveys in the study area are required for reconstructing palaeo-ice drainage patterns and bottom current pathways. Topographically steered flows of dense water masses follow the deepest path. By interacting with the seafloor morphology these flows can result in locally enhanced or reduced bottom current strength. Enhanced bottom current flow can result in the formation of erosional or depositional features (e.g. furrows, sediment waves) that can be identified on high resolution bathymetric maps. These features can then be used to reconstruct modern and past bottom current pathways and intensities for (palaeo-)oceanographic and sedimentological studies and to provide environmental information for habitat studies.

Work at sea

The main task of the bathymetry group is to plan and run surveys using the Atlas Hydrosweep DS3 systems in the study area and during transit, to provide information for station planning and sediment sampling. The raw bathymetric data will be corrected for sound velocity changes in the water column and further processed and cleaned for erroneous soundings and artefacts on board. Detailed seabed maps derived from the bathymetric data will provide information on the general and local topographic setting of the survey area and on the distribution of glacial-geomorphological features and erosional structures (channels, gullies) and depositional features (slumps, slides, fans). High resolution seabed data recorded during the surveys will promptly be made available for site selection and cruise planning. The acoustic surveys will be carried out by three operators in a 24/7 shift mode.

Preliminary (expected) results

Expected results are high resolution bathymetric and geomorphological maps of the study areas in the Drake Passage, offshore Chile and the Antarctic Peninsula. The bathymetric data will be analysed to provide environmental parameters for the study areas.

Data management

The raw multibeam echosounder data collected during the expedition will be stored in the PANGAEA data repository at the AWI. Processed hydroacoustic data are stored at the AWI and can be requested at infobathy@awi.de. Bathymetric data sets will be provided to mapping projects and included in regional data compilations, such as the International Bathymetric Chart of the Southern Ocean (IBCSO) and the General Bathymetric Chart of the Ocean (GEBCO).

6.2. Marine sediment echosounding (PARASOUND)

G. Kuhn (AWI), L. Jensen (AWI), H.W. Arz (IOW), C. Hass (AWI), S. Papenmeier (AWI), H. Grob (U Hamburg), S. Stratmann (U Hamburg)

Objectives

The sediment echosounder PARASOUND DS III - P70 (Atlas Hydrographic, Bremen, Germany) is permanently installed aboard *Polarstern*. It records sea floor and sub-bottom reflection patterns and thus characterizes the upper sediment layers according to their acoustic behaviour.

The objectives of sediment echosounding during PS97 (ANT-XXXI/3) included:

- Selection of coring stations based on acoustic patterns and backscatter
- Obtaining different pattern of high-resolution acoustic stratigraphy useful for lateral correlation over shorter and longer distances thereby aiding correlation of sediment cores retrieved during the cruise.
- Providing a high-resolution supplement of the uppermost sediments as part of the IODP seismic pre-site survey
- Improvement of information on the sediment distribution in the Southern Ocean

A transducer array is mounted in the ship's hull. It transmits an acoustic signal, which propagates through the water column down to the sea floor where parts of the signal are reflected. Other parts penetrate the sea floor and are reflected at boundaries between sediment layers.

PARASOUND uses the parametric effect. It produces additional frequencies through non-linear acoustic interactions of finite amplitude waves. By emitting two primary sound waves of higher frequency (18.8 and 22.8 kHz) a signal of the differential frequency (4 kHz) is generated. Due to its longer wavelength the secondary low frequency (SLF) signal allows a sub-bottom penetration of up to 200 m (depending on the thickness of the sediment cover and its density and composition) with a vertical resolution of 30 cm. Due to the parametric effect the pulse is generated within the narrow emission cone (4°) of the primary high frequencies (PHF) and thereby a very high lateral resolution compared to conventional 4 kHz-systems is provided.

Work at sea

After pre-selection of working areas based on oceanographic and marine geological background information, PARASOUND acoustic profiles will play a key role in locating coring stations with undisturbed sediment sequences. Site selection will be based on acoustic patterns such as the strength of characteristic reflectors, their spacing, and the total sub-bottom penetration.

Data management

The raw PARASOUND data collected during the expedition will be stored in the PANGAEA data repository at the AWI.

6.3 Seismic imaging for iodp pre-site survey

J. Gossler (KUM), F. Lamy (AWI), C. Hübscher (U Hamburg; not on board), H. Grob (U Hamburg), S. Stratmann (U Hamburg), K. Gohl (AWI, not on board), A. Polonia (ISMAR/CNR, not on board)

Objectives

The Subantarctic Southeast Pacific is a particularly sensitive region where atmosphere-ocean changes between high-, mid- and low latitudes are strongly coupled. The SEP provides a unique opportunity to obtain exceptionally highly-resolved sediment records to document millennial and orbital-scale Plio/Pleistocene changes and their implications for global climate. We plan to submit an IODP Full Proposal for two drilling areas located in the central Subantarctic Pacific (both flanks of the East Pacific Rise) and in the eastern Subantarctic Pacific (Chilean Margin, entrance to the Drake Passage). Whereas seismic data have been successfully obtained for the central South Pacific during PS75 (ANT- XXVI/2) such data is partly missing for the Chile margin. In addition to complete seismic surveys, our cruise will additionally collect bathymetric and PARASOUND information as well as sediment cores in vicinity of the Chile Margin Sites. Only the combination of hydroacoustic surveys and piston coring will produce the appropriate pre-site survey database needed for drilling of Cenozoic sediments in the Subantarctic Pacific Ocean.

Work at sea

A multichannel seismic (MCS) reflection technique will be used to record the seismic record of sediments and basement in the area of the proposed drill sites off the mouth of the Strait of Magellan (site CHI-4A at transect SCM I; Fig. 1.1) and further south in a forearc basin at the Chilean margin (sites CHI-1A to CHI-3A). Each site will be surveyed with a cross profile with each axis of about 20-50 nm track length. Seismic recording is performed using a towed 600 m long hydrophone streamer and high-frequency GI-Guns as airgun source. On board quality control and data display will help determine the drill site characterisation. This is combined with bathymetric and sediment-echosounding survey as well as with the recovery of long piston cores to provide information on the sediment composition and sedimentation rates at the proposed drill sites.

Data management

The raw seismic data collected during the expedition will be stored in the PANGAEA data repository at the AWI.

7. IRON LIMITATION AND CYCLING IN CONTRASTING SOUTHERN OCEAN PROVINCES UNDER CURRENT AND FUTURE CLIMATE

S. Blanco (Uni Geneva), D. Cabanes (Uni Geneva), C. Hassler (Uni Geneva), J. P. Heiden (AWI, Uni Bremen), P. Karitter (AWI), F. Koch (AWI), F. Lelchat (Uni Geneva), M. Sieber (ETHZ), H. Simon (Uni Oldenburg), S. Trimborn (AWI/Uni Bremen), C. Völkner (AWI), R. Zimmermann (AWI)

Objectives

Southern Ocean phytoplankton is a major driver of global carbon cycling, accounting for 20 % of the global annual primary production. One of the most challenging issues is to understand how trace metal limitation and cycling operates and how global change will impact the Southern Ocean ecosystem. The availability of trace metals, in particular iron, is considered the key factor governing Southern Ocean phytoplankton productivity and community composition. However, since phytoplankton are part of a complex food web, their interactions with other trophic levels can have profound effects on the dynamics of the system. This project aims to study the interconnected microbial processes that are driving the biogeochemical cycles of carbon as well as of trace metals such as iron, zinc, cobalt and manganese and B-vitamins. Our work will focus on viral-bacterial-phytoplankton interactions considering biologically excreted organic matter as a control for trace metal chemistry, the bioavailability of these trace metals to the plankton community, their effects on primary productivity and species composition and succession. The increase in atmospheric CO_2 has already resulted in a significant increase in aquatic CO_2 concentrations and thus lower pH values ('ocean acidification') compared to pre-industrial times, potentially affecting plankton community structure as well as iron chemistry. This study will also evaluate the sensitivity of phytoplankton of different regions to climate change scenarios and trace metal availability in order to predict the response of the plankton community to these future changes. This project will carry out ship-board incubation experiments with water collected from contrasting Southern Ocean sites; namely the naturally iron-enriched waters of the Antarctic Peninsula and the open ocean and iron-limited waters of the Drake Passage. Given that organic matter drives the biogeochemical cycle of carbon and trace metals, *in-situ* marine dissolved organic carbon will be sampled for further characterization back in the laboratory. The proposed research will improve our current understanding of how trace metals and carbon biogeochemical cycles inter-connect, characterize organic materials present at the contrasting sites and establish how microbial interactions control the biogeochemical cycle of trace metals in the Southern Ocean under current and future climatic conditions.

Work at sea

The proposed work involves chemical and biological methods to isolate and purify DOC, bacteria and viruses. In addition, incubation experiments will be conducted to assess the bioavailability and chemistry, as well as the limitation imposed on phytoplankton by Fe, Zn, Co, and Mn and measure their impact on bacterial dynamics. We propose to conduct the incubation experiments in two open ocean, high nutrient low chlorophyll (HNLC) regions and two coastal sites close to the Western Antarctic Peninsula using the same initial batch of trace metal clean (TMC) seawater:

Bacterial and viruses isolation

Natural community of viruses specific of the DOC-producing host will be concentrated by tangential ultrafiltration (100 kDa cut-off). Bacteria will be isolated using a sterile 10 L Niskin X bottle deployed on the regular rosette using ethanol rinses. The selection of bacterial candidates will be realized following a phenotypic screening on agar plate kept in a fridge. A specific agar media with a low N/C ratio will allow us to determine the probable EPS-excreting bacteria by selecting the most mucoid strains. This biological material will then be characterized back at the University of Geneva and used to produce large quantity of bacterial EPS, measure viral degradation rates of EPS isolated at sea including impact for Fe biogeochemistry. This data will thus be vital to complement information gathered at sea.

DOC isolation

Large volume (1000 L) of 0.2 micron filtered water will be collected to isolate natural organic matter (NOM) larger than 100 kDa contributing to small organic particle and colloids. The role of such compounds on Fe biogeochemistry has been widely recognised (e.g. Boye et al. 2010, Hassler et al. 2011a,b). This NOM will then be used in incubation experiments at sea and brought back for further work in the laboratory in order to revel the nature of marine DOC with respect to Fe biogeochemistry. For that purpose state-of-the art techniques will be collaboratively used at AWI and Uni Geneva.

Assessing the effect of EPS on Fe microbial recycling and the physiological status of phytoplankton in contrasted regions of the SO

The effect of freshly isolated EPS amendments on Fe bioavailability, the bacterial and phytoplankton community composition and productivity will be assessed using 24h up to 4-5 days *in-situ* experiments on size-fractionated planktonic communities (pre-filtered on a 200 μm mesh: large and small phytoplankton as well as bacterioplankton). The organic carbon source used for heterotrophic bacteria and Fe binding ligands will be saccharides, EPS (a form of DOC) and a widely studied siderophore (desferrioxamine B). The bioavailability for the bacterio- and phytoplankton community of the different forms of Fe will be determined using ^{55}Fe uptake rates and sequential filtration. Growth will be measured using flow cytometry for bacteria and POC for phytoplankton. The structure of the plankton community will be described as above using flow cytometry, HPLC, and by light microscopy. *In-situ* Fe limitation will be assessed using F_v/F_m and Fe uptake rates. Fe chemistry and dissolved trace metal concentrations will also be determined. As different phytoplankton species, have different requirement for Fe, and possibly varying uptake strategies, the bioavailability of Fe to the natural phytoplankton population cannot be directly compared between sites. In order to be able to quantitatively compare data from the selected contrasted regions, the impact of all the EPS isolated on Fe bioavailability will be addressed using model species of phytoplankton in controlled laboratory experiments.

Impact of Fe limitation on Si and Zn isotopic signature

Because diatoms are a dominating phytoplankton group in the SO and the Si associated with their frustules is slow to remineralize, the SO acts as an Si trap with consequences for the global Si distribution. Thus Fe limitation, by controlling the growth of diatoms across the SO, has also consequences for the global Si distribution and primary productivity. Zn may also also be impacted as it is required for the biological uptake of Si. Here, we will check how Fe enrichment affects the isotopic signatures of Si and Zn following 5 days incubations. As isotopic signatures can be used to track processes, comparison of our results with isotopic signatures measured worldwide will provide a unique insight of the influence of Fe limitation in the SO at large.

Incubation experiments with Fe, light and pCO₂

Shipboard perturbation experiments with natural phytoplankton communities from the Drake Passage will be performed to address the question of how CO_2-related changes in carbonate chemistry (e.g. ocean acidification) in combination with Fe and light limitation will affect primary productivity and phytoplankton species composition. Therefore, incubations of natural assemblages will be exposed to CO_2 levels of present-day (390 µatm), and those projected for the year 2100 (750 µatm). To elucidate the impact of light, experiment will be conducted under light-limiting (20 µmol m^{-2} s^{-1}) and saturating (100 µmol m^{-2} s^{-1}) conditions. These shipboard perturbation experiments will be run for 3 weeks. The experiments will be run in a temperature-controlled growth chamber (2 °C) with a constant daylight irradiance of 20 or 100 µmol m^{-2} s^{-1}. Nitrate, silicate and phosphate concentrations will be measured daily over the course of the experiments. Using a fast repetition rate fluorometer (FRRF, Chelsea) F_v/F_m of all incubations will be regularly measured to determine the physiological state of the cells. At the beginning and the end of each dilution, taxonomic species composition and cell density will be determined. While pH will be measured on-board on a regular basis, samples for alkalinity and DIC will be stored at 4 °C and analyzed at the AWI. Samples for chlorophyll a, biogenic silica (BSi), particulate and dissolved organic carbon (POC and DOC, respectively) as well as pigments will be taken. Samples for dissolved Fe concentrations and Fe chemical and redox speciation will be taken and analyzed using ICP-MS and CLE-AdSV at the AWI. Ligands regulating the bioavailability of Fe will be identified using reversed-phase high performance liquid chromatography hyphenated to inductively coupled plasma sector field mass spectrometry (HPLC-ICP-MS). Molecular characterization of NOM and potential ligands will be performed for selected experimental samples using ultrahigh resolution Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR-MS). Humic acid like substances, Fe chemical and redox speciation will be analysed by CLE-AdCSV. This is to explore the link between Fe chemistry and its bioavailability.

Incubation experiments with Fe and light

To investigate how the availability of light influences phytoplankton growth and community composition in the iron-limited Drake Passage as well as in the naturally iron-enriched coastal waters of the WAP short-term shipboard perturbation experiments will be carried out. These short-term shipboard perturbation experiments will be run for 7-12 days. Phytoplankton incubations will be exposed to undersaturating (20 µE), saturating (100 µE) and oversaturating (250 µE) irradiance. All light treatments will be carried out either under the natural Fe concentration or after addition of 1 nM inorganic Fe. Effects will be assessed using the same parameters described for the experiments with Fe, light and pCO_2.

Incubation experiments with Fe, Zn, Co, Mn and vitamin B_{12}

This research project aims to identify whether Zn, Co, Mn and B12 are limiting or co-limiting with Fe primary productivity or shape plankton community composition in different regions of the SO. For identification of the limiting (or co-limiting) trace metal/vitamin, short-term shipboard perturbation experiments with natural phytoplankton communities will be carried using single or multiple trace metal additions. Target regions will be the Drake Passage and the Scotia Sea. These short-term shipboard perturbation experiments will be run for 5-7 days. To promote phytoplankton growth triplicate bottles will be amended with either 2 nM inorganic Fe,,4 nM Zn, 100 pM Co, 1 nM Mn, 100pM B12. In order to assess potential colimitation with Fe, in HNLC waters the later compounds will also be added in conjunction with Fe. The same set of parameters will be taken as described for the incubation experiments with Fe, light and pCO_2. Additionally, samples will be taken to determine the cellular quota of Fe, Zn, Co and Mn by ICP-MS.

In-situ sampling at 15 stations

To detect trace metal co-limitation, we will sample 15 locations in the HNLC as well as in the coastal waters along the WAP. Using a GoFlo bottle, 20L TMC seawater will be sampled from 20 m depth. From this water, phytoplankton community composition and productivity will be determined. To identify potential trace metal limitation, also samples for cellular quota of Fe, Zn, Co and Mn by ICP-MS will be taken.

Preliminary (expected) results

The research scheduled at sea will address several outstanding challenges with respect to trace metal biogeochemistry and the ecosystem functioning of the Southern Ocean under current and future climate conditions. Regarding chemistry, a better characterisation of the link of Fe biogeochemistry with DOC will help to characterise the nature of organic ligands – a prerequisite to develop tracers and improve our understanding as well as the modelling of iron biogeochemistry. Our results will also help to better understand the role of viruses on biogeochemistry. The different planned experiments will further indicate how simultaneous changes in multiple parameters will affect the productivity and the biodiversity of Southern Ocean phytoplankton. The joint effect of trace metals, vitamins, organics, light as well as pCO_2 will hence provide a better understanding of the dynamic of Southern Ocean primary producers. Finally, by measuring the impact of Fe limitation on isotopic signature we will contribute to enhance our understanding of the impact that the Southern Ocean exerts at a global scale.

Data management

All data will be uploaded to the PANGAEA database. Unrestricted access to the data will be granted after about three years, pending analysis and publication.

8. WATER COLUMN AND SURFACE SEDIMENT STUDIES FOR MICROFOSSIL-BASED PROXY CALIBRATIONS

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Objectives

The oceanographic processes on the southern Chilean margin, in Drake Passage and the Scotia Sea have a fundamental influence on the Pacific – Atlantic – Southern Ocean inter-basin exchange of water masses and thus on the global Meridional Overturning Circulation (e.g. Meredith et al., 2011). Biogeocheochemical and physical processes in the Southern Ocean play a crucial role in initiating and shaping climatic changes not only on modern, but also on geological, i.e. millennial and orbital timescales. As the Southern Ocean is the largest High-Nutrient-Low Chlorophyll (HNCL) area in the World Ocean, it thus has the potential to act as a major CO_2 sink, when the efficiency of the biological pump increases, as proposed for glacial periods (e.g. Kohfeld et al., 2005, Yu et al., 2014, Anderson et al., 2014). In addition, air-sea interactions in the Southern Ocean exert a strong influence on the global ocean circulation and are supposed to be important in setting the rate of global overturning (Marshall and Speer, 2012). In addition, the study region acts as a major junction of the Antarctic Circumpolar Current with associated oceanographic fronts and currents, leading to an intensely dynamic and heterogenous ecological setting for both calcareous and siliceous planktic and benthic species that are widely used as signal carriers in paleoceanographic proxy reconstructions.

Over the past years, the “toolbox” of paleoceanographers and their ability to (semi-) quantitiatively reconstruct changes in the oceans’ nutrient inventories and physical dynamics has steadily increased in number of proxies and their sophistication. Planktonic foraminifera from surface waters will be studied in order to understand the taxonomy and the diversity of the investigated species and to better understand the population dynamics of planktonic foraminifera (in particular *N. pachyderma*) north and south of the Subantarctic front using the ship's seawater supply. Apart from such species assemblage and established stable oxygen and carbon isotope analyses, additional geochemical and isotope-based tools that use foraminiferal test carbonate have opened new avenues towards the quantitative reconstruction of physical paleoceanographic parameters. The application of Mg/Ca elemental ratios, when combined with stable oxygen isotopes, permits the reconstruction of upper and deep ocean water temperatures, and as a result allows to differentiate effects of temperature, salinity and ice sheets on geological time scales. However, while already some of the earliest works on Mg/Ca – temperature relationships from planktic foramininfera used samples from the subpolar latitudes (Nürnberg, 1995), large ucertainties in using both planktic and benthic foraminifera, especially in the high latitudes remain (Kozdon et al., 2009). Recent studies point to complex inter-dependencies of Mg/Ca and other trace metal signals in *N. pachyderma* (s) with secondary environemental effects (sea ice – CO_3^{2-}) in polar and subpolar southern latitudes (Hendry et al., 2009). On the other hand, benthic foraminiferal stable oxygen and carbon isotopes, and trace metal/elemental ratio such as Cd/Ca, B/Ca and their isotopes deliver the means, to disentangle the complex signals of physical (T, S) and chemical (CO_3^{2-}, PO_4, O_2) changes of deep water masses through Earth’s history. Such results provide critical information to understand past variations in the Southern Ocean’s carbon cycle dynamics and the nature of the southern-sourced branch of the meridional overturning circulation (e.g. Yu et al., 2010; Elderfield et al., 2012).

New tools based on the use of stable isotopes ($\delta^{30}Si$, $\delta^{18}O$) from siliceous microfossils (diatoms, radiolarians, sponge spicules) have emerged, which can be used to reconstruct changes in environmental conditions such as ice volume, surface salinity and nutrient dynamics (cf. e.g. Egan et al., 2012; Hendry et al., 2012; Maier et al. 2013). For the interpretation of the geochemical data obtained from siliceous microfossils and the understanding of the complex mechanisms ecological information (e.g. depth habitat) of living species in combination with hydrographic data, chlorophyll and nutrient measurements as well as stable isotope data ($\delta^{30}Si$, $\delta^{18}O$) from the water column (surface to bottom) are needed.

Any of the above proxy methods is critically dependent on their established relationship to actual tracers and quantitative parameters in the modern ocean. Especially the subpolar and polar Southern Ocean is seriously undersampled both in the water and sediment domain, thus remains in critical need for precise calibration of proxies under modern conditions, next to the necessity for validating and mechanistically understanding the proxydata — instrumental data relationships. Previous works in the Southern Ocean have so far mostly focussed only on the subpolar Atlantic sector and the Weddell Sea, thereby leaving large areas upstream the ACC towards the Pacific effectively unsampled. We aim to close this gap and supplement existing water and sediment surface data (e.g. Mackensen, 2012), using the acquired samples to refine existing, or establish new proxy calibration datasets. Particularly in this study region, a focus will be put on (1) locations along the subantarctic and mesopelagic Chilean margin due to its importance for the export Southern-sourced intermediate to deep water masses into the South Atlantic and (2) on the Drake Passage transect to better resolve North — South physical and chemcial oceanographic gradients across the ACC.

Work at sea

Our work at sea focuses on three different sampling programs and corresponding activities to track the siliceous and calcareous microfossil proxy carriers from their respective habitats (water column/sediment surface/fluff) into the sedimentary taphocoenosis:

(1) Water column sampling

We will sample water hydrocast deployments with the CTD rosette system on selected stations for characteriziation of modern physical (T, S, $\delta^{18}O$) and chemical (PO_4, DIC, NO_3, Si, $\delta^{13}C$, $\delta^{30}Si$) oceanographic parameters. The anticipated number of stations we target corresponds to the hydrocast stations along the track of the Cape Horn current and the cross-pofile over the northern limb of the ACC in Drake Passage. Additional stations along the cruise track may be sampled depending on time permitting. In total a maximum of 400-500 samples will be taken, corresponding to 20-40 hydrocast stations, depending on the deployment of either 2x12 or 24 bottle profiles. The needed sample volume taken per Niskin bottle is small with ca. 1-2 liter, subdivided into 50 ml for DIC concentrations and $\delta^{13}C_{DIC}$, 50 ml for phosphate and nitrate concentrations, 100 ml for $\delta^{18}O$, plus 3x wash and overflowing water each. Samples will be taken immediately after recovery of the hydrocasts and be stored refrigerated (stable isotopes, silicate) or deep-frozen (nitrate, phosphate). Sample processing at sea requires space with a dedicated fume hood with sink due to the handling of toxic $HgCl_2$ solution to poison the samples for stable carbon isotope analyses of DIC.

Samples for measurements of silicate concentrations and $\delta^{30}Si$ will be taken on a smaller subset of samples due to the larger sample volume (8-10 liter) that is needed and the higher amount of preparatory work as these water samples need filtration before they are stored at 4°C. Priority for silicate system water sampling will be given to sites where the Multi-Net and also multicorer for surface sediment sampling will be deployed, with water depth sampling at depths similar to the multinet depth levels, to shed light on the relationship between hydrography, nutrient availability, isotope fractionation, species distribution and abundances of microorganisms.

Net community production (NCP) and community respiration (CR) will be measured as oxygen production and consumption using light/dark 125-ml biological oxygen demand (BOD) bottles incubated for 12 h (daylight). Three light and three dark bottles, taken from surface waters, will be incubated on deck (or under light and temperature controlled chamber) at selected stations during the PS97 track cruise. Oxygen concentration will be measured before and after incubation in all bottles using either the OxyMini optode system (World Precision Instruments) with the O -sensitive membrane glued to the inside wall of the BOD bottles or using the micro-Winkler (Dosimat) method.

(2) Collection of plankton samples from the water column via filtration and net tows

Collection of calcareous plankton samples from the water column will be performed by (1) filtration of vertical water profiles from hydrocasts, (2) continuous pumping of sea water, with focus on the surface waters (upper 5 m), and (3) a limited number of Multi-Net casts using an opening/closing net (multinet Type MPS 92 B, "Hydrobios" Kiel, Germany) over five precisely defined depth intervals of the upper 200-400 m of the water column, depending on the physical structure of the respective planktic habitat along the planned transects. Due to the location mainly along the subantarctic transect stations, we expect to generate sufficient catches of planktic foraminifera with one or two deployments to minimize the needed ship time on station (ca. 1-2 hr). Water column samples of 2-5 liters from the CTD casts and surface water (large volumes in the range of m^3) from the ship's uncontaminated sea water supply will be investigated along the ships track to understand how the habitats of phytoplankton and planktonic foraminifera are affected by the extreme environments of low water temperature, seasonal ice cover and large surface salinity variations and how information on these pelagic habitats are incorporated into microfossil remains of the plankton. Water samples will be transferred into canisters and vacuum filtered through polycarbonate membrane filters with a diameter of 47 mm and pore size of 0.45 µm. A filtration device (*sensu* Bollmann et al., 2002) will be installed. Filters will be dried and stored for investigations of the coccolithophore flora by shore-based scientists interested in the calcareous nannofossils. These pump samples of defined water volume will be obtained for the >32 µm sieve fraction, which later will be splitted, wet-sieved and counted in order to extract different planktonic foraminiferal species/morphotypes and size fractions. Specimens will be dried and kept in micropalaeontological slides.

The vertical distribution of siliceous microorganisms and their isotopic compositions will be documented on one or two selected stations in the Scotia Sea characterized by high productivity but not too close to the continental slopes to minimize bias by nepheloid flows. Radiolarians that live in surface and deeper water layers will be sampled at selected depth intervals in the uppermost 600 m by using the aforementioned Multi-Net Type MPS 92 B, "Hydrobios" Kiel, Germany. For the enrichment of radiolarians for isotope measurements, the multinet has to be deployed more often than for foraminifera tows, we recommend to undertake at least ten repetitive tows at the selected stations in the Scotia Sea, thus scaling up the needed ship time for these one or two stations to roughly 12 hr.

(3) Sediment surface sampling

Collection of surface sediment samples with a boxcorer and multicorers along the Chilean margin transect and across the Drake Passage transect are planned to characterize the transfer of habitat information into foraminifera, diatom and radiolarian tests as well as coccoliths prior to its integration and modification during transport into the deeper sediment, in order to facilitate the interpretation of paleoproxy records. We plan to sample a sufficiently large patch of box corer surfaces, where applicable (typically min. 20x20 cm) for analyses of the planktic and benthic foraminiferal faunae. Different planktonic foraminiferal dissolution proxies will be applied to evaluate the corrosiveness of deeper waters with respect to foraminiferal calcite. Initial biostratigraphic assessments and dating of surface sediments and long sediment cores will be carried out offshore based on calcareous nannofossil and planktonic foraminiferal evidences, whereby the presence and absence of species or specimens might already be indicative for warm cold climate regimes, respectively. Smear slides will be prepared on board and examined under a light microscope, even though vibration due the ships motors and swell may preclude precise stratigraphic interpretation relating on the smaller species. Moreover, the sedimentary record of calcareous nannoplankton south of the Subantarctic Front is supposed to be extremely poor.

Ethanol and rose Bengal will be used for sample conservation and later identification of benthic foraminifera specimen that were alive during sampling. For multicorer deployments, one tube each for planktic foraminiferal and nannofossil species assemblages, one for benthic foraminiferal faunal and foraminiferal geochemical analyses, and up to three for siliceous analyses need to be sampled as MUC-profiles in 1 cm sample intervals. In case of the benthic foraminiferal samples, the upper 10-15 cm will be sampled into plastic bottles and fixed with 98 % denatured Ethanol/rose Bengal solution for later onshore laboratory work on benthic microhabitat characterization. The remaining deeper parts of the MUC-profiles will be sampled into conventional sealable, plastic bags (Whirlpack®) down to the end of core.

Preliminary (Expected) Results

The research scheduled at sea will address several outstanding challenges with respect to nutrient biogeochemistry and the dynamics of the subantarctic Southern Ocean and the highly dynamic and narrow, jet-like structure of the Cape Horn Current under modern climate conditions. Regarding the respective nutrient inventories we expect to move towards a better characterisation of the link between major nutrient biogeochemistry with the organic carbon cycle. For the interpretation of isotope data from biogenic opal, this study represents a crucial prerequisite and it is among the first of such works explicitly designed to simultaneously cover surface, subsurface-intermediate and bottom water conditions. Our results wil be combined with complementary studies on surface sediment samples e.g. sortable silt size validations for oceanic current transport and provenance studies of terrigenous componenents in order to move towards a better application of quantitative proxies for the paleochemical and –physical characterization of upper and intermediate water masses in highly dynamic continental margin settings.

The planned experiments with both carbonaceous and siliceous microfossil groups will further indicate how simultaneous changes in multiple oceanic parameters might affect the productivity and the biodiversity of Southern Ocean phytoplankton and their bentho-pelagic coupling through time. The interactions of trace metals, organic matter supply, light as well as pCO_2 will hence provide a better understanding of the Southern Ocean primary producers and the response of benthic communities.

Data and sample management

Data collected during the cruise will be stored in the PANGAEA data repository. Data to be used in subsequent onshore works remain at the proprietory disposal of the shipboard and onshore PS97 Science Party members for a moratorium period of three years, after which they will be made publicly accessible, pending the finalisation of ongoing studies and publications. Samples not distributed among members of the shipboard and onshore PS97 Science Party members, or those returned after use, will be stored in the AWI Bremerhaven Marine Geology Core Repository for permanent access under established curation guidelines and be searchable via the PANGAEA/PanCore interface.

Links: http://www.pangaea.de/advanced/PanCore.php

http://www.awi.de/en/science/geosciences/marine-geology/tools/facilities/core-repository.html)

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05.	Hering, Igor	2.0ffc.
06.	Fallei, Holger	2.0ffc.
07.	Schmidt, Rüdiger	Doctor
08.	Fröb, Martin	Comm.Off
09.	Grafe, Jens	2.Eng.
10.	Krinfeld, Oleksandr	2.Eng.
11.	Holst, Wolfgang	3. Eng.
12.	Redmer, Jens	Elec.Tech
13.	Christian, Boris	Electron.
14.	Hüttebräucker, Olaf	Electron.
15.	Nasis, Ilias	Electron.
16.	Himmei,Frank	Electron
17.	Loidl, Reiner	Boatsw.
18.	Reise, Lutz	Carpenter
19.	Michaels, Jürgen-Dieter	A.B.
20.	Kittmann, Markus	A.B.rrr.
21.	Scheel, Sebastian	A.B.
22.	Hagemann, Manfred	A.B.
23.	Burzan, Gerd-Ekkehard	
24.	Brück, Sebastian	A.B.
25.	Wende, Uwe	A.B.
26.	Bäcker, Andreas	A.B.
27.	Grunenberg, Mark Jan	A.B.rrr.
28.	Preußner, Jörg	Storek.
29.	Teichert, Uwe	Mot-man
30.	Rhau, Lars-Peter	Mot-man
31.	Lamm, Gerd	Mot-man
32.	Schünemann, Mario	Mot-man
33.	Pinske, Lutz	Mot-man
34.	Müller-Homburg, Ralf-Dieter	Cook
35.	Silinski, Frank	Cooksmat
36.	Martens, Michael	Cooksmat
37.	Czyborra, Bärbei	1.Stwdess
38.	Wöckener, Martina	Stwdss/KS
39.	Dibenau, Torsten	2.Steward
40.	Silinski, Carmen	2.Stwdess
41.	Arendt, Rene	2.Steward
42.	NN	2.Steward
43.	Sun, Yong Shen	2.Steward
44.	Yu, Kwok Yuen	Laundrym.