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Förderkennzeichen:
03F0613A

Vorhabenbezeichnung:
ERANET EUROPOLAR: Verbundprojekt HOLOCLIP,
Vorhaben: Klimatische Signale während des Holozäns (Climate signals during the Holocene)

Laufzeit des Vorhabens:
01.01.2010-31.12.2012 (3 Jahre)

Berichtszeitraum:
01.01.2010-31.12.2012

Bremerhaven, 11. Februar 2013

Schlussbericht (*Final Report*)

I. Kurze Darstellung zu (*Short description of*)

1. Aufgabenstellung (*Tasks*)

The Individual Project 3 (IP3) "Climatic Signals during the Holocene" of the JRP HOLOCLIP focused on the climatic signals for the Holocene, which are archived in the Antarctic Ice Sheet in Dronning Maud Land (DML) and their relation to Holocene sediment composition in the Scotia Sea. Work should be done on ice cores and sediment cores, which had already been taken before. Within Antarctica, DML shows relatively high snow accumulation rates and therefore ice cores from DML can provide high-resolution time series for the Holocene.

2. Voraussetzungen unter denen das Projekt durchgeführt wurde (*Prerequisites under which the project was carried out*)

The project was carried out as Individual Project 3 (IP3) in the frame of the ERANET EUROPOLAR Joint Research Project HOLOCLIP (Climate signals during the Holocene). The JRP HOLOCLIP aimed to bring together the ice core, the sediment core and the modelling scientific communities to understand the processes linking different components of the climate system and linking climatic response to external forcing over the Holocene. The areas on which the European research efforts in Antarctica concentrated over the past decades are suited for integrating existing ice and marine records, in terms of amount and quality of collected materials.

3. Planung und Ablauf des Vorhabens (*Planning and performance of the project*)

The ice cores and sediment cores, which were analysed within the project, had already been drilled earlier. Therefore no additional field work was needed. The first two years of the project were dedicated mainly to lab work (stable isotopes for ice cores and XRF scanning, magnetic susceptibility, grain size, ^{14}C, ^{210}PB

for sediment cores), also making use of most of the budget for student assistants. During the third year the measurements should be interpreted in a common effort within HOLOCLIP and used as input data for climate models. The project was carried out more or less according to the proposal.

4. wissenschaftlichem und technischem Stand, an den angeknüpft wurde (*state of the art of science and technology when the project started*)

The large number of investigations, assessing changes in the Southern Hemisphere (SH) atmospheric temperature and circulation, have depicted a large warming over the western Antarctic Peninsula (a temperature increase of 2.5°C over the past 50 years); in contrast, no clear trends were observed for the other Antarctic regions. Parts of these temperature changes have been related to the increase in the intensity of the Southern Annular Mode (SAM) index over the past 30 years. Recently, a positive continent-wide near-surface temperature trend since the IGY in 1957/58 was reported. Regional differences of sea-ice variability were reported for the same period, with a sea-ice concentration decrease in the Bellingshausen and Amundsen Seas and an increase in part of East Antarctica and the Ross Sea. However, the direct (instrumental) climate records available for the SH are limited both in time and space. Only few proxy based reconstructions of the Holocene climate are available for the SH high latitudes compared with the NH.

Holocene climate variability reconstructions from Antarctic sediment cores (existing data) demonstrated changes at various timescales. At millennial scales, the Holocene can be separated in two multi-millennial periods, namely the warmer early-mid Holocene hypsithermal followed by the cooler neoglacial. The amplitude and timing of the transitions are regionally variable around Antarctica. A weakening of bottom water-circulation strength between 5 and 3 ka BP was observed in the Mertz drift (George V Land margin). It was attributed to changes in sea ice, polynyas, katabatic winds, and ocean circulation. At the sub-millennial timescale, cyclic, large amplitude climate changes were identified. They are thought to be forced by solar activity and oceanic circulation. We still do not know whether higher frequency climate modes (e.g. ENSO, Antarctic Dipole) existed during the Holocene because of the lack of ultra-high resolution records.

References supporting the scientific case

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5. Zusammenarbeit mit anderen Stellen (*cooperation with other institutions*)

The main cooperation with other institutions was the cooperation with the partners of the JRP HOLOCLIP:

IP 1: University of Trieste, Italy (Barabara Stenni)
IP 2: University of Bordeaux, France (Xavier Crosta)
IP 3: Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Germany (Hans Oerter/Gerhard Kuhn))
IP 4: University of Granada, Spain (Carlota Escutia)
IP 5: University of Amsterdam, Netherlands (Hans Renssen)
IP 6: University of Louvain, Belgium (Hughues Goosse)
IP 7: University of Cardiff, UK (Jennifer Pike)

II. Eingehende Darstellung (*detailed description*)

1. der Verwendung der Zuwendung und des erzielten Ergebnisses im Einzelnen, mit Gegenüberstellung der vorgegebenen Ziele (*description of the use of the provided budget and the results, including a comparison with the proposed aims*)

Personnel costs for student assistants were the main share of the whole budget. In total the budget allowed to employ student assistants for 28 months. 14 months were used for the ice-core work and 14 month for the work with the sediment cores.

In addition, some costly consumables for the isotope analyses were covered by the budget of the project, syringes and IAEA water-isotope standards, as well as the measurements of ^{210}PB on sediment samples.

The analysis of ^{14}C on sediment samples had to be done commercially by "Leibniz-Labor für Altersbestimmung und Isotopenforschung" at Kiel University, Germany.

Part 1: Ice cores

The work with the ice cores was twofold. At first the ice cores had to be cut in the cold lab (-20°C) to get the right sample size, and second those samples had to be analysed with respect to the stable isotopes δ^{18}O and δD. For the isotope analyses a Finnigan-DeltaS mass spectrometer and two more recently developed PICARRO liquid water analysers (Li-1102i and Li-1210i) were used.

The ice cores (drilled around Kohnen station (Oerter et al., 2009)) which were analysed are listed in Table 1.

Ice core ID (length)	**Longitude**	**Latitude**	**Elevation**	**Depth interval measured within HOLOCLIP**	**Amount of 50cm samples**	**Amount of high resolution samples**
EPICA-EDML (2774m)	0.0678°E	75.0017°S	2892m	12-114m	200	1384
B34 (200m)	0.066917°E	75.000783°S	2892m	0-110m	400	4407
B37 (123m)	0.078683°E	75.000517°S	2892m	0-57m	92	1520
B31 (115m)	3.430333°W	75.5815°S	2680m			
B32 (150m)	0.007000°E	75.002333°S	2892m			
B33 (130m)	6.498500°E	75.167000°S	3160m			
B25 (181m)	45.72433°W	79.614167°S	866m			

Table 1: Ice cores used within HOLOCLIP: Coordinates (WGS84) and samples, which were measured by HOLOCLIP IP3 (AWI).

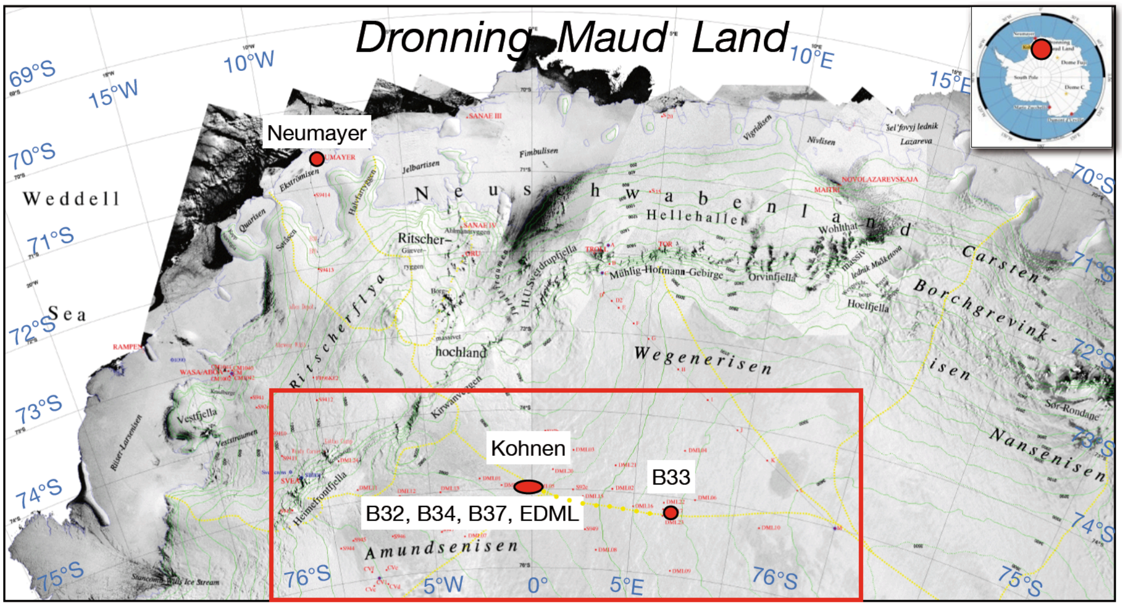

Figure 1: Map showing the location of the ice cores used within HOLOCLIP. (Satellite Image Map Dronning Maud Land 1:2 000 000, Draft Vers. 4.2, BKG, Frankfurt am Main, Nov. 1998 (detail), modified)

The cutting of the samples had been finished according to the proposed schedule in the first year. Due to technical problems in the isotope lab the isotope analyses had been slightly delayed according to the original milestones.

So far the topmost 114 m from the deep EDML ice core (EPICA Community members, 2006) had not been measured. Older data of AWI-ice cores B31, B32, B33, and B25 as well as the already published 200-years time series of firn cores (Oerter et al., 2000) drilled in the 1997/98 season were archived at data base PANGAEA and provided within HOLOCLIP as input for climate modelling of the past two millennia. Also the new data were provided as soon as they had been available.

Thus, data of IP3 were used by the modelling work of H. Goosse et al. (2012): Antarctic temperature changes during the last millennium: evaluation of simulations and reconstructions. *Quaternary Science Reviews* **55,** 75-90 (2012).

The main outcome of the isotope work on ice cores from Dronning Maud Land (Fig. 1) can be summarized by the following graphs.

Figure 2 shows as an example for the other cores those data, which were used for ice core B34 (Tab. 1 and Fig. 1). These are depth profiles of the high-resolution $\delta^{18}O$ values (proxy for temperature variations) and electrical conductivity (indicator for volcanic events and used to synchronize the ice cores). A unique pattern for dating and synchronization are the volcanic events of Tambora (eruption 1815) preceded by an unknown volcano six years earlier and the unknown volcano from 1258, which was followed by three other very distinct volcanic peaks. Earlier than 1258 the pattern of volcanic signals is not as unique as in later times.

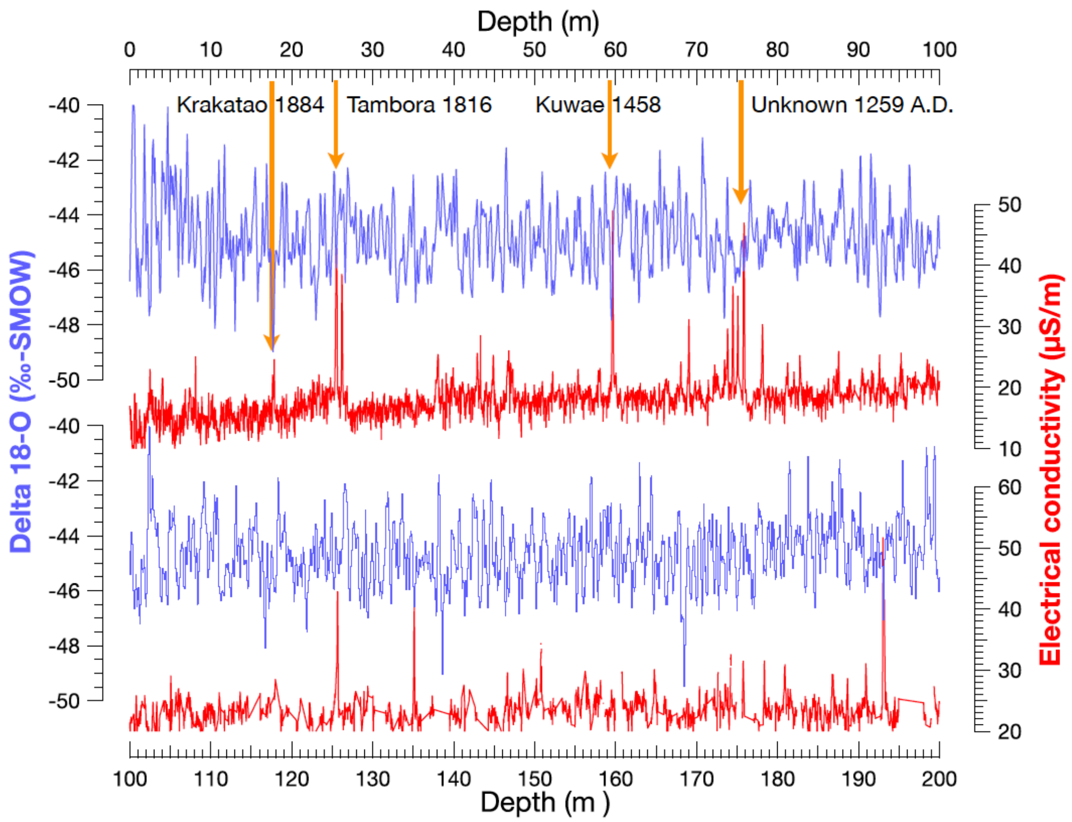

Figure 2: Ice core B34: $\delta^{18}O$ and electrical conductivity (measured by di-electric profiling, DEP) plotted against depth. The yellow arrows indicate major volcanic events and the years when the volcanic aerosols had been deposited in the Antarctic snow. The depth resolution for the $\delta^{18}O$ data is 10 cm, 6.67 cm and 5 cm for the depth intervals 0-50 m, 50-100 m and 100-200 m, respectively.

Figure 3 shows the profiles of the electrical conductivity from the five ice cores

B33 (Oerter et al., 2000), EDML, B34, B37 and B32 (Oerter et al., 2000). At ice core B32 also sulphate concentrations had been measured to prove that the peaks in the electrical conductivity profile are caused by nss-sulphate peaks. Thus the electrical conductivity provides good means to indicate volcanic events (Traufetter et al., 2004). To eliminate the influence of increasing density with depth and to get comparable depth scales, the depth scales were converted into water equivalent (w.e.) scales.

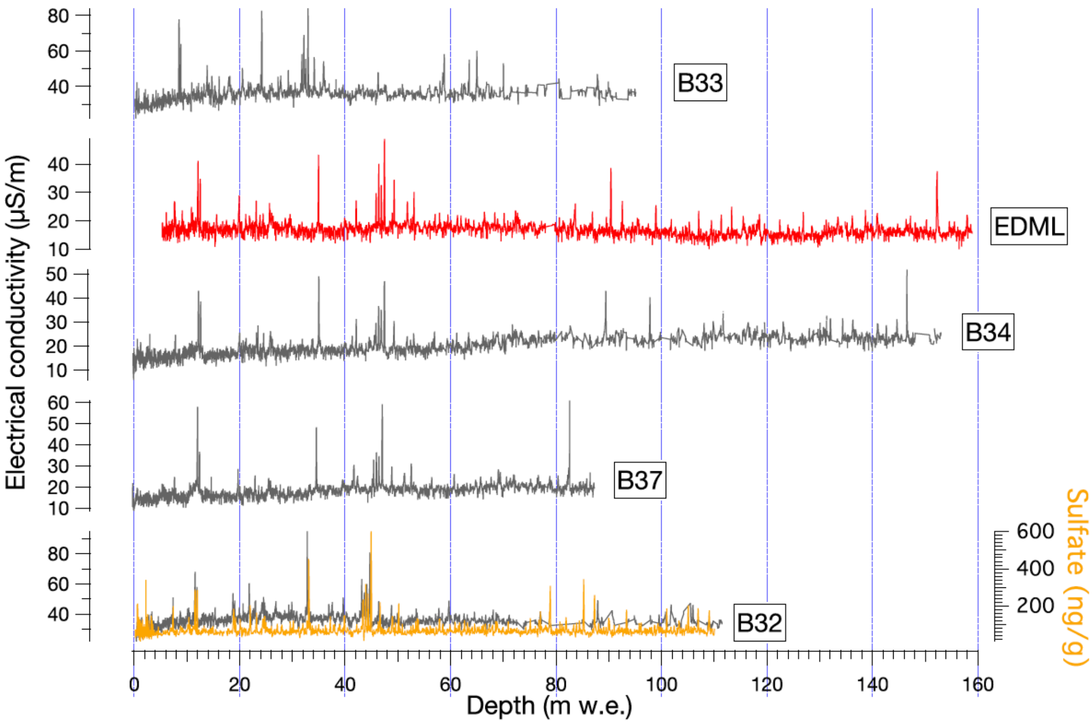

Figure 3: Profiles of electrical conductivity (measured by di-electric profiling, DEP) plotted against depth in metres water equivalent (m w.e.) for ice cores B33 (Oerter et al., 2000), EDML, B34, B37 and B32 (Oerter et al., 2000). For B32 the nss-sulphate concentrations are also shown (Traufetter et al., 2004). DEP data are available in PANGAEA for B32 (doi:10.1594/PANGAEA.58815), B33 (doi:10.1594/PANGAEA.58816). Data for B34, B37, and EDML are so far unpublished.

To synchronize the five ice cores the years 1816 and 1259 were used as the main reference horizons. Figure 4 shows the resulting synchronized profiles. Long term mean accumulation rates at EDML, B34, B37 and B32 are almost equal (63-65 kg $m^{-2}a^{-1}$) whereas at the B33 site the accumulation is much smaller (47 kg $m^{-2}a^{-1}$).

This adjusted depth scale was adopted to the isotope records. All isotope data were resampled to a common depth interval of 65 mm w.e. using the AnalySeries 2.0 software (Paillard et al., 1996). Afterwards the deviation from the mean value for the period 1259-1816 was calculated. The results are plotted in Figure 5. The mean values for EDML (-44.98 ‰), B37 (-45.07 ‰), B34 (-44.81 ‰) are in good agreement with an overall mean of -44.95 ±0.13 ‰.

The single isotope records are quite different from each other due to the spatial variability of the isotope content in the accumulated snow layers. To overcome this difficulty a composite record was calculated which is displayed in Figure 6.

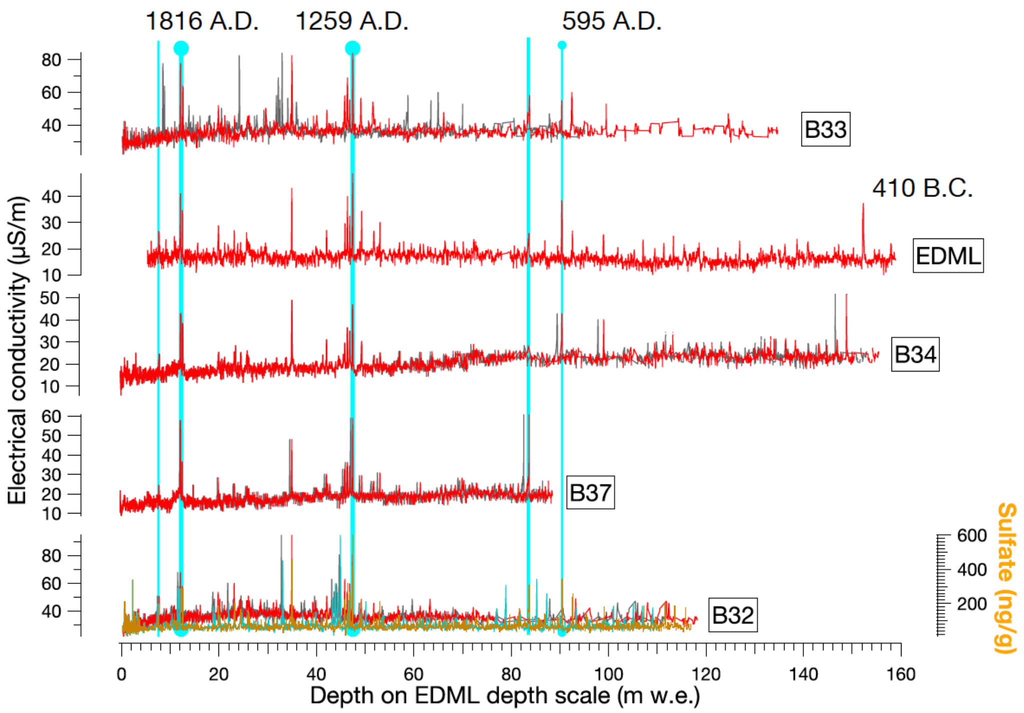

Figure 4: Electrical conductivity (measured by di-electric profiling, DEP) of the cores B32, B34, B37, EDML, and B33 (cf. Fig. 3). The grey curves show the original depth profile, the red curves were adjusted to fit in depth (given in metre water equivalent) or time, respectively, with the dated EDML record. The EDML1 age scale (Ruth et al., 2007) will later be used as the reference age scae. The blue and yellow curves in the lowest panel show the original and adjusted depth profiles of nss-sulfate concentrations for core B32 (Traufetter et al., 2004). The zero depth equals January 2000.

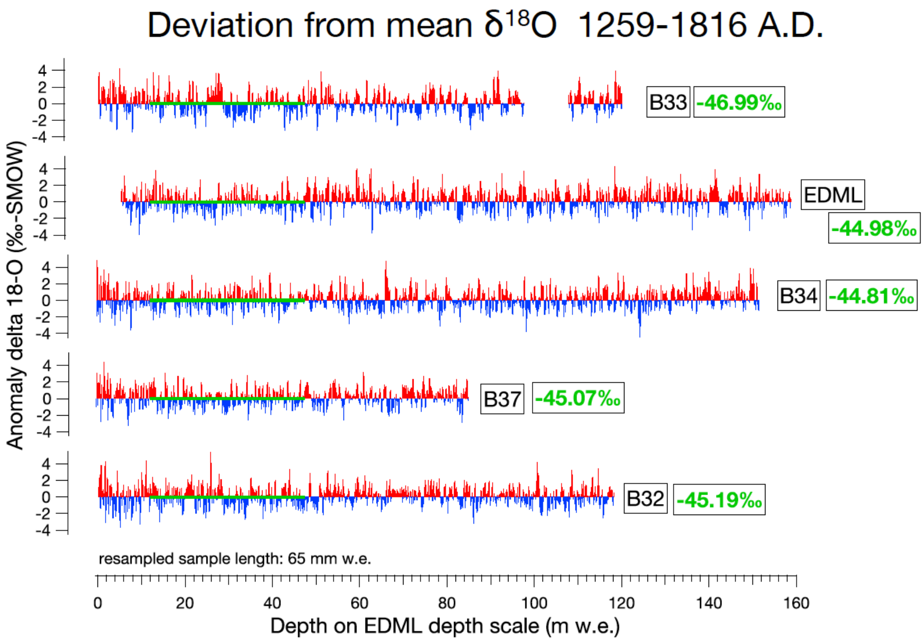

Figure 5: Anomalies of $\delta^{18}O$ content for cores B32, B34, B37, EDML, and B33 (for location see Fig.1). Shown is the deviation from the mean value for the period 1259-1816 (indicated by green horizontal bars; 47.45-12.10 m w.e.). The numerical value of the mean is displayed in green. Isotope data for B32 (doi:10.1594/PANGAEA.104862) and B33 (doi:10.1594/PANGAEA.728240) and EDML (doi:10.1594/PANGAEA.754444) were taken from the PANGAEA data base www.pangaea.de) The isotope data for B34 (unpubl.), B37 (unpubl.) and the topmost 113m (80m w.e.) of the EDML core were measured within the HOLOCLIP project (http://www.holoclip.org/).

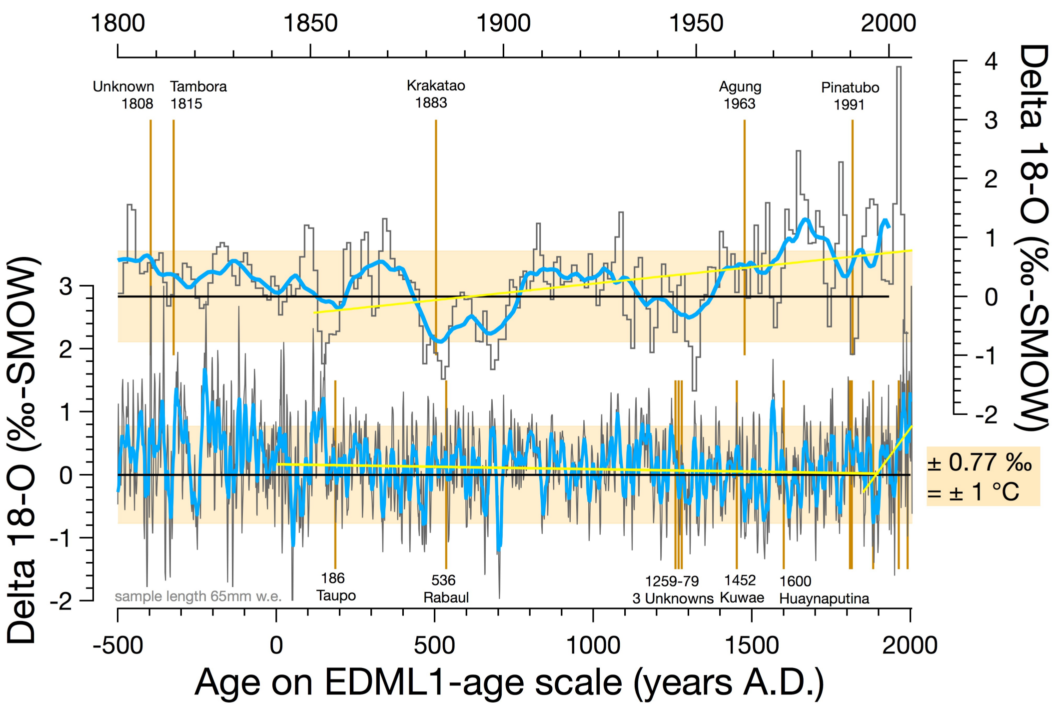

Figure 6: Stacked anomalies of $\delta^{18}O$ content (mean 1259-1816) for the periods 500 B.C. - 2005 A.D. (lower axis) and 1800-2005 A.D. (upper axis) on the EDML1-age scale (Ruth et al., 2007) Shown are in grey colour the composite from 5 cores (B32, B34, B37, EDML, B33) and with a bold blue line the moving average over 11 samples. The vertical bars mark selected volcanic events. The ochre coloured area marks a temperature variation of ±1°C using the local isotope-temperature gradient of 0.77 ‰/°C (Graf et al., 2002). The yellow lines are linear regression lines for the periods 1-1900 A.D. and 1850-2005 A.D., respectively.

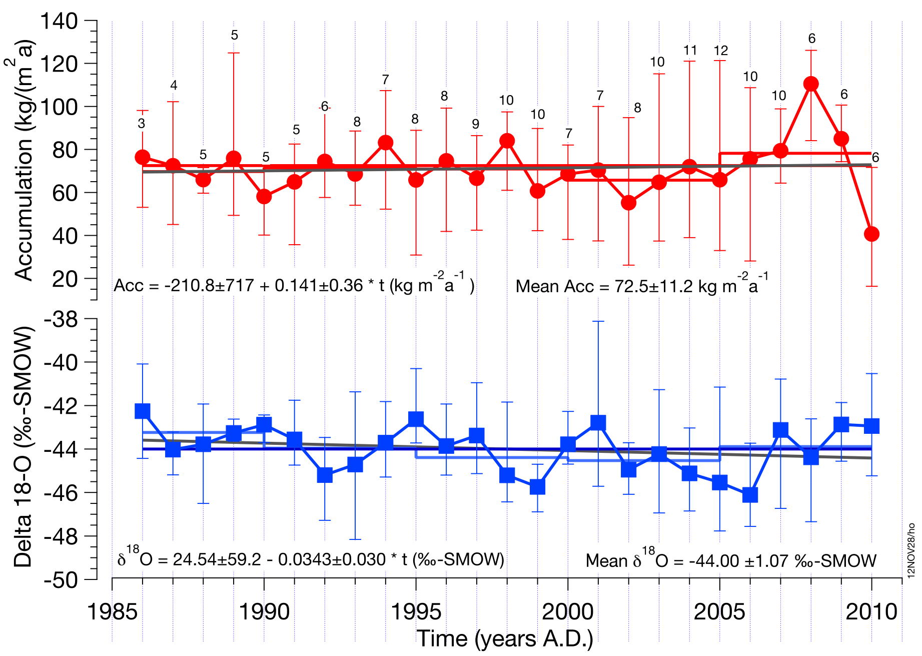

Figure 7: Mean annual accumulation (upper panel) and mean annual $\delta^{18}O$ content (lower panel) for the period 1986-2010. The numbers of overlapping yearly layers are given in the upper panel above the bars, which show the observed maximum and minimum values for the respective yearly layer. 5-year averages are plotted for both accumulation and isotope content as well. The grey curves represent linear fits.

Longer periods with positive anomalies occurred during the Roman period (before A.D.) and during the medieval times (appr. 1050-1250 A.D.). For the time 1-1900 A.D. one can recognize a slight cooling trend of 0.08 ‰/100a. This trend would increase if one starts earlier in the Roman period. Starting at 1850 up to 2005 one observes a warming trend of 0.68 ‰/100a. The warming was interrupted from 1870-1900 and during the 1940ies and 1980ies. Most of the volcanic events in low latitudes were followed by a temperature decrease through the next 1-3 years.

There is still a controversial discussion about whether or not global warming can be detected in East Antarctica. Between December 1997 and January 2011 20 snow pits were dug in the surroundings (radius approximately 3 km) of Kohnen station and sampled for isotope analysis with a depth resolution between 1.5cm and 5cm. The summarizing results are shown in Figure 7. Linear fits for accumulation and $\delta^{18}O$ content do not show a significant trend. However, for the year 2008 an outstanding accumulation rate was found in all six snow pits dug in January 2011. For the period 1986-2010 the mean $\delta^{18}O$ content equals -44.00 ±1.07 ‰-SMOW, which is 1 ‰-SMOW higher than the average $\delta^{18}O$ content of the four closest cores (B32, B34, B37 and EDML) for the period 1259-1816 (-45.01 ±0.16 ‰-SMOW) (cf. Fig. 5). The mean accumulation rate calculated from the pit study is 72.5 ±11.2 kg $m^{-2}a^{-1}$ whereas the cores showed 62.3 ±1.9 kg $m^{-2}a^{-1}$ for the period 1259-1816. This indicates that for the past 25 years both isotope content and accumulation rate are well above the long-term average for 1259-1816.

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Part 2: sediment cores

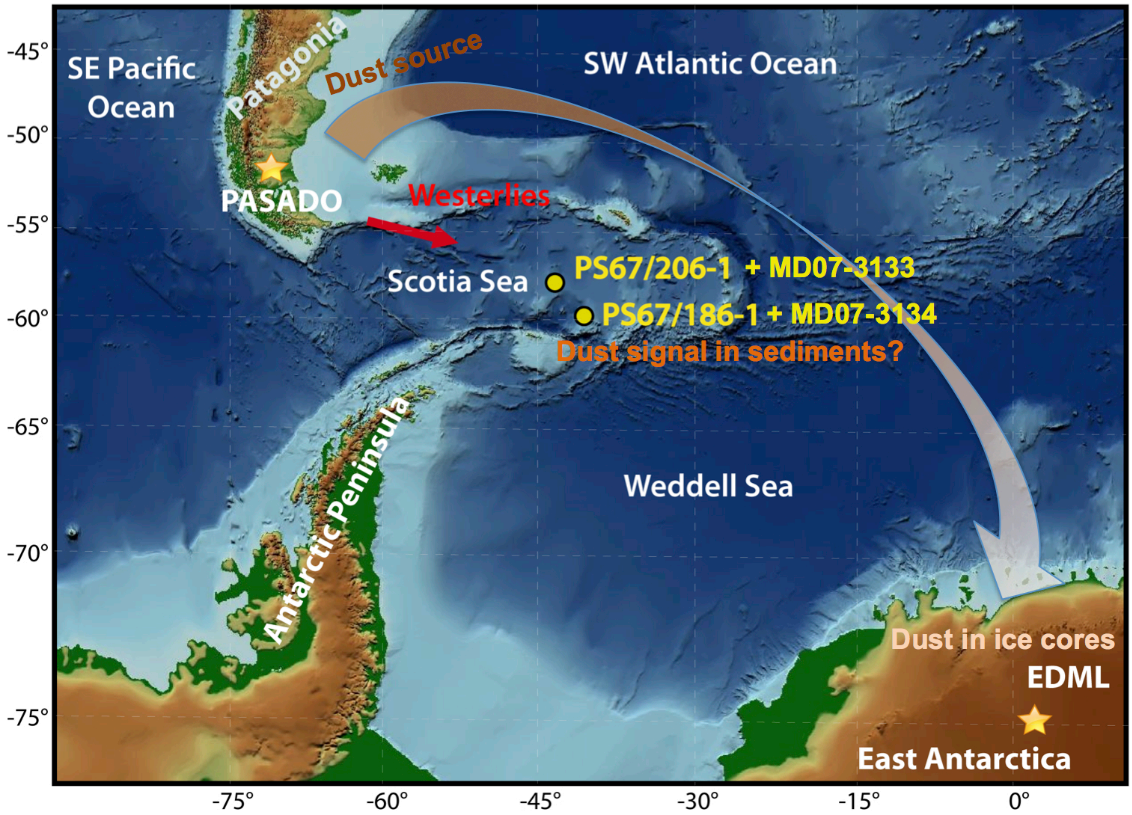

Figure 8: The sediment cores from the Scotia Sea are positioned below the trajectories for dust from Patagonia to Antarctica. The resolution of the map does not allow to distinguish between the sites of the PS cores and the DM cores.

Core	Latitude	Longitude	Water depth (m)	Recovery (m)
PS67/186-1	59°30'S	41°20'W	3671	23.8
PS67/206-1	57°25'S	43°28'W	3206	23.7
MD07-3133	57°26'S	43°27'W	3101	32.8
MD07-3134	59°25'S	41°28'W	3663	58.2

Table 2: Metadata of sediment cores used for HOLOCLIP IP3 (AWI).

For the two POLARSTERN sediment cores PS67/186-1 and PS67/206-1 age determination was done by radiocarbon ^{14}C and ^{210}Pb isotopes. The sediments contain no dateable organic carbonate, therefore a differentiated radiocarbon determination on the alkali-soluble (humic acid) and insoluble (residue, humin) organic fraction was performed (Tab. 3). Both cores show ^{14}C ages too old already on their tops. The ^{210}Pb data indicate that they are younger than about 100 years. Reworking of old carbon in both the residual but also in the humic fraction (which normally gives more reliable dates) produces ages, which are too old. Also the age differences of both measurements vary showing that the reworking of old carbon was not uniform during time. The age models could be interpolated from the ^{14}C ages of the humic fraction subtracting the upper ages as reservoir values (PS67/186-1 2210 years, PS67/206-1 2360 years) from the deeper values and applying the regular ^{14}C calibration (Data from PS67/206-1

Sediment core ID	Depth interval (cm)	Residue ^{14}C age (a)	error (a)	Humic acid ^{14}C age (a)	error (a)
PS67/186-1	16 - 18	8090	±30	2210	±25
PS67/186-1	472 - 474			6200	±30
PS67/186-1	676 - 679	11970	±45	7485	±35
PS67/186-1	702 - 704			8270	±35
PS67/186-1	811 - 813	15220	±80	9455	±40
PS67/186-1	1009.5 - 1011.5	25170	±140	16400	±160
PS67/206-1	0 - 5	3445	±35	2360	±35
PS67/206-1	157 - 160	4630	±40	3370	±35
PS67/206-1	365 - 368	6000	±40	4180	±50
PS67/206-1	862 - 865	7650	±60	5710	±40
PS67/206-1	1557 - 1560	10440	±60	8470	±50
PS67/206-1	2358 - 2362	15190	±120	11990	±90

Table 3: Radiocarbon ^{14}C ages from sediment core PS67/186-1 and PS67/206-1.

are published in the PhD thesis from Wenshen Xiao, Data from PS67/186-1 after calibration, will be transferred to the PANGAEA Data base)

In addition to POLARSTERN cores PS67/186-1 and PS67/206-1 we added two long piston cores to our investigations, which recovered also a thick Holocene sequence and were taken by RV MARION DUFRESNE (MD07-3133 and MD07-3134) in the Scotia Sea close-by.

We were able to correlate the non-sea-salt Ca^{2+} signal from the EDML ice core, that was interpreted as a dust signal by Fischer et al. (2007), with the volume magnetic susceptibility signal of these nearby long and high resolution sediment cores. These results were published by Weber et al. (2012) and provide a good stratigraphic control for the Last Glacial Maximum and Holocene transition that will be of great value for the HOLOCLIP work. During the evaluation of the ^{210}Pb analyses we noticed that recalibration is necessary to correct the ^{210}Pb activities for the high sea-salt content of the samples. Basic parameters like water content of the samples are needed for these recalculations that are still due (some measurements are still missing, because of construction work in the geochemical laboratory of AWI) for a decent Holocene age model of the two sediment cores.

Biogenic opal is the main biogenic sediment component and ranges between 30 and 70 % (mass) in the Holocene sediments. Organic carbon and biogenic Opal are both indicators for paleoproductivity that show fast changes interpreted as paleo-environmental variability in a paper by Sprenk et al. (in press) about Southern Ocean bioproductivity during the last glacial cycle.

The accumulation of iceberg rafted debris (IBRD) detected in the sediment cores gave a record of the variability of iceberg related sediment transportation. This could be related to the ocean - ice sheet interaction and ice sheet destabilisation after the Last Glacial Maximum (LGM) and during the Holocene. We identified the Antarctic ice sheet to be sensitive to forcing related to sea level and ocean heat flux. Ice-sheet sensitivity is also crucial to ice-sheet and climate modellers with respect to developing improved projections for future sea-level rise based on the modern Antarctic ice sheet. Our partly revised chronology for

Antarctic deglaciation is also required to improve our understanding of the long-term glacial isostatic adjustment (GIA). Estimations about the variability and the decay history of the Antarctic ice sheet and associated sea level rise are a very important issue scientifically but also for public policy. We detected a clear IBRD signal at 11.3 ka, synchronous to meltwater pulse (mwp) 1b. This actually is a hot topic and was accepted for review in Science (Weber et al., in review).

Grain size investigations on selected samples from the Holocene and LGM are processed in cooperation with Nick McCave, University of Cambridge, to indicate ACC strengths and variability. No significant differences between LGM and Holocene non-biogenic sortable silt mean grain-size were detected.

In cooperation with Italian HOLOCLIP partners (Ester Colizza and Massimo Presti) we measured sediment cores from off Wilkes Land with the AWI XRF-core-scanner. A manuscript about elemental proxies for paleoceanographic variability is in preparation and presentations were given by Colizza et al. (2012, 2013)

References:

Fischer, H. et al. (2007): Reconstruction of millennial changes in dust transport, emission and regional sea ice coverage using the deep EPICA ice cores from the Atlantic and Indian Ocean sector of Antarctica. *Earth and Planetary Science Letters* **260**, pp. 340-354 .

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Sprenk, D. et al. (in press): Southern Ocean bioproductivity during the last glacial cycle – new detection method and decadal-scale insight from the Scotia Sea. In: *Antarctic Palaeoenvironmental Evolution.* – Geological Society of London, Special Publications.

Weber, M.E. et al. (2012): Dust transport from Patagonia to Antarctica – a new stratigraphic approach from the Scotia Sea and its implications for the last glacial cycle. *Quaternary Science Reviews*, **36**, 177-188, doi: 10.1016/j.quascirev.2012.01.016.

Weber, M. E., Clark, P. U., Kuhn, G., Timmermann, A., Sprenk, D., Gladstone, R., Zhang, X., Lohmann, G., Menviel, L., Chikamoto, M., Friedrich, T. (in review): Millennial-scale variability of the Antarctic Ice Sheet throughout the last deglaciation. *Science*.

2. der wichtigsten Positionen des zahlenmäßigen Nachweises (*major shares of the budget*)

The total budget of IP3 was limited to only 45 k€ to fit within the given budget of the ERANET EUROPOLAR project HOLOCLIP.

Half of the budget was used for personnel costs, i.e. student assistents (28 month).

The two other big shares of the budget of ca. 8 k€ each were costs for radio-isotope analyses and travel costs.

3. der Notwendigkeit und Angemessenheit der geleisteten Arbeit (*need and suitability of the work carried out*)

The need for our work is founded in the benefit for understanding natural climate related processes around Antarctica during a time (Glacial - Holocene transition) of high gradient warming and with respect to the ice cores especially the past 2000 years. Questions of ice sheet stability and sea level rise are related to our work. Unfortunately, the younger parts (past 2000 years) of the sediment cores, where we have a time overlap with the well dated records seen in the ice cores from Dronning Maud Land, are quite invariable and not well dated up to now to get a good correlation. Therefore we work also on cores from the Maxwell Bay area (King George Island) where higher resolution Holocene sediments were recovered.
Our scientific output from this project would have been even greater under a less restricted budget (due to ERANET EUROPOLAR programme specifications) providing funding also for scientific man power in addition to the technical support (mainly for student assistants).

4. des voraussichtlichen Nutzens, insbesondere der Verwertbarkeit des Ergebnisses im Sinne des fortgeschriebenen Verwertungsplans (*usability of the results*)

The ice core data contribute to the present discussion of the global climate variability during the past 2000 years.

Ocean thermal forcing is apparently a key player in Antarctic ice sheet disintegration today, yet it is not well implemented into any of the Intergovernmental Panel on Climate Change (IPCC AR4 report, 2007) scenarios, although it holds the potential to contribute substantially to future sea-level rise.

Our study changes perceptions of Antarctic ice-sheet history in some aspects. A new reconstruction on the contribution of Antarctic ice sheets to meltwater pulses during the natural sea-level rise after the LGM includes previously unknown instabilities in the East Antarctic Ice Sheet (EAIS) and other parts of the Antarctic Ice Sheet. Thus, our findings will influence projections for future sea-level rise, mainly through invoking higher contributions by so-called 'ocean thermal forcing'. Since 90 % of the world's population lives within 200 km of the coast in urban regions that manage the globally-networked trade through shipping, those centres will be heavily impacted by a fast future sea-level rise, which is considered one of the most dangerous threat for mankind among all possible impacts of climate change. Our findings will help improving the model predictions, which again, will help to reduce the costs for adaptation measures. In this respect, we consider our findings economically and socially very valuable.

5. des während der Durchführung des Vorhabens dem ZE bekannt gewordenen Fortschritts auf dem Gebiet des Vorhabens bei anderen Stellen (*advanced knowledge of other groups gained during the project period*)

With respect to climate variability during the past 2000 years PAGES[1] established working groups to study climatic variations separately for each continent. A common publication summarizing the results for each continent was submitted to *Nature Geoscience* and is at present in review. The PI of HOLOCLIP IP3 is a member of the Antarctica2k group.

6. der erfolgten oder geplanten Veröffentlichungen des Ergebnisses nach Nr.11 (Publications)

Poster and talks at conferences:

Colizza, E., Finocchiaro, F., **Kuhn, G**., Langone, L., Melis, R., Mezgec, K., Severi, M., Traversi, R., Udisti, R., Stenni, B., and Braida, M. (2013): Late Holocene sedimentation in coastal areas of the northwestern Ross Sea (Antarctica). Geophysical Research Abstracts, Vol. 15, European Geoscience Union, General Assembly, Vienna, EGU2013-8804 (poster)

Oerter, H. , Kipfstuhl, S. , Meyer, H. and Wilhelms, F. (2011): Stable isotope records for the past 2000 years from four (five) ice cores in central Dronning Maud Land, Antarctica, XVIII INQUA-Congress, Bern, Switzerland, July 2011. hdl:10013/epic.37117 (talk)

Oerter, H. , **Kipfstuhl, S.** and **Wilhelms, F.** (2011): Stable isotope records for the past 1000 years from five ice cores in Central Dronning Maud Land, XXV IUGG General Assembly, 28 June - 7 July 2011, Melbourne, Australia. hdl:10013/epic.38276

Oerter, H. , **Kipfstuhl, S.** and **Wilhelms, F.** (2012): Stable isotope records for the past 2000 years from ice cores in central Dronning Maud Land, Antarctica., EGU General Assembly 2012, Vienna, Austria, 23 April 2012 - 27 April 2012. hdl:10013/epic.38935 (talk)

Oerter, H. (2011):Shallow firn cores and stable isotopes used as a tool to detect climate change during the past 50 years in Dronning Maud Land, 5th Malaysian International Antarctic Seminar, Kuala Lumpur, Malaysia, 15. June 2011. hdl:10013/epic.36929 (invited talk)

Oerter, H., Kipfstuhl, S. and Wilhelms, F. (2012): Stable isotope records for the past 2000 years from ice cores in central Dronning Maud Land, Antarctica, XXXII SCAR Open Science Conference, Portland, Oregon, Hilton Hotel, 16 July 2012 - 19 July 2012. hdl:10013/epic.39810 (poster)

Oerter, H., Kipfstuhl, S. and Wilhelms, F. (2012): Stable isotope studies on ice cores and snow pits in DML, Antarctica, covering the past 2000 years, AGU Fall Meeting, San Francisco, California, USA, 3 December 2012 - 7 December 2012 . hdl:10013/epic.40525 (poster)

Sprenk, D., Weber, M.E., **Kuhn, G.,** Rosén, P., Röhling, H.-G. (2012): Bioproductivity in the Southern Ocean since the last Interglacial – new high-resolution biogenic opal flux records from the Scotia Sea. Geophysical Research Abstracts, Vol. 14, European Geoscience Union, General Assembly, Vienna, EGU2012-10939 (poster)

[1] The PAGES (Past Global Changes) project is an international effort to coordinate and promote past global change research. PAGES is a core project of IGBP and is funded by the U.S. and Swiss National Science Foundations and NOAA.

Papers

Goosse, H. , Braida, M. , Crosta, X. , Mairesse, A. , Masson-Delmotte, V. , Mathiot, P. , Neukom, R. , **Oerter, H.** , Philippon, G. , Renssen, H. , Stenni, B. , Van Ommen, T. and Verleyen, E. (2012): Antarctic temperature changes during the last millennium: evaluation of simulations and reconstructions. *Quaternary Science Reviews* **55**, 75-90.doi:10.1016/j.quascirev.2012.09.003, hdl:10013/epic.40594

Weber, M.E., **Kuhn, G.,** Sprenk, D., Rolf, C., Ohlwein, C., and Ricken, W. (2012): Dust transport from Patagonia to Antarctica – a new stratigraphic approach from the Scotia Sea and its implications for the last glacial cycle. *Quaternary Science Reviews* **36**, 177-188, doi: 10.1016/j.quascirev. 2012.01.016.

PAGES 2k Consortium (in review): Continental-scale temperature variability over the Common Era. *Nature geoscience*.

Sprenk, D., Weber, M.E., **Kuhn, G.,** Rosén, P., Frank, M., Molina-Kescher, M., Liebetrau, V., Röhling, H.-G. (in press): Southern Ocean bioproductivity during the last glacial cycle – new detection method and decadal-scale insight from the Scotia Sea. In: *Antarctic Palaeoenvironmental Evolution*. – Geological Society of London, Special Publications.

Weber, M. E., Clark, P. U., **Kuhn, G.,** Timmermann, A., Sprenk, D., Gladstone, R., Zhang, X., Lohmann, G., Menviel, L., Chikamoto, M., Friedrich, T. (in review): Millennial-scale variability of the Antarctic Ice Sheet throughout the last deglaciation. *Science*.

III. Anlage: kurzgefasster Erfolgskontrollbericht (Appendix: Short success control report)

1. Beitrag zu förderpolitischen Zielen
   Die Arbeiten wurden im Rahmen des europäischen Programms ERA-Net EUROPOLAR ausgeführt und leistete einen Beitrag zur Klimavariabilität während des Holozäns in der Südhemisphäre, vor allem für den Zeitbereich der letzten 2000 Jahre.

2. Wissenschaftlich-technische Ergebnisse
   Die wissenschaftliche Ergebnisse beziehen sich auf die Klimavaribiltät der letzten 2000 Jahre sowie den Übergang vom Letzten Glazialen Maximum (LGM) in das Holozän. Es wurde bei den Laboruntersuchungen auf bewährte Messtechniken zurückgegriffen. Aus den Eiskernen konnte eine gestapelte Zeitreihe des $\delta^{18}O$-Gehalts (Temperaturproxy) für das zentrale Dronning-Maud-Land (DML) für die letzten 2000 Jahre aufgestellt werden. Die neu gewonnenen Daten sowie aus DML bereits vorliegende Daten wurden den Modellierern im HOLOCLIP-Projekt zur Verfügung gestellt. Aus den Sedimentkernen konnten, trotz Schwierigkeiten bei der Datierung, wichtige Rückschlüsse auf die Wechselwirkung zwischen Ozean und Eisschild in der Zeit des Übergangs vom LGM zum Holozän und während des Holozäns gewonnen werden, die den bedeutenden Einfluss eines sich verändernden Meeresspiegels auf die Stabilität des Antarktischen Eisschildes erkennbar werden lassen.

3. Fortschreibung Verwertungsplan
   Erfindungen/Schutzrechtsanmeldungen kommen nicht in Betracht. Die gewonnenen Messdaten werden nach endgültiger Veröffentlichung in die Datenbank PANGAEA eingegeben und stehen so allgemein zur Verfügung.

4. Arbeiten, die zu keiner Lösung geführt haben
   Die Datierung der Sedimentkerne bedarf noch einer weiteren Kalibrierung, da sich offensichtlich Umlagerungen im Sediment störend ausgewirkt haben.

5. Präsentationsmöglichkeiten für mögliche Nutzer
   Die bisherigen Ergebnisse wurden bereits auf mehreren internationalen Konferenzen vorgestellt (s. II.6). Die entsprechenden Publikationen in Fachzeitschriften sind in Bearbeitung.
6. Einhaltung der Kosten- und Zeitplanung
   Die Kostenplanung wurde eingehalten. Betreffs Zeitplanung wurden die geförderten Labormessungen zeitgerecht durchgeführt, die vollständige Veröffentlichung der Ergebnisse in Fachzeitschriften wurde nicht erreicht.

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	14. Tabellen 3
	15. Abbildungen 8

16. Zusätzliche Angaben ERANET EUROPOLAR Verbundvorhaben HOLOCLIP

17. Vorgelegt bei (Titel, Ort, Datum)

18. Kurzfassung

Im ERANET EUROPOLAR Verbundprojekt HOLOCLIP (Klimatische Signale während des Holozäns) arbeiteten europäische Gruppen, die Sedimentkerne aus dem Südlichen Ozean und antarktische Eiskernen bearbeiten sowie Klimamodellierer zusammen, mit dem Ziel, ein besseres Verständnis von den Klimaschwankungen im Holozän zu gewinnen. Das Teilprojekt 3 (AWI, Bremerhaven), trug Daten von Eisbohrkernen aus Dronning-Maud-Land sowie von marinen Sedimentkernen aus dem Scotiameer bei. Aus 5 Eiskernen wurde eine gestapelte Zeitreihe für $\delta^{18}O$ (Temperaturproxy) aufgestellt. Von 1-1900 AD ergibt sich ein leicht negativer Trend, von 1850-2005 AD ein positiver Trend (+0.68 ‰-SMOW/100a). Die jüngsten 25 Jahre sind zwar relativ stabil, aber gegenüber dem langfristigen Mittelwert (1259-1816 AD) um 1 $\delta^{18}O$-‰ erhöht. Es war schwierig die Sedimentkernen mit ^{14}C zu datieren, da offensichtlich organisches Material im Sediment umgelagert wurde und sich so zu alte ^{14}C-Alter ergaben. Die Messergebnisse der magnetischen Suszeptibilät an den Sedimentkernen des Scotiameeres bieten eine wichtige Kontrolle für den Übergang vom Letzten Glazialen Maximum (LGM) ins Holozän. Aus von Eisbergen transportiertem Material in den Sedimenten konnten wichtige Rückschlüsse auf die Wechselwirkung zwischen Ozean und Eisschild beim Übergang vom LGM zum Holozän und im Holozän gewonnen werden. Der Einfluss des sich verändernden Meeresspiegels auf die Stabilität des Eisschildes erscheint bedeutend zu sein.

19. Schlagwörter
Climate variability, ice cores, sediment cores, Holocene, LGM

20. Verlag	21. Preis

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16. Supplementary Notes ERANET EUROPOLAR JOINT RESEARCH PROPOSAL HOLOCLIP

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18. Abstract

Within the ERANET EUROPOLAR JRP HOLOCLIP (Climate signals during the Holocene) European groups worked together, who deal with sediment cores from the Southern Ocean and with Antarctic ice cores as well as climate modellers. The aim was to get a better knowledge of the climate variations during the Holocene. The Individual Project 3 (AWI, Brerhaven), delivered ice-core data from Dronning Maud Land as well as sediment-core data from the Scotia Sea. A composite $\delta^{18}O$ record (temperature proxy) was established by using 5 ice cores. From 1-1900 CE the $\delta^{18}O$ record shows a slightly negative trend, from 1850-2005 CE a positive trend (+0.68 ‰-SMOW/100a). The past 25 years are rather stable on a level that is 1 $\delta^{18}O$-‰ higher then the long term average (1259-1816 CE). It was difficult to date the sediment cores by ^{14}C. Obviously, the organic matter in the sediment had been reworked resulting in too old ^{14}C ages. We were able to correlate the nss-Ca signal from the EDML ice core (proxy for dust) with the volume magnetic susceptibility signal of the sediment cores from the Scotia Sea. These data provide a good stratigraphic control for the transition from the LGM into the Holocene. The accumulation of iceberg rafted debris (IBRD) detected in the sediment cores gave a record of the variability of iceberg related sediment transportation. This could be related to the ocean - ice sheet interaction and ice sheet destabilisation after the LGM and during the Holocene. We identified that the Antarctic ice sheet is very sensitive to forcing related to sea level and ocean heat flux.

19. Keywords

CLIMATE VARIABILITY, ICE CORES, SEDIMENT CORES, HOLOCENE, LGM

20. Publisher

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