WP1: Past polar climate and inter-hemispheric coupling (Rainer Gersonde, Hubertus Fischer)

We study polar processes as documented in sediment and ice-core records to understand past climate coupling and feedbacks for reliable forecasting of future changes.

Objectives and Challenges

WP1 research will enhance our knowledge of past polar climate-related processes as well as of meridional and zonal climate variability at colder (glacial) to warmer than present conditions at highest time resolution possible. WP1 will reconstruct and model abrupt changes, and attempt to quantify associated thresholds. The strategic approach of this research is to merge atmosphere and ocean signals from ice, marine and land (lake/permafrost) climate records at orbital, millennial, and up to decadal time scales to decipher their complex inter-relationship and impact, their relation with processes in low and middle latitudes, and the effect of external forcing. Data based scenarios that document the status and development of past climate will be tested with numerical models that simulate ice-atmosphere-ocean processes at regional and global scale. The studies will focus on the present warm period (Holocene), Pleistocene glacials and interglacials (particularly those with higher-than-present sea level such as Marine Isotope

Stages 5.5, 9.3, 11.3, 31), but also on cooling and warming periods in the Pliocene. Although the early Pliocene does not represent a perfect analog of a future warmer than present Earth it represents the most recent period in Earth's history when long-term climate was on average warmer (by ca. 3°C) and when northern ice sheet size as well as major ocean currents were similar to the modern situation. Key challenges for the study of past polar climate processes, feedbacks, teleconnections, and linkages to mid- and low-latitude regions include:

- to unravel past zonal climate linkages (e.g. between the North Pacific, the North Atlantic/Nordic Seas realm, and the East Asian Climate System around the Siberian High) as well as meridional operating mechanisms of bipolar climate teleconnections in order to understand their impact on global circulation modes (e.g. Atlantic bipolar seesaw) and climate signal propagation at decadal to orbital timescales during the Holocene, Pleistocene and Pliocene;
- to understand the mechanisms of polar ocean stratification and its impact on the biological productivity, carbon export and atmospheric CO_2, water mass formation, and ocean/atmosphere gas and heat exchange;
- to unravel the effect of dry arctic shelves on the climate system during glacial times, in respect to modified albedo conditions and vegetation cover and the climate relationships between glaciated and non-glaciated northern Eurasia;
- to estimate the potential impact of microbial methane emissions from permafrost soils and lake sediments on the atmospheric greenhouse gas inventory in the past as documented in polar ice cores.

Implementation

For integrated data collection and interpretation the WP1 objectives will be tackled by a group of terrestrial and marine geologists, geochemists, glaciologists, marine geophysicists and modellers located at AWI-Bremerhaven and AWI-Potsdam. Expertise on modern physical and biological processes as well as on global modelling comes from studies in PACES T1 and T4. The WP1 studies can rely on material and data established during the MARCOPOLI program and earlier activities with Polarstern, as well as from international ice core (EPICA), marine (ODP/IODP, ANDRILL, IMAGES) and continental (ICDP) drilling programs. During PACES additional new land, ice and marine climate records will be collected. Marine geological, geophysical and bathymetric sample and data gathering will focus on yet less explored areas in the polar North and South Pacific and the Arctic Ocean. New ice core records are expected from the Greenland NEEM drilling designated to document the yet unexplored Greenland climate variability during the Eemian as well as for the last deglaciation from higher resolution coastal Antarctic sites (e.g. Talos Dome). The potential of finding > 1.2 Ma old ice in Antarctica will be explored together with T1-WP1. Land-based expeditions will concentrate on locations in Patagonia, East Siberia, but also on the Tibetan Plateau. Together with sediments recovered from the Ross Ice Shelf embayment (ANDRILL) and the East Siberian El G´ygytgyn crater lake (ICDP), the WP1 related fieldwork will generate a new set of polar data and samples between the Arctic Ocean and West Antarctica across east Siberia, the polar North and South Pacific and Patagonia. The collection of echosounding and bathymetric data includes the development of an interdisciplinary Southern Ocean Geographic Information System (SOGIS) by integration of different marine and geoscientific data and models. These efforts represent a major pre-site survey contribution to the generation of IODP and Aurora Borealis polar ocean drill proposals.

The reconstruction of climate conditions at orbital to submillenial time scales will be based on a large stock of ice and sediment proxies, which allow for qualitative and quantitative estimations of physical ocean and atmosphere and biological productivity and export conditions. The testing and development of new proxies will accompany such multiproxy approach with well-established and innovative paleobiological, geochemical and sedimentological methods. Required high-resolution dating and correlation of ice, marine, and land climate records at highest accuracy possible will be achieved with stratigraphic methods including radiometric dating, cosmogenic isotopes and geomagnetic records.

Innovative steps will be made to combine data and modelling results. Earth system models will

include the atmosphere-ocean dynamics as well as biogeochemical cycles and the cryosphere (Topic 4). Transient simulations of the last deglaciation and the Holocene under appropriate forcing conditions will be performed. Motivated by recent ice core and marine sediment records, different Pleistocene interglacials will be simulated and compared with each other. Special emphasis will be on the validation through direct modelling of proxies as well as through the analysis of spatio-temporal patterns. Isotope modelling offers the possibility to obtain the direct information for the comparison with marine and terrestrial data. As a new activity, we will address the question of Northern Hemisphere glaciation during the Pliocene. Different hypotheses (North Pacific thermocline changes, ocean gateways, astronomical forcing) will be tested using a complex circulation model.

Many of the topics addressed in WP1 represent a continuation and integration of the MARCOPOLI additional funding project NEW KEYS in the new research programme PACES. NEW KEYS successfully established palaeoclimate and biogeochemical studies on polar ice cores over the last 5 years and has become an international reknown working group.

Milestones

- Decipher the polar mechanisms (ice-permafrost-ocean-atmosphere) and thresholds in triggering rapid (10^2-10^3 yr) climate changes during warm and cold climate conditions and compare the spatial and temporal evolution of such changes in both polar regions and their link with the low latitude development.
- Reveal mechanisms and timing of past bipolar climate tele-connections in the Arctic-North-South Pacific-Antarctic sector and their relation to the Atlantic “bipolar seesaw”.
- Describe past zonal climate linkages e.g. between the North Pacific, the North Atlantic/Nordic Seas realm, and the Asian Climate System around the Siberian High.
- Study the Pleistocene linkage of climate and biogeochemical cycles on orbital time scales in the 100 ka and potentially the 40 ka world in particular those that impact the global carbon budget and greenhouse gas concentration over glacial-interglacial time scales.
- Examine the polar region’s impact on and response to major changes in Earth climate states (Late Pliocene steps in Northern Hemisphere glaciation, Mid-Pleistocene revolution, Mid-Brunhes event) and compare the sequence and timing of events in both polar regions.
- Develop climate scenarios and models over a broad range of climate variability including “extreme” cold and warm natural conditions (Pleistocene, Pliocene) to enhance our capacity to generate reliable estimations of future climate and sea level development

Deliverables

- New sediment, permafrost and ice core material, seismic and bathymetric data, with special emphasis on the Arctic Ocean, the Polar Pacific, East Siberia, Patagonia, and the Greenland and Antarctic ice sheets.
- Networks of multi-proxy-based climate records that document the status (e.g. last glacial maximum, last interglacial optimum) and the development of past climate and sea level in polar regions at glacial to warmer than present conditions at highest resolution possible.
- Stratigraphic correlation and age determination of polar sediment, permafrost and ice core records at highest accuracy possible.
- Integration of atmosphere, cryosphere, land and ocean palaeodata and verification of hypotheses with numerical earth system models.