Two-stage climate response to Heinrich events

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Florian A. Ziemen / florian.ziemen@mpimet.mpg.de / Max Planck Institute for Meteorology
Co-author: Marie Kapsch, Max Planck Institute for Meteorology;
Uwe Mikolajewicz, Max Planck Institute for Meteorology;
Abstract:
Heinrich events are among the most prominent events of climate variability recorded in proxies. Nevertheless, their governing processes and climatic impacts are far from being fully understood. We address open questions by studying Heinrich events in transient glacial simulations with a coupled ice sheet - general circulation model framework, where Heinrich events occur as part of the model generated internal variability. The framework consists of a Northern Hemisphere setup of the modified Parallel Ice Sheet Model (mPISM) bidi- rectionally coupled to the global atmosphere-ocean-vegetation model ECHAM5/MPIOM/LPJ. The simulations were performed with transient orbital and greenhouse gas forcing. The modeled Heinrich events show a peak ice discharge of about 0.05 Sv and raise sea level by 2.3 m on average. A two-stage response in the climate system is evident. First, the freshwater release decreases the deepwater formation in the North Atlantic, resulting in a slowdown of the Atlantic Meridional Overturning Circulation and a Northern Hemispheric cooling. In the second phase, the lowered surface elevation after the surge results in a widening and zonalization of the jet stream. The experiments show that both response pathways need to be considered to understand the climatic impacts of Heinrich events.

The Last Termination simulated with a complex ESM with interactive northern northern ice sheets

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Uwe Mikolajewicz / uwe.mikolajewicz@mpimet.mpg.de / Max-Planck-Institut f. Meteorologie
Co-author: Florian Ziemen, Max-Planck-Institut f. Meteorologie;
Marie Kapsch, Max-Planck-Institut f. Meteorologie;
Virna Meccia, Max-Planck-Institut f. Meteorologie;

Abstract:
One of the major challenges in climate modelling is the simulation of glacial-interglacial transitions. Here we presents results from our first successful attempt to simulate a substantial part of the last glacial cycle with the ECHAM5/MPIOM AOGCM coupled interactively to a northern hemisphere set up of the dynamical ice sheet model PISM. This model is integrated from the late Glacial into the Holocene using insolation and greenhouse gas concentrations as transient forcing. The land sea mask remains fixed at the LGM state. River routing and surface elevation for the atmospheric model component are calculated interactively. To make these long simulations feasible, the atmosphere is accelerated by a factor of 10 relative to the other model components using a periodical-synchronous coupling technique. A mini-ensemble with different initial conditions is run. Additionally, one simulation is run fully synchronously without acceleration in the atmosphere. In all simulation the northern hemispheric deglaciation starts around 20 kyr BP, the warming at around 17 kyr BP. During the deglaciation the interactive river routing has a strong impact on the simulated NAMOC, which weakens in the course of the deglaciation and collapses for part of the time, before it recovers in the early Holocene.

Transient climate simulations of the deglaciation 21-9 thousand years before present (version 1): PMIP4 Core experiment design and boundary conditions

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Ruza F. Ivanovic / R.Ivanovic@leeds.ac.uk / University of Leeds

Co-author: Lauren J. Gregoire, University of Leeds;
Masa Kageyama, Laboratoire des Sciences du Climat et de l’Environnemen;
Didier M. Roche, Laboratoire des Sciences du Climat et de l’Environnemen; Vrije Universiteit Amsterdam;
Paul J. Valdes, University of Bristol;
Andrea Burke, University of St. Andrews;
Rosemarie Drummond, University of Toronto;
W. Richard Peltier, University of Toronto;
Lev Tarasov, Memorial University of Newfoundland and Labrador;

Abstract:

The last deglaciation, which marked the transition between the last glacial and present interglacial periods, was punctuated by a series of rapid (centennial and decadal) climate changes. Numerical climate models are useful for investigating mechanisms that underpin the climate change events. The last deglaciation PMIP working group coordinates transient simulations 21-0 ka, and facilitates the dissemination of expertise between modellers and those engaged with reconstructing the climate for this period. Here, we present the design of a coordinated Core experiment over the period 21–9 thousand years before present (ka) with time-varying orbital forcing, greenhouse gases, ice sheets and other geographical changes. A choice of two ice sheet reconstructions is given, and we make recommendations for prescribing ice meltwater (or not) in the Core experiment. Additional focussed simulations will also be coordinated on an ad hoc basis by the working group, for example to investigate more thoroughly the effect of ice meltwater on climate system evolution, and to examine the uncertainty in other forcings. Some of these focussed simulations will target shorter durations around specific events in order to understand them in more detail and allow for the more computationally expensive models to take part.

Collapse of the North American ice saddle 14,500 years ago caused widespread cooling and reduced ocean overturning circulation

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Ruza F. Ivanovic / R.Ivanovic@leeds.ac.uk / University of Leeds
Co-author: Lauren J. Gregoire, University of Leeds;
Andrew D. Wickert,, University of Minnesota;
Paul J. Valdes, University of Bristol;
Andrea Burke, University of St. Andrews;
Abstract:
Collapse of ice sheets can cause significant sea level rise and widespread climate change. We examine the climatic response to meltwater generated by the collapse of the Cordilleran-Laurentide ice saddle (North America) ~14.5 thousand years ago (ka) using a high-resolution drainage model coupled to an ocean-atmosphere-vegetation general circulation model. Equivalent to 7.26 m global mean sea level rise in 340 years, the meltwater caused a 6 sverdrup weakening of Atlantic Meridional Overturning Circulation (AMOC) and widespread Northern Hemisphere cooling of 1–5°C. The greatest cooling is in the Atlantic sector high latitudes during Boreal winter (by 5–10°C), but there is also strong summer warming of 1–3°C over eastern North America. Following recent suggestions that the saddle collapse was triggered by the Bølling warming event at ~14.7–14.5 ka, we conclude that this robust submillennial mechanism may have initiated the end of the warming and/or the Older Dryas cooling through a forced AMOC weakening.

Connecting Antarctic sea ice to deep ocean circulation in modern and glacial climate simulations

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Alice Marzocchi / amarzocchi@uchicago.edu / University of Chicago
Co-author: Malte Jansen, University of Chicago;
Abstract:
Antarctic sea ice formation plays a key role in shaping the abyssal overturning circulation and stratification in all ocean basins, by driving surface buoyancy loss through the associated brine rejection. Changes in Antarctic sea ice have, therefore, been suggested as drivers of major glacial-interglacial ocean circulation rearrangements. Here, the relationship between Antarctic sea ice, buoyancy loss, deep-ocean stratification, and overturning circulation is investigated in Last Glacial Maximum and preindustrial simulations from the Paleoclimate Modelling Intercomparison Project (PMIP). The simulations show substantial inter-model differences in their representation of the glacial deep-ocean state and circulation, which is often at odds with the geological evidence. We argue that these apparent inconsistencies can largely be attributed to differing (and likely insufficient) Antarctic sea ice formation. Discrepancies can be further amplified by short integration times. Deep-ocean equilibration and sea ice representation should, therefore, be carefully evaluated in the forthcoming PMIP4 simulations.

Malte Jansen, University of Chicago, mfj@uchicago.edu

Compensating effects of greenhouse gas concentrations and ice sheets on the AMOC during the Last Glacial Maximum in a coupled climate model

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Marlene Klockmann / marlene.klockmann@mpimet.mpg.de / Max Planck Institute for Meteorology

Co-author: Uwe Mikolajewicz, Max Planck Institute for Meteorology;
Jochem Marotzke, Max Planck Institute for Meteorology;

Abstract:

There is a large intermodel spread regarding the glacial Atlantic Meridional Overturning Circulation (AMOC) within the PMIP ensemble, and many models fail to capture the shoaling of the glacial AMOC indicated by proxy-based reconstructions. The glacial AMOC response in the coupled model MPI-ESM is the sum of two large opposing effects: the glacial ice sheets cause a deepening and a strengthening of the AMOC; the glacial greenhouse gas (GHG) concentrations cause a shoaling and a weakening. The two effects partly compensate for each other. As a result, the glacial AMOC does not shoal with respect to the modern state. The key mechanism for the GHG effect is brine release in the Southern Ocean, which increases the density of Antarctic Bottom Water; the key mechanism for the ice-sheet effect is the salt transport into the North Atlantic, which enhances the density of North Atlantic Deep Water. The magnitude of the respective effects depends on the background climate and likely also on the model-specific implementation of sea-ice dynamics and continental ice sheets. Already small differences in the magnitude of either effect can change the sign of the total AMOC response, which provides a good explanation for the spread within the PMIP ensemble.

Simulating the climate of Marine Isotope Stage 3

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Chuncheng Guo / chuncheng.guo@uni.no / Uni Research Climate, and Bjerknes Centre for Climate Research

Co-author: Kerim Nisancioglu, Department of Earth Science, University of Bergen, and Bjerknes Centre for Climate Research;
Mats Bentsen, Uni Research Climate, and Bjerknes Centre for Climate Research;
Ingo Bethke, Uni Research Climate, and Bjerknes Centre for Climate Research;
Zhongshi Zhang, Uni Research Climate, and Bjerknes Centre for Climate Research;

Abstract:
With recent model developments at the Bjerknes Centre for Climate Research (Norway), a new and efficient Norwegian Earth System Model (NorESM) version with 2-degree atmosphere and 1-degree ocean has been configured for paleo-modelling. Here we present fully coupled climate simulations of a pre-industrial control run and a MIS3 experiment at 38 ka BP, both integrated for 2000 years . We will discuss the large scale climate features of MIS3 relative to today, including ocean overturning circulation, surface temperatures, and atmospheric circulation patterns. We focus on the climatic conditions in the Arctic Ocean and Nordic Seas and discuss ocean circulation, vertical stratification and sea ice conditions. Simulated surface temperature during MIS3 is globally colder except in the periphery of the North Atlantic subpolar gyre region; AMOC is slightly stronger compared to modern day, with a deeper penetration of NADW; MIS3 also exhibits a stronger and more contracted subpolar gyre. Additional sensitivity experiments with freshwater input mimicking ice rafting events from the large land based ice sheets are also analysed. Preliminary results from these sensitivity experiments show a significant difference in ocean and sea ice response as well as Greenland temperature to freshwater input from the Laurentide versus the Fennoscandian ice sheets.

Changing topography and land-sea mask in transient simulations of the last deglaciation using CESM

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Anna Matulka / amatulka@marum.de / MARUM
Co-author: Andre Paul, MARUM;
Matthias Prange, MARUM;

Abstract:
The land-sea mask in Earth-system models is usually fixed. However, in the case of large changes in sea level, time-dependent ocean boundaries and bottom topography need to be considered (e.g. for simulations of the last deglaciation through which the global sea level increased by about 120 m). The aim of this project is to make the ocean component POP (Parallel Ocean Program) of the CESM (Community Earth System Model) capable of dealing automatically with those changes. A suitable algorithm was developed and tested. Manual checks were performed regarding the control of key straits, modification of through-flow depths at important sills, connection of ocean basins and determination of closed basins (where necessary, isolated points were removed). The algorithm applies changes in the land-sea mask whenever sea level change crosses a z-level of the vertical grid. The land-sea changes take place upon a restart of the model, which requires a modification of restart files. New ocean cells are initialized with nearest-neighbour values.

Andre Paul, MARUM - Center for Marine Environmental Sciences, apual@marum.de

North Pacific atmospheric rivers at the Last Glacial Maximum

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Juan M. Lora / jlora@ucla.edu / UCLA
Co-author: Jonathan L. Mitchell, Westmont College & UCLA;
Camille Risi, LMD;
Aradhna E. Tripati, UCLA;
Abstract:
Paleo-precipitation reconstructions indicate that during the Last Glacial Maximum, northwestern and southwestern North America were drier and wetter than present, respectively. These changes have been associated with southward shifts in the positions of the midlatitude jet stream and wintertime North Pacific storm track, observed in LGM simulations from a variety of models. But the source and delivery processes of water at the LGM have been recently debated. Using the ensemble of PMIP3 LGM simulations, supplemented with reanalysis and additional atmospheric simulations, we explore the role of atmospheric rivers—plumes of water vapor transport of critical importance to western North America—in delivering water to the region during the glacial. Deepened Aleutian Low and weakened North Pacific High pressure systems at the LGM concentrated water transport in atmospheric rivers into California relative to the present, enhancing moisture and precipitation in the southwest and shifting it away from the northwest. While the PMIP3 simulations were crucial for this work, uncertainties remain that will be addressable with PMIP4 results, like the effects of uncertainties in ice-sheet topography. Furthermore, the lack of daily model output and certain derived variables in the PMIP3 archives limited the range of possible analyses; PMIP4 offers opportunities to fill these gaps.

Aradhna E. Tripati, UCLA, atripati@g.ucla.edu (postdoctoral advisor); Jonathan L. Mitchell, Westmont College & UCLA, jonmitch@ucla.edu (postdoctoral advisor)

Impacts of polar ice sheets on the East Asian monsoon during the MIS-13 interglacial

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Feng Shi / feng.shi@uclouvain.be / Georges Lemaître Centre for Earth and Climate Research, Earth and Life Institute, Université catholique de Louvain, Louvain?la?Neuve, Belgium

Co-author: Qiuzhen Yin, Georges Lemaître Centre for Earth and Climate Research, Earth and Life Institute, Université catholique de Louvain, Louvain?la?Neuve, Belgium;
Irina Nikolova, Georges Lemaître Centre for Earth and Climate Research, Earth and Life Institute, Université catholique de Louvain, Louvain?la?Neuve, Belgium;
Zhengtang Guo, 2. Key Laboratory of Cenozoic Geology and Environment, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China;
Andre Berger, Georges Lemaître Centre for Earth and Climate Research, Earth and Life Institute, Université catholique de Louvain, Louvain?la?Neuve, Belgium;

Abstract:

Among all the interglacials of the last one million years, Marine Isotope Stage (MIS) 13 has the highest ?18O value over the past 800 ka in the deep-sea sediments. This would indicate that MIS-13 is the coolest interglacial if assuming ?18O mainly represents global ice volume. The Antarctic ice core records show also that MIS-13 is the coolest interglacial over Antarctica with almost the lowest greenhouse gases concentrations (GHG). However, many proxy records from the northern hemisphere (NH) indicate that MIS-13 is at least as warm as or even warmer than the recent interglacials, with extremely strong summer monsoon and a possible melting of Greenland ice sheet. In this study, based on proxy reconstructions, different scenarios regarding the size of the Greenland and Antarctic ice sheets are made, and the response of the East Asian summer monsoon to these scenarios are tested by using the models HadCM3 and LOVECLIM as well as factor separation analysis and under the astronomical and GHG configurations of MIS-13. The results show that the influence of the disappearance of Greenland ice sheet on the surface temperature is quite localized, mainly over the northern high latitudinal regions, however, the influence of the bigger Southern Hemisphere ice sheet on the surface temperature is very global, especially in the southern hemisphere. This ice sheet condition has an impact on the precipitation pattern over tropical-subtropical regions. It causes much more summer precipitation over all the East Asian monsoon region, in consistent with the paleosol record from southern China. The scenario of melted Greenland ice sheet and of larger SH ice sheets provides one of the explanations of the strong monsoon rainfall documented by the proxy data.

Modeling the last deglaciation with an ice sheet – solid earth model system

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Marie-Luise Kapsch / marie.kapsch@mpimet.mpg.de / Max Planck Institute for Meteorology, Bundesstraße 53, 20146 Hamburg, Germany

Co-author: Florian Ziemen, Max Planck Institute for Meteorology;
Meike Bagge, Helmholtz Centre Potsdam, GFZ Research Centre for Geosciences, Potsdam, Germany;
Volker Klemann, Helmholtz Centre Potsdam, GFZ Research Centre for Geosciences, Potsdam, Germany;
Virna Meccia, Max Planck Institute for Meteorology;
Uwe Mikolajewicz, Max Planck Institute for Meteorology;

Abstract:
Massive climate changes were evident during the last deglaciation. Melting of ice sheets resulted in about 100 m of sea level rise within 10 kyr, which on average is comparable to future projections of sea level rise. The exact location and timing of the meltwater releases is crucial for the response of the ocean circulation. To account for such processes and interactions between climate components and ice sheets it is important to integrate ice sheet models into state-of-the-art climate models. To investigate ice sheet changes throughout the last deglaciation we present results of the Parallel Ice Sheet Model PISM coupled to the solid earth model VILMA, as a first step towards a fully coupled ice sheet – climate model system. By including VILMA, we account for isostatic adjustment and gravitational sea level effects. Linear combinations of twelve stand-alone climate experiments with the Max Planck Institute Earth System Model for different orbital configurations, GHG concentrations and ice sheets are used to calculate the ice sheet surface mass balance (SMB) using an energy balance model. The SMB is then used to force the ice sheet – solid earth model setup. Ocean temperatures and salinities are used to obtain basal shelf melt rates.

The Caspian Sea during Pre- and Post-LGM as natural lab for investigation of climate changes

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: A.Kislov / avkislov@mail.ru / M.V.lomonosov Moscow State University

Abstract:
The level fluctuations of closet lakes depend on regional-scale climate variations. Such lakes (especially such huge lake as the Caspian Sea (CS)) could be treated as natural labs, allows us to explore reaction of regional climate conditions to global climate changes. During a long part of its history, the CS was a closet lake, separating by sill from the Black Sea. Sometimes, the CS level raised so high that the CS overflowed to the Black Sea. They were so-called the Early Khvalynian transgression (age ~35-25 ka BP) and the Late Khvalynian transgression (age ~17-12 ka BP). At the time of the Early Khvalynian transgression, the level of the CS was estimated up to 50 m above the modern state and sea area spread out far to north. The Late Khvalynian transgression was modest; the level of the CS achieved +27 m above the modern state. The main question concerning these events is what was source of additional water needed to providing these anomalies? The Khvalynian phenomena did not occur due to high precipitations/river runoff over the East European Plain because model experiments (Sima et al., 2013) do not support this idea. The contribution of melting water of the Scandinavian Ice Sheet is excluded too. Indeed, its boundary was located beyond the Volga River catchment area; the ice wall was permeable and the water could drain in the north direction (Sidorchuk et al., 2006). The Khvalynian transgressions cannot be realized as the “stochastic anomaly”. Indeed, despite the CS level dynamics is represented by a system of undergoing random walk, the “super large” anomalies (like the Khvalynian transgressions) are impossible (Kislov, 2016). Water volume was proposed to be increased due to an increase of the runoff coefficient due to permafrost (Sidorchuk et al., 2006). In addition, the melting of permafrost could provide a contribution to the runoff. So far, it is unclear whether this event was sufficient to ensure the Khvalynian transgressions. Now we are faced with a paradox: «The event was, but it was inexplicable».

A transient fully coupled climate-ice-sheet simulation of the last glacial inception

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Marcus Lofverstrom / marcusl@ucar.edu / National Center for Atmospheric Research
Co-author: Bette Otto-Bliesner, National Center for Atmospheric Research;
William Sacks, National Center for Atmospheric Research;
Esther Brady, National Center for Atmospheric Research;
William Lipscomb, Los Alamos National Laboratory;
Jeremy Fyke, Los Alamos National Laboratory;
Shawn Marshall, University of Calgary;

Abstract:
The last glacial inception occurred around 115 ka, following a relative minimum in the Northern Hemisphere summer insolation. It is believed that small and spatially separated ice caps initially formed in the high elevation regions of northern Canada, Scandinavia, and along the Siberian Arctic coast. These ice caps subsequently migrated down in the valleys where they coalesced and formed the initial seeds of the large coherent ice masses that covered the northern parts of the North American and Eurasian continents over most of the last glacial cycle. Sea level records show that the initial growth period lasted for about 10 kyrs, and the resulting ice sheets may have lowered the global sea level by as much as 30 to 50 meters. Here we examine the transient climate system response over the period between 118 and 110 ka, using the fully coupled Community Earth System Model, version 2 (CESM2). This model features a two-way coupled high-resolution (4x4 km) ice-sheet component (Community Ice Sheet model, version 2; CISM2) that simulates ice sheets as an interactive component of the climate system. We impose a transient forcing protocol where the greenhouse gas concentrations and the orbital parameters follow the nominal year in the simulation; the model topography is also dynamically evolving in order to reflect changes in ice elevation throughout the simulation. The analysis focuses on how the climate system evolves over this time interval, with a special focus on glacial inception in the high-latitude continents. Results will highlight how the evolving ice sheets compare to data and previous model based reconstructions.

Bette Otto-Bliesner, National Center for Atmospheric Research, ottobli@ucar.edu

The Indian Ocean Walker circulation at the Last Glacial Maximum (revisited): Old models versus new data

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Matthias Prange / mprange@marum.de / MARUM - Center for Marine Environmental Sciences, University of Bremen, Germany

Co-author: Mahyar Mohtadi, MARUM - Center for Marine Environmental Sciences, University of Bremen, Germany;
Enno Schefuß, MARUM - Center for Marine Environmental Sciences, University of Bremen, Germany;
Tim Jennerjahn, Leibniz Centre for Tropical Marine Research, Bremen, Germany;

Abstract:

Climate models predict a slowdown of the Walker circulation for the twenty-first century. However, historical records and observations of the Walker circulation over the twentieth century disagree on the sign of change, and thus necessitate longer climate records to test both the simulated history and fate of the Walker circulation. Here we present a suite of records of sea surface and thermocline temperatures, and of the isotopic composition of rainfall, from the eastern tropical Indian Ocean for the Last Glacial Maximum (LGM) and the late Holocene. Our results indicate an increase in both thermocline depth and rainfall suggesting a stronger-than-today Indian Ocean Walker cell during the LGM. Analysis of PMIP2 and PMIP3/CMIP5 climate model results confirms the thermocline deepening in the eastern Indian Ocean in model simulations with a stronger Walker circulation during the LGM. However, our analysis of model output also reveals a considerable scatter of model results, with some models even simulating a shoaling of the thermocline along with a weakening of the Indian Ocean Walker cell under LGM conditions. In the two models with maximum Walker circulation strengthening (CCSM3 and FGOALS-g1.0) the deepening of the thermocline is sufficiently strong to induce even warmer-than-today eastern equatorial Indian Ocean subsurface temperatures in the LGM in accordance with our new thermocline records. We conclude that during the LGM, convection and rainfall over the eastern equatorial Indian Ocean was stronger than today as a result of an intensified Indian Ocean Walker circulation, while further to the east, anomalous subsidence resulted in drier conditions over the Maritime continent, as indicated by various previous proxy studies. An intensified Walker circulation during the globally cooler last glacial period underscores the sensitivity of tropical circulation to temperature change and implies a further weakening of the Walker circulation in response to greenhouse warming.

British-Irish Ice Sheet during the LGM consistent with weakened North Atlantic heat transport

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Matthias Prange / mprange@marum.de / MARUM - Center for Marine Environmental Sciences, University of Bremen, Germany

Co-author: Irina Rogozhina, MARUM - Center for Marine Environmental Sciences, University of Bremen, Germany;
André Paul, MARUM - Center for Marine Environmental Sciences, University of Bremen, Germany;
Pepijn Bakker, MARUM - Center for Marine Environmental Sciences, University of Bremen, Germany;
Julien Seguinot, Laboratory of Hydraulics, Hydrology and Glaciology, ETH Zürich, Switzerland;
Jorge Bernales, GFZ German Research Centre for Geosciences, Helmholtz Centre Potsdam, Germany;

Abstract:
The British-Irish Ice Sheet of the last glacial was situated in a region that is critically sensitive to the poleward oceanic heat transport in the Atlantic. We employ the results of two Last Glacial Maximum (LGM) global climate simulations by the Community Climate System Model (CCSM) versions 3 and 4 at about 1° resolution in both the ocean and the atmosphere. The simulated North Atlantic sea-surface conditions are compared to temperature reconstructions by the Multiproxy Approach for the Reconstruction of the Glacial Ocean Surface (MARGO) project, while the atmospheric model output is used to force an ice-sheet model of the northern hemisphere. The results show that a reduced northward ocean heat transport associated with a weakened AMOC in the glacial CCSM3 simulation is consistent with extensive ice-sheet cover over the British-Irish Isles as inferred from independent geological evidence for the LGM. By contrast, a strong AMOC in the glacial CCSM4 simulation results in North Atlantic surface temperatures that are several degrees warmer than the MARGO reconstructions. As a consequence, the advection of relatively warm air from the North Atlantic towards Europe prevents the formation of a British-Irish Ice Sheet in the corresponding ice-sheet simulation. We suggest that ice-sheet modelling provides a powerful tool to evaluate paleoclimate model simulations within the framework of PMIP4.

Modelling nutrients and marine radiocarbon through the last deglaciation

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Rhian L. Rees-Owen / rlro@st-andrews.ac.uk / University of St Andrews
Co-author: Andrea Burke, University of St Andrews;
James W. B. Rae, University of St Andrews;
Rosanna Greenop, University of St Andrews;
Andy Ridgwell, University of California, Riverside;
Abstract:
Ocean circulation in the high latitudes strongly influences global heat transport, ocean-atmosphere CO2 transport and biological productivity. Rapid reorganisations in ocean circulation during the last glacial cycle have been linked to millennial-scale abrupt climate events. These events had widespread impact on global carbon and nutrient cycling, and can be traced using marine radiocarbon. Here, we present results from transient model runs using the GENIE Earth System Model, simulating nutrients and marine radiocarbon for the glacial climate and stadial events. We explore links between circulation change, nutrients and carbon cycling for the Northern high latitudes, and show that overturning plays a dominant role in North Pacific nutrient budgets and CO2 release. We also demonstrate that the relationship between circulation state and ?14C can vary through time as a function of atmospheric radiocarbon history, and explore spatial and temporal variations in surface reservoir ages.

Andrea Burke, University of St Andrews, ab276@st-andrews.ac.uk

The effect of glaciogenic dust on LGM climate

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Rumi Ohgaito / ohgaito@aori.u-tokyo.ac.jp / AORI, U. Tokyo
Co-author: Ayako Abe-Ouchi, AORI, U. Tokyo;
Ryouta O'ishi, AORI, U. Tokyo;
Toshihiko Takemura, Kyushu Univ.;

Abstract:
Last Glacial Maximum (LGM) is known with the enhancement of the dust deposition from the ice/sediment core data (Winckler et al. 2008, Dome Fuji Ice Core Project members 2017), especially over the polar regions. Using an earth system model, MIROC-ESM (Watanabe et al. 2011), we investigated the impact of glaciogenic dust by Mahowald et al. (2006) on LGM climate. We have found that the effect of the enhancement of dust is less cooling in the polar regions. One of the major reason of the less cooling is that the aging of snow or ice albedo by high dust deposition mainly in the northern hemisphere. Although the net radiative forcing at the lee of high glaciogenic dust provenances are negative, warming by aging of snow overcomes the change of the radiative forcing in MIROC-ESM. The model ability of aging of snow under the glacial climate should be evaluated. On the other hand, the radiative forcing by high dust load in the troposphere acts for the surface warming surroundings of the Antarctica mainly caused by the indirect effect of dust.

Status of the IPSL simulations for PMIP4-CMIP6 and for PMIP4

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Masa Kageyama / Masa.Kageyama@lsce.ipsl.fr / LSCE-IPSL

Co-author: Pascale Braconnot, LSCE-IPSL;
Myriam Khodri, LOCEAN-IPSL;
Olivier Marti, LSCE-IPSL;
Jean-Yves Peterschmitt, LSCE-IPSL;
Gilles Ramstein, LSCE-IPSL;
Pierre Sepulchre, LSCE-IPSL;
Ning Tan, LSCE-IPSL;
Yannick Donnadieu, CEREGE;

Abstract:

LSCE is currently actively preparing its PMIP4-CMIP6 experiments. Our target is to model the five PMIP4-CMIP6 periods, as well as PMIP4 sensitivity and transient experiments. We will base our strategy on two models of the IPSL family: IPSLCM6, which is the main model to be used by the IPSL team for CMIP6, and IPSLCM5A2, which runs much faster than IPSLCM6 and which will be used for transient and long-term experiments. Our poster will present these models, the implementation of the experiments, and first results.

Role of Ice Sheet uncertainty on the PMIP4 Last Glacial Maximum simulations

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Xu Zhang / xu.zhang@awi.de / Alfred Wegener Institute Helmholtz centre for Polar and Marine Research
Co-author: Evan Gowan, Alfred Wegener Institute Helmholtz centre for Polar and Marine Research;
Martin Werner, Alfred Wegener Institute Helmholtz centre for Polar and Marine Research;
Gerrit Lohmann, Alfred Wegener Institute Helmholtz centre for Polar and Marine Research;
Abstract:
An uncertainty in PMIP4 glacial simulations is the ice sheet reconstruction (height and geometry) that appears to play an important role on glacial climate (e.g the strength of Atlantic meridional overturning circulation). Here we use an isotope-enabled fully coupled AOGCM to assess the transient and equilibrium features of glacial climate in response to five available ice sheet reconstructions of the Last Glacial Maximum (Licciardi et al 1998; ANU; GLAC-1; ICE-6g; ICESHEET). Here we mainly focus on different LIS reconstructions since the Laurentide Ice Sheets (LIS) play a more important role on Atlantic meridional overturning circulation than the Fennoscandia Ice Sheets (FIS). According to the ice volume, LIS reconstructions from Licciardi and ICESHEET (Gowan et al 2016) can be classified into a low class, while the rest belongs to a high class. The initial ocean state of the experiments are identical to each other and derived from a previous PMIP3 LGM simulation. During the integrations, we find that the equilibrium timescale in ocean circulation is much shorter in the high class than in the low class. In particular, the ocean circulation experiences a pronounced weakening in its transient phase under the low ice sheets, followed by a rapid recovery to a strong ocean state. As the system gets equilibrium, the simulated climate states regarding sea surface temperature, sea ice cover and precipitation patterns are also distinguished, especially between low and high ice sheet classes. Our results suggest that various ice-sheet reconstructions will be a considerable source of uncertainty for inter-comparisons of PMIP4 LGM simulations.

Gerrit Lohmann Alfred Wegener Institute Helmholtz centre for Polar and Marine Research
Gerrit.Lohmann@awi.de

Millennial-scale climate variability, scientific objectives and experimental design for PMIP4 simulations of abrupt glacial climate changes

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Xu Zhang / xu.zhang@awi.de / Alfred Wegener Institute Helmholtz centre for Polar and Marine Research

Co-author: Gerrit Lohmann, Alfred Wegener Institute Helmholtz centre for Polar and Marine Research;

Abstract:

Various climate archives suggest that abrupt climate changes are an intrinsic characteristic over much of the last million years. Millennial-scale climate variability, known as Dansgaard-Oeschger events, has been linked to changes in the Atlantic Meridional overturning circulation (AMOC). However, whether the abrupt changes are related to the nonlinearity of climate system itself or to nonlinear forcing to a linear system remains elusive. To reproduce the abrupt transition between strong and weak circulation regimes, a common trigger mechanism in climate modelling studies is ad-hoc freshwater perturbations in the North Atlantic. This approach does not require a nonlinear climate system to trigger abrupt climate shifts because responses of ocean circulation can be just followed by the nonlinear forcing. Recently, Zhang et al (2014; 2017) find that changes in ice sheet height and atmospheric CO2 are capable of triggering abrupt circulation transitions associated with a regime of AMOC bi-stability. This indicates that climate system is intrinsic nonlinear and abrupt climate changes can be caused by gradual external forcing. Since this feature is only derived from one climate model (ECHAM5/MPIOM), it is of critical importance to evaluate its re-productivity in other climate models that are used to guide policy makers to make adaption strategy to future climate changes. Accordingly, we propose a series of simplified experiments that will provide a quantitative assessment of inter-model performances on abrupt glacial climate changes. This project will be promoted as a working subgroup within the PMIP4 framework.

Gerrit Lohmann Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research
Gerrit.Lohmann@awi.de

Holocene lowering of the Laurentide Ice Sheet weakens North Atlantic gyre circulation and affects climate

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Lauren J. Gregoire / l.j.gregoire@leeds.ac.uk / University of Leeds
Co-author: Ruza Ivanovic, University of Leeds;
Amanda C. Maycock, University of Leeds;
Paul J. Valdes, University of Bristol;
Abstract:
Ice sheet topography is an important control on glacial climate. The presence of the large North American Laurentide Ice Sheet (LIS) at the Last Glacial Maximum (LGM; 21 ka) produces a stronger and more zonal jet stream, modifies surface climate and storminess over the North Atlantic and affects North Atlantic gyre circulation and the Meridional Overturning Circulation. By the start of the Holocene, 9.0 ka, the size of the LIS was much reduced, yet, it has been suggested that the demise of the LIS played a role in the 8.2 ka abrupt cooling event through its topographical influence on atmospheric circulation. Here, for the first time, we evaluate how the demise of the LIS 9.5-7 ka directly influences atmospheric circulation through changing topography, and the wider implications for climate. We ran a series of 500 year-long equilibrium experiments using the HadCM3 ocean-atmosphere-vegetation General Circulation Model with LIS topographies and ice masks taken from a transient simulation of the ice sheet, using snapshots at 9.5, 9.0, 8.5 and 8.0 ka. We find that the lowering of the LIS produces a dipole pattern of surface ocean and air temperature anomalies over the North Atlantic. Between 9.5 and 8.0 ka, we model a progressive 2 °C cooling south of Iceland and 1 °C warming between 40-50° N, matching sedimentary records. This is associated with a weakening of the Subtropical and Subpolar Gyres caused by a decreasing wind stress curl over the gyres as the ice sheet lowers. However, topographical changes between 8.5 ka and 8.0 ka induce minor climatic change relative to the ~160 year-long cooling pattern of the 8.2 kyr event.

Ocean modelling with varying topographic boundaries

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Virna Meccia / virna.meccia@mpimet.mpg.de / Max Planck Institute for Meteorology, Hamburg, Germany

Co-author: Uwe Mikolajewicz, Max Planck Institute for Meteorology, Hamburg, Germany;

Abstract:

In most standard Earth System Models (ESMs) the land-sea mask is fixed throughout simulations. However, for long-term simulations with large changes in sea level, topography and ice extents, it is necessary to consider transient ocean boundaries. This is one of the main problems towards simulating a complete glacial cycle with GCM models. We present a tool to allow for an automatic computation of changes in the bathymetry used in the Max Planck Institute Ocean Model (MPIOM). As a first step, the tool remaps a high-resolution topography from ice sheet and glacial isostatic adjustment modelling to the coarse MPIOM grid. In order to avoid isolated domains, our algorithm ensures that ocean areas are connected. Then, it modifies the bathymetry at some key straits to provide for sufficient through-flow depths according to the values found in the high-resolution data. As a second step, the tool adapts MPIOM restart files to changes in bathymetry and land-sea mask. Important aspects are the conservation of mass and tracers. We present the concepts of the algorithms together with first test simulations. Once tested thoroughly the module can be used with MPI-ESM to allow for transient simulations of the last terminations with interactive land-sea mask and bathymetry.

The Last Glacial Maximum tropical oceans: impacts of paleoclimatic indicators' habitat on the recorded temperature change, potential benefits of taking this habitat into account

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Masa Kageyama / Masa.Kageyama@lsce.ipsl.fr / LSCE-IPSL

Co-author: Tilla Roy, ECOCEANA;
Pascale Braconnot, LSCE-IPSL;

Abstract:

The Last Glacial Maximum (LGM) tropical sea surface temperatures (SSTs) may have a high potential to constrain the climate sensitivity to CO2 (e.g. Hargreaves et al., 2007). Careful comparison of the PMIP model results to SST reconstructions (such as MARGO, 2009) could, therefore, be crucial in our evaluation of the climate models used for prediction. The MARGO reconstructions are based on several indicators including foraminifer assemblages, alkenones and Mg/Ca. These do not always yield the same SST estimates for the LGM, and collectively show larger spatial variability than the model results. Here, we examine the changes in the habitat of coccolithophores and foraminifera (in particular G. ruber) between the Last Glacial Maximum and the pre-industrial. We use the IPSL model to represent the coccolithophores, in which a representation of nanophytoplankton is included via the PISCES ocean biogeochemistry model, and the FORAMCLIM model to compute the abundance of 8 species of foraminifera. We show that coccolithophores could record temperatures at a deeper depth than G. ruber, which could help reconstruct the thermal gradients of the upper ocean. Ultimately, this could lead to an increased knowledge of the ocean circulation, and could provide additional constraints on the atmospheric circulation since it is tightly coupled to the ocean circulation in this region. This last part of the work is based on the PMIP3 results and could be extended to PMIP4 results if available at the time of the conference.

Reanalysing the deglaciation with models and data

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: James Annan / jules@blueskiesresearch.org.uk / Blue Skies Research
Co-author: Julia Hargreaves, Blue Skies Research;
Ruza Ivanovic, University of Leeds;
Lauren Gregoire, University of Leeds;
Paul Valdes, University of Bristol;
Bette Otto-Bliesner, NCAR;
Abstract:
Using data assimilation techniques for climate reanalysis should provide the best description of how and why our climate has changed through the past and up to the present. Due to both computational and data limitations, previous paleoclimate reanalyses of the authors and others have typically focussed either on time slices (such as the Last Glacial Maximum or mid-Pliocene Warm Period) or the relatively short transient of the last millennium, using a wide variety of methods. The forthcoming PMIP6 simulations of the last deglaciation, together with recently published compilations of core data, should provide us a new opportunity to reconstruct the fully global transient evolution of the climate state over this period with more detail and accuracy than previously achieved. Here we present some initial investigations and results using transient simulations which have been produced by the FAMOUS model (low-resolution HadCM3) and CCSM3, which builds on our previous work in state (LGM) reconstruction. We show that in principle it is possible to blend the data and model simulations in order to give a realistic reconstruction of the full deglatiation. Future challenges include handling errors in the timing and magnitude of forcing time series used to drive the models, and also in the chronologies of proxy data.

High Resolution Simulations of the LGM and mid-Holocene

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Paul Valdes / p.j.valdes@bristol.ac.uk / University of Bristol, UK
Co-author: Ruza Ivanovic, Leeds University, UK;
Lauren Gregoire, Leeds University, UK;
Peter Hopcroft, University of Bristol, UK;

Abstract:
The latest climate models for CMIP6/PMIP4 will generally be higher resolution than previous generations and increased resolution will often be suggested as the cause for any resulting changes. However, in the majority of cases many other aspects of the model will also have been changed and it can be difficult to rigorously attribute the changes to a specific increase of resolution. We have therefore investigated the role of resolution in simulating past climate change through a series of simulation using one particular model, HadAM3. The advantage of using this model is that high resolution versions of this model were extensively used for weather forecasting so the model physics is optimised for both low (climate) and high (weather) resolution versions. We have performed a series of atmosphere-only LGM and mid-Holocene PMIP simulations with a range of resolutions from those typical of PMIP2 and PMIP3 models (3.75 x 2.5 degrees) to much higher resolution (maximum resolution of 0.56 x 0.38) which is relatively high resolution even for CMIP6. The results show that increased resolution improves the simulation of modern precipitation patterns by better representing the detailed orographic and coastal processes, but that palaeo changes in large scale precipitation are relatively robust and insensitive to resolution scale. The exception to this is at the LGM, when the flow direction changes (causing a shift in rain shadows etc.) and when land area expands with the reduced sea level. The effects of resolution on the changes in extreme events will also be discussed. Furthermore, we will present analyses of the simulations with respect to “the wet gets wetter” paradigm. Initial work suggests that this is not especially effective at explaining the modelled changes.

Marine environmental changes in front of the Scandinavian Ice Sheet during the last deglaciation

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Nadine Quintana Krupinski / nadine.krupinski@geol.lu.se / Dept. of Geology, Lund University
Co-author: Karen-Luise Knudsen, Aarhus University;
Yasmin Bokhari-Friberg, Helena L. Filipsson;
Andreas Mackensen, Alfred Wegener Institute;
Jeroen Groeneveld, Bremen University;
Anne-Sophie Fanget, Aarhus University;
Marit-Solveig Seidenkrantz, Aarhus University;
Helena L. Filipsson, Helena L. Filipsson;

Abstract:
The Kattegat-Baltic Sea region shows evidence of strong coupling with North Atlantic climate over recent glacial-interglacial cycles, but insufficient long, continuous, high-resolution Baltic area climate records have often limited evaluating such links. New ultra-high-resolution sediment cores collected during IODP Expedition 347 allow such records to be generated, including foraminiferal geochemistry records reflecting seawater environmental changes directly adjacent to the Scandinavian Ice Sheet (SIS) during the most recent deglaciation. We present benthic foraminiferal stable isotope (d18O and d13C) and trace element (Ba/Ca, Mn/Ca and Mg/Ca) records from IODP Site M0060 (located between Sweden and Denmark in the southern Kattegat) to constrain bottom water salinity, temperature and oxygenation changes from 18-13ka (chronology is based on 14C dating). Because of the large salinity changes (fresh to near-marine) during the past 20ka in this region, we interpret d18O as reflecting salinity changes more than temperature here, while d13C reflects ventilation, productivity, and salinity. Ba/Ca, Mn/Ca, and Mg/Ca may indicate salinity, oxygenation, and temperature variations, although these proxies are less straightforward to interpret in this setting. Stable isotope results suggest fjord-like, poorly ventilated conditions during early Deglaciation, with three clear phases from 18-13ka : 1) an initial rapid, large freshening event; 2) subsequent slower, step-wise freshening (likely linked to the decay of the SIS); 3) more marine, ventilated, saline conditions after ~15.7ka. These events may be linked to regional and global climate changes during this period of global climate changes, and may help us evaluate the interplay between the SIS and climate in the North Atlantic and beyond.

Post-doctoral supervisor: Prof. Helena Filipsson, Lund University, helena.filipsson@geol.lu.se

Glacial-Interglacial Fire variability in Southern Africa

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Tim Brücher / tbruecher@geomar.de / GEOMAR, Kiel; Germany
Co-author: Anne-Laure Daniau, CNRS, University of Bordeaux, Bordeaux; France;
Gitta Lasslop, Max Planck Institute for Meteorology, Hamburg; Germany;
Paul Valdes, Cabot Institute and School of Geographical Sciences, University of Bristol, UK;

Abstract:
Southern Africa (south of 20°S) paleofire history reconstruction obtained from the analysis of microcharcoal preserved in a deep-sea core located off Namibia reveals changes of fire activity on orbital timescales in the precession band. In particular, increase in fire is observed during glacial periods, and reduction of fire during interglacials such as the Eemian and the Holocene. The Holocene was characterized by even lower level of fire activity than Eemian. Those results suggest the alternance of grass-fuelled fires during glacials driven by increase in moisture and the development of limited fuelled ecosystems during interglacial characterized by dryness. Those results question the simulated increase in the fire risk probability projected for this region under a warming and drying climate obtained by Pechony and Schindell (2010). To get better understanding of fire variability in South Africa we compare data of a deep sea record to model results obtained by JSBACH - the land component of the Max Planck Institute Earth System Model. Fire dynamics over the last 130.000 years is simulated in an offline mode. Climate data like precipitation and temperature as well as vegetation data like soil moisture, productivity (NPP) on plant functional type level are used to explain the trends and variability of fire activity over the last glacial cycle - trends which are driven by vegetation and climate, while vegetation itself is coupled to fire.

Paleo-ice sheet reconstructions constrained by GIA and geological data for use in climate models

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Evan J. Gowan / evan.gowan@awi.de / Alfred Wegener Institute
Co-author: Xu Zhang, Alfred Wegener Institute;
Sara Khosravi, Alfred Wegener Institute;
Gerrit Lohmann, Alfred Wegener Institute;
Klaus Grosfeld, Alfred Wegener Institute;
Abstract:
Paleo-ice sheet reconstructions are complicated by large uncertainties, particularly since it is usually only possible to infer thickness from indirect means such as the response of glacial isostatic adjustment (GIA). GIA itself has large uncertainties with respect to the rheological structure of the Earth, and it is possible to get multiple possible best fitting ice sheet configurations using different Earth models. Usually the best geological constraints for paleo-ice sheets are ice margin location, via dating methods and geomorphological features. Using the program ICESHEET (Gowan et al 2016), it is possible to exploit this knowledge and create glaciologically consistent ice sheet reconstructions for use in GIA modeling. We demonstrate this by applying them to the North American Laurentide and Innuitian ice sheets, and show that it is possible to have an ice sheet that has a much lower profile than other GIA constrained reconstructions such as ICE-6G, GLAC-1 and ANU. A lower profile ice sheet has profound implications for past climate reconstructions, including radically different atmospheric and Atlantic Ocean circulation at the Last Glacial Maximum. Such a reconstruction is better able to fit geological constraints in the near field, but are at odds with global sea level reconstructions that require much larger ice volume. We discuss possible solutions to this issue. Another benefit of ICESHEET is that it does not require climatic information, since the ice thickness is adjusted by changing a spatially and temporarily variable basal shear stress parameter. Using these reconstructions in climate models do not face the circularity of dynamic ice sheet models that require a climatic input that was often derived from a-priori ice sheet reconstructions.

The influence of the ocean circulation state on ocean carbon storage and CO2 drawdown potential in an Earth system model

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Malin Ödalen / malin.odalen@misu.su.se / Dpt. of Meteorology, Stockholm University
Co-author: Jonas Nycander, Dpt. of Meteorology, Stockholm University;
Kevin Oliver, National Oceanography Centre, University of Southampton, UK;
Laurent Brodeau, Barcelona Supercomputer Center, Barcelona, Spain;
Andy Ridgwell, School of Geographical Sciences, Bristol University, UK;
Abstract:
During the four most recent glacial cycles, atmospheric CO_2 during glacial maxima has been lowered by about 90-100 ppm with respect to interglacials. There is widespread consensus that most of this carbon was partitioned in the ocean. It is however still debated which processes were dominant in achieving this increased carbon storage. Here, we use an Earth system model of intermediate complexity to constrain the range in ocean carbon storage for an ensemble of ocean circulation equilibrium states. We do a set of simulations where we run the model to pre-industrial equilibrium, but where we achieve different ocean circulation by changing forcing parameters such as wind stress, ocean diffusivity and atmospheric heat diffusivity. As a consequence, the ensemble members also have different ocean carbon reservoirs, global ocean average temperatures, biological pump efficiencies and conditions for air-sea CO_2 disequilibrium. We analyse changes in total ocean carbon storage and separate it into contributions by the solubility pump, the biological pump and the CO_2 disequilibrium component. We also relate these contributions to differences in strength of ocean overturning circulation. In cases with weaker circulation, we see that the ocean's capacity for carbon storage is larger. Depending on which ocean forcing parameter that is tuned, the origin of the change in carbon storage is different. When wind stress or ocean vertical diffusivity is changed, the response of the biological pump gives the most important effect on ocean carbon storage, whereas when atmospheric heat diffusivity or ocean horizontal diffusivity is changed, the solubility pump and the disequilibrium component are also important and sometimes dominant. Finally, we do a drawdown experiment, where we investigate the capacity for increased carbon storage by maximising the efficiency of the biological pump in our ensemble members. We conclude that different initial states for an ocean model result in different capacities for ocean carbon storage, due to differences in the ocean circulation state. This could explain why it is difficult to achieve comparable responses of the ocean carbon pumps in model intercomparison studies, where the initial states vary between models.

Jonas Nycander, jonas@misu.su.se

Role of dynamical ice loss during the demise of the early-Holocene Laurentide ice sheet

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Ilkka Matero / eeisom@leeds.ac.uk / School of Earth and Environment, University of Leeds, Leeds, United Kingdom

Co-author: Lauren J Gregoire, School of Earth and Environment, University of Leeds, Leeds, United Kingdom;
Stephen L Cornford, School of Geographical Sciences, University of Bristol, Bristol, United Kingdom;

Abstract:

At the start of the Holocene, the Laurentide Ice Sheet (LIS) experienced rapid ice loss associated with the disintegration of the ice saddle over Hudson Bay. Constraining the early Holocene rates of ice loss is important as meltwater flux from the LIS has been identified as a likely major forcing of the abrupt 8.2 ka northern hemisphere cooling evenet, the most profound climate change event of the Holocene. Holocene LIS retreat is thought to have been largely driven by surface mass balance processes. However, the influence of Hudson strait ice stream and interactions with ocean and proglacial lakes likely provided an important feedback mechanism for surface mass balance processes in the disintegration of the ice saddle, leading to higher rates of ice loss. Simulating such processes require computationally expensive ´higher order´ ice sheet models scarcely used for past ice sheets. Now the recent BISICLES 3D ice sheet model, thanks to its unique adaptive mesh refinement is capable of accurately and efficiently resolving ice stream dynamics and grounding line migration, allowing us to accurately simulate the demise of the Laurentide Ice Sheet. We drive BISICLES (offline) with temperature and precipitation forcings from a climate model (FAMOUS) under climatic conditions 9,000 years ago. We investigate the contribution of dynamical ice loss through ice streaming and marine interactions, and combine this with changes driven by surface energy balance. This experiment provides constraints on rates of ice sheet changes and mechanisms of rapid, sub-century ice sheet changes during the early Holocene.

Lauren Gregoire (PhD Supervisor) School of Earth and Environment, University of Leeds, Leeds, United Kingdom l.j.gregoire@leeds.ac.uk

Transient simulations of the last deglaciation in the framework of the PalMod project as contributions to PMIP4

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Gerrit Lohmann / Gerrit.Lohmann@awi.de / Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research

Co-author: Peter Köhler, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research;
Mojib Latif, Helmholtz Center Geomar, Kiel;
Michael Schulz, Marum, University of Bremen;
Martin Claussen, Max-Planck-Institute for Meteorology Hamburg;
Uwe Mikolajewicz, Max-Planck-Institute for Meteorology Hamburg;
Tatjana Ilina, Max-Planck-Institute for Meteorology Hamburg;
Victor Brovkin, Max-Planck-Institute for Meteorology Hamburg;
Stefan Rahmstorf, PIK, Potsdam;
Michal Kucera, Marum, University of Bremen;
Stefan Mulitza, Marum, University of Bremen;
Thomas Slawig, University of Kiel;
Joachim Biercamp, DKRZ Hamburg;

Abstract:

The last deglaciation (21-9 kyr BP), which marked the transition between the last glacial and present interglacial period, was punctuated by a series of rapid (centennial and decadal) climate changes. Numerical climate models are useful for investigating mechanisms that underpin these events, especially now that – due to availability of increased computational power – some of the complex models can be run over the period of multiple millennia. In phase 1 of the Palmod project, we aim to perform transient simulations of the last deglaciation in order to quantify contributions of different climatic factors using complementary models and coupling strategies, including a setup in which the climate models are fully coupled to land-ice sheet models. In a 2nd phase also the full interaction with biogeochemical cycles is envisaged. Within PalMod continuous time series of the three greenhouse gases CO2, CH4, and N2O have now been constructed, based on a state-of-the-art compilation of available ice core data, which have been carefully selected, partially corrected and spline-smoothed to an equidistant time step of 1 year. The full data sets, including uncertainty estimates, are covering the last 156 kyr and are supported by instrumental measurements until the year 2016 CE. These data might be used for the deglaciation and other PMIP4 related experiments covering parts of the last 150 kyr, We suggest that other PMIP participants use the same GHG data sets to force their models, which might then facilitate the intercomparisons. This GHG data compilation is documented here: Köhler, P., Nehrbass-Ahles, C., Schmitt, J., Stocker, T. F., and Fischer, H.: A 156 kyr smoothed history of the atmospheric greenhouse gases CO2, CH4, and N2O and their radiative forcing, Earth Syst. Science Data, 2017, doi: 10.5194/essd-2017-6. The related GHG data and simplified estimates of the related radiative forcing can be accessed at doi: 10.1594/PANGAEA.871273. Link to the project: www.palmod.de

Cold ocean, warm summers? The role of atmospheric blocking

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Frederik Schenk / frederik.schenk@geo.su.se / Stockholm University
Co-author: Arne Johansson, Royal Institute of Technology, KTH Stockholm;
Barbara Wohlfarth, Stockholm University;
Abstract:
The late deglaciation over the Euro-Atlantic region is characterized by rapid climate shifts between warm and cold states. Proxy- and modelling-evidence suggest a consistent link between cold annual/winter climates with cold ocean states over the North Atlantic. However, it remains unclear whether and, if so, how these cold ocean states should lead to cold European summers in the presence of very high and further increasing summer insolation. Here we present results from ongoing high resolution (~100 km) time slice simulations for the late deglaciation with the Community Earth System Model (CESM1). We study the link between cold/warm ocean states and European summer temperatures under different solar and greenhouse gas forcing. In these simulations (Bølling, Older Dryas, Allerød, Younger Dryas and Early Holocene), we use a realistic paleo-topography with ice sheets and low sea-level stands. Global SSTs and sea-ice concentrations for the different warm/cold states are prescribed from a previous coarse resolution (~375 km) but fully coupled transient simulation with CCSM3 (TraCE). We show that atmospheric blocking over Europe is a dominant mechanism leading to warm summers during the late deglaciation in addition to orbital forcing. The cold ocean state of the Younger Dryas (YD, GS-1) leads to enhanced blocking. A cold-ocean-only experiment confirms that the ocean state alone leads already to warmer summers. Increased solar forcing weakens blocking over central Europe but instead leads to stronger warming over continental Eurasia. The warm but very short summers during the YD are confirmed by plant indicator species from European lakes. The strong cooling in other seasons with extreme winters may explain the dominance of cold proxy evidence. We briefly show that the summer temperature response and atmospheric blocking are model resolution dependent. In addition, we show how the positive feedback of low soil moisture, late summer heating and atmospheric blocking in response to cold SSTs in our simulation are confirmed by recent observations linking unusually cold North Atlantic SSTs with European heat waves.

Heavy impacts of climate model resolution on the simulated ice sheets at the Last Glacial Maximum

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Irina Rogozhina / irogozhina@marum.de / University of Bremen, MARUM - Center for Marine Environmental Sciences

Co-author: Matthias Prange, University of Bremen, MARUM - Center for Marine Environmental Sciences;
Pepijn Bakker, University of Bremen, MARUM - Center for Marine Environmental Sciences;
Jorge Bernales, Helmholtz Centre for Geosciences, GFZ Potsdam;
Ute Merkel, University of Bremen, MARUM - Center for Marine Environmental Sciences;
André Paul, University of Bremen, MARUM - Center for Marine Environmental Sciences;
Michael Schulz, University of Bremen, MARUM - Center for Marine Environmental Sciences;
Julien Seguinot, Laboratory of Hydraulics, Hydrology and Glaciology, ETH Zürich;
Arjen P. Stroeven, Geomorphology and Glaciology, Department of Physical Geography, Stockholm University;

Abstract:
Geometries and flow regimes of modeled ice sheets strongly depend on applied climate forcing. In paleoglaciological reconstructions, climate forcing is commonly derived from paleoclimate proxy data combined with present-day observations. However, such strategy fails to account for largely dissimilar patterns of the atmospheric and ocean circulation during past periods, in particular related to the effects of the ice sheets themselves. An alternative approach is to use the products of climate model intercomparison initiatives that include ice sheets as boundary conditions but often suffer from low spatial resolution. Here we present global ice sheet simulations driven by near-surface climate fields from Last Glacial Maximum (LGM) simulations, which were conducted with prescribed ice sheets and at different resolutions of the atmospheric (T31, T42 and T85) and ocean (3º and 1º) model components using the Community Climate System Model (CCSM3). Our analysis yields that ice sheet simulations forced by the highest-resolution climate fields (T85/1º) arrive at ice geometries that are largely consistent with available geomorphological constraints from end moraines. In contrast, lower-resolution fields (T31/3º and T42/1º) either inhibit the growth of the documented ice sheets or trigger ice-sheet buildup in places where the paleorecord indicates otherwise. All ice sheets exhibit high sensitivity to a decrease in the spatial resolution of the climate forcing but the response of the Eurasian Ice Sheet is most dramatic: When exposed to the low-resolution forcing, it loses its important counterpart over the British Isles, while gaining too much volume across northern Eurasia. We demonstrate that this is due to important differences between the three climate model solutions over large portions of the North Atlantic and the Arctic and conclude that such deficiencies of low-resolution climate experiments cannot be corrected using statistical down-scaling. It is therefore important to enhance the quality of climate simulations by increasing the grid resolution when setting up PMIP4 experiments with the latest generation of general circulation models. We also propose to validate the resulting climate states and examine their consistency with the prescribed ice sheet boundary conditions by flanking PMIP4 baseline simulations with a combination of global ice sheet simulations and geological evidence.

Simulating the Last Deglaciation with the isotope-enabled CESM

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Esther Brady / brady@ucar.edu / National Center for Atmospheric Research
Co-author: Bette L. Otto-Bliesner, National Century for Atmospheric Research;
Zhengyu Liu, University of Wisconsin, Madison;
Robert Tomas, NCAR;
Alex Jahn, University of Colorado, Boulder;
Chengfei He, University of Wisconsin, Madison;
Sifan Gu, University of Wisconsin, Madison;
Jiaxu Zhang, University of Wisconsin, Madison;
Jiang Zhu, University of Wisconsin, Madison;
Abstract:
A suite of four transient simulations of the last deglaciation are underway with the isotope-enabled CESM. We are using the CESM implemented with stable water isotope tracers in the atmosphere, land-surface, ocean, runoff, and sea-ice components, and new passive ocean tracers for abiotic 14C and 12C, Protactinium, Thorium, and Neodymium isotopes. These tracers are designed to improve comparison to paleoclimate proxy records and to investigate proxy-climate relationships. The baseline simulation is forced with prescribed changes in insolation, atmospheric greenhouse gas concentrations, continental ice sheet variations, and meltwater fluxes. In addition, three experiments will be performed with different sets of forcings and boundary conditions combined to factor out the relative contributions to the climate evolution of the last deglacial period. The boundary conditions and forcings are taken from the PMIP4 deglacial protocols (Ivanovic et al. 2016.) The ice sheet reconstruction used is ICE-6G (Peltier et al. 2015.) In comparison with our previous transient simulation of the deglacial period using the CCSM3, TraCE-21, run at T31 resolution in the atmosphere and nominally 3 deg. in the ocean, these simulations will be run at a higher resolution (2 deg. in the atmosphere and 1 deg. in the ocean) and with improved physical parameterizations. Preliminary results will highlight both the simulated transient climate response to different forcings in comparison to our TraCE-21, and how the isotopic signals in the water cycle vary in response to climate change globally. Ivanovic, R. F., L. J. Gregoire, M. Kageyama, D. M. Roche, P. J. Valdes, A. Burke, R. Drummond, W. R. Peltier, and L. Tarasov (2016), Transient climate simulations of the deglaciation 21–9 thousand years before present (version 1)-- PMIP4 Core experiment design and boundary conditions, Geosci. Model Dev., 9, 2563-2587, doi:10.5194/gmd-9-2563-2016. Peltier, W. R., Argus, D. F., and Drummond, R.: Space geodesy constrains ice age terminal deglaciation: The global ICE-6G_C (VM5a) model, J. Geophys. Res.-Sol. Ea., 120, 450–487, doi:10.1002/2014JB011176, 2015.

Tropical hydroclimate change during Heinrich Stadial 1 – A proxy-model synthesis

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Tianyi Sun / t.sun@utexas.edu / Jackson School of Geosciences, University of Texas at Austin

Co-author: Pedro DiNezio, Jackson School of Geosciences, University of Texas at Austin;
Timothy Shanahan, Jackson School of Geosciences, University of Texas at Austin;
Kiara Gomez, Jackson School of Geosciences, University of Texas at Austin;
Allison Lawman, Jackson School of Geosciences, University of Texas at Austin;
Natallia Piatrunia, Jackson School of Geosciences, University of Texas at Austin;
Chijun Sun, Jackson School of Geosciences, University of Texas at Austin;
Xian Wu, Jackson School of Geosciences, University of Texas at Austin;
Masa Kageyama, LSCE/IPSL – Laboratoire des Sciences du Climat et de l'Environnement;
Ute Merkel, Center for Marine Environmental Sciences, University of Bremen;
Bette Otto-Bliesner, National Center for Atmospheric Research;
Ayako Abe-Ouchi, Atmosphere and Ocean Research Institute, University of Tokyo;
Gerrit Lohmann, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research;
Joy Singarayer, School of Archaeology, Geography and Environmental Science, University of Reading;

Abstract:

We explore the response of tropical climate to abrupt cooling of the North Atlantic (NA) during Heinrich Stadial 1 (HS1) combining paleoclimate proxies with model simulations. The proxies reveal large-scale patterns of hydroclimate change relative to glacial conditions, confirming previously reported weaker Indian summer monsoon, drier Sahel and wetter south Africa, and drying over the Caribbean. Our synthesis also reveals drying over the Maritime continent as well as wetter northern Australia and southern tropical South America. We explore mechanisms driving these changes using a multi-model ensemble of so-called "hosing" simulations. We propose that ventilation of colder mid-latitude air explains the consistent reduction in the North African monsoon and Indian summer monsoon simulated by most models. The best-agreeing models indicate that cooling over the tropical NA maybe essential to drive remote tropical hydroclimate changes. Cooling of the NA also induces warming over the tropical South Atlantic (SA) via wind-evaporation-SST feedback, driving wetter conditions in South Africa and southern tropical South America. We find that the response over the warm pool is driven by El Nino-like changes in the Pacific initiated by cooling of the Caribbean. Together these results show a dominant role for altered tropical SST gradient driving changes in tropical rainfall.

Pedro DiNezio University of Texas at Austin pdn@ig.utexas.edu

Preliminary results of the changes in ocean circulation and ocean carbon cycle during Heinrich event

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Akitomo Yamamoto / akitomo@aori.u-tokyo.ac.jp / University of Tokyo
Co-author: Ayako Abe-Ouchi, University of Tokyo;
Abstract:
Paleoproxy records suggest that weakening of the Atlantic Meridional Overturning Circulation (AMOC) during Heinrich events was associated with the atmospheric CO2 increase of 10?20 ppm over 1000 years (Ahn and Brook, 2008). However the mechanism of CO2 increase and this linkage to the AMOC have remained unclear. In this study, the response of deep ocean circulation and ocean biogeochemical properties to glacial freshwater perturbations in the northern North Atlantic are investigated using a coupled atmosphere?ocean circulation model MIROC and offline ocean biogeochemical model. In associate with the AMOC weakening from 26 Sv to 6 Sv and the decrease in global export production by 20%, the atmospheric CO2 increases by 4.5 ppmv. Preliminary analyses show that the carbon reservoir of the upper ocean (above 2000m) except the Southern Ocean decreases resulting in atmospheric CO2 increase. On the other hand, enhanced export production in the Southern Ocean increases the carbon reservoir of the deep ocean leading to atmospheric CO2 reduction. We will also discuss the response of biological pump in the Southern Ocean and changes in carbon isotope in this presentation.

Key mechanisms for simulating glacial changes in warm pool climate: implications for the future

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Pedro DiNezio / pdn@ig.utexas.edu / Institute for Geophysics, Jackson School of Geosciences, University of Texas at Austin

Co-author: Jessica E. Tierney, The University of Arizona, Department of Geosciences;
Bette L. Otto-Bliesner, National Center for Atmospheric Research, Climate and Global Dynamics Division;
Axel Timmermann, IBS Center for Climate Physics, Pusan National University;
Tripti Bhattacharya, The University of Arizona, Department of Geosciences;
Nan Rosenbloom, National Center for Atmospheric Research, Climate and Global Dynamics Division;
Esther Brady, National Center for Atmospheric Research, Climate and Global Dynamics Division;

Abstract:
The mechanisms driving glacial-interglacial changes in the climate of the Indo-Pacific warm pool (IPWP) are unclear. We addressed this issue combining model simulations and paleoclimate reconstructions of the Last Glacial Maximum (LGM). Two drivers – the exposure of tropical shelves due to lower sea level and a monsoonal response to ice sheet albedo – explain the proxy-inferred patterns of hydroclimate change. Shelf exposure influences IPWP climate by weakening the ascending branch of the Walker circulation. This response is amplified by coupled interactions akin to the Bjerknes feedback involving a stronger sea-surface temperature (SST) gradient along the equatorial Indian Ocean (IO). Ice sheet albedo enhances the import of cold, dry air into the tropics, weakening the Afro-Asian monsoon system. This “ventilation” mechanism alters temperature contrasts between the Arabian Sea and surrounding land leading to further monsoon weakening. Additional simulations show that the altered SST patterns associated with these responses are essential for explaining the proxy-inferred changes. Our results show that ice sheets are a first order driver of tropical climate on glacial-interglacial timescales. While glacial climates are not a straightforward analogue for the future, our finding of an active Bjerknes feedback deserves further attention in the context of future climate projections.

Impact of glacial ice sheets on the duration of the stadials: Role of surface wind and surface cooling

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Sam Sherriff-Tadano / tadano@aori.u-tokyo.ac.jp / Atmosphere and Ocean Research Institute, the University of Tokyo

Co-author: Ayako Abe-Ouchi, Atmosphere and Ocean Research Institute, the University of Tokyo;

Abstract:

It has been shown from ice core reconstructions that glacial periods experienced frequent climate shifts between interstadials and stadials. The duration of these climate modes varied during glacial periods, and both the interstadials and stadials were shorter during Marine Isotope Stage 3 (MIS3) compared to MIS5. Recent studies showed that the duration of the interstadials is controlled by the Antarctic temperature, which has an impact on the stability of the Atlantic Meridional Overturning Circulation (AMOC). However, a similar relation could not be found for the stadials, suggesting that another climate factor (e.g. differences in ice sheet size, greenhouse gases and insolation) may play a role. Thus, for a better understanding of the stability of the climate, it is very important to evaluate the impact of these climate factors on the duration of the stadials. In this study, we investigate the role of glacial ice sheets. For this purpose, freshwater hosing experiments are conducted with an atmosphere-ocean general circulation model MIROC4m under several ice sheet configurations computed in an ice sheet model Icies (Abe-Ouchi et al. 2013). The impact of glacial ice sheets on the duration of the stadials is evaluated by comparing the behavior of the weak AMOC after the freshwater forcing is reduced. All experiments show a drastic weakening of the AMOC in response to the freshwater hosing, accompanied by a cooling over the North Atlantic, a southward shift of the tropical rain belt and a warming over the Antarctic. We find that experiments with smaller ice sheets take longer to recover after the freshwater hosing is reduced. Sensitivity experiments with MIROC4m reveal that differences in surface winds are important in causing the shorter stadial with larger ice sheet configurations, while differences in the surface cooling have an opposite effect.

Seasonal and latitudinal climate response to individual orbital parameters with MIROC-GCM

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Kanon Kino / kanon@aori.u-tokyo.ac.jp / AORI, The University of Tokyo
Co-author: Ayako Abe-Ouchi, AORI, The University of Tokyo;
Abstract:
Orbital parameters (eccentricity, obliquity and precession) play important roles in determining glacial climate changes. We investigate the sensitivity of atmospheric GCM coupled to slab ocean and dynamical vegetation model (MIROC-LPJ; O'ishi and Abe-Ouchi, 2011) to changes in orbital parameters. We examine various orbital parameters to set eccentricity to 0, 0.01671, 0.03 and 0.0493, obliquity to 22.079, 23.439 and 24.480, and precession angles to every 30 degrees from 0 to 330 under different CO2 levels. We will discuss the dependence of seasonal and latitudinal temperature and precipitation on orbital parameters. We will also examine the role of dynamical vegetation change on temperature response to orbital parameters.

The importance of the ice sheet feedbacks over the last deglaciation

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: A. Quiquet / Aurelien.Quiquet@lsce.ipsl.fr / LSCE, France

Co-author: D. Roche, LSCE; Earth and Climate Cluster, Faculty of Earth and Life Sciences, Vrije Universiteit Amsterdam, the Netherlands;
C. Dumas, LSCE, France;

Abstract:

The disintegration of the Northern Hemisphere ice sheets during the deglaciation, starting from ~ 21 kaBP, resulted in large and global modifications of the Earth climate. Multiple feedbacks are associated with the ice sheets (albedo, topography, runoff) and their importance remains debated. To further advance on this topic, we use the climate model of intermediate complexity iLOVECLIM v1.1. This coupled climate system includes atmospheric, ocean and vegetation components dynamically coupled. In its latest version, it most notably also includes an interactive ice sheet model, coupled to the atmosphere thanks to an online and conservative dynamical downscaling procedure for heat and moisture. Freshwater fluxes due to ice sheet melt and calving are transferred to the ocean in a consistent and conservative way, hence allowing for a complete closure of the water cycle. In the proposed paper, we will analyze results from multiple 21 ky long integrations of the model with both interactive and prescribed ice sheets. The importance of the corresponding ice sheet geometries and freshwater fluxes on the global climate can thus be readily evaluated together with the associated feedbacks. The simulations with prescribed ice-sheets follow the PMIP4 protocol using both provided transient reconstructions. This work is hence a contribution to the PMIP4 last glacial maximum and last deglaciation working groups.

Glacial Atlantic Overturning in CMIP/PMIP models controlled by the Southern and Northern high latitude changes

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Ayako Abe-Ouchi / abeouchi@aori.u-tokyo.ac.jp / AORI, University of Tokyo

Abstract:
Deep Ocean circulation indicated by geochemical tracers varied during the ice age cycle with climate and the Milankovitch cycle. Multiple tracer evidence at the Last Glacial Maximum (LGM) particularly show that the water originated from the North Atlantic (NADW) was shoaler than the present day ocean and the Atlantic meridional overturning circulation (AMOC) may have been weaker. Athough it is expected to be a good test for the fully coupled atmosphere-ocean general circulation models (GCM) which are used for future climate projection, many models forced with glacial condition, however, fail to simulate the glacial AMOC, which is an obstacle to understand the response of ocean to climatic forcings. Here we analyse multi-climate models including the latest CMIP5/PMIP experiments and show that most of the climate models show a stronger and deeper AMOC associated with the insufficient cooling in the LGM Southern ocean. We further show that the models which fail to have shoeler glacial AMOC is even strengthened because of the feedback between the AMOC, sea ice and wind stress in the north Atlantic. Our additional study using MIROC AOGCM show that by eliminating the warm bias at southern ocean, which most of the climate models suffer from, the sufficiently vigorous Antarctic bottom water formation under glacial condition and proxies (MARGO and delta 13C) can be simulated. We suggest that the improvement of cloud scheme in GCM atmosphere-ocean-ice processes in the high latitude region and sufficient calculation to obtain the equilibrium state especially around Antarctica is crucial for more appropriate AMOC simulation both for the glacial and future climate change.We discuss the implication for the future climate change by analyzing the runs in the glacial and future projection using MIROC model.

Simulated abrupt recovery of overturning circulation during Bølling-Allerød using MIROC AOGCM

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Takashi Obase / obase@aori.u-tokyo.ac.jp / AORI, University to Tokyo
Co-author: Ayako Abe-Ouchi, AORI, University to Tokyo;
Abstract:
During the last deglaciation, a major global warming was punctuated by several abrupt climate changes, likely related to Atlantic Meridional Overturning Curculation (AMOC). A transient simulation from the Last Glacial Maximum (21,000 years ago) to Bolling-Allerod (BA, 14,000 years ago) is conducted using an atmosphere-ocean coupled general circulation model. Changing insolation, greenhouse gas concentrations and glacial meltwater fluxes are applied based on reconstructions. An abrupt recovery of the AMOC occurred at around the period of BA, even under the glacial meltwater flux that is equivalent to a sea level rise of approximately 5 meters in 1,000 years. The simulated transition of Greenland climate occurs in approximately 100 years, which is consistent with reconstructions. The results indicate that the increasing summer insolation and greenhouse gas concentration could trigger an abrupt recovery of the AMOC without large fluctuations of glacial meltwater flux in the North Atlantic in MIROC AOGCM.

Sensitivity of the LGM climate to the uncertainty in PMIP4 ice sheet boundary conditions

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)
Author: Pepijn Bakker / pbakker@marum.de / MARUM, University of Bremen, Germany
Co-author: Matthias Prange, MARUM, University of Bremen, Germany;
Irina Rogozhina, MARUM, University of Bremen, Germany;
Abstract:
The elevation of the Last Glacial Maximum (LGM) ice sheets that covered large parts of North America and Eurasia is uncertain. This is reflected in the PMIP4 LGM protocol through the option to use either the ICE-6G or GLAC-1D ice sheet reconstructions. Previous work has shown that the climate is especially sensitive to changes in the elevation of the Laurentide Ice Sheet, with possible impacts on the strength of the Atlantic Meridional Overturning Circulation, and temperatures over the North Atlantic, northeastern Asia and the North Pacific. Here we use the CESM1.2 coupled atmosphere (CAM5 at 2°-resolution), ocean (POP2 at 1°-resolution) and sea-ice (CICE4 at 1°-resolution) general circulation model. Firstly, we force LGM simulations with these two different ice sheet reconstructions to test the sensitivity of the LGM climate to the uncertainty in the PMIP4 ice sheet boundary conditions and analyze the underlying mechanisms. Subsequently we use the simulated climate states to force an ice sheet model, which allows us to evaluate the paleoclimate simulations in terms of their consistency with the imposed boundary conditions and with the reconstructed ice-sheet extents.

The 8.2 ka cooling event caused by Laurentide ice saddle collapse

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Ilkka S. O. Matero / eeisom@leeds.ac.uk / University of Leeds
Co-author: Lauren J. Gregoire, University of Leeds;
Ruza F. Ivanovic, University of Leeds;
Julia C. Tindall, University of Leeds;
Alan M. Haywood, University of Leeds;

Abstract:
The 8.2 ka event is a period of abrupt cooling of 1-3 °C across large parts of the Northern Hemisphere, which lasted for about 160 years. The consensus on the cause for this event has been the outburst of the proglacial Lakes Agassiz and Ojibway. These drained into the Labrador Sea in ~0.5-5 years and slowed the Atlantic Meridional Overturning Circulation (AMOC), thus cooling the North Atlantic region. However, climate models haven’t been able to reproduce the duration and magnitude of the cooling with this forcing without including additional centennial-length freshwater forcings, such as rerouting of continental runoff and ice sheet melt in combination with the lake release. Here, we show that instead of being caused by the lake outburst, the event could have been caused by accelerated melt from the collapsing ice saddle that linked domes over Hudson Bay in North America. We forced a General Circulation Model with time varying meltwater pulses (100-300 year) that match observed sea level change, designed to represent the Hudson Bay ice saddle collapse. A 100 year long pulse with a peak of 0.6 Sv produces a cooling in central Greenland that matches the 160 year duration and 3 °C amplitude of the event recorded in ice cores. The simulation also reproduces the cooling pattern, amplitude and duration recorded in European Lake and North Atlantic sediment records. Such abrupt acceleration in ice melt would have been caused by surface melt feedbacks and marine ice sheet instability. These new realistic forcing scenarios provide a means to reconcile longstanding mismatches between palaeoclimate reconstructions and models. They also allow for a better understanding of both the sensitivity of the climate models and processes and feedbacks in motion during the disintegration of continental ice sheets. In addition, they provide insights into the stability of the Atlantic Multidecadal Oscillation and freshwater-driven perturbations of the AMOC resulting from the accelerating melting of the Greenland Ice Sheet.

Searching for the deglaciation: sampling spatio-temporal climate uncertainty for simulating ice sheet evolution

Session: Glacial Climates (LGM, Last deglaciation, Ice sheet uncertainties, Glacial-interglacial cycles)

Author: Lauren Gregoire / l.j.gregoire@leeds.ac.uk / University of Leeds, UK
Co-author: James Salter, University of Exeter, UK;
Daniel Williamson, University of Exeter, UK;
Tamsin Edwards, The Open University, UK;

Abstract:
Ice sheet models fail to reproduce reconstructed patterns of Northern Hemisphere ice sheet retreat through the last deglaciation (21,000-6,000 years ago). This is the main barrier to understanding the role of ice sheets in past abrupt climate and sea level changes and constraining the post-glacial isostatic adjustment of the solid Earth. The primary reason for this failure is the large uncertainty in the boundary conditions to the ice sheet models, which are derived from global climate simulations. Simulations of the transient evolution of climate over the last 21,000 years are computationally expensive to produce and have large biases and uncertainties in their inputs (e.g. ice sheet melt input to the oceans). It is thus impossible to produce large ensembles of climate simulations that would span plausible deglaciation climates. We developed a statistical method to systematically explore the spatio-temporal uncertainty in climate (temperature and precipitation) through this period, by combining output from transient General Circulation Model (GCM) simulations of the last 21,000 years with surface air and sea surface temperature change proxy records. The method consist of producing basis vectors of climate change through single value decomposition of an ensemble of climate simulations. We then define a set of linear combinations of the basis vectors which match a compilation of proxy records of temperature changes within their uncertainty. We present a pilot application of this method using a compilation of surface temperature records from Shakun et al. (2012) and output from a perturbed physics ensemble of FAMOUS simulations as well as the Trace-21k simulation produced with CCSM3. A set of 500 plausible spatio-temporal temperature field were thus produced. With this, we ran an ensemble of 500 simulations of the North American ice sheet evolution from 21,000 to 6,000 years ago with the Glimmer-CISM ice sheet model, where climate and ice sheet parameters are varied. An evaluation of the output against reconstructed ice extent is performed to identify plausible ice sheet simulations and their corresponding climate input.