Studies on variations of climate and ice sheet under the international deep ice core project at the North East Greenland Ice Stream

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The Greenland Ice Sheet has recently been experiencing drastic changes, such as extended summer melting and increasing mass losses. There is an urgent need to understand the mechanisms of such changes because they are directly linked to global sea level rise. Greenland ice cores have so far provided valuable information on melt events and changes in the surface mass balance in the past. Moreover, the data obtained from multiple deep ice cores drilled during the last few decades, combined with modeling studies, have recently enabled us to reconstruct the past changes of Greenland Ice Sheet elevation. The previous ice cores were drilled at sites with minimal horizontal ice flow, as the main purpose of the past ice coring projects was to reconstruct the past climate and environment at the drill sites. Information on ice flow dynamics obtained from such ice cores has therefore been limited.
Understanding the mechanisms of basal sliding and ice deformation is a prerequisite for better projections of the future changes of the Greenland Ice Sheet and sea level rise. To understand the Greenland Ice Sheet dynamics, the East Greenland Ice Core Project (EGRIP) was proposed by the University of Copenhagen. Japan, Germany, Norway, U.S.A., France and Switzerland have been invited to participate in this international project. Under EGRIP, a deep ice core to the bed will be drilled at the onset of the North-East Greenland Ice Stream (NEGIS), where horizontal flow velocity is expected to be several tens of meters per year. As NEGIS is the largest ice stream in Greenland, the EGRIP ice core will certainly advance our knowledge on the dynamics and past changes of the Greenland Ice Sheet. The EGRIP core will also give us an ideal opportunity to reconstruct the climate and environment changes during the early Holocene, which was considered to be warmer than today and should be an excellent analogue to the future Greenland affected by global warming. The results from the EGRIP core will fill the gap of our knowledge due to the lack of high-resolution, detailed ice core records from the early Holocene.
Japan will participate in the EGRIP under the ArCS (Arctic Challenge for Sustainability) project, a recently funded national project. The first EGRIP steering committee meeting was held in Copenhagen in late October 2015. At the meeting, drilling and fieldwork plans were presented by the University of Copenhagen. Scientific plans were proposed by all the participant nations. At the JpGU meeting, we will present the scientific purposes and plans, together with the current status of the EGRIP and logistic plans.

Keywords: EGRIP, Greenland, Ice core

Japanese glaciological activity in Antarctica for the next six years (JARE Phase IX)

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The Dome Fuji ice core covers the past 720,000 years, and its analyses have been conducted. During the Phase VIII of Japanese Antarctic Research Expedition, we made advancements in glaciological activities such as transportation of the second Dome Fuji ice core, shallow and intermediate drillings, and large-area glaciological surveys.
International Partnership in Ice Core Science (IPICS), to which Japan has participated, has identified the “oldest ice core” project, which aims to collect 1.5 million-years-old ice cores from Antarctica, as a most important and challenging project for the international ice core community. We plan to contribute to this project and started the consideration of next deep drilling site in the vicinity of the current Dome Fuji station.
During the next six years, we aim to conduct glaciological surveys, identify a suitable coring site, and start drilling to the first few hundred meters. In addition to the new drilling, a part of the second Dome Fuji core, stored at the station, must be transported to Japan for the study of this core.
In the presentation, we will also introduce our planned coastal activities and updates on international circumstances about the oldest ice project.

Keywords: Japanese Antarctic Research Expedition, Climate change, Ice core

Determination of the ice drilling site in the next deep ice coring project of the “oldest ice” at Dome Fuji

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In the next phase of the Antarctic research activities of Japan, National Institute of Polar Research along with Dome Fuji Ice Core Consortium (ICC) in Japan plan to perform various activities related to drilling of the “oldest ice” with ages much older than 800 kyr ago, in the vicinity of Dome Fuji. We call the planned ice core as “the 3rd DF deep core”. In the near future, we aim to: (i) investigate glaciological conditions (ice sheet surface conditions, englacial conditions and subglacial conditions) of the candidate site area; (ii) determine the exact location of the drilling site and (iii) start to perform pilot hole drilling, casing and shallow/middle range deep drilling.Prerequisites of presence of the very old ice are as follows. (i) The ice/bed boundaries must be frozen. (ii) The ice layers near the bed must be maintained as undisturbed by the ice sheet flow. (iii) During glacial/interglacial cycles, surface mass balance must be generally positive.To satisfy the prerequisite (i), presence of subglacial highland is necessary in the glaciological condition of the inland of Antarctica. We have shown in our earlier observational studies that in the vicinity of Dome Fuji ice sheet bed is frozen when ice thickness is less than ~2850 m. We have confirmed, at area ~50 km of the Dome Fuji summit, there is a wide area with ice thickness of ~2200 m, where the ice sheet bed is frozen. To satisfy the condition (ii), the site must be close to the present summit of Dome Fuji. The area ~50 km of the Dome Fuji summit satisfy this condition. It has been estimated that ice layers with ages older than ~800 kyrs ago are highly compressed within the deepest 5 % of the ice sheet thickness. Thus conditions for presence of such compressed ice and rheology is also a major subject of the ice coring project. As for the condition (iii), we have confirmed the condition is satisfied based on the internal layering observations with ice sounding radars.We already started the preliminary investigation of the radar sounding in 1997, and accumulated data since then. We have identified area for the site, and performed shallow drilling at the base camp of the area. In the near future, we will carry out radar surveys spatially in more detail, to determine the exact location of the deep ice coring.

Keywords: Antarctica, ice sheet, ice core

Ice core drilling and related observations by Jare57 in 2015/2016 austral summer on the coastal region of Antarctic ice sheet

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We were carried out an ice core drilling on the coastal region of Antarctic ice sheet as a part of the 57th of Japanese Antarctic Research Expeditions (2015/2016 of austral summer). We selected the H128 site for drill site (69.40S, 41.55E, 1,380m a.s.l . 100km inland from the coast). Advantages of H128 site were as below; high time resolution, few changes of annual snow accumulation rates, low annual mean temperature (10m depth ice temperature) -24 C. We finally drilled to 260m in depth. We will be able to analyze the climate changes of past 2000 years. Firn air samplings were also carried out. We also conducted the borehole logging, snow pit observation, setup of automatic weather station.

Keywords: Antarctic ice sheet, ice core drilling, firn air sampling

Organic aerosol tracer records in NGRIP ice core during the period from MCA to LIA

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Secondary organic aerosol (SOA) formed by the photooxidation of biogenic volatile organic compounds (BVOCs) and biomass burning organic aerosol are major components of organic aerosol in the atmosphere. Those aerosols are thought to play an important role in atmospheric chemistry and physics, as well as regional and global climate via direct and indirect effects on radiative balance. However, substantial impact of those aerosols on the Earth's climate remains unclear. To better understand the substantial role of those aerosols in the climate system, it is vital to investigate long-term variability of those aerosol components and property in a past. Here we for the first time report biogenic SOA- and biomass burning- (levoglucosan) tracers and UV absorption spectra of organic matter in ice cores from Greenland ice core (NGRIP) during the period from Medieval Climate Anomaly (MCA) to Little Ice Age (LIA). We find that the concentrations and composition of biogenic SOA- and biomass burning- tracers relate to climate with increases in the organic aerosol concentrations during MCA. On the other hand, UV absorption spectra of organic matter in NGRIP ice core also drastically changes associated with climate change. These results suggest dramatic changes in source, loading and property of organic aerosol from the warm MCA to cold LIA.

Keywords: ice core, organic aerosol, Medieval Climate Anomaly, Little Ice Age

CH_4 concentrations during the Holocene reconstructed from the NEEM (Greenland) and Dome Fuji (East Antarctica) ice cores

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Methane (CH_4), the second most important anthropogenic greenhouse gas, has increased in the atmosphere by a factor 2.5 since the onset of the Industrial Revolution, which account for ~20% of the total increase in radiative forcing over that time[1]. Ice cores from both polar regions preserve the past atmospheric CH_4, and thus have the potential to constrain the changes in CH_4 concentration difference between the polar regions. The inter polar difference of CH_4 is one of the approaches to understand the evolution of CH_4 budget and its relationship with climate. To reconstruct the CH_4 inter polar difference during the Holocene, we have been measuring CH_4 concentrations in the NEEM (Greenland) and Dome Fuji (Antarctica) ice cores over the period from 200 to 14500 years before present (yr BP), with a mean time resolution of ~50 years. Since most of this time period is overlapping with the brittle zone in the Greenland core, it is challenging to reconstruct accurate CH_4 concentration during the Holocene from the NEEM ice core.
Ice samples without visible cracks were carefully selected from the NEEM and Dome Fuji ice cores. We employed a newly established wet extraction system (an improved version of ref. 2) the National Institute of Polar Research, with a typical sample size of ~80 g (ice). The air released from ice was first collected into a sample tube (electropolished stainless steel tube with a metal-seal valve), and then it was split into two aliquots. One aliquot was measured by a gas chromatograph (Agilent Technologies 7890A) for CO_2, CH_4 and N_2O concentrations, and the other was measured by a mass spectrometer (Thermo DELTA V Plus) for $\delta^{15}N$ of N_2, $\delta^{18}O$ of O_2, $\delta(O_2/N_2)$, $\delta(Ar/N_2)$ and total air content. We have measured 181 samples for the NEEM ice core. Analytical precision of CH_4 concentration was estimated to be ±2.4 ppb from the pooled standard deviation from duplicate measurements (n=53).
Before the Holocene, the NEEM CH_4 concentration is relatively high (620-705 ppb) during the Bø lling-Allerød, and it rapidly decreases to <500 ppb during the Younger Dryas, and then increases to ~750 ppb at the beginning of the Holocene. During the Holocene, CH_4 concentration first decreases to the minimum of ~610 ppb around 5000 yr BP, and it increases afterwards. Our record agrees well with a high resolution CH_4 concentration record from the GISP2 ice core for last 2000 years[3], and that of the NEEM ice core measured by a CFA system between 9500 and 14500 yr BP[4].
We completed the NEEM measurements and started the Dome Fuji measurements, and the resulting CH4 inter polar difference will be deduced and discussed in the presentation.
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Keywords: Ice core, methane, Holocene, Greenland, Antarctica

Glacial climate states and abrupt climate change in MIROC AOGCM

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Millennial climate change such as D-O cycles and AIM recorded in ice cores in both Hemispheres is knownto show a relatively higher amplitude in the middle-level of a glacial cycle than in the interglacial state or severeglacial state. Here we ran several sensitivity experiments using a coupled atmosphere and ocean GCM (MIROC4m,renamed from MIROC3.2.2) and show that the response to fresh water release to the ocean and bipolar responseis highly dependent on the background climate. The experiments were conducted with 500 years water hosingof 0.05 to 0.1 Sv (where 1 Sv is equivalent to the water flux of 10m sea level rise in 100 years) in the NorthAtlantic 50-70N under different basic states; modern climate state with the pre-industrial condition, middle glacialclimate state and full glacial condition, mainly differing in the ice sheet configuration and atmospheric amount ofGreenhouse Gases. The results under middle glacial condition show largest cooling/warming response in NorthAtlantic and a reasonable bipolar warming/cooling signal revealed in the ice core data of the both hemisphere. Wediscuss the responses under different background climates which involve the strong coupling between atmosphere,ocean and sea ice and their dependence on the configuration of ice sheet.

Keywords: Paleoclimate, Climate Model

Long-term periodicities in solar activity between 170 and 200 kyr ago reconstructed from ^{10}Be in ice-core and sediment archives

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Centennial to millennial periodicities of past solar activity in the Holocene epoch have been well investigated by using cosmogenic-nuclides records from tree-ring (^{14}C) and ice-core (^{10}Be) archives. However, those of the older ages are quite unclear because high-resolution records of cosmogenic nuclides are scarce. We obtained multiple high-resolution ^{10}Be records (atmospheric ^{10}Be flux and authigenic ^{10}Be/^{9}Be ratio) of 170–200 kyr ago, the period that includes the Iceland Basin geomagnetic excursion interval (Horiuchi et al., in press). Strong consistency among the records enables us to construct a robust ^{10}Be stack of this interval. A wavelet analysis of the stacked record reveals 4-kyr and 8-kyr periodicities, both of which can be interpreted as intrinsic geomagnetic cycles. We also found a cycle of 1.7 kyr in the ^{10}Be stack record, but it is significant only near the ^{10}Be maximum (the minimum of the geomagnetic paleointensity). A relative enhancement of solar modulation in ^{10}Be production is predicted with reduced paleointensity (Masarik and Beer, 1999; Beer et al., 2012). Therefore, it is possible to attribute this cosmogenic 1.7-kyr cycle to the long-term solar cycle that is identified in this period. The wavelet spectrum of the highest-resolution ^{10}Be record (obtained from the Dome Fuji ice core) shows more a detailed structure than the stacked record. The 4- and 1.7-kyr cycles show similar tendencies to, and are clearer than, those of the stack. The spectrum also shows somewhat intermingled multi-centennial (0.3, 0.5 and 0.7 kyr) cycles around the maxima of ^{10}Be, which likely represent solar cycles in this period (note: 200-yr Suess/de Vries cycle is under the detection limit of our record). On the other hand, the 2.2–2.4-kyr Hallstatt cycle and 1-kyr Eddy cycle, which are frequently documented in Holocene cosmogenic records, are not dominant in our records.

Research of annual cosmic ray events using 10Be in the Dome Fuji ice core

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Cosmogenic nuclides, 14C and 10Be, are produced in the atmosphere by cosmic rays from ourside the Earth. Carbon-14 is stored in tree-rings, and beryllium-10 is stored in ice sheets. Then, we can investigate past cosmic ray intensities by analyzing concentrations of 14C or 10Be. Annual cosmic ray increase events (AD 775 and AD993 or AD994) were found in 14C data of tree-rings. These events were also shown in quasi-annual 10Be data in the ice cores from the Antarctica and the Greenlands. We analyzed quasi-annual 10Be concentration in the Dome Fuji ice core, and detected the cosmic ray events. In this presentaion, we will report the results of quasi-annual 10Be measurments, and discuss a comparison with 14C data.

Keywords: cosmogenic nuclide, annual cosmic ray event

Micro-droplets containing sulfate in the Dome Fuji deep ice core, Antarctica: Findings using micro-Raman spectroscopy

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Climatic signals in deep ice cores, particularly from ion concentrations, may be affected by the diffusion of liquid solution along grain boundaries of ice. Such solutions include sulfates. Because of the difficulty of detecting sulfate liquids in the ice matrix, we must infer the phase state of the sulfates from the ice temperature and inclusion properties. In this study, we use micro-Raman spectroscopy to determine the phase state of three sulfate micro-inclusions in the Dome Fuji ice core at 2798.5-m depth. Using a temperature-ramp test, we find a peak position at 984 cm^{-1} and a change in the full width at half maximum (FWHM) of the S-O stretching mode that identifies the sulfate in the micro-droplets. Considering the peak position and FWHM of sulfate inclusions, we argue that the sulfate would have existed as a micro-droplet liquid on an air hydrate in the ice. Additionally, the increase in the low frequencies of the Raman spectrum below 30 cm^{-1} that we detect can be generally used to identify liquids in natural ice. Our investigation also indicates that the surface of air-hydrates in ice is a preferred location for liquid micro-inclusions. The importance of this finding will be discussed.

Carbonate mineral particles observed in a layer of an ice core drilled from Grigoriev ice cap in Kyrgyz Tienshan, Central Asia

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In 2007, an 87 m-deep ice core were successfully drilled on Grigoriev Ice Cap (4600 m a.s.l.) located in the Tien Shan Mountains, Kyrgyztan. We report a layer rich in carbonate mineral particles found at 53.5 m deep in the ice core. Although a number of dust layers consisting of silicate mineral particles were contained in the ice core, the layer contained less silicate, but abundant carbonate mineral particles. Significant negative stable isotope values and higher concentrations of major chemical solutes were also observed at the layers. Pollen based dating of the ice core showed that the layer corresponded to 1833 A.D. Results suggest that the layer was derived from a huge storm. Although the origin of the carbonate minerals is still mystery, it is probably far distant arid area.

Keywords: ice core, carbonate minerals, Central Asia

Reconstructions of past cyanobacteria flora from ice core samples on Gregoriev Glacier, Kyrgyz Tienshan

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Cryoconite, a microbe-mineral aggregate found on glaciers worldwide is formed by the action of microbial phototrophs, principally Cyanobacteria.
The species composition of cyanobacteria in the ice cores could reflect the environmental condition at that time. Thus, these microorganisms in ice cores could be useful to reconstruct past environments. Despite the ecological importance in glacial environments, the phylogeographic distributions and genetic structures of glacial cyanobacteria are still highly limited.
We report results of cyanobacterial species and their evolution by molecular DNA analysis collected from the ice core samples collected on Gregoriev Glacier, Kyrgyz Tienshan. We reconstruct the organisms and their interactions within the community and with the environment on the sampled sites. We also present detailed pictures of cyanobacterial distribution patterns on glaciers over the Arctic, Antarctic, and Asian high mountains combination of 16S rRNA and 16S-23S internal transcribed spacer (ITS) regions. The results implied cyanobacteria could migrate across Asian glaciers for the last 10,000 years.

Keywords: glacier, ice core, DNA, cyanobacteria

Environmental change study based on the physical-chemical analysis of permafrost core

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Analysis of ice-sheet core can provide paleoenvironmental information that is needed for the future climate change and global warming prediction. However, the application of ice-sheet core analysis is restricted in Arctic and Antarctic regions where ice-sheet still exists [IPCC 4th Report (2007)]. Therefore new method that can extract paleoenvironmental record in non ice-sheet area is required. Permafrost that is widely distributed in north hemisphere's terrestrial area has focused as paleoenvironmental record source in recent years since permafrost shows long-term variation [Schuur et al. (2015), Nature]. Permafrost has varied in mid-term and local climate change after last glacial period, so that the internal properties and freezing-thawing history have 100 - 1000 years scale climate record. Furthermore, quantitative understandings of permafrost components and physical properties such as heat conductivity or ice volume content are necessary for the high accuracy prediction of climate changes.
We have bored permafrost at Spitsbergen, Svalbard and Mt. Fuji and obtained permafrost cores with 1-2 m length. Cores reflect environment such as climate and aggradation condition, so that internal structures and properties of permafrost are greatly different at each boring site. In this presentation, we discuss the environmental dependence of permafrost, and the possibility of paleoenvironmental reconstruction from the physical-chemical analysis of permafrost core.

Keywords: permafrost, Mt. Fuji, Svalbard

Potential of paleogenomics on plant species by using pollen in ice cores

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Many pollen grains in glaciers contain protoplasm, genetic information of pollen grains should enable identification of plant taxa at the species level and estimation of plant genetic diversity. It therefore may allow reconstructions of past vegetation and forestry ecosystem in association with climate and environment in ice core study. This study attempted to obtain genetic information from a single *Pinus* pollen grain by whole genome amplification method. Pollen grains used in this study were *Pinus* extracted from a pit and an ice core obtained from the Belukha glacier in the summer of 2003. The pollen grains were collected from the layers of 1.8-1.9 m depth, 45.3-45.9 m depth and 101.5-101.7 m depth, and these grains seemed to have deposited on the glacier in 2002, 1923 and the 1600s, respectively. The results in this study showed the success rates in obtaining the sequence data were 23.8% (n=21) for the pollen in the year 2002, 13% (n=68) for the pollen in 1923 and 26% (n=19) for the pollen in the 1600s.

Keywords: glacier, ice core, pollen analysis, DNA, Russian Altai Mountains

Chemical solutes and mineral particles in a shallow ice core from Tienshan Urumqi No.1 Glacier

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Ice cores drilled from glaciers in central Asia usually contain a number of dust layers because dust storms frequently occur and supply dust on such mountain glaciers. Dust layers are usually used to distinguish annual layers, however, chemical and mineralogical characteristics of each dust layer have not been studied well. In this study, we analyzed an 8 m-deep ice core drilled from Tienshan Urumqi Glacier No.1 in 2006 in order to characterize dust layers chemically and mineralogically. Microscopy revealed 10 dust layers in the core. The concentration of dust particles did not agreed with those of Ca or Mg, which are derived from dust particles. Furthermore, Ca/Mg ratio varied among the dust layers, suggesting that the mineralogical composition of dust layers differed from year to year.

Keywords: Ice core, dust, Central Asia

Climate dependent contrast in surface mass balance in East Antarctica over the past 216 kyr

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Documenting past changes in the East Antarctic surface mass balance is important to improve ice core chronologies and to constrain the ice sheet contribution to global mean sea level change. Here we reconstruct the past changes in the ratio of surface mass balance (SMB ratio) between the EPICA Dome C (EDC) and Dome Fuji (DF) East Antarctica ice core sites, based on a precise volcanic synchronisation of the two ice cores and on corrections for the vertical thinning of layers. During the past 216,000 years, this SMB ratio, denoted SMB_{EDC}/SMB_{DF}, varied between 0.7 and 1.1, being small during cold periods and large during warm periods. Our results therefore reveal larger amplitudes of changes in SMB at EDC compared to DF, consistent with previous results showing larger amplitudes of changes in water stable isotopes and estimated surface temperature at EDC compared to DF. Within the last glacial inception (Marine Isotope Stages, MIS-5c and MIS-5d), the SMB ratio deviates by up to 0.2 from what is expected based on differences in water stable isotope records. Moreover, the SMB ratio is constant throughout the late parts of the current and last interglacial periods, despite contrasting isotopic trends. These SMB ratio changes not reflected in the isotope profiles are one of the possible causes of the observed differences between the ice core chronologies at DF and EDC. Such changes in SMB ratio may have been caused by (i) climatic processes related to changes in air mass trajectories and local climate, (ii) glaciological processes associated with relative elevation changes, or (iii) a combination of climatic and glaciological processes, such as the interaction between changes in accumulation and in the position of the domes. Our inferred SMB ratio history has important implications for ice sheet modeling, for which SMB is a boundary condition, or atmospheric modeling, for which our inferred SMB ratio could serve as a test.

Keywords: Antarctica, Surface mass balance, ice sheet, ice core

The role of glacial meltwater in the both hemispheres on the Southern Ocean during the last deglaciation

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Recent geological records suggest that West Antarctic Ice Sheet (WAIS) retreated and contributed to global sea level considerably during the Eemian Interglacial although WAIS survives during the deglaciation in the Holocene. Previous ice sheet modeling studies show that warmer seawater temperature around Antarctic ocean and higher rate of basal melting beneath ice shelves are essential to retreat WAIS (Pollard and Deconto 2009; Sutter et al., 2016). According to climate model experiments aiming Eemian interglacial climate, however, Antarctic Ocean is not so warm to account for higher basal melting of Antarctic Ice Shelves (Lunt et al., 2013; Otto-Bliesner et al., 2013). Recent climate modeling studies suggest that during interglacial, glacial meltwater release in the North Atlantic due to deglaciation of northern hemispheric ice sheets could weaken of thermohaline circulation and warms Southern Hemisphere (Holden et al., 2010), glacial meltwater from Antarctic Ice Sheet (Golledge et al., 2014) or North Atlantic (Dome F community members, submitted) could strengthen the stratification of Southern Ocean and warm seawater at subsurface to increase the rate of basal melting of Antarctic ice shelves. The impact of glacial meltwater on Southern Ocean and Antarctic ice sheet during deglaciations, however, is less investigated. In this study we perform freshwater hosing experiments using atmosphere-ocean coupled GCM. Realistic amount of freshwater perturbations are applied to the climate state of a deglaciation, and analyze the response and the evolution of atmospheric and oceanic fields in the Antarctic region.

Keywords: Antarctic Ice Sheet, Southern Ocean, interglacial, deglaciation, glacial meltwater

Investigating stadial-interstadial climate changes with the MIROC climate model

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The Late Pleistocene was a period which started about 126,000 years ago and, in the northern hemisphere, was mostly characterized by glaciation across much of North America and Eurasia. Ice core data from Greenland show a series of abrupt climate changes known as Dansgaard-Oeschger events within that period. These events begin with a relatively rapid warming giving rise to the milder climates of the interstadials, followed by progressive cooling over 1,000 years. Some of these cool states, known as stadials, coincide with Heinrich events during which large amounts of freshwater from melting icebergs were released into the North Atlantic Ocean, altering the global ocean circulation and climate. These abrupt changes may have had a profound effect on the lives of early modern humans, both directly and indirectly through changes in vegetation and the environment.
To investigate how these two extreme climates differed, we used results from a coupled atmosphere-ocean model (MIROC) experiment to run further experiments using a stand-alone atmospheric model, in particular a high-resolution version, with the advantage that these types of models perform faster than the coupled ones. The effects of large freshwater discharge into the Atlantic Ocean are taken into account by specifying the corresponding sea ice and sea surface temperature. The freshwater forcing leads to a bipolar climate pattern with cooler and drier conditions across most of the northern hemisphere and warmer and wetter conditions in parts of the southern hemisphere. We compare with a variety of proxy data globally, for example speleothems which can act as markers of long-term changes in paleomonsoons. Furthermore, we apply our climate model results to a separate dynamical vegetation model to assess how vegetation, especially across Europe, responds to such climate changes. Access to a variety of proxy data can increase confidence in model results while model results are of particular use in locations where proxy data are sparse.

Keywords: Paleoclimate, Climate modeling, Late Pleistocene, Stadial-Interstadial, Vegetation modeling

The impact of glacial ice sheets on abrupt climate change

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Reconstruction from ice cores show that millennial climate change such as D-O invents frequently occurred during mid-glacial period, when atmospheric amount of Greenhouse Gases and ice sheets over the continent were lower/larger compare to the interglacial period, but not as full glacial period. Couple modeling experiments using MIROC recently showed that the climatic response to fresh water release to the ocean becomes larger and more abrupt under larger ice sheets. This suggests that the expansion of the ice sheets may paly a role in modifying the abruptness and the amplitude of the climate change, though the mechanism behind this remains elusive. Here we conducted several sensitivity experiments using an atmospheric general circulation model (AGCM) and ocean general circulation model (OGCM) to investigate the results reported in MIROC. Using the AGCM, modern and glacial ice sheets are applied under large and small sea ice conditions. Using the OGCM, changes in the surface wind are applied at different magnitudes, ranging from the full glacial to modern levels. The results suggest that stronger interaction between the Icelandic Low, cold advection into the northern North Atlantic and surface heat flux from the ocean is important. Results from the OGCM sensitivity experiments are also discussed.

Keywords: abrupt climate change, glacial ice sheet, Icelandic Low

