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

