

Preliminary Modelling of the vegetation-climate, wet area and past methane emission by a general circulation model and a dynamical global vegetation model

*Ryouta O'ishi¹, Ayako Abe-Ouchi^{1,2}

1. Atmosphere and Ocean Research Institute, the University of Tokyo, 2. JAMSTEC

Past time series of methane concentration in the atmosphere is reconstructed from ice core. Generation and emission of methane depend on temperature, wetness and amount of soil organic carbon which reflects climate change and vegetation change. Hence past methane information is useful for validation of paleoclimate modelling. In the present study, we predict some typical past climate (mid-Holocene, the Last Glacial Maximum, the Last interglacial and mid-Glacial) by a general circulation model MIROC and corresponding past vegetation by a dynamical global vegetation model LPJ-DGVM. Furthermore, by introducing a formulation based on Cao et al. 1996, we try to predict the distribution of past methane emission and its total global amount.

Keywords: paleoclimate, vegetation, methane

Response of oceanic carbon cycle during Heinrich events

*Akitomo Yamamoto¹, Ayako Abe-Ouchi¹

1. Atmosphere and Ocean Research Institute, The University of Tokyo

Paleoproxy indicate that a substantial weakening of the Atlantic Meridional Overturning Circulation (AMOC) during Heinrich events was often accompanied by a notable atmospheric CO₂ increase. However, previous modeling studies show conflicting atmospheric CO₂ responses to an AMOC shutdown. In this study, we investigate the response of ocean carbon cycle to weakening AMOC using freshwater experiment conducted with a coupled atmosphere-ocean general circulation model MIROC and offline ocean biogeochemical model. The weakening of AMOC under mid-Glacial condition leads to an oceanic carbon reservoir decrease and to a 4 ppmv atmospheric CO₂ increase, which is smaller than the ice core date of 15 ppmv CO₂ rise. The weakening of the North Atlantic leads to a loss of DIC in the North Atlantic intermediate and deepwaters, resulting in CO₂ outgassing into the atmosphere. In contrast, the greater mixing in the Southern Ocean enhances biological pump and thus increases CO₂ uptake from the atmosphere. Because these two processes cancel each other out, our simulation underestimates the observed atmospheric CO₂ increase. We also discuss the potential mechanisms which cause the additional CO₂ increase of 10 ppmv in this presentation.

Keywords: Heinrich events, Carbon cycle

Precise dating of cosmic ray events in the 17th century found by the analysis of beryllium-10 content in Antarctic ice core

*Hiroko Miyahara¹, Kazuho Horiuchi², Fuyuki Tokanai³, Toru Moriya³, Yusuke Yokoyama⁴, Hiroyuki Matsuzaki⁴, Hideaki Motoyama⁵

1. Musashino Art University, 2. Hirosaki Univ., 3. Yamagata Univ., 4. The Univ. of Tokyo, 5. National Institute of Polar Research

The records of beryllium-10 content in ice cores from Greenland and Antarctica have indicated five events of cosmic ray flux enhancement around the Maunder Minimum from the late 17th century to the early 18th century. These events are suggested to have occurred associated with the change in the heliospheric environment due to the disappearance of sunspots. In order to determine absolute ages of these events, we conducted high precision measurements of carbon-14 in tree rings. Although the peaks in carbon-14 content is strongly attenuated in carbon cycle, they have been detected by the measurement with 0.1% precision.

Keywords: Ice core, Cosmogenic nuclide, Solar activity

Seasonal scale dating of a shallow ice core from Greenland using oxygen isotope matching between data and simulation

Ryoto Furukawa¹, *Ryu Uemura², Koji Fujita³, Jesper Sjolte⁴, Kei Yoshimura⁵, Sumito Matoba¹, Iizuka Yoshinori¹

1. Institute of Low Temperature Science, Hokkaido University, 2. Department of Chemistry, Biology, and Marine Science, Faculty of Science, University of the Ryukyus, 3. Graduate School of Environmental Studies, Nagoya University, 4. Department of Geology, Quaternary Science, Lund University, 5. Institute of Industrial Science, the University of Tokyo

A precise age scale based on annual layer counting is essential for investigating past environmental changes from ice core records. However, the uncertain seasonal cycle (i.e., non-sinusoidal pattern) of oxygen isotope ($\delta^{18}\text{O}$) records causes inevitable errors in the dating. Here, we propose a dating method based on matching the $\delta^{18}\text{O}$ variations between ice-core records and records simulated by isotope-enabled climate models. We applied this method to a new $\delta^{18}\text{O}$ record from an ice core obtained from a dome site in southeast Greenland. The close similarity between the $\delta^{18}\text{O}$ records from the ice core and models enabled correlation and the production of a precise age scale, whose accuracy was ± 2 months. A missing $\delta^{18}\text{O}$ minimum in the 1995/1996 winter is an example of the uncertain $\delta^{18}\text{O}$ seasonal cycle, which hampers annual layer counting. Our analysis suggests that the missing $\delta^{18}\text{O}$ minimum was likely caused by a combination of warm air temperature, weak moisture transport, and cool ocean temperature. Based on the age scale, the average accumulation rate from 1960 to 2014 was reconstructed as 1.02 m yr^{-1} . The annual accumulation rate increases with a slope of $3.6 \text{ (mm year}^{-1}\text{)}$, which is mainly caused by the increase in the autumn accumulation rate (2.6 mm year^{-1}), which is likely linked to the enhanced hydrological cycle caused by the decrease in Arctic sea ice area. On a seasonal time-scale, our reconstructed accumulation suggests that the ERA re-analysis data overestimates the seasonality in this southeast dome region.

Keywords: Greenland, ice core, seasonal scale dating, oxygen isotope, air temperature, annual accumulation rate

A 60-year record of atmospheric sulfate and nitrate depositions preserved in the high-accumulation dome ice core, South East Greenland

*Iizuka Yoshinori¹, Koji Fujita², Shohei Hattori³, Ryu Uemura⁴, Osamu Seki¹, Chihiro Miyamoto⁵, Toshitaka Suzuki⁶, Naohiro Yoshida^{3,7}, Hideaki Motoyama⁸, Sumito Matoba¹

1. Institute of Low Temperature Science, Hokkaido University, 2. Graduate School of Environmental Studies, Nagoya University, 3. Department of Chemical Science and Engineering, School of Materials and Chemical Technology, Tokyo Institute of Technology, 4. Department of Chemistry, Biology, and Marine Science, Faculty of Science, University of the Ryukyus, 5. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 6. Department of Earth and Environmental Sciences, Faculty of Science, Yamagata University, 7. Earth-Life Science Institute, Tokyo Institute of Technology, 8. National Institute of Polar Research

Southeastern Greenland has a dome whose elevation is higher than 3000 m a.s.l. with high accumulation rate (about 1 m yr⁻¹) in water equivalent, which is suitable conditions for reconstructing past environmental changes with a high-time resolution. In this study, we measured major ion fluxes in 90 m ice core drilled from the SE-Dome region in 2015, and obtained records of annual ion fluxes from 1957 to 2014. High average NO₃⁻ flux (68.9 mg m⁻² yr⁻¹) with low δ¹⁵N value in the SE-Dome ice core suggests negligible effect of the post depositional NO₃⁻ loss. Thus, the SE-Dome region is one of the best locations for reconstructing nitrate fluxes. Decreasing trend of non-sea-salt (nss) SO₄²⁻ flux from 1970 to 2010 follows well that of anthropogenic SOx emission from North America, suggesting that the SO₄²⁻ flux in SE-Dome ice core mainly records anthropogenic emission of SOx from North America. In contrast, the decadal trend of NO₃⁻ flux in SE-Dome ice core differs from the decreasing trend of anthropogenic NOx emission in North America. The exact cause of the apparent non-linear relationship remains unclear but a formation of ammonium nitrate particles enhanced by SOx reduction appears to be an important mechanism as suggested by excess ammonium flux over sulfate. Our NO₃⁻ flux record is similar to other ice cores in Greenland high elevation sites on 5-yr running average, suggesting that NO₃⁻ concentrations records from these ice cores are reliable.

Keywords: Greenland, ice core, sulfate ion, nitrate ion, Anthropogenic emission

The triple isotopic composition of oxygen for sulfate and nitrate in surface snow in a latitudinal transect in East Antarctica

*Shohei Hattori¹, Ryu Uemura², Kazushi Noro³, Kotaro Fukui⁴, Motohiro Hirabayashi⁵, Norimichi Takenaka³, Joel Savarino⁶, Kenji Kawamura⁵, Hideaki Motoyama⁵, Naohiro Yoshida¹

1. Department of Chemical Science and Engineering, School of Materials and Chemical Technology, Tokyo Institute of Technology, Japan, 2. University of the Ryukyus, Japan, 3. Osaka Prefectural University, Japan, 4. Tateyama Caldera Sabo Museum, Japan, 5. National Institute of Polar Research, Japan, 6. Univ. Grenoble Alpes, CNRS, IRD, IGE, F-38000 Grenoble, France

The isotopic compositions of sulfate (SO_4^{2-}) and nitrate (NO_3^-) reflect their sources and oxidation pathways. In particular, triple oxygen isotope compositions ($\Delta^{17}\text{O}$) are potential tool to reconstruct how the oxidants work in past and present atmosphere. Antarctica is an ideal place to investigate the past proxy, because the ice core preserves in past hundred thousands Earth's history. However, recently we found the annual mean $\Delta^{17}\text{O}$ values for atmospheric SO_4^{2-} at coastal Antarctica is not matched with the $\Delta^{17}\text{O}$ values preserved in the inland Antarctic ice core records. In addition, the lack of observation, spatial variations of $\Delta^{17}\text{O}$ values are limitedly reported.

In order to test spatial variation of isotopic compositions, especially for the difference in $\Delta^{17}\text{O}$ values between coastal site and inland site, here we present latitudinal variation of $\Delta^{17}\text{O}$ value and conventional isotopic compositions ($\delta^{34}\text{S}$, $\delta^{15}\text{N}$, and $\delta^{18}\text{O}$) of SO_4^{2-} and NO_3^- in surface snow in eastern Dronning Maud Land, East Antarctica. Snow samples were collected from the surface at low- and high-elevation sites during the 54th and 57th Japanese Antarctic Research, respectively. $\Delta^{17}\text{O}$ values of non-sea-salt (nss)- SO_4^{2-} at the East Antarctica ranges from 2.2 to 3.3‰, and the $\Delta^{17}\text{O}$ value of nss- SO_4^{2-} for coastal site was lower than those for inland site. Thus, this result suggest that oxidizing chemistry for biogenic sulfur is different among coastal and inland sites, although small sulfur isotopic variations are observed and source of sulfur is biogenic and homogeneous. For the isotopic compositions of NO_3^- , considerably increasing values of $\delta^{15}\text{N}$ of NO_3^- are observed from coastal to inland sites. The $\delta^{18}\text{O}$ and $\Delta^{17}\text{O}$ of NO_3^- values, on the other hand, decreases with increasing of $\delta^{15}\text{N}$ values, indicating the secondary formation of NO_3^- . Thus, spatial variations of isotopic compositions of NO_3^- reflect the post-depositional processes on the East Antarctic snow.

Keywords: stable isotope, triple oxygen isotopes, sulfate, nitrate

A year-round observation of sulfur stable isotopic compositions of atmospheric sulfate at Dumont d' Urville, coastal Antarctica

*Sakiko Ishino¹, Shohei Hattori¹, Joel Savarino², Michel Legrand², Suzanne Preunkert², Bruno Jourdain², Naohiro Yoshida^{1,3}

1. School of Materials and Chemical Technology, Tokyo Institute of Technology, 2. Univ. Grenoble Alpes, CNRS, IRD, IGE, F-38000 Grenoble, France, 3. Earth-Life Science Institute, Tokyo Institute of Technology

Sulfur stable isotopic compositions ($^{34}\text{S}/^{32}\text{S}$, $^{33}\text{S}/^{32}\text{S}$ and $^{36}\text{S}/^{32}\text{S}$) of sulfate in the Antarctic snow and ice cores have been used to investigate the contribution of its sources such as marine biogenic activity and volcanic emissions, as well as its formation pathways (e.g., Patris et al., 2000; Uemura et al., 2016; Baroni et al., 2007). However, temporal variability of those signatures in the present Antarctic atmosphere has never been examined. Here we report a year-round observation of sulfur isotopic compositions of sulfate in aerosol samples collected at Dumont d' Urville (66°40' S, 140°01' E), coastal Antarctica, throughout the year 2011. In summer months, $^{34}\text{S}/^{32}\text{S}$ ratios were similar to the values observed in dimethyl sulfide (DMS) produced by marine biota (Amrani et al., 2013; Oduro et al., 2012), in contrast to ^{34}S depletion during winter, which suggest the contribution of other sources or unknown processes. Throughout the year, $^{33}\text{S}/^{32}\text{S}$ and $^{36}\text{S}/^{32}\text{S}$ ratios suggested no significant contribution of reactions causing mass independent fractionation.

Keywords: Stable isotope, Antarctica, Sulfate

Stable isotope analysis of pollen grains for terrestrial paleoclimate reconstruction revisited

*Yuichi Naito¹

1. Japan Agency for Marine-Earth Science and Technology

Pollen grains in terrestrial sediments are used for estimating paleoenvironmental change through Quaternary period because of their well preservation. Stable isotopic composition of pollen has also been proposed as paleoclimate indicators such as temperature and humidity while the validity of this approach has been questioned. In this study, isotopic compositions of pollen obtained from several tree species in Japan were analysed for reevaluating the potential as paleoclimate indicator.

Keywords: stable isotopes, pollen, paleoclimate

Variation trend of ^{17}O -excess in an Arctic ice core

*Akane Tsushima¹, Vasileios Gkinis², Kumiko Goto-Azuma³, Sumito Matoba⁴, Hideaki Motoyama³

1. Research Institute for Humanity and Nature, 2. Niels Bohr Institute, University of Copenhagen, 3. National Institute of Polar Research, 4. Institute of Low Temperature Science, Hokkaido University

Ice cores obtained from glaciers and ice sheets are important archives for reconstructing changes in the paleoclimate. The most important climate changes, such as the variation in temperature, precipitation, and the hydrological cycle, are reconstructed from stable water isotope ratios ($\delta^{18}\text{O}$, δD , and a second-order parameter, the d-excess, defined as $\text{d-excess} = \delta\text{D} - 8\delta^{18}\text{O}$) measured in ice cores. With the improvement of water isotope analyzers, the ability to measure $\delta^{17}\text{O}$ in water with high precision provided another second-order parameter, the ^{17}O -excess, defined as $^{17}\text{O-excess} = \ln(\delta^{17}\text{O}+1) - 0.528 \ln(\delta^{18}\text{O}+1)$. Previous studies reported that ^{17}O -excess in polar snow is mainly controlled by the relative humidity in the water vapor source region, therefore expected as a new proxy of past climate change. However, at the present, there are few studies of ^{17}O -excess in ice core, and therefore an understanding of variation factor of that is incomplete. In this study, we analyzed $\delta^{17}\text{O}$ and ^{17}O -excess in an ice core which was drilled in Alaska. We also discussed the variation factors of those associated with environmental change.

Keywords: ice core, Arctic region, ^{17}O -excess

SEM observation of insoluble particles in an ice core drilled from Grigoriev Ice core, Tien Shan Mountains.

*Yu Aosaki¹, Nozomu Takeuchi¹, Koji Fujita², Vladimir Aizen³

1. Chiba Univ., 2. Nagoya Univ., 3. Ikhkhov Univ.

Ice cores usually contain insoluble particles, such as volcanic ash, pollen and mineral particles, which have been blown on glaciers by wind. Volcanic ash has been used to identify the age of layers and mineral dusts are used as proxies of land surface or climate. Ice cores drilled from mountain glaciers in mid or low latitude areas contain abundant mineral dust. Although the abundance of mineral particles is often quantified with a particle analyzer, the morphology and elemental composition of each particle has not been studied well. In this study, we analyzed mineral particles in the ice core drilled from Grigoriev Ice Cap in Tien Shan in Central Asia, with a scanning electrical microscope (SEM) and classified them based on their elemental compositions analyzed with EDS.

The size of mineral particles in the ice core ranged up to 30 μm in diameter, but was mostly smaller than 10 μm . Based on the elemental composition, 60 - 90% of analyzed particles were Si or Al-rich particles. They are likely to be quartz or feldspar derived from desert surrounding the glacier. The remaining particles were Mg, Fe, or Ca-rich particles. Their abundance varied among the different layers. The variation may be due to different provenance of the particles.

Shallow ice cores from the western Cwm of the Khumbu Glacier of Mt. Everest in Himalayas drilled in 1980

*YOICHIRO HORI¹, Nozomu Takeuchi¹, Minoru Yoshida², Yoshiyuki Hujii³

1. Chiba University Graduate school of Science, 2. Hakusan Corporation, 3. National Institute of Polar Research

Two shallow ice cores have been drilled on the Western Cwm of Khumbu Glacier of Mt. Everest in winter of 1980 by the Japanese winter climbing expedition of Mt. Everest led by a famous climber, Naomi Uemura. The cores were successfully transported in frozen state to a cold room of National Institute of Polar Research in Japan. Since then, the ice cores have just been stored for a long time -without any analysis. In 2016, we recognized the cores and decided to restart the analysis. In this study, we reported the description of stratigraphy and results of stable isotope and soluble ion analyses. The ice cores were analyzed Core1 drilled at 6100 m a.s.l. and 8.83 m in length, and Core2 drilled at 6400 m a.s.l. and 4.06 m in length. The visual stratigraphy of the cores revealed that the two cores have a distinct stratigraphy. Core1 showed that 98% of the length were the granular snow and 2% were the refrozen ice layer. A dust layer was observed at a depth of around 7.3m. In contrast, In Core2 showed that, 15% of the length were the granular snow and 85% were the ice layer. The sand and gravel layers was observed frequently in the core, in particular at a depth of 0.40~0.60 m, 1.2m, 3.4~4.0 m. The results suggest that Core1 consists of continuous snow layers without significant melt, while Core2 consists of abundant refrozen ice layers and affected by avalanche snow from the south wall of Mt. Everest. The mean Hydrogen and oxygen isotope ratios were -126.4 and -17.6 permil for Core1, -163.3 and -21.5 permil for Core2. The lower isotope ratio for Core2 is probably due to the snow of lower isotopes supplied from the high elevation of the south wall by avalanche. The soluble ion composition were also distinctive between the two cores. Core1 was dominated by Na⁺ and Cl⁻ while Core2 was dominated by Ca²⁺. The difference was also due to debris supplied from the wall and effect of melt and refrozen of the snow.

Keywords: Shallow icecore, Snow chemistry, Himalayas, Mountain Glacier