Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

ACC29-01 Room:301A Time:May 26 14:15-14:30

Inconsistent relations among water stable isotope in Antarctic snow under different accumulation environments

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Water stable isotopes and major soluble ions are important for reconstructing paleo-environment and atmosphere circulation. It is also known that ion and isotope signals are modified after deposition if firn or ice core samples are analyzed at high temporal resolution such as seasonal scale.

We compared oxygen isotope, major ions and accumulation rate in shallow ice cores and snow pits from Antarctica with highly temporal resolution data. We showed seasonal cycle of oxygen isotope and major ions were surely preserved at sites over the threshold of accumulation rate with calm wind condition. In order to analyze the samples widely collected from east and west Antarctica, we calculated correlation coefficients of annually averaged major ions to oxygen isotope and then compare with accumulation rate among which the accumulation rate highly correlates. The correlations of most ions change from no correlation to negative one with decrease of accumulation rate. The negative correlations in inland Antarctica could be formed by inconstant accumulation due to low but larger inter-annual variability. The relations among major ions and oxygen isotope may not be those reflecting climatic footprint but be formed as a unique signal in the extremely arid environment.

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

ACC29-02 Room:301A Time:May 26 14:30-14:45

Estimation of the age-depth relationship of Dome Fuji Ice Core using a sequential Bayesian approach

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We have developed a method for estimating the age as a function of depth in Domu Fuji Ice Core and evaluating its uncertainty. The age–depth relationship is mainly determined by the accumulation of snow at the site of the ice core and the thinning process due to the horizontal stretching and vertical compression of the ice layer. However, since neither the accumulation process nor the thinning process are fully understood, it is essential to incorporate observational information into a model that describes the accumulation and thinning processes. In the proposed technique, the age as a function of depth is estimated from age markers and delta-O-18 data. The estimation is achieved using the particle Markov chain Monte Carlo method, in which the sequential Monte Carlo method is combined with the Markov chain Monte Carlo method. The performance of the proposed technique is demonstrated by applying it to ice core data from Dome Fuji in Antarctica.

Keywords: ice core, dating method, Bayesian estimation

Japan Geoscience Union Meeting 2015
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ACC29-03 Room:301A Time:May 26 14:45-15:00

Volcanic synchronization of Dome Fuji and Dome C Antarctic deep ice cores over the past 216 kyr

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Two deep ice cores, Dome Fuji (DF) and EPICA Dome C (EDC), drilled at remote dome summits in Antarctica, were synchronized to better understand their chronology. A total of 1401 volcanic tie points were identified covering the past 216 kyr. DFO2006, the chronology for the DF core characterized by strong constraining by the O_2/N_2 age markers, was compared with AICC2012, the chronology for 5 cores including the EDC core, and characterized by glaciological approaches combining ice flow modelling with various age markers. The age gaps between the two chronologies are within 2 kyr, except at Marine Isotope Stage (MIS) 5. DFO2006 gives ages older than AICC2012, with peak values of the gap of 4.5 kyr and 3.1 kyr at MIS 5d and MIS 5b, respectively. Accordingly, ratios of duration DFO2006/AICC2012 are 85% at a period from the late stage of MIS 6 to MIS 5d and 114% at a period from MIS 5d to 5b. We then compared the DFO2006 with another chronology of the DF core, DFGT2006, characterized by glaciological approaches with weaker constraining by age markers. Features of the DFO2006/DFGT2006 age gaps are very similar to those of the DFO2006/AICC2012 age gaps. This fact lead us to hypothesize that a cause of the systematic DFO2006/AICC2012 age gaps at MIS 5 are associated with differences in the dating approaches. Besides, ages of speleothem records from China agreed well with DFO2006 at MIS 5c and 5d but not at MIS 5b. Thus, we hypothesize at least at MIS 5c and 5d, major sources of the gaps are systematic errors in surface mass balance estimation in the glaciological approach. Compatibility of the age markers should be carefully assessed in future.

Keywords: ice core, dating, Milankovitch, Dome Fuji, Dome C, Antarctica

Japan Geoscience Union Meeting 2015
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ACC29-04 Room:301A Time:May 26 15:00-15:15

Millennial scale site and source temperatures variability in Antarctica over the past 700,000 years

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Deuterium-excess (d-excess = δD ? 8δ^{18}O) provides the information on the ocean surface conditions in the moisture source for polar precipitation. We show a new d-excess record from the 3,035m-depth Dome Fuji ice core (DF2), which was obtained at the Dome Fuji station (77?19S, 39?42S, 3,810m a.s.l.). The new part of DF2 core (2400m to 3034m depth) extends back to 700ky BP with fine time-resolution. The ΔTsite and ΔTsource histories were reconstructed based on the d-excess data.

Keywords: ice core, oxygen isotope, hydrogen isotope, d-excess, Antarctica

Japan Geoscience Union Meeting 2015
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ACC29-05 Room:301A Time:May 26 15:15-15:30

Glacial abrupt climate changes and thermal threshold of the Atlantic meridional overturning circulation

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Abrupt climate changes known as Dansgaard-Oeschger events (DO events) took place frequently in glacial periods. Many geological evidences support the idea that changes of the Atlantic meridional overturning circulation (AMOC) are related to these events, but question on what triggers the AMOC changes remains unsolved. Although the most of studies have regarded freshwater flux from melting ice sheet as a cause of the AMOC changes, we recently identified the existence of the thermal threshold of the AMOC during glacial climate. Here, from the results of climate model simulations about the glacial AMOC, we report that the thermal threshold of the AMOC can be a triggering mechanism of DO events. We investigated the structure of the thermal threshold in glacial climate by conducting ocean general circulation model simulations under various thermal conditions in which degrees of sea surface cooling are systematically changed separately or simultaneously in northern and southern hemispheres. The results suggest that the threshold is located near the condition in which the climate is slightly warmer than the coldest glacial conditions. We also found that the amplitude of AMOC changes in crossing this threshold depends on thermal conditions in northern and southern hemispheres. This amplitude becomes the largest when the southern hemisphere is slightly warmer than the coldest glacial conditions. It is also demonstrated that gradual warming in the southern hemisphere from the colder glacial climate leads to crossing the threshold and can cause very large strengthening of AMOC. Therefore, the thermal threshold could be a triggering mechanism of DO events accompanying the warming of southern hemisphere before their abrupt warming in northern hemisphere.

Keywords: Atlantic meridional ocean circulation, Dansgaard-Oeshger events, Abrupt climate changes, Climate model

Japan Geoscience Union Meeting 2015
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ACC29-06 Room:301A Time:May 26 15:30-15:45

The influence of glacial ice sheet on Atlantic meridional overturning circulation through atmospheric circulation change

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Several atmosphere-ocean coupled general circulation model (AOGCM) studies suggest that glacial ice sheets exert a large impact on the Atlantic meridional overturning circulation (AMOC). However, the process by which the ice sheets impact on the AMOC is not yet fully understood because of the complicated nature of the AOGCMs. On the other hand, recent oceanographic studies showed that surface wind changes play a crucial role on changes to the AMOC under glacial climate. Therefore, in this study, we investigate in detail, the process by which the ice sheet modifies the AMOC through surface wind change. Moreover, recent modeling study using MIROC AOGCM showed that the effect of the glacial ice sheet on the AMOC depends on the background climate. In their study, they suggested that a strong relation between sea ice coverage and the wind field might play an important role. However, it is still unclear to what extent the sea ice coverage affects the surface wind change induced by the glacial ice sheet. Therefore, we will also explore the effect of the sea ice distribution on the ice sheet induced wind change. Here we conduct numerical experiments using an atmospheric general circulation model (AGCM) and an ocean general circulation model (OGCM) separately. Our method consists of 2 steps. First, from AGCM experiments, we evaluate the effect of glacial ice sheets on the surface wind. Second, from OGCM experiments, we evaluate the influence of the wind stress change on the AMOC by applying the surface wind change as a boundary condition, while leaving other boundary conditions (surface heat and water fluxes) unchanged. In this way, we can evaluate the wind effect of glacial ice sheet on the AMOC. In addition, we conduct several sensitivity experiments. Using the AGCM, we changed the sea ice distribution. Moreover, using the OGCM, we change the surface wind gradually or apply the surface wind change only at a specific region in order to explore the wind change effect in detail.

We find that glacial ice sheets largely intensify the AMOC by surface wind change under glacial climate. Compare to other regions, it reveals that the wind change at the North Atlantic mid-high latitude (NAMH) is a key region. There, the positive wind stress curl enhances, which intensifies the salt and heat transport at NAMH surface through strengthening the gyre circulation and the Ekman upwelling. As a result, the AMOC intensifies. On the other hand, we find that this wind effect of glacial ice sheet strongly depends on the NAMH sea ice cover, as the expansion of sea ice reduces the positive wind stress curl anomaly induced by the glacial ice sheet. This supports the important role of the sea ice coverage on glacial ice sheet effect suggested by the study using MIROC AOGCM.

Keywords: AMOC, surface wind, sea ice, glacial ice sheet

Japan Geoscience Union Meeting 2015
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ACC29-07 Room:301A Time:May 26 15:45-16:00

Intermediate depth ice core drilling project 2015/2016 and some results of deep borehole logging, Antarctic ice sheet

MOTOYAMA, Hideaki[1*] ; FURUSAKI, Atsushi[2] ; MATOBA, Sumito[8] ; SUGIYAMA, Shin[8] ; TAKAHASHI, Akiyoshi[3] ; TANAKA, Yoichi[4] ; MIYAHARA, Morihiro[5] ; TAKATA, Morimasa[6] ; SAWAGAKI, Takanobu[7] ; SHINBORI, Kunio[8] ; MORI, Shoichi[8]

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We plan the intermediate depth drill in 2015/2016 on the coastal region of Antarctic ice sheet. We decided the dry drilling for 300-500m deep. Problems are bad core quality and borehole closure.

The deep ice core drilling in depth of 3,035m was succeeded at Dome Fuji Station, Antarctica in January, 2007. It is almost depth of the bedrock. We used butyl acetate as borehole liquid. The liquid level was approximately 120m from the surface. We carried out borehole logging observation from surface to bottom in January 2007, 2011 and 2013. Measurement items were liquid temperature, ice temperature, liquid pressure and borehole diameter. The resolution of temperature was 0.05 degree Celsius. We discuss the diameter change/inclination of borehole, distribution of heat flow rate in ice sheet using the data of some years.

Keywords: ice core, Antarctic ice sheet, intermediate depth ice core drilling, borehole logging, heat flux

Japan Geoscience Union Meeting 2015
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ACC29-08 Room:301A Time:May 26 16:15-16:30

Comparison of different measurement techniques of micro-particles in polar snow and ice

GOTO-AZUMA, Kumiko[1*] ; HIRABAYASHI, Motohiro[1] ; MOTOYAMA, Hideaki[1]

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Water-insoluble micro-particles in ice cores have been extensively analysed to investigate the past climatic and environmental changes. Temporal and spatial variations of size distribution and flux have been discussed in many papers. Definition of particle size, however, is not always straightforward. Flux of particles is calculated from particle volume, particle density and snow accumulation rate, thus affected by the definition of particle size, which depends on the measurement technique. Comparison of the size distribution and flux data from different measurement techniques requires caution. Here we compare the measurement results from traditionally used three types of micro-particle analysers: (1) Coulter Multsizer 4, which directly measures volume of each particle; (2) Klotz Abakus, which detects shading of laser light caused by each particle; and (3) Met One Model 211, a laser scattering type particle analyser. We also show the results from a newly introduced micro-particle analyser JASCO IF-200nano, which is based on image processing technique. The new analyser indicated that Abakus and Met One Model 211 gave size distribution different from Coulter Multisizer 4 when particle shape departed greatly from spherical shape.

Our results suggest that dust particles in Antarctic Dome Fuji core have spherical shape during glacials, while they have irregular shapes during inter-glacials. Changes in particle shape would give additional information on the past climate and environment. Our results also indicate that comparison of size distribution and flux data obtained with different measurement techniques requires much more caution than previously thought.

Keywords: micro-particles, analytical techniques, polar snow and ice

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

ACC29-09 Room:301A Time:May 26 16:30-16:45

Physically based reconstruction of summer temperature from ice layers in ice cores

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Previous studies, which have reconstructed summer temperature from ice layers in ice core, relied on approximate relationship between ice layer and instrumental temperature observed nearby station. Here we demonstrate a novel method to reconstruct summer temperature from ice layers in ice core using an energy balance model, in which heat conduction through firn and refreezing of meltwater are taken into account. Parameters used in the model are firstly calibrated with 2-year meteorological data observed at the SIGMA-A site, northwest Greenland. Using the ERA-Interim reanalysis dataset, we calculate amount of refrozen water within firn under different settings of summer temperature and annual precipitation, and then prepare a lookup table containing summer temperature, annual precipitation, and refrozen amount. We then estimate summer mean temperature from refrozen amount and annual accumulation, which are available from an ice core, by referring the lookup table. We apply this method to three ice cores under different climates; Belukha in the Russian Altai, Aurora in the Alaska, and SIGMA-A in the northwest Greenland. Reconstructed summer temperatures show large inter annual variability, which is comparable to those of observed temperature, but show some biases, which are affected by albedo setting. This method allows us to estimate summer temperature using information solely available in ice core without making any approximate relationship between temperature and ice layer.

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ACC29-10 Room:301A Time:May 26 16:45-17:00

Ice core records of organic aerosol tracers over the past 450 years

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Carbonaceous aerosols, which include a mix of light absorbing and light-scattering components, influence the global climate via direct and indirect effects on radiative balance. However, the natural variability and factors controlling the emissions, transport and role in the climate system of carbonaceous aerosols are highly uncertain both for the past and future. Here we analyzed organic molecule tracers in ice-cores collected from Greenland and Kamchatka Peninsula over the past 450 years. Newly generated and previously published organic tracer records (Kawamura et al., 1996, 2012) were derived from Greenland Site-J and the Kamchatka Ushkovsky ice-cores. Concentrations of specific organic tracers: soil bacteria derived long-chain dicarboxylic acids (hereafter di-acids), higher plant leaf-wax derived long-chain monocarboxylic acids (hereafter leaf-waxes), and biomass burning derived levoglucosan are applied to reconstruct changes in the deflation and transport of soil organic matter (di-acids and leaf-waxes) and biomass burning products (levoglucosan and leaf-waxes). The concentrations and composition of biomass burning-, soil bacterial- and plant wax -tracers in the two ice cores were found to correspond with Arctic and regional temperatures from the different parts of the world over solar modulated multi-decadal time-scales with order of magnitude decreases (increases) in abundance during the colder (warmer) phases of the Little Ice Age. Thus, our study suggests a strong link between Arctic climate and carbonaceous aerosol loading in the high latitude.

Keywords: ice core, Greenland, Kamchatka, organic aerosol, Little Ice Age, Arctic Oscillation

Japan Geoscience Union Meeting 2015
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ACC29-11 Room:301A Time:May 26 17:00-17:15

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

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Analyses of ice cores have often been used as a means to reconstruct past environments. The species composition of the organism such as microorganism in the ice cores could reflect the environmental condition at that time. Thus, organisms in ice cores could be useful to reconstruct past environments. However, analysis of the biological contents of ice cores is still highly limited. The ice core samples collected on Gregoriev Glacier, Kyrgyz Tienshan were melted using a device that enabled us to obtain water only from the inner portion of the cores. Complete separation of the inner and outer cores is required to avoid contamination microorganisms such as bacteria and fungi that can adhere to the cores during drilling and storage. We report results of cyanobacterial species and their evolution by molecular DNA analysis collected from the ice core sample (about 8,000 and 12,500 years old). We also attempted to reconstruct the organisms and their interactions within the community and with the environment on the sampled sites. The results implied genomic information used as an environmental marker for past environmental studies.

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ACC29-12 Room:301A Time:May 26 17:15-17:30

Reconstruction of paleo-environmental changes in the northern North Pacific region from an alpine ice core

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A 180.17-m ice core was drilled at Aurora Peak in the central part of the Alaska Range, Alaska, in 2008 to allow reconstruction of centennial-scale climate change in the northern North Pacific. The 10-m-depth temperature in the borehole was -2 ℃, which corresponded to annual mean air temperature at the drilling site. In this ice core, there were many melt-refrozen layers due to high temperature and/or strong insolation during summer seasons. We analyzed stable hydrogen isotopes (δD) and chemical species in the ice core. The ice core age was determined by annual counts of δD and seasonal cycles of sodium ions, and we used reference horizons of tritium peaks in 1963 and 1964, major volcanic eruptions , and a large forest fire in 2004 as age controls. Here, we show that the chronology of the Aurora Peak ice core from 180 m to the top corresponds to the period from 1666 to the summer season of 2007, with a dating error of $\pm$3 years. Our results suggest that temporal variations in δD and annual accumulation rates are strongly related to shifts in the Pacific Decadal Oscillation index (PDOI). The remarkable increase in annual precipitation since the 1970s has likely been the result of enhanced storm activity associated with shifts in the PDOI during winter in the Gulf of Alaska.

Keywords: Alpine ice core, Northern North Pacific region, δD, d-excess

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ACC29-13 Room:301A Time:May 26 17:30-17:45

Variations in oxygen and nitrogen stable isotopes in nitrate in an ice core of Tienshan Mountains

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Nitrate is one of the common soluble ions in snow and ice of glaciers and is usually supplied as aerosols derived from natural or anthropogenic processes. Nitrogen and oxygen stable isotopes of nitrate can provide a means to determine its main source and microbial process including nitrification and denitrification in snow and ice. In this study, we analyzed nitrogen and oxygen stable isotopes of nitrate in selected depths of the ice core drilled from Grigoriev Ice cap in Kyrgyz Tien Shan Mountains of Central Asia in 2007. The ice core was 87 m from the surface to the bottom, and covered approximately 12700 years, which was dated with radiocarbon. Mean nitrate concentration was 288 ppb in this ice core. Nitrogen isotope of nitrate showed that it was distinctively higher in the 20th century, but lower before the 20th century, indicating that the source of nitrate changed from natural to anthropogenic in the 20th century. Oxygen isotope of nitrate showed that it generally varied from +70 to +80 ‰, but was remarkably lower ranging from +30 to +60 ‰ in 1960s and 6000-7000 bp. This suggests that nitrate was mostly atmospheric origin, but was occasionally derived from microbes on the glacier surface.

Keywords: ice core, stable isotope, nitrate, glacial microbe, central asia, tine shan mountains

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

ACC29-P01 Room:Convention Hall Time:May 26 18:15-19:30

Studies of melting ice using laser for ice drilling

SAKURAI, Toshimitsu[1*] ; CHOSROWJAN, Haik[1] ; SOMEKAWA, Toshihiro[1] ; FUJITA, Masayuki[1] ; MOTOYAMA, Hideaki[2] ; WATANABE, Okitsugu[2] ; IZAWA, Yasukazu[1]

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We have studied the melting properties of ice using CO_2 laser at 10.6 micro-meter wavelength. At this wavelength ice strongly absorbs and a hole is drilled along the path of the laser irradiation. The melting speed of ice has been measured at several irradiation intensities and laser excitation angles relative to the horizontal axis. The melting speed of ice increased almost proportionally with the increasing laser excitation intensity. For the laser excitation intensity of about 50 W/cm^2, for instance, the melting speed was estimated to be 4 mm/s and 0.8 mm/s for snow (0.15 g/cm^3) and ice, respectively. Experimental results show that for elevated excitation angles melt-water accumulate in the hole adversely affecting the melting speed of ice. Though the problem of accumulating water during the drilling into ice is necessary to take into consideration, we believe that our concept of a fiber coupled IR laser drilling system could be employed for drilling ice sheets and glaciers.

Keywords: ice, laser, absorption, melt, drilling, ice sheet

Japan Geoscience Union Meeting 2015
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ACC29-P02 Room:Convention Hall Time:May 26 18:15-19:30

State dependence of climatic instability from ice-core records over the past eight glacial cycles

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Climatic variability on millennial timescales with bipolar seesaw pattern during glacial period has been documented in palaeoclimatic records, but their frequencies and relationships with mean climatic state are still unclear. Here we investigate the long-term characteristics of such variability using a new 700,000-year ice core record from Dome Fuji, East Antarctica, combined with another long Antarctic record. The 10^3- to 10^4-year warming events over the past eight glacial-interglacial cycles are most frequent when Antarctic temperature is slightly below average, equivalent to an intermediate climate during glacial periods. With the ice core data and climate modeling, we suggest that the prerequisite for the most frequent climate instability with bipolar seesaw pattern during the late Pleistocene is not only the extent of continental ice sheets but also low CO2. North Atlantic cooling sets high sensitivity of AMOC and climate to small perturbations such as moderate freshwater anomaly.

Keywords: Dome Fuji ice core, Abrupt climate change, Millennial-scale variability

Japan Geoscience Union Meeting 2015
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ACC29-P03 Room:Convention Hall Time:May 26 18:15-19:30

Modelling the state dependency of abrupt climate change and bipolar seesaw

ABE-OUCHI, Ayako[1*] ; OHGAITO, Rumi[2] ; YOSHIMORI, Masakazu[3] ; OKA, Akira[1] ; TAKAHASHI, Kunio[2] ; KAWAMURA, Kenji[4]

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Millennial climate change such as D-O cycles, AIM recorded in ice cores in both Hemispheres is known to show a relatively higher amplitude in the middle-level of a glacial cycle than in the interglacial state or severe glacial state. Although massive discharge or melt water of Ice sheet to ocean is one of the cause thought to be responsible for the millennial climate change, the thermal response to fresh water release in North Atlantic in global models and/or the paleoclimatic data in the region far from North Atlantic do not agree and even do not explain the dependence of the amplitude upon the level of climate state. Here we ran several sensitivity experiments using a coupled atmosphere and ocean GCM (MIROC3.2.2) and show that the response to fresh water release to the ocean and bipolar response is highly dependent on the background climate. The experiments were conducted with 500 years water hosing of 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 North Atlantic 50-70N in the same manner and position as CMIP/PMIP protocol under different basic states; Modern Hosing under modern climate with the pre-industrial condition, and Glacial hosing under LGM condition (21ka as PMIP, with ice sheets and lowered Greenhouse Gases). The results show largest cooling response in North Atlantic and a reasonable bipolar warming signal as in the ice cores of Antarctica, and the dependence upon background climate is not relatively the same for the both hemisphere. The mechanism of different responses are discussed in detail through the analysis of model experiment of atmosphere, ocean and sea ice coupling.

Keywords: climate model, abrupt climate change