# ILTS International Symposium on Low Temperature Science

# Program and Abstracts

**30 November – 2 December 2015**

**Auditorium**

**Institute of Low Temperature Science (ILTS)**

**Hokkaido University**

# ILTS International Symposium on Low Temperature Science

30 November – 2 December 2015

Auditorium, Institute of Low Temperature Science (ILTS), Hokkaido University

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## Program

### ► Monday, 30 November 2015 ◄

**Plenary Session, 13:00-14:30**                                     Chair: Gen Sazaki

13:00-13:10 Opening
  Ralf Greve (Local Organizing Committee, ILTS)
  Hiroyuki Enomoto (Director, Arctic Environment Research Center, NIPR)

K-01  13:10-13:50 Keynote Speech
  Naoto Ebuchi (Director of ILTS)
  Challenges toward a new era in low temperature science

K-02  13:50-14:30 Keynote Speech
  Ilka Weikusat (AWI, Bremerhaven, Germany)
  Ice physics studies in the light of global warming

**Coffee Break, 14:30-15:00**

**Session 1. Water and Material Cycles, 15:00-18:00**             Chair: Tsutomu Watanabe

1-01  15:00-15:30 Tetsuya Hiyama (Nagoya University)
  Changes in hydrologic cycle under current global warming in eastern Siberia

1-02  15:30-16:10 Gabriel Katul (Duke University, Durham, NC, USA)
  Optimality theories at the leaf scale and their role in regulating the hydrological cycle

1-03  16:10-16:35 Yuzo Miyazaki (ILTS)
  Origin and formation mechanisms of atmospheric organic aerosols in marine and terrestrial ecosystems

1-04  16:35-17:05 Shoshiro Minobe (Graduate School of Science, Hokkaido University)
  Ocean to atmosphere influences in mid-latitudes

1-05  17:05-17:35 Hiroyuki Enomoto (NIPR / SOKENDAI, Tokyo)
  Sea ice decrease in the Arctic and increase in the Southern Ocean – Discussions from the bi-polar perspectives

1-06  17:35-18:00 Shigeru Aoki (ILTS)
  ROBOTICA: Research of Ocean-ice BOundary InTeraction and Change around Antarctica

## ► Tuesday, 1 December 2015 ◄

**Session 2. Frontier Ice and Snow Science, 09:00-12:00**          Chair: Akira Kouchi

2-01    09:00-09:25 Ayako Abe-Ouchi (University of Tokyo)
How and when to terminate the ice ages?

2-02    09:25-09:45 Fuyuki Saito (JAMSTEC, Yokohama)
Development and performance of a numerical ice-sheet/shelf/stream model IcIES

2-03    09:45-10:15 Heinz Blatter (ETHZ, Switzerland)
Modelling polythermal ice sheets and glaciers

2-04    10:15-10:35 Shin Sugiyama (ILTS)
Ice mass loss in northwestern Greenland

2-05    10:35-11:00 Shuji Fujita (NIPR / SOKENDAI, Tokyo)
Recent progress in understanding densification phenomena of polar firn: textural effects and some soluble impurities control creep deformation

2-06    11:00-11:20 Gen Sazaki (ILTS)
In-situ visualization of quasi-liquid layers on ice surfaces by advanced optical microscopy

2-07    11:20-11:40 Yuki Kimura (ILTS)
Nucleation from a supersaturated vapor

2-08    11:40-12:00 Hidekazu Tanaka (ILTS)
Homogeneous SPC/E water nucleation in large molecular dynamics simulations

**Lunch Break, 12:00-13:30**

**Session 3. Environmental Biology, 13:30-16:30**          Chairs: Mia Terashima, Atsushi Takabayashi

3-01    13:30-14:10 Wilhelm Hagen (University of Bremen, Germany)
Life history traits and ecophysiological adaptations in polar zooplankton and fish

3-02    14:10-14:35 Yasuhiro Kasahara (ILTS)
Proteome analysis of bacterial genes specifically expressed in soil

3-03    14:35-15:00 Akihiro Sumida (ILTS)
Boreal forest ecosystems as related to recent advances in ecological and physiological studies of trees

3-04    15:00-15:25 Ryouichi Tanaka (ILTS)
Photosynthesis at low temperatures: The roles of light-harvesting-like proteins in the biogenesis and protection of photosystems

3-05    15:25-15:50 Makio Yokono (ILTS)
PSI-PSII megacomplex in evergreen plants

3-06    15:50-16:30 Michael Hippler (University of Münster, Germany)
Calredoxin mediates calcium- and redox-dependent regulation of photosynthesis and ROS defense in Chlamydomonas reinhardtii

**Poster Session (with coffee and tea), 16:30-18:00**                    Chair: Gen Sazaki

P1-01    Poonam Tyagi (ILTS / GSES)
Soil microorganisms and terrestrial plant metabolites in marine aerosols from the western North Pacific: molecular distribution of hydroxy fatty acids over Chichijima Island

P1-02    Md. Mozammel Haque (ILTS / GSES)
Contribution of biogenic VOCs to secondary organic aerosols in Alaska atmosphere

P1-03    Fumihiro Mori (ILTS / GSES)
Turbulence structure measurement in atmospheric surface layers visualized by a PIV technique

P1-04    Haruhiko Kashiwase (NIPR, Tokyo / ILTS)
Ice-ocean albedo feedback effect on recent drastic reduction in Arctic sea ice cover

P1-05    Takuya Nakanowatari (NIPR, Tokyo / ILTS)
Predictability of the Barents Sea ice in early winter: Remote effects of oceanic and atmospheric thermal conditions from the North Atlantic

P1-06    Tatsuru Sato (ILTS)
Investigation of ice-ocean interaction on Lutzow-Holm Bay, East Antarctica, from geographic, ocean data analysis and modeling

P2-01    Takashi Obase (University of Tokyo)
Antarctic ice shelves' basal melting in glacial and warm climates

P2-02    Ralf Greve (ILTS)
A simple parameterisation of ice-shelf basal melting for long-term, large-scale simulations of the Antarctic ice sheet

P2-03    Hakime Seddik (ILTS)
Towards a GPU-accelerated ice sheet model: design philosophy and implementation

P2-04    Yoshinori Iizuka (ILTS)
Shallow ice core project on south-east dome in Greenland – Drilling report and science trench of the ice core

P2-05    Evgeny A. Podolskiy (ILTS)
Tide-modulated seismicity in the Bowdoin glacier calving front, Northwestern Greenland

P2-06    Masahiro Minowa (ILTS / GSES)
Seasonal variations in the dynamics of Bowdoin Glacier, northwest Greenland

P2-07    Daiki Sakakibara (ILTS / GSES)
Seasonal changes in ice front position and flow speed of marine terminating outlet glaciers in northwestern Greenland

P2-08  Shun Tsutaki (NIPR, Tokyo / ILTS)
Field observations of surface mass balance, ice velocity and ice temperature on Qaanaaq ice cap, northwestern Greenland

P2-09  Naoki Katayama (ILTS / GSES)
Elevation change of calving glaciers in northwestern Greenland analyzed by satellite data

P2-10  Naoya Morimoto (ILTS / GSES)
Surface elevation change on Trambau Glacier, Nepal Himalaya, based on remote sensing techniques

P2-11  Ken-ichiro Murata (ILTS)
Wetting of quasi-liquid layers on ice surfaces: statics and dynamics

P2-12  Ken Nagashima (ILTS)
Liquid layers on ice surfaces induced by hydrochloric gas

P3-01  Atsushi Takabayashi (ILTS)
Evolution of photosystems in green algae through ice ages

P3-02  Mia Terashima (ILTS)
Intracellular "energy bento-box": Flow cytometry as a method to sort microalgae and bacteria based on cell energy reserves

P3-03  Miho Watanabe (ILTS / GSES)
Characterization of a novel sulfate-reducing bacterium possessing desulfoviridin and vibroid morphology

P3-04  Tomohiro Watanabe (ILTS)
Diversity of sulfate-reducing and sulfur-oxidizing organisms in sediments of Antarctic lakes

P4-01  Hiroyuki Enomoto (NIPR / SOKENDAI, Tokyo)
Okhotsk study and connection to the Arctic – Sea ice, environment and life

P4-02  Akane Tsushima (NIPR, Tokyo)
Reconstruction of paleo-environmental changes in the northwestern North Pacific region from an alpine ice core

P4-03  Tatsuro Karaki (ILTS / GSES)
On the structure and dynamics of the Soya Warm Current from the viewpoint of buoyancy arrest

P4-04  Kaoru Ito (ILTS / GSES)
Interactions of internal waves and submeso-scale vortex

P4-05  Ryu Saiki (ILTS / GSES)
A mechanism of ice-band pattern formation caused by resonant interaction between sea ice and internal waves

P5-01  Toru Takatsuka (ILTS)
Technical Support in ILTS, 2015

**Reception, 18:00-20:00 (ILTS Lecture Room 215)**

## ► Wednesday, 2 December 2015 ◄

**Session 4. Research on the Pan-Okhotsk Region, 09:00-12:00**      Chair: Humio Mitsudera

4-01    09:00-09:40 Takeshi Nakatsuka (RIHN, Kyoto)
        Climate variations in East Asia and Japan during the last two millennia

4-02    09:40-10:20 Wonsun Park (GEOMAR, Kiel, Germany)
        Predictability in the North Pacific

4-03    10:20-11:00 Teruo Aoki (MRI, Tsukuba)
        Modeling of the radiative properties of snow and its application to climate study

4-04    11:00-11:30 Sumito Matoba (ILTS)
        Climate changes in the North Pacific region reconstructed from alpine ice cores

4-05    11:30-12:00 Jun Nishioka (ILTS)
        Biogeochemical system in the Pan-Okhotsk area

**Closing, 12:00-12:15**
        Atsumu Ohmura (ETHZ, Switzerland)
        Ralf Greve (Local Organizing Committee, ILTS)


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**Note**

In the above program, only the speakers are listed.
For the full list of authors, please see the corresponding abstracts.


**Abbreviations**

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| AWI | Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research |
| ETHZ | Swiss Federal Institute of Technology Zurich |
| GEOMAR | GEOMAR Helmholtz Centre for Ocean Research Kiel |
| GSES | Graduate School of Environmental Science (Hokkaido University) |
| ILTS | Institute of Low Temperature Science (Hokkaido University) |
| JAMSTEC | Japan Agency for Marine-Earth Science and Technology |
| MRI | Meteorological Research Institute |
| NIPR | National Institute of Polar Research |
| RIHN | Research Institute for Humanity and Nature |
| SOKENDAI | Graduate University for Advanced Studies |

# Keynote Speeches

# Challenges toward a new era in low temperature science

Naoto Ebuchi

Institute of Low Temperature Science, Hokkaido University, Sapporo, Japan

The Institute of Low Temperature Science was founded in 1941 as the first research institute affiliated with Hokkaido University. The institute owes its establishment to the achievements of Dr. Ukichiro Nakaya, professor of the department of physics, who was the first in the world to create artificial snow crystals. Since then, our institute has achieved development in areas of basic studies on snow and ice, and natural sciences in the cryosphere. We are going to celebrate the 75th anniversary in November 2016.

In April 2010, our institute was designated as a Joint/Use Research Center of Low Temperature Science by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan. We recognized that the main mission of the institute is to promote interdisciplinary cooperative researches with domestic and international research communities in parallel with proceeding high-level scientific researches in low temperature science. To enhance international cooperation, our institute has concluded academic exchange agreements with 21 foreign universities and research institutes in 12 countries. Under these agreements, we promote international joint research projects pioneering a new field of low temperature science.

In 2008, we reorganized the institute and established the Joint Research Division, which functions as a community center for supporting joint research in low temperature science. In April 2015, five new programs, such as "Antarctic Cryosphere-Ocean System," "Arctic Glacier and Ice Sheet Change," "Low-temperature Nano-material Science," "Photosynthesis under Low Temperature Conditions," and "The role of Pacific Marginal Seas in Linking Adjacent Lands with Oceans," were launched as main activities of the Joint Research Division. Under these programs, we strongly promote and support the interdisciplinary cooperative researches challenging toward a new era of low temperature science.

Needless to say, the cryosphere plays crucial roles in the global climate system and ecosystem. We believe that interdisciplinary researches on environmental sciences in cryosphere based on robust fundamentals in physics and chemistry of ice and snow and biology under low temperature conditions will significantly contribute to solve problems in the global climate changes. The programs listed above also tackle these issues.

In addition, we recognized that education of graduate students and young scientists is also our important mission for the next generation. Our institute joined the International Antarctic Institute Program and has organized several lecture and field courses. We believe that this is a unique challenge of advanced education in the top-level international and interdisciplinary research atmosphere.

# Ice physics studies in the light of global warming

Ilka Weikusat[1,2]

(1) Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research,
Bremerhaven, Germany
(2) Department of Geosciences, University of Tübingen, Germany

Our changing climate will affect human lives in manifold ways. Especially sea-level rise is driven by diminishing amounts of snow and land ice. The cryosphere as part of the Earth's climate system provides interconnecting feedbacks between its components, leading to multifaceted changes. To understand these feedback mechanisms we have to consider the various interactions between the atmosphere, the oceans and the ice covering both polar land and seas. The state and evolution of Earth's glaciers and ice sheets play a key role therein and thus profound ice physics knowledge with respect to ice sheet dynamics is required. Ice sheet dynamics on multiple scales, from microscopic processes to continental-sized phenomena, are in the focus of scientific attention to improve climate predictions on a global scale.

Snow and ice physics are mutual research interests for AWI glaciologists and ILTS researchers. The state and evolution of ice sheets and glaciers is partly recorded in deep ice cores drilled through the Antarctic and Greenlandic ice. Two upcoming drilling projects will further strengthen the Japanese-German cooperation in glaciological research: *EGRIP* (Greenland) focusing on questions concerning the dynamics of ice streams and *IPICS Oldest Ice* (Antarctica) focusing on obtaining oldest paleao-climate information from ice cores. Advanced analysis of ice core material can teach us the climate history of our planet and reveal physical mechanisms leading to ice motion. Selected ice-related research topics relevant for AWI and ILTS will be presented, as for example, the mapping of ice micro-structures, which are reflecting the deformation and recrystallisation processes that control ice sheet flow. The connection between ice dynamics, microstructures, and climatic changes is tackled by additional application of palaeo-climate record methods on impurities measured in ice cores. Experiments on pure and doped ice material (e.g. with solved or insoluble chemicals and antifreeze proteins) provide better understanding of basic processes in ice polycrystals. Process modelling as well as phenomenological modelling of ice deformation then tests and completes our current understanding of ice sheet dynamics and result in improved future projections.

# Session 1.
# Water and Material Cycles

# Changes in hydrologic cycle under current global warming in eastern Siberia

Tetsuya Hiyama[1], Takeshi Ohta[2], Ayumi Kotani[2], Yoshihiro Iijima[3], Hotaek Park[3]

(1) Institute for Space-Earth Environmental Research (ISEE), Nagoya University, Nagoya, Japan
(2) Graduate School of Bioagricultural Sciences (GSBS), Nagoya University, Nagoya, Japan
(3) Institute of Arctic Climate and Environment Research (IACE), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Japan

Water, energy, and carbon cycles in the Lena River basin have been investigated in plot and watershed scales from 1998 to 2013. In this presentation, seasonal, interannual, and decadal variations of water, energy, and carbon cycles in the region will be summarized with special emphasis on current global warming. Papers listed below will be introduced and several research issues in near future will be also suggested. Drought - waterlogging variabilities and those effects for permafrost ecosystem in high-latitude region would be one of the critical research issues. Dynamic global vegetation models including waterlogging processes should be strongly developed for the permafrost ecosystem.

## References:

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Fedorov AN, Gavriliev PP, Konstantinov PY, Hiyama T, Iijima Y, Iwahana G. 2014. Estimating the water balance of a thermokarst lake in the middle of the Lena River basin, eastern Siberia. *Ecohydrol.* **7**, 188-196.

Hiyama T, Asai K, Kolesnlkov AB, Gagarin LA, Shepelev V. 2013. Estimation of the residence time of permafrost groundwater in the middle of the Lena River, eastern Siberia. *Environ. Res. Lett.* **8**, 035040, doi:10.1088/1748-9326/8/3/035040.

Iijima Y, Fedorov AN, Park H, Suzuki K, Yabuki ,H, Maximov TC, Ohata T. 2010. Abrupt increases in soil temperature following increased precipitation in a permafrost region, central Lena River basin, Russia. *Perm. Periglac. Proc.* **21**, 30-41.

Iijima Y, Ohta T, Kotani A, Federov AN, Kodama Y, Maximov TC. 2014. Sap flow changes in relation to permafrost degradation under increasing precipitation in an eastern Siberian larch forest. *Ecohydrol.* **7**, 177-187.

Kotani A, Kononov AV, Ohta T, Maximov TC. 2014. Temporal variations in the linkage between the net ecosystem exchange of water vapour and $CO_2$ over boreal forests in eastern Siberia. *Ecohydrol.* **7**, 209-225.

Ohta T, Hiyama T, Tanaka H, Kuwada T, Maximov TC, Ohata T, Fukushima Y. 2001. Seasonal variation in the energy and water exchanges above and below a larch forest in Eastern Siberia. *Hydrol. Proc.* **15**, 1459-1476.

Ohta T, Kotani A, Iijima Y, Maximov TC, Ito S, Hanamura M, Kononv AV, Maximov AP. 2014. Effects of waterlogging on water and carbon dioxide fluxes and environmental variables in a Siberian larch forest, 1998-2011. *Agric. For. Meteorol.* **188**, 64-75.

Oshima K, Tachibana Y, Hiyama T. 2015. Climate and year-to-year variability of atmospheric and terrestrial water cycles in the three great Siberian rivers. *J. Geophys. Res. Atmos.* **120**, 3043-3062.

Park H, Iijima Y, Yabuki H, Ohta T, Walsh J, Kodama Y, Ohata T. 2011. The application of a coupled hydrological and biogeochemical model (CHANGE) for modeling of energy, water, and $CO_2$ exchanges over a larch forest in eastern Siberia. *J. Geophys. Res.* **116**, D15102, doi:10.1029/2010JD015386.

Park H, Fedorov A, Zheleznyak M, Konstantinov P, Walsh J. 2015. Effect of snow cover on pan-Arctic permafrost thermal regimes. *Clim. Dyn.* **44**, 2873-2895.

Sakai T, Hatta S, Okumura M, Hiyama T, Yamaguchi Y, Inoue G. 2015. Use of Landsat TM/ETM+ to monitor the spatial and temporal extent of spring breakup floods in the Lena River, Siberia. *Int. J. Remote Sens.* **36**, 719-733.

# Optimality theories at the leaf scale and their role in regulating the hydrological cycle

Gabriel Katul[1,2], Stefano Manzoni[3], Sari Palmroth[1], Amilcare Porporato[2,1],
Danielle Way[4], and Ram Oren[1]

[1]Nicholas School of the Environment, Duke University, Durham, NC, USA; [2]Department of Civil and Environmental Engineering, Duke University, Durham, NC, USA; [3]Department of Physical Geography, Stockholm University, Stockholm, Sweden; [4]Department of Biology, University of Western Ontario, London, ON, Canada

The dynamics of biological systems, from cells to communities and ecosystems, have been hypothesized to follow optimal trajectories shaped by selection pressure that force organisms to maximize their fitness and reproductive success. This concept has been particularly successful in explaining the form and function of terrestrial vegetation from eco-hydrological and carbon-economy perspectives, and across spatial and temporal scales. Any optimality model is based on three key ingredients: an objective function that describes the gain that needs to be maximized or loss to be minimized, a control variable that shifts the dynamics in the desired direction, and a set of constraints that account for environmental conditions and conservation laws bounding the system. All three ingredients are difficult to define and quantify – especially in complex biological and ecological systems. Despite these difficulties, optimality approaches may complement process-based approaches when mechanistic knowledge is scarce. At the leaf scale, it is often hypothesized that carbon gain is maximized, thus providing a quantifiable objective for a mathematical definition of optimality conditions. Eco-physiological trade-offs and fluctuating resource availability introduces natural bounds to this optimization process. In particular, carbon uptake from the atmosphere is inherently linked to water losses from the soil as water is taken up by roots and evaporated. Hence, fluctuating soil moisture constrains the amount of carbon that can be taken up and assimilated into new biomass. The problem of maximizing photosynthesis at a given water availability by modifying stomatal conductance, the plant-controlled variable to be optimized, has been traditionally formulated for short time intervals over which soil moisture changes can be neglected. This simplification led to a mathematically open solution, where the undefined Lagrange multiplier of the optimization (equivalent to the marginal water use efficiency) is heuristically determined from data fitting. Here, a set of models based on different assumptions that account for soil moisture dynamics over an individual dry-down are proposed so as to provide closed analytical expressions for the carbon gain maximization problem for varying soil moisture resources, atmospheric CO2 levels, and vapor pressure deficit. Upscaling these theories to the ecosystem and exploring their consequences to initiation of convective rainfall is also discussed.

**Reference:**

Katul, G.G., S. Manzoni, S. Palmroth, and R. Oren, 2010, A stomatal optimization theory to describe the effects of atmospheric CO2 on leaf photosynthesis and transpiration, *Annals of Botany*, 105(3):431-442.

Katul, G.G., R. Oren, S. Manzoni, C. Higgins, and M.B. Parlange, 2012, Evapotranspiration: A process driving mass transport and energy exchange in the soil-plant-atmosphere-climate system, *Reviews of Geophysics*, 50, RG3002.

Manzoni, S., G. Vico, A. Porporato, S. Palmroth, and G. Katul, 2013, Optimization of stomatal conductance for maximum carbon gain under dynamic soil moisture, *Advances in Water Resources*, 62, 90-105.

# Origin and formation mechanisms of atmospheric organic aerosols in marine and terrestrial ecosystems

Yuzo Miyazaki[1], Pingqing Fu[1,2], Maki Sawano[1], Jinsang Jung[1,3], Katsumi Yamanoi[4], Mitsuo Uematsu[5], Rainer Volkamer[6], Kimitaka Kawamura[1]

(1) Institute of Low Temperature Science, Hokkaido University, Sapporo, Japan
(2) Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China
(3) Korea Research Institute of Standards and Science, Daejeon, South Korea
(4) Hokkaido Research Center, Forestry and Forest Products Research Institute, Sapporo, Japan
(5) Atmospheric and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan
(6) CIRES, University of Colorado, Boulder, CO, USA

Atmospheric organic aerosols (OAs) scatter and absorb solar and terrestrial radiation, and are involved in the formation of clouds and precipitation as cloud condensation and ice nuclei. Marine and terrestrial ecosystems provide substantial emissions of a variety of biogenic volatile organic compounds (BVOCs) and subsequent formation of secondary organic aerosols (SOAs) as well as direct emissions of OAs. However, the formation mechanisms of OAs from natural sources remain highly uncertain. This presentation will provide an overview of our recent findings on sources and formation processes of OAs, based on ambient OA measurements over the subarctic ocean and in cool-temperate forest environments.

On the basis of shipboard measurement of atmospheric OAs, we successfully quantified the contribution of oceanic microbial origin to marine atmospheric OAs with methods of stable carbon isotope analysis and organic molecular markers (Miyazaki et al., 2010). Water-insoluble fraction of organic nitrogen was found to be the most abundant nitrogen aerosol in the subarctic western North Pacific. This fraction of OAs was suggested to be associated with marine microbial activity and may potentially influence the acidity, hygroscopicity, and light-absorbing properties of aerosols (Miyazaki et al., 2011). We also found low-molecular-weight hydroxyacids in marine aerosols for the first time, which are key intermediates for OA formation by marine microbial activity and atmospheric photochemistry (Miyazaki et al., 2014). These findings point to the importance of ocean-derived OAs, which control water-solubility, volatility, and light-absorbing properties of atmospheric aerosols.

Our results from several field measurements of OAs in forest environments provided a quantitative understanding of the roles of each vegetation types in the formation of biogenic OAs. They also provided direct observational evidence of a strong temperature dependence of α-pinene-derived SOA, and anthropogenically enhanced new particle formation and subsequent biogenic SOA formation (Miyazaki et al., 2012a; 2012b). We also proposed some new aerosol indices of biogenic origin and chemical aging of OAs to understand the mechanism of biogenic SOA formation and evolution. Directions for future researches will be discussed on interactions between the atmosphere and biosphere via atmospheric OAs.

**References:**

Miyazaki, Y. et al. 2010. Size distributions of organic nitrogen and carbon in remote marine aerosols: Evidence of marine biological origin based on their isotopic ratios. Geophysical Research Letters, 37, L06803, doi:10.1029/2010GL042483.

Miyazaki, Y. et al. 2011. Latitudinal distributions of organic nitrogen and organic carbon in marine aerosols over the western North Pacific. Atmospheric Chemistry and Physics, 11, 3037-3049.

Miyazaki, Y. et al. 2012a. Seasonal variations of stable carbon isotopic composition and biogenic tracer compounds of water-soluble organic aerosols in a deciduous forest. Atmospheric Chemistry and Physics, 12, 1367-1376.

Miyazaki, Y. et al. 2012b. Evidence of formation of submicrometer water-soluble organic aerosols at a deciduous forest site in northern Japan in summer. Journal of Geophysical Research, 117, D19213, doi:10.1029/ 2012JD018250.

Miyazaki, Y. et al. 2014. Low-molecular-weight hydroxyacids in marine atmospheric aerosol: Evidence of a marine microbial origin. Biogeosciences. 11, 4407-4414, doi:10.5194/bg-11-4407-2014.

# Ocean to atmosphere influences in mid-latitudes

Shoshiro Minobe

Graduate School of Science, Hokkaido University, Sapporo, Japan

In this presentation, I would like to review recent advancements of studies for ocean-to-atmosphere influences mainly in mid-latitudes, where I have been working on, with some discussions on the implications to higher latitudes.

To understand how mid-latitude oceans influence the atmosphere is a long lasting problem, but high resolution satellite observations of atmospheric variables enable us to find evidences of oceanic forcings to the atmosphere. This becomes possible by detecting patterns coherent with oceanic structures, such as fronts and currents, in those atmospheric variables. Such detection indicates that oceanic forcing play an important role, because scales of free-atmospheric variations are one order larger than oceanic ones. Since this strategy utilizes the difference of spatial scales between the atmosphere and ocean, it can be referred to as "scale-separation strategy". I will explain how scale-separation strategy has been employed for air-sea interaction studies in mid-latitudes using satellite data and other high resolution outputs including atmospheric analysis and numerical modelling. Scale-separation strategy has intrinsic imitation, but it can be overcome to some extent using other approaches such as numerical experiments.

Scale-separation strategy may works also in high-latitudes. However, observational data that can be used for direct assessments or verification of the strategy are rather poor in high-latitudes than in mid-latitudes. This suggests that modellings may have larger importance in high-latitude air-sea interaction studies, but of course a wise use of observational data or observational experiments are necessary for verification of findings obtained by modelling studies.

# Sea ice decrease in the Arctic and increase in the Southern Ocean – Discussions from the bi-polar perspectives –

Hiroyuki Enomoto[1,2]

(1) National Institute of Polar Research, Tokyo, Japan
(2) The Graduate University for Advanced Studies, Tokyo, Japan

Arctic and sub-Arctic sea ice conditions show general tendencies of decrease, however sea ice in the Southern Ocean shows increase. As sea ice coverages in the Arctic and Southern Ocean are showing both common and different seasonal, long-term trends, bi-polar perspective will be important for understanding sea ice change in the consequence of global climate change.

Both variations were considered to be occurring under the influence of global warming. There are common and different characteristics in the Arctic and Antarctic:

Common aspects:
– Changes in polar region
– Phenomena in sea ice and/or cryospheric and polar components
– Ice area changes associated with thickness change
– Driving by dynamic conditions
– Concerns on snow cover

Different aspects:
– Decreasing or increasing in sea ice
– Arctic or Antarctic
– Summer or winter
– Seasonal march
– Long-term trend
– Climate influences and feed backs

Sea ice map often focuses extreme condition of sea ice and seasonal march and long-term trend. Sea ice data is indicated usually separated in the Arctic or Antarctic. This study tried to put together and summarized characteristics of their extent, seasonal differences, seasonal march and long-term trends. Arctic sea ice was thick and their mobility was not large, however recent decrease of ice area is making new condition of Arctic sea ice. Sea ice in the Arctic is showing high mobility in summer and also evidenced even in winter season. Recent study introduces importance of sea ice dynamics for the ice thickness change in the Arctic.

Sea ice area around Antarctic Continent can be separated in to several zones by latitude and season. Ice dynamics are important factor in the Antarctic sea ice change due to its high mobility. Relationships between sea ice and snow condition are also of interest.

As the available data base, Arctic Data archive System (ADS) was developed in the GRENE Arctic project. Same as in situ data in the Arctic research field, satellite data was archived in the ADS. JAXA is supporting Arctic project by providing satellite data. The satellite data archiving and visualization tools are expanded to the Antarctic data. ADS is covering bi-polar data. ADS has the data visualization tool "VISHOP" can indicate multi-data on the projection.

# ROBOTICA: Research of Ocean-ice BOundary InTeraction and Change around Antarctica

Shigeru Aoki[1], Takeshi Tamura[2], Team ROBOTICA

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The unique characteristics of interactions among climate subsystems in East Antarctica have recently been revealed, and evidence of variations on various time scales - from decades to millennia - have been accumulating. Beneath the Totten Glacier Ice Shelf off Wilkes Land, ice discharge is accelerating, and a new potential pathway of warm water access has been discovered (Greenbaum et al., 2015). At the same time, coastal polynyas are ubiquitous along the East Antarctic coast. Sea ice formation and subsequent brine rejection in polynyas, including Cape Darnley and Vinceness Bay Polynyas, result in the production of Dense Shelf Water and lead to the export of bottom water (Ohshima et al., 2013; Kitade et al., 2014). Changes in the icescape, such as a Glacier Tongue calving, have a significant impact on oceanic conditions, changes in sea ice production, and the subsequent formation of Dense Shelf Water (Tamura et al., 2013; Kusahara et al., 2013). The environment is quite different in the neighborhood of the Lützow-holm Bay off Enderby Land, where Japan has maintained a year-round station ever since the IGY era. Coastal polynyas are rare here, but fast ice develops and the icescape varies from year to year. A trace of oceanic temperature variability on decadal time scale has been observed, and disintegration/stabilization of the landfast ice and Shirase Glacier Tongue have a quasi-periodicity of one to two decades.

ROBOTICA is initiated to understand the wide range of ice-ocean interactions and long-term variabilities off the East Antarctic Coast. For the coming 9th six-year plan (2016-2023) of the Japanese Antarctic Research Expedition (JARE), we plan to implement broad under-ice oceanographic, geographical, and cryospheric surveys using ROV/UAVs, sustained oceanographic observations using tethered and moored profiling platforms, and an ice-surface network of ice/ocean motion and deformation using GPS/ GNSS. Combining such new technologies with conventional and robust observational techniques will enable us to acquire more detailed environmental information, both in time and space. Applying these remote observation techniques to insufficiently explored regions will enhance our understanding of the mechanisms of different ice-ocean interaction regimes. In cooperation with the international research community, ROBOTICA will contribute to the development of the future observational network.

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# Session 2.
# Frontier Ice and Snow Science

# How and when to terminate the ice ages?

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Climate change with wax and wane of large Northern Hemisphere ice sheet occurred in the past 800 thousand years characterized by 100 thousand year cycle with a large amplitude of sawtooth pattern, following a transition from a period of 40 thousand years cycle with small amplitude of ice sheet change at about 1 million years ago. Although the importance of insolation as the ultimate driver is now appreciated, the mechanism what determines timing and strength of terminations are far from clearly understood. Here we show, using comprehensive climate and ice-sheet models, that insolation and internal feedbacks between the climate, the ice sheets and the lithosphere-asthenosphere system explain the 100,000-year periodicity. The responses of equilibrium states of ice sheets to summer insolation show hysteresis, with the shape and position of the hysteresis loop playing a key part in determining the periodicities of glacial cycles. The hysteresis loop of the North American ice sheet is such that after inception of the ice sheet, its mass balance remains mostly positive through several precession cycles, whose amplitudes decrease towards an eccentricity minimum. The larger the ice sheet grows and extends towards lower latitudes, the smaller is the insolation required to make the mass balance negative. Therefore, once a large ice sheet is established, a moderate increase in insolation is sufficient to trigger a negative mass balance, leading to an almost complete retreat of the ice sheet within several thousand years. We discuss further the mechanism which determine the timing of ice age terminations by examining the role of astronomical forcing and change of atmospheric carbon dioxide contents through sensitivity experiments and comparison of several ice age cycles.

# Development and performance of a numerical ice-sheet/shelf/stream model IcIES

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Ice sheet model for Integrated Earth-system Studies (IcIES) has been developed to simulate past and future ice sheets evolution. The model adopts the shallow ice approximation for grounded part, the shallow shelf approximation for floated part, and optionally adopts Schoof (2007) parametrization for computing grounding-line flux. Recent development and application of IcIES to various topics are introduced.

Because of strong non-linearity in the governing equation, large computing resources are demanded to solve the equation with high accuracy. Practically, truncation at some stage has to be decided on the basis of the balance between available computer resources and numerical accuracies, especially for long-term application. This study presents impact on the ice-sheet/shelf simulation of various time scales by different technical details such as a convergence criteria in the matrix solver, under ideal and realistic configuration including Antarctic ice sheet.

Many ice cores are drilled at present ice domes, the ice core sites may not necessary have been the "summit" throughout the time of interest. To help interpretation of the ice core analysis possible change in the simulation of the position of the summits by numerical modelling can be a vulnerable information. Sensitivity experiments are performed to evaluate how the position reacts to the boundary conditions such as local bedrock topography and ice-sheet margin using IcIES.

# Modelling polythermal ice sheets and glaciers

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Ice sheets and glaciers may be temperate or cold; however, most of them are always or at least temporarily polythermal with both cold and temperate regions. In cold ice, a change in energy content leads to a change in temperature, whereas in temperate ice, it leads to a change in the content of liquid water. Between the different regions, there is a cold-temperate transition surface (CTS), either with melting conditions if cold ice flows into the temperate region, or with freezing conditions if temperate ice flows into the cold region.

In order to model the thermal structure of polythermal ice sheets accurately, energy-conserving schemes and correct tracking of the CTS are necessary. Various models include a polythermal scheme; a two-layer polythermal scheme was implemented in SICOPOLIS (Greve, 1997), Aschwanden and Blatter (2005, 2009) applied a trajectory model to compute the water content in the temperate zone and Aschwanden et al. (2012) introduced a one-layer scheme based on enthalpy to track the melting CTS in ice sheets.

We compare four different thermodynamics solvers in the ice sheet model SICOPOLIS. A two-layer polythermal scheme and a single-phase cold-ice scheme already existed. Two one-layer enthalpy schemes, namely a conventional scheme and a melting-CTS scheme (Blatter and Greve, 2015) were added. The comparison uses two scenarios of the EISMINT Experiments (Payne et al., 2000). In terms of temperate ice layer thickness, CTS positioning and smoothness of temperature profiles across the CTS, the polythermal two-layer scheme performs best, and thus its results are used as a reference against which the performance of the other schemes is tested. Both the cold-ice scheme and the conventional one-layer enthalpy scheme fail to produce a continuous temperature gradient across the CTS, and both overpredict temperate ice layer thicknesses. In the one-layer melting-CTS enthalpy scheme, a continuous temperature gradient is explicitly enforced, and results match those obtained with the polythermal two-layer scheme well.

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# Ice mass loss in northwestern Greenland

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The Greenland ice sheet and peripheral ice caps are losing ice mass (e.g. Khan and others, 2015). Overview of the mass change has been revealed over the last decade thanks to the advance in satellite remote sensing techniques, but more detailed studies are needed to understand controlling mechanisms, and spatial and temporal variations of the mass loss. Recently, mass loss is increasing particularly along the coast in northwestern Greenland (Enderlin and others, 2014). Despite the importance of this region, in-situ data are sparse in northern part of Greenland.

To quantify ice mass loss in northwestern Greenland and better understand the mechanisms driving ongoing changes in this region, we have been working on the ice sheet and glaciers in the Qaanaaq region, as a part of GRENE Arctic Climate Change Research Project. Field and satellite observations were performed on the ice sheet, outlet glaciers and ice caps. We also performed ocean measurements to better understand ice-ocean interaction. These studies include mass balance and ice speed monitoring on Qaanaaq Ice Cap since 2012, integrated field observations and hot water drilling near the calving front of Bowdoin Glacier since 2013, and ocean measurements near the front of Bowdoin Glacier and in other fjords in the region.

Our data showed that the glaciers and ice caps are losing mass at increasing rates. Ice caps are thinning at a rate $>1$ m a$^{-1}$, which is significantly greater than previously reported estimate. Rising air temperature is the primary reason of this change, but ice surface darkening due to biological activity also enhances ice melt in the ablation area (Sugiyama et al., 2014). Calving glaciers are retreating, thinning, and accelerating as reported in southern Greenland. Initial retreat of the glaciers is probably due to atmospheric and/or oceanic warming, but successive rapid changes are driven by glacier dynamics controlled by ocean and glacier bed geometry (Sugiyama et al., 2015). These results indicated the rapid changes in northwestern Greenland, and therefore the importance of continuous observations in the future. Particularly, it is urgent to study more details of oceanic changes to accurately understand the ongoing change and its impact on human society in Qaanaaq region. In this contribution, we present these results of the GRENE Greenland project, and introduce the next project planned under the framework of ArCS (Arctic Challenge for Sustainability Project).

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# Recent progress in understanding densification phenomena of polar firn: textural effects and some soluble impurities control creep deformation

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For observation of the polar ice sheets under the ongoing global warming, understanding the evolution of polar firn is fundamental to better understand (i) ice core signals, (ii) surface elevation changes of polar ice sheets and (iii) data of microwave remote sensing of polar ice sheets. Metamorphism and initial layering of snow is known to be dependent on various surface conditions, such as the accumulation rate, temperature, temperature gradient, and mechanical forcing by wind. After the initial processes of firn formation at the ice sheet surface, firn subsequently undergoes various further processes of both metamorphism and deformation with both increasing time and depth. Such processes, including initial fractures, rearrangement of ice grains, creep deformation, pressure sintering with shrinkage of either pore spaces or closed air bubbles, and grain growth, are complex. Our knowledge is still limited to reliably model the densification phenomena of polar firn for various applications.

To improve our understanding, firn cores drilled at several sites at Dome Fuji in the East Antarctic Plateau, and an inland site of Greenland called NEEM were investigated, using surrogates of density: dielectric permittivities $\varepsilon_v$ and $\varepsilon_h$ at microwave frequencies with electrical fields in the vertical and the horizontal planes, respectively. Dielectric anisotropy $\Delta\varepsilon$ ($= \varepsilon_v - \varepsilon_h$) was then examined as a surrogate of the anisotropic geometry of firn. In addition, major ions were measured to investigate effects of impurity ions. We found that layered densification is explained as a result of complex effects of two independent phenomena that commonly occur at the investigated sites. Basically, layers with initially smaller density and smaller geometrical anisotropy deform preferentially throughout the densification process due to textural effects. Here, the textural effects include ice-ice bonding, c-axis orientation fabrics and geometrical structure of ice and pore spaces. Second, layers having a higher concentration of $Cl^-$ ion, a higher concentration of $F^-$ ions or a smaller concentration of $NH_4^+$ ions deform preferentially. We hypothesize that sites of oxygen within crystal lattice of ice are substituted by these ions dissociated from sea salts or mineral dusts, and that these ions modulated dislocation movement. Moreover, firn differs markedly between the investigated sites in terms of strength of geometrical anisotropy, mean rate of densification, and density fluctuation. We hypothesize that these differences are caused by textural effects resulting from differences in depositional conditions within various spatial scales.

Overall, actual densification of polar firn and ice is dominantly controlled by creep deformation associated with the dislocation motion at wide depths from the ice sheet surface to deeper (~100m) depths. Our observed features are apparently different from the traditional view that the firn densification phenomena is a sequence of several stages such as; (i) initial fractures, (ii) rearrangement of ice grains, and (iii) creep deformation. In future, firn densification models need more focus on creep deformation mechanism throughout the densification process.

# Prism and other high-index faces of ice crystals exhibit two types of quasi-liquid layers

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Surface melting of ice significantly governs a wide variety of phenomena in nature, such as the generation of thunder, regelation, frost heave, the conservation of foods, ice-skating, the preparation of a snowman and crystal growth of ice. We recently succeeded in directly observing the surface melting on ice basal faces by our advanced optical microscopy, which can detect 0.37-nm-thick elementary steps on basal faces [1]. Then we found, on basal faces, that two types of quasi-liquid layers (QLLs) appear: drops and thin layers [2]. However the direct observation of surface melting on the other prism and high-index faces remains an experimental challenge. To fully obtain comprehensive understanding, we need to examine the surface melting on these faces. Here we show the appearance of two types of QLLs also on prism and high-index faces just below the melting point [3].

It is well acknowledged that thermal roughening occurs on an ice prism face at temperatures higher than –2°C: an ice prism face becomes rounded and high-index faces appear in this temperature range. We first observed the thermal roughening processes of ice prism faces in situ, and found that the thermal roughening needs a time scale of about one hour. Then next, we quickly raised a temperature of ice crystals and then observed prism and high-index faces during the roughening process. We found that with increasing temperature, round liquid-like droplets ($\alpha$-QLLs) first appeared at temperatures higher than –1.4 ~ –0.5°C, and then thin liquid-like layers ($\beta$-QLLs) also appeared at temperatures higher than –0.8 ~ –0.3°C, as in the case of basal faces. This result demonstrates that the presence of two types of QLL phases with different morphologies plays an intrinsically important role in the surface melting of ice crystals, irrespective of face indexes. We also revealed that the roughening process was caused thermally.
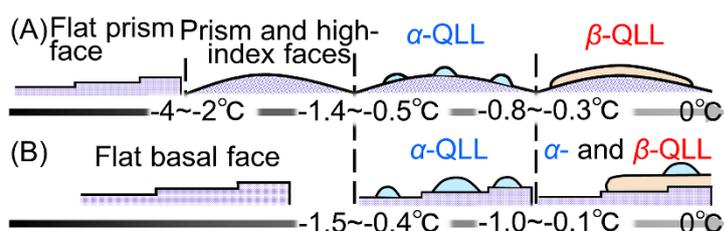


Fig. 1. A summary of the main findings on prism and high-index faces in this study (A) and those on basal faces in our previous study [1] (B). Schematic illustrations show cross sectional views.

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# Nucleation from a supersaturated vapor

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In the current universe, cosmic dust particles have mainly been produced in gas out flow from dying stars such as asymptotic giant branch stars and super novae. It is not easy to form a particles via homogeneous nucleation, which is a process to overcome a free energy barrier for phase transition without an assistance of a substrate. Gas atoms or molecules are condensed on a substrate, called heterogeneous nucleation, much more efficiently than homogeneous nucleation. Therefore, pre-existing dust is able to work as a substrate for heterogeneous nucleation of remaining gas species. One of our motivation is to know what kind of mineral firstly nucleates around dying stars, because first dust works as a substrate for heterogeneous nucleation of remaining gases. Since nucleation process determines characters, such as size, size distribution, composition, crystalline structure and morphology, of final products, first dust is essential in the process of material evolutions accompanying with stellar life.

We know homogeneous nucleation can be occurred far from thermal equilibrium. However, we do not know how far it is. The efficiency for nucleation strongly depends on the materials. Particularly, surface free energy and sticking probability are the most important physical parameters to predict nucleation. Unfortunately, however, these physical parameters have large uncertainties, because actual size of dust is less than 100 nm in diameter and the nucleation processes are progressed in nanometer scale. These physical parameters should be different from that of the bulk. Nevertheless, generally, bulk values have been used. To evaluate the formation sequences of minerals and find the character and formation condition of first dust, we are trying to reproduce cosmic dust particles in our laboratory and observed the nucleation environment to determine above mentioned two physical parameters (Kimura et al. 2011, 2012).

Another important aspect is the difference of the formation condition between natural cosmic dust particles and mimic laboratory dust. Ordinarily, our knowledges have been accumulated by ground based experiments and the formation and alteration processes of cosmic materials have been discussed based on such knowledges. However, natural cosmic dust particles form under microgravity condition, where surface tension contributes more strongly and gravity effects, such as weight and convection, are suppressed. Therefore, we believe that understanding of the microgravity effects and difference between on earth and in universe on the material formation is required to make clearer view of the formation of materials in space. Therefore, we have performed microgravity experiments in parabolic flights using airplane and sounding rockets (Kimura et al. 2014). Here we will show our results showing how large supersaturation is required for homogeneous nucleation and how formation of cosmic dust particles is difficult.

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# Homogeneous SPC/E water nucleation in large molecular dynamics simulations

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We perform 18 runs of direct large molecular dynamics simulations of homogeneous SPC/ E water nucleation with the LAMMPS code for various vapor temperatures and number densities, using up to ~ 4 x $10^6$ molecules. Our large system sizes allow us to measure extremely low and accurate nucleation rates, down to ~$10^{19}$ cm$^{-3}$ s$^{-1}$ from ~$10^{24}$ cm$^{-3}$ s$^{-1}$ in the previous simulations. Our results help the filling of the gap to experimentally measured rates ~$10^{17}$ cm$^{-3}$ s$^{-1}$. We are also able to precisely measure size distributions, sticking efficiencies, cluster temperatures, and cluster internal densities. To obtain accurate steady nucleation rates from simulations with the Yasuoka-Matsumoto nucleation rate measurement technique, we introduce a new fitting functional form, by taking into account a lag time before the steady nucleation. Comparison to nucleation models shows that classical nucleation theory over-estimates nucleation rates by a few orders of magnitude. The semi-phenomenological nucleation model does better, under-predicting rates by at worst a factor of ~20, as well as in the laboratory experiments. Unlike what has been observed in Lennard-Jones simulations, post-critical clusters have temperatures consistent with the run average temperature. Also, we observe that post-critical clusters have densities very slightly higher, ~5%, than bulk liquid. We re-calibrate a Hale-type J-S scaling relation using both experimental and simulation data, finding remarkable consistency in over 30 orders of magnitude in the nucleation rate range and 180 K in the temperature range (see the figure).
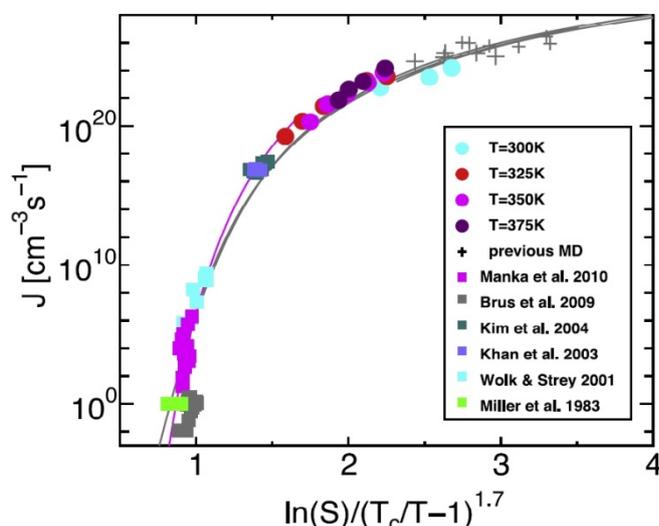


**Figure:** Nucleation rates $J$ as function of $\ln S/(T/T_c-1)^{1.7}$ for MD simulations and laboratory experiments. In the horizontal axis, $S$ is the super-saturation ratio and $T_c$ is the critical temperature. MD simulations are plotted with filled circles (present work[1]) and crosses (previous work[2]). Various experimental data are plotted with squares. The thin curves show the SP model.

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# Session 3.
# Environmental Biology

# Life history traits and ecophysiological adaptations in polar zooplankton and fish

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Polar zooplankton species exhibit quite diverse life history traits. A major driving force determining their life strategies is the seasonal variability in food supply, which is most pronounced at high latitudes, where fluctuations in primary production are extreme. Therefore, seasonal adaptations are closely related to the trophic level of zooplankton species, with strongest environmental pressures occurring on herbivorous organisms. The dominant grazers, calanoid copepods and krill (Euphausiacea), have developed fascinating solutions for successful overwintering at higher latitudes during the dark period, when primary production is at a minimum. These herbivores usually exhibit a very efficient storage and utilization of energy reserves to reduce the effect of a highly seasonal primary production. The predominant larger *Calanus* species from the Arctic and *Calanoides acutus* from the Antarctic biosynthesize large amounts of high-energy wax esters. These compounds consist of unusual long-chain monounsaturated fatty acids and alcohols (20:1 and 22:1 isomers) as major components. They survive the winter period at depth in a stage of dormancy called diapause. In contrast, the Antarctic *Calanus propinquus*, a winter-active species, synthesizes primarily triacylglycerols, which are dominated by long-chain monounsaturated fatty acids with 22 carbon atoms (2 isomers) and yield even higher calorific contents. Herbivorous copepods usually channel this energy towards reproductive processes in late winter/early spring. They do not utilize much of their enormous lipid reserves for maintenance during overwintering, as does the Antarctic krill, *Euphausia superba*, which stays active in winter and reproduces rather late in the summer season. Timing of reproduction is critical especially at high latitudes due to the short primary production period, and lipid reserves often ensure early spawning independent of external resources. These energetic adaptations (dormancy, lipid storage) are supplemented by other life strategies such as extensive vertical migrations, change in the mode of life, and trophic flexibility. Omnivorous and carnivorous species, which are less subjected to seasonal food shortage, usually do not exhibit such an elaborate lipid biosynthesis.

The carnivorous pelagic Antarctic silverfish, *Pleuragramma antarctica*, is an exception from this rule, as this fish species permanently accumulates massive amounts of triacylglycerols in special lipid sacs during its early ontogenetic development. However, in this dominant fish species, which lacks a swim bladder, the lipids primarily function as buoyancy aid rather than energy reserve.

# Proteome analysis of bacterial genes specifically expressed in soil

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Bacterial cells living in natural soil environments respond to physical, chemical and biological changes. Knowing the gene expression pattern, function, and physiological state of a single bacterial strain is important for understanding of bacterial ecology. To clarify the gene expression and functional data for each of bacteria from special habitats, general information has been obtained through *in vitro* studies under various conditions. However, the information would considerably differ for bacteria exposed to various environmental factors in the original soil habitat. Particularly, genes specifically expressed in soil and not in laboratory media are considered to provide important information.

We performed differential proteomics analysis using a standard sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS–PAGE) technique, combined with liquid chromatography-tandem mass spectrometry (LC–MS/MS), and identified *Pseudomonas putida* F1 genes specifically expressed in soil. The strain F1 was inoculated into three different types of soil (soybean, maize, and forest) and incubated for 3 days, and also cultured to logarithmic and stationary phase in rich and minimal media, and the proteome datasets were compared. For the genes specifically expressed in soil, their expression stimuli were identified.

From comparative analyses of the proteome datasets, 187 distinct proteins were differentially detected in the three soil samples, not detected in liquid samples. Among those, nine proteins were found to be commonly detected in all three samples. Finally, seven genes were identified as specifically expressed in soil, including two genes coding for a hypothetical protein and a nitric oxide dioxygenase, respectively, and a cluster consisting of five genes. The expression factor analysis revealed that the gene coding for nitric oxide dioxygenase was induced by nitric oxide, and five clustered genes were induced under phosphate starvation.

These results suggest that our soil metaproteome approach is useful for understanding the autecology and lifestyle of a single bacterial strain in soil environment, and that it allows the prediction of the microenvironment surrounding the bacterial cells.

# Boreal forest ecosystems as related to recent advances in ecological and physiological studies of trees

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The boreal forest occupies ca. one-third of the total forest area on Earth. Diversity of dominant plant species is low, and a large amount of carbon is stored in the soil. How the boreal forest ecosystem may respond to global warming is of concern. As trees in the cold region naturally have the ability to survive the winter environments of their native habitats, their responses to the environment in the growing season (summer) are more relevant than those in winter. In this presentation, some of the recent advances in ecological and physiological studies of the boreal forest and forests in cold regions are introduced by focusing on studies at individual-tree levels.

One of the noticeable recent advances relates to symbiotic interaction between trees and some groups of fungus in the soil called mycorrhizas. About 90% of tree species observed have been found to retain mycorrhizas on the surface of or inside of their fine root tips. Mycorrhizas provide trees with soil nutrients such as nitrogen in return for non-structural carbohydrates (NSC) soluble in water, the product of the photosynthesis by trees. However, further studies revealed that in harsh environments where resources are difficult to obtain as in cold environments, the symbiotic activity of mycorrhizas may be opportunistic (Näsholm et al. 2013). On the other hand, it had long been assumed that the major factor limiting growth of trees was the amount of NSC within a tree body. This assumption has been questioned as many recent studies have demonstrated that NSC exist somewhere in a tree body throughout the year, and that the amount of NSC is enough to meet current-year growth of a tree (Sala et al. 2012). The findings have given rise to revisions of the factors limiting tree growth and the relevance of NSC for trees.

Plants retain a large amount of enzyme protein called RuBisCO, the key enzyme limiting photosynthesis, within their leaves. In winter, evergreen trees in the cold region have known to accumulate a certain amount of inactive RuBisCO more than necessary for their photosynthesis during winter. This seemingly inexplicable phenomenon is regarded as trees' adaptation to nitrogen-limiting environments; nitrogen is a major element composing RuBisCO. The nitrogen stored in the RuBisCO in older leaves is remobilized to newly developing leaves in spring (Millard et al. 2010). When the air temperature increases in the spring of a cold region, the soil temperature cannot increase as fast as the air temperature. Hence activities of roots to absorb soil nutrients are low in early spring. The remobilization of nitrogen from old to new leaves in early spring could serve for producing new leaves as early as possible in spring, and for increasing the duration of photosynthesis in the growing season in a cold region.

As these examples demonstrate, recent physiological and ecological knowledge of trees relates not only to the above-ground processes but also to the below-ground ones, and suggest concrete mechanisms of the interactions between them in relation to physical environments of cold regions. Incorporating the knowledge as stated above into ecosystem-level analyses could lead to better understanding of the boreal forest ecosystem.

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# Photosynthesis at low temperatures: The roles of light-harvesting-like proteins in the biogenesis and protection of photosystems

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At low-temperatures, many metabolic processes in plants are slowed down. As a consequence, the energy captured by photosynthesis is not sufficiently consumed within cells, which ultimately results in uncontrolled oxidation of proteins, lipids and other biological molecules. It is hypothesized that plants in the boreal regions adopt several strategies to avoid such destructive oxidation of biological molecules under low-temperature conditions. In particular, evergreen trees must have effective methods to cope with temperature-induced damages.

Gene expression analyses of evergreen trees indicate that they express specific sets of genes encoding chloroplast proteins in wintertime. It is plausible that those genes are involved in the protection or maintenance of photosystems in wintertime. Among them, those encoding Light-harvesting-like (LIL) proteins are of particular interests, because some of the LIL proteins are reported to be interacting with the photosynthetic machinery under the conditions where the machinery is prone to damages.

Here, we report our investigation on the function of representative LIL proteins in the model plant, *Arabidopsis thaliana*. We found that a member of LIL proteins, LIL3, forms a stable complex with geranylgeranyl reductase (GGR) which catalyses the formation of phytyl-diphosphate, a key intermediate in chlorophyll, tocopherol and phylloquinone biosynthesis. For better understanding of the function of the LHC motif in LIL3, we have modified the LIL3 and GGR sequences and analyzed the effects of these modifications in transgenic Arabidopsis plants. When the membrane-spanning domains of LIL3 were fused with GGR, GGR was stabilized in the absence of LIL3. The results indicate that anchoring GGR to membranes is a main function of LIL3.

LIL8 (alternatively called PBS33) is another LIL protein in thylakoid membranes. We found that lack of LIL8 leads to an altered excitation balance between PSI and PSII. It is likely that LIL8 is involved in the control of excitation balance between these photosystems. Taken together, it is found that multiple LIL proteins are involved in photosynthesis-related functions.

LIL2 (alternatively called OHP1) is a thylakoid protein with a single membrane-spanning domain. Its amino acid sequence is similar to that of cyanobacterial Hlip proteins which are involved in the assembly of photosystem (PS) II. The Arabidopsis *ohp1* mutant lacking LIL2 has a reduced level of PSII. Purification of a protein complex containing LIL2 from Arabidopsis leaves revealed that LIL2 forms a complex with LIL6, and other components that are similar to the cyanobacterial proteins in the Hlip complex. These results suggest that plants have a PSII-assembling system similar to the cyanobacterial one.

Taken together, it is indicated that LIL proteins are involved in the biogenesis and regulation of photosystems. The functions of LIL proteins might be essential in the overwintering of evergreen trees.

# PSI-PSII megacomplex in evergreen plants

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Traditionally, two types of photosystem reaction centers (PSI and PSII) are thought to be spatially dispersed. However, we showed that about 60% of PSIIs are physically connected to PSIs, and formed PSI-PSII megacomplex in *Arabidopsis thaliana* [1]. PSII can transfer excess excitation energy directly to PSI, then the excess energy was quenched by PSI. This mechanism is very important to deal with excess excitation energy, then we focus on non-model photosynthetic organisms to reveal diversity of the mechanism.

In evergreen species, excess excitation energy is very severe problem. While plant looks green, red- and blue-light are absorbed, and the excitation energy is continuously generated. Under a mild climate, the excitation energy is converted to electron flow in the PSI and PSII, and the electron is used to fix CO2. However, under low temperature, electron flow is inhibited, and most excitation energy becomes excess. Plant should convert the excess excitation energy to heat immediately, because the excitation energy easily change its character ($\sim 10^{-7}$ sec.) and causes cell death. Here, we report how evergreen species utilize the PSI-PSII megacomplex.

We analyzed three species, Yew tree, Birthroot, and Black pine. The former two were harvested in campus of Hokkaido University, and the latter one was harvested in campus of Kobe University. In summer, all species utilized the PSI-PSII megacomplex, and the excitation energy dynamics looked the same to in *A. thaliana*. Next, we examined seasonal change of the PSI-PSII megacomplex in Yew tree.

In winter Yew needles, we also observed the PSI-PSII megacomplex, where PSII transfer its excitation energy to PSI. However, PSI showed different fluorescence property, which reflects modified PSI antenna in winter Yew tree. Previously, we reported that Yew tree showed seasonal change in character of PSI antenna [2]. In summer, the PSI antenna showed similar character to *A. thaliana*. In winter, the PSI antenna showed different fluorescence peak as observed in this study. The modified PSI showed higher ability to convert excitation energy to heat. Therefore, in winter, Yew tree transferred excess excitation energy from PSII to PSI, then PSI may convert the energy to heat efficiently by the modified PSI antenna.

The winter Yew needles showed drastic change when the needles transfer to 20 ℃ condition. After 1 h, the modified PSI antenna in the winter Yew needles was detached from reaction centers, while most PSII may still bind to PSI. Yew tree may switch over from defense mode to photosynthesis mode by detachment of the modified PSI antenna from PSI-PSII megacomplex.

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# Calredoxin mediates calcium- and redox- dependent regulation of photosynthesis and ROS defence in *Chlamydomonas reinhardtii*

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Calcium ($Ca^{2+}$) and redox signaling play important roles in acclimation processes from archaea to eukaryotic organisms. Herein we characterized a unique protein from *Chlamydomonas reinhardtii* that has the competence to integrate $Ca^{2+}$ and redox-related signaling. This protein, originally identified in a proteomic study (Hohner et al., 2013), was designated as calredoxin (CRX), as it combines four $Ca^{2+}$-binding EF-hands and a thioredoxin (TRX) domain. A protein crystal structure of CRX, at 1.6 Å resolution, revealed an unusual calmodulin-fold of the $Ca^{2+}$-binding EF-hands, which is functionally linked via an inter-domain communication path with the enzymatically active TRX domain. CRX is chloroplast-localized and interacted with a chloroplast 2-Cys-peroxiredoxin (PRX1). $Ca^{2+}$-binding to CRX is critical for its TRX activity and for efficient binding and reduction of PRX1. Thereby CRX represents a new class of $Ca^{2+}$-dependent "sensor-responder" proteins. Genetically engineered Chlamydomonas strains with strongly diminished amounts of CRX, revealed altered photosynthetic electron transfer and impact in ROS defense underpinning a function of CRX in stress acclimation.

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# Session 4.
# Research on the Pan-Okhotsk Region

# Climate variations in East Asia and Japan during last two millennia

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Recently, high resolution datasets on past climate, annually-resolved past temperature and precipitation, have been created using tree rings all over East Asia including Japan for last few millennia. Although tree growth is not controlled by temperature in warm regions, it is sensitive to summer temperature in cold regions. Because pattern of temporal variation in temperature is quite similar within a wide area of East Asia, past summer temperature reconstructed by Tibetan and/or Mongolian trees can be applied to estimate past change in average temperature in East Asia including Japan. By compiling all available tree ring datasets in Asia, Cook et al (2013) successfully reconstructed average summer temperature since 800 CE at annual time resolution in East Asia. Reconstructed temperature variation in East Asia was arrayed with those in other continents over world to illustrate spatio-temporal variability in temperature during last two millennia (PAGES 2k consortium, 2013). Characteristics in combined temperature variations beyond continents are as follows. (1) Temperature had been gradually decreasing until 19th century all over world. (2) Except for Antarctica, temperature had suddenly become to increase in 20th century. (3) There were not any universal decades or centuries of "Medieval Warm Period" or "Little Ice Age" in the world except for some cold episodes following large volcanic eruptions and/or solar minima. All indicate the serious influence of human-emitted greenhouse gases to the climate after 20th century.

Contrary to temperature, it has been difficult to estimate past change in precipitation in pluvial region like Japan. It is not only because tree growth in humid area is not influenced by precipitation, but also because spatial distribution of precipitation is more heterogeneous than that of temperature so that it is impossible to infer precipitation history in pluvial areas using tree-ring data in continental arid region. This difficulty has been solved by utilization of tree-ring oxygen isotope ratio, a consistent dendrochronological parameter which can tell us past variations in summer precipitation precisely. In Japan, we have reconstructed past summer precipitation back to 4300 years ago in annual time resolution at several sites using various kinds of wood such as living trees, old architectural wood, excavated archaeological wood and buried natural logs. Tree-ring oxygen isotope ratios have been unraveling past precipitation history in East and Southeast Asia, too (Xu et al., 2003). The oxygen isotope ratios have been increasing recently all over Asia monsoon region, suggesting that Asia summer monsoon has become weaker (drier) due to the increased tropical sea surface temperature.

In fact, the reconstructed variations in temperature and precipitation have apparent tight relationships with historical and archaeological records, such that amplifications in multi-decadal climate variability, i.e. occurrence of decadal length of drought, flood or coldness, often resulted in notorious famines and/or warfare in Japan and Asia. Because of preciseness in the newly obtained paleoclimate data, we can start interdisciplinary studies on climate-society relationship in human history by direct collaborations between historians, archaeologists and paleoclimatologists in the world.

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# Predictability in the North Pacific

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North Pacific sector climate exhibits variability on a wide range of time scales, from interannual to centennial. Predictability is related to both internal climate variability and external forcing, where respective contributions can be time scale dependent. Here we focus on a multiyear predictability generated by internal variability. As ocean-atmosphere interaction is heavily involved in this process, identifying related ocean process, its generation mechanism and atmospheric response to the ocean signal are important. We present level of predictability naturally existing in the North Pacific climate system (Wu et al. 2015) and sensitivity of atmosphere model in representing the response to ocean anomalies (Zhou et al. 2015).

We first examine multiyear predictability of Northern Hemisphere surface air temperature (SAT) in a multi-millennial control integration of the Kiel Climate Model, a coupled ocean–atmosphere–sea ice general circulation model. Multiyear SAT predictability exists near the sea ice margin in the North Atlantic and mid-latitude North Pacific sector. In the North Pacific, the most predictable SAT pattern is characterized by a zonal band in the western and central mid-latitude Pacific, which is linked to the sea surface temperature (SST) anomalies that are associated with re-emergence processes. Pacific Decadal Oscillation (PDO) driven SST anomalies subduct into deeper ocean layers and re-emerge at the sea surface during the following winters, providing multiyear memory.

We further show, by means of dedicated high-resolution atmospheric model experiments, that daily variability in the extratropical background SST needs to be resolved to force a statistically significant large-scale atmospheric response to North Pacific SST anomalies. The large-scale response is mediated by atmospheric eddies.

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# Modeling of the radiative properties of snow and its application to climate study

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Snow and ice conditions are presently undergoing drastic changes, which is significant in the Arctic and mid-latitude cryosphere. For understanding and predicting the climate change in the cryosphere, the detailed observational studies and physically based modeling studies on snow physical parameters (albedo, solar heating profile, snow height, temperature, density, grain size, shape, liquid water content, impurities, etc.) are needed. Among them surface albedo is a key factor of heat budget in cryosphere. The near-infrared (NIR) albedo mainly depends on snow grain size (Wiscombe and Warren, 1980) and the visible albedo on concentrations of light absorbing snow impurities (LASI) (Warren and Wiscombe, 1980). We developed a physically based snow albedo model (PBSAM, Aoki et al., 2011) for general circulation models that simulates broadband albedo and the solar heating rate in the snowpack from snow physical parameters and solar illumination conditions. The PBSAM is incorporated into snow metamorphism and albedo process model (SMAP, Niwano et al., 2012) by which snow grain size and the other snow parameters are calculated. PBSAM was validated with the snow pit and albedo data measured during 5 winters from 2006 to 2011 in study plot of Institute of Low Temperature Science, Hokkaido University, Sapporo, Japan. The root mean square error of shortwave albedo calculated with PBSAM was 0.069. The estimated albedo reduction (radiative forcing) due to LASI (black carbon [BC] and mineral dust) by PBSAM were 0.055 (6.6 $Wm^{-2}$). The contribution to albedo reduction from BC was much larger (77%) than dust (23%). SMAP simulated that the recent snowpack durations at Sapporo were shortened by 16-19 days caused by LASI during the 2007–2009 winters. These models have been incorporated into earth system model of Meteorological Research Institute. The models can be applicable to simulation of albedo and snow microphysics on a stand-alone as well.

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# Climate changes in the North Pacific region reconstructed from alpine ice cores

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Ice cores obtained from glaciers and ice sheets are one of the most important archives of paleo-climatic and paleo-atmospheric information. Variations in chemical signals in ice cores can be used as indicators of past air temperature, annual precipitation rate, source area of water vapor, and many other parameters. In the mid- and low latitudes, suitable locations for ice-core drilling are limited to the high-elevation sites of alpine glaciers, where the effects of snowmelt in summer on chemical signals in ice cores are not significant. Generally, accumulation rate in the drilling sites of the alpine ice cores is much higher (more than 1m water eq.) than inland ice sheet site (e.g. Dome Fuji in Antarctica and GRIP in Greenland), and ice thickness of the alpine ice core site is approximately 100 to 300 m. Therefore, the time ranges intended by alpine ice core studies are several hundred years. Noteworthy climate change events for several hundreds in the North Pacific region are the Little Ice Age, recent global warming, the Pacific Decadal Oscillation and so on.

We have obtained several ice cores in the North Pacific region to reconstruct the changes in climate and environment in this region. On the Asian side, we have drilled in the Kamchatka Peninsula, Russia, at Ushkovsky mountain in 1998 and Ichinsky mountain in 2006. On the North American side, we have drilled in Alaska, at Mount Wrangell in 2003 and 2004 and at the flat saddle north of Aurora Peak in 2008.

Reconstructed annual accumulation at Aurora Peak showed a significant increase from 1970s to the present at the rate of 28 mm/yr. This significant trend of increase has not been observed at any meteorological stations at ground level. Annual accumulation at Mount Wrangell showed high values before 1977, low values from 1977 to 1990, and high values after 1990 again. The variation of accumulation in 1977 is likely associated with the climatic shift called Regime Shift. The annual accumulation in the Wrangell ice core after 1990 anti-correlated with surface level pressure over the Gulf of Alaska. The variations of accumulation rates likely associate with the intensity of low pressure systems in the Gulf of Alaska and Bering Sea.

We also analyzed several kinds of chemical substances in the ice cores such as organic compounds, soluble salt and heavy metals as new tracers for the records of environmental changes. We will also brief the results of new tracers.

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# Biogeochemical system in the Pan-Okhotsk area

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Iron (Fe) is an essential nutrient and plays an important rolls in the control of phytoplankton growth and biogeochemistry in the Ocean. The subarctic Pacific is known to have High Nutrient Low Chlorophyll (HNLC) area, where nutrient concentrations are not depleted through all season and the phytoplankton growth is broadly limited by Fe availability. However, even with the Fe limitation, the western subarctic Pacific (WSP) has effective phytoplankton growth and more seasonality in the lower trophic levels than the eastern subarctic Pacific. Therefore, differences in Fe supply processes must explain the west-to-east decrease in seasonal phytoplankton growth. Although we recognize several Fe supply processes in the WSP, the mechanisms that account for controlling phytoplankton growth have not been understood. Here we demonstrate the pivotal role of marginal sea, the Okhotsk Sea, system for suppling Fe to the Pacific Ocean. A basin-scale Fe section shows that sedimentary Fe is discharged from the Okhotsk Sea to the western North Pacific in the intermediate layer. The re-distribution of this Fe-rich intermediate water by intensive mixing as it crosses the Kuril Island Chain (KIC) is the predominant process determining the ratio of micro-nutrient to macro-nutrients in subsurface waters. This ratio can quantitatively explain the differences in surface macro-nutrient consumption between the western and eastern subarctic, as well as the formation of the HNLC region in the North Pacific. Therefore, the existence of a sub-polar marginal sea that connects with the North Pacific through the KIC is essential, and diapycnal mixing in the KIC is a key process, for controlling the Fe supply and the seasonal amplitude of the biogeochemical cycle in the WSP. This natural Fe fertilizing system simultaneously explains one of the largest biological pumps in the world [Buesseler et al., 2007] and the formation of the HNLC region in the WSP [Tsuda et al., 2003].

Recent weakening of overturning in the intermediate water in this system has been reported [Nakanowatari et al., 2007]. Clarifying what causes these long-term changes of oceanic physical and biogeochemical conditions is an essential step for predicting future global climate changes. Our findings contribute to predicting of the future changing of the biogeochemical cycles in the North Pacific.

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# Poster Session

# Soil microorganisms and terrestrial plant metabolites in marine aerosols from the western North Pacific: molecular distribution of hydroxy fatty acids over Chichijima Island

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Air- and soil-borne microorganisms can be pathogenic to humans and can cause severe allergies during their atmospheric transport. Several studies have been conducted to measure bacteria associated with dust and their health impacts [*Griffin*, 2007 and references therein]. However, atmospheric researchers face difficulties in the identification and quantification of these pathogenic bacteria during their long-range atmospheric transport. To solve this, hydroxy FAs, specifically β-isomers, can serve as the markers for bacteria and plant metabolites during their atmospheric transport over the Pacific. Along with β-hydroxy FAs, other α- and ω-isomers of these hydroxy FAs have also been employed as tracer for soil microorganisms such as bacteria, fungi as well as for algae and higher plants in airborne particulate matter.

Hydroxy fatty acids (FAs) were measured in the aerosol samples collected from Chichijima Island (27°04'N; 142°13'E) in the western North Pacific during January 2001–January 2003. These fatty acids showed a clear seasonal variation with winter/spring maxima and summer/autumn minima along with an even C-number predominance. This seasonal pattern clearly indicates their atmospheric transport from the continents during winter/spring and from the ocean in summer/autumn. Further, in winter/spring we found good correlations between hydroxy FAs and biomass burning tracers such as levoglucosan and nss-K as well as with nss-$SO_4$ ions. This suggests that hydroxy FAs are co-transported with dust and biomass burning plumes from the Asian continent to the remote marine island via westerlies during winter/spring. Moreover, cluster analysis showed that spring and winter seasons are characterized by the aeolian transport of hydroxy FAs from North China, Korea, Russia, and Mongolia. Their terrestrial sources include higher plant metabolites as well as soil- and air-borne microorganisms (bacteria, fungi, yeasts, etc.). In contrast, during summer/autumn 2001, we observed good correlations between ω-hydroxy FAs and Cl and Mg ions. Additionally, α- and β-hydroxy FAs in summer/autumn 2002 were well correlated with methylsulfonic acid (MSA) and ammonium ($NH_4$) ions. As wind pattern shifts during summer/autumn, hydroxy FAs are brought from the sea to the island and their sources include algae, cyanobacteria and other marine phytoplankton.

Overall, continental sources overwhelm hydroxy FAs in the atmospheric particles over Chichijima Island than marine sources. Our results indicated that hydroxy FAs (specific Gram- negative bacterial tracers) are adhered to soil particles and transported long distances over the western North Pacific and can be further carried to the central Pacific. These results have implications towards assessing the atmospheric transport of bacterial and plant lipids in the continental outflow over the open ocean.

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# Contribution of biogenic VOCs to secondary organic aerosols in the Alaskan atmosphere

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Organic constituents are recently highlighted because they account for a substantial portion of atmospheric particles up to 50% in mass and potentially influence the hygroscopic properties, affecting the earth climate, air quality and public health. Biogenic secondary organic aerosol (SOA) is a significant portion of atmospheric trace gases and aerosols. SOA is produced via the oxidation of biogenic volatile organic compounds (BVOCs) with $O_3$, OH and $NO_3$ radicals (Atkinson and Arey, 1998). Vegetation can release substantial amounts of BVOCs, including isoprene, monoterpenes, sesquiterpenes and oxygenated hydrocarbons.

Total of 32 total suspended particle (TSP) samples were collected in Fairbanks, Alaska from June 2008 to June 2009 using a low volume air sampler. Here, we report the molecular characterization of isoprene-, $\alpha$-/$\beta$-pinene- and $\beta$-caryophyllene-SOA tracers, which were measured using solvent extraction/TMS-derivatization technique followed by gas chromatography-mass spectrometry (GC-MS) determination. The concentration ranges of isoprene, $\alpha$-/$\beta$-pinene and $\beta$-caryophyllene oxidation products were 0.02-18.6 ng m$^{-3}$ (ave. 4.14 ng m$^{-3}$), 0.42-8.24 ng m$^{-3}$ (2.01 ng m$^{-3}$) and 0.10-9 ng m$^{-3}$ (1.53 ng m$^{-3}$), respectively. Isoprene-SOA tracers showed higher concentrations in summer (ave. 8.77 ng m$^{-3}$), whereas $\alpha$-/$\beta$-pinene- and $\beta$-caryophyllene-SOA tracers exhibited highest levels in spring (3.55 ng m$^{-3}$) and winter (4.04 ng m$^{-3}$), respectively. $\beta$-Caryophyllinic acid and levoglucosan showed a positive correlation, indicating that biomass burning may be a major source for $\beta$-caryophyllene. The mean contributions of SOA tracers to organic carbon (OC) and water-soluble organic carbon (WSOC) were found to be 0.92% and 1.9%, respectively during the sampling period. Using a tracer-based method, we estimated the concentrations of secondary organic carbon (SOC) produced from isoprene, $\alpha$-/$\beta$-pinene and $\beta$-caryophyllene as 159 ngC m$^{-3}$, 35 ngC m$^{-3}$ and 66.3 ngC m$^{-3}$, respectively. The contributions of isoprene, $\alpha$-/$\beta$-pinene and $\beta$-caryophyllene to SOC were estimated to be 14.4%.

# Turbulence structure measurement in atmospheric surface layers visualized by a PIV technique

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Particle Image Velocimetry (PIV) is a powerful tool to measure spatial structures of atmospheric turbulence since the method allows us to measure instantaneous velocity in two-dimensional vector field. However, PIV have been generally used in wind tunnel experiments and rarely adopted for the field observations. In this study, we developed a PIV observation system designed for field experiments aiming at acquiring velocity vectors in vertical or horizontal sections of up to 30m width.

The PIV system consists of portable equipments; laser, video camera and the tracer seeding devices, in order to arrange the observing scale to variable conditions of turbulence. Two-dimensional image is captured with market production models of digital video camera by AVCHD, MOV and MPEG formats. Spatial coverage and adequate density of tracer particles for the measurement are optimized using 6 sets of the specially designed seeding discharge ports. They output a tracer particles at similar temperature with environments and a uniform flowing velocity from an overall lateral width, 2.5m, of the port.

Field experiment of PIV was done over a flat homogeneous grass field. The measurement section was a vertical-streamwise cross-section; analysis range and a vector calculation points were 8.35m and 76 points in the horizontal direction and 4.0m and 36 points in the vertical direction, respectively. The measurement period was 10 minutes with the wind direction that was along the sheet of laser light. To examine the accuracy of the field PIV, instantaneous velocities and mean statistics obtained from PIV and a supersonic anemometer set in the measurement section were compared. The PIV's time series in both horizontal and vertical wind speed traced well the variation trend obtained by the sonic anemometer. Although a limitation due to the resolution of images was apparent in the variance of the vertical velocity, that of horizontal velocity was reasonably comparable.

During the analysis period, the characteristic structure that updrafts while convecting in the main flow direction was generated repeatedly in a short period of time. As a result of the traditional conditional sampling procedure (Adrian et al. 2000), the tip section swirling and the ejection motion following it were selectively observed. Thus, even on the ground surface, observed were structures similar to the hairpin vortex that was seen in the wind tunnel and numerical experiments. The structure may contribute significantly to the transport of momentum in the surface layer. Further analysis using the field PIV system may enhance our understanding of the surface layer turbulence structures.

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# Ice-ocean albedo feedback effect on recent drastic reduction in Arctic sea ice cover

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Associated with the recent global warming, sea ice conditions in the Arctic Ocean has drastically changed (e.g. reduction of summer ice extent, decrease of mean ice thickness, and decrease of multi-year ice fraction) particularly in the Pacific Arctic sector beginning in the 2000s. In seasonal ice zones such as the Antarctic Ocean and Sea of Okhotsk, a positive feedback caused by the albedo contrast between water and ice surfaces (~0.7 and ~0.07, respectively), termed as "ice-ocean albedo feedback", enhances ice melt and partly controls its interannual variability *(Nihashi and Cavalieri, 2006)*. Recently, this feedback has also received attention in the context of drastic decreases in summer Arctic ice extent. However, key questions, such as how much of the recent decline and interannual variation in sea ice extent are explained by the heat input through the open water fraction, or the specific physical processes at work in triggering and translating the feedback, remain unanswered. This study examines how the ice-ocean albedo feedback affects the Arctic sea ice retreat and recent drastic reduction of summer ice extent, based on analyses using sea ice data from satellite microwave radiometers (e.g. ice concentration and drift speed) and a simplified ice-ocean coupled model.

First, focusing on the Pacific Arctic sector, we calculated the daily net heat budget over the ice covered area (defined as ice concentration $\geq 30\%$) and the volume of ice melt and export. Results of heat budget analysis indicate that the necessary conditions for the ice-ocean albedo feedback are satisfied in the study area: (1) net heat budget at the water surface is much larger than at the ice surface even if the effect of melt ponds is included as their maximum impact, (2) ice retreat is mainly explained by ice melt, and (3) heat input through the open water fraction corresponds well with the ice melt volume for both seasonal and interannual variations. Then we compared the ice divergence with the ice melt volume, and found that the divergence on early melt season (from mid-May to early-June) has significant correlation with the 1-2 months lagged ice melt. This means that a small difference in ice concentration induced by the ice motion acts as the trigger of ice-ocean albedo feedback. Also it is remarkable that the heat input through the open water fraction, ice melt volume, and early summer divergence has a distinct increasing trend beginning in the 2000s, suggesting that recently this feedback has become sensitive and thus contributes to the drastic ice reduction in the study area (or the entire Arctic Ocean as well).

Finally seasonal sea ice retreat and its interannual variability in the Pacific Arctic are examined with a simplified ice-upper ocean coupled model in which the heat input through the open water fraction is the only heat source for ice melt *(Ohshima and Nihashi, 2005)*. The model explains that ice motion and distribution of multi-year ice as key factors of the seasonal/interannual variability of ice retreat through the ice-ocean albedo feedback.

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# Predictability of the Barents Sea ice in early winter: Remote effects of oceanic and atmospheric thermal conditions from the North Atlantic

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The sea ice variability of the Barents Sea in early winter (December) and its resultant dynamical atmospheric response is considered to be the triggers of a dynamic atmospheric response with severe consequences for weather conditions over the Eurasia continent including Japan [e.g., *Inoue et al*., 2012; *Mori et al*. 2014]. In this study, predictability of sea ice concentrations (SICs) in the Barents Sea in early winter (November−December) is studied using canonical correlation analysis with atmospheric and ocean anomalies from the NCEP Climate Forecast System Reanalysis (NCEP-CFSR) data [*Saha et al*. 2010]. We find that the highest prediction skill for a single-predictor model is obtained from the 13-month lead subsurface temperature at 200-m depth (T200) and the in-phase meridional surface wind ($V_{sfc}$). T200 skillfully predicts SIC variability in 35% of the Barents Sea, mainly in the eastern side. The T200 for negative sea-ice anomalies exhibits warm anomalies in the subsurface ocean temperature downstream of the Norwegian Atlantic Slope Current (NwASC) on a decadal timescale. The diagnostic analysis of NCEP-CFSR data suggests that the subsurface temperature anomaly stored below the thermocline during summer re-emerges in late autumn by atmospheric cooling and affects the sea-ice. The subsurface temperature anomaly of the NwASC is advected from the North Atlantic subpolar gyre over ~3 years. $V_{sfc}$ skillfully predicts SIC variability in 32% of the Barents Sea, mainly in the western side. The $V_{sfc}$ for the negative sea-ice anomalies exhibits southerly wind anomalies. $V_{sfc}$ is related to the large-scale atmospheric circulation patterns from the subtropical North Atlantic to the Eurasian continent, which is similar to the atmospheric response of the upper troposphere in the linear baroclinic model driven by the wintertime diabatic heating in the Gulf Stream [*Sato et al*. 2014]. Our study suggests that both atmospheric and oceanic remote effects have a potential impact on the forecasting accuracy of SIC. These results were published by Journal of Climate [*Nakanowatari et al*. 2014].

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# Investigation of ice-ocean interaction on Lutzow-Holm Bay, East Antarctica, from geographic, ocean data analysis and modeling

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Observations suggest that the Southern Ocean is changing. Warming in this region and the West Antarctic Ice Sheet melt changes its thermal conditions. In the East Antarctica, land fast ice and sea-ice area is also increasing (Massom et al., 2013). Ice-ocean interaction studies are important to reveal these changes in each region of the Southern Ocean. Here we would like to present an investigation of ice-ocean interaction on Lutzow-Holm Bay, East Antarctica, from geographic, ocean data analysis and numerical modeling. This study focuses on this interactions on ice shelves along the Riiser-Larsen Peninsula and land fast sea-ice region around the bay. In this region, morphology was not well assembled. First we investigated the topography, the grounding line and the calving front of ice shelves using observational and satellite based data.

There is a trough which connects abyssal ocean to ice shelf cavities in Riiser-Larsen Peninsula and Soya coast. The observation based topography is not clear in the west part of this trough due to coarse observations and ice shelves along the Riiser-Larsen Peninsula. Some of these ice shelf cavity topographies are estimated using Bedmap2 dataset (Fretwell et al., 2013). Since topography dataset under these ice shelves is limited, it is preferable to perform observations in this area. Landfast sea-ice area in this region was detected by MODIS images (Fraser et al., 2012). Although this area changes seasonally (Ohshima et al., 2000; Fraser et al., 2012), it is nearly constant except for several months in summer and autumn.

The grounding line and islands are detected using the combination of observational data, Bedmap2 and a digital elevation map based on ERS1 and Icesat satellite. Ice shelf drafts are also estimated from these surface elevation map. Ice shelf drafts are about 600 m at the grounding area. Since these ice shelf drafts are not so deep, sub-ice-shelf melting would depends on water and heat transport though the trough and fast ice. When sub-ice-shelf melting is limited, calving, which would have relationship between fast ice evolution, would be the main ablation mechanism of ice shelves in this region.

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# Antarctic ice shelves' basal melting in glacial and warm climates

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Basal melting of the Antarctic ice shelves is an important factor in the retreat of marine Antarctic ice sheet in the past or future, but little consensus exists on how the rate of basal melting changes against climatic forcing. Antarctic ocean and basal melting of Antarctic ice shelves under the Last Glacial Maximum (LGM) and equilibrium CO2 doubling climate are investigated using a circumpolar ocean model with ice shelf cavity component forced by outputs of a climate model. To focus on the role of climatic forcings, identical present-day topography is used in these experiments.

The rate of basal melting increases as the climate is warmed, but change in basal melting in the CO2 doubling climate is much larger than that in the LGM in spite of close magnitude of global radiative forcing. The model show that difference in basal melting is a result of difference in water mass formation of cold water in the shelf seas, and water mass formation in the Antarctic Coast influences on the intrusion of warm subsurface water from the Southern Ocean. Active sea ice production in the Antarctic Coast forms saline and cold shelf water, which keeps basal melting to be inactive under cold climate and present-day. In contrast, under a warmer climate, basal melting increases by increased ocean temperature outside the continental shelf break and active intrusion of warm subsurface water to approach ice shelves.

A parameterization of basal melting for ice sheet model is formulated using observed and modelled ocean temperature outside the shelf break and the thickness of the ice shelf. The impact of basal melting on the retreat of West and East Antarctic Ice Sheet will be investigated using a 2-d ice sheet model.

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# A simple parameterisation of ice-shelf basal melting for long-term, large-scale simulations of the Antarctic ice sheet

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Ice-shelf basal melting is the largest ablation process of the recent Antarctic ice sheet, and it is very unevenly distributed (half of the meltwater originates from ten small, warm-cavity Southeast Pacific ice shelves; Rignot et al., 2013). Therefore, ice-shelf basal melting, and its change with time, plays a crucial role for the past and future evolution of the Antarctic ice sheet and its contribution to global sea level (Bindschadler et al., 2013). Since integrating coupled ocean and ice sheet models for long time periods is hard to achieve within a reasonable amount of time using present-day computers, long-term simulations of the Antarctic ice sheet require that ice-shelf basal melting is parameterised.

Here we describe a simple, physically-based parameterisation that calculates the basal melting of ice shelves as a function of both the ice-shelf draft (depth of the ice base below mean sea level) and the thermal forcing. The latter is taken as the difference between the ocean temperature at 500 m depth just outside the ice-shelf calving front (World Ocean Atlas 2009; Locarnini et al., 2010) and the freezing temperature of sea water at the ice-shelf base. The parameterisation is tuned differently for eight Antarctic sectors [(1) Western East Antarctica, (2) Amery/Prydz Bay, (3) Sabrina Coast/Aurora subglacial basin, (4) George V Coast/Wilkes subglacial basin, (5) Ross Sea, (6) Amundsen Sea, (7) Bellingshausen Sea, and (8) Weddell Sea] in order to achieve reasonable agreement with the modern spatial distribution of ice-shelf basal melting. For each sector, this yields a dimensionless sensitivity parameter $\Omega$ and an exponent $\alpha$ that describes the nonlinearity of the explicit dependence on the ice-shelf draft. In addition, we consider an optional dependence on water column thickness in order to reduce melting to zero very close to the grounding line.

By construction, the parameterisation reproduces total and sectorial melting rates, as well as large melting rates under deep and small melting rates under shallower parts of the ice shelves, very well. However, due to different physics, neither locally enhanced melting near calving fronts nor accretion of frazil ice (that can lead to net basal freezing instead of melting) are described. The parameterisation is implemented in the Antarctica module of the dynamic/thermodynamic, large-scale ice sheet model SICOPOLIS (www.sicopolis.net), and we discuss several future climate runs over the next centuries in order to explore the sensitivity to various forcings.

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# Towards a GPU-accelerated ice sheet model: design philosophy and implementation

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Recently, numerous models capable of modeling the thermo-dynamics of ice sheets have been developed within the ice sheet modeling community. Their capabilities have been characterized by a wide range of features with different numerical methods (finite difference or finite element), different implementations of the ice flow mechanics (shallow-ice, higher-order, full Stokes) and different treatments for the basal and coastal areas (basal hydrology, basal sliding, ice shelves). Shallow-ice models (SICOPOLIS, IcIES, PISM, etc) have been widely used for modeling whole ice sheets (Greenland and Antarctica) due to the relatively low computational cost of the shallow-ice approximation but higher order (ISSM, AIF) and full Stokes (Elmer/Ice) models have been recently used to model the Greenland ice sheet.

The advance in processor speed and the decrease in cost for accessing large amount of memory and storage have undoubtedly been the driving force in the commoditization of models with higher capabilities, and the popularity of Elmer/Ice (http://elmerice.elmerfem.com) with an active user base is a notable representation of this trend. Elmer/Ice is a full Stokes model built on top of the multi physics package Elmer (http://www.csc.fi/english/pages/elmer) which provides the full implementation of the complex finite element procedure and is fully parallel (mesh partitioning with OpenMPI communications). Elmer is mainly written in Fortran 90 and targets essentially traditional processors as the code base was not initially written to run on modern coprocessors (yet adding support for the recently introduced Xeon Phi, x86-based coprocessors is an ongoing work within the Elmer developers). Furthermore, a truly modular and object-oriented implementation is required for quick adaptation to fast evolving capabilities in hardware (Fortran 2003 provides an object-oriented programming model while not being clean and requiring a tricky refactoring of Elmer code).

In this work, the object-oriented, coprocessor-accelerated finite element code Sainou is introduced. Sainou is an Elmer fork which is reimplemented in Objective-C and used for experimenting with ice sheet models running on coprocessors, essentially GPU devices. GPUs are highly parallel processors that provide opportunities for fine-grained parallelization of the full Stokes problem using the standard OpenCL language (http://www.khronos.org/opencl/) to access the device. Sainou is built upon a collection of Objective-C classes that service a modular core class which provides the methods to solve the finite element problem. Those classes and their implementation form an API (Application Programming Interface) and are compiled into a Framework, a single package that encapsulates header files, dynamic shared libraries, shared resources and reference documentation.

The capabilities of this framework will be presented and the possibility to build a simple finite element application using the framework will be demonstrated. The strategy for parallelizing the finite element global matrix assembly will also be presented. Sainou uses a greedy coloring algorithm (Dimitri et al., 2010) to partition the finite element mesh so that elements with the same color but with distinct nodes are assembled in parallel on the GPU. This algorithm allows for memory access correctness without the need of expensive atomic or synchronization primitives, but with the added computational cost that the mesh has to be colored only once. The preliminary GPU implementation is then tested with simple applications.

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# Shallow ice core project on south-east dome in Greenland
## – Drilling report and science trench of the ice core –

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We conducted ice core drilling on the southeastern Greenland Ice Sheet on May 2015 to reconstruct concentrations and compositions of anthropogenic substances after the industrial revolution, and to understand physical properties of snow and ice and densification processes at the high accumulation site of an ice dome. We obtained a 90 m long ice core with an electrical mechanical drill developed by the Institute of Low Temperature Science (ILTS), Hokkaido University. The ice cores were packed in plastic bags and stored in insulation boxes, and transported at frozen condition to Japan.

The core has unique characteristics as below;
– The drilling position is N67°11', W36°22', and 3170 m asl.
– One of the domes on Greenlandic ice sheet.
– Very high accumulation region (0.9 m/y in w.e.; 5 times than NEEM; 30 times than DC, DF).
– The depth at 90 m is corresponding to about AD 1950.
– We can chase seasonal variation; in spite of a Greenlandic dome more than 3000 m asl.
– Close-off depth is about 86 m, which is so deeper than the other domes in the ice sheet.
– Less and thin melted layers (–21°C at 20 m in depth).
– Weather is controlled by Icelandic Low, with high winter accumulation.
– Southeast Greenland is highly affected by NAO. It may be detectable decadal scale of climate fluctuation.
– Southeast Greenland is highly preserved anthropogenic materials from Europe.
– It is seldom papers around the region. There is only papers from DAS2 core.

We have started the science trench in cold rooms for preliminary analyses and ice core cutting. The preliminary analyses are layer stratigraphy, density of bulk and x-ray methods, photographic interpretation of visible and near-infrared wavelengths, and dielectric profiling. Also, we cut the ice sections for chemical analyses. We will present the latest results of these analyses at the meeting.

# Tide-modulated seismicity in the Bowdoin Glacier calving front, northwestern Greenland

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A seismic array consisting of four on-ice stations was installed in July 2015 at the central part of the Bowdoin Glacier calving front, northwestern Greenland, as part of a larger network established for near-source monitoring of frontal dynamics. Lennartz LE-3D short- and long-period seismometers, powered by solar panels, were arranged in a triangle-shaped array (with a distance between stations of ~150 m), located ~200 m from the marginal ice cliff, where icebergs are discharged into the fjord.

Using the classic seismological approach ("Short Term Averaging / Long Term Averaging" trigger algorithm) we analyzed the temporal variability of microseismic events, which were continuously recorded over a period of two-weeks. The results show a double-peak diurnal oscillation in a number of events per hour. A comparison with time-series of tide height data shows that the maximum seismic activity occurred during falling tides.

The present and previous field work at Bowdoin Glacier (*Sugiyama et al.*, 2015) reveal that ice flow velocity is also tide-modulated and that the glacier accelerates during falling tides due to reduced back-pressure. However, this diurnal modulation can be obscured by other factors that affect the rate of glacier movement, such as high air temperature or rain. The distinct and stable double-peak microseismic pattern seems to originate directly from local elastic vertical displacements induced by tides. Presumably, the mechanical cause of such behavior stems from a high-strain-rate extensional stretching of the glacier surface, which favors the opening of tensional crevasses.

The *in situ* observations of the present study shed light onto the seemingly chaotic fracture mechanics of difficult-to-access processes operating at the calving front of the glacier. At this stage of analysis, we already found major differences between the present data and previously reported tide-modulated ice-quakes in the Mertz Glacier, east Antarctica (*Barroul et al.*, 2013). For example, the great sensitivity of the present instruments to high frequencies and their unique near-source location means that we were able to observe that seismic activity did not cease at low tidal velocities, contrary to the results reported for the Mertz Glacier; instead, hundreds of events were recorded per hour during such periods. Further analyses of microseismic data and the integration of other instruments (e.g., infrasound array), would provide greater insights into calving front dynamics.

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# Seasonal variations in the dynamics of Bowdoin Glacier, northwest Greenland

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Submarine melting and ice-mélange weakening are suspected as triggering mechanisms of rapid retreat of tidewater glaciers in the Greenland Ice Sheet (e.g. Straneo et al., 2013). To better understand these key processes at the ice-ocean interface, we measured ice-front position and glacier/ice-mélange movement by processing daily photographs taken by a time-lapse camera operated near the ice-front of Bowdoin Glacier in the northwest Greenland over two years since 2013. The results showed clear seasonal variations in the ice-front position with an amplitude of ~600 m, as well as in ice speed at the centerline of the glacier (Fig 1). During summer, the ice-front position was relatively stable, but retreated occasionally by large calving events (Fig 1a Period 1). Most of the calving events occurred near buoyant plume caused by upwelling of subglacial discharge where a large submarine melt rate is expected. The glacier began to advance in September approximately when air temperature dropped below 0 °C (Fig. 1a Period 2). The glacier advanced the most in winter when the fjord was jammed by ice-mélange (Fig 1a Period 3). After winter, extended portion of the glacier rapidly disintegrated by a few calving events (Fig 1a Period 4). Such event coincided with initiation of fast ice-mélange movement in front of the glacier (Fig 1b) and temperature increase above 0 °C (Fig 1c). These results indicate both ice-mélange and submarine melting play roles in seasonal advance and retreat of Bowdoin Glacier. Moreover, the onset of glacier advance (retreat) was coincided with seasonal air temperature change from positive to negative (negative to positive), implying glacier surface melt water is a controlling process of ice-front position.

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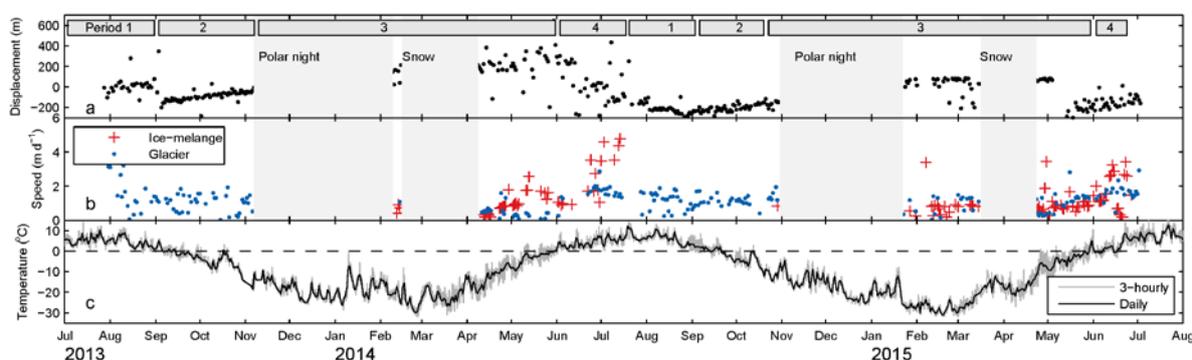
Figure 1. Seasonal variations in the ice-front position (a), glacier/ice-mélange speed (b) and air temperature at Qaanaaq airport.

# Seasonal changes in ice front position and flow speed of marine terminating outlet glaciers in northwestern Greenland

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Mass loss from the Greenland ice sheet has been increasing, resulting in an enhanced contribution to sea level rise (e.g. Rignot et al., 2011). The mass loss is driven by two processes: increases in surface melting and ice discharge from marine-terminating outlet glaciers (e.g. Enderlin et al., 2014). Therefore, it is important to include evolution of the outlet glaciers in future projection of the sea level rise. To achieve this, influences of atmosphere and the ocean on the glacier dynamics should be better understood. Thus, it is important to study variations of the outlet glaciers in connection with atmospheric and the ocean conditions. We analyzed satellite images to measure frontal positions, ice speeds, and conditions of sea ice / ice mélange in front of the termini of 19 marine terminating outlet glaciers in northwestern Greenland over the period from 2013 to 2015. The results were utilized to investigate the processes controlling seasonal changes in the frontal positions and ice speeds in comparison with the atmosphere and the ocean conditions.

Most of studied glaciers showed seasonal changes in ice fronts and ice speeds. Bowdoin, Verhoeff, Morris Jesup, and Diebitsch Glaciers advanced from spring to early summer and retreated in mid-summer. The retreated position continued through the fall. Magnitude of seasonal variations of these glaciers ranged between 100 and 150 m. Heilprin, Tracy, Farquhar, Melville and Sharp Glaciers often rapidly retreated following gradual advance. Difference between maximum and minimum terminus positions of these glaciers is a range from 150 to 400 m. Frontal variations of these glaciers are likely controlled by formation and breakup of the floating tongue. Frontal retreat of the studied glaciers often began when sea ice / ice mélange in front of the glacier terminus disappeared. These results suggest that sea ice / ice mélange in front of terminus suppress the glacier retreat. In general, ice speeds of studied glaciers increased from spring to mid-summer and then decreased from the mid-summer to the fall. Difference between minimum and maximum speed of the glaciers is a range between 100 and 500 m a$^{-1}$. Because changes in the ice speeds well agreed with change in air temperature, it is suggests that the speedups of the studied glaciers mainly result from enhanced basal sliding driven by meltwater input to the bed.

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# Field observations of surface mass balance, ice velocity and ice temperature on Qaanaaq ice cap, northwestern Greenland

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Glaciers and ice caps (GICs) physically separated from the Greenland ice sheet are losing significant amount of ice mass, and this mass loss plays important contribution to sea level rise. Because the GICs are located at relatively lower elevations, they are susceptible to recent warming trend in Greenland. Despite the large mass loss of the GICs revealed by recent satellite data analysis, only a few field observations have been reported in this region. To investigate recent change of Greenland's GICs by in-situ data, we measured surface mass balance, ice velocity and ice temperature on Qaanaaq Ice Cap (QIC) in northwestern Greenland in the summer 2012–2015. QIC (77°28´N, 69°13´W) is covering an area of 288 km$^2$. We carried out field campaign on Qaanaaq Glacier, an outlet glacier in the southern part of the QIC. We installed 7 poles along the survey route spanning the glacier terminus to the ice cap summit in order to measure surface mass balance and ice velocity. We installed 15 m-long cables equipped with three thermistor censers at three survey points in different elevations (243, 739 and 944 m a.s.l.) on August 4, 2013 to measure ice temperature at the depth of 3, 8 and 13 m from ice surface.

Surface mass balance near the terminus in 2012–13, 2013–14 and 2014–15 was −1.2, −1.6 and −2.1 m w.e. a$^{-1}$, respectively. Mass balance at 968 m a.s.l. was 0.56 m w.e. a$^{-1}$ in 2012–13, 0.30 m w.e. a$^{-1}$ in 2013–14 and −0.16 m w.e. a$^{-1}$ in 2014–15. Because mass balance has large variability from year to year during the study period, equilibrium line altitude ranged from 900 to 980 m a.s.l. Ice flows faster in the middle part of the survey route, and the greatest horizontal velocity was observed at 584 m a.s.l.. Ice temperature at the depth of 13 m was −10.7°C near the terminus, while it was −8.0°C at the upper most site. In summer 2014, we observed about 40 cm thickness of refrozen ice on the ice surface in summer 2012 at the upper most site, while no refreezing occurred near the terminus. This result suggests that ice temperature in the upper reaches was influenced by latent heat from refreezing.

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# Elevation change of calving glaciers in northwestern Greenland analyzed by satellite data

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A large number of calving glaciers is distributed along the Greenland coast. After 2005, ice mass loss has increased in northwestern Greenland, according to Gravity Recovery and Climate Experiment (GRACE). In this region, ice thinning, retreat and ice speed accelerated (e. g. Khan and others, 2010). These factors are important for ice mass loss, but few data are available for the rate of ice thinning.

We analyzed surface elevation change of the seven calving glaciers near Inglefield Bredning in northwestern Greenland, using ALOS PRISM data. We processed stereo pair satellite images with a digital map plotting instrument (ERDAS Inc., LPS:Leica Photogrammetry Suite; Planar Systems Inc., SD2020) to generate Digital Elevation Models (DEMs). Generated DEMs were compared to measure ice surface elevation changes during periods of 2007–2010.

The surface elevation of all glaciers decreased and the rate of the elevation change increases downglacier. Tracy Glacier thinned at the greatest rate of 5–7 $\pm$1.7 m $a^{-1}$ near the terminus. Surface lowering were also observed in other glaciers; Farquhar Glacier (3–4 $\pm$1.1 $ma^{-1}$), Melville glacier (2–4 $\pm$ 1.1 m $a^{-1}$), Heilprin glacier (2$\pm$1.7 m $a^{-1}$), Sharp glacier (2$\pm$1.0 m $a^{-1}$), Hart glacier (0–2$\pm$1.0 m $a^{-1}$) and Hubbard glacier (0–2$\pm$0.9 m $a^{-1}$).

According to previous study, glaciers in the Melville Bay region in northwestern Greenland thinned at rates of 2–10 m $a^{-1}$ over the period 2005–2010 (e. g. Kjær and others, 2012). These rates are comparable to those observed in this study.

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# Surface elevation change on Trambau Glacier, Nepal Himalaya, based on remote sensing techniques

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Himalayan glaciers have been retreating and losing mass since the end of the Little Ice Age (Bolch et al., 2012). The glacier retreat results in formation of glacial lakes and poses potential hazard due to glacial lake outburst flood (GLOF). Tsho Rolpa is one of the largest glacial lakes in the Himalaya formed at the terminus of the Trambau Glacier. Studying changes in Trambau Glacier is important to assess the potential of the GLOF as well as to project water supply to the region. In this study, we analyze the surface elevation change on Trambau Glacier from 2000 to 2010 by differencing digital elevation models (DEMs) generated by remote sensing techniques.

The Trambau Glacier is located in the east Nepal Himalaya (27.9 ° N, 86.5 ° E). It covers an area of 76.5 $km^2$ and elevation range of 4500–6850 m a.s.l. The glacier is characterized by a thick debris cover (~0.3 to 0.5 m) and a 400 m high icefall at the middle part of the glacier. In our analysis, surface elevation change was obtained by differencing two DEMs, one from the Panchromatic Remote-Sensing Instrument for Stereo Mapping (PRISM) images taken by the Advanced Land Observing Satellite (~2.5 m resolution) on December 15 2010 (ALOS DEM), and another one from Shuttle Radar Topography Mission in 2000 (SRTM DEM) (~90 m resolution). The ALOS DEM was generated by analyzing a stereo pair image with a digital workstation equipped with a stereo monitor (SD2020; Planar System, Inc.) and digital photogrammetry software (ERDAS IMAGINE Photogrammetry; ERDAS Inc.). Surface elevation changes were measured in four separated areas; debris-covered ablation area, debris-free ablation area, equilibrium line altitude (ELA) area, and accumulation area.

The mean elevation change in debris-covered ablation area was $-2.6 \pm 1.0$ m $a^{-1}$, which was approximately three times greater than that in debris-free ablation area ($-0.97 \pm 0.8$ m $a^{-1}$). This result indicates the importance of a process, which more effectively controls the surface elevation change than the heat insulation by the debris cover. At ELA and accumulation areas, the elevation change rates were $-0.55 \pm 1.4$ m $a^{-1}$ and $1.1 \pm 3.3$ m $a^{-1}$, respectively.

As compared with other debris-covered Himalayan glaciers, the surface elevation change in the ablation area was more negative in the Trambau Glacier. A previous study showed that a glacier with a large proglacial lake loses more ice than other glaciers because of calving caused by wind-driven water currents (Sakai et al., 2009). Such ice loss in the proglacial lake is a possible driver of the enhanced thinning on the debris-covered ablation area. We are currently working on accuracy evaluation of the ALOS DEM with field data, as well as generation of additional DEMs from KH-9 Hexagon images. Results of these analysis will be presented in the symposium.

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# Wetting of quasi-liquid layers on ice surfaces: Statics and dynamics

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Studies of surface melting (or premelting) have a long history going back to the pioneering prediction by Michael Faraday. In 1842, he first hypothesized that thin water layers, now called quasi-liquid layers (QLLs), cover ice crystal surfaces even at a temperature below the melting point. This intriguing phenomenon has attracted considerable attention due to a link to various natural phenomena in our daily life: lubrication on ice surfaces, frost heave by ice columns, morphological change of snow crystals and electrification of thunderclouds [1]. At present, surface melting is known to be not limited only to ice but is common in a wide range of crystalline solids, such as metals, semiconductors, rare gases, and various inorganic, organic and colloidal systems. The significance of surface melting and the resulting quasi-liquid layer in condensed matter is therefore hard to overestimate.

Here we propose a simple model for surface melting on ice crystals with the aid of the wetting theory. We show that QLLs, resulting from surface melting, exhibit complex wetting behavior: partial, pseudo partial, complete wetting and their coexistence, relying on the relationship between the spreading coefficient of QLLs and van der Waals potentials between ice, water and vapor. We demonstrated the thermodynamic criterion for three types of wetting from the force balance of interfacial tensions and the tangent construction of the interfacial potential. This criterion indicates that the spreading coefficient is of negative sign near the solid-vapor equilibrium, meaning that QLLs are fundamentally the transient (metastable) state formed as a result of Ostwald's step rule, and thus exists only in the non-equilibrium process from ice to vapor or vice versa. Our model casts a serious doubt on the conventional theory presupposing the coexistence of QLLs with vapor and ice in equilibrium.

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# Liquid layers on ice surfaces induced by hydrochloric gas

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## Introduction

It is important for the atmospheric environment to understand the interaction between ice crystals in clouds and ambient gases [1]. We directly observed ice crystal surface in the presence of hydrogen chloride gas by laser confocal microscopy combined with differential interference contrast microscopy (LCM-DIM) [2-4].

## Experimental

Details of the LCM-DIM and the growth chamber are shown in Sazaki (2010) [2]. Samples of ice single crystals were grown in the chamber on AgI single crystals. The ambient gas was $N_2$ (<95%), HCl (<5%), and $H_2O$ (0.1~1%) at 1 atm. The sample temperature and ambient water vapor pressure were independently controlled by using Peltier elements for sample ice and for evaporation source ice, respectively.

## Results

The presence of hydrogen chloride gas induced liquid droplets on the ice surface. The liquid droplets were estimated to be hydrochloric acid by dissolution of hydrogen chloride gas in water. Because the melting point of hydrochloric acid is lower than 0°C, the droplets did not exist as quasi-liquid layer and could stably exist as the solution. Under the condition of evaporation, the concentration of the droplets gradually increased. Therefore, the ice crystal continued to dissolve in the droplets of hydrochloric acid until the melting point of droplets reached the ambient temperature by the decrease of the concentration (fig.1). If ice crystals in clouds also have the hydrochloric acid droplets, there is a possibility to cause various chemical reactions as difficult gas-gas reactions.



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Figure 1. LCM-DIM images of liquid layers on an ice basal face at –0.5°C. The liquid droplets intensely moved around on the ice surface and the droplets sometimes coalesced each other. Although the height of the droplets were emphasized by LCM-DIM, the actual heights were smaller than 500 nm, which was calculated by the contact angle (a few degree).
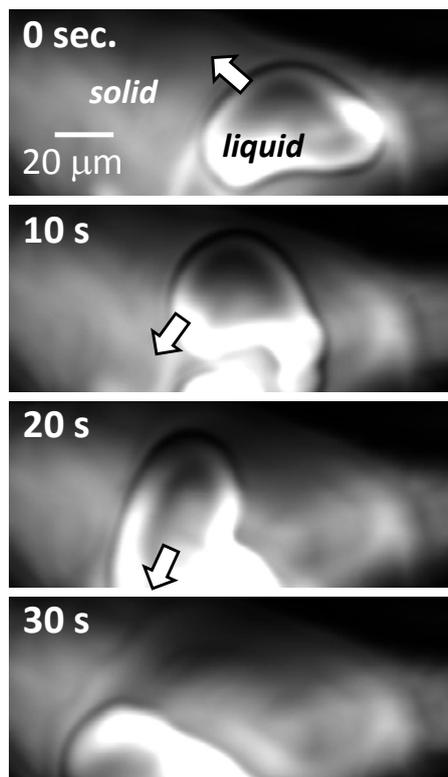
# Evolution of photosystems in green algae through ice ages

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Photosynthetic organisms have various chlorophyll and carotenoid pigments to form their own photosystems, which help them adapt to various environments. Chlorophyll $b$ is used primarily in green plants, while chlorophyll $a$ is used in all the oxygenic photosynthetic organisms. The absorption spectrum of chlorophyll $b$ is slightly different from chlorophyll $a$, suggesting that chlorophyll $b$ in green plants enables them to absorb broader spectrum of solar energy efficiently. In addition, chlorophyll $b$ is expected to be more suitable to absorb available light spectrum in clear sea water than that of chlorophyll $a$. However, the evolutionary importance of chlorophyll $b$ acquisition has not been fully understood.

Green plants are divided into two groups; chlorophytes and streptophytes. Chlorophytes includes prasinophytes and core chlorophytes. Prasinophytes are mainly lived in marine environments, whereas core chlorophytes are lived in freshwater/marine environments. Core chlorophytes are believed to be evolved from prasinophytes. Stroptophytes including some freshwater green algae and land plants and members of streptophytes had evolved to land plants. Common ancestors of chlorophytes and streptophytes have not been found. However, streptophytes was thought to be evolved in freshwater environments, while chlorophytes was thought to be evolved in marine environments. It should be noted that both groups of green algae have survived through ice ages, especially through the Sturtian and Marinoan glaciations. Earth in these periods are thought to be completely covered with ice, which referred to as "Snowball Earth". How the eukaryotic algae including green algae have survived through these periods have been under debate.

Here, we cultured and collected various green algae and compared their photosystems. Chlorophyll $b$ was highly accumulated in the photosystems of prasinophyte algae as reported previously. Given the marine habitats of prasinophytes, this is consistent with the fact that chlorophyll $b$ is more suitable for light harvesting in clear seawater than chlorophyll $a$. Light-harvesting systems in green algae was classified into two systems; core antenna and peripheral LHC (light-harvesting complex) antenna. The core antennae of photosystems were thought to be highly conserved among green plants and consisted of chlorophyll $a$, while LHC antennae were quite divergent and consisted of both chlorophyll $a$ and chlorophyll $b$. Then, we separated core antennae and LHC antennae and analyzed their pigment contents.

Surprisingly, prasinophytes accumulate much chlorophyll $b$ in both core antennae and LHC antennae, although streptophytes and freshwater chlorophytes accumulate chlorophyll $b$ only in LHC antennae. These data demonstrated that prasinophytes have developed their unique photosystems to adapt marine habitats, where light intensity is very low and available light spectrum is quite limited. On the other hand, streptophytes have developed their photosystems to adapt to freshwater environments, where light irradiance is strong and fluctuating. The characteristics of the streptophyte photosystems should have a great advantage in colonization of terrestrial habitats. Based on the data, we hypothesized that the photosystems of prasinophytes have an advantage in surviving under thick covering of ices, where the available light intensity was quite limited. In contrast, the photosystems of streptophytes have an advantageous in surviving on ice, where the tolerance for strong and fluctuating light illumination is required.

# Intracellular "energy bento-box": Flow cytometry as a method to sort microalgae and bacteria based on cell energy reserves

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Many microorganisms accumulate high-energy compounds such as triacylglycerols (TAG) and polyphosphate (polyP) in intracellular granules. These compounds provide energy reserves for the cell to survive suboptimal conditions. Additionally, recent findings have suggested that these high-energy granules are not simply for energy storage, but have important cellular roles involved in protein folding, gene expression and signaling, among others (Gao 2015, Gray 2015). In addition to understanding the functional significance of these energy reserves, identifying mutants or strains with increased accumulation of TAG or polyP is of biotechnological interest due to our current dependence on non-renewable energy and phosphate sources (i.e. fossil fuel and phosphate mining).

Here, I will present the use of flow cytometry as a high-throughput screen to detect and enrich for cells hyper-accumulating TAG or polyP by using fluorescence dyes that have a specific emission profile for TAG or polyP. Both methods employ sorting of living cells, which allow for the recovery of cells after the screen. I will first talk about the method we have developed for isolating mutants with increased lipid accumulation in model alga *Chlamydomonas reinhardtii* (Terashima 2015). The method was optimized using a mutant strain of *C. reinhardtii* known to accumulate high levels of TAG. This was followed by screening a pool of ~ 60,000 mutants and enriching for cells with increased lipid fluorescence. Follow-up analysis of 24 isolated mutants revealed that 50 % of the mutants have a reproducible high lipid phenotype.

Secondly, I will present ongoing work on wastewater bacterial community screening for polyP hyper-accumulating strains. Wastewater contains a diversity of microbial organisms, but the growth conditions stimulate different bacteria to dominate a given community. We tested growing the community by varying carbon sources and time periods and found that dominant polyP accumulating species varied among the growth conditions. Initial findings suggest that bacterial species stemming from the phylum Firmicutes and alphaproteobacteria were among the polyP hyper-accumulators and may have a larger role in phosphate removal from wastewater than previously expected.

In the final section, I will discuss applying this method to analyze microalgae and bacteria found on alpine snowfields. Such psychrophilic organisms face extreme changes in temperature, light, water and nutrient availabilities and have developed mechanisms for long-term survival. These coping strategies include accumulating protective pigments such as astaxanthin and intracellular high-energy granules, which are parameters that can easily and rapidly be monitored using methods established in these studies.

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# Characterization of a novel sulfate-reducing bacterium possessing desulfoviridin and vibroid morphology

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**Background**: The order *Desulfovibrionales* is organized in four families; *Desulfovibrionaceae*, *Desulfonatronumaceae*, *Desulfohalobiaceae* and *Desulfomicrobiaceae*. The genus *Desulfomicrobium* is a sole member of family *Desulfomicrobiaceae* at the time of writing. The genus have been characterized as rod- or ellipsoidal-shaped morphology and absence of desulfoviridin. In this study, a novel strain Pf12B[T] related to *Desulfomicrobium* species was isolated in pure culture.

**Objective**: The aim of our study is characterization of the strain Pf12B[T].

**Methods:** Strain Pf12B[T] was obtained from an enrichment culture established under sulfate-reducing conditions at 45°C with an inoculum of sediment from a brackish meromictic lake. Isolation of the strain was carried out by repeated agar shake dilution method.

**Results**: Cells were vibroid, and motile. The closest relative of the strain was *Desulfomicrobium baculatum* with 16S rRNA gene sequence similarity of 91%. Phylogenetic analysis based on the 16S rRNA gene sequence revealed that the strain Pf12B[T] belonged to the family *Desulfomicrobiaceae*, in the order *Desulfovibrionales, Deltaproteobacteria*. This result was also supported by the phylogenetic analysis based on DsrA amino acid sequence. Sulfate, sulfite, thiosulfate were used for electron acceptors. Formate and fumarate were used for substrate in the presence of sulfate. Yeast extract enhanced growth of the strain. The isolate grew at temperatures between 13-50°C with an optimum temperature range of 42-45°C. The strain was desulfoviridin positive. Major cellular fatty acids of the isolate were $C_{16:0}$ and $C_{18:0}$.

**Conclusion**: It was suggested that the strain Pf12B[T] is a representative of novel species of novel genus within the family *Desulfomicrobiaceae*.

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# Diversity of sulfate-reducing and sulfur-oxidizing organisms in sediments of Antarctic lakes

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Sulfur is essential for all organisms as major components of cell materials. There are also a variety of abundant inorganic sulfur compounds in the biosphere, and prokaryotic respiratory processes depending on these chemical species are major driving force of sulfur cycle in ecosystems. In the sulfur cycle, reductive processes are mainly mediated by sulfate-reducing prokaryotes (SRP). SRP are capable of dissimilatory sulfate reduction coupled with oxidation of organic matter, and this reaction is thought to contribute largely to anaerobic mineralization in aquatic sediments. Activity of SRP results in generation of sulfide, which supports growth of sulfur-oxidizing prokaryotes (SOP). Both SRP and SOP are polyphyletic, and their diversities in natural environments are often investigated with analyses of functional genes that encode key enzymes for dissimilatory sulfate reduction or sulfur oxidation. One of such genes, *aprA* encoding adenosine phosphosulfate reductase is involved in both sulfate reduction and sulfur oxidation. In the present study, diversity of microorganisms involved in sulfur cycle in sediments of Antarctic lakes was investigated by analyzing *aprA* genes. Sediment samples were obtained from lakes located in coastal area around Lutzow-Holm Bay. From the genomic DNA directly extracted from the samples, fragments of aprA genes were amplified using a primer pair designed for concomitant detection of SRP and SOP. From the resulting PCR products, clone libraries were constructed for sequencing and phylogenetic analysis. Both SRP and SOP were detected, and their community structures differed among the lakes. Some of them were closely related to known SRP or SOP, but others had no cultivated close relatives. Despite diversity of detected organisms, lineage specific for Antarctic lakes was not found. A lineage predominant in one of the lakes was also dominant in a temperate mesotrophic lake, but its physiological characteristics could not be inferred since it only distantly related to known organisms.

# Okhotsk study and connection to the Arctic
# – Sea ice, environment and life –

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Sea ice and environmental researches have been implemented in the long time. The understanding of sea ice in the climate, environment, industries and societies have been improved by the long-term effort of many researchers in the last many decades.

The Arctic summer sea ice coverage has been declining significantly. The winter sea ice coverage in the Northern Hemisphere varies due to decrease of sea ice area in the sub-Arctic seas. Sea of Okhotsk, Barents Sea, Greenland Sea and Baffin Bay are driving the winter sea ice variabilities in the Northern Hemisphere.

In the case of sea ice variation in the Sea of Okhotsk, long-term decreasing trend is recorded, and there are also decadal fluctuations. In the variation of ice-covered seas, we may be able to compare Arctic condition and sub-Arctic conditions. There are many common concerns and common problems. Regarding industries, increasing opportunity of navigation in the less ice conditions, maritime disaster prevention and search and rescue (SAR) are important issues.

After Shiretoko Peninsular region became the World Natural Heritage in 2005, we experienced oil spill damage nearing coast. It was difficult to detect its happening, origin and causes as due to sea ice coverage. Those case, if happens in the Arctic, their difficulties will be much severe.

With recent developments of Japanese Arctic studies, we have strengthened connection among Arctic researchers and also local communities in many countries. Okhotsk study can be a pilot study of discussion on sea ice and life relationships, new research technology, long-term monitoring, and utilizing of traditional knowledge and local experimental activities.

# 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 °C, 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 ($\delta D$) and chemical species in the ice core. The ice core age was determined by annual counts of $\delta D$ and seasonal cycles of sodium ions, and we used reference horizons of tritium peaks in 1963 and 1964 and 8 major volcanic eruptions 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 ±3 years. This interval has been divided into three phases; that is, Warm-Wet, Warm-Dry, and Cold-Wet, based on temporal variation of $\delta D$ and annual accumulation rate.

We found that the increasing period of precipitation amounts were shown after 1850 and before 1760. Before 1760, $\delta D$ values are low and d-excess values are high, therefore we considered that due to weakened and/or westerly AL, fraction of water vapor from western side increased, as a result, precipitation increased. After 1850, $\delta D$ values are high and d-excess values are Low, therefore we considered that due to strengthened and/or easterly AL, fraction of water vapor from southern side increased, as a result, precipitation increased. Our results suggest that the fraction of water vapor from western side become an important factor for Alaskan environmental changes.

**Reference:**

Tshusima, A., S. Matoba, T. Shiraiwa, S. Okamoto, H. Sasaki, D. J. Solie and K. Yoshikawa. 2015. Reconstruction of recent climate change in Alaska from the Aurora Peak ice core, central Alaska, Clim. Past, 11, 217-226, doi:10.5149/cp-11-217-2015.

# On the structure and dynamics of the Soya Warm Current from the viewpoint of buoyancy arrest

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This study presents an investigation of the dynamics of the Soya Warm Current along the Hokkaido coast in the Sea of Okhotsk. The major goal is to develop simple mathematical model to describe dynamical feature of this geophysical flow, especially the formation mechanism of a jet and a density front. The model is formulated from the viewpoint of buoyancy arrest (Brink and Lentz 2010) and theoretical results will be compared to simple numerical ocean model, namely the Princeton Ocean Model (POM). A steady flow over a constant sloping bottom in a stratified ocean is treated in each model.

Buoyancy arrest is a dynamical steady state of ocean current influenced by the bottom boundary layer. In general, the force of friction between ocean current and bottom topography can lead to a halt of the current system. However, the frictional effect could be prevented by the presence of stratification and sloping bottom. In such a care the bottom boundary layer can produce buoyancy (i.e., density front) and introduce vertical shears in the current that, in turn, can reduce the bottom stress. Reduced bottom stress then leads to weaker deceleration of the ocean current and possibly a situation in which bottom stress vanishes and the deceleration of the flow stops entirely. This steady state is known as buoyancy arrest.

According to buoyancy arrest, we can focus on the following three points about the formation mechanism of the jet and the density front of the Soya Warm Current. The first is a seasonal thermocline in the Sea of Okhotsk. The second is a continental slope along the northeastern coast of Hokkaido. The third is a coastal inflow whose volume transport is about 1 Sv (Fukamachi et al., 2010) from the Soya strait.

To investigate the relationship between the Soya Warm Current and three points discussed above, we conducted numerical experiments using a primitive equation ocean model. The model is configured in a stratified straight channel with a coastal slope and reproduces the jet structure of the Soya Warm Current. Analysis of the model also shows the situation in which bottom stress vanishes. Because we are struggling to develop theoretical model, we will show the result in this symposium.

**Reference:**

Brink, K. H., and S. J. Lentz, 2010: Buoyancy arrest and bottom Ekman transport. Part 1: Steady Flow. J. Phys. Oceanogr., **40**, 621-635

# Interactions of internal waves and sub-mesoscale vortex

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Mixing of sea water is important for water mass formation and as a drive motor of the global thermohaline circulation. Mixing mechanism have been argued in the context of breaking of the internal waves. Main source of the wave energy is tidal flow over bottom topography (Polzin, 1997). Recent studies uncovered that interaction between eddies and internal waves plays important roles in mixing and the formation of local internal wave spectra. The interaction has attracted attention, and remarkable theories, say, wave capture (Buhler and McIntyre, 2005) were achieved in the parameter range of weak mesoscale eddies with relatively short internal waves, which allows a WKB like approach.

However, the interaction outside of the above parameter range are not well known; in particular, universally located sub-mesoscale vortices with tide-induced internal waves of various wavelengths. For example, around Kuril Islands, there are many submeso-scale vortices with various spatial scales and strengths (Nakamura *et al*., 2012). Internal waves with various wavelengths are excited concurrently (Nakamura and Awaji, 2004). Therefore waves should frequently collide with these vortices. In such a situation, incident wavelength is sometimes comparable to spatial scale of a vortex. This requires a nonWKB like approach. Interactions in such a range of parameter have not been considered in previous studies.

Here, we investigated the interaction between a vortex and incident internal waves in a wide parameter range, with using theoretical analysis and a numerical model. We started with theoretical analysis in scattering of monochromatic internal waves by a single vortex. We obtained scattered wave solutions for azimuthal modes, whose sum gives the total scattered wave field. The analysis revealed a nondimensional parameter useful for classifying the interaction dynamics. This parameter represents a product of ratios of length and nonlinearity scales.

We then performed numerical experiments with a three-dimensional nonhydrostatic model in a wide range of the parameter. In almost linear range, waves are scattered and form contrast of energy flux. Besides, in nonlinear region, waves are trapped into the vortex and their wavenumber become high, leading to wave breaking. This indicates that mixing is induced by the interaction of internal waves and a sub-mesoscale vortex.

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# A mechanism of ice-band pattern formation caused by resonant interaction between sea ice and internal waves

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Ice bands are often observed over marginal ice zones (MIZ) in polar seas. A typical ice band pattern has a regular spacing of about 10 km and extends over 100 km in marginal ice zone. Further, the long axis of an ice band lies to the left (right) with respect to the wind direction in the Northern (Southern) Hemisphere. Here we show that the resonance between ice-band pattern propagation and internal inertia-gravity waves below the sea ice well explains the ice-band pattern formation. Internal waves are generated by the difference between the stress on the open water and the stress on ice-covered water, as well as the difference in the angle between these stresses. This in turn reinforces to form ice band pattern with a regular band spacing. Specifically, we have found that:

1: A band spacing on the order of 10 km is selected for by the resonance condition in which the ice-band pattern propagation speed coincides with the phase speed of internal inertia-gravity waves.

2: The ice bands tend to develop favorably when the wind direction and the band-propagation direction are nearly parallel. The velocity acceleration caused by the periodic differential stress associated with the ice bands, driven by the wind parallel to the band propagation direction, is important. The wind direction may turn to the left (right) slightly in the Northern (Southern) Hemisphere as a result of the Coriolis effects.

We qualitatively confirmed the first conclusion by investigating whether the band spacing from satellite images (e.g. AVHRR, MODIS) are coincide with the theoretical band spacing. As the result, we found that this band spacing in the satellite images are able to represent as the consistent scales in the hydrostatic condition. Further, we use a numerical model and the satellite images then we discuss about ice-band pattern formation in the continuous stratification.

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# Technical Support in ILTS, 2015

Toru Takatsuka, Shunichi Nakatsubo, Takeshi Chigai, Shoichi Mori, Kazuya Ono, Yukako Kato, Kazuyuki Fujita, Fumiaki Saito, Kunio Sinbori, Masayuki Ikeda, and Naoki Watanabe

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Technical supports in various research fields by the Technical Division of the Institute of Low Temperature Science, Hokkaido University, are introduced. Technical staffs in the Division support equipment developments, field observations, laboratory experiments, data analyses, and biological and chemical analyses in various fields covering physics, biology, chemistry, electronic engineering and information sciences. This division technically contributes to several ILTS research projects. Some members participate in expeditions to Arctic, Antarctic, and Pan-Okhotsk regions, successfully carrying out the technical supports. The Technical Division is composed of three shops; Technical Development Shop, Advanced Technical Support Shop, and Facility Maintenance Shop. The Technical Development Shop is responsible for design and production of experimental and observational equipment. The Advanced Technical Support Shop is responsible for design and production of electric instruments and information technology, supports of physical and biochemical analyses, and resolving networking troubles. The Facility Maintenance Shop maintains the low temperature rooms and air-conditioning.

The followings are our outstanding technical developments and contributions in recent years:

- Developments for zero-gravity experiments of ice crystal growth in the Japanese Experiment Module KIBO of the International Space Station.
- Technical support for the oceanic observations in Polar Regions.
- Development of the new astronomical camera system at sub millimeter wavelengths mounted on the Atacama Desert of Chile.
- Development of over 350 polyvinyl chloride chambers.
- Created automatic image disclosure system using DSLR camera in Monbetsu City.
- Analysis of photosynthesis under changing environments.
- Construction of weather station system in Moshiri, Horokanai Town.
- Support for International Antarctic Institute (IAI) curriculum.

One of the members teaches industrial techniques in Bolivia as JICA (Japan International Cooperation Agency) Training and Dialogue Program member. Every year, we introduce our works by technical reports and conference in ILTS. In the symposium, we will show our prominent works in details.

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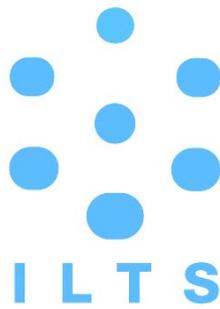
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