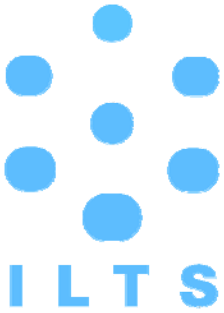
ILTS International Symposium

"Frontier of Low Temperature Science"

Book of Abstracts



November 9-10, 2009

Auditorium,

Institute of Low Temperature Science,

Hokkaido University

ILTS International Symposium "Frontier of Low Temperature Science"

November 9-10, 2009
Auditorium, Institute of Low Temperature Science, Hokkaido University
(See http://www.lowtem.hokudai.ac.jp/english/eaccess.html.)

Program

<Monday, 9 November 2009>

Plenary Session, 10:00-11:20 **Chair: Naoto Ebuchi**

10:00-10:10 Welcome Address
Prof. Takeo Hondo, Vice President of Hokkaido University

10:10-10:40 Keynote Speech
Prof. Akira Kouchi, Director of ILTS, Hokkaido University
Towards a new era in low temperature science

10:40-11:20 Keynote Speech
Prof. Frank Wilhelms (Alfred Wegener Institute)
How can ice science satisfy the public attention in a warmer world?

Lunch Break, 11:20-13:30

Session 1. Environmental Biology, 13:30-16:30 **Chair: Ayumi Tanaka**

1-1 13:30-14:10
Rudolf Amann, Bernhard Fuchs, Paola Gomez, Martha Schattenhofer, Marga Schüler (Max Planck Institute for Marine Microbiology)
Analyzing the microbial catalysis of biogeochemical cycles by combining quantitative single cell studies with environmental genomics

1-2 14:10-14:35
Swingley, W. D., Takizawa, K., Iwai, M., Kato, N., and Minagawa, J. (ILTS, Hokkaido University)
Photoacclimation of a marine picophytoplankton *Ostreococcus tauri*

1-3 14:35-15:00
Satoshi D. Ohdachi (ILTS, Hokkaido University)
Biogeographic characteristics of terrestrial mammals in Hokkaido

1-4 15:00-15:25
Hisaya Kojima (ILTS, Hokkaido University)
Deposited snow as a habitat of bacteria: a case of snow coloration associated with iron accumulation

1-5 15:25-16:05
Hiroyo Otaki, R. Craig. Everroad (Tokyo Metropolitan University), Satoshi Hanada (Tokyo Metropolitan University/Institute for Biological Resources and Functions), Shin Haruta, and Katsumi Matsuura (Tokyo Metropolitan University)
Electron cycling in ecosystems: An analysis in microbial community

1-6 16:05-16:30
Toshihiko Hara, Kiyomi Ono, Norifumi Ukaji, Akihiro Sumida, Ryouichi Tanaka, Ayumi Tanaka (ILTS, Hokkaido University), Aya Iwasaki, Ken'ichi Ogawa (Research Institute for Biological Sciences), Kazuko Uchiyama, Kazuhito Kita, Ichirou Watanabe, Michiyasu Yasaka (Hokkaido Forestry Research Institute)
Molecular and ecological studies on boreal forests in the cryosphere

Session 2. Poster Session (with coffee and tea), 16:30-18:00 Chair: Ayumi Tanaka

2-1 Hisashi Ito and Ayumi Tanaka (ILTS, Hokkaido University)
Photosystem development of marine cyanobacterium *Prochlorococcus*

2-2 Yasuhito Sakuraba, Ryouichi Tanaka, and Ayumi Tanaka (ILTS, Hokkaido University)
Delayed leaf senescence by enhanced chlorophyll *b* biosynthesis

2-3 Edgard A. Bontempo e Silva, Toshihiko Hara, Akihiro Sumida, Kyomi Ono, Yuji Kodama, Taro Nakai (ILTS, Hokkaido University), and Shigeru Uemura (Field Science Center for Northern Biosphere, Hokkaido University)
Ecophysiological responses of *Abies sachalinensis* seedlings to two contrasting environments in a sub-boreal forest of Hokkaido, Japan

2-4 Azusa Tabata, Kiyomi Ono, Akihiro Sumida, and Toshihiko Hara (ILTS, Hokkaido University)
Effects of soil water conditions on the morphology, phenology and photosynthesis of *Betula ermanii* in the boreal forest

2-5 Masanori Ochiai (ILTS, Hokkaido University), Kiyohiro Takahasi, and Fuyuhiko Inagaki (Graduate School of Pharmaceutical Sciences, Hokkaido University)
Insect immunity: Solution structure of the silkworm ßGRP N-terminal domain reveals the mechanism for ß-1,3-glucan-specific recognition

2-6 Ryutaro Tokutsu and Jun Minagawa (ILTS, Hokkaido University)
Molecular characterization of photosynthetic protein complexes of marine diatoms

2-7 Masazumi Tsutsumi, Hisaya Kojima (ILTS, Hokkaido University), Tomoya Iwata (Department of Ecosocial System Engineering, University of Yamanashi), and Manabu Fukui (ILTS, Hokkaido University)
Community structure of methane-oxidizing bacteria in water column of a freshwater lake

2-8 Kato, Y., M. Iwasaki, M. Ochiai, K. Shimada, and C. Katagiri (ILTS, Hokkaido University)
Weta Lipophorin – Comparison with other insects –

2-9 Shigeru Aoki (ILTS, Hokkaido University), Mikio Naganobu (Fisheries Research Agency), Takashi Ishimaru (Tokyo University of Marine Science and Technology), Stephan R. Rintoul (CSIRO), Nathaniel L. Bindoff (University of Tasmania), and Keiichiro Ohshima (ILTS, Hokkaido University)
Stable oxygen isotope ratio of sea water and its spatial distribution at the continental margin of Antarctica

2-10 Takenobu Toyota (ILTS, Hokkaido University), Christian Haas (University of Alberta), and Takeshi Tamura (ILTS, Hokkaido University)
Size distribution of sea ice floes in the Antarctic marginal ice zones in late winter

2-11 Yamamoto, S. and Kawamura, K. (ILTS, Hokkaido University)
Stable hydrogen isotopic compositions of *n*-alkanes in atmospheric aerosols from Tokyo as a potential tracer to decipher the source region tracer of terrestrial plant waxes

2-12 Chusei Fujiwara, Kazuya Yamashita (Graduate School of Environmental Science, Hokkaido University), Yasushi Fujiyoshi (ILTS, Hokkaido University)
Detection of organized airflow structure in the atmospheric boundary layer using a 3D-scannnig Doppler lidar

2-13 Takuya Nakanowatari and Kay I. Ohshima (ILTS, Hokkaido University)
Changes in the Sea of Okhotsk due to global warming – Weakening pump function to the North Pacific –

2-14 Yasushi Fukamachi, Kay I. Ohshima, Shigeru Aoki, Daisuke Simizu, Takeshi Tamura (ILTS, Hokkaido University), Yujiro Kitade, Daisuke Hirano (Faculty of Marine Science, Tokyo University of Marine Science and Technology), Shuki Ushio, and Gen Hashida (National Institute of Polar Research)
Direct observations of newly-found Antarctic Bottom Water and the associated sea-ice production - Cape Darnley Project -

2-15 Takeshi Tamura, Kay I. Ohshima, and Sohey Nihashi
Mapping of sea ice production in the Southern Ocean

2-16 Tomoyasu Kuno, Yuji Kodama, and Taro Nakai (ILTS, Hokkaido University)
Evaluation of snowfall interception of boreal forest

2-17 Sasakawa, M. (Center for Global Environmental Research, NIES), K. Shimoyama (ILTS, Hokkaido University), T. Machida (Center for Global Environmental Research, NIES), N. Tsuda (Global Environmental Forum), H. Suto (Japan Aerospace Exploration Agency), M. Arshinov, D. Davidov, A. Fofonov, O. Krasnov (Institute of Atmospheric Optics of SB RAS), T. Saeki, Y. Koyama, and S. Maksyutov (Center for Global Environmental Research, NIES)
Continuous measurement of carbon dioxide and methane concentration using 9-tower network over Siberia

2-18 Shoko Abe (Graduate School of Environmental Science /ILTS, Hokkaido University) and Tomohiro Nakamura (ILTS, Hokkaido University)
Energy transfer in a breaking internal wave

2-19 Hirotaka Sasaki (Graduate School of Environmental Science, Hokkaido University), Sumito Matoba (ILTS, Hokkaido University), and Takayuki Shiraiwa (Research Institute for Humanity and Nature)
Iron flux to the northern North Pacific estimated from the ice core of Mt. Wrangell, Alaska

2-20 Yoshinori Furukawa (ILTS, Hokkaido University), Etsuro Yokoyama (Gakushuin University), Izumi Yoshizaki, Shinichi Yoda, Tetsuo Tanaka (JAXA), Taro Shimaoka (JSF), Takehiko Sone (JAMSS), and Toshiyuki Tomobe (IHI Aerospace)
Pattern formation during ice crystal growth in pure D_2O water –ISS-KIBO Experiments–

2-21 Gen Sazaki (ILTS, Hokkaido University/JST-PRESTO), Salvador Zepeda, Shunichi Nakatsubo (ILTS, Hokkaido University), Etsuro Yokoyama (Gakushuin University), and Yoshinori Furukawa (ILTS, Hokkaido University)
Direct visualization of elementary steps and quasi-liquid layers at air-ice interfaces by advanced optical microscopy

2-22 Salvador Zepeda, Hiroyuki Nakaya (ILTS, Hokkaido University), Etsuro Yokoyama (Gakushuin University), and Yoshinori Furukawa (ILTS, Hokkaido University)
Antifreeze protein kinetics at the ice/solution interface

2-23 Hakime Seddik, Ralf Greve (ILTS, Hokkaido University), Thomas Zwinger (CSC–IT Center for Science Ltd.), and Olivier Gagliardini (Laboratory of Glaciology and Environmental Geophysics, CNRS)
Steady-state simulations of the Greenland ice sheet using a three-dimensional full-Stokes model

2-24 Thorben Dunse (Department of Geosciences, University of Oslo/ILTS, Hokkaido University), Thomas V. Schuler, Jon Ove Hagen (Department of Geosciences, University of Oslo), Ralf Greve (ILTS, Hokkaido University), Geir Moholdt, and Trond Eiken (Department of Geosciences, University of Oslo)
Modelling flow dynamics and geometry of the Austfonna ice cap, Svalbard

2-25 Shun Tsutaki, Daisuke Nishimura, Takeshi Yoshizawa (Graduate School of Environmental Science, Hokkaido University), and Shin Sugiyama (ILTS, Hokkaido University)
Impact of proglacial lake formation on the retreat of Rhonegletscher, Switzerland

2-26 Iizuka Yoshinori Iizuka, Akira Tsuchimoto, Toshimitsu Sakurai (ILTS, Hokkaido University), Motohiro Hirabayashi (National Institute of Polar Research), Toshitaka Suzuki (Faculty of Science, Yamagata University), Takayuki Miyake (National Institute of Polar Research), Ryu Uemura (LSCE, CEA-CNRS), Shuji Fujita, Hideaki Motoyama, Yoshiyuki Fujii (National Institute of Polar Research), and Takeo Hondoh (ILTS, Hokkaido University)
Constituent elements of soluble particles of the Dome Fuji surface snow and ice core

2-27 Hidaka, H., M. Watanabe, A. Kouchi, N. Watanabe (ILTS, Hokkaido University)
Formation of deuterated formaldehyde and methanol by quantum tunneling H-D substitution and H(D) addition reactions on low temperature surfaces

2-28 Manabu Fukui, Shin Sugiyama, Shigeru Aoki (ILTS, Hokkaido University), Masanobu Yamamoto (Faculty of Environmental Earth Science, Hokkaido University), Takenobu Toyota (ILTS, Hokkaido University), Takanobu Sawagaki, Genta Mizuta (Faculty of Environmental Earth Science, Hokkaido University), Keiichiro Ohshima, Yasushi Fukamachi, Sumito Matoba, Kou Shimoyama, Yoshinori Iizuka, and Tomoko Endo (ILTS, Hokkaido University)
Antarctic Science Curriculum of Hokkaido University – Contribution to the International Antarctic Institute –

2-29 Kunio Shinbori, Toru Takatsuka, Shunichi Nakatsubo, Takeshi Chigai, Kazuya Ono, Yukako Kato, Kenta Chubachi, Kazuyuki Fujita, Masao Ishikawa, Hiroki Fukushi, Masayuki Ikeda, and Naoto Ebuchi (ILTS, Hokkaido University)
Technical supports in ILTS

Reception, 18:00-19:30 (Room 215)

<Tuesday, 10 November 2009>

Session 3. Water and Material Cycles, 9:30-12:00 Chair: Yasushi Fujiyoshi

3-1 9:30-10:00
Ding Yihui, Wang Zunya, and Song Yafang (National Climate Center, China Meteorological Administration)
Cause of the unprecedented freezing disaster in January 2008 and its possible association with the global warming

3-2 10:00-10:30
Toshio Koike (The University of Tokyo)
Data integration and analysis system for water cycle

3-3 10:30-11:00
Yasunobu Iwasaka (Kanazawa University)
Kosa (Asian dust) particles and atmospheric constituents on particle surface

3-4 11:00-11:30
Naohiro Yoshida (Tokyo Institute of Technology)
Isotopomer studies to trace water and material cycles featuring some extreme environments

3-5 11:30-12:00
Yasushi Fujiyoshi (ILTS, Hokkaido University)
Why cloud science?

Lunch Break, 12:00-13:00

Session 4. Pan-Okhotsk Researches, 13:00-15:30 Chair: Jun Nishioka

4-1 13:00-13:50
Bo Qiu (School of Ocean & Earth Science & Technology, University of Hawaii at Manoa)
Decadal variability in the North Pacific Subpolar Gyre circulations

4-2 13:50-14:20
Sumito Matoba (ILTS, Hokkaido University)
50-year records of climate changes in ice-cores from Kamchatka and Alaska

4-3 14:20-14:50
Osamu Seki (ILTS, Hokkaido University)
Large changes in seasonal sea ice, sea surface temperature and productivity in the Sea of Okhotsk during the last deglaciation

4-4 14:50-15:20
Tomohiro Nakamura (ILTS, Hokkaido University)
Modeling the Pan-Okhotsk region

15:20-15:30 Discussion

Coffee Break, 15:30-16:00

Session 5. Frontier Ice and Snow Science, 16:00-18:30 **Chair: Yoshinori Furukawa**

5-1 16:00-16:50
John Wettlaufer (Yale University)
Letters from the Sky: Nakaya, Sapporo and the broad scientific reach of the physics of ice

5-2 16:50-17:25
Shuji Fujita (National Institute of Polar Research), Junichi Okuyama, Akira Hori, and Takeo Hondoh (ILTS, Hokkaido University)
Metamorphism of stratified firn at Dome Fuji, Antarctica: A mechanism for local insolation modulation of gas transport conditions during bubble close-off

5-3 17:25-17:45
Ralf Greve (ILTS, Hokkaido University)
Dynamic/thermodynamic modeling of ice sheets in changing climates

5-4 17:45-18:05
Naoki Watanabe (ILTS, Hokkaido University)
Ice surface reactions: its role in chemical evolution in space

5-5 18:05-18:25
Gen Sazaki (ILTS, Hokkaido University)
Direct visualization of elementary steps and quasi-liquid layers at air-ice interfaces by advanced optical microscopy

Closing Remarks
Prof. Manabu Fukui, Vice Director of ILTS, Hokkaido University

Keynote Speeches

Towards a New Era in Low Temperature Science

Akira Kouchi
Institute of Low Temperature Science, Hokkaido University
kouchi@lowtem.hokudai.ac.jp

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. In the half century, the institute had conducted unique research on various natural phenomena occurring in climatic low temperatures.

As it became clear that the cryosphere has an important role in the global climate system and ecosystem, nature in the cryosphere had gained attention in recent years as an important subject of study regarding environmental earth science. To promote interdisciplinary studies beyond the existing scientific framework such that they are pursued jointly by its own and other researchers, the Institute of Low Temperature Science had reorganized in 1995.

In 2008, we established a new system incorporating Joint Research Division with three large divisions (Water and Material Cycles Division, Frontier Ice and Snow Science Division, and Environmental Biology Division) and Pan-Okhotsk Research Center in order to increase opportunities for conducting interdisciplinary cryosphere research with domestic and foreign researchers. Joint Research Division has various functions, such as “Program”, “Joint Research and Collaboration”, and “Technical Support” to enhance the function as the community center. “Program” is accomplished in full-time faculty members’ lead with complete support of three research divisions and the Pan-Okhotsk Research Center. Furthermore, to promote further joint research, we concluded an agreement between one domestic and four foreign institutions in 2008 and 2009. As a leading research center for low temperature science, we have been promoting joint research in this way.

Academic advancement requires a broad point of view as well as intense investigation. Joint research fusing various research fields can be said to be the sprit of our institution’s foundation. In the present symposium, results of “Programs” ranging various fields will be presented. To evaluate almost finished “Programs” critically and to further activate ongoing interdisciplinary “Programs”, we anticipate active discussion and critical comments.

How can Ice Science Satisfy the Public Attention in a Warmer World?

Frank Wilhelms
Alfred Wegener Institute
Frank.Wilhelms@awi.de

The worldwide public is aware that humankind lives in a changing environment. Typical questions to scientists addressed by the public are e.g.: How much will sea level rise at our shores in 100 years? How will average seasons and the distribution of precipitation be in 30 years in our country? Will we be able to send ships over the North Pole in a few decades?

To address these questions one has to understand the various interactions between the atmosphere, the oceans and the ice covering both polar land and seas. The changing physical properties are tightly coupled to the biological and geochemical cycles which have therefore to be included to forecast the fate of the earth system. Ice is a key player in the earth system as the polar ice sheets store an equivalent of more than 60 m of sea level difference. Sea ice has compared to open water a much higher ability to reflect radiation instead of heating by absorption.

Both the Alfred Wegener Institute (AWI) and the Institute of Low Temperature Science (ILTS) have some of their major research topics covering aspects of ice beginning with the basic physical properties of ice crystals and their inclusions, formation of meteoric and sea ice, internal structure of ice sheets towards modelling and observing the evolution of ice sheets and sea ice in the earth system. Together both institutes cover an almost complete portfolio of research addressed to ice and lay the basis for research towards answering the questions by the public.

Selected ice research topics relevant for the AWI and the ILTS will be presented, as e.g. microstructure of ice, internal electromagnetic reflections in ice sheets, air content in natural ice, modelling the evolution of ice sheets and distribution of sea ice under different climatic conditions. Latest reconstructions of sea ice extent and ice sheet geometry from proxy parameters in ice and sediment cores permit the comparison with modelling results.

Session 1. Environmental Biology

1-1

Analyzing the Microbial Catalysis of Biogeochemical Cycles by Combining Quantitative Single Cell Studies with Environmental Genomics

Rudolf Amann, Bernhard Fuchs, Paola Gomez, Martha Schattenhofer, and Marga Schüler
Max Planck Institute for Marine Microbiology
ramann@mpi-bremen.de

Central steps of global biogeochemical cycles are catalyzed by marine microorganisms. Molecular fingerprints have long indicated novel, often high microbial diversity, but fell short of quantify specific population sizes and biomasses. Fluorescence in situ hybridization (FISH) with rRNA-targeted oligonucleotide probes yields such quantitative data on spatio-temporal distributions. By catalyzed reporter deposition fluorescence in situ hybridization (CARD-FISH) abundant marine "key species" can even be quantified in very oligotrophic environments[3]. For some of them, e.g. for heterotrophic polymer-degrading bacteria, representative pure cultures have recently become available.

We are studying coastal bacteria involved in carbon cycling like "*Gramella forsetii*" (Phylum *Bacteroidetes*)[1], and "*Congregibacter litoralis"* (NOR5/OM60 clade of *Gammaproteobacteria*)[2]. The genome of *"G. forsetii"* shows ample adaptations to the degradation of polymeric materials, whereas *"C. litoralis"* turned out to be the first gammaproteobacterial aerobic anoxygenic photoheterotroph (AAnP). The existence of this novel clade of AAnPs had been predicted by metagenomics. Massive sequencing efforts are now enabling comparative genomics of additional marine *Bacteroidetes*, confirming their central involvement in carbon cycling.

Metagenome projects at the MPI Bremen have so far focussed on benthic processed such as the anaerobic oxidation of methane, and have only been started for marine planktonic settings. By the combination of quantitative single cell studies and environmental genomics we hope to gain a more detailed understanding of specific functions of particular marine microbial populations. Our data could in the future contribute to predictive models of the role and fate of particular microbial populations at defined environmental settings.

References

[1] Bauer, M. Et al., 2006. Environ. Microbiol. 8: 2201-2213.
[2] Fuchs, B.M.et al., 2007. Proc. Natl. Acad. Sci. USA 104: 2891-2896.
[3] Schattenhofer, M. et al., 2009. Environ. Microbiol. 11: 2078-2093.

1-2

Photoacclimation of a Marine Picophytoplankton *Ostreococcus tauri*

Swingley, W. D, Takizawa, K., Iwai, M., Kato, N., and Minagawa, J.
Institute of Low Temperature Science, Hokkaido University
minagawa@lowtem.hokudai.ac.jp

Paradoxically, the primary stress on photosynthetic organisms is their life-giving sun. One of the methods land plants have developed to deal with this high-light stress is the xanthophyll cycle, but the extent of its use is not clear in marine algae, which are responsible for nearly half of the global carbon fixation. In this work we characterized non-photochemical quenching, including xanthophyll cycling, and photosynthetic efficiency in a marine phytoplankton, Prasinophyceae, which is a broad class of early-branching eukaryotic green algae. They are found ubiquitously throughout the ocean and contribute considerably to global carbon-fixation. *Ostreococcus tauri*, as the first completely sequenced prasinophyte, is an ideal model species for studying the photosynthesis and its acclimation to the environments. We found that under high-light stress, *O. tauri* rapidly de-epoxidated up to 50% of its violaxanthin to antheraxanthin, but converted less than 20% to zeaxanthin. This one-step xanthophyll cycle correlated to an extremely large capacity for non-photochemical quenching (NPQ > 2.8); a level that is comparable to the globally successful diatoms. When grown under a variety of light intensities, *O. tauri* cells drastically adjusted both their xanthophyll pool size and photosynthetic efficiency. Such changes help *O. tauri* dynamically balance photoprotection with light-harvesting.

1-3

Biogeographic Characteristics of Terrestrial Mammals in Hokkaido

in Hokkaido

Satoshi D. Ohdachi
Institute of Low Temperature Science, Hokkaido University
ohd@lowtem.hokudai.ac.jp

Hokkaido is separated from Honshu (the mainland of Japan) by Tsugaru Strait, with the narrowest point of 18 km. It is well known that bird fauna quite differs beyond this strait, which was first pointed out by Thomas. W. Blakiston and his colleague based on his bird specimens collected by in the late 19th century. Later, it was demonstrated that faunae of other terrestrial vertebrates are also rather different between Honshu and Hokkaido, divided by the strait. Therefore, Tsugaru Strait is often called Blakiston's line, which is one of the most important biogeographic lines in the Japanese Archipelago. As the northern demarcation, Hokkaido is also separated from Sakhalin (Karafuto) by Soya (La Pérouse) Strait with 40 km shortest distance. Soya Strait was also proposed as a biogeographic line (Hatta's Line), especially for amphibian and reptile faunae. It however is now regarded as a less important. Further, Sakhalin and Primorski/Khabarovsk region (North-eastern Asian Continent) are separated by Mamiya (Tatar) Strait with 7 km narrowest point. The final opening of this strait occurred 5-7,000 years ago and it does not play an important role to segregate terrestrial vertebrate fauna Sakhalin and the continent. In terrestrial mammals, species composition of Hokkaido fauna is a part of Sakhalin or Honshu fauna, and Hokkaido shares much more common "species" with Sakhalin than Honshu. Thus, terrestrial mammalian fauna of Hokkaido is correlated to that of East Siberia more strongly than Honshu. In addition to such classic "present/absent" biogeographic information, we can infer more detailed process of biogeographic history based on molecular phylogeny and population genetics. In the present talk, I introduce phylogeographic characteristics and uniqueness of Hokkaido for some terrestrial mammals. You will see not only that Hokkaido fauna is strongly affected by East Siberian fauna but also that Hokkaido has a unique position in biogeographic events for some mammal species.

1-4

Deposited Snow as a Habitat of Bacteria: a Case of Snow Coloration Associated with Iron Accumulation

Hisaya Kojima
Institute of Low Temperature Science, Hokkaido University
kojimah@lowtem.hokudai.ac.jp

The importance of biogeochemical processes in snow and related environments has been increasingly appreciated in recent years. Although biological activities in such cold environments tend to be suppressed to a low level, their contributions to annual nutrient budgets can be significant when they are cumulated through the winter to early spring. In several cases, these activities are tightly linked to physical characteristics of snow. In several mires in Japan, reddish-brown colored snow is observed at the time of melting snow. Colorations of snow by microbial cells are typically caused by oxygenic phototropic organisms, referred to as snow algae. The brown snow contains abundant spherical brown particles resembling snow algae in size, however, the color of particles is entirely distinct from that of typical snow algae. In addition, these particles are accumulated in deeper layers of snow, e.g., 1 m under the surface, where no light would be available for photosynthesis. In order to characterize this remarkable phenomenon, microbial community was analyzed along with chemical analyses. A core sample of snow which had colored region was investigated to reveal vertical shifts in physicochemical characteristics and microbial community structure. The abundance of particles peaked within the colored layer, and correlated with amount of microbially reducible Fe(III). Interstitial water of colored layer was enriched with Fe(II), and characterized by reduced concentration of dissolved methane. The bacterial community structure in the colored region was characterized by higher relative abundance of iron-reducing bacteria (the genus *Geobacter*) and methane-oxidizing bacteria (the genus *Methylobacter*). These bacteria seem to take ecological advantage of environmental conditions in the snow coverage on wetlands, and iron compounds and methane are suggested to be the key substances that can be investigated to understand the mechanism of this phenomenon.

1-5

Electron Cycling in Ecosystems: An Analysis in Microbial Community

Hiroyo Otaki [1], R. Craig. Everroad [1], Satoshi Hanada [1,2], Shin Haruta [1], and Katsumi Matsuura [1]
[1] Department of Biology, Tokyo Metropolitan University
[2] Institute for Biological Resources and Functions, National Institute of Advanced Industrial Science and Technology (AIST)
matsuura-katsumi@tmu.ac.jp

Cyclings of carbon, oxygen, nitrogen, sulfur, and hydrogen in ecosystems interact each other through redox reactions, i.e., electron flow between the cycles. Although the electron flow is closely related to the energy flow in ecosystems, the concept of electron flow in energy flow is not so important in aerobic world because the carbon cycle is in parallel with the electron cycle. Electrons move from water to CO_2 and return from organic compounds to oxygen. However, in the whole biosphere, which includes both aerobic and anaerobic environments, the concept of electron flow between the nutrient cycles becomes important for the energy flow.

We have been studying hydrogen production and consumption in hot spring microbial mats. In the course of study, we have realized that electrons are cycling in the community through various nutrients. In the cycle, electrons are pumped by solar energy in anoxygenic photosynthetic bacteria.

Microbial mats were collected at Nakabusa hot spring and their hydrogen production was measured in artificial hot-spring water at 65°C. In the presence of an inhibitor of sulfate reduction, molybdate, significant production of hydrogen gas was detected. This hydrogen production largely decreased under illumination. The fermentative bacterium, *Fervidobacterium* sp., seem to produce hydrogen in the mats, and that this hydrogen is consumed by the sulfate-reducing bacteria, *Thermodesulfobacterium* sp. The anoxygenic photosynthetic bacterium, *Chloroflexus aggregans*, affected hydrogen production under illumination, and considered to provide organic compounds to the fermenter. By disrupting the mat structure and cell-cell interactions, hydrogen production was observed despite the lack of inhibitor, demonstrating this structural disruption interfered with hydrogen consumption.

The production and consumption of hydrogen in the microbial mat seem to connect both to the carbon cycle and sulfur cycle in the community. Moreover, hydrogen production and consumption in the mat is thought to be part of the electron cycling in the mat. The microbial mat community may then be a model for the combination of nutrient and electron cycling in various ecosystems, which include anaerobic environments, on the earth.

1-6

Molecular and Ecological Studies on Boreal Forests in the Cryosphere

Toshihiko Hara [1], Kiyomi Ono [1], Norifumi Ukaji [1], Akihiro Sumida [1], Ryouichi Tanaka [1], Ayumi Tanaka [1], Aya Iwasaki [2], Ken'ichi Ogawa [2], Kazuko Uchiyama [3], Kazuhito Kita [3], Ichirou Watanabe [3], Michiyasu Yasaka [3]
[1] The Institute of Low Temperature Science, Hokkaido University
[2] Research Institute for Biological Sciences, Okayama
[3] Hokkaido Forestry Research Institute, Bibai
t-hara@pop.lowtem.hokudai.ac.jp

The boreal forest (N 45 – 70 degrees) occupies about 1/3 of the total world forest area. It is assumed that the boreal forest is most sensitive to global climate change such as global warming. Our research groups are conducting molecular, physiological, biochemical and ecological studies on boreal forests. The characteristics of the cryosphere, where the boreal forest occurs, are low precipitation and low temperature. We assume that photooxidative stress occurs strongly under such environmental conditions. We have found that (1) photooxidative stress in the spring triggers flowering in boreal forest trees; (2) the gap regeneration that occurs in tropical or temperate forests does not occur in boreal forests, that is, seedlings can survive under the canopy of adult trees (in low light) but not in gaps (in high light) in boreal forests; (3) evergreen conifers have several protective mechanisms against photooxidative stress in the autumn and winter as compared with deciduous trees in boreal forests. Therefore, photooxidative stress plays a key role in the reproductive strategy, survival strategy and biodiversity of trees in the boreal forest. We will talk about the molecular and ecological mechanisms of how photooxidative stress affects the dynamics of boreal forests with reference to climate change.

Session 2. Poster Session

2-1

Photosystem Development of Marine Cyanobacterium *Prochlorococcus*

Hisashi Ito, and Ayumi Tanaka
Institute of Low Temperature Science, Hokkaido University
ito98@lowtem.hokudai.ac.jp

We analyzed the *Synechocystis* sp. PCC6803 transformant to understand the development of *Prochlorococcus* photosystem. Two genera of marine cyanobacteria, *Prochlorococcus* and marine *Synechococcus*, are abundant in the oceanic waters. *Prochlorococcus* is considered to be derived from marine *Synechococcus*. *Prochlorococcus* genus is dominating to a latitudinal belt of the oceans bounded by the latitudes around 45ºN to 40ºS. In contrast, marine *Synechococcus* is found in the ocean ubiquitously up to the polar circle. These cyanobacteria contribute significantly to primary production in the ocean. Higher plants and cyanobacteria possess monovinyl chlorophyll. However, *Prochlorococcus* possesses divinyl chlorophyll, of which C-8 vinyl group is not reduced to ethyl group. The presence of divinyl chlorophyll is a trait common to all *Prochlorococcus* strains. We used model freshwater cyanobacterium *Synechocystis* sp. PCC6803 as the material. The structure of the main components of the photosynthetic apparatus of *Synechocystis* sp. PCC6803 is similar to that of marine *Synechococcus*. Divinyl chlorophyll accumulated in *Synechocystis* sp. PCC6803 by the disruption of the essential gene in the reduction of divinyl chlorophyll to monovinyl chlorophyll. The transformed *Synechocystis* sp. PCC6803 was photosensitive. When the conserved amino acid residues in *Prochlorococcus* were introduced into the chlorophyll protein of the transformant, photosensitivity was suppressed. These observations suggest that modification of both chlorophyll and chlorophyll protein is critical in the branching of *Prochlorococcus* with *Synechococcus*. The intermediate of *Synechococcus* and *Prochlorococcus* would be photosensitive. We could expect that this is the reason why we can not find the intermediate in the ocean now.

2-2

Delayed Leaf Senescence by Enhanced Chlorophyll *b* Biosynthesis

Yasuhito Sakuraba, Ryouichi Tanaka, and Ayumi Tanaka
Institute of Low Temperature Science, Hokkaido University
rtanaka@lowtem.hokudai.ac.jp

Leaf senescence is not merely termination of cellular activities at the end of the plant life cycle: upon leaf senescence, plant cells execute a genetically encoded program that defines the order and the timing of multiple specific cellular processes. These processes are prerequisite for recovering cellular resources (sugars, amino acids and other nutrients) and transfer them to storage organs such as seeds. Since these processes should be conducted in multiple organelles within a cell, it would be reasonable to assume that the progresses of these processes are monitored by the cell itself (or by the nucleus) and in turn, the nucleus exerts a certain control over these organelles by means of gene expression. In other words, it is likely that the organelles communicate each other to proceed multiple events in leaf senescence in a coordinated way. Several mechanisms for such intracellular communication have been proposed: tetrapyrrole metabolism is one of the hypotheses to explain intracellular communications. Here, we report that a modification of chlorophyll metabolism led to delayed leaf senescence, which phenomenon may involve a communication between the chloroplast and the nucleus. In this study, we analyzed a transgenic *Arabidopsis* plant that overexpressed chlorophyllide *a* oxygenase (CAO), an enzyme responsible for chlorophyll *b* biosynthesis. We incorporated a modification of the CAO sequence (deletion of the N-terminal domain), which liberated this enzyme from its regulatory mechanism, leading to excess accumulation of chlorophyll *b* in the transgenic plant. Under continuous illumination, the leaves of the wild-type *Arabidopsis* plant turned yellowish after 7 weeks of germination, while the leaf yellowing of the CAO-overexpressing plant delayed one week to that of the wild type plant. The decrease in the CO_2 uptake was also slowed down in the CAO-overexpressing plant during senescence, indicating that enhanced chlorophyll *b* biosynthesis affected not only chlorophyll-*b* binding LHC proteins but also the entire process of photosynthesis. Simultaneously, the steady state levels of *Lhcb1, HemA1* and *RbcS* were maintained at a high level in the CAO-overexpressing plant at this stage, while the steady state level of *SAG12* mRNA, which is a good indicator of the onset of leaf senescence, was lower than that of wild type. These results indicate that enhanced chlorophyll *b* biosynthesis modified the cellular program and delayed leaf senescence. We will discuss possible mechanisms that mediate the communication between the chloroplast and the nucleus during leaf senescence.

2-3

Ecophysiological Responses of *Abies sachalinensis* Seedlings to Two Contrasting Environments in a Sub-boreal Forest of Hokkaido, Japan

Edgard A. Bontempo e Silva [1], Toshihiko Hara [1], Akihiro Sumida [1], Kyomi Ono [1], Yuji Kodama [1], Taro Nakai [1], and Shigeru Uemura [2]

[1] Institute of Low Temperature Science, Hokkaido University

[2] Field Science Center for Northern Biosphere, Hokkaido University

silva@pop.lowtem.hokudai.ac.jp

In cold climate areas canopy coverage can protect seedlings from environmental stresses such as radiant frost and cold-induced photoinhibition. The comprehension of how plants respond to such pressures in the event of a canopy opening, or when colonizing an open area, is important to explain the present species distribution and to predict shifts in forest dynamics in response to climate change.

The influences of environmental conditions on the photosynthesis of *Abies sachalinensis* (Sakhalin Fir) seedlings at two contrasting sites, under a deciduous canopy and in a wide canopy gap, were studied by making photosynthetic light curves, measuring chlorophyll fluorescence, growth, soil temperature, soil water content, nitrogen content, and gathering meteorological data. The measurements were made from September 2007 to May 2009, at the Uryu Experimental Forest of Hokkaido University.

Seedlings were photoinhibited in both sites in May and June, but at the open canopy site the photoinhibition persisted until late July. *Abies* growing at the closed canopy site showed a greater degree of photoinhibition than those at the open canopy site, but recovered quickly after the canopy's new leaves flushed, reflecting its acclimation to the shaded condition. Although chlorophyll fluorescence values were positively correlated to photosynthetic rates, seedlings showed statistically similar photosynthetic rates at both sites during most of the growing season. This species' ecophysiological responses and acclimation capacity at seedling stage can help to explain its life history strategy and role in Hokkaido's sub-boreal forest dynamics.

2-4

Effects of Soil Water Conditions on the Morphology, Phenology and Photosynthesis of *Betula ermanii* in the Boreal Forest

Azusa Tabata, Kiyomi Ono, Akihiro Sumida, and Toshihiko Hara
Institute of Low Temperature Science, Hokkaido University
atabata@pop.lowtem.hokudai.ac.jp

Betula ermanii is an early-successional tree species which is widely distributed over subalpine forests in Japan and other regions of boreal forest zone. To investigate the effects of low soil water content on photosynthesis and photoprotective responses of leaves and on whole-plant growth of 4-year-old *B. ermanii* seedlings, four 2-year watering treatments were applied to *B. ermanii* seedlings: ID (irrigated well (I) in the previous year and water deficit (D) in the current year), DD, DI, and II. Relative growth rate (RGR) of the seedlings was smaller in current-year water deficit without experiencing previous-year water deficit (ID) than in irrigated well in both years (II). Surprisingly, RGR did not differ significantly between two-year-water-deficited (DD) and -well-irrigated (II) treatments. The difference in area-based photosynthetic rate of the late leaves (= leaves formed in the current year environment) was not significant between the four water treatments, but their leaf longevity was shortened by water deficit. As for the early leaves (buds of which formed in the previous year environment) the photosynthetic rate was smaller in ID than in II, but it did not differ between DD and II. Leaf mass per area (LMA = leaf dry weight / leaf area) did not differ among the four water treatments. Specific root length (SRL = root total length / root dry weight) did not differ between ID and II. It was greater in DD than in II, probably resulting in increased water uptake efficiency under two-year water deficit conditions. Photoprotective systems such as xanthophyll contents and antioxidant enzyme activities did not differ among the four treatments. Morphological responses of *B. ermanii* roots (SRL) seem to be important as whole-plant-level responses to water deficit for maintaining RGR, in addition to leaf-level photosynthetic and phenological responses of two types of leaves. Our results partly explain how *B. ermanii* seedlings can survive and maintain growth even under varying soil water conditions in the boreal forests.

2-5

Insect Immunity: Solution Structure of the Silkworm ßGRP N-terminal Domain Reveals the Mechanism for ß-1,3-glucan-specific Recognition

Masanori Ochiai [1], Kiyohiro Takahasi [2], and Fuyuhiko Inagaki [2]
[1] Institute of Low Temperature Science, Hokkaido University
[2] Graduate School of Pharmaceutical Sciences, Hokkaido University
ochiai@lowtem.hokudai.ac.jp

Infection by a variety of pathogens such as Gram-positive and Gram-negative bacteria, fungi, viruses and parasites evoke a host-defense system termed innate immunity. Activation of innate immunity by micro-organisms is initiated by pathogen-associated molecular patterns including peptidoglycan, lipopolysaccharide, and ß-1,3-glucan, components of microbial cell walls recognized by pattern-recognition proteins. Insects lack adaptive immunity, and here innate immunity is the sole defense system against pathogens and has a crucial role in host survival. The ß-1,3-glucan recognition protein (ßGRP) is a crucial pattern-recognition protein that specifically binds ß-1,3-glucan, a component of fungal cell walls. It evokes innate immunity against fungi through activation of anti-microbial defense systems such as the prophenoloxidase (proPO) cascade and Toll signaling pathway for the expression of antimicrobial peptides in insects. The ßGRP consists of an N-terminal ß-1,3-glucan recognition domain and a C-terminal glucanase like domain, with the former reported to be responsible for the proPO cascade activation.

To elucidate the functional mechanism of the ß-1,3-glucan recognition, the solution structure of the N-terminal ß-1,3-glucan recognition domain of silkworm ßGRP was determined by NMR. Although the N-terminal domain of ßGRP has a ß-sandwich fold, often seen in carbohydrate-binding modules, both NMR titration experiments and mutational analysis showed that ßGRP has a unique binding mechanism which is distinct from those observed in previously reported carbohydarate-binding domains. Our results suggest that ßGRP is a novel ß-1,3-glucan recognition protein that specifically recognizes a triple-helical structure of ß-1,3-glucan.

2-6

Molecular Characterization of Photosynthetic Protein Complexes of Marine Diatoms

Ryutaro Tokutsu, and Jun Minagawa
Institute of Low Temperature Science, Hokkaido University
tokutsu@pop.lowtem.hokudai.ac.jp

Diatom (Bacillariophyceae) is one of the most successful taxonomic groups of organisms throughout the world's ocean and fresh water. They contribute nearly 25% of global production, which is comparable to that of all terrestrial rain forests. Hence, diatom has been recognized as an important photosynthetic organism in the biochemical carbon cycles. Due to their ecological significance, the complete nuclear and chloroplast genome of a centric diatom, *Thalassiosira pseudonana*, and a pennate diatom, *Phaeodactylum tricornutum* had been revealed as model diatoms.

We are studying the molecular details of photosynthetic protein-pigment complexes of *T. pseudonana* and *P. pseudonana* as a model of centric and pennate diatoms, respectively. At first, thylakoid membranes were obtained after disruption of the cells, and the *β*-dodecyl maltoside was used for mild solubilization of the thylakoid membranes. The solubilized thylakoids were subjected to sucrose density gradients, followed by gel filtration to purify the photosynthetic pigment-protein complexes. Presented herein are data on the compositions of each photosynthetic protein complexes by biochemical analyses, spectroscopic measurements, and MS/MS identification, revealing the differences of living strategies between these diatoms. To our knowledge, this is the first molecular characterization and comparison of two representative diatoms.

2-7

Community Structure of Methane-oxidizing Bacteria in Water Column of a Freshwater Lake

Masazumi Tsutsumi [1], Hisaya Kojima [1], Tomoya Iwata [2], and Manabu Fukui [1]
[1] Institute of Low Temperature Science, Hokkaido University
[2] Department of Ecosocial System Engineering, University of Yamanashi
tsutsumi@pop.lowtem.hokudai.ac.jp

Most of the methane produced in anoxic sediment of freshwater lakes is consumed in oxic sediment and/or water column. This consumption is attributed to activity of aerobic methane-oxidizing bacteria (MOB), which oxidize methane with oxygen. Known methane-oxidizing bacteria were classified into more than 13 genera. Vertical changes in community composition and abundance of MOB were analyzed in water column of a freshwater lake. This lake is characterized by permanent stratification and the temperature of the lower layer was kept at approximately 5 ºC through a whole year. Almost all detected MOB were closely related to psychrophilic or psychrotolerant species belonging to one genus. However, the community compositions of MOB in water column were different between the upper and lower water depths. Around the boundary of the shift of these compositions, physicochemical factors were shifted dramatically and MOB were the most abundant among all water depths.

2-8

Weta Lipophorin – Comparison with other Insects –

Y. Kato, M. Iwasaki, M. Ochiai, K. Shimada, and C. Katagiri
Institute of Low Temperature Science, Hokkaido University
gotohy@lowtem.hokudai.ac.jp

Weta, an endemic orthopteran in New Zealand, overwinters in every life stage; egg, nymph, and adult. At the end of 2006, we started the biochemistry of weta, concerning its tolerance to low temperature. We report the characterization of weta lipophorin, a major lipoprotein in insect hemolymph. Lipophorin is known as a reusable shuttle to transport various lipids ; diacylglycerol, unesterified cholesterol, and hydrocarbons. It transports lipids between the sites of storage, synthesis and absorption, and the tissues that use lipids as energies or as structural components. Its molecular mass is about 600 kDa, and it has two apolipoproteins; apolipophorins (apoLp)-I and -II. Some insects have another apolipoprotein, apoLp-III, which attaches to the surface of lipophorin to transfer more diacylglycerol as fuel during long distance flight.

We isolated and purified lipophorin from the adult hemolymph of two weta species ; tree weta (*Hemideina femorata*) living in plains, and alpine weta (*Hemideina maori*) living in mountainous area. We compared the lipophorin from wetas with that from cricket adults (*Gryllus bimaculatus*) and silkworm larvae (*Bombyx mori*). SDS-PAGE showed that weta has apoLp-I and II, but apoLp-III wasn't detected. We also characterized the lipid composition of weta lipophorin. Weta lipophorin has only saturated hydrocarbons. In comparison with silkworm lipophorin, weta lipophorin has higher percentage of phosphatidylcholine and lower percentage of diacylglycerol in the total lipids.

Acknowledgments---We thank Drs. H. Nishino (Hokkaido University) and L. H. field (University of Canterbury) and D. A. Wharton (University of Otago) for helping us to collect wetas.

2-9

Stable Oxygen Isotope Ratio of Sea Water and its Spatial Distribution at the Continental Margin of Antarctica

Shigeru Aoki [1], Mikio Naganobu [2], Takashi Ishimaru [3], Stephan R. Rintoul [4], Nathaniel L. Bindoff [5], and Keiichiro Ohshima [1]

[1] Institute of Low Temperature Science, Hokkaido University

[2] Fisheries Research Agency

[3] Tokyo University of Marine Science and Technology

[4] CSIRO

[5] University of Tasmania

shigeru@lowtem.hokudai.ac.jp

Salinity is the key variable that controls the sea water density in the polar oceans. Recently, long-term salinity changes of Antarctic waters have been reported in a few regions and they can have a significant impact on the global meridional overturning circulation. To examine the causes of the changes, it is useful to monitor stable oxygen isotope ratio ($\delta^{18}O$) as well as salinity. To determine the spatial distribution and set a baseline for the future state, intensive $\delta^{18}O$ observations have been made. More than five cruises from 2005 were conducted by Australia and Japan in the Ross Sea, Australian-Antarctic Basin, and Weddell-Enderby Basin. Waters on the Antarctic continental shelf region are processed and described.

Salinity- $\delta^{18}O$ relationship of most Antarctic Surface Water and Winter Water is aligned on the same Melting-Freezing lines, possibly reflecting the near-surface sea ice formation/melting processes. Significantly isotopically light waters are found at some locations, revealing the melting of land ice. In the Ross Sea, High Salinity Shelf Water/Ice Shelf Water in the western region are isotpoically depleted, and Low Salinity Shelf Water in the eastern region is even lighter. This suggests a relatively strong influence of land ice in the eastern region. Long-term salinity- $\delta^{18}O$ change in High Salinity Shelf Water is consistent with that due to land ice melting, when combined with the historical data set of Jacobs et al. (2002). At the Adelie Depression where the source of the Adelie Land Bottom Water is located, High Salinity Shelf Water is relatively isotopically heavy. This may reflect a relatively short residence time in the Depression. At the eastern mouth of Prydz Bay, isotopically light High Salinity Shelf Water is found.

As such the $\delta^{18}O$ is a useful indicator in defining the freshwater budget and the sustained observations of $\delta^{18}O$ will surely contribute to the further understanding of the Antarctic climate change.

2-10

Size Distribution of Sea Ice Floes in the Antarctic Marginal Ice Zones in Late Winter

Takenobu Toyota [1], Christian Haas [2], and Takeshi Tamura [1]
[1] Institute of Low Temperature Science, Hokkaido University
[2] University of Alberta
toyota@lowtem.hokudai.ac.jp

In the marginal sea ice zone (MIZ), where relatively small ice floes are dominant, floes size distribution is an important parameter to a melting process because smaller ice floes are subject to stronger lateral melting due to their larger perimeters. However, the available data have been very limited so far. The analysis of the Okhotsk sea ice revealed that while floe size distribution is basically scale invariant, regime shift occurs at a size of about 40 m. In order to extend this preliminary result to the Antarctic MIZ, the ice floe size measurements were conducted in the northwestern Weddell Sea and off Wilkes Land with a heli-borne digital video camera in late winters of 2006 and 2007. The floe size analyzed ranges from 2 m to 100 m. In the same region, ice thickness measurements were also performed to examine the controlling factor. The analysis shows: 1) the scale invariance and regime shift are confirmed in both regions; 2) the floe size at which regime shift occurs slightly increases from 20 to 40 m with ice thickness, consistent with the theory of flexural failure of sea ice; and 3) the aspect ratio is 1.6-1.9 on average, close to the previous results. For floes smaller than 2 m, a field measurement was conducted for ice pieces stranded on the seashore facing the southern Sea of Okhotsk as an alternative in the same season. It is found that such small ice pieces are affected more by melting and grinding. Based on these results, the formation process of size distribution and its effect on a melting process are discussed.

2-11

Stable Hydrogen Isotopic Compositions of *n*-alkanes in Atmospheric Aerosols from Tokyo as a Potential Tracer to Decipher the Source Region Tracer of Terrestrial Plant Waxes

Yamamoto, S., and Kawamura, K.
Institute of Low Temperature Science, Hokkaido University
s.yamamoto@pop.lowtem.hokudai.ac.jp

A long-range atmospheric transport of terrigenous organic materials to the open ocean is one of the important pathways in global carbon cycle. Studies on molecular composition and compound-specific carbon isotopic ratio ($\delta^{13}C$) of leaf wax *n*-alkanes in atmospheric aerosols have revealed details of their long-range atmospheric transport over the south Atlantic and western Pacific Oceans. However, molecular and $\delta^{13}C$ compositions of terrestrial plant waxes in the eastern part of the Asian continent are relatively constant reflecting C_3-dominated vegetation, which makes it difficult to specify the source regions of plant materials in the atmospheric aerosols over the East Asia and northwest Pacific regions. Recent observation displays a large (>100‰) spatial variation in hydrogen isotopic composition (δD) of rainwater in East Asia. Because δD values of terrestrial higher plants sensitively reflect those of precipitation waters, δD of leaf waxes are expected to provide information on their source region. In this study, we measured the δD of *n*-alkanes in atmospheric aerosols from Tokyo to better understand the origin of leaf wax *n*-alkanes in atmospheric aerosols. The δD values of fossil fuel *n*-alkanes (C_{21} to C_{24}) in Tokyo aerosols range from –65 to –94‰, which are within the range of those reported in marine crude oils. In contrast, the δD of longer chain (C_{29} and C_{31}) *n*-alkanes (δD_{LA}) show much lower values by ~70‰ than those of fossil fuel *n*-alkanes. Their values were found to exhibit concomitant variations with carbon preference index (CPI), suggesting that the δD_{LA} reflect the δD of leaf wax *n*-alkanes with a variable contribution from fossil fuel *n*-alkanes. Nevertheless, a good positive correlation ($r = 0.89$, $p < 0.01$) is found between the δD_{LA} and CPI values, which enables us to eliminate the contribution of fossil fuels using a mass balance approach with an assumption that CPI of fossil fuel is 1 and CPI of plant waxes is 5-15. Calculated *n*-alkane δD values averaged from –163 to –178‰ for C_{29} and from –159 to –172‰ for C_{31}. These values are consistent with those reported from growing leaves in Tokyo, which confirms the usefulness of the δD of long chain *n*-alkanes as a tracer for the source region of terrestrial plant waxes in atmospheric aerosols.

2-12

Detection of Organized Airflow Structure in the Atmospheric Boundary Layer Using a 3D-scannnig Doppler Lidar

Chusei Fujiwara [1], Kazuya Yamashita [1], and Yasushi Fujiyoshi [2]
[1] Graduate School of Environmental Science, Hokkaido University
[2] Institute of Low Temperature Science, Hokkaido University
chuchu@lowtem.hokudai.ac.jp

The organized airflow structures in the atmospheric boundary layer (ABL) are responsible for vertical transportation of most of the turbulent fluxes of momentum, buoyancy and material. Within the ABL, plants and most animals, including human beings spend most of their lives. An understanding of organized structures in the ABL is therefore crucial for directing future development not only in meteorological and climate modeling but also in wind engineering, environmental science, disaster science, urban engineering and bionomics. Using a 3D-scanning coherent Doppler lidar (3D-CDL), we succeeded in detecting various kinds of atmospheric phenomena such as streaks, fish nets, invisible dust devils and wake of building. Some of these phenomena were observed for the first time through the use of 3D-CDL. In addition, we simulated some of these phenomena by using Large Eddy Simulation and results obtained were compared with those observed by the 3D-CDL.

2-13

Changes in the Sea of Okhotsk due to Global Warming

– Weakening Pump Function to the North Pacific –

Takuya Nakanowatari, and Kay I. Ohshima
Institute of Low Temperature Science, Hokkaido University
nakano@lowtem.hokudai.ac.jp

The Sea of Okhotsk is the southern limit of sea ice in the Northern Hemisphere. This is because the cold pole in the Northern Hemisphere is located in the upwind region of the Sea of Okhotsk. When sea ice is formed, most of the salt content is rejected from the ice and thus cold, saline and dense water is released into the ocean below. Since large amounts of sea ice are formed in the Sea of Okhotsk, the densest water on the surface of the North Pacific is produced there. Sinking of this dense water creates the vertical circulation (overturning) down to the intermediate depths (approx. 200 to 800 m deep) in the North Pacific. The Okhotsk thus plays a role as the pump of the North Pacific. We found that the water temperature in the intermediate layer of the Okhotsk has increased over the past five decades while the oxygen has decreased. This means that sinking of cold oxygen-rich surface water into the intermediate layer has decreased. These signals have spread to the North Pacific along the pathway of the seawater flowing out of the Okhotsk. The Okhotsk is a sensitive area to global warming: the wintertime air temperature has significantly increased and sea ice extent has decreased by about 20% for the past three decades. We propose that decrease of sea ice production caused the decline in dense water sinking, leading to the weakening of overturning in the North Pacific. The weakened overturning possibly affects the iron circulation, since the iron in the western North Pacific presumably originates from the dense (intermediate) water from the Okhotsk, further from the Amur River. Recent studies suggest that iron is a substantial factor in determining biological productivity. Current global warming, through sea ice reduction, might decrease the iron supply in the North Pacific as well as in the Okhotsk, thus reducing levels of biological productivity and fishery resources.

2-14

Direct Observations of Newly-found Antarctic Bottom Water and the Associated Sea-ice Production - Cape Darnley Project -

Yasushi Fukamachi [1], Kay I. Ohshima [1], Shigeru Aoki [1], Daisuke Simizu [1], Takeshi Tamura [1], Yujiro Kitade [2], Daisuke Hirano [2], Shuki Ushio [3], and Gen Hashida [3]
[1] Institute of Low Temperature Science, Hokkaido University
[2] Faculty of Marine Science, Tokyo University of Marine Science and Technology
[3] National Institute of Polar Research)
yasuf@lowtem.hokudai.ac.jp

Global deep ocean circulation is essentially driven by dense waters (North Atlantic Deep Water and Antarctic Bottom Water) produced and sunk in the North Atlantic and Southern Ocean. For the formation of such dense waters, saline water rejected during sea-ice formation is an essential component. In the Southern Ocean, sea ice is mainly formed in open and thin-ice areas (called polynyas) near the continent, and the Weddell and Ross Seas, and the region off the Adelie Land are known as the three main production sites of Antarctic Bottom Water (AABW).

Using the satellite sea-ice data and objectively-analyzed meteorological data, Tamura et al. (2008) estimated sea-ice production in the entire Southern Ocean. They revealed that a polynya off the Cape Darnley northwest of the Amery Ice Shelf has the second highest production rate next to a polynya in the Ross Sea. This fact suggests that the Cape Darnley Polynya is possibly another important AABW production site.
To examine this hypothesis, we conducted hydrographic and mooring observations in this area in 2008-2009. Hydrographic data reveal the existence of thick AABW layer along sections downstream (westward) of the Cape Darnley Polynya. Time-series data at the moorings downstream of this polynya show that high density signals appeared in April and May following the onset of sea-ice formation in this polynya. These data clearly indicate that AABW is locally formed due to the high salinity water produced in the Cape Darnley Polynya.

Following our pilot experiment in 2008-2009, we are going to expand our observations in the framework of the Japanese Antarctic Research Expedition in next four years. We are planning to measure sea-ice production directly within the polynya in 2010-2011 and 2012-2013 by mooring ice-profiling sonars, and evaluate the volume transport of the AABW export in 2011-2013 by an array of current-meter moorings.

2-15

Mapping of Sea Ice Production in the Southern Ocean

Takeshi Tamura, Kay I. Ohshima, and Sohey Nihashi
Institute of Low Temperature Science, Hokkaido University
tamutake@lowtem.hokudai.ac.jp

Most of coastal polynyas are latent heat polynyas, which are formed by the divergent ice motion due to prevailing winds or oceanic currents. Salt rejection due to active sea ice formation there produces dense water, which can be a source of bottom or intermediate water in the world ocean. Antarctic coastal polynyas are responsible for Antarctic Bottom Water (AABW) formation. Because in-situ observation of coastal polynyas is extremely difficult, detection of polynya areas by use of satellite data are very useful way for the investigation of coastal polynyas. This study gives the first mapping of sea ice production in the Southern Ocean from the satellite microwave data and heat flux calculation, and discusses the spatial distribution of sea ice production and interannual variability of the production.

We develop an algorithm that estimates thin ice thickness in coastal polynyas from the SSM/I data, based on the comparison with ice thickness estimation from the AVHRR data. This algorithm uses 37 and 85 GHz brightness temperature data, and can also detect large icebergs and landfast ice. Using thin ice thickness distribution derived from this new algorithm and surface input data from the ECMWF Re-Analysis, heat flux calculation is performed on a daily basis and we estimate sea ice production under the assumption that heat loss in polynyas are assumed to coincide with the ice production, ignoring the effect of oceanic heat flux from below.
The highest ice production area in the Southern Ocean is the Ross Ice Shelf Polynya, which is consistent with the production area of AABW with the highest salinity. Along the coast of East Antarctica, high ice production areas of coastal polynyas appear on the west side of peninsulas and glacier tongues, downstream of the Antarctic Coastal Current. It is noted that the second highest ice production area is the Cape Darnley polynya west side of Prydz Bay, suggesting the bottom water formation there. Highest interannual variability in the production is found in the Ross Sea among the Antarctic coastal polynyas. The ice production there has decreased by 30% from the 1990's to 2000's, which may be a candidate for a recent change of the bottom water there. According to our estimation, around 10% of Southern Ocean sea ice is produced in the major Antarctic coastal polynyas. The mapping provides surface heat- and salt-flux conditions in the ice-covered region, which have not been well understood.

Evaluation of Snowfall Interception of Boreal Forest

Tomoyasu Kuno [1], Yuji Kodama [2], and Taro Nakai [3]
[1] Graduate School of Environmental Earth Sciences, Hokkaido University
[2] Institute of Low Temperature Science, Hokkaido University
[3] International Arctic Research Center, University of Alaska
kuno@pop.lowtem.hokudai.ac.jp

Introduction Snowfall interception by canopy is an important factor for the variation of snow water equivalent (SWE) of snowy forest watershed. Intercepted snow stays on canopy from several days to a few months, a part of which eventually evaporates back to atmosphere or falls down to ground. The fallen snow from the canopy becomes a part of snowpack on the ground, and the sublimated snow becomes a loss to precipitation. Therefore, it is important to estimate the amount evaporation loss of the intercepted snow. This research aims to evaluate the interception loss by measuring the snow water equivalent inside and outside a boreal forest and discusses on the seasonal variation of the interception coefficient, and their relationship with canopy density and atmospheric conditions.

Observation site and method The observation was carried out at a mixed forest of coniferous and broad leaf trees and a birch forest in the Uryu Research forest of Northern Biosphere Field Research Ceter, Hokkaido University from November 2007 to March 2008. The SWE of inside and outside of forest, canopy sky view factor (SVF), profiles of sublimation from a block of ice are observed with meteorological terms by boundary layer tower. A snow survey was carried by setting a 5 meter grid in a plot of 50 m x 100 m.in the mixed forest, and line measurement of 50 m with 1m interval at the open site. Sublimation profiles ice was measured by measuring the weight change of a block of ice, which hung at several heights on the tower.

Discussion and results The difference in SWE of inside and outside of forest is small at the Birch forest site through the observation period and at the Mixed forest site, it was small in early winter but became larger towards the end of the observation period. The average interception loss is 14.4% for Mixed forest and 7.8% for Birch forest.

The SWE inside the Mixed forest increased with sky view factor (SVF), and the interception fraction is closely related to the canopy density. The SVF within the zenith angles less than 60 degree is better assessed the above result than the SVF within the zenith angle less than 10 degree, therefore, the SWE is related to the canopy density not just above canopies but with wider area.

The profiles of evaporation from ice blocks showed larger rate with height for the period longer than 1 week. This is mainly due to the wind and specific humidity profiles. This result must be concerned in snowfall interception models.

2-17

Continuous Measurement of Carbon Dioxide and Methane Concentration using 9-Tower Network over Siberia

M. Sasakawa [1], K. Shimoyama [2], T. Machida [1], N. Tsuda [3], H. Suto [4], M. Arshinov [5], D. Davidov [5], A. Fofonov [5], O. Krasnov [5], T. Saeki [1], Y. Koyama [1], and S. Maksyutov [1]

[1] Center for Global Environmental Research, NIES
[2] Institute of Low Temperature Science, Hokkaido University
[3] Global Environmental Forum
[4] Japan Aerospace Exploration Agency
[5] Institute of Atmospheric Optics of SB RAS
sasakawa.motoki@nies.go.jp, k-shimo@lowtem.hokudai.ac.jp

Continuous measurements of CO_2 and CH_4 mixing ratios have been carried out with a tower network in Siberia in order to study the spatial and temporal variations of these trace gases in the forest, steppe, and wetland regions and estimate the distribution of their fluxes over this huge area where only few atmospheric investigations were made. The network consists of 9 towers located at Berezorechka (BRZ; 56.09'N, 84.20'E) since 2002, at Karasevoe (KRS; 58.15'N, 82.25'E) and Igrim (IGR; 63.11'N, 64.25'E) since 2004, at Demyanskoe (DEM; 59.47'N, 70.52'E), Noyabrsk (NOY; 63.26'N, 75.47'E) and Yakutsuk (YAK; 62.50'N, 129.21'E) since 2005, at Savvushka (SVV; 51.20'N, 82.08'E) since 2006, at Azovo (AZV; 54.42'N, 73.02'E) since 2007, and at Vaganovo (VGN; 54.30'N, 62.19'E) since 2008. Air samples taken at two heights (5-85 m) on each tower are analyzed with a NDIR (LI-COR, LI-820) for CO_2 and SnO_2 semiconductor sensor for CH_4 after passing through the line with a glass water trap, a Nafion membrane drier and a magnesium perchlorate.

Seasonal maximum of daytime mean CO_2 (13:00-17:00 local time determined by geographical location) occurred in mid-winter (Dec.-Jan.) due to temporally observed high concentration more than 390 ppm. The high concentration spell seemed to be associated with the Siberian high because strongly suppressed vertical mixing in the anticyclonic field resulted in the accumulation of anthropogenic and biospheric CO_2 sources in the surface layer. Remarkable CO_2 drawdown started almost simultaneously around the beginning of May at the western Siberian sites. Seasonal minimum occurred during the summer (Jun. – Aug.) and showed latitudinal difference (~ 6 ppm) as lower values in the southern sites, which obviously reflected the distribution of CO_2 sequestration by Siberian boreal ecosystem. Mean seasonal CO_2 amplitudes from 2002, 2004 and 2005 to 2007 were 32.4, 33.3, 29.8, 28.4, 28.4 and 29.5 ppm in BRZ, KRS, IGR, DEM, NOY and YAK, respectively, which were rather large compared with the data from the coastal sites at similar latitude as Siberia (Fig. 2). Furthermore, ranging from 20 to 30ppm of amplitude was occurred during growing season. These results strongly suggested that important rolls of Siberian ecosystem on atmospheric CO_2. The seasonal amplitude remarkably differed (~8 ppm) year-by-year, which depended not only on the summer but also on magnitude and frequency of high-CO_2 event due to Siberian high during winter.

Siberian daytime mean CH_4 always shows heiger concentration than that of the NOAA sites and

characteristically have double seasonal peak (winter and summer). Contribution of CH_4 from wetlands calculated with the Lagrangian particle dispersion model FLEXPART, which releases 10000 particles from each monitoring site, is the largest during summer among several potential sources (animal, landfill, coal mining etc), which suggests that CH_4 emission from wide spread wetlands over the northwestern Siberia caused summer CH_4 peak. Higher mixing ratio than that of the coastal sites even during winter implies that unknown CH_4 source keeps the mixing ratio high. Synoptic CH_4 feature over Siberia will be clarified more using this 9-tower network and CH_4 budget calculation in continental scale will be done with the coming data in the near future.

2-18

Energy Transfer in a Breaking Internal Wave

Shoko Abe [1,2], and Tomohiro Nakamura [2]
[1] Graduate School of Environmental Science, Hokkaido University
[2] Institute of Low Temperature Science, Hokkaido University
abe-s@lowtem.hokudai.ac.jp

Strong vertical mixing in the Kuril Island Chain is one of important physical processes because it affects changes in water properties and the strength of the thermohaline circulation in the Sea of Okhotsk, which is known as an origin of North Pacific Intermediate Water. It is thought that it influences not only physical processes but also distributions of materials, such as iron, and the ecosystem in the surrounding area. It is considered that the vertical mixing in the region is caused by breaking of large-amplitude internal waves induced by the K1 tidal flow. Although the construction of realistic parameterization schemes for global circulation models, which cannot explicitly resolve such mixing, needs an understanding of the detail of the mixing, processes after breaking are unrevealed because of their nonlinearity. Therefore, to clarify the vertical mixing processes, we attempted to simulate transition from breaking of an internal wave to turbulent state using a two-dimensional non-hydrostatic model with a realistic topography, and investigate the energy transfer associated with the processes.

2-19

Iron Flux to the Northern North Pacific Estimated from the Ice Core of Mt. Wrangell, Alaska

Hirotaka Sasaki [1], Sumito Matoba [2], and Takayuki Shiraiwa [3]
[1] Graduate School of Environmental Science, Hokkaido University
[2] Institute of Low Temperature Science, Hokkaido University
[3] Research Institute for Humanity and Nature
hsasaki@pop.lowtem.hokudai.ac.jp

We measured iron concentration in an ice core (50 m) drilled in 2003 at Mt. Wrangell, Alaska which located the lee of the transport path of the Kosa. The ice core recoveres 1992 to 2003 and the iron concentration peak appeared in spring every year. These peaks may reflect the Kosa event in spring. And we calculated the iron flux of each peak, and estimated the impact to the iron concentration of the ocean. The iron flux of maximum peaks can increase the iron concentration of the ocean twice.

Introduction

The northern North Pacific Ocean is one of the High Nutrient Low Chlorophyll (HNLC) ocean areas where biological productivity is low for high nutrient. Martin (1990) hypothesized that the iron plays a key role in phytoplankton growth in these areas. Kosa is the huge dust storm that occurs in the East Asian Continent and includes the iron as basis. It is deposited into the northern North Pacific Ocean region while on a transporting through this area. To make out the iron flux that deposited from the atmosphere, we measured high resolution iron concentration of the ice core drilled at Mt. Wrangell, Alaska in 2003.

Iron concentration profile

We measured iron concentration in the ice core from 0 to 50 m. Yasunari et al. (2007) estimated that the ice core recoveres 1992 to 2003. The profile of iron concentration shows that high concentration appeared in every spring from 1992 to 2003. Especially, remarkable high concentrations were shown in 2001 and 2002 when drastic Kosa phenomena in spring were observed in Japan. Accordingly, we suggest the iron profile of the ice core reflect on the variation of the dust flux from the Asian Continent.

Iron flux from atmosphere

We calculated iron flux from the iron concentration in the ice core sample from the length and the density of the ice core sample. The iron fluxes in spring from 1992 to 2000 ranged 2.8-9.3 $mg/m^2/yr$. These values are comparable to the iron fluxes estimated by Duce and Tindale (1991), and Mahowald et al. (2003). We assume that one peak of iron concentration observed in 2001 and 2002 correspond to one Kosa event. The average of iron fluxes of each Kosa event in 2001 and 2002 was 10 $mg/m^2/yr$.

The impact to the ocean's iron concentration

Several previous works showed that dissolved rate of air-borne iron in the ocean was 2-10 %. The depth of vertical mixing layer in winter at the northern North Pacific is approximately 30 m (Nishioka personal communication). If we assumed that 2 % of airborne iron can be dissolved in surface 30 m of ocean, 0.13 nM of iron can be dissolved from 10 mg/m^2 of air-borne iron flux, and can increase the concentration of iron in ocean

twice.

References:

Duce, R. A. and N. W. Tindale (1991), Atmospheric transport of iron and its deposition in the ocean, *Limnol. Oceanogr.*, **36**, 1715-1726.

Mahowald, N. M. and Chao Luo (2003), A less dusty future? *Geophys. Res. Lett.*, **30**, 1903.

Martin, J. (1990), Glacial-Interglacial CO2 Change: The Iron Hypothesis, *Paleoceanography*, **5**, 1-13.

Sasaki, H. (2008), Iron flux to the northern North Pacific estimated from the ice core of Mt. Wrangell, Alaska, M. S. thesis., Hokkaido University, Sapporo.

Yasunari, T. J., T. Shiraiwa, S. Kanamori, Y. Fujii, M. Igarashi, K. Yamazaki, C. S. Benson and T. Hondoh (2007), Intra-annual variations in atmospheric dust and tritium in the North Pacific region detected from an ice core from Mount Wrangell, Alaska, *J. Geophys. Res.*, **112**, D10208.

2-20

Pattern Formation During Ice Crystal Growth in Pure D_2O Water

–– ISS-KIBO Experiments ––

Yoshinori Furukawa [1], Etsuro Yokoyama [2], Izumi Yoshizaki [3], Shinichi Yoda [3], Tetsuo Tanaka [3],
Taro Shimaoka [4], Takehiko Sone [5], and Toshiyuki Tomobe [6]
[1] Institute of Low Temperature Science, Hokkaido University
[2] Gakushuin University, [3] JAXA, [4] JSF, [5] JAMSS, [6] IHI Aerospace
frkw@lowtem.hokudai.ac.jp

Crystal growth experiments of ice in supercooled D_2O water were carried out in the Japan Experiment Module KIBO of the International Space Station (ISS) in the period between December 2008 and March 2009. Overview of this project and tentative results are presented.

Growth process of an ice crystal is divided in two stages. First stage is the stable-growth in which the ice crystal grows with maintaining the shape of the thin circular disk. The growth of the edge plane of an ice disk is dominantly controlled by the thermal diffusion efficiency of the latent heat released during growth, but the growth of the basal planes with flat interface is controlled by the layer-by-layer kinetics. That is, two kinds of growth planes with completely different growth mechanisms coexist in one crystal and its pattern formation is dominated by the interaction between both planes.

The discriminative properties observed during the ice crystal growth are completely different from the general mechanism of dendritic growth based on such the theoretical prediction as the classical model. Understanding the pattern formation mechanism of ice crystal will give a new perspective for studies of pattern formation and morphological instability. For the delicate properties of the ice crystal patterns, the experiments under the microgravity condition without any disturbance give the most ideal observations of pattern developments.

An experimental apparatus for ice growth experiment in ISS-KIBO, which was recognized as "Ice Crystal Cell", was developed. The apparatus was launched by the Space Shuttle flight (STS126) on 14 November 2008 (EST) and installed in the Solution Crystallization Observation Facility (SCOF) of KIBO. Experiments started on 2 December 2008 (JST) and finished on March 2009.

Dendritic pattern observed was more symmetric compared of that grown on the ground. Though the detailed analysis obtained by space experiments is in operation at the present time, the results obtained until the present are briefly summarized as follows: 1) 134 experiments were successfully repeated for various conditions of supercooling temperatures. 2) Images by two-axes interference microscopes were separately obtained and used for the analysis of 3D-patterns of ice crystals and the thermal diffusion fields around the growing crystals. 3) The symmetry breaking at the edge plane during morphological instability was not always observed for ice crystals growing in space. 4) The growth rates of basal planes were qualitatively reduced for the ice crystal growth in space.

2-21

Direct Visualization of Elementary Steps and Quasi-liquid Layers at Air-Ice Interfaces by Advanced Optical Microscopy

Gen Sazaki [1,2], Salvador Zepeda [1], Shunichi Nakatsubo [1], Etsuro Yokoyama [3], and Yoshinori Furukawa [1]
[1] Institute of Low Temperature Science, Hokkaido University
[2] JST-PRESTO
[3] Gakushuin University
sazaki@lowtem.hokudai.ac.jp

Growth and melting processes of ice crystals govern wide variety of phenomena on earth. Hence, this issue has been a subject of interest for centuries. To understand crystal growth of ice at the molecular level, one has to observe in-situ "elementary steps", which play a key role during growth and melting processes on ice crystal surfaces. However, since observation of ice crystal surfaces by scanning probe microscopy is very difficult, so far only one group has succeeded in such observation by atomic force microscopy [1]. In this study, we adopted laser confocal microscopy combined with differential interference contrast microscopy (LCM-DIM), by which elementary steps of protein crystals (3-6 nm in height) could be visualized with sufficient contrast levels [2], and tried to visualize molecular-level surface morphologies on ice crystal surfaces.

We first attempted to observe the air-ice interface, since this interface has a much larger reflectivity than water-ice interfaces. By further improving LCM-DIM and growing ice crystals of higher quality, we finally succeeded in observing ice crystal surfaces grown by the two-dimensional (2D) nucleation growth mechanism. When steps of neighboring 2D islands coalesced with each other, the contrast of steps disappeared completely. Such disappearances of the step contrasts were commonly observed all over the crystal surface confirming that we succeeded in observing elementary steps (0.37 nm in height), for the first time, by optical microscopy. We also succeeded in observing surface melting processes at air-ice interfaces. We could visualize the appearances of two types of quasi-liquid layers (bulk-liquid like drops (BLD) and thin-liquid like layers (TLL)) and growing elementary steps simultaneously on the same crystal surface.

References:
1) S. Zepeda, Ph.D. thesis, University of California Davis, 2004.
2) G. Sazaki, et al., *J. Crystal Growth*, **262**, 536-542, 2004.

2-22

Antifreeze Protein Kinetics at the Ice/Solution Interface

Salvador Zepeda [1], Hiroyuki Nakaya [1], Etsuro Yokoyama [2], and Yoshinori Furukawa [1]
[1] Institute of Low Temperature Science, Hokkaido University
[2] Gakushuin University
zepeda@lowtem.hokudai.ac.jp

Antifreeze proteins and glycoproteins help fish, plants, insects, and bacteria survive sub-freezing environments. They inhibit the growth and recrystallization of ice while radically modifying the growth shapes. It is well understood that the larger part of the effect of the proteins is a non-equilibrium phenomenon, since the melting temperature essentially remains unchanged, while the freezing temperature is lowered about 1 degree in case of the fish AFPs and up to 5 degrees in case of some insect AFPs. Through indirect evidence it was postulated that the AFPs function by binding to the ice surface to alter the surface free energy, effectively lowering the freezing temperature. The freezing temperature lowering should depend on the protein coverage and how strongly the proteins should adhere to the surface. Until recently, no measure of this coverage was available and little work studying the proteins conformational states during the freezing and melting processes.

In our lab, we focus on learning about the fundamental mechanism of the proteins functions by studying the ice crystal growth kinetics and protein kinetics at the ice interface as well as the proteins conformation in the solid and liquid states. We have labeled AFPI, AFPIII, and AFGPs, with fluorescent compounds and carried out measurements during free growth and uni-directional growth from the melt.[1-3] AFPIII are rigid globular proteins and the AFPI are an α-helical rod whereas the AFGPs are a flexible extended helix with a disacharide unit every third residue. Despite the wide range of structures and composition the proteins show nearly identical function. We see the protein coverage saturate at about a 10 nm nearest neighbor distance on the ice surface and interestingly this value is the same at different solution concentrations. This value is orders of magnitude greater than that predicted by previous models. However, at the surface only the AFPIII bind strongly enough to become trapped in the ice crystal matrix, whereas the AFPI and AFGP are rejected entirely rejected from the crystal even at the slowest growth rates studied.

In supercooled solutions the AFGP becomes significantly more ordered and gradually relaxes to the solution state conformation upon heating. This gradual loosening of the structure directly correlates with the thickening of the quasi-liquid layer (QLL) found on the ice surface. Additionally, the thickness of the QLL increases up to 3-fold when the AFGP are present compared to pure water ice. This indicates that the proteins interaction may vary quite dramatically even over the small temperature ranges usually studied.

References:

1. Zepeda, S.; Uda, Y.; Yokoyama, E.; Furukawa, Y.,. In *Physics and Chemistry of Ice*, Kuhs, W., Ed. Royal Society of Chemistry: Cambridge, 2007.
2. Zepeda, S.; Yokoyama, E.; Uda, Y.; Katagiri, C.; *Cryst. Growth Des.* **2008**, 8, (10), 3666-3672.
3. Uda, Y.; Zepeda, S.; Kaneko, F.; Matsuura, Y.; Furukawa, Y., *J. Phys. Chem. B* **2007**, 111, (51), 14355-14361.

2-23

Steady-state Simulations of the Greenland Ice Sheet Using a Three-Dimensional Full-Stokes Model

Hakime Seddik [1], Ralf Greve [1], Thomas Zwinger [2], and Olivier Gagliardini [3]
[1] Institute of Low Temperature Science, Hokkaido University
[2] CSC – IT Center for Science Ltd.
[3] Laboratory of Glaciology and Environmental Geophysics, CNRS
hakime@lowtem.hokudai.ac.jp

A three-dimensional, thermo-mechanically coupled model is applied to the Greenland ice sheet. The model implements the full-Stokes equations for the ice dynamics, and the system is solved with the finite-element method (FEM) using the open source multi-physics package Elmer (http://www.csc.fi/elmer/).

The finite-element mesh for the computational domain has been created using the Greenland surface and bedrock DEM data with a spatial resolution of 10 km. The study is particularly aimed at better understanding the ice dynamics near the major Greenland ice streams. For this purpose, mesh refinement to obtain improved computed solutions on these areas has been introduced. The meshing procedure starts with the bedrock footprint where a mesh with triangle elements and a resolution of 5 km are employed at the vicinities of the North-East Greenland Ice Stream (NEGIS) and the Jakobshavn (JIS), Kangerdlugssuaq (KL) and Helheim (HH) ice streams. A size function is then applied so that the mesh resolution becomes coarser away of the ice streams up to a maximum horizontal element size of 20 km. The final three-dimensional mesh is obtained by extruding the 2D footprint with 10 vertical layers, so that the resulting mesh contains 118944 prism elements and 69170 nodes.

The numerical solution of the Stokes and the heat transfer equations involves direct and iterative solvers depending on the simulation case, and both methods are coupled with stabilization procedures. The boundary conditions are such that the temperature at the surface is parameterized as a function of the latitude and the surface elevation, the geothermal heat flux at the bedrock is prescribed as spatially constant and the lateral sides are open boundaries.

The simulations have been conducted in order to obtain steady-state results for the velocity and temperature fields for the entire ice sheet. The model computes the results with both bedrock sliding and melting used alternatively so that their effects on velocities and temperature are assessed separately. The results are also compared with a shallow-ice approximation model. The project goal is to better assess the effects of dynamical changes of the Greenland ice sheet on sea level rise under global-warming conditions.

2-24

Modelling Flow Dynamics and Geometry of the Austfonna Ice Cap, Svalbard

Thorben Dunse [1,2], Thomas V. Schuler [1] , Jon Ove Hagen [1], Ralf Greve [2], Geir Moholdt [1], and Trond Eiken [1]
[1] Department of Geosciences, University of Oslo
[2] Institute of Low Temperature Science, Hokkaido University
thorben.dunse@geo.uio.no

The Austfonna ice cap covers an area of 8120 km^2 and is by far the largest glacier on Svalbard. Almost 30% of the entire area is grounded below sea-level, while the figure is as large as 57% for the known surge-type basins in particular. Marine ice dynamics, as well as flow instabilities presumably control flow regime, form and evolution of Austfonna. During the past few decades, most drainage basins of Austfonna have experienced retreat and thinning of the ice margins and thickening at higher elevations in the interior. There is, however, considerable uncertainty to which extent these changes are driven by surface processes (accumulation and ablation) or ice dynamics (possible build up towards surge activity).

To better understand the behaviour of the ice cap, we complement ongoing glacier observations with numerical modelling. We employ the thermodynamic, large-scale ice sheet model SICOPOLIS (http://sicopolis.greveweb.net/) which is based on the shallow-ice approximation. We test if the observed overall flow regime of the ice cap can be reproduced by the model.

Space-borne interferometric snapshots of Austfonna revealed a velocity structure of a slow moving polar ice cap (< 10 m/a) interrupted by distinct fast flow units with velocities in excess of 100 m/a. However, observations of flow variability are scarce. In spring 2008, we established a series of stakes along the centrelines of two fast-flowing units. Repeated DGPS and continuous GPS measurements of the stake positions give insight in the temporal flow variability of these units and provide constrains to the modeled surface velocity field.

Austfonna's thermal structure is described as polythermal. However, direct measurements of the temperature distribution is available only from one single borehole at the summit area. The vertical temperature profile shows that the bulk of the 567 m thick ice column is cold, only underlain by a thin temperate basal layer of approximately 20 m. To acquire a spatially extended picture of the thermal structure (and bed topography), we used low-frequency (20 MHz) GPR profiling across the ice cap and the particular flow units. The measurements indicate that the gross volume of Austfonna is cold. This observation is supported by model results which suggest that regional fast flow occurs despite the lack of considerable temperate-ice volumes. This in turn indicates that fast flow is accomplished exclusively by basal motion in regions where the glacier base is at pressure-melting conditions, and not by enhanced deformation of considerable volumes of temperate ice.

2-25

Impact of Proglacial Lake Formation on the Retreat of Rhonegletscher, Switzerland

Shun Tsutaki [1,2], Daisuke Nishimura [1,2], Takeshi Yoshizawa [1,2], and Shin Sugiyama [1]
[1] Institute of Low Temperature Science, Hokkaido University
[2] Graduate School of Environmental Science, Hokkaido University
tsuta@lowtem.hokudai.ac.jp

After the retreat of Rhonegletscher over a bedrock ridge, a proglacial lake has been forming at the glacier forefront since 2005. The lake and the glacier draw glaciological attention because the retreat may be accelerated by calving into the lake. To investigate the impact of the lake formation on the glacier, field measurements have been carried out at the terminal part of Rhonegletscher from 2007 to 2009. The measurements aimed to understand the mechanism of the ice motion of Rhonegletscher and its change under the influence of the lake water. The goal of the project is to predict the retreat of Rhonegletscher in the next decades.

Using the technique of hot water drilling, more than 50 boreholes were drilled down to the bed and used for subglacial and englacial measurements. Near the glacier terminus, borehole inclinometry together with surface flow speed measurements showed that the glacier motion was principally due to subglacial flow processes, i.e. basal sliding and subglacial sediment deformation. Borehole camera observations at glacier bed confirmed that the glacier was partly underlain by a 200-300 mm thick sediment layer, and the deformation this layer dominated the glacier motion at the bed. On the other hand, sliding over bedrock was also observed in other boreholes, suggesting that the subglacial flow processes are inhomogeneous. Therefore, the influence of the lake water on the glacier dynamics should be examined under the consideration of basal conditions. Water levels in the boreholes were at the level of the lake surface in the region as far as 300 m from the terminus, which indicates the subglacial water pressure was directly controlled by the lake water. Continuous survey of stakes installed near the terminus revealed upward ice motion immediately after the borehole water level exceeded the ice flotation level. This measurement suggests that the glacier terminus is going to get afloat as a result of thinning of the ice due to surface melting and imbalance of ice flux. The rate of ice thickness change was determined as 2.8 m a^{-1} for the period from 2000 to 2007. This result indicates that glacier thinning has accelerated in the 21st century, probably because of the recent warming climate and the formation of the lake.

2-26

Constituent Elements of Soluble Particles of the Dome Fuji Surface Snow and Ice Core

Yoshinori Iizuka [1], Akira Tsuchimoto [1], Toshimitsu Sakurai [1], Motohiro Hirabayashi [2], Toshitaka Suzuki [3], Takayuki Miyake [2], Ryu Uemura [4], Shuji Fujita [2], Hideaki Motoyama [2], Yoshiyuki Fujii [2], and Takeo Hondoh [1]

[1] Institute of Low Temperature Science, Hokkaido University
[2] National Institute of Polar Research
[3] Faculty of Science, Yamagata University
[4] LSCE, CEA-CNRS, France
iizuka@lowtem.hokudai.ac.jp

The polar ice cores preserve aerosols in the past atmosphere. As concern with soluble aerosols, most studies have been discussed ion fluxes by the melting of the ice cores using ion chromatography or continuous flow analysis. However, the chemical compounds of the soluble aerosols being studied were unclear, due to the ionization of the aerosols being caused by the melting.

We identified several soluble salts (aerosols) in Dome Fuji (DF) ice core by using Raman spectroscopy. Raman spectroscopy helped identify soluble inclusions, and provides the chemical forms of several tens inclusions per ice sample. However, it is difficult to compare data on solid inclusions compounds with the number density of dust particles or ion concentrations in a statistically meaningful way. So, we have designed a sublimating system that operates at –50 °C, below the eutectic temperatures of major salts. This system permits us to obtain a great many nonvolatile particles. We thereby analyzed, by using SEM-EDS, a total of more than 30,000 nonvolatile particles taken from through surface snow (MIS1) to MIS17 ice in the DF. Our results indicate that sodium sulfate is major soluble aerosol in the interglacial ice; sodium sulfate in the early-glacial ice; calcium sulfate and sodium chloride in the late-glacial ice. We will discuss mainly three topics for the aerosol composition at the meeting; first, post-depositional effect of sodium sulfate formation from sodium chloride and sulfuric acid in the surface snow; second, tracing the history of major aerosol compositions during the glacial/interglacial cycles; third, proposing sea salt origin between open sea and sea ice derived from the ratio of magnesium and sodium chlorides.

Formation of Deuterated Formaldehyde and Methanol by Quantum Tunneling H-D Substitution and H(D) Addition Reactions on Low Temperature Surfaces

H. Hidaka, M. Watanabe, A. Kouchi, and N. Watanabe
Institute of Low Temperature Science, Hokkaido University
hidaka@lowtem.hokudai.ac.jp

The chemical reactions on the low temperature solid surface are one of the great interests in physics and chemistry. Especially in the reactions involving light particles such as hydrogen atoms, quantum mechanical tunneling reaction is relatively enhanced when compared to thermally activated reaction. In astrophysics, the tunneling reactions on the cold solid surfaces are key processes for the chemical evolution in cold regions of molecular clouds.

High-gas phase abundances of deuterated formaldehyde (formaldehyde-*d*) and methanol (methanol-*d*) have been observed in molecular clouds [1]. Although the cosmic abundance of deuterium is quite low (D/H~10^{-5}) [2], deuterium enrichment in various molecules (e.g. D_2CO/H_2CO, CHD_2OH/CH_3OH) has been reported to be several percent. This enrichment cannot be achieved by pure-gas phase chemical network model in space. The developments of gas-grain (surface) models are still desirable, especially to account further formation mechanisms (routes) for deuterated molecules on the grain surfaces. In this study, formation routes of formaldehyde-*d* and methanol-*d* are investigated by the D and H atoms exposure of solid H_2CO and D_2CO on amorphous solid water (ASW) at 15 K, respectively.

For D + H_2CO on ASW, H_2CO was converted to HDCO and D_2CO by the H-D substitution reactions, and CD_3OD was slightly formed by the subsequent D atoms addition to D_2CO. Doubly- and triply-deuterated methanol, CH_2DOD and CHD_2OD, were not observed, indicating that D atoms addition to H_2CO and HDCO are much slower than the H-D substitution reactions. Thus the H-D substitution reaction in formaldehyde ($H_2CO \rightarrow HDCO \rightarrow D_2CO$) is dominant reaction route. For H + D_2CO on ASW, the conversions of D_2CO to H_2CO proceeded though HDCO, and CH_3OH was produced by the H atoms addition reactions to H_2CO. The doubly-deuterated methanol, CHD_2OH, which was formed by the successive hydrogenation of D_2CO, was observed significantly. In contrast to D + H_2CO, the methanol formation is efficient and is competitive to the D-H substitution reaction. Therefore, the dominant routes are found to be $D_2CO \rightarrow HDCO \rightarrow H_2CO \rightarrow CH_3OH$ and $D_2CO \rightarrow CHD_2OH$. The asymmetry property in reaction routes between both reaction systems could be understood by the potential tunneling model.

References

[1]L. Loinard et al., *Planet Space Sci*. **50**, 125 (2002).
[2]J. L. Linsky, *Space Sci. Rev.* **84**, 285 (1998).

Antarctic Science Curriculum of Hokkaido University

-– Contribution to the International Antarctic Institute -–

Manabu Fukui [1], Shin Sugiyama [1], Shigeru Aoki [1], Masanobu Yamamoto [2], Takenobu Toyota [1], Takanobu Sawagaki [2], Genta Mizuta [2], Keiichiro Ohshima [1], Yasushi Fukamachi [1], Sumito Matoba [1], Kou Shimoyama [1], Yoshinori Iizuka [1], and Tomoko Endo [1]

[1] Institute of Low Temperature Science, Hokkaido University

[2] Faculty of Environmental Earth Science, Hokkaido University

iai@lowtem.hokudai.ac.jp

The international Antarctic Institute (IAI) is an international program of education in cryosphere science. IAI aims to offer international standard education programs at undergraduate and graduate level with a special emphasis on Antarctic and cryosphere sciences. The universities and institutions share their curriculums within the framework of IAI partnership so that the students are able to take lectures and courses internationally. As a member of this partnership, the Graduate School of Environmental Science, Hokkaido University, has launched a new program, the Antarctic Science Curriculum. This unique program offers graduate students an opportunity to study a broad field of polar sciences, including ocean and atmospheric processes in polar regions, ice and snow sciences, glaciers, sea ice, permafrost, and global environmental changes. The curriculum consists of special lectures given by polar scientists from IAI partner institutions, field courses held on Swiss glaciers and at Lake Saroma, and additional lectures offered by the staff of the graduate school. Those who complete the program will be awarded a Diploma of Antarctic Science, independently of the master's degrees and doctorates. The diploma certifies that the student has acquired special knowledge and experience in polar science. Further cooperation with IAI partners will strongly merit in enhancing understanding for cryospheric and global environments.

2-29

Technical Supports in ILTS

Kunio Shinbori, Toru Takatsuka, Shunichi Nakatsubo, Takeshi Chigai, Kazuya Ono, Yukako Kato, Kenta Chubachi, Kazuyuki Fujita, Masao Ishikawa, Hiroki Fukushi, Masayuki Ikeda, and Naoto Ebuchi
Institute of Low Temperature Science, Hokkaido University
naka-tech@lowtem.hokudai.ac.jp

Technical supports in various research fields by the Technical Services Section of the Institute of Low Temperature Science, Hokkaido University, are introduced. Technical staffs in the Section 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. Some members participate in expeditions to Arctic, Antarctic, and Pan-Okhotsk regions, successfully carrying out the technical supports. This section technically contributes to several ILTS research projects. Outstanding technical developments and contributions in recent years include developments of ice-core drills and ice-core drilling at the Dome Fuji Station in Antarctica, developments of equipments for ice crystal growth experiments under microgravity in the space station, operation of high-frequency ocean radar system and monitoring of the Soya Warm Current in the Sea of Okhotsk, development of an automated platform for meteorological, oceanographic and sea-ice observations, and building a precise clock-synchronize system using GPS on research vessels. The Technical Services Section is composed of three shops; Equipment Development, Advanced Technical Support, and Facility Maintenance. The Equipment Development Shop is responsible for design and production of experimental and observational equipments. The Advanced Technical Shop is responsible for design and production of electric instruments, supports of biochemical analyses and ocean modeling. The Facility Maintenance Shop maintains the low temperature rooms and air-conditioning.

Session 3. Water and Material Cycles

3-1

Cause of the Unprecedented Freezing Disaster in January 2008 and its Possible Association with the Global Warming

Ding Yihui, Wang Zunya, and Song Yafang
National Climate Center, China Meteorological Administration
dingyh@cma.gov.cn

Under the condition of global warming, the frequency of cold waves coming from Siberia has been decreasing during last 50 years and China has experienced 21 significant warm winters (Dec.-Feb.) since 1986. However, in the context of warmer climate, outbreaks of very intense cold waves can be also observed and they rapidly intruded into China, thus leading to great low temperature injury and snow /frozen rains disaster. The winters of 2004/2005 and 2007/2008 were exemplified as extreme strong and prolonged cold waves in China. The present study has made a detailed analysis of the latter case to show whether or not the unusual cold waves could affect or change the trend of global or regional warming.

The unprecedented disaster of low temperature, rain and snow and ice freezing in 2008 January in the Yangtze River basin and South China is not local or regional event, but a part of chain events of large-scale low temperature and snow storms in the same period in Asia. Its severity and impacts were most significant in South China among them, characterized by three major features: (1) co-existence of snowfall, freezing rains and rainfalls, with freezing rains being the dominant factor responsible for this disaster; (2) extreme great intensity of above weather phenomena, with record-breaking meteorological elements based on statistics made by China National Climate Center and provincial Meteorological services in the Yangtze River basin and South China; (3) very long persistence of disastrous weathers, with most of them breaking historical records.

The causes responsible for this event are not single one, but cooperative and superimposed consequences of multiple factors. Among them, the La Nina event is its climate background, which provided the prerequisite condition of invasion of cold airs in South China; anomalously stable atmospheric circulation features in Eurasia is the direct cause responsible for invasions of 4 processes of cold air in South China, and the northward transport of warm and moist airflows coming from the Bay of Bengal and the South China Sea is the necessary condition of formation of freezing rains and snow storms and their prolonged occurrence in the southern part of China.

A preliminary discussion of possible association of this disastrous event with the global warming is presented. This event may be viewed as a short-term, regional perturbation for the global warming trend, without any possibility of diverting the long-term trend and global pattern of the global warming.

Finally, the present paper has also made a comparison of major similarities and difference of extreme cold events between cold and warm climates during recent 50 years, in order to gain a better insight of global warming on extreme cold events in China.

3-2

Data Integration and Analysis System for Water Cycle

Toshio Koike
The University of Tokyo
tkoike@hydra.t.u-tokyo.ac.jp

Water-related hazards usually occur as causes and consequences of large energy and water cycle fluctuations on global and regional scales, while disasters and damages due to the hazards happen through strong linkage with human activities on a local scale. The observations and predictions of the water-related hazards and their damages can be enhanced by combining global Earth observation and prediction systems and local information. By making maximum use of the opportunities of global observations and predictions provided by the Coordinated Energy and Water Cycle Observations Project (CEOP), this paper develops an data integration system, CEOP-DIS, that converts global Earth observation data and prediction outputs to usable information for sound decision making in flood control on a river basin or smaller scale. CEOP provides in-situ reference site observation data, satellite observation data, numerical weather prediction model outputs. The CEOP-DIS consists of four components: satellite remote sensing, data assimilation, hydrological modelling and decision making support tools. CEOP-DIS is now being developed on the GEOSS Data Integration and Analysis System (DIAS).

Satellite-based microwave remote sensing is an effective method for collecting global information on land surface hydrology. Soil moisture, water content in vegetation, snow and permafrost can be monitored effectively by the passive microwave sensors. In addition, they are effectively combined with visible-infrared sensor data for getting integrated products. The CEOP reference site data sets can improve the algorithms as well as validate the accuracy of the product.

A land data assimilation system was developed at the University of Tokyo (LDAS-UT) by employing Simple Biosphere Model (SiB2) as the dynamic model to calculate surface fluxes and soil moisture, a radiative transfer model (RTM) as the observation operator to estimate microwave brightness temperature, and several optimization schemes. The passive microwave remote sensing data observed by the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) and the model located time series (MOLTS) archived CEOP are used for applying the LDAS-UT. The assimilated results are validated by the CEOP reference site data. A satellite-based cloud microphysics data assimilation system (CIMDAS) was developed by coupling a cloud microphysics scheme embedded in the advanced regional prediction system (ARPS), a physically based land-atmosphere coupled radiative transfer model, and several optimization schemes. CIMDAS was applied to the National Centers for Environmental Prediction global forecast system reanalysis data and AMSR-E archived in CEOP, for downscaling from a global scale to a meso-scale area by introducing more accurate initial condition.

CEOP-DIS includes an integrated distributed hydrological model, WEB-DHM, which couples a realistic land surface model, the widely used SiB2, with a geomorphology-based hydrological model. The results of application of the WEB-DHM to the Little Washita river basin in USA and the upper Tone river basin of Japan, using the digital elevation model show good performance in simulating floods, including those after periods of

low water flow, soil moisture, surface temperature and fluxes. This means the WEB-DHM can provide reasonable initial conditions by itself for the flood prediction after long-term low water flow. Challenges on application of WEB-DHM to cold regions are now on-going.

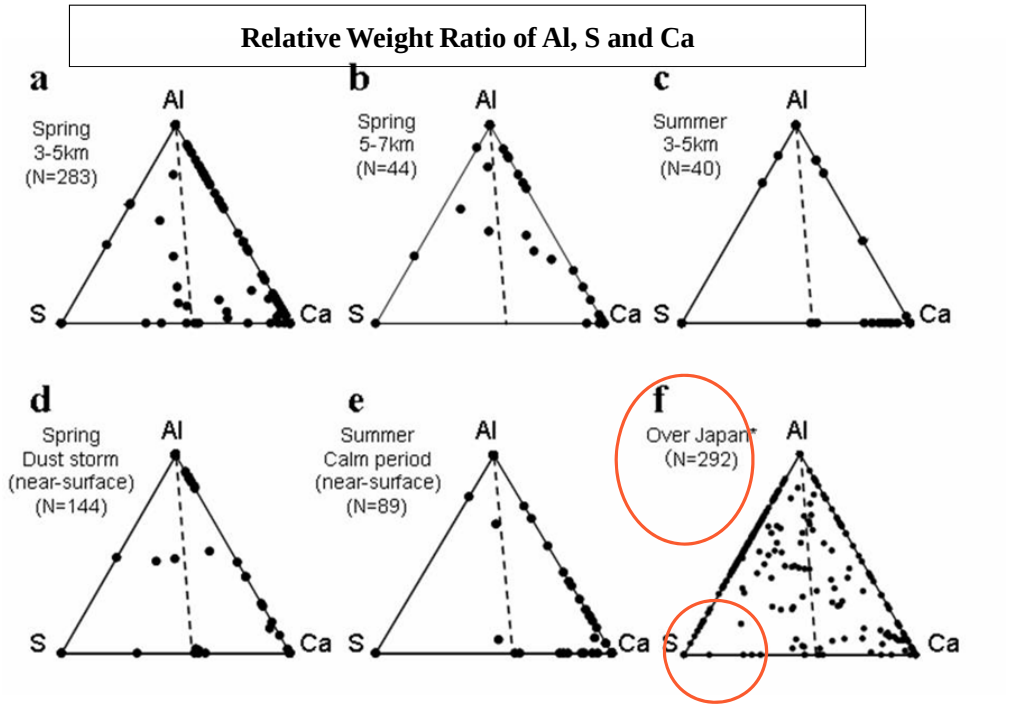
3-3

Kosa (Asian Dust) Particles and Atmospheric Constituents on Particle Surface

Yasunobu Iwasaka
Frontier Science Organization, Kanazawa University
kosa@t.kanazawa-u.ac.jp

Kosa particles have been recognized as an important constituent characterizing air quality in North-East Asia. The particles are transported long-range by westerly and various atmospheric constituents make interesting reactions on the particle surface during the long-range transport of KOSA. Anthropogenic constituents emitted from the coast areas of China land frequently deposit on the particle surface and react with particle materials. Balloon-borne and aircraft borne measurements strongly suggested that sulfur dioxide gas reacts with KOSA materials and sulfate were produced on the surface (Figure). Air masses from the arid region meet not only polluted air but also the air with high humidity, and atmospheric water seems to be important factor activating the surface reactions.

More recently KOSA has been suggested as carrier of not only pollutants but also micro-organisms, and mixture of KOSA and micro-organisms attracts great concern from view point of cloud physics since those particles can act as extremely active ice nuclei. East China Sea and Japan Sea have been known as strong sources of water vapor and the high humidity possibly affect KOSA surface reactions, activities of micro-biota on particle surface during KOSA particle long-range transport. Therefore it can be said that long-range transport of KOSA particles strongly link with water cycle of north-east Asia.



3-4

Isotopomer Studies to Trace Water and Material Cycles Featuring Some Extreme Environments

Naohiro Yoshida
Dept. of Environmental Science and Technology, also Dept. of Environmental Chemistry and Engineering, and Global COE Research Center for the Evolving Earth and Planets, Tokyo Institute of Technology
yoshida.n.aa@m.titech.ac.jp

The Earth's environment when the life was born was a severest one without oxygen and ozone which protects life from UV flux. The life evolved and modified the Earth's environment more habitable. Material cycle on the Earth's surface has been modified from the abiotic to biotic domination. There have been several severe events in a global scale and life survived. I have worked on material cycle analysis from the early Earth to the present day global change to better understand the relationship between the Earth's environment and the life. Some examples of these will be discussed featuring the background of isotopomers (isotope containing molecules) and their applications for material cycles in the fields from the earth and planetary, environment, to biological metabolisms.

Methanogenic microbes may be one of the most primitive organisms, though it is uncertain when methanogens first appeared on Earth. During the Archaean, methanogens may have played an important role in regulating climate, because they could have provided sufficient amount of greenhouse gas, CH_4 for avoiding a severely frozen condition due to the lower solar luminosity and methane has been important in controlling both the surface temperature and atmospheric chemistry of the Earth. Nevertheless, no direct geological evidence has been available in favor of the existence of methanogens in the Archaean period, except for circumstantial evidence from the ~2.8-Gyr-old ^{13}C-depleted kerogen. We (Ueno et al., 2006) have performed crushing extraction and carbon isotope analysis of CH_4-bearing fluid inclusions in ~3.5-Gyr-old hydrothermal precipitates from Pilbara Craton, Australia. The results indicate that the extracted fluids contain microbial CH_4 with carbon isotopic compositions of less than –56‰ that was entrapped in original precipitates. This provides the oldest evidence of methanogen (>3.46 Gyr ago), which predates previous geochemical evidence by approximately 700 million years.

Photolysis of SO_2 is believed to be responsible for Mass Independent Fractionation (MIF) of sulfur isotopes observed in stratospheric aerosol and in minerals deposited before 2.3 billion years ago. In order to simulate the photochemical MIF, we (Danielache et al., 2008) obtained high-resolution UV absorption spectra of isotopomers of SO_2 ($^{32}SO_2$, $^{33}SO_2$ and $^{34}SO_2$) and calculated wavelength dependence of $^{34}S/^{32}S$ and $^{33}S/^{32}S$ fractionation factors. The fractionation factors both for $d^{34}S$ and $D^{33}S$ are very sensitive to wavelength, which implies that single line photolysis by artificial laser UV causes MIF, but should not be directly applied to atmospheric environment, in which solar irradiation has broad UV spectrum. We then calculated MIF effect resulted from solar UV as a function of overhead column densities of O_2, O_3, CO_2, H_2O and SO_2 itself. SO_2 dissociation by solar irradiation causes significant MIF. Assuming 190-220 nm photolysis of SO_2 is responsible for the MIF, our calculation also suggests that aerosol sulfate may have positive $D^{33}S$ anomaly under O_2-free condition even if including self-shielding effect. This is inconsistent with the inferred negative $D^{33}S$ of Archean

sulfate aerosol. The Archean MIF reaction pathways should have been more related to the atmospheric chemistry (Ueno et al., 2009). This finding is also applicable to the present day MIF and its implications for the present atmospheric chemistry.

References:

Danielache, S. O., C. Eskebjerg, M. S. Johnson, Y. Ueno, and N. Yoshida (2008), High-precision spectroscopy of ^{32}S, ^{33}S, and ^{34}S sulfur dioxide: Ultraviolet absorption cross sections and isotope effects, **J. Geophys. Res., 113**, D17314, doi:10.1029/2007JD009695.

Ueno, Y., K. Yamada, N. Yoshida, S. Maruyama, and Y. Isozaki (2006), Evidence from fluid inclusions for microbial methanogenesis in the early Archaean era, **Nature, 440**, 516-519.

Ueno, Y., M. S. Johnson, S. O. Danielache, C. Eskebjerg, A. Pandey, N. Yoshida (2009), Geological sulfur isotopes indicate elevated OCS in the Archean atmosphere, solving faint young sun paradox, **Proceedings of the National Academy of Science**, doi:10.1073:pnas.0903518106.

3-5

Why Cloud Science?

Yasushi Fujiyoshi
Institute of Low Temperature Science, Hokkaido University
fujiyo@lowtem.hokudai.ac.jp

Clouds are the most familiar aspect of our atmospheric environment. Followings are the manifest of the Cloud Appreciation Society (http://www.cloudappreciationsociety.org/, my membership number is 9042).

@We believe that clouds are unjustly maligned and that life would be immeasurably poorer without them.
@We think that they are Nature's poetry, and the most egalitarian of her displays, since everyone can have a fantastic view of them.
@We pledge to fight 'blue-sky thinking' wherever we find it. Life would be dull if we had to look up at cloudless monotony day after day.
@We seek to remind people that clouds are expressions of the atmosphere's moods, and can be read like those of a person's countenance.
@Clouds are so commonplace that their beauty is often overlooked. They are for dreamers and their contemplation benefits the soul. Indeed, all who consider the shapes they see in them will save on psychoanalysis bills.

And so we say to all who'll listen: *Look up, marvel at the ephemeral beauty, and live life with your head in the clouds!*

Clouds play a significant role in determining the radiation budget of the earth and serve as an important link in the water and material cycles. The role of clouds is very large in the high latitude or polar region. In the prediction of surface temperature due to increased carbon dioxide using climate models, a temperature variation of two or three times the average of the entire earth has been predicted in the polar region. What kinds of clouds they are, how high they are distributed, and how much snowfall they bring are big questions for growth and decay of sea ice. Impacts of diamond dust on radiation and water budgets at polar regions are also significant.

Aerosol direct effect can be evaluated by knowing the increase of optical thickness of man-made aerosols. Conversely for indirect effect, phenomenon itself is not well known because the modification mechanism of clouds is very complicated. The role of clouds can switch from heating to cooling, depending on the altitude of clouds, how many layers the clouds have, and vertical distribution of detailed physical quantity, such as cloud particle distribution, and difference between water and ice.

The aerosol-cloud interaction is not enough to evaluate aerosol indirect effect. Vertical and horizontal air-motion, that is, the wind is the key factor that connects water and material cycles. Water vapour evaporated from ground and sea surfaces is carried away by the wind, condenses to form clouds at various altitudes, and returns to the earth's surface as rain or snow. The speed of water cycle in the atmosphere depends on the ratio between the amount of cloud water (liquid and ice) and that of rain or snow, and on the rate at which cloud particles change into rain or snow in clouds. Understanding temporal change of three dimensional structure of wind fields is an

extremely important subject to study transportation and mixing of many materials (e.g., water vapour, aerosols, gaseous components, insects, bacteria etc.).

Therefore, Cloud Science whose research topics cover the interactions between air-sea, -land surface, -snow/ice, -topography, -ecosystem, and -culture is indispensable to study water and material cycles.

Session 4. Pan Okhotsk Researches

Decadal Variability in the North Pacific Subpolar Gyre Circulations

Bo Qiu
School of Ocean & Earth Science & Technology, University of Hawaii at Manoa
bo@soest.hawaii.edu

Large-scale ocean circulation changes in the subpolar gyre of the North Pacific Ocean are investigated using satellite altimetry data of the past 17 years. Our particular interests are on the three broad-scale current systems: the North Pacific Current (NPC), the Alaska Gyre, and the Western Subarctic Gyre (WSG). To facilitate the understanding of the observed changes, we adopted a two-layer ocean model that includes first-mode baroclinic Rossby wave dynamics and time-dependent barotropic Sverdrup dynamics. The NPC intensified steadily over the period of 1992 to 1999 and its strength modulated on the interanual timescales in the recent decade. Much of this intensification/modulation is due to the SSH fluctuations on the northern side of the NPC. Similar SSH changes are also found in the interior of the Alaska Gyre. Both of these SSH changes are shown to be the result of surface wind stress curl forcing related to the Pacific decadal oscillations (PDOs) and accumulated along the baroclinic Rossby wave characteristics initiated from the eastern boundary. The WSG changed interannually from a zonally elongated gyre in 1993-1995 to a zonally more contracted gyre in 1997-1999. It remained in the latter, weakened state over the past 10 years. The structural change of the WSG is due to the decadal SSH anomalies within the WSG as a result of the baroclinic Rossby wave adjustment attenuated by eddy dissipation. Along the western boundary of the subpolar North Pacific, variability of the East Kamchatka Current (EKC) and Oyashio is in balance with that of the interior Sverdrup flow on the annual and year-to-year time scales. On the decadal time scales, the EKC/Oyashio variability is determined by the baroclinic incoming SSH signals.

4-2

50-year Records of Climate Changes in Ice-cores from Kamchatka and Alaska

Sumito Matoba
Institute of Low Temperature Science, Hokkaido University
matoba@lowtem.hokudai.ac.jp

Ice-core from polar glaciers and ice sheets is one of the most important archives of paleo-environmental information. Ice-core drillings were started in 1960s at the ice-sheet in Greenland and Antarctic. The ice-core studies contributed innovated knowledge to clarification of paleo-environmental variations in Quaternary, such as Dansgaard-Oeschger Cycle, increase of greenhouse gases concentrations, and so on (e.g. Dansgaard et al, 1993). Ice-core studies from mountain glacier were started in 1970s. Thompson and others carried out glaciological expedition and ice-core drilling at Qelkaya glacier in Peru, and demonstrated the fact that to reconstruct obvious paleo-climate record from the mountain glacier in tropical region (Thompson et al, 1984).

We have obtained several ice-cores from Kamchatka and Alaska, where is the most backward region in the world in terms of ice-core studies in mid and low latitude, since 1998 (e.g. Shiraiwa et al., 2004; Matoba et al., 2006). Our analyses of the ice-core from the summit of Mount Ichinsky (55.6°N, 157.7°, 3600 m a.s.l) in Kamchatka indicate the following. 1) Neither dD profile nor stratigraphy of the ice-core indicates signals of significant global warming. 2) The increase of percentages of ice layer from 1950s to 1960s reflects the increase of the amount of solar radiation in summer time since increase of air temperature was not observed at any meteorological stations in Kamchatka. 3) We assume that the remarkable negative peaks of δD from 1960s to 1970s were formed by not only low temperature in winter but also by changes of moisture source caused by expansion of sea ice area at the Sea of Okhotsk in winter. From this point of view, high frequency of appearances of negative peak of δD from 1960s to 1970s shows production of sea ice was relative higher. In Alaskan side, δD profile in ice-core from the summit of Mount Wrangell (62°N, 144°W, 4000m a.s.l.) did not show a signal of significant global warming. On the other hand, bore-hole temperature profile of Aurora Peak glacier (63.5°N, 146.5°W, 3070m a.s.l.) indicates recent warming.

References:

Dansgaard, W., Johnsen, S.J., Clausen, H.B., Dahl-Jensen, D., Gundestrup, N.S., Hammer, C.U., Hvidberg, C.S., Steffensen, P.S., Sveinbjornsdottir, A.E., Jouzel, J. and Bond, G. (1993) Evidence for general instability of past climate from a 250-kyr ice-core record, Nature, 364(6434), 218-220.

Matoba, S., S. V. Ushakov, K. Shimbori, H. Sasaki, T. Yamasaki, A. A. Ovshannikov, A. G. Manevich, T. M. Zhideleeva, S. Kutuzov, Y. D. Muravyev, and T. Shiraiwa. 2007. The glaciological expedition to Mount Ichinsky, Kamchatka, Russaia. Bulletin of Glaciological Research, 24, 79-85.

Shiraiwa, T., Kanamori, S., Benson, C.S., Solie, D. and Muravyev, Y.D. (2004) Shallow ice-core drilling at Mount Wrangell, Alaska, Bulletin of Glaciological Reaserch, 21, 71-77.

Thompson, L.G., Mosley-Thompson, E., Arnao, B. M. (1984) El Nino-Southern Oscillation events recorded in the stratigraphy of the Tropical Quelccaya Ice Cap, Peru, Science, 226, 4670, 50-53.

4-3

Large Changes in Seasonal Sea Ice, Sea Surface Temperature and Productivity in the Sea of Okhotsk during the Last Deglaciation

Osamu Seki
Institute of Low Temperature Sciences, Hokkaido University
seki@pop.lowtem.hokudai.ac.jp

Changes in the senvironment of the central Sea of Okhotsk were reconstructed using multiple biomarkers in order to investigate paleoenvironmental changes during the glacial-interglacial cycles. The alkenones, $CaCO_3$, and biogenic opal records indicate that the dominant phytoplankton species during deglaciation was the coccolithophorid, which was replaced by diatoms in the late Holocene. The TEX_{86} temperature records reveal ~3 ºC lower summer SST during glacial maxima than during interglacial periods and significant warming during the deglaciations (15-10 ka and 136-130 ka). This is consistent with previous inferences of more expanded and persistent seasonal sea ice during the glacial periods than the present day and its substantial retreat during the deglaciation. Timing of the deglacial warming also coincided with a distinct increase in coccolithophorid productivity indicated by $CaCO_3$ and alkenone records, suggesting a causal relationship between sea surface warming and coccolithophorid blooms during the deglaciations. As for terrestrial paleoclimate, hydrogen isotopic compositions of *n*-alkanes in peat core taken from the northeast China indicate that lake water levels reached their maxima during the deglacial period, suggesting high effective precipitation in Amu River basin. The relationship could reflect an increase in the supply of fresh and warm water from the Amur River during deglaciation, which significantly impacted hydrology by facilitating sea surface stratification, which in turn promoted production of coccolithophids. The last deglaciation is also characterized by remarkable increases in terrestrial organic matter input. This finding was interpreted by the outflow of terrestrial organic matter from the submerged land shelf to the Sea of Okhotsk through the East Sakhalin Current.

4-4

Modeling the Pan-Okhotsk Region

Tomohiro Nakamura
Institute of Low Temperature Science, Hokkaido University
nakamura@lowtem.hokudai.ac.jp

The Okhotsk Sea and the surrounding area are called as the Pan-Okhotsk region. This area affects the climate in Japan through the formation of the Okhotsk high in summer and the Siberian high in winter, for example. Further, outbreaks of cold air from the Siberian High cause a large amount of sea ice production in the Okhotsk Sea. During the ice formation, the rejection of salt from seawater and cooling by cold air produce dense water, which subsequently spreads in the intermediate layer of the Okhotsk Sea and the North Pacific Ocean. This dense water formation, together with tidal mixing in the Kuril Straits, induces significant heat and freshwater fluxes and carries various gases, such as greenhouse-effect gases, from the atmosphere to the oceanic intermediate layer, thus affecting the climate formation and variability. The spreading of the dense water also involves the transport of nutrients, particularly iron supplied from the Amur River. This results in high primary-production (associated with oceanic phytoplankton) in the Pan-Okhotsk region, thus making the carbon cycle active in addition to fishery.

These processes are varying in various time-scales, associated with the Pacific Decadal Oscillation (PDO), an 18.6-year variation in tidal mixing, the Arctic Oscillation (AO), and so on. The Pan-Okhotsk region is also sensitive to the global warming, which is causing warming in Siberia, decrease in sea ice production, and warming of the oceanic intermediate layer. These changes are suggested to result in changes in iron and nutrient supplies and thus in primary production, as well as in the oceanic and atmospheric circulation. For a much longer time-scale, glacial-interglacial cycles affect the role of the Pan-Okhotsk region in the climate through the changes in ice production and sea surface salinity.

Our attempts to modeling such climate formation and variability in the Pan-Okhotsk region, which is being conducted at the Pan-Okhotsk Research Center, shall be presented.

Session 5. Frontier Ice and Snow Science

Letters from the Sky:

Nakaya, Sapporo and the Broad Scientific Reach of the Physics of Ice

John S. Wettlaufer
A.M. Bateman Professor of Geophysics and Physics
Professor of Applied Mathematics
Yale University
john.wettlaufer@yale.edu

Nakaya was trained as a nuclear physicist and turned his keen intuition and skills toward the many facets of the beauty and mysteries of snow and ice. He eventually sought to understand many of these phenomena to illuminate aspects of meteorology and yet we now know that the surface of ice exhibits the swath of phase-transition phenomena common to all materials and as such it acts as an ideal test bed of both theory and experiment. It is readily available, transparent, optically birefringent, and probing it in the laboratory does not require cryogenics or ultrahigh vacuum apparatus. Systematic study reveals the range of critical phenomena, equilibrium and nonequilibrium phase-transitions, and, most relevant to this review, premelting, that are traditionally studied in more simply bound solids. While this makes investigation of ice as a material appealing from the perspective of the physicist, its ubiquity and importance in the natural environment also make ice compelling to a broad range of disciplines in the Earth and planetary sciences. In this talk I describe many aspects of physics of ice and their relationship with the behavior of other materials more familiar to the condensed-matter community. I then discuss the many tendrils of the basic phenomena as they play out on land, in the oceans, and throughout the atmosphere and biosphere.

5-2

Metamorphism of Stratified Firn at Dome Fuji, Antarctica: A mechanism for local Insolation Modulation of Gas Transport Conditions during Bubble Close-off

Shuji Fujita [1], Junichi Okuyama [2,3], Akira Hori [2,4], and Takeo Hondoh [2]
[1] National Institute of Polar Research, Research Organization of Information and Systems
[2] Institute of Low Temperature Science, Hokkaido University
[3] Advanced Applied Science Department, Research Laboratory, IHI Co., Ltd.
[4] Department of Civil Engineering, Kitami Institute of Technology
sfujita@nipr.ac.jp

The evolution of the structure of a 112.59-m-long firn core recovered at Dome Fuji, East Antarctica, was investigated in order to improve understanding of firn densification and bubble formation processes, which are important for interpreting local insolation proxies used for astronomical dating of deep ice cores. Using selected samples, we measured physical properties including: (i) the relative dielectric permittivities in both the vertical and horizontal planes, (ii) the bulk density at a resolution of millimeters, (iii) the three-dimensional geometric structure of pore space, and (iv) crystal orientation fabrics. We found that the firn at Dome Fuji contains horizontal strata with thicknesses of several centimeters. Near the surface of the ice sheet, these strata are characterized by contrasting bulk density. Earlier field studies suggest that summer insolation causes densification of surface firn. Down to ~30 m, density maxima exhibited a clear positive correlation with the strength of structural anisotropy and c-axis clustering around the vertical. In contrast, the correlation is negative in deeper firn, confirming previous findings that initially less-dense firn became denser than initially dense firn. In addition, numerous examples of textures indicating that deformation preferentially occurred in weaker layers were found. Moreover, the initially dense firn layers were more permeable for air near the bottom of firn. We propose a model linking firn properties with conditions for the gas transport processes near the bottom of firn. The model explains how stronger insolation can lead to bulk ice with a lower O_2/N_2 ratio and smaller total gas content.

5-3

Dynamic/Thermodynamic Modelling of Ice Sheets in Changing Climates

Ralf Greve
Institute of Low Temperature Science, Hokkaido University
greve@lowtem.hokudai.ac.jp

An ice sheet is a land-based ice body with an area greater than 50,000 km^2. The only current ice sheets on Earth are in Antarctica and Greenland; during the last glacial period at the Last Glacial Maximum (LGM) the Laurentide Ice Sheet covered much of Canada and North America, the Fennoscandian Ice Sheet covered northern Europe and the Patagonian Ice Sheet covered southern South America. Ice sheets feature gravity-driven free surface flow ("glacial flow"), controlled by internal stresses, temperature and basal friction (e.g., Greve and Blatter 2009).

Since the late 1970s, numerical modelling has become established as an important technique for the understanding of ice sheet dynamics. Ice sheet models are particularly relevant for predicting the possible response of ice sheets to climate change, and thus a number of such models have been developed over the years. SICOPOLIS (SImulation COde for POLythermal Ice Sheets; http://sicopolis.greveweb.net/) is an established model currently operated at the Institute of Low Temperature Science. It is based on the widely-used shallow ice approximation, so that longitudinal stress gradients are neglected. Its particularity is the physically adequate implementation of basal layers of temperate ice (regions with a temperature at the pressure melting point).

Recent observations suggest that ice dynamics could play a crucial role in predicting the contribution of ice sheets to future sea level rise under global warming conditions. The need for further research into the matter was even explicitly stated in the Fourth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change (IPCC): *"Dynamical processes related to ice flow not included in current models but suggested by recent observations could increase the vulnerability of the ice sheets to warming, increasing future sea level rise. Understanding of these processes is limited and there is no consensus on their magnitude."* (IPCC 2007).

In this talk, the state of the art and current problems of ice sheet modelling will be reviewed. The ice sheet model SICOPOLIS will be introduced briefly, and exemplary applications of SICOPOLIS to the past glaciation of Greenland and Antarctica over climatic cycles as well as future global warming scenarios will be presented.

References:

Greve, R. and H. Blatter. 2009. *Dynamics of Ice Sheets and Glaciers*. Springer. ISBN 978-3-642-03414-5.

IPCC, 2007. Summary for Policymakers. In: Solomon, S., and 7 others (eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 1–18. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. URL: http://ipcc-wg1.ucar.edu/wg1/wg1-report.html.

5-4

Ice Surface Reactions: Its Role in Chemical Evolution in Space

Naoki Watanabe
Institute of Low Temperature Science, Hokkaido University
watanabe@lowtem.hokudai.ac.jp

Among the many kinds of interstellar molecules observed, the abundances of some major species such as H_2, H_2O, and organic molecules can not be explained by gas-phase synthesis; therefore, surface reactions on cosmic ice dust are considered for the synthesis of such molecules. In an interstellar molecular cloud where the temperature is as low as 10 K and the radiation field is very weak, the energetic processes in/on ice dust is inefficient and thus tunneling surface reactions involving hydrogen atom become important for chemical evolution. We report the experiments on reactions of hydrogen atoms with O_2 and CO on the ice dust analogue, namely amorphous solid water (ASW), at very low temperatures.

Below 20 K, successive addition of hydrogen atoms to CO and O_2 efficiently produces H_2CO, CH_3OH, and H_2O_2, H_2O, respectively. At such low temperatures, some of hydrogen additions such as H + CO → HCO proceed via tunneling reactions rather than thermally-activated reactions. Effective reaction rates and isotope effect of the tunneling reactions to produce HCO and H_2O were measured. The surface of ASW was found to enhance the effective rate of hydrogen addition to CO at relatively higher temperatures, namely 15-20 K. Our experiments first demonstrated that the interstellar molecules abundantly observed in ice dust, H_2O, H_2CO, and CH_3OH, are efficiently produced via the tunneling H-atom addition reactions in the interstellar environments. A series of our experiments was summarized in *Progress in Surface Science* 83 (2008) 439.

5-5

Direct Visualization of Elementary Steps and Quasi-liquid Layers at Air-ice Interfaces by Advanced Optical Microscopy

Gen Sazaki [1,2], Salvador Zepeda [1], Shunichi Nakatsubo [1], Etsuro Yokoyama [3], and Yoshinori Furukawa [1]
[1] Institute of Low Temperature Science, Hokkaido University
[2] JST-PRESTO
[3] Computer Center, Gakushuin University
sazaki@lowtem.hokudai.ac.jp

Growth and melting processes of ice crystals govern wide variety of phenomena on the earth. Hence this issue has been a subject of interest for centuries. To understand crystal growth of ice at the molecular level, one has to observe in-situ "elementary steps", which play a key role during growth and melting processes, on ice crystal surfaces. However, since observation of ice crystal surfaces by scanning probe microscopy is very difficult, so far only one group succeeded in such observation by atomic force microscopy [1]. In this study, hence we adopted laser confocal microscopy combined with differential interference contrast microscopy (LCM-DIM), by which elementary steps of protein crystals (3-6 nm in height) could be visualized with sufficient contrast levels [2], and tried to visualize molecular-level surface morphologies on ice crystal surfaces.

We tried to observe air-ice interfaces, since this interface has much larger reflectivity than water-ice interfaces. By further improving LCM-DIM and growing ice crystals of higher quality, we finally succeeded in observing ice crystal surfaces grown by the two-dimensional (2D) nucleation growth mechanism. When steps of neighboring 2D islands coalesced each other, the contrast of steps disappeared completely. Such disappearances of the step contrasts were commonly observed all over the crystal surface. Hence we concluded that we succeeded in observing elementary steps (0.37 nm in height), for the first time, by optical microscopy. We also succeeded in observing surface melting processes at air-ice interfaces. We could visualize the appearances of two types of quasi-liquid layers (bulk-liquid like drops (BLD) and thin-liquid like layers (TLL)) and growing elementary steps simultaneously on the same crystal surface.

References:
1) S. Zepeda, Ph.D. thesis, University of California Davis, 2004.
2) G. Sazaki, et al., *J. Crystal Growth*, **262**, 536-542, 2004.

Secretariat of the ILTS International Symposium
"Frontier of Low Temperature Science"

Naoto Ebuchi, ILST Hokkaido University
Yasushi Fujiyoshi,, ILST Hokkaido University
Yoshinori Furukawa, ILST Hokkaido University
Jun Nishioka , ILST Hokkaido University
Ayumi Tanaka, ILST Hokkaido University
symposium@lowtem.hokudai.ac.jp
http://www.lowtem.hokudai.ac.jp

Hokkaido University
Sustainability Week 2009