Mass loss of outlet glaciers and ice caps in the Qaanaaq region, northwestern Greenland

*Shin Sugiyama[1], Shun Tsutaki[2], Daiki Sakakibara[3], Evgeny A. Podolskiy[3], Masahiro Minowa[1], Yoshihiko Ohashi[1], Jun Saito[1], Takanobu Sawagaki[7], Sumito Matoba[1], Naoya Kanna[3], Hiroyuki Enomoto[6], Martin Funk[4], Riccardo Genco[5], Yvo Weidmann[4], Guillaume Jouvet[4], Julien Seguinot[4]

1. Institute of Low Temperature Science, Hokkaido University, 2. Earth Observation Research Center, Japan Aerospace Exploration Agency, 3. Arctic Environment Research Center, National Institute of Polar Research, 4. Laboratory for Hydraulics, Hydrology and Glaciology, ETH-Zurich, Switzerland, 5. Department of Earth Science, University of Florence, 6. National Institute of Polar Research, 7. Hosei University

The Greenland ice sheet and peripheral ice caps are rapidly losing mass. Recently, ice mass loss is increasing particularly in northwestern Greenland (e.g. Enderlin and others, 2014). It is urgently important to understand the ongoing changes in this region, but observational data are sparse in northern Greenland. To quantify current ice mass loss in northwestern Greenland and better understand processes driving the mass loss, we studied outlet glaciers and ice caps in the Qaanaaq region as a part of GRENE Arctic Climate Change Research Project. Field and satellite observations were performed to quantify ice surface elevation change of outlet glaciers and ice caps (Saito et al., 2016; Tsutaki et al., 2016). Frontal position and ice speed of outlet glaciers were mapped by satellite data. We also studied processes occurring near the front of outlet glaciers to investigate interaction of the glaciers and the ocean (Ohashi et al., 2016). Our field activities include mass balance monitoring on Qaanaaq Ice Cap since 2012 (Sugiyama et al., 2014), integrated field observations near the calving front of Bowdoin Glacier since 2013 (Sugiyama et al., 2015; Podolskiy et al., 2016), and ocean measurements in front of the glaciers. In this contribution, we present the overview of the results obtained in the GRENE project, and introduce a new project established under the framework of ArCS (Arctic Challenge for Sustainability Project). Our presentation aims to stimulate community discussion on research plan in Greenlnad for Master Plan 2020 called by Science Council of Japan.

References

Enderlin, E. et al., 2014, An improved mass budget for the Greenland ice sheet. Geophys. Res. Lett., 41, 866–872.

Ohashi, Y., T. Iida, S. Sugiyama and S. Aoki. 2016. Spatial and temporal variations in high turbidity surface water off the Thule region, northwestern Greenland. Polar Science, 10(3), 270-277.

Podolskiy, E., S. Sugiyama, M. Funk, R. Genco, S. Tsutaki, F. Walter, M. Minowa, M. Ripepe. 2016. Tide-modulated ice flow variations drive seismicity near the calving front of Bowdoin Glacier, Greenland. Geophysical Research Letters, 43, doi:10.1002/2016GL067743.

Saito, J., S. Sugiyama, S. Tsutaki and T. Sawagaki. 2016. Surface elevation change on ice caps in the Qaanaaq region, northwestern Greenland. Polar Science, 10(3), 239-248.

Sugiyama, S., D. Sakakibara, S. Tsutaki, M. Maruyama and T. Sawagaki. 2015. Glacier dynamics near the calving front of Bowdoin Glacier, northwestern Greenland. J. Glaciol., 61(226), 223–232.

Sugiyama, S., D. Sakakibara, S. Matsuno, S. Yamaguchi, S. Matoba and T. Aoki. 2014. Initial field observations on Qaanaaq Ice Cap in northwestern Greenland. Ann. Glaciol., 55(66), 25–33.

Tsutaki, S., S. Sugiyama, D. Sakakibara and T. Sawagaki. 2016. Surface elevation changes during 2007-2013 on Bowdoin and Tugto Glaciers, northwestern Greenland. J. Glaciol.62(236), 1083-1092.

Keywords: Greenland, ice sheet, ice cap, calving glacier

Establishment of a new integrated geodetic observation system in Syowa Station for mm Global Geodetic Reference Frame (GGRF)

*土井 浩一郎[1,2]、青山 雄一[1,2]
*Koichiro Doi[1,2], Yuichi Aoyama[1,2]

1. 国立極地研究所、2. 総合研究大学院大学
1. National Institute of Polar Research, 2. The Graduate Univ. for Advanced Studies

Syowa Station has three independent techniques for space geodetic observation, namely, Very Long Baseline Interferometry (VLBI), Global Navigation Satellite System (GNSS), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS). Observations by the three techniques have been continued for more than 15 years. Hence Syowa Station is one of the most critical geodetic sites in southern hemisphere for maintaining the current International Terrestrial Reference Frame (ITRF).
In addition to these space geodetic observations, continuous gravity observation with superconducting gravimeters have been carried out for more than 20 years as well as repetitive absolute gravity measurements. This means that Syowa Station is a promising site to realize and maintain the GGRF with mm accuracy which is an integrated geodetic reference frame incorporating the ITRF, the International Celestial Reference Frame, the International Height Reference Frame and the Global Absolute Gravity Reference System.
To accomplish mm accuracy of the position coordinates of Syowa Station, we plan the following actions; (1) Replacement of the current VLBI system to the next generation VLBI system, (2) New installation of a next generation Satellite Laser Ranging (SLR) system, (3) Implementation of co-location survey between the space geodetic observation sites and the absolute gravity measurement site with an accuracy of 1 mm, and (4) Realization of gigabit data communication between Syowa Station and Japan.
Establishment of the new space geodetic site can provide co-located position coordinates of 1 mm accuracy combined with the absolute gravity value. The coordinates and gravity value will contribute to realization and maintenance of the mm GGRF. At the same time, the provided temporal variations of the coordinates and the gravity value allow us to investigate solid Earth deformation induced by Glacial Isostatic Adjustment (GIA), plate motion and current change in cryosphere, ocean and atmosphere.

キーワード：グローバル測地基準座標系、宇宙測地観測、GIA
Keywords: GGRF, space geodetic observation, GIA

A perspective for observations on ecosystem response in the Arctic

*鄭 峻介[1]、杉本 敦子[1]、マキシモフ トロフィム[2,3]
*Shunsuke Tei[1], Atsuko Sugimoto[1], Trofim Maximov[2,3]

1. 北海道大学 北極域研究センター、2. ロシア科学アカデミーIBPC、3. ロシア北東連邦大学BESTセンター
1. Arctic Research Center, Hokkaido University, 2. Institute for Biological Problems of Cryolithozone SB RAS, 3. BEST center, North Eastern Federal University

Arctic and sub-Arctic ecosystems are exposed to a larger magnitude of warming in comparison with the global average, as a result of warming-induced environmental changes. Understanding the sensitivity of tree growth to climate in these ecosystems is an important factor in the accuracy of future projections of the terrestrial carbon cycle, and also of global climate. However, it is not certain how these ecosystems respond to these changes.
We have conducted research on tree growth response to climate change over the Arctic and sub-Arctic ecosystems using ring width indices (RWI) from a tree-ring width dataset accessed through the International Tree-Ring Data Bank (ITRDB) and found that the responses differed among regions, depending on the characteristics of each region. Tree radial growth decreased with recent rapid warming in southern boreal forests located on continental dry climate region such as inner Alaska and Canada, southern part of Europe, southern part of Lena river basin of eastern Siberia and Mongolia. Conversely, radial growth increased in the Arctic ecosystems. It is clear that spatial heterogeneity in Arctic and sub-Arctic ecosystems response to climate change existed.
However, we still have following questions with regard to advancing our understanding of these ecosystems response; (i) to which extent does the clear spatial heterogeneity in those ecosystems response deduced from RWI data set correspond to that from other kinds of data set?; (ii) what is controlling factor for the spatial heterogeneity in those ecosystems response?; (iii) how can we expect future carbon cycling in the Arctic and sub-Arctic ecosystems?
To answer these questions, we plan to conduct observation-based multilateral study in which we investigate relationship among tree-ring parameters, i.e., ring width (RWI) and stable carbon isotope ratio, remotely sensed spectral vegetation indices, i.e., normalized difference vegetation index (NDVI) and CO_2 flux observations. The comparisons are conducted for linking those data sets each other and for obtaining better estimate of vegetation activity response to climate change over Arctic and sub-Arctic ecosystems. For example, our comparative analysis between RWI and NDVI (Tei et al., in preparation) showed disagreement in their trends over extensive areas; the accelerated RWI trend over some regions did not correlate with greening and, inversely, with browning where tree experienced a slower growth. Comparison of such proxies with direct CO_2 flux observational data set is also useful to know what NDVI and RWI represent at the ecosystem level, how to optimally integrate them each other, and what related challenges need to overcome. Such efforts are expected to improve our understanding of forest carbon cycling in the Arctic and sub-Arctic ecosystems and place current developments into a long-term perspective. It could also help to evaluate the performance of earth system models regarding the simulated magnitude and dynamics of forest carbon uptake, and inform these models about growth responses to climatic drivers.

キーワード：北極域生態系、炭素循環、樹木年輪、CO2フラックス、リモートセンシング
Keywords: Arctic and sub-Arctic ecosystems, carbon cycle, tree ring, CO2 flux, remote sensing

Characteristics of total ozone measured in the western Antarctica

Ja-Ho Koo[1], Taejin Choi[2], Hana Lee[1], Jhoon Kim[1], Joonghee Park[1], Dha Hyun Ahn[1], Jaemin Kim[3], *Yun Gon Lee[3]

1. Yonsei University, 2. Korea Polar Research Institute , 3. Chungnam National University

To figure out the temporal variation and spatial distribution of Antarctic ozone loss, we investigate the characteristics of long-term (at least longer than 15 years) total ozone columns measured by Dobson or Brewer spectrophotometer at five ground stations in the western Antarctica: King Sejong, Marambio, Belgrano, Halley, and Belgrano stations. All measured total ozone columns, well evaluated through an inter-comparison with OMI total ozone measurements, recently show the recovery pattern, particularly in September. They are generally analogous but often different during the austral springtime when the stratospheric ozone loss strongly occurs. As shown in the comparison of potential vorticity among stations, regional differences of total ozone are attributed to the spatial scale of polar vortex. Additional analyses of other meteorological factors also indicate the large spatiotemporal variations of atmospheric pattern over the western Antarctica. This probably implies that the total ozone variation in this region has higher sensitivity to the large-scale circulation and even climate change compared to the eastern Antarctica. We also find the well-known positive correlation between total ozone and lower stratospheric air temperature all the year round, particularly at 50-100 hPa heights during austral spring. But this positive correlation is not apparent in the upper stratosphere (higher than 10 hPa). Correlation with tropical sea surface temperature is not clear, but the signal looks meaningful and somewhat asymmetry between austral spring and summer. Further analysis will be required for better understanding of this feature.

Keywords: Antarctica, Ozone, Brewer, Dobson

南大洋・南極氷床変動の分野横断研究
Integrated multidisciplinary study on change in the Southern Ocean and the Antarctic ice sheet

*野木 義史[1]、川村 賢二[1]
*Yoshifumi Nogi[1], Kenji Kawamura[1]

1. 国立極地研究所
1. National Institute of Polar Research

The Antarctic ice sheet holds 90% of ice, which is equivalent to about 70 m height of sea level. On the other hand, the Southern Ocean produces densest seawater, called the Antarctic bottom water, which drives ocean circulation. The Antarctic ice sheet and the Southern Ocean are the most significant components that control global climate and sea level changes. However, the Antarctic ice sheet and the Southern Ocean are the mostly unknown components in the Earth system due to the difficulties of the observation in these areas, especially in the East Antarctica.
The primary processes and the mechanism of the interactions among the atmosphere, ice sheet, solid earth and ocean should be made clear in the context of the global environmental changes driven by the Antarctic ice sheet and the Southern throughout the various kinds of the interactions. The integrated multidisciplinary study is required with the different fields of the observation data from geological to present time scale together with modeling studies. Furthermore, the developments of the observation instruments are important element to obtain the field observation data in the unexplored under and edge of sea ice. The project of the integrated multidisciplinary study focused on changes in the Southern Ocean and the Antarctic ice sheet are introduced, and the prospects of this program are discussed.

キーワード：南大洋、南極氷床、海洋循環、海水準
Keywords: Southern Ocean, Antarctic ice sheet, ocean circulation, sea level

東南極の気候変動の検出と解明に向けた大気・氷床・海洋の長期的観測
Long-term field experiment for detection and study of climatological change in East Antarctica

*平沢 尚彦[1]、青木 輝夫[2]、林 政彦[3]、藤田 耕史[4]、飯塚 芳徳[5]、栗田 直幸[4]、本山 秀明[1]、山内 恭[1]、末吉 哲雄[1]
*Naohiko Hirasawa[1], Teruo Aoki[2], Masahiko Hayashi[3], Koji Fujita[4], Yoshinori Iizuka[5], Naoyuki Kurita[4], Hideaki Motoyama[1], Takashi Yamanouchi[1], Tetsuo Sueyoshi[1]

1. 情報・システム研究機構　国立極地研究所、2. 岡山大学、3. 福岡大学、4. 名古屋大学、5. 北海道大学
1. National Institute of Polar Research, 2. Okayama University, 3. Fukuoka University, 4. Nagoya University, 5. Hokkaido University

1. はじめに

本発表は、人類が地球全体の観測を始めて以来の数 10 年間における南極域の気候の変化に関する知見を振り返り、現在の変化のメカニズムを知るための観測・研究の提案を行う。南極氷床の質量収支は海水準変動に最も大 きな影響を与える可能性を持っているため、その将来の変化を予測によって知ることは人類の目標でもある。本 研究の成果となる現在の変化のメカニズムの理解は、南極氷床の質量収支の将来を考察する上で有意義な知見で あるとともに、将来予測をするための気候モデルにそのメカニズムを組みこむことで、予測精度の向上に貢献す る。

2. IGY 以降の南極域の気候変化の特徴

地球温暖化が進行する中、西南極の温暖化は地球の平均より速いペースで温暖化している。このことは polar amplification として理解される。しかし、東南極では、この 50 年間に温暖化や寒冷化の時期がめまぐるしく入れ 替わり、一定の傾向は現れていない。ただし、最近 10 年間には昭和基地周辺の温暖化が見出されるようになって きたかに見える。これまでの東南極の温暖化抑制や最近の温暖化傾向はオゾンホールの 1980 年来の長期的発達と フロンガス規制を反映した最近のオゾンホール回復が関係している可能性があるという議論がある(平沢、 2016)。

南極氷床の質量収支では、西南極の消耗が明瞭で、東南極では著しい変化は観測されていなかった。ところが、 これについても最近 10 年間で東南極の西半分にあたる Droning Maud Land(昭和基地やドームふじ基地はこの領域 にある)において、これまでの観測で捕らえられたことのない著しい涵養が観測された。その結果としてこの地 域の低標高域での涵養が著しいことが、衛星による重力観測で示唆されている。一方、この時期の高標高域にお ける涵養量は絶対量としては目立たないが、通常の涵養量に対する比率として見ると、低標高域から高標高域ま で同程度であることは興味深い(Motoyama et al., 2015)。

3. 本研究の概要

この観測・研究は、これらの最近起こっているいくつかの著しい現象を含めて、今後 10 年以上に亘る Droning Maud Land の気候の変化を検出し、そのメカニズムの理解から将来の変化傾向を知るための重要な気候プロセスを 示す。このために、気象だけでなく、雪氷及び海洋の観測と研究を併合して行う。

東南極のこれまでの温暖化の抑制や今後の変化傾向を知るために最も必要なことは氷床の内陸域における現場観 測をおいて他にない。この計画では、高層気象ゾンデ観測(ゾンデ観測)と無人気象雪氷観測(AWS)網の展開 を基盤とする。例えば、ゾンデ観測は、米国の南極点基地(図1の SP)において IGY 以来の長きに渡って実施され、2005 年からはフランス・イタリアが運営するドーム C 基地 (同 DC)において実施されるように

なった。ロシアは DC の南西 方にあるボストーク基地で長く観測を行っていたが現在は行われ ていない。結果として、南極氷床上の対流圏・成層圏の 50 年以上 の変化を示すデータは SP からの一つしかない。今後の変化は、 DCが加わって2つとなる。しかし、Droning Maud Landにおける 最近の顕著な涵養など、南極氷床の地域的な変化を含めて捕らえ るためにはゾンデ観測網は足りない。少なくとも Droning Maud Land の内陸に必要である。その第一候補はドームふじ基地(図 1 の DF)である。尚、西南極の内陸にはかつてバード基地があった が、最近、米国ではこの地域での活動を強化しつつあり、現在の 体制に DF とバード基地が加われば、南極氷床上の対流圏・成層 圏の大気構造の観測は格段に向上するはずである。これらの観測の結果は、当然ながら、ERA や NCEP、JRA などで知られる気候 再解析データの品質も必ず向上させる。これまで、南極域のデー タの信頼度はそれほど高くなかったが、その改善に貢献する。DF を再び通年の観測基地にしたい。

これまでのドーム計画などにより、Droning Maud Land の内陸域 の観測について、日本の国際的な期待は大きい(ICPM, International Committee on Polar Meteorology, 推奨レター, 2015 な ど)。内陸通年基地だけでなく、AWS 網の展開によって(図2)、 面的な現場観測を実現したい。この計画で構築する AWS 網では、 通常の気象要素に加えて、放射 4 成分、積雪深、雪温の計測を実 施する。観測データは衛星回線を通じて研究者のもとに届き、い くつかのデータ補正を施した後、国際的に公開する計画である。

先の最近の Droning Maud Land の氷床涵養の増加で述べたように、 氷床の頂上部から末端部まで注意深く分析する必要がある。AWS 拠点は、氷床末端部(S17)、カタバ風帯(Mizuho)、カタバ風 帯上部(MD246)、カタバ風発生域(Relay Station)、氷床頂上 部(Dome Fuji、図1のDFと同じ)である。これらは氷床上に現 れる典型的な気候区を代表する。これらの地点では、夏季や冬季 に 1 ヶ月程度のキャンペーン期間を設けてゾンデ、係留気球、無 人飛行機(UAB)を用いた観測を実施する。また、氷床表面状態 やピット観測によって氷床の表層の経年変化を捕らえる。地域ご との集中的な観測を定期的に組み合わせることによって、南極内 陸域の対流圏・成層圏の大気構造の変化や氷床質量収支の変化、 及びそれらのメカニズムの解明を目指す。他に、定期的に南極域 の航海を実施する「しらせ」での船上観測によって、海洋表層と 大気との相互作用を考慮する。

キーワード：大気、南極、北極
Keywords: atmosphere, antarctic, arctic

A new perspective on atmospheric and geospace sciences in the Arctic with EISCAT_3D

*宮岡 宏[1]、野澤 悟徳[2]、小川 泰信[1]、大山 伸一郎[2]、中村 卓司[1]、藤井 良一[3]、Heinselman Craig[4]
*Hiroshi Miyaoka[1], Satonori Nozawa[2], Yasunobu Ogawa[1], Shin-ichiro Oyama[2], Takuji Nakamura[1], Ryoichi Fujii[3], Craig Heinselman[4]

1. 国立極地研究所、2. 名古屋大学宇宙地球環境研究所、3. 情報・システム研究機構、4. EISCAT科学協会
1. National Institute of Polar Research, 2. Institute for Space-Earth Environmental Research, Nagoya University, 3. Research Organization for Information and Systems, 4. EISCAT Scientific Association

The European Incoherent Scatter(EISCAT) radar system in northern Feno-Scandinavia and Svalbard have been playing a pivotal role in advancing cutting edge sciences in various area including atmospheric, ionospheric and geospace studies, space weather and global change. Affiliated in the EISCAT Scientific Association in 1996, the EISCAT user community in Japan has jointly contributed to understanding of the magnetosphere-ionosphere-thermosphere coupling processes using the coordinated ground-based and rocket/satellite simultaneous observations with EISCAT radars.
EISCAT_3D is the major upgrade of the existing EISCAT mainlamd radars, with a multi-static phased array system composed of one central active (transmit-receive) site and 4 receive-only sites to provide us 50-100 times higher temporal resolution than the present system. The core site will transmit radio waves at 233MHz with 10MW power, and all five receiving sites will have sensitive receivers to detect the returned signal using phased-array antenna with 10,000 cross-Yagi elements.
The new radar is expected to overcome current observational difficulties and then open new scientific world that have been never realized. One of the great characteristics is continuous measurements of the space environment-atmosphere coupling in the auroral oval and at the southern edge of the polar vortex. High time resolution data with 3D volume-metric will be obtained by EISCAT_3D. Scientific topics addressed in the Science Case documents (i.e.. McCrea, et al., 2015) are as follows:

1. Atmospheric physics and global change
-a. Vertival coupling between the atmospheric layers
-b. Turbulence and waves in the mesosphere and lower thermosphere
2. Space and plasma physics
-a. Multiple scale interactions in ionosphere-magnetosphere plasmas
-b. Plasma turbulence and active experiments
3. Inflow and outflow of matters in the Earth’ s atmosphere
4. Space debris, near-earth objects and space weather
5. Radio astronomy

In this paper, we will overview scientific subjects to be challenged by the new EISCAT_3D radar facility in the Arctic, as well as the possible inter-hemispheric coupling studies with the PANSY radar in the Antarctic.

キーワード：非干渉散乱レーダー、両極、上下結合
Keywords: incoherent scatter radar, bipolar, vertical coupling

