# Validation of soil moisture contribution to near surface temperature by numerical sensitivity experiment in Northeastern Asia

*Enkhbat Erdenebat[1]

1. Hokkaido University

Variations of near surface temperature of June-August due to difference soil moisture (SM) product is investigated by numerical experiments utilizing WRF model in Northeastern Asia. A 30-year (1981-2010) numerical experiment has conducted using ERA-interim reanalysis data as an initial and boundary condition to clarify the importance of SM contribution to the JJA extreme temperature and heat wave (HW). SM is known to be an important parameter to influence temperature by regulating surface energy balance through latent and sensible heat fluxes. To evaluate SM contribution to JJA temperature under similar atmospheric circulation, two experiments, reanalysis-SM (R-SM) as a control and satellite-SM (S-SM), have been compared. Both experiments were conducted during 20th May through 1st September. The S-SM experiment used initial SM condition derived from European Space Agency-Climate Change Initiative (ESA-CCI) dataset. During the numerical integration, SM can evolve as a result of atmosphere-land interaction. The model experiment has successfully generated the increasing trend of HW for frequency and intensity in R-SM. The result shows that S-SM experiments have improved the maximum surface air temperature and HW by 1.1˚C and 0.7 days year$^{-1}$ on average during 1981-2010 in Mongolia. The amount of rainfall is reduced due to using S-SM as an initial condition in comparison to R-SM. In addition to rainfall, enhanced interaction of land and atmosphere is simulated in S-SM run, which higher positive anomaly at 500 hPa has developed in S-SM than R-SM by major HWs. Therefore sensitivity experiments confirm that ERA-interim estimates more SM in Northeastern Asia which results underestimate temperature and overestimates rainfall by model.

# Time-lag effects of forest ecosystem response to climate change in continental dry climate zones over the circum-Arctic; a multiple approach using satellite images and tree-rings analyses

*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

Circumboreal forest 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.
In this study, we compared past 30 years spatio-temporal variation of Global Inventory Modeling and Mapping Studies (GIMMS) satellite derived normalized difference vegetation index NDVIg, its recent successor version NDVI3g, and tree-ring width index (RWI) on International Tree-Ring Data Bank (ITRDB) over circum-arctic region (>50N) with respect to relationship with climate change. The comparisons are conducted for linking those indices each other and for obtaining better estimate of vegetation activity response to climate change.
We calculate correlation coefficients between those indices and both previous and current year meteorological data, for each grid/site, and higher correlation coefficients were considered as actual response of forest ecosystem. Given the time lag effects of RWI or NDVI response to climate change, above indices in continental dry regions such as inner Alaska and Canada, southern part of Europe and southern sections of the Rena river basin in eastern Siberia tend to show significant negative correlation with summer temperature of previous year, suggesting further reduction of ecosystem carbon uptake with future warming.
Our findings highlight that the time lag effects of forest ecosystem response to climate change significantly affects relationships between both NDVI and RWI, and climate variables and it therefore should be incorporated into future carbon cycle studies. Otherwise, future projection of forest ecosystem carbon uptake may be overestimated under expected future further warming.

キーワード：周北極圏陸域生態系、炭素循環、樹木年輪、リモートセンシング
Keywords: Arctic and sub-Arctic ecosystems, carbon cycle, tree ring, remote sensing

# The role of vegetation change upon polar amplification in warm climate by feedback analysis

*大石 龍太[1]、吉森 正和[2]、阿部 彩子[1,3]
*Ryouta O'ishi[1], Masakazu Yoshimori[2], Ayako Abe-Ouchi[1,3]

1. 東京大学大気海洋研究所、2. 北海道大学、3. 海洋開発研究機構
1. Atmosphere and Ocean Research Institute, the Universitoy of Tokyo, 2. Hokkaido University, 3. JAMSTEC

Previous studies revealed that vegetation change in high latitude (e.g. from tundra to forest) in warm climate strengthen a polar amplification. This is due to lower vegetation albedo of forest then tundra, snow-albedo feedback caused by early snow melt due to forest coverage and ocean heat emission in autumn and winter. In the present study, we run a vegetation–coupled general circulation model with a slab-ocean, MIROC-LPJ, for two kinds of warming experiments. One is due to higher atmospheric CO2 concentration (2xCO2 and 4xCO2) and the other is due to the difference of the Earth’ s orbit (mid-Holocene and the Last Interglacial). The result shows different mechanisms of warming amplification between CO2-induced vegetation feedback and orbit-induced vegetation feedback. We also try to apply a feedback analysis (Cai and Luo 2009; Yoshimori et al. 2014) to result of MIROC-LPJ experiments.

キーワード：極域増幅、植生、古気候
Keywords: polar amplification, vegetation, paleoclimate

# 凍土動態を考慮した全球陸面-植生モデルによる将来予測
# Projecting future greenhouse gas release by global land surface-vegetation coupled model with explicit permafrost dynamics

*横畠 徳太[1]、斉藤 和之[2]、大野 浩[3]、岩花 剛[4]、伊藤 昭彦[1]、高田 久美子[1]
*Tokuta Yokohata[1], Kazuyuki Saito[2], Hiroshi Ohno[3], Go Iwahana[4], Akihiko Ito[1], Kumiko TAKATA[1]

1. 国立環境研究所、2. 海洋研究開発機構、3. 北見工業大学、4. アラスカ大学フェアバンクス校
1. National Institute for Environmental Studies, 2. Japan Agency for Marine-Earth Science and Technology, 3. Kitami Institute for Technology, 4. University of Alaska Fairbanks

永久凍土は、寒冷な高緯度域に広く分布している。高緯度域は特に地球温暖化の影響を受けやすく、凍土層の温度が上昇し、夏に解ける上部の層（活動層）が深くなるという現象が、すでに観測されている。また近年「エドマ層」と呼ばれる非常に高い割合で氷を含んでいる永久凍土が、急激に融解し、大規模な地盤陥没が起こっていることなども報告されている。永久凍土には、氷河期の頃から分解せずに堆積された多くの有機物が含まれており、その炭素総量は、不確実性が大きいものの、大気中炭素の2倍程度、陸域土壌炭素と同程度の量であると推定されている（IPCC 第5次評価報告書）。永久凍土の融解は、土壌中の有機炭素を大気に放出し、大気の温室効果ガス濃度を上昇させる。これにより地上気温が上昇することで、永久凍土の融解がさらに加速するという、正のフィードバックがある。しかし、その実態解明は不十分であり、特に近年観測されているエドマ層の不可逆的な融解がもたらす影響については、これまで十分に研究がなされていない。そこで本研究（環境省「環境研究総合推進費」2-1605, H28-30）では、エドマ層のような高含氷な永久凍土の不可逆的な融解による温室効果ガス放出量の現状評価と将来予測を行う。アラスカやシベリアにおける現地調査、衛星データ解析、全球陸面過程モデル•陸域生態系モデルの改良を有機的に組み合わせて行うことで、永久凍土の融解過程に関する脆弱性分布や、気候変動に対する相対的な寄与を解明することを目標とする。

全球モデル開発に関しては、陸面過程モデルMATSIROおよび陸域生態系モデルVISITの改良を行っている。陸面過程モデルの開発に関しては、土壌の熱物理過程を評価する際に、凍結土壌水分•土壌有機層•不凍結水を考慮すること、また土壌の鉛直解像度を増やすことにより、凍土融解過程の高度化を行った。土壌物理を高度化することにより、地下氷の量が減少すること、また凍土の季節進行に関して、より現実的な分布が得られる傾向にあることが分かった。また、陸域生態系モデルの開発に関しては、永久凍土融解による温室効果ガス放出過程の定式化の検討を行った。二酸化炭素の放出に関しては、凍土融解によって生じた有機物を、土壌微生物が従属栄養呼吸することによって放出される項を追加する。またメタンに関しては、永久凍土の融解による湿原の拡大によって、追加的に放出されるメタンの量を評価する。発表では、全球モデル開発によって得られた知見を報告する。

キーワード：永久凍土、温室効果ガス、気候変動
Keywords: Permafrost, Greenhouse gas, Climate change

# 領域モデルWRF/Chemを用いた2016年9月のシベリア森林火災由来のBCおよびオゾン輸送推定

# Estimation of the Siberian fire in September 2016 on the concentration of ozone and BC in the Pan-Arctic region using a regional chemical transport model

*滝川 雅之[1]、竹谷 文一[1]、金谷 有剛[1]、宮川 拓真[1]、Petr Mordovskoi[1]、山口 将大[1]
*Masayuki Takigawa[1], Fumikazu Taketani[1], Yugo Kanaya[1], Takuma Miyakawa[1], Petr Mordovskoi[1], Masahiro Yamaguchi[1]

1. 独立行政法人海洋研究開発機構
1. Japan Agency for Marine-Earth Science and Technology

ブラックカーボン(BC)粒子は化石燃料やバイオマスなどの不完全燃焼により発生する黒色のエアロゾル粒子で、PM2.5の一成分として知られている。BCは大気中で光を吸収する性質を持ち、IPCCなどでも二酸化炭素やメタンなどに次ぐ主要な温室効果気体の一つとして考えられている。とくに高緯度域においてはBCを含むことにより雪や氷のアルベドが大きく変化し、その融解を加速させることから、気候変動に大きな影響を持つことが示唆されている。BCの発生源としては全球的には工業、輸送、家庭などでの化石燃料や薪などに由来するものと森林火災とがそれぞれほぼ同程度と推定されている(cf. Lamarque et al., 2010)が、周北極域内での放出源としてはシベリア、北米大陸高緯度域などでの森林火災の寄与がかなり大きいと考えられる。これら周北極域でのBCの気候および環境への影響を評価するため、周北極域を対象とした領域化学輸送モデルWRF-Chem version 3.8.1 を用いた数値計算を実施した。気象場の初期条件、境界条件はNCEP-GFSを利用した。また人為起源エミッションについては EDGAR4.2を使用した。森林火災エミッションについては NCAR FINNを用い、かつ森林火災由来の熱対流による鉛直分布も考慮している。生物起源エミッションについてはモデル内でオンラインモジュール化されたMEGAN2.1を用いた。気相およびエアロゾルモジュールはそれぞれRACMおよびGOCARTを使用した。BCについては疎水性BCとして放出され、2.5日の時定数で親水性BCに変換されるものとした。NCAR FINNのシベリア域での森林火災エミッションについて2014年以降を比較したところ、2016年9月は過去3年間の中でも顕著なイベントが見られていたため、対象期間を 2016年8月から9月の2か月間として計算を行った。また領域内での森林火災の影響を評価するため、人為起源、生物起源、森林火災のすべてを考慮した場合と人為起源および生物起源のみ考慮した場合の２ケースの実験を行った。当該計算期間は観測船「みらい」の北極航海期間中であり、モデルによる気象場(風速、風向、気圧、気温)を「みらい」による観測値と比較したところ概ね妥当な再現性を示していた。また9/25以降ベーリング海周辺でBC濃度の増加が見られていたが、２ケースを比較したところ、9/20以降にバイカル湖周辺で見られた森林火災に由来すると推定された。当該火災域ではBC以外にもNOxおよびCOなどのオゾン前駆物質の濃度も森林火災により顕著に増加していたため、モデル結果ではオゾン濃度も最大で40ppbv程度、森林火災により増加していた。

キーワード：ブラックカーボン、領域化学輸送モデル、周北極域、森林火災
Keywords: Black Carbon, regional chemical transport model, Pan-Arctic, biomass burning

# シベリアでの大規模森林火災期間中の気象条件　-　サハ南部での条件
# Weather Conditions During Large-Scale Widespread Forest Fires in Siberia: Conditions in Southern Sakha

*早坂 洋史[1]
*Hiroshi Hayasaka[1]

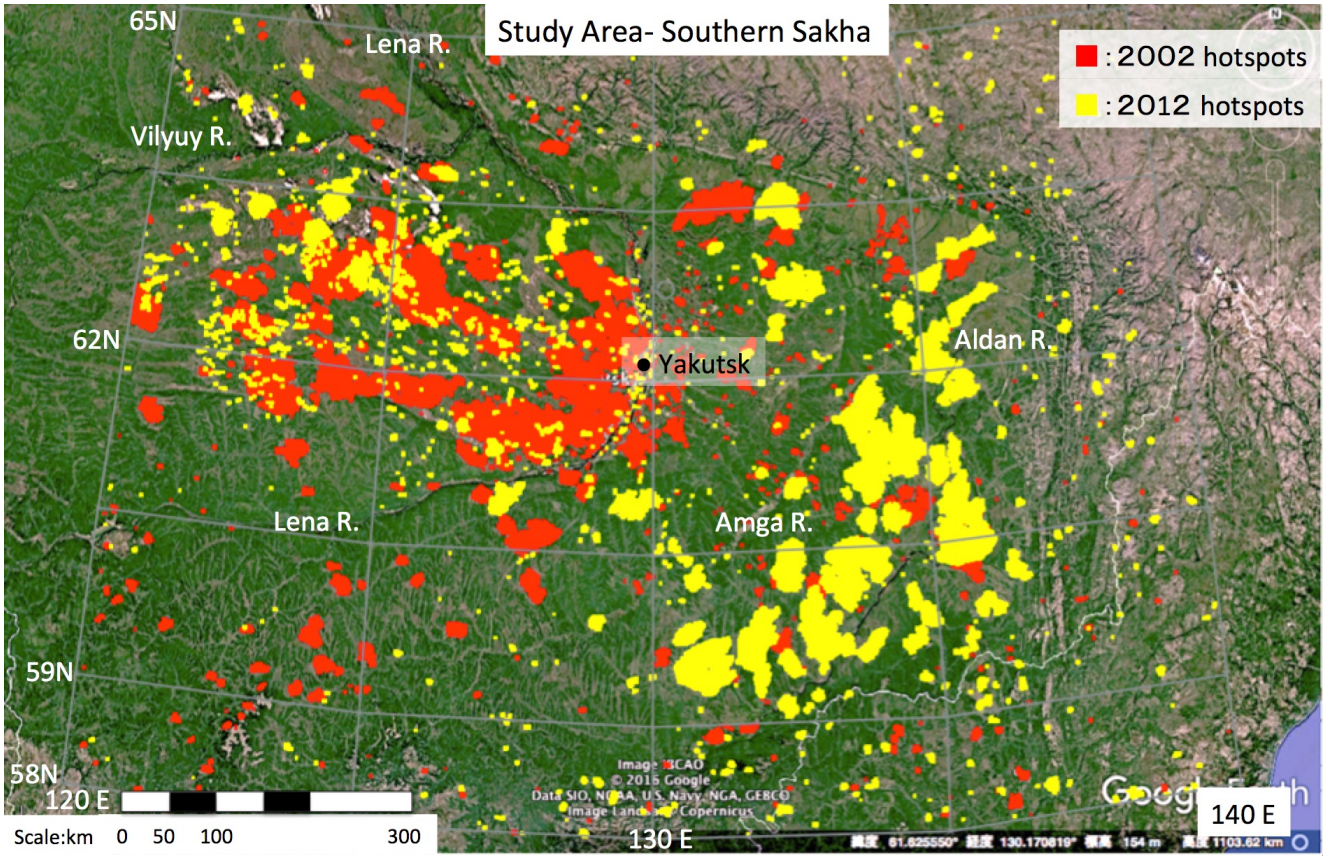
1. NPO北海道水文気候研究所
1. NPO Hokkaido Institute of Hydro-climate

北方林（タイガ）の総面積は約12,000万km$^2$で，世界の森林面積の約3分の1を占めている．世界の北方林の約70%がユーラシアにあり，ロシアには北方林約6,200,000 km$^2$がある．この広大なロシアの北方林では，毎年，いろいろな所で森林火災が発生している．10年以上のMODISのホットスポット・データ（HSと略）を解析することで，ロシアの北方林での火災頻発域が次第に明らかになってきている．今回は，サハ南部の北方林での大規模森林火災の気象条件を分析した結果を報告する．大規模な森林火災は火災発生後の気象条件に依存している．著者らは既にアラスカの総観的大規模火災の気象条件をMODISのHSデータ（2003~2015年）解析で明確にし，報告済みである．アラスカでは，上位4つの大火災期間は，ロスビー波砕波（Rossby wave breaking (RWB)）に関連した類似した独特な高気圧火災気象条件下で発生した．火災の発生後，RWB現象に関連する典型的な火災気象条件下で，高気圧システムがアラスカを南から北に移動する前後に2つのHSピーク（大火災）が生じた．最初のHSピークは，アラスカ湾の気圧の尾根による南西風で生じた．2番目のHSピーク（最大の火災）は，RWB条件下で高圧システムが北に移動した後，ビューフォート・シー高気圧（Beaufort Sea High）が発達し，アラスカ州内陸で比較的強い東寄りの風を吹き込み，発生した．これらの気象現象に加えて，北極での低気圧発達に伴う低気圧関連で発生する火災気象条件下でも，南西風が単一の大きなHSピークを伴って高い火災活動を引き起こしていた．

サハ南部の北方林では，2002年と2012年に大規模森林火災が発生した．両年の7月と8月のホットスポットのピークの気象条件を調べた結果，アラスカと同様に高気圧と低気圧の二つのパターンが確認された．高気圧タイプでは，ヤクーツク北方に気圧の尾根が形成されていた．低気圧タイプでは，北極海の低気圧が重要な役割を果たしていることが明らかとなった．

キーワード：広域森林火災、MODISホットスポット、ジェット気流蛇行
Keywords: Widespread fires, MODIS hotspot, Jet stream meandering



# Interannual variability of summer precipitation over northern Eurasia in multiple climate models

*阿部 学[1]、藤波 初木[2]、檜山 哲哉[2]
*Manabu Abe[1], Hatsuki Fujinami[2], Tetsuya Hiyama[2]

1. 海洋研究開発機構、2. 名古屋大学宇宙地球環境研究所
1. Japan Agency for Marine-Earth Science and Technology, 2. Institute for Space-Earth Environmental Research, Nagoya Univ.

Global warming is projected to be amplified in high-latitude region. Because the Arctic sea ice loss has been already beginning to appear, hydrological cycle in the northern part of Eurasia may be affected by the global warming and the Arctic sea ice reduction. Fujinami et al. (2016) showed summer precipitation increased after 1980 in northern Eurasia, and Hiyama et al. (2016) discussed a possible effect of the recent Arctic sea ice reduction on the modulation of interannual variability of summer precipitation. Such changes are important issues for the current environment including the ecosystem over northern Eurasia In addition, the reliable future projection and understanding of the hydrological cycle system are also important for mitigation and adaptation of future environmental changes.
In this study, we investigated characteristics of interannual variability of summer precipitation in northern Eurasia in 16 climate/earth system models, which have been used for the projection of future climate change, to assess whether recent global warming and the Arctic sea ice reduction affect realistically the northern Eurasian environment in the models. To reduce uncertainty related to oceanic change, we used data of the historical simulations of CMIP5 from 1979 to 2008 with observed sea surface temperature (SST) and sea ice conditions.
The spatial distribution of precipitation averaged for summer (June-July-August) in northern Eurasia in each model is similar to the observed one. Unlike the observed increase in summer precipitation in Siberian region (Fujinami et al. 2016), there is no model showing a remarkable increase trend of summer precipitation averaged over Siberian region. EOF analysis was performed for each model to extract the leading modes of interannual variability of summer precipitation in northern Eurasia. Although the EOF spatial patterns differs among the models, the first three EOF patterns of many models includes a pattern similar to the east-west seesaw pattern, which is a leading mode of the observed interannual variability. Furthermore, Hiyama et al. (2016) showed difference in the interannual variation pattern of observed summer precipitation in the northern Eurasia between the two periods before and after 1990, and also discussed the relationship between this difference and the Arctic sea ice reduction. Then we compared the frequency of EOF score values between the first 10 years (1979-1988) and the last 10 years (1999-2008) in each model. In many models, the mean or variance of score values at an EOF mode changed significantly between the periods. However, the spatial pattern of the EOF where the frequency change of the score value occurred was not similar between models.
As a result, the characteristics of interannual variability in northern Eurasia differ greatly among the models. However, it turned out that the observed east-west seesaw mode was included as one of the interannual variability in almost all of the models. In addition, some models revealed that the interannual variability of summer precipitation in northern Eurasia modulated after 1980, as discussed in Hiyama et al. (2016). In this presentation, atmospheric circulations related to the EOF modes are also shown.

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キーワード：夏季降水量の経年変動、ユーラシア北部、地球温暖化
Keywords: Interannual variability of summer precipitation, northan Eurasia, global warming

 

# How Predictable Summer Arctic Cyclones in 2012 and 2016 Were?

*山上 晃央[1]、松枝 未遠[1,2]、田中 博[1]
*Akio Yamagami[1], Mio Matsueda[1,2], Hiroshi Tanaka[1]

1. 筑波大学計算科学研究センター、2. オクスフォード大学物理学部
1. Center for Computational Sciences, University of Tsukuba, 2. Department of Physics, University of Oxford

Arctic cyclones (ACs) have a long lifetime and a wandering track in the Arctic region. The structures of the ACs are characterized by the warm and cold cores at upper and lower levels, downward and upward drifts at upper and lower levels, and barotropic relative vorticity. ACs have large impacts on the Arctic systems like the sea water temperature and the sea ice. ACs also have social impacts on the Northern Sea Route of ships and the Polar Route for airplanes. Therefore, accurate predictions of ACs are important for environmental and social concerns.
Extreme ACs occurred in August 2012 and 2016. The AC in 2012 (AC2012) was generated over the north of the Eurasia on 2 August 2012. The minimum sea level pressure (SLP) of 964 hPa for the AC2012 was recorded on 6 August 2012. On the other hand, the cyclogenesis of the AC in 2016 (AC2016) was over the north of the Scandinavian Peninsula on 11 August 2016. The minimum SLP of 967 hPa for the AC2016 was recorded on 16 August 2016. Although the positions of the cyclogenesis were different, both ACs recorded the minimum SLP over the Pacific sector of the Arctic Ocean. In both cases, the AC merged with a cyclone connecting with an upper polar vortex over the Arctic Ocean few days before the development of the AC. Some previous studies indicated that the AC2012 contributed greatly to the record low sea-ice extent in that summer. Similarly, it is thought that the AC2016 could have an influence on the decrease in sea-ice cover, since sea ice extent in early September of that year was the second lowest on record.
In this study, we investigated the predictability of the extreme ACs in August 2012 and 2016, using operational medium-range ensemble forecasts provided by The Interactive Grand Global Ensemble (TIGGE). The minimum SLP of the AC2012 on 6 August was well predicted by CMC, ECMWF, and JMA (NCEP and UKMO) members 2 (3) days in advance. Some ECMWF and NCEP members initialized in late July 2012 also predicted the development of the AC2012. On the other hand, the minimum SLP of the AC2016 was more predictable than that of the AC2012. The development of the AC2016 was well predicted by ECMWF members 6 days in advance and by CMC, JMA, NCEP and UKMO 3 –5 days in advance. Comparisons between higher- and lower-skill members revealed that the accurate prediction for the development of the upper warm core could lead to the accurate prediction of the AC development in both cases. Baroclinic growth and subsequent nonlinear dynamics during the merging contributed to the development of the upper warm core. Even if the baroclinic growth was predicted well, predicted AC did not develop when the merging was not predicted accurately. Therefore, a correct prediction of for the AC track is one of the important factors for accurate prediction of the AC development. The predicted cyclone track was similar to the observed cyclone track when the upper-level wind was predicted well. In conclusion, the accurate prediction of the upper-level wind can lead to the correct prediction of the ACs through the development of the upper warm core.

キーワード：北極低気圧、暖気核、低気圧の併合、アンサンブル予報
Keywords: Arctic cyclone, warm core, cyclone merging, ensemble forecast

 

# シベリアの春季積雪減少が東アジア域の大気循環場に与える影響
# Influence of Springtime Eurasian Snow Cover Retreat on Atmospheric Circulation over East Asia

*野沢 徹[1]、藤原 昴[1]
*Toru Nozawa[1], Subaru Fujiwara[1]

1. 岡山大学大学院自然科学研究科
1. Graduate School of Natural Science and Technology, Okayama University

気候変動に関する政府間パネルの第5次評価報告書によれば、北半球春季の積雪域が1990年以降大きく減少していることが報告されている。また、最近の研究では、この変化が大気循環場に影響を及ぼしている可能性も指摘されている。本研究では、人工衛星観測に基づく広域積雪データおよび客観解析データを用いて、春季シベリアにおける積雪減少が東アジア域の大気循環場に及ぼす影響を調査した。

西シベリアで領域平均した4月の積雪被覆率を基準として、大気場および陸面の合成図解析を行った。積雪被覆率が大きい年に比べ、小さい年には4月だけでなく6月にも日本付近で上層のジェット気流が南へ蛇行することが確認された。また、西シベリア南部から中央アジアにかけて、積雪被覆率が小さい年の6月には地表面温度が有意に上昇し、土壌水分量が有意に減少していることが確認された。さらに、積雪被覆率が小さい年の5-6月には、地表面から大気への顕熱輸送量が有意に増加し、上層の大気温度も有意に上昇していた。以上のことから、積雪減少に伴う融雪水の減少が消雪後の土壌水分を減少させることで、陸面から大気への蒸発を抑制して地表面が加熱されるとともに、地表面から大気への顕熱輸送量が増加して大気を加熱し、大気循環場に影響を与えている可能性の高いことが示唆された。

キーワード：地球温暖化、積雪、大気陸面相互作用
Keywords: Global warming, Snow cover, Land and atmosphere interaction

 

# 東グリーンランド深層氷床掘削プロジェクト（EGRIP）キャンプにおける2016年ピット観測から明らかになった近年の堆積量の変動
# Variation of recent annual snow depositions estimated on the 2016 pit observation at the East Greenland Ice Core Project (EGRIP) camp

中澤 文男[1,2]、*永塚 尚子[1]、東 久美子[1,2]、Dahl-Jensen, Dorthe[3]、Steffensen, Jørgen Peder[3]
Fumio Nakazawa[1,2], *Naoko Nagatsuka[1], Kumiko Goto-Azuma[1,2], Dorthe Dahl-Jensen[3], Jørgen Peder Steffensen[3]

1. 国立極地研究所、2. 総合研究大学院大学、3. コペンハーゲン大学
1. National Institute of Polar Research, 2. SOKENDAI (The Graduate University of Advanced Studies), 3. Niels Bohr Institute, University of Copenhagen

グリーンランドにおける気候・氷床変動を明らかにするため，デンマークのコペンハーゲン大学が主導して実施する、東グリーンランド深層氷床掘削プロジェクト（EGRIP計画）が2015年より開始されている。日本は北極域研究推進プロジェクト（Arctic Challenge for Sustainability: ArCS）の一環としてEGRIP計画に参加し、各国と共同研究を行っている．本研究では、近年の年間堆積量、季節毎の堆積量、そして積雪中の様々な化学種・ダストの濃度レベルを把握する目的で、2016年7月にEGRIPキャンプ（75° 37' N，35°59' W）の2地点にて、4.02 m深と3.18 m深のピット観測を実施した。ピット観測では、0.03 m毎に雪氷試料の採取と密度測定を行った。現在、4.02 m深のピットについて、積雪の水安定同位体比（$\delta^{18}$Oと$\delta$D）の測定が終了している。$\delta^{18}$Oと$\delta$Dの深さプロファイルは明瞭な季節変動を示しており、降雪が年間を通じて定期的に生じていることを示唆した。また季節サイクルの数から、4.02 mの積雪は、2008～2016年までの9年間分の堆積に相当することが分かった。年間堆積量は水当量（water equivalent：w. e.）で99～247 mm w.e.の間で推移し、その平均値は167 mm w.e.であった。北グリーンランドの NEEM（North Greenland Eemian Ice Drilling）キャンプで実施されたピット観測では、2006～2008年の年間堆積量の平均値は176 mm w.e.と報告されており、本研究の結果はそれと同程度であった。また、密度の深さプロファイルは、冬に高密度、夏に低密度になる季節変動を示した。同じような傾向がNEEMキャンプやグリーンランドのSummitにおいて確認されており、これら先行研究で議論されているwind-pack effectがその要因の一つとして考えられた。発表当日は、化学種・ダストの分析結果および、3.18 m深ピットの結果についても発表する。

キーワード：グリーンランド、アイスコア、質量収支、積雪、安定同位体比
Keywords: Greenland, ice core, mass balance, snowpack, stable isotope ratio

 

# MODISおよびAMSR-2を用いたグリーンランド氷床表面反射率と輝度温度の季節変化解析

# Seasonal variations of Greenland ice sheet surface reflectance and brightness temperature derived from Terra/MODIS and GCOM-W/AMSR-2

*島田 利元[1,2]、堀 雅裕[1]、竹内 望[3]、青木 輝夫[2,4]
*Rigen Shimada[1,2], Masahiro Hori[1], Nozomu Takeuchi[3], Teruo Aoki[2,4]

1. 宇宙航空研究開発機構、2. 気象研究所、3. 千葉大学、4. 岡山大学
1. Japan Aerospace Exploration Agency, 2. Meteorological Research Institute, 3. Chiba University, 4. Okayama University

Dark ice area expansion on the Greenland ice sheet is one of the factors to cause albedo reduction and mass loss of the ice sheet in recent years. Dark ice appears on ablation area in summer and accelerates melting of the ice sheet due to its intense light absorption. Dark ice is due to impurities in the surface ice such as mineral particles, glacial microbes, organic matter and their aggregate called cryoconite granules. Cryoconite granules are formed by microbial activities and are darker than abiotic mineral particles. Since the microbes can be active only on melting ice surface, duration of surface melting on the ice sheet possibly affect the microbial activities and thus formation of cryoconite granules. Therefore, spatio-temporal variation in surface melting is important to understand the darkening process.
We report seasonal variations in surface reflectance and brightness temperature derived from Terra/MODIS and GCOM-W/AMSR-2 satellite images in order to understand relationship between darkening and surface melting processes of the ice surface from April to August in 2013, 2014, 2015 and 2016. Reflectance (660 nm) and brightness temperature (18 GHz Horizontal polarization) were investigated at the nearest neighbor pixel of the Automatic Weather Station (67.07N, 48.83W) installed by PROMICE. The brightness temperature showed similar timing of the onset of surface melting in 2013 and 2015. In these years, the melting onset occurred in early June. On the other hand, the melting onset occurred in mid May in 2014 and 2016. The surface reflectance started to decrease down to around 0.4 in mid July 2013 and early July 2015. In contrast, it rapidly decreased down to around 0.4 in the end of June 2014 and early June 2016. These results suggested that earlier onset and prolonged period of the surface melting causes the earlier appearance of the dark ice surface.

キーワード：グリーンランド氷床、衛星リモートセンシング、暗色域
Keywords: Greenland ice sheet, satellite remote sensing, dark ice

 

# 北極域における雪氷域面積および海色の長期変動
# Long-term variability in land snow cover, sea ice extent and ocean color in Arctic region

*津滝 俊[1]、堀 雅裕[1]、村上 浩[1]
*Shun Tsutaki[1], Masahiro Hori[1], Hiroshi Murakami[1]

1. 宇宙航空研究開発機構
1. Japan Aerospace Exploration Agency

Satellite-based observations revealed that sea ice extent and land snow cover in the Arctic region have decreased since 1979 under the influence of warming trend. Reduced sea ice cover increases open water area, a longer growing season, and annual net primary production (NPP) by phytoplankton. The greatest contribution to the Arctic Ocean’s fleshwater input is the discharge from terrestrial rivers. Because river inflow supplies a large amount of nutrient salts and organic matter to the ocean, change in the discharge affects the Arctic Ocean’s NPP. Thus, successive observations on sea ice extent and land snow cover are crucial to understand the influence of those area reductions on marine ecosystems in Arctic region. In this study, we used multiple optical and microwave radiometric satellite data for 1978–2015 to analyze land snow cover, sea ice extent and ocean color in the northern hemisphere. Sea ice extent deceased during the observation period with the mean rate of 200 $km^2$ $a^{-1}$. Snow cover extent decreased in all seasons (winter, spring, summer and autumn) from 1978 to 2015. Decreases in land snow cover and sea ice extent are likely to affect to seasonal and inter-annual variabilities in the amount of freshwater inflow to the Arctic Ocean. However, no clear trend of the ocean color (chlorophyll-a concentration) was observed with statistically significant in this study. To better understand relationship between spatiotemporal variabilities in these factors and other physical parameters, we also analyze variability in sea surface temperature and meteorological parameters and examine their cross-correlation relationship in space and time.

 

# グリーンランド北西部Bowdoin氷河の高濁度融解水流出過程がフィヨルドの基礎生産に与える影響

# Effect of subglacial meltwater plume formation on phytoplankton growth in the fjord of Bowdoin Glacier in northwest Greenland

*漢那 直也[1]、杉山 慎[1,2]、大橋 良彦[2,3]、榊原 大貴[1]、西沢 文吾[4]、浅地 泉[2,3]、深町 康[1,2]
*NAOYA KANNA[1], Shin Sugiyama[1,2], Yoshihiko Ohashi[2,3], Daiki Sakakibara[1], Bungo NISHIZAWA[4], Izumi ASAJI[2,3], Yasushi FUKAMACHI[1,2]

1. 北海道大学　北極域研究センター、2. 北海道大学　低温科学研究所、3. 北海道大学　環境科学院、4. 北海道大学　水産科学研究院
1. Arctic Research Center, Hokkaido University, 2. Institute of Low Temperature Science, Hokkaido University, 3. Graduate School of Environmental Science, Hokkaido University, 4. Faculty of Fisheries Sciences, Hokkaido University

In Greenland, marine-terminating outlet glaciers discharge turbid subglacial meltwater into fjords. The area influenced by the turbid water near the calving front is well known as an important foraging hotspot for higher trophic animals. Glaciers may therefore play an important role in ecosystem productivity within the fjords by releasing an essential macronutrient for primary producers. However, since there are few available data on the macronutrient delivery with the meltwater inputs, processes of macronutrient supply to surface waters are poorly understood. Here we present a hydrographic and geochemical dataset from Bowdoin Glacier and its fjord in northwestern Greenland during the summer of 2016.
On the glacier, meltwater contained few macronutrients (<0.5 $\mu$M $NO_3$+$NO_2$) indicating that supraglacial meltwater is not a significant source of macronutrients in the fjord. At the surface of a meltwater plume near the calving front, water properties were largely different from surface waters outside of the plume. The concentration of surface macronutrients inside the plume was an order of magnitude higher (~12.8 $\mu$M $NO_3$+$NO_2$) than that outside of the plume (<1.6 $\mu$M $NO_3$+$NO_2$). Additionally, salinity (~33.0) and the content of suspended particles (~132 mg/L) inside the plume were notably higher than those outside of the plume (salinity ~15.4; suspended particles ~22.3 mg/L), suggesting upwelling of nutrient-rich, saline deep water including substantial sediment derived from subglacial weathering. Oxygen isotopic compositions of the glacial meltwater, plume, and fjord water also indicated that the glacial meltwater upwells as a buoyant flow, drawing the nutrient-rich deep water into the fjord. Within a vertical cross-section along the centerline of the fjord, highly turbid water was observed in sub-surface layer at depths of 10–50 m. Less saline water with low macronutrients concentration was on top of this highly turbid water. Phytoplankton blooms (~6.5 $\mu$g/L chlorophyll a) was observed near the boundary between the less saline water and the turbid water. The concentration of macronutrients was sufficiently high (~10 $\mu$M $NO_3$+$NO_2$) in this area to generate the bloom. Overall, our study results show that turbid meltwater discharge from Bowdoin Glacier affects nutrient availability and the subsequent growth of phytoplankton in the fjord. Upwelling and transport of macronutrients associated with subglacial meltwater plume formation is an important process for phytoplankton growth in the near-surface layer.

キーワード：グリーンランド、Bowdoin氷河、主要栄養塩、高濁度融解水の流出
Keywords: Greenland, Bowdoin Glacier, Macronutrient, Turbid meltwater discharge

 

# Fe, Mn, Cd, and Pb Quantitatively Analysed in Sea Ice

*La Kenya Evans[1,3], NAOYA KANNA[2], Jun Nishioka[3]

1. Graduate School of Environmental Sciences, Hokkaido University, 2. Arctic Research Center, Hokkaido University, 3. Institute of Low Temperature Sciences, Hokkaido University

Sea ice plays a significant role in polar oceans. During sea ice formation both dissolved and particulate sea water constituents (trace metals, macro-nutrients, sediments, etc) accumulate through scavenging or suspension freezing (Reimnitz et al., 1992,1993; Nürnberg et al., 1994). This can allow for sea ice to hold trace metal concentrations higher than the underlying water (Grotti et al. 2005; Tovar-Sanchez et al. 2010). Floating (pack) sea ice can then transport incorporated materials into new areas as it melts, seeding the water community below (van der Merwe et al., 2011). Although many studies have looked at sea ice and trace metals, the mechanism and geochemical cycling role for trace metal accumulation is still largely unknown (Kanna et al., 2014). In this study we examined the following metal fractions for Fe, Mn, Cd and Pb: Dissolved (D, <0.2μm), and Labile Particulate (LP, Total Dissolvable - Dissolved) from Chukchi Sea pack ice and the surrounding seawater (shelf and coast). Samples were pre-concentrated utilizing the solid-phase extraction NOBIAS Chelate PA1 resin (Hitachi High-Technologies) following a modification of Sohrin et al. (2008) and Kondo et al. (2016) methods. Finally, samples were analyzed on a Graphite Furnace Atomic Absorption Spectrometer (GFAAS). Applying the modified solid-phase extraction method on sea ice measurements allowed us to accurately detect low levels of trace metals. Utilizing this method allowed us to gain insightful information on the geochemical cycling of trace metals within sea ice.

LPFe, LPMn and LPPb composed 98-99% of Fe, Mn and Pb in Chukchi sea ice where LPCd was 84%. Although Cd and Pb were detectable, the concentrations for the dissolved and labile particulate fractions were very low (0.05±0.04nM –6.3±5.9nM). Overall in sea ice and seawater, the labial particulate fraction had higher concentrations than the dissolved. Sea ice has been shown to have a temporal decoupling of trace metals (i.e. Fe), with the dissolved metals being released with the brine and particulate metals release with advanced melting (van der Merwe et al., 2011). Since our samples were collected during summer, advanced melting could have led to the dominance of the labile particulate fraction.

Chukchi seawater (shelf and coast) samples also showed the same trends where Fe and Mn had higher concentrations than Cd and Pb. LPFe and LPPb composed 99-100% of Fe and Pb in Chukchi seawater. One interesting point was that Pb was detectable in sea ice for both the dissolved and labile particulate factions but only detectable as LPPb in seawater. Mn and Cd composition in Chukchi seawater was dominated by the dissolved fraction (75% and 43% respectively). DFe is removed from seawater by oxyhydroxide formation and particle scavenging, which can give it have lower concentrations than DMn (Landing and Bruland, 1987).

Keywords: Sea Ice, Trace Metals, Dissolved, Labile Particulate

 

# アナディール湾からベーリング海峡にかけてのアナディール水の分布
# Distribution of the Anadyr Water near the Gulf of Anadyr and the Bering Strait

*平譯 享[1]、中川 一成[2]、西岡 純[3]
*Toru Hirawake[1], Issei Nakagawa[2], Jun Nishioka[3]

1. 北海道大学大学院水産科学研究院、2. 北海道大学大学院環境科学院、3. 北海道大学低温科学研究所
1. Faculty of Fisheries Sciences, Hokkaido University, 2. Graduate School of Environmental Science, Hokkaido University, 3. Institute of Low Temperature Science, Hokkaido University

Primary production in the Bering Strait (BS) especially in the Russian side is extremely high and it is found not only in spring but also in summer and autumn seasons. It has been suggested that the continuous high phytoplankton activity is attributed to rich amount of nutrients in the Anadyr Water (AW). Although some literatures reported higher nutrients concentration in the Gulf of Anadyr (GA), similar level of primary production as the BS is difficult to be observed in the GA. In this study, we obtained a historical CTD dataset (1930–2005) compiled at the Far Eastern Regional Hydrometeorological Research Institute (FERHRI) in Russia and investigated water mass structure form the GA to the BS. We analyzed the dataset climatologically because stations of each cruise distribute sparsely. In August, while the AW with high salinity (>35 PSU) distributed near the bottom of the GA, the Bering Shelf Water was covered the surface of the Gulf. The AW was spread along coast of Russia and a part of it was found in the surface of BS. The water mass structure in this study suggests that the AW from the AG continuously supports high primary production in summer of the BS.

キーワード：アナディール湾、アナディール水、ベーリング海峡
Keywords: Gulf of Anadyr, Anadyr Water, Bering Strait

 

# Interannual variability of bottom oxygen concentration and primary production in the southern Chukchi Sea biological hotspot

*藤原 周[1]、西野 茂人[1]、平譯 享[2]、菊地 隆[1]
*Amane Fujiwara[1], Shigeto Nishino[1], Toru Hirawake[2], Takashi Kikuchi[1]

1. 国立研究開発法人海洋研究開発機構、2. 北海道大学
1. Japan Agency for Marine-Earth Science and Technology, 2. Hokkaido University

Hope valley located in the southern Chukchi Sea is known as one of the biological hotspot (southern Chukchi Sea hotspot, SCH). Large benthic biomass in the SCH is supported by high primary productivity of the water column. The dissolved oxygen (DO) sharply decreases at the bottom toward fall as a result of the high sediment community oxygen consumption in the benthic fauna, while it is saturated during winter. We examined annual/inter-annual variability of bottom DO and its mechanisms analyzing ship-board and mooring hydrographic data, satellite derived primary production, and ecosystem model. The bottom DO showed large interannual variability (104–300 $\mu$M) and it was negatively and significantly correlated with cumulative primary production ($r$ = -0.66, $p < 0.05$). Such negative correlation suggests organic carbon flux to the sea floor drives the activity of the benthic community. Environmental process of decreasing in DO was assessed using one box ecosystem model optimized for the SCH bottom layer. The model also captured bottom DO is sensitive to the flux of primary production from the upper layer. Our results suggest inter-annual variability of primary production is a key factor determining the recent changes in biomass and distribution of the benthic organisms.

キーワード：生物学的ホットスポット、基礎生産、底層溶存酸素濃度
Keywords: biological hotspot, primary production, bottom oxygen concentration

 

# 西部北極海バロー峡谷沖における陸棚物質の水平輸送の通年モニタリング
# Annual monitoring on lateral advection of shelf materials off the Barrow Canyon, western Arctic Ocean

*小野寺 丈尚太郎[1,2]、渡邉 英嗣[2]、溝端 浩平[3]、田中 裕一郎[4]、小栗 一将[5]、原田 尚美[1,2]
*Jonaotaro Onodera[1,2], Eiji Watanabe[2], Kohei Mizobata[3], Yuichiro Tanaka[4], Kazumasa Oguri[5], Naomi Harada[1,2]

1. 海洋研究開発機構地球環境観測研究開発センター、2. 海洋研究開発機構北極環境変動総合研究センター、3. 東京海洋大学海洋科学部海洋環境学科、4. 産業技術総合研究所地質調査総合センター、5. 海洋研究開発機構海洋生物多様性研究分野
1. Research and Development Center for Global Change, JAMSTEC, 2. Institute of Arctic Climate and Environment Research, JAMSTEC, 3. Tokyo University of Marine Science and Technology Department of Ocean Sciences, 4. The Research Institute of Geology and Geoinformation, AIST, 5. Department of Marine Biodiversity Research, JAMSTEC

北極海カナダ海盆南西部において陸棚から海盆への熱や物質の水平輸送は、当該海域の生態系や物質循環を理解するうえで重要である。当海域の海洋物理モデルによると、バロー沖で形成される海洋渦は陸棚物質を取り込み、その渦のボーフォート海洋循環に沿った西方への移動はノースウィンド深海平原南部Station NAP (75˚N165˚W）における一時的な沈降粒子フラックスの増加に寄与している。そこでStaion NAPの上流域であるバロー沖における海洋物理と沈降粒子フラックス変動との関係を観測するため、2015年10月から2016年9月にかけてバロー沖Station NBC15t（72.47˚N 155.41˚W）にセジメントトラップと各種センサーを投入した。セジメントトラップに捕集された粒子は陸源砕屑物を多く含んでいた。トラップを係留した深度約243mにおける全粒子フラックスは、セジメントトラップが詰まった2016年6月以降を除くと14.6-3413.9mg $m^{-2}$ $d^{-1}$で推移し、その最大値はStation NAPより1桁高かった。全粒子フラックスの極大は2015年10月5-18日と2016年5月12-24日に観測された。またセジメントトラップが機能しなかった2016年9月にも、トラップに取り付けた水中カメラ映像に多くの粒子が記録されていた。各種係留センサーや水中カメラ映像の記録から、2015年10月と2016年9月の粒子フラックス極大期の陸棚起源物質は、セジメントトラップ係留深度より浅い亜表層の水平流の強化によって供給された可能性が高い。2016年5月の粒子フラックス極大は、ADCPを係留した約125mとセジメントトラップ係留深度との間のより限られた深度帯で流速が増加することで形成されたことが推測された。

キーワード：北極海、カナダ海盆、沈降粒子フラックス、陸棚-海盆間相互作用
Keywords: Arctic Ocean, Canada Basin, Settling particle flux, Shelf-basin interaction

 

# 海氷減少に対する河川水の熱フラックスの影響
# Impacts of terrestrial river heat flux on the declining Arctic sea ice

*朴 昊澤[1]、大島 和裕[1]、吉川 泰弘[2]、渡邉 英嗣[1]
*Hotaek Park[1], Kazuhiro Oshima[1], Yasuhiro Yoshikawa[2], Eiji Watanabe[1]

1. 海洋研究開発機構、2. 北見工業大学
1. Japan Agency for Marine-Earth Science and Technology, 2. Kitami Institute of Technology

In the Arctic, the recent warming speed of surface air temperatures are the fastest among the past historical records. The consequent influences are found in changes in the Arctic freshwater system, such as increasing river discharge, changing river-ice phenology, and warming of river water temperature. The warming water temperature can result in higher heat flux flowing into the Arctic Ocean, combining with the larger river discharge, which likely enhances the melt of sea ice in the shelf area. However, very few studies quantitatively assessed influences of the river heat flux on the Arctic sea ice are available. A land surface model (CHANGE) coupled with models of river discharge, ice-cover, and water temperature through channel network was applied to the Arctic river basins over the period 1979–2013, and then we assessed influences of the river processes on sea ice, including trends of river discharge, water temperature, and heat flux. The simulation indicated obvious increases in river discharge and water temperatures over the pan-Arctic rivers, consequently flowing considerable amount of heat to the ocean. The heat fluxes were significantly correlated with changes of sea surface temperature and sea ice concentration in the coastal areas of the Arctic Ocean, especially in the spring season when the sea ice begins to melt. This emphasizes that the heat flux of terrestrial freshwater is an important factor influencing the melting process of sea ice at specifically seasonal and local scales.

キーワード：河川熱フラックス、海氷減少、陸面過程モデル、海氷密接度
Keywords: river heat flux, sea ice retreat, land surface mode, sea ice concentration

 

# Interannual variation of solar heating in the Chukchi Sea, Arctic Ocean

*塚田 雄志郎[1]、上野 洋路[1]、太田 直紀[3]、伊東 素代[2]、渡邉 英嗣[2]、菊地 隆[2]、西野 茂人[2]、溝端 浩平[4]
*Yushiro Tsukada[1], Ueno Hiromichi[1], Naoki Ohta[3], Motoyo Itoh[2], Eiji Watanabe[2], Takashi kikuchi[2], Shigeto Nishino[2], Kouhei Mizobata[4]

1. 北海道大学大学院水産科学院、2. 国立研究開発法人　海洋開発研究機構、3. 北海道大学大学院環境科学院、4. 東京海洋大学大学院海洋科学技術研究科
1. Graduate School of Fisheries Sciences, Hokkaido University , 2. Japan Agency for Marine-Earth Science and Technology, 3. Graduate School of Environmental Science, Hokkaido University, 4. Graduate School of Marine Science and Technology, Tokyo University of Marine Science and Technology

Arctic sea ice cover in summer has declined rapidly over the past few decades. The albedo of sea ice is much higher than that of open water; reduction of sea ice cover is associated with increase of solar heating in the Arctic Ocean. In this study, we focus on solar heating in the Chukchi Sea located in the Pacific side of the Arctic Ocean where remarkable sea ice reduction has occurred. The Chukchi Sea is a pathway of Pacific Water from the Bering Strait to the Arctic Basin. The heat transport of the Pacific Water through the Bering Strait, which has increased recently, plays an important role in a decrease in sea-ice formation during winter as well as sea-ice melt in summer in the Canada Basin. Although the Pacific Water heat transport through the Bering Strait is becoming clearer, we expect that solar heating significantly modifies the Pacific Water in the Chukchi Sea. Therefore, we estimate solar heating in the Chukchi Sea through analysis of satellite-derived sea ice concentration data as well as reanalysis data of shortwave radiation, and discuss the role of the solar heating in the Chukchi Sea in the heat transport into the Arctic Basin. We also use in-situ shortwave radiation data obtained by R/V Mirai to validate the reanalysis data of shortwave radiation in the Chukchi Sea.

キーワード：チャクチ海、太陽放射加熱
Keywords: Chukchi Sea, solar heating

 

# バロー海底谷における太平洋水のフラックスと北極海の温暖化への影響
# Pacific water fluxes through the Barrow Canyon and its effect on warming in the Arctic Ocean

*伊東 素代[1]、菊地 隆[1]、西野 茂人[1]
*Motoyo Itoh[1], Takashi Kikuchi[1], Shigeto Nishino[1]

1. 海洋研究開発機構
1. Japan Agency for Marine-Earth Science and Technology

近年の北極海における夏季の海氷減少は、太平洋側の海盆域で特に顕著で、ベーリング海峡から流入する太平洋水の増加が原因の一つと指摘されている。チャクチ海北西部に位置するバロー海底谷は、太平洋水の海盆域への主要な流出口である。本研究では、バロー海底谷における流量、熱、淡水フラックスの定量的な見積もりと、そのカナダ海盆の温暖化への役割に注目している。JAMSTECでは、バロー海底谷で2000年から20016年まで通年の係留系観測を実施しており、年平均の流量、淡水、熱フラックスは、0.43 Sv、31 mSv、2.12 TWであることを明らかにした。熱フラックスは非常に経年変動が大きく、年平均で0.93 TW から3.34 TWの幅があった。係留系によるバロー海底谷の熱量と、衛星によるバロー域の海面水温を比較することで、北向き熱フラックスのほとんどが観測される夏季の熱量の長期変動を調べた。その結果、1980年代から2010年代の間に、熱量は1.5倍に増加したことが示唆された。海盆域の海洋観測データから、カナダ海盆域の亜表層は、1990年代以降に水温上昇傾向があり、特に2010年以降は急激に水温上昇が観測されていることが分かった。これは、2007、2010、2012年にバロー海底谷の熱フラックスが多かったことの影響と考えられる。

キーワード：北極海、海洋温暖化、海氷減少
Keywords: Arctic Ocean, Ocean warming, Sea ice reduction

 

# Seasonal variability of near-inertial internal waves and its kinetic energy in the ice-diminishing Arctic Ocean

*Yusuke Kawaguchi[1], Motoyo Itoh[1], Takashi Kikuchi[1], Jonaotaro Onodera[1], Naomi Harada[1], Yasushi Fukamachi[2], Erika Moriya[3]

1. JAMSTEC Japan Agency for Marine-Earth Science and Technology, 2. Arctic Research Center, Hokkaido University, 3. Hydro System Development, Inc.

In the Arctic ocean, the internal wave activity and its contribution to the turbulent mixing has been considered to be quite low. In the modern era, the Arctic sea-ice extent has been dramatically diminishing, and therefore there is an increased chance of kinetic energy input from the air at ocean surface. In this study, the seasonal change of near-inertial internal wave (NIW) kinetic energy is examined in comparison with local sea ice compactness and draft thickness. The local sea-ice information was obtained using an ice profiling sonar mounted at top of a moored instrumentation in the Northwind Abyssal Plain. The band-passed kinetic energy was recorded with a moored ADCP for depths within upper 110 m. The data clearly documented that the depth-integrated NIW kinetic energy varied in line with the ice seasonality, i.e., ice thickness and mobility. During ice covered months, the upper water NIW kinetic energy was approximately 1/10 of the Garrett-Munk (GM) canonical level. In the meantime, during the ice absent months of September and October, the kinetic energy levels built up closer to the GM level. The fine-scale parameterization (Gregg, 1989) estimates the turbulent mixing dissipates the incident wave energy at a rate of $O(10^{-10} - 10^{-9}$ W kg$^{-1})$. According to a mixed layer slab model (Pollard & Millard 1970), the energy input from the ice movement was 1.6 kJ m$^{-2}$, in which 13% was presumably dissipated through the wave-wave interaction in the upper 110 m. The ice-water combined velocity data also indicated that the mobility of sea ice floes can affect the kinetic energy amount in the upper water, suggesting the occurrence of increased turbulent energy as more unconsolidated ice exists in the future.

Keywords: Arctic Ocean , Near-inertial internal wave, Sea ice retreat

 