山形県月山の樹林帯の積雪上に現れる雪氷藻類のブルームとその要因
Environmental factors associated with snow algal bloom in the deciduous forest of Mt. Gassan, Yamagata prefecture, Japan

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Snow algae are photosynthetic microbes inhabiting alpine and polar snow fields. They bloom on melting snow and change snow color from white to red or green. Colored snow appears widely in mountainous regions in Japan. However, the conditions for the algal bloom are still not understood well. In this study, we aim to describe the temporal change of snow algae and physical and chemical conditions of surface snow in Mt. Gassan, Yamagata prefecture, Japan. Study site is located in the Japanese beech forest at an elevation of 750 m a.s.l. Field studies were carried out three times from April to May of 2016. We collected samples of surface snow and snow pit down to the ground surface at the study site. In laboratory, we measured chlorophyll-a concentrations, EC, pH, and soluble chemical compositions in the samples.
Field observations revealed that algal green snow appeared patchy after the late April. The algal patches were frequently observed in the snow surface under trees compared with the open sunny surface. The chlorophyll-a concentration in the surface snow gradually increased during the study period. The analysis of major soluble ions revealed that the phosphate concentration in the surface snow under the trees increased up to 51.4 μeq/L while it in the open snow surface kept low value during the study period. Results suggest that the phosphate is supplied with rain water from canopy of the trees to the snow surface and that it causes the patchy algal bloom on the snow surface.

キーワード：雪氷藻類、栄養塩、落葉樹林
Keywords: snow algae, nutrients, deciduous forest

札幌で8冬期間に観測された積雪不純物がアルベドに与える効果
Effect of snow impurities on albedo observed during 8 winter seasons in Sapporo

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近年、積雪面積や積雪期間は主に北極域において減少している。雪氷は一般にアルベドが高いため、地球温暖化に伴う雪氷の融解はアルベドを低下させる。その結果、地表面による太陽放射の吸収の増加し、地球温暖化をさらに加速させる。代表的な豪雪地帯である札幌において、積雪アルベドは積雪粒径と積雪不純物濃度に強く依存していることが報告されている（Aoki et al., 2003, 2007）。本研究では、札幌の積雪アルベドにおける積雪不純物濃度の影響を、Aoki et al. （2011）によって開発された積雪アルベド物理モデル（PBSAM）を用いて調べた。観測場所は北海道大学低温科学研究所の気象観測露場（43°04'56"N, 141°20'30"E, 15 m a.s.l.）で、観測期間は2007-2015年の8冬期間である。積雪断面観測及び放射観測データをPBSAMに入力して得られる広波長帯域アルベドの理論計算値と観測値を比較した。さらに、積雪不純物によるアルベドの変化に関する感度実験も行った。

解析期間の各年で時系列の観測値とモデル計算値を比較すると、積雪粒径や積雪不純物濃度の変化に対応したアルベド変動の計算値は観測値とよく一致していることが分かった。全解析期間において、短波長域（SW）におけるアルベド観測値と計算値の比較から得られる決定係数（R^2）と二乗平均平方根誤差（RMSE）はそれぞれ0.831と0.045で、これらの結果からPBSAMの高い精度が確認された。次に、ブラックカーボン（BC）と鉱物性ダストからなる積雪不純物の有無による、可視域、近赤外域、短波長域のアルベド変化に関する感度実験を行った。全解析期間における積雪不純物（BC+ダスト）によるアルベド変化は可視域で-0.085、近赤外域で-0.016、短波長域で-0.053であった。また、短波長域のアルベド変化へのBCとダストそれぞれからの寄与を調べた結果、全解析期間の短波長域のアルベド変化はBCのみにより-0.043、ダストのみにより-0.009であった。さらに、涵養期と融雪期の間の短波長域のアルベド変化の比（融雪期/涵養期）はBCが4.1倍、ダストが12.0倍、BC+ダストが4.9倍であった。

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Observational study on spatial development structure of blowing snow

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Reducing visibility and forming snow drifts by blowing snow are still social natural disaster and a major problem. Although a large number of studies have been made on the vertical development of blowing snow, little is known about the horizontal development of blowing snow especially focused on near the snow surface. For a better understanding of spatial development structure of blowing snow, observations about the horizontal development of blowing snow near the surface have been carried out. The results obtained by the cold wind-tunnel experiments showed if the wind became strong, the development to a horizontal direction became weaker than that to a vertical direction. In addition, the results of field observations in blowing snow at Sapporo showed blowing-snow flux remarkably increased when the wind blew from the direction of a long fetch. It is necessary to carry out the spatial observation above the blowing snow layer using such as a kite in the field in future while investigating the horizontal development of blowing snow experimentally in detail.

キーワード：吹雪、空間発達
Keywords: blowing snow, spatial development

Assimilation of all-sky GCOM-W/AMSR2 brightness temperature using a strongly coupled atmosphere-land data assimilation system in snowy Siberia

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Coupled numerical models address the interaction between processes in the atmosphere, ocean, land surface, biosphere, chemistry, cryosphere, and hydrology. Including the interaction between such processes can potentially extend the predictability and eventually help in reducing the uncertainty of the prediction. Coupled data assimilation is a branch of data assimilation that deals with coupled modeling systems. There are two kinds of coupled data assimilation systems such as weakly and strongly coupled data assimilation. Recently we developed a strongly coupled atmosphere-land data assimilation system (Suzuki et al., 2017). In this article the fundamentals of bias correction for the all-sky GCOM-W/AMSR2 brightness temperature using coupled data assimilation are described. Through a series of data assimilation experiments, we analyze the effectiveness of bias correction coefficients and predictors. Through this study, we analyze the impact of all-sky brightness temperature in reanalysis. Finally, applying coupled data assimilation can visualize more details of coupled atmosphere-land interaction.

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キーワード：結合データ同化、大気積雪相互作用、降雪
Keywords: Coupled data assimilation, Atmosphere-Snow interaction, Snowfall

The method for identification of the cryoconite distribution by using satellite image

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Cryoconite, which is very small dark substance on glacier containing cyanobacteria and growing tangling with minerals, can absorb sunlight much, causing the faster melting than usual white snow. The valuable field survey enables us to study the cryoconite, albeit applying in the small area and with long interval. And a few remotesensing study uncover the glacier darkening and regression. Nevertheless no one knows how to point out its distribution over a wide area.
Here, according to luminance difference of between the glacier and the cryoconite, we propose new method with using multispectral bands of Landsat8 (resolution 30m), band2(450-515nm, B2) and band5(850-880nm, B5) to distinguish those two by making a new formula” (B5-B2)/(B5+B2)” (R). In the range of B2, the cryoconite’s reflectance is about 10 %; otherwise the glacier has high percentage. In the range of B5, the cryoconite’s one is about 20%; in contrast the glacier’s almost half. The satellite images we use in 2016 July 30th, are analyzed since the cryoconite appeared widely and well in the period of 2016 late July to the beginning of August. We were successful in remove the shadow on this image by comparing R and RGB image. If a pixel in R is brighter than the other images, the place of the pixel should be cryoconite or sand.
The calculated index(R), in their spectra from previous study, applied that both of the cryoconite and the sand take a positive value while the glacier take a negative value in the pixel. The criterion will be shown in the presentation.

キーワード：クリオコナイト、リモートセンシング、氷河
Keywords: cryoconite, remote sensing, glacier

ひまわり8号熱赤外域バンドを用いたオホーツク海海氷面温度と薄氷域の抽出

Retrieval of ice surface temperature and thin ice area using thermal infrared bands of Himawari-8/AHI

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Ice surface temperature (IST) has been an important observation target from space not only for calculating radiation budget but also for estimating the production of thin ice thickness in the cryosphere. In particular, the latter is important for assessing the amount of dense water with high salinity produced under newly formed thin ice. In this study we developed an algorithm for estimating IST and emissivity simultaneously using a semi-empirical emissivity model which can simulate the dependence of spectral emissivity on the surface snow/ice type and exitance angle. In this analysis we neglected the effect of water vapor absorption in the atmosphere and applied the algorithm to the data of AHI sensor onboard the Japanese geostationary satellite Himawari-8. Channel 13 (center wavelength: 10.4 μm) and 15 (12.4 μm) were used for the retrieval. The results show that emissivity as well as IST seemed to be successfully retrieved over the Okhotsk ice areas (but not validated with in-situ data). From the retrieved emissivity image, the area of thin sea ice such as nilas were easily determined. In addition, from the comparison with the case using a fixed emissivity for all snow and ice type, possible error in the IST retrieval with the fixed emissivity could be estimated to be up to a few Kelvin, which is due to the low emissivity of thin sea ice and the large viewing zenith angle of AHI around 60 degrees when observing the area of Okhotsk Sea. The same approach can also be applied to the data of polar orbit satellite such as the coming Japanese satellite mission “Global Change Observation Mission-Climate” (GCOM-C) to be launched in 2017.

キーワード：氷面温度、氷タイプ、射出率、リモートセンシング、AHI、SGLI
Keywords: Ice surface temperature, Ice type, Emissivity, Remote Sensing, AHI, SGLI

Inter-annual modulation of seasonal glacial velocity changes in the Eastern Karakorum detected by ALOS-1/2 data

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Whereas the ice sheets all over the world are receding, the glaciers in Karakoram are either stagnant or advancing, which is known as ‘Karakoram anomaly’. The surging dynamics and mass balance have been extensively studied in this area. However, in the Eastern Karakorum Range, the spatial and temporal changes in glacial velocity have been so far poorly understood. We have analyzed nearly all the available ALOS-1/2 data in this area and have examined the inter-annual modulation of five glaciers. The glaciers with size >30km, i.e. Siachen, Baltoro and Eastern tributary of Kundos, are mostly showing a considerable velocity change in their various parts, accompanying clear seasonal changes both in ALOS-1/2 data. However, this change mostly depends upon the individual glacier and is variable in space and time. On the other hand, the smaller glaciers (<30km), i.e. Singkhu, Gasherbrum and Western tributary of Kundos glaciers, are showing a slowdown in ALOS-2 data. Analysis of the local air surface temperature data at five observatories indicates that during the same season, the temperature trend in the study area is uneven and probably varies significantly between different glaciers. It can result in localized warming/cooling that can affect the availability of melt-water for an individual glacier. The excess surface melt-water at each individual glacier may undergo a variety of en/sub-glacial hydraulic and hydrological processes that are further different at each glacier. Thus, it will result in a complex velocity behavior in this region.

Keywords: Eastern Karakorum, Pixel offset, Glacier velocity, Inter-annual modulation

Measurement of mass balance with high altitude, and thermal property of debris-covered area at the Trambau Glacier, Nepal

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Shrinkage of Himalayan glaciers is unabated and thus contributes to sea level rise. In this region, in-situ measurements of mass balance of large glaciers have been conducted at few glaciers due to the difficult accessibility to their accumulation area. Moreover, many large glacier tongues are covered with debris, which makes the ablation process complicate. Thus, it is required to carry out in-situ measurement at debris-covered glaciers with accessible accumulation area.
We carried out in-situ measurements at Trambau glacier in the Nepal Himalaya pre- and post-monsoon seasons in 2016. We installed stakes network from ablation to accumulation area, and obtained direct mass balance data. An automatic weather station was set beside the glacier to obtain basic meteorological data during observation period. In order to establish a model for ablation at debris-covered ice, we also measured thermal conductivity and water content in debris layer, and set temperature sensors at different depth in the debris layer. Observed mass balance ranges from -2.62 m to +0.12 m w.e. a^{-1} during the period. The maximum ablation is found at 5280 m a.s.l., which is the lower bound of debris-free area, and a liner relationship is found between mass balance and elevation ($r = 0.94$, $p < 0.01$). In contrast, no significant correlation is found between mass balance and elevation in debris-covered area whereas a coefficient correlation between mass balance and thermal resistance, which is a proxy of debris thickness, is 0.71 ($p < 0.05$).

キーワード：氷河、ヒマラヤ、質量収支、デブリカバー
Keywords: glacier, Himalaya, mass balance, debris cover

山岳氷河域研究のための全球スケール無償DEMの定量評価
Quantitative evaluation of global-scale free DEMs for mountain glaciology

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航空機や人工衛星を用いた写真測量の原理による地形データの作成は、数値標高モデル（DEM: Digital Elevation Model）として近年まで様々な方法で実施され、数多くのデータセットが整備されてきた。特に人工衛星を用いたDEM作成は雪氷山岳地域において均一な地形情報を得る上で非常に重要であり、氷河研究の進展への影響も大きい。本発表では近年整備が進められてきた無償公開の全球スケールDEMを日本国内の起伏の異なる地形およびヒマラヤ氷河域で比較し，生じる差異を検証し、山岳氷河研究での有効性を議論する。

様々なDEMデータセットのうち、最近になって画素サイズ30 mのASTER GDEM，SRTM1，ALOS World 3D-30m（AW3D30）が整備された。これらの標高データについて国土地理院・基盤地図情報から三角点・測量点（CP: Check Point）の標高値を取得し、精度評価を北アルプスの氷河地形、富士山裾野、利根川流域の沖積平野にて実施した。The

その結果、どの場所においてもAW3D30が地理院CPに近い値を示すことが分かった。DEM間でもっともばらつきが大きいのが北アルプスであり、ASTER GDEM，SRTM1について13-18 mほどCPより低く、ばらつき（CP値とDEM値の差分の標準偏差）は15-20 mとなった。起伏が緩やかな地形ほど、DEMによる精度の差異は小さくなり、利根川流域のほぼフラットな水田地帯ではSRTM1とAW3D30がほぼ等しい精度となった（＋0.1±3.1 m）。ASTER GDEMにおいてもCP標高値との差の平均および標準偏差はともに5 m以下であった。このようにDEMが異なれば、地形によって精度が大きく異なることが示された。AW3D30が北アルプスの急峻地形においても最も高精度であるが、より平坦な地形ではSRTM1の精度も大きく改善されることがわかった。

DEM作成ではステレオペア画像間で対応点の取得が十分にできない部分で欠損が生じる。欠損そのものは有益ではないが、どこにどのように欠損が生じるかは、研究に最も適したDEMを選ぶ際に重要な知見となる。そこでネパールヒマラヤにおいて，上記三種DEMの欠損がどのように生じているかを検証した。AW3D30の欠損はヒマラヤ主脈周辺で多く見られた。これはALOS衛星の光学画像によって取得されたため、山頂付近・氷河涵養域では積雪によって上手く対応点をマッチングできないことが原因と考えられる。SRTM1では、より低標高で斜度45°付近に最も欠損が集中していることが分かった。軌道横方向斜め下にレーダを照射して地形計測を行うため、急峻な山に妨げられるシャドーイングやレイオーバー（近くの谷より遠くの山の方が先に電波を反射することに起因する受信順序の反転）が原因と考えられる。一方、最も長期にわたる観測データから作成されたASTER GDEMでは対象地域内に欠損は見られなかった。精度は高くないが、集水域の作成など、抜け目のないデータが必要となる際に有用なDEMであると言える。

キーワード：SRTM、GDEM、AW3D
Keywords: SRTM, GDEM, AW3D

InitMIP-Greenland experiments with the ice sheet model SICOPOLIS

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The Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6) brings together a consortium of international ice sheet and climate models to explore the contribution from the Greenland and Antarctic ice sheets to future sea level rise. For such projections, initialisations are required that provide initial states of the respective ice sheet. Therefore, as one of the first initiatives within ISMIP6, InitMIP-Greenland was launched in order to explore this issue for the Greenland ice sheet across a variety of models and initialisation techniques. Two different initialisation techniques are common, namely spin-up methods (paleoclimatic simulations until the present) and assimilation methods (assimilation of observations of the present-day ice sheet). We contribute to InitMIP-Greenland with the ice sheet model SICOPOLIS and two different spin-up techniques, (1) a SeaRISE-legacy spin-up over 125 ka with essentially fixed topography, and (2) a new spin-up over 135 ka with freely evolving topography. New methods applied for spin-up (2) are monthly-mean (rather than mean annual) input data for the present-day precipitation, a sub-grid-scale ice discharge parameterisation and an iterative correction of the present-day precipitation based on the misfit between the simulated and observed present-day ice thickness. The agreement between simulated and observed ice topography is naturally better for the fixed-topography case (1) than for the freely evolving case (2). Both spin-ups produce a realistic distribution of the surface velocity, including the major ice streams and outlet glaciers (at 5 km horizontal resolution). InitMIP-Greenland also comprises two future climate scenarios, ctrl (present-day climate over 100 a) and asmb (prescribed schematic surface mass balance anomaly over 100 a due to global warming), both to be run with freely evolving ice topography. The response of the ice sheet (mass loss) to the asmb forcing is, in absolute terms, ~50% larger for spin-up (2) than for spin-up (1), and relative to the respective control run ctrl even ~85% larger. This demonstrates impressively that, even with the same ice sheet model, different initialisation methods can lead to a major spread of results of future climate experiments.

Keywords: Greenland, Ice sheet, Climate change, Sea level rise, Modelling

The Effects of H2SO4 on the Flow and Fabric of Polycrystalline Ice

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It is well established that the Earth’ s large continental ice sheets contain a variety of naturally occurring impurities, both soluble and insoluble. Understanding how these impurities affect the rheology, intrinsic thermodynamic properties, and ultimate fate of these ice sheets is much less understood. Previous work has shown that H_2SO_4 dramatically reduces the strength and increases the ductility of single crystal ice, but its effects on polycrystalline ice are unknown. In order to investigate the effects that trace amounts of H_2SO_4 have on the flow and ductility of polycrystalline ice a series of mechanical tests were conducted at -6˚C, -10˚C, -12˚C, and -20˚C using laboratory-prepared ice with a mean grain diameter of 1 mm and doped with 1-10 ppm of H_2SO_4. Parallel tests were performed on identical, but undoped polycrystalline ice. Mechanical testing included uniaxial tensile creep tests at a constant load of 38 kg (0.75 MPa initial stress) and uniaxial compression tests at constant strain rates ranging from 1×10^{-6} s^{-1} to 1×10^{-4} s^{-1}. The tensile tests showed that H_2SO_4-doped specimens exhibited faster creep rates than undoped ice, while the compression tests demonstrated that H_2SO_4-doped specimens exhibit a significantly lower peak stress than undoped ice. Post-mortem microstructural analyses were performed using cross-polarized light thin section imaging, X-ray computed microtomography, Raman spectroscopy, and electron backscatter diffraction. These analyses showed that H_2SO_4-doped specimens had a much larger grain size at strains 15%, and an earlier onset of micro-cracking at lower strain rates than the undoped ice. Further, a liquid-like phase containing H_2SO_4 appears to be present at the grain boundaries of the H_2SO_4 doped ice.

Keywords: Ice, Sulfuric , Acid, Microstructure, Rheology