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Regular Articles

Circulation system of an Antarctic electromechanical bedrock drill

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For bedrock core drilling below 3000 m in the Antarctic ice sheet, Jilin University has designed a set of modular electromechanical drills with a local reverse circulation system, which works at the bottom of the borehole to remove the rock powder. Thorough removal of the rock powder is critically important to prevent it from accumulating in the bottom of the hole and eventually blocking the drill or causing other problems. During drilling, rock powder is carried by the drilling fluid, which flows from a down-hole pump to the chip chamber. If drilling fluid in the bottom of the hole cannot overcome the flow resistance or if its velocity is too low, the rock powder will not be carried to the chip chamber, and will remain in the borehole or gather in the clearance of the circulation system. Therefore, the down-hole pump performance characteristics are of vital importance. The selection of the down-hole pump for bedrock core drilling should consider both flow rate and outlet pressure. This paper reports a specific calculating method for the rEquired flow rate of the drilling fluid and the pressure losses in the circulation system.

Detailed subglacial topography and drumlins at the marginal zone of Múlajökull outlet glacier, central Iceland: Evidence from low frequency GPR data

Kristaps Lamsters, Jānis Karušs, Agnis Rečs, Dāvids Bērziņš

New ground penetrating radar (GPR) observations on the Múlajökull surge-type outlet glacier, central Iceland, are presented. Overall 10.5 km of GPR profile lines were recorded parallel to the glacier margin in August, 2015. Detailed GPR investigations combined with high-accuracy GPS measurements allowed to build a high-resolution model of the subglacial topography. We provide new evidence of streamlined ridges beneath Múlajökull's marginal zone interpreted as drumlins and show the location of the upper edge of the drumlin field. This discovery improves understanding of the location, morphology and development of drumlins as other geophysical observations of subglacial bedforms beneath modern outlet glaciers are quite rare. The location of drumlins corresponds with the position of the major sets of crevasses in the digital elevation model (2008) suggesting the presence of additional drumlins beneath such crevasses in the ice-marginal zone. We suggest this semi-circular pattern of crevasses to be formed due to the variable glacier strain rates

created by the subglacial topography. Numerous hyperbolic diffractions representing reflections of englacial channels are found in radar profiles suggesting a well-developed channelized drainage system of a surge-type glacier in its quiescence phase. The calculated thinning of the ice surface in the investigated area (0.65 km^2) is on average 17.9 m during 2008–2015.

Visible and near-infrared spectral survey of lunar meteorites recovered by the National Institute of Polar Research

T. Hiroi, H. Kaiden, A. Yamaguchi, H. Kojima, K. Uemoto, M. Ohtake, T. Arai, S. Sasaki

Lunar meteorite chip samples recovered by the National Institute of Polar Research (NIPR) have been studied by a UV–visible–near-infrared spectrometer, targeting small areas of about 3 × 2 mm in size. Rock types and approximate mineral compositions of studied meteorites have been identified or obtained through this spectral survey with no sample preparation required. A linear deconvolution method was used to derive end-member mineral spectra from spectra of multiple clasts whenever possible. In addition, the modified Gaussian model was used in an attempt of deriving their major pyroxene compositions. This study demonstrates that a visible-near-infrared spectrometer on a lunar rover would be useful for identifying these kinds of unaltered (non-space-weathered) lunar rocks. In order to prepare for such a future mission, further studies which utilize a smaller spot size are desired for improving the accuracy of identifying the clasts and mineral phases of the rocks.

Phenology of *Racomitrium lanuginosum* growing at a seasonally snow-covered site on Mt. Fuji, Japan

Fumino Maruo, Satoshi Imura

We investigated the seasonality of the development of the gametangia and sporophytes of *Racomitrium lanuginosum* growing at a seasonally snow-covered site (ca. 2200 m altitude) on Mt. Fuji, Central Honshu, Japan. Shoots of *R. lanuginosum* were collected every 2 weeks during the snow-free period (June–November) in 2014. The number of inflorescences and the numbers, sizes, and developmental stages of the male and female gametangia and sporophytes were recorded. Archegonia developed quickly in early spring, but antheridia took longer to develop from the previous summer. Fertilization occurred in June and July and spore dispersal occurred in June of the following year. The archegonia took 1 month to mature, the antheridia took 7–10 months, and the sporophytes took 10 months. The development of the antheridia and sporophytes stopped during the winter when the study site was covered by snow.

Regional patterns and controlling factors on summer population structure of *Calanus glacialis* in the western Arctic Ocean

Kohei Matsuno, Yoshiyuki Abe, Atsushi Yamaguchi, Takashi Kikuchi

In the Arctic Ocean, *Calanus glacialis* is the most dominant species in zooplankton biomass. While important, little information is available concerning the factors controlling their population. In this study, we evaluated regional patterns and environmental factors controlling the population structure

of *C. glacialis* in the western Arctic Ocean in summer months (July–October) in 1991, 1992, 2007, 2008, 2010, 2012, 2013 and 2014. To evaluate regional patterns, environmental parameters (temperature, salinity and chlorophyll *a*) and *C. glacialis* population parameters (abundance, biomass, mean copepodid stage and lipid accumulation) were divided into three latitudinal regions. In all three regions from July to October, chlorophyll *a* decreased, while the mean copepodid stage increased. These results suggest phytoplankton blooms occurred early in the sampling period, and *C. glacialis* grew during the period. From Structural Equation Model (SEM) analysis, the controlling factors on the *C. glacialis* population were evaluated. The results of the SEM analysis indicated positive correlations between abundance and biomass; Julian day and mean copepodid stage; and temperature and mean copepodid stage. Additionally, a negative correlation between abundance and mean copepodid stage was observed.

Exposure of bovine dermal tissue to ultraviolet light under the Antarctic ozone hole

Tetsuya Takahashi, Takayuki Ogura, Keisuke Tanaka, Shunji Hattori, Sakae Kudoh, Satoshi Imura

Bovine dermis was exposed outdoors in the Antarctic in 2013 to study the skin damage caused by short-wavelength ultraviolet light under the ozone hole. Collagen was extracted from the exposed dermis with pepsin. The amount of solubilized collagen in the exposed dermis was only 20%–40% of that in dermis shielded from ultraviolet light. The dermis was most difficult to extract when exposed in summer, and then when exposed in spring. Differential scanning calorimetry was used to determine the melting endothermic behavior of the dermal tissue. The peak temperature was highest for the dermis exposed in summer. The exposed dermis was degraded with cyanogen bromide to determine whether cross-linking had occurred. Cross-linked peptides were detected in the dermis exposed in summer or spring, but the dermis exposed in autumn did not differ markedly from the light-shielded dermis. These data show that cross-linkages were readily formed in the collagen molecule chains in dermis exposed to ultraviolet light in summer, when solar elevation is highest and the period of sunshine is longest. A comparison of the dermis exposed in spring and that exposed in autumn showed that cross-linkages were formed more readily by ultraviolet light in spring, when the ozone hole occurred.

Distribution of detrital minerals and sediment color in western Arctic Ocean and northern Bering Sea sediments: Changes in the provenance of western Arctic Ocean sediments since the last glacial period

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This paper describes the distribution of detrital minerals and sediment color in the surface sediments of the western Arctic Ocean and the northern Bering Sea and investigates the relationship between mineral composition and sediment provenance. This relationship was used to determine the provenance of western Arctic Ocean sediments deposited during the last glacial period. Sediment color is governed by water depth, diagenesis, and mineral composition. An a*–b* diagram was used to trace color change during diagenesis in the Arctic Ocean sediments. The mineral composition of

surface sediments is governed by grain size and provenance. The feldspar/quartz ratio of the sediments studied was higher on the Siberian side than on the North American side of the western Arctic Ocean. The (chlorite + kaolinite)/illite and chlorite/illite ratios were high in the Bering Sea but decrease northwards in the Chukchi Sea. Thus, these ratios are useful for provenance studies in the Chukchi Sea area as indices of the Beaufort Gyre circulation and the Bering Strait inflow. The sediments deposited during the last glacial period have a lower feldspar/quartz ratio and a higher dolomite intensity than Holocene sediments on the Chukchi Plateau, suggesting a greater contribution of North American grains during the last glacial period.

What influences heavy metals accumulation in arctic lichen *Cetrariella delisei* in Svalbard?

Michał Węgrzyn, Paulina Wietrzyk, Maja Lisowska, Beata Klimek, Paweł Nicia

The main aim of this study was to identify variations in heavy metal concentrations in *Cetrariella delisei* along a transect from a High Arctic glacier forehead to the shoreline as well as determine the main environmental factors influencing the deposition of heavy metals in arctic lichens. The macrolichen *Cetrariella delisei* appears to be an interesting alternative to those lichen species used in the past (e.g. *Flavocetraria nivalis*, *Cladonia* sp.) for heavy metal biomonitoring purposes in the Arctic: it is widely distributed, easy to identify and reluctantly grazed by reindeer. Fieldwork was conducted in the summer of 2012 in the Kaffiøyra Plain, Oskar II Land, NW Spitsbergen. *C. delisei* and soil samples were collected from 5 localities. Concentrations of Cr, Mn, Ni, Cu, Zn, Pb, and Cd were measured in each sample. A bioaccumulation factor (BAF) was calculated for all the analyzed elements. The BAFs for Cu, Mn, and Ni showed a relatively low accumulation level in lichen thalli. On the other hand, the BAFs for Cr, Pb, and Zn, revealed an increased accumulation level in *C. delisei*. The Cd content in lichen is almost equal to its level in the soil. The statistical analyses covered three environmental factors: soil pH, substrate type and distance from the shoreline. The data were examined using the Kruskal-Wallis test, canonical correspondence analysis and a permutation test. The results show that distance from the shoreline had the greatest influence on the majority of the heavy metal concentrations in the lichen thalli and the soil. However, the level of Mn accumulated in the soil is determined by its source in the glacier. Moreover, the soil pH had the greatest effect on the Cd accumulated in the soil and the Mn accumulated in the lichen thalli.

Inter-annual dynamics of the Barents Sea red king crab (*Paralithodes camtschaticus*) stock indices in relation to environmental factors

Alexander G. Dvoretsky, Vladimir G. Dvoretsky

Knowledge of relationships between environmental variables and biological processes can greatly improve fisheries assessment and management in commercially important species. We analyzed the effects of environmental factors (climatic indices and water temperature) on the stock characteristics (total population number, number of pre-recruits and number of legal males) of the red king crab (*Paralithodes camtschaticus*), an introduced species in the Barents Sea. Stock trends in red king crab appear to be related to decadal climate shifts. Abundances were negatively related to the North Atlantic Oscillation index (NAO) in August and positively related to water temperature in late

winter–early summer. Total and commercial stock abundance were negatively correlated with the lag-1 Arctic Oscillation index (AO) in August and the lag-2 winter NAO index. The total number of *P. camtschaticus* was most strongly associated with water temperature in spring and summer and NAO/AO indices in April and May. Lagged NAO indices in February and August (9 or 10 yr) had a positive relationship to the commercial stock of *P. camtschaticus*. These findings suggest that temperature conditions of current and previous year affect natural mortality of larvae and juvenile red king crabs. Warmer temperature conditions lead to increased biomass of red king crab food items. Negative correlations between climatic indices and the red king crab stocks may be associated with predator pressure on juvenile red king crabs or higher mortality because of predator or parasite pressure and diseases. The associations between stock indices and environmental variables could help better predict recruitment patterns of *P. camtschaticus*.

Enhancing calculation of thin sea ice growth

Igor Appel

The goal of the present study is to develop, generate, and integrate into operational practice a new model of ice growth. The development of this Sea Ice Growth Model for Arctic (SIGMA), a description of the theoretical foundation, the model advantages and analysis of its results are considered in the paper. The enhanced model includes two principal modifications. Surface temperature of snow on ice is defined as internal model parameter maintaining rigorous consistency between processes of atmosphere-ice thermodynamic interaction and ice growth. The snow depth on ice is naturally defined as a function of a local snowfall rate and linearly depends on time rather than ice thickness. The model was initially outlined in the Visible Infrared Radiometer Suite (VIIRS) Sea Ice Characterization Algorithm Theoretical Basis Document (Appel et al., 2005) that included two different approaches to retrieve sea ice age: reflectance analysis for daytime and derivation of ice thickness using energy balance for nighttime. Only the latter method is considered in this paper. The improved account for the influence of surface temperature and snow depth increases the reliability of ice thickness calculations and is used to develop an analytical Snow Depth/Ice Thickness Look up table suitable to the VIIRS observations as well as to other instruments. The applicability of SIGMA to retrieve ice thickness from the VIIRS satellite observations and the comparison of its results with the One-dimensional Thermodynamic Ice Model (OTIM) are also considered. The comparison of the two models demonstrating the difference between their assessments of heat fluxes and radical distinction between the influences of snow depth uncertainty on errors of ice thickness calculations is of great significance to further improve the retrieval of ice thickness from satellite observations.

Operational high latitude surface irradiance products from polar orbiting satellites

Øystein Godøy

It remains a challenge to find an adequate approach for operational estimation of surface incoming short- and longwave irradiance at high latitudes using polar orbiting meteorological satellite data. In this presentation validation results at a number of North Atlantic and Arctic Ocean high latitude stations are presented and discussed. The validation results have revealed that although the method works well and normally fulfil the operational requirements, there is room for improvement. A number of issues that can improve the estimates at high latitudes have been identified. These improvements are partly related to improved cloud classification using satellite data and partly related to improved handling of multiple reflections over bright surfaces (snow and sea ice), especially in broken cloud conditions. Furthermore, the availability of validation sites over open ocean and sea ice is a challenge.