SCAR 2020

Antarctic Science - Global Connections

SCAR OPEN SCIENCE CONFERENCE 2020

SESSION 11

REMOTE SENSING OF THE POLAR REGIONS

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ABSTRACTS SUBMITTED TO THE (CANCELLED) SCAR 2020 OSC IN HOBART

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Glacier-Ocean Interface as an Important Mechanism in the Carbon Cycle: a case study from in situ measurements and remote sensing in Antarctica

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Recently glaciers and ice sheets have been recognized as hot spots for biogeochemical weathering with implications in the global carbon cycle (Bhatia et al., 2013; Hood et al., 2015; Wadham et al., 2019). Meltwater runoff contains significant amounts of dissolved and particulate organic carbon (DOC, POC) normally dominated by supraglacial melting (Stibal et al., 2012). Assessing both organic carbon (OC) reservoirs are important as they are likely to be influenced by different processes and to have positive and negative impacts on aquatic ecosystems (Musilova et al., 2017), as in ice sheets and glaciers (Hu et al., 2018). Although satellite data has been used to address the contribution of ice mass to the ocean, we still lack precise estimates of calving, melt runoff, and oceanographic properties to quantify accurately the release and impacts of DOC and POC in the marine ecosystems. Satellite and in situ data were collected in Lange glacier and Almirantazgo bay, King George Island during the summer of 2020 to quantify the glacial input of freshwater to the marine system. Three shallow ice cores were extracted to determine the concentrations per volume, as different features of DOC and POC. Moreover, an oceanographic transect and profiles were performed to assess OC characteristics, primary productivity, and bio-optical properties in terms of glacial influence. All the data collected is being analyzed and results will be presented during the framework of the SCAR Conference 2020.

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RESOURCE
Radio Sciences Research on AntarCtic AtmosphEre

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We report the application to establish a Programme Planning Group for developing a SCAR (Scientific Committee on Antarctic Research) Scientific Research Programme (SRP) entitled “Radio Sciences Research on AntarCtic AtmosphEre” (RESOURCE). The proposed SRP aims to gather the communities that investigate the polar atmosphere, with particular reference to Antarctica but with a bi-polar perspective, by means of radio probes into a common shared initiative. The scope is to improve the current understanding of the Antarctic atmosphere by sharing the expertise and the experience achieved by several scientific teams in the world, thus facilitating the advancement in the field and avoiding any duplication of activities already in action. SCAR is the best platform to create the necessary environment to assess the actual current understanding and to address the efforts to fill the gaps. The radio techniques enabled by ground and satellite-based sensors have proved to be very effective when probing the lower, middle and upper atmosphere. In parallel, several scientific communities using radio techniques spent significant efforts to remove (what they consider) “atmospheric noise” to extract the desired information from their measurements. However, these communities do not sufficiently interact. The RESOURCE SRP aims to take advantage of the experience of the SCAR Expert Group GRAPE (GNSS Research and Application for Polar Environment). The proposed SCAR scientific programme RESOURCE will build upon this important legacy by enhancing interactions between the scientists who measure and utilise the entire radio spectrum, either as an auxiliary or principal observation.

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Multi-scale mapping and monitoring of permafrost conditions in a high Arctic polar desert

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With the Arctic warming at twice the rate of the rest of the planet, permafrost landscapes are facing accelerated thawing and thermokarst (ground subsidence). In the face of this change, it is critical to monitor Arctic permafrost landscapes. However, the remoteness, inaccessibility, and vastness of Arctic sites can make high spatial and spectral resolution data collection difficult, and therefore mapping and monitoring problematic. To comprehensively evaluate the ground surface conditions in such environments, we propose a multi-scale remote sensing framework, combining medium and high resolution multi-spectral imagery (Landsat 7 and 8, Worldview 2 and 3) with high resolution unmanned aerial vehicle (UAV) RGB and thermal imagery, ground penetrating radar (GPR), and field observations. The derived surface conditions can be used as a proxy for changes in sub-surface conditions such as active layer depth or thermokarst. This framework was applied in the Eureka Sound Lowlands of Ellesmere Island, Nunavut to characterize permafrost conditions. Multispectral imagery was used to compute various vegetation and soil moisture indices (NDVI, SAVI, NDMI, TCB, TCG, TCW) over 20 years on a regional scale. UAV RGB and thermal images were used to create high resolution surface models using structure from motion on a local or landform scale, along with GPR and ground observation data to inform and validate the coarser satellite imagery analysis. Overall, the presented framework effectively bridges the gap between ground data collection, which is typically accurate, but limited in scope and satellite remote sensing, which covers large spatial extents, but is limited in accuracy.

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Investigating the seasonal dynamics of the Ross Ice Shelf, Antarctica using remote sensing data

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The Ross Ice Shelf (RIS) buttresses both the West Antarctic Ice Sheet (WAIS) and the East Antarctic Ice Sheet (EAIS) and thus has a strong potential to control future sea-level rise (Rignot et al. 2013). Understanding the processes that control RIS dynamics today can help interpret ice sheet changes due to atmospheric and oceanic warming that occurred in the past (Lowry et al. 2019) as well as what is projected for the future (Dinniman et al.2016).

This project aims to use remote sensing and fieldwork to better characterise short-term environmental variability in Ross Ice Shelf dynamics, because the sensitivity of the Antarctic Ice Sheet (AIS) system to internal environmental varaibility - as opposed to externally-forced large-scale climate perturbations - remains poorly understood and constrained (Gwyther et al. 2018; Holland et al. 2019). Remote sensing data can provide invaluable insights into Antarctica's ice flow rates and mass loss (Mouginot et al. 2017; Rignot et al. 2013), and this has led to improvements in ice sheet model initializations and parameter estimation (Pattyn et al. 2017). This presentation will present satellite and GPS ice velocity estimates for the RIS, and will compare these to observations of oceanic and atmospheric changes. Methodological as well as seasonal differences in ice velocity magnitudes will be discussed in the context of their ability to constrain ice sheet model simulations that explore how ice shelf behaviour may be influenced by short-term environmental forcing.

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Quantification of lateral stream channel migration on a basin-wide scale using lidar and Support Vector Machines: Taylor Valley, Antarctica

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The McMurdo Dry Valleys (MDV), are located adjacent to the Ross Sea and Transantarctic Mountains in East Antarctica. Nearly all of the precipitation (<100 mm/year.) in the MDV sublimates, while temperatures fluctuate above and below the melting point during austral summer producing irregular glacial runoff. Geomorphologic processes can therefore be seen as a function of regional climatic change. The MDV is remote, expensive to access, and too extensive to collect ample field data during the summer field season, making manual methods for migration tracking infeasible. An increase and then leveling off of solar radiation causes an increase in temperature in low albedo sediment and dirty glacial ice, resulting in mobilization of ice and sediment. Toolboxes for measuring migration are labor intensive and lack the capability of quantifying migration at a larger-scale. A toolbox for locating and quantifying lateral migration variability on a valley-wide scale was developed with the utilization of DEMs from both satellite and airborne derived lidar from 2001 to 2019. Geometric patterns of lateral change were used as input parameters to a support vector machine (SVM) for location of lateral migration. Additionally, climatic, topographic, and geologic controls on migration were assessed. This study evaluates and quantifies the stability of the MDV, which is projected to change at faster rates in upcoming decades due to regional climate change. This research will not only advance our understanding of channel geomorphology in the MDV but will also provide tools that will simplify locating lateral migration in larger-scale regions.

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Recent glaciological mass balance of Znosko glacier, King George Island, Antarctic Peninsula

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Climate variations over the last decades show a strong warming trends in the atmospheric surface layer over the Antarctic Peninsula, concurrent with the glacial retreat, an increase in melt areas and disintegration of ice shelves. Little is known about glacier mass balance changes in this region because of the logistical difficulty involved, the large glacier areal extent and the extreme weather conditions the year around. This study present new glacier mass balance field data from Znosko glacier, King George Island, Antarctic Peninsula obtained by glaciological method, carried out in two field campaigns (austral summer 2018/19 and 2019/20) during the XXVI and XXVII Peruvian Antarctic Operation. The glacier has an estimated total area of 1.77 km^2 (January 2020), a length around of 1.9 km and maximum elevation of 300 meters above sea level (m.a.s.l.). 19 stakes were fixed on the glacier surface, in situ mass balance data were collected from yearly stake measurements. The glaciological observations reflects a heterogeneous pattern of accumulation and ablation areas, with an ELA of 124 (austral summer 2018/19) and 161 (austral summer 2019/20) meters above sea level (m.a.s.l.). Also, glacier surface digital elevation model (DEMs) were generated using UAV by photogrammetry method (Drone).

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Modelling glacier thickness distribution and bed topography of Znosko glacier, King George Island, Antarctic Peninsula

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The on-going drastic changes in the climatic systems have caused a substantial decline for the most glacier in the world. This phenomena has been observed at different locations on the Antarctic Peninsula and especially on King George Island. Ice thickness distribution and volume are important parameters for glaciological applications. The current study has been performed over Znosko glacier, King George Island, Antarctic Peninsula. The glacier has an estimated total area of 1.7 km^2, a length around of 1.9 km and maximum elevation of 300 meters above sea level (m.a.s.l.). We estimated the ice thickness distribution and bed topography for Znosko glacier using Glacier Bed Topography (GlabTop) model. We validated the model with ground penetrating radar (GPR) profiles and the glacier surface topography (DEM) obtained by photogrammetry method (Drone) with a sub metric resolution from two field campaigns carried out in the austral summer 2018/19 and 2019/20, during the XXVI and XXVII Peruvian Antarctic Operation, respectively. The results show that the ice thickness distribution varies at different parts in the tongue of the glacier, with a maximum value of 155 m at the central part. We bounded areas in the bedrock topography below sea level, which can be seen as potential sites for future lake formation.

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Airborne-validated satellite altimetry assessment of ice shelf-influenced fast ice

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The outflow of supercooled Ice Shelf Water from the McMurdo Ice Shelf cavity drives the formation of thicker land-fast sea ice and a sub-ice platelet layer in McMurdo Sound. Here, we investigated if the CryoSat-2 satellite radar altimeter is capable of detecting anomalously higher freeboard driven by the thicker ice shelf-influenced sea ice and the buoyant forcing of the sub-ice platelet layer beneath. CryoSat-2 ice freeboard obtained from Level 2 SAR interferometric surface elevation retrievals over fast ice in McMurdo Sound was compared with five years of drill hole measured sea ice and snow freeboard, and sea ice and SPL thicknesses, and snow layer depths in November 2011, 2013, 2016, 2017 and 2018. Trends of increasing CryoSat-2 obtained freeboard and ice thickness were observed with concurrent increases in sea ice and sub-ice platelet layer thickness towards the McMurdo Ice Shelf every year. The spatial distribution of anomalously higher CryoSat-2 derived ice freeboard correlated with the distribution of thicker ice shelf-influenced sea ice and the sub-ice platelet layer. Laser altimeter snow freeboard measurements from the ICESat-2 satellite altimeter and airborne electromagnetic induction surveys provided further validation to the CryoSat-2 observed freeboard anomalies over ice shelf-influenced fast ice. We demonstrated that the CryoSat-2 satellite radar altimeter is indeed capable of detecting freeboard anomalies driven by supercooled Ice Shelf Water outflow in McMurdo Sound, and is an applicable tool to identify regions of ice shelf-influenced fast ice elsewhere around the Antarctic coastline.

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Differentiating rock and ice in RGB and/or multispectral data

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In the high latitudes of the Polar Regions, deep shadows are a permanent presence. Consequently, the NDSI (Normalised Difference Snow Index) is ineffective in differentiating snow and ice from Earth observation imagery.

We present our past and continuing efforts to develop new methods to resolve this problem, including the fully automated multispectral method for mapping rock outcrop extent across Antarctica, and a new semi-automated method for mapping outcrop extent from RGB imagery.

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A lava lake in the South Sandwich Islands: Remote sensing of Mt. Michael, Saunders Island

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We show how Landsat and Sentinel multi-spectral satellite data was used to in the discovery of the world's fifth currently active lava lake.

Mt. Michael is an active stratovolcano on Saunders Island in the South Sandwich Islands volcanic arc. Previous analysis of satellite data from the 1990s suggested the existence of a lava lake inside Mt. Michael's crater, but the resolution was insufficient to prove the presence of a lake.

As in-situ observations of Mt. Michael are extremely difficult due to its remote location, dangerous surrounding sea and inhospitable surface, satellite data was used to monitor activity and detect thermal anomalies within the crater. We identified persistent volcanic eruptions and plumes throughout the thirty-year period studied. On five occasions in 2006 and 2018 a thermal anomaly within the crater was detected in shortwave infrared bands centred on 1.65 µm and 2.2 µm. Conversion of at-sensor radiance to land surface temperature using the Planck Equation estimated the pixel-integrated temperature of the lava lake at 233-427 °C. Further analysis using the well-established dual-band method estimated the molten lava to be radiating at 1040-1259 °C, assuming a cooler crustal lava of 200 °C. These observations suggest the lava lake is a permanent feature.

Associated publication:
Gray, D. M., Burton-Johnson, A. & Fretwell, P. (2020). Evidence for a lava lake on Mt Michael volcano, Saunders Island (South Sandwich Islands): Application of Landsat, Sentinel-2 and ASTER satellite imagery. Journal of Volcanology and Geothermal Research.

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Spatiotemporal evolution of the seasonal decay of snow albedo over Hurd Peninsula, Livingston Island, Antarctica, in the period 2000-2016.

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We have studied the correlation between topographic variables (altitude, slope, orientation, curvature, Topographic Roughness Index, Topographic Position Index, wind exposition and diurnal heating) and the seasonal albedo decay over Hurd Peninsula, Livingston Island, Antarctica from 2000 to 2016. We have used a Digital Terrain Model with a spatial resolution of 30 m. Snow albedo with a spatial resolution of 500 m was obtained from the MODIS (MOD10A1) daily snow albedo product. Only dates with a Sun Zenith Angle below 70° around midday are considered (September 1 to April 10 each season). The seasonal evolution of snow albedo was fitted to the exponential decay law $\alpha(t) = \alpha_{min}+A\exp(-\beta t)$. For each pixel and each season we obtain: the albedo decay rate (β), the minimum albedo (α_{min}) and A. The albedo decay parameters exhibits a significant correlation with some topographic variables for certain seasons. We explored the influence of the air temperature and the surface temperature on the correlations found. The air temperature in autumn (March, April, May) and spring (September, October, November) determine the correlation between A and α_{min} and the topographic variables, while the air temperature in winter (June, July, August) and summer (December, January, February) determine the correlation between β and the topography. These results suggest that when the temperature gradient over the study area is small, the influence of topography on the snow albedo decay is not significant. This research has been funded by the Spanish Ministry of Science and Innovation (projects CTM2014-52021-R and CTM2017-84441-R).

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On site radiometric snow and bare soil patterns characterization to improve albedo estimation via satellite images for integration into glacier balance studies

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Radiometric response of snow albedo depends on snow properties such as density, hardness, water content, temperature and grain size, as well as on the impurities content. In addition, properties of bare soil such as color, texture and mineralogy are strongly related to albedo response of the surfaces. Due to this, the spatial and temporal variability of albedo distribution in polar areas is very high. During the 2017-18 and 2018-19 Spanish polar campaigns, we carried out several transects of distributed albedo measurements over Deception and Livingston Islands. In order to obtain the distributed measurements we devised a portable albedometer, consisting on two pyranometers, one facing the Earths's surface and the other facing the sky. Simultaneously to snow radiometric measures we performed snow pits. In addition, color of soils samples was characterized. For each sampled surface, the histograms of albedo were fitted to a normal distribution. Preliminary statistical analysis shows significant relations between snow properties, like grain size and water content, and albedo. On the other hand, soil color and texture showed to have a strong relation with albedo in bare soil areas. Recent results seem to indicate a slight increase in albedo in areas near Johnsons Glacier. It is necessary to characterize the albedo of the different surfaces in order to estimate the percentage of each one from orbital sensor data. This research has been funded by the Spanish Ministry of Science and Innovation (projects CTM2014-52021-R and CTM2017-84441-R)

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Interannual and Intra-annual Surface Velocity Variations at the Southern Grounding-Line of Amery Ice Shelf from 2014 to 2018

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The grounding line is the boundary indicating the transition from grounding ice to floating ice. The ice flow rate through the grounding line of the Amery Ice Shelf (AIS) is vital to understanding mass discharge received from three primary tributary glaciers into the ice shelf. This study investigated the interannual and intra-annual surface velocity variation along the southern segment of the AIS grounding-line from 2014 to 2018. Feature tracking was used to derive the surface velocity for five consecutive austral summer and winter seasons. Over the study period, AIS's southern end was observed a steadily ~ 5% annual increase of surface velocity since 2014. Two sharp surface velocity increases were observed in 2014/2015 (0.22 m/d) and in 2017/2018 (0.20 m/d) respectively. Moreover, an average interannual surface velocity increase of 16.45% and 12.11% exhibited at velocity peak in 2014/2015 and 2017/2018 respectively. The surface velocity of the winter season presents to be higher than the summer season every other year since 2015. The slowest flowing glacier in the study area, Fisher Glacier, exhibited the highest interannual increase (8.34%) and the largest intra-annual variation (5.58%) of surface velocity. This study offers new observations of surface velocity measurements on a yearly basis and detailed analysis of surface velocity variations. In addition, this study showed the capability of feature tracking to monitor the multidecadal changes of surface velocity from a limited number of observations of surface velocity, which is still undocumented in the AIS area.

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Characterization of gravity waves in the lower ionosphere using VLF observations at Brazilian Antarctic Station

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Here we present the investigation of the gravity waves (GWs) characteristics in the low ionosphere using very low frequency (VLF) radio signals. The spatial modulations produced by the GWs change the electron density at reflection height of the VLF signals, producing fluctuations of the electrical conductivity in the D-region, which are detected as variations in the amplitude of VLF signals. The analysis considered the VLF signal transmitted from the US Cutler/Marine (NAA) station that was received at Comandante Ferraz Brazilian Antarctic Station (EACF, 62.1o S, 58.4o W), with its great circle path crossing longitudinally the Drake Passage. The wave periods of the GWs are obtained using the wavelet analysis applied to the VLF amplitude, used as a new aspect for monitoring GW activity. The technique was validated comparing the wave characteristics of one GW event observed simultaneously with a co-located airglow all-sky imager both operating at EACF. The statistical analysis of the wave periods detected using VLF technique for 2007 showed that the GW events occurred all observed days, with the waves with period between 5 and 10 min dominating during night hours from May to September. During daytime hours the waves with period between 0 and 5 min are predominant all over the year and dominate all days from November to April. The results show that VLF technique is a powerful tool to obtain the characteristics of GW events, with the advantage to be independent of sky conditions, and can be used during all day and year-round.

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GeoMAP on REMA

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GeoMAP is a geological GIS dataset describing exposed bedrock and surficial geology of Antarctica. Recently constructed by a SCAR Action Group, v.202008 will be released at the Hobart OSC meeting. This poster illustrates the GeoMAP dataset draped over another recently released continent-wide dataset - the Reference Elevation Model of Antarctica (REMA).

GeoMAP comprises over 83,000 polygons that describe 'known geology' of rock exposures, rather than 'interpreted' sub-ice features. The map displayed here renders polygons with colours reflecting rock or deposit age, many of which are difficult to see at a continent scale. A rich attribute table enables data to be displayed or queried in a wide-variety of ways. Other data captured, but not displayed here, includes a source bibliography, fault lines and structural data. GeoMAP is primarily intended for continent-wide perspectives and cross-discipline science.

GeoMAP has been displayed over a shaded greyscale image of REMA relief, downscaled to 200 m resolution with data gaps filled by a 100 m DEM to provide visual continuity (Howat et al. 2019, The Cryosphere 13:665-674). REMA was constructed using the Blue Waters supercomputer and SETSM open source photogrammetry software. A series of individual DEM's were developed from DigitalGlobe optical stereoscopic satellite images acquired from 2009-2017, then registered vertically to satellite altimetry measurements from Cryosat-2 and ICEsat. REMA has absolute uncertainties of less than 1m over most of its area and relative uncertainties of decimetres. Version 1 was developed into a high resolution (8 m) terrain map covering ~98% of the Antarctic continental landmass.

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The effect of the diurnal cycle of surfactant-associated bacteria in the sea surface microlayer

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The upper 1 mm of the ocean's surface, the sea surface microlayer (SML), is occupied by a variety of organisms including bacterial genera capable of producing surface active agents (surfactants). Bacteria in the subsurface water (SSW) produce organic material containing surfactants, which accumulate in the SML. Surfactant accumulation forms sea surface slicks, which dampen short gravity-capillary waves. Surfactant-associated slicks are visible via synthetic aperture radar (SAR). Our current research is focused on the effect of UV exposure on the abundance of surfactant-associated bacteria within the SML and SSW. We have implemented the sampling approach described in detail in Parks et al. (IJRS Special Issue 2020). The in situ microlayer samples were collected in July-August 2018, November 2019 and January 2020 at two sites in the Straits of Florida (Looe Key and Fort Lauderdale) during RADARSAT-2 satellite overpasses. The DNA data was analyzed at the Argonne National Laboratory using the Illumina MiSeq. This data indicates a significant difference in the bacterial abundance between day and night in the SML. We hypothesize that the daily UV exposure of the SML results in a lower abundance of surfactant-associated bacteria sensitive to UV radiation. The diurnal variability of the surfactant-associated bacteria in the SML may affect the presence of sea surface slicks visible in airborne SAR. Assessing the microlayer in the Antarctic is particularly important because research is severely lacking on this environment, and this location is higly productive within the sea surface microlayer.

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Comparison of Sea Ice Detection Methods in the Atlantic Sector of the Southern Ocean

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Antarctic sea ice is characterized by extreme spatial and temporal variability. Remote sensing is a fundamental tool used in observing this variability, however, almost all satellite derived sea ice concentration detection methods have been developed for Arctic sea ice. In this study, different satellite processing algorithms have been compared against known sea ice conditions obtained during two cruises of the SA Agulhas II. The AMSR2 derived products used in this study included the Arctic radiation and turbulence interaction study Sea Ice (ASI), bootstrap (BST) and the Environment Canada's Ice Concentration Extractor (ECICE). This study shows that the traditional sea ice concentration-only based ASI and BST products are insufficient at describing important sea ice processes and mechanisms associated with short term sea ice variability. This was shown by considering two case studies, both of which investigated the effect of meteorological forcing on the Antarctic sea ice. The ASI and BST products showed the response of the 15% concentration ice-edge well, but failed to show any response in the ice interior. Conversely, the ECICE product showed substantial change at both the ice-edge and the ice interior. These processes show that both the ice-edge and ice interior are not only influenced by meteorological forcing, but also that these processes happen within daily timescales. Here it is argued that it is therefore necessary to further improve and validate ice detection methods for Antarctic sea ice, and that concentration-only based products do not sufficiently explain short term sea ice variability.

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Estimation of flow distribution of Shirase Glacier, East Antarctica derived from ERS-1/2 tandem mission SAR data

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Shirase Glacier is one of the fastest flowing ice streams in Antarctica with flowing speed of greater than 2 km/year (Nakamura et al., 2007, Aoyama et al., 2016). It is flowing into the southernmost of Lützow-Holm Bay in Dronning Maud Land, East Antarctica. It is important to clarify the spatial flow velocity distribution with a high-resolution to investigate causes of the fast flow and the temporal flow rate changes. We applied an interferometric Synthetic Aperture Radar (InSAR) technique to InSAR pair data acquired by European Satellite of Remote sensing (ERS)-1/2 during the tandem missions in 1996 and 1999.
We successfully obtained three SAR interferograms over Shirase Glacier from the tandem mission data pairs acquired at 1996/06/02-1996/06/03, 1999/11/14-1999/11/15 and 1999/12/19-1999/12/20. We estimated surface displacements along range direction (direction of radar illumination) by applying differential InSAR (DInSAR) with a TanDEM-X 90m DEM (Rizzoli et al., 2017) to remove topographic phase. We also estimated displacements along azimuth direction (direction perpendicular to range direction) by applying a split beam interferometry (SBI) (Bechor and Zebker, 2006) technique to the data pairs. We obtained flow velocity distributions by combining the range and azimuth displacements.
In the presentation, we will indicate accuracies of the obtained surface displacements as well as comparison with displacements derived from GNSS measurements on the Shirase Glacier. We will also discuss temporal changes in flow velocity and direction of the glacier.

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Nighttime Medium-scale traveling ionospheric disturbances observed by an All-Sky image at Antarctic Peninsula

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Medium-scale traveling ionospheric disturbances (MSTIDs) were observed in the red line emission, OI 630.0 nm, using an airglow all-sky imager at Comandante Ferraz Antarctica Station (62.1° S, 58.4° W; Magnetic Coordinates: 52.7 S, 10.9 E for 2015) between 2015 and 2016. These waves most occur during the winter and presented horizontal wavelengths between 75 and 200 km, observed periods mainly distributed between 10 and 50 min, and observed horizontal phase speeds range between 75 and 175 m/s. The waves showed a preferential propagation direction towards the Northwest. The most probable wave source could be associated with the Perkins instability mechanism. On the other hand, the Antarctica Peninsula is known as the source of strong tropospheric dynamics processes such as orographic forcing, cold fronts or strong cyclonic activity, that could be generating upward gravity waves that reach the thermosphere/ionosphere and thereby expanding the possibilities of sources to the MSTIDs. Furthermore, we are going to show the effects of magnetics storm above the Brazilian Antarctic station in the form of a stable auroral red arc.

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Continuing the satellite altimetry record over Antarctic ice shelves

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Antarctica's ice sheet is losing net mass to the ocean, and so are its fringing ice shelves. Although ice shelf mass loss does not directly lead to sea-level rise, it does lead to increased dynamic loss of grounded-ice mass because it reduces the back-stress ("buttressing") that ice shelves provide to the grounded ice. To fully understand how the ice sheet is changing overall, and predict how it will change in the future, it is crucial to quantify the rates of ice-shelf mass change and the relative contributions of the processes driving these changes. Since the early 1990's, satellite radar and laser altimetry has provided a long, continuous record of ice shelf height, allowing us to identify ice shelf responses to different drivers (ocean state, atmospheric state, and glaciological controls on grounded-ice flow and calving) which occur on a broad range of timescales. The current altimeter satellites (CryoSat-2 and ICESat-2) have extended the record to 2020, now covering all of the ice shelves, and allowing us to examine small-scale features related to critical mass-loss processes, e.g. rifts, basal channels, surface meltstreams and grounding zones. It is vital that we continue this sequence of polar-orbiting satellite altimeter missions so we have no gap in our ice shelf monitoring capability. Simultaneously, our community needs to develop a coordinated plan for acquiring in situ data for validating basal melt rate estimates derived from satellite altimetry, so we can improve our understanding of ice-shelf/ocean interactions all around Antarctica.

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Metamorphism of layered firn at Dome Fuji, East Antarctica: Evolution of relations between Near-infrared reflectivity and the other textural/chemical properties

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Evolution of polar firn was investigated at sites at Dome Fuji on the dome summit of East Antarctica, to better understand signals of both radio remote sensing data and deep ice cores. Using samples from a 4-m-deep pit and a 122-m-deep core, relations between major textural and chemical properties, such as Near-infrared light reflectivity R, density ρ, microwave dielectric anisotropy Δε, and concentration of major ions, were investigated at a depth range of 0 – 122 m, with high spatial resolutions. At the near-surface depths, we found: (i) Fluctuations of R, ρ, and Δε are positively correlated; (ii) Δε ranges 0.03 – 0.07 immediately below the snow surface at ~0.1 m depth; (iii) These properties of R, ρ, and Δε are not correlated to major ions. With increasing depths during reported phenomena of density crossover, the positive correlation of R to Δε persistently remains with a slight decrease. Besides, R becomes weakly negatively correlated to concentration of Na+ which is the sea salt marker. These facts suggest that textural features of the near-surface depths are preserved in both R and Δε at a depth range immediately below bubble-close-off, being weakly affected by reported softening of ice by Cl- ions. We therefore suggest that optically layered features in ice cores are directly linked to the metamorphism.

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Sea Ice Thickness and Snow Depth records from altimetry in Antarctica

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The main difficulties to retrieve Sea Ice Thickness (SIT) in Antarctica come from the lack of in-situ observation. For instance, whereas polar expeditions and in-situ observations over the Arctic have enabled to construct snow depth climatologies (e.g the Warren climatology), there is no equivalent data in the southern hemisphere. Then, except for a few studies (e.g Zwally et al, 2008 or Kurtz et al, 2012) based on ICESat, SIT estimations in Antarctica nearly remain nonexistent and no valid sea ice volume estimations have yet been drawn (SI-CCI-2015 report). In this presentation, we review our recent developments leading towards altimetric Sea Ice Thickness estimations in Antarctica.

First, we detail the methodology to derive sea ice freeboard from altimetric measurements and we present a 2002-2017 Envisat/Cryosat-2 sea ice freeboard time serie. The continuity between the 2 satellites is ensured by a recalibration of the Envisat Low Resolution Mode on the Cryosat SAR mode.
Thereafter, one of the most important obstacle to compute SIT is related to snow depth. Meanwhile, Guerreiro et al, 2016, has demonstrated the ability to retrieve snow depth from the combination of CryoSat-2 and Saral/AltiKa satellite data. Following this approach, we will present 2013-2019 bi-frequency altimetric snow depth estimations in Antarctica (computed within the ESA CryoSat + project). From these results, among the first SIT time series in Antarctica will be shown. Finally, we will explain how these data will be used for future climate studies such as sea level re-evaluation and the revisit of the freshwater budget.

1705

Influence of snowpack characteristics on TanDEM-X DEM - validation with REMA and field datasets acquired on the Ellsworth Mountains, Antarctica

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The penetration and interaction of X-band synthetic aperture radar (SAR) with snowpack depends on the snow layers physical characteristics related to snow accumulation processes. We use the new Reference Elevation Model of Antarctica (REMA) as a reference surface to subtract from the TanDEM-X elevation model (TDX) and evaluate the X-band interferometric bias in dry snowpack. We confirm the REMA's high accuracy with 70-km-long geodetic measurements on Union Glacier in the Ellsworth Mountains. A mean error of 1.01 ±0.61 meters was found. TDX presented a higher mean error of 2.05 ±2.37 m. We demonstrate that the TDX surface covaries with ice depth and accumulation layering changes in the GPR profiles. Furthermore, we propose that both DEMs' data can be used to investigate the subsurface feature changes and ultimately, the accumulation dynamic changes. Negative (positive) differences indicate high (low or negative) accumulation rate areas where deeper (shallower) penetration occurs.

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Importance of blowing snow during cloudy conditions in East Antarctica: comparison of ground-based and space-borne retrievals over ice-shelf and mountain regions

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Continuous measurements of blowing snow are scarce, both in time and space, despite its importance in local and regional antarctic surface mass balance. Satellites now provide the opportunity to derive blowing snow occurrence, transport and sublimation rates over Antarctica. These continental-wide assessment of blowing snow are extremely valuable. However, little ground truth is available to validate these retrievals. In addition, optically-thick clouds block the penetration of the satellite signal , limiting blowing snow detection to clear-sky conditions.
The application of ceilometers for detection of blowing snow provide an opportunity to validate the satellite retrievals of blowing snow frequencies at two coastal sites in East Antarctica for the 2011-2016 time period. Thanks to their ground-based location, ceilometers are able to routinely detect blowing snow events in the presence of clouds and precipitation, which can be missed by the satellite. This is important, since the proportion of events missed by the CALIPSO and ICESat-2 satellites due to the presence of cloud decks is currently unknown. Over coastal areas, up to 90% of blowing snow occurs under cloudy conditions. In addition, differences in sensors limit the surface identification by the satellite, and the spatial in homogeneity of the blowing snow event can lead to events identified as blowing snow by the satellite but not by the ceilometer. These results indicate that while blowing snow transport and sublimation rates derived from satellite retrievals are a valuable product, further investigation is required to reduce uncertainties on coastal blowing snow occurrence.

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Assessment of East Antarctic sea-ice thickness during spring using ICESat-2, Operation IceBridge and in situ measurements

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The satellite records provides clear evidence of dramatic reduction of the annual maximum Antarctic sea-ice extent. However, little is known about concomitant changes in the ice structure including ice thickness. The dynamics nature of the Southern Ocean plus a generally thick snow cover result in a complex vertical layering of the sea ice, and its thickness is difficult to derive using remote-sensing techniques. To improve the translation of satellite information, and capitalizing on near-coindent data collection as part of NASA's Operation IceBridge [OIB], we collected a range of in situ sea-ice (and ice-sheet) measurements off East Antarctica during austral spring 2019. Here we anlyse a three-tiered dataset based on the ICESat2 laser profiles, OIB data from dual- colour laser altimeter, radars, as well as optical and thermal imagers and in situ transect measurements of sea-ice and snow thickness. The study was carried out on landfast ice, so that temporal offsets between measurements may be accounted using a column (thermodynamic) sea-ice model. We note locally very thick snow over the fast ice in late 2019, and explore its effect on ice thickness derived from total freeboard measurements.

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Mass Balance Constraints on Ice Sheets and Glaciers from Reflected GNSS Signals

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GNSS receivers are routinely deployed on ice sheets and glaciers to measure the speed of the ice surface. While the primary derived quantity from these geodetic receivers is three-dimensional position, signal power data (generally termed signal to noise ratio (SNR) data) are also recorded by the receiver. These SNR data can be used with the GNSS Interferometric-Reflectometry (GNSS-IR) technique to measure the vertical distance between the GNSS antenna phase center and the surface below. Because GNSS signals are transmitted at L-band and very low elevation angle data are used, there is very little penetration of the snow/ice surface. GNSS-IR measurements thus can provide a tight constraint on snow accumulation within a relatively large footprint (~1000-5000 m^2 for typical sites). Amplitudes of the reflection signals provide information about surface roughness and dielectric constant and thus can be used, for example, to examine surface melt. Examples will be given for 9-year records on the Greenland ice sheet as well as new GNSS reflection results from the Ross Ice Shelf, Thwaites, Kohler, Sorsdal, and Totten glaciers.

746

The anomalous sea ice conditions in McMurdo Sound during the winter of 2019

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The winter 2019 sea ice conditions in McMurdo Sound, Antarctica were affected by frequent and extensice landfast sea ice break-out events. This resulted in the unusually late formation of a stable landfast sea ice cover in the southern reaches of the Sound, which in turn affected winter / spring sea ice operations for the United States and New Zealand Antarctic programmes operating in the region. The greater than average number of break-out events were related to an increase in the number and intensity of southerly wind events in the region in the late spring / early winter period. Here we investigate the correlation between sea ice break-out events and southerly storms to elucidate this relationship. We first present the current understanding of the climatology of landfast sea ice in McMurdo Sound. We then characterise the 2019 winter sea ice cover using a combination of space-borne remote sensing products and sea ice mass balance station observations to quantify the nature and extent of the break-out events. Finally we compare these break-out events to the near-surface wind field and discuss how the southerly storms influenced the formation of landfast sea ice in the different regions of the Sound. An improved understanding of the way in which winter storms affect the landfast sea ice in McMurdo Sound has the potential to improve operational confidence in sea ice operations in McMurdo Sound during the late winter / spring period.

1503

DeepBedMap: Resolving the bed topography of Antarctica with a deep neural network

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To better resolve the bed elevation of Antarctica, we present DeepBedMap - a deep learning method that produces realistic Antarctic bed topography from multiple remote sensing data inputs. Our super-resolution deep convolutional neural network model is trained on scattered regions in Antarctica where high resolution (250 m) groundtruth bed elevation grids are available, and then used to generate high resolution bed topography in less well surveyed areas. DeepBedMap takes in a low resolution (1000 m) BEDMAP2 dataset alongside other high spatial resolution inputs such as ice surface elevation, velocity and snow accumulation to generate a four times upsampled (250 m) bed topography map even in the absence of ice-thickness data from direct seismic or ice-penetrating radar surveys. Our DeepBedMap model is based on an Enhanced Super Resolution Generative Adversarial Network architecture that is adapted to minimize per-pixel elevation errors while producing realistic topography. We show that DeepBedMap offers a more realistic topographic roughness profile compared to a standard bicubic interpolated BEDMAP2, and also run model inversions to compare the basal traction of our DeepBedMap_DEM with other bed elevation models.

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High spatiotemporal resolution land surface temperature for the Antarctic Dry Valleys

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The McMurdo Dry Valleys (MDV) are one of the few ice free areas on the Antarctic continent with biodiversity thriving on available liquid water. Accordingly, Land surface temperature (LST) is a critical variable influencing the terrestrial ecosystem. In an environment characterized by steep gradients in temperature, elevation, and availability of water and photosynthetic light, microorganisms largely depend on microclimates. Hence, to model the current habitat distribution, and predict possible changes induced by anthropogenic climate change, high spatial and temporal resolution LST data is indispensable.
As such data is currently unavailable for the MDV, this project aims at downscaling LST acquired by the MODIS sensor, which comes at a high temporal (sub-daily close to the poles) but low spatial (1000 m) resolution. High spatial resolution (30 m) information can be gained from the thermal channel of Landsat 8, which comes only at a low temporal resolution, though. Thus, MODIS LST is downscaled from 1km to 30m using Landsat 8 data as a reference. Land cover and terrain properties are used as additional high resolution predictors. Machine Learning models are applied to account for the complex relations between those variables. Training data are generated based on all temporally matching and cloud free scenes from 2013 to 2019. The trained model is applied to make predictions of 30m resolution LST for the entire MDV for all available MODIS scenes, i.e. from 2002 on.
The high resolution LST product will present a baseline dataset for subsequent ecological modelling of species distribution in the MDV.

1703

Investigating the magnitude of snow redistribution over the Antarctic Ice Sheet using ICESat-2, IceBridge, and atmospheric reanalysis data

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Snow that accumulates at the ice sheet surface is subject to redistribution (i.e., erosion or deposition) that is strongly dependent on the local topography and predominant wind direction and speed. Most atmospheric models do not account for these post-depositional processes; however, those that do can only resolve redistribution over large length scales (10s of kilometers) because of resolution restrictions. Improved understanding of snow redistribution will improve our interpretations of local mass balance as well as height changes derived from satellite altimeters (e.g., ICESat-2, CryoSat-2).
Here, we take a novel approach of combining fine resolution topography from NASA's next generation laser altimeter, ICESat-2, with patterns of small-scale snow accumulation variability from Operation IceBridge snow radar data to build a simple model of snow redistribution. Sensitivity tests suggest that the ideal resolution for studying snow redistribution is 1 kilometer, so we built a 1-km DEM over the entire grounded Antarctic Ice Sheet (AIS) using the first three orbital cycles of ICESat-2 (October 2018 – June 2019). In such a manner, we take advantage of the pointing bias early in the mission to fill in a denser grid. We next compare the curvature of this DEM with mapped snow accumulation variability and reanalysis wind speed and direction from MERRA-2 to build a statistical redistribution model. This model is next applied to the entire DEM, allowing us to quantify the spatial patterns as well as magnitude of snow redistribution over the entire grounded AIS.

Spatiotemporal variations of snowmelt in Antarctica (1978–2019) derived from passive microwave radiometer data

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A Spectral Linear Mixing Model (SLMM) was applied for the snowmelt pixel estimation in passive microwave radiometer images covering the Antarctic continent. We used SMMR, SSMI and SSM/IS EASE-Grid calibrated data (25 km spatial resolution) and spectral signatures for the endmembers Wet Snow Zone (WSZ), Dry Snow Zone (DSZ) and Rock Outcrops (RO) to estimate daily Snowmelt Fraction Images (SFI) of Antarctica from 1978 to 2019. Each SFI pixel can have values from 0 to 1, that means a given snowmelt proportion (0 to 100%) in an area of 625 km2. To assess the accuracy of SFI images, we compared them with correspondent classified ENVISAT ASAR images (150 m) of the Antarctic Peninsula on 11 dates (2007 to 2009). The RMSE of the estimated SFI was lower than 0.06 for all dates, excepting for one with 0.29, pointing to low errors in general. The daily SFI data series was used to calculate the austral summer total and median area of snowmelt for seven different regions of Antarctica: Antarctic Peninsula, Filchner-Ronne Ice Shelf, Mary Bird Land, Ross Ice Shelf, Dronning Maud Land, Amery Ice Shelf and Wilkes Land. The spatiotemporal analysis of the estimated SFI images indicated that the most persistent and intensive melt in austral summer was observed on the Antarctic Peninsula, mainly on Larsen and Wilkins ice shelves. Other main regions with persistent and intensive melt were Mary Bird Land and Wilkes Land, followed by Dronning Maud Land, Amery Ice Shelf, Filchner-Ronne Ice Shelf and Ross Ice Shelf.

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Response of the southern polar ionosphere to CME and CIR driven storms

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In this paper, we studied the response of the high-mid latitude ionosphere during two geomagnetic storms driven respectively by Coronal Mass Ejection (CME) and Corotating Interaction Region using Global Positioning System (GPS) derived Total Electron Content (TEC) measurements. These storms occurred during the month of June 2015, when the southern polar region is bereft of solar radiation which is the main source of ionization. We observed large enhancements in the TEC during the main phase of the CME driven storm of 21 June 2015 as compared to the CIR driven storm that commenced on 8 June 2015. The factors that led to the observed ionospheric storm effects over the southern high-mid latitude ionosphere during both the storms are investigated using topside ionospheric measurements from the Defence Meteorological Satellite Program (DMSP) and NOAA/POES satellite measurements. We show that the TEC enhancements over the high latitude ionosphere are topside enhancements caused by the formation of the polar Tongue of Ionization (TOI). The topside enhancements in the TEC at the southern polar region are shown to be related to the appearance of positive ionospheric storms in the mid latitude regions. The role of stormtime electric fields and neutral winds in causing the ionospheric storm effects during both the storms are presented in detail. This study highlights the importance of the Solar wind-Magnetosphere-Ionosphere coupling in modulating the high latitude space weather during geomagnetic storms.

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Seasonal variations of snow height in Antarctica using GNSS Interferometric Reflectometry

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A reliable surface mass balance assessment is essential for a trustworthy Antarctic ice sheet total mass balance estimation. Snow accumulation is the primary ice sheet mass input, and is normally derived from satellite-borne altimetry, ice core studies or regional climate models, as in-situ data are scarce. By exploiting the GNSS Interferometric Reflectometry (GNSS-IR) technique, the current Antarctic GNSS antenna network can be used to retrieve local information on snow accumulation/ablation.
GNSS-IR uses signal-to-noise ratios (SNR) to sense the antenna near field environment. Reflected signals, usually considered as a detriment in positioning, are here turned into a source of information on the reflecting surface. The frequency of the SNR interference sinusoidal pattern depends on the vertical distance between the phase centre of the GNSS receiver antenna and the reflecting surface, and on the signal wavelength.
Applied to antennas in Antarctica, GNSS-IR allows to retrieve snow height variations, and to study snow precipitation/ablation in a meteorological sense. The homemade software ROB-IONO and Atomium are used to access the snow height variations at several GNSS stations. The first antenna considered has been deployed by the Royal Observatory of Belgium on the Derwael Ice Rise, in the coastal Dronning Maud land. This station provided continuous data from late 2012 to early 2016. Taking the antenna subsidence into account, we highlight an annual variation of snow accumulation in April-May (~30-50 cm) and ablation during spring/summer period. No long term trend is observed. Results from GNSS stations belonging to the POLENET network are also presented.

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The 3-dimensional structure of snowfall over Antarctica from remote-sensing observation and reanalyses

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Understanding atmospheric processes and variables in the polar regions is a key element of climate studies. In particular in Antarctica, precipitation is the single most important term controling te surface mass balance, but it is still not well known. The main challenges are the limited number of data and the measurement difficulties because instruments are not well adapted to the extreme weather conditions of this region.

In addition, the traditional 2D approach of precipitation (surface field) may not be sufficient to properly describe the microphysics and dynamics involved, in particular in the antarctic region where low-level atmospheric processes such as sublimation or blowing snow have a major impact on surface accumulation.

Fortunately, remote-sensing technologies have been deployed both on ground and in space. A precipitation radar at Dumont d'Urville station (Adélie lLand) and the Cloud Profiling Radar (CPR) on-board CloudSat which covers a wide part of the continent, – both have continously provided measurements over a large part of the atmospheric column both over 4 years. The latter made it possible to build the first 3D climatology of snowfall flux above the antarctic ice sheet (Lemonnier et al., 2019). Those two instruments are powerful source of information to assess the quality of atmospheric circulation models in this area – respectively at local and continental scale – and in particular reanalyses which suffer from a lack of observations there.

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Spatiotemporal variations in Antarctic ice mass revealed by GRACE and GRACE Follow-On

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This study presents a new Gravimetric Mass Balance (GMB) product for the Antarctic Ice Sheet (AIS), derived within the ESA Climate Change Initiative continuation project AIS_cci+. For the first time, the GMB product is based on satellite gravimetry data acquired by both GRACE and its successor GRACE-FO (Follow-On). This product comprises (a) time series of monthly mass changes for the entire ice sheet and for individual drainage basins, and (b) gridded mass changes covering the entire ice sheet, spanning almost 19 years between 2002 and 2019. Our results are based on the monthly solution series CSR RL06, which was chosen based on a quality assessment conducted for a wide range of available solutions.

Temporal changes in Antarctic ice mass are derived on basin scale as well as from the gridded product, providing insights on the temporally varying spatial distribution of mass changes. The quality of the GMB products is assessed based on the quantification of their noise level. Spatial and temporal variations of surface mass balance (SMB) are derived by means of the regional atmospheric climate model RACMO2.3p2. The modelled cumulative effects of SMB variations are utilized to partition the overall mass changes observed by GRACE and GRACE-FO. This allows us to also investigate variations of ice dynamical changes over time. The GMB products as well as up-to-date mass balance estimates for the AIS and its drainage basins, along with their corresponding contribution to global sea level change, are freely available through a data portal hosted by TU Dresden (data1.geo.tu-dresden.de/ais_gmb).

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Compilation and application of the northern Antarctic Peninsula region spectral library to characterize and validate satellite data and monitor change in ice-free areas

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Ice-free areas in the northern Antarctica Peninsula region are mainly located within coastal areas. They are hotspots of terrestrial biodiversity that are closely related to dominant glacial, periglacial, fluvial, and coastal processes and landforms. Visible-near infrared and shortwave infrared (400–2500 nm) spectral reflectance has been shown to be a useful method for characterizing and monitoring soil surface and land cover features and conditions. The objective of this work was to compile site-specific spectral libraries for ground truthing and validation of remotely sensed satellite information to characterize and monitor the highly dynamic surface covers within ice-free areas of the South Shetland Islands and along the Danco Coast of the Antarctic Peninsula. Field and laboratory spectra were obtained from selected test sites using field measurements and samples taken during several field campaigns. The spectral libraries were compiled into a georeferenced database containing additional information such as field observations and determinations as well as soil and sediment laboratory analysis. Results have shown that the spectral libraries provide necessary details to spectrally differentiate complex land surface covers and processes. Furthermore, this information was key to interpret and validate multispectral satellite data such as LANDSAT (5, 7 and 8) and SENTINEL2 that cover larger ice-free areas and where changes were detected over time through the extensive available time-series. A random forest machine learning classification was used to obtain changes in the spatial distribution of the different surface covers and to determine recent retreat of glacial ice-fronts that are liberating further terrestrial land surfaces.

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Observing Evolving Subglacial Conditions with Muti-Temporal Radar Sounding

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Airborne radar sounding is the primary geophysical method for directly observing conditions beneath ice sheet and glaciers at the catchment to continent scale. From single flow-lines to regional surveys to ice-sheet wide gridded topographic datasets, radar sounding profiles provide information-rich constraints on the englacial and subglacial environment. This can include roughness, lithology, hydrology, thermal state, melt, fabric, and structure for both grounded and floating ice. However, the snap-shot view provided by one-time soundings fails to capture subsurface processes across the time-scales over which they evolve and control ice flow. Doing so requires advancing multi-temporal radar sounding instruments, platforms, and data analysis. For example, point-measurements by ground-based or stationary sounder can be used produce local time-series observations of englacial and subglacial conditions. However, low-cost, low-power active and/or passive radar-sounder networks can dramatically extend the reach and scope of such measurements. Further, repeat surveys by sled-drawn or airborne sounders can capture seasonal and interannual subsurface variations. However, digitization of archival radar film are extending the temporal baseline for such comparison by decades, making multi-decadal studies of subsurface changes possible. Finally, the development of autonomous rover, drone, and satellite sounding platforms and systems promise to enable pervasive, stable, and frequent monitoring of subglacial conditions. Here, we discuss the advances, challenges, and the path forward to observing subsurface conditions across the full range spatial and temporal scales at which they occur.

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Present-Day Antarctic Ice-Sheet Mass Balance Estimates

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Contemporary studies on mass balance estimates of ice-sheets during the late 20th and early 21st century, including the 2019 Intergovernmental Panel for Climate Assessment (IPCC) Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC), and the 2012 reconciled ice-sheet mass balance estimate study, seem to still exhibit large discrepancies in the estimates of Antarctic ice-sheet mass balance. The IPCC SROCC study stated with very high confidence, that during 2006–2015, Antarctic ice-sheet lost mass at an average rate of 155 ± 19 Gt • yr^{-1}. However, the reconciled ice-sheet mass balance study reported the Antarctica mass loss rate of 71 Gt • yr^{-1}, 1992–2011, more than 50% differences. The plausible error sources include inadequate knowledge of firn compaction/density to compute ice mass from elevation changes, when satellite altimetry data are used, and coarse spatial resolution (>333 km), and inaccurate knowledge of subglacial topography uplift resulting from glacial isostatic adjustment (GIA), when satellite gravimetry (GRACE/GRACE-FO) data are used. We used different contemporary satellite gravimetry data products, including mascons, Level 2 data products, and employed different post-processing methods, including leakage, Earth oblateness, GIA and other corrections, as a means to assess the uncertainty of Antarctica gravimetry estimated mass balance. In this contribution, we combine multi-mission satellite altimetry (ERS, Envisat, CryoSat-2, etc), and satellite gravimetry (GRACE, Swarm, GRACE-FO) at interannual scales, with gravimetry data contribute to nominal density estimates to correct satellite altimetry data, to obtain an improved estimate of Antarctic ice-sheet mass balance, and assess feasibility of acceleration signal detections.

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Understanding multi-scale ionospheric structuring processes in the polar ionosphere using GNSS measurements alone

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The polar ionosphere is primarily driven by magnetospheric convection and neutral circulation and undergoes structuring over a wide range of temporal and spatial scale sizes. This structuring is due to the interplay of mechanical forces, electrodynamics, and ionization chemistry. The ionosphere and its structures affect the propagation of any radio signal from ground- or satellite-based sources, thereby posing an array of challenges for these systems. These effects can be broadly classified into deterministic and stochastic based on their impact and scale sizes. Ionosphere affects radio signal through refraction, diffraction, scattering, and absorption and these effects are scale dependent. During this talk, I will demonstrate how GNSS measurements alone can be used to understand the multi-scale structures in the polar region. I will also give an outline on how this can be used for the predictions of ionospheric conditions for planning and real-time observations for correction/mitigation of ionospheric effects detrimental to the performance and accuracy of communication links and navigation systems.

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Spatio-Temporal Variation in Ice Flow Velocity of Polar Record Glacier, East Antarctica during 2016-2019

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Polar Record Glacier, one of the outlet glacier of East Antarctica has calved a few decades back detaching 26 km x 16 km part of this glacier between 1973 and 1989. Remote sensing based investigation of ice flow dynamics of Polar Record glacier has been conducted in this work. The study was carried out to estimate the flow velocity using offset tracking method for the melt season (December – February) of 2016-2019. The offset tracking based approach, due to its advantage over loss of coherence and phase unwrapping, was utilized. The Sentinel-1 Synthetic Aperture Radar (SAR) images (due to its high quality and high revisit time for continuous monitoring of 6 days interval) were utilized in this study. Ice flow velocity near the glacier terminus indicated higher velocity during January and subsequently showed lower values in December during 2016-2019. During February, the velocity showed variations in the region of higher velocity compared to the previous month. The maximum and minimum velocity of the glacier was found to be ~860 m/a and 10.8 m/a for the period 2016-2017, ~871.2 m/a and 7.2 m/a for the period 2017-2018, ~831.6 m/a and 10.8 m/a for the period 2018-2019. Results indicated that the maximum velocity occurred in the terminus part of the glacier and minimum was detected on the ice sheet portion of the glacier. Mechanisms contributing to the velocity changes near the tongue are highlighted.
Keywords: Polar Record Glacier, Sentinel-1 SAR data, offset tracking, flow velocity

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Physical habitat characterisation in the Sør Rondane Mountains using satellite remote sensing

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Less than a quarter percent of the Antarctic continent consists of ice-free areas (Burton-Johnson et al., 2016). The environmental conditions in these areas are among the most extreme on earth, and life is dominated by bacteria, mosses and lichens, which show a high degree of endemism (Vyverman et al., 2010). Microbial soil crusts grow slowly and are sensitive to the terrain and climate conditions (Tytgat et al., 2016). A structuring factor may be the total received solar energy, which impacts the local variability of soil temperature and humidity. The present study evaluates satellite remote sensing for the mapping of physical habitat characteristics of ice-free regions in the Antarctic Sør Rondane Mountains, in order to aid identification of favourable habitats for microbial soil crust development in remote and inaccessible areas. In particular, the generation of Digital Surface Models (DSM) from high resolution stereoscopic imagery and derivation of Land Surface Temperature (LST) from the Thermal InfraRed Sensor (TIRS) on board Landsat 8 is examined. The DSM elevation data are compared against in situ recorded GPS positions and tracks, and the 8 m resolution Reference Elevation Map of Antarctica (REMA) released in Mid 2018 (Howat et al., 2019). DSM derived from satellite acquisitions made over multiple years are compared. Satellite derived LST is compared against temperature loggers installed in the 2018-2019 and 2019-2020 field seasons, and finally the multispectral data from the Operational Land Imager (OLI) on board Landsat 8 is used to classify ice-free pixels in broad classes.

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UKANET-GPS: a geodetic network to record crustal deformation in the Antarctic Peninsula and around the Weddell Sea embayment

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Present-day rates of vertical and horizontal motion observed by GPS can be used to constrain and validate models of Glacial Isostatic Adjustment in Antarctica, but are also affected by shorter-term elastic or viscoelastic loading deformation in response to changes in surface mass in recent decades. This shorter-term transient response can be used to constrain mantle rheological parameters in regions where the recent history of surface mass balance is well known, and hence the relationship between rheological and seismological parameters can be better calibrated for wider regional use. This is particularly useful in areas where the mantle viscosity is thought to be low (of order 10^{19} Pa s or less), which has recently been suggested for parts of West Antarctica.

We report here on the upgrade of GPS sites along the Antarctic Peninsula and around the Weddell Sea embayment to enable near-real-time return of data to the scientific community, allowing transient solid-Earth responses to be monitored continuously. The data will also enable tectonic deformation and atmospheric parameters to be derived with much lower latency than was previously imposed by the logistical difficulties of servicing these GPS instruments. Preliminary results documenting the evolving surface velocity field across West Antarctica will be presented.

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Monitoring Evolutions of Abrupt Weather Episodes in Antarctica Using Daily-Sampled Space Gravimetry Solutions and Acceleration Approach

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As the primary input to the Antarctica ice sheet, exact knowledge of snowfall is important for Antarctica mass balance quantification, and its contribution to present-day global sea-level rise. Within which, the extreme precipitation events have been estimated to contribute to more than 40% of annual precipitation for the majority of Antarctica. However, because of the extreme weather conditions, limited in-situ precipitation observation is available. Nominal monthly GRACE solutions have been widely used to study Antarctic long term mass balance. By nature, GRACE observation has a denser coverage at the polar region and it is possible to improve the gravity field temporal resolution for polar region. Here, we developed an acceleration approach with improved error mitigation schemes to process the GRACE/GRACE-FO KBR data and estimate sub-month temporal gravity field (11 days) with daily sampling over Antarctica, enabling detecting and quantifying the evolution of large snow-storm events, such as the 2006 episode on the Antarctic Peninsulas.

ISBN: 978-0-948277-59-7

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