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Antarctic Science - Global Connections

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SESSION 2

POLAR ATMOSPHERIC PROCESSES: WATER CYCLE, SNOW, CLOUDS, AEROSOLS, RADIATION AND GRAVITY WAVES

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

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Southern Ocean and Antarctic cloud, precipitation and aerosol observations made from ship- and land-based platforms

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The large warm bias in sea surface temperatures over the summertime Southern Ocean present in numerous climate models is likely due to an incorrect representation of cloud, precipitation and aerosol processes within these models. Specifically, a higher super-cooled liquid water cloud fraction and low levels of anthropogenic aerosols make this region unique on earth. Recent major field campaigns involving aircraft, ships and island have provided key data to allow the community to quantify microphysical properties and characterise the thermodynamic environment in which Southern Ocean clouds exist. We present some highlights of observations made during these campaigns , including ship-based observations of multi-layered super-cooled liquid clouds, supercooled drizzle, ice seeding, vertical profiles of remote marine coarse-mode aerosols and precipitation events over sea ice.

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Activity Concentrations and Sources of 210Pb and 7Be in the Antarctic Peninsula

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The current knowledge of the natural radioactivity in the Antarctica is very limited. The radioactive isotope lead-210 is formed in the atmosphere from radon-222 noble gas, which is nearly solely produced over the land surfaces. For this reason, 210-Pb concentration in aerosol provides a good tracer for a recent continental contact of the air mass. Atmospheric beryllium-7 isotope is formed via the cosmic radiation interactions and deposited with the aerosols and provides also a method to monitor large-scale air mass dynamics.
The activity concentrations of 210Pb and 7Be were determined from the aerosol samples collected in the Antarctic Peninsula, Argentine station Marambio during years 2005-2013 (210Pb) and 2007-2009 (7Be). High-volume (120m3 h-1) aerosol particle samples were collected onto glass-fiber filters (Munktell MGA) and a new filter was exchanged every 2–5 days. The 7Be concentration was determined using semiconductor gamma spectrometry and the lead-210 concentration using the alpha counting of the in-grown daughter nuclide polonium-210 with an automatic alpha/beta analyzer.
The intra- and interannual changes of those radioactive isotope concentrations were determined. Their dependence on the local wind direction was analysed and the source regions determined with a back-trajectory analysis.
In general, very low radioactive concentrations were measured but an occasional continental influence in the air mass was observed.

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Horizontal and vertical propagation of small scale gravity waves observed in 2017 at Ferraz Antarctic Station

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Gravity waves observed at Comandante Antarctic Ferraz Station have been analyzed by using blocking diagrams to estimate the vertical blocking region for the small scale gravity waves observed in 2017. The wave blocking diagrams are constructed by using vertical neutral winds profiles from the troposphere to the mesosphere. The physical parameters of the observed waves were obtained by applying a two-dimensional Fast Fourier Transform (2D-FFT) in a given set of images where a wave event is clearly identified. The investigation of the horizontal and vertical (upward) wave's propagation was conducted by using results from images analyses, vertical wavenumber and blocking diagrams, which are a superposition of the horizontal wind components from the lower troposphere up to the mesosphere. The wind utilized for each night for the blocking diagrams is an averaged wind obtained with all the nocturnal wind profiles. The final average is obtained with the nights where there were observed waves, centered on the new moon, and such averages correspond to the observed month. The winds database was obtained from MERRA reanalysis and from the King Sejong Station (KSS) meteor radar. In this work, it will be presented the wave characteristics, the blocking diagrams, and the vertical propagation conditions near the mesopause. The blocking diagrams well represent the wave filtering, showing the preferential propagation direction of the waves in the mesosphere, i.e., the waves that reach the mesosphere propagates in a different horizontal direction from the average wind in all altitudes levels or are faster than the mean wind.

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Shape, Size, and Qualitative Elemental Compositions of Nano- and Micro-particles Found Within the Ancient Ice of Taylor Glacier, Antarctica, Measured Using Transmission Electron Microscopy and Energy Dispersive Spectroscopy

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Aeolian dust affects Earth's climate directly through the reflection, scattering and absorption of incoming solar radiation and indirectly by acting as condensation nuclei in cloud formation. Iron-containing nanoparticles may also be an important source of iron into the oceans for micronutrient limited phytoplankton which could lead to CO2 drawdown and cycling. In aeolian dust, particles larger than 450 nm account for most of the total mass while nanoparticles smaller than 200 nm are likely greater in number. Nearly all studies of particles entrapped in Antarctic ice have used dissolved, bulk elemental analyses that include particles smaller than 200 nm. Alternatively, Coulter counter particle analyzers are also used to determine particle size distributions for particles larger than 500 nm. We have analyzed individual particles in ice cores from Antarctica's Taylor Glacier, which spans 46.7 ky to 8.7 ky BP, covering Earth's most recent glacial, glacial-interglacial transition, and interglacial period into the Holocene. Transmission Electron Microscopy (TEM) and TEM-Energy Dispersive Spectroscopy (EDS) were used to determine the shape, size, and qualitative elemental composition of many individual nanoparticles. Together, this preliminary characterization could provide insight into changes in Antarctic dust composition, transportation, deposition, and provenance over a glacial-interglacial time scale.

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Polar WRF simulations of Antarctic cloud microphysics at McMurdo Station

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The physics of Antarctic clouds remains poorly understood, and the DOE-NSF AWARE year-long measurement campaign at McMurdo Station, Antarctica was designed to redress this problem. Supercooled liquid water is frequently present at McMurdo, even at temperatures well below -15°C. Yet, numerical models tend to aggressively produce ice condensate at these temperatures. The pristine atmosphere must play some role in the characteristics of Antarctic clouds. Sensitivity experiments with the Morrison two-moment microphysics and other microphysics schemes examine the role of aerosols in simulated Antarctic cloud formation. Furthermore, the complex topography near Ross Island modulates the mesoscale circulations that induce observed cloud structures. Nudging of simulations to the observed radiosondes at McMurdo and regional automatic weather station observations appears to be important to obtain the lower tropospheric conditions observed at McMurdo so that the performance of microphysics parameterizations can be evaluated rather than the simulations being dominated by circulation errors.

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A low cost holographic microscope for cloud and precipitation microphysics studies

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Clouds and precipitation play a crucial role in the thermodynamic and hydrological systems of the planet. A key challenge in modelling such processes lies in the parameterisation of particle sizes, shapes and spatial distributions at microscopic scales. This talk will present a low cost instrument for measuring such properties that exploits the technique of digital holography to obtain 3D particle images and allows for automated retrieval of relevant morphological parameters.

Preliminary results from a 2018 field campaign in the Australian Snowy Mountains will be presented along with measurements from Davis Station, Antarctica during 2018-2019. The instrument was deployed in both cases alongside a range of other meteorological instruments allowing calibration and validation of such techniques and potentially providing a means to help in distinguishing pristine particles from wind blown snow based on morphological features.

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Metal atoms and ion layers observed with a frequency-tunable resonance scattering lidar at Syowa

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The National Institute of Polar Research (NIPR) is leading a prioritized project of the Antarctic research observations. One of sub-project is entitled the whole atmosphere system revealed by precise profiling over the Antarctic. Profiling dynamical parameters such as temperature and wind, as well as minor constituents is the key component of observations in this project, together with a long term observations using existent various instruments at Syowa, Antarctic (69°S, 40°E). As a part of the sub-project, a resonance scattering lidar system with frequency-tunable alexandrite laser was developed and installed at Syowa Station by the 58th Japan Antarctic Research Expedition (JARE 58). Density profiles of minor constituents such as potassium (K), iron (Fe), and calcium ion (Ca+) in the mesosphere and lower-thermosphere (MLT) region were successfully observed in 2017 and 2018. The K and Fe layers were observed 37 and 55 nights in total, respectively, from February to October except April. The Ca+ layer was observed 8 nights in September and October. The MLT temperature was measured by K or Fe lidar measurements. In this presentation, we will show seasonal variations of K and Fe layers and characteristics of Ca+ layer at the high latitude as preliminary results of the frequency-tunable resonance scattering lidar observations at Syowa.

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CRIOSFERA 1 Remote Lab: An automatic and multidisciplinary platform for near-real time atmospheric monitoring at West Antarctica

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CRIOSFERA 1 is the first Brazilian remote atmospheric research laboratory located at West Antarctica (84o00'S, 079o29'39''W - 667 km from the South Pole). It is endowed with wind and solar systems that allow it to run continuously during summer and winter and transmit data by satellite. Main ongoing research lines comprises: (1) meteorology and snow accumulation monitoring; (2) aerosol composition and black carbon science; (3) physics of high energy; and (4) aerobiology and polar microbiology. At that site we conducted fresh snow d18O(d2H) and air temperature calibration curves for climate reconstruction and have implemented several aerosol sampling methods. Aerosols sampled are submitted to EPMA and multi-element synchrotron-based scanning transmission X-ray microscopy (STXM/NEXAFS). These techniques allowed investigating in details the formation process of the aerosols, their size distribution and how they are formed in terms of composition and molecular structure. Bio-aerosols such as polen grains, spores, palynomorphs, algal fragments and bacteria were detected in Criosfera 1. The laboratory also hosted experiments on snow and ice microbiology trying to help understand how microorganism are transported to West Antarctica and how they persist in the oligotrophic and freezing snow's environment. Criosfera 1 monitors cosmic rays (muons flux) - CRE@AT (Cosmic Ray Experiment in Antarctica) Project - using plastic scintillators coupled to multianodic photomultipliers. For summer 2020 campaign we intend to start the continuous monitoring of O3, UV-(a/b/c) and bioaerosols. Criosfera 1 is a platform open to international cooperation and exchange of polar experience. Join us (https://www.criosfera1.com)!

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A multi-instrument observational study of the impact of sky condition on atmospheric boundary layer structure and surface radiation over Dome C, Antarctica

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A multi-instrument observational study of the impact of sky condition on atmospheric boundary layer structure and surface radiation over Dome C, Antarctica

Antarctica's pristine environment makes the continent an ideal testbed for studying cryosphere-atmosphere interactions and their variability, and may greatly benefit from combining long-term remote sensing and in-situ measurements. Here, we carry out a multi-year investigative study of the impact of sky condition (clouds, blowing snow) on the atmospheric boundary layer structure and downwelling longwave surface radiation, using ground-based and space-borne observations at Dome C during a 2-yr time period (from May 2009 to April 2011). High vertical resolution profiles of temperature, moisture, and winds obtained from daily upper-air soundings at Dome C, are used to investigate the variability of the atmospheric boundary layer structure. Information regarding sky condition (blowing snow, cloudy, clear) is obtained from quasi-synchronous and contiguous Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) tracks using the Lidar Level 2 Blowing Snow product and Combined CloudSat and CALIPSO (2B-GEOPROF-LIDAR) cloud fraction. High temporal resolution measurements of in-situ surface meteorological variables (temperature, pressure, relative humidity, and winds) and downward longwave radiation are used to estimate the individual and net impact of meteorology, clouds, and blowing snow on the atmospheric boundary layer structure and surface radiation budget. Results based on this multi-instrument study are summarized, highlighting the need for continuous earth observations to monitor and improve our understanding and predictive capability of cryosphere-atmosphere coupled processes.

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Atmospheric Dust and Aeolian Iron: New Lessons Learned from the US Palmer Station, Antarctica

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During the period from November 2015 to January 2017, atmospheric field measurements were carried out at the US Palmer Station located on the Antarctica Peninsula. The primary goal of this research was to quantify the properties of atmospheric dust and aeolian iron under climate warming conditions in the Antarctic Peninsula. To undertake air sampling, a new platform was erected on a rocky hill between the research station and glaciers, and a series of atmospheric instruments were installed on this platform to collect atmospheric aerosols and deposition samples. In this presentation, we will share and discuss our new results, including (1) particle-size distributions of dust and aerosol iron from size-segregated aerosol samples, (2) seasonal variability of atmospheric dust and Fe along with selected organic and inorganic substances based on bulk aerosol samples, (3) atmospheric deposition fluxes of nutrients derived from field measurements and implications for the Southern Ocean biogeochemical cycles, and (4) the potential impact of local and regional dust sources in Antarctica on the composition of the marine atmosphere over the Antarctic Peninsula.

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New insights on the formation and long-term accumulation of perchlorate in West Antarctica

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The Antarctic environment has been used as a field laboratory for the search of life on Mars. Its dryness, lakes salinities, and the extreme environmental conditions are home to extremely tolerant organisms. The discovery of perchlorate on Mars by the Phoenix Mars Lander addressed the issue of existing liquid water as salty concentrated brines. Perchlorate salts have supercooling properties and high stability. For Antarctica, reports of high perchlorate concentrations were restricted to the DryValleys. Here we present a new insight of higher perchlorate concentrations in West Antarctica/Ellsworth Mountains (1.02 ± 0. 25 mg kg-1 and 25.92 ± 5.58 mg kg-1), suggesting a broad spatial distribution and accumulation of perchlorate over Antarctica. Our aerosol measurements, combined with ice core data, support that an active origin for perchlorate may exist in the Antarctic troposphere due to the action of UV-radiation and the snowpack geochemistry interacting with sea salt. Using a microscopic/molecular speciation of individual aerosols by X-ray chemical imaging, it revealed a unique signal of ClxOy-type-molecules, reveling that Antarctica has undergone successive warming phases during interglacials that allowed the accumulation of salty crusts contain perchlorate.

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Organic content in Antarctica aerosols

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The organic contain on aerosols describes an interesting climate behavior and paint one of the significant fractions of tropospheric particles. We analyzed individual particles via microscopic and molecular speciation by Scanning Transmission X-ray microscopy with near edge X-ray absorption fine structure spectroscopy (STXM/NEXAFS). This method provided an accurate fraction of internally mixed inorganic and organic particles for an aerosol campaign of 2014 in West Antarctica (at Brazilian module, Criosfera 1). The results were revealing a lack of organic aerosol on Antarctica that could be driven by the oxidizing process during the transport of the coast to the sampling point. Oxidation reactions (primarily by the hydroxyl radical) of organic species can dramatically change the reactivity, amount, properties and hence the ultimate impacts of atmospheric particles, as the type of aging, with the potential to affect the optical properties, hygroscopicity, and cloud condensation nucleus activity of particulate matter. In Antarctica, photochemistry driven by locations with elevated levels of NOx results in the accumulation of tropospheric ozone that can double the background concentration. As a consequence of the high OH concentration above the snowpack (found at the South Pole) and by the ozone oxidation caused process, almost all organic aerosol found in our samples should be impacted and oxidized during the transport to the center of Antarctica. The organic suppression of organic matter observed at Antarctica aerosols can increase the water uptake of particles, reducing the Albedo effect, and impacting the local environment.

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Spatiotemporal variation of surface atmospheric 7Be from Australia to Syowa Station, and S17, Antarctica

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Deposition of atmospheric minor constituents on the ice sheet surface alters the radiation budget and creates climate markers in ice cores. Such minor constituents are not only of origin in the Antarctic but are also supplied by transport from distant sources. To clarify the mechanism of long-distance transport is to know the mechanism of climate change and to clarify the past atmospheric circulation. ^{7}Be is a radioactive element produced in stratosphere by cosmic ray, and the higher concentration of ^{7}Be implies higher contamination of stratospheric air.
This study measured the concentration of ^{7}Be on the Southern Ocean from Australia to Syowa Station on an island, Antarctica, and at S17 Station on the coastal Antarctic ice sheet during three summer seasons of December to January in 2014/15, 2016/17, and 2017/18. Few past studies discussed daily variation in concentration of ^{7}Be in Antarctica. Time series of the concentration of ^{7}Be shows the increases in the concentration as the latitude increase with the fluctuation from about 1 mBq/m^{3} or less (the detection limit) to about 10 mBq/m^{3}. The latitude effect may be due to the descending flow in the polar vortex. The time-scale of the fluctuation is about a week or so, and tropopause folding associated with synoptic-scale disturbances may play a role.

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Neutron spectrometer operated in the Concordia station since 2015 and its contributions on Antarctica research activities

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The Earth is constantly bombarded by primary cosmic rays (CR) that can be either of galactic or solar origin. CRs concerns are interdisciplinary field, including impacts on human activities (electronics, biological effect) and applications such as archaeology, volcanology, geophysics or the cosmogenic nuclide dating. Moreover, Polar-region development induces an important issue related to space weather.
In the framework of the CHINSTRAP project supported by the French Polar Institute, a CR-induced-neutron spectrometer is operated since December 2015 in the inner Antarctic Plateau, at Concordia station. Several parameters can influence the CR measurement, the atmospheric pressure, the hydrometric environment and the atmospheric water vapor. These parameters were monitored in Concordia thanks to HAMSTRAD polar project which measure of the trends in water vapor and temperature profiles from the lower part of the troposphere to the lower part of the stratosphere. Then, atmospheric CR-shower modelling associated to a primary cosmic ray model allows for deducing a global secondary CR model. This allowed contributing to some scientific fields such as the dose ambient risk for polar workers, the cosmogenic nuclide dating activities, the development of solar flare paleo models or the space weather applied to electronic systems. This paper proposes to analyze four-year measurements from December 2015 to 2020, and to present CR contributions on Antarctica research activities, in the point of view of radiation characterization, human dose and cosmogenic nuclide dating. This work will also illustrate the importance of the neutron spectrometry in Antarctica for the development of an atmospheric-radiation global model.

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Wind filtering of mesospheric short-period gravity waves: Evidence revealed from all-sky images at King Sejong Station (62°S, 59°W)

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We have analyzed all-sky images observed with an OH airglow filter at King Sejong Station (62°S, 59°W), Antarctica for the period of 2012–2016. Using the M-transform method, 2D-power spectra were obtained from 107 image sequences. From the power spectral densities, it is evident that the mesospheric wave activity is the strongest during winter. We also constructed climatological wind blocking diagrams using the horizontal winds obtained from MERRA-2 reanalysis data for the altitudes of z = 10–64 km, and from KSS meteor radar data for z = 80–90 km. We find that the wind blocking diagrams clearly explain the dominant propagating directions of the observed short-period (< 1 hr) waves except for spring season. The strong south-eastward waves were observed in spring when wind blocking above z = 50 km are too weak for these waves, suggesting that the mesospheric waves may be generated above ~50 km.

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Propagation And Sources of the Short Period Gravity Waves over Syowa Station (69S, 40E) and Davis station(69S, 78E) Studied by Airglow Imaging in 2016

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We recently compared the gravity waves over Syowa and Davis, which have similar terrain and meteorological conditions, to show their horizontal variation over the East Antarctic. Propagation characteristics are observed by airglow imaging measurements of 90 km altitude. The comparison in April-May 2013 have indicated that the major propagation directions were westward at Syowa, but at Davis, GWs seems to propagate in all the directions [Matsuda et al., 2017]. The goal of this study is to reveal what causes the difference in the gravity wave characteristic over Syowa and Davis. Ground-based horizontal phase speed spectra at 87 km altitude over the two stations were derived from OH imagers in more detail. The mean spectra were then calculated in winter (May to August) and fall (September). The winter means spectra and directionality are similar. The comparison with transmission diagrams [Tomikawa, 2015] showed that the phase velocity regions of turning and critical level filterings are almost same at both stations. The variance of the gravity wave perturbations was very similar both in magnitude and seasonal variations (maximum in winter), except for September/October. In September, directionalities are similar at both stations but power in Syowa is much larger than that in Davis. The phase velocity spectra are also calculated for 6 different period band in 8 – 60 min. We found that peaks of the phase velocity spectra for period bands smaller than 11 min were located at prohibited propagation areas. This suggests that such high-frequency gravity waves were generated in the mesosphere.

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Satellit observation of secondary gravity waves over the Southern Andes during an intense mountain wave event

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The Southern Andes are well known as one of the mountain wave hot spots. Recently, Vadas and Becker [2019] demonstrated with numerical modeling that the breaking of mountain waves over the Andes can create secondary GWs at about 50-80 km of altitude, yielding concentric ring structures. Some observational studies support this hypothesis [e.g., Liu et al., 2019], but the observational evidence is still limited and indirect, and the characteristics of the secondary GWs are not well understood. The purpose of this study is to look for signatures of secondary GW generation in observations from a space-based instrument (VIIRS/Suomi-NPP) and compare their characteristics in the real atmosphere with model simulations.

This study focuses on a mountain wave event with significant amplitudes (>3 K) and ~500 km horizontal wavelengths over the Southern Andes, observed on 24 and 25 July 2017 with AIRS/Aqua satellite data [Hoffman et al., 2017]. VIIRS/Suomi-NPP (can resolve GWs with > several km horizontal wavelengths at ~85 km) did not detect mountain waves but instead observed concentric ring-like GWs with a few hundred km wavelengths at 4.5 UT on the same night (25 July 2017) over the Southern Andes and its east side.

We will show the observational results and discuss the relationship between the mountain waves observed and the concentric GWs. In particular, we will focus on what altitude the observed mountain waves broke and why the observed concentric ring-like GWs extended leeward.

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Application of tritium tracer technique to the partitioning between clear-sky and synoptic precipitation on the Antarctic plateau

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In Antarctic plateau, precipitation falling from clear sky (known as diamond dust) occurs almost daily, but a few major synoptic events can give a significant fraction of the annual accumulation. Thus, it is not clear how much contribution of clear-sky precipitation to the total accumulation on the plateau. Here we introduce alternative method for partitioning between synoptic and clear-sky precipitation: tritiated water (HTO). Tritium (T) is one of the cosmogenic nuclides, which mainly produce in the upper atmosphere over the Antarctica. After the HTO generation, HTO follows the pathway through hydrological cycle, with only small perturbations owing to fractionation effect during phase changes. Consequently, HTO concentrations in diamond dust formed by condensation of local Antarctic water are characterized by higher HTO than the synoptic precipitation accompanied with moisture transported from the surrounding ocean. We analyzed HTO in surface Antarctic snow collected by repeated traverses between Syowa and Dome Fuji and found two prominent spatial features; the gradual increase trend from the coast to plateau region and the rapid increase in HTO toward inland on the plateau. In addition, a good anticorrelation is observed between HTO and $\delta^{18}O$ of snow on the plateau. These features indicate that much of the plateau accumulation results from clear-sky precipitation with no synoptic-scale moisture transport. To support this interpretation, here we use the atmospheric circulation model incorporated into HTO and show that the balance between clear-sky and synoptic precipitation is a key driver controls HTO distribution on the Antarctic plateau.

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Local, distant and cosmogenic sources of dust from the glaciers of Svalbard

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The glaciers of Svalbard are an excellent repository of aeolian dust. In order to determine provenance of such dust as locally or globally derived, we examined particulates collected in shallow (0.5-1m long) firn cores from the glaciers of Southern Spitsbergen: Hansbreen, Storbreen, Flatbreen, Recherchebreen and Werenskioldbreen. Various minerals were identified, including pyrite, iron oxides, quartz, K-feldspar and rutile. Iron oxides are predominantly magnetite and no hematite is present, as it would be expected from subtropical/moderate climate sources. This supports high-latitude provenance for the dust. Coarser grains probably stem from proximal areas, whereas finer grains may have been transported from more distal sources. Particulates composed of elemental carbon have been found in a number of specimens; although their origin is still unknown they may be derived from anthropogenic sources or from forest fires. An alloy of Ni+Fe composition may be a micrometeorite grain. Zircon and monazite are also present, with grains of the latter being large enough for electron microprobe dating. These reveals mostly Silurian (syn-Caledonian) ages, which are also found in bedrock of the Nordaustlandet region of Svalbard. One grain was ca. 1.3 Ga and may be derived from basement rocks. We suppose that eroded Svalbard mountain ranges are a major source of dust, which is deposited on and preserved in the local glaciers. However, there are evidence for all kind of sources and future studies are planned on dust distribution, anthropogenic dust contamination and potential cosmogenic sources over Svalbard.

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Measuring Precipitation and Sublimation Rates on the Ross Ice Shelf

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A two-year collaboration between the University of Colorado (CU)-Boulder and the National Center for Atmospheric Research (NCAR) studied precipitation measurements gathered from four locations on the Ross Ice Shelf in Antarctica from November 2017 to November 2019. These year-round measurements were made possible by funding from the United States Antarctic Program (USAP). An autonomous precipitation measurement system was developed to withstand extreme weather conditions while drawing very little power to record measurements. The precipitation measurement system utilized a combination of sensors including an OTT Pluvio2 weighing precipitation gauge nested inside a double Alter-style wind shield, a snow-height sensor, solar-radiation sensors, a wind-speed sensor, particle counters, and disdrometers. Web cameras were also used to record periods of precipitation and distinguish between blowing, versus falling, snow. Although the primary goals of the project were focused on collecting accurate measurements of precipitation in the Antarctic region, broadening the body of knowledge of the surface mass balance, and assessing numerical model precipitation estimates, it was also discovered that sublimation could be measured by the same system. Based on initial observations of both precipitation and sublimation amounts from the precipitation gauge, a new methodology was developed to derive accurate precipitation and sublimation rates. A high-level overview of the project will be presented with a focus on the results of this work, including precipitation and sublimation rates, and comparisons of measured snowfall amounts to model-predicted accumulations.

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Measuring elemental composition and number of individual mineral nano- and micro-particles in ancient Antarctic ice cores by single particle inductively coupled plasma mass spectrometry

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To date, there is no comprehensive Antarctic study of the elemental composition of individual atmospheric nano- and micro-particles and the number concentration with each composition despite the role that they play in climactic processes (i.e. influencing planetary albedo by reflecting and scattering radiation, absorbing radiation, or acting as nuclei for ice and clouds). Previously the average elemental composition of atmospheric mineral particles entrapped in Antarctic ice has been obtained by dissolving the particles and determining trace elements in the bulk solution by inductively coupled plasma sector field mass spectrometry (ICP-SFMS). We measured the elemental chemical composition of thousands of individual mineral particles by single particle inductively coupled plasma mass spectrometry (spICP-MS). We will briefly describe how spICP-MS works. Two different instruments were used: ICP-Quadrupole MS (ICP-QMS) which measures one isotope at a time and ICP-Time of Flight MS (ICP-TOFMS) which acquires a complete elemental mass spectrum for every particle. Particles in the horizontal ice core from Taylor Glacier (East Antarctica) spanning part of the last glacial-interglacial cycle (9-44 kyr BP) have been analyzed by spICP-QMS and spICP-TOFMS. Our primary goal is to determine if and how the number concentration and elemental composition of individual atmospheric mineral particles have changed over time.

1120

The Joint US NSF-DOE Atmospheric Radiation Measurement (ARM) Program West Antarctic Radiation Experiment (AWARE)

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AWARE was a year-long atmospheric and climate science field program on Ross Island that deployed many of the most advanced meteorological and remote sensing instruments currently available. The suite of instruments included with the Second ARM Mobile Facility (AMF2) included research radars in the Ka-, W- and X-bands, high spectral resolution and micropulse lidars, microwave radiometers for water vapor and cloud liquid water content, broadband and spectral radiometers in the shortwave and longwave, and equipment for measuring aerosol microphysics and chemistry. The AMF2 operated on Ross Island from December 2015 through December 2016, and a smaller instrument suite optimized for surface energy balance measurement operated at the WAIS Divide Ice Camp in West Antarctica during December 2015 and January 2016. AWARE data reveal unique properties of the Antarctic troposphere that provide stringent case studies for cloud microphysical evaluation in climate models, including supercooled liquid water at lower temperatures than found in the high Arctic troposphere, and influence from gravity waves. The aerosol observation suite provides an annual cycle of aerosol properties showing chemical and microphysical contrasts with comparable high Arctic data. Triple-frequency cloud scanning radar observations from AWARE are the first of their kind in Antarctica, and can differentiate between various modes of cloud ice water including small crystals, rimed particles and large aggregates. This presentation discusses these varied observational cases and their incorporation into climate model evaluation. AWARE data are fully available to the worldwide research community in the ARM Program archive, which provides efficient data search and access.

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Evaluation of Blowing Snow Impacts on the Low Atmosphere and Surface for A Severe Cyclone System over Antarctic Peninsula using WRF-ice Model

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To better capture the air-snow-ice interaction, a snow/ice enhanced Weather Research and Forecasting (WRF-ice) model has been developed. This study examines the overall performances of WRF-ice and its blowing snow component with a mesoscale cyclone that occurred during 23-26 October 2017 over the Antarctic Peninsula. The evolution of the mesoscale cyclone is well reproduced by WRF-ice and the simulated surface temperatures reasonably agree with satellite observations, with root-mean-square errors and bias scores for surface temperatures of land-ice (sea-ice) of 3.55 and 0.3 K (3.11 and 0.23 K) during the daytime, respectively.

Comparisons between control simulation and a sensitivity simulation with blowing snow processes suppressed show that blowing snow sublimation is prominent within lower atmosphere when the air is dry and clear, and accordingly moistens and cools the air. Over relatively warm humid areas, enhanced clouds by blowing snow lead to either colder or warmer surface, as the surface temperature depends on the competing effects of longwave and shortwave cloud radiative forcings (CRF). Additional moisture from blowing snow sublimation can slightly intensify precipitation over the mountain. Surface energy budget analyses indicate that downward shortwave (Sa) and longwave (Ld) CRF, and outgoing longwave CRF (Lu) are dominant surface heat fluxes components. Combined with increased sensible heat flux, Ld, Lu, and decreased Sa, latent heat flux due to blowing snow, a negative surface net heat flux occurs during the daytime. As a consequence of increased precipitation, reduced runoff and sublimation, a positive domain-total surface mass balance (~5 Ton) is generated during the cyclone.

1417

Recent observations of clouds and their radiative effect over the Southern Ocean.

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Clouds over the Southern Ocean are poorly simulated in climate models (Trenberth and Fasullo, 2010; Hyder et al., 2018), leading to a net bias in the amount of radiation arriving into the ocean (Bodas-Salcedo et al., 2013). Our knowledge of the different contributions of meteorological and aerosol influences, and how these vary spatially and temporally, is still limited in this region.

We use recent cloud, aerosol and meteorological observations in the Southern Ocean to try and improve our understanding of these processes that govern the cloud radiative effect. These observations include 200 days of ship-based measurements across three campaigns between 2016 and 2018, as well as 2 years of measurements at Macquarie Island over the same period.

Using these observations, in combination with the reanalysis data and satellite measurements, we use gradient boosted regression to model the cloud radiative effect and isolate the influence of the contributing factors. This methodology will be extended to better understand biases in the cloud radiative effect in the Australian Community Climate and Earth System Simulator (ACCESS) model and highlight the paramaterisations that need improvement.

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Solar activity reflection in ozone vertical distribution over Antarctica

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Zonal average monthly Solar Backscatter Ultraviolet Radiometer (SBUV) satellite data have been used to study the vertical ozone distribution in 1979–2018. The quasi-11-year period solar activity cycle from the ozone data series was investigated with the wavelet transform. Solar activity was characterized by sunspot numbers and F10.7 solar radio flux data. Wavelet power spectra were calculated for periods of 1–24 years. Zonal ozone distribution in the high southern latitudes was studied as well. We have considered SBUV ozone profiles over the Antarctic stations Vernadsky and Casey located in the opposite longitudinal sectors. It is shown that quasi-11-year disturbances in the ozone distribution were observed at lower altitudes over Vernadsky (22–31 km) than over Casey (31–37 km). Vernadsky located during spring in the edge region of the ozone hole where ozone is significantly destroyed near its typical maximum in its vertical profile with penetration of ultraviolet radiation to the lower heights. The solar activity influence is non-uniform to a considerable degree. The periods close to 11 years are the most noticeable (i) in the equatorial lower stratosphere, (ii) in the summer upper stratosphere of the high latitudes, (iii) in the middle-upper stratosphere of the southern hemisphere in distinction on the northern one. The zonal asymmetry between solar activity manifestations in the stratosphere over West and East Antarctica was noticed.

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Utilising Radiosonde Observations Around Antarctica: Studying Stratospheric Gravity Waves

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Regular radiosonde launches occur at many Antarctic bases and on scientific ship cruises as part of their associated metrological programmes. These radiosonde observations can be used to study atmospheric gravity wave properties.

The UK funded DRagon pAssaGe and sOuthern oceaN Wave Experiment (DRAGON-WEX) aims to use a range of instrumentation and modelling to determine the sources of gravity waves close to 60°S, to try and determine where the "missing momentum flux" that is present in atmospheric models is coming from.

As part of DRAGON-WEX we present the results of the preliminary analysis of stratospheric gravity waves observed using radiosondes from around Antarctica. This work also aligns with the aims of the ANtarctic Gravity Wave Instrument Network (ANGWIN).

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Quasi 10- and 16-day planetary waves in the MLT winds at Ferraz station, Antarctica

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The meteor radar has been used to measure winds in the mesosphere and lower thermosphere region at Ferraz station (62.1S, 58.4W) Antarctica. Winds obtained from February 2011 to mid-February 2012 were analyzed and results reveal the presence of oscillations with periods around 10 and 16 days from late autumn to late spring, which has been interpreted as planetary waves. The characteristics of these planetary waves identified over Ferraz station will be discussed and presented in this work. In addition, MERRA reanalysis data from stratosphere and VLF signals obtained by receivers at Ferraz station are used to study possible stratosphere-mesosphere coupling by planetary waves including the lower ionosphere region.

935

Antarctic gravity-wave activity in the mesosphere and lower thermosphere as measured with radars in the ANGWIN network

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Atmospheric gravity waves play an important role in transporting energy and momentum vertically through the atmosphere, and drive circulations that affect key processes such as formation of the ozone hole and the cold summer polar mesosphere. The lack of comprehensive observations over the Antarctic region has an impact on our understanding of these processes. The ANtarctic Gravity Wave Instrument Network (ANGWIN) seeks to use a network of observations to measure gravity waves continent wide and through all levels of the atmosphere, in order to fully understand their impact and to constrain their parameterization in models.

Atmospheric radars are one of the instruments included in the ANGWIN network. Meteor radars detect meteor trails at heights in the mesosphere and lower thermosphere and track them to build estimates of wind speed. Medium frequency radars carry out a similar task by tracking the patterns of radio reflections from turbulent structures.

This presentation will describe the application of common gravity-wave analysis techniques to the different types of radars at our various Antarctic sites. Access to co-located radars provides insights into the potential effects of the radar wind determination method on our analysis and allows a continent wide comparison to be made. The characteristics of gravity waves at the radar sites are then determined through a common observation year (2016).

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ANGWIN: ANtarctic Gravity Wave Instrument Network

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Atmospheric gravity waves play an important role in transporting energy and momentum between atmospheric spheres and drive circulations that affect key processes such as formation of the ozone hole and the cold summer polar mesosphere. The lack of comprehensive observations over the Antarctic region has an impact on our understanding of these processes. The ANtarctic Gravity Wave Instrument Network (ANGWIN) is a highly successful grassroots programme that was started in 2011. It seeks to use a network of observations to measure gravity waves continent wide and through all levels of the atmosphere, in order to fully understand their impact and to constrain modelling work. Although ANGWIN initially focused on the Antarctic, the group is now aiming to develop collaborations in both polar regions.

Current member countries of ANGWIN are Australia, Brazil, Japan, South Korea, the United Kingdom and the United States of America. The objective of ANGWIN network include; Qualify the longitudinal variations in gravity waves and determine causes; Characterize wave propagation and influence; Relate observed gravity waves to sources throughout the atmosphere; Study interactions of gravity waves with planetary scale waves; Compare polar wave observations to model parameterizations; Determine the effects of gravity waves on polar stratospheric cloud formation.

The ANGWIN network, its objectives and some recent results will be included in this presentation.

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Supercooled Liquid Water Cloud observed, analysed and modelled at the Top of the Planetary Boundary Layer above Dome C, Antarctica

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A comprehensive analysis of the water budget over the Dome C (Concordia, Antarctica) station has been performed during the austral summer 2018-2019 as part of the YOPP international campaign. Thin (~100-m deep) supercooled liquid water (SLW) clouds have been detected and analysed using remotely sensed observations, at the station (LIDAR, microwave radiometer HAMSTRAD, net surface radiation from BSRN, radiosondes) and on satellite (CALIOP LIDAR) combined with a specific configuration of the NWP model ARPEGE-SH. Two case studies are used to illustrate this phenomenon. On 24 December 2018, the atmospheric planetary boundary layer (PBL) evolved following a typical diurnal variation, which is to say with a warm and dry mixing layer at local noon thicker than the cold and dry stable layer at local midnight. Our study showed that the SLW clouds were observed at the top of the PBL. The second case study takes place on 20 December 2018, when a warm and wet episode impacted the PBL with no clear diurnal cycle of the PBL top. The amount of liquid water measured by HAMSTRAD was ~20 times greater in this perturbed PBL than in the typical PBL. In both cases, ARPEGE-SH was not able to accurately reproduce these SLW clouds, and the discrepancy between the observed and calculated net surface radiation was reaching +50 W m-2. The model was then run with a new liquid water partition function and was able to generate SLW clouds on 24 December 2018.

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Precising dust provenience in Western Antarctica by the integration among Sr-Nd isotopic signatures in fresh snow, remote sensing and atmospheric modeling

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Eolian dust is widely accredited as an important player to climate and environmental change, Nevertheless, gaps in the knowledge of determining their provenance still exist. We present here a method which objective is to improve the determination of dust sources based on the combination of 3 parameters: (1) the radiogenic isotope signal of the fresh snow conducted at the Brazilian Antarctic remote laboratory, Criosfera1 (84°S, 79°W); (2) the dust activity of the postulated sources (using aerosol index); (3) the air mass trajectory frequencies linking the site in Antarctica and the postulated sources. The backward air mass trajectories derived from the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT), cannot alone guarantee the origin of aerosols due to model limitations and extrapolations to the polar region, additionally, the radiogenic signal can be quite similar at sites from different continents as South America, Africa, and Australia depending on the geological formation. Finally, the Aerosol index, product from the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY), can be a decisive component in the interpretation of provenance. For the present work, we present an integrated measurement of isotopic ratios for Sr and Nd of snow deposited during a 5 month integration (August to December 2013) and 3 months integration (October to December 2015) obtaining the values 0,709929 <87Sr/86Sr <0,729392 and -33,7 < ℇNd <-14,6 as well as the corresponding trajectory frequencies and aerosol index. Our results point to the importance of the combined use of the above parameters to the accuracy in identifying dust provenance.

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In Situ Precipitation Observations for the Northwest Ross Ice Shelf, Antarctica: A Review of the Instrument Systems and Analysis of the Observations

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Four low-power, autonomous Antarctic Precipitation Systems (APSs) were installed on the Ross Ice Shelf, Antarctica for year-round in situ measurement of precipitation. The APS sites were installed for two years, starting in November 2017, as a part of the United States Antarctic Program (USAP). The liquid-water-equivalent precipitation was measured using an Ott Pluvio2 weighing precipitation gauge installed inside a double-alter wind shield. Additional measurements, such as snow height, wind speed, particle counts, and videos, were included in the APS sites to provide supporting observations. The precipitation measurements, and supporting observations, are providing a "ground truth" in understanding precipitation and snow accumulation in Antarctica. A review of the instrument systems will be provided, including an assessment of the successes and lessons learned during the two-year field deployment. The presentation will also include analyses of precipitation events and a comparison across the different instruments. Analyses will also be provided by studying event-by-event accumulation of precipitation at the four sites in comparison to the numerical model results of liquid-water-equivalent precipitation. The results will provide insights on the capability and validity of in situ precipitation observations for assessing numerical models and future capabilities in the measurement of precipitation.

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Investigation of Black Carbon aerosols over the Antarctic region using a regional climate model

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Aerosols and their interaction with sea, cryosphere and clouds can have crucial impact on radiation balance over the Polar region. They absorb and scatter incoming solar and outgoing terrestrial radiation to a different extent depending on their concentrations, types and size. They can also modify the cloud properties (lifetime and scattering properties) by acting as cloud condensation nuclei. Black Carbon (BC) (which is generated by biomass and fossil fuel burning) can trap radiation and warm the atmosphere; and are reported to be the second strongest contributor to global warming after carbon dioxide. The simulations of Weather Research and Forecasting model coupled with Chemistry (WRF-CHEM) were investigated and compared with the aerosol observations over the East Antarctic region. The model simulations were performed at horizontal grid resolution of 50 km × 50 km. The 6-h initial and lateral boundary conditions for the meteorological fields from National Centre for Environmental Predictions, Final Analysis (NCEP/FNL) were utilized in the simulations. The chemical mechanism for gas-phase chemistry in WRF-CHEM simulations was provided from MOZART4 and for aerosol process based on Goddard Chemistry Aerosol Radiation and Transport (GOCART) bulk aerosol scheme (MOZCART). BC mass concentration was found to higher over the Eastern Antarctic region during the forest fire seasons in Australia. This may be due to transport of BC produced by biomass burning. The detailed results on spatial and seasonal variations of BC over the Antarctic and surrounding regions will be presented and discussed.

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Snow surface pattern observations along traverse routes between Showa Station and Dome-Fuji Station of Antarctica using camera images

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Snow surface patterns in Antarctica are of practical concern and are important for assessing the surface mass balance of the ice sheet. Snow depth measurements between Syowa Station and Dome Fuji Station using snow stakes at 2 km intervals have been carried out by the Japanese Antarctic Research Expedition at the time of a traverse as part of a monitoring program. It is not clear how the snow depth changes seasonally. In this study, we have carried out snow surface pattern observations indicating erosion and deposition to grasp the actual situation of the snow surface. Firstly, to obtain the image of the snow surface state, an interval camera was installed in a snow vehicle making a round-trip traverse between the coast and the inland in summer of 2017. Secondly, to obtain the seasonal variation of the snow surface state, four interval cameras were installed at selected points along a latitudinal transection between the coast and the inland in summer of 2017. Snow surface patterns were classified in three kinds by sight. Analyzed results of altitude dependence of the snow surface patterns fairly agreed with a previous research. However, a difference was confirmed in altitude dependence of large sastrugi formation in comparison with the previous research. This presentation describes the progress of the snow surface observations using camera images and also discusses extracted problems.

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Ground-based measurements of total ozone column amount with a multichannel moderate-bandwidth filter instrument at the Troll research station, Antarctica

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Combining information from several channels of the Norwegian Institute for Air Research (NILU-UV) irradiance meter, one may determine the total ozone column (TOC) amount. A NILU-UV instrument has been deployed and operated on two locations at Troll research station in Jutulsessen, Queen Maud Land, Antarctica, for several years. The method used to determine the TOC amount would be presented, and the derived TOC values are compared with those obtained from the Ozone Monitoring Instrument (OMI) located on NASA's AURA satellite. The findings show that the NILU-UV TOC amounts correlate well with the results of the OMI and that the NILU-UV instruments are suitable for monitoring the long-term change and development of the ozone hole. Because of the large footprint of OMI, NILU-UV is a more suitable instrument for local measurements.

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LODEWAVE: LOng-Duration balloon Experiment of gravity WAVE over Antarctica

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Super-pressure balloons (SPBs) can float at a constant density surface in the troposphere and stratosphere for long duration (i.e., several months). They can follow Lagrangian motions of air parcels, which is beneficial for gravity wave studies. Gravity waves are one of uncertain factors in current climate models, in which it is required to obtain their stochastic features as well as their spatial and temporal mean behavior. SPBs enable us to obtain stochastic features of gravity waves in a full frequency range from Brunt-Vaisala frequency to inertial frequency. On the other hand, the PANSY radar, which is only MST/IS radar in the Antarctic, has been operated at Syowa Station since 2012. It measures three-dimensional winds with high temporal and vertical resolution and can obtain stochastic features of gravity waves in a full frequency range. It is expected to obtain three-dimensional gravity wave features in the Antarctic by combining SPB and PANSY observations. Thus, our group proposes new SPB observations in the Antarctic.

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Characteristics of Marine Boundary Layer Clouds over the Southern Ocean

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Marine boundary layer (MBL) clouds over the Southern Ocean (SO) remain poorly understood due, primarily, to sparse observations. It has been hypothesized that this poor understanding directly contributes to persistent large biases found in the radiation budget over the SO in both climate models and reanalysis products. Motivated by the need to improve the understanding of key atmospheric processes of the SO climate system, a range of field campaigns have taken place in recent years (e.g. CAPRICORN, SOCRATES, MARCUS and MICRE), yielding an unprecedented wealth of measurements ranging from Hobart to the edge of Antarctica. In total, 2186 soundings are employed to map out characteristics of the ABL and their clouds over the SO.

The analysis explores variations in the MBL characteristics in relation to the sea surface temperature (SST) and synoptic meteorology (e.g. distance to fronts/cyclone). The analysis further examines the macroscopic properties for clouds between 0.5 and 4km altitude. The cluster analysis were readily sorted by the underlying SST leading to a warm cluster, four storm-track clusters and two cold-ocean clusters. The four storm-track clusters can, to first order, be approximated by the classic Norwegian model of mid-latitude cyclones. The warm cluster commonly characterises an air mass off the Australian continent. The two cold-ocean clusters are found to be highly distinct. The coldest cluster, commonly found at the coast of Antarctica, is often cloud-free, while the soundings primarily located off the coast commonly have multiple cloud layers and a complex thermodynamic structure.

Keywords: MBL, multi-layer clouds

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Simulating the contribution of marine organic carbon to Southern Ocean aerosol and clouds

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The marine aerosol burden is often described as being dominated by sea salt and sulfate. However, observations and laboratory studies have highlighted a significant contribution to marine aerosol from emission of organic carbon. Despite this, even the latest generation of aerosol schemes included in climate models neglect organic carbon emissions, introducing potential biases to the simulated clouds, precipitation, and radiative budget.

Marine organic carbon emissions can be primary (direct release of organic carbon in particles) or secondary (organic carbon emitted in the gas-phase). The lifetime and fate of aerosol from the two distinct source mechanisms are quite different, and require individual representation in an aerosol scheme to quantify their role in the climate system.

We have used the ACCESS-UKCA composition-climate model (which includes the GLOMAP-mode aerosol microphysics scheme) to simulate the emission and fate of primary and secondary organic carbon. We compare the model against observations made during the Surface Ocean Aerosol Production (SOAP) ship campaign in the productive seas east of New Zealand, and also against long-term observations from fixed stations (e.g. Cape Grim). We quantify the contribution marine organic carbon makes to Southern Ocean aerosol mass and number, and the subsequent impacts on cloud optical properties and radiation. Including emissions of marine organic carbon can reduce the Southern Ocean radiation bias, and opens the door to including paramterisations of ice nuclei number concentration.

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Comparison of wind frequency spectra over Syowa Station between the ERA5 reanalysis and the PANSY radar

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The latest objective and reanalysis data have horizontal resolution fine enough to partially resolve gravity waves (GWs), which enable us to estimate their momentum flux and energy. It is reported that the European Centre for Medium-Range Weather Forecasts (ECMWF) operational analysis reproduced the horizontal distribution of momentum flux due to GWs, which was similar to but smaller than the observations by a factor of 3-5.
In this research, we evaluate how much GWs over Syowa Station (39.6E, 69.0S) are reproduced in the ERA5 reanalysis data by comparison with the PANSY radar observation. The ERA5 reanalysis is the latest meteorological reanalysis dataset provided by the ECMWF. The PANSY radar at Syowa Station is the only Mesosphere-Stratosphere-Troposphere/Incoherent Scatter (MST/IS) radar in the Antarctic and can observe GWs in all frequency bands and estimate their momentum flux in the troposphere and lower stratosphere. We compared frequency spectra of three-dimensional winds between the ERA5 reanalysis and the PANSY radar from January to March 2016. While the frequency spectra of horizontal winds showed a good agreement between ERA5 and PANSY in a frequency range lower than the inertial frequency, those of ERA5 were smaller than those of PANSY in a frequency range higher than the inertial frequency. Also, we found that the frequency spectra of vertical wind in ERA5 were smaller than those of PANSY in all frequency bands. We will discuss why such a difference between ERA5, and PANSY appears especially in the vertical wind.

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Modeling the Lower Atmosphere and Surface Mass Balance of Antarctic Peninsula Ice Sheet with a Snow-Ice Enhanced WRF-ice Model

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Antarctic Peninsula (AP) is among the most rapidly changing regions in the world , which makes it an ideal target for developing a model framework suitable for understanding the climate change impacts on the ice sheets/shelves. As thus a snow/ice enhanced Weather Research and Forecasting model WRF-ice has been developed. This study examines the overall performances of WRF-ice and its blowing snow component with a case study of mesoscale cyclone during October 23-26 2017 over AP. WRF-ice simulated surface temperatures over ice sheet, ice shelf and sea ice are in reasonably good agreement with the MODIS surface temperatures. Blowing snow effects in the WRF-ice simulation show that water vapor in the lower atmosphere increases owing to the blowing snow sublimation, and more clouds and precipitation are generated when enough moisture and lifting are present. Blowing snow sublimation is prominent when the air is dry and clear, and accordingly moistens and cools the air. Over relatively warm and humid areas, enhanced clouds by blowing snow lead to either colder or warmer air and surface temperatures depending on the competing effects of longwave and shortwave cloud radiative forcings (CRF). Additional moisture from blowing snow sublimation can intensify precipitation over the mountain areas. Furthermore, surface energy budget indicates decreased (increased) latent (sensible) heat flux due to blowing snow. Combined with increased (decreased) longwave (shortwave) CRF, a negative surface net heat flux occurs during daytime. As a consequence of increased precipitation and reduced runoff and sublimation, a more positive surface mass balance is generated.

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