INTERNATIONAL CONFERENCE ON HIGH LATITUDE DUST 2017

Conference Handbook

May 22nd – May 25th

Hosted by the University of Iceland, Reykjavik

Table of Contents

The organisers would like to thank all the individuals, societies and organisations who have contributed towards the success of this conference. We would particularly like to thank The Leverhulme Trust, University of Iceland, Loughborough University and The British Society for Geomorphology for their sponsorship and support.

Welcome to the International Conference on High Latitude Dust

Dear Delegates,

Iceland has been identified as a major high latitude dust source in the northern hemisphere. Dust sources in Iceland are linked to proglacial landscapes, where volcanic and glacial-derived material is stored in outwash plains (sandurs) before being deflated by the wind. It has been suggested that, as ice masses in Iceland continue to melt, proglacial landscapes may expand increasing the potential amount of sediment which is available to be transported during dust storms.

Dust storms in Iceland have a significant regional effect on people and the environment. High PM10 concentrations are often recorded in the city of Reykjavik, where approximately 85% of Iceland's population reside, causing a regional health concern. Dust also plays a role in regional cryospheric, oceanic, lacustrine and soils environments.

Hosting the first International Conference on High Latitude dust in Iceland will give delegates an opportunity to explore the landscapes where high latitude dust plays an important role within all aspects of geoscience. We are delighted that the Mayor of Reykjavik will be hosting an event for the conference, indicating the importance that the work presented has on day to day life in Iceland.

This conference has been organised by members of the 'High Latitude Cold Climate Dust Network' which has been funded by The Leverhulme Trust over the past 3 years. The aim of the network is to facilitate collaboration amongst researchers to improve understanding of contemporary and future high latitude dust emissions, focusing on consolidating existing knowledge, identifying research gaps and prioritizing strategic, inter-disciplinary research questions. We are therefore delighted to be welcoming 51 researchers from 15 countries to Iceland to exchange ideas on cold climate aeolian processes and sediment supply, remote sensing and modelling the impacts of high-latitude dust, contemporary impacts of high-latitude dust and the long term palaeo-environmental record of high latitude dust. We hope that all delegates will have the opportunity to network widely and hopefully to develop new collaborative research partnerships.

Organising Committee

Joanna Bullard (J.E.Bullard@lboro.ac.uk)

Tom Mockford (T.Mockford@lboro.ac.uk)

Throstur Thorsteinsson (ThrosturTh@hi.is)

Conference Venue and Registration

Registration, oral sessions, poster sessions, refreshments and lunches will be in the Askja building (see attached map). The building address is Sturlugata 7 101 Reykjavík.

Registration on the University of Iceland campus will be open from 09:00 – 10:30 on Monday 22nd May. If you're planning on arriving outside of this time period, please contact the conference organisers.

All lunches and coffee breaks are provided during the conference. If you have informed us of any dietary requirements, your lunches will be marked with your name. If you have not informed us but you do have particular dietary requirements, please inform the conference organisers as soon as possible.

Additional Information

Guide for Oral Papers

Delegates are allocated a 20 minute slot for oral presentations. This includes times for questions so please plan your talk times accordingly. Session chairs will inform speakers when they have 5 minutes left.

PowerPoint slides should be uploaded via USB prior to the beginning of the session.

Guide for Poster presentations

Poster presentations can be displayed from the beginning of the conference on the boards in the main foyer. They can be left up for the entirety of the conference. A dedicated poster session will take place on Tuesday; however delegates are encouraged to use the whole conference to view posters.

Posters can be up to A0 (Portrait or Landscape).

Car Parking

There is free car parking outside of the Askja building. If you require disabled access parking, please contact the conference organisers so this can be arranged.

WIFI

The University of Iceland uses Eduroam (the universal University Wi-Fi system). If you do not have access to Eduroam, guest log in details can be provided at registration.

Local Transport

Reykjavik can be accessed relatively easy on foot. The conference venue is located approximately 20 minutes walking from the city centre.

There are a number of taxi companies which are available 24 hours a day:

1) Hreyfill +354 588 5522
2) BSR +354 561 0000

Buses also run from the town centre to the BSI bus terminal, which is located 5 minute walk away from the conference venue.

Icebreaker (Monday 22nd May)

This event is being hosted at the Reykjavik Town Hall (see attached map). It is approximately a 10 minute walk from the conference venue .Canapés and drinks are provided from 16:30. This icebreaker is being hosted by the Mayor of Reykjavik and is partially funded by the British Society for Geomorphology.

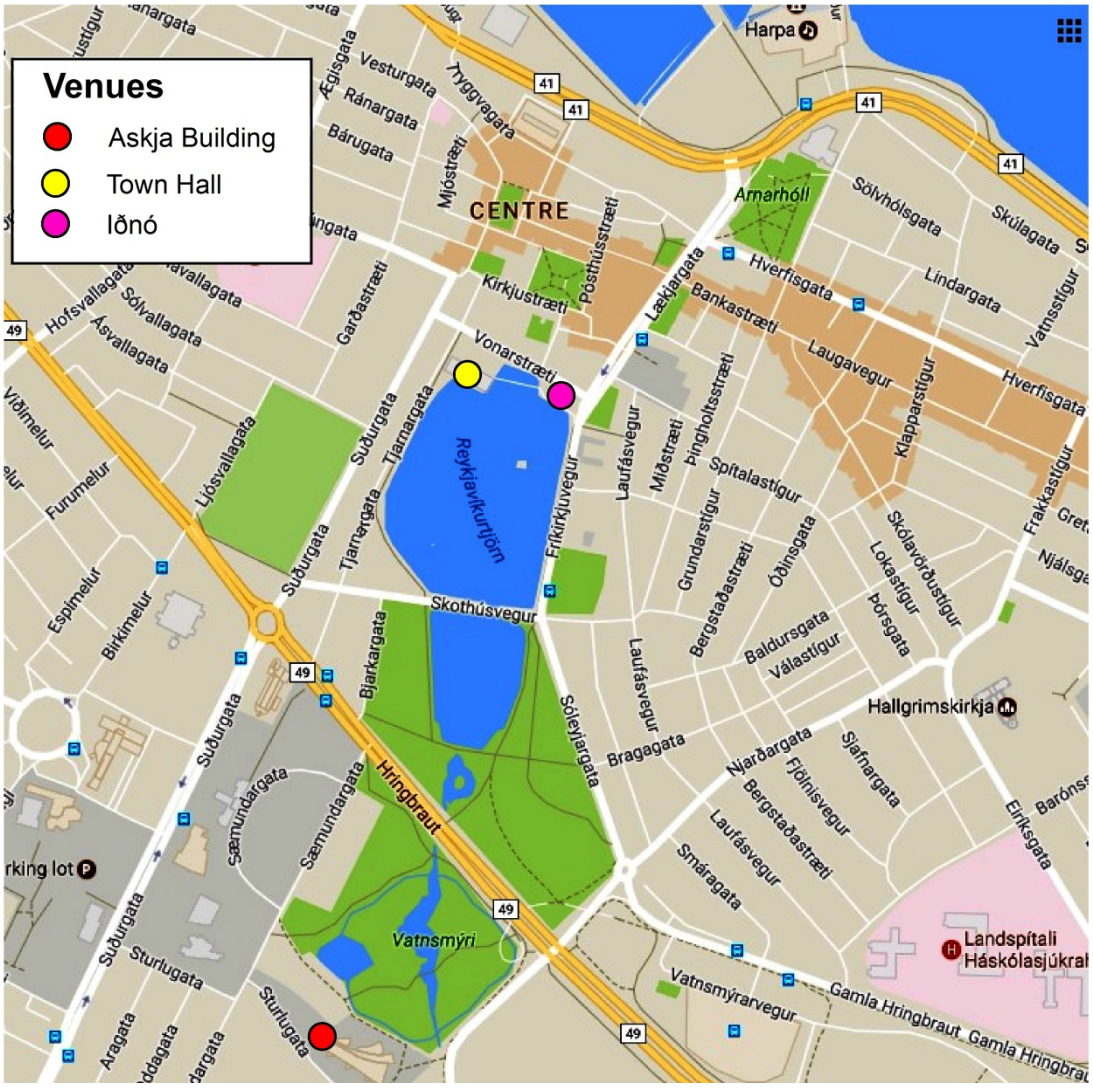
Conference Dinner (Tuesday 23rd May)

The conference dinner is taking place at Iðnó in the city centre (see attached map). The venue is very close to the Town Hall. The meal is included in your registration and will include a 3 course Icelandic dinner and wine. The meal will begin at 7pm.

Restaurants and bars

Reykjavik city centre has a wide range of bars and restaurants. Streets adjacent to and around Laugavegur will provide a variety of options for delegates from traditional Icelandic dishes to other European cuisines.

Venues Map



Addresses

Askja Building (Conference venue) – Sturlugata 7, 101 Reykjavík, Iceland
Town Hall (Icebreaker venue) – Tjarnargata 11, 101 Reykjavík, Iceland
Iðnó (Conference Dinner venue) - Vonastræti 3, Vonarstræti, 101 Reykjavík, Iceland

Campus Map – Conference venue is building number 10

Programme

Monday 22nd May

Session 1: 10:00 – 12:00 **Chair: Joanna Bullard**		**Aeolian Processes 1**
10.00 - 10:40	Joanna Bullard	Welcome and High-latitude dust in the Earth system: past, present and future
10:40 -11:20	Cheryl McKenna Neuman	Keynote: Aeolian transport processes in high latitude regions
11:20-11:40	James King	Dust emissions from the Yukon Valley, Canada
11:40 - 12:00	Neelratan Singh	Formation of sand dunes in Nubra and Shyok valleys, Ladakh Himalaya
12:00 – 1:00	**Lunch**	

Session 2: 13:00 – 14:30 **Chair: Throstur Thorsteinsson**		**Aeolian Processes 2**
13:00 - 13:20	Ólafur Arnalds	The hyperactive dust sources of Iceland
13:20 - 13:40	Pavla Dagsson Waldhauserová	Iceland – the largest and most active desert in the arctic
13:40 - 14:00	Mary Butwin	The frequency of dust and volcanic ash resuspension events in Iceland using varying observational techniques
14:00 - 14:20	Diego Gaiero	Drivers, seasonality and grain-size of dust fluxes at the Patagonian coast
14:20 – 14:50	**Coffee**	

Session 3: 14:50 – 16:20 **Chair: Richard Hodgkins**		**Dust in the Cryosphere**
14:50 – 15:10	Aubry Vanderstraeten	Dust deposition in snow and passive sampler in Dronning Maud Land (NE Antarctica); geochemical tracing of dust sources
15:10 – 15:30	Thomas Cahill	Aerosol measurements from the Greenland Summit
15:30 – 15:50	Helen Johnson	Representing the snow darkening effect of black carbon within the JULES land surface model
15:50 – 16:10	Outi Meinander	Experiments towards understanding the role of Icelandic dust in the Arctic cryosphere
16:30	**Icebreaker and reception at Reykjavik Town Hall**	

Tuesday 23rd May

Session 4: 09:00 – 11:00 **Chair: Matt Baddock**		**Remote Sensing**
09:00 - 09:20	Christina Hsu	Quantifying high latitude dust over Land and Ocean using VIIRS deep blue aerosol products
09:20 - 09:40	Keyvan Ranjbar	Remote sensing of dust over the Arctic
09:40 – 10:00	Edward Nowottnick	CATS observations of high latitude dust and near real time data products
10:00 - 10:20	Rune Solberg	Developing and approach for satellite observations of black carbon in snow surfaces in the Arctic
10:20 – 10:40	Verity Flower	Observations of remobilized volcanic ash in the Kamchatka Peninsula, Russia using the space-borne MISR multi-angle imaging
10:40 - 11:00	Santiago Gassó	Characterisation of 40 years of dust observations at the largest source in Patagonia (Colhue Huapi Lake) in South America
11:00 – 11:30	**Coffee**	

Session 5 11:30 – 12:50 **Chair: James King**		**Modelling**
11:30 - 11:50	Christine Groot Zwaaftink	Modelling emission, transport and deposition of Icelandic mineral dust
11:50 – 12:10	Kerstin Schepanski	Meteorological situations favouring the development of dust plumes over Iceland
12:10 - 12:30	Anne Kubin	Sensitivity studies on glacigenic dust mobilisation in Greenland with a global and a mesoscale model
12:30-12:50	Paul Vallelonga	Dust in Antarctica – models vs ice cores
12:50 – 14:20	**Lunch and Posters**	

Session 6: 14:20 – 15:40 **Chair: Bob McCulloch**		**Sediment Supply**
14:20-14:40	Megan Madden	Investigating the mineralogy, surface area, and chemical reactivity of fine-grained fluvial sediments produced in glacial systems
14:40-15:00	Richard Hodgkins	Proglacial sediment supply under contrasting runoff regimes
15:00-15:20	Tom Mockford	Aeolian abrasion as a dust particle generator in cold climate environments
15.20-15.40	Ken Pye	Particle size of atmospheric dust and dust deposits - methods and significance of interpretation of results
15:40 – 16:10	**Coffee**	

Session 7: 16:10 – 17:00 **Chair: Joanna Bullard**		
16:10 - 16:50	Cliff Atkins	Keynote: Antarctic dust: Sources, distribution and impact. Links between dust, biogeochemical cycles and climate change
16:50 – 17:00	Tom Mockford	Briefing on conference dinner
19:00	**Conference Dinner**	

Wednesday 24th May

Session 8: 09:30 – 10:50 **Chair: Cliff Atkins**		**Impacts of High Latitude Dust**
09:30 - 9:50	John Crusius	Observational and modelling constraints on dust source dissolved Fe supply to the Gulf of Alaska from the Alaskan coastline
09:50 – 10:10	Matt Baddock	Two decades of Icelandic high-latitude dust pathways
10:10-10:30	Throstur Thorsteinsson	Natural sources of particulate matter in Reykjavik
10:30-10:50	James Hooper	The role of Patagonian Dust-Fe in fertilisation of the Southern Ocean
10:50 – 11:20	**Coffee**	

Session 9: 11:20 – 12:40 **Chair: Tom Bradwell**		**Paleoenvironmental Records 1**
11:20 - 12:00	Dan Muhs	Keynote: Loess, Paleosols and Climate Change in Alaska: 3 Million years of dust records to decipher
12:00 - 12:20	Francois De Vleeschouwer	Fuegian peatlands: Recorders of Holocene environmental change
12:20 - 12:40	Bob McCulloch	Glacial influences on high latitude and cold climate records of dust deposition
12:40 – 13:40	**Lunch**	

Session 10: 13:40 – 15:00 **Chair: Ken Pye**		**Paleoenvironmental Records 2**
13:40 - 14:00	Elena Korotikh	A 2000-year record of atmospheric dust variability developed from a South Pole ice core.
14:00 - 14:20	Bess Koffman	Abrupt late Holocene shift in atmospheric circulation recorded by mineral dust in the Siple Dome Ice Core, Antarctica
14:20 - 14:40	Marius Simonson	Local dust influences on the Renland (East Greenland) ice core
14:40 - 15:00	Patrick Saylor	1500-year record of trans-Pacific dust transport from the Denali ice core, Mt. Hunter, Alaska
15:00 – 15:20	Sam Marx	Temporal variability in arid (sup-tropical) versus cold climate (high-latitude) dust emissions: Examples from the Australasian region
15:20 – 15:50	**Coffee**	

15:50 - 16:00	Joanna Bullard	Closing comments
16:00 - 16:15	Tom Mockford	Fieldtrip briefing
16:15	**Conference Close**	

Posters

Name	Title
Bess Koffman	New Zealand's South Island as a potential source of glacigenic dust to the atmosphere and ocean: characterization using Sr-Nd-Pb isotopes and trace elements
Alejandro Montes	Hydrographic evolution and dust storms: The Colhue Huapi lake case study
Francois De Vleeschouwer	MICRODUST: Micro-organisms and Dust – Signatures, Interactions, Transport and Dissemination
Heejn Hwang	Characterization of dust particles in the snow pit on Styx Glacier, Antarctica
JH Kang	Aeolian dust record in the GV7 firn core from Northern Victoria Land, East Antarctica
Joanna Bullard	High latitude and cold climate dust network
Kitae Kim	Simultaneously enhanced iron oxide dissolution and iodide oxidation in cold environment
Mary Butwin	Evolution of aging volcanic ash and physical characteristics of dust in Iceland
Maud van Soest	Biogeochemical impacts of dust deposition on Arctic soils
Pavla Dagsson Waldhauserová	Aerosol and dust association in Iceland
Tamar Richards	Micro-scale characteristics of Icelandic dust particles
Tom Mockford	Seasonal and decadal variability of dust observations in the Kangerlussuaq area, West Greenland
Tom Bradwell	Increased North Atlantic dust deposition linked to Icelandic glacier fluctuations over the last 5000 years

Oral Abstracts

Session 1 Aeolian Processes 1

High-latitude Dust in the Earth System: past, present and future

Joanna Bullard
Department of Geography
Loughborough University

Estimates of the total amount of dust entering Earth's atmosphere converge around 2000 Tg. Sources of natural dust are concentrated in the subtropical deserts, but significant dust events have been reported from other regions and it is suggested at least 5% of global dust emissions come from sources covering >500,000 km2 in the high latitudes (≥50° N and ≥40° S). Many contemporary sources of high-latitude dust are either modern proglacial floodplains or paraglacial regions that have been conditioned by glacial activity. This relationship with glacial activity is sustained over glacial-interglacial timescales as during glacial periods dust emissions increase due to the combined effects of aridity, strong winds, low terrestrial biomass and extensive fine sediment availability. Atmospheric dust was, for example, on average at least twice as high during the Last Glacial Maximum compared to at present. Records of aeolian activity over different timescales are recorded in terrestrial, lacustrine and marine sediments and are a key source of information for understanding variations in dust emissions, transport pathways and deposition at a range of timescales and in response to forcing factors including not only variations in climate but also in sediment systems and human activities. A substantial proportion of dust from high-latitude sources remains within the high latitudes and is deposited in marine and terrestrial environments within environmental sensitive polar regions. It is increasingly recognised that understanding the depositional pathways of dust sourced from within the high latitudes is vital for understanding the roles of the polar regions in the global system and for predicting future climate dynamics and ecosystem responses.

Aeolian transport processes in high latitude regions

Cheryl McKenna Neuman
Trent Environmental Wind Tunnel Laboratory
Trent University

Little is known and little work has been carried out with regard to the physics of the wind borne transport of particles in cold climate regions. From isolated observations of this phenomenon in a wide range of high latitude field settings to paleoenvironmental reconstructions of large scale aeolian transport originating around the margins of continental ice caps, there is growing recognition of the importance of these processes. With glacial retreat and the melting of permanent snow packs in a warming climate, the exposure of fresh sediment to atmospheric boundary layers flows has the potential, at least in principle, to increase the contribution of suspended mineral particles from high latitude sites to the global dust load. However, there are many variables to consider in this highly complex geophysical system. A wide range of factors govern the sediment supply, inclusive of vegetation, pore water and ice, soil crusts, and armouring. At the most fundamental level, we are only beginning to understand and quantify the interdependent effects of wind speed, wind gusting, turbulence intensity, humidity and temperature on particle saltation and dust entrainment. Some of this work can be considered to be in its 'infancy' and is largely carried out under highly controlled conditions in laboratory wind tunnels. We have been able to ascertain in such work that humidity may play an equal, or in some instances, an even more important role than wind speed in dust transport in high latitude and seasonally cold regions, whereas temperature appears to be of secondary importance. This paper will provide a brief overview of the physics of dust emission with specific regard to cold regions, present some recent findings based on our laboratory simulation work, and identify several future challenges.

Dust emissions from the Yukon Valley, Canada

James King
Department of Geography
University of Montreal

The Kaskawulsh glacier in Yukon, Canada, part of the St. Elias Mountain Glacier system, is experiencing increased ablation from rising air temperatures and in 2016 changed its main fluvial outlet (the Slims River and Kluane Lake) for the first time in over 300 years to drain into the Gulf of Alaska. In the recent earth history, changes in temperature within glaciated valleys produced large amounts of wind-blown dust, evident in layers of loess within surrounding soils. Mineral aerosols in the atmosphere affect the environment of the earth through their direct effect on solar radiation, modifying cloud processes, and ground insolation. Furthermore, the deposition of mineral aerosols can provide essential nutrients for ocean and terrestrial productivity. This potential drastic reduction in fluvial inputs into Kluane Lake will result in the rapid exposure of deltaic sediments and extended periods of dust emissions, similar to those suggested to occur during the rapid warming in the early Holocene. This drastic change already starting to occur makes this system an excellent natural laboratory for investigating the impact of dust storms under past and future climates. Current research is analyzing the connection between proglacial valley dust emissions and glacier dynamics, within ancient and modern climates using a multi-method approach of 1) remote sensing imagery for links between erodibility potential, dust emissions, and glacier mass balance; and 2) historical and in situ climatology and sediment transport analyses.

Formation of sand dunes in Nubra and Shyok Valleys, Ladakh Himalaya

Neelratan Singh
Hydro-Geology and Environmental-Geology Group
School of Environmental Sciences
JNU-New Delhi

Nubra and Shyok Valleys are located in Ladakh Himalaya. The area is a cold desert. Sand Dunes occur in clusters along the courses of Nubra and Shyok Rivers. Their occurrence is restricted to selected parts along the course of both the rivers. Three geomorphic processes appear to have played role in formation of these dunes. Three processes viz. Glacial, Fluvial and Aeolian. Lithology of sand dunes controlled by litho units of the region. For example where ever granitic suit of rock dominate formation of sand dunes is more. Available data suggest that the formation of sand dunes in the area is controlled by lithology and geomorphic agents involving Fluvial, Glacial and Aeolian processes. Among these geomorphic processes, role of Aeolian processes predominates compare to others.

The hyperactive dust sources of Iceland

Ólafur Arnalds
Landbúnaðarháskóla Íslands /Agricultural University of Iceland

Iceland has the largest area of volcaniclastic sandy desert on Earth or 22,000 km2. The sand has been mostly produced by glacio-fluvial processes, leaving behind fine-grained unstable sediments which are later re-distributed by repeated aeolian events. Volcanic eruptions add to this pool of unstable sediments, often from subglacial eruptions. Icelandic desert surfaces are divided into sand fields, sandy lavas and sandy lag gravel, each with separate aeolian surface characteristics such as threshold velocities. Storms are frequent due to Iceland's location on the North Atlantic Storm track. Dry winds occur on the leeward sides of mountains and glaciers, in spite of the high moisture content of the Atlantic cyclones. Surface winds often move hundreds to more than 1000 kg m-1 per annum, and more than 10,000 kg m-1 have been measured in a single storm. Desertification occurs when aeolian processes push sand fronts and have thus destroyed many previously fully vegetated ecosystems since the time of the settlement of Iceland in the late ninth century. There are about 135 dust events per annum, ranging from minor storms to >300,000 t of dust emitted in single storms.

Dust can be generated from all the major sandy areas of Iceland; however the amount of finer particles that become dust varies with the surfaces. There are areas that produce more dust by far compared to the general sandy deserts; they have therefore been termed "dust plume areas" or "dust hot-spots". They are characterized by repeated charging of fine sediments with a relatively high proportion of finer (silty) materials which, upon repeated wind erosion become sorted downwind from the sources with loss of silt (dust) and an increasing saltation component (sand). Dust production is on the order of 30-40 million tons annually, some travelling over 1000 km and deposited on land and sea. Dust deposited on deserts tends to be re-suspended during subsequent storms. High PM10 concentrations occur during major dust storms. They are more frequent in the wake of volcanic eruptions, such as after the Eyjafjallajökull 2010 eruption. Airborne dust affects human health, with negative effects enhanced by the tubular morphology of the grains, and the basaltic composition with its high metal content. Dust deposition on snow and glaciers intensifies melting. Moreover, the dust production probably also influences atmospheric conditions and parameters that affect climate change.

Iceland – the largest and most active desert in the Arctic

Pavla Dagsson-Waldhauserova
Department of Physics
University of Iceland

Iceland is located in high-latitude cold region where both volcanic and glacial activity affect most of the areas. It is extremely active and with over 44,000 km^2 counts as the largest Arctic and European desert. Frequent dust events, up to 135 dust days annually, transport dust far distances, sometimes >1,000 km, towards the Arctic and Europe (MODIS). The dust deposition is about 31-40 million tons yr^{-1}, including land, oceans and glaciers (> 500,000 km^2). Major dust storm transports > 1 million tons of dust.

Dust events in South Iceland are often in winter or at sub-zero temperatures. The Snow-Dust Storm phenomena was observed with polluted black snow showing impurities over 250 km distance from the source. PM_{10} concentration was > 6500 µg m^{-3} with median PM_{10} of 1,170 µg m^{-3} day^{-1}. Dust is also suspended during rains and low winds as a result of surface heating. Particle number concentration (PM~0.3-10 µm) about 150,000 particles cm^{-3} min^{-1} with the highest numbers of submicron particles (300-337nm). $PM_1/PM_{2.5}$ ratios of >0.9 and PM_1/PM_{10} ratios of 0.34–0.63 are comparable to urban air pollution rather than dust storms.

Dust particles in Iceland are different to crustal dust areas. We have observed unusual dust events, not reported from elsewhere, pointing to differences such as size, colour and shape: 1. An extreme wind erosion event of fresh volcanic ash, 2. A Snow-Dust Storm, and 3. A suspended dust during moist and low wind conditions. Freshly deposited ash increases the dust frequency and prolongs impacts of frequent volcanic eruptions as we observed after the 2010 Eyjafjallajokull eruption. The storm (WS = 38.7 ms^{-1}, saltation = 6825 pulses min^{-1}, aeolian flux = 11,800 kg m^{-1}, black volcanic glasses > 2 mm in 1.5 m height) is among the most extreme wind erosion events recorded on Earth.

The frequency of dust and volcanic ash resuspension events in Iceland using varying observational techniques

Mary Butwin
University of Iceland/Icelandic Meteorological Office

Iceland has the largest volcaniclastic (primarily volcanic sand) desert in the world, covering 22,000 km2. These deserts were mainly created by glacio-fluvial processes, which created mineral sand and dust from surface igneous rocks and old volcanic ash. The frequent volcanic eruptions also add to the volume of loose surface material. Due to Iceland's location along the North Atlantic storm track, Iceland frequently receives high winds from synoptic scale events. However, due to varying land use types and strong thermal gradients, Iceland can also receive high winds on the mesoscale. Having loose sand and ash and high winds, Iceland is prone to dust storms and resuspended volcanic ash events. Determining the frequency of such events in Iceland is important when considering erosion rates, sand and dust dispersion, air pollution, and the forecasting of such events.
Because of Iceland's climate, proximity to the Arctic, frequent cloud cover (~200 days annually), and the remoteness of some source locations, multiple techniques, both airborne and ground-based, must be used to get an accurate assessment of the frequency of dust and ash events. We have used CALIPSO and MODIS satellite imagery, ceilometer, and weather observations from AWS as well as human observers to analyze the frequency of dust and volcanic ash resuspension events in Iceland from 2010-2016. We will summarize the time series and show the conditions under which each technique is best used. By examining the frequency of detected/missed events, it can be determined which combination of techniques provides the most accurate picture of the frequency of dust and volcanic ash resuspension events, as well as how to improve observations.

Drivers, seasonality and grain size of dust fluxes at the Patagonian coast (40°S-53°S).

Diego Gaiero
CICTERRA/Universidad Nacional de Córdoba

There is a growing scientific interest to account with modern dust flux measurements in a high latitude dust source like Patagonia as it is of significance for regional climatic studies. This region is the only important landmass below the 40°S which are strongly influenced by the SH westerlies and dust emitted from this region may have direct impact on the Southern Ocean. Dust research focusing in this area of the globe is lacking and scant information is available for proper model parameterizations. Since 2004 a dust monitoring program is being performed at 4 localities along the Patagonian coast. Each site is equipped with passive collectors; a 40-cm deep, inverted epoxy-coated fiberglass pyramidal receptacles suited to estimate vertical fluxes (VF) by gravitational deposition and BSNE samplers, to measure wind-blown horizontal fluxes (HF).

At Patagonia both, VF and HF, point toward a similar annual variation indicating higher fluxes during spring-summer according to the increase of the mean monthly wind speed and the decrease of the mean monthly relative humidity. Previous estimations based on VF data indicated that ~30 Tg of Patagonian dust are annually supplied to the South Atlantic shelf. New estimations based on HF contradicts this figure, indicating annual fluxes of 900-1400 Tg to the shelf. Having in mind the low efficiency of BSNE devices, these new data should be taken as a minimum estimation. Turbulent conditions at Patagonia promote transport of coarse dust particles. The median grain-size of HF fluctuate between 16 to 67 µm (mean=31 µm), contrasting with a range between 12-33 µm (mean=21 µm) measured at lower latitudes in South America (e.g., The Pampas). Finally, we observed that the natural process of dust emission is being enhanced by the anthropogenic activities developed in the region. The importance of this modern driver will be discussed in this work.

Dust deposition in snow and passive sampler in Dronning Maud Land (NE Antarctica); geochemical tracing of dust sources

Aubry Vanderstraeten
Département des Géosciences, Environnement et Société
Université Libre de Bruxelles

Mineral dust is a major source of micronutrients (e.g. Fe) in open oceans and “High Nutrient Low Chlorophyll” (HNLC) zones. The southern Ocean is by far the largest of all HNLC regions and thus has the potential to greatly enhance the biological CO2 pump at the global scale. As the aerosol fluxes in the southern ocean are not well constrained and the potential impact of anthropogenic airborne particles may be larger than expected, a multidisciplinary study is ongoing to trace the source and chemical reactivity (in terms of Fe) of dust deposited in NE Antarctica.

Dust were recovered from snow as well as through passive dust collectors located along a transect from the coast to 200km inland, near the Sør Rondane Mountains. These samples were analysed for the grain size distribution, morphology, chemistry and mineralogy of dust by single particle analyses (automated-FEG-SEM-EDS). In parallel, trace elements analyses were achieved to determine the origin, the geographical variability and the relative contributions of natural and anthropogenic sources.

Overall, dust samples exhibit a particle-size distribution where >98% (n=5000) of the particles are <5µm and with ~50% of the particles that contain Fe, either in the crystalline structure, coating on the mineral surface or both. The coastal dust samples are slightly smaller in grain size and exhibit an higher amount of Fe surface coatings compared to inland samples. Interestingly coastal dust has a strong enrichment in Cr, Zn, Cu, Cd and Pb (x10 to x100 relative to upper continental crust) suggesting a significant anthropogenic dust contribution. In contrast, inland dust mineralogy appears to be similar to the Sør Rondane Mountains rocks, suggesting a local origin. Rare Earth Elements profiles confirmed this local input and also identify at the coast and at different sampling period distant Patagonian and/or interestingly African fingerprint as main dust sources.

Aerosol measurements from the Greenland Summit

Thomas Cahill
University of California, Davis

The 2003 upgrade at the Greenland summit site to year round operation opened up new opportunities for measurements. Beginning in June, 2003, we have continuously measured aerosols at the Greenland Summit site by time (12 hr), size (8 modes, from ~ 15 µm to 0.09 µm diameter), composition (up to 32 elements, to sub picogams/m3 levels), and optical characteristics. Two goals were 1) to establish a transfer function for aerosols that would be deposited onto snow and into the ice cores, with UC Merced and DRI Reno collaborators, and 2) enhance our understanding of aerosol impacts on the global albedo. Technical problems caused breaks to the record, especially while we had to operate in a buried shipping container, and additional gaps were incurred from loss of federal funding. Nevertheless, a fully QA-validated 45 Mb data set in Excel is available, while re recent summary has been published for the first decade (VanCuren, et al, Atmospheric Environment, 52:82-97 (2012)) The results of the first task have shown a poor correlation between settling dust onto the snow surface, dominated by the 15 to 5.0 µm size mode, and airborne dust above the ice sheet. The optically efficient fine aerosols < 5.0 µm diameter can occur with little coarse dust, hinting at more significant cooling from dust aerosols than just the cores might suggest. The results of the second task have resulted in our ability to identify dust sources from large part of the Northern Hemisphere. This has allowed identification of other current critical aerosols (sulfur, wood smoke, industrial sources, volcanoes, etc.) back to their sources, including a previously ignored cross polar transport from China. Measurements of the aerosol optical parameters show that the albedo of Asian aerosols is lower than aerosols derived from United States of western European sources.

Representing the snow darkening effect of black carbon within the JULES land surface model

Helen Johnson
Met Office, UK

Within land surface models, snow albedo is considered to be a parametrized process of particular importance for forecasting snow related variables such as snow mass and depth. An important process that can affect snow albedo but which is often not represented in weather and climate models is the deposition of aerosols from the atmosphere onto snow. In particular, the deposition of black carbon (BC) onto snow can have a large impact on the snow albedo due to its strong absorption of solar radiation.

Recent improvements to the multi-layer snow scheme in the Joint UK Land Environment Simulator (JULES), a key component of the Met Office Unified Model for weather and climate forecasting (UM), allow for BC mass to be incorporated into the snowpack and it's concentration to be considered when calculating snow albedo. This opens up opportunities to consider effects of snowpack BC content on snow accumulation and melt.

Using a set of plausible BC deposition values generated using the CLASSIC aerosol scheme within the UM, offline JULES tests are performed to investigate the impact of including snow darkening aerosol effects in land surface model runs. Methodology and initial results shall be presented.

Experiments towards understanding the role of Icelandic dust in the Arctic cryosphere

Outi Meinander
Finnish Meteorological Institute

Light-absorbing impurities in the cryosphere are of hydrological, environmental and climatic importance. The wet and dry deposition of black carbon (BC), organic carbon (OC), and dust particles affect the optical properties and melt of snow and ice. In the Arctic region, the climatic effects are amplified, and surface albedo feedback, the 'albedo effect' is often cited as the main contributor. Icelandic dust is one of the most abundant dust sources in the climate system and there are about 135 dust events per annum, originating from 7 major sources (Arnalds et al. 2016).The properties of Icelandic dust particles vary according to the source; some particles are dark in color, similarly to soot, and capable of being long-transported. Yet, the influence of Icelandic dust in darkening and melt of Arctic snow and ice has been largely ignored in scientific investigations and modeling approaches (Bullard et al. 2016). To fill in some of the gaps in our knowledge of the cryospheric effects of BC, OC, and Icelandic dust on snow in the European Arctic, we have carried out a series of field and laboratory experiments.

We have found that the absorbing contaminants of BC and dust on snow enhanced the metamorphism of snow under strong sunlight in our experiments. Immediately after deposition, the contaminated snow surface appeared darker than the natural snow in all viewing directions, but the absorbing particles sank deep into the snow in minutes. The nadir measurement remained the darkest, but at larger zenith angles, the surface of the contaminated snow changed back to almost as white as clean snow. Thus, for a ground observer the darkening caused by impurities can be completely invisible, overestimating the albedo, but a nadir-observing satellite sees the darkest points, underestimating the albedo. Our experimental results on Icelandic volcanic ash on snow and ice also showed that a thin layer increases the snow and ice melt but that an ash layer exceeding a certain critical thickness causes insulation. Our results showed that during spring time snow melt, a change in the properties of the snow may be diurnally dominant over the solar zenith angle (SZA) symmetric albedo. This results in SZA asymmetric snow albedo signal. Our radiative transfer (RT) modeling results show that the observed solar zenith angle asymmetry results in a 2–4 % daily error for satellite snow albedo estimates. Albedo also changes wavelength specifically. For example, albedo changes due to BC are expected in the ultraviolet (UV) part of the electromagnetic spectrum. We found that the hydrophobic and hydrophilic properties of LAI can play an important role in albedo changes and in snow melt. In addition, the optical properties and mass absorption cross section (MAC) values to be determined for each type of impurity would be of need, e.g. in the SNICAR snow albedo modeling approaches.

Quantifying high latitude dust over land and ocean using VIIRS deep blue aerosol products

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The impacts of natural and anthropogenic sources of high latitude dust on climate and ecosystem have gained increasing attention from the scientific community. In order to facilitate these effects, high quality long-term global aerosol data records from satellites are highly desired. In this study, we will show systematically the global (land and ocean) distribution of high latitude dust from Version 1 of the VIIRS Deep Blue data set. The preliminary validation results of these new VIIRS Deep Blue aerosol products using data from AERONET sunphotometers over land and ocean will be discussed. We will also demonstrate the impact of the newly enhanced aerosol type products (including dust, smoke, fine mode air pollutant, and marine aerosols) from the VIIRS Deep Blue data suite on determining the spatial distributions of hot spots of dust sources at high latitudes.

Remote sensing of dust over the Arctic

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We report on remote sensing investigations of coarse and fine mode (sub- and super-micron) dust events over the Arctic. Sunphotomery and starphotometry (polar summer and polar winter) retrievals of coarse and fine mode aerosol optical depths (AOD) , coupled with ground-based and satellite-based (CALIOP) backscatter and depolarization ratio profiles and derived CALIOP AODs, satellite radiance imagery along with satellite retrievals of AOD and aerosol index (AI) as well as the predictions of a chemical transport model (GEOS-Chem) were employed to perform preliminary identification and characterization of both the extensive (mass dependant) and intensive per-particle) parameters of dust aerosols in the Canadian and European Arctic. The study will focus on the regional nature of the springtime and dust events that have been observed by various researchers.

CATS observations of high latitude dust and near real time data products

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In February 2015, the NASA Cloud-Aerosol Transport System (CATS) high repetition rate backscatter lidar began operation on the International Space Station (ISS) as a technology demonstration for future Earth Science Missions. CATS has continued operation through the present, providing vertical measurements of cloud and aerosols properties at 532 and 1064 nm. Owing to its orbit on the ISS, CATS provides diurnally varying observations from +/- 51°, including southern high latitude dust source regions and transport pathways. Here, we present observations of southern high latitude dust events and characterize transport pathways using approximately 2 years of CATS data. Additionally, due to its location on the ISS, a cornerstone technology demonstration of CATS is the capability to acquire, process, and disseminate near-real time (NRT) data within 6 hours of observation time. Here, we also present CATS NRT data products and outline CATS algorithms used to identify dust events. CATS NRT data has several applications, including providing notification of hazardous events for air traffic control and air quality advisories, field campaign flight planning, as well as a data source validating simulated dust events in aerosol transport models.

Developing an approach for satellite observations of black carbon in snow surfaces in the Arctic

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The overall objective of the ESA project *Remote sensing of black carbon in the Arctic* is to try developing a satellite remote sensing retrieval algorithm for the black carbon (BC) content in snow surfaces in the Arctic. Retrieval of BC impurities at expected 'background levels' (1-10 µg/l) in the snow surface is a very challenging task. The measurable signal from the optical effects of BC is very small and close to the noise level.

In our project we have combined field measurements in various sites in Svalbard with satellite measurements where we have progressively advanced our understanding and the approach. We started with measurements of dust and soot from local sources at three sites using glaciers (Longyearbreen, Grønfjordbreen and Foxfonna) as to avoid influence of bare ground surfaces. Background levels were finally studied on large ice fields and ice caps using the inner parts of Olav V land, Austfonna and Vestfonna.

For the retrieval of BC, we followed an approach of doing accurate modelling of the spectral reflectance of the snow and comparing it with observations. Modelling results similar or close to observations were assumed to represent the truth. The two main factors influencing the spectral reflectance in visible and near-infrared wavelengths are impurities and snow grain size. BC affects mainly the short-wave part of this spectral window, while grain size mainly affects the long-wave part. For modelling of the snow reflectance we have used DISORT. However, the DISORT code is demanding computationally, so we used a code for faster processing provided by the DISORT team, the AccuRT software. Our algorithm first determines the actual, effective optical snow grain size by comparing near-infrared observations and modelling results. When model and observations agree, 'soot' particles are added iteratively until observations in the visual part of the spectrum agree with the model. This 'convergent model' then gives the volume fraction of soot particles in the snow.

The algorithm is very sensitive to atmospheric effects. In the few cases of a completely clear sky, the retrieval result from the algorithm gave clear distributions of low-level BC concentrations in the three large ice fields and ice caps we used as study sites. High spatial variability of in situ measured BC made it difficult to validate the retrieval accurately, but the satellite-based retrieval results are within the ranges found in situ.

Observations of remobilized volcanic ash in the Kamchatka Peninsula, Russia using the space-borne MISR multi-angle imaging

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Observation and analysis of primary volcanic hazards are routinely performed with both ground and satellite based remote sensing techniques. In contrast, secondary hazards such as ash remobilization are routinely excluded from these volcanological studies. To understand these events analyses of the timing, size and extent must be undertaken. This work details observations of ash remobilization events in Kamchatka, Russia imaged with the Multi-angle Imaging SpectroRadiometer (MISR). The MISR instrument, deployed on NASA's Terra satellite, provides an over-16-year record that includes over 100 volcanic plume observations from volcanoes in Kamchatka. Fifteen of these plumes were confined to the planetary boundary layer in the form of remobilized ash. Plume height and dispersion characteristics of identified plumes can be calculated from the MISR multi-angle images. Particle microphysical properties can also be derived. These capabilities have been used previously to characterize dust, volcanic and wildfire smoke plumes. Remobilized ash imaged in Kamchatka ranged in length from 10 to 400 km and were confined to ~1 km above the terrain level. The low altitude nature of these plumes poses a significant risk to the respiratory health of any local populations, and the destruction of local infrastructure and interference with the aviation industry can severely impact the local economy. The timing of these ash remobilization events displays seasonality, as they occur predominantly between July and November, with exceptions following large eruptive events. Ash remobilization was determined to result from a complex combination of meteorological, hydrological and volcanological factors. Most events occurred when primary volcanic activity was ongoing and surface moisture levels were reduced due to low precipitation in preceding months.

Characterization of 40 years of dust observations at the largest source in Patagonia (Colhué Huapi Lake) in South America

Santiago Gassó
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While the Patagonia desert has been singled out as the largest source of dust in South America, it is notable the lack of dedicated studies characterizing basic features of dust production such as its frequency and seasonality. This information is essential in order to understand recent increases of dust deposition observed in the Antarctica and the nutrient budget relevant to primary productivity the Atlantic sector of the Southern Ocean.

This work reports the results an ongoing characterization of the last 40 years of dust activity occurring at the Colhué Huapi Lake (46 S, about 100km west from the coast), the largest and most active single source of dust in the region. A combined study involving satellite imagery (Landsat, TOMS and Aura-OMI satellits) and surface observations (visibility from the Comodoro Rivadavia airport, 60 km downwind from the lake and river flow gauges upstream) will be presented.

First results provide a consistent picture of alternating periods of dust activity with peak emission occurring in the late Spring/Summer and early Fall months and a minimum in Winter. While there have been periods of heightened activity because droughts, the last two decades have been characterized by enhanced activity even during the winter. Satellite observations of dust confirm this trend. Landsat estimation of the lake area show a clear correlation between lake size and dust activity. Probable causes that lead to the variable dust production will be discussed.

This study represents the first comprehensive analysis of modern dust activity in Patagonia exclusively based on observations. This work provides important constraints and validation data for global modeling studies of dust in the Southern Hemisphere as well information to validate recent observations of dust in the Antarctic Peninsula.

Modelling emission, transport and deposition of Icelandic mineral dust

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Sandur areas in Iceland are known for frequent dust storms. These dust storms can influence terrestrial and oceanic ecosystems, human health, transport and the cryosphere. So far, most estimates of dust emission specifically from Iceland, rely on storm frequency observations, visibility observations and interpretation of satellite images.

In this study, we adapted the dust mobilization module FLEXDUST and use the atmospheric transport model FLEXPART, to investigate dust emission and transport in Iceland. We used a high-resolution map of soil types in Iceland and threshold friction velocity in dust sources was based on previous observations. Snow cover and precipitation were included as factors limiting dust mobilization.

In a one-year high resolution simulation for 2012, driven with ECMWF data at 0.2°, we distinguish most important dust sources and study dust concentrations at remote distances from sources based on long- term PM10 measurements in and near Reykjavik. Some dust events were described well with the model, while the model appears to overpredict dust concentrations in Reykjavik in late fall.

In order to investigate interannual variability of dust emission, we did a series of simulations on a rough resolution over more than a decade (years 1998 - 2013) based on ERA Interim meteorological data. Here, we found that annual dust emission from Iceland varies by roughly 30% and is on average about 4.4 Tg. In some years, near-coast southern dust sources are especially active, while in others the inland sources in the region of Dyngjusandur are most prominent.

Meteorological situations favouring the development of dust plumes over Iceland

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The knowledge on mineral dust emitted at high latitudes is limited, but its impact on the Arctic environments is divers. Within a warming climate, dust emitted from regions in cold climates is expected to increase due to the retreat of the ice sheet and increasing melting rates. Therefore, and for its extensive impacts on different aspects of the climate system, a better understanding of the atmospheric dust life-cycle at high latitudes/cold climates in general, and the spatio-temporal distribution of dust sources in particular, are essential.

At high-latitudes, glacio-fluvial sediments as found on river flood plains e.g. supplied by glaciers are prone to wind erosion when dry and bare. In case of the occurrence of strong winds, sediments are blown out and dust plumes develop. As dust uplift is controlled by soil surface characteristics, the availability of suitable sediments, and atmospheric conditions, an interannual variability in dust source activity is expected.

We investigated atmospheric circulation patterns that favour the development of dust plumes over Iceland, which presents a well-known dust source at high latitudes. Using the atmosphere model COSMO (COnsortium for Small-scale MOdeling), we analysed the wind speed distribution over the Iceland region for identified and documented dust cases. As one outcome of the study, the position of the Icelandic low, the anticyclones located over Northern Europe, and the resulting pressure gradients are of particular relevance. The interaction of the synoptic-scale winds with the Icelandic orography may locally enhance the wind speeds and thus foster local dust emission. Results from this study suggest that the atmospheric circulation determined by the pressure pattern is of particular relevance for the formation of dust plumes entering the North Atlantic.

Sensitivity studies on glacigenic dust mobilisation in Greenland with a global and a mesoscale model

Anne Kubin
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Glacial outwash plains are a significant source of dust in high latitudes and cold climate zones. Aeolian dust transport associated with these sources has recently gained growing attention also in view of paleo-climate model simulations of glacial-interglacial cycles. Projections of glacier retreat in a warming climate motivate additional studies on the entrainment of glacigenic dust into the atmosphere.

Since glacigenic dust sources are of relatively small spatial extent compared to low-latitude sources such as the Sahara, and, moreover they appear to be limited by sediment supply and availability, it is challenging to include these sources in global models with coarser resolution. We designed a study to revisit the description of dust sources and the emission process as used by state of the art atmosphere- dust models. Dust source properties and the emission scheme will be tested and adapted accordingly by using an off-line version of the dust model, which is initialised by atmospheric fields from atmosphere model simulations. This way, in a computationally efficient approach different setups and source descriptions can be examined. We will present first results for atmospheric fields from a set of different models (the global-scale ECHAM model and the regional-scale COSMO model) run with different grid spacing. The focus is on Northern Hemisphere high latitude sources in Greenland under current climate conditions.

Ultimately, results from this study will contribute to an enhanced representation of the global atmospheric dust cycle, including emissions from high-latitude dust sources that become of increasing importance in a changing climate.

Dust in Antarctica – models vs ice cores

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The origin of dust in Antarctic ice is a topic of ongoing debate despite decades of rigorous measurements and generations of model-based studies. Analytical approaches to dust provenance determination include the investigation of: geochemical isotopic systems such as Strontium/Neodymium (Sr/Nd) or Lead (Pb); isotope ratios of Helium; and compositions of mineral and/or rare earth elements (REEs). Modelling approaches to dust provenance determination vary from simple 1-D transport models to atmosphere-only models such as HYSPLIT and fully-coupled earth-ocean general circulation models (eg CCSM).

There is general agreement that Southern South America is the dominant source of dust during the coldest maxima of the last 8 glacial cycles, with supporting data from sediment cores retreived from the Southern Ocean. In contrast, there is substantial uncertainty and debate regarding the sources of Antarctic dust during interglacial climates – particularly the roles of Australia and ice-free areas in Antarctica. We evaluate the various modelling studies of Antarctic dust provenance in the context of the available ice core data, with particular emphasis on the areas in which these two approaches disagree.

Investigating the mineralogy, surface area, and chemical reactivity of fine-grained fluvial sediments produced in glacial systems

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Fine-grained sediments produced in glacial environments and transported through proglacial streams are a primary source for high-latitude dust. Here, we investigate the mineralogy, surface area, and chemical weathering potential of mud-sized sediments (<63 µm) in proglacial fluvial systems and compare with analogous sediments collected in non-glacial fluvial/alluvial systems. Muds collected from proglacial streams in Norway (Storelvi draining Jostedalsbreen) and Peru (Rio Llullan) are dominated by primary minerals, with less than 1% secondary phases observed. In contrast, muds from the Onyx River in the McMurdo Dry Valleys (MDV) Antarctica contain 6% secondary minerals, muds from Anza Borrego Desert (ABD, S. California) contain 17% secondary minerals, and muds from Rio Guyanés Puerto Rico contain over 40% secondary minerals. The relative abundance of secondary phases in MDV muds compared to other proglacial systems may be due to eolian sediment transport from the MDV to the surrounding ice sheets. There, sediments may be chemically weathered by surficial meltwater which delivers sediments to MDV streams. In contrast, Norway and Peru sediments are transported from beneath the glaciers at higher water:rock ratios, which may completely dissolve fine sediments. Indeed, Norway muds have the highest silt content and lowest BET surface area (1.4 m^2/g), followed by Peru (9.5 m^2/g), whereas MDV muds exhibit higher values (21.1 m^2/g), even greater than those of hot arid ABD (13.8 m^2/g), and approaching Puerto Rico muds (33.3 m^2/g). While Puerto Rico muds were largely unreactive, muds from Norway, Peru, ABD, and MDV released significant solutes in laboratory weathering experiments. Norway muds were most reactive. MDV, Peru, and ABD muds released moderate Ca and Mg, but less Si and Al. Therefore, glacial sediments can potentially weather quickly in liquid water, sequestering CO_2 as secondary carbonates and thus impacting the global carbon cycle.

Proglacial sediment supply under contrasting runoff regimes

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The availability of proglacial sediment for aeolian entrainment is a complex product of multi-scale, spatio-temporally-variable processes within and beyond the glacier margin. This can be illustrated with reference to patterns of glacier drainage efficiency and proglacial runoff and sediment budgets at Finsterwalderbreen, Svalbard, Norwegian Arctic (68 km2 catchment, 44 km2 glacierised), in two contrasting melt seasons. Whereas both seasons had similar rates of specific runoff (1.6 m a–1 in 1999, 1.5 m a–1 in 2000), they had different sediment fluxes into the 4 km2 proglacial area (4300 t km–2 a–1 in 1999, 2400 t km–2 a–1 in 2000). Moreover, the proglacial area experienced a net increase in sediment storage of 690 t km–2 a–1 in 1999, but a net decrease in storage of 3800 t km–2 a–1 in 2000. Flow-recession analysis and linear-reservoir simulation of glacier drainage indicate the presence in both years of a fast-draining pathway: in 1999 this had a reservoir coefficient of 16 h, whereas in 2000 this was 41 h, signifying less efficient drainage; the snow cover was more persistent in 2000, so that slow percolation through snow forms a greater proportion of overall flow pathways. So although the overall fluxes were similar, meltwater was delivered much more intermittently in 1999 as a result of the more responsive glacier drainage system. 1999 was consequently a year of relatively episodic sediment transfer, in which relative supply exhaustion occurred. Two major flood episodes inundated the proglacial area and allowed the aggradation of sediment which subsequent flows were not sufficient to re-mobilise. 2000 on the other hand, was a year of more sustained sediment transfer without relative supply exhaustion, facilitating a steady throughput of sediment and net erosion of the proglacial area. Efficient glacier drainage therefore enabled rapid meltwater release and high rates of proglacial sediment input, which led to a net gain in sediment storage. Hence it is suggested that increased availability of proglacial sediment for aeolian entrainment is favoured by responsive glacier drainage systems characterised by intermittently-high rates of meltwater release

Aeolian abrasion as a dust particle generator in cold climate environments

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Aeolian abrasion has been shown to be an important process in dust particle creation in hot, arid regions. However, the relative importance of this process has not been quantified in high latitude cold climate environments. Aeolian abrasion may be a more effective particle generator in a high latitude cold climate environment where wind speeds are generally higher than in hot, arid deserts. A series of experiments were conducted using a laboratory abrasion chamber with surface sediments from 3 Icelandic dust sources. Surface sediments between the dust sources vary considerably sedimentologically varying from sand-dominated and silt-dominated environments. The experiments assessed the relative importance of the removal of resident fines, the chipping and breaking of particles and the removal of surface grain coatings. Particles from the experiments were trapped and recorded at 4 time intervals (1, 2, 4 and 8 hours) to assess total sediment loads and particle size distribution variation through time. Experiments were conducted at two temperatures (5 and 15°C) to assess the impact of temperature.

Particle size of atmospheric dust and dust deposits – methods and significance of interpretation of results

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The particle size distribution characteristics of suspended and settled dust are of importance in relation to a range of issues including impact on weather and atmospheric energy balance, global nutrient transfer, palaeoclimate reconstruction, and risks to human health. On Earth dust particles typically range in size from nano-particles (<0.001 – 0.1 µm) to very fine sand (63 – 125 µm), although small numbers of larger ('giant') particles are sometimes found in far travelled 'distal' dust and mixtures of silt-dominated dust and sand occur in many continental areas.

Several different methods and instruments have been used to determine the size distributions of dust. The size of predominantly fine grained suspended matter in the marine and upper atmosphere has commonly been determined using cascade impactors; small samples from ice cores and thin slices of deep ocean cores have frequently been analysed by Coulter Counter or X-ray Sedigraph, while terrestrial dust deposits have, in the past 20 years, been analysed predominantly by laser diffraction.

Down-section and down-core variations in a range of particle size characteristics in loess deposits and marine cores have been used to infer temporal variation in wind speed, wind direction, potential source area supply, and post-depositional weathering conditions. However, no standard approach has been adopted to the preparation analysis of samples for laser diffraction analysis, or the comparison and presentation of results, leading to uncertainty regarding the reliability of interpretations and conclusions.

This presentation demonstrates how results obtained by laser diffraction obtained using a single instrument (Coulter LS13320) can be influenced by sample preparation methods, choice of instrument operating parameters, optical model, and post-analysis manipulation of the raw results. It is also demonstrated, using case study data for a thick section of late Pleistocene loess on the margins of the Mississippi Valley (USA) that, provided an appropriate analytical protocol is followed, very subtle variations in size distribution characteristics can be reliably identified which provide very useful information about relative rates of dust accumulation and palaeo-environmental conditions, and about potential risks to human heath. A number of generic recommendations are made regarding methods of sample preparation, choice of optical model, parameter specification, raw data transformation and comparison.

Session 7

Antarctic dust: Sources, distribution and impact

Links between dust, biogeochemical cycles and climate change

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Dust transport and deposition in Antarctica is an important process that influences both terrestrial and marine environments on local, regional and global scales. Ice cores show that Antarctica receives small amounts of dust from South America, Australia and New Zealand and that the flux varies considerably through climate cycles. However, much less is known about dust derived from small, ice-free areas in Antarctica. This local dust is transported over terrestrial landscapes and also offshore by katabatic winds onto ice shelves and sea ice, altering albedo and surface melting before being released into the ocean. The dust contributes sediment to the Antarctic shelf and is one source of iron (Fe) involved in triggering vast phytoplankton blooms which regulate the oceanic biological pump, drawing down atmospheric CO_2. Despite the importance, the source, distribution and impact of the dust is still poorly constrained.

McMurdo Sound in the Ross Sea is widely recognised as the dustiest place in Antarctica. Our group analysed dust from potential source areas, dust traps on sea ice and ice shelves and also sea-floor samples. Combined with reanalysis of wind field data and numerical modelling, the dust distribution can be mapped and its composition matched to source areas and geological terranes. Locally derived dust is recognised in sea floor samples 10’s of km offshore, but modelling suggests the dust is distributed much farther (hundreds km) offshore where the major phytoplankton blooms occur.

Ongoing research aims to better constrain the modern flux, distribution and transport processes of Antarctic derived dust to better understand the impact of local dust on nutrient and biota dispersal, sedimentation and biogeochemical cycling in the Ross Sea. In addition, this will assist the interpretation of drill core records of past environmental change and help predict future change in a warming Antarctic and Southern Ocean.

Observational and modelling constraints on dust source dissolved Fe supply to the Gulf of Alaska from the Alaskan coastline

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Published estimates of dust deposition on surface waters of the subarctic N. Pacific, together with published estimates of Fe dissolution from dust, suggest that dust is an important Fe source to the Fe-limited waters of the Gulf of Alaska (GoA). Dust derived from coastal Alaskan glacierized river valley sediments is suggested to be an important part of that dust supply, despite a very wet climate. Previous work shows that erosion of a surficial sediment layer less than 1 mm thick, followed by long-range transport from source area sediments, is sufficient to sustain the observed dust storms emanating from sediments of the Copper River valley, one prominent dust source. Therefore, brief intervals of dry conditions, together with strong offshore winds, are sufficient to cause dust storms. Part of the reason why dust is an important Fe source offshore is that coastal Fe sources transported through the water column are removed fairly rapidly, which limits Fe transport beyond the continental shelf break. Available data from the northern GoA region suggest coastal dissolved and particulate Fe sources are largely confined to within ~100 km of the shelf break. This is consistent with observations from across the world's oceans. This suggests that other Fe sources, including dust, are important seaward of the continental shelf break. This work will examine satellite imagery to evaluate where dust is observed to be transported offshore, and where it is not observed, along the GoA coastline. We will examine factors that control these locations of prominent offshore dust transport along this GoA coastline. One hypothesis is that dust transport from potential sources is largely a function of the predominance of mineral-rich glacial flour within the riverine sediments, the dust source surface area and the likelihood of strong winds that can drive this dust flux offshore.

Two decades of Icelandic high-latitude dust pathways

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The contribution of mineral dust from high-latitude sources has remained an under-examined feature of the global dust cycle. Dust events originating at high latitudes can provide inputs of aeolian sediment to regions lying well outside the subtropical dust belt. Identifying the preferential pathways of high latitude dust is important for understanding the potential impacts have on wider environmental systems, such as nearby marine or cryospheric domains. This study quantifies dust pathways from two areas exhibiting different emission dynamics in the north and south of Iceland. The analysis uses (HYSPLIT) air parcel trajectory modelling, and explicitly links trajectory simulations to meteorological observations of suspended dust. This approach maximises the potential for trajectories to represent dust, and illustrates that trajectory climatologies not limited to dust can overestimate the potential for dust transport.

Preferential pathways demonstrate the role of Iceland in supplying dust to the Northern Atlantic and sub-Arctic oceans. For dust emitted from northern sources, a dominant route exists to the northeast, into the Norwegian, Greenland and Barents Seas, although there is also potential for delivery to the North Atlantic in summer months. From southern sources, the primary pathway extends into the North Atlantic, with a high density of trajectories extending as far south as 50ºN, particularly in spring and summer. Common to both southern and northern sources is a pathway to the west-southwest of Iceland into the Denmark Strait and towards Greenland. For trajectories simulated at ≤500 m, the vertical development of dust plumes from Iceland is limited, likely due to the stable air masses of the region suppressing the potential for vertical motion. Trajectories rarely ascend high enough to reach the central portions of the Greenland Ice Sheet. The overall distribution of trajectories suggests that contributions of Icelandic dust are relatively more important for neighbouring marine environments than the cryosphere.

Natural sources of particulate matter in Reykjavik

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Some of the most active source areas for dust storms in Iceland, contributing to the particulate matter load in Reykjavik, are on the south coast of Iceland, with more than 20 dust storm days per year (in 2002 - 2011). Particle size measured at the source area shows an extremely fine dust creation. Dust storms contribute to the particular matter pollution in Reykjavik and their small particle size, at least from that source area, might be a serious health concern.

The PM10 health limit was exceeded in Reykjavik (GRE station) on average 22 times per year in the years 2007 - 2011, and 8 times per year in 2012 - 2015. Dust storms, and resuspended ash at least the year of eruption, are the source of particulate matter in about 22% of the cases on average; ranging from 0% to 42%.

The role of Patagonian Dust-Fe in fertilisation of the Southern Ocean

James Hooper
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Although Antarctic ice cores show relative agreement on dust flux over the last glacial cycle, the same cores show marked differences in Methane Sulphonic Acid (MSA) deposition – commonly regarded as a proxy for oceanic phytoplankton growth – over the same period. This contradiction has complicated our understanding of the fertilisation effect of dust on the High-Nutrient Low-Chlorophyll (HNLC) Fe-limited Southern Ocean. The uncertainty surrounds whether it is dust fertilisation, or another mechanism such as marine nutrient upwelling, or changes in temperature and/or solar radiation, which is the main factor driving primary productivity in this region. If dust fertilisation is important, why is it that in some ice cores dust and MSA deposition is correlated, while in others they are out of phase? Questions such as these have fuelled doubt over the precise role of dust in ocean fertilisation.

We present new, contemporary, ice core evidence of event-scale correlations between dust Fe and MSA deposition in the high latitude South Atlantic Ocean. This suggests there is a strong relationship between dust and HNLC ocean fertilisation in this region at the present time, that is, dust fertilisation is a major driver of marine productivity. The difference between this finding and the variability in the MSA/dust flux relationship over glacial/interglacial time periods implies that while dust deposition drives event/centennial scale ocean productivity under current climate conditions, over longer time periods the relationship is less clear. Why this is the case is the subject of on-going research, although fluctuating dust and MSA concentrations in Antarctic ice cores over paleo time scales are perhaps subject to other factors such as changes in atmospheric and ocean circulation patterns, aeolian transport pathways, sea ice duration and extent, and the location of HNLC regions. Despite this, because our results imply dust emissions are linked to marine productivity over the recent past we use dust deposition data from Patagonian peat cores to explore what impact dust may have had on oceanic fertilisation during the Holocene and Anthropocene.

Loess, paleosols and climate change in Alaska: 3 Million years of dust records to decipher

Daniel Muhs
USGS, Boulder

The State of Alaska is the northernmost territory of the United States, spanning ~20° of latitude. It is geologically diverse, characterized by accreted terrains, volcanism and active tectonics. Climates are also diverse, ranging from cool temperate to Arctic. Biomes include coastal forest and boreal forest, as well as maritime, shrub, and Arctic tundra. Tectonic activity has produced rugged mountain ranges, all of which have a rich Quaternary glacial history. Glaciers still exist in several of these mountain ranges and feed sediment via outwash to major river systems that in turn sort fine-grained materials for aeolian dust transport. Glaciers were much more extensive during cold periods of the Quaternary. As a consequence, much of the unglaciated interior of Alaska contains loess deposits that record dust accumulation that may go back to ~3 million years. Episodes of loess accumulation from dust were punctuated by periods of vegetation establishment and pedogenesis, leaving paleosols in the geologic record as well. Study of the loess deposits can tell us much about the nature of dust entrainment, transport and deposition over many climate periods. Because contemporary glaciers still produce dust-sized particles in Alaska, the region also provides a natural laboratory for understanding modern processes of high-latitude dust particle generation and transport. Questions about dust that can be addressed in Alaska through current study include: (1) Are there particular rock types that are more favorable than others for dust particle generation? (2) Is seasonality critical for dust entrainment and transport? (3) How far can dust be transported under the present climatic regime? (4) What role does vegetation play in trapping dust to accumulate as loess? (5) Does loess accumulate at a given locality from more than one source? (6) Does dust contain significant amounts of bioavailable iron that is critical for primary production in the world's oceans?

Fuegian peatlands: Recorders of Holocene environmental change

Francois De Vleeschouwer
Centre National de la Recherche Scientifique

Little attention has been given to Holocene pre-anthropogenic dust records in terrestrial environments, especially in the Southern Hemisphere. Yet they are important to 1/ better understand variations in particle provenance, 2/ tackle the linkage between atmospheric dust loads and climate change and 3/ better understand the impact of dust onpalaeoclimate and palaeoenvironments in an area critical for ocean productivity. Here, we explored the use of trace elements and radiogenic isotopes (Pb, Nd) as dust proxies in three peat bogs from southern Patagonia and Tierra del Fuego to assess dust-climate interactions in southern South America since the deglaciation. The distribution of trace elements within the cores indicates, besides tephra layers, episodes of increased mineral dust deposition during the Holocene and beyond. Our main results show that the glacial-interglacial transition can be observed in the oldest record (at ca. 11,500 cal yr BP), marked by a drop in dust flux from 102 g.m-2.yr-1 to 10 g.m-2.yr-1. The most significant episode of mineral dust deposition during the Holocene is concentrated at ~1,600 cal yr BP with a maximum dust flux of 108 g.m-2.yr-1. Its neodymium isotopic signature of -1 suggests crustal admixing, compared to the εNd values of ~2 for tephra layers. This episode is related to neoglacial activities in the Cordillera Darwin (southern Andes). Our results show not only that Fuegian peatlands are efficient recorders of dust fluxes over time, but also that variations in the dust fluxes and provenance can provide clues on paleoclimatic and paleoenvironmental changes.

Glacial influences on high latitude and cold climate records of dust deposition

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The extensive glacial outwash plains of southern Iceland and southern Patagonia represent the largest contemporary dust emission areas in the high-latitude North Atlantic and South Atlantic regions respectively. Previous studies have shown a strong temporal coincidence between peaks in dust flux, recorded in Antarctic ice cores, and ice sheet growth and decay in southern Patagonia on a glacial-interglacial timescale. More recently, other studies in the same region have linked glacial sediment availability and high dust fluxes to glacier fluctuations on a centennial to millennial scale, with emphasis on glacier retreat phases. The issues surrounding high-latitude dust production and transportation as a proxy for Holocene glacier or climate fluctuations are clearly complex. Here we highlight the wider role of glaciers and meltwater systems in Iceland and Patagonia as mechanisms for producing large volumes of iron-rich fine-grained material for aeolian transportation to high latitude oceans and their terrestrial margins. This work also seeks to highlight process differences between specific high-latitude glaciated regions; the drivers of these dust emissions; and the pathways and trajectories of long-distance aeolian transportation.

A 2000-year record of atmospheric dust variability developed from a South Pole ice core

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Antarctic ice core records are an important source for reconstructing past dust variability in the Southern Hemisphere. Most of the dust deposited in Antarctica originates from South America and Australia; where the Southern South America dust source is more significant for the South Pole region. Here we discuss records of atmospheric dust deposition obtained from a South Pole ice core record. A suite of major and trace elements was measured using ICP-SFMS (Inductively Coupled Plasma Sector Field Mass Spectrometry) analysis in the upper 200-meter of the South Pole ice core at a temporal sample resolution of ~9 samples per year. Crustal enrichment factor calculations and empirical orthogonal function analysis indicate that crustal dust is a significant source for La, Ce, Pr, Al, Ti, V, Fe and Sr in the South Pole record. We observed high variability in dust element concentrations during the last 2000 years. A significant decrease in dust element concentrations occurs ~1450 C.E. The timing of the shift coincides with the beginning of the Little Ice Age and is most likely attributed to changes in the patterns and/or intensity of atmospheric circulation (e.g. weakening of the Southern Hemisphere Westerlies). Changes in dust deposition could also be influenced by changes in precipitation in the dust source area (e.g. drier conditions in Patagonia).

Abrupt Late Holocene Shift in Atmospheric Circulation Recorded by Mineral Dust in the Siple Dome Ice Core, Antarctica

Bess Koffman
Dartmouth College

Dust provenance information from Antarctic ice cores has until now been limited to sites in East Antarctica. Here we present some of the first provenance data from West Antarctica. We use Sr-Nd isotopes to characterize dust extracted from late Holocene ice (~1000-1800 C.E.) from the Siple Dome ice core. The data form a tight array in Sr-Nd isotope space, with 87Sr/86Sr ranging between ~0.7087 and 0.7102, and εNd ranging between ~ -7 and -16. This combination is unique for Antarctica, with low Nd and low Sr isotope ratios compared to high-elevation East Antarctic sites, requiring a dust source from ancient (Archean to early Proterozoic) and unweathered continental crust, which mixes with young volcanic material. Both components are likely sourced from Antarctica. We also observe significant, systematic variability in Sr and Nd isotopic signatures through time, reflecting changes in the mixing ratio of these sources, and hypothesize that these changes are driven by shifts in circulation patterns. A large change occurs over about 10 years at ca. 1125 C.E. (ΔεNd = +3 and Δ87Sr/86Sr = -0.0014). This shift coincides with changes in climate proxies in Southern Hemisphere paleoclimate records reflecting variability in the Westerlies. We therefore interpret the shift in dust provenance at Siple Dome to be related to larger-scale circulation changes. In general, the observed shifts in the particle source signatures indicate that dust transport pathways to and around the West Antarctic Ice Sheet are highly responsive to perturbations in atmospheric circulation, and can record rapid shifts in provenance.

Local dust influences on the Renland (East Greenland) ice core

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Ice cores provide a high resolution record of the climate of the past. The 585 m long RECAP ice core was drilled on the Renland ice cap in the Scoresbysund fjord on the east coast of Greenland. Dust particle concentration and size distribution were measured throughout the core in 1 cm resolution. This gives annual or subannual resolution in the upper 470 m, spanning 4000 years. The last glacial period is covered in only 30 m.

Central Greenlandic ice cores typically have 10-100 times more dust in the glacial than in the Holocene, with a modal diameter of the particle mass distribution between 1 and 2 microns. The RECAP ice core shows a similar pattern during the glacial, both during stadials and interstadials. In the Holocene however, the dust mass is as high as in the glacial, but now with more large than small particles, giving a mode of around 10 microns. This is interpreted as local dust sources emerging after the retreat of the glaciers during the deglaciation. After the transition from glacial to Holocene, the large particle concentration increases over several thousand years, giving an indirect measure of the local deglaciation history. Throughout the Holocene variability on millennial scale in the large particle concentration has been found.

1500-year record of trans-Pacific dust transport from the Denali ice core, Mt. Hunter, Alaska

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Dust aerosols influence the climate system by altering atmospheric radiative forcing, serving as cloud condensation nuclei, and depositing nutrients into the surface ocean, where they can impact ocean productivity. Despite these important roles played by dust, our understanding of the controls on dust emissions and transport is hampered by the availability of records. Annually resolved records of atmospheric deposition that span the preindustrial to modern are limited. Here we present a new high resolution (sub-annual) 1500-year record of dust deposition from the North Pacific in order to investigate dust-climate interactions and to provide paleoclimatological context for 20th century dust activity. Two ice cores (208 m long, drilled to bedrock) were collected in 2012 and sampled at mm-scale resolution using a continuous melter system with continuous flow analysis for dust concentration and size distribution (Klotz Abakus) and discrete analyses for major ions (Dionex ion chromatograph), trace elements (Element2 inductively coupled plasma-mass spectrometer), and stable water isotope ratios (Picarro laser ringdown spectroscopy). We find that physical particulate and glaciochemical data demonstrate remarkable fidelity at sub-annual resolution, with both displaying a strong springtime peak consistent with periods of high dust activity over Asian desert source regions. Preliminary results suggest the dust volumetric mode diameter typically ranges from 4.5 - 6.5 um, with a mean value of 5.5 um. We compare the ice core dust record to modeled Asian dust emissions and climate reanalysis data from the instrumental period in order to evaluate climatic controls on dust emission and trans-Pacific transport. Preliminary interpretations of circulation dynamics indicate that years with elevated dust concentrations on Mt. Hunter are associated with increased surface wind speeds over Asian desert source regions and stronger meridional winds over the Gulf of Alaska, associated with the negative phase of the Arctic Oscillation (AO-).

Temporal variability in arid (sup-tropical) versus cold climate (high-latitude) dust emissions: Examples from the Australasian region

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Variability in dust emissions in palaeo-dust studies have traditionally been attributed to changing patterns in aridity, with periods of enhanced dust emissions attributed to increased aridity [e.g. 1, 2]. The controls on dust entrainment and transport are however complex and involve not simply aridity, but also sediment availability and windiness [3]. Thus the response of dust output to changing conditions is likely to be non-linear [4]. Moreover, different dust source regions (i.e. climatic/geomorphic settings) may respond distinctively to changes in these parameters through time.

High-latitude dust sources are known to have been major dust sources during glacial periods, evidenced by the timing and distribution of loess deposits. This is presumably driven by increased glacial outwash (sediment production). The behaviour of high latitude dust sources during deglacial and interglacial conditions are less well understood. Retreating glaciers result in greater sediment exposure and therefore greater dust emissions, however, reduced sediment production and increased biological activity may reduce dust emissions. By comparison, variability in subtropical dust emissions, during interglacial periods, has largely been attributed to either changing aridity or changing sediment availability (driven by climate variability) [5]. Thus the relative influence of factors may result in different dust contributions from different dust sources through time.

In this study we examine the significance and controls on dust emissions from high latitude sources versus dust emitted from subtropical sources in the Australasian region over the late Pleistocene and Holocene. This is achieved by reconstructing dust deposition rates through time in peat deposits in New Zealand and from the sub-Antarctic Islands.

Poster Abstracts

New Zealand's South Island as a potential source of glaciogenic dust to the atmosphere and ocean: characterization using Sr-Nd-Pb isotopes and trace elements

Bess Koffman
Dartmouth College

The geochemical composition of sediments and dust can be used to trace their provenance, thereby providing insights into a range of Earth surface processes. During past glacial climates, New Zealand's South Island was blanketed by an erosive ice cap, which produced significant volumes of sediment. In order to trace the extent of aeolian and oceanic transport of this material, and thus its potential impact on climate and ecological systems, it is necessary to characterize its composition. We present geochemical analyses, including Sr-Nd-Pb isotopes and major/trace elements, of over 20 fine-grained (<5 μm diameter) sediments from the major dust-producing regions of the South Island. We find that sediment composition strongly reflects local lithology. The central South Island, including the Canterbury Plains and Mackenzie Basin, has a relatively homogenous isotopic composition, with 87Sr/86Sr = 0.7095-0.7165, εNd = -6.5 to -4.0, 208Pb/207Pb = 2.470-2.485, and 206Pb/207Pb = 1.198-1.215. The southern South Island, including southern Otago and Southland, has an isotopically younger and more variable composition, reflecting the presence of Paleozoic volcanic complexes. Here 87Sr/86Sr = 0.7041-0.7140, εNd = -4.0 to +5.3, 208Pb/207Pb = 2.463-2.483, and 206Pb/207Pb = 1.196-1.208. We estimate the expansion of glacial outwash plains based on a sea level lowering of 130 m at the Last Glacial Maximum (LGM), and find that the Canterbury Plains and Mackenzie Basin outwash region likely covered an estimated 35,600 km2 while the Southland/Otago Plains may have extended to 37,700 km2. Considering New Zealand's extreme uplift and erosion rates (~10 m kyr-1), we suggest that the South Island, though limited in extent compared to larger southern landmasses, may have served as an important dust source to the high-latitude atmosphere and ocean during the LGM.

Hydrographic evolution and dust storms: The Colhué Huapi lake case study (45°S, Patagonia, Argentina)

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Centro Austral de Investigaciones Científicas (CONICET)

Patagonia (40°-60° S) is the only continental territory exposed to the southern westerlies. The velocity and frequency of these westerly winds generate extensive dust storms. The winds coming from the Pacific Ocean ascend on reaching the Andes, while cooling adiabatically and generating high precipitation on the western slopes, whereas the eastern side of the Andes is in the rain shadow, which generates true desert conditions.

The dust sources are located in numerous pans distributed in the Extra-Andean Patagonia and north of Tierra del Fuego. These pans are located in the bottom of deflation and enclosed drainage basins, generally fed by ephemeral streams. The Lake Colhué Huapi is the largest pan of Patagonia reaching 811 km2 in expansion periods and it is the major source of atmospheric dust as recognized by satellite images.

The main tributary to the Colhué Huapi basin is the Senguerr River, which its seasonal behavior generates seasonal fluctuations in the lake surface. Maximum flows are associated with spring snowmelt in the Andes Mountains and minimum flows occur at the end of the hottest and driest season coincident with summer. In turn, this hydrographic basin is used for caters to human consumption of more than 350 thousand habitants of surrounding cities and towns, irrigation channels in rural belt areas of Sarmiento city and extraction pumps to drilling and secondary recovery stages of hydrocarbon industry.

Dunefields developed from the beach-lake moved in west-east direction affecting the soils and vegetation of the livestock areas and dust storm plumes affect directly the cities of Comodoro Rivadavia and Rada Tilly due to the persistent of the westerly winds. The sediments supply is related to the lake dynamic, subject to a clear tendency to desiccation.

MICRODUST: Micro-organisms and Dust – Signatures, Interactions, Transport and Dissemination

Francois De Vleeschouwer
Centre National de la Recherche Scientifique

The MICRODUST consortium explores the geochemical signatures dust particles collected at the Pic du Midi, Pyrenees Mountains, France, and the bacterial/fungal assemblage found on those particles. Thanks to the geochemical tools available at the Observatoire Midi-Pyrénées, the origin of collected dust will be precisely determined by comparing their mineral and neodymium isotope composition with those of topsoil dust samples from east and west Saharan regions where dust uprising are occurring. Physico-chemical interactions between microorganisms and large topsoil or small collected particles will be investigated. Using the service of the high throughput DNA sequencing platform available in Toulouse, the molecular phylogenetic relationships between the transported bacterial/fungal species and the native species constituting the regional soil microbial communities will be determined. For the first time, MICRODUST will provide insights of the impact of exotic microbes on the diversity of native microbial communities.

Characterization of dust particles in the snow pit on Styx Glacier, Antarctica

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Single particle analytical technique, named low-Z particle electron probe X-ray microanalysis (low-Z particle EPMA), was applied for the characterization of individual Antarctic dust particles. The main purpose of this study is to identify individual particles contained in snow pit and trace their sources by use of low-Z particle EPMA. The low-Z particle EPMA uses an X-ray detector equipped with an ultrathin window and thus allows the quantitative determination of concentrations of low-Z elements such as C, N, and O as well in individual particles of micrometer size. The capability of the quantitative determination of low-Z elements in individual environmental particles improves the applicability of single particle analysis; many environmentally important atmospheric particles (e.g. sulfates, nitrates, ammonium salt, and carbonaceous particles) contain low-Z element. Therefore, this technique is expected to provide more conclusive and detailed analysis on the chemical compositions of Antarctic dust particles. The single particle analysis has been performed for 14 samples collected from the wall of a 1.6 m snow pit at Styx Glacier plateau (73° 51.10′ S, 163° 41.22′ E) in Antarctica, during 2014/2015 austral summer season. The sample contained 4 austral winters and summers, from late austral summer 2011 to austral summer 2014/2015. Totally 1400 individual particles were characterized. The particles were classified into the various types of particles based on their morphology and elemental concentrations of individual particles available from the low-Z particle EPMA.

Aeolian dust record in the GV7 firn core from Northern Victoria Land, East Antarctica

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We conducted the scientific ice coring project led by PNRA and KOPRI during the 2013/2014 Italian-Korean Antarctic Expedition in the framework of International Partnerships in Ice Core Science (IPICS) for investigating natural and anthropogenic climate change and understanding the climatic variability over the last two millennia. In the part of the project, we collected a 78 m-depth firn core at the site of GV7 (S 70°41'17.1", E 158°51'48.9", 1950 m a.s.l.), Northern Victoria Land, East Antarctica, where snow accumulation is very high (about 3 times Talos Dome, 10 times EPICA Dome C). Here, we present the results obtained from the analysis of the water isotope compositions, the major ion concentrations, and the mineral dust concentrations from the firn core. Densities and electrical conductivities also measured during the ice core processing at KOPRI. A novel Coulter Counter (Multisizer 4e, Beckman Coulter) has been set up in order to extend mineral dust particle size spectra down to 600 nm. Insoluble mineral dust particles in the firn core characterized with the differences of the concentration and the particle size distribution by the seasonality. These data allow us to estimate the dust flux at the coastal sites of Northern Vitoria Land, which associated with atmospheric mobilization of dust from the Pacific /Ross Sea region.

The High latitude and cold climate dust network

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Dust in the earth-atmosphere-ocean system affects natural and anthropogenic activities. Most research into dust emissions has focused on the hot, arid subtropics. Whilst dust is often associated with hot deserts, there are 5 million km2 of cold arid lands on Earth and significant dust events have been reported from these (e.g. the Arctic). Strong winds and sparse vegetation mean some humid cold climate areas, as in New Zealand and Iceland, are also important dust sources. Until recently existing knowledge concerning the impacts of high latitude and cold climate dust in the Earth system has been scattered amongst a diverse group of scientists. This aim of the High Latitude and Cold Climate Dust Network is to facilitate collaboration amongst researchers to improve understanding of contemporary and future high latitude dust emissions, focusing on consolidating existing knowledge, identifying research gaps and prioritizing strategic, inter-disciplinary research questions.

The HLCCD Network was established in 2014 by an initial group of 7 researchers from 5 different countries (Argentina, Canada, Iceland, UK, USA). They have held two workshops to which additional colleagues and early-career researchers have also been invited. One outcome of these has been a comprehensive review of the state of knowledge concerning the expanse, characteristics and dynamics of contemporary high-latitude dust sources that has also identified many of the research gaps still be addressed. Ongoing work is the creation of a comprehensive digital database of contemporary HLCCD sources and associated data. Such databases have been successfully compiled by the glaciological, hot desert and planetary research communities to integrate diverse sources of data and identify new, strategic research goals. The HLCCD is using some of its funding from The Leverhulme Trust to support the first International Conference on High Latitude Dust to further broaden the group of researchers discussing this topic.

Simultaneously enhanced iron oxide dissolution and iodide oxidation in cold environment

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Iron(Fe) is one of the most important trace elements for living species and the limiting component to control primary production in HNLC(High Nutrient and Low chlorophyll) regions including Southern Ocean. Consequently, this stimulated primary production by bioavailable iron can absorb atmospheric CO2 and then affect climate change. Most of the iron in environment is existed as iron oxide or (oxy)hydroxides form and they are not directly bioavailable for living organisms. Dissolution of iron oxides increases their bioavailability. The chemical fate of active halogen compounds in the polar atmosphere controls ozone and mercury depletion events, oxidizing capacity, and dimethyl sulfide(DMS) oxidation to form CCN(cloud-condensation nuclei). The sources and mechanisms of iodine species in polar atmosphere are not well understood compared to those of chlorine and bromine. It is known that the chemical processes taking place in ice phase is different from that in aqueous water. This difference between two phases might control the mobility, bioavailability, toxicity, and the environmental fate of organic and inorganic species. In general, most chemical reactions slow down as the reaction temperature decreases. However, various redox chemical processes are accelerated when the solution is solidified. In this work, we studied the reductive dissolution of iron oxide particles to produce bio-available Fe(II)aq and simultaneous oxidation of I- (iodide) to produce I3- (tri-iodide) in ice phase under UV irradiation or dark condition. The reductive dissolution of iron oxide and oxidation of iodide was markedly enhanced in ice phase regardless of presence or absence of light. The detailed experimental conditions and mechanism will be discussed in the presentation.

Evolution of aging volcanic ash and physical characteristics of dust in Iceland

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The definitions of dust and volcanic ash can vary between scientific disciplines. Geologically, dust is defined as particles that originated from surface material, which may include weathered volcanic ash, where volcanic ash is relatively new unconsolidated particulate matter with a diameter less than 2 mm. Meteorologically, dust is defined as any solid particle, of any size, suspended in the atmosphere, with volcanic ash simply being dust made of rock with sharp edges. Because of the varying definitions, defining the difference between a dust storm and an ash resuspension event can be difficult. The distinction is important, as communicating the risk of and impact from dust storms can be different from ash resuspension events. No matter the material, for any particulate matter to be picked up it must be unconsolidated and there must be some surface disturbance. Dry weather and high winds are the optimal conditions for dust storms and resuspended volcanic ash, however, sand and ash can be suspended in the atmosphere associated with some precipitation events, as well as with little turbulence near the surface.

Volcanic ash can sometimes have properties that allow it to travel into lungs with elongated grains, sharp edges, and small size which poses an extreme health hazard in high concentrations. Due to this risk, determining when volcanic ash loses some of these health-hazard related qualities is important. When volcanic ash has lost some of its defining properties and mixed in with the surrounding surface material it can then be defined as dust when suspended in the atmosphere. In this study, we have collected samples of volcanic ash and dust from source areas in Iceland and analyzed them for size and physical properties using SEM. We will draw some conclusions about the ash to dust process in Iceland.

Biogeochemical impacts of dust deposition on Arctic soils

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Arctic soils are generally limited in nutrient availability. Characteristically slow turnover rates and the gradual burial of organic matter in permafrost mean that nutrients become available to plants at very slow rates. Melting and retreating glaciers produce fine dusty material and as more land surface area will be exposed to wind action, local dust emissions are likely to increase. This aeolian input might be a source of additional nutrients to soils, which could overwhelm conventional soil-forming processes. The aim of this project is to understand how Arctic soils become colonized and productive under contemporary conditions focusing on the relative importance of soil-forming processes vs dust inputs. Frisbee traps are deployed during a first field visit in April 2017 along a transect between the Greenland ice sheet and Kangerlussuaq (66˚00'N and 50˚43'20"W) with an inferred gradient of dust deposition from high near the ice to near zero 30 km west. During this field visit the amount of dust in snow layers is also documented for an estimation of deposition over the winter. The dust samplers will be emptied during a second field visit in the early summer of 2017 when detailed descriptions will be made of vegetation cover and existing soil profiles.

Aerosol and dust association in Iceland

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The Aerosol and Dust Association in Iceland was established in the year 2016 to promote collaboration and communication in the field of aerosol research in Iceland with the emphasis on local volcanic dust. Currently, our association includes members from the Agricultural University of Iceland, University of Iceland, Icelandic Meteorological Office, and the Environmental Agency of Iceland. International researchers with interest in Icelandic volcanic desert environments are invited to join the Association.

We have several working groups at different research institutions in Iceland which monitor or research aerosols, volcanic dust and fresh volcanic ash. The groups focus is on:

i. field monitoring of dust sources at the surface

ii. atmospheric conditions and aerosol concentrations near surface as well as in the upper atmosphere

iii. radar and lidar monitoring

iv. health impacts of dust and volcanic ash

v. dust modeling and forecasting

vi. remote sensing

Iceland is the largest Arctic and European desert with high dust event frequency. This Association serves as a platform for communication between the Icelandic aerosol researchers, in addition to providing information to other academic bodies located in Iceland and abroad. We want to provide easy-to-understand information on aerosol for the public and media to increase public awareness of the matter.

Micro-Scale Characteristics of Icelandic Dust Particles

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Dust events in high-latitude cold-climate (HLCC) regions are understudied in comparison to dust events in hot sub-tropical regions. However, global climate projections suggest that with glacial recession, the supply of fine particles (<100 µm) will expand and replenish outwash surfaces[3]. Major dust events in Iceland that affect local areas such as Reykjavík are associated with glacio- fluvial processes and the resuspension of volcanic tephra[2;4]. While researchers often ignore the role of micro-scale particle in transport, there is need for better parameterization of these effects in dust flux modelling[1;2]. Hence, this study aims to quantify the physical and chemical properties of Icelandic dust inorder to better understand their effect on the mechanisms of dust production. Samples were collected by Professor Throstur Thorsteinsson of the University of Iceland at five different locations in Southern Iceland: Vik, Landeyjasandur, Álftaver (Eyjafjallajökull deposits), Markarflótssandur and Markarflótsaurar in May 2015 and January 2016. Each sample contained varied amounts of dust, but the dustiest samples (>90% of fine minerals, <63 µm) are from Álf- taver (ALF01) and Markarflótsaurar (MFAU01). Particles from these samples were measured for their circularity, sphericity, bulk density, settling velocity and size distribution. Matlab image processing software was used to analyze the circularity and sphericity of the particles. A pycnome- ter was used to obtain a particle density profile of the dustiest samples. The free fall velocity of Icelandic dust released in a square tube (13 cm × 9 cm × 128 cm) was measured using Laser doppler anemometry (LDA). Particle-size distributions were obtained using an Horiba-Partica LA-950 V2. X-ray diffraction (XRD), thin-sections, X-ray fluorescence (XRF) and Scanning electron micro- scope energy-dispersive X-ray (SEM-EDX) techniques were used to quantify the chemical and mineral properties of the Icelandic dust samples. The results show that these particles are highly porous, angular, abrasive, while their pores are cemented with ultrafine dust. These results also show that the particle density decreases with increasing diameter.

Seasonal and decadal variability of dust observations in the Kangerlussuaq area, West Greenland

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Since the early 1900s expedition records from west Greenland have reported local dust storms. The Kangerlussuaq region, near the inland ice, is dry (mean annual precipitation 75 in 1995-2004 and 2005-2015. The seasonality of dust observations has remained consistent throughout most of the period. Dust days occur all year round but are most frequent in May-June and September-October and are associated with minimum snow cover and glacial meltwater-driven sediment supply to the outwash plains during spring and fall flood events. Wind regime is bimodal dominated by katabatic winds from the northeast, which are strongest and most frequent during winter months (Nov-Jan), with less frequent, southwesterly winds generated by Atlantic storms mostly confined to spring (May, June). The southwesterly winds are those most likely to transport dust onto the Greenland ice sheet.

Increased North Atlantic dust deposition linked to Icelandic glacier fluctuations over the last 5000 years

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Iceland is a major cold-climate high-latitude dust source. In particular, the extensive glacial outwash plains (sandar) of southern Iceland represent the largest contemporary dust emission areas in the high-latitude North Atlantic region (>50°N). Using sedimentological, geochemical and isotopic analyses, we find a strong temporal association between peaks in minerogenic dust, recorded in peat sequences in northern Scotland, and the timing of glacier fluctuations in Iceland. A marked peak in increased dust deposition, c. 2.5-3.0 ka BP, in a high-resolution Holocene peat core from Caithness occurs against a backdrop of low dust deposition in the preceding and subsequent millennia (i.e. 5.0-3.0 ka and 2.5-1.5 ka BP); whilst a second marked dust peak occurs between 0.5-0.2 ka BP. Dust peaks, though different magnitude, are also seen in peat records from sites on Shetland ~200 km to the northeast during the same time intervals, centred around c. 2.5-3.0 ka BP and at 0.5-0.2 ka BP, reinforcing this temporal pattern. Sedimentological and geochemical analyses, coupled with previous tephrochronological studies, show that neither of these dust peaks relate to specific volcanic events. We suggest that these major dust peaks reflect enhanced availability of silt-sized material produced by Icelandic glaciers and transported by strong winds during the Neoglacial and Little Ice Age glacier advance-retreat cycles. This work highlights the wider role of Icelandic glaciers and their meltwater systems in producing large volumes of iron-rich fine-grained material for aeolian transportation to the North Atlantic Ocean and its terrestrial margins.