HIGH LATITUDE DUST OBSERVATIONS WITH FOCUS ON ICELAND AND ANTARCTICA

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EUMETSAT WORKSHOP:
REMOTE SENSING FOR OCEAN-ATMOSPHERE INTERACTIONS STUDIES AND APPLICATIONS

1-3 DECEMBER 2021
HLD TALK OUTLINE

• **HIGH LATITUDE DUST** SOURCES (HLD) AND THEIR CONTRIBUTION TO GLOBAL DUST BUDGET
• HLD RESEARCH – UPDATE FROM ICELAND AND ANTARCTICA
• SAHARAN DUST IN ICELAND
• ICELANDIC AEROSOL AND DUST ASSOCIATION (ICEDUST)
HIGH LATITUDE DUST AREAS

• THE MAIN SOURCES OF DUST EMISSIONS IN THE NORTHERN (ALASKA, CANADA, GREENLAND, AND ICELAND) AND SOUTHERN (ANTARCTICA, NEW ZEALAND, AND PATAGONIA) HEMISPHERES

• HIGH-LATITUDE SOURCES COVER >500,000 KM²

• CONTRIBUTION OF 80 – 100 TG YR⁻¹ OF DUST TO THE EARTH SYSTEM

(〜5% OF THE GLOBAL DUST BUDGET)
Figure 3. Global observations of high-latitude dust where filled circles indicate dust storm frequency based on visibility data, and black triangles indicate georeferenced published observations of dust storms (see text for details). Areas where the precipitation: potential evapotranspiration ratio < 0.65 (aridity index) [United Nations Environment Programme, 1997] and subtropical dust emission zones are included for reference.
Figure 18. (left) MODIS Aqua image 28 March 2009 showing multiple dust plumes in Patagonia caused by strong westerly winds extending over the south Atlantic. The most dense plume originates from the Colorado and Negro River mouths in the north which were particularly active in 2009 due to combined drought and poor rangeland management. (right) Aerial photograph of dust storm in October 2004 caused by winds gusting to 29 m s⁻¹ at San Sebastián Bay, Tierra del Fuego, 800 km south of Comodoro Rivadavia.

Uplift of fine mineral material in the forefield of the Sven glacier (Petuniabukta) (photo by T. Wawrzyniak). This region has a drier, continental climate and more deglaciated bare land surfaces, with sediment to be uplifted in comparison with the more maritime climate of Hornsund area in the southern part of Svalbard.

Kavan et al. (2020)
HIGH LATITUDE DUST AREAS – N EUROASIA

New paper in preparation by Meinander et al. on Merging > 60 new HLD sources
HIGH LATITUDE DUST AREAS

Vukovic, 2019. Sand and Dust Storms Source Base-map

https://maps.unccd.int/sds/

UNCCD 1km global dust mask (Ana Vukovic, 2019)

Dust sources in high latitudes
Sand and Dust Storms Source Base-map for the AMAP report 2021

G-SDS-SBM: HIGH-LATITUDE SOURCES

latitude > 60°N

SDS index

-includes seasonal variability!

Ana Vukovic, 2019
https://maps.unccd.int/sds/
10. New High Latitude Dust sources – in situ measurements/remote sensing


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- **SAHARAN DUST IN ICELAND**
- **IMPACTS OF ICELANDIC DUST ON ATMOSPHERE AND CLIMATE**
METHODS: A NETWORK OF 30 WEATHER STATIONS IN ICELAND (1949-2011)

- AN AVERAGE OF 34.4 DUST DAYS PER YEAR,
- BUT 135 DUST DAYS PER YEAR INCLUDING

"VISIBILITY REDUCED BY VOLCANIC ASHES" + "DUST HAZE"

DUST DAY IS DEFINED AS A DAY WHEN AT LEAST ONE STATION RECORDED AT LEAST ONE DUST OBSERVATION.
SEASONAL VARIABILITY OF DUST EVENTS

- NE ICELAND
  "ARCTIC DUST EVENTS"
  SUMMER

- S ICELAND
  "SUB-ARCTIC DUST EVENTS"
  WINTER-SPRING

Transport to Greenland and Svalbard

Transport to Europe
HLD RESEARCH – UPDATE FROM ICELAND

• 2021 – ICEDUST ASSOCIATION - 48 INSTITUTIONS, 18 COUNTRIES, 100 MEMBERS, > 60 PAPERS
• 2020 – FIRST OPERATIONAL HLD FORECAST AT THE WMO SDS-WAS

The largest (HLD) dust field campaign, NE Iceland, July-Sep 2021: European Research Council (FRAGMENT), German Research Foundation (HiLDA), NASA (EMIT), French Nat. Res. Inst. (INRAE), the Helmholtz Ass. of German Res. Centers (Helmholtz YI Group on Min. Dust), Icelandic Centre for Research (Rannís), Czech Science Foundation (GACR)

- 11 institutions
- 6 countries
- >70 instruments
DYNGJUSANDUR DUST CAMPAIGN
> AN ANALOGUE FOR MARS?

Participants institutions:
- Barcelona Supercomputing Center (BSC)
- Environmental Assessment and Water Research – Spanish Research Council (IDAEA-CSIC)
- Technical University Darmstadt, Germany
- Freie Universität Berlin
- Karlsruhe Institute of Technology, Germany
- CALTECH, JPL, NASA
- National Research Institute for Agriculture, Food and Environment (INRAE), France
- Agricultural University of Iceland
- Czech University of Life Sciences Prague

DESERT AREA with high erosion rates marked orange and red!

volcanic sandy deserts (22% of Iceland)

glacial riverbeds and ice-proximal areas = “dust hot spots”
Field measurements in three Icelandic deserts 2020

One-minute average of PM$_{10}$ (µg/m$^3$) at Sandvikavatn - 27 July, 2020

Location: 64.339643, -20.990819
DUST IMPAIRS AIR QUALITY AT HIGH ATMOSPHERIC ALTITUDES DURING ARCTIC WINTER

Jan 13 2016

MODIS

100 km

Clean profiles PNC < 5 particles cm\(^{-3}\)
Polluted profiles PNC > 250 particles cm\(^{-3}\)

Clean Arctic conditions
Dirty Saharan dust layer

Vertical distribution of aerosols in dust storms during the Arctic winter

Particle sizes
- Surface
  - up to 20 μm
  - submicron + few 10 μm
  - < 5 μm
  - submicron

10 JAN 2016
Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)

Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) instrument that operates at two wavelengths (532 nm and 1064 nm)
NORTHERN HLD SOURCES AND THEIR CONTRIBUTION IN THE ARCTIC

LONG-RANGE TRANSPORT OF ICELANDIC DUST?

~ 3% of global dust emission from HLD sources

Total atmospheric dust loads in the Arctic:
Asia (~38%)
Africa (~32%)
HLD (27%)

Icelandic dust:
• About 7% of emitted dust is deposited in the high Arctic (>80°N)
• Europe deposition (3% of emitted dust)

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IS THERE ANY EVIDENCE THAT ICELANDIC DUST HAS REACHED SVALBARD OR EUROPE?

Yes, in Svalbard

Volcanic dust travelled > 3000 km

Yes, in Ireland

Volcanic sulphate and arctic dust plumes over the North Atlantic Ocean

Yes, in Serbia

A case study
24th October 2019

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<th>Feb</th>
<th>Mar</th>
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<td>29</td>
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<td>30</td>
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<td>30</td>
<td>26</td>
<td>17</td>
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<td>20</td>
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<td>7</td>
<td>8</td>
<td>7</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>31</td>
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<td></td>
<td></td>
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<td>71</td>
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</table>
Mean (median) mass concentrations:

**PM$_{10}$** were $6.4 \pm 1.4$ (3.9 ± 1) μgm$^{-3}$

**PM$_{2.5}$** were $3.1 \pm 1$ (2.3 ± 0.9) μgm$^{-3}$

for the period January-March 2018

PM$_{10}$ in Antarctica similar to North Europe!
ANTARCTICA 2021 – preliminary results

Daily concentrations much higher than 6 ug m$^{-3}$
Icelandic dust has different composition that crustal dust

Figure 6: A-B. Mineralogy of Icelandic dust (MIR45 and Land1; PM10). C. Mineral composition of North African desert dust (PM20), representing the average bulk composition by X-ray diffraction of Tibesti, Western Sahara, Niger, and Mali samples (Shi et al., 2011b). D. Mineral composition of Asian dust (PM10), average bulk composition by X-ray diffraction of dust from arid regions in Mongolia and North China collected in Seoul (Korea) during eight dust events in 2003-2005 (Jeong et al., 2008).
DUST FROM ICELAND OR DUST TO ICELAND?

Saharan dust depositional events (SDE#1-2) in Iceland

→ 15 Saharan dust events in Iceland in 2008-2020

Giant quartz particles traveling > 4,500 km
Saharan dust and giant quartz particle transport towards Iceland

György Varga1,2, Pavla Dagsson-Walhauserová3,4, Fruzsina Gresina1,4 & Agusta Helgadottir2
ICELANDIC DUST MAKES ICE IN CLOUDS

- Icelandic volcanic dust is an active Ice-Nucleating Particle (INP) similarly to Low Latitude Dust (LLD).

- Airborne Icelandic dust sampled from the aircraft is more active INP than LLD at temperatures above $-17^\circ C$.

- The greatest contribution of Icelandic dust to the INP population occurs during the summer over large areas of the North Atlantic and the Arctic at altitudes between 3-5.5 km, where mixed-phased clouds are known to occur.

- In future, increased INP concentrations would lead to a reduction in supercooled water and a decrease in shortwave reflectivity of clouds to produce a positive climate feedback, which has not yet been considered in climate simulations.

- Ice crystals in a mixed-phase cloud make the cloud instable.
- Ice phase will grow at expenses of the liquid one, removing the liquid content.
- Clouds optically thinner, and therefore they have less albedo (less bright).
Severe albedo reduction due to dust storms in June 2019

Vatnajökull – 7,900 km² glacier in Iceland

Annual and inter-annual variability and trends of albedo of Icelandic glaciers

Andri Gunnarsson¹, Sigurður M. Gardarsson, Finnur Pálsin, Tómas Jóhannesson, and Öfi G. B. Sveinsson

Figure 9. Annual spatial patterns for melt season (MJJA) albedo anomalies for 2000–2019.
Soil on Snow experiment: bidirectional reflectance factor measurements of contaminated snow
L. Polonski1, M. Grégoire1,2, T. Habata1,2, P. Dagsson-Wahlgren1,2, O. Arvidsson3, K. Antón2,3, H-H. Hauck1, N. Veldkamp2, H. Eduards1, O. Mészáros2, A. Svensson1, A. Virkola2, and G. de Luca3

- VOLCANIC DUST DECREASES SNOW ALBEDO SIMILARLY AS BLACK CARBON
- SOOT DECREASES WATER RETENTION CAPACITY AND DENSITY OF SNOW

\[ y = -0.2681x + 440.6 \]
\[ R^2 = 0.6587 \]
CONCLUSIONS

Icelandic Aerosol and Dust Association (IceDust)
Rykrannsóknafelag Íslands (Rykls)

Witnessed dust storm?

Dust experts meet in Dynjúpsandur to conduct the largest field campaign in Iceland

The potential of Icelandic dust to affect the Arctic clouds

Workshop on Effects and Extremes of High Latitude Dust (HLD Workshop), Reykjavik

Open call for travel grants to the Workshop on Effects and Extremes of High Latitude Dust (HLD Workshop)

Search for topic on IceDust:
Search...

Upcoming Dust Events
• HLD Workshop 2023
  February 13, 2023
• HLD Workshop 2022
  February 16, 2022

HLD Workshop VI
February 15-16 2022
Reykjavik

➢ 48 research institutions
➢ from 18 countries
➢ 100 members
➢ > 60 scientific papers published

HTTPS://ICEDUSTBLOG.WORDPRESS.COM/
Dust storms from the agricultural fields in Central Europe

Poland – April 23rd 2019
Thank you for your attention!

pavla@lbhi.is

Geldingadalur eruption, 19.3.2021