Landbúnaðarháskóli Íslands
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UNIVERSITY OF ICELAND

SPECTRAL REFLECTANCE MEASUREMENTS OF ABSORBING IMPURITIES ON SNOW

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CHOPOK, FEBRUARY 16TH, 2016

OBJECTIVES

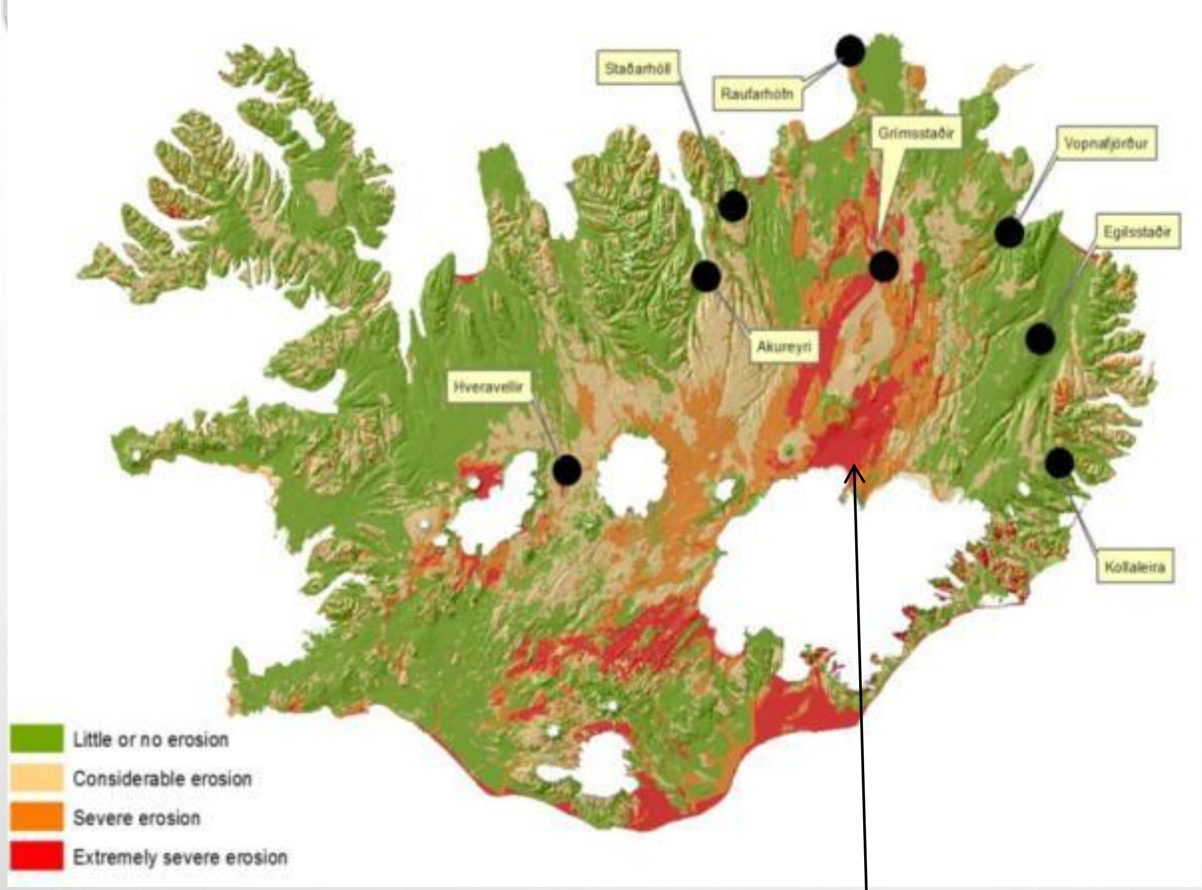
- ICELAND AS A MAJOR DESERT
- IMPURITIES ON SNOW (BC AND DUST)
- **SOOT ON SNOW PROJECT**

>> FIELD MEASUREMENTS ON DUST-ON-SNOW DEPOSITION AND OPTICAL PROPERTIES OF VOLCANIC DUST

BACKGROUND

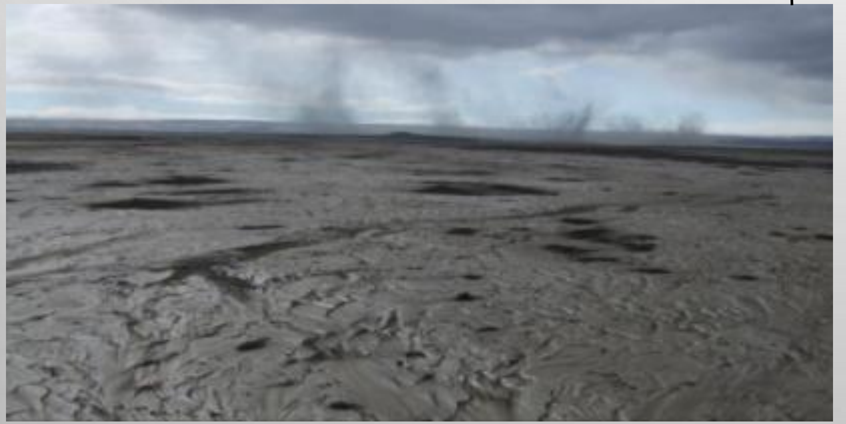
ICELAND AND SOURCES OF AIR POLLUTION

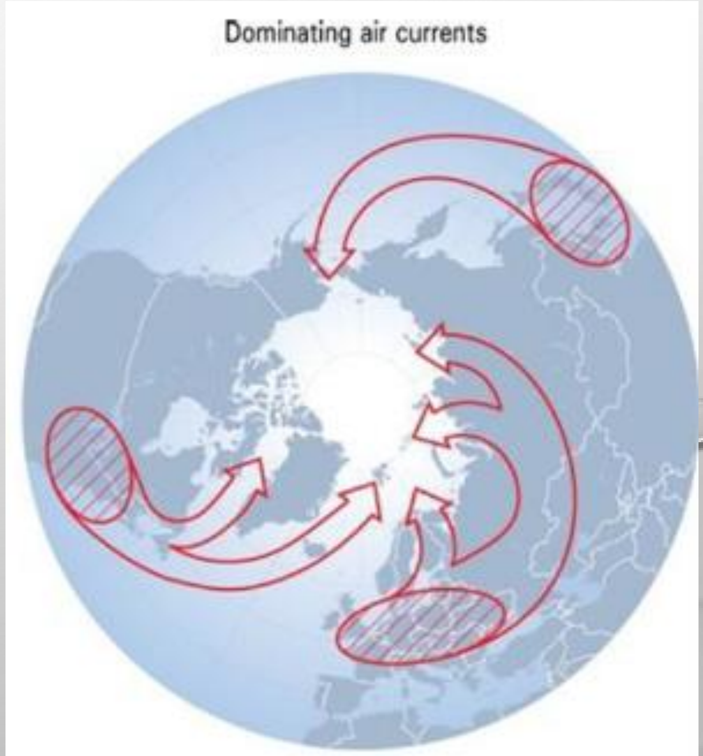
- LESS POPULATED AND INDUSTRIALIZED COUNTRY THAN EUROPE OR NORTH AMERICA
- ABOUT 22 % OF THE COUNTRY ARE VOLCANIC SANDY DESERTS
- > 40 % OF ICELAND IS CLASSIFIED WITH CONSIDERABLE TO VERY SEVERE EROSION
- FREQUENT VOLCANIC ERUPTIONS
- FREQUENTLY STRONG WINDS



volcanic sandy deserts (21%)

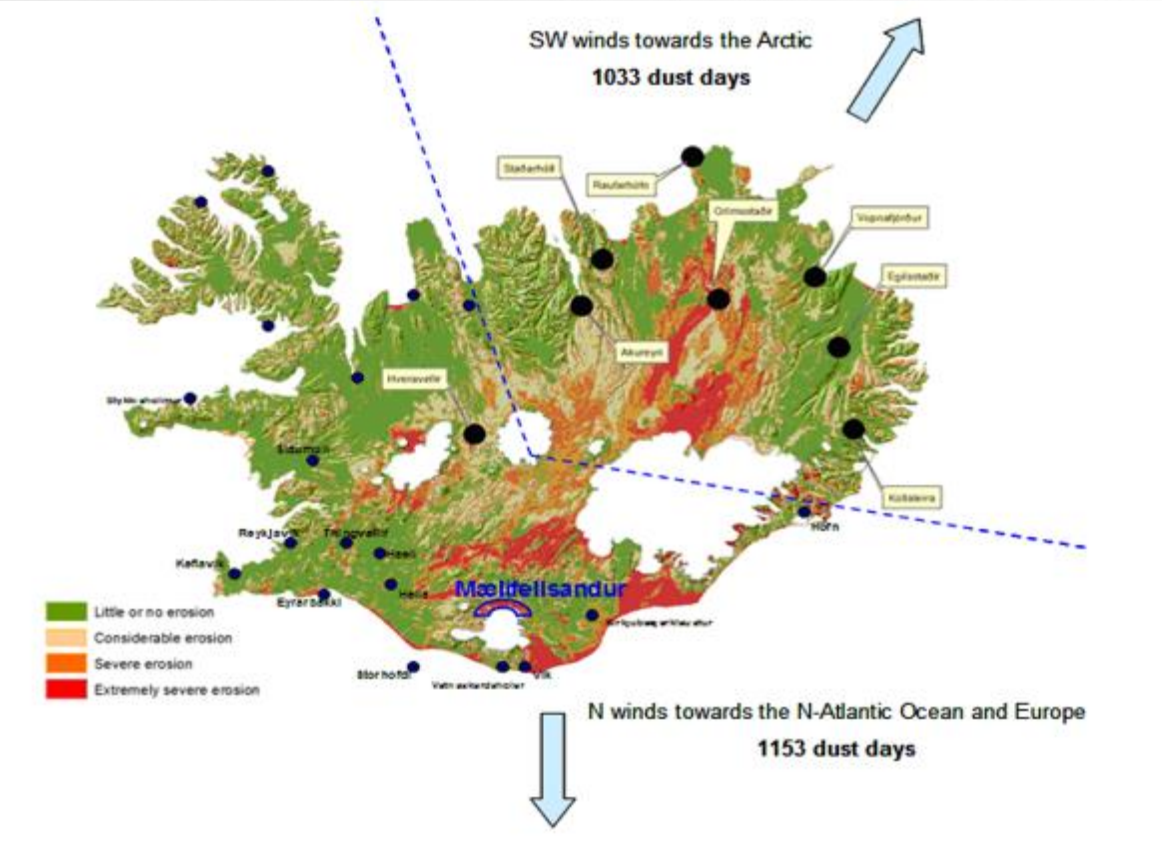
glacial riverbeds and ice-proximal areas





FREQUENCY OF DUST EVENTS AND ESTIMATION OF AMOUNTS OF DUST DEPOSITION

- 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

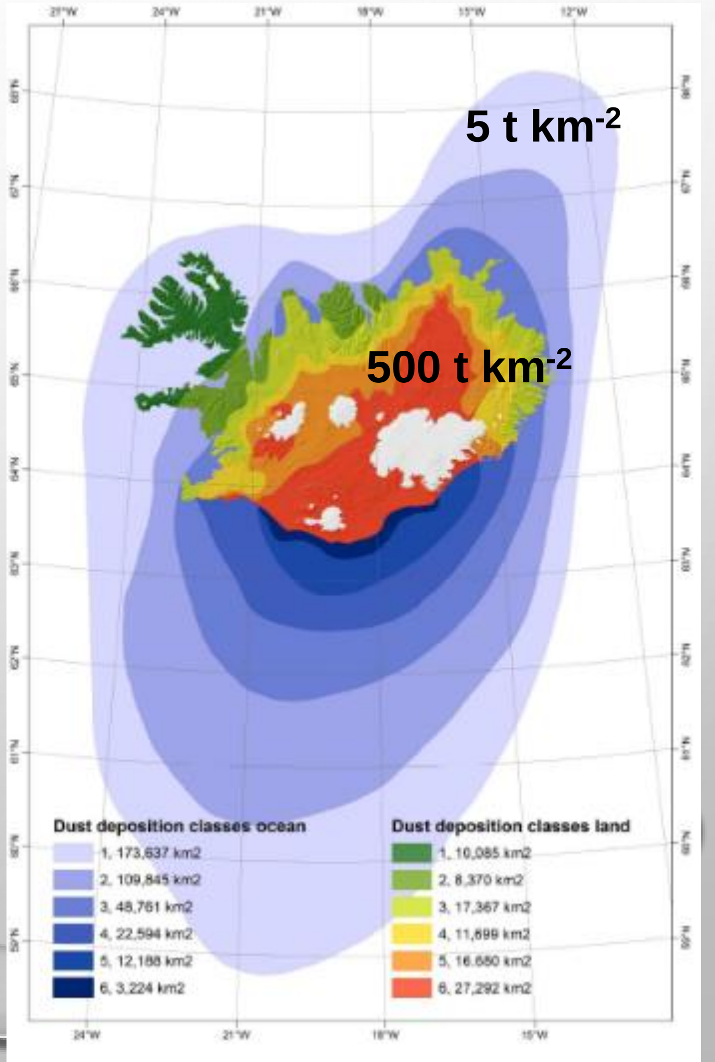
“VISIBILITY REDUCED BY VOLCANIC ASHES” + “DUST HAZE”

DUST DAY IS DEFINED AS A DAY WHEN AT LEAST ONE STATION RECORDED AT LEAST ONE DUST OBSERVATION

AVERAGE DISTRIBUTION OF DUST DEPOSITION

- TOTAL EMISSIONS RANGE FROM **30.5 TO 40.1** MILLION T
- TWO APPROACHES: 1. DUST EVENT BASED CALCULATION

  2. DEPOSITION RATES (ARNALDS, 2010)
- LAND DEPOSITION: 25-26 MILLION TONS
- OCEAN DEPOSITION: 5.5 TO 13.8 MILLION TONS
- CALCULATED IRON DEPOSITION: 0.56 TO 1.4 MILLION T
- ICELANDIC **GLACIERS**: **4.5 MILLION TONS ANNUALLY**



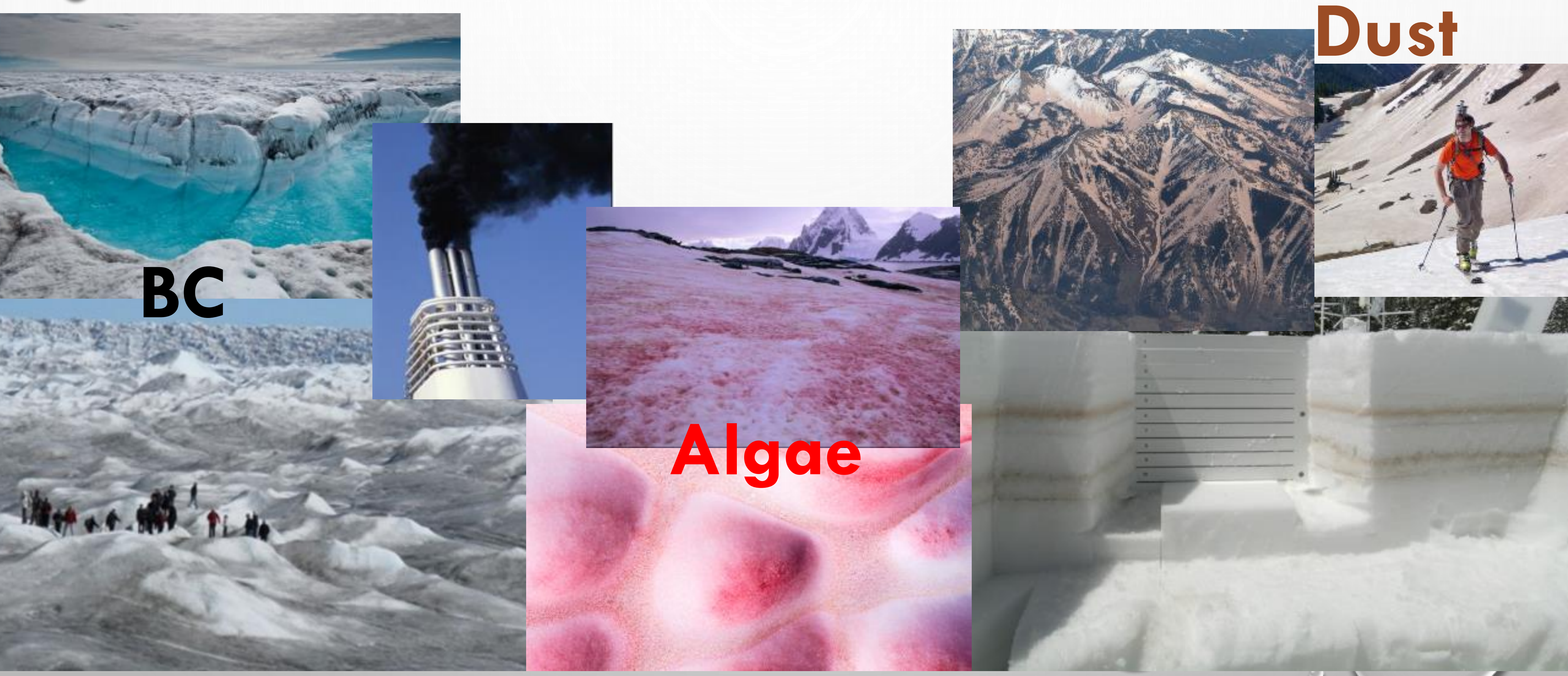
This is not Eyjafjallajokull volcanic plume!

This is a dust plume!

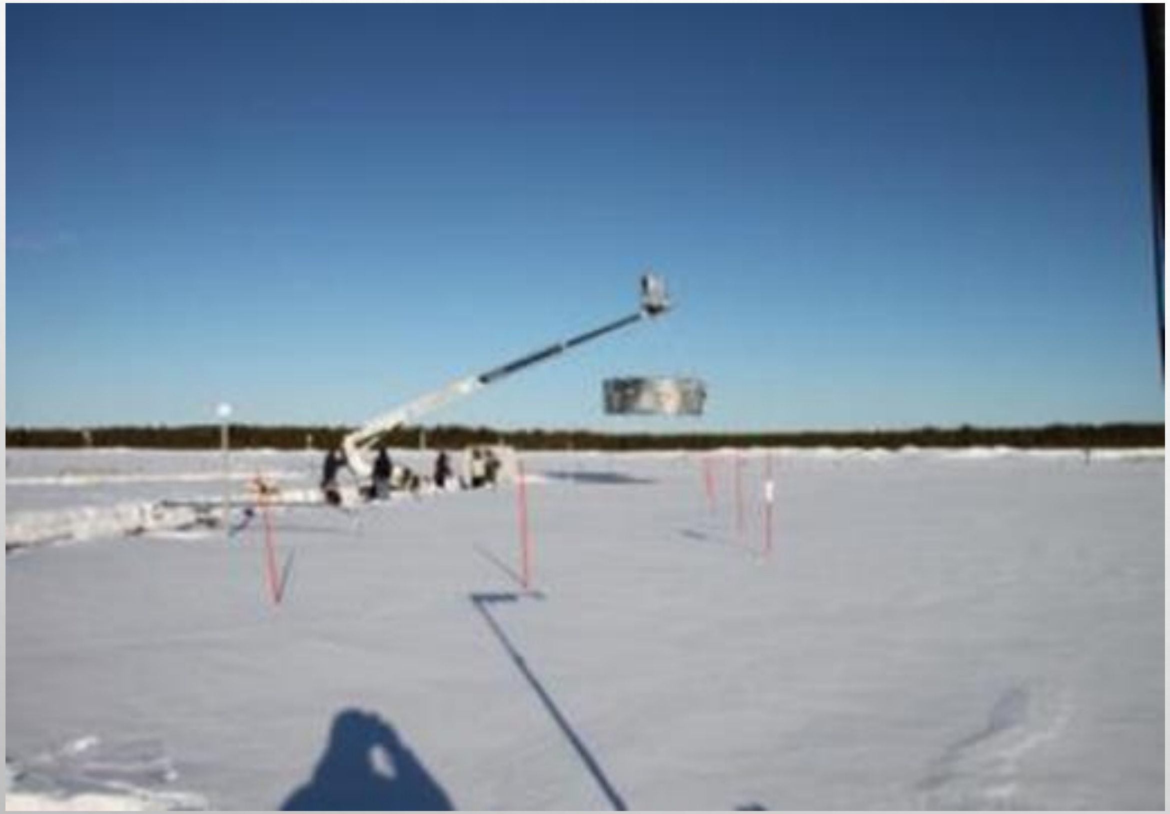
REYKJAVÍK HAZE, SEPTEMBER 11, 2011

HVALFJÖRÐUR SUSPENDED DUST, MARCH 24, 2012

IMPURITIES ON SNOW



SOOT ON SNOW PROJECT IN LAPLAND
SOS 2013



ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

CRAICC

LANDBÚNAÐARHÁSKÓLI ÍSLANDS

UNIVERSITY OF ICELAND

FINNISH GEODETIC INSTITUTE

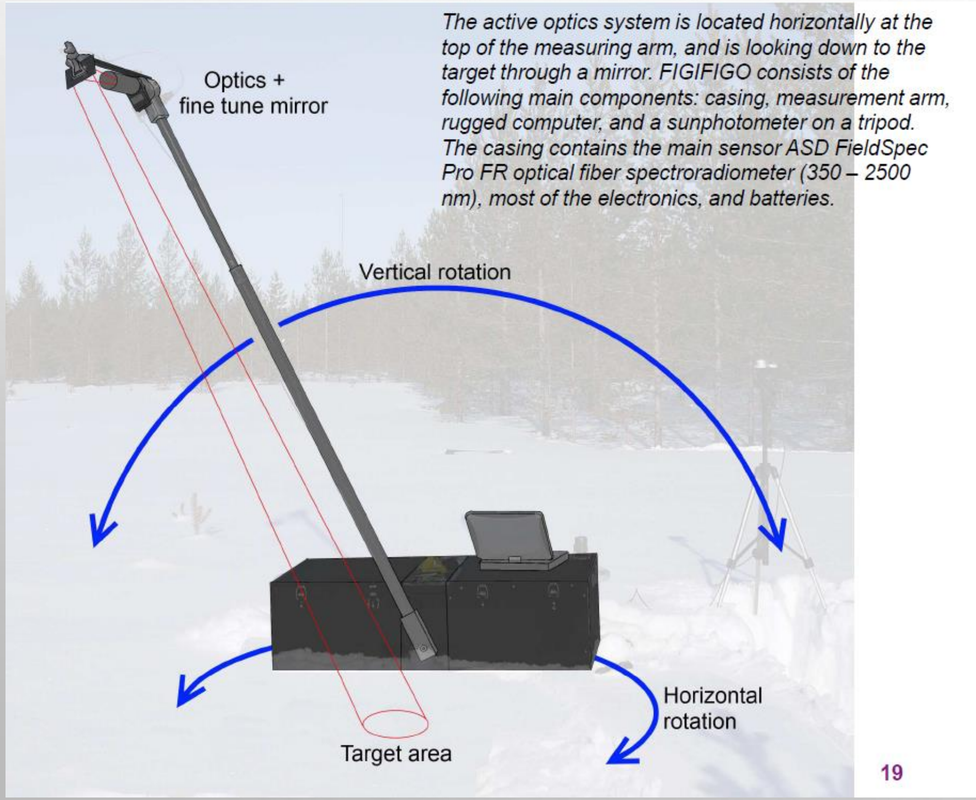
HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

THE SPECTRAL REFLECTANCE OF MELTING SNOW AND DUST IN LABORATORY WAS MEASURED

- THE ANALYTICAL SPECTRAL DEVICE (ASD) SPECTROMETER FOR 325-1075 NM
- THE GONIOSPECTROMETER FIGIFIGO

- SPECTRAL REFLECTANCE OF SNOW WAS MEASURED FIRST DAYS OF THE DEPOSITION (FIGIFIGO) AND TWO WEEKS AFTER THE DEPOSITION (ASD).

THE FINNISH GEODETIC INSTITUTE FIELD GONIOSPECTROMETER FIGIFIGO



- THIS INSTRUMENT USES MULTIANGULAR REFLECTANCE TO MEASURE THE ALBEDO AND POLARIZATION, HEMISPHERICAL DIRECTIONAL REFLECTANCE FACTOR (HDRF), AND OTHER SNOW PROPERTIES

Key measurement components:

1. Snow

Primarily component for the experiment. Natural snow pack at Sodankylä airport. Begining of April, 2013

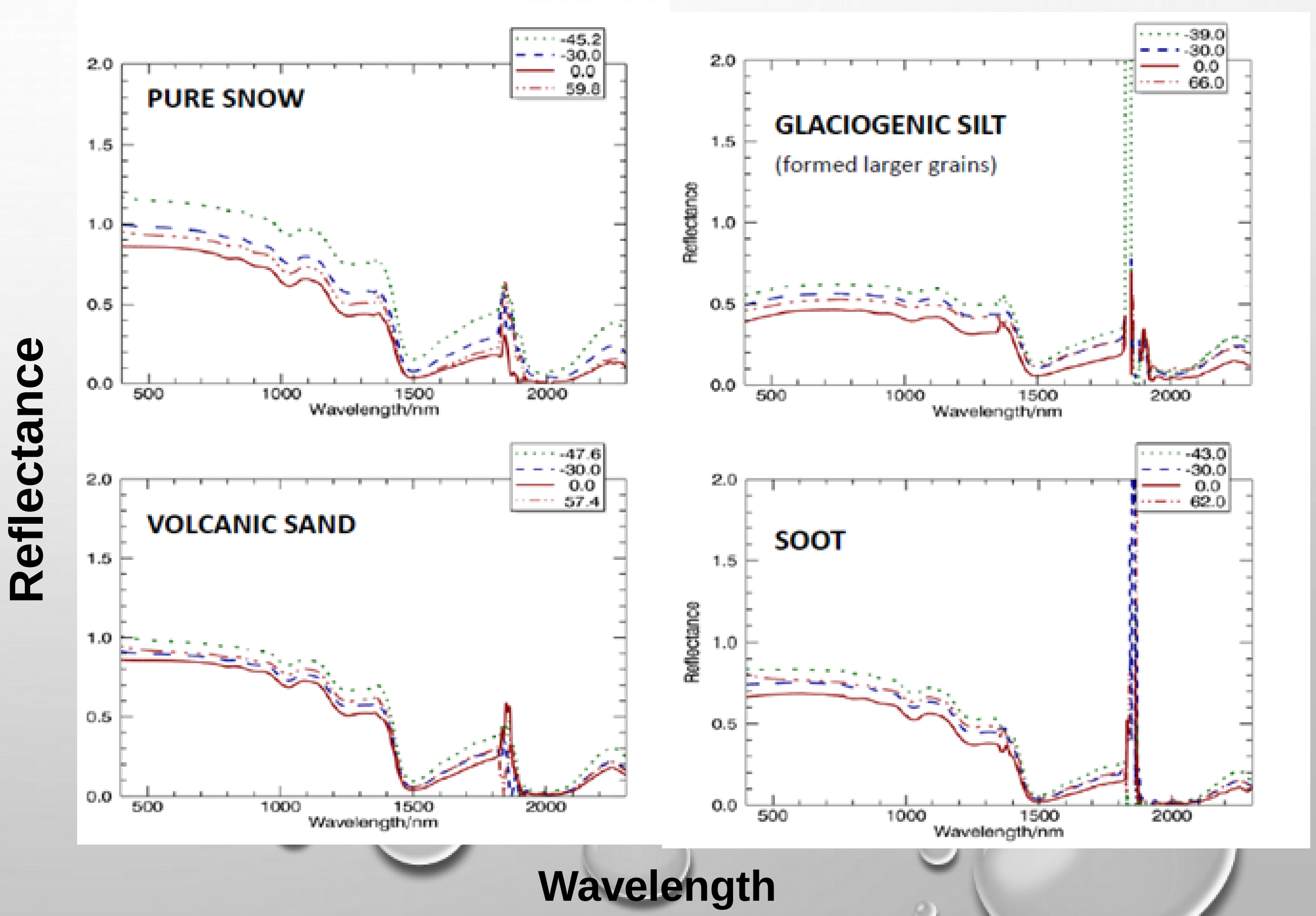
2. Volcanic sand

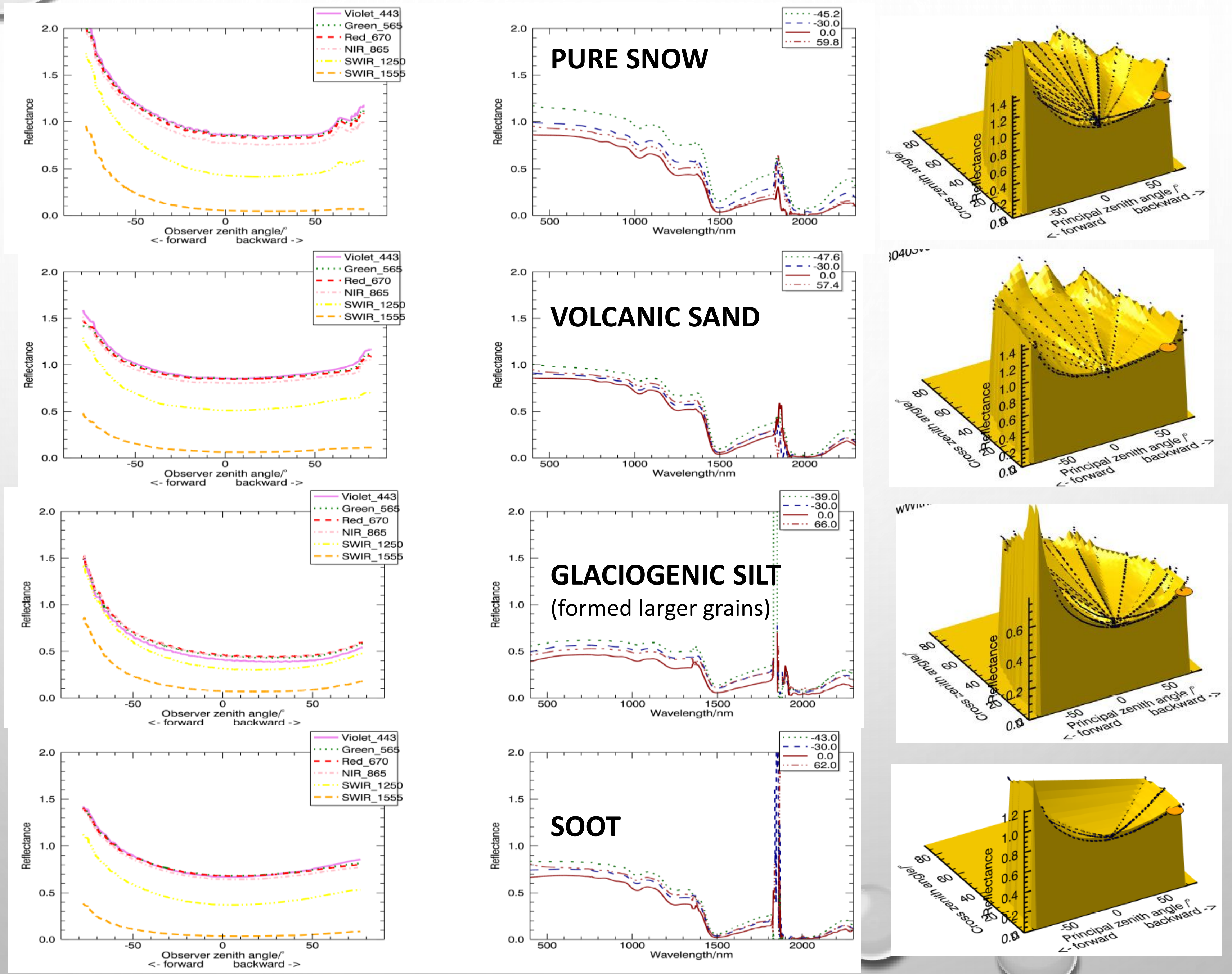
A near black mixture of the volcanic ash of glaciofluvial nature. Origin: under the Myrdalsjokull glacier

3. Glaciogenic silt

Collected from the glacial river Mulakvisl, it consists mainly of silt and some coarse clay sized particles

SPECTRAL REFLECTANCE AT THE TIME OF THE DEPOSITION




PURE SNOW
VOLCANIC SAND
GLACIOGENIC SILT
(formed larger grains)
SOOT
Violet_443
Green_565
Red_670
NIR_865
SWIR_1250
SWIR_1555
Reflectance
Observer zenith angle/°
<- forward backward ->
Wavelength/nm
-45.2
-30.0
0.0
59.8
-47.6
57.4
-39.0
66.0
-43.0
62.0
Cross zenith angle/°
Principal zenith angle /°
<- forward backward ->

CLUMPING MECHANISM

SILT

SOOT

CLUMPING MECHANISM
- FIRST TIME REPORTED FROM THE NATURAL CONDITIONS

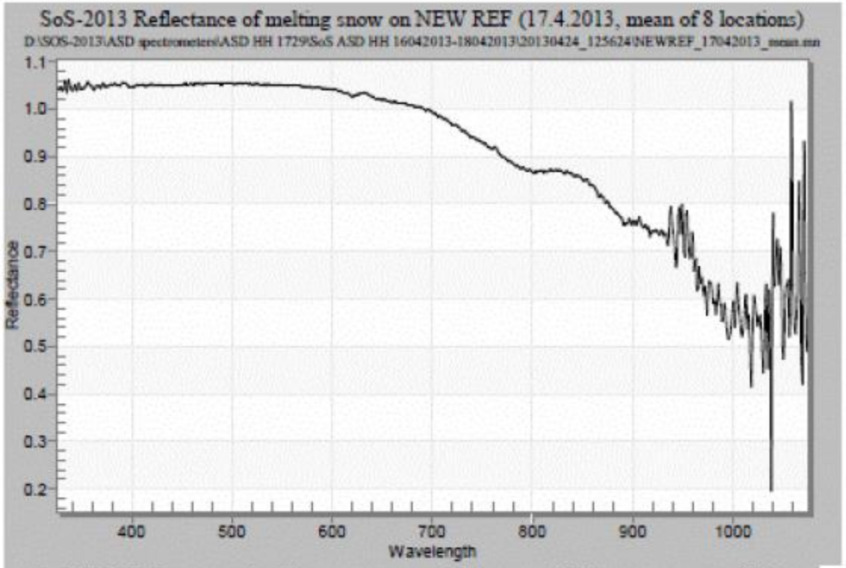
ARTIFICIAL DEPOSITION IN LAPLAND

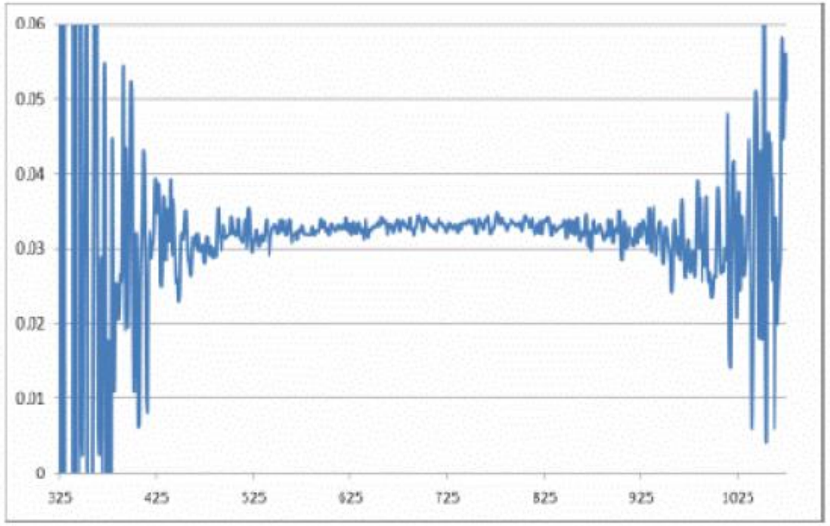
NATURAL CONDITIONS, ICELAND

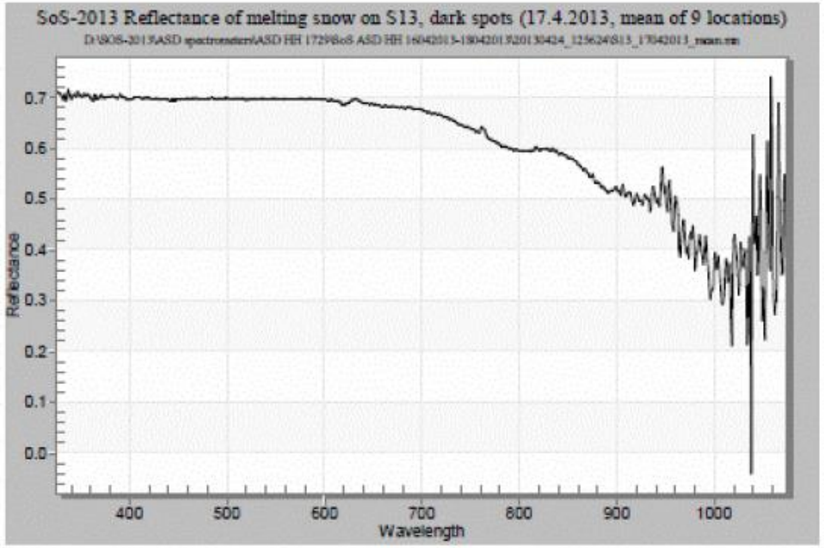
Kirkjubaejarklaustur   March 6-7, 2013   Reykjavik

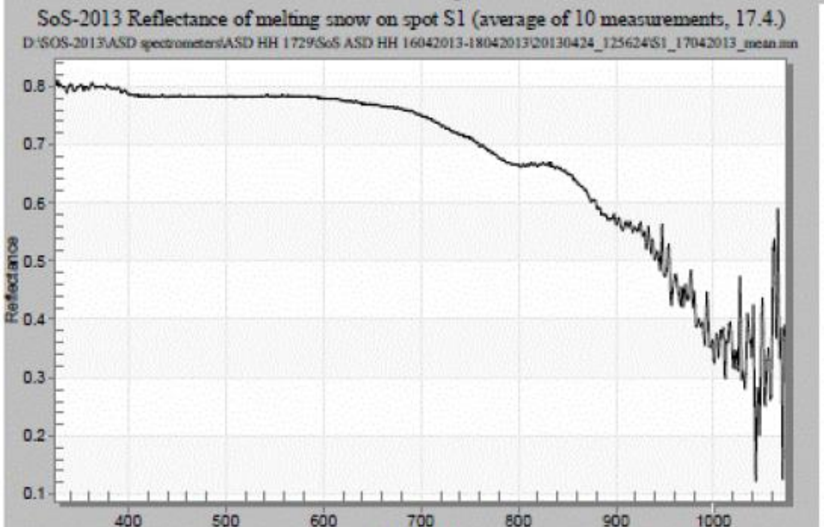
REFLECTANCE MEASUREMENTS 2 WEEKS AFTER THE DEPOSITION

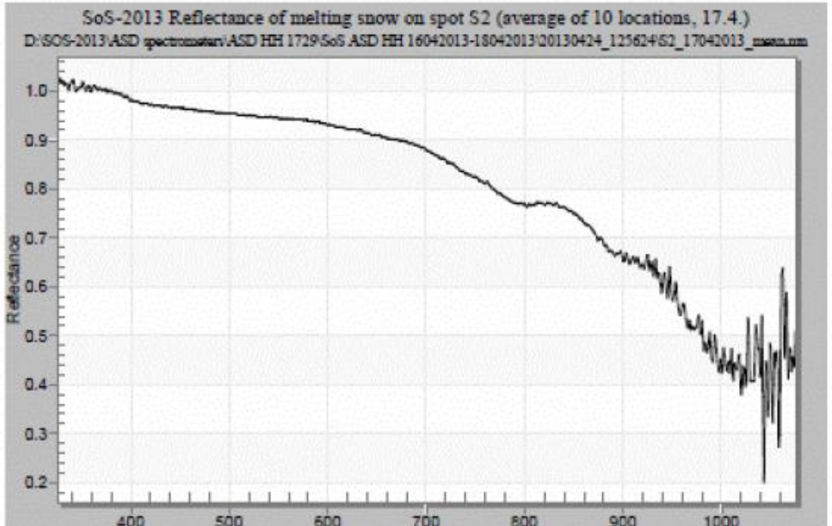
weeks after the artificial depositions. Up. Left: The reference spot with reflectance close to 1 at the beginning of the measurement range. Middle: The reflectance of the volcanic sand measured in the laboratory by spectroradiometer coupled with a contact probe. Right: Reflectance of the spot with volcanic sand deposited on snow. Down. Left. Wood burning soot on snow; reflectance spectrum starting around 0.8. Middle: Silt on snow, reflectance starts around 1. Right. Reflectance o vegetation under the snow spots. The results demonstrate that soot and volcanic sand reduce snow reflectance at UV and VIS more than glaciogenic silt, compared to natural reference snow.

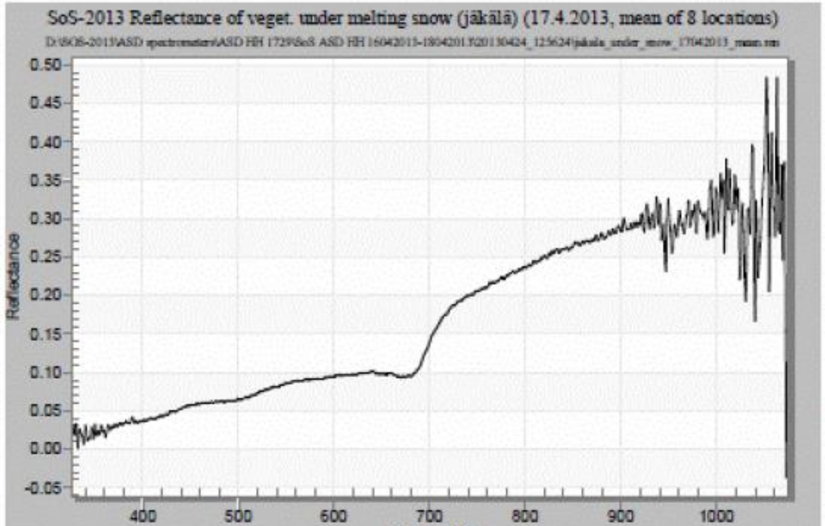






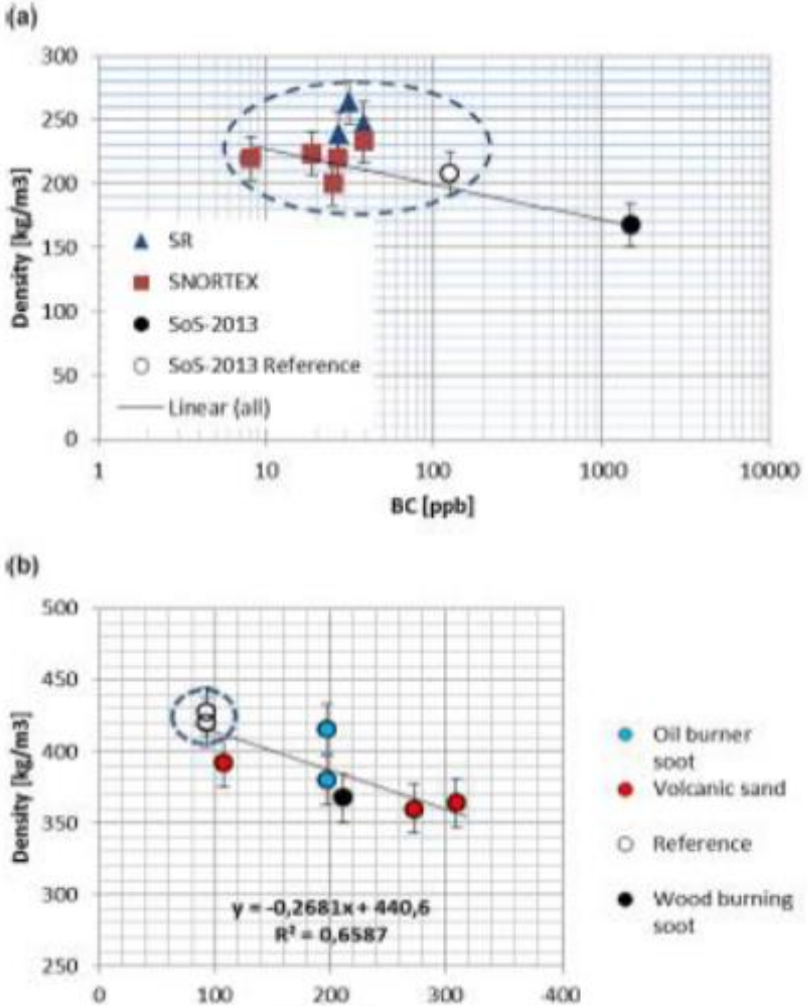


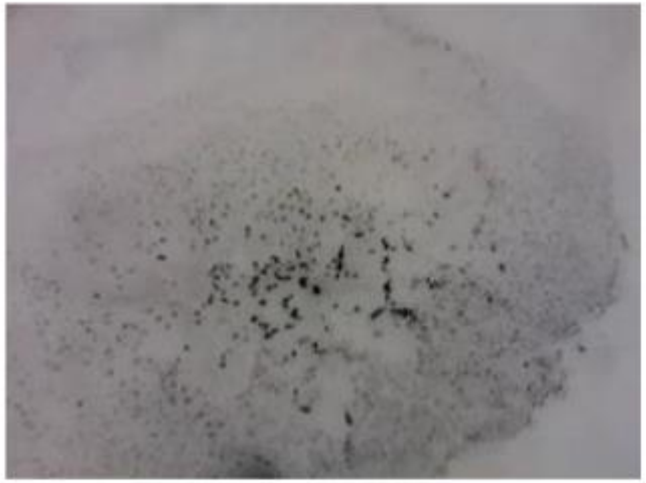




New hypothesis: Snow Density & BC /5/

- We found that BC and snow density correlate, in case of seasonally melting Arctic snow.
- In a new lab experiment we found that <u>soot decreased the water retention capacity</u> of snow
- **WHY?** We explain that absorbing impurities would cause melt and/or evaporation of the surrounding snow, resulting in air pockets around the impurities, and thus lower snow density. -> Other explanations?

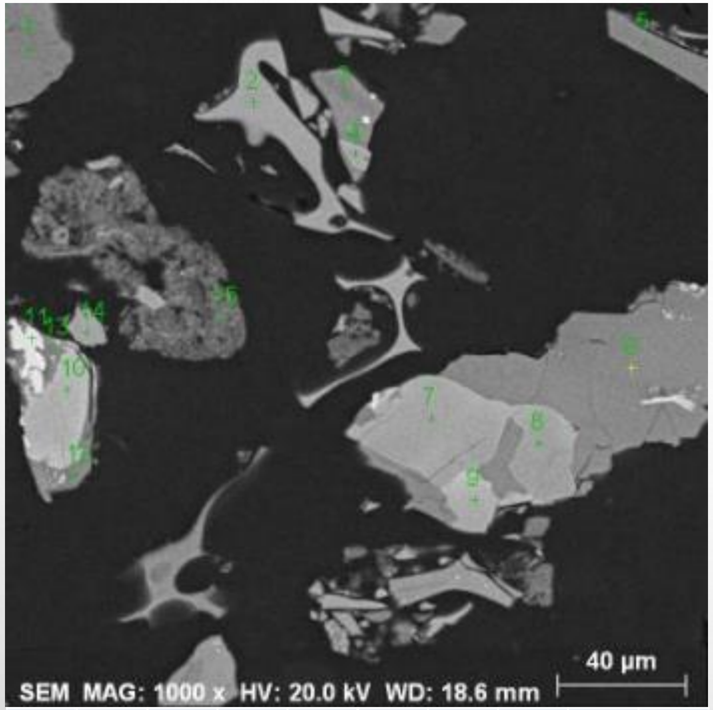




Artificially added hydrophobic impurities clustered and remained on the snow surface when snow was melting intensively.

Fig.4. Melting snow: BC versus snow density, reference spots within the circle.

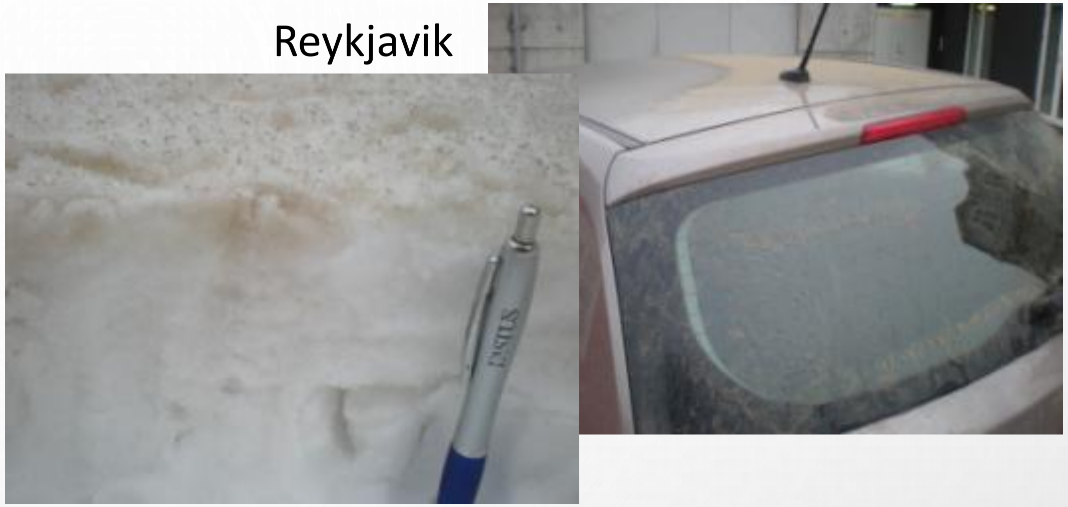
BACK TO ICELAND / WHAT IS ACTUALY TRANSPORTED IN THE AIR?



Spectrum	Na2O	Al2O3	SiO2	K2O	CaO	FeO	MgO	TiO2	MnO
1	6,79	17,85	67,98	1,13	4,83	1,42			
2	3,44	14,82	45,81	0,57	11,40	13,83	5,87	4,27	
3	7,47	18,09	61,75	3,25	4,91	3,90		0,62	
4	0,96	2,56	44,73		19,21	17,82	13,13	0,86	0,74
5	4,41	14,09	71,91	3,92	1,23	4,44			
6	4,81	33,36	47,46		13,59	0,78			
7	0,84	3,82	45,14		20,25	13,29	15,13	1,53	
8		1,43	46,63		24,60	13,34	12,65	0,91	0,43
9			32,20		0,61	36,64	30,55		
10		0,78	43,08		14,30	31,43	8,86	0,96	0,60
11						45,61		54,39	
12	8,19	22,26	58,23		9,94	1,38			
13	4,14	14,53	69,01	5,46	1,72	4,28		0,86	
14	1,87	9,80	43,01	0,29	13,03	15,15	13,63	3,22	
15	3,06	18,62	34,03	0,44	1,57	29,57	0,97	11,74	
%	4	13	51	2	10	16	13	8	1

Mechanical erosion potencial

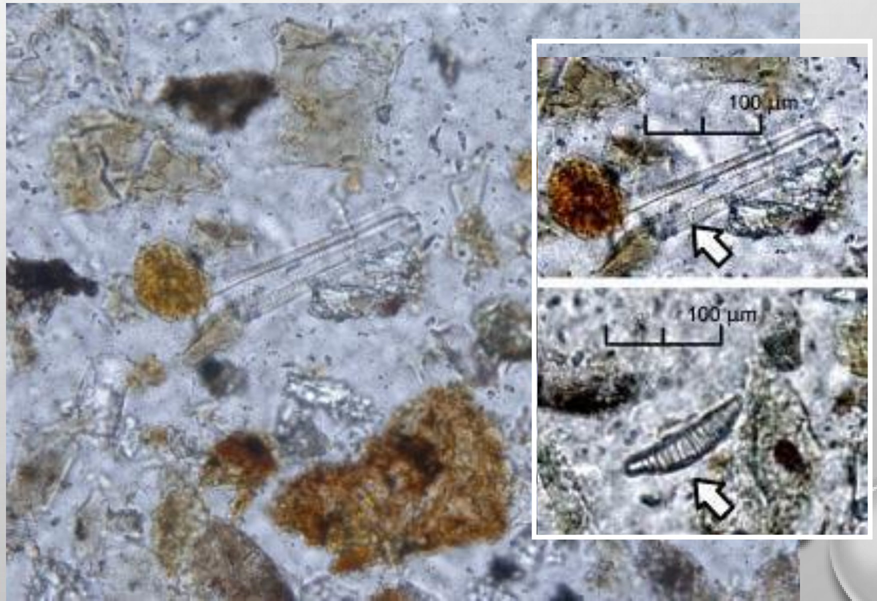
Reykjavik



High organic content (Detritus of decayed organic matter (from algae to vascular plants, ~0.25 vol. %)

+

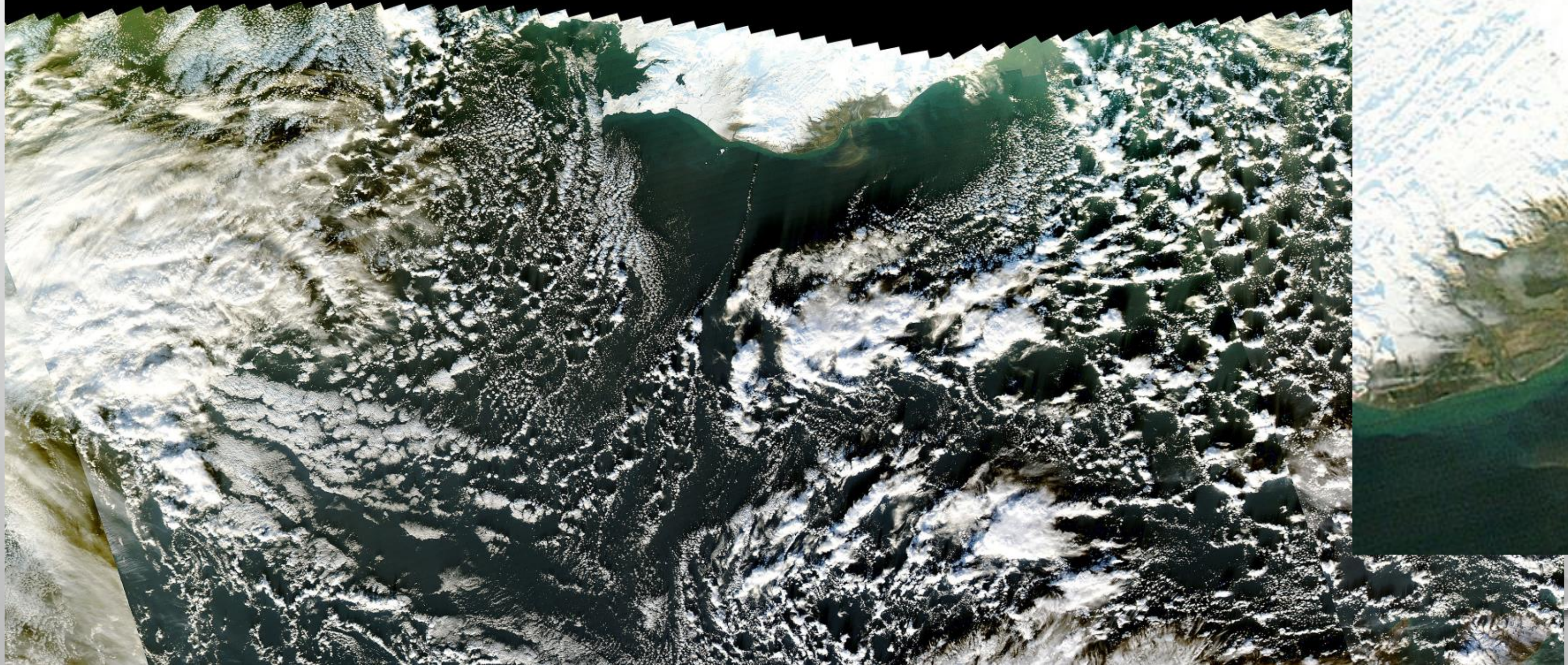
flying diatoms



CONCLUSIONS

- ABSORBING IMPURITIES ARE ACTIVELY DEPOSITED ON SNOW AND GLACIERS AROUND THE WORLD
- FIELD EXPERIMENTS SHOWED THAT VOLCANIC DUST DECREASES SNOW ALBEDO SIMILARLY AS BC
- LABORATORY EXPERIMENTS SHOWED THAT VOLCANIC DUST IS AN EXTREMELY ABSORBING AEROSOL
- SOOT DECREASES WATER RETENTION CAPACITY AND DENSITY OF SNOW
- CLUMPING MECHANISM OF THE IMPURITIES CAN BE OBSERVED IN NATURAL CONDITIONS

THANK YOU FOR YOUR ATTENTION!



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The Cryosphere
Open Access

Brief communication: Light-absorbing impurities can reduce the density of melting snow

O. Meinander[1], A. Kontu[2], A. Virkkula[1], A. Arola[3], L. Backman[1], P. Dagsson-Waldhauserová[4,5], O. Järvinen[6], T. Manninen[1], J. Svensson[1], G. de Leeuw[1,6], and M. Leppäranta[6]

1. *A semi-direct effect of absorbing impurities*. Absorbing impurities would cause melt and/or evaporation from the liquid phase and sublimation from the solid phase of the surrounding snow, resulting in air pockets around the impurities, and thus lower snow density. We have empirical observations, where impurities (both organic and inorganic) in the snow have been surrounded by air pockets.

2. *BC effect on the adhesion between liquid water and snow grains*. If BC reduces adhesion, the liquid-water holding capacity decreases. For linear warming the influence on the density of wet snow is then max 5 % (at this level water flow starts in natural snow). However, with daily cycles, warm days and cold nights, the weaker adhesion may push liquid water down more day-by-day and then the influence to the density would be larger. This way also melt–freeze metamorphosis would produce less dense snow.

3. *BC effect on the snow grain size*. Absorbing impurities would increase the melting and metamorphosis processes, resulting in larger snow grains, which would lower the water retention capacity. Earlier, Yamaguchi et al. (2010) have suggested that the water retention curve of snow could be described as a function of grain size using soil physics models. Here our data showed some slight indication for the possibility of soot in snow to result in larger snow grain sizes via increased melt and metamorphosis, and our data did not show clear evidence against this possibility.