Report on the Short Term Scientific Missions (STSMs) to Iceland for the ESSEM COST Action ES1404 "A European network for a harmonised monitoring of snow for the benefit of climate change scenarios, hydrology and numerical weather prediction"

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travel dates: March 14-20

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Place: University of Iceland, Faculty of Physical Sciences, Reykjavík, Iceland
Host: Dr. Pavla Dagsson-Waldhauserova, University of Iceland, Faculty of Physical Sciences, Reykjavík, Iceland

INTRODUCTION

Snow surface reflectance and albedo depend on snow properties as well as on environmental conditions; e.g. on impurities deposited on the snow (e.g., Warren and Wiscombe, 1980). Our ongoing snow reflectance and albedo related activities include: *a)* long-term UV albedo measurements on Arctic seasonal snow at Sodankylä, North-Finland, combined with weekly analysis of EC/OC in snow, as well as Antarctic surface UV albedo measurements at Marambio, Antarctic Peninsula; *b)* experimental field campaign measurements on snow and ice melt, density and albedo and reflectance changes at 320-2500 nm, induced by light-absorbing impurities in snow.

In order to quantify the effects of absorbing material on snow and define its contribution to climate change, we have recently conducted a series of dedicated bidirectional reflectance measurements, see e.g. (Meinander et al. 2014, Peltoniemi et al. 2015, Svensson et al. 2016). For these measurements chimney soot, volcanic sand, and glaciogenic silt were deposited on snow in the selected test sites in Finland in a controlled way. The two STSMs reported here enabled us to collect unprecedented experimental data under actual field conditions with impurities deposited on snow in the natural way (Fig.1). The research was done in close cooperation with Pavla Dagsson-Waldhauserova and her research group and it lead to the pioneer experimental results of this kind which will be reported at the ESA Living Planet Symposium 2016 in Prague by Gritsevich et al. as well as in the dedicated journal publication by Meinander et al. The knowledge gained during the STSMs and through the subsequent data analysis will be used for the benefit of the COST Action ES1404, and will advance current state of snow research in general.

MATERIALS AND METHODS

The STSMs allowed us to extend *in situ* data collected in Arctic Sodankylä and Antarctic Marambio GAW stations (Meinander et al. 2016, under review for GI), and during experiments in Sodankylä and Kumpula, Helsinki, with a series of pioneer measurements conducted in Iceland. Since 2007, the local UV albedo of snow at the Sodankylä Arctic Research Centre (67^{o}22’N, 26^{o}39’E, 179 m asl), Finland, is measured at the operational albedo field. The Arctic UV albedo measurements were planned and initiated as part of the International Polar Year IPY-2007 activities (IPY project ORACLE-O3) (Meinander et al., *ACP*, 2008). Two sensors of UV Biometer Model 501from Solar Light Co. (SL501) with similar spectral and cosine responses are used, one facing upwards and one downwards, at a height of 2 m. The SL501 spectral response resembles the action spectrum for erythema, wavelengths in the UVB (280–310 nm) are most weighted. The albedo of snow (A) is the ratio of the up-welling UV irradiance to the down-welling irradiance (A = UVery↑/UVery↓), at 2π angle.

Figure 1. Icelandic glacier Solheimarsjokull in March 2016. Snow and ice were sampled from the glacier for further filtering, and filter analysis in the FMI laboratory.

Our Soot on Snow (SoS-2013) experiment (Meinander et al. 2014, Peltoniemi et al. 2015, Svensson et al. 2016) was carried out in Sodankylä (67°22'N, 26°39'E, 179 m a.s.l.), Finland, North of the Arctic Circle, to study the effects of deposition of BC, Icelandic volcanic sand and glaciogenic silt on the surface albedo, snow properties and melt of the seasonal snow (Fig. 2a). The BC was soot originating from chimneys above residential wood-burning fireplaces, except for one experimental spot with soot from a chimney of an oil burner, and another one with soot from a peat-burning power plant. The Icelandic volcanic sand used in our experiments is a dark mixture of the volcanic ash of glaciofluvial nature, originating from under the Myrdalsjokull glacier, which may be mixed with the ash of the Eyjafjallajokull eruption in 2010 and the Grimsvotn eruption in 2011. The glaciogenic silt is lighter in color than sand, from light-brown to slightly yellowish color consisting mainly of silt and some coarse clay sized particles, which could be deposited on the local glaciers as well as transported over several hundreds of kilometers towards Europe.

Climatic effects of the deposition of light-absorbing particles on snow have been proposed to result from reduced snow albedo and increased melt. Such effects are usually linked to soot (BC), but also volcanic ash and dust from Iceland have an influence which may be larger in the Arctic region than that of soot. There are over 30 active volcanoes or volcanic systems in Iceland, and seven major dust sources. The properties of ash and dust from these sources show considerable physical and chemical variability. One of the objectives of the reported STSMs is to study the influence of the deposition of volcanic ash and dust on snow properties (albedo, density and melt), and compare these to soot (BC). For this purpose, further outdoor and laboratory experiments, as well as modeling will be applied. The collected Icelandic ash and dust samples will also be measured at 325-2500 nm with an ASD spectroradiometer coupled to a contact probe, as well as with the FGI's goniospectrometer FIGIFIGO (Fig. 2b), see e.g. Peltoniemi et al. (2014) and Zubko et al. (2016).

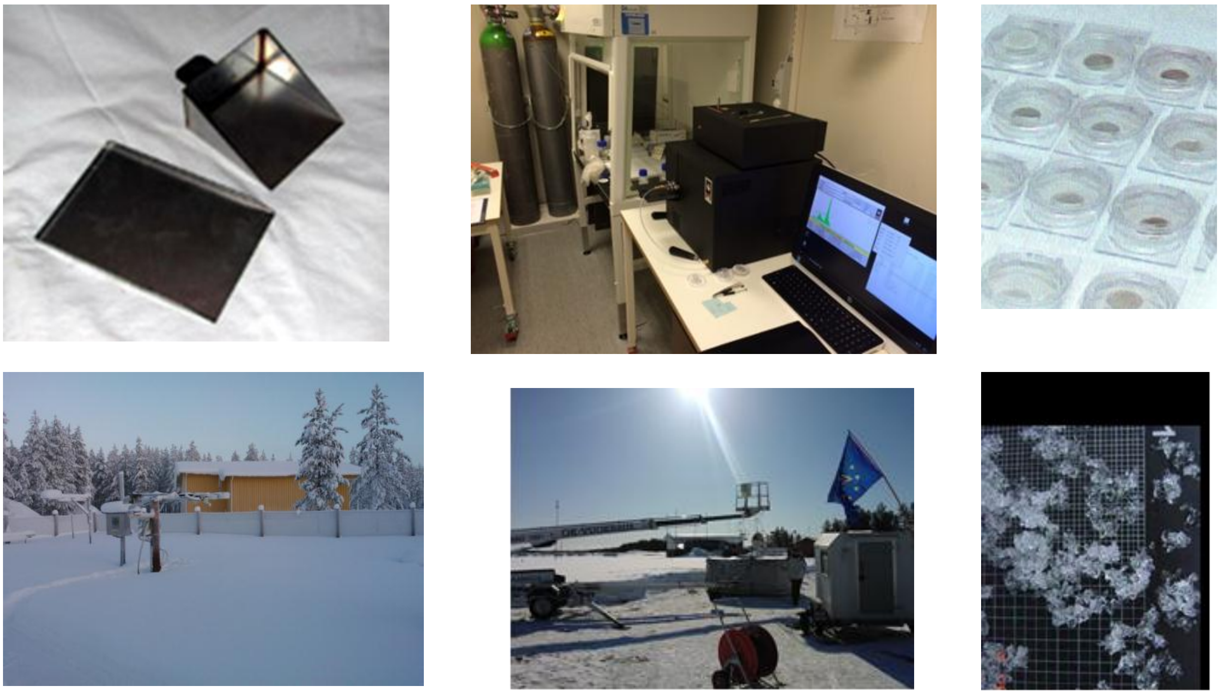

Figure 2a. Examples of the methods used in our work. Top panel: The Snow density cutter, the Sunset OC/EC Laboratory analyzer, snow impurity filters to be analyzed. Lower panel: Sodankylä albedo field. SoS field campaign in Sodankylä. Snow grain size visual detection plate.

Figure 2b. The Finnish Geodetic Institute's field goniospectrometer, FIGIFIGO, can be used to measure the reflectance properties of different targets, such as snow, various types of vegetation, planetary analogues, sand, gravel, as well as many man-made targets. The potential use of the results from these measurements are diverse; including their use as ground truth references for remote sensing studies, testing and validation of theoretical scattering models, estimating climate change over time, measuring other ecological effects caused by changes in land cover, and more generally, to aid in the identification and analysis of both seasonal, and nonseasonal variations of targets of interest.

IDEAS FOR FUTURE PUBLICATIONS

1. BC, OC and albedo

Meinander et al. (2013) reported unexpectedly low snow albedo values of Arctic seasonally melting snow in Sodankylä, north of Arctic Circle. These low albedo results of melting snow were confirmed by three independent data sets. These low values were explained to be due to: (i) large snow grain sizes up to ~3 mm in diameter (seasonally melting snow); (ii) meltwater surrounding the grains and increasing the effective grain size; (iii) absorption caused by impurities in the snow, with concentration of elemental carbon (black carbon) in snow of 87 ppb, and organic carbon 2894 ppb. The high concentrations of carbon were due to air masses originating from the Kola Peninsula, Russia, where mining and refining industries are located. SNICAR-model showed that the impurities absorb irradiance more with the shorter wavelength.

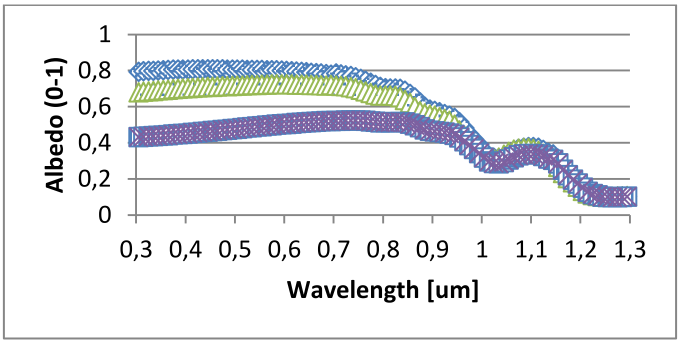

Figure 3. The SNICAR-model (Flanner et al. 2007) using realistic input parameter values showed that the impurities absorb irradiance the more the shorter the wavelength. The biggest change is at the ultraviolet (UV)

2. BC and snow density

Meinander et al. (2014) presented a hypothesis that Black Carbon (BC) may decrease the liquid-water retention capacity of melting snow. We also presented our first data, where both the snow density and elemental carbon content were measured. In our snow density related experiments, artificially added light-absorbing impurities decreased the density of seasonally melting natural snow. No relationship was found in case of natural non-melting snow.

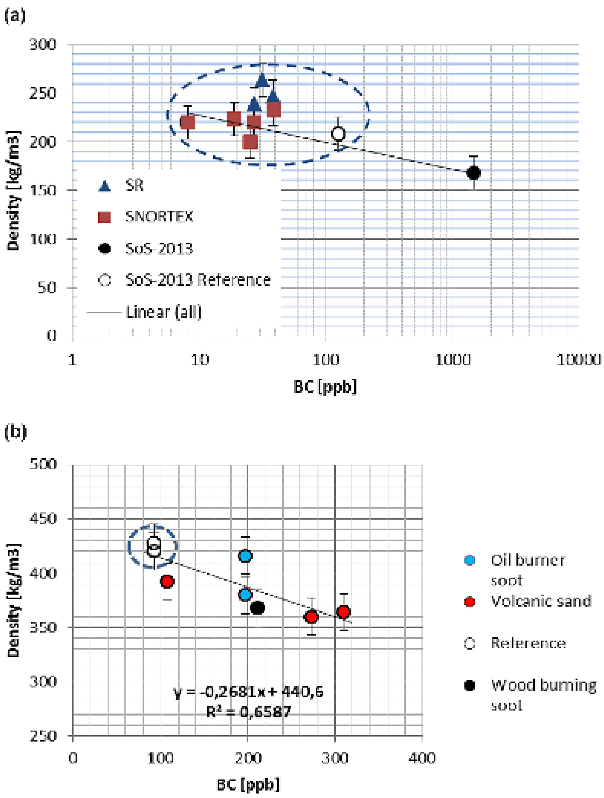

Figure 4. The density of melting snow (b) suggested a density decline for snow containing BC. For nonmelting snow (a) this was not obvious (adapted from Meinander et al. 2014)

3. Depending of the amount and properties of the particles on snow/ice surface, the impurities can either melt snow or insulate snow from melting (see Dragosics et al. 2015).

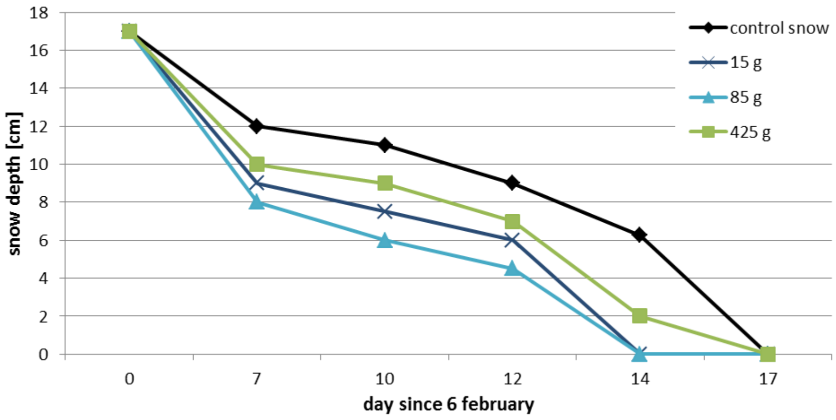

Figure 5. Artificially added Icelandic tephra particles (15 g, 85 g and 425 g) on snow increased snow melt compared to control snow.However, the snow with biggest amount of particles melted slower than the snow with smaller amounts of particles suggesting a possible insulation effect.

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APPENDIX

Helpful links to the data relevant to the conducted field work:

SM4 sensor, snow temperature profiles

http://snowsense.is/is/

snow depth daily:

http://brunnur.vedur.is/athuganir/urkoma/snj0.html?

http://www.vedur.is/vedur/athuganir/urkoma/#teg=urkoma

snow forecast:

SWE

http://brunnur.vedur.is/kort/harmonie/2016/03/23/06/harmonie_island_sd.html

http://brunnur.vedur.is/kort/harmonie/2016/03/23/06/harmonie_island_snowcovermobility.html

http://brunnur.vedur.is/kort/harmonie/2016/03/23/06/harmonie_island_snowcoverage.html

http://brunnur.vedur.is/kort/harmonie/2016/03/23/06/harmonie_island_snowdriftaccumulation.html

http://brunnur.vedur.is/kort/harmonie/2016/03/23/06/harmonie_island_snowdrift.html

all maps and models:

http://brunnur.vedur.is/kort/spakort/

Researchers we met during the STSMs and who enhanced us with new ideas and useful discussions:

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Ragnar Heiðar Þrastarson

Sigríður Sif Gylfadóttir

University of Iceland

Inga Jonsdottir

Throstur Thorsteinsson

<u>Details on the Field Trips, Measurements and Places</u>

Tuesday 15 March

Mt. Esja

Points: Esja F, Esja 2

Wednesday 16 March

Ostabuðin lunch

Reykjavik University

Öskjuhlíð forrest

Points: Forrest 3

Nautholtsvik geothermal beach

Thursday 17 March

Bláfjöll Ski Resort

Points: Ski 4

Hveragerði bananahusid – greenhouse visit

Sólheimajökull glacier, glacial tongue from Myrdalsjokull glacier

Points: Glacier 5, Glacier Snow 6

Myrdalssandur desert

Points: Desert 7

Friday 18 March

Icelandic Meteorological Office, University of Iceland, Faculty of Earth Sciences

Mt. Esja

Points: Esja F melted, Esja 8, Esja vegetation on snow