TNA User Report

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Project title	Optical properties of Icelandic dust: implication for the radiative balance
Name of the accessed chamber	CESAM
Number of users in the project	2
Project objectives (max 100 words)	The aim of this project is to investigate the optical properties of mineral dust samples from Iceland, which are necessary to estimate its impact on the radiative budget. In particular, the scientific objectives of this project are: 1. To determine the wavelength dependent optical properties (mass absorption, scattering, and extinction efficiencies, respectively MAE, MSE, and MEE, in m2/g, and the complex refractive index, m = n-ik) of Icelandic dust particles from major dust storm source regions in Iceland 2. To understand the role of mineralogical composition and iron speciation in light absorption efficiency of Icelandic dust
Description of work (max 100 words):	Soil samples were collected from 5 main dust hot spots in Iceland. Size distribution and optical measurements were carried out in a 4.2 m^3 stainless-steel atmospheric simulation chamber “CESAM”. Mineral dust was generated by mechanical shaking of parent soil and injected in the chamber. The size distribution and the aerosol optical properties were measured on-line. Filter samples were collected over the duration of the experiment to analyse the elemental composition and mineralogy of the dust particles.

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[1] Physics; Chemistry; Earth Sciences & Environment; Engineering & Technology; Mathematics; Information & Communication Technologies; Material Sciences; Energy; Social sciences; Humanities.
[2] UNI= University and Other Higher Education Organisation;
RES= Public Research Organisation (including international research organisations and private research organisations controlled by public authority);
SME= Small and Medium Enterprise;
PRV= Other Industrial and/or Profit Private Organisation;
OTH= Other type of organization.
[3] UND= Undergraduate; PGR= Post graduate; PDOC= Post-doctoral researcher; RES= Researcher ENG= Engineer; ACA= Academic; TEC= Technician.
[4] Reproduce the table for each user who accessed the infrastructure

Trans-National Access (TNA) Scientific Report

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Instructions

Please limit the report to max 5 pages, you can include tables and figures. Please make sure to address any comments made by the reviewers at the moment of the project evaluation (if applicable, in this case you were informed beforehand). Please do not alter the layout of the document and keep it in Word version.
The report will be made available on the eurochamp.org website. Should any information be confidential or not be made public, please inform us accordingly (in this case it will only be accessible by the European Commission, the EUROCHAMP-2020 project partners, and the reviewers). Please include:

- Introduction and motivation
- Scientific objectives
- Reason for choosing the simulation chamber/ calibration facility
- Method and experimental set-up
- Data description
- Preliminary results and conclusions
- Outcome and future studies
- References

Name of the PI: Zongbo Shi
Chamber name and location: CESAM, CNRS-LISA
Campaign name and period: Iceland Dust, 14/01/2019-25/01/2019
Text:

Introduction and motivation

High latitude dust sources contribute to 5% of the global dust budget (Bullard et al., 2016). Iceland is an important source of dust at high latitudes. Iceland volcanoclastic sandy desert is the largest on Earth. It covers 22,000 Km^2 (Arnalds, 2010), and represents a source of dust to the North Atlantic, Europe and the Arctic (Prospero et al., 2012, Bullard et al., 2016, Meinander et al., 2016, Zwaaftink et al., 2016).

Iceland dust has volcanogenic origin and primarily consists of poorly crystallized (amorphous) basaltic material with about 10% Fe content (Arnalds et al., 2014). In particular, magnetite (Fe_3O_4) has been used as mineralogical marker of Iceland dust sources (Moroni et al., 2018). Magnetite strongly absorbs light (Matsui et al., 2018) but its content is usually low in low latitude dust (Lazaro et al., 2008). Magnetite content in Iceland dust may be relatively high but data is lacking.

Quantifying the content of iron oxide/oxyhydroxide in dust is the key to estimate the radiative forcing of dust aerosols (Lafon et al., 2006, Balkanski et al., 2007, Caponi et al., 2017, Di Biagio et al., 2019) as well as the feedback effects between dust aerosol and snow albedo (Meinander et al., 2016). Deposition of Iceland dust on snow has been shown to lower its albedo, as much as black carbon, the strongest light absorbing species in aerosol (Meinander et al., 2014, Dagsson-Waldhauserova et al., 2015, Peltoniemi et al., 2015). There is evidence of Iceland dust deposition in Greenland and dust transport to the Arctic region (Prospero et al., 2012, Dagsson-Waldhauserova et al., 2013, Dagsson-Waldhauserova et al., 2017, Zwaaftink et al., 2017). Consequently, Iceland dust may contribute to the Arctic warming and its amplification, which is twice faster than global average.

The iron speciation as well as the mineralogical composition could be a key factor controlling the Iceland dust spectral absorption properties but at present limited information exist. The results of this study will thus provide valuable data to feed global models to estimate the radiative effect of Icelandic dust. This will help us to reduce the uncertainties in climate change prediction.

Scientific objectives

The aim of this project is to investigate the optical properties of mineral dust samples from Iceland, which are necessary to estimate its impact on the radiative budget.

In particular, the scientific objectives of this project are:

1. To determine the wavelength dependent optical properties (mass absorption, scattering, and extinction efficiencies, respectively MAE, MSE, and MEE, in m^2/g, and the complex refractive index, m = n-ik) of Iceland dust particles from major dust storm source regions in Iceland

2. To understand the role of mineralogical composition and iron speciation in light absorption efficiency of Iceland dust

Reason for choosing CESAM

To measure the optical properties, first the soil dust have to be re-suspended. The absorption and scattering properties of the re-suspended particles, their size distribution, and composition will then need to be measured in order to characterize their coupled changes. The CESAM atmospheric chamber available at LISA is particularly adapted to this aim, where specific protocols have been developed to provide repeatable and realistic generation of particles from parent soils. The chamber is also equipped with a number of state-of-the-art instrumentation (aethalometer, nephelometer, extinction cavities, online FTIR) to determine the spectral aerosol absorption, scattering, and extinction coefficients. The particle number size distribution can be measured from 20 nm to 30 µm. LISA also offers capability to measure the chemical and mineralogical composition of the particles, including the amorphous fraction, by X-ray fluorescence (XRF) and X-ray diffraction (XRD). Thus, the CESAM chamber at LISA enables us to study the spectral optical properties of Iceland dust and their relationship with the particle composition and mineralogy (Di Biagio et al., 2014, Di Biagio et al., 2017a, Di Biagio et al., 2017b).

Method and experimental set-up

Soil samples were collected from 5 main dust hot spots in Iceland. Size distribution and optical measurements were carried out in a 4.2 m^3 stainless-steel atmospheric simulation chamber "CESAM". Mineral dust was generated by mechanical shaking of parent soil and injected in the chamber. The size distribution and the aerosol optical properties were measured on-line. Filter samples were collected over the duration of the experiment to analyse the elemental composition and mineralogy of the dust particles.

Mineral dust samples

Chamber experiments were conducted on 7 soil samples from 5 different dust source area in Iceland (Figure 1).

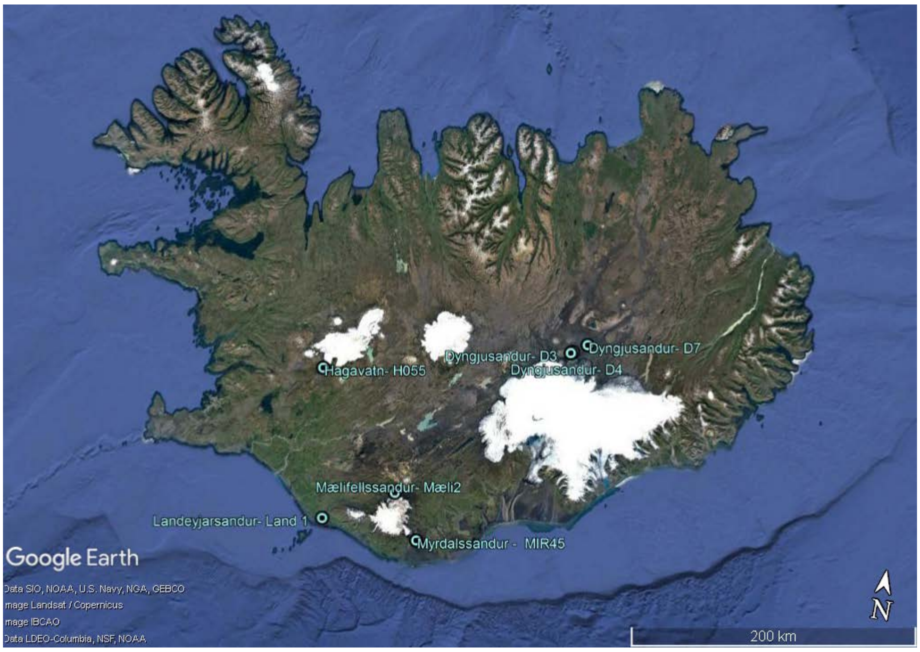

Figure 1. Sample collection points

Experiment Protocol

<u>CESAM chamber experiments</u>

Before being processed, the soil samples were sieved to <1 mm to remove the non-erodible fraction.

15 g of soil were placed in a Buchner flask and flushed with pure N_2 for 10 minutes at 5 L/min to eliminate gaseous contamination. The sample was then shaken for 5 minutes at 70 Hz on a Retsch AS 200 sieve shaker, and injected in CESAM for 10 minutes at 10 L/min by compressed nitrogen.

A number of instruments were used to measure the aerosol size distribution and optical properties during the campaign (Table 1). Figure 2 shows a schematic diagram of the chamber.

Table 1. List of instruments used during the campaign

Instruments type	Measurement	Operating wavelength
Aethalometer (Magee Scientific, Model AE31)	7 Wavelength absorption	(370, 420, 470, 520, 660, 870, 950 nm)
Nephelometer (TSI Inc., Model 3596)	3 Wavelength aerosol light scattering	(450, 550, 700 nm)
Cavity attenuated phase shift SSA analyser (CAPS-PMssa, by Aerodyne)	particle single scattering albedo (SSA)	630 nm

Cavity attenuated phase shift extinction analyser (CAPS-PMex, by Aerodyne)	particle extinction	450 nm
in-situ FTIR (Bruker Tensor 37)	extinction coefficient in the infrared	2 -16 µm
Scanning mobility particle sizer (SMPS). Composed of a differential mobility analyser (DMA, Model 3080) and a condensation particle counter (CPC, Model 3772)	Aerosol size distribution	0.02-0.88 µm
SkyGrimm optical particle counter (Grimm Inc., Model 1.129)	Aerosol size distribution	0.25-32 µm
Grimm optical particle counter (Grimm Inc., Model 1.109)	Aerosol size distribution	0.25-32 µm

Mineral dust was collected on polycarbonate filters (47 mm Nuclepore, nominal pore size 0.4 µm) at 7 L/min for XRF (clipped filters) and XRD (unclipped filters) analysis. The filter collection started 10 minutes after the injection process was completed. Since the XRF and XRD analysis require respectively ~300 µg and ~1mg of dust, we collected one XRD filter for 3 hours and two XRF filters in succession for each sample. This will allow us to verify if any change in composition occurred throughout the experiment as larger particles deposit sooner.

The chamber was manually cleaned before loading a new sample to avoid contamination. 3 “Chamber blanks” were collected for 1 hour to check the background in the chamber. 6 “Filter blanks” were sampled for 20 seconds to estimate the initial concentrations on the filters. 12 “Lab blanks” (filter with no exposure) were stored to be used to calculate the method detection level (MDL) and the reliable quantitation level (RQL). The experiment was repeated two times on two dust samples, D4 and MIR 45, to test the reproducibility of the method. Ammonium sulphate was run as control at the end of the campaign.

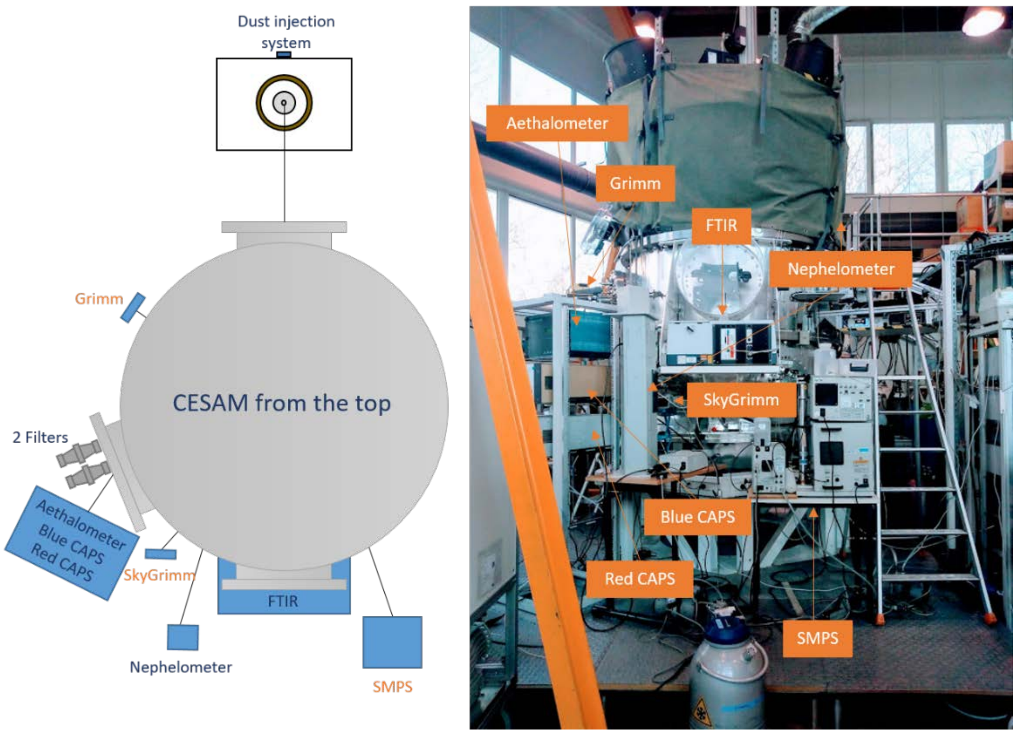

Figure 2. Schematic diagram of the chamber and the instrument setting

Manifold experiments

A PM_{10} collection system was built at CESAM (Figure 3). This was composed of three main parts:

- Injection area - Buchner flask, Retsch AS 200 sieve shaker (Figure 3a)
- Resuspension chamber - Glass Manifold, two HEPA filters (Figure 3b)
- Sampling apparatus - PM_{10} sampling head, filter holder, vacuum pump (Figure 3c)

15 g of dust were sieved to 1 mm, and then purged with pure N_2 for 10 minutes at 5 L/min in the Buchner flask. To ensure an initial particle-free environment, the system was flushed for 5 minutes with pure N_2. The sample was shaken at 70 Hz and injected in the chamber by compressed nitrogen at 10 L/min, while the air was pumped at a flow rate of 30 L/min into the PM_{10} sampling head. PM_{10} fractions were collected on 0.4 µm polycarbonate filters and stored in centrifuge tubes.

The system was cleaned manually between different samples. Before the dust injection, 3 blanks were sampled for 5 minutes to check the background level.

The particle size distribution was tested by an optical counter (Grimm) on a mineral dust sample. Filter samples were collected for XRD and XRF analysis. These will be used to verify whether the PM_{10} sample composition is the same as the mineral dust collected by CESAM.

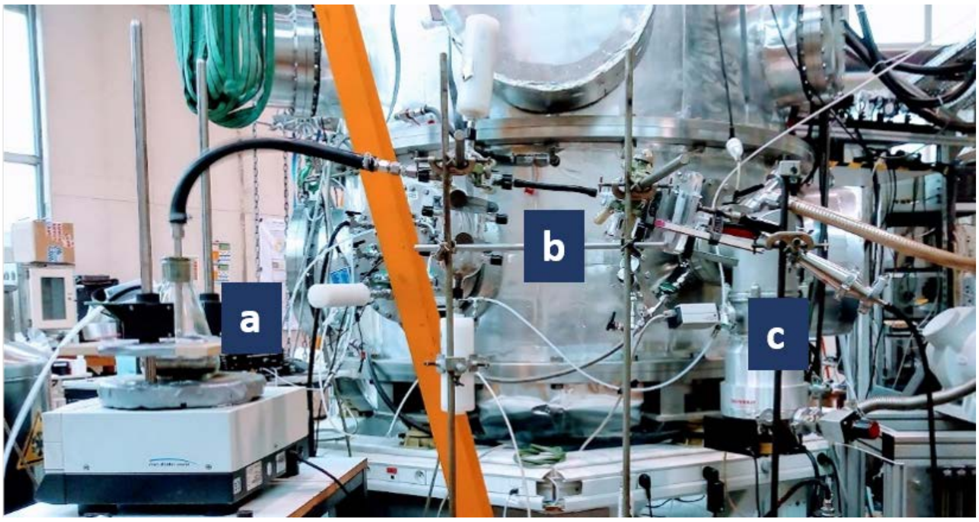

Figure 3. PM_{10} collection system. a) Injection area, b) Resuspension chamber, c) Sampling apparatus

Sequential Extractions

Extraction procedures were conducted on the PM_{10} fraction at the home laboratory to quantify specifically the content of iron oxide, magnetite and total iron in the dust samples following Poulton and Canfield (2005), Shi et al. (2009, 2011, and 2012).

Preliminary results

The density of the samples was determined at the home laboratory by the use of a He-pycnometer. The measured values were in the range from 2.8 g/cm^3 to 3.1 g/cm^3.

The Fe speciation analysis shows that the iron oxide content varied from 0.3%(wt) to 0.8%(wt), while the magnetite fraction from 0.9%(wt) to 1.7%(wt). This is completely different from what observed in the mineral dust from Asia and Africa.

Data collected at CESAM (optical measurements and size distribution) is currently being analysed. Overall, there is a good correlation between the Grimm and SkyGrimm data (Figure 4). Moreover, the total mass on filters calculated using Grimm/SkyGrimm measurements is in good agreement with the total mass estimated based on the XRF data (Figure 5).

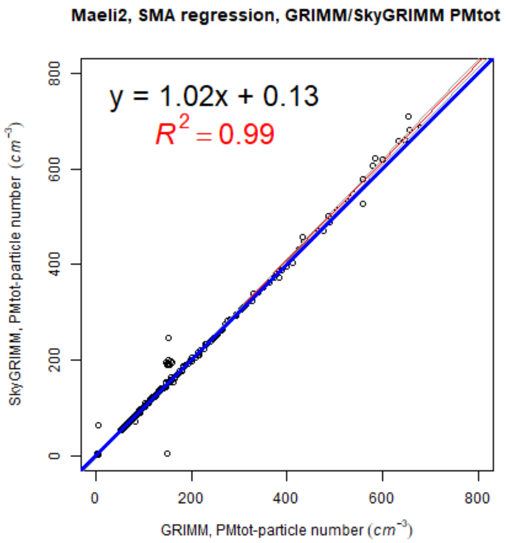

Figure 4. Reduced major axis regression, Grimm~SkyGrimm measurements for the sample "Maeli2"

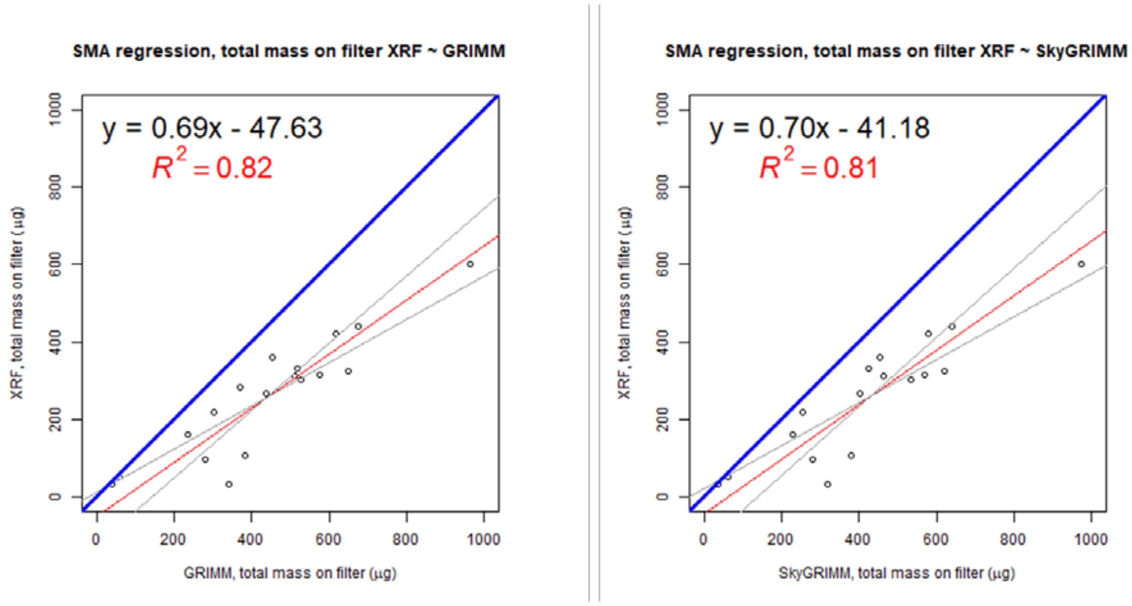

Figure 5. Reduced major axis regression, calculation of the total mass on filters, Grimm/SkyGrimm~XRF

Future plan

Further data analysis on the CESAM results are being carried out. The optical properties (mass absorption/scattering/extinction efficiency, single scattering albedo, complex refractive index) of the Iceland dust will be calculated following Formenti et al. (2014), Di Biagio et al. (2014), Di Biagio et al. (2017a), Di Biagio et al. (2017b).

The sample mineralogical characterisation will be completed by October 2019:

- XRD analysis – CNRS-LISA, July-September 2019
- Determination of total iron content (nitric acid extraction) – University of Birmingham, June 2019
- XANES analysis – DIAMOND synchrotron, July 2019

Preliminary data will be presented at the UK Arctic Science Conference (Loughborough, September 11-13th 2019).

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