SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: ECOST-STSM-Request-CA16202-45179
STSM title: Optical properties of Icelandic dust: Implication for the radiative balance
STSM start and end date: 30/09/2019 to 31/10/2019
Grantee name: Clarissa Baldo

PURPOSE OF THE STSM:

The purpose of this STSM was to gain the skills to process optical data to study the optical properties of mineral dust. These skills can be applied to my current research on the Icelandic dust to build a new dataset of optical parameters. These data can be used in models to evaluate the radiative effects of Icelandic dust, and to improve the understanding of the impact of mineral dust on the Artic climate. This STSM also aimed to establish connection with the host partner LISA-CNRS and other institutions to promote collaboration in the study of the physical properties of mineral dust.

The specific scientific objectives are:
1. To determine the wavelength dependent optical properties of Icelandic dust, in particular the complex refractive index (m = n + k, where n is the real part and k is the imaginary part of the refractive index)
2. To understand the role of the mineralogical composition in the light absorption efficiency of Icelandic dust

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

During the STSM, I received training at LISA (Creteil, France) on processing the size distribution and optical measurements of mineral dust. We worked on a method to process the size distribution data and to perform optical calculations on the Icelandic dust. We also made a first estimation of the complex refractive index based on the Icelandic dust mineralogical composition.

The Icelandic dust complex refractive index was calculated from the mineralogical composition of the dust samples. Then, the size distribution and optical data were processed to estimate the complex refractive index of Icelandic dust by using the Mie theory (the data were collected during the campaign in January 2019 at the CESAM atmospheric simulation chamber at LISA.).

The volume−average complex refractive index ($\tilde{n}$) was calculated based on the chemical and mineralogical composition of the Icelandic dust samples as in Formenti et al. (2014):

$$\tilde{n} = \sum_{j} f_j \times \tilde{n}_j$$

Where f_j is the mineral volume fraction, and $\tilde{n}_j$ is the complex refractive index of the mineral.
The mineral volume fractions were calculated using the mineral mass fractions and reference mineral densities. The mineral mass fractions were determined based on the results from the XRD analysis and sequential extractions, while the mineral densities and complex refractive indices were found in literature.
Subsequently, the calculated volume−average complex refractive index was applied in the optical calculations.

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Regarding the optical calculations, the first step was to process the size distribution measurements (Formenti et al., 2018). The size distribution of Icelandic dust was measured by two optical counters (OPC) between 0.25 -32 µm, and by the scanning mobility particle sizer (SMPS) from 0.02 to 0.88 µm. Before starting the optical calculations, it was necessary to combine the measurements from these two instruments.

First, the optical and mobility diameters were converted to geometric diameters. For the conversion from optical diameter to geometric diameter, the complex refractive index of the dust particles is required. It was assumed that the complex refractive index (m = n + k) of the Icelandic dust was within the range estimated from the calculation of the volume−average complex refractive index. For the SMPS, the conversion from mobility diameter to geometric diameter was applied by varying the shape faction (X) from 1 to 1.8. The different OPC-SMPS combinations were visually examined in the overlap region to define the parameters (n, k and X) for the conversion to geometric diameters.

The second step was to merge the data: a boundary diameter (D_p) was defined in the overlap region. All the bin sizes from the SMPS were considered, while the OPC data were discarded for $D_{OPC} < D_p$.

The next step was the linear interpolation. New high-resolution intervals (dlog = 1/256) were set to interpolate the merged data. After the interpolation, the data were normalized to keep the same number of particles.

In order to estimate the real size distribution in the chamber, the data were corrected for the OPC and SMPS particle loss. It was then necessary to estimate the actual size distributions based on the particle loss of each instruments.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The main results from my training at LISA are:

First, I learned the method to calculate the volume−average complex refractive index ($\tilde{n}$) of mineral dust. And, this method was applied to the Icelandic dust. Icelandic dust has basaltic composition, the main minerals are plagioclase (anorthite) and pyroxene (augite), while the glass fraction is generally between 60-90%.
To calculate the volume−average complex refractive index, the highest uncertainty was to assign a complex refractive for the glass fraction. Three different scenarios are proposed:

1) $m_{glass} = m_{augite}$
2) $m_{glass} = m_{anorthite}$
3) $m_{glass} = m_{basaltic\ glass}$

At 638 nm (the OPC operating wavelength), the real part (n) of the volume−average complex refractive varied from 1.57 to 1.64, while the imaginary part (n) was between 0.001-0.003. The values were in the range reported in literature for volcanic ash, sand and rocks from Iceland.

Second, a method to merge the size distribution data from the OPC and SMPS measurements (see section 2) has been implementing. This is a crucial part before the optical calculations.

Third, I have learned how to perform the optical calculations of mineral dust. The variation of the extinction efficiency $Q_{ext}(\lambda)$ with the particle radius, is calculated using the Mie theory for different n and k. The extinction coefficient $\sigma_{ext}(\lambda)$ is then calculated as:

$$\sigma_{ext}(\lambda) = \int \frac{\pi D^2}{4} \times Q_{ext}(\lambda) \times \frac{dN}{d\log D} \times d\log D$$

Where N is the number concentration of particles in cm^{-3}, and D is the particle diameter.

The same approach is used to calculate the scattering and absorption coefficients.

The scattering and extinction coefficients were measured during the campaign at CESAM by a Nephelometer at 450, 550, 700 nm, and by two Cavity attenuated phase shift extinction analyzers (CAPS) at 630 and 450 nm. A truncation correction is applied to both datasets, as nephelometer and CAPS measure scattering and extinction for solid angles θ between 7-170° and 4-176°, respectively.

The absorption coefficient is calculated from the attenuation measured by the Aethalometer at 370, 420, 470, 520, 660, 870, 950 nm. Corrections for particle loading, aerosol particle scattering, and multiple scattering by filter fibers are applied to convert the attenuation coefficient into absorption coefficient (Di Biagio et al., 2017).

To retrieve the real and imaginary part of the complex refractive index, the measured scattering, absorption and extinction coefficients are input into a software, which processes the data by comparing the optical measurements with the calculated extinction/scattering coefficients for different n and k.

FUTURE COLLABORATIONS (if applicable)

This project allowed me to extend my research network, and to build cooperation with new institutions. First, I have established connection with the LISA-CNRS, where I received my training. Also, I discussed my project with international researchers at the University Paris Diderot and the IMT Lille Douai in France, and we have started some new collaborations on the study of Icelandic dust.

During this training, I gained new valuable technical skills. I learned how to process size distribution data and optical measurements to assess the optical properties of mineral dust. These skills can be applied to other studies related to the physical properties of dust particles in the future.

I will keep collaborating with the research team at LISA to determine the optical parameters, and in particular the complex refractive index of Icelandic dust. We are working forward two publications. In the end, this project will provide a new dataset of optical parameters, which can be fed to global models to estimate the radiative impact of Icelandic dust, contributing to assess the role of mineral dust in the Arctic climate change.

We are now in contact with modelers from the University of Exeter (UK) and from the Institute of Physics Belgrade (RS), which has further extended my network, and it is also contributing to expand the network and the activity of the inDust community.

References

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