Characterisation of atmospheric aerosol sampled from an aircraft using scanning electron microscopy

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Atmospheric aerosol particles are known to have an **important effect on climate** via reflecting sunlight and affecting cloud properties.

Aerosol size and composition **measurements** are needed at cloud-relevant altitudes.
Aim of this work:

- Develop a technique to measure a and characterise aerosol particles in the atmosphere using a **Scanning Electron Microscope (SEM)**
- Some of our applications:
  - Test inlet efficiency on FAAM aircraft
  - Complement other measurements we do (INP)
  - Quantify the amount of mineral dust at locations remote from the source
• Description of the technique
  • Applications
SEM: background

- A SEM is a microscope that works with electrons instead of photons (optical microscope)

- The smaller wavelength of electrons compared with photons allows to go to higher resolutions
SEM: background

• Beam of electrons impact the sample:

• A detector processes the outgoing electrons and produces images from them.

• Two types of outgoing electrons:
  – Backscattered: (inelastic scattering with the atoms). **Z contrast**
  – Secondary electrons (elastic scattering with the atoms). **Topographic contrast**
SEM: EDS

- **Energy Dispersive Spectroscopy (EDS)**
  - Excited electrons go to lower energy states
  - Z dependent X-Ray emission

- Compositional information of the elements in the sample
SEM: single aerosol measurements

• Sample aerosol particles on polycarbonate filters (mainly using FAAM aircraft)

• Use of **Tescan VEGA3 XM SEM** at LEMAS (University of Leeds)

• Software: **AZtecFeature** (for particle analysis on the SEM)

• Scanning the filter under the SEM and getting images of the aerosol
SEM: single aerosol measurements

- **AZtecFeature**: Aerosol are identified based on their brightness.
- **Morphological information** (spherical approximation) → **Size distribution**
- **EDS** in each aerosol. Size-resolved categorization of particles based on their composition:
  - Aluminosilicate, Clay, Sea salt, Sulfate…

![Graph showing size distribution](image1)
![Composition chart of 170720 at 1251](image2)

- **Legend**:
  - Mineral dust
  - Carbonaceous
  - Ca-rich
  - Sulfate
  - Sea salt
  - Aged sea salt
  - Other

- **Composition of 170720 at 1251**
  - N = 4802
- Single aerosol studies have been done in the past:
  - Krejci et al., 2005. (Amazone, not automated)
  - Chou et al., 2008. (Africa, not automated)
  - Young et al., 2015 (Arctic, automated)
  - Price et al. in prep. (Cape Verde, automated)

- Different set ups with different advantages and disadvantages
**SEM: our set up**

- **Secondary electron detector:**
  - Some particles are transparent under the BSE detector.
  - Potential source of error in previous similar works.

- **30nm Ir or Au coating:**
  - Minimizes artefacts from pores

- **Automated data collection:**
  - Allows to get size and composition of thousands of particles per session
• Description of the technique

• Applications
Applications: FAAM BAe 146 inlet

Sub-isokinetic sampling

Inertial removing of droplets (can be kept off or on through a bypass)

Bent

To the filter

Theoretical calculations done by S. T. Parker and J. Trembath

- Sub-isokinetic sampling: leads to an enhancement of large aerosol particles
- Bent: adds an inertial cut-off for large aerosol particles
- Bypass: modifies the flow (less sub-isokinetic sampling when it is on, therefore smaller enhancement of large aerosol)
Two studies (we will do more):
- Small effect of the bypass
- Certain enhancement of large aerosol particles (also seen in Price et al., In prep.)
- Representative sampling when comparing with optical probes
Applications: Mineral dust size distribution

- Difficult to quantify the amount of mineral dust in the atmosphere
- Large differences on dust evolution among models
- Dust is one of the most efficient ice-nucleating materials

- Single particle analysis SEM technique:
  - Allows to estimate the size, number, surface and mass of atmospheric dust.
Applications: Mineral dust size distribution

- Surface size distribution
- Size-resolved compositional analysis
- Dust: particles with compositional signatures of silicates, aluminosilicates, clays...

\[ S_{\text{dust}} = 60 \pm 15 \mu m^2/cm^3 \]
Conclusions

- We developed a technique to obtain a size-segregated composition distribution of atmospheric aerosol particles.

- We are using this technique on samples collected with the FAAM aircraft.

- This technique is being used to help the characterisation of the FAAM aircraft inlet and quantify the amount of atmospheric dust.