

Individual particle characterization of long range transported wildfire aerosols in the Arctic region

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Abstract

Wildfires pose a serious question on climate change in the Arctic as a source of particles which are able to modulate the net radiative forcing in the atmosphere and the albedo properties of the exposed surfaces [1]. Recent studies [2,3] on the mineral chemistry and geochemical signature of aerosols sampled at ground level and along vertical profiles at the scientific base of Ny-Ålesund, Svalbard Islands (78°55'30"N 11°55'20"E), have shown a significant contribution of biomass burning forest fire on this area especially in summertime when the prevailing northern circulation is able to transport wildland fire emissions far from their sources located in North America and Eurasia tundra regions. A strong advection event of biomass burning aerosol from Alaska affected Ny-Ålesund in the mid of July, 2015 (see Figure 1).

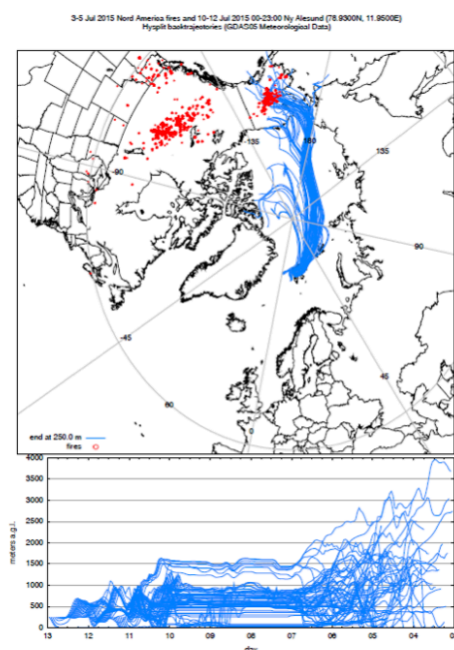


Figure 1 - Hourly back trajectories (blue lines) ending in Ny Alesund (Svalbard Islands) on 10-12 July 2015. Fire spots are indicated by red circles (source: NASA-FIRMS, Fire Information for Resource Management System).

The event was exceptionally intense as it extended in the troposphere over of the Arctic region for a long period of time with well documented direct effects on the regional radiative budget and weather forecast. For these reasons it was the subject of a complete characterization research project based on a combined multidisciplinary approach. This preliminary contribution is focused on the

single particle characterization. To this aim the sampling was performed at the Gruvebadet station [4], near Ny-Ålesund (Svalbard) (from July 13th 17.30 UTC to July 14th 6.30 UTC) using a DEKATI 12-stage (0.045-0.085-0.14-0.22-0.35-0.58-0.76-1.06-1.66-2.68-4.08-8.5 μm cut-off size ranges from 0.045 to > 8.5 μm) low volume impactor (flow rate 118 L min⁻¹) operating with nucleopore polycarbonate filters (Whatman, $\text{O} = 25$ mm, porosity 0.1 μm) in order to obtain a sample suitable for scanning electron microscopy techniques.

Four different main particle types have been recognized, namely carbonaceous particles (CPs), ammonium sulfate (AS), potassium chloride (KC) and mineral dust (MD). CPs consist of tar balls (TBs) and organic particles (OPs). TBs are combustive spherical CPs with no internal structure and good resistance to electron beam damage. Fine and giant TBs (Fig. 2a,b) are present in the sample but the number of the fine largely exceeds that of the giant TBs. Both fine and giant TBs stand isolated within the particulate matter and show the same brightness at variable accelerating voltage of the incident electron beam. These features reveal massive surface oxidation and reduced surface reactivity of TBs, likely the result of intense atmospheric aging associated with prolonged long range transport of the aerosol. OPs are combustive rounded to capsule-shaped CPs. They are very similar to TBs except for a lower resistance of the exposed surface to electron beam damage (Fig. 2c), likely the result of ammonium sulfate and/or more volatile organic carbon coatings upon the particles. Both TBs and OPs contain only carbon and oxygen but the C/O atomic ratio could not be determined due to the carbon coating treatment of the samples. This ratio was estimated assuming a 100Å regular thickness of the carbon film coating upon the particles giving a 70/30 value. This value is consistent with those obtained experimentally on North American forest burning plants. Tar balls are typically found in stage 1, while the organic particles are the main phase present in stage 4. AS consists of platy regular shaped crystals forming typical elongated aggregates (Fig. 2d). This feature suggests rapid growth of AS crystals upon the sampling filter just after collection. The peculiarity of AS particles is to be very unstable under the electron beam leaving a carbonaceous residue upon irradiation. As a typical constituent of haze it reveals the occurrence of a mixing between the biomass burning plume and a secondary aerosol of possible distinct origin (biomass burning and/or anthropogenic sources). AS is the main constituent phase in stages 5 and 6.

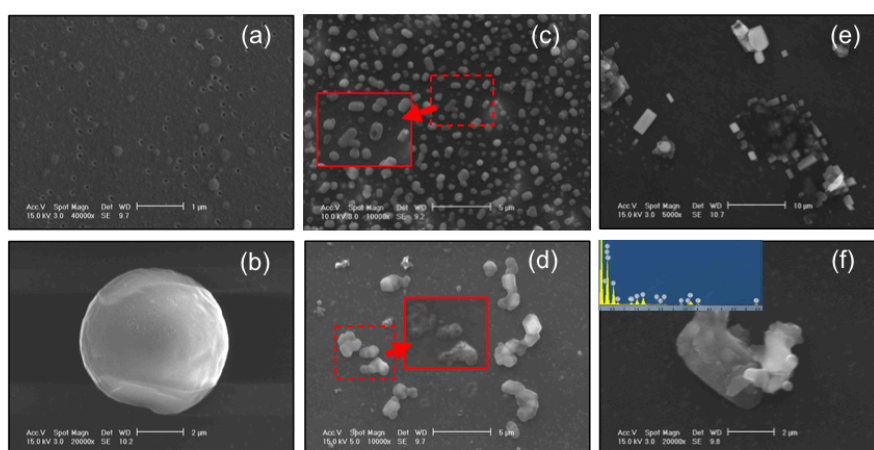


Figure 2 - SEM micrographs (SE images) of the particle types. (a) fine TB particles (stage DK1); (b) a coarse TB (stage DK12); (c) organic carbon roundish particles coated by unstable ammonium sulfate (stage DK4); (d) externally mixed ammonium sulfate particles containing organic carbon refractory cores and mantles (stage DK5); (e) potassium sulfate precipitates from water droplets (stage DK10); (f) externally mixed sheet mineral (left) and carbonate (right) grains partially coated by mixed chloride and sulfate salts with corresponding EDS spectrum (stage DK8). The larger particle size in stages 1, 4 and 5 is ascribed to lower density in respect to the model (a, c) and particle growth upon the filter after collection (d), while the smaller particle size in stage 10 is associated with salt precipitation from water droplets after collection

KC consists of euhedral crystals with rectangular to square section forming coarse grained isolated crystals and/or large aggregates of fine grained well sorted particles (Fig. 2e). These features suggest direct precipitation of the salt from oversaturated water droplets as the origin for these particles. This may be the reason for KC is ubiquitous in many stages (2, 3, 7, 10 and 12).

MD includes different classes of minerals such as silicates (quartz, feldspar, sheet minerals), metal oxides (Fe- and Ti-oxides) and carbonates. (calcite and dolomite).

The particle size is generally coarse in the silicates and carbonates and fine in the oxides, while the shape mostly depends on the particle type (i.e., platy and rounded to irregular and indented in the silicates, stocky in the carbonates and acicular in the oxides). The composition of the sheet minerals (biotite, muscovite, illite, chlorite, montmorillonite and smectite) is compatible with that of silicate minerals during summer. Externally mixed silicate and/or carbonate grains are frequently coated by sulphate/chloride salts precipitates (Fig. 2f). MD is typically found in the upper stages (7 to 11) of the impactation pile. Sodium chloride (halite) and calcium sulfate (gypsum) are ubiquitous minerals in the sample [4]. They consist of typically cubic (halite) or needle-shaped (gypsum) fine grained crystals and are present in all the stages. The composition of the bulk sample is dominated by CPs (about half of total number of particles) followed by AS (about one third of the particles), while TBs, MD and KC share the rest. The proportion between TBs and OPs is compatible with a mechanism of aging by particle condensation from organic gases or, by transformation of pre-existing biomass burning organic particles. Results of analyses show similarities but also significant differences with those found in the case of freshly emitted wildfires developed at much lower latitudes in summer [5, 6].

References

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