Aerosol deposition in the main African dust transport region: establishing a long-term time series at São Vicente, Cape Verde

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Introduction

Mineral dust is one of the dominating aerosol species in the atmosphere. Particularly, the tropical North Atlantic Ocean is heavily affected by dust, changing cloudiness, precipitation, nutrient fluxes into the ocean, radiation balance etc.

A number of field experiments with different foci recently investigated dust properties (e. g., SAMUM, AMMA, SHADE, PRIDE, GERBILS). However, these experiments usually lasted a short time, usually a few weeks, some a season. As a result, they captured a low number of dust episodes only. Given the highly episodic nature of dust outbreaks and a potential inter-annual variation, the question arises, how these experiments should be rated with respect to an annual average, or how they can be compared to each other.

This actual problem arises from the nonexistence of longer time series in the tropical North Atlantic Ocean (except at Barbados; Trapp et al, 2010).

To overcome these shortcomings, a quasi-continuous measurement of aerosol deposition was installed in the middle of December 2011 at the Cape Verde Atmospheric Observatory (http://ncasweb.leeds.ac.uk/capeverde/), at São Vicente Island, Cape Verde.

Sampling and Analysis

Particle collection

- sedimentation trap with rain shelter (Fig. 1)
- dry deposition, mainly by sedimentation
- dominated by particles larger than approximately 1 µm
- carbon adhesive substrate
- collection time between few hours (during dust events) and ten days, data shown here between Jan 24 and Feb 19, 2012

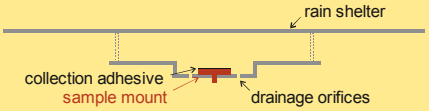

Fig. 1: Cross section of sedimentation trap

Analysis

- automated scanning electron microscopy with energy-dispersive X-ray detection
- particle size (projected area diameter) and shape measurements by image analysis (Fig. 2)
- scanning of 80% of the particle cross section with electron beam to get chemical information representative for the total particle
- quantification of single particle chemical composition with particle size correction
- statistical significant numbers of particles are analyzed (for this work, 22,000)
- classification according to chemical composition

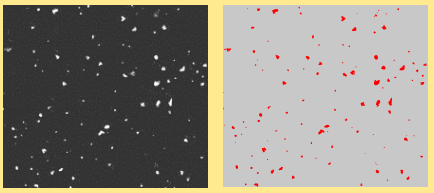

Fig. 2: Backscatter electron image of sampling substrate (left) and particle masks used for analysis (right); image width is 370 µm (180 nm/pixel)

Particle mixing state and deposition coincidence

- a particular detection problem exists for internal mixtures of different aerosol species (e. g., dust/sea-salt, dust/sulfate): the coincidence of one particle depositing on (or close) to another, so a false internal mixture is measured
- for an infinitesimal small particle – which is, in our case, a particle smaller than the lateral resolution of a single pixel – the mixing coincidence probability (MCP) equals to the area fraction covered by the already deposited particles
- for larger particles, the MCP depends on the size distribution: assuming a monodisperse distribution of spherical particles and widely spaced deposition (i. e. low area coverage), the MCP of an incoming particle
  - of the same size is four times the covered area fraction
  - of the double size is nine times the covered fraction, and so on

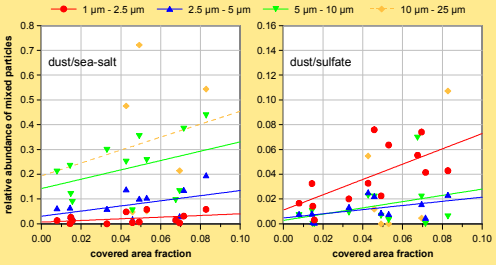

Fig. 5: Relative abundance of strongly internally mixed particles (SIMP) as function of the area fraction covered by particles; the lines give the linear regressions

- the number of detected strongly internally mixed particles (SIMP; at least 20 atom% contribution of different aerosol species) is dependent on the substrate loading (Fig. 5)
- for dust/sulfate the abundance of SIMP follows MCP for small particles, for the dust/sea-salt mixing it follows a MCP for equal-sized particles (at 5 µm)
- the occurrence of SIMP on substrate is no direct proof for their atmospheric existence
- an extrapolation to zero coverage (regression) shows that in average there is a (size-dependent) fraction of SIMP (e. g. 0.15 for particles between 5 µm and 10 µm)

- the ratio of abundance of different species influences the MCP (inter-species MCP is highest for similar abundance) – subject to further modeling
- apart from SIMP, weak internal mixtures, i. e. small amounts of sulfate attached to silicate particles, are always very abundant (> 95 % of the particles)

Sampling on Cape Verde

- unique situation due to extremely uniform wind direction distribution (trade winds – NNE)
- as result, the sedimentation trap acts as horizontal elutriator
- gradients in particle concentration (Fig. 3)
- gradients in particle size distribution (Fig. 4)
- to achieve comparability between samples, analysis of the very center only (approximately 1 mm²)
- in future to be overcome by a particle deposition model
- with a deposition model, inference on atmospheric size distribution might be feasible

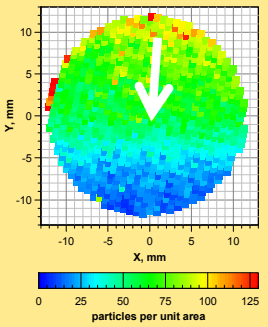

Fig. 3: Map of particle number concentration per area on the sampling substrate for particles with diameters between 2 and 4 µm (marine phase, Jan. 30, 2012 to Feb. 2); main wind direction is shown by the white arrow

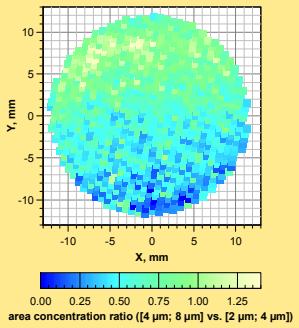

Fig 4: Same as Fig. 3, but instead the ratio of the concentration of larger particles (4 µm < d < 8 µm) to smaller ones (2 µm < d < 4 µm) is shown

General composition

- composition varies extremely between dust and marine phases (Fig. 6)
- during dust phases, a Ca-rich mode is present as reported before (Kandler et al., 2009)
- pure sulfate particles are a minor component

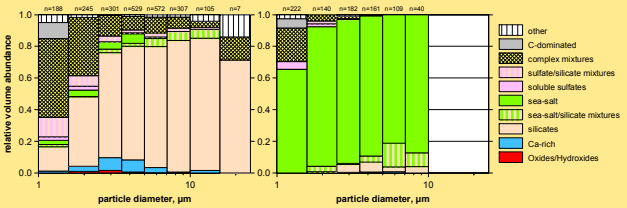

Fig. 6: Size-resolved composition of deposited aerosol at Cape Verde during a dust phase (left, Feb 7, 2012) and a marine phase (right, Jan 30 to Feb 2, 2012)

Iron distribution (Fig. 7)

- similar behavior as reported before for Cape Verde (Kandler et al., 2011) for particles smaller than 10 µm, but higher iron content for larger particles
- "other" particles are mixtures of dust with sulfate and sea-salt
- low variation in iron distribution during this particular dust event

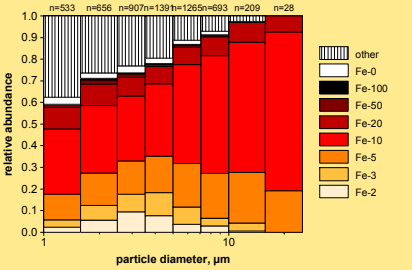

Fig. 7: Size-resolved iron distribution among the particles during the dust phase Feb 6 to 10, 2012

References

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