Mineral dust chemistry, mineralogy, shape, mixing state, complex refractive index and microphysics - determined by electron/optical microscopy and by X-ray diffraction at Praia, Cape Verde, in winter 2008

DFG-Forschergruppe samum SAharan Mineral dUst experiMent

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INTRO

The Saharan Mineral Dust Experiment (SAMUM) is focussed on the understanding of the radiative effects of mineral dust.

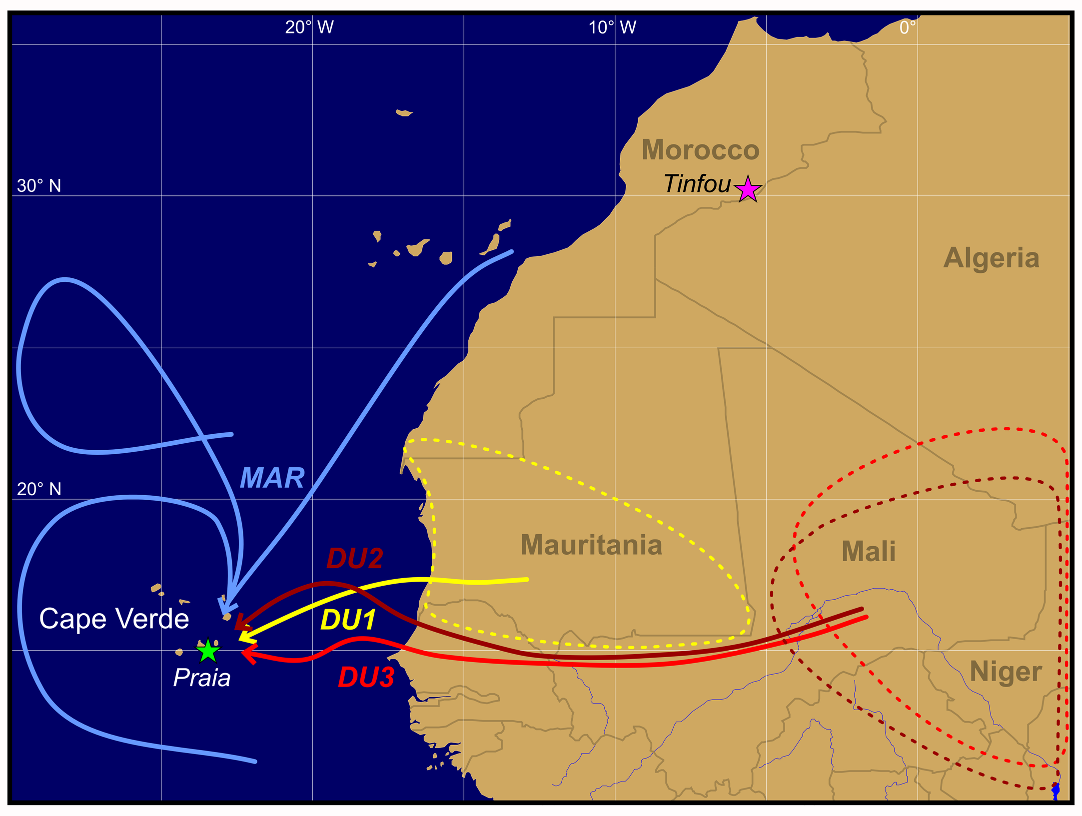
The winter campaign of the Saharan Mineral Dust Experiment 2 in 2008 was based in Praia, Island of Santiago, Cape Verde. It was dedicated to the investigation of transported Saharan mineral dust.

For this work, samples were collected ground-based with a miniature impactor system, a sedimentation trap, and a free-wing impactor. The size-resolved chemical composition was determined by scanning electron microscopy and energy-dispersive X-ray microanalysis of single particles.

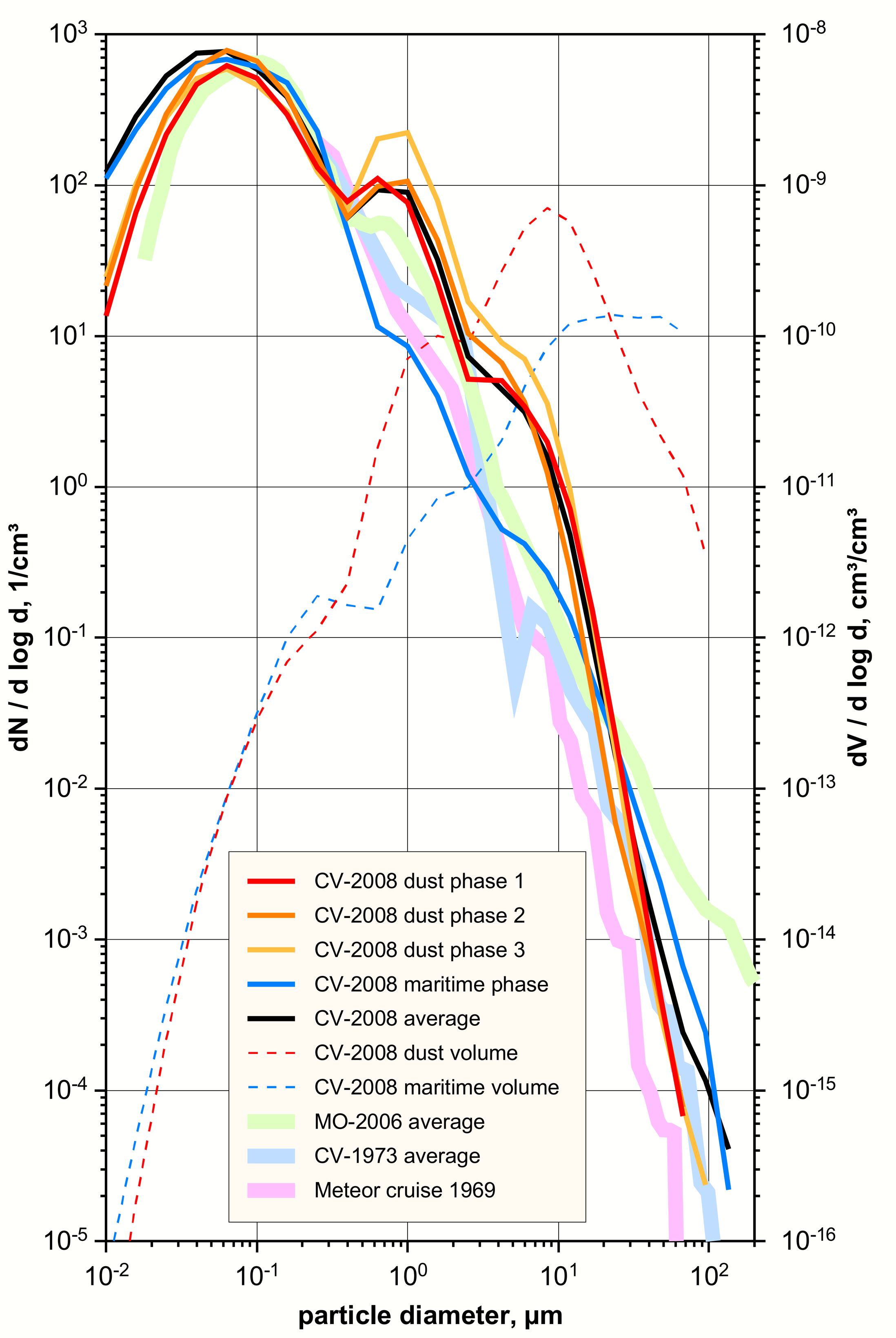
Size distribution measurements were performed by a combination of a scanning mobility particle sizer, an aerodynamic particle sizer, and optical microscopy of nozzle- and free-wing impactor-collected aerosol.

Mass concentrations were determined by gravimetry of filter samples (TSP, PM_{10}, and $PM_{2.5}$). The same filter samples were investigated by X-ray diffraction to assess the mineralogical composition of the dust.

Map of the measurement region. The measurement sites of Praia and Tinfou are marked. Air mass transport trajectories during the three dust events are shown together with the source regions identified by satellite remote sensing and operational dust observations. For the maritime phases, example trajectories are displayed.



Particle number and volume size distribution of the aerosol at Praia, Cape Verde, in 2008. For comparison, size distributions from Tinfou, Morocco (2006, SAMUM-1) and earlier measurements in the same region are shown (1)



RESULTS

Three major dust events were recorded. During the dust events, the total mass concentration is raised by a factor of more than 10 over the maritime mass concentration, demonstrating the strong impact of Saharan dust advection on the aerosol load at Cape Verde.

The size distribution measurements (Fig. 1) show number maxima around 50 to 70 nm particle diameter in four modes (50 to 70 nm: sea-generated and sulfate aerosol; 700 nm: superposition of marine aerosol and advected mineral dust; 5 to 10 µm: sea-salt and dust in changing proportions; 10 to 50 µm: pure mineral dust). During DU1 slightly more particles around 10 µm diameter were found, corresponding to shorter transport distances.

The chemical composition of the aerosol is strongly size-dependent, and three size regimes were identified (Fig. 2). During dust situation, particles smaller than 500 nm in diameter consist mainly of sulfate and mineral dust; between 500 nm and 2.5 µm, a transition range with increasing abundance of mineral dust towards larger particles is observed; larger particles are mineral dust only. During maritime situations, a higher amount of sea-salt is present for all particle sizes larger than 300 nm.

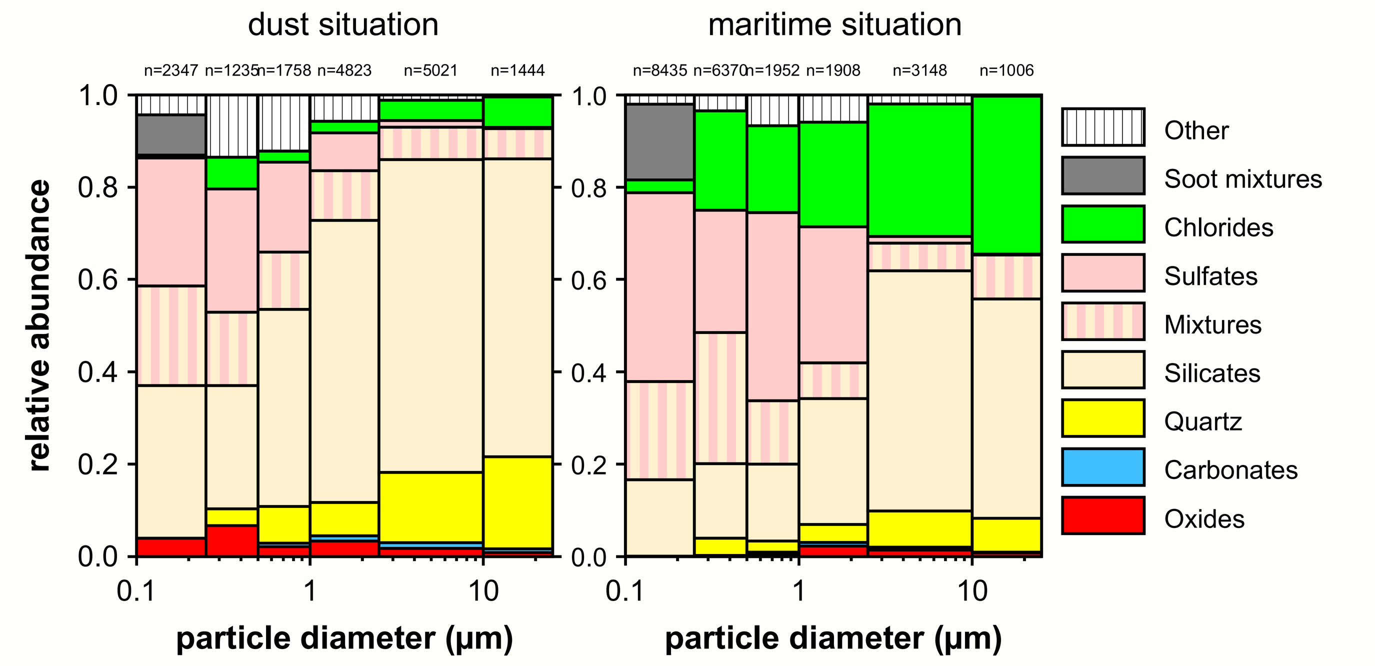
The mineralogical composition reveals kaolinite as the dominating clay mineral (Fig. 3a). It also confirms that the aerosol during the three dust periods was composed – within experimental errors – of the same components. A large contrast was found to the maritime periods when a considerable amount of halite and gypsum was present. Lower amounts of plagioclase and slightly higher amounts of K-feldspar as well as the lower clay fraction abundance (Fig. 3b) during the maritime situations underline the change in particle source. Using electron microscopy on size-segregated samples (not shown), from the chemical fingerprint of the particles three different types of silicate particles were distinguished: quartz, feldspars, and clay mineral aggregates. The clay mineral aggregate group is most abundant and shows the highest chemical variability. With increasing particle size the abundance of the feldspars and quartz increases at cost of the clay minerals in the aerosol.

The abundance of internal mixtures of different aerosol types at Cape Verde is low in general (Fig. 3c), except for mineral dust mixtures with sulfate and for soot mixtures with sulfate. Internal mixtures are more frequently observed among small particles than among large ones (not shown). An internal mixture between mineral dust and soot was not detected. The abundance of mineral dust sulfate mixtures is higher for the DU2 and DU3 events, pointing to their longer transport times.

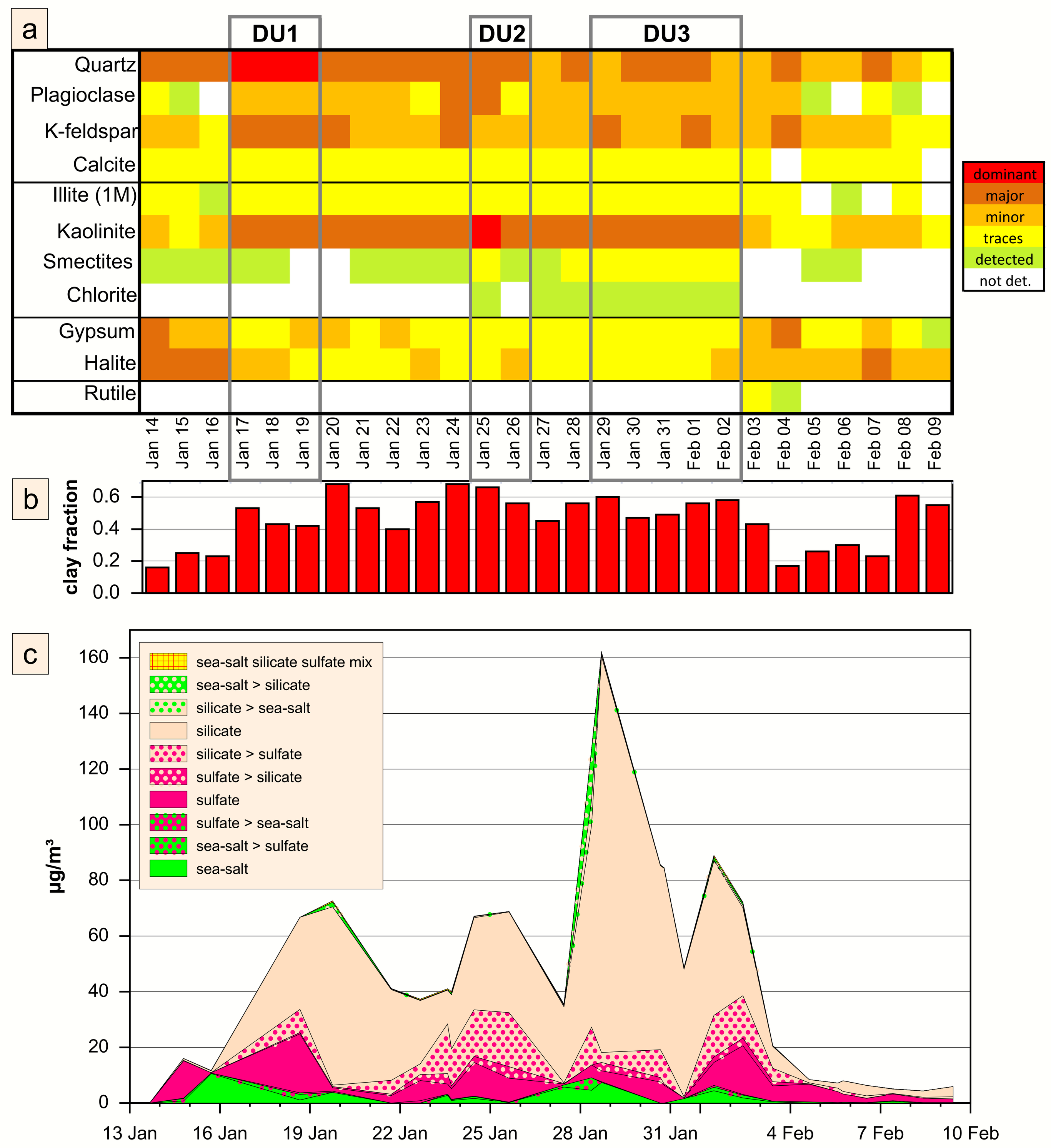
Complex refractive indices were modeled from the chemical composition. While generally the variation for the real part is low, the imaginary parts exhibit complex multimodal distributions as function of particle size and meteorological situation (Fig. 4). Depending on the wavelength, separate modes exist. The main mode of absorbing mineral dust in the super micron size range shows a decreasing imaginary part with increasing particle size. During the maritime periods, a much higher abundance of non-absorbing particles is present, but also a significantly higher amount of highly-absorbing soot is observed. Soot mainly impacts the absorption for wavelengths longer than the hematite absorption edge, while for shorter wavelengths mineral dust absorption is dominating.

The shape of the particles was found to be very similar to that of earlier measurements of Saharan dust (Fig. 5). Depending on the meteorological situation, three to four size ranges of aspect ratio were observed. In general smaller particles showed lower aspect ratio values than larger ones, depending on their composition. Different aspect ratio distributions were found for humid and dry situations (not shown).

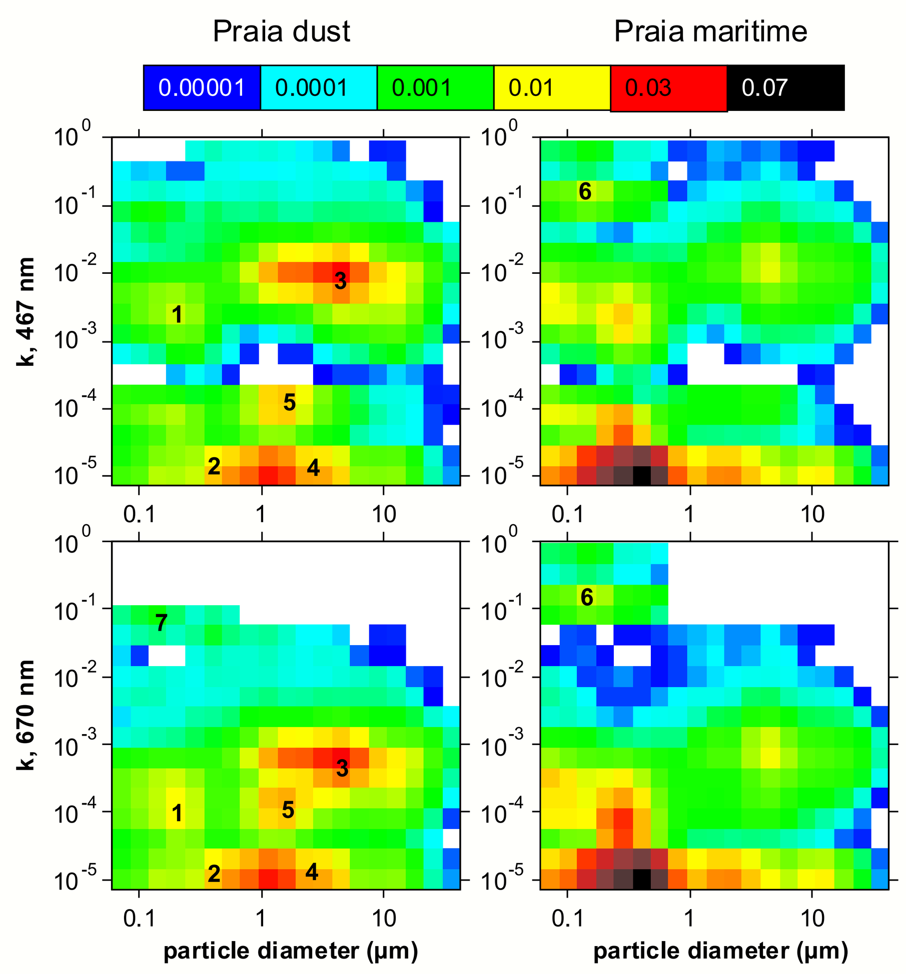
Average composition of the aerosol at Praia, Cape Verde, in winter 2008. Particle composition was determined by electron microscopy and energy-dispersive X-ray analysis (2)



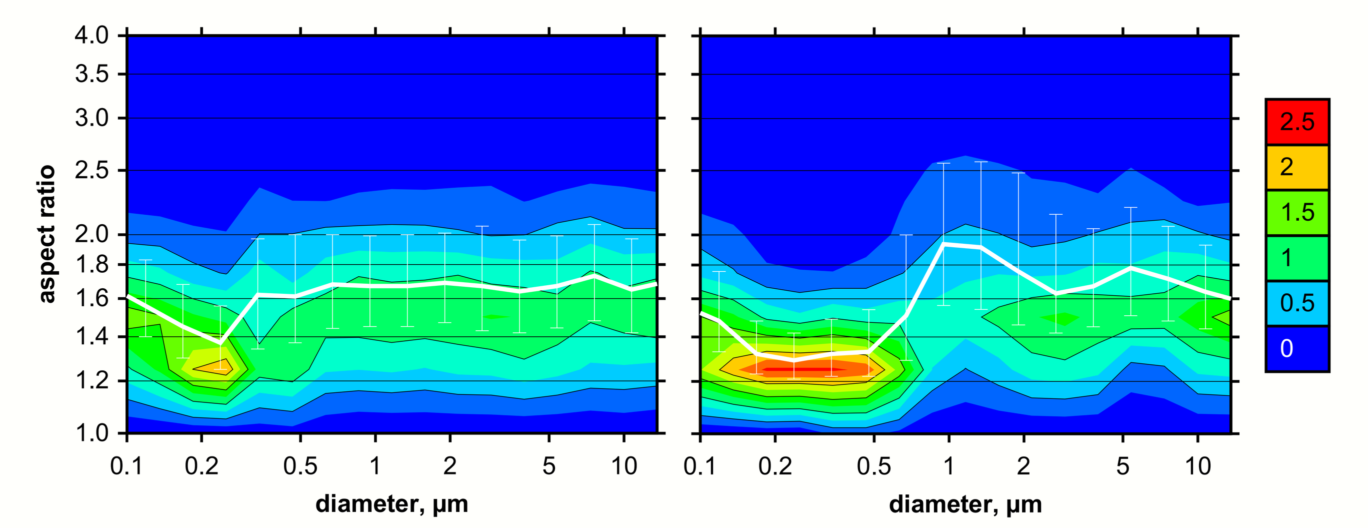
Time series of compositional properties at Praia, Cape Verde, in 2008:
a) mineralogical composition of the total suspended particle matter
b) clay mass fraction (particles with diameter smaller 2 µm) determined by settling velocity
c) mixing state of the individual particles with diameters between 1 and 2.5 µm determined by electron microscopy and parameterized by a three-component model (dust/sea-salt/sulfate); the relative values are weighted with the mass concentrations ($PM_{2.5}$) for the according time interval (3)



Multimodal distribution of the imaginary part of the complex refractive index as function of particle size at Praia. Particle compositions are marked as follows: (1) dust/dulfate mixture; (2) pure sulfate; (3) mineral dust; (4) sodium sulfate/chloride; (5) mix of (3) and (4); (6) and (7) soot/sulfate mixtures (4)



Particle shape distribution density (2D aspect ratio) as function of particle size for dust (left) and maritime situation (right) at Praia, Cape Verde. The white curves show median and interquartile range (5)



Acknowledgements

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References (Special issues on SAMUM: Tellus 61B and 63B)

Kandler, K., Schütz, L., Jäckel, S., Lieke, K., Emmel, C. and co-authors 2011. Ground-based off-line aerosol measurements at Praia, Cape Verde, during the Saharan Mineral Dust Experiment: Microphysical properties and mineralogy. Tellus 63B, in press. doi: 10.1111/j.1600-0889.2011.00546.x.

Kandler, K., Lieke, K., Benker, N., Emmel, C., Küpper, M. and co-authors 2011. Electron microscopy of particles collected at Praia, Cape Verde, during the Saharan Mineral dust experiment: particle chemistry, shape, mixing state and complex refractive index. Tellus 63B, in press. doi: 10.1111/j.1600-0889.2011.00550.x