Atmospheric Aerosol in Dronning Maud Land, East Antarctica: physical and chemical properties and source region analysis

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Objective

Knowledge on atmospheric aerosols is essential because aerosols affect the Earth's radiation budget and also cloud properties by acting as cloud condensation (CCN) or ice nuclei. Antarctica is considered the best preserved region on Earth from anthropogenic emissions. However, a detailed underdanding of present-day atmospheric transport pathways of particles and of volatile organic compounds (VOCs) from source to deposition in Antarctica is essential in order to document biogeochemical cycles and the transport of micro-pollutants to Antarctica. We present seasonal physical aerosol properties, source region analysies and first results of particle chemistry and VOC analyses.

Instrumentation

Since 2010, the aerosol total number (TSI3776; > 3 nm) and size distribution (TSI3340; 90 – 7000 nm), the aerosol absorption coefficient and mass concentration of light absorbing aerosol (Magee Sci. AE31 aethalometer), and the aerosol total scattering coefficient (Ecotech Aurora 3000 nephelometer) have been measured. A DMT cloud condensation nuclei counter (CCNc) has been installed during three austral summers (Herenz et al., 2019). A CIMEL sunpphotometer has been installed during austral summers since 2009 and a MAX-DAOS (multi-axis differential optical absorption spectroscopy) was installed from Dec 205 to February 2018. Atmospheric particles for chemiical analyses have been collected during the last three austral summers by high-volume sampling on pre-baked quartz-fibre filters (organics), polyurethan foam filters (VOCs), and on Teflon filters (inorganics). Passive samplers have been installed at 7 locations along a 250 km transect from the coast to the plateau for year-round collection and analysis on organics, VOCs and inorganics.

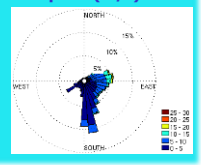
Station

The Belgian Antarctic station Princess Elisabeth is situated in Dronning Maud Land, East Antarctica, (71°57'S, 23°20'E, 1390 m asl; Pattyn et al., 2010), around 180 km inland. **The station is inhabited mid-November to end of February. Between March and November, the station and instruments operate continuously under remote control.**

Meteorology

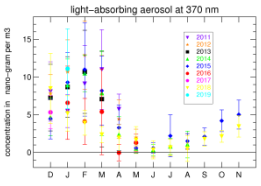
Overviews of meteorological, cloud, and precipitation conditions are given in Gorodetskaya et al., 2013, 2015. The graph shows multi-annual averages of **wind direction and speed (m/s)**.

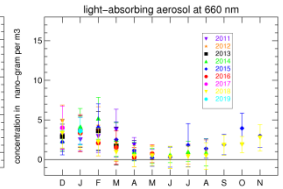
There are 2 predominant Meteorological regimes: cold catabatic (air masses from Antarctic interior) and synoptic (extratropical cyclones, frontal systems)

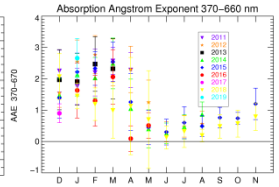


Seasonal Aerosol Properties

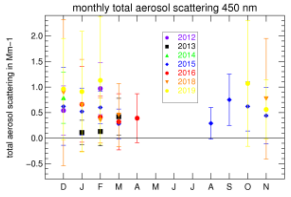
Below, the multi-annual cycles of montly means for the mass concentration of light-absorbing aerosol at 370 nm (left), 660 nm (middle) and the Absorption Angstrøm Exponent (AAE; right) are shown. The AAE values for summer indicate the presence of particles absorbing stronger at shorter wavelengths, i.e., not only soot, as soot has a flat absorption spectrum. AAE values distinctly < 1 are a consequence of measurements at the detection limit.

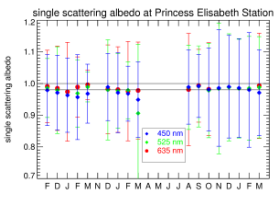




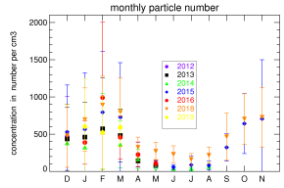


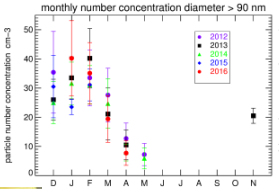
The aerosol total scattering coefficient at 450 nm (first graph to the right) showed a less distinct seasonal cycle and the low values and larger errors underline the overall low aerosol amount. The single scattering albedo (second graph to the right) was directly derived from measured absorption and scattering coefficients.

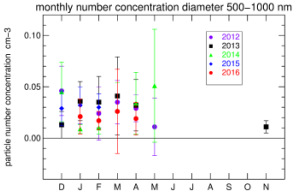




The multi-annual cycle of monthly means of the total particle number concentration (N_{tot}; #/cm³) is shown in the left graph below. Particle number larger than 90 nm is shown in the middle graph. Particle number > 500 nm is very low (right graph).





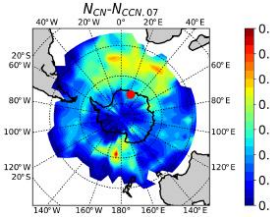


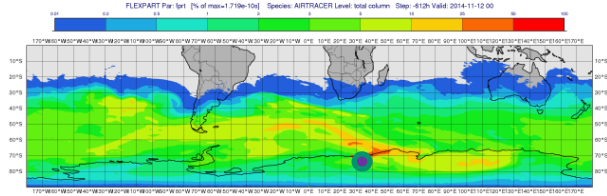
N_{CCN} @	Median (10%-, 90%-perctl.) #/cm³
0.1 % ss :	14 (10 – 23)
0.2 % ss :	81 (56 – 110)
0.3 % ss :	121 (90 – 168)
0.5 % ss :	177 (125 – 260)
0.7 % ss :	212 (138 – 326)

The concentration of CCN (N_{CCN}) was measured for supersaturations (ss) between 0.1% and 0.7%. The table to the left gives results from 3 austral summers (2013/14; 2014/15; 2015/16). More detailed results in Herenz et al., 2019.

Source Regions

Potential source contribution functions (PSCF) were calculated for the three austral summers when the CCNc was installed (Herenz et al., 2019). PSCF is a receptor modelling method, based on 10-days air mass back trajectories and used to identify regions that have the potential to contribute to measured concentrations at the receptor site. The graph below to the left shows as example the PSCF for the fraction of total particles (N_{ch}) which are not activated to CCN at ss=0.7% ($N_{CCN,0.7}$). For all summers, this fraction of very small particles averaged to 36%. The Southern Ocean close to PE station (red dot in graph) has the highest potential as source for these particles.

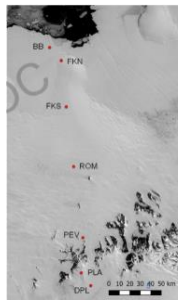




The FLEXPART particle dispersion transport model has been used to identify potential source regions for the chemical trace compounds of the particle chemical analyses. FLEXPART was driven with ECMWF ERA-Interim meteorological fields and was run in backward mode for the duration of around one month. The upper right graph shows an example for a sample taken near the coast on 7 December 2014, showing the percentage of contribution of a certain area to the simulated received particle mass at the reception location.

Chemistry

In addition to the active and passive sampling mentioned above ('Instrumentation'), also surface snow samples have been taken, near the coast and at the seven sites of passive sampling (see right image). With the help of the method developed by Vanderstraeten et al., 2020 and the analysis of 14 so-called rare-earth elements (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu), different source areas in South America, Southern Africa or in Australia could be distinguished. For the sample taken on 7 Dec 2014, the analysis points to Southern Africa as a source. The The FLEXPART calculations (graph above) support that Southern Africa can indeed be a source region.



Preliminary results for VOCs like Benzaldehyde, Acetophenone or Dimethylsulfone show decreasing trends from coast to the plateau. CFC-11 instead seems to increase from coast to the plateau.

TAKE HOME:

- total particle number: seasonal cycle + inter-annual variation
- particle number donminated by particles < 100 nm (around 90 %)
- seasonal cycle of light-absorbing aerosol properties // SSA directly measured
- N_{CCN} varied between 14 (at 0.1% ss) and 212 (at 0.7 % ss)
- Southern Ocean close to PE station important source for very small particles
- Emissions from lower latitudes reach Antarctica after long circumpolar transport times
- Organics, VOCs, Inorganics measured along a transect from coast to plateau

REFERENCES: Gorodetskaya et al., J. Geophys. Res. Atmos., 118, doi:10.1002/jgrd.50177, 2013 // Pattyn et al., J., Antarctic Science, 22(1), 79-85, 2010 // Gorodetskaya et al., The Cryosphere, 9, 285-304, 2015 // Herenz et al, Atmos., Chem. Phys., 19, 275-294, 2019 // Vanderstraeten et al., doi:10.1111/ggr.12320, 2020

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