Observations of atmospheric composition, clouds and precipitation in Dronning Maud Land, East Antarctica

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Objective and Instrumentation

- Aerosols attenuate, scatter and absorb solar radiation, influencing e.g. the radiation balance or photochemical reactions. In addition, they act as cloud condensation and ice nuclei and affect the formation and properties of clouds, which are important agents in the Antarctic hydrological cycle, essential for the Antarctic surface mass balance.

INSTRUMENTS

- total aerosol mass concentration by a **TEOM-FDMS**;
- aerosol absorption coefficient and mass concentration of light absorbing aerosol by a Magee Sci. 7-wavelength **aethalometer** (370, 470, 520, 590, 660, 880, 950 nm);
- aerosol total scattering coefficient by an Ecotech **nephelometer** (450, 525, 635 nm);
- total aerosol number concentration (3 – 3000 nm size) by a TSI3776 **condensation particle counter** (CPC) with n-butanol as working liquid, operated at 1.5 LPM;
- aerosol number size distribution by a TSI3340 **laser aerosol spectrometer** (LAS) (90-7500 nm, 100 log-channels) applying a He-Ne laser at 633 nm;
- **Size class < 90 nm** is derived by combination of LAS and CPC data.
- A **Cimel sun photometer** provides total atmospheric column aerosol optical depth (AOD) at 7 wavelengths (UV-A to near-IR) and integrated water vapour at 936 nm.
- A **Brewer ozone spectrophotometer** (total ozone) is installed on the station's roof, from which also AOD at 340 nm is derived (De Bock et al., 2010).
- Backscatter profiles of a Vaisala CL31 **ceilometer** show if clouds are optically thin icy or optically thick liquid-containing and if there are virga or precipitaiton to the surface.
- Precipitation occurrence and snowfall rate is derived from a 24 GHz vertically pointing **precipitation radar** (Metek MRR-2).
- Daily **radiosonde** balloon launches have been started in January 2014.
- A DMT **Cloud Condensation Nuclei counter** (CCNc) was installed from December 2013 to end of February 2014.

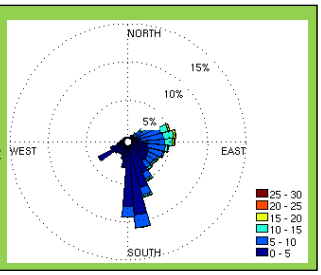
Station

The Belgian Antarctic station Princess Elisabeth, is situated north of the Sør Rondane Mountains in Dronning Maud Land, East Antarctica (71°57'S, 23°20'E, 1390 m Asl; Pattyn et al., 2010) and around 180 km inland. The station is manned mid-November to end of February. In winter, station and instruments operate under remote control. The in situ aerosol instruments are located in a container 60m south of the station.

Meteorology

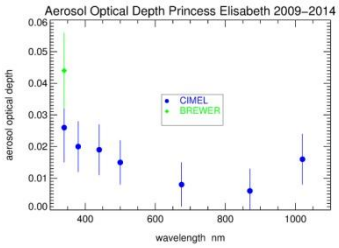
A general overview of meteorological conditions is given in Gorodetskaya et al., 2013.
Data come from an Automatic weather station, 300 m east of station. The graphic shows multi-annual averages of **wind direction and wind Speed (m/s)**. The aerosol container is thus most of the time exposed to non-contaminated air.

2 predominant meteorological regimes:
- cold catabatic (air masses Antarctic interior)
- synoptic (extratrop. cyclones, frontal systems)



Atmospheric column aerosol data

The sun photometer (aeronet.gsfc.nasa.gov, 'Utsteinen') provides data since February 2009 each austral summer (Nov–Feb) and is calibrated yearly in Europe. The Brewer spectrophotometer was installed in January 2011 and measured during three austral summers since then. The graph below shows AOD for both Cimel and Brewer, averaged over all available data (5449 Cimel, 1199 Brewer values). Cimel values belong to quality level 1.5. Further manual checks covering, e.g., thin cloud contamination were done.



The table below gives additional parameters both for the complete covered time period and for individual austral summers. Aeronet's spectral deconvolution algorithm gives the fine mode fraction (fraction of particles smaller than 1 µm size). Values for summers 2008/09 and 2009/10 are not separately listed due to short measurement periods.

Parameter	2009-2014	2010/11	2011/12	2012/13	2013/14
Angstrøm Exponent 440-880nm	2.0 ± 0.7	2.4 ± 0.6	1.4 ± 0.4	1.9 ± 0.5	2.1 ± 0.8
AOD at 500 nm	0.015 ± 0.007	0.017 ± 0.007	0.018 ± 0.008	0.016 ± 0.007	0.009 ± 0.004
Integrated water vapour (cm)	0.14 ± 0.06	0.15 ± 0.06	0.15 ± 0.04	0.12 ± 0.05	0.18 ± 0.06
Number of values	5449	1048	481	2350	1146
Fine mode fraction (< 1 µm)	0.68 ± 0.23	0.76 ± 0.18	0.71 ± 0.21	0.69 ± 0.24	0.53 ± 0.22
Number of values	1195	208	230	524	131

Aerosol total and BC mass concentration

The Tapered Element Oscillating Microbalance with Filter Dynamics Measurement System **(TEOM)** was operated with a bulk inlet on top of the aerosol container and an averaging time of 1 hour (24hr running mean). There are data since austral summer 2010/11. The **average total aerosol mass concentration** for the whole period was **1.3 ± 0.8 µg/m³** and did not show significant seasonal variations.
The **aethalometer** was operated at a flow of 5.5 LPM and an averaging time of 60 min. The bulk inlet is on top of the aerosol container. There are data since austral summer 2009/10. In the table below the **mass concentrations (BC), absorption coefficients (Abs) and the Absorption Angstrøm exponent (AAE)** are given for the individual seasons. The absorption coefficients have been calculated following Weingartner et al. 2003.

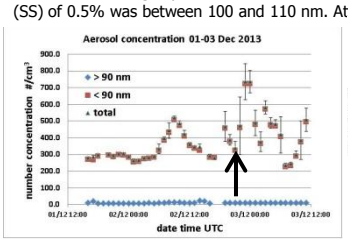
	BC at 370nm [ng/m³]	BC at 660 nm	Abs at 370 nm [Mm⁻¹]	Abs at 660 nm	AAE 370-880nm [-]
Summer 09/10	9.1 ± 7.7	10.3 ± 8.8	0.04 ± 0.03	0.02 ± 0.02	1.0 ± 0.7
Summer 10/11	8.0 ± 5.6	6.7 ± 5.6	0.03 ± 0.02	0.01 ± 0.01	1.5 ± 1.1
Summer 11/12	11.7 ± 6.6	7.4 ± 6.0	0.05 ± 0.03	0.02 ± 0.01	1.9 ± 1.2
Summer 12/13	11.1 ± 6.9	9.0 ± 6.6	0.05 ± 0.05	0.02 ± 0.03	1.6 ± 1.1
Summer 13/14	10.8 ± 6.4	7.9 ± 6.7	0.03 ± 0.03	0.01 ± 0.01	1.5 ± 1.1
Autumn 2011	10.5 ± 5.7	5.9 ± 4.3	0.04 ± 0.02	0.01 ± 0.01	2.1 ± 1.3
Autumn 2012	5.9 ± 4.4	3.8 ± 3.3	0.02 ± 0.02	0.01 ± 0.01	1.8 ± 1.3
Autumn 2013	9.2 ± 7.6	5.2 ± 4.0	0.04 ± 0.03	0.01 ± 0.01	1.8 ± 1.3
Autumn 2014	6.1 ± 6.0	4.1 ± 3.9	0.01 ± 0.01	0.01 ± 0.01	1.3 ± 1.1
Winter 2012	3.4 ± 3.2	4.6 ± 4.6	0.01 ± 0.01	0.01 ± 0.01	0.7 ± 0.8

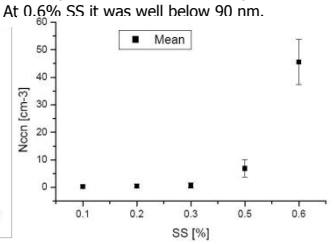
Aerosol scattering properties

The **nephelometer** was operated at 5 LPM, 5 min averaging time. First measurements were done in summer 2011/12. The average **total scattering coefficients** were:
450 nm: 0.8 ± 0.5 Mm^{-1} / 525 nm: 0.8 ± 0.5 Mm^{-1} / 635 nm: 0.8 ± 0.5 Mm^{-1}
The **single scattering albedo (SSA =sca / (sca+abs))** was derived from simultaneous aethalometer and nephelometer measurements. Preliminary calculations yield SSA values around 0.96 – with high uncertainty due to the very low aerosol concentrations.

Aerosol concentration, size, and CCN

The **CPC** has been operated at 1 min averaging time and the **LAS** with an integration time of 60 min. The number of particles < 90 nm is indicative of the nucleation/Aitken size mode. The left plot below shows hourly values for a time period when the latter mode distinctly increased. The right plot shows preliminary **CCN concentrations** for the hour indicated in the right plot. The critical diameter for particle activation at a supersaturation (SS) of 0.5% was between 100 and 110 nm. At 0.6% SS it was well below 90 nm.

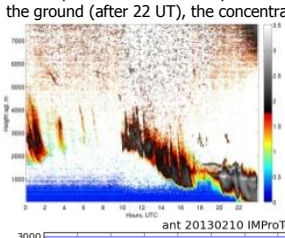


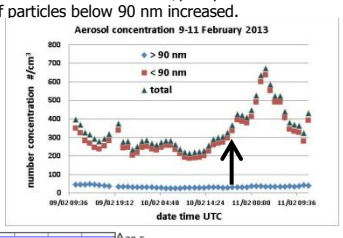


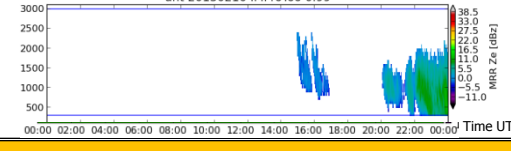
CPC number concentrations were 385 ± 72 cm^{-3} during summers and 91 ± 64 cm^{-3} for autumn 2013. The **Count Median Diameters** from the **LAS** measurements were in the range 110 – 140 nm and the presence of particles above 2 µm was neglible.

Aerosol properties during precipitation

The ceilometer (left graph) measured cloud base height and potential backscatter signals from droplets, crystals, or aerosols. The MRR-2 (bottom graph) measured the reflectivity of hydrometeors. Shown is a time-profile image for 'Ze', the radar reflectivity, a measure for precipitation intensity. Graphs are for 10 February 2013. The CPC-LAS graph (right) shows the temporal evolution of the particle concentration. When the clouds/precipitation reached the ground (after 22 UT), the concentration of particles below 90 nm increased.







References: De Bock et al., Atmos. Meas. Tech., 3, 1577-1588, 2010. // Gorodetskaya et al., J. Geophys. Res. Atmos., 118, doi:10.1002/jgrd.50177, 2013. // Pattyn, F., Matsuoka, K. and Berte, J., Antarctic Science, 22(1), 79-85, 2010. // Weingartner et al., J. Aero. Sci., 34, 1445-1463, 2003.

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SUMMARY:

- BC mass concentrations differed by season, with high standard deviations
- Sun photometer Angstrøm exponent indicated dominance of particles << 1 µm size
- AAE values showed that several light absorbing aerosol types were present
- derived SSA values > 0.9, however, with very high uncertainty
- aerosol number in nucleation/Aitken mode often increased, also before snowfall