Sea ice and frost flowers as sources of sea salt aerosols? A trajectory study

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Our project tries to answer:

- Can sea ice and frost flowers be the potential source of sea salt aerosols in the polar regions?
- Which meteorological parameters play an important role for the formation and transport of sea salt aerosols?
- How to interprete the polar ice core records?
- Are sea ice and sea salt aerosols sources of reactive Bromine and other halogen compounds?
- How do sea ice and sea salt aerosols influence ozone depletion in the troposphere?

Method:

- Trajectory analysis, contact time with different surface types.
- A Lagrangian model for sea salt aerosol emission and transport.
- Comparison with 25 years of continuous aerosol measurement at Neumayer station.
- Global model with detailed aerosol physics and chemistry to investigate the global influence of sea ice on the tropospheric chemistry.

Results:

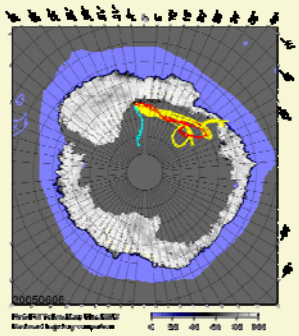


Fig.1 Trajectories calculated with JRA, NCEP reanalysis and DWD data with SSM/I ice concentration as background

- Backward trajectories were calculated 4 times daily in a 6 hours time step for 120 hours based on Japanese Reanalysis data (JRA).
- Comparison of trajectories based on various data products (JRA , NCEP (calculated with Hysplit program), DWD).
- Good agreement between NCEP and JRA trajectories (Fig.1).

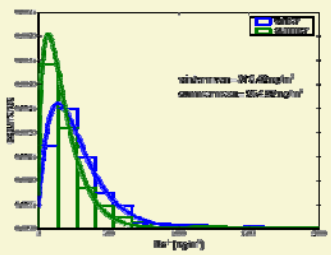
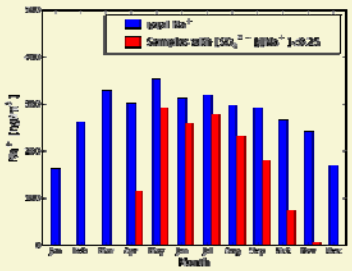


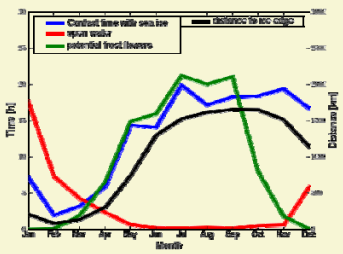
Fig. 2 Histogram of Na^+ in aerosol samples measured at Neumayer Air Chemistry Observatory with High Volume aerosol sampler in the period of 1983-2005.
Blue and green lines are fitted curves for winter and summer.

- Different distribution between winter and summer Na^+ in aerosol.
- In summer more samples with low Na^+ loadings in aerosol than in Winter.
- 20% more Na^+ in winter than in summer.
- If only sea salt aerosol production from open sea water is considered, in winter the value should be much lower than in summer because of the large distance to the open water from the Antarctic coast in winter (see distance to ice edge from Neumayer station in Fig. 4).



- No aerosol samples with $[SO_4^{2-}]/[Na^+] < 0.25$ (sulfate depletion) in Antarctic summer whereas in winter most of Na^+ samples are with $[SO_4^{2-}]/[Na^+] < 0.25$
- In sea water $[SO_4^{2-}]/[Na^+] = 0.25$
- Sulfate depletion also observed in new sea ice and frost flowers

Fig. 4 Monthly mean value of Na^+ in aerosol measured at Neumayer Air Chemistry Observatory with High Volume Aerosol Sampler in the period of 1983-2005.



- Along each trajectory the contact times with sea ice, open water and frost flowers are calculated based on SSM/I ice concentration which is available from 1992 on daily.
- The high values of contact times with sea ice and frost flowers in winter time can explain the higher Na^+ loadings in aerosol samples.

Fig. 4 Contact time of atmospheric boundary layer trajectories arriving at Neumayer station with sea ice, open water and potential frost flowers. Distance to ice edge is from Neumayer station at the longitude -8.25°.

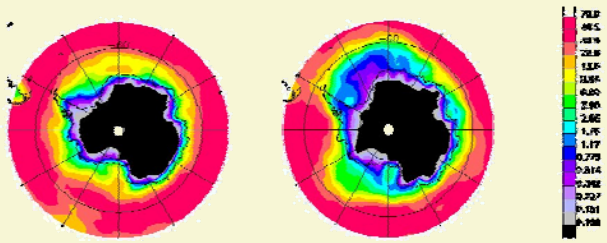


Fig. 5 Particulate mass weight (dry) of sea salt aerosols at Antarctica, Jan. 2000 (left) and Jul. 2000 (right) . Scale is logarithmic. Unit is µg/m^3. A result from Echam5-Ham model from MPI Hamburg.

- The sea salt aerosols and their role in tropospheric chemistry are poorly presented in most global models or are just ignored.
- Extremely low sea salt aerosol concentration in winter and overestimation in summer.
- In summer the sea salt aerosol particulate mass weight can be as high as 10 µg/m^3 which is 10 times higher than that measured at Neumayer station.

Summary and Outlook

- The analysis of Na+ concentration in aerosol samples from Neumayer station and contact time of trajectories with sea ice, open water and frost flowers shows that sea ice can be a primary and important source of sea salt aerosol. In winter it can be even the dominant source, playing much more important role than open water due to the far distance from ice edge to the continent.
- The producing process of sea salt aerosol is very complicated. More time is needed to investigate the individual and complete roles of meteorological parameters in the process of aerosol production and emission.
- Cooperattion with Max Planck Institute of Meteorology, Hamburg to implement the emission rate of sea salt aerosol from sea ice surface to the global model of MPI.
- Together with Alfred Wagner Institute (G. Dieckmann) it is planned to investigate the freezing calcium carbonate precipitation.
- With the box model from Max Planck Institute of Chemistry, Mainz and satellite data analysis from Institute of Environment Physics, University of Bremen, bromine emission and its role in the tropospheric chemistry will be validated.

References:

Hall et al.,Causes of seasonal and daily variations in aerosol sea-salt concentrations at a coastal Antarctic station, Atmos. Environ., 32, 3669-3677, 1998.

Kaleschke et al.,Frost flowers on sea ice as a source of sea salt and their influence on tropospheric halogen chemistry, Geophysical research letters, 31, L16114.doi:10.1029/2004GL020655, 2004.

Kaleschke et al., SSM/I Sea Ice Remote sensing for Mesoscale Ocean-Atmosphere Interaction Analysis, Can. J. Remote Sensing 27,5,526-537, 2001.

König-Langlo et al., The Meteorological Observatory at Neumayer Stations (GvN and NM-II) Antarctica, Polarforschung 76(1-2), 25-38,2007.

Kottmeier et al., Trajectories in the Antarctic lower troposphere, J. Geophys. Res., Vol. 103, D9, 10947-10959, 1998.

Martin et al., The temperature dependence of frost flower growth on laboratory sea ice and the effect of the flowers on infrared observations of the surface, J.Geophys. Res., 101, 12111-12125, 1996.

Rankin et al.,Frost flowers as a source of fractionated sea salt aerosol in the polar regions, Geophysical research letters, 27, 21,3469-3472, 2000.

Rankin et al., Frost flowers:Implications for tropospheric chemistry and ice core interpretation, J. Geophys. Res., 107,D23,4683, doi:10.1029/2002JD002492, 2002.

Wagenbach et al., Sea-salt aerosol in coastal Antarctic regions, J. Geophys. Res., 103, D9, 10961-10974, 1998.

Weller et al., The Air Chemistry Observatory at Neumayer Station (Antarctica), Polarforschung, 76 (1-2), 39-46, 2006.

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