A lagrangian backward trajectory model for the sea salt aerosol production and transport in coastal antarctic regions

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Introduction

Sea salt aerosol (SSA) is produced from open sea water via wave breaking and bubble bursting. Recent studies have indicated that in the sea ice covered polar regions sea ice is the main source of SSA in winter. However, the production mechanism of SSA over sea ice is still not known. In this study we investigate the SSA production and transport processes in coastal regions of Antarctica with a Lagrangian backward trajectory model, together with year-round aerosol measurements from coastal stations Neumayer, Syowa, and Dumont d'Urville. Based on sea ice remote sensing and atmospheric reanalysis data, the model calculates along each backward trajectory the emission, deposition, and transport of SSA in accumulation and coarse modes respectively. Dry deposition velocities and a constant boundary layer depth are assumed. Summer SSA data from the three stations are used to validate the model which is in turn applied to explore the possible production mechanisms of SSA in winter.

Methods and Data

Data

- SSA measurement data from Neumayer, Syowa, and Dumont d'Urville (DDU)
  Neumayer: daily data from 2004 to 2006; bi-weekly data from 1983 to 2007
  Syowa: 3 days resolution data from 2004 to 2006
  DDU: daily data from 2004-2006
- Satellite derived sea ice concentration
- JRA-25 atmospheric reanalysis

A Lagrangian backward trajectory model (Fig.1):

- A constant boundary layer depth (600 m in summer 100 m in winter)
- Two modes of SSA particles (accumulation mode: 0<radius<1μm, coarse mode: 1<radius<5μm)
- Parameterized dry deposition velocities for each mode (0.001m/s for accumulation mode, 0.02 m/s for coarse mode)
- Neglect wet deposition
- Simplified turbulent diffusion

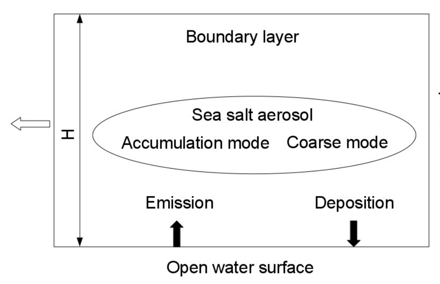

Fig. 1 Sketch of sea salt aerosol production, deposition and transport processes used in the model for a single lagrangian grid cell.

SSA generation mechanisms

Over open water:

- SSA generation from open water according to Monahan et al., 1986

Over sea ice we test following hypotheses:

- Blowing snow (Yang et al., 2008)
- Potential frost flower (PFF) area (Kaleschke et al., 2004) multiplied by different degree of wind velocity
- Polynya area multiplied with wind velocity, temperature, and relative humidity

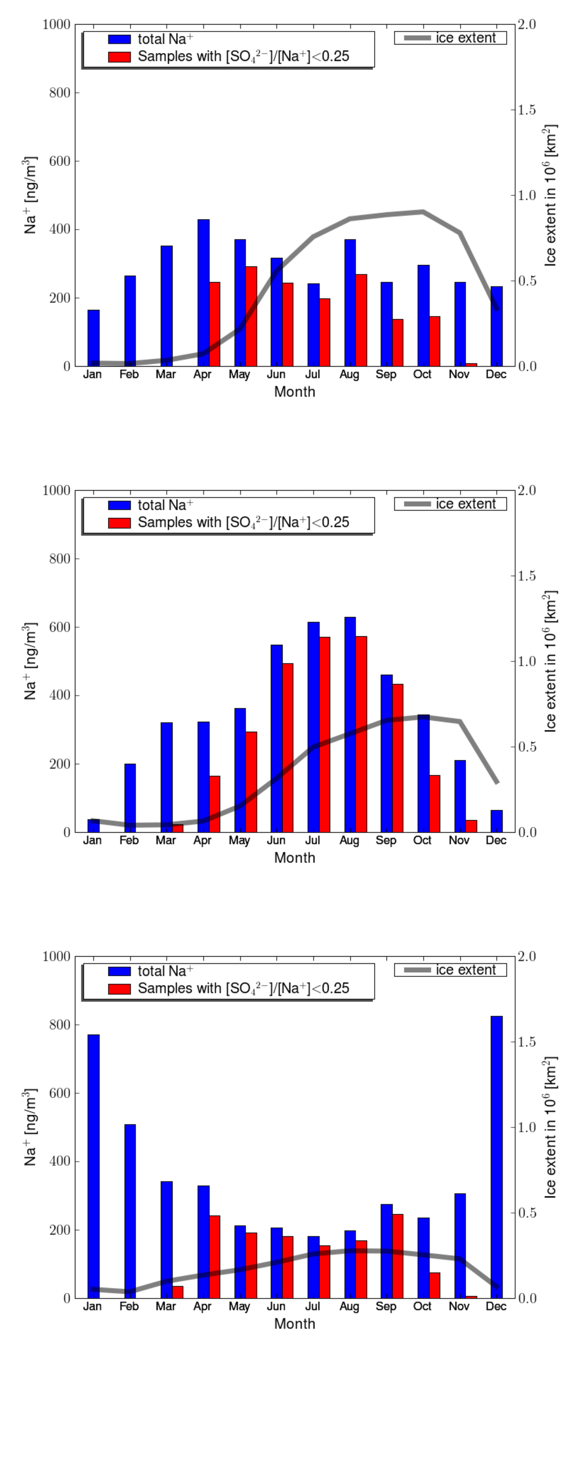

Fig. 2 Seasonality of sodium concentration in the total and sulphate depleted SSA samples from Neumayer (top), Syowa (middle), and DDU (bottom), together with sea ice extent. Period: 2004-2006

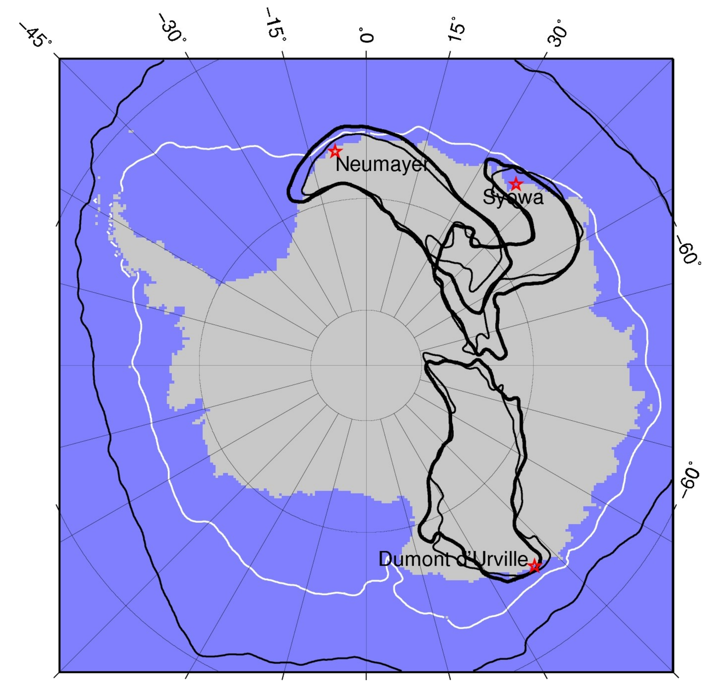

Fig. 3 Contour lines around the stations show the region which contains 67% of trajectory endpoints. thin line: summer thick line: winter

Period
Neumayer: 1983-2007
Syowa and DDU: 2004-2006

In the background are the contour lines of 15 % sea ice concentration from 1983 to 2007.
white: summer black: winter

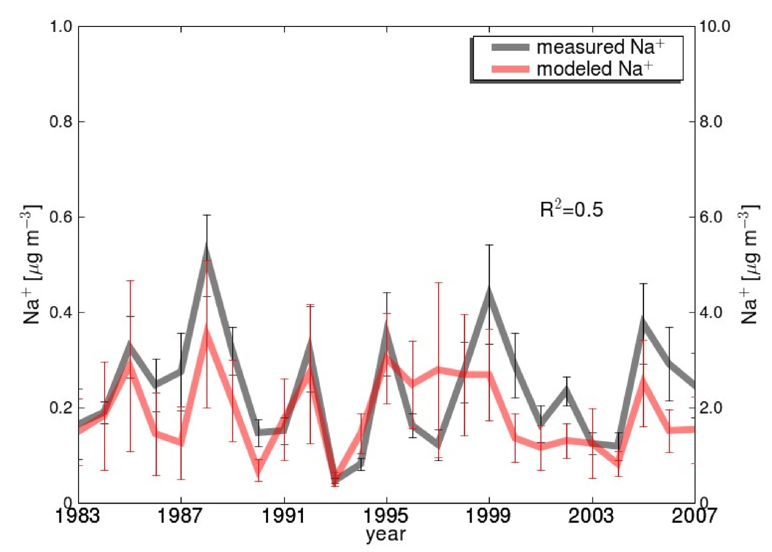

Fig. 4. Comparison of measured (left y axis) and modelled (right y axis) mean of SSA sodium from the months Jan. Feb. Mar. with ¼ standard deviation at Neumayer in the period of 1983-2007.

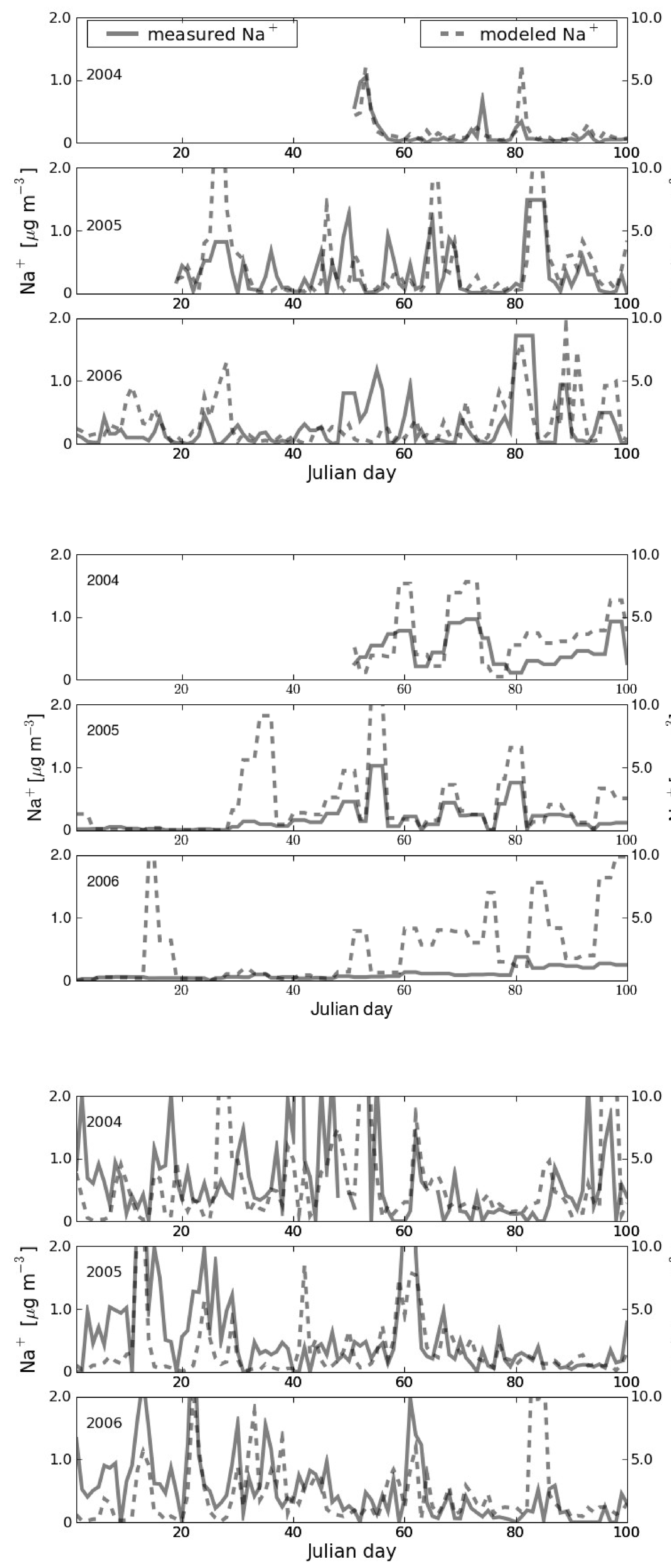

Fig. 5. Comparison of daily measured and modelled SSA sodium from 2004 to 2006 in summer. Top: Neumayer, Middle: Syowa, Bottom: DDU

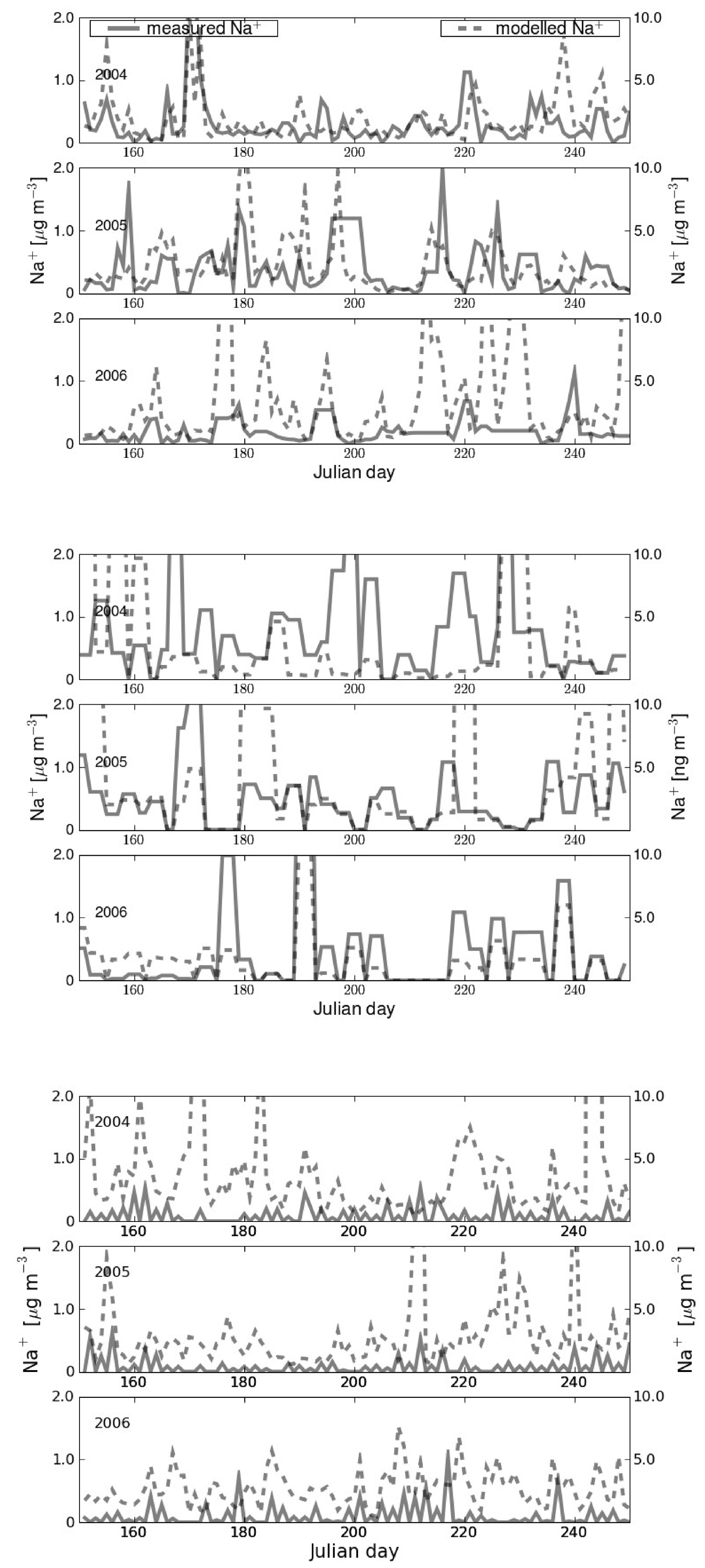

Fig. 6. Comparison of daily measured and modelled SSA sodium from 2004 to 2006 in winter. We used polynya area multiplied by square of surface wind velocity as SSA production mechanism. Top: Neumayer, Middle: Syowa, Bottom: DDU

Discussions and Conclusions

- In summer topography and wind velocity determine the SSA loading at the three stations (Fig.2, Fig. 3 and Fig.5).
- Both local SSA production and long range transport are important.
- The assumption of constant boundary layer depth, neglect of wet deposition, simplification of horizontal turbulent diffusion, and the assumption of the integrity of air parcels during long transport are the main uncertainties in the model.
- With this simple lagrangian model we can well reproduce the variability of summer daily (for Syowa 3 days resolution) SSA data at the three stations (Correlation coefficient R^2 up to 0.3 with more than 99 % significance level (Fig.5).
- Neither PFF nor blowing snow explain variability in winter.
- Mechanism in winter not identified.
- The model can reconstruct half of the interannual linear variability of SSA at Neumayer from 1983 to 2007 during summer months (Fig.4).
- Best correlation (R^2 up to 0.1) is found at Neumayer and Syowa between measured and modelled daily data in winter when we multiply polynya area covered with thin ice with square of wind velocity and use this item as SSA production flux. At DDU no correlation can be found between measured and modelled data (Fig. 6).
- Thin ice covered area and wind velocity play a role in SSA production in winter at the coast of Antarctica.
- More measurements are needed until consolidated conclusions can be drawn.

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