We would like to thank referee #1 for very helpful comments.

Reply to comments by Anonymous Referee #1

This paper describes atmospheric cycles of sea-salt aerosols in polar regions using model and remote sensing measurement (CALIOP). Authors applied and improve the model, GEOS-chem., to simulate spatial distribution and origins of sea-salt aerosols on basis of various parameters such as salinity of surface snow. They derived an interesting conclusion that sea-salt aerosols in the winter were involved in blowing snow rather than frost flowers on sea-ice. On the whole, the topic of the manuscript is relevant and suitable for the scope of the "Atmospheric Chemistry and Physics. The topics and results deserve to be made available to the scientific community and to be exploited in terms of atmospheric aerosols and ice core community in polar regions. Therefore, this study adds very useful information to our knowledge on the sea-salt cycles involved in blowing snow in polar regions. From this reason, I support publication of this work in ACP. However, the current version contains obvious weaknesses, therefore I recommend a major revision. Details are shown as follows.

1. Size distributions of sea-salt aerosols In the GEOS-Chem. Model, spatial distributions of the concentrations of sea-salt aerosols were calculated on assumption of dry deposition velocity and emission from some origins (e.g., open water, frost flowers, and snow). Sea-salt aerosols were distributed from ultrafine to coarse modes in the polar regions during winter – spring (e.g., Hara et al., ACP, 2011).

Hara, K., et al.: Seasonal features of ultrafine particle volatility in the coastal Antarctic troposphere, Atmospheric Chemistry and Physics, doi:10.5194/acp-11-9803-2011, 2011.

What is procedure to calculate and treat size distributions and concentrations of sea- salt aerosols? What are the initial size distributions of particles immediately after emission from sea-ice and ocean? I think that these parameters are probably as same as those in your previous work (Huang and Jaegle, ACP, 2017). If so, add short explanation about processing of aerosol size distribution in the model for readers. If not, details should be mentioned.

Yes, our size distribution assumptions are the same as in Huang and Jaeglé (2017) and we have clarified this in the revised manuscript:

"We use two SSA size bins: accumulation mode (rdry = 0.01−0.5 μm) and coarse mode (rdry = 0.5–8 μm)."

"The size distribution of wind-lifted snow particles follows a two-parameter gamma distribution (Yang et al., 2008 and references therein). Once sublimated, snow particles are released as SSA particles. We assume that 5 SSA particles are produced per snowflake (N=5) based on a comparison against observations of submicron SSA mass concentrations at Barrow, Alaska (Huang and Jaeglé, 2017). The size distribution of blowing snow SSA is determined from the size distribution of snow particles, N (=5), and salinity. The resulting emitted mass of blowing snow SSA is obtained by integrating this size distribution into the two SSA size bins."

"The size distribution of SSA from frost flowers follows a lognormal size distribution with a geometric mean diameter of 0.015 μm and a geometric standard deviation of 1.9 (Xu et al., 2013). This size distribution is integrated into the two GEOS-Chem SSA size bins to obtain the emitted mass of SSA from frost flowers."

2. Dry deposition velocity. In this study, aerosol dry deposition velocity was fixed to 0.03 cm s-1, corresponding to that of particles with size of ca. 2um in diameter. As shown by Rhodes et al. (2017) and Hara et al. (2017), sea-salt aerosols and ice particles containing sea-salts were released from snow and frost flowers on sea-ice. Then, size of sea-salt particles and ice particles containing sea-salts can be changed through sublimation and efficient dry deposition of larger sea-salt particles in the atmosphere. In general, the coarser aerosols have larger dry deposition velocity (shorter residence time). Therefore, processing of initial size distribution and modification of size distribution involved simultaneously with dry deposition and sublimation is the most important to simulate the concentrations and spatial distribution of sea-salt aerosols. Because aerosol dry deposition velocity has size-dependence, the fixed and assumed aerosol dry deposition velocity can result in mis-estimation. I understand that it is difficult to input all parameters in model calculation. However, sensitivity of dry deposition on the sea-salt concentrations should be checked. Ideally, size dependence of dry deposition velocity is included in the model (I do not require it this time, but I hope it for progress in the future).
Rhodes, R., Yang, X., Wolff, E., McConnell, J. and Frey, M.: Sea ice as a source of sea salt aerosol to Greenland ice cores: a model-based study, Atmospheric Chemistry and Physics, 17(15), 9417–9433, doi:10.5194/acp-17-9417-2017, 2017.

Our description of the dry deposition parameterization in GEOS-Chem was unclear and incomplete. The constant 0.03 cm/s dry deposition velocity over snow and ice applies to all aerosols except dust and sea salt. For sea salt in particular, we do assume a size dependent dry deposition velocity. More detail on the sea salt deposition velocity parameterization is now given in the revised manuscript:

"Dry deposition in the GEOS-Chem follows a standard resistance-in-series scheme based on Wesely (1989) as described by Wang et al. (1998). Dry deposition of SSA in the model follows the Zhang et al. (2001) size-dependent scheme over land, and is calculated based on the Slinn and Slinn (1980) deposition model over ocean and sea ice, as implemented by Jaeglé et al. (2011) in GEOS-Chem. The strong size-dependence of SSA deposition is taken into account by integrating the dry deposition velocity over each of the 2 SSA size bins using a bimodal size distribution including growth as a function of local relative humidity (RH). Sedimentation of SSA is calculated throughout the atmospheric column based on the Stokes velocity scheme."

3. Potential frost flower (PFF) coverage PFF were estimated using air temperature and thickness of sea-ice in the study. Actually, frost flower can be formed on new and young sea-ice. In this study, threshold of newly formed sea-ice thickness is 10 cm. In my experience, this value is small, because frost flower can be appeared on sea-ice even with thickness of ca. 30cm. If the threshold was smaller, the model results can be underestimated. What is the impact of sea-ice thickness in the model?

The assumed thickness threshold in the model has relatively little impact on our frost flower emissions. Following the suggestion of this reviewer, we conducted a sensitivity study inhibiting the frost flower emission with sea ice thickness over 30cm. We find that frost flower emissions increase by less than 10% over the Arctic, and less than 1% over the Antarctic. This small sensitivity to the assumed the sea ice thickness threshold is a result of the significant decrease in frost flower growth rate with increasing ice thickness (Kaleschke et al., 2004).

Kaleschke, L., Richter, A., Burrows, J., Afe, O., Heygster, G., Notholt, J., Rankin, A. M., Roscoe, H. K., Hollwedel, J., Wagner, T., and Jacobi, H.-W.: Frost flowers on sea ice as a source of sea salt and their influence on tropospheric halogen chemistry, Geophys. Res. Lett., 31, L16114, doi:10.1029/2004GL020655, 2004.

4. Spatial distribution (Figs. 1 and 4) Spatial distribution of aerosol extinction coefficients and model results during cold seasons were depicted in Figs. 1 and 4. These plots provide us very interesting information to understand atmospheric sea-salt cycles in Arctic and Antarctica. However, these periods correspond to develop sea-ice extent, so that these distributions included also seasonal feature of sea-ice extent, which is associated with origins of sea-salt aerosols. Seasonal and spatial variations of source strength and origins of sea-salt aerosols should be taken into account. To exclude influences of the seasonal features, I suggest that the selected months are shown, for example month with maximum of sea-ice extent (March in Arctic and September in Antarctica).

Following the suggestion of this reviewer, we have now added two figures showing monthly mean aerosol extinction coefficients from CALIOP and models during each cold month (November-April in Arctic and May-October in Antarctica) in the Supplementary material (Figures S5 and S6). Overall, the monthly comparisons are consistent with the cold-season comparison, with STD+Opt. Snow best capturing the spatial distributions of CALIOP aerosol extinction coefficients among four model simulations.