We thank the anonymous reviewer for their thoughtful comments and suggestions. We address each one directly below and outline changes that will be made to the revised manuscript.

Reply to Anonymous Reviewer #2

Specific comments:

P1 Line 23: Does "in size range of 0.4-10µm" refer to radius or diameter?

Answer: Size refers to diameter. Text has been updated.

P3 Line 10-13: What is the size converting ratio from blowing snow particles to SSA? Are all/most SSA with size of 0.375-10µm being generated by from snow particles in 46-500µm?

Answer: The conversion factor varies as a function of initial snow particle size, snow salinity and the production ratio number N (following equation 11). The added figure shown below indicates calculated corresponding dry SSA diameter (µm) of initial blowing snow particles in size range 1-1000 µm and at snow salinity range 0.0001 - 100 psu (under N=1). As can be seen that for an initial snow particle =10 µm, the corresponding SSAs under different salinity are most in sub-micron size. For an initial snow particle=100 µm, the dry SSAs formed are most <10 µm, apart from at high salinity of a few tens psu. For snow particles in range of 46-500 µm, at salinity of 0.01-0.1 psu (close to the median salinity, see salinity distribution figure in page 5 below), SSAs formed are most in size 0.5-10 µm. At low salinity=0.001 psu, the corresponding SSAs are mainly sub-micron sized. At high salinity=1 psu, SSAs are most micron sized. Note, at N=10, the corresponding dry SSA size will be roughly half of the values for N=1. The above text and the Figure will be included in the revision.

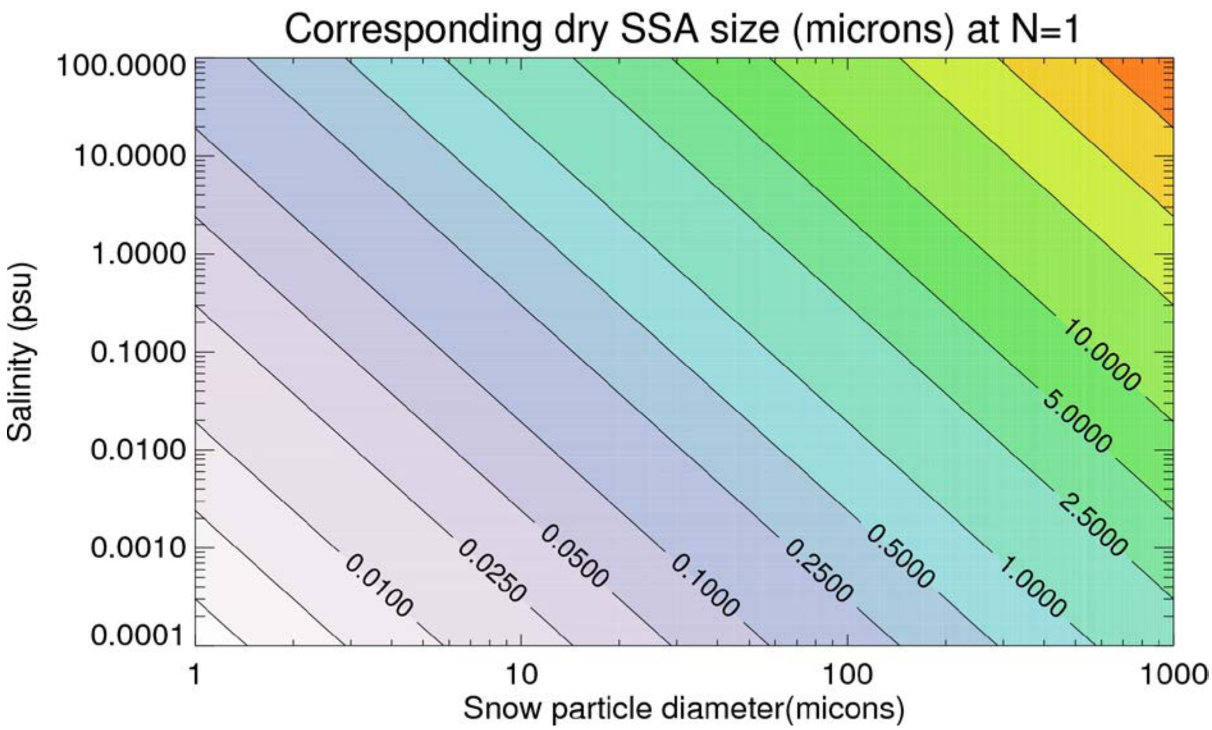


Figure: Equivalent dry SSA diameter (µm) as a function of initial snow particle diameter (µm) and snow salinity (psu) for N=1, calculated following equation 11.

P7 Line 26: Adding a plot showing the probability distribution of surface snow salinity used in the model can be very helpful. Also, does the probability distribution of surface snow salinity changes in times during the cruise period? For example, is the surface snow more saline in the earlier winter time?

Answer: The observed snow salinity distribution has been included in the companion manuscript (by Frey et al., acp-2019-259), we thus will not show it in this manuscript, but show it below for your information. As can be seen from the figure, snow salinity over young sea ice is indeed higher than that when the vessel is over multi-year sea ice. Snow salinity also change with time during the blowing snow event, for example, during 10-13 July, 2013, bulk snow salinity increased by a factor of two, likely due to the wind erosion effect.

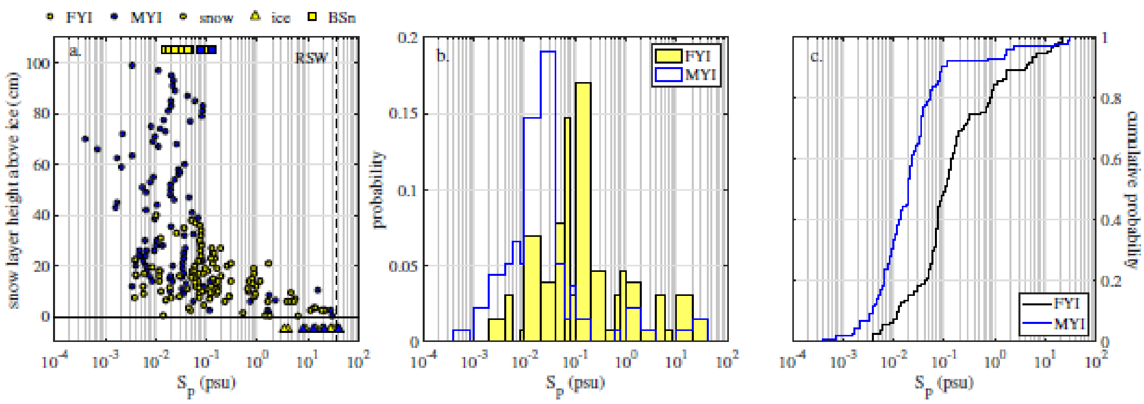


Figure 12 in the companion manuscript (Frey et al., acp-2019-256): Panel (a) shows salinity Sp of snow on first-year sea ice (FYI, yellow symbols) at ice stations S1-6 and multi-year sea ice (MYI, blue symbols) at ice stations S7-9 in the Weddell Sea during austral winter 2013 as a function of snow layer height above the sea ice surface. For comparison Sp of the sea ice surface (triangles) and blowing snow at 1-17 cm above the snowpack (squares) are shown as well. The vertical dashed line indicates Sp (=35.165 psu) of reference sea water (RSW). Panel (b) shows salinity Sp probability distributions for shallow snowpacks (mean depth 21 cm) above first-year sea ice (FYI) at ice stations S1-6 and for deep snowpacks (mean depth 50 cm) above multi-year sea ice (MYI) at ice stations S7-S9 in the Weddell Sea during austral winter 2013. Panel (c) shows respective cumulative probabilities of Sp.

P8 L1: Does the cruise travel mostly in the first-year sea ice area or multi-year sea ice area? Does the measured SSA mostly come from first-year or multi-year sea ice?

Answer: The ship was in or near multi-year sea ice from 24 July to 6 August 2013. Thus, SSA are measured over both first-year and multi-year sea ice. Which is included in the manuscript.

P8 L15: If the snow age = 0, does it mean that they are fresh fallen snow? If this is the case, can they get saline in such short time period? Will the surface snow salinity can be substantially lower for those snow age = 0, compared to 1-3 days? Please justify for this assumption of snow age=0.

Answer: Snow age was initially introduced to the parameterization to counteract the relatively high snow salinity used (Yang et al., 2008). At present, this parameter amounts to a crude tuning tool with no clear physical meaning. Snow age =0 gives the largest coefficient (=1) to the production flux, therefore, by setting snow age to zero, we effectively remove this

parameter altogether. 'Snow age' should not be interpreted as the time elapsed after the snowfall.
Actually, the 'snow' here refers to all ice crystals on surface of snow pack that can be mobile or wind-lifted to airborne. These include fresh fallen snow, diamond-dust, wind-cropped frosts or even 'aged' snow that has been re-mobilized by wind-erosion. The mixing of fresh snow and 'old' saline snow changes the salinity distribution, a process has not been considered by the model so far. Due to lack of data, we do not know how fast fresh fallen snow acquires salts. This process may be fast and efficient during a windy condition through physical contact to the salt-rich crystals. With further data, we may have a better representation of this process.

The above text has been included in the revision.

P9 L17: Please justify why N=10 or 20 are chosen here.
Answer: The selection of N=10 or 20 was arbitrary and simply based on model experiment trial which gives a good agreement to the observations.

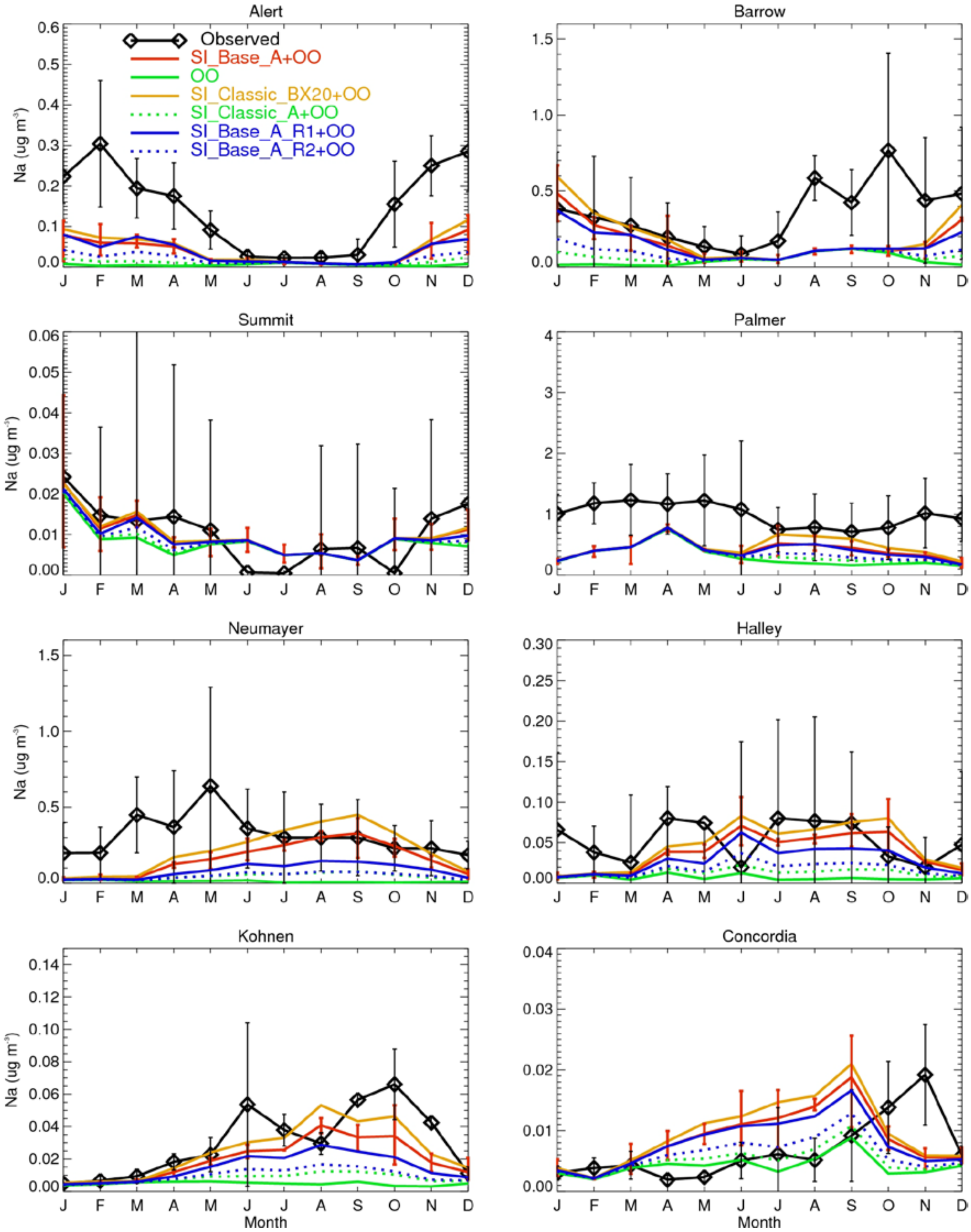
P10 L15: I don't quite understand this sentence. Open ocean contributes to ~20% and sea ice contributes to 40-50%. Are the rest of observations (20-30%) contribute by non-sea-salt source? Please provide a little bit more details.
Answer: What the sentence meant is that, in marginal ice, model (a combination of sea spray and sea ice sourced SSA) underestimates the observation by 30-40%. To avoid confusion, we re-phrase the sentence and merge it with the first sentence in the same paragraph: 'In marginal ice (Figure 3b), our simulation suggests that both sea-ice and open ocean sourced SSA are making a contribution to the observations, but they underestimate the observations by 30-40%. As shown in Table 2 that sea spray accounts for ~20% of the observations and sea-ice sourced SSA accounts for 40-50%.'

P12 L2: As the cruise traveled through marginal sea ice and packed sea ice region, I am curious if there are any signals in the aerosol samples indicating the salinity difference between these two regions?
Answer: We do not have aerosol salinity data, but aerosol [Na^+] concentrations do not show significant different between marginal ice and packed sea ice region. Blowing snow data (in the companion paper) show that 'As expected the mean salinity of the shallow FYI snowpack (=1.4psu) was larger than that of the deep MYI snowpack (0.82 psu), and corresponding salinity probability distributions for snow on FYI are shifted to higher salinities when compared to above MYI.'

P12 L15: As mentioned in previous section (P11 L13), the model runs with reduced RH (SI_Base_A_R1 and SI_Base_A_R1) outperformed the run SI_Base_A, with SI_Base_A overestimating the aerosol number observation. However, from Figure 5, run SI_Base_A seems to underestimate Na at some of the sites (Alert, Barrow, Palmer). How are the run with reduced RH perform comparing to these global sites? Also, it seems that the RH is too high (low?) in the model, causing the overestimates of blowing snow production. Meanwhile, the model does not consider the drifting snow at low wind speeds, causing underestimates of the model. These two effect seem compensate each other in the model. Please elaborate in a little bit more details in how the model can be better constrained. For example, what types of observations are required or suggested to distinguish the effect of these two factors? In *addition, the comparison between the three model runs here (SI_Base_A, SI_Classic_AX10 and SI_Classic_BX20) are using different evaporation rate. Will the SI_Classic_A perform differently compared to SI_Base_A in the comparison in Figure5?*

Answer: In the revised Figure 5 (shown below) we add model results from SI_Base_A_R1 (purple line), SI_Base_A_R2 (dashed purple line) and SI_Classic_A (dashed green line). It can be found from the Figure that SI_Classic_A gives the least SSA production and could not explain the winter SSA observations. This is consistent with the result shown in Figure 4 and Figure 7. The SI_Clasic_A allocates more sublimated water to large blowing snow particles than the SI_Base_A, as a consequence, there are more large SSA (in micron size) and less sub-micron sized SSA being generated. The experiment with a fixed *RH*=90% (with respect to ice) in SI_Base_A_R1 gives a reduced SSA mass concentration comparing to the SI_Base_A (red line), but still shows clear winter SSA peaks in most polar sites. However, the SSA production in SI_Base_A_R2 (at *RH*=95%) is much supressed and will not give a good representation of the winter peaks. Given that mass concentration is dominated by large particles and number density is mainly by small particles, the overestimated SSA number density and the underestimated mass concentration at sites (Alert, Barrow and Neumayer) in SI_Base_A run indicates the current model setups and parameterizations applied need further constraints and evaluation against data. Model runs with higher *RH* values (in SI_Base_A_R1 and SI_Base_A_R2) reduce both SSA number density and mass concentration, thus model moisture will not reconcile the discrepancy between the model and the observations in number density and mass concentration. Inclusion of the missed drifting snow as a source of SSA will add extra SSA to polar sites and affect SSA mass concentration and number density in the same way.

As discussed in section 3 and 4, apart from the evaporation rate, there are other parameters that also affect SSA size spectrum. An outstanding one is blowing snow size distribution: the shape parameter α and the mean diameter (they determine scale parameter beta ß). As shown in Figure 4a, for example, the run with a larger alpha α=3 (in SI_Base_B) gives much reduced SSA number densities in submicron size mode comparing to the result in SI_Base_A (where a smaller α=2 is applied with same mean diameter). In addition, cruise data show that blowing snow particle size distribution varies as a function of height (above the surface) and wind speed (see companion manuscript by Frey et al.). Therefore it is important to apply more realistic blowing snow distribution to constrain this key parameter. We plan to investigate this issue further by applying a time-series of observed blowing snow size distribution along the cruise track to further constrain this parameter to narrow down the uncertainty. Other parameters such as snow salinity distribution and number N of SSA formed per snow particle may also affect the spectrum. Due to lack of data we could not check them in detail.



Updated Figure 5.

Figure 1: Please providing lat/lon and/or location map for this plot if possible.

Answer: The cruise track location map has been given in the companion paper. Here for your information we show it below.

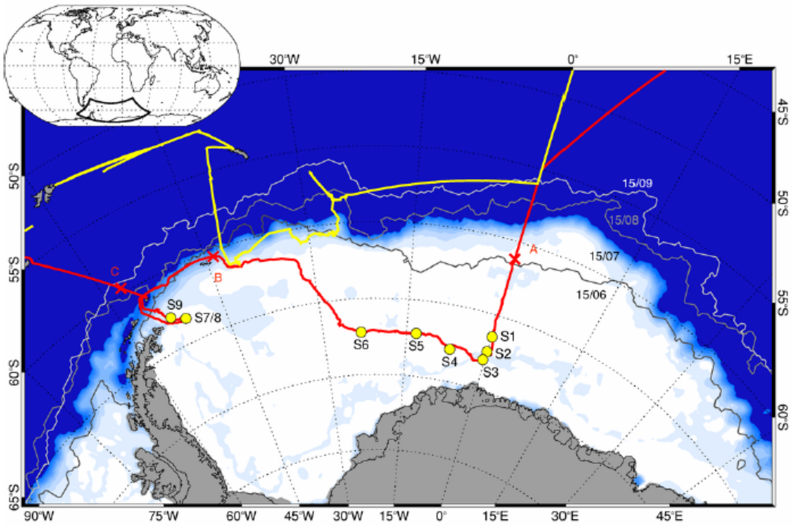


Figure 1 of the companion manuscript by Frey et al.: Cruise tracks of RV Polarstern in the Weddell Sea for the winter expedition ANT-XXIX/6 from 8 June to 12 August 2013 (red line) and the spring expedition ANT-XXIX/7 from 14 August to 16 October 2013 (yellow line). Symbols indicate the location of ice stations S1–9 (Table 1). Crosses show ship positions when entering the sea ice on (A), reaching the marginal sea ice zone MIZ (B) and returning to the open ocean (C). Sea ice concentrations on 15 July 2013 are shown as shaded area, and sea ice extent on 15 June, 15 August and 15 September 2013, respectively, as grey solid lines, all based on Nimbus-7 satellite microwave radiometer measurements (Comiso, 2018).

Table 1: SI_Base_A_T1 is named here, but in the manuscript, it is mentioned asSI_Base_A1_T1. Please check the simulation names for T1, T2 and T3 as well. Also,the model result for SI_Base_A1_T3 is not discussed in the manuscript.

Answer: Thank you for pointing out the mistake made. Now they are SI_Base_A_T1, SI_Base_A_T2 and SI_Base_A_T3 in the revised manuscript. We also corrected a misused experiment name 'SI_Base_T3' (Page 11 line 3), it is now 'SI_Base_A_T3'. Thus the missed 'SI_A_T3' is discussed in the text.