Summary

The paper presents a detailed study on the contribution of sea ice leads to sea salt aerosol (SSA) emissions and their impact on atmospheric chemistry in the Arctic. The authors utilize satellite data and the GEOS-Chem chemical transport model to quantify these emissions and assess their significance. The combination of satellite observations with a chemical transport model is an approach that can improve the understanding of SSA emissions from sea ice leads. The SSA emissions associated with sea ice leads are generally not well known and this approach may be a good approach to help solve this problem. A clearer focus of the paper would be helpful. There are discussions of climatological scale change, but results are based on a relatively short AMRS-E dataset. If the aim is to present climate scale change, the inclusion of AMRS-2 data and/or IR based lead detections would be necessary. If the intention is only to focus on presented dataset, then it would seem better to limit discussion to the observed inter-annual variability and save discussion of climate scale change for a larger study.

The intention here is to focus on a first Arctic-wide quantification of the potential importance of lead emissions. As there is concern with the short time period of AMSR-E to discuss the climatological scale, we remove a majority of this discussion from the paper and focus on the seasonal and inter-annual variability of our selected time period.

Specific comments

1. Line 57: There would not be any scattering of incoming solar radiation during the season when there is no incoming solar radiation. Or at least the impact would be small given the darkness dominates the region in the winter season.

We add text to clarify: “In the Arctic, these processes are relevant during the fall and spring, but negligible during polar night, when there is no sunlight.”

2. Section 2.1: It would be helpful to include a description of the operational lifespan of AMSR-E and how that is a constraint on the period of study. Also, the study seems quick to dismiss the use of thermal IR techniques for lead detection. While it is true that microwave bands are less sensitive to clouds, the IR sensors have higher spatial resolution. There could be more discussion on the lifespan of SSA in the atmosphere and the relationship between SSA and clouds. For example, it would seem that SSA would have negligible radiative forcing when under a canopy of opaque clouds, the observation of cloud may be larger SSA sink than a source (even if there are leads under cover of clouds), and how does the lifespan of SSA in the atmosphere compare to clouds (if they are on the same order of magnitude, then detection of SSA under clouds may be irrelevant)?

We include this information in Sect 2.2: “The Advanced Microwave Scanning Radiometer-Earth Observation System (AMSR-E) sensor aboard NASA’s Aqua satellite recorded brightness temperatures from Earth from 2002-2011 at six different frequencies…”

We modify the discussion of AMSR-E data selection in Sect 2.1: "We use the AMSR-E lead area product for this study as it avoids cloud interference when detecting leads and provides nearly consistent daily resolution. A limited quantitative validation by Röhrs and Kaleschke (2012) of one day (March 21, 2006) of the AMSR-E product against Moderate Resolution Image Spectroradiometer (MODIS) showed 50% of the total lead area visible in 500 m MODIS images was detected in the AMSR-E product. However, leads greater than 3 km in size ("large leads") are detected with certainty (Röhrs and Kaleschke, 2012), so our results effectively estimate emissions from large leads only."

We also clarify that GEOS-Chem only represents one-way interactions between meteorology and chemistry: "GEOS-Chem represents one-way interactions between meteorology and chemical constituents, meaning meteorology can affect the concentration of chemical species but not vice versa." Lines 179-182

3. Line 153: There is mention that 50% of the total lead area visible in MODIS is detected by AMSR-E. But presumably the AMRS-E would have a bias towards detected the wider leads. Has there been any work to study a correlation between lead with and SSA emission? There seems to be an assumption that leads emit SSA at an equal rate as a function of width. However, I would suspect that narrow leads are more likely to emit SSA at a higher rate per area because there would be more thermal contrast (and convective mixing) associated with narrow leads and a lower rate of SSA emission for wider leads. But this is my own speculation, and a literature review on this may be necessary to see if there have been any studies on this.

There is no existing information regarding the relationship between lead width and SSA emission. We include in the text our assumption of an equal rate as function of width: "We assume that leads emit SSA at an equal rate as a function of lead area." Lines 202-203

4. Line 155: The reference to the Hoffman et al 2022 paper does not seem appropriate here. That paper uses the Level 1 brightness temperatures for the lead detection not the Level 2 SST product. The SST product is in fact limited to clear sky conditions. But lead detection in Hoffman et al '22 is possible under optically thin cloud conditions (under a wider range of conditions where a sea surface temperature retrieval is possible).

We remove this part of the sentence and citation.

5. Line 262: It would be helpful to identify regions by the name of the sea rather than location relative to a country.

We change the text as follows: "Generally, emissions tend to be higher from 70° to 80° N and more concentrated within the Bering Strait, Nares Strait, Wynniatt Bay in the Canadian archipelago, and the eastern Greenland Sea, as opposed to off the coast of Northern Russia and Europe." Lines 280-282

6. Line 277: Is there a trend in the inter-annual viability? If so, could results be presented as a slope rather than a constant?

We clarify what is meant by interannual variability by revising the sentence: “The standard deviations in Table 1 represent the year-to-year variability in emissions, as the calculation is performed across the 7-year simulation time period for each month.” Lines 291-292

7. Line 279: It might be helpful to show the corresponding lead area, mean wind, and mean SST to get a better sense of how these relate to the plotted SSA emissions.

Because of the highly nonlinear nature of the relationships between SSA emissions and SST and windspeed (Equation S.1), unlike the lead area fraction which is a linear scaling, we would not expect the monthly mean SST or windspeed to have a strong relationship with monthly mean lead emissions. We add more detail referencing Equation S.1 in lines 311-316: “We find that the magnitude of lead emissions varies by month and year, as well as seasonally (see Fig. 3 and Figs. S.1 and S.2). Monthly total lead emissions and lead area have low correlation (R^2= 0.13, see Fig. S.3), indicating the variance in monthly total lead emissions is dominated by the nonlinear dependencies on wind speed and sea surface temperature (Eq. S.1 in SI), as the lead emissions are calculated with the Jaegle et al. (2011) wind speed and sea surface temperature source function.”

See also Figure S.3 referenced here.

8. Line 305: It seems surprising that the largest increase in SSA appears in the Canadian Archipelago, but Figure 1 did not show this region to have especially high lead fractions. There is a brief mention of this in the conclusion, but more explanation may be appropriate in Section 3.2. For example, is the lead fraction low in this region because the denominator includes water area plus land area; would the lead fraction be higher if the denominator is only water area?

We change Figure 1 to show the lead area fraction from 01/01/2003 (formerly it was for November 1, 2002), to give a better representation of the lead area with respect to lead emissions in January. We also change the color scheme to make it clearer where the leads are located. As seen in the figure, the location of leads is throughout the Canadian archipelago, and spatially consistent with the location of lead emissions and SSA concentrations from lead emissions. We change lines 275-276 to “We find the lead emissions and lead area are spatially consistent (Figs. 1 and 2a)”

9. Line 392, 399, and 400: given the ranges of uncertainty, 2 significant digits may be more appropriated than the 3 digits that are given.

These values are changed to 2 significant digits.

10. Line 428: This may be a reason to use IR based lead detections and focus on lead emissions under clear sky conditions. Might your bias be because clouds are a net sink for SSA – even if leads are occurring under opaque clouds?

We revise the sentence describing the use of AMSR-E in this study for lead area only (lines 162-163) in the methods section for clarity: “We use the AMSR-E lead area product for this study as it avoids cloud interference when detecting leads and provides nearly consistent daily resolution.” We also clarify Section 2.2 describing the GEOS-Chem model, including the use of and interaction with meteorology, emissions, transport, and deposition.

11. Line 451: Replace “too-low” with “under predicted”.

Replaced.

12. Line 452: How good of an observation site can a station on land be for an observation of oceanic processes? For example, if you have a land-breeze the station might not be representative of the air over the ocean. Have you filtered the observations to only include observations when the wind is in the direction of the ocean and/or exclude observations wind the wind is coming from the continent?

For this study, we use available long-term observations in the Arctic for the time period of this study, which are sparse and limited to the stations we chose. The output from GEOS-Chem is monthly mean data, so we are unable to filter the data according to days with a certain wind direction. If the observational data is filtered according to wind direction, we would need to also filter the simulation data for consistency, which is not possible.