Atmospheric Chemistry and Physics Discussions

Atmos. Chem. Phys. Discuss., referee comment RC1
https://doi.org/10.5194/acp-2021-621-RC1, 2021

Review for Shi et al. entitled “Relative importance of high-latitude local and long-range transported dust to Arctic ice nucleating particles and impacts on Arctic mixed-phase clouds“, submitted to Atmospheric Chemistry and Physics

Anonymous Referee #1

Referee comment on "Relative Importance of High-Latitude Local and Long-Range Transported Dust to Arctic Ice Nucleating Particles and Impacts on Arctic Mixed-Phase Clouds" by Yang Shi et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-621-RC1, 2021

In this manuscript, Shi et al. use the E3SM model nudged to MERRA-2 reanalysis to determine the relative contribution of dust from six different regions to the Arctic dust load, including the local effect. They then investigate the impact of both dust from local Arctic sources (referred to as “high-latitude dust” (HLD) and dust transported from lower latitudes (referred to collectively as “low-latitude dust” (LLD) on Arctic mixed-phase clouds and the Arctic radiative budget at the surface and top of the atmosphere (TOA). The authors find that HLD, LLD from Asia and LLD from North Africa contribute to 31%, 44% and 24% of the total dust burden in the Arctic, respectively. The influence of HLD on Arctic mixed-phase clouds was found to be limited to the surface due to frequent stable thermodynamic conditions, while LLD particularly from Asia were found to influence mixed-phase clouds at colder isotherms at higher altitudes. In terms of the seasonal variations, HLD exhibited more variation and peak concentrations at summer and autumn, whereas seasonal variability was minimal for LLD, although the largest concentrations were found in spring and winter. Overall, the HLD was found to have a net cooling cloud radiative effect (CRE) at the surface to a decrease in warm liquid clouds near the surface during autumn when sunlight is relatively weak.

HLD is currently poorly characterized yet of great importance, especially in a warming world where new sources may be emitted and is thus now becoming the focus of an increasing number of studies. The work of Shi et al. is both interesting and insightful in this regard. I recommend publication of the manuscript after the authors consider some additional suggestions below.

- The limited vertical transport of HLD was claimed to be due to the existence of a stably stratified Arctic lower-troposphere. I would suggest to actually quantify this using the lower tropospheric stability (e.g. as the difference in potential temperature between 850 hPa and 2m). Are there differences over sea-ice and open ocean surfaces when LTS is substantially different? Does E3SM simulate LTS in reasonable agreement with observations? Please evaluate.
- Lines 38-42: The influence of these various cloud microphysical processes may also interact nonlinearly with one another and impact the phase partitioning of mixed-phase clouds as shown by Tan & Storelvmo (2016).
- Source-tagging on lines 158-161: There is insufficient description of this technique in the manuscript itself. In addition to citing these references, please briefly describe the methodology and implementation of the technique. It seems that the six different regions are set up such that in addition to tagging them, they can also be separately tuned.
- Is aging of aerosols and the addition of coatings of pollutants that may modify the ice-nucleation efficiency of dust INPs represented in E3SM?
- Given the large discrepancy between model and observations in Alert, the authors should consider utilizing long-term observations of dust available in Alert as described in Sirois and Barrie (1999).
- Are the observations and simulated AOD, dust concentrations and deposition flux directly comparable? For example, observations of cloud properties cannot be directly compared with remote sensing observations without a simulator to account for differences in the definitions of these quantities. One would expect the same for aerosol properties as well.
- The discrepancy (up to almost twice) between this study and previous studies in terms of the contribution of North African dust to the Arctic dust burden is quite large. Potential reasons are listed on lines 308-310: Of these processes, which process dominates?
- Figures 12 and 13: It would be useful to compare how E3SM simulates Arctic CREs at the surface and TOA (e.g. comparing with the NASA CERES instrument), and how HLD vs LLD contributes to biases in the Arctic CREs in an additional column. Similarly for the LWP. The MODIS simulator can be used for the sunlit months.
- Comparison with CALIOP: Why use observations from 2007-2009? The record extends well beyond that and the 2007 observations are partially impacted by the change in the tilt of the nadir-viewing angle. Also, what CALIOP product was used and what was the version of the product? Arctic aerosol layers are frequently too tenuous to be detected by CALIOP and are also furthermore impacted by the presence of clouds that can interfere with the cloud-aerosol discrimination algorithm.

Typographical error:

- Line 137: “hour” should be “hours”

References:

Tan, Ivy, and Trude Storelvmo. "Sensitivity study on the influence of cloud microphysical parameters on mixed-phase cloud thermodynamic phase partitioning in CAM5." *Journal of the Atmospheric Sciences* 73.2 (2016): 709-728.

Sirois, Alain, and Leonard A. Barrie. "Arctic lower tropospheric aerosol trends and composition at Alert, Canada: 1980–1995." *Journal of Geophysical Research: Atmospheres* 104.D9 (1999): 11599-11618.