Synoptic-timescale variability of Arctic aerosol in three reanalyses and its relationship to the atmospheric circulation in summer

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The Arctic has warmed faster than the global average. Atmospheric aerosols can change the radiation budget through aerosol–radiation interaction, aerosol-cloud interaction, and decreasing surface albedo over snow and sea ice. Hence, aerosol influence is considered one of the most important factors for the Arctic climate system. Still, the estimation of Arctic aerosol effects contains large uncertainties. Although several observational campaigns have been conducted, the sparse observation network over the Arctic is one of the reasons for the uncertainties. Aerosol reanalyses, which fill the gap between observations through model dynamics, provide spatiotemporal distributions over the globe. Recently, Xian et al. (2022) showed that three aerosol reanalyses generally reproduce the monthly climatological variabilities, and negative (positive) trends in spring (summer) of aerosol optical depth (AOD) over the Arctic as estimated from satellite observations. However, no study has yet investigated the relationship between Arctic aerosol behaviors and synoptic disturbances in summer, when Arctic cyclones (ACs) are most frequently observed.

In this study, we assessed the Arctic AOD variability in three reanalyses (JRAero, CAMSRA, and MERRA2) and investigated its relationship to synoptic-scale atmospheric circulation. In all the Arctic regions, except in the North Atlantic, the AOD becomes highest in July–August. The temporal variabilities (average, median, and quartile values) (Fig. 1a) and horizontal distribution of total AOD in summer were generally consistent among the three reanalyses. In contrast, the contributions of individual aerosol species to the total AOD are quite different among the reanalyses (Fig. 1b-f). The first and second largest contributions to the total AOD were organic carbon and sulfate in all reanalyses, but the sea salt contribution was comparable to the sulfate contribution in JRAero. Compared to the limited satellite observations, the summertime AOD variability is generally represented in all reanalyses (R>0.6), albeit its magnitude exhibited an error as large as the average AOD (RMSE was equal to the average). The EOF analysis showed large variabilities over Northern Eurasia on the synoptic timescales. Our results highlighted that the essential role of the generation and development of summertime Arctic cyclones and the associated moisture and precipitation in aerosol transportation and deposition over the Arctic (Fig. 2).

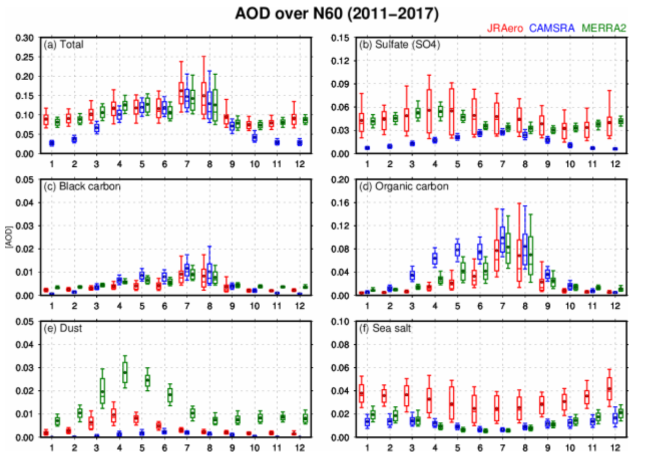

Figure 1. (a) Histogram of the six-hourly total AOD and the contributions of (b) sulfate, (c) black carbon, (d) organic carbon, (e) dust, and (f) sea salt aerosol to the total AOD in JRAero (red), CAMSRA (blue), and MERRA-2 (green) over north of 60ºN.

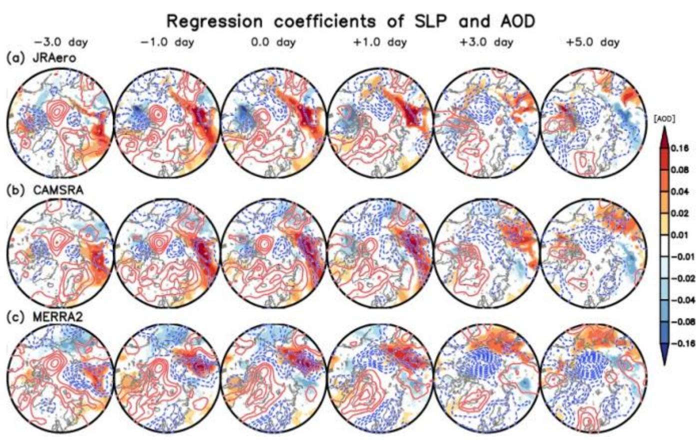

Figure 2. Total AOD (shading) regressed onto PC-1in (a) JRAero, (b) CAMSRA, and (c) MERRA2 from the −3 to +5-day lag. The blue (positive) and red (negative) contours show the SLP in JRA-55 regressed onto EOF-1 for each aerosol reanalysis.

References

Xian, P., Zhang, J. et al., Arctic spring and summertime aerosol optical depth baseline from long-term observations and model reanalyses – Part 1: Climatology and trend. Atmospheric Chemistry and Physics, 22(15), 9915–9947, 2022.

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