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Aerosols in the central Arctic cryosphere: Satellite observations and Model simulations during Spring and Summer

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Abstract

The Arctic is currently warming rapidly, at a rate four times higher than the global average. This warming has significant consequences, leading to increased precipitation in the Arctic. Aerosols play a crucial role in cloud formation, cloud condensation nuclei (CCNs) and ice-nucleating particles (INPs), influencing rain and snowfall. However, uncertainties remain in the modelling of aerosols and their impact on precipitation due to a lack of high-resolution spatio-temporal observations. This is particularly the case in the central Arctic cryosphere due to the presence of extensive cold, bright snow and ice surfaces coupled with widespread cloud cover.

This study addresses the observational data gap and provides an opportunity to refine model simulations at different spatio-temporal scales. We achieve this by using total aerosol optical depth (AOD) datasets generated by the AEROSNOW algorithm over the extensive central Arctic cryosphere. AEROSNOW retrieves AOD data using top-of-atmosphere reflectance measurements obtained through the Advanced Along-Track Scanning Radiometer (AATSR) aboard the ENVISAT satellite, spanning from 2003 to 2011. AEROSNOW integrates an aerosol retrieval algorithm with a rigorous cloud masking scheme and introduces a novel quality flagging methodology tailored for the central Arctic region (≥ 72°N).

Using the AEROSNOW retrieved dataset for the central Arctic, we evaluate different models participating in the sixth phase of the Coupled Model Intercomparison Project (CMIP6). Our results show significant differences in the spatio-temporal aerosol load and its annual and seasonal variations with

precipitation. In particular, there is a decrease in aerosol loading that coincides with increased precipitation along the northern periphery of Alaska and the Bering Sea.
Significant discrepancies and variations of up to 6.2 mm/day in precipitation are observed between models, with higher aerosol loading leading to lower precipitation and vice versa. Furthermore, the spatially averaged multi-model mean overestimates aerosol concentrations in spring and underestimates them in summer compared to satellite observations. The CMIP6 models do not reproduce the seasonal variations in aerosol distribution seen with AEROSNOW, particularly an increase in aerosol loading during the summer coinciding with the sea ice retreat cycle. These discrepancies may be due to the lack of advanced natural aerosol formation mechanisms in the models, as a consequence of Arctic warming, and exposure to open ocean emissions.

In summary, our study has led us to speculate that as model sophistication increases, modelled aerosol processes become increasingly uncertain. Ultimately, this investigation has the potential to elucidate the critical link between aerosols and the prevailing rain-dominated Arctic conditions under ongoing Arctic warming in future CMIP projects.