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# Characterizing Aerosol-Cloud Interactions during Nitrogen-Dominated Episodes over the Netherlands

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Aerosol-cloud interactions (ACI) are a significant source of uncertainty in climate projections. Nitrogen-dominated aerosol episodes are emerging over the Netherlands, strongly influencing local air quality and climate, but our understanding of aerosol-cloud interactions under these nitrogen-dominated conditions is still not well quantified. Ground-based remote-sensing instruments like cloud radars can provide us high temporal and spatial resolution data for cloud microphysics, like cloud droplet number concentration, and aerosol properties can be obtained using lidar measurements. In this study, we quantify how these aerosol particles in nitrogen-polluted episodes affect low-level clouds by combining remote-sensing observations with aerosol speciation measurements at the Ruisdael Observatory in the Netherlands.

Generally, column aerosol optical depth (AOD) from sun photometers and vertically resolved attenuated backscatter (ATB) from ceilometers are used as aerosol proxies. A key difference is that AOD represents extinction integrated over the full atmospheric column, whereas ATB is a vertically resolved backscatter profile, and ATB must therefore be vertically integrated for a meaningful comparison. However, both respond differently to meteorological parameters, aerosol loadings, and the instrument’s configurations. Therefore, understanding the variation of ATB and AOD in response to meteorology is essential. Overall, our framework will provide consistent conditions under which ceilometer ATB can be used as an aerosol proxy along with the column AOD during nitrogen-dominated episodes.

Here, we use a Mie model framework to investigate how ATB and AOD behave under different aerosol compositions, loadings, and meteorological conditions. Further, using a long-term observation from Cabauw (the Netherlands) as a case site, we focus on periods when nitrate clearly dominates the aerosol composition. Surface data from aerosol mass spectrometry and size-distribution measurements are combined with ceilometer profiles, sun-photometer retrievals, and meteorological data. Together, these measurements allow nitrogen-dominated episodes to be grouped by composition, relative humidity, and boundary-layer conditions, providing a consistent

way to quantify aerosol-cloud interactions.

Our initial results indicate that, during nitrate-dominated episodes, hygroscopic aerosol particles build up in the boundary layer and strongly enhance light extinction. Extinction, backscatter, and other related aerosol optical properties respond strongly to RH-driven particle growth, making the growth factor a key control on the observed signals. We will investigate these relationships in more detail using measurements from both the RITA-2021 and the CAINA-2025 campaign datasets. These nitrate-rich aerosols act as cloud condensation nuclei (CCN), and they are expected to increase cloud droplet number concentration with more but smaller cloud droplets, which can be detected by ground-based cloud radar observations.

The resulting framework provides insight into how nitrogen-rich aerosol pollution affects clouds' microphysical properties and strengthens the understanding of aerosol-cloud interactions in nitrate-dominated environments.