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Influence of sea surface microlayers and phytoplankton blooms on sea spray aerosol hygroscopicity and the possible implications for mixed-phase clouds

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Introduction:
Breaking waves on the ocean surface lead to sea spray aerosol emission to the atmosphere. Sea spray aerosols are a major source of uncertainty in climate models. The physical processes governing sea spray aerosol production play an important part in determining sea spray aerosol emission, size distribution, and chemical composition. Sea spray often contains organic material, but it is unclear how this material affects the ability of particles to act as cloud condensation nuclei (CCN).

Methods:
We have measured the CCN-derived hygroscopicity of different types of aerosol particles generated from the following seawater proxies and real seawater using a sea spray simulation tank (Christiansen et al., 2019), AEGOR, or an atomizer in a laboratory setup (Christiansen et al., 2020):

- Artificial seawater
- Artificial seawater spiked with diatoms cultured in the laboratory
- Samples of sea surface microlayer (SML) collected during field campaigns in the North Atlantic and Arctic Ocean.
- A continuous supply of fresh seawater during a three-week field campaign (June 2019) on the Faroe Islands, while following oceanic biogeochemical parameters.

Large-eddy simulation (LES) has been used to evaluate the general role of aerosol hygroscopicity in governing mixed-phase low-level cloud properties in the high Arctic.

Conclusions:

- We show that sea spray aerosols generated using diatom cultures and surface microlayer water exhibit CCN activity similar to that of inorganic sea salt (κ value of ~1.0), independent of dry particle size (50, 75, and 100 nm).
- The critical supersaturation of dry 80 nm SSA was relatively invariable (0.158±0.04%), corresponding to the overall hygroscopicity parameter κ of 1.08±0.05% derived from CCN during the phytoplankton bloom. This is despite indications that the chemical composition of both the seawater and the SSA were impacted by the presence of the phytoplankton.
- For accumulation mode aerosol, the simulated mixed-phase cloud properties do not depend strongly on κ, unless $\kappa < 0.4$. In addition, the cloud is sustained for all simulated cases.
- For Aitken mode aerosol, the hygroscopicity is more important changing the microphysical structure of the cloud and its radiative properties; here the particles can sustain the cloud only when $\kappa \geq 0.4$.

The experimental and model results combined suggest that the internal mixing of biogenic organic components in SSA does not have a substantial impact on the cloud droplet activation process and the cloud lifetime in Arctic mixed-phase clouds.

References:

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