Observations of Aerosol-Cloud Interactions during the North Atlantic Aerosol and Marine Ecosystem Study

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Background

- CDNC: a cloud microphysical property that impacts radiative forcing, cloud evolution, precipitation, local and global climate and... discussions, can be used to monitor and predict the cloud albedo effect, as the first moment effect (Zhang et al., 2011).
- Aerosol-cloud interactions is a mechanism whereby an increased aerosol concentration results in increased cloud droplet number concentration leading to changes in the radiation properties of the cloud (Schneider 1977) as well as the lifetime of the cloud (Albrecht, 1989, Gao and, 1999).
- Number concentration can be related to cloud albedo through the simplified expression:

  \[ \alpha \sim 1 - 10 \times \frac{N_{\text{CDNC}}}{N_{\text{CDNC}} + 1} \]

  (Platnick &.Toomey, 1994).

- Aerosol-cloud interactions, as the first indirect effect, can be obtained through monitoring cloud droplet number concentration.

Research Objectives

1. To assess the strength of the connection between cloud properties and aerosol concentration and composition during NAAMES
2. To determine which cloud properties are least and most sensitive to aerosol concentrations
3. To explore variations in aerosol and cloud properties on daily and seasonal timescales

Instruments

- Portable for AEROSOL PolyLidar (POL) (Grenfell et al., 2013).
- All cloud scattering -152 viewing angles per frame (cloud 1/4) 1/s foot of view
- Polarimetric and full intensity measurements in the visible and ultraviolet range near 940, 475, 555, 671, 849, 1020, 1280, 2240 nm.

Results: Aerosol Mass

- Condensation Realizer Counter (CRC): CDNC measures the concentration of cloud condensation nuclei (CCN) at several supersaturation levels
- Supersaturated levels range from 0.07% to 10% as high as 2%.
- Droplet sizes from 0.75 to 1.0 micrometers.
- Provides organically aerosol analysis of aerosol size and spherical mass leading transitions.
- Particle size range: 0.5% - 1.0 micrometers

- North Atlantic Aerosols and Marine Ecosystems Study (NAAMES)
- 4 aircraft and ship measurement campaigns over 5 years (each campaign is aligned to a specific annual event in the planktonic cycle).
- Goals:
  - Characterize planktonic ecosystems properties during primary phases of the annual cycle in the North Atlantic and their dependence on environmental forcings.
  - Determine how marine aerosol and boundary layer cloud are influenced by planktonic ecosystems in the North-Atlantic (and their feedbacks).

Measurements

- Cloud Interactions during the North Atlantic Aerosol and Marine Ecosystem Study (NAAMES)
- Four aircraft and ship measurement campaigns over 5 years. Each campaign is aligned to a specific annual event in the planktonic cycle.

Results: Np and CCN

- Np and CCN
- CCN at 0.35% supersaturation

- Cloud Property Correlations

- Key finding: Aerosol cloud dust loading has a strong positive correlation with liquid water path.

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- Cloud Property Variability

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Conclusions

1. Meteorological conditions can explain some variability of aerosol effect on cloud properties.
2. Increased aerosol was found to have a detectable effect.
3. Strong correlation was found between Np and CCN.
4. High correlations also for R_{0.35\%}, R_{0.4}, R_{0.8}, R_{0.95}, R_{0.99} (p < 0.05).
5. Cloud property and aerosol concentration changes are found to be consistent with the Timescale effect.
6. Cloud relative humidity has a strong inverse correlation with liquid water path and therefore plays an important role.
7. A seasonal change in aerosol chemical composition is observed, which correlates with a seasonal change in cloud properties.
8. Cloud droplet size is found with increasing NW between campaigns.

Future Work

A. Use a LES model to better determine cloud property dependencies on meteorological properties
B. Use the in situ UHSAS instrument to assess aerosol size distribution and hygroscopicity on CCN Np sensitivity

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