The Relationship between Dimethyl Sulfide and Marine Cloud Condensation Nuclei in the Northern Atlantic Ocean

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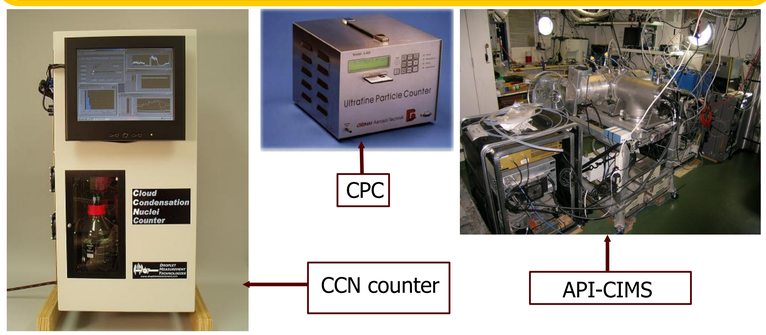
Abstract

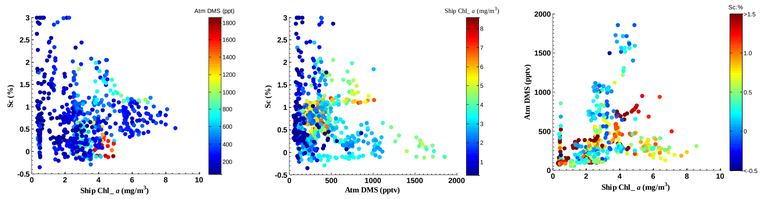
Despite numerous studies since the CLAW hypothesis was first suggested in 1987, the extent to which marine dimethyl sulfide (DMS) contributes to marine atmospheric aerosol populations and the ability of those aerosol to act as cloud condensation nuclei (CCN) remains unclear. Here, we present data from a cruise aboard the R/V *Knorr* in the Northern Atlantic during June-July 2011which passed through areas of relatively high and low phytoplankton biomass. Continuous ambient measurements of aerosol concentration, cloud condensation nuclei (CCN) concentration, aerosol particle size distributions, and seawater and atmospheric dimethyl sulfide (DMS) concentrations were performed simultaneously during the three-week-cruise. Throughout the cruise, CCN concentration was measured at a series of five supersaturation levels and used to derive the critical superstation required for aerosols to activate as CCN. Our preliminary data analysis shows that the maximum atmospheric DMS concentration and the lowest critical supersaturation were both observed on July 7th – 8th (UTC). However, while our data suggests that phytoplankton blooms result in increases in aerosol available to act as CCN, other factors, including meteorological conditions and non-marine contributions to the aerosol populations, influence the properties of aerosols and formation of marine clouds. Factors contributing to the cloud nucleation ability of aerosol particles will be presented and the atmospheric implications discussed.

Instrumentation



CCN counter and CPC were used to measure cloud condensation nuclei and CN concentrations respectively. API-CIMS was used to measure both atmospheric and seawater DMS levels.

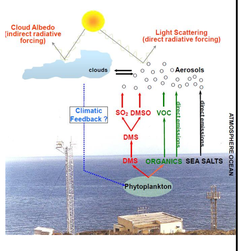
Intercomparison Results



A. Chl_*a* is not a reliable indicator of marine biological activity.
B. Chl_*a* is not a good predictor of cloud formation, even in the unpolluted open ocean.
C. Under high Chl_*a* conditions, critical supersaturations were constrained to a range between 0.6 and 1.0%.
D. Aerosols with lowest critical supersaturations (most effective for cloud formation) were observed during conditions of high DMS levels.

Hypothesis and Background

CLAW hypothesis:



(Sciare *et al*, 2008)

Goals of the research:

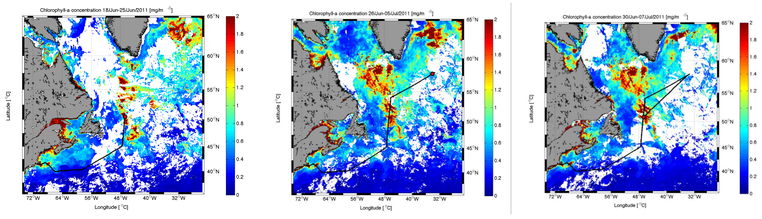
To better understand the relationship among chlorophyll *a* (Chl_*a*), DMS and CCN activity of aerosol in marine atmosphere and its impact on global climate.

To measure in-situ aerosol concentration (CN) and cloud condensation nuclei (CCN) concentration at a series of supersaturation (SS) conditions → Critical supersaturation (S_c): An indication of cloud nucleation ability;

To measure seawater surface and atmospheric DMS concentrations→ precursors of nss-SO_4^{2-} and MSA;

To compare S_c and DMS with ship measured Chlorophyll *a* concentrations and understand their interconnections.

Phytoplankton Blooms

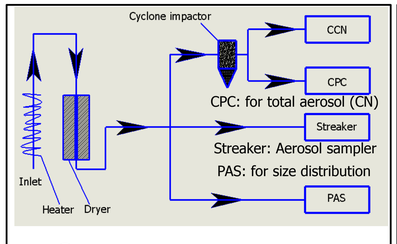


The route of the cruise is gradually modified from the original plan when chasing the phytoplankton bloom signified by the satellite retrieved Chl_*a* concentrations.

Conclusions

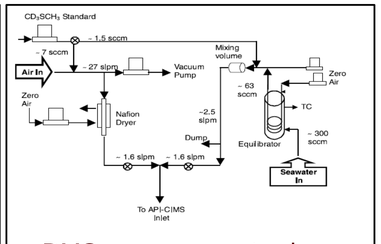
- Cruise chased a phytoplankton bloom successfully
  Chl_*a* reached a maximum of 5.4 mg/m^3; Atmospheric DMS concentration reached a maximum of 1.86 ppbv
- Temporal and spatial variation of measured species are observed
- There are no simple linear relationships among Chl_*a*, DMS and S_c
- DMS levels and aerosol cloud nucleation ability peaked before reaching bloom
- Chlorophyll *a* concentration is not a precise indicator for other parameters
- Also, under high DMS level conditions:
  The range of observed critical supersaturations narrows to lower than 0.4% (when DMS level higher than 1400 pptv) and sharply drops to smaller than 0% (when DMS concentration exceeds 1800 pptv) , indicating that all aerosol are highly effective nuclei at that DMS level
- The influence of marine DMS on climate needs further research

Measurements



S_c measurement scheme

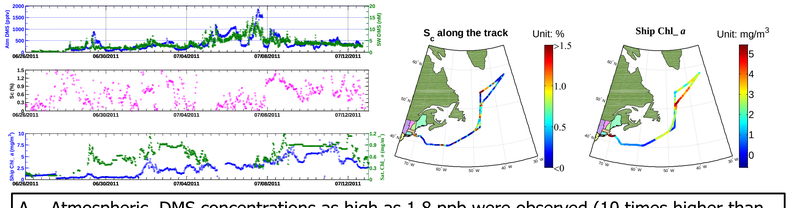
CCN instrument is running in a series of five super-saturation (SS) levels (0.15, 0.25, 0.5, 0.9 and 1.2%). The SS at which 50% CCN/CN is achieved is defined as critical supersaturation (S_c).



DMS measurement scheme

On the left is for atmospheric DMS sampling and on the right for surface water DMS sampling. Flow rates are shown in standard cubic centimeter per second and liter per minute.

Temporal and Spatial Variation



A. Atmospheric DMS concentrations as high as 1.8 ppb were observed (10 times higher than a typical coastal level).
B. At most times, critical supersaturation is highly variable.
C. However, under conditions of high DMS, the mean critical supersaturation is reduced to a narrow range of supersaturations, <0 – 0.4 %, representing efficient CCN.
D. The peaks of atmospheric and Seawater DMS concentrations and the trough of S_c both happened (July 7th to 8th) before the phytoplankton bloom (July 9th to 12th). In spatial perspective, they happened before reaching bloom region, which may be due to transportation.

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- Crew members of R/V *Knorr* cruise