Air Mass History of Southern Ocean Cloud Droplet Number (N_d) Concentrations

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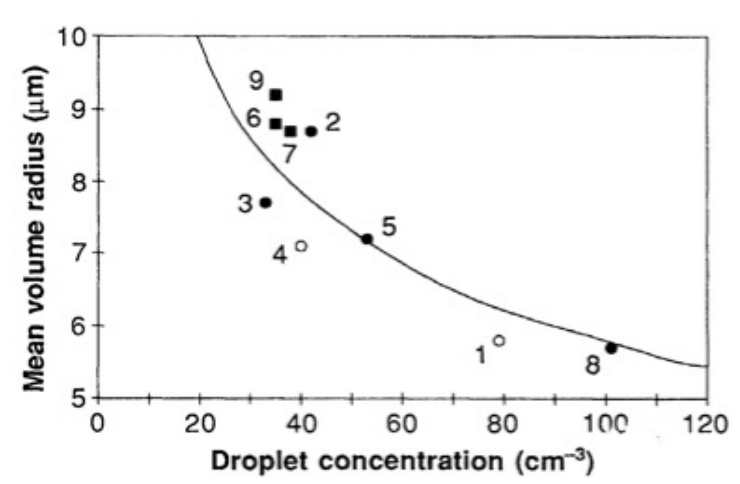
Question: Are there differences in air mass history between cases of high and low concentrations of cloud droplet number (N_d)?

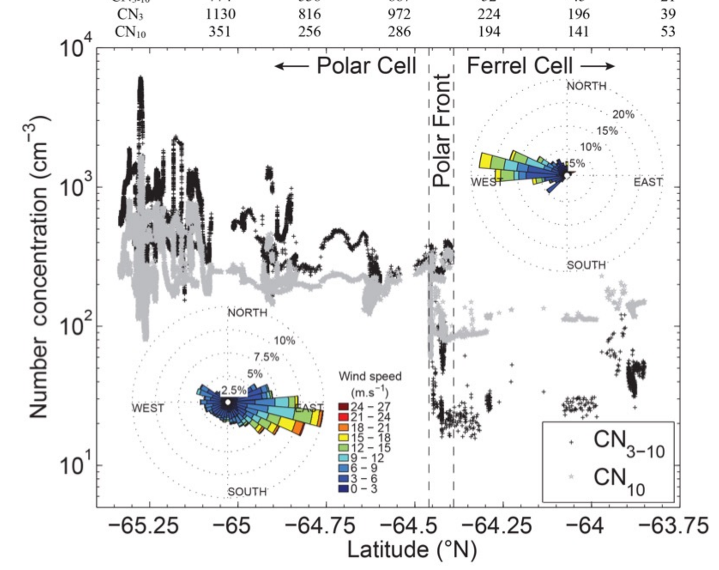
Introduction

- Cloud condensation nuclei (CCN) concentrations are important in the modulation of cloud optical thickness and precipitation production in shallow clouds (Twomey, 1977 ; Albrecht, 1989).
- When CCN concentrations exceed 150 cm^{-3}, drizzle production experiences a significant decrease (Albrecht, 1989).
- Low aerosol concentrations are observed in the Ferrel cell and high aerosol concentrations are observed in the polar cell (Humphries et. al., 2016).
- A relationship between aerosol number concentrations and atmospheric pressure was found showing low pressure systems are associated with the highest concentrations *and air mass trajectories over the Antarctic, and high pressure systems are associated with low aerosol concentrations and trajectories over the open ocean* (Humphries et. al., 2016).



(Albrecht, 1989)

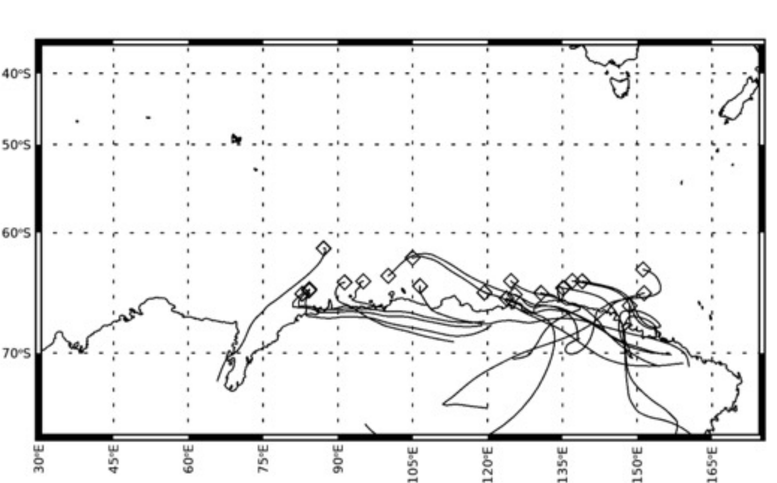
Aerosol Size Range	Polar Cell Concentration (cm^{-3}) Mean	Median	IR	Ferrel Cell Concentration (cm^{-3}) Mean	Median	IR
CN_{3-10}	774	536	667	52	45	21
CN_3	1130	816	972	224	196	39
CN_{10}	351	256	286	194	141	53



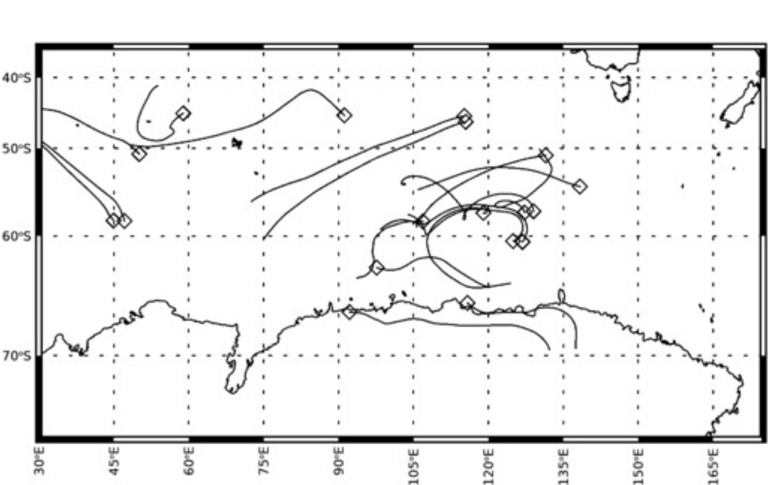
(Humphries et. Al., 2016)

Method

- We take the MODIS cloud product (MOD06_L2) and calculate cloud particle number density using the method described by Grosvenor et al (2018).
- To avoid precipitation, we focus on liquid phase clouds with effective radius less than 50µm and liquid water path less than 250 g/m^2. We create histograms of the microphysics of these clouds in a 2° longitude by 1° latitude bin.
- We selected MODIS aqua histograms of cloud microphysics in January of 2017. The region of interest was -45° to -67° latitude and 40° to 152° longitude. We ordered the histograms based on the mean Nd in the grid boxes. We then selected the 20 highest Nd histograms and the 20 lowest Nd histograms. We ran the HYSPLIT program to track the air parcels in these histograms back in time 3 days.



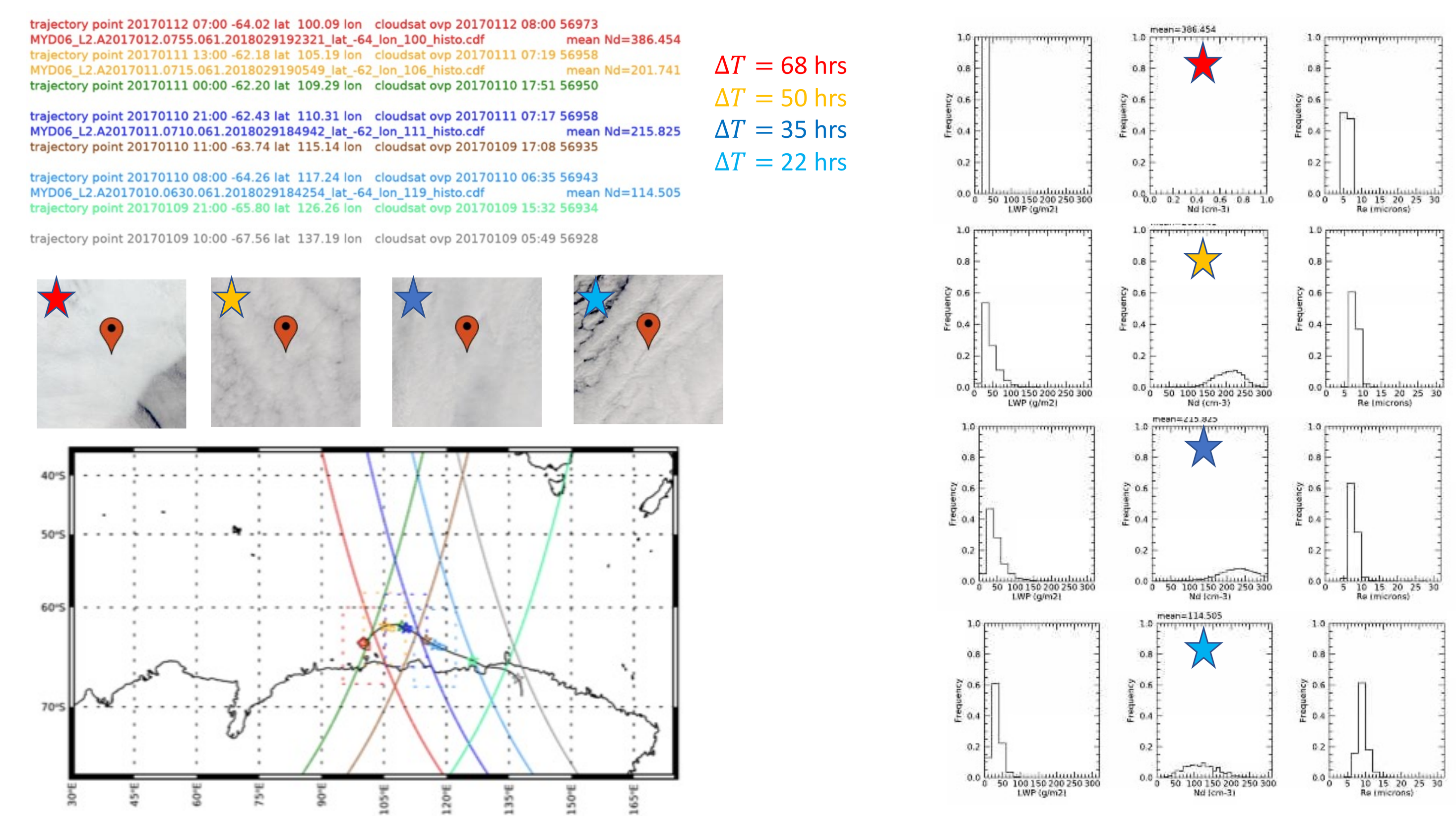
All trajectory tracks consisting of high n_d cases



All trajectory tracks consisting of low n_d cases

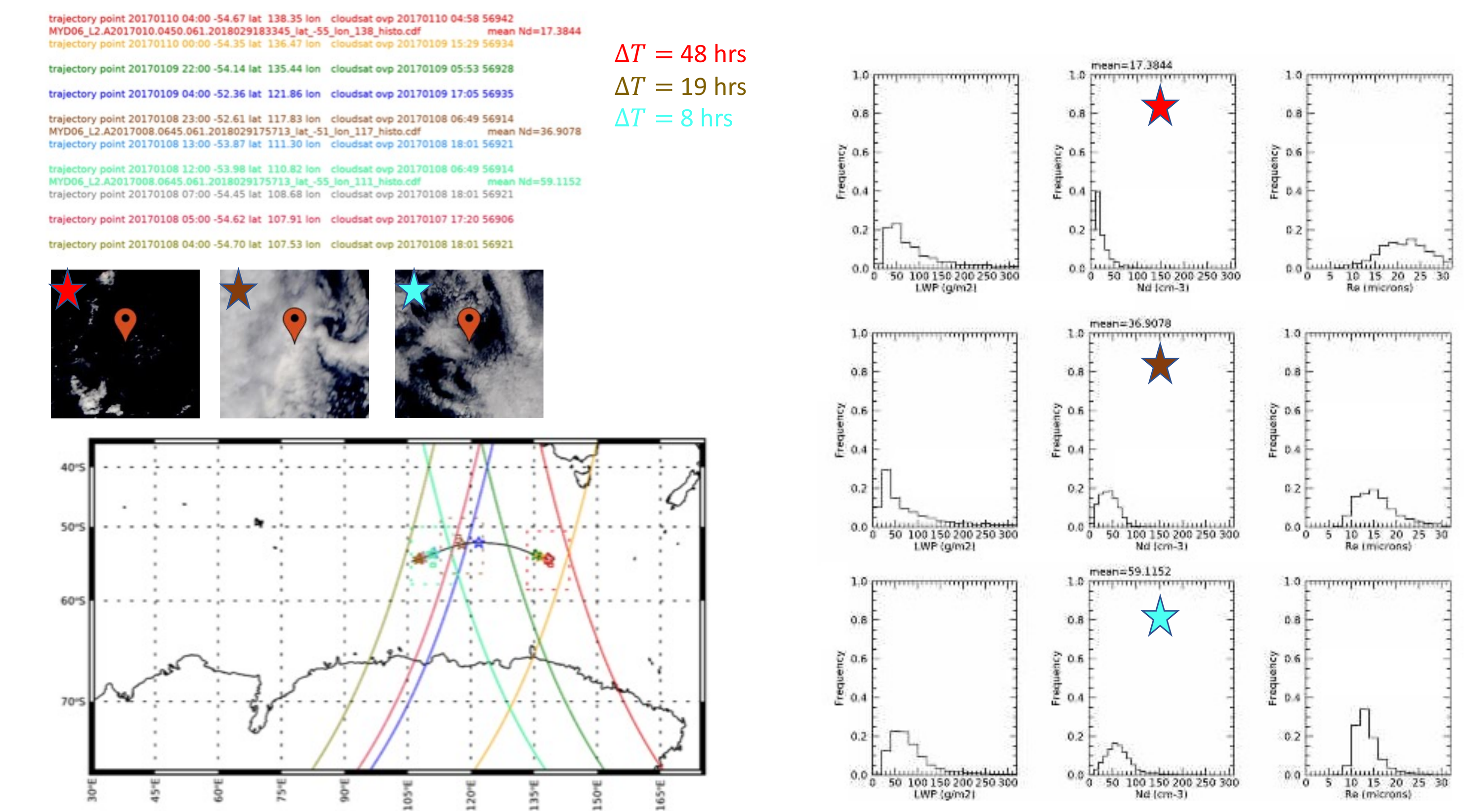
Results

High Trajectory Case Study



- MODIS histograms were examined along the 3-day back trajectory of the air mass.
- This case starts over land and ends over the Southern Ocean.
- **Liquid water paths remains generally constant throughout the trajectory.**
- **Cloud droplet number increased throughout the lifetime of this trajectory.**
- **Layer mean effective radius decreased slightly during this trajectory.**

Low Trajectory Case Study



- MODIS cloud properties were sampled along the air mass back trajectory.
- Liquid water path decreased over time.
- Drizzle lowers the cloud droplet number by the process of scavenging.
- **Cloud droplet number decreased over time.**
- **Layer mean effective radius increased over time.**
- **This is a case where drizzle was prominent during the trajectory.**

Conclusions/Findings

- High droplet number cases typically started over Antarctica and moved over the ocean.
- Low droplet number cases typically occurred further North over the open ocean above 60ºS latitude.
- The Ferrel cell continued to experience low aerosol concentrations while the polar cell experienced high concentrations.
- In the high trajectory case study, liquid water path remained generally the same, cloud droplet number increased, and layer mean effective radius slightly decreased during the backwards trajectory.
- In the low trajectory case study, due to drizzle, liquid water path and cloud droplet number decreased over time.
- **We suspect that biogenic sulfate aerosols in the summer months suppresses precipitation over the high latitude Southern Ocean in a way that does not happen over the open oceans further North.**

Bibliography

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