SOCRATES: Overarching goals and science hypothesis guiding development of experiment in Southern Ocean

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GCM Biases over Southern Ocean are critical for global climate sensitivity

↑ Insufficient cloud cover and albedo in CMIP3 models over Southern Ocean (50-70°S)

Cloud biases correlate with global climate sensitivity ➔

Trenberth and Fasullo (*J. Climate*, 2010)
What clouds cause the large SW bias?

Largest biases are:
...in “mid-topped” ISCCP cloud cluster
...are really a mix of low and mid-level clouds
... on the poleward side and in cold sector of storms

Bodas-Salcedo et al. (J. Climate, 2014)
Why do we care? Mixed phase processes and satellite validation

CloudSat-CALIPSO cloud phase (Delanoë and Hogan 2010, Hu et al. 2009)

The Southern Ocean hosts the largest amount (by far) of supercooled liquid water in the world. 25% of clouds have SLW at -10°C, still 10% at -30°C according to DARDAR.

These products/model features need validation over the Southern Ocean.
Strong seasonal cycle of aerosols and cloud droplet concentration $N_d$ over Southern Ocean

- Marked annual cycle of $N_d$ in low clouds over Southern Ocean
- Summer maximum likely biogenic (DMS, organics)
- Low values, esp. in winter, have implications for strength of AIEs (e.g. Hoose et al. 2009)
- In-situ and satellite observations consistent
- Would lead to summertime albedo enhancement (Twomey) of $\sim 25\%$

Wood et al. (2014)
What factors control the magnitude and uncertainty of the global AIE?

- Accumulation mode width
- Cloud thickness
- Low cloud fraction
- Updraft velocity
- Cloud water replenishment time
- Threshold radius for autoconversion
- Anthro BC+POM emissions
- Anthro SO2 emissions
- Anthro SOA emissions
- Primary mode radius
- Mass fraction new particles
- Mass fraction secondary aerosol mass on accumulation mode

Ghan et al. (J. Geophys. Res., 2013)

....also Carslaw et al. (Nature, 2013)
Sea Spray $\rightarrow$ IN $\rightarrow$ cloud microphysics in obs & GCMs

- **Hypotheses (Paul Demott)**
  - Ice nuclei (IN) from sea spray differ strongly from land sources and their variability is tied to ocean microbiological processes.
  - Differences in microphysical properties and radiative forcing of cold clouds over remote mid-high latitude oceans reflect the influence of these varied IN properties.

![Graph showing ice nuclei concentration vs. temperature](image)

**Need** surface and aircraft measurements to validate lower average IN sources over pristine oceans, high IN at bloom times, identify nuclei source.
Preliminary science questions

1. What are the causes of GCM biases in cloud, aerosol, and radiative properties over the Southern Ocean?
2. To what extent is the Southern Ocean aerosol-cloud system a good proxy for the preindustrial environment?
3. What are the characteristics of the boundary layer over the Southern Ocean and how is it impacted by air-sea interaction?
4. What controls the ubiquitous nature of mixed-phase clouds and the occurrence of supercooled water in the Southern Ocean clouds?
5. What are the main processes involved in the life cycle of frontal cloud systems?
6. How can we better characterize the Southern Ocean clouds, aerosols and meteorology using satellites?
SOCRATES
Southern Ocean Cloud, Rain/Radiation, Aerosol Transport Experimental Study

The Socratic method is a form of inquiry and debate between individuals with opposing viewpoints based on asking and answering questions to stimulate critical thinking and to illuminate ideas.
SOCRATES Objectives

(i) To characterize the physical properties of cloud systems over the Southern Ocean, and the processes involved in the life cycle of cold fronts.

(ii) To characterise microphysical and chemical properties of aerosols and precursor compounds that play a role in regulating CCN and IN over the Southern Ocean and to investigate the relative significance of these on cloud formation, maintenance and radiative properties.

(iii) To improve the quality of satellite cloud, aerosol, precipitation, and upper ocean (phytoplankton, carbon products) products.

(iv) To evaluate and improve the skill of models at different scales to reproduce the observed properties of the Southern Ocean cloud systems, aerosol physicochemical properties, and aerosol-cloud-precipitation interactions.
SOCRATES Sampling (tent.)

- Aircraft
  - Low level heavy-lift a/c to sample clouds/aerosols in the PBL/lower FT
  - HIAPER for deep sawtooth
  - High altitude remote sensing a/c
- Ships
  - Australian Marine National Facility (MNF) R/V Investigator
  - US NOAA or UNOLS ship for aerosol/chemistry/biogeochemistry
- Island
  - Macquarie Island research station (DoE AMF?)
  - Other islands in the Southern Ocean?

Tentative dates Jan-Feb 2018
SOCRATES: Next Steps

- Directions for future research (this workshop)
- White paper on future research directions
- Scientific Program Overview document
Southern Ocean microphysical biases in CAM5

- Annual cycle of cloud droplet concentration (marine liquid clouds)
- Clear Southern Ocean annual cycle (30-60°S) not well-captured in CAM 5