In-situ observations of Southern Ocean clouds

Outline

- Introduction and motivations
- The Hiaper Pole to Pole Observations (HIPPO) missions to the Southern Ocean
- Wintertime research flights from Tasmania

Introduction

- Southern Ocean (SO) clouds present a challenge to the meteorological community.
  - Very cloudy environment with about 90% cloud year round (Morrison et al, 2011).
  - Large biases in radiation budget over Southern Ocean due to cloud/albedo sensitivity (Trenberth and Fasullo 2010).
  - Frequent low (<3 km) cloud cover and multiple cloud layers (Haynes et al, 2011)
- These low-level clouds are “mixed phase” in the sense that they contain supercooled liquid for extended periods
  - Much of the research to date (especially in-situ) has been focussed on Arctic clouds.

Introduction

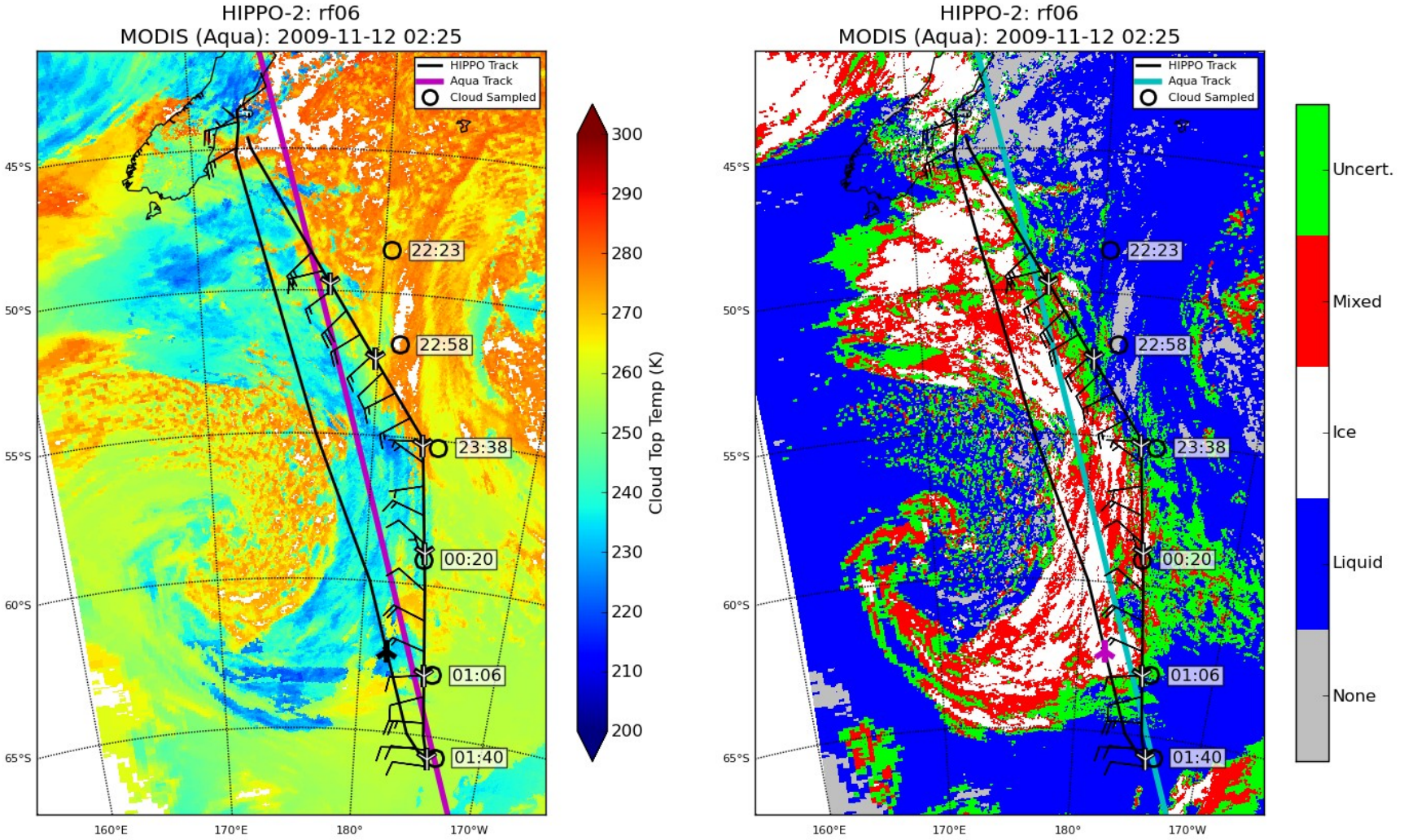
- Only observations of Southern Ocean cloud are remotely-sensed (satellite).
  - Merged radar/lidar products provide the best cloud phase determination, but there are limitations and uncertainties to this (Huang et al, 2012)
- In-situ cloud observation campaigns are hard work, expensive and the conclusions can be limited.
- Can provide “ground truth” to substantiate remotely sensed observations.
- Can give insight into physical processes undetected by remote sensing.

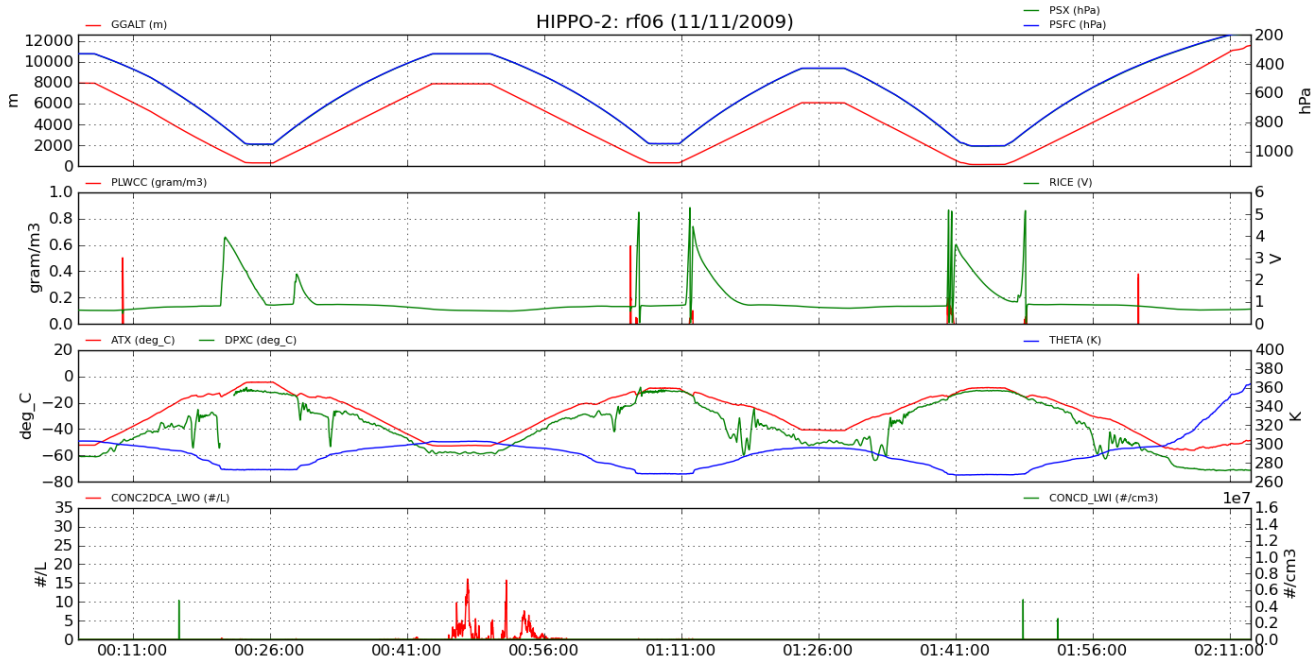
The HIPPO project

- Hiaper Pole to Pole Observations (HIPPO; Wofsy et. al. 2011) measured trace gas and aerosol concentrations across five global transects in different seasons.
- Used the NCAR/NSF G-V jet
- Secondary payload included basic cloud physics instrumentation (LWC, 2DC, CDP)

- Each mission included a segment over the Southern Ocean from Christchurch to 67º S
- Cloud physics data has been largely ignored, and there are some limitations to its use, but is interesting in that it is the only aircraft data over the SO in the last decade.

HIPPO-2 RF06


HIPPO-2: rf06
MODIS (Aqua): 2009-11-12 02:25
HIPPO Track
Aqua Track
Cloud Sampled
22:23
22:58
23:38
00:20
01:06
01:40
45°S
50°S
55°S
60°S
65°S
160°E
170°E
180°
170°W
Cloud Top Temp (K)
300
290
280
270
260
250
240
230
220
210
200
HIPPO-2: rf06
MODIS (Aqua): 2009-11-12 02:25
HIPPO Track
Aqua Track
Cloud Sampled
Uncert.
Mixed
Ice
Liquid
None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GGALT (m)
PSX (hPa)
PSFC (hPa)
m
hPa
PLWCC (gram/m3)
RICE (V)
gram/m3
V
ATX (deg_C)
DPXC (deg_C)
THETA (K)
deg_C
K
CONC2DCA_LWO (#/L)
CONCD_LWI (#/cm3)
1e7
#/L
#/cm3
00:11:00
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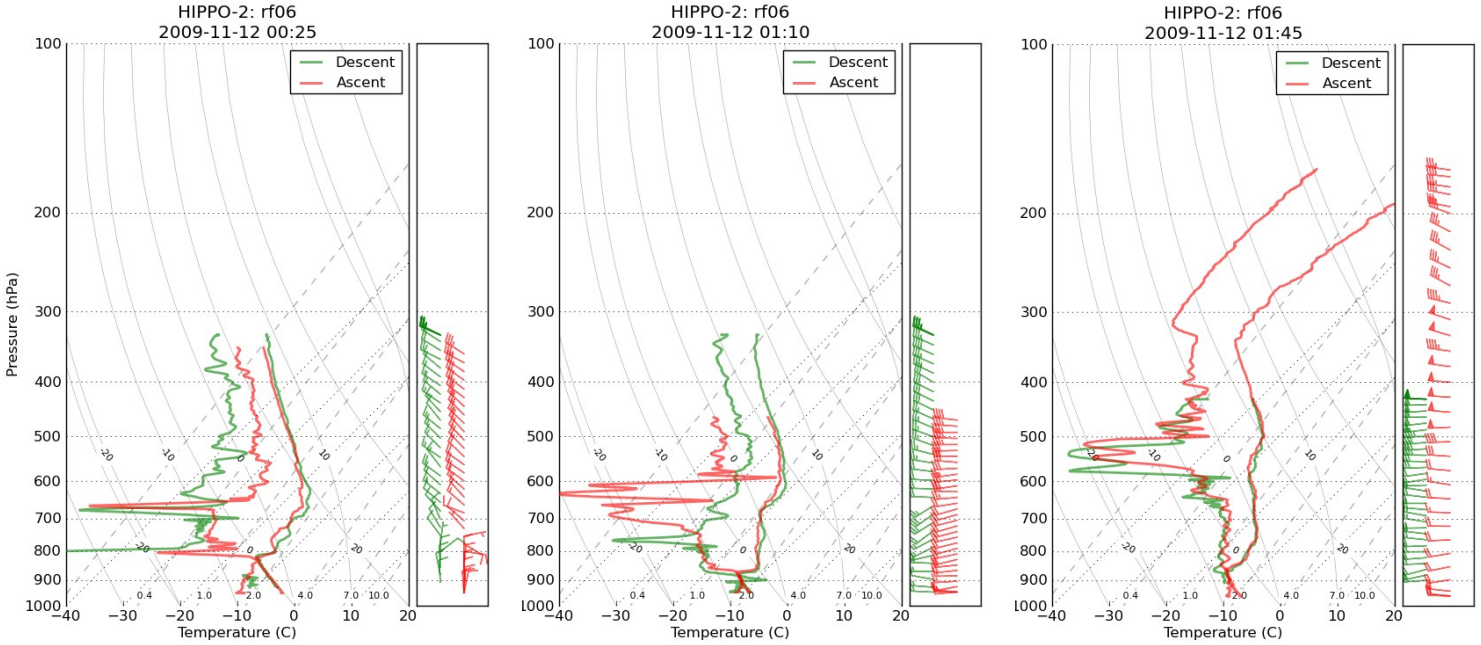
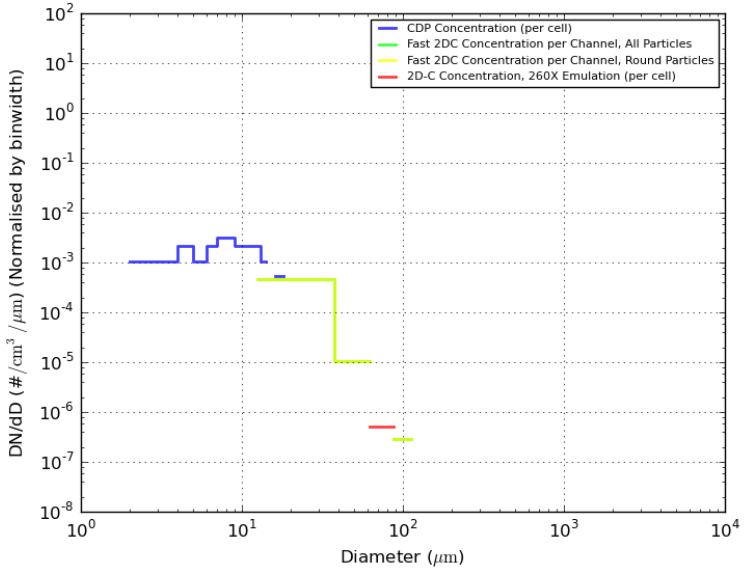
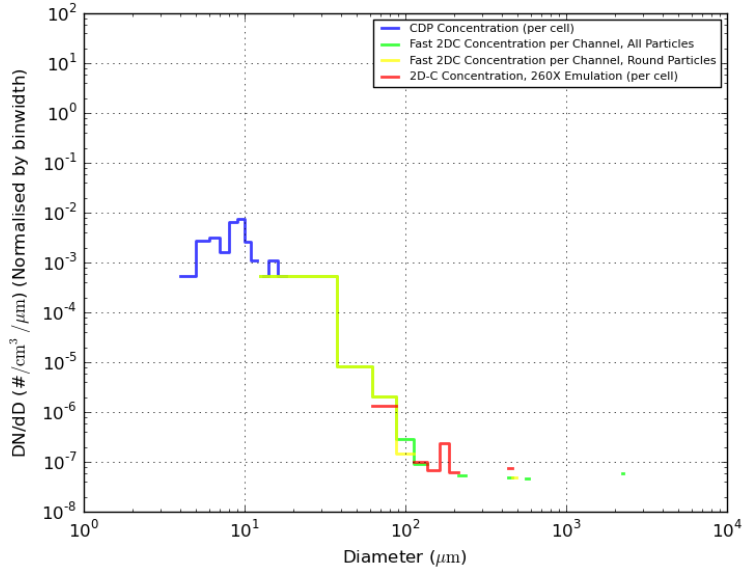
01:26:00
01:41:00
01:56:00
02:11:00

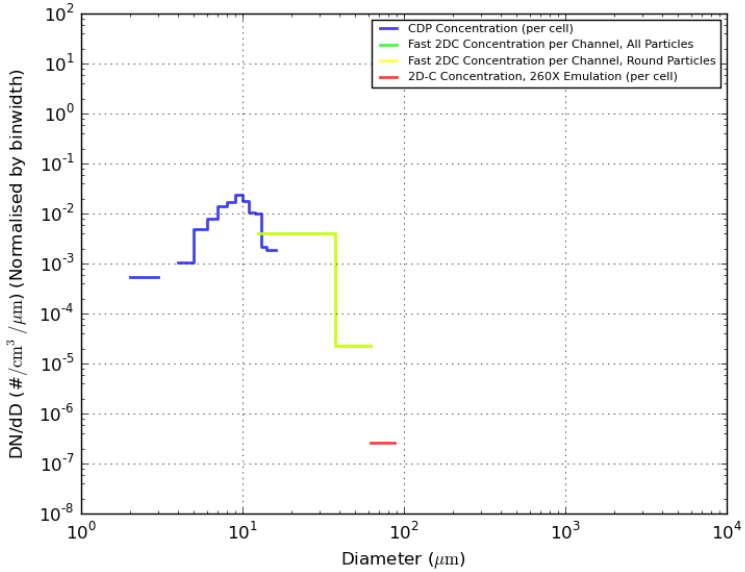

HIPPO-2: rf06
2009-11-12 00:25
HIPPO-2: rf06
2009-11-12 01:10
HIPPO-2: rf06
2009-11-12 01:45
Descent
Ascent
Pressure (hPa)
Temperature (C)

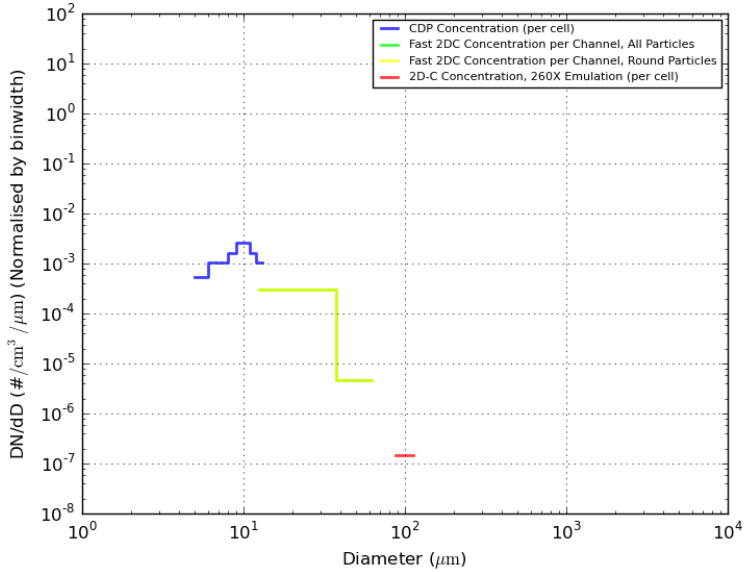
Particle spectra for cloud at 01:10



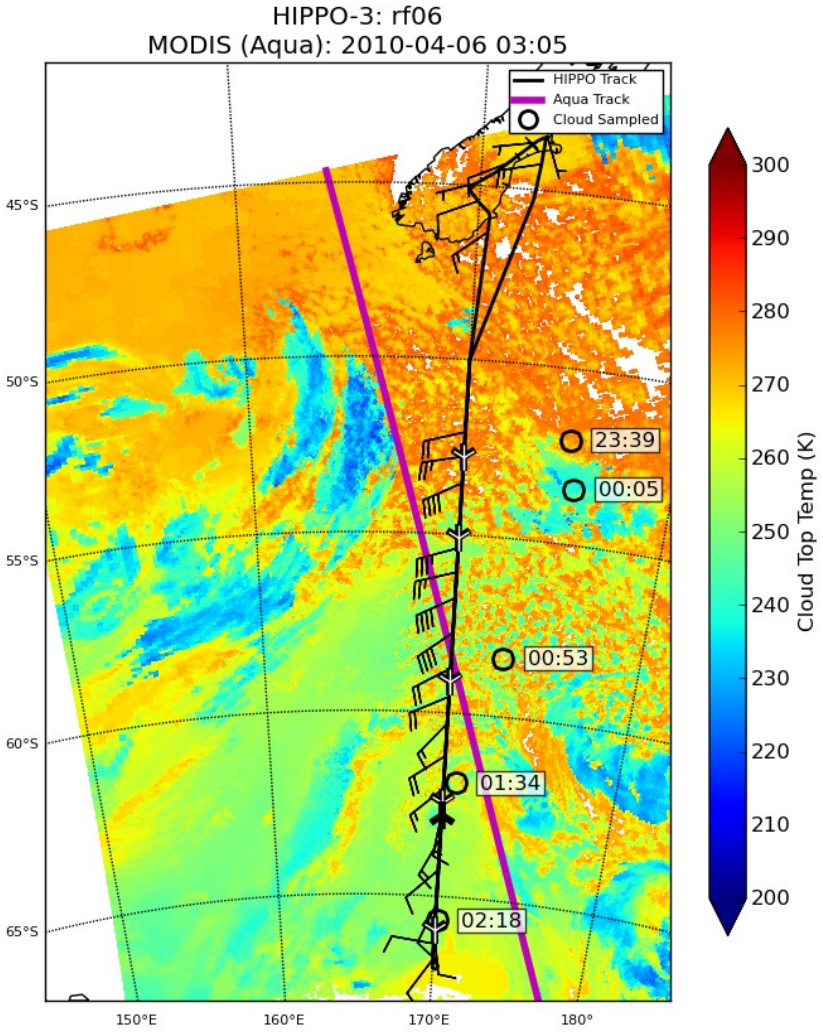


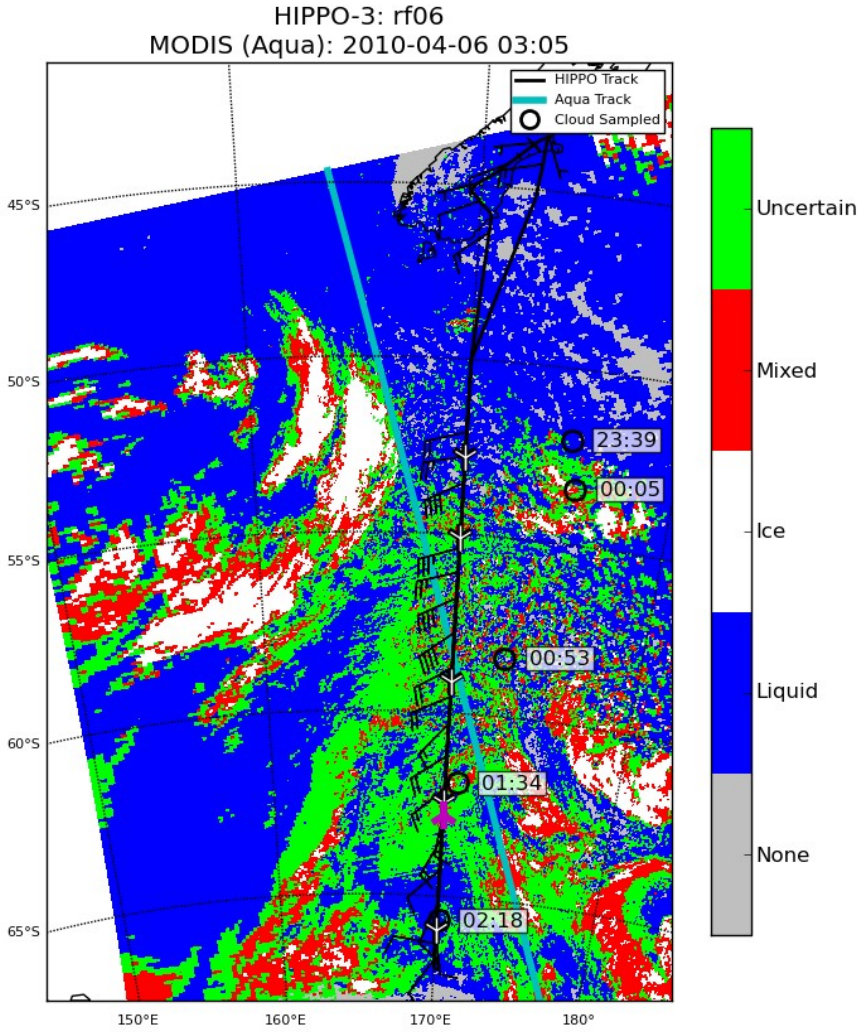
Particle spectra for cloud at 01:45

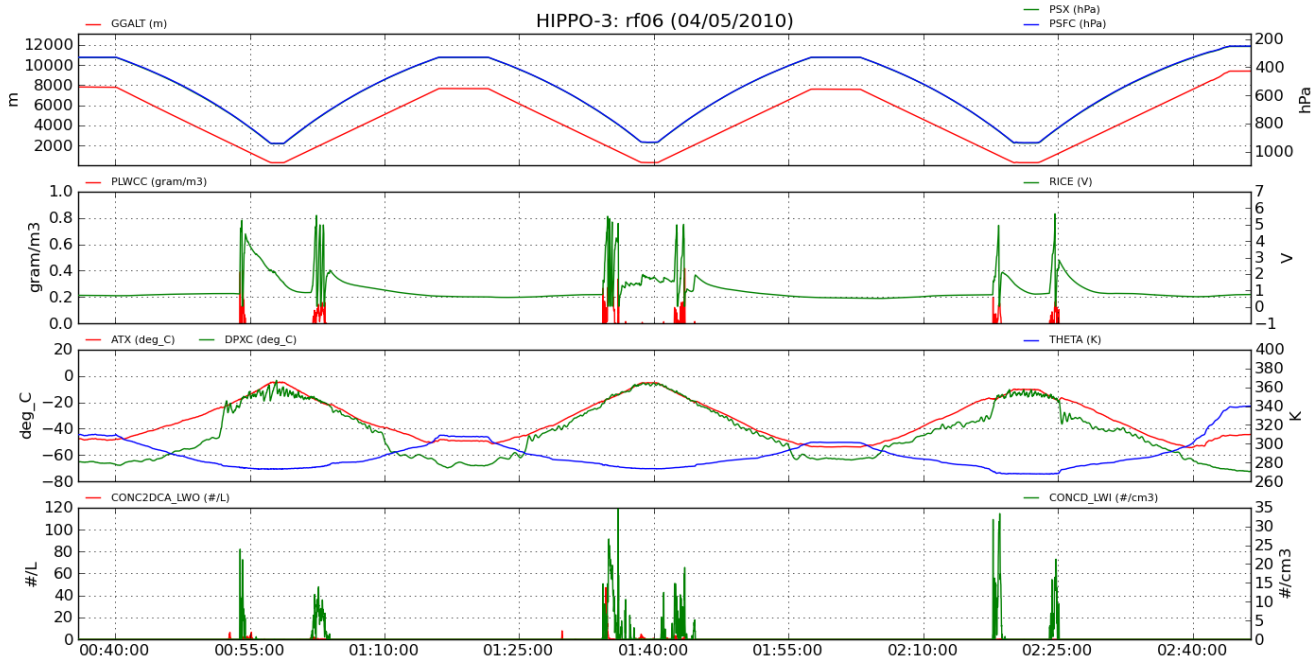




HIPPO-3 RF06


HIPPO-3: rf06
MODIS (Aqua): 2010-04-06 03:05
HIPPO Track
Aqua Track
Cloud Sampled
23:39
00:05
00:53
01:34
02:18
45°S
50°S
55°S
60°S
65°S
150°E
160°E
170°E
180°
300
290
280
270
260
250
240
230
220
210
200
Cloud Top Temp (K)


HIPPO-3: rf06
MODIS (Aqua): 2010-04-06 03:05
HIPPO Track
Aqua Track
Cloud Sampled
23:39
00:05
00:53
01:34
02:18
45°S
50°S
55°S
60°S
65°S
150°E
160°E
170°E
180°
Uncertain
Mixed
Ice
Liquid
None


HIPPO-3: rf06 (04/05/2010)
GGALT (m)
PSX (hPa)
PSFC (hPa)
m
hPa
PLWCC (gram/m3)
RICE (V)
gram/m3
V
ATX (deg_C)
DPXC (deg_C)
THETA (K)
deg_C
K
CONC2DCA_LWO (#/L)
CONCD_LWI (#/cm3)
#/L
#/cm3
00:40:00
00:55:00
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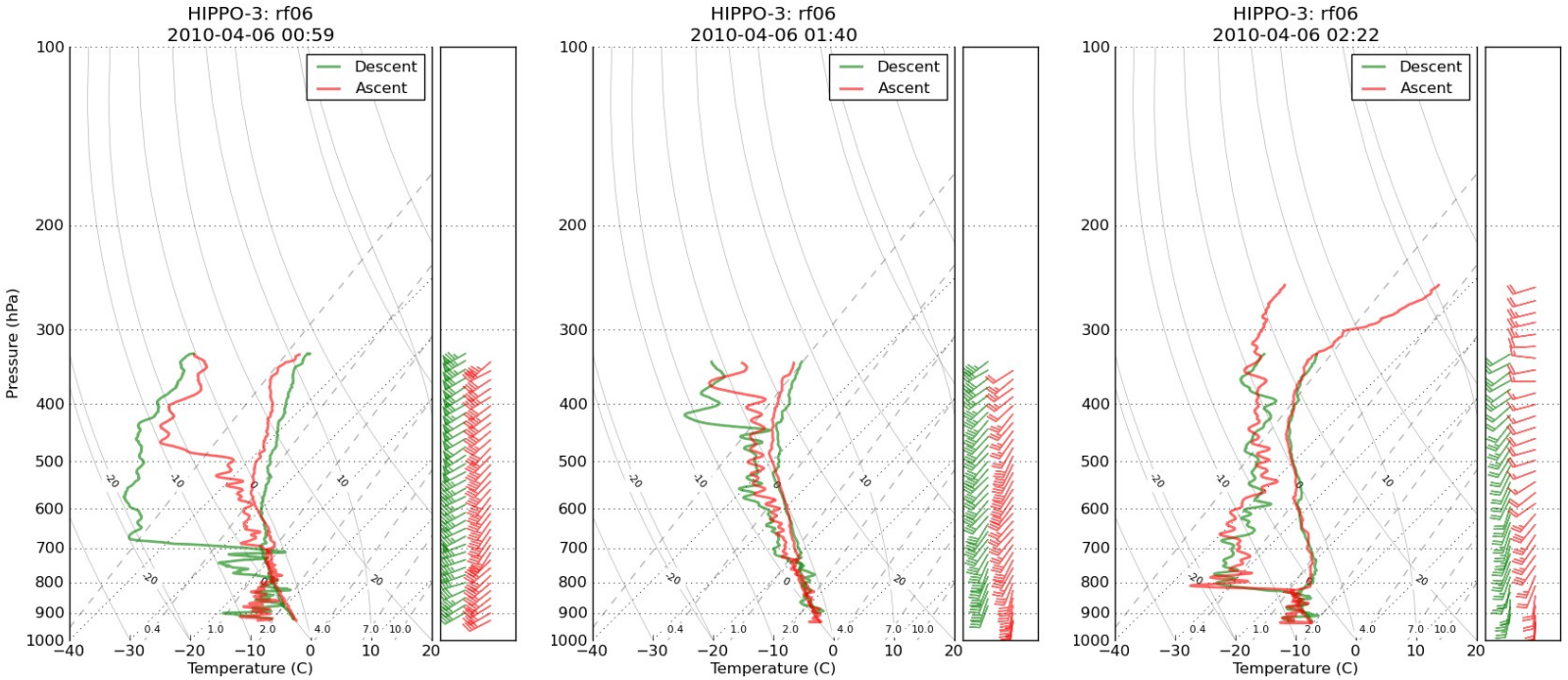
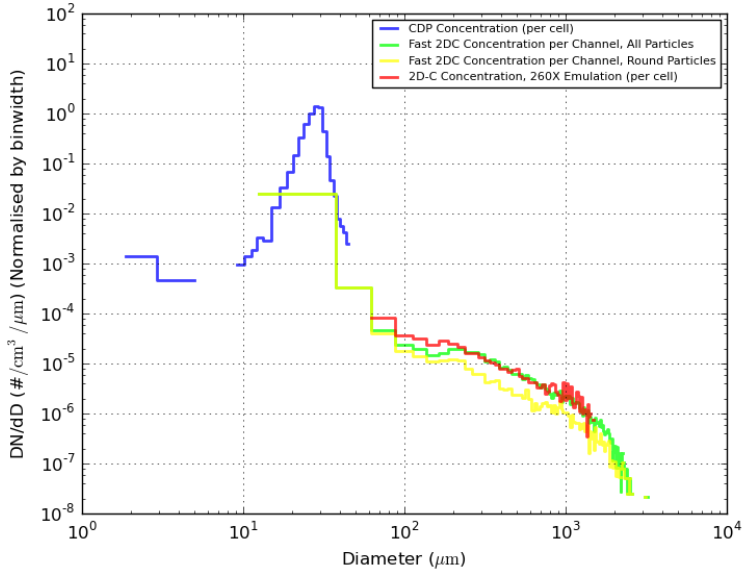
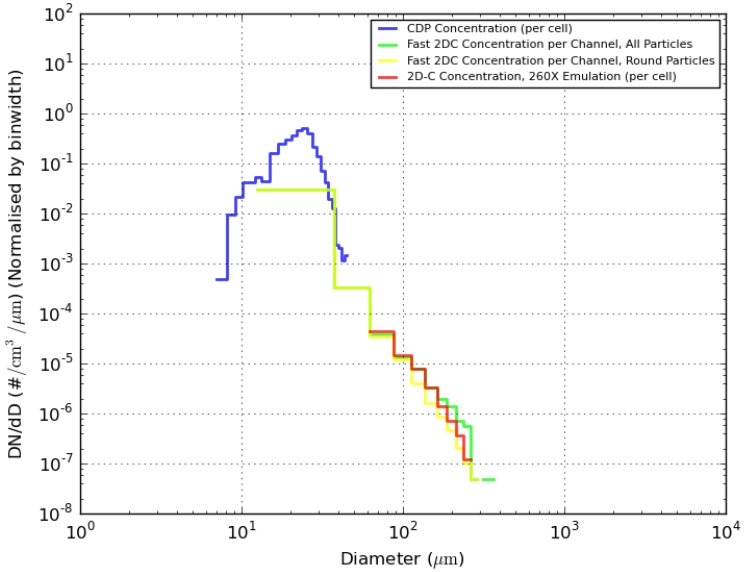
01:55:00
02:10:00
02:25:00
02:40:00

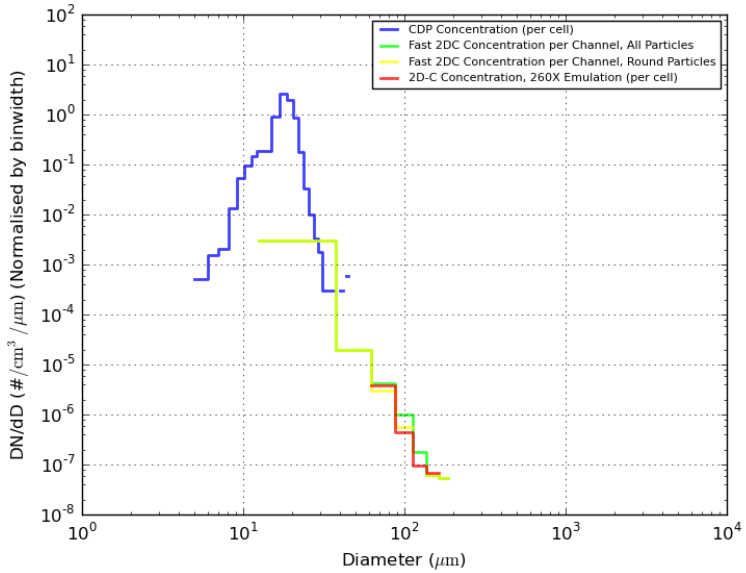

HIPPO-3: rf06
2010-04-06 00:59
HIPPO-3: rf06
2010-04-06 01:40
HIPPO-3: rf06
2010-04-06 02:22
Descent
Ascent
Pressure (hPa)
Temperature (C)

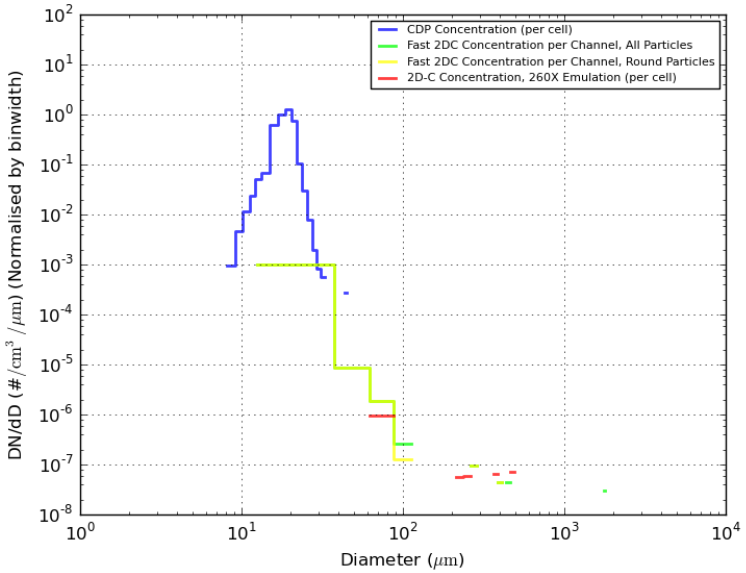
Particle spectra for cloud at 01:40





Particle spectra for cloud at 02:22





Summary of HIPPO cloud physics observations

- Supercooled liquid water was observed in stratiform cloud during the two flights discussed, as well as in the other missions.
- The stratiform clouds presented were presumably quite static given the similarities between the satellite and the in-situ observations.
- The nature of the flight plan (climb/descent), and the relatively basic instrumentation presents difficulties in further interpretation of the cloud structure
  - WRF simulations could shed some light on physical processes

Meanwhile, in Tasmania...

- Received ARC funding to perform research flights from Hobart in conjunction with Hydro Tasmania.
- Current focus is on performing flights simultaneously with NASA A-Train overpasses (about two opportunities per week).
- There are a number of instrumentation issues that we are currently working with.

References

- Wofsy, S. C., and Hippo Science Team (2011), HIAPER Pole-to-Pole Observations (HIPPO): Global distributions and emission sources for CH4, N2O, Black Carbon, and other trace species inferred from five aircraft missions, *AGU Fall Meeting Abstracts,* p. J2.
- Morrison, Anthony E., Steven T. Siems, Michael J. Manton, 2011: A Three-Year Climatology of Cloud-Top Phase over the Southern Ocean and North Pacific. J. Climate, 24, 2405–2418.
- Haynes, John M., Christian Jakob, William B. Rossow, George Tselioudis, Josephine Brown, 2011: Major Characteristics of Southern Ocean Cloud Regimes and Their Effects on the Energy Budget. J. Climate, 24, 5061–5080.
- Trenberth, Kevin E., John T. Fasullo, 2010: Simulation of Present-Day and Twenty-First-Century Energy Budgets of the Southern Oceans. *J. Climate,* 23, 440–454.