Deriving Ice Water Content and Particle Morphology from Cloud Particle Imagery: Future Application to Southern Ocean Clouds

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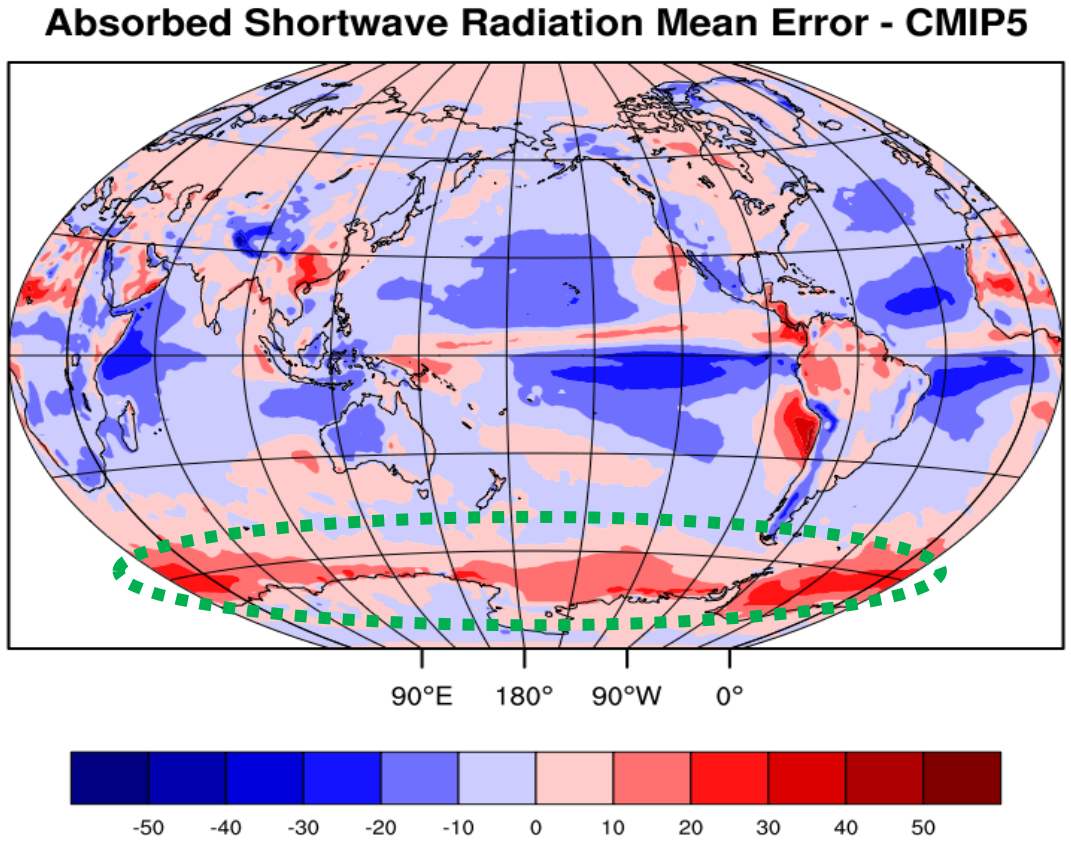
Outline

- Motivation for measurements of clouds, radiation, precipitation and aerosols over the Southern Ocean(SO).
  - *Climate model biases and observational knowledge gaps over SO*
  - *Ambiguity in satellite retrievals*
  - *Uncertainties in cloud property estimation*
- Methodology for deriving Ice Water Content(IWC)
- Planned measurements during MARCUS and SCORATES

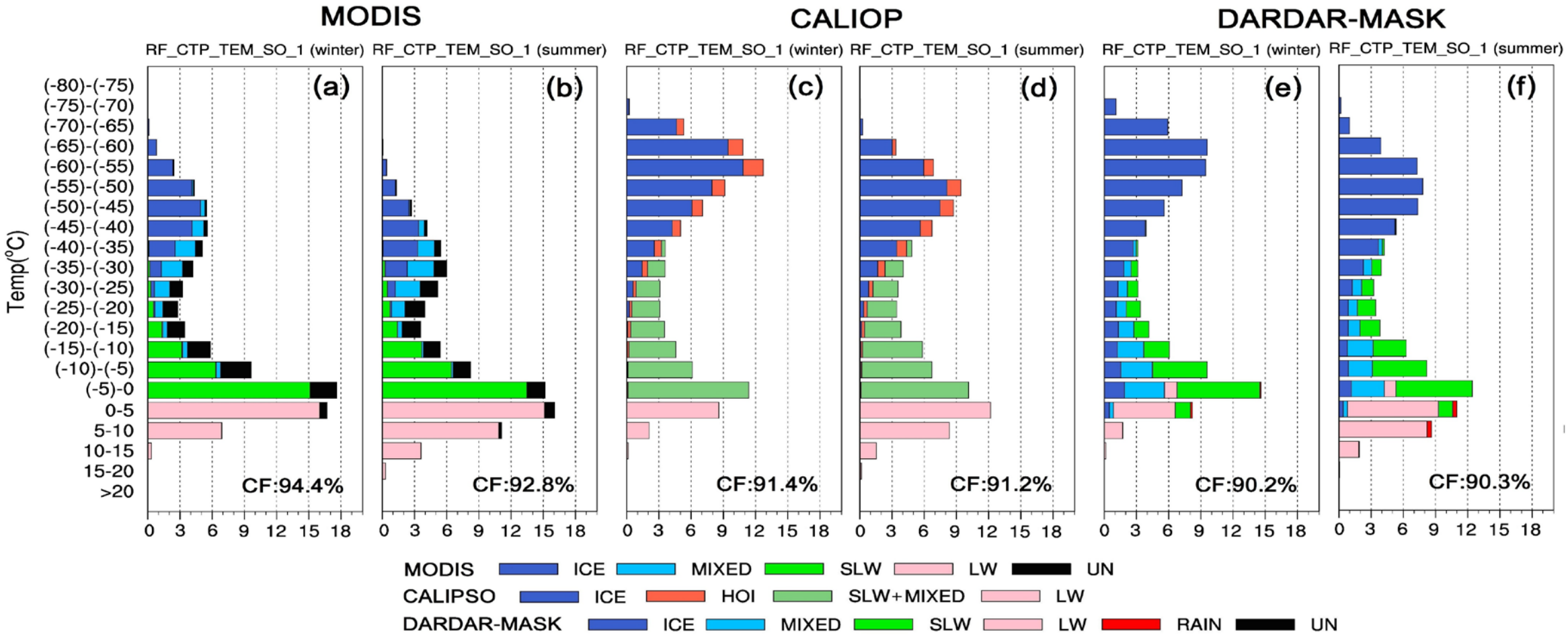
Climate model biases & observational knowledge gaps over the SO

The representation of cloud processes in climate models have been recognised for decades as a continuing source of much of the uncertainty associated with our understanding of changes in the climate system.



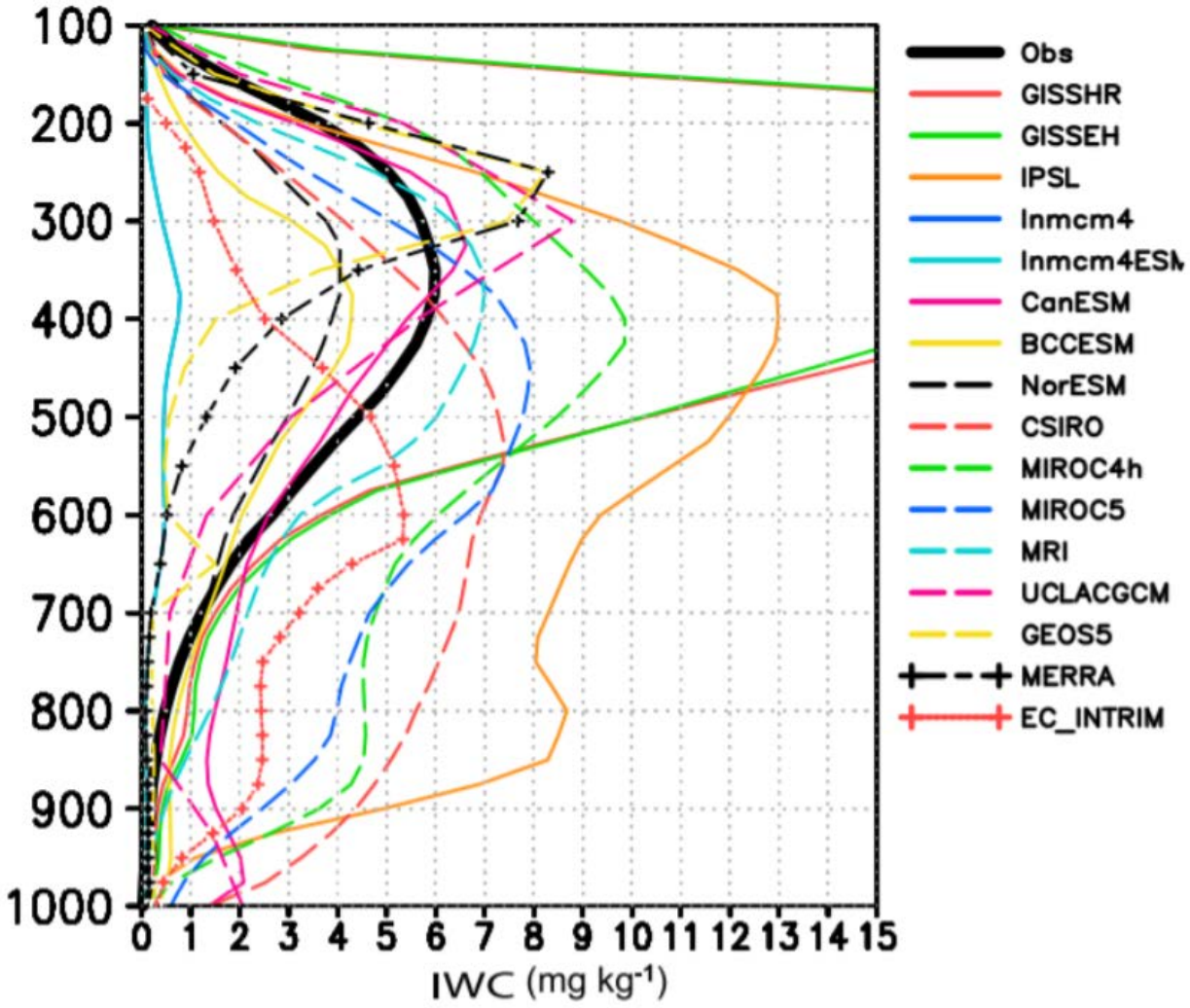
CMIP5 model clouds do not reflect enough sunlight over SO. Ensemble mean error for CMIP5 models in shortwave radiation absorbed by the Earth System. Positive values indicate too much shortwave radiation absorbed.

Satellite retrievals over the SO are challenging



Vertical distribution of cloud top phase retrieved from MODIS operations product (Platnick et al. 2003), CALIOP (Hu et al. 2010) and DARDAR algorithm (Delanoë and Hogan 2010). From Huang et al (2014b).

Model evaluation of IWC

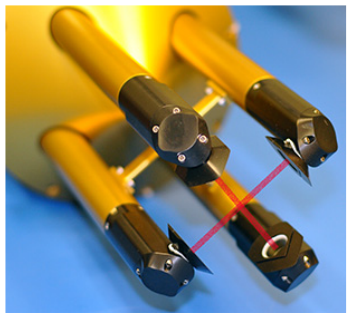


Globally averaged(80N-80S), annual mean, verticle IWC profiles from the CMIP5 GCMS, UCLA CGCM, GEOS5 AGCM, EC Interim and MERRA reanalysis. (Li et al., 2012)

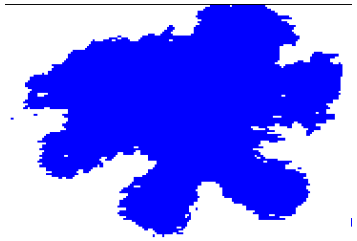
- Different climate models produce a very different ice water content/path, significant IWC biases are identified in CMIP3 and CMIP5.
- Showing the need for in-situ observational constraints.

The gap in available observations for cloud water mass and/or their lack of use in constraining the models was clearly evident from the wide disparity in the cloud ice and liquid water path (CIWP and CLWP) values exhibited in the CMIP3 GCMs [Li et al., 2008; Waliser et al., 2009]

In-situ measurements

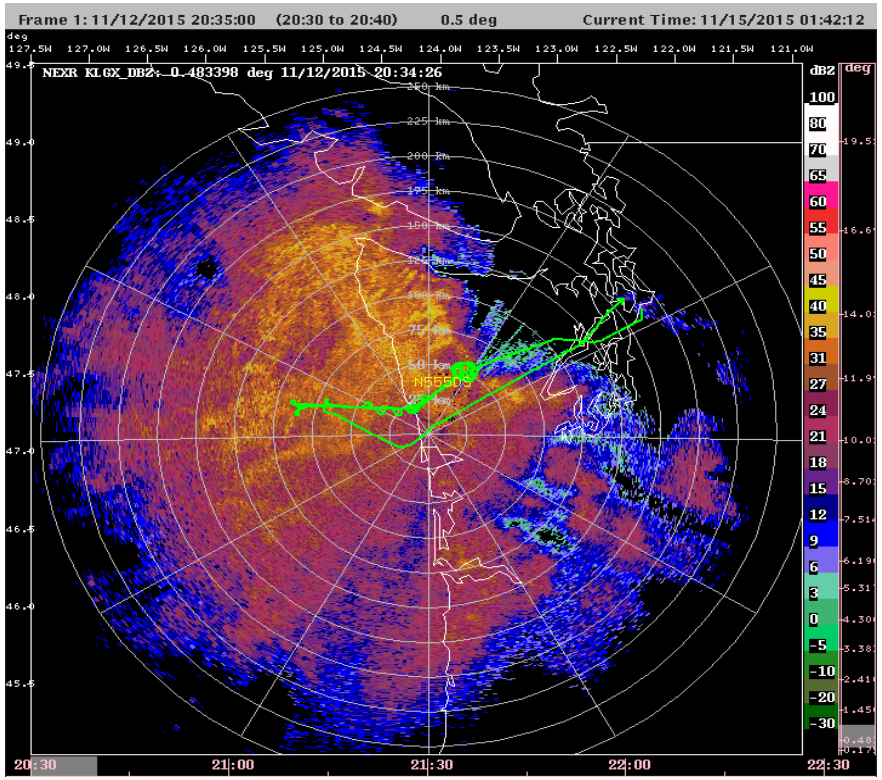


CPI



2DS

HVPS

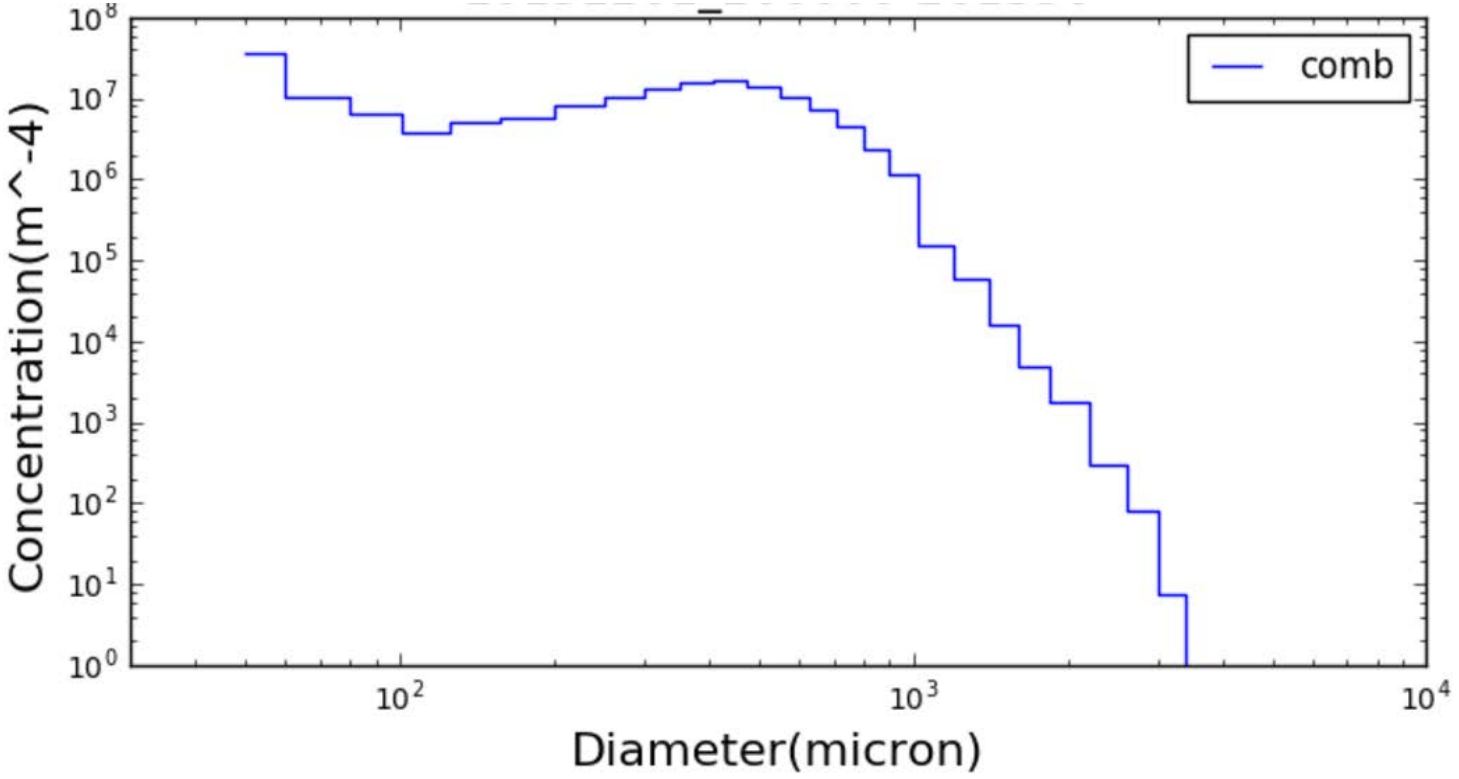


Flight track map on Nov 12,2015, OLYMPEX

Realistic particle size distributions (PSDs) and bulk properties of ice clouds are needed and are typically obtained from in-situ observations.

Deriving IWC from Particle Size Distribution(PSD)

Integration of the measured ice particle size distribution.



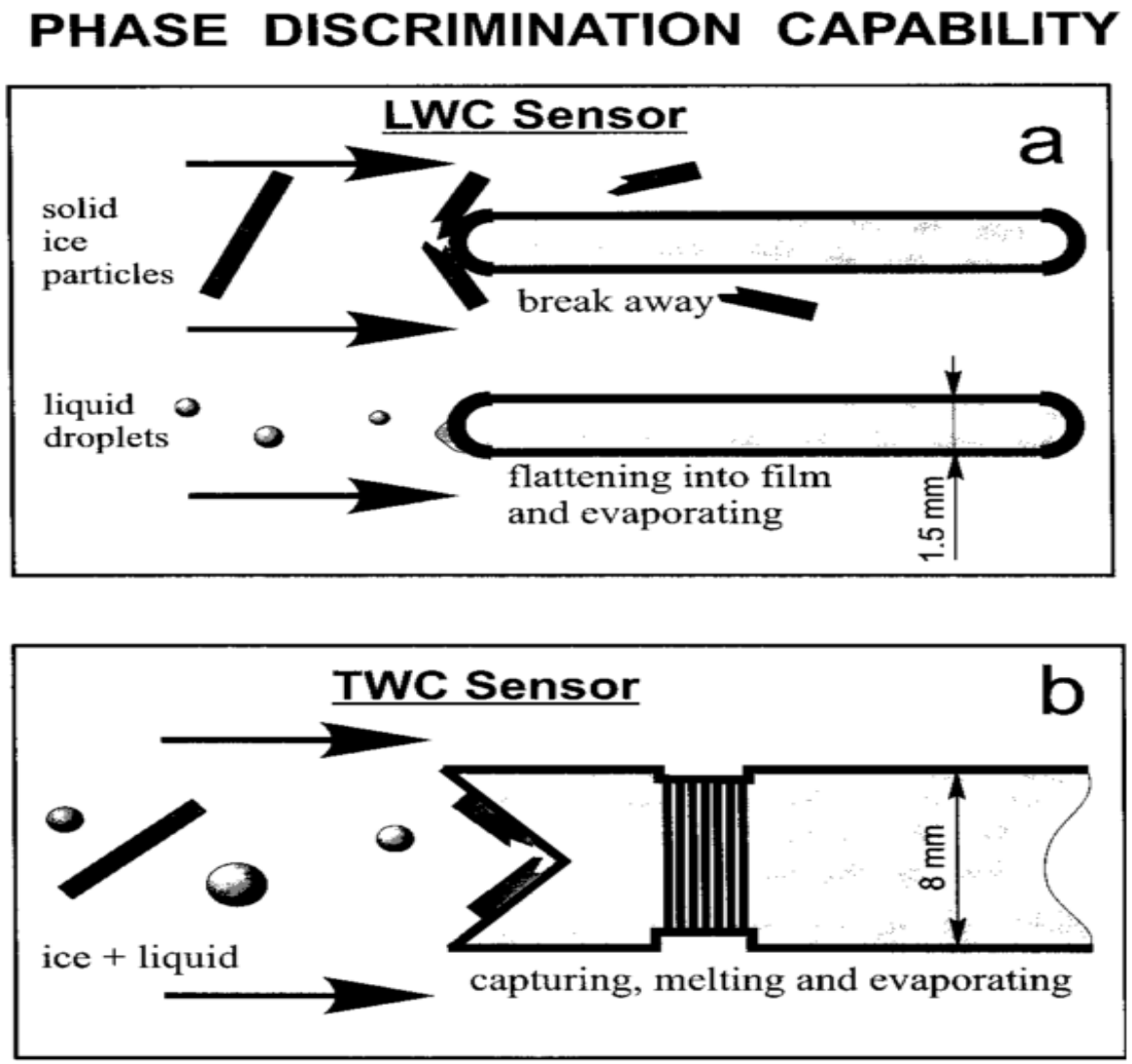
$$M = aD^b$$

$$IWC = \sum_{D_{min}}^{D_{\max}} n(D) M \Delta D$$

(Locatelli and Hobbs, 1974)

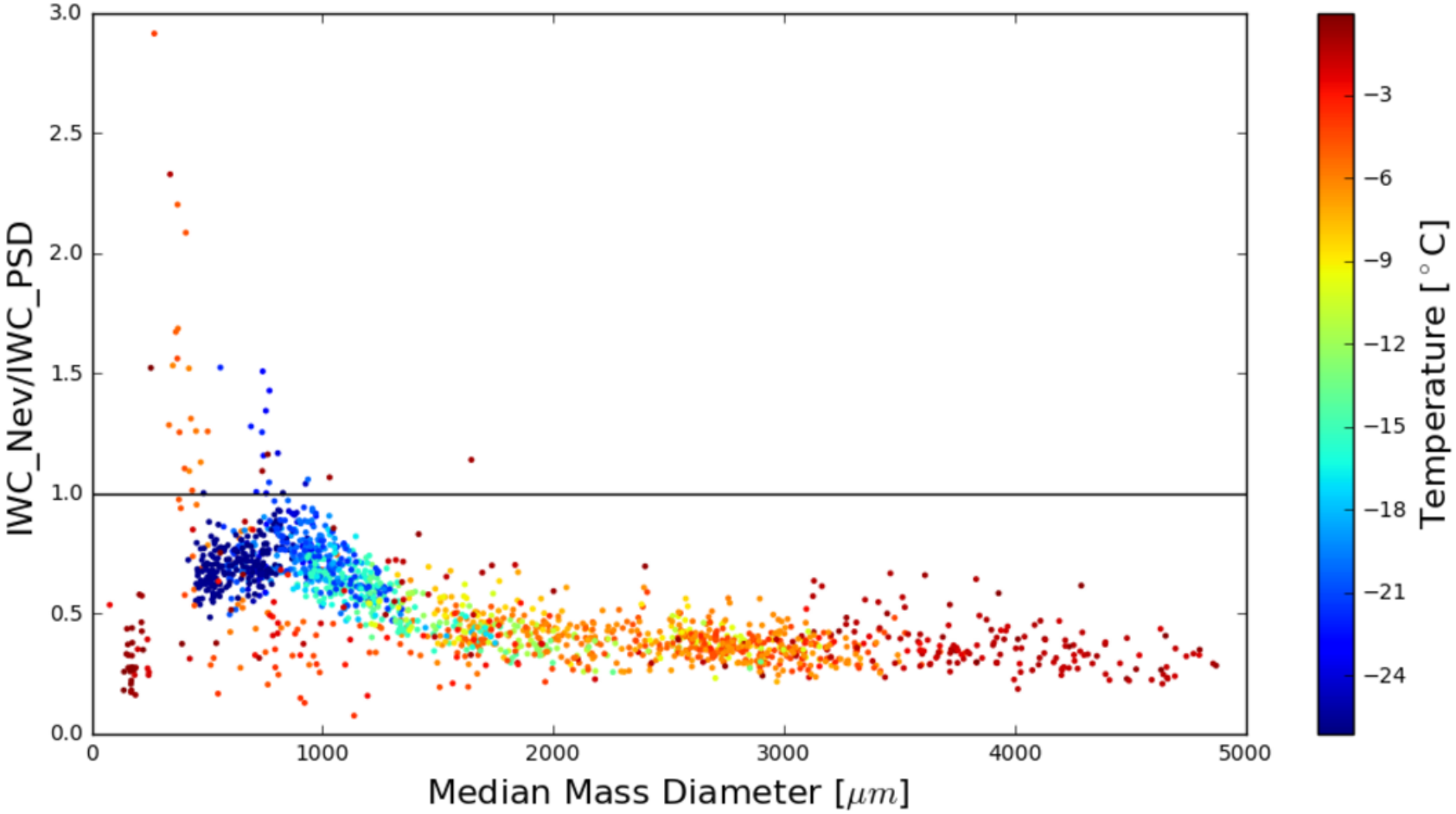
In-situ bulk measurements of IWC: Nevzorov probe

(Korolev et al., 1997)

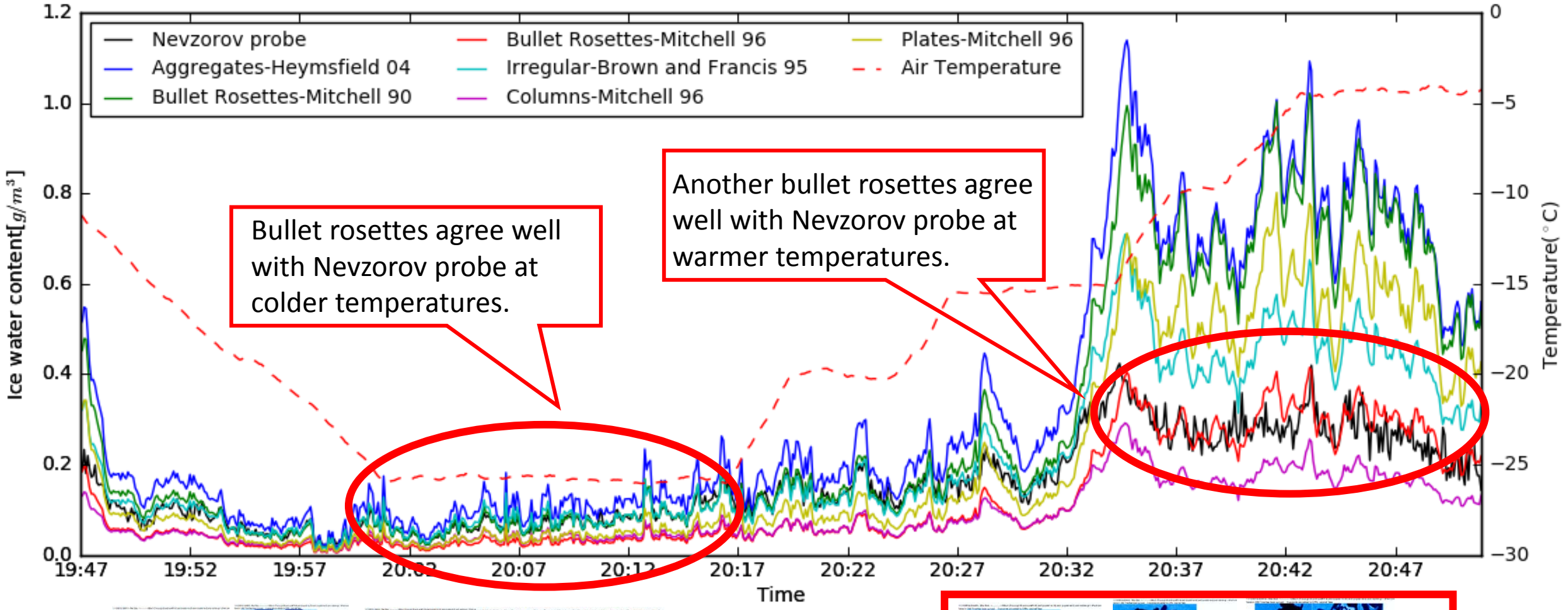


Case study: Nov 12, 2015

--Comparison of two techniques

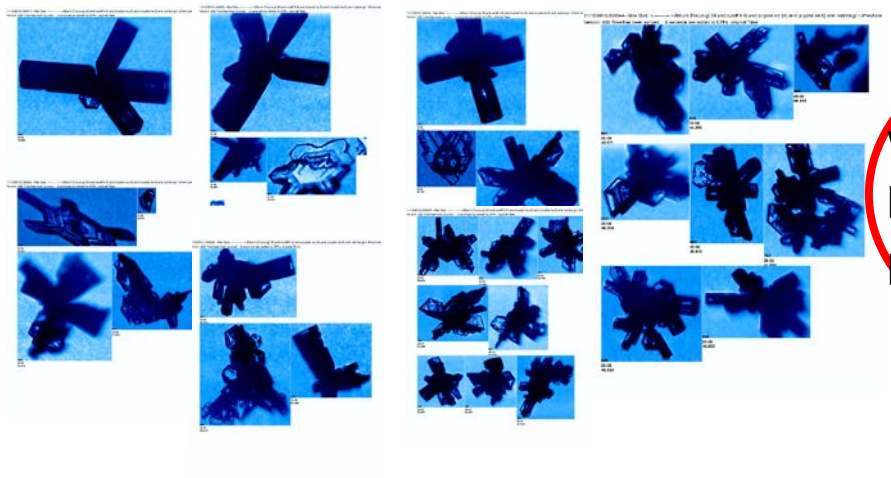


IWC from PSDs computed using m-D relation from Heymsfield et al. (2004) appropriate for aggregates, $m = .0061D^{2.05}$

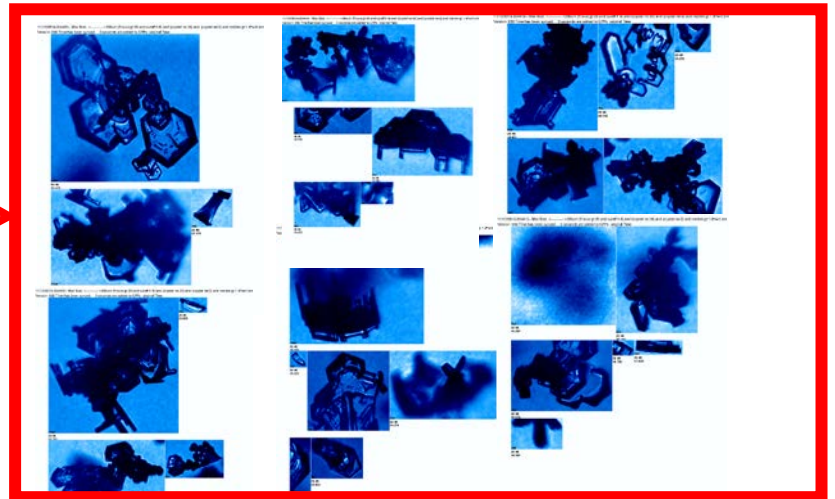


Bullet rosettes agree well with Nevzorov probe at colder temperatures.

Another bullet rosettes agree well with Nevzorov probe at warmer temperatures.

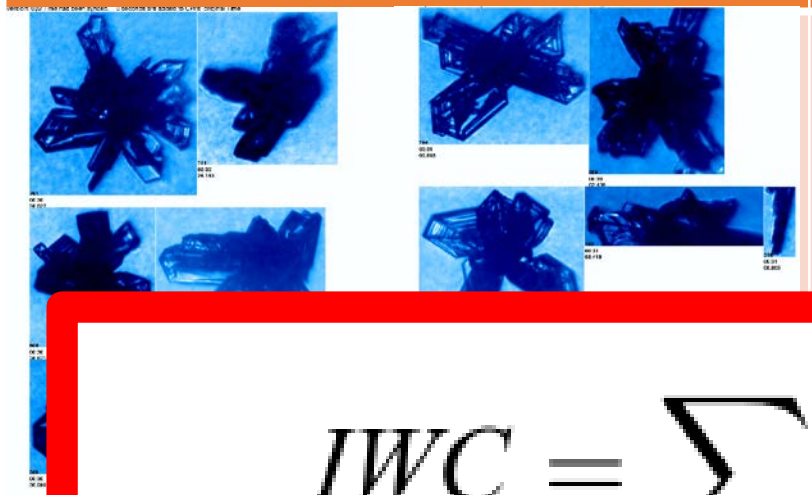


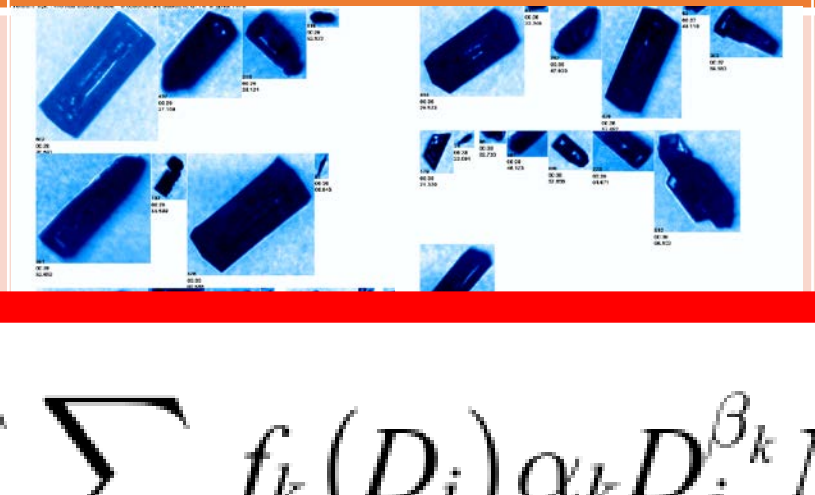
We don't have real bullet rosettes in this period.

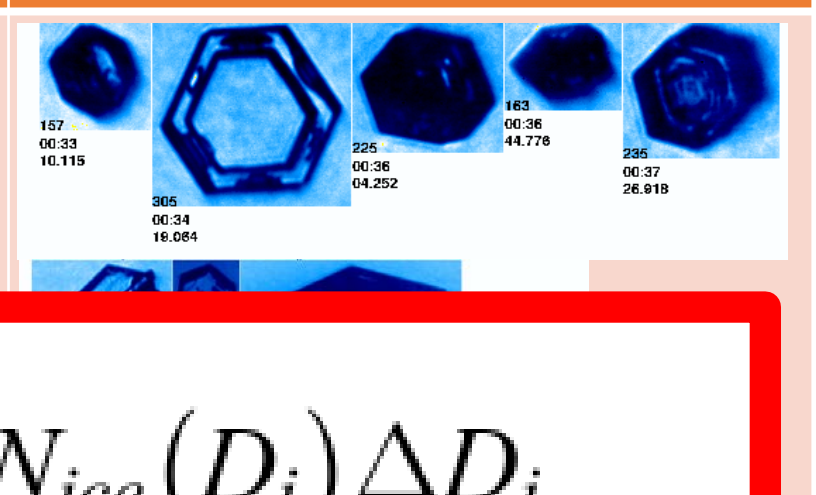


Habit classification scheme

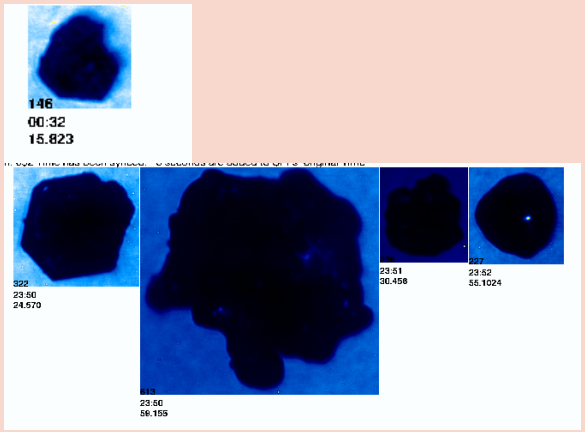
Bullet rosettes	column	plate

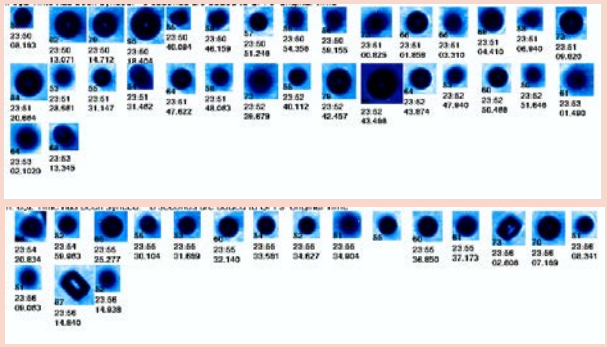


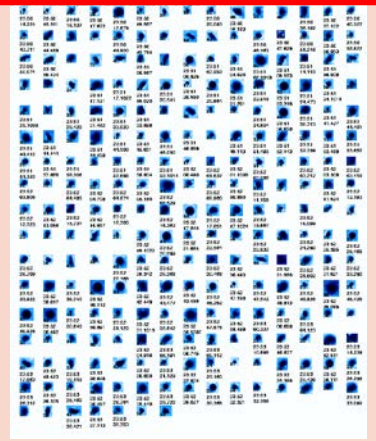


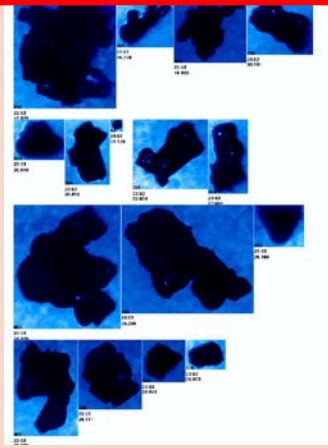


$$IWC = \sum_j \sum_k f_k(D_j)\,\alpha_k D_j^{\beta_k} N_{ice}(D_j)\,\Delta D_j$$





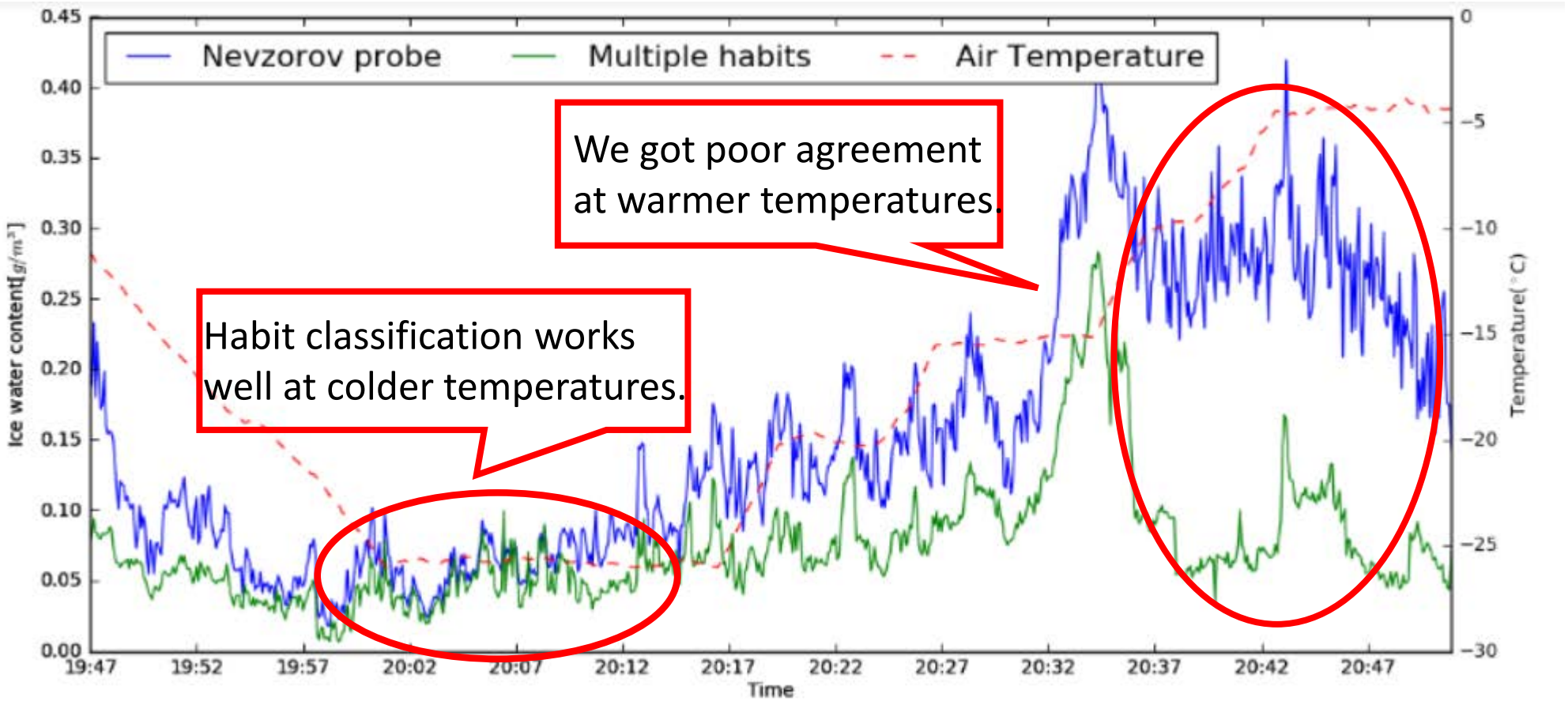




Improved IWC derivation

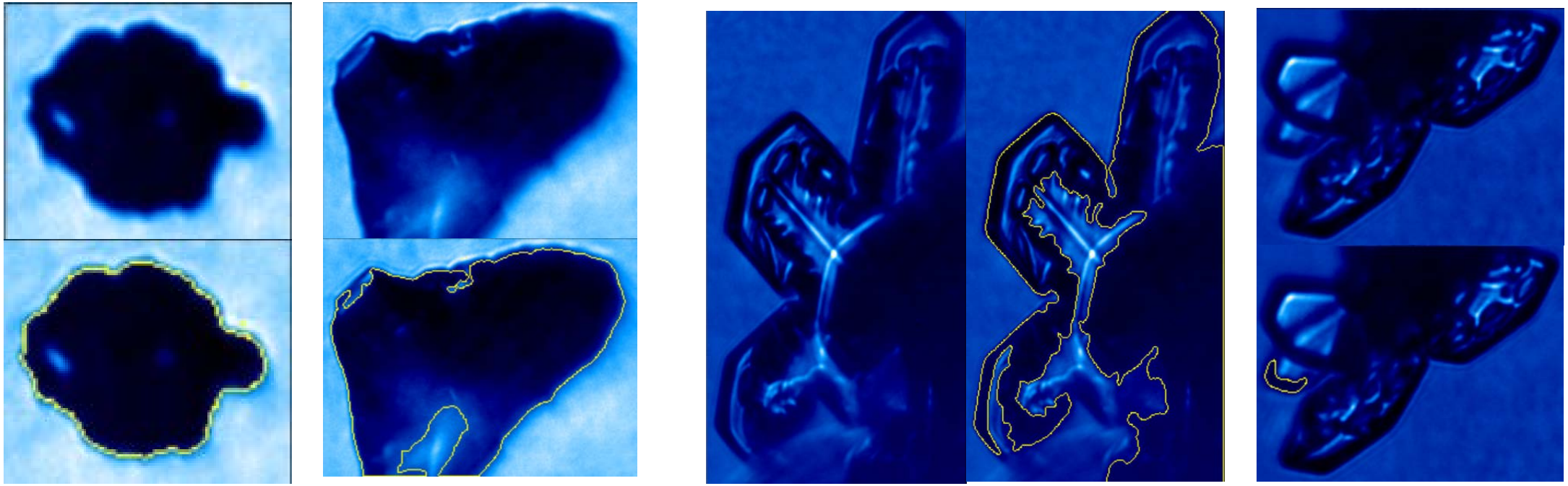
--Habit-dependent IWC

$$IWC = \sum_j \sum_k f_k(D_j)\,\alpha_k D_j^{\beta_k} N_{ice}(D_j)\,\Delta D_j$$



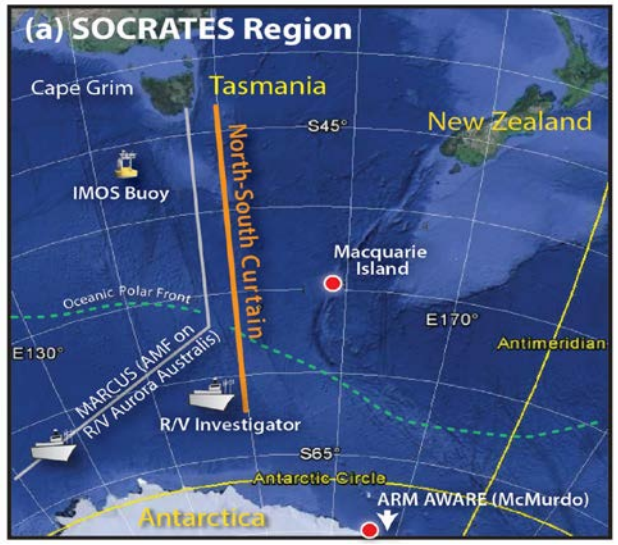
Problems with our habit classification

- Classification designed for colder temperatures does not work as well at warmer temperatures of some of OLYMPEX observations
- Particle boundaries identification



- Currently working with Alexis Berne to develop better classification schemes for T > -10˚C

Future application to the SO clouds



SOCRATES Region

Southern Ocean Cloud Radiation Aerosol Transport Experimental Study (SOCRATES)

Australian Antarctic supply vessel *Aurora Australis*

Measurements of Aerosols, Radiation and Clouds over the Southern Oceans (MARCUS)

HIAPER NSF/NCAR G-V aircraft

Planned studies

- IWC over the SO will be derived and compared with IWC over the North Pacific. Will try to figure out whether there are systematic differences between Northern and Southern Hemisphere in terms of the IWC.

- Document boundary layer structure, and associated vertical distributions of liquid and mixed-phase cloud and aerosol (including CCN and INP) properties over the SO under a range of synoptic settings.

Thank you!