ISDAC Model Simulations and Observations - Preliminary study of Wegener-Bergeron-Findeisen Process

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Contributed by:

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Objectives

- **To simulate ISDAC mixed-phase clouds and improve understanding of the Wegener-Bergeron-Findeisen (WBF) process based on CRM simulations and the previous work of Korolev [*Korolev 2006; 2008*]**
  - **WBF process occurs only in the limited range of conditions in the mixed-phase clouds based on *Korolev 2006, 2008*.**

(1) $e > e_s > e_i \quad \rightarrow u_z^* = \dfrac{e_s - e_i}{e_i}\eta N_i r_i$ **Both droplets and ice particles grow**

(2) $e_s > e > e_i$ **WBF**

(3) $e < e_i < e_s \quad \rightarrow u_z^o = \dfrac{e_i - e_s}{e_s}\chi N_w r_w$ **Both droplets and ice particles evaporate**

- *What's the u_z^* and u_z^0 for WBF in the CRM?*
- *What are the fractions of these 3 regimes in the CRM?*

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Introduction

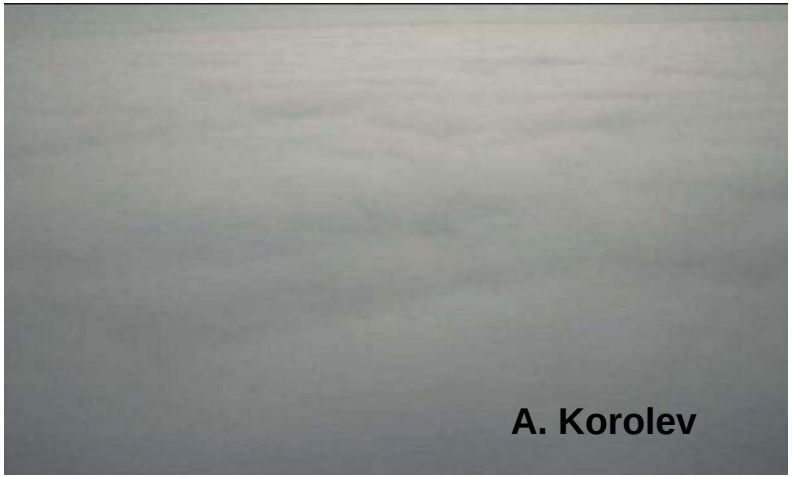
Case: 26 April 2008 –A "golden" day of ISDAC

- Boundary layer mixed-phase clouds

  Liquid dominates and flat cloud top and base

- Radiatively driven (no surface fluxes)
- Relatively polluted (CCN~200 cm^{-3})

26 April 2008, flight 31



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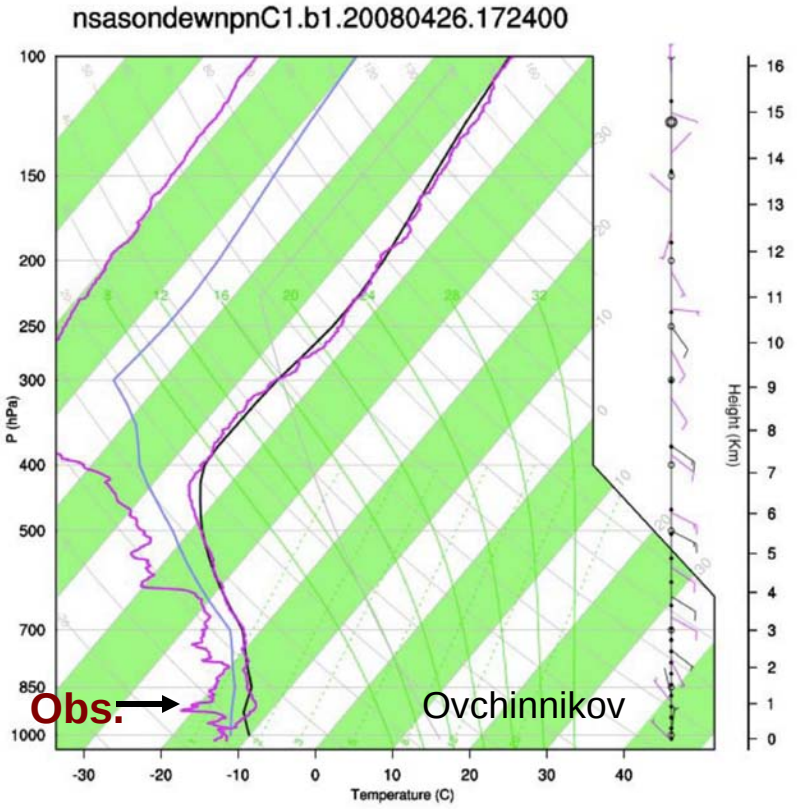
Model Setup

- SAM coupled with spectral-bin microphysics [*Fan et al. 2009*]
- 3D runs: 128*128*120 grids. 100 m horizontal and 20 m vertical resolutions.
- ECMWF derived initial and boundary conditions (modified to capture the structure of the shallow boundary layer)
- CAM radiation scheme-called every 3 min.



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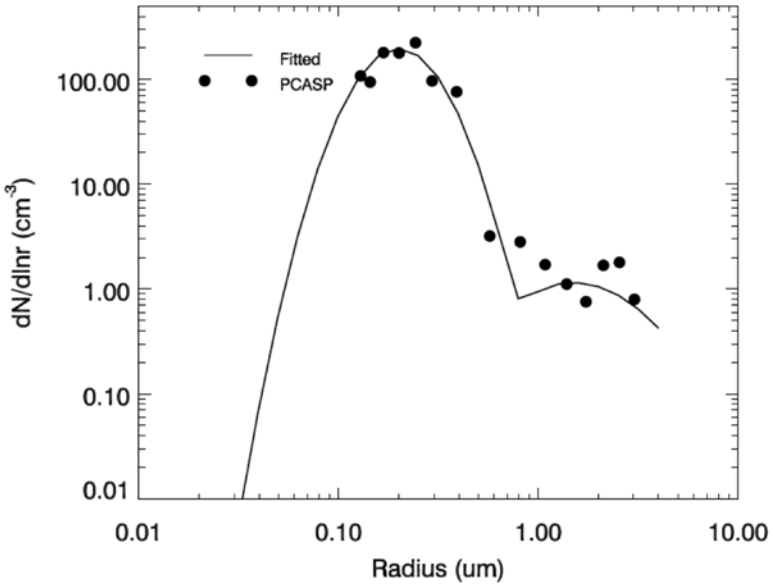
Methods

- CCN spectrum from PCASP size distribution



- Ice nucleation is constrained by the observed N_i (0.5 L^{-1}) - nucleation rate is required to keep the total N_i when S_i>5%.

$$dN_i/dt = \max(0,(N_{in} - N_i)/\Delta t), S_i > 5\%$$

$$dN_i/dt = 0, otherwise$$

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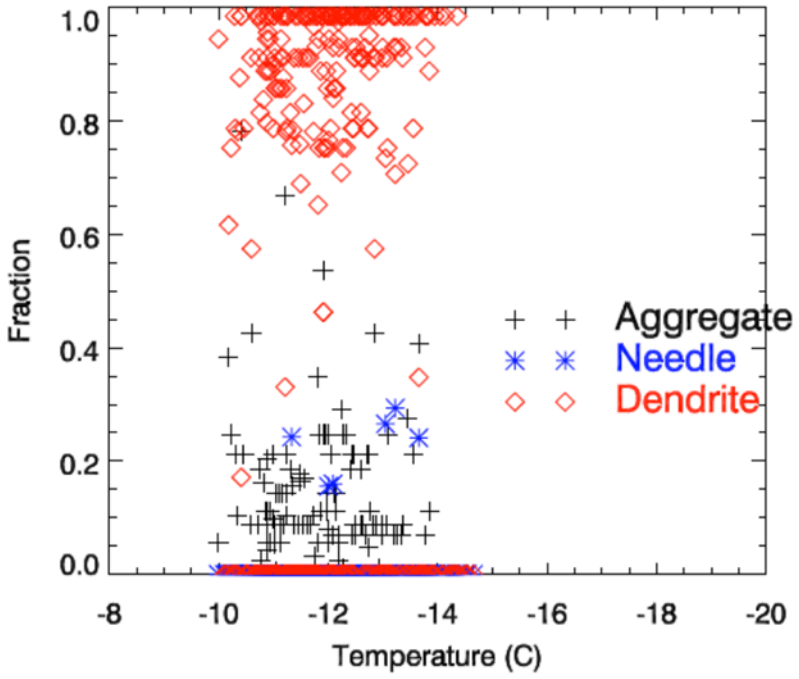
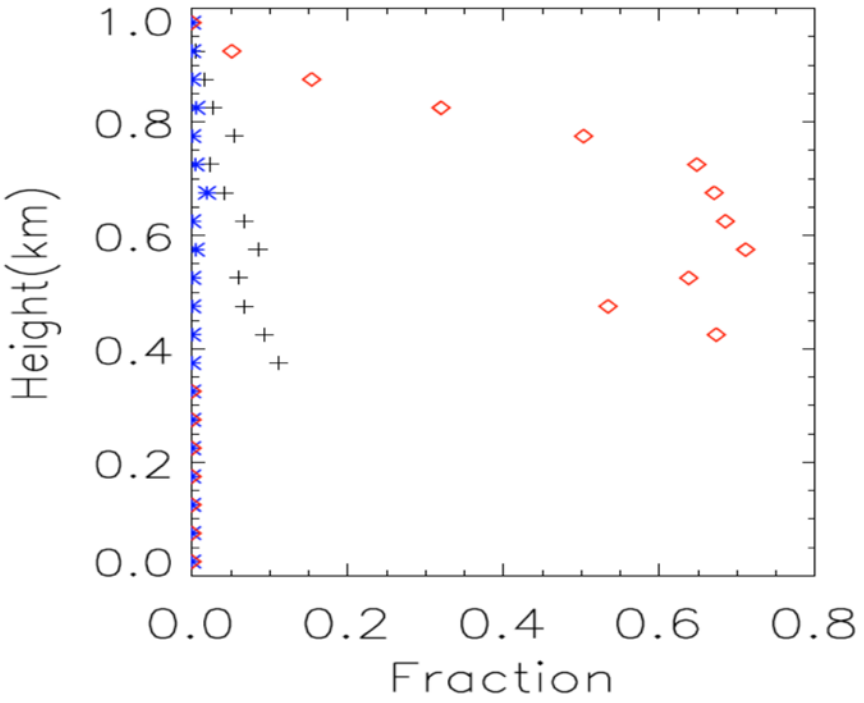
- Ice crystal shape is assumed to be dendrite based on the aircraft observations.



Data of A. Kolorev



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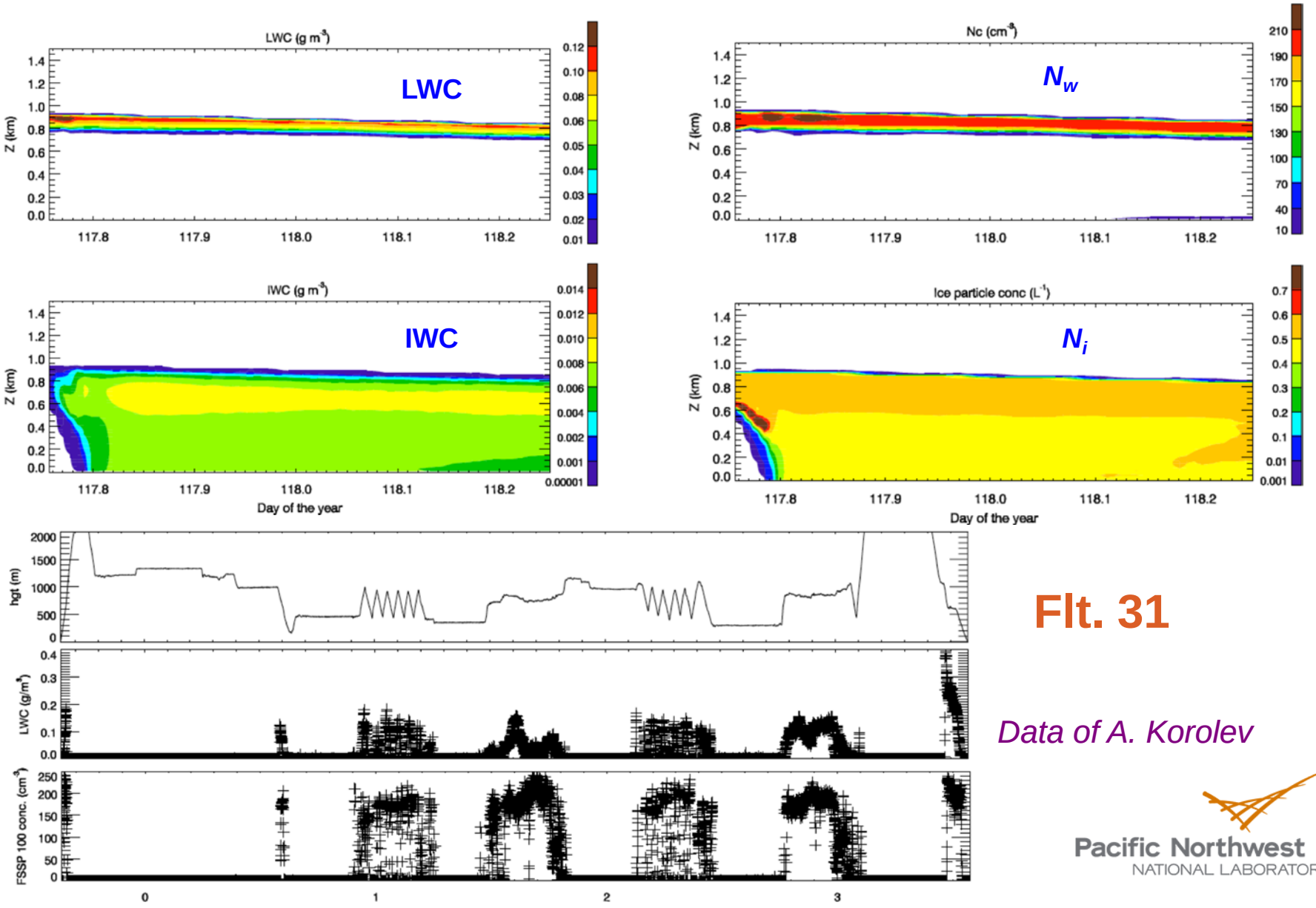
Results



Flt. 31

Data of A. Korolev

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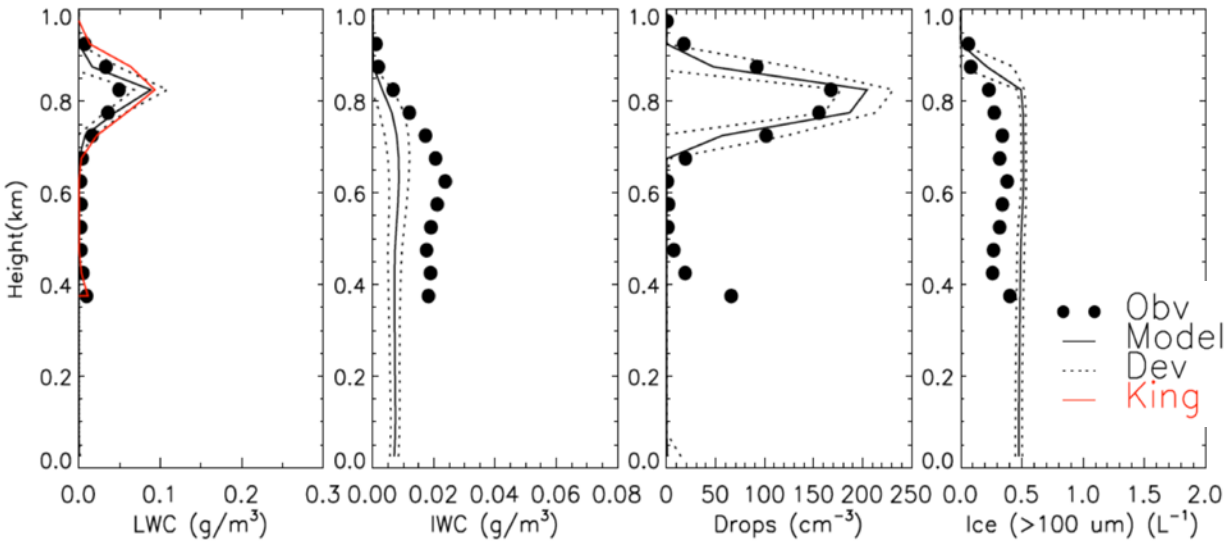
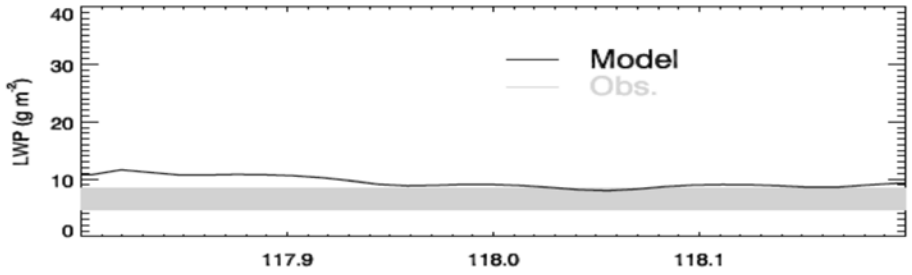
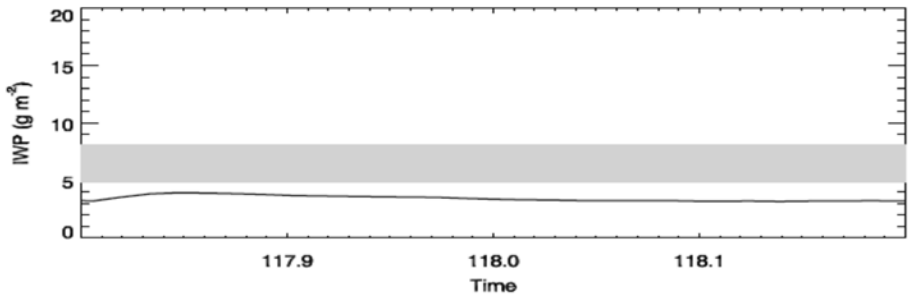
Comparison with aircraft observations



- LWC and droplet number agree with the observations very well
- Constrained by the observed ice number, model predicts lower IWC (IWC has 2 times of uncertainty).





- LWP and IWP above 400 m compared with the aircraft observations

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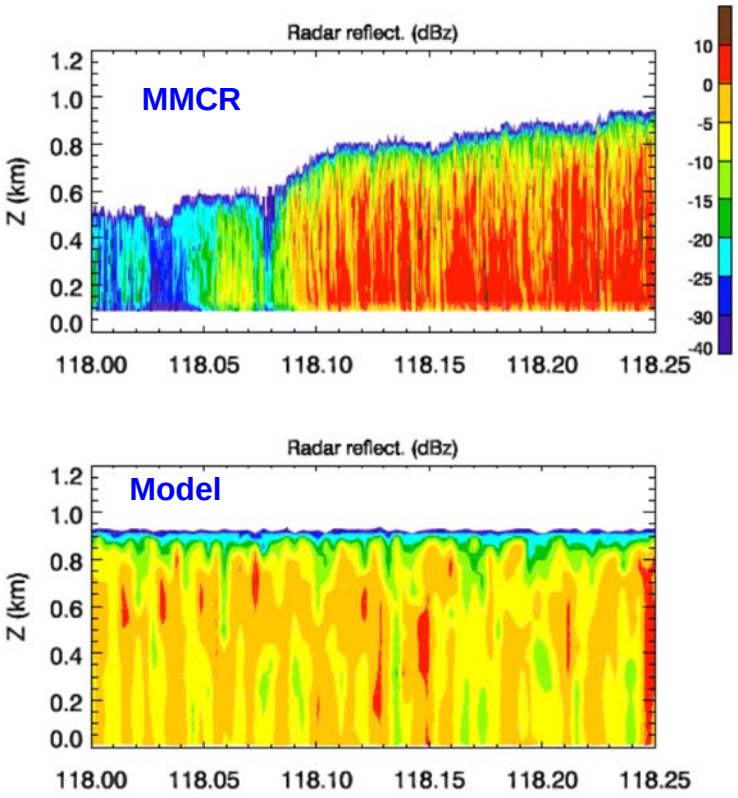
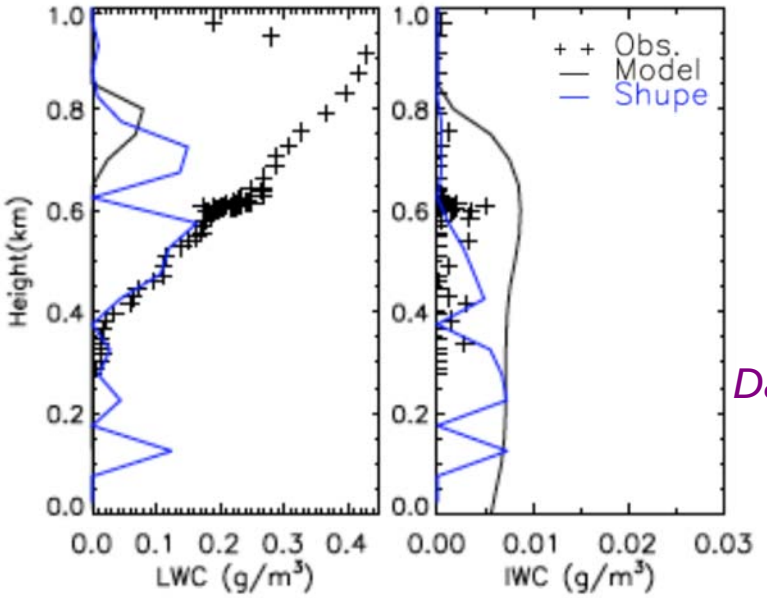
Radar and Lidar



- The modeled Ze is 5-10 dBZ lower. MMCR Ze is questioned.
- Cloud properties are different near Barrow!



Data of M. Shupe

The aircraft obs. near Barrow and the retrievals at Barrow

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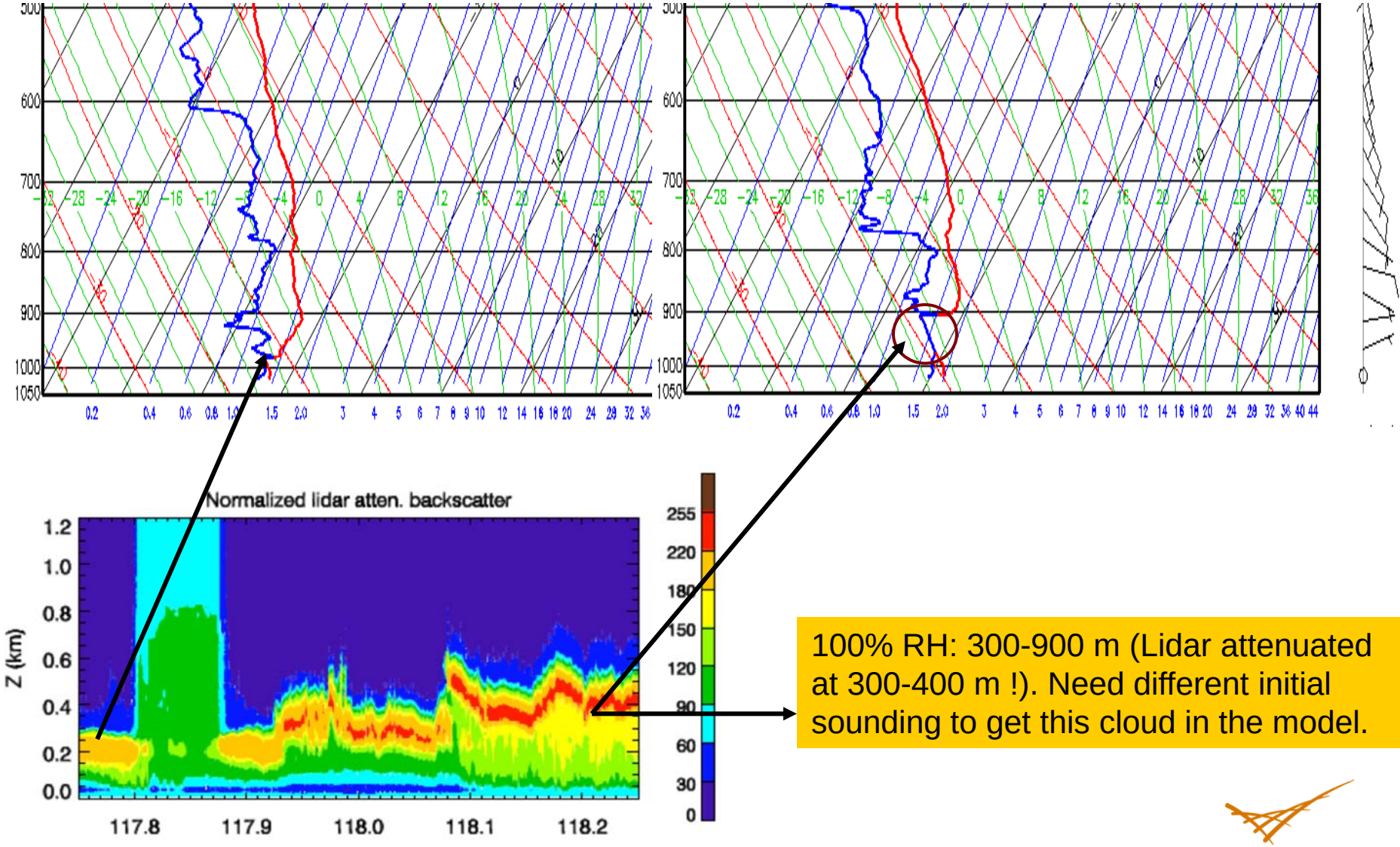

100% RH: 300-900 m (Lidar attenuated at 300-400 m !). Need different initial sounding to get this cloud in the model.

Data of C. Flynn

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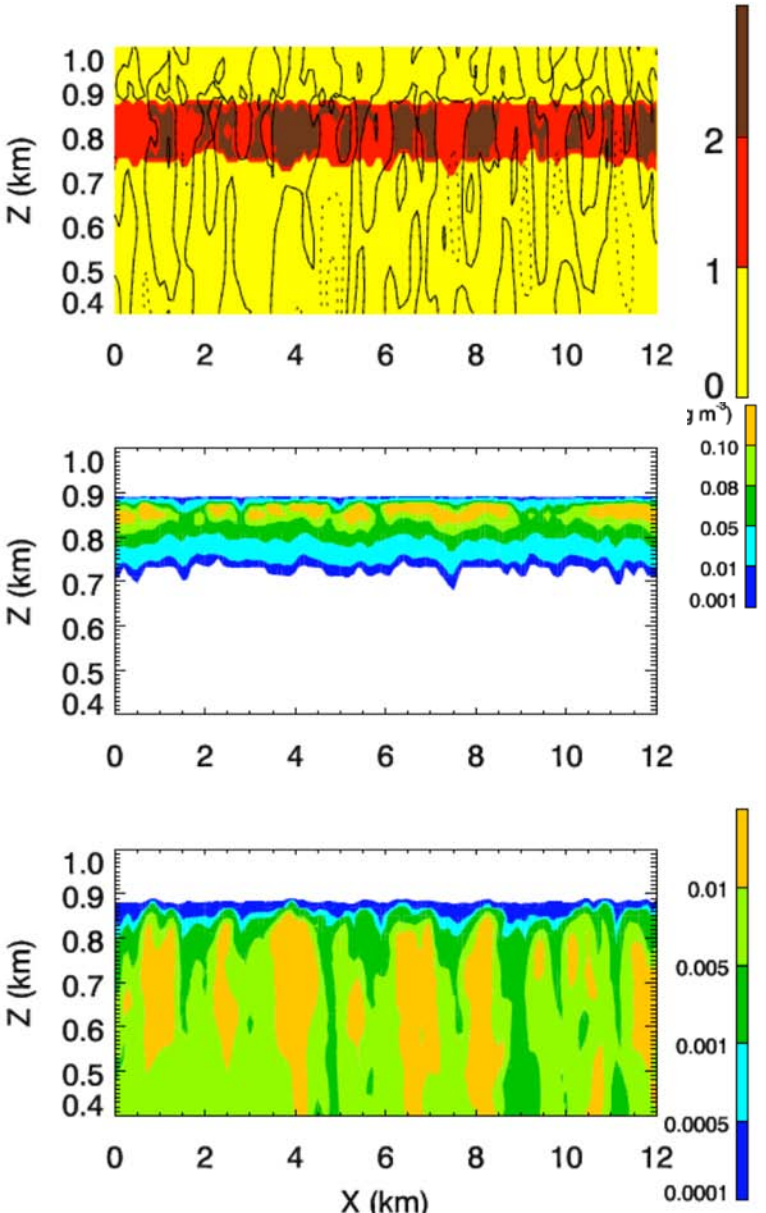
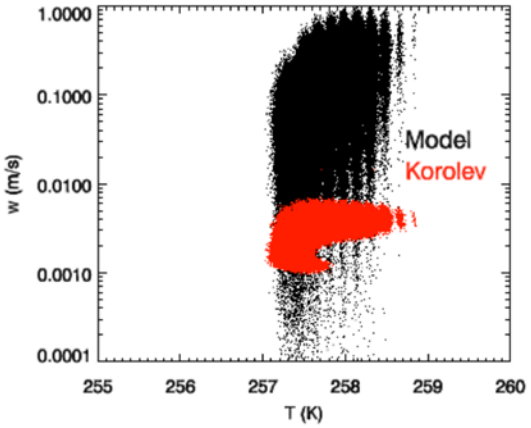
WBF Process

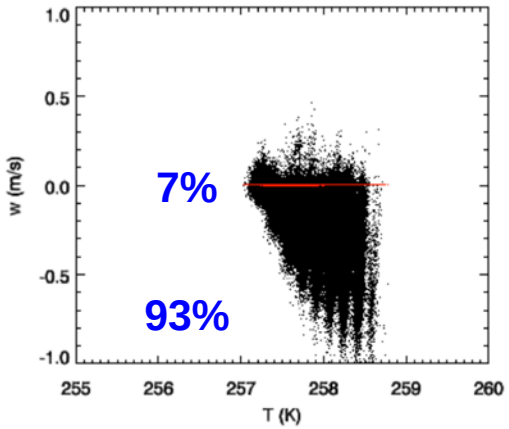


- **Both growth: 51%**
- **WBF: 49%**

Both growth



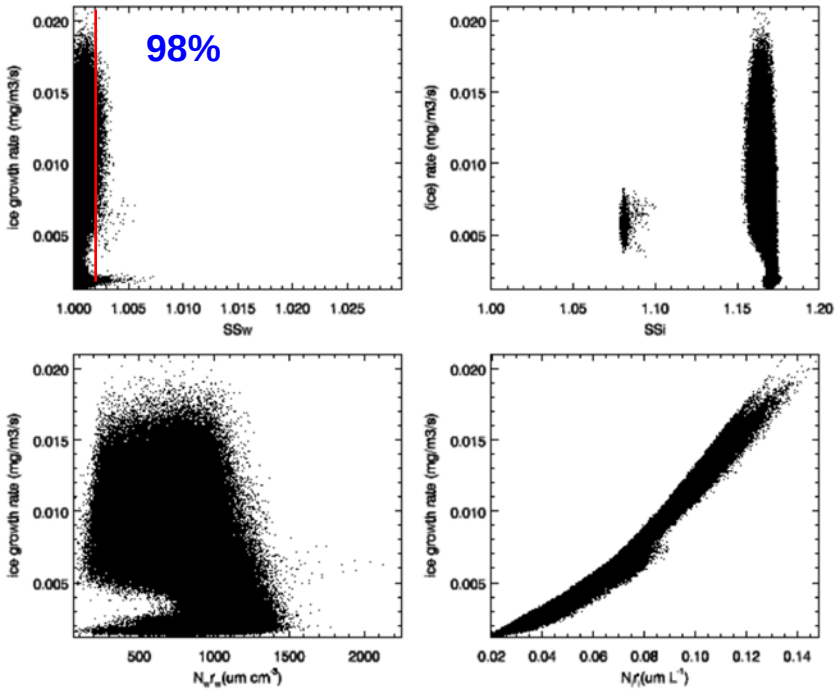
WBF



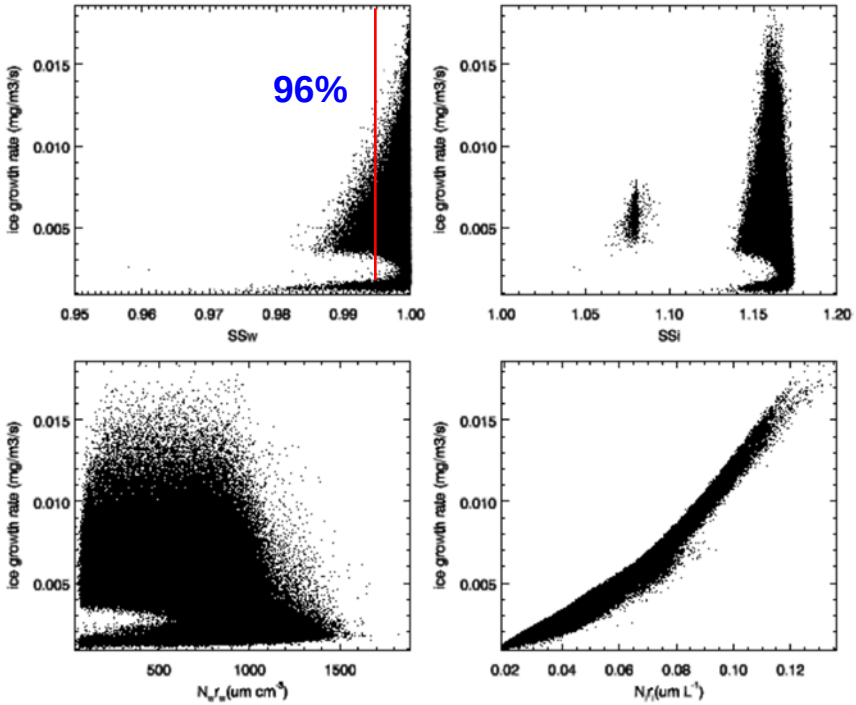
- Both growth: w exceeds the w_{max} from Korolev
- WBF: w can be over 0.1 m/s, 10 times larger than w_{max} from Korolev (0.01)
- Only 7% of WBF in the updraft (can be ignored and use w_{max} of 0 in the climate model).

Ice particle growth

Both growth



WBF



- Ice growth can be also calculated based on water saturation. What about liquid growth?
- Water saturated in WBF, validating the ice growth calculation in CAM4.

- In both regions, ice growth is proportional to $N_i r_i$, no correlation with $N_w r_w$.

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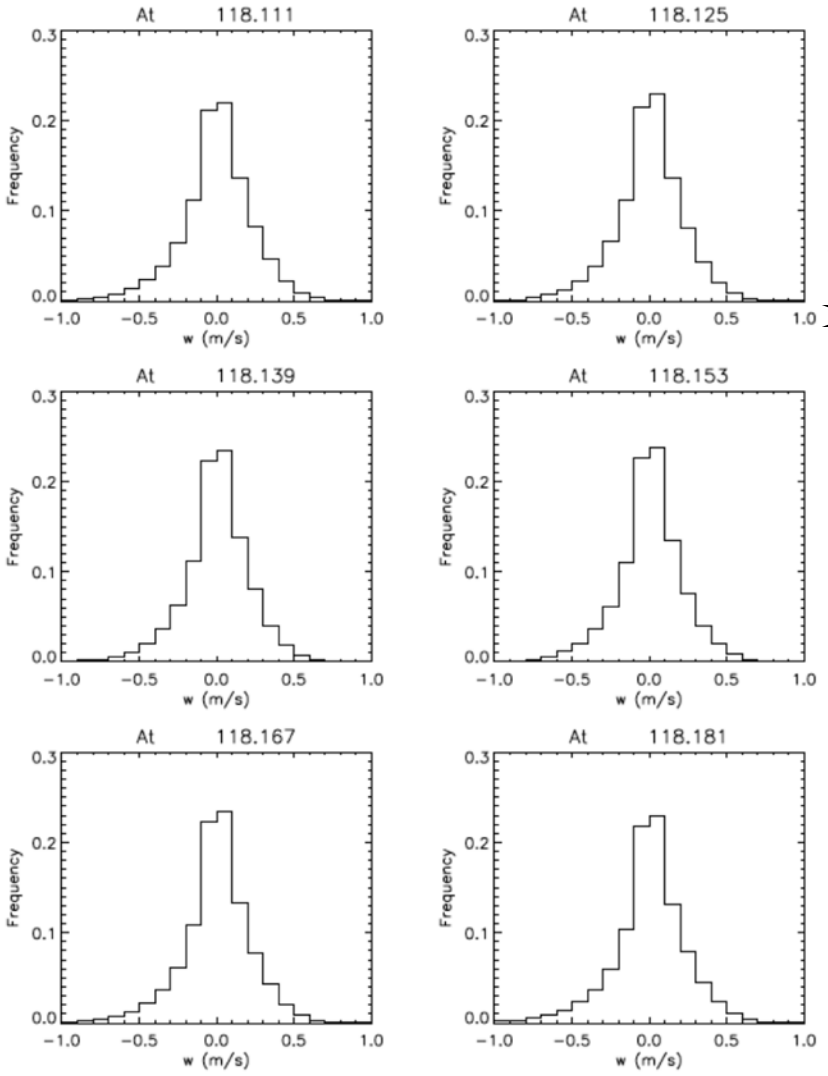
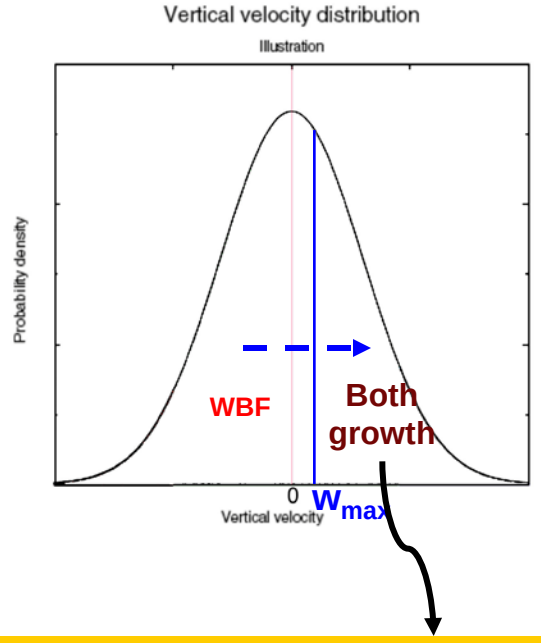
PDF of w

CRM:



validate

Climate model:



To more accurately implement WBF process in the climate model, liquid growth in this region must be accounted more physically. Our tests indicate current implementation of WBF in CAM4 still leads to a large fraction of cloud with droplet growth and ice evaporation, which is not physically possible.

Summary and Next Work

- The modeled ISDAC boundary-layer mixed-phase clouds agree well with aircraft obs.
- Clouds over the open ocean are very different from those near coastal area at Barrow.
- Regimes of both growth and WBF account for 51% and 49%, respectively.
- CRM results validate (a) ice growth can be calculated by assuming water saturation, which is implemented in CAM4; (b) normal distribution of W employed in CAM4.

- ***Look into this process in the other type of mixed-phase clouds such as MPACE multi-layer clouds.***
- ***Examine the scale differences of CRM results (averaged over the large-scale to see the differences).***
- ***Apply to CAM4 and work on liquid growth representation to look into the differences.***

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Acknowledgements

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