Seasonal Variations of Ice Number Concentration in Stratiform Mixed-phase Clouds over the ACRF NSA site

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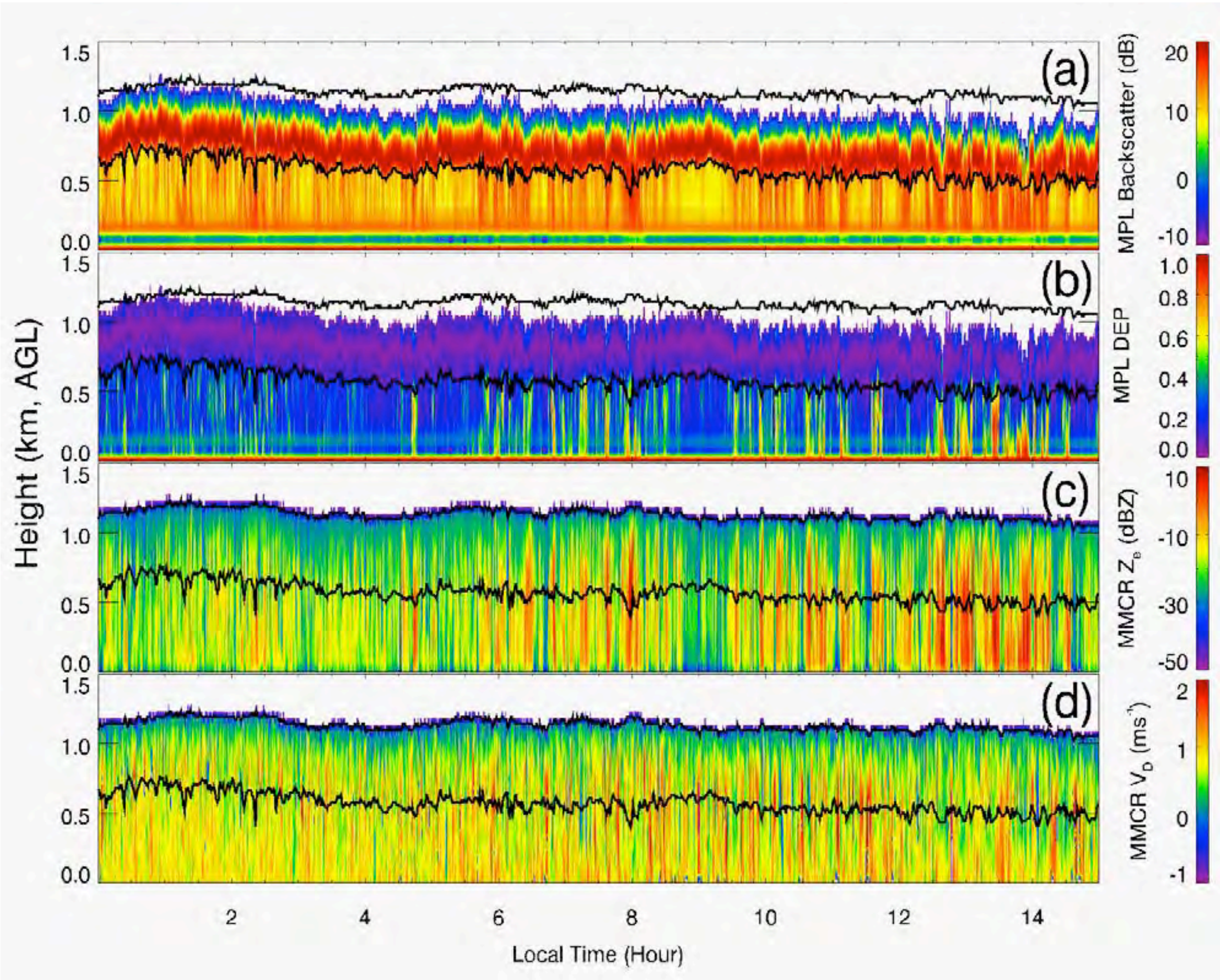
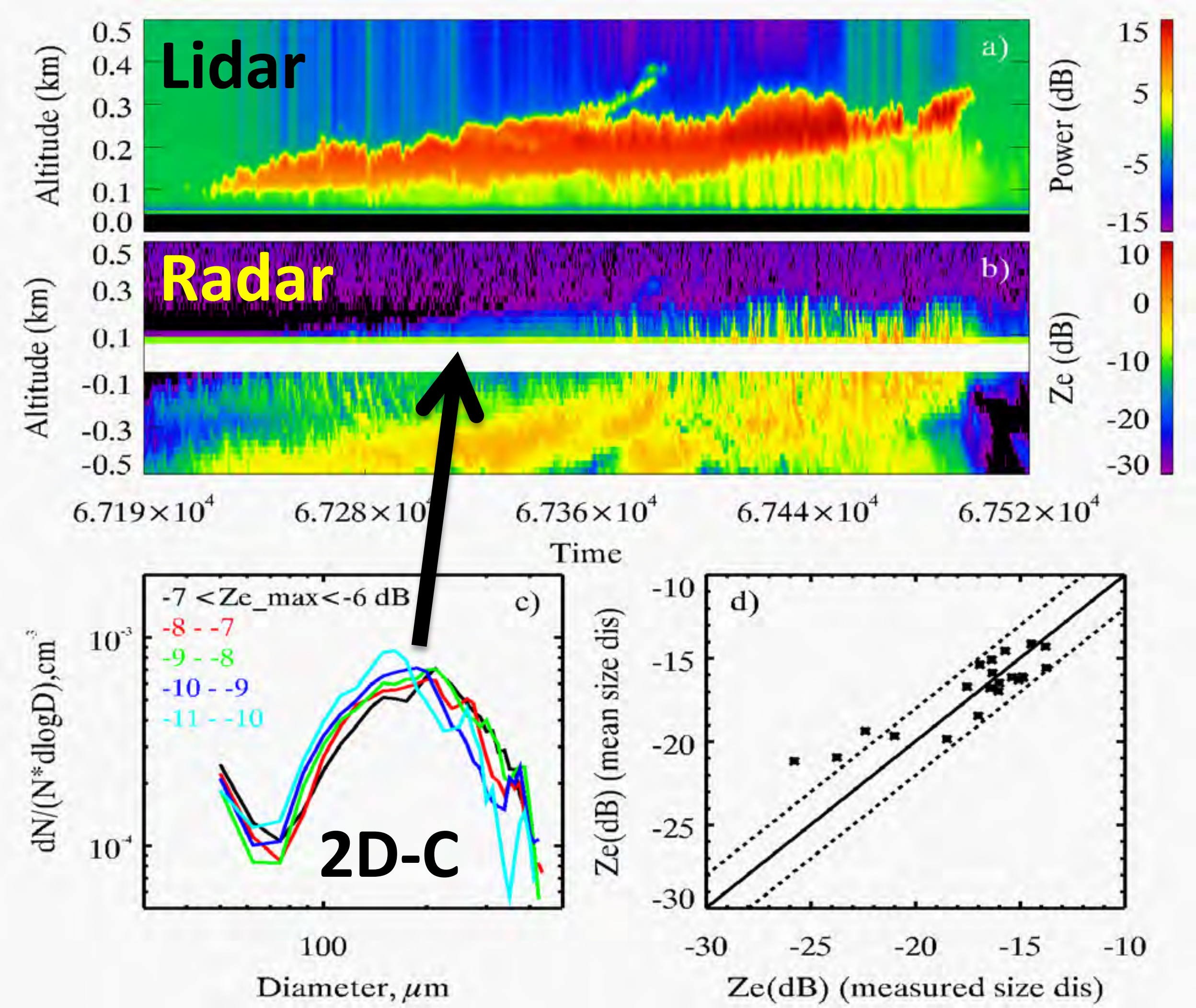
Stratiform Mixed-phase Clouds (SMCs)

- Long-lived, high occurrence over the Arctic Region.
- Liquid dominated layer at the top, ice below.
- Lidar can reliably detect the liquid layer, radar signals are dominated by ice particles.



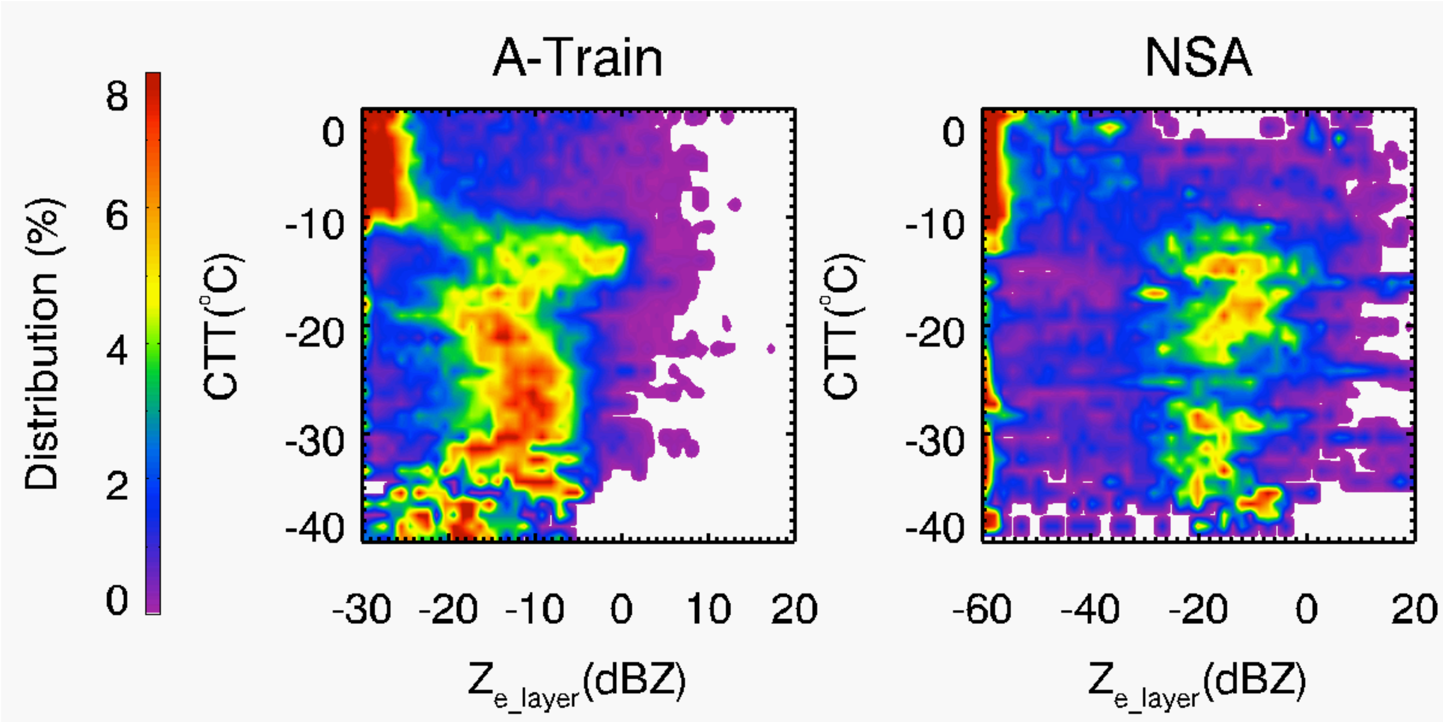
The Similarity of Ice Crystal Size Distribution in Similar SMCs

Similar clouds in terms of cloud top temperature (CTT) and LWP.



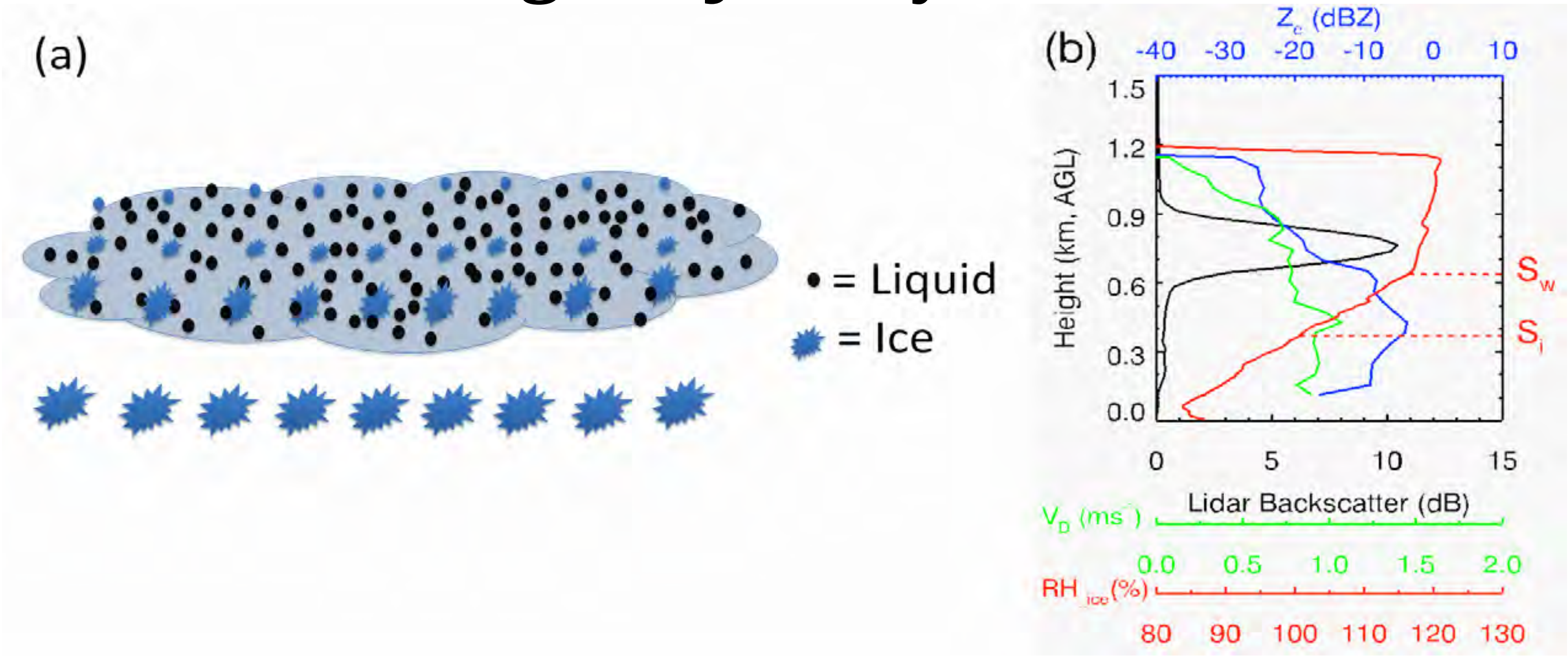
(Zhang et al 2012, JRL)

Temperature-dependent Ice Generation Characteristics in middle-level SMCs



- Z_{e_layer}(the mean Z_e between cloud top and 500 m below) is a strong function of cloud top temperature (CTT).
- Temperature-dependent ice growth rate needs to be considered in order to use Z_{e_layer} to infer the temperature dependence of ice concentration ($\boldsymbol{N_i}$).

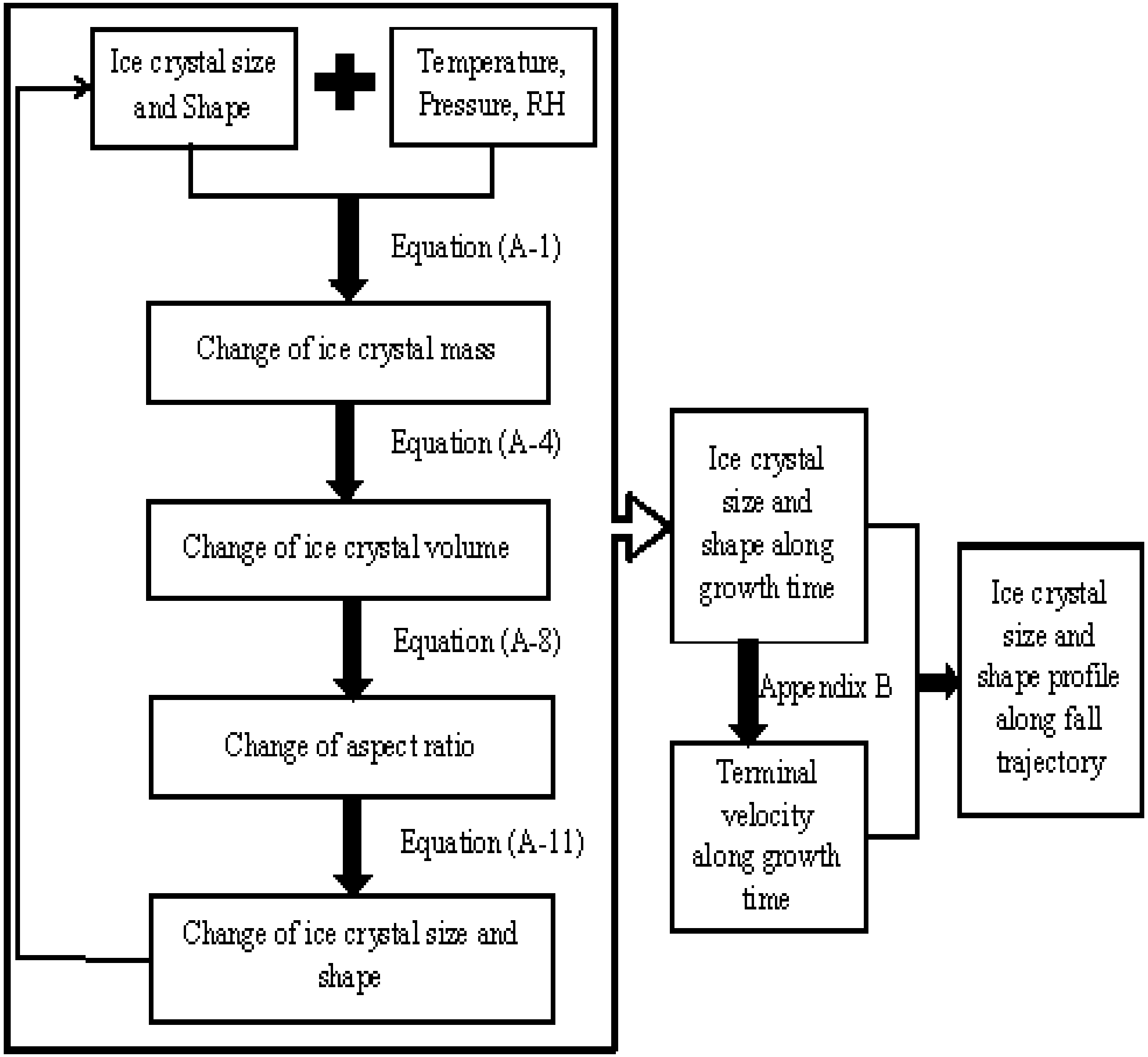
A Conceptual Model of Ice Crystal Growth along Falling Trajectory in SMCs



- Ice particles are formed from liquid, grow large and fall down.
- Diffusion growth and riming growth.
- Thermodynamic environment conditions determined by CTT LWP, and *w*.

1-D Ice Growth Model for SMCs

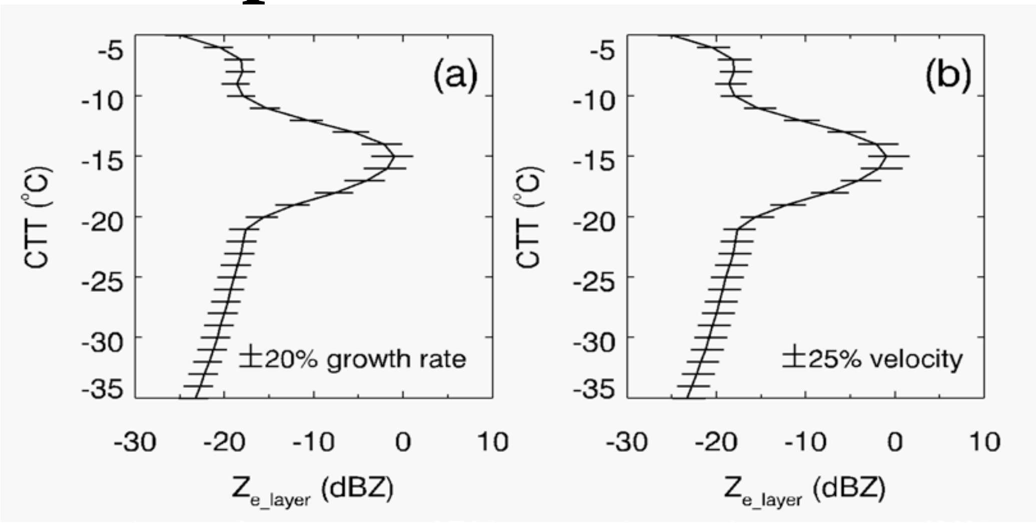
- Temperature-dependent ice growth habit (Chen and Lamb 1994).
- Accretion growth (Heymsfield 1982).
- Adaptive habit prediction (Harrington et al. 2013).
- Shape and size dependent falling speed (Heymsfield and Westbrook 2010).



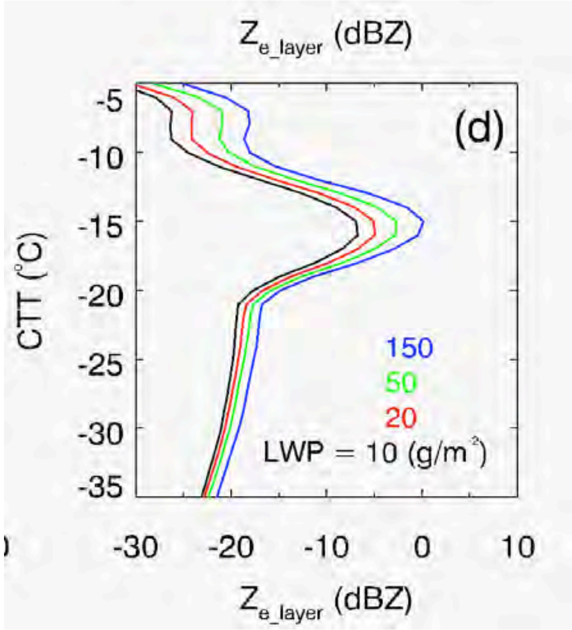
(Zhang et al. 2014, JAS, in revision)

Sensitivity of Z_{e_layer} to Model Assumptions and Cloud Properties

- 20% uncertainties in growth rate and velocity cause approximately ± 3 dBZ variations in the simulated Z_{e_layer}.

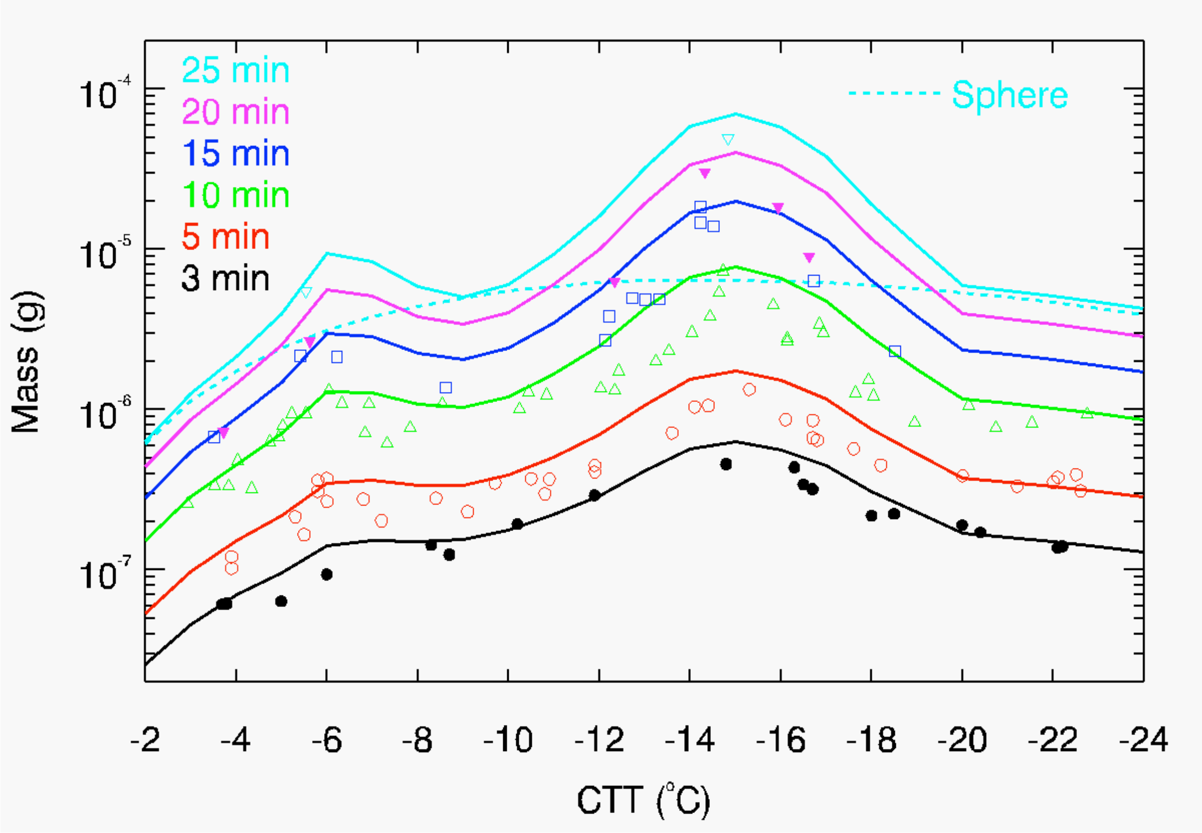


- LWP as an input of the retrieval.



Evaluations of the 1-D Ice Growth Model Simulations and the Retrieved N_i

- **Evaluations with laboratory cloud chamber measurements (Takahashi et al. 1991).**
- Evaluations with ACRF grounded-base radar measurements.
- N_i evaluations with integrated airborne measurements.
- N_i evaluations with 3D model simulations.



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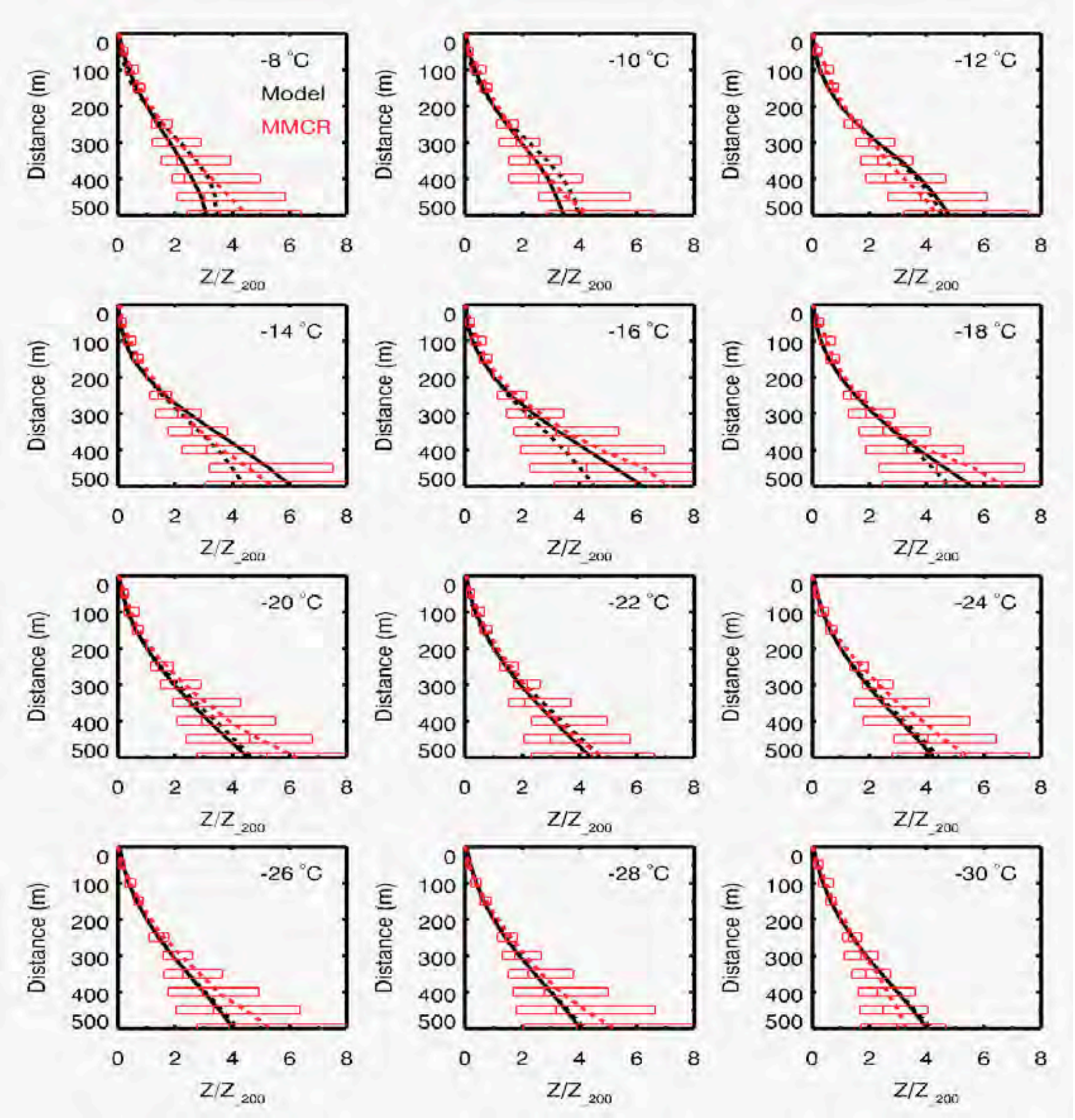
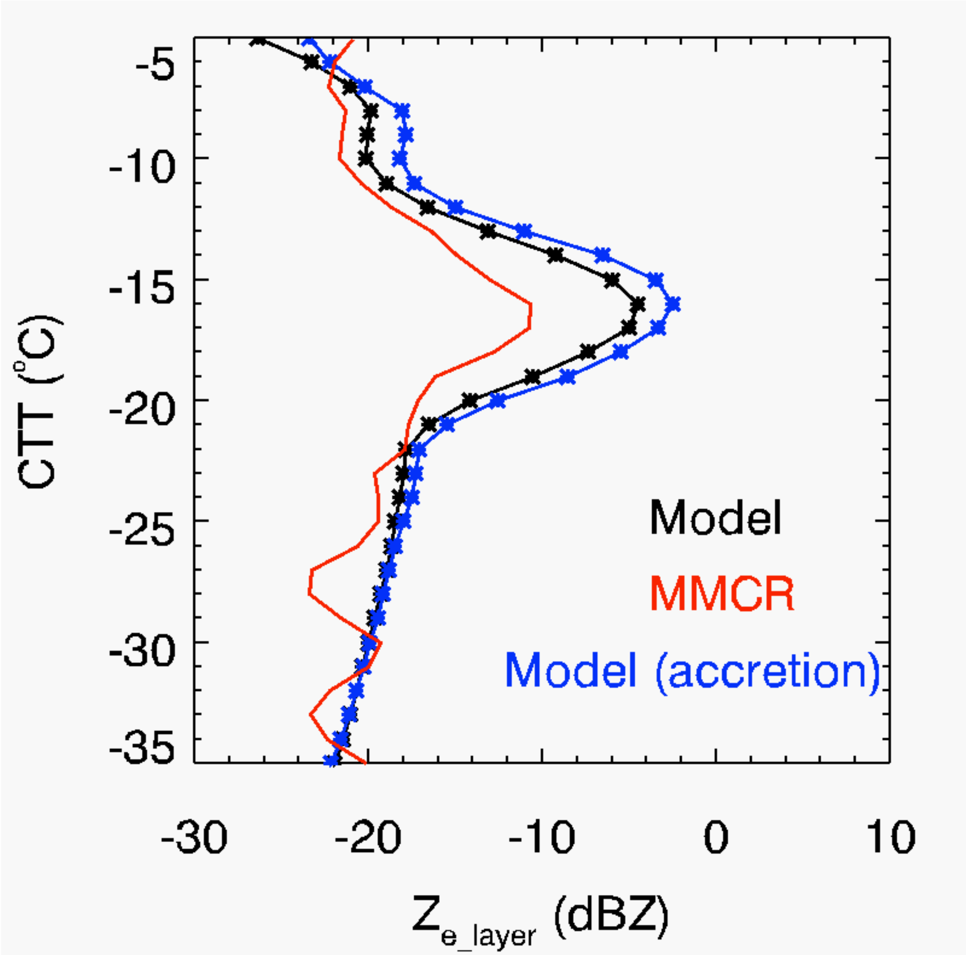


N_i Retrieval

- Observed Z_{e_layer}.
- 1D ice growth model calculated Z_{e_layer} for 1 L^{-1} $\boldsymbol{N_i}$.

$$N_i = \frac{Z_{layer}(Observation, mm^6 m^{-3})}{Z_{layer}(Model, mm^6 m^{-3} L)}$$



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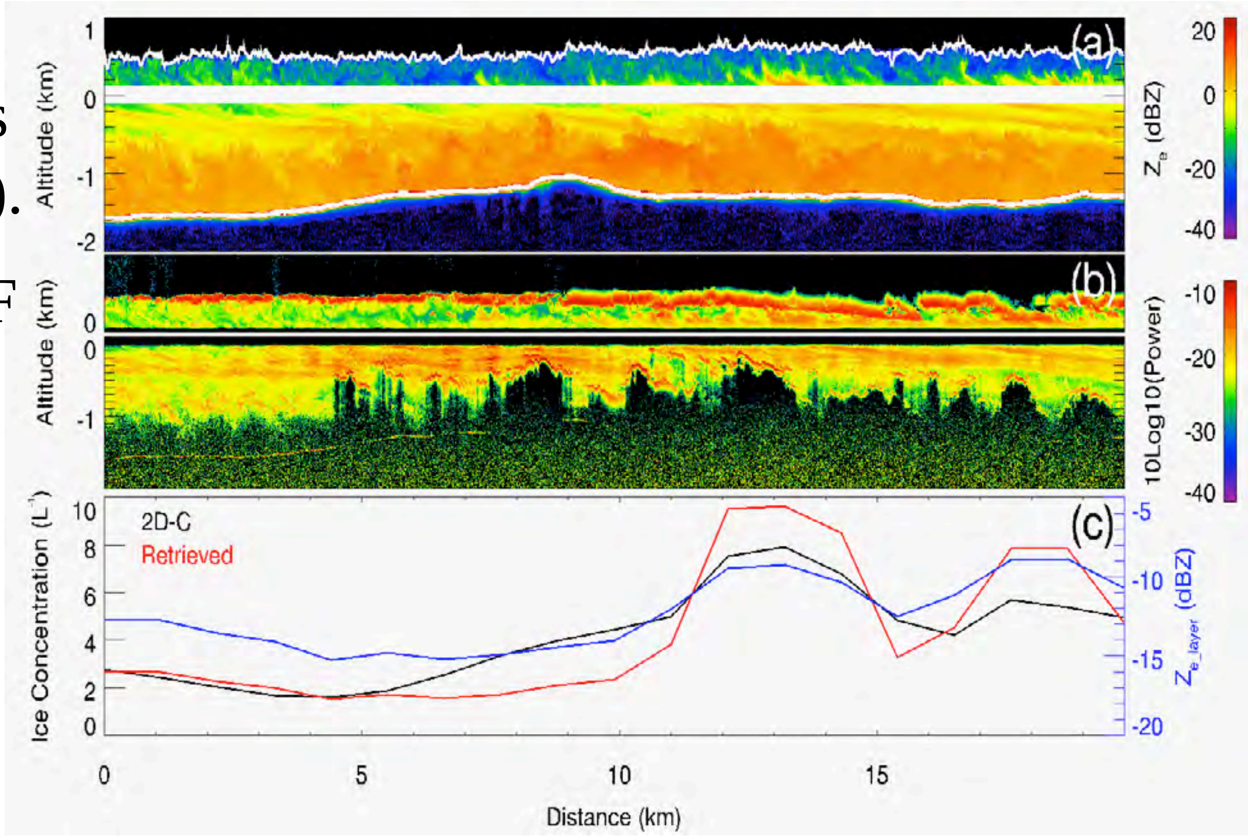

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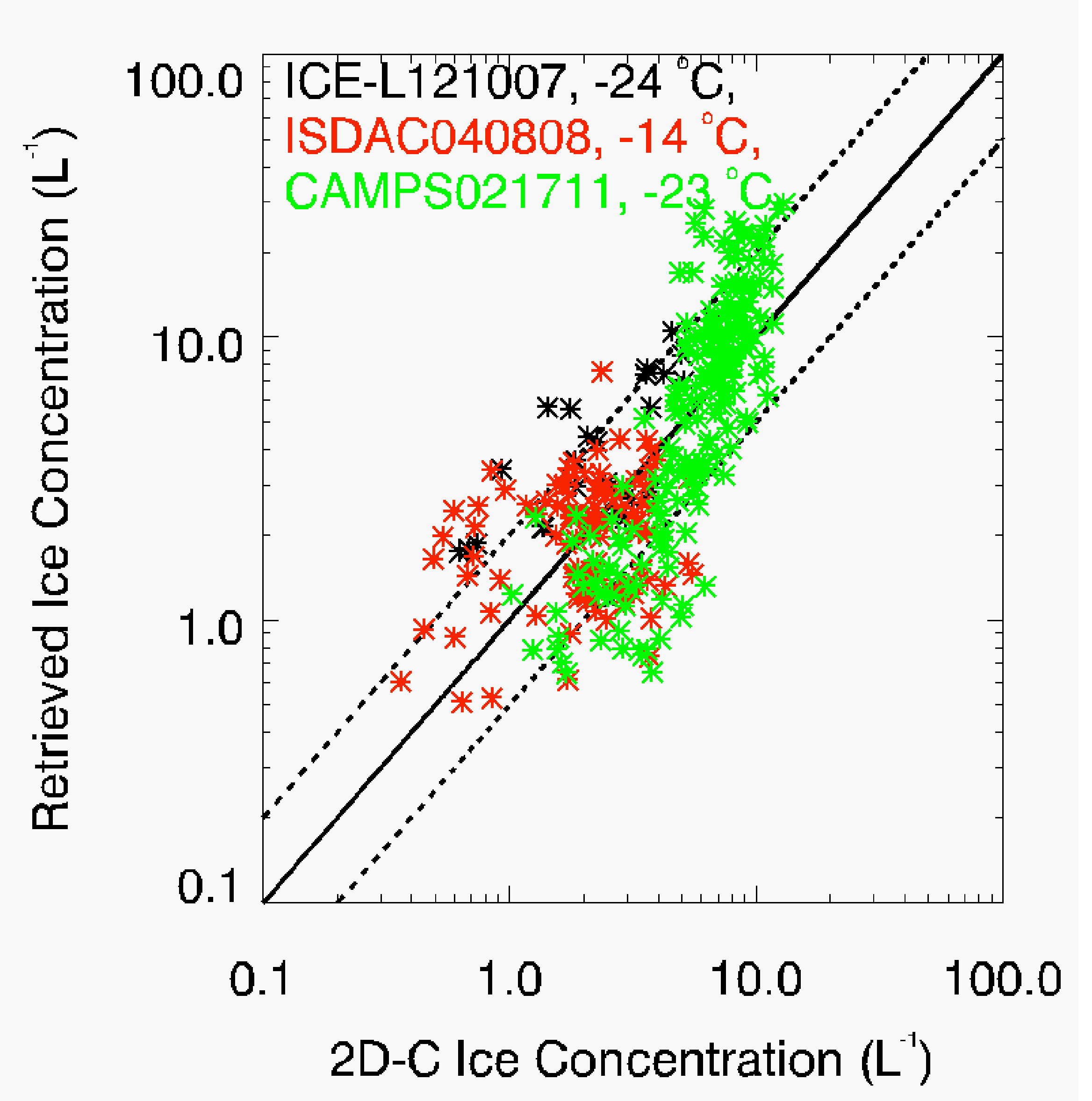

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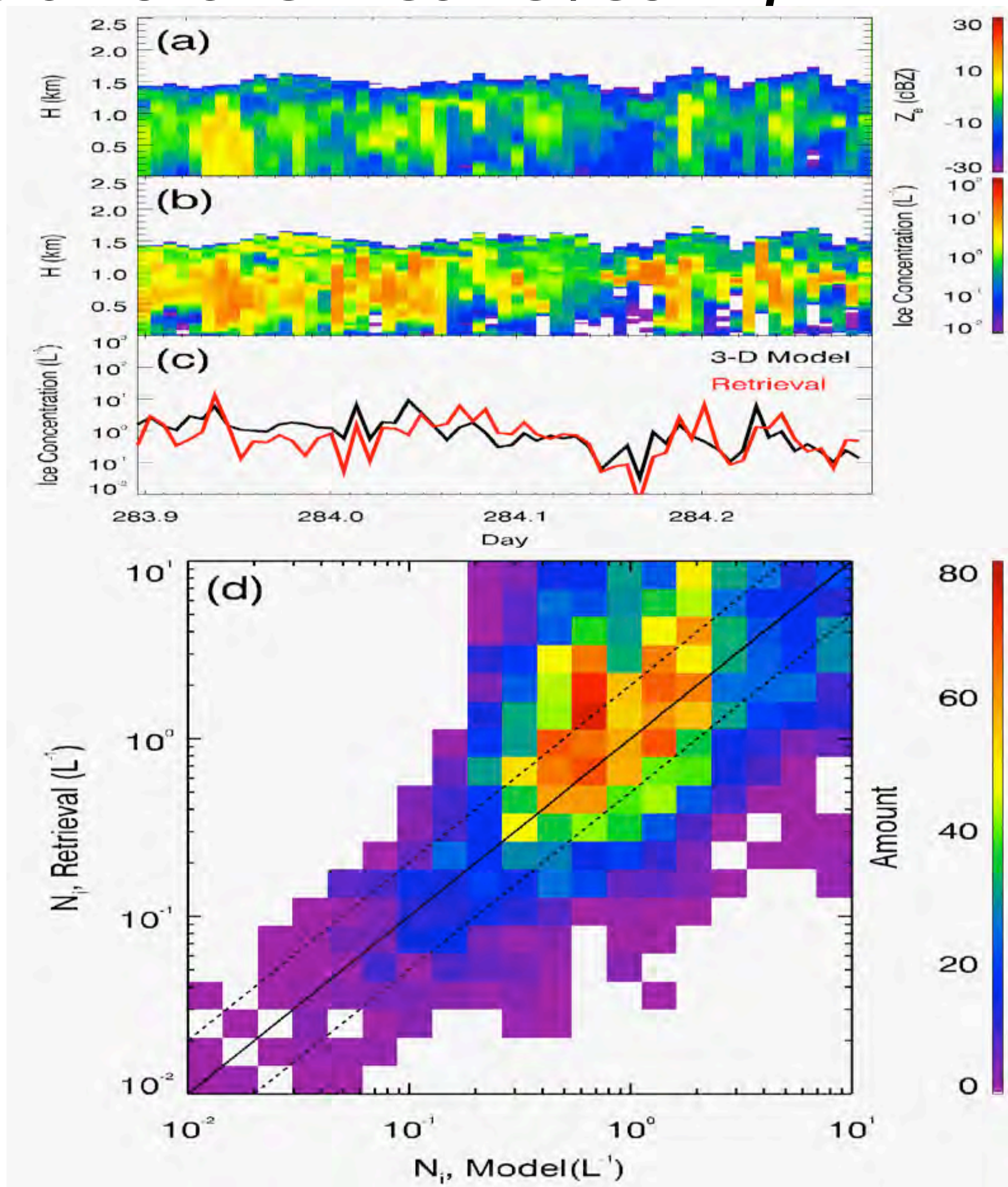
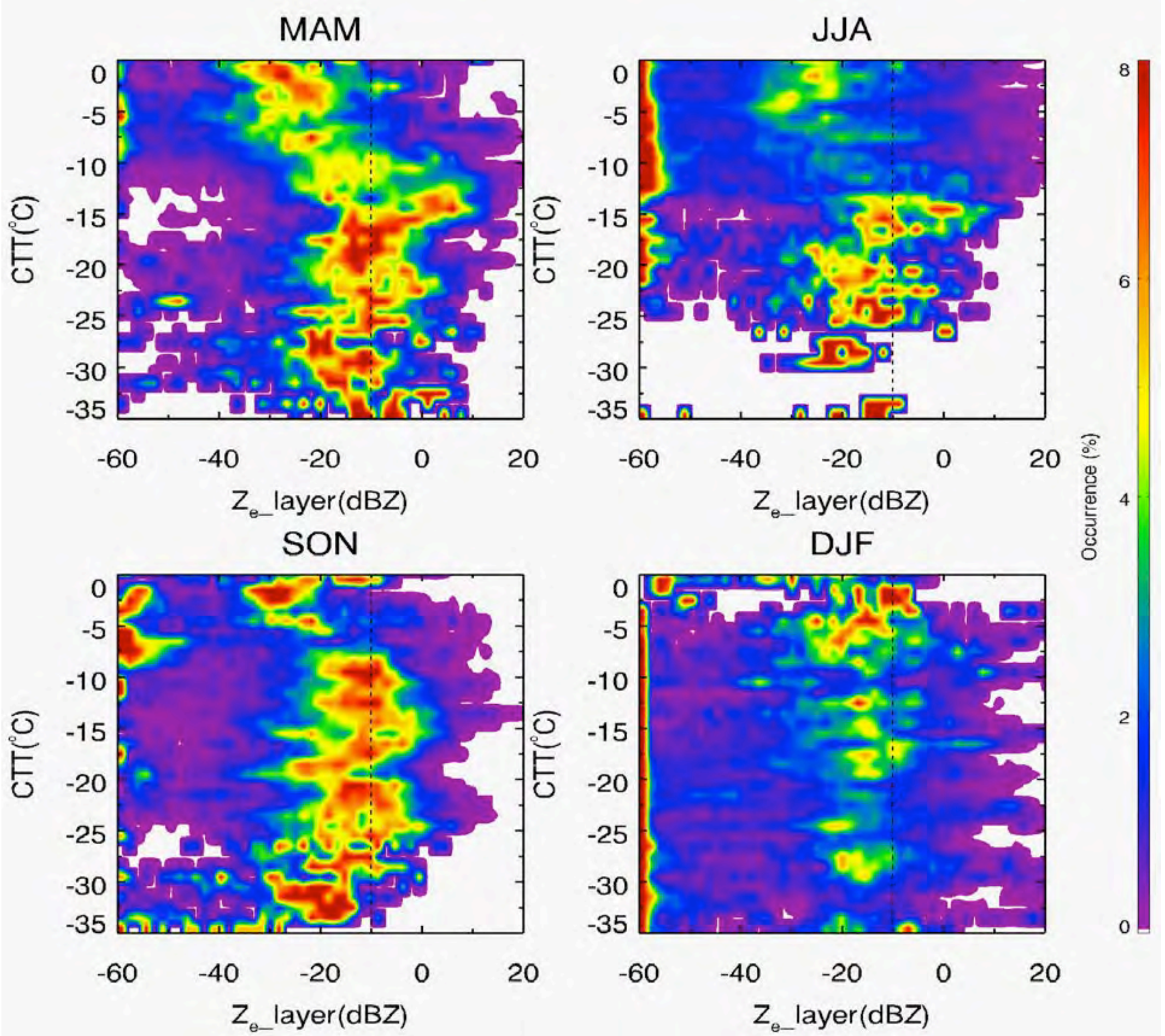


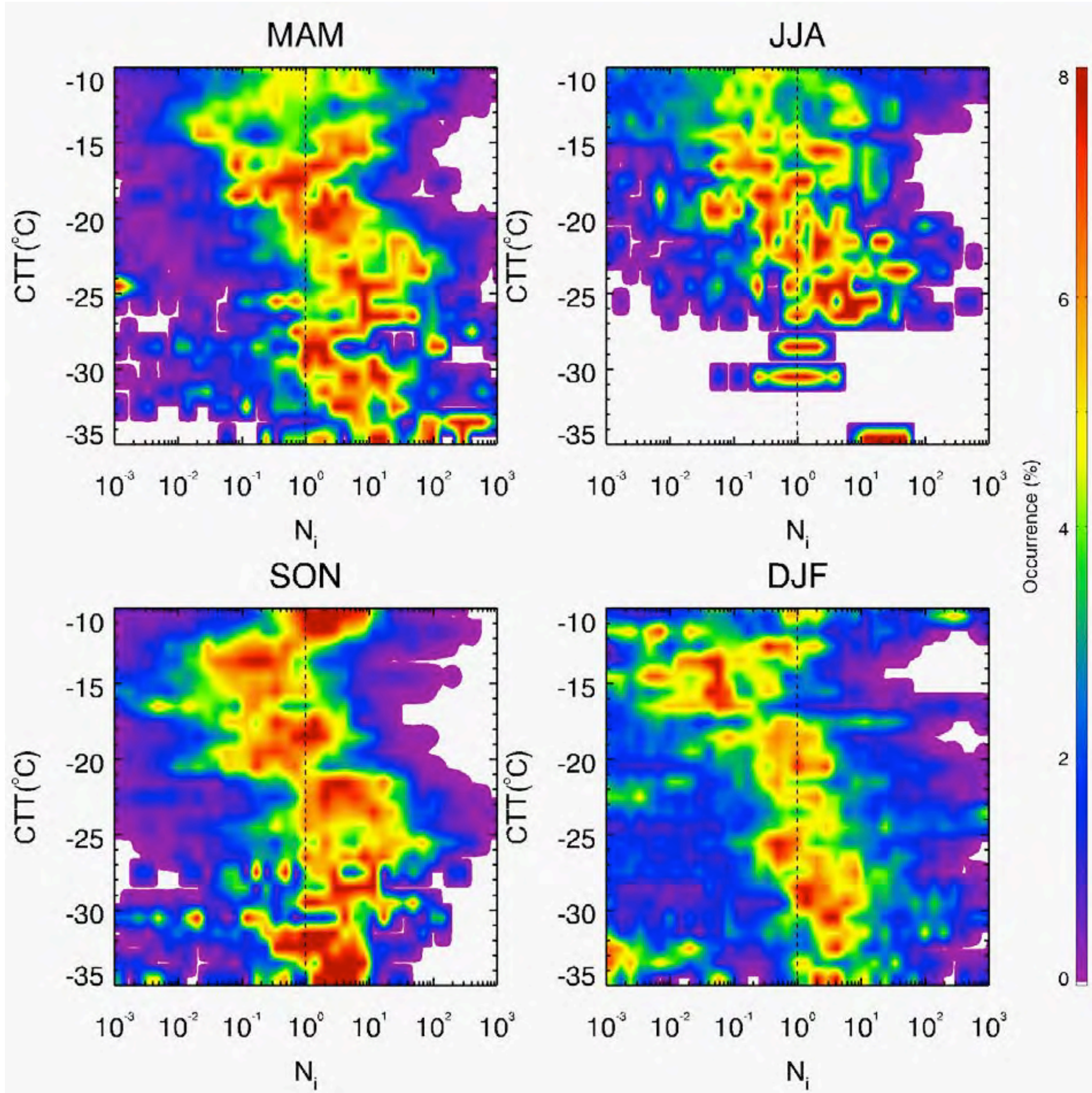
Seasonal Variations of Ice Generation at the NSA site in terms of Z_{e_layer}

- Spring time (MAM) has higher Z_{e_layer} than the other seasons.
- Winter (DJF) has more supercooled liquid stratiform clouds.
- Potential impacts from aerosols.



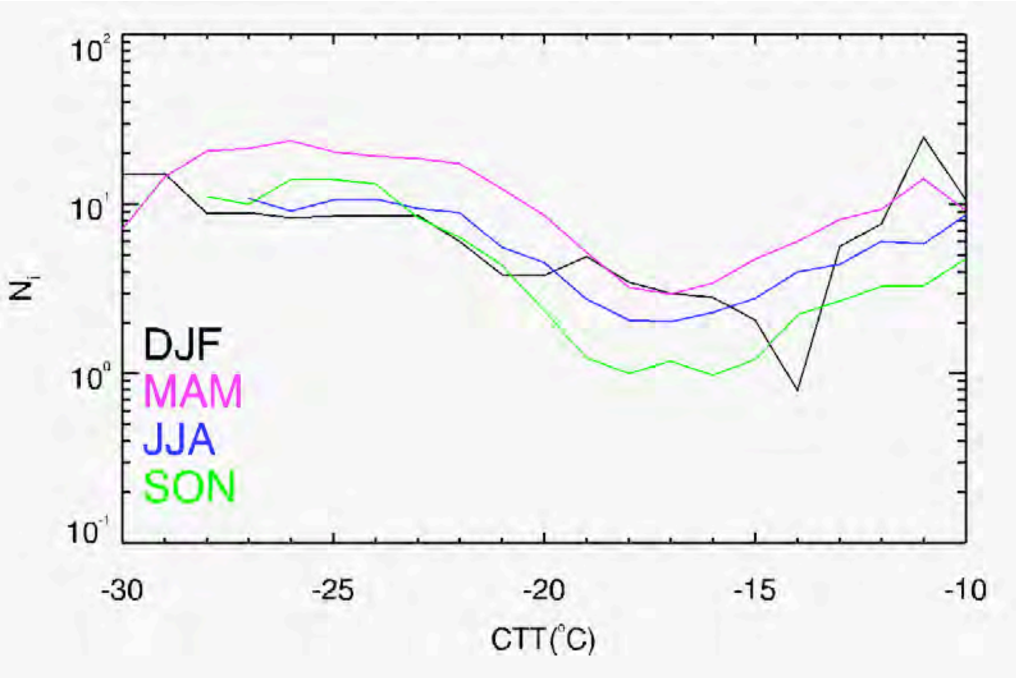
Seasonal Variations of N_i in SMCs over the ACRF NSA site

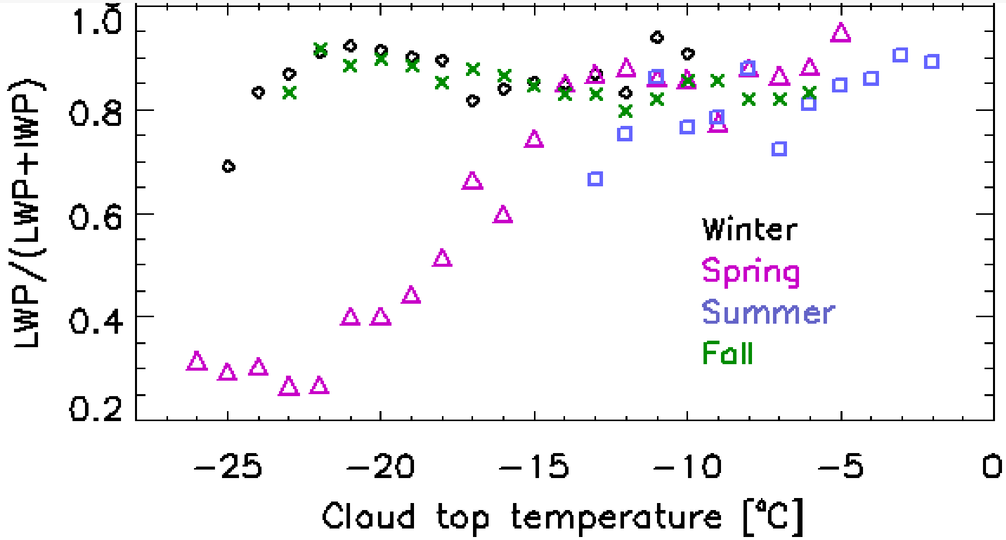
- N_i increase from 0.1 L^{-1} to 100 L^{-1} as CTT decrease to ~-35 °C.
- Spring time (MAM) has higher N_i than other seasons.



Seasonal Variations of N_i and Liquid/Ice Mass Partition in SMCs

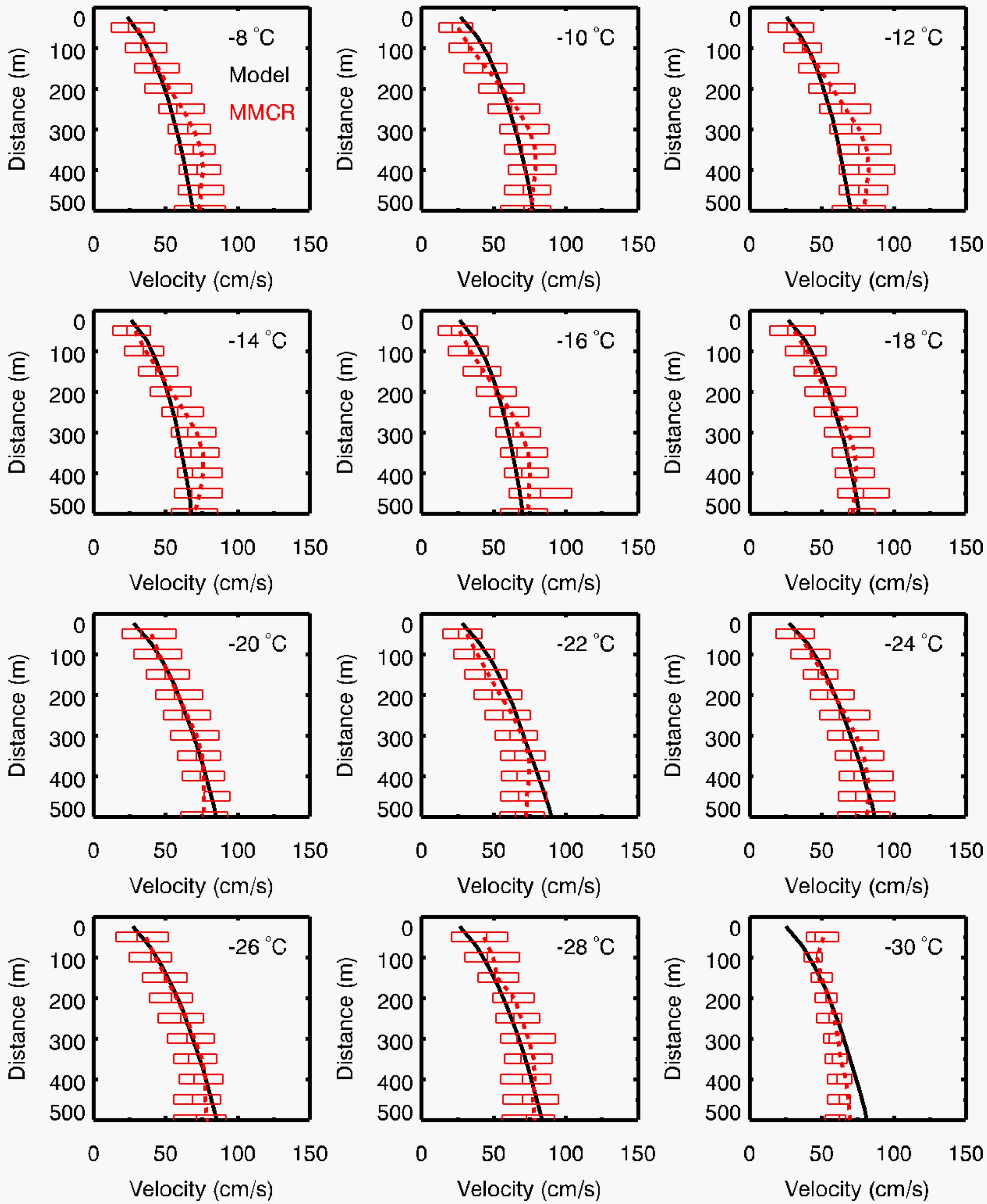
- The higher N_i results in a lower liquid mass partition in SMCs.
- High dust occurrence in Spring time at the NSA site could be responsible for the observed high N_i .

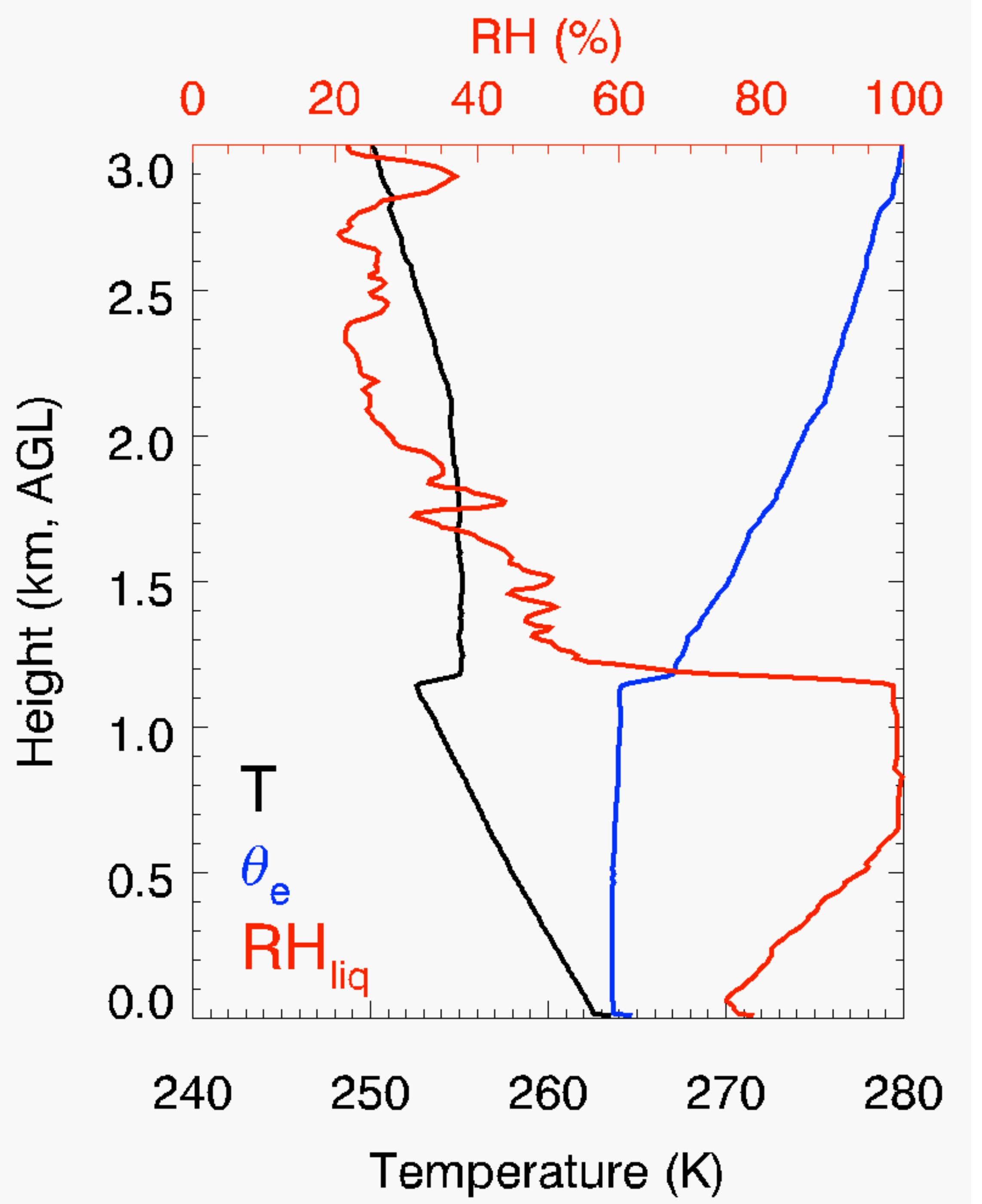




Next Step

- Generate a SMC $\boldsymbol{N_i}$ database at the NSA site and release it as a PI product.
- Use the database to explore aerosol impact on $\boldsymbol{N_i}$ in SMCs.
- Use the database to evaluate and improve model simulations of SMCs.


-8 °C
Model
MMCR
-10 °C
-12 °C
-14 °C
-16 °C
-18 °C
-20 °C
-22 °C
-24 °C
-26 °C
-28 °C
-30 °C
Distance (m)
Velocity (cm/s)
0
100
200
300
400
500
0
50
100
150



RH (%)
0
20
40
60
80
100
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Height (km, AGL)
T
θ_e
RH_{liq}
240
250
260
270
280
Temperature (K)