Phase partitioning in tropical maritime convective clouds: airborne observation and model simulation

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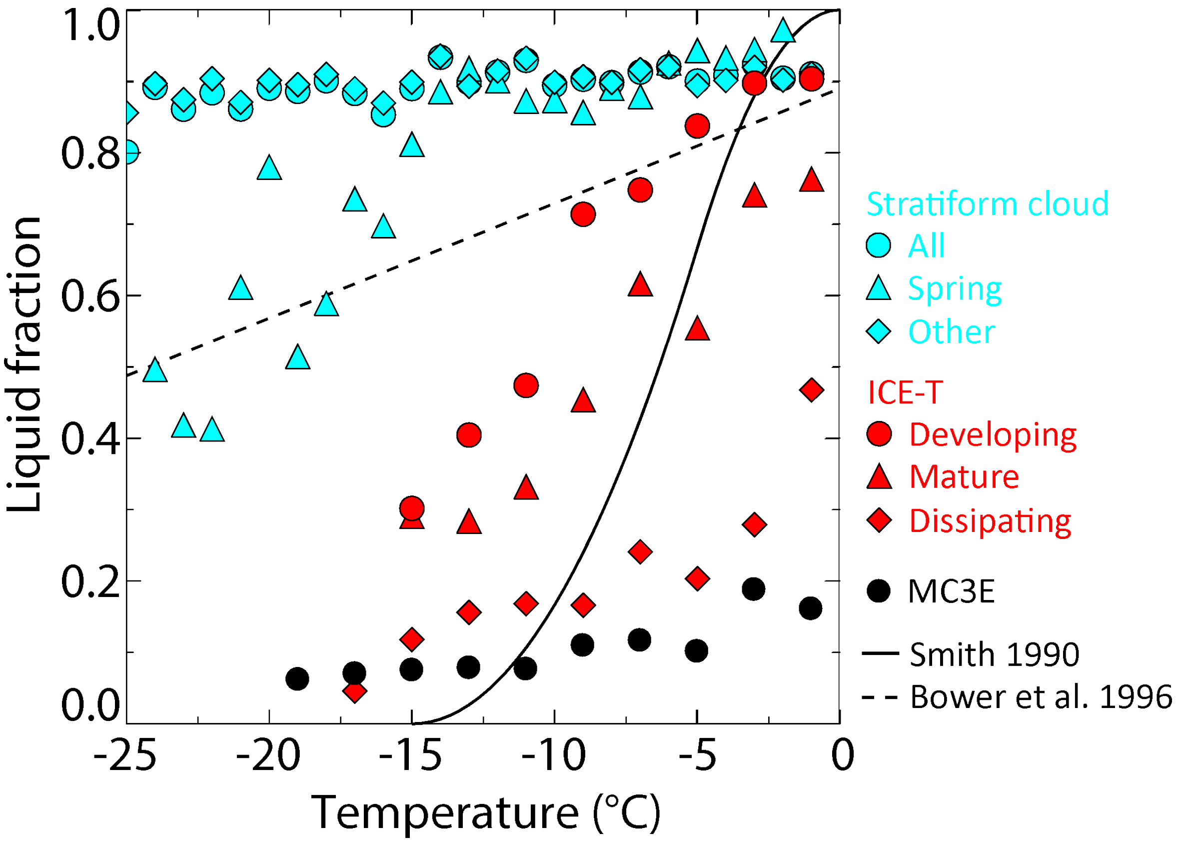
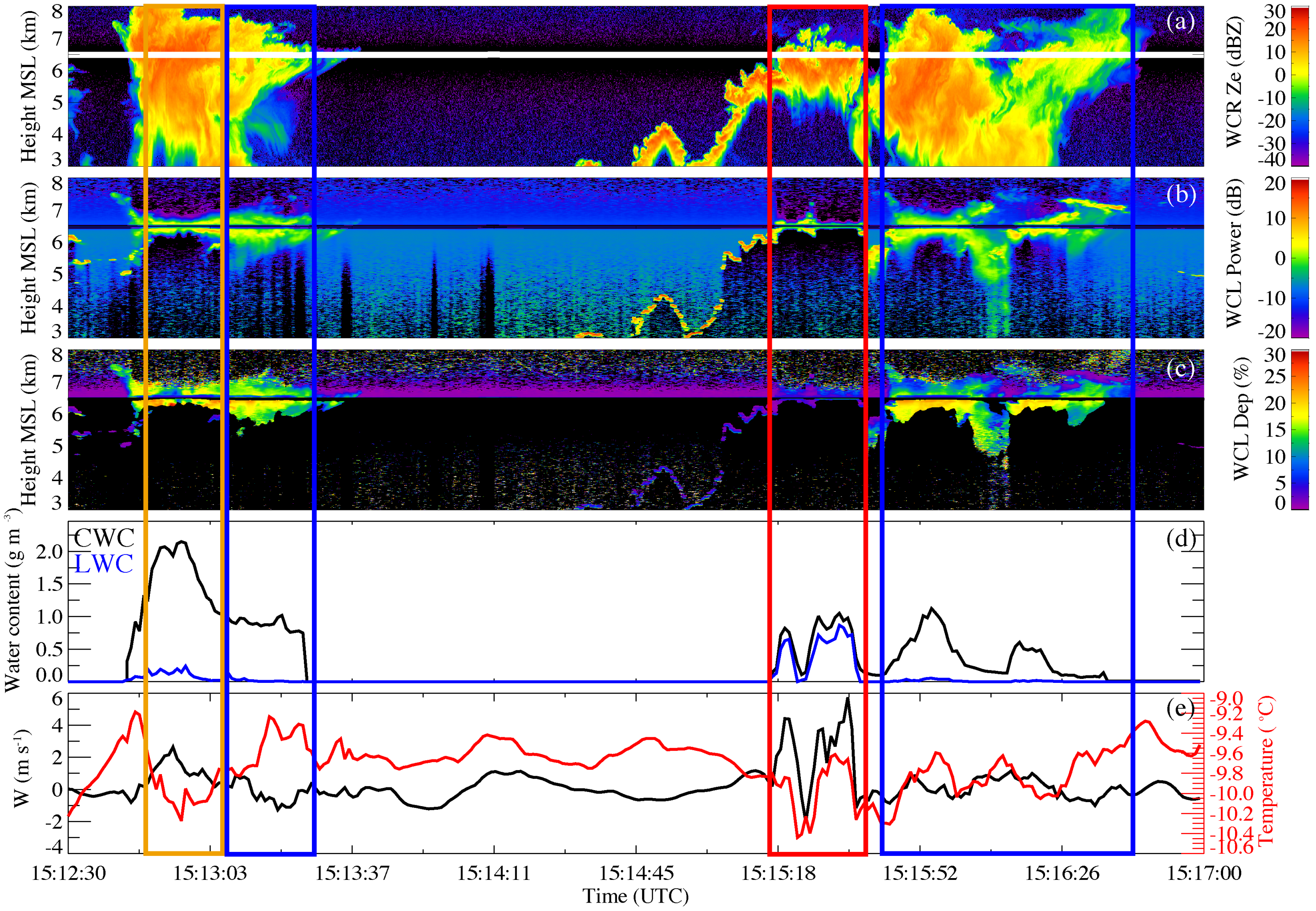
Motivation

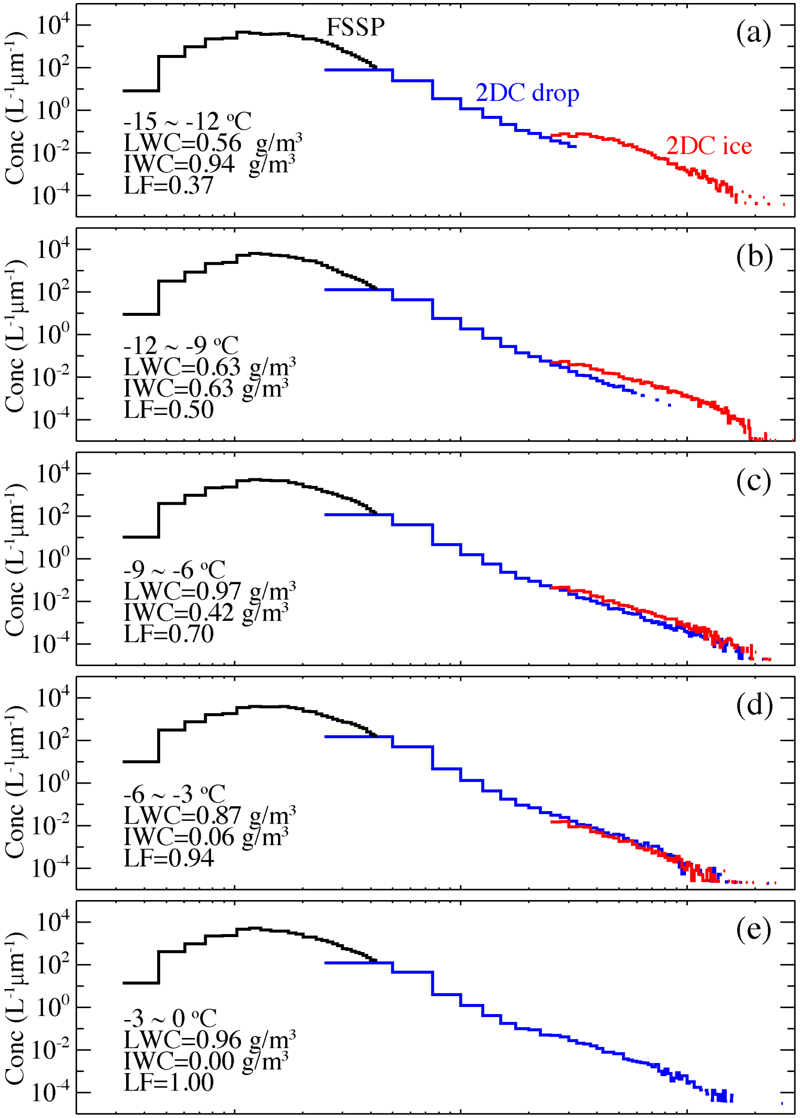
- Phase partitioning in mixed-phase clouds is important to global energy balance and water cycle;
- Ice generation, especially in convective clouds, is still poorly understood;
- Models have large uncertainties in simulating phase partitioning in mixed-phase clouds;
- In this work, the phase partitioning in tropical maritime convective clouds are explored using the in-situ observations and model simulations.



ICE-T cloud example (tropical ocean)



Observed particle size distributions in developing convective clouds

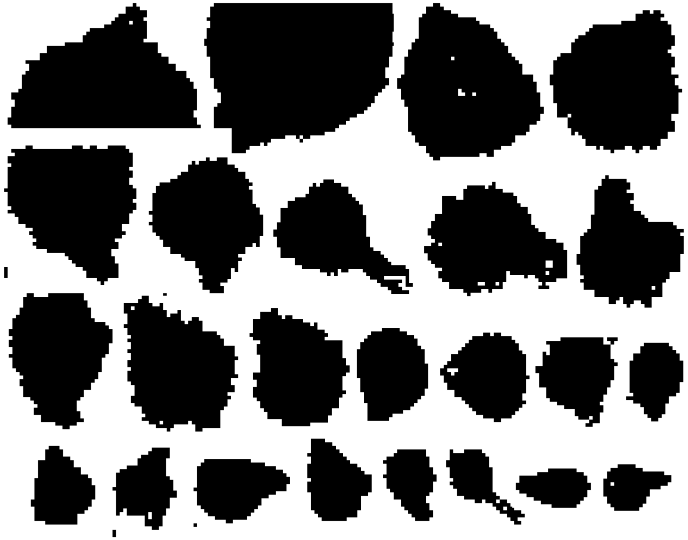


- Large supercooled drops;
- Ice observed at warm temperature;
- Fast ice generation.

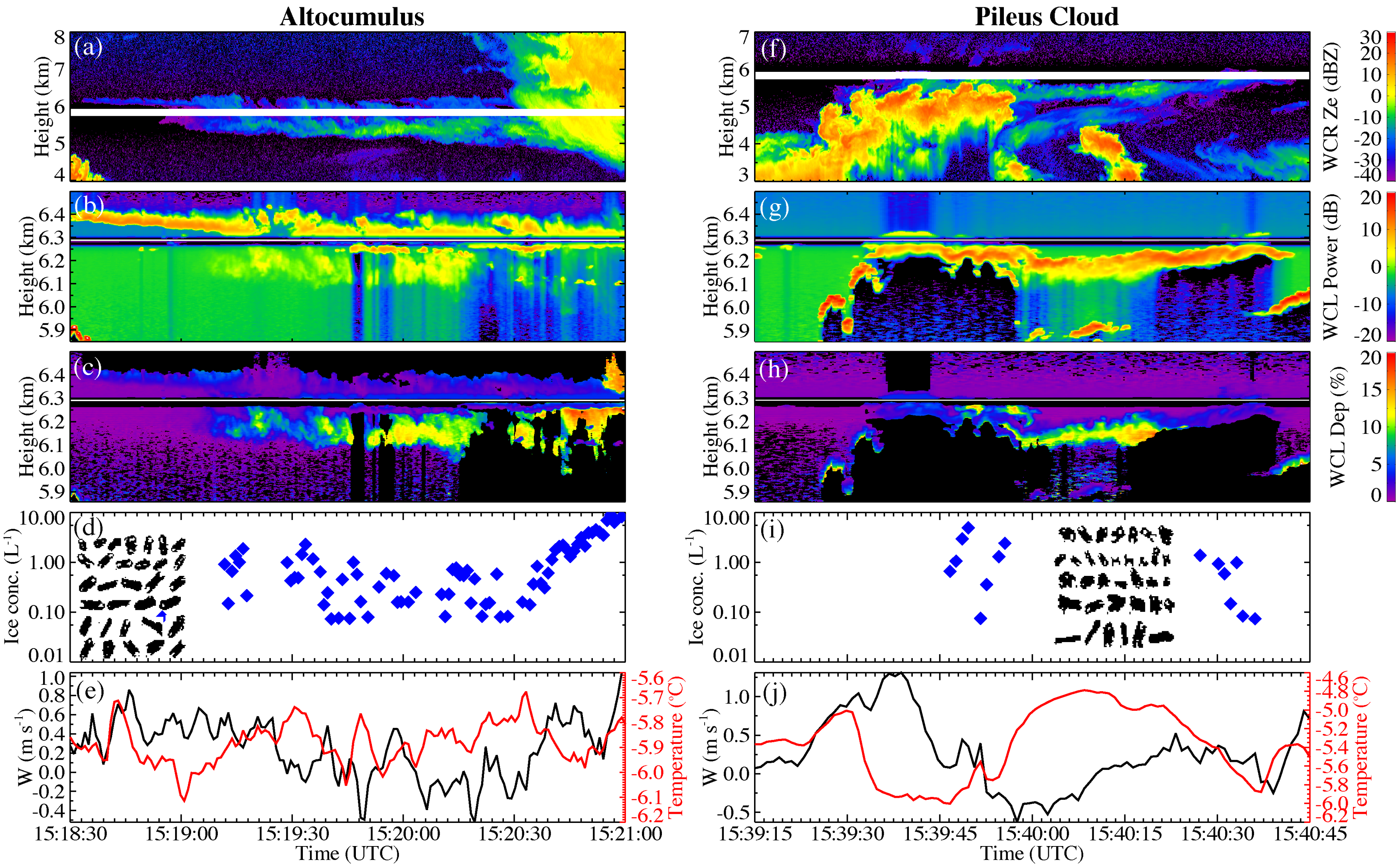
Example of Ice Images

Frozen drops with spicules

(a)



Ice observed at warm temperature in stratiform clouds



Parcel model simulation

Parcel Model Configuration

1. 800m depth; W=5m/s
2. Parcel base temperature: 0C; Top temperature: -4C
3. Using observed drop size distribution at 0 C as input.
4. SBM with 33 bins for each hydrometeor type;
5. Ice generation mechanisms: Bigg's immersion freezing (IF), Meyer deposition/ condensation nucleation (DN), Meyer contact nucleation (CN); Hallet-Mossop process (HM), Freezing splinter (FS) and droplet collisional freezing (CF).

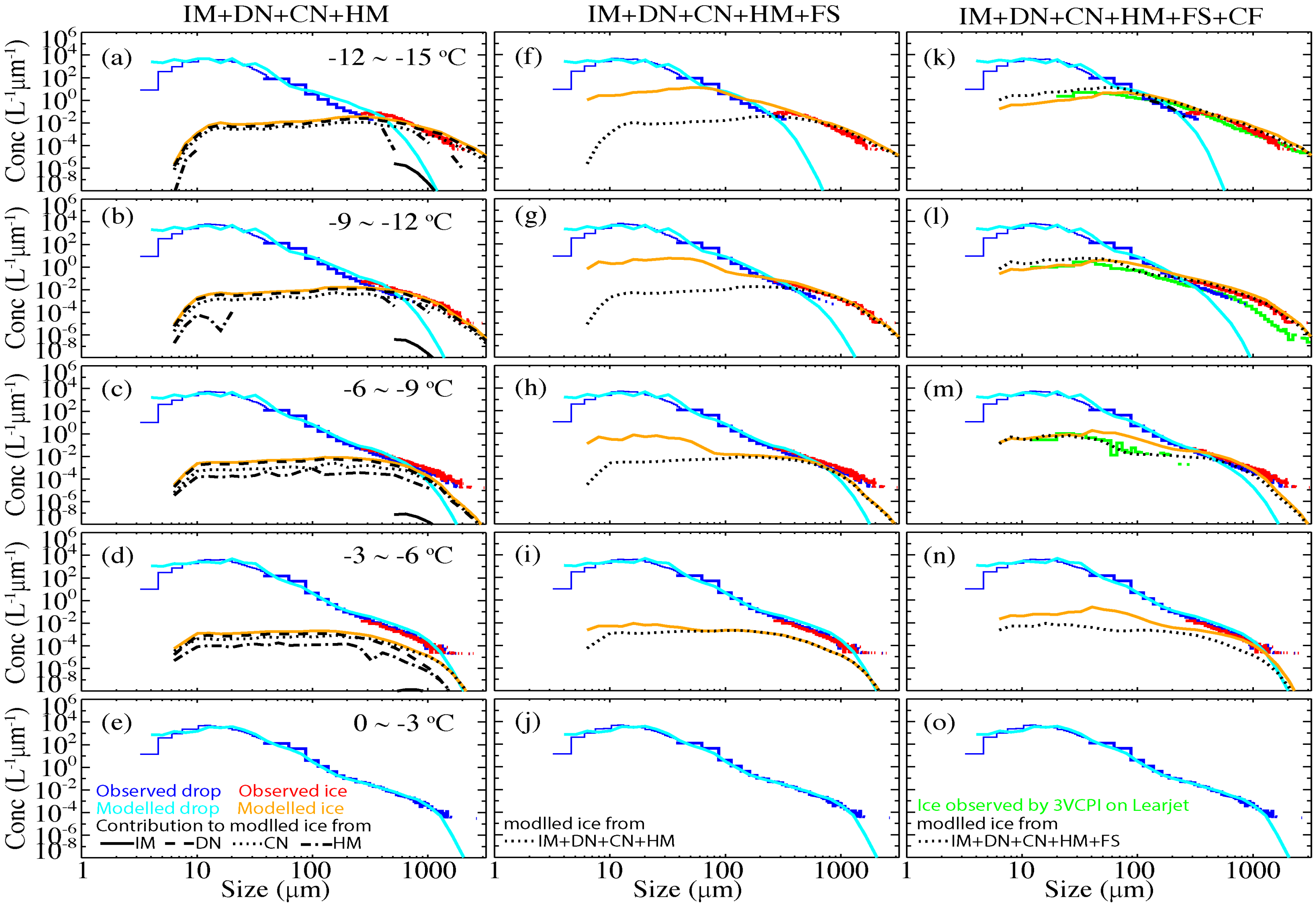
- Based on limited laboratory experiment data from previous studies, we assume the splinter produced by a freezing drop is: $N_{splinter}=a(d/d_0)^{b}\cdot P(T)$, assuming d_0=50 μm, a=2,b=2, Function of *P(T)* follows Leisner et al. (2014).

- Ice generated from drop collision is:

$$\Delta f(d)=\sum\sum f(d_1)f(d_2)K(d_1,d_2)P(T)$$

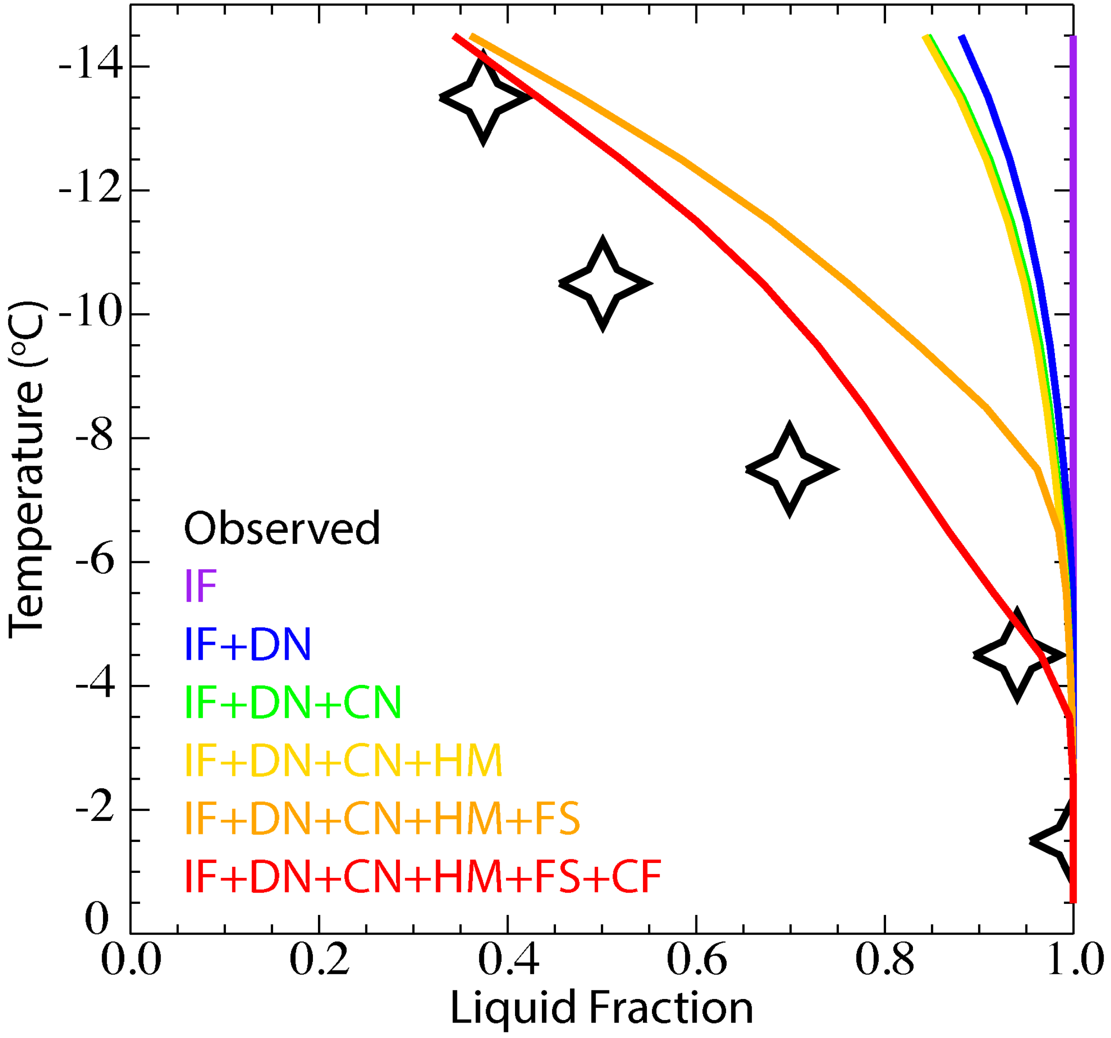
d_1 and d_2 are drop size in adjacent bins. No data are available to determine *P(T)*, we simply assume *P(T)* increases from 0 to 1 from -3 C to -40 C.

Comparison of modelled and observed size distribution

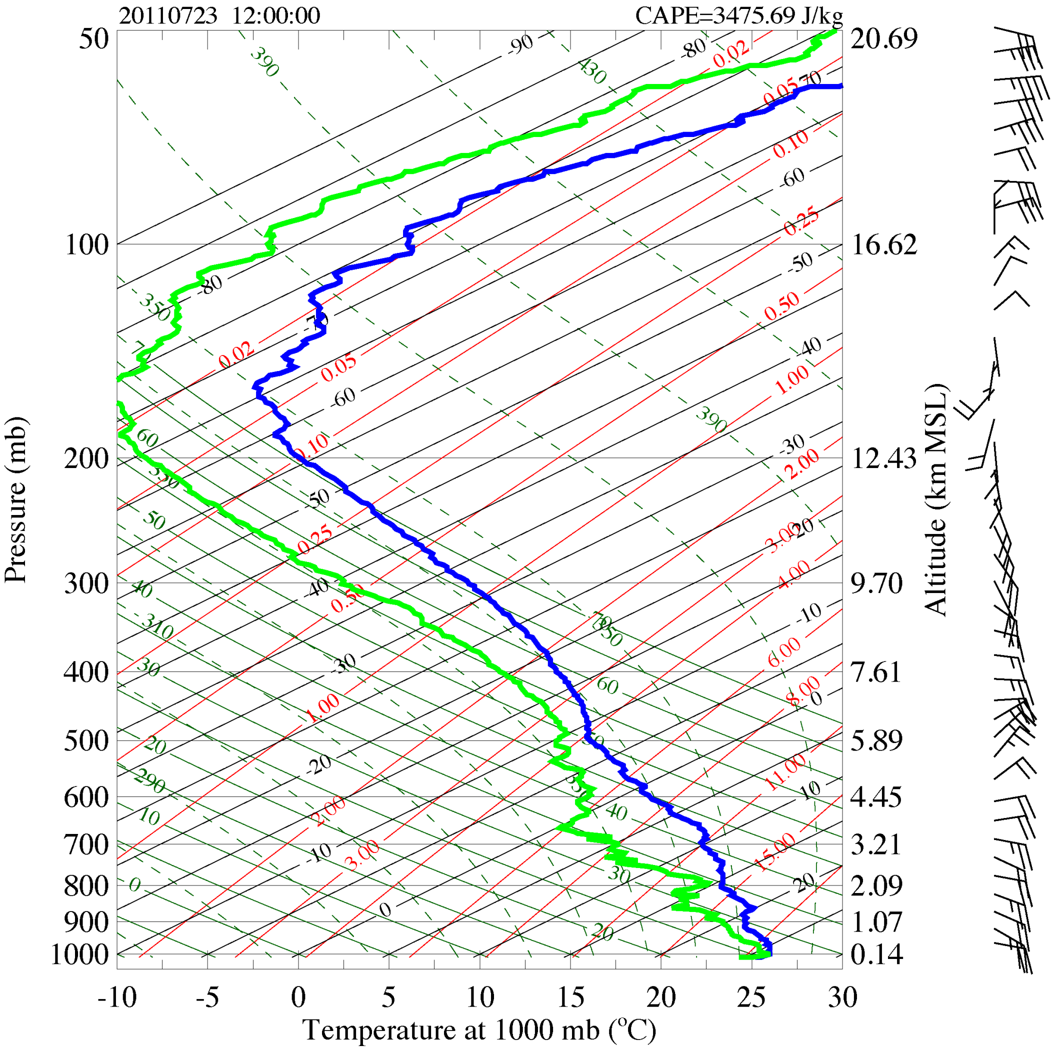


- IM, DN, CN and HM mechanisms cannot explain the observed high ice concentration;
- DN has relatively larger contribution to the ice initiation than other primary ice generation mechanisms.
- Measurements from Learjet, which penetrated in strong updrafts at cloud top, suggest most of the initial ice are small.
- FS largely increase ice concentration smaller than 100 μm at T<-6 C.
- CF mechanism may contribution to ice initiation at T > -6 C.

Comparison of modelled and observed liquid fraction



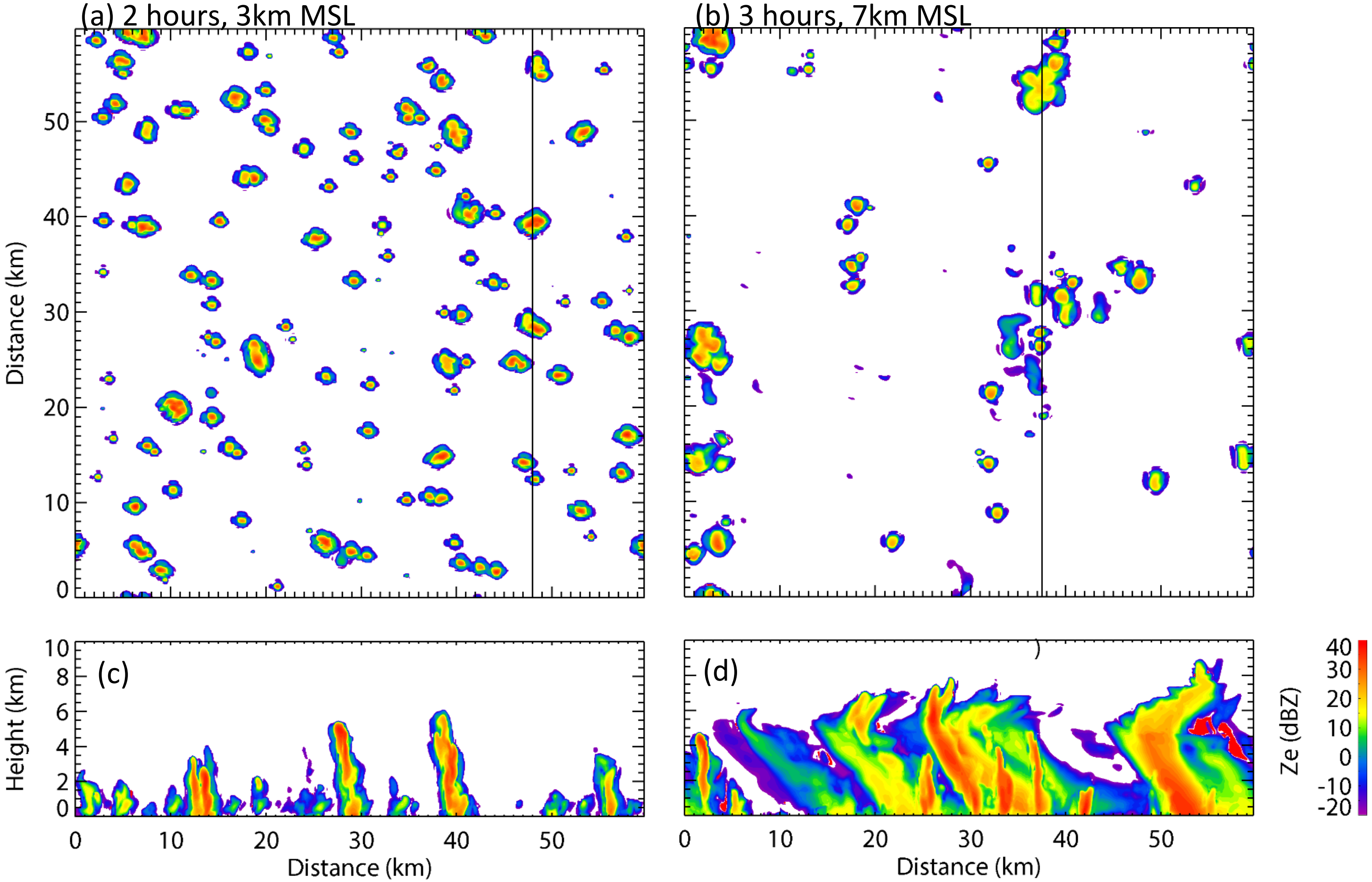
WRF model simulation



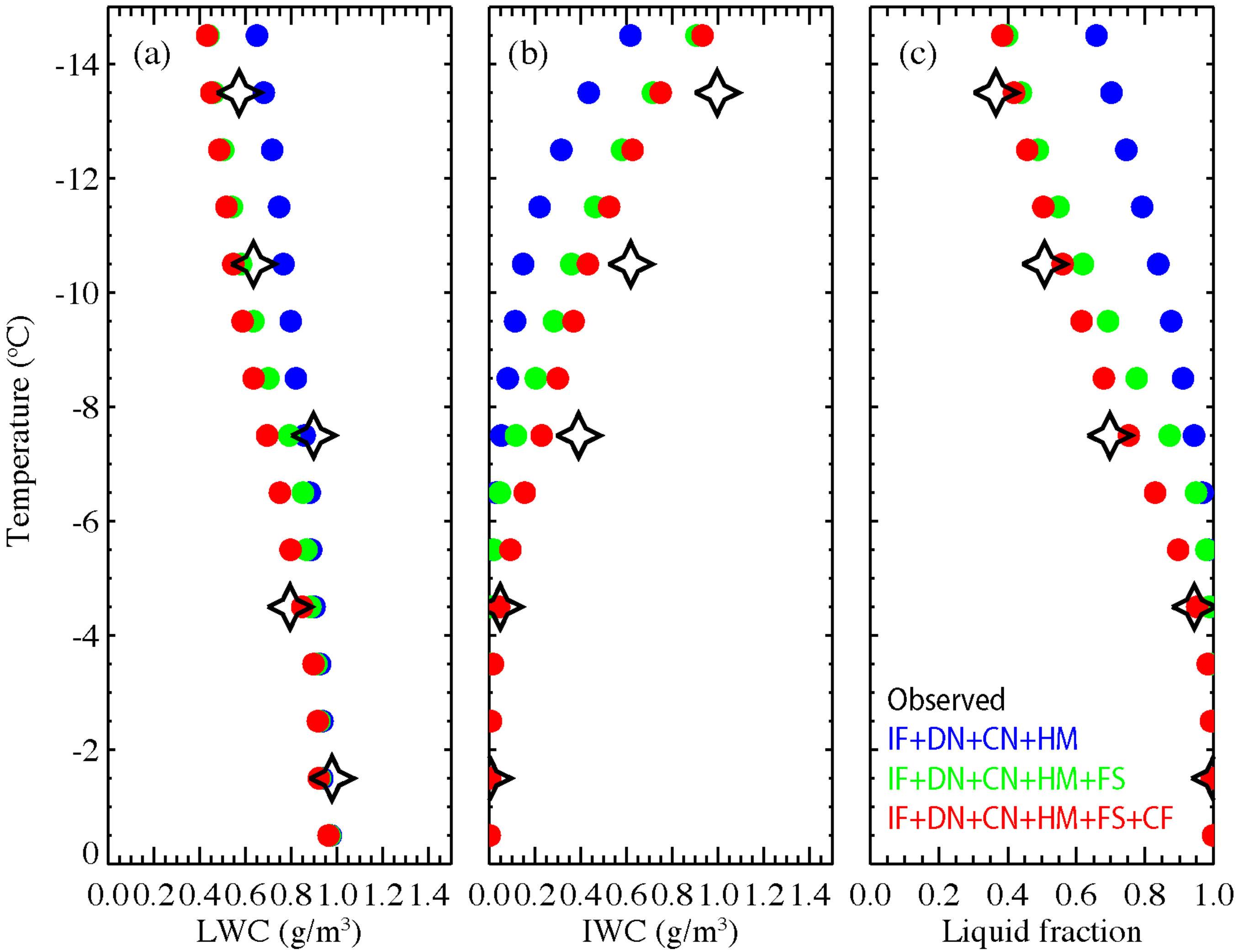
<u>WRF Configuration</u>

1. Idealized large eddy permitting simulation;
2. 1 domain: 60km x 60km x 30km;
3. Resolution: 150m x 150m, 250 vertical levels;
4. Using sounding measurement as input;
5. Weak temperature perturbation is applied for the lowest 30 levels at the beginning of simulation;
6. SBM microphysics; RRTMG radiation; Noah MP land surface; MM5 Monin-Obukhov surface layer.

Examples of modelled clouds



Comparison of modelled and observed LWC, IWC and liquid fraction



Conclusion

- Models with IM, DN, CN and HM ice generation mechanisms underestimates the IWC, and overestimates liquid fraction in developing convective clouds.

- With FS and CF included, the modelled results are more consistent with observation, suggesting these two ice generation mechanisms maybe important in turbulent convective clouds.

- Improving ice generation mechanisms is critical to reduce the uncertainty in simulation of convective cloud.