Ongoing Analysis Regarding the Hallett-Mossop Process in ICE-T Clouds

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ICE-T Workshop

Oct 17 2013

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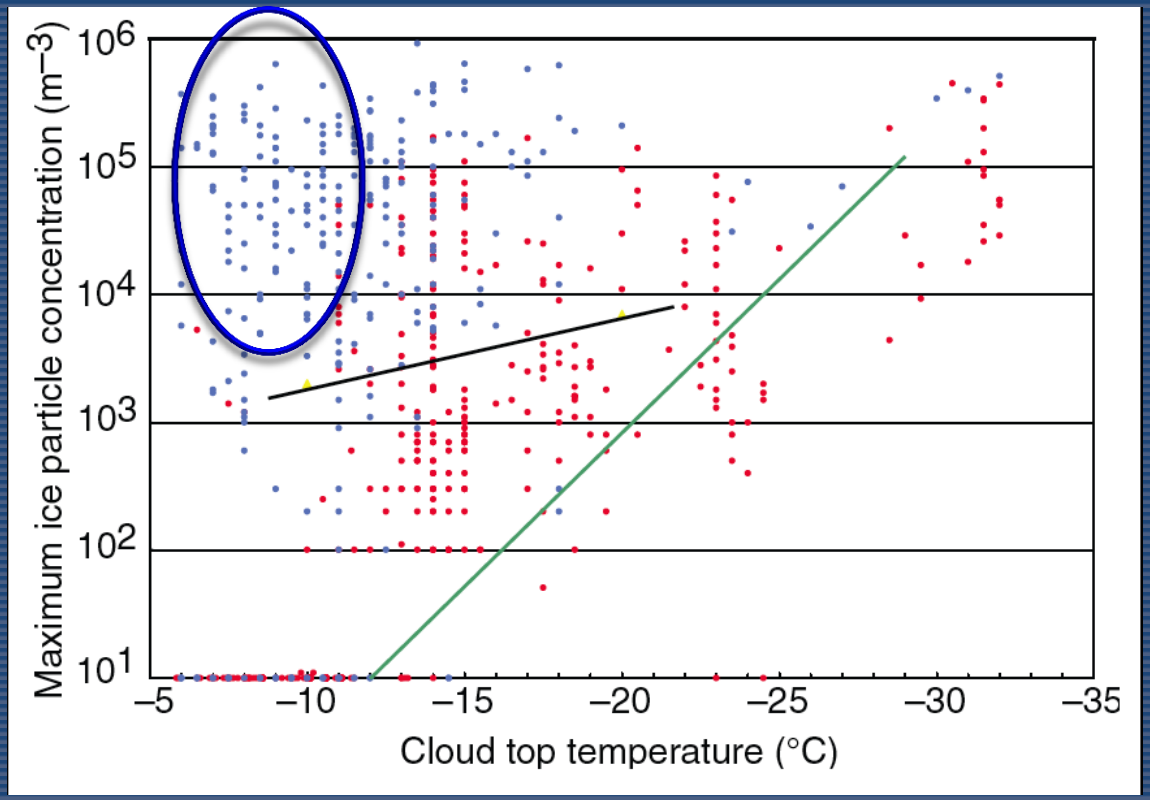
PURDUE CLOUD MICROPHYSICS

How Many Graupel get the HM Process started in Tropical Maritime Clouds?

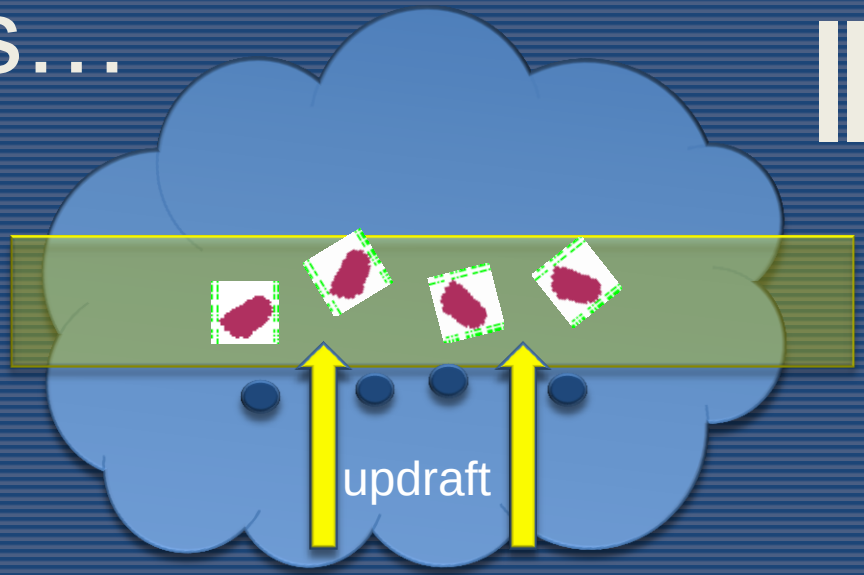
- Can Hallet-Mossop process explain these high ice concentrations at high temperatures in maritime clouds?
- How many graupel particles (and thus ice nuclei) are needed to get it started?
  - Need graupel
  - Supercooled droplets ≥ 25 μm
  - Only occurs in zone with temp -3 to -9 °C



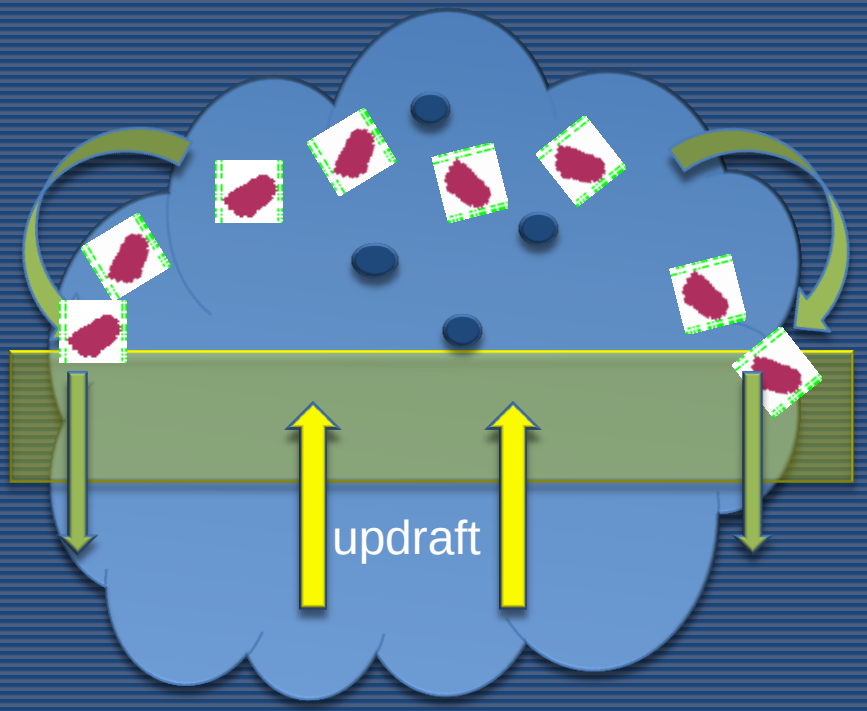
from Wallace & Hobbs (2006)

Working Hypothesis…

- A strong warm rain process produces big raindrops capable of freezing during ASCENT INTO H-M temperature zone.



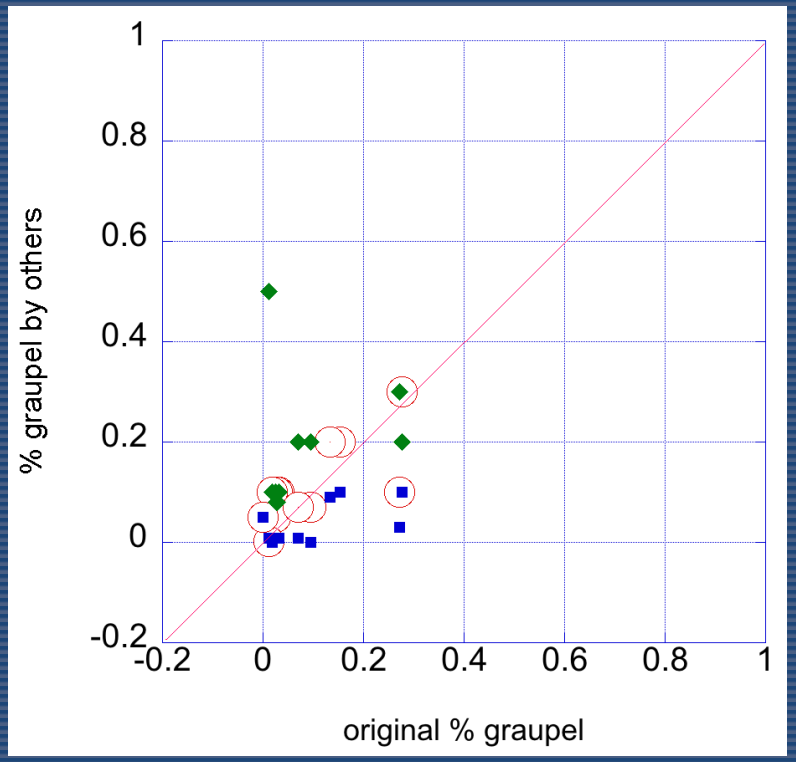
- Clouds with a weaker/slower warm rain process must wait to start H-M until bigger graupel particles (from frozen raindrops, or rimed particles) FALL INTO H-M zone

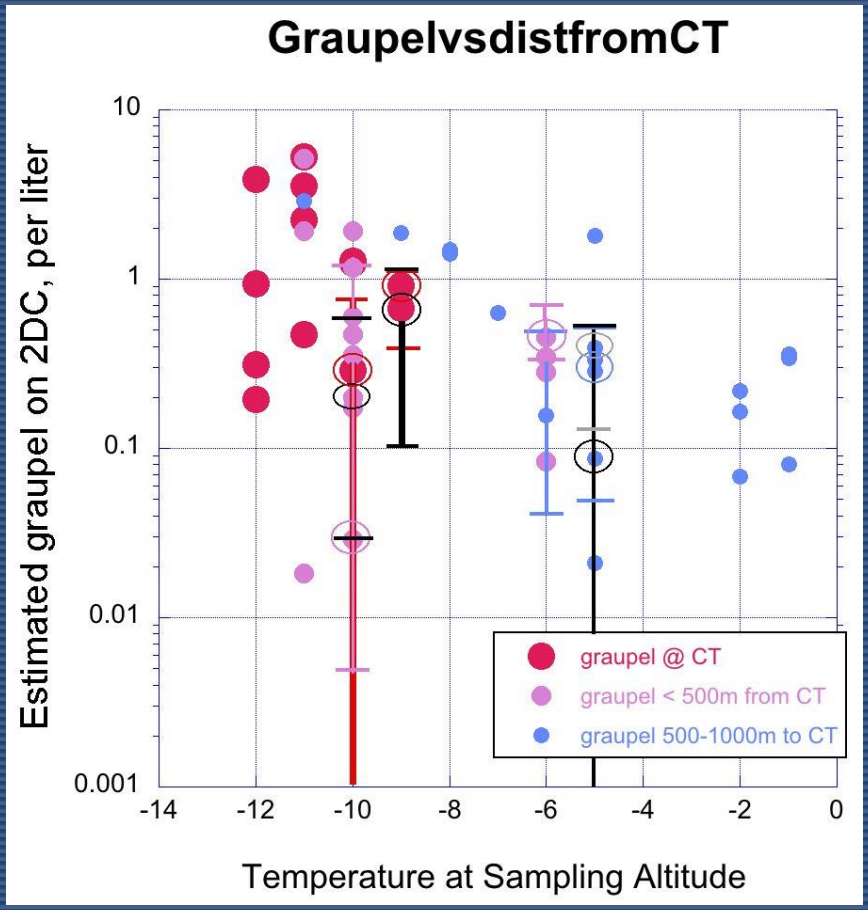


Being very careful…

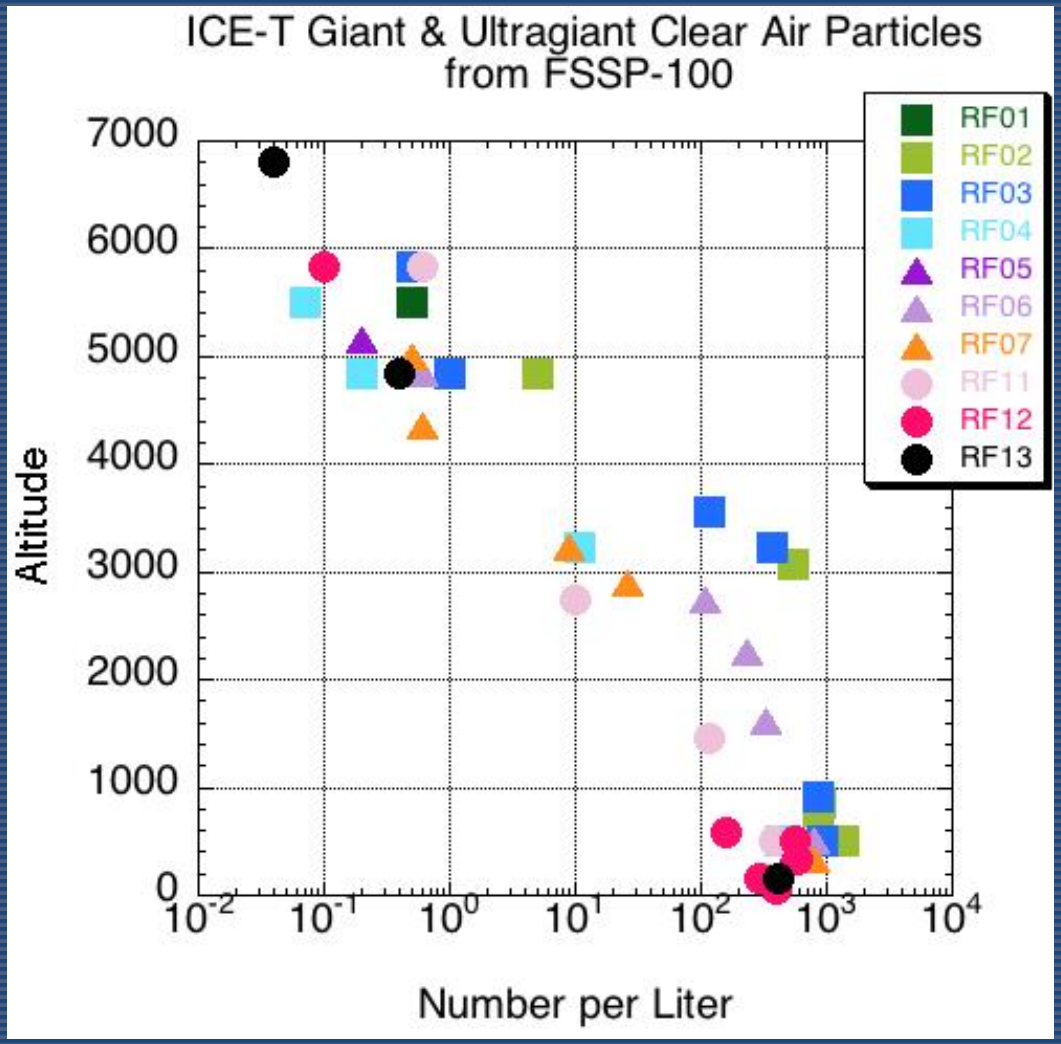
- First aircraft passes through the clouds near cloud tops, when we have radar data to assess cloud top, vertical velocity structure…
- Isolated clouds
- Manual counting of graupel and columns from 2DC images and comparison with CPI data (when available),2D-S, SID-2H, LDR from Wyoming Cloud Radar

Counting Graupel Particles from 2DC images





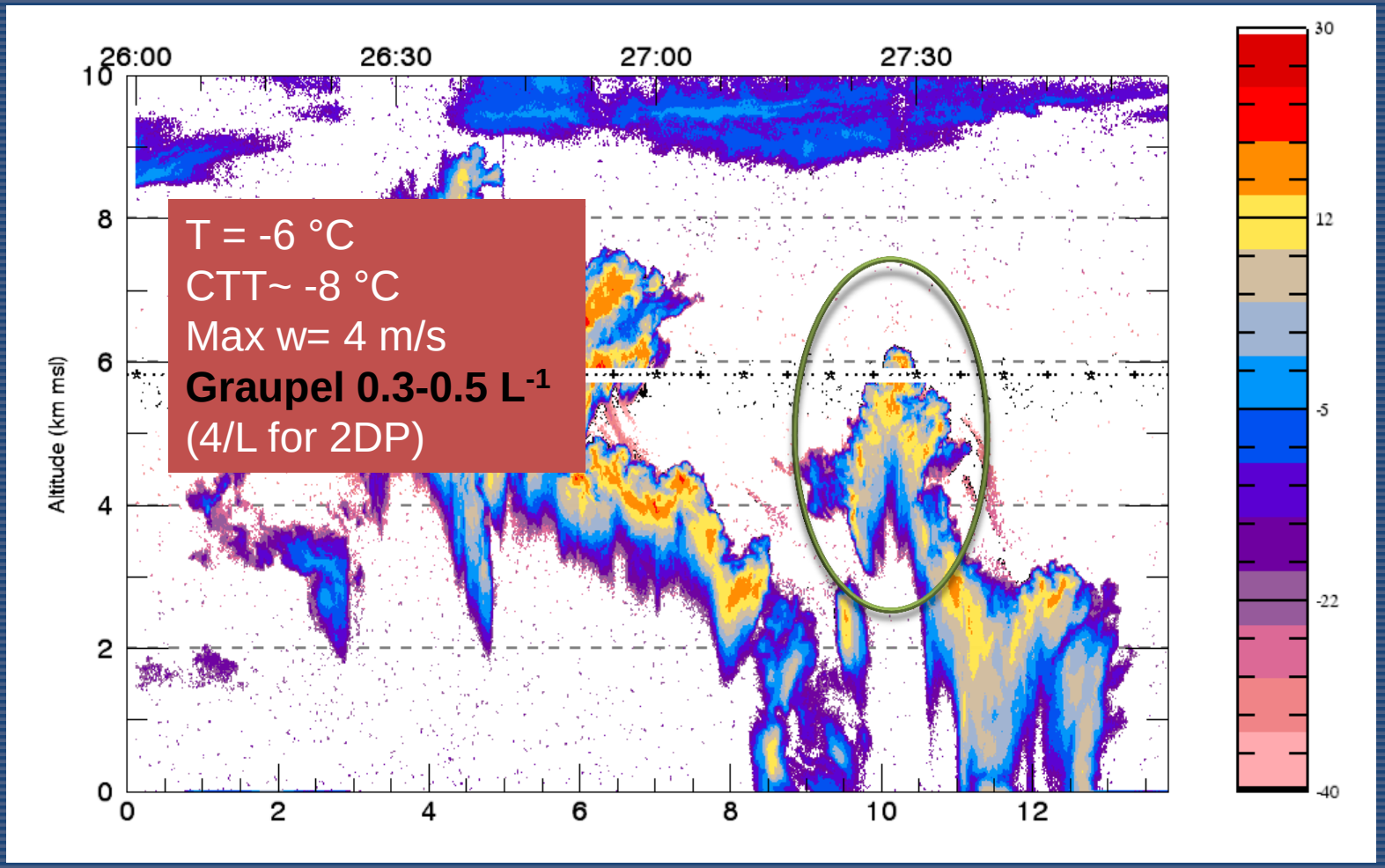
Giant Aerosol ??



Is some subset of these particles initiating ice at high T, ~ 0.1/L at -5 C?

Note some of these particles could be evaporating cloud drops…

Graupel Entering HM Zone from Below

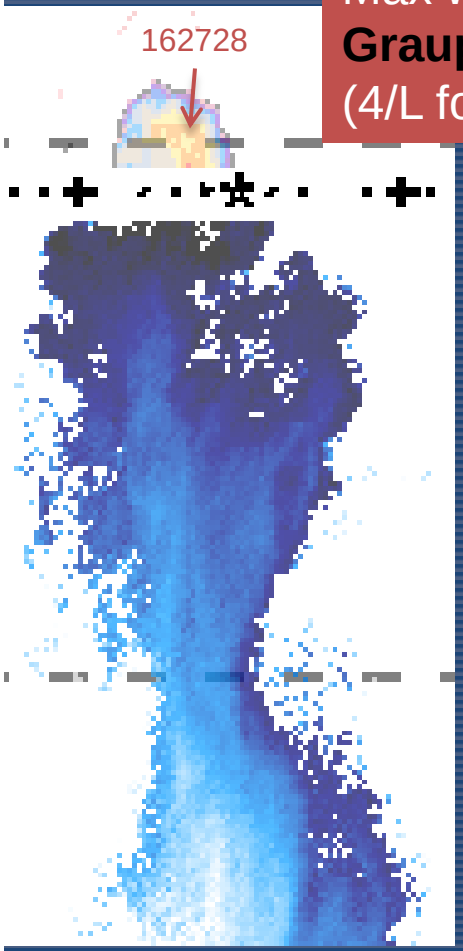


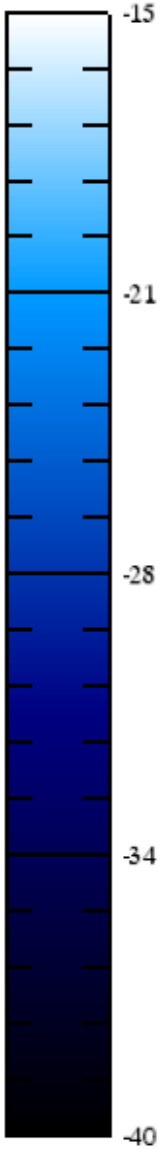
RF13, July 30

Graupel Entering HM Zone from Below*

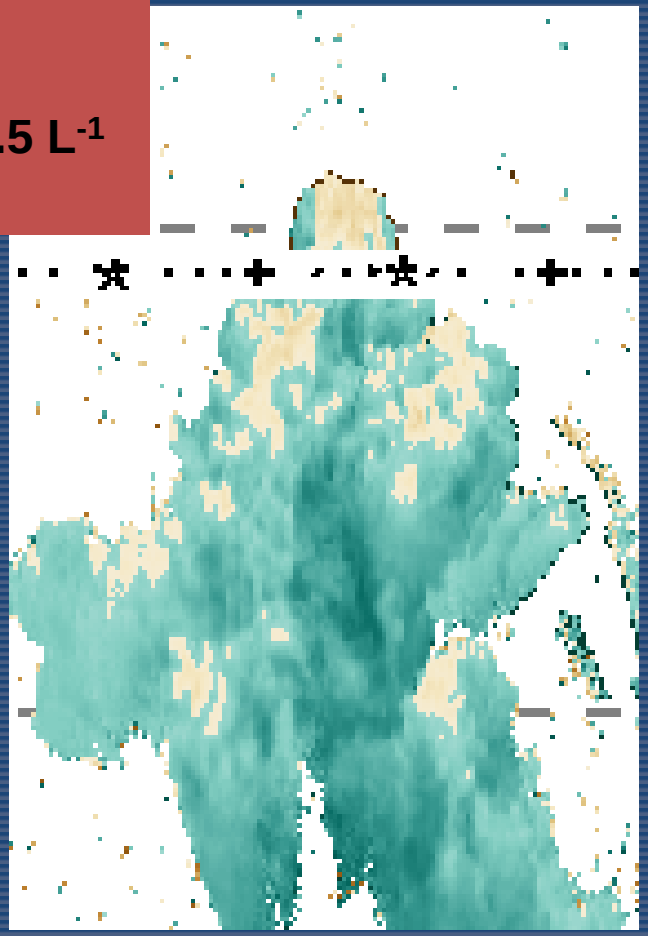
T = -6 °C
CTT~ -8 °C
Max w= 4 m/s
Graupel 0.3-0.5 L^{-1}
(4/L for 2DP)

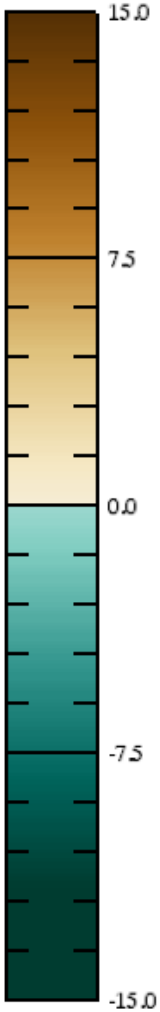
LDR

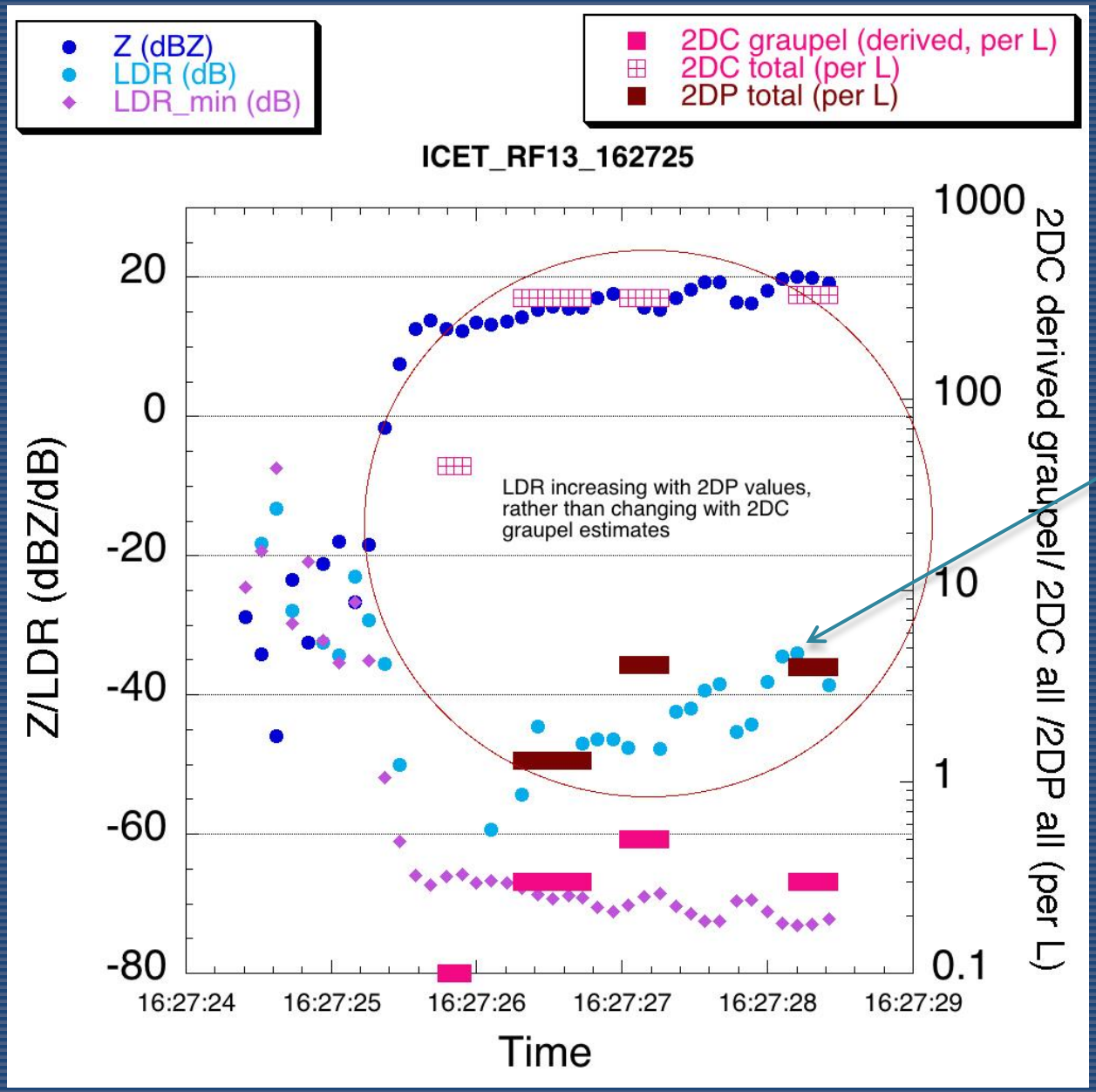




Vertical velocity







LDR of -19 dB would imply most 2DP particles are frozen.

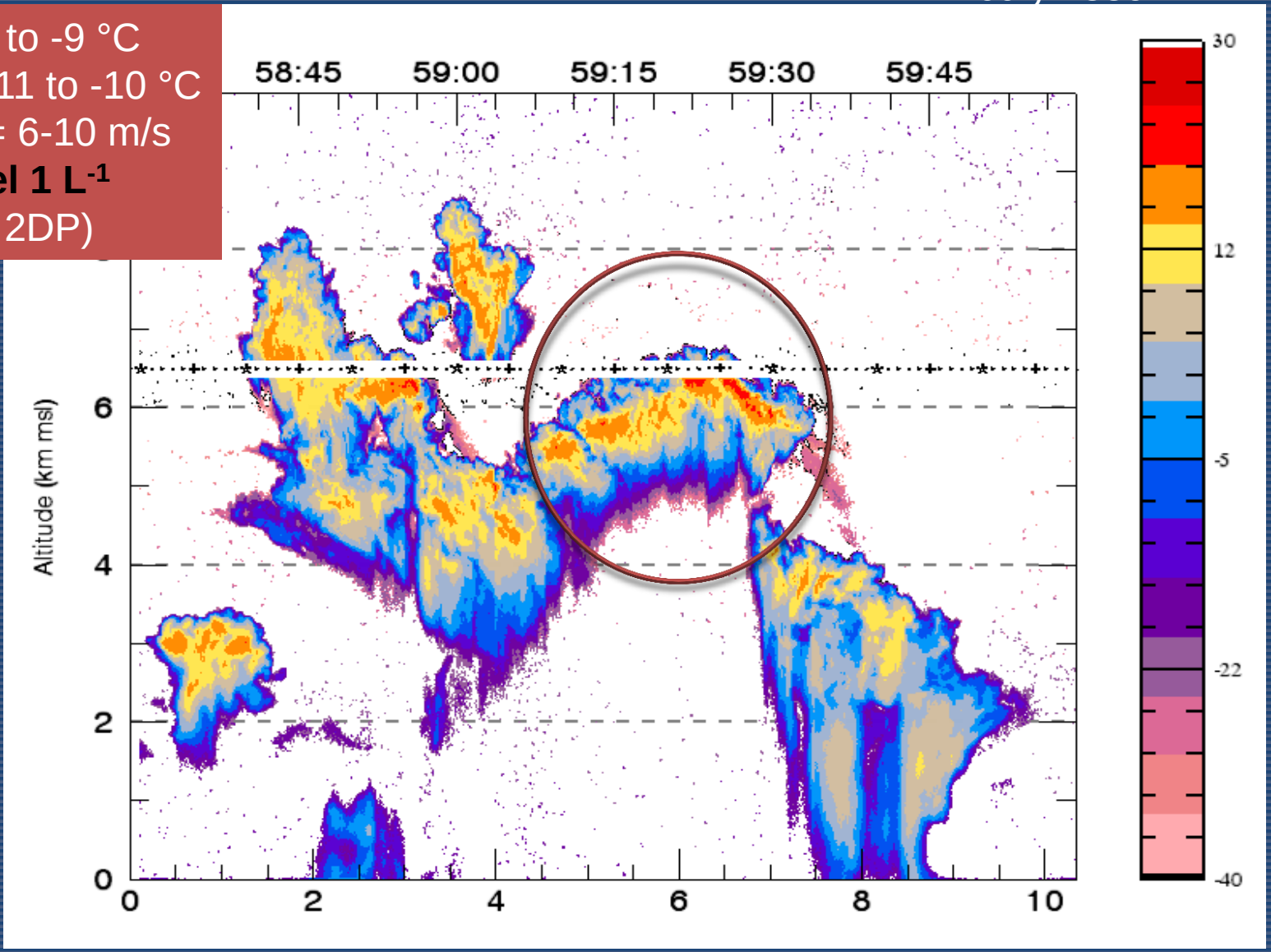
Given LDR ~ -35 dB, implies ~ 2.5% of dBZ (<0.4/L) of these are frozen.

So total frozen on 2DC & 2DP < 0.8 /L.

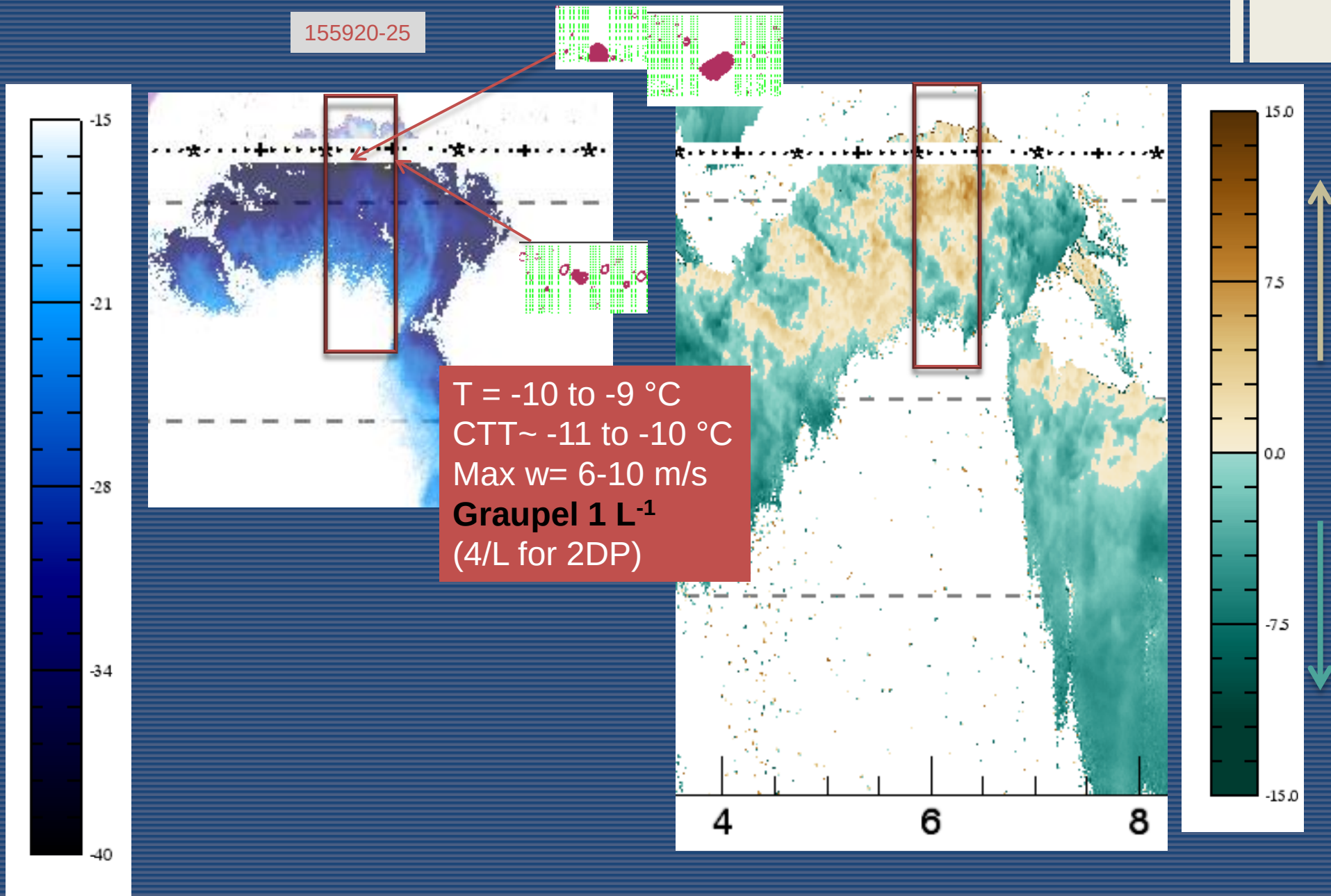
After Ascent through HM Zone

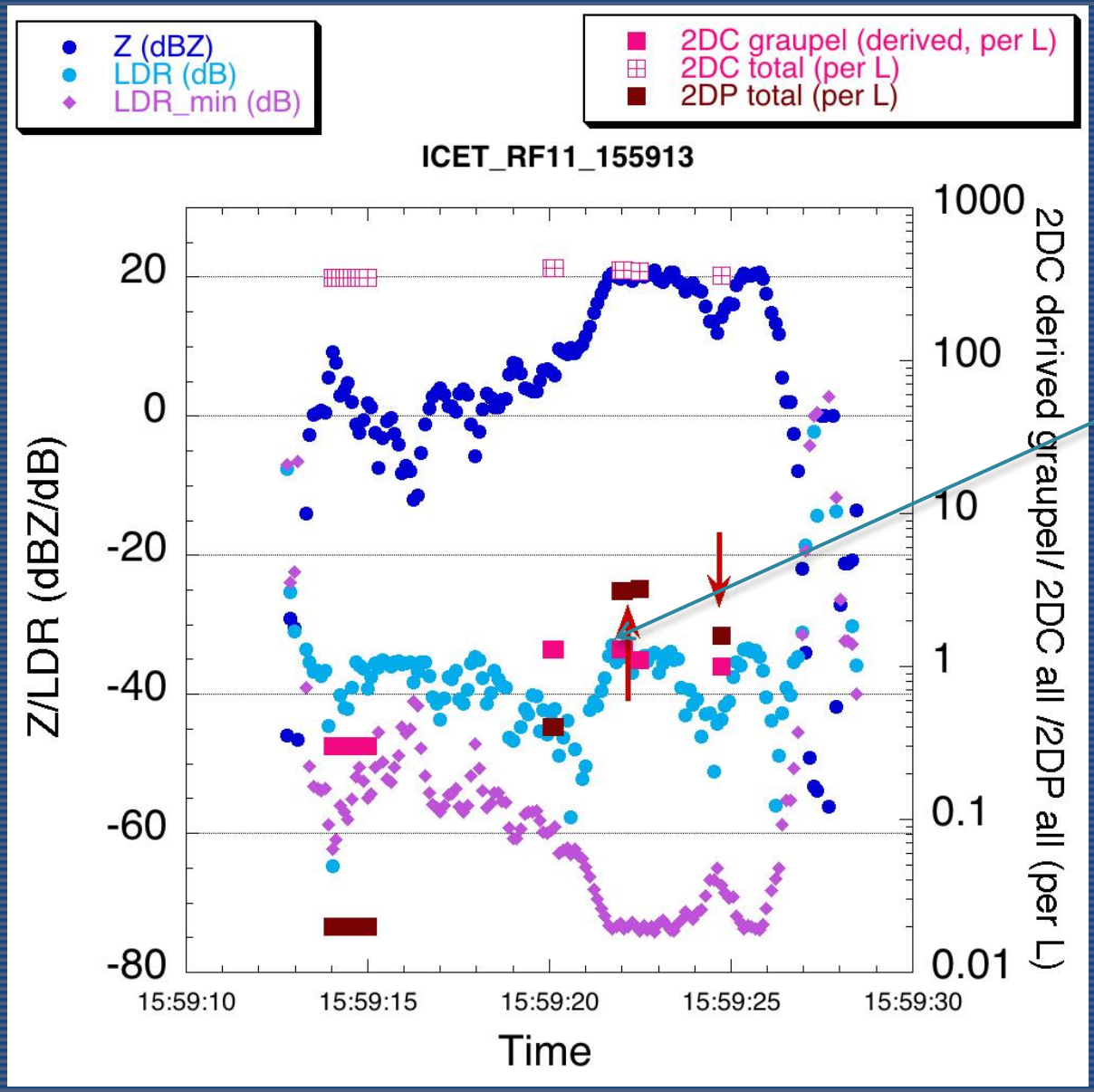
RF11- 27 July 1559+

T = -10 to -9 °C
CTT~ -11 to -10 °C
Max w= 6-10 m/s
Graupel 1 L^{-1}
(4/L for 2DP)



After Ascent through HM Zone





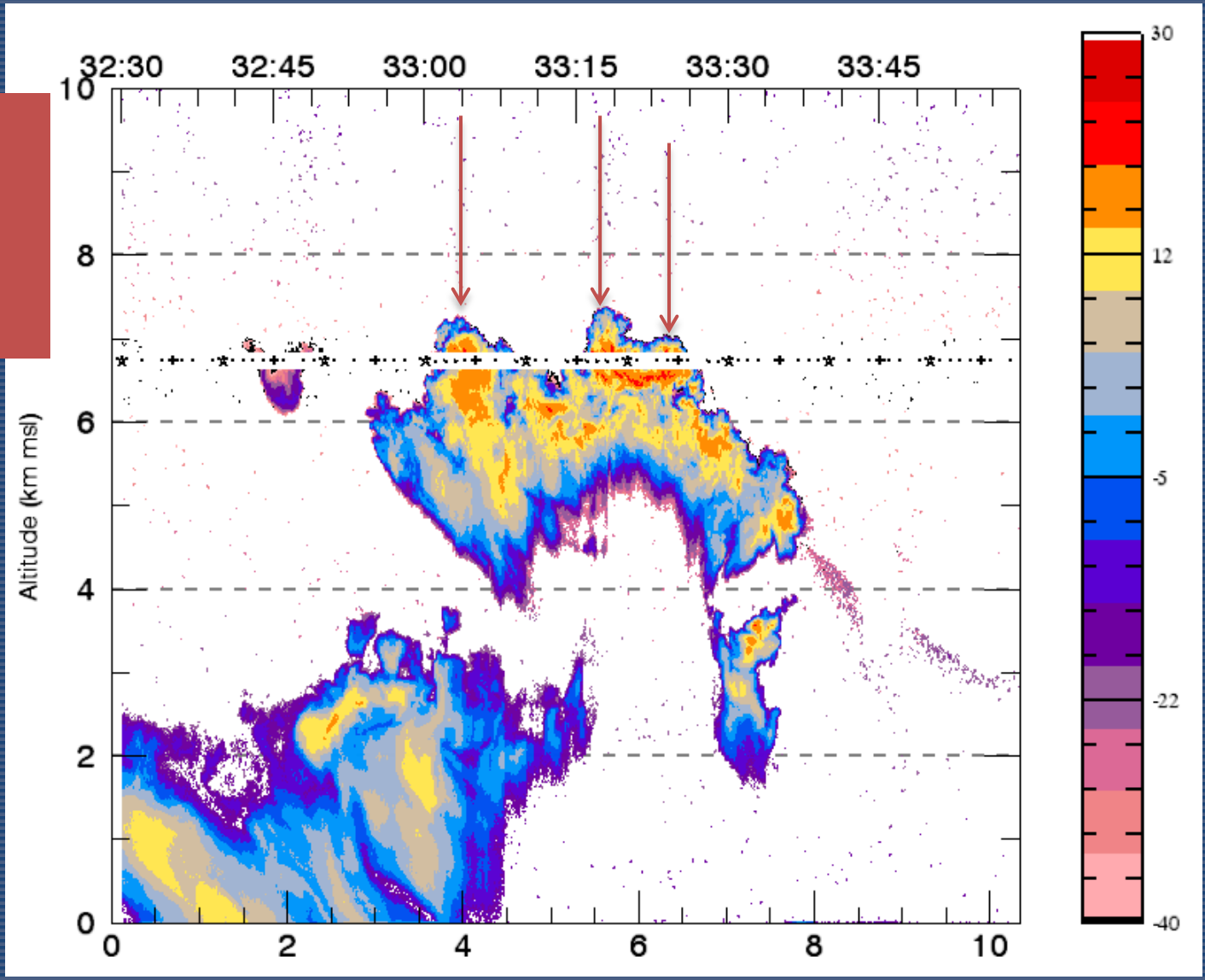
LDR of -19 dB would imply most 2DP particles are frozen.

Given LDR ~ -33 dB, implies ~ 4% of dBZ (< 0.15/L) of these are frozen.

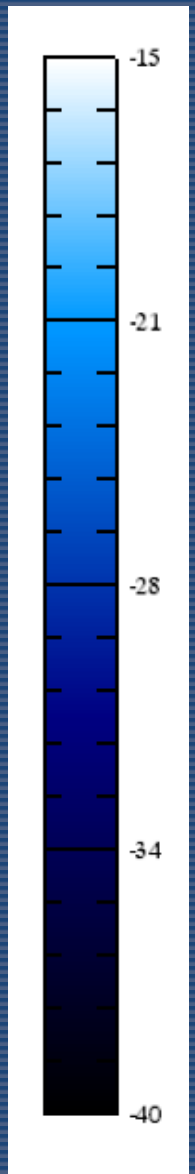
So total frozen on 2DC & 2DP < 1.2 /L.

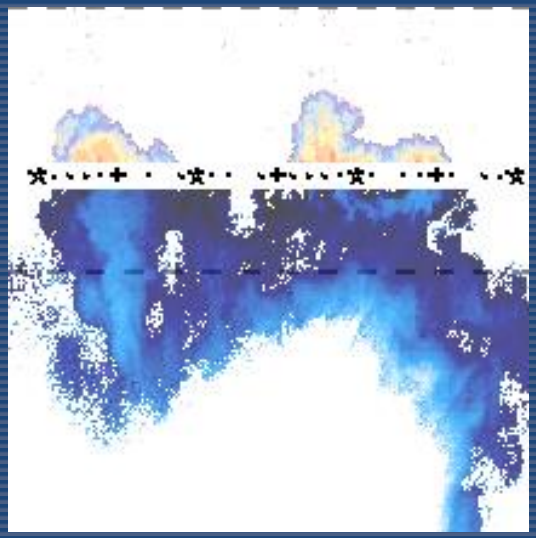
Higher Above H-M Zone: RF12 183301-27

T = -11 to -10 °C
CTT~ -13°C
Max w= 7 m/s
Graupel 2-5 L^{-1}
(4/L on 2DP)

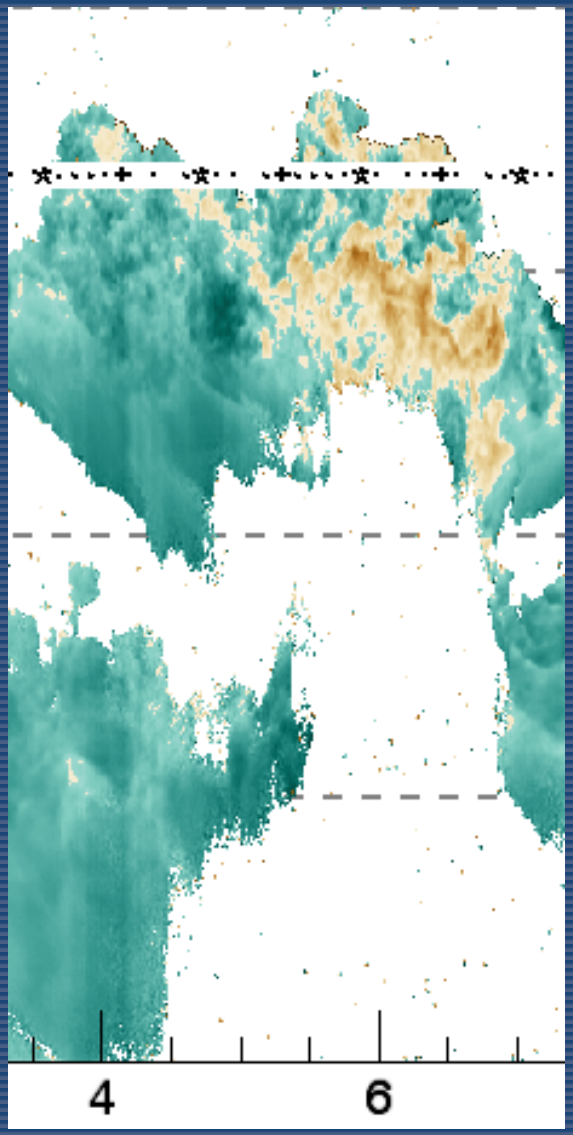


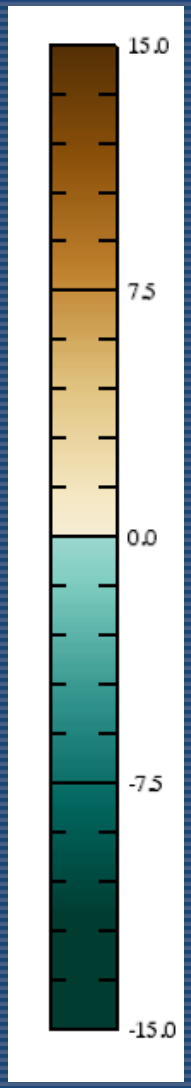
Higher Above H-M Zone

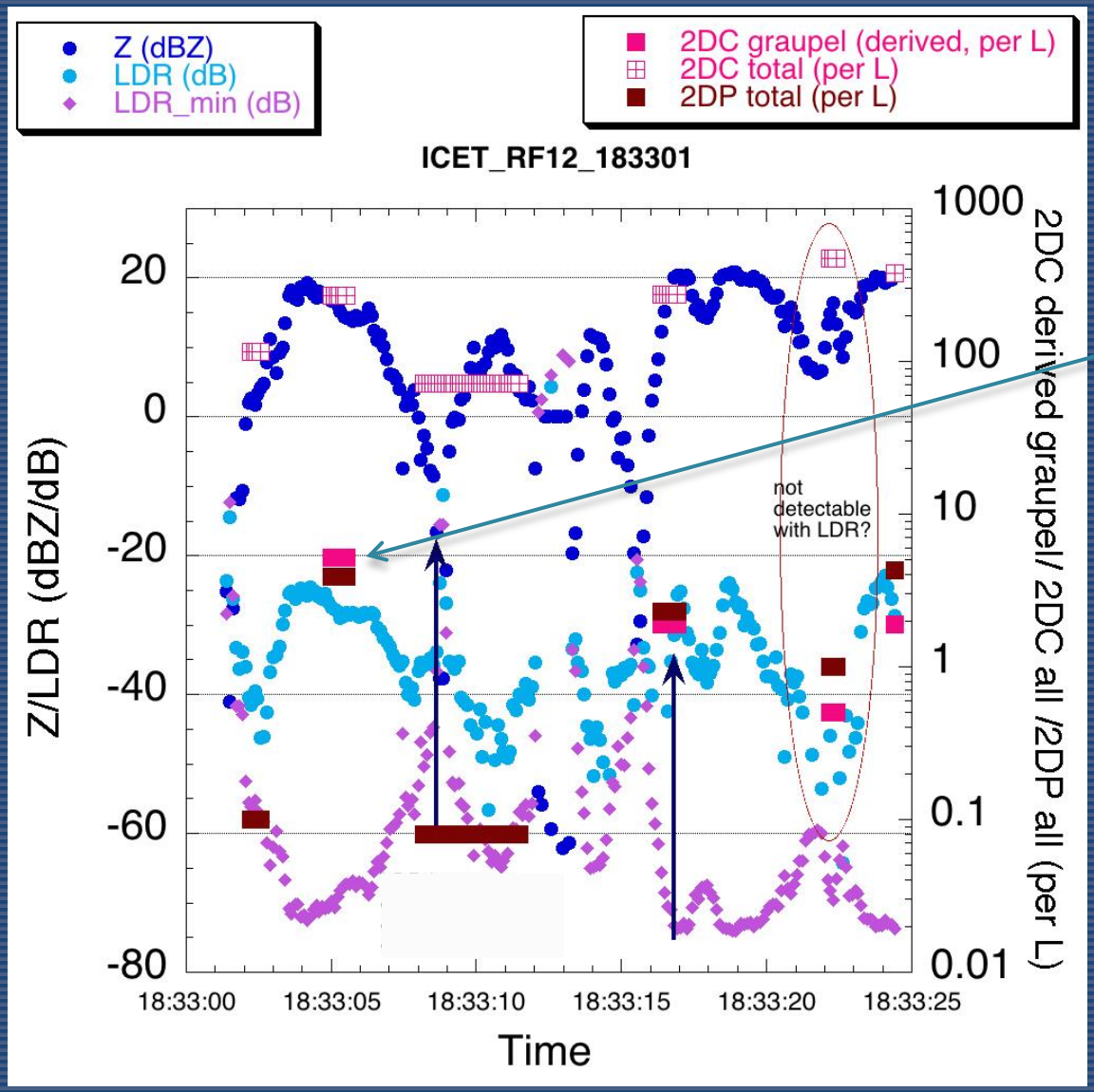




T = -11 to -10 °C
CTT~ -13°C
Max w= 7 m/s
Graupel 2-5 L^{-1}
(4/L on 2DP)





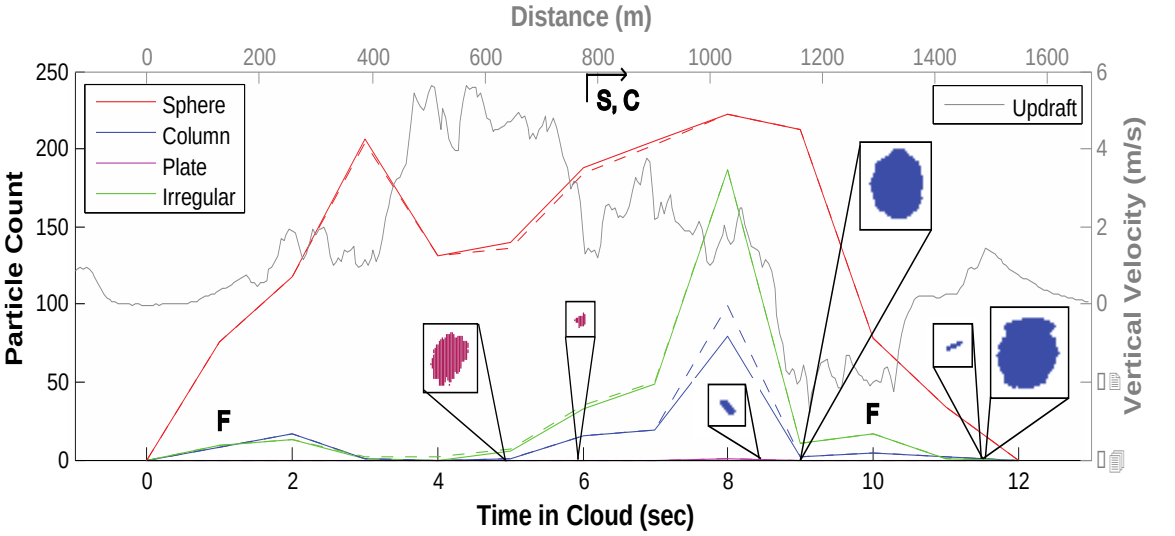


LDR of -19 dB would imply most 2DP particles are frozen.

Given LDR ~ -25 dB, implies ~ 26% of dBZ (< 1/L) of these are frozen.

So total frozen on 2DC & 2DP < 6 /L.

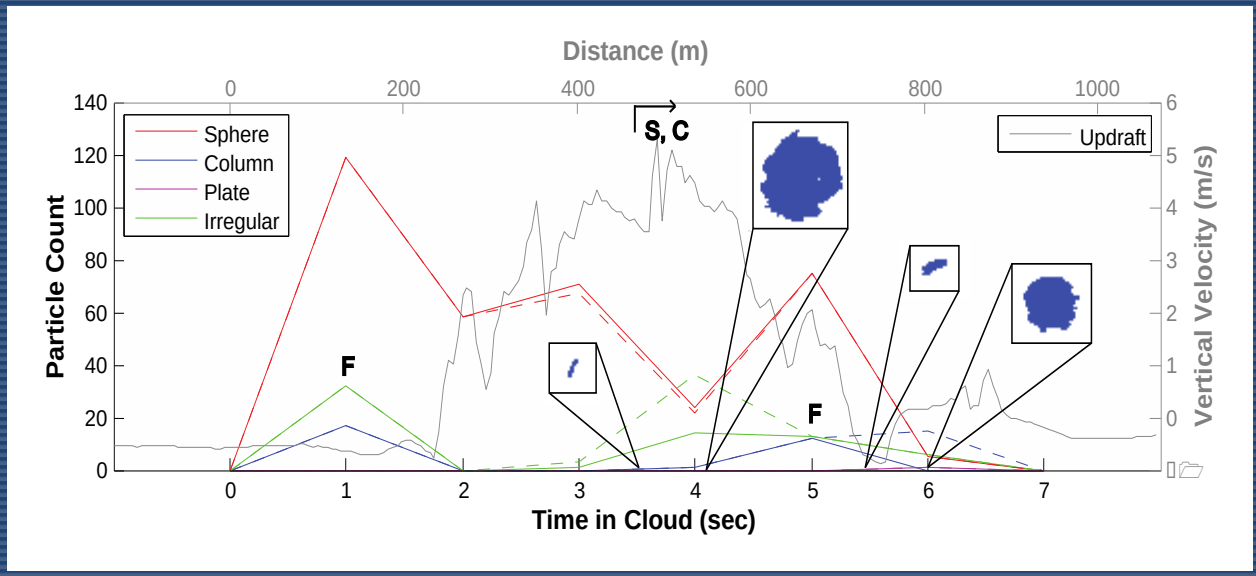
What Does SID-2H See?



12 July 2011, starting at 181843 UTC
T= -6/-7C

from Johnson et al., in revision for J. Tech.

30 July 2011, starting at 162725 UTC
T= -5/-6C



Observational Summary

- We've found graupel ascending near cloud top at temperatures as warm as -5, on the order of 0.1 L-1.

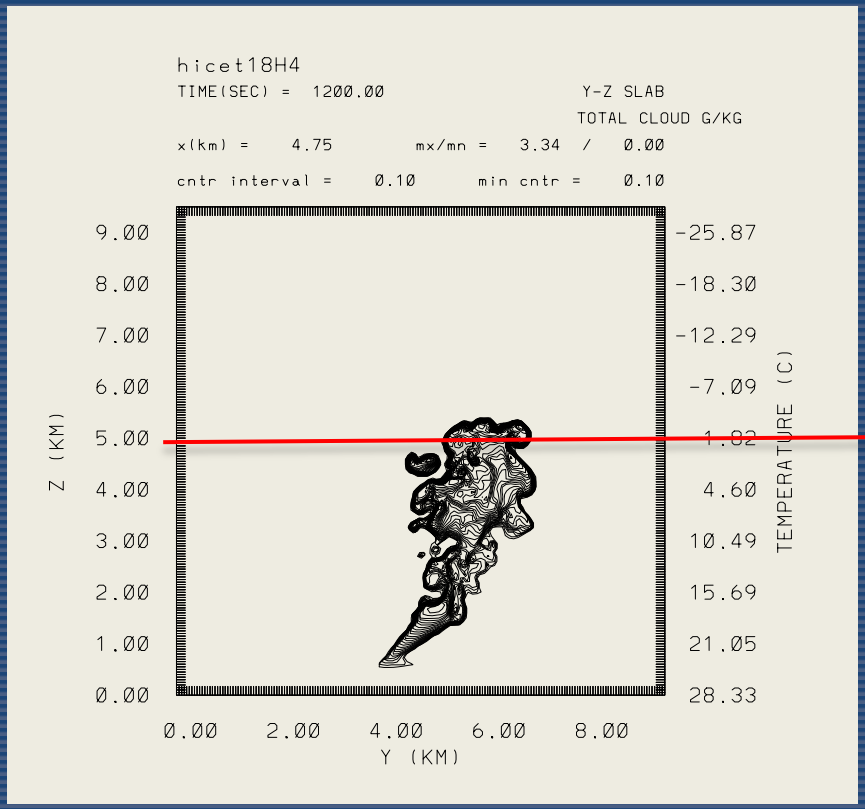
- For colder cloud tops at -10C, we have found on the order of 1 L-1.

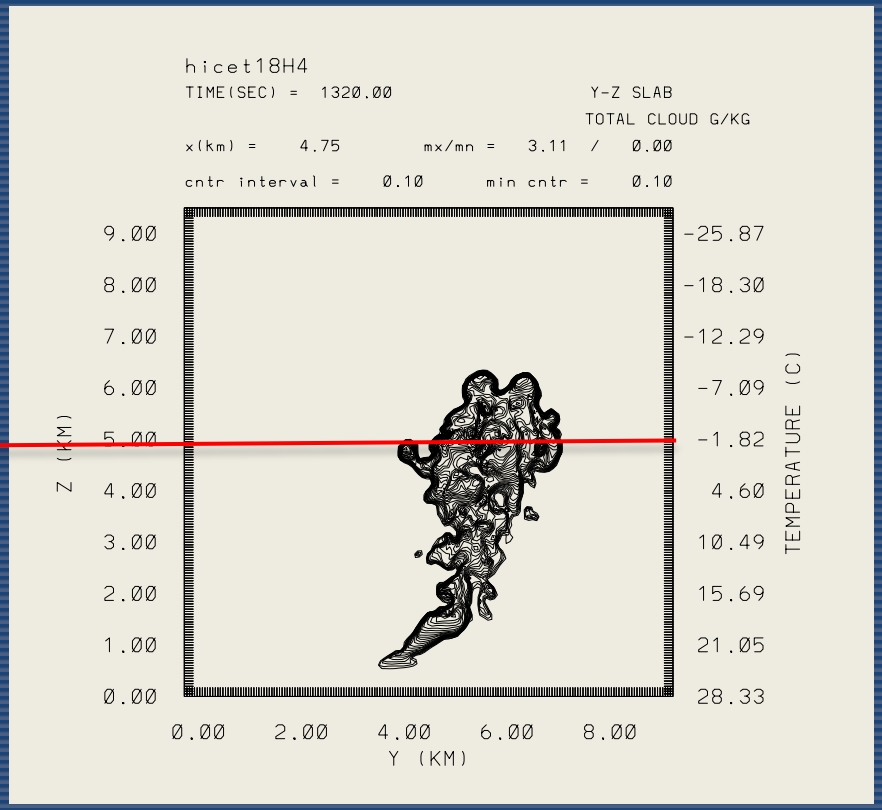
QUESTIONS: Is this the H-M process producing this increase in graupel, or primary nucleation?

How important is the WRP to getting the HM process started (ascent vs descent)?

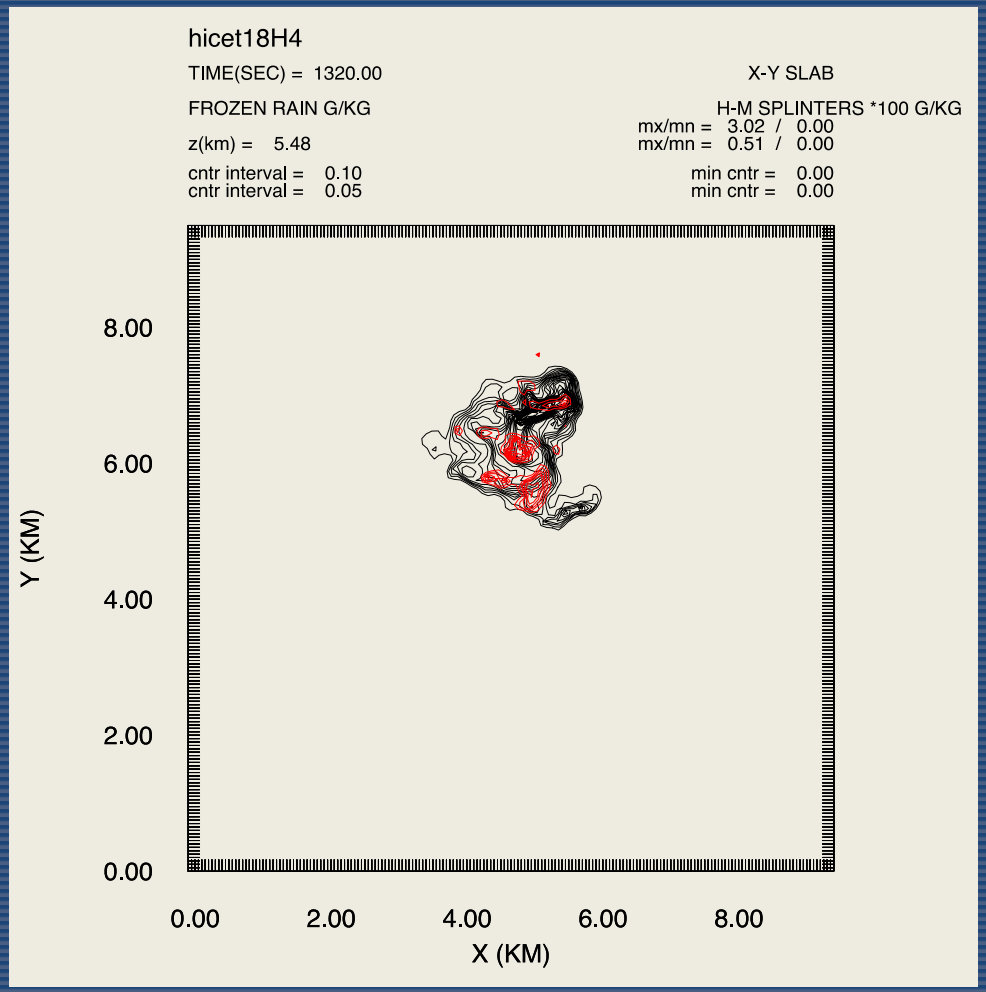
How few graupel are needed?

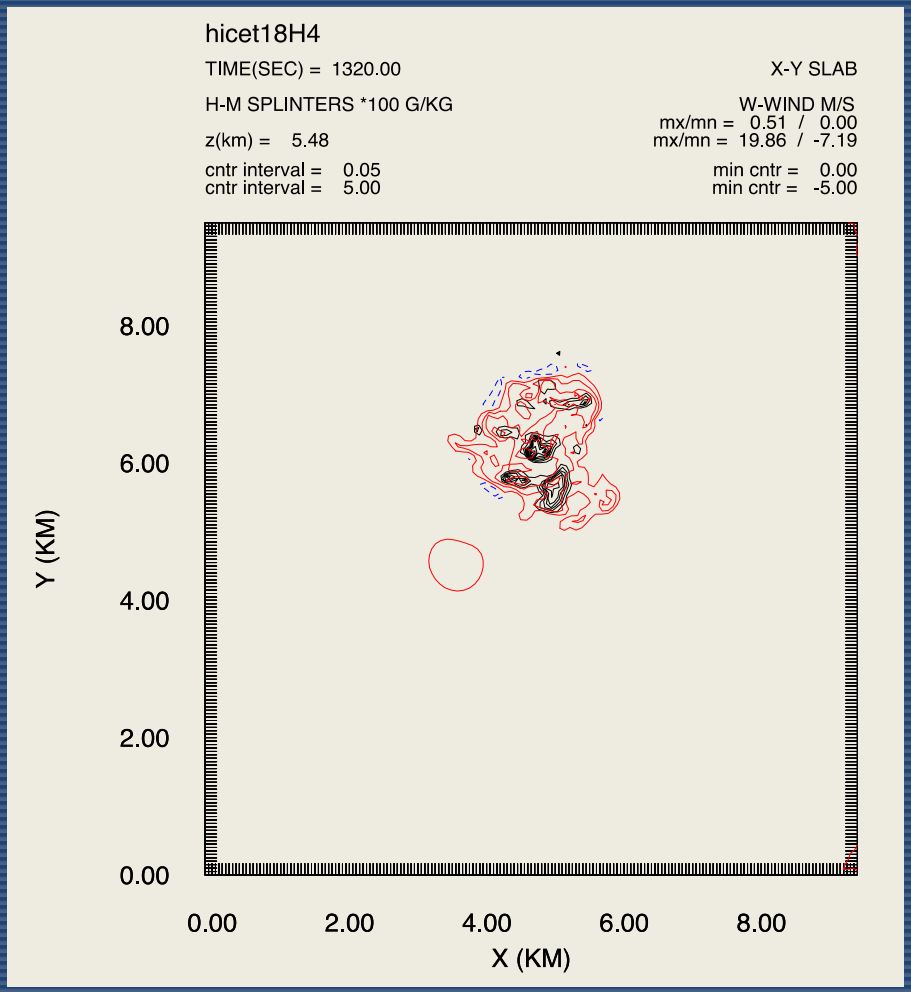
Numerical Modeling



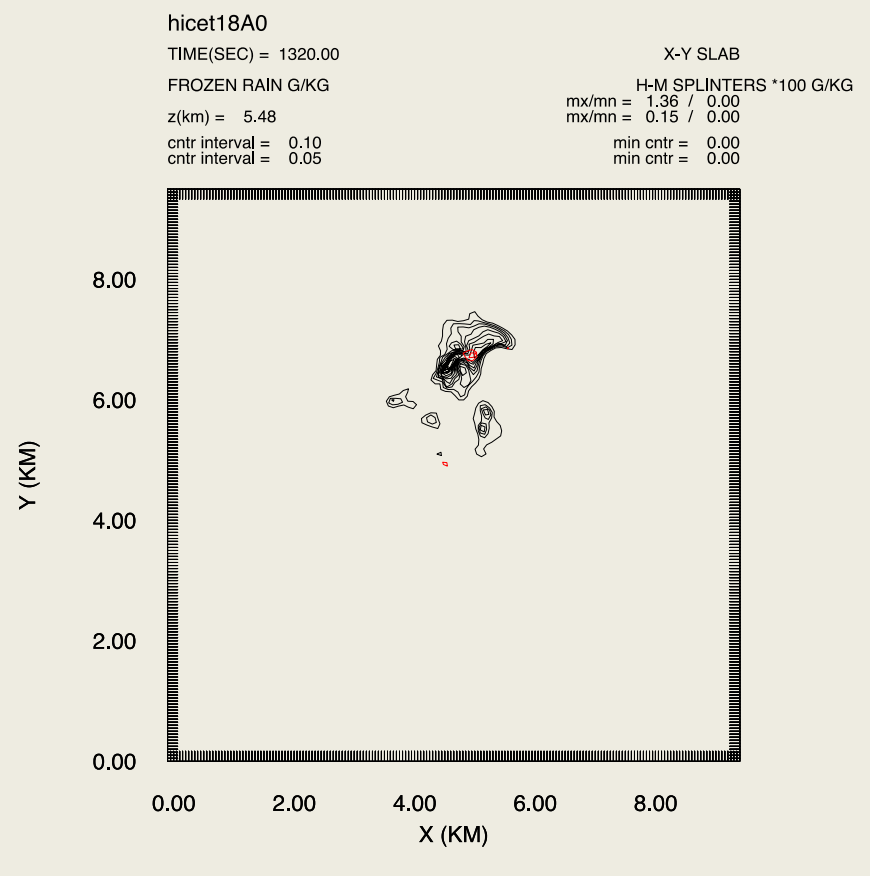


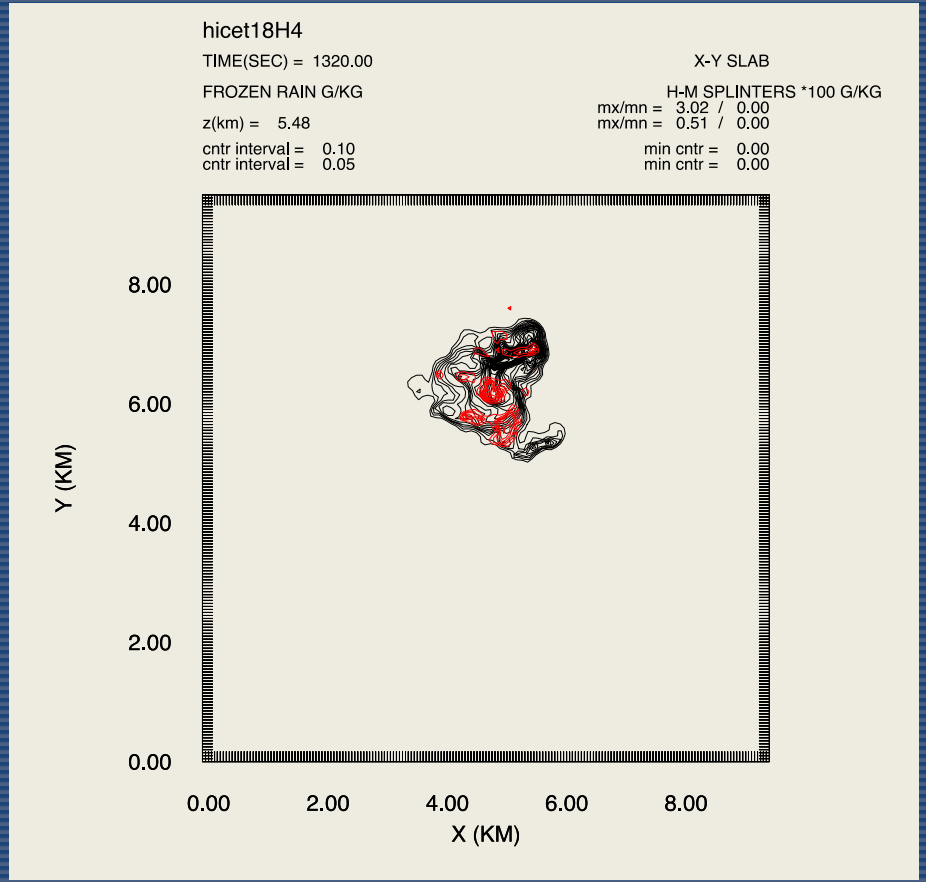
Hallet-Mossop Splinters



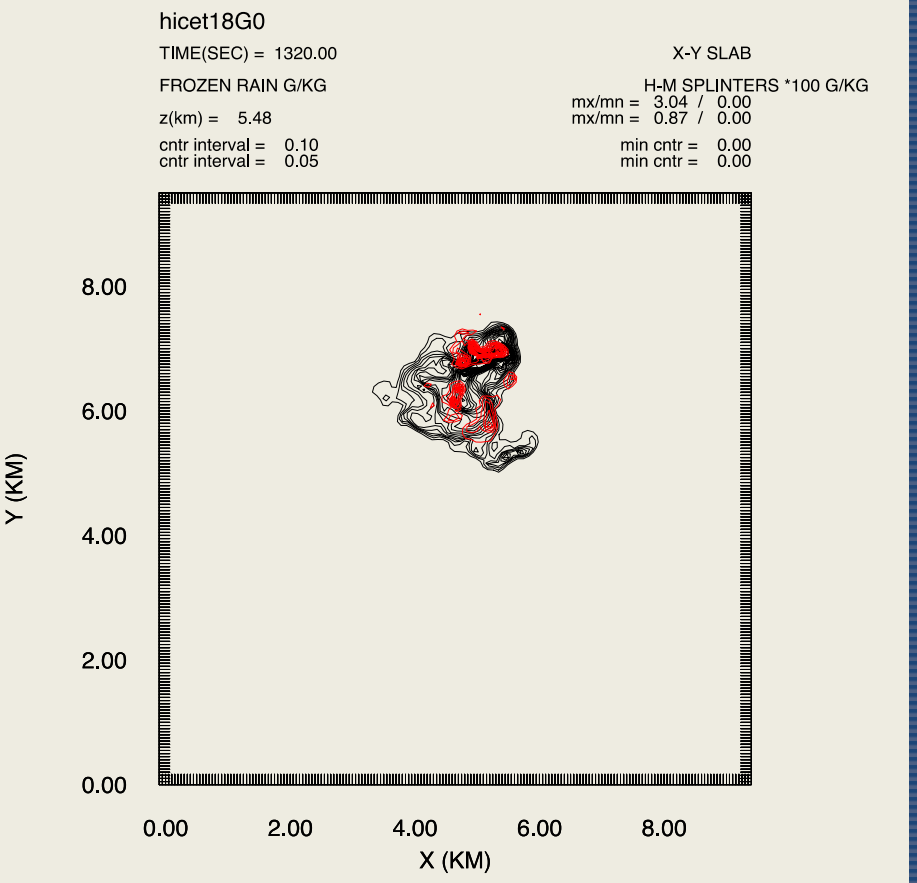


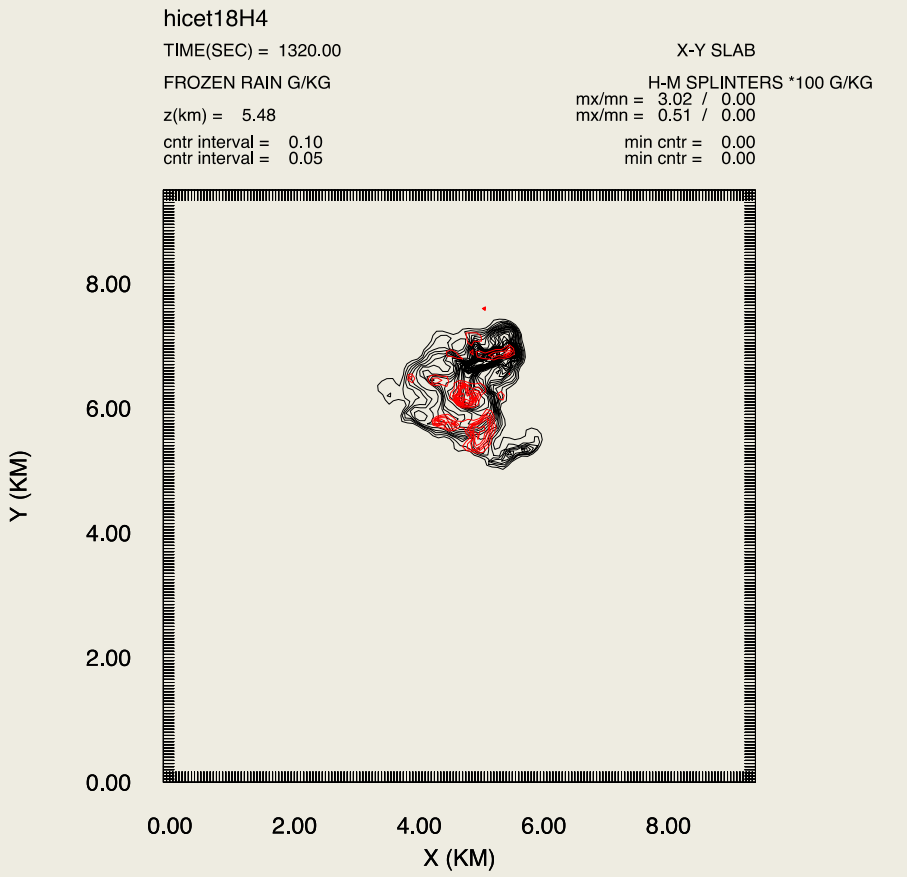
If I slow down the Warm Rain Process…





If I decrease the amount of IN acting for T > -10C





What Holes Can be Filled in Here with Aerosol/IN Data?

- Can we identify what might be acting as IN at very high T, on the order of 0.1/L (or maybe fewer)?

Proposed Papers

- Leon et al. Importance of Warm Rain Process to Ice Formation in ICE-T Clouds Part I: Observations
- Lasher-Trapp et al. Part II: Modeling
- Lasher-Trapp et al. First Graupel in Tropical Maritime Cumuli
- Johnson, A., S. Lasher-Trapp, A. Bansemer, Z. Ulanowski and A. J. Heymsfield, 2013: Detection and Quantification of Ice with the Small Ice Detector 2 HIAPER (SID-2H). *J. Atmos. Ocean. Tech*., accepted.
- Johnson et al. 2014: Modeling paper