Using ATTREX3 Data to Improve the Representation of TTL Cirrus in CAM5

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CT3LS Meeting

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CAM5 Ice Microphysics

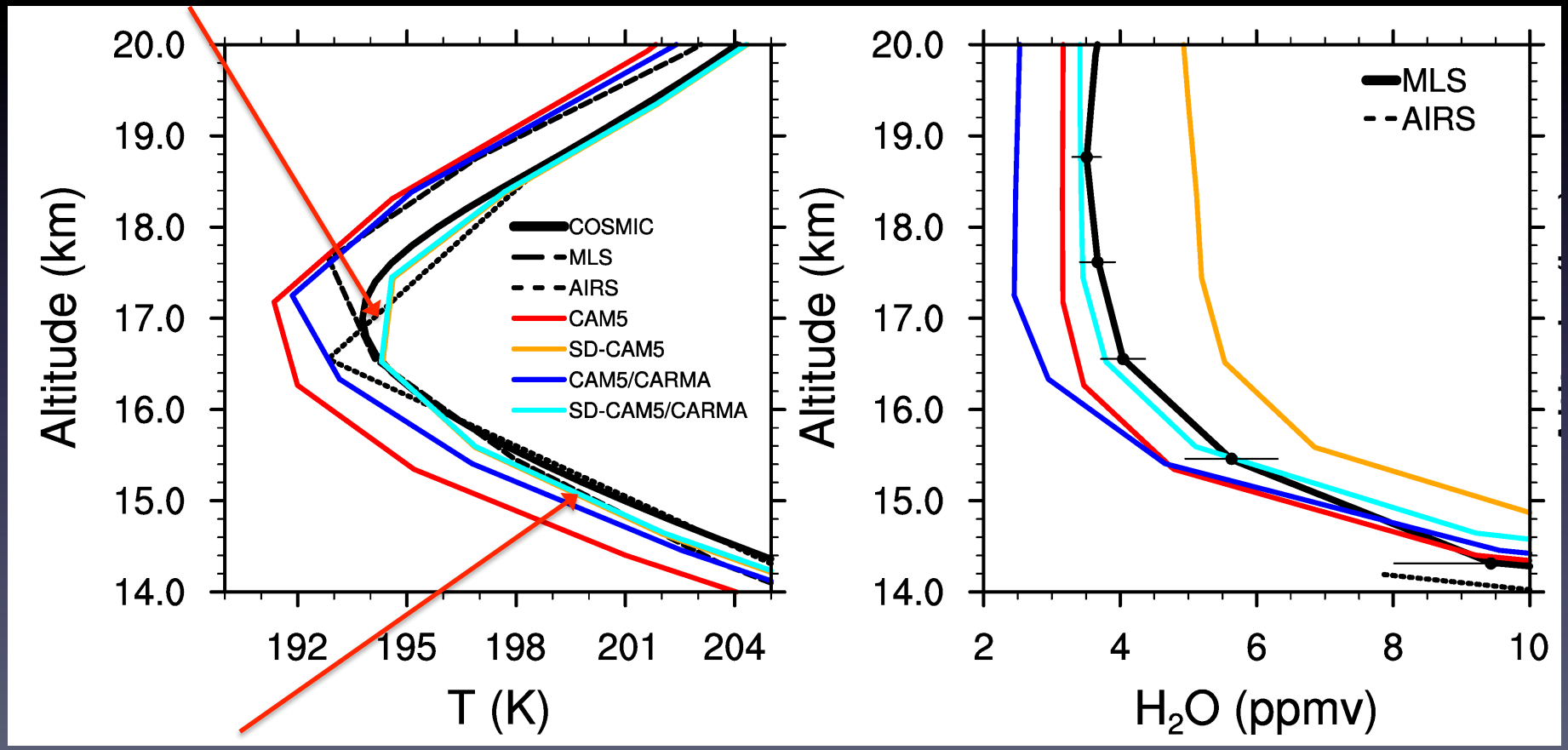
	Morrison-Gettelman (Morrison & Gettelman, 2008)	**CARMA (Bardeen et al., 2013)**
Representation	Two-Moment (mass, number)	Sectional (2x28 bins)
Hydrometeors	Ice, Snow	In Situ, Detrained
Shape	Sphere	Hexagonal Plate, Sphere
Density	0.5, 0.1	0.9, Power Law
Autoconversion	Yes	No
Precipitation	Diagnostic	Prognostic
Subgrid Saturation	No	Yes

Methodology

- Use SD-CAM5 (1.9˚ x 2.5˚, 56 levels)
- Nudge to Assimilated Meteorology (GEOS-5)
- Sample Simulations Along Aircraft Flight Tracks
- Compare Model to ATTREX3 Observations

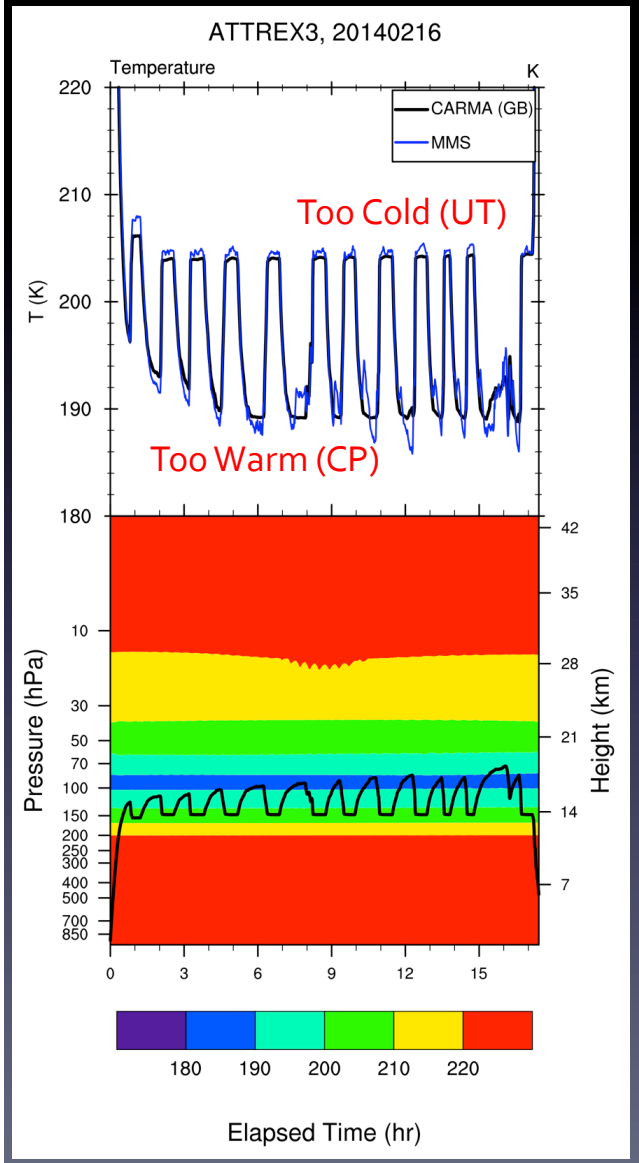
GEOS-5 Tropical Average T Bias

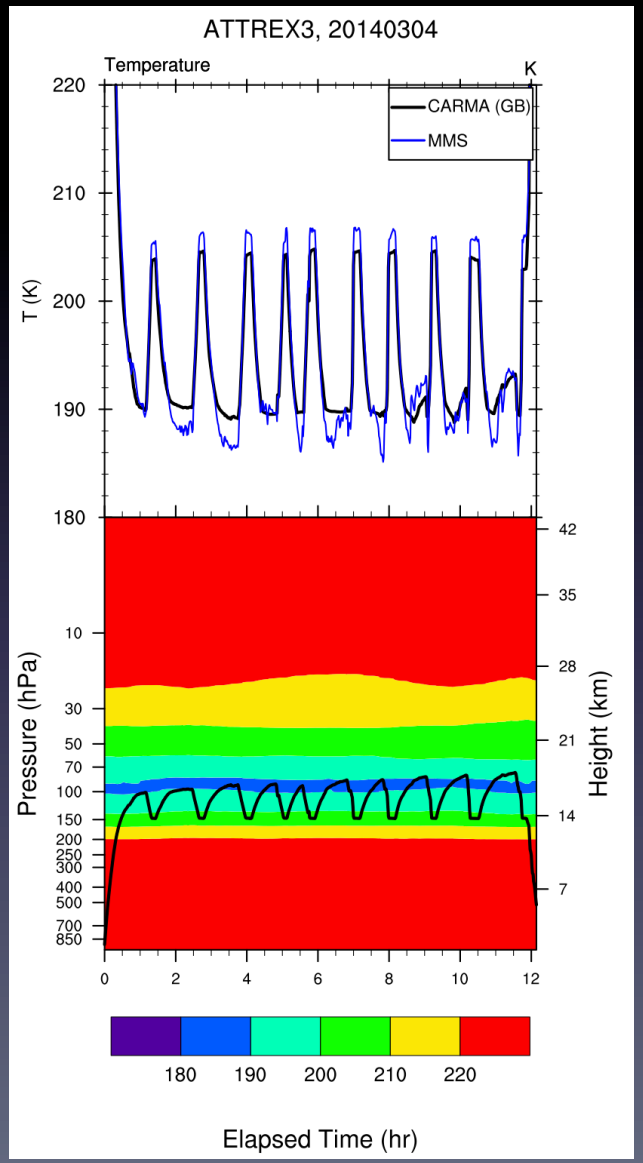
1K CPT Bias because no level at 17 km

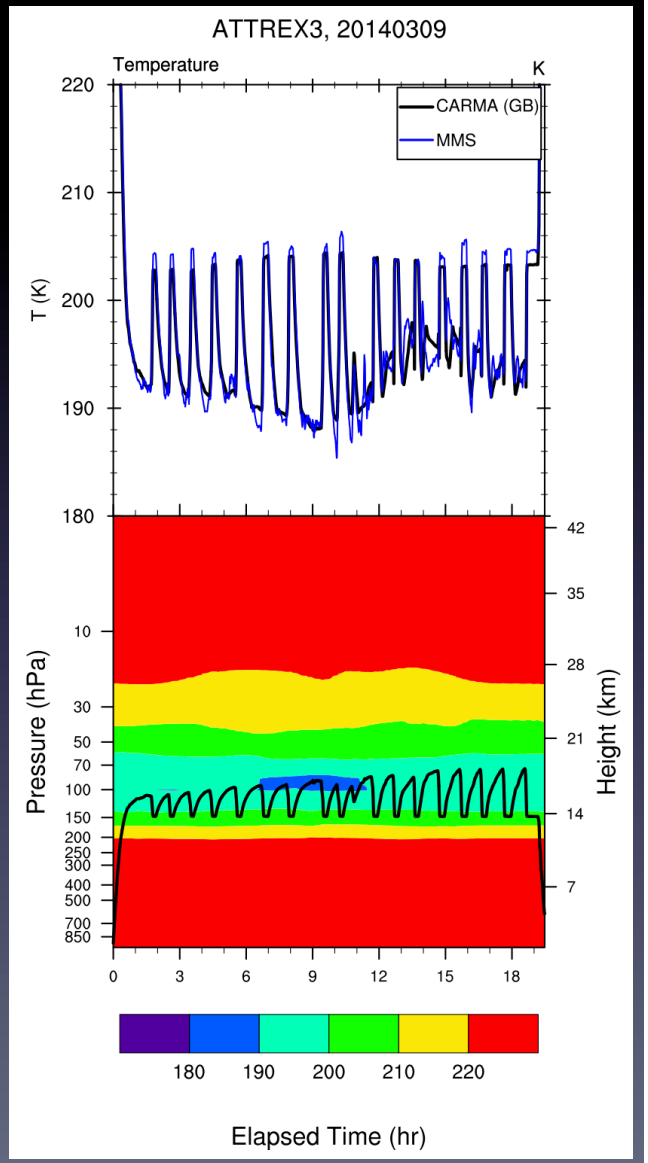


-1K UT Bias

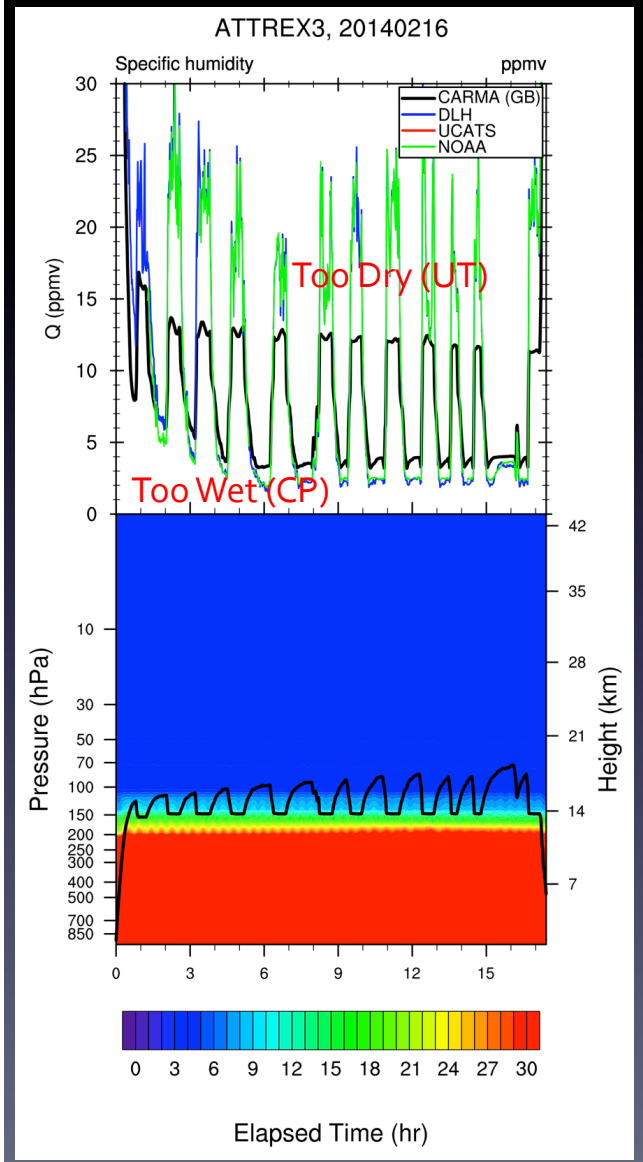
Similar T Bias with ATTREX3 Data

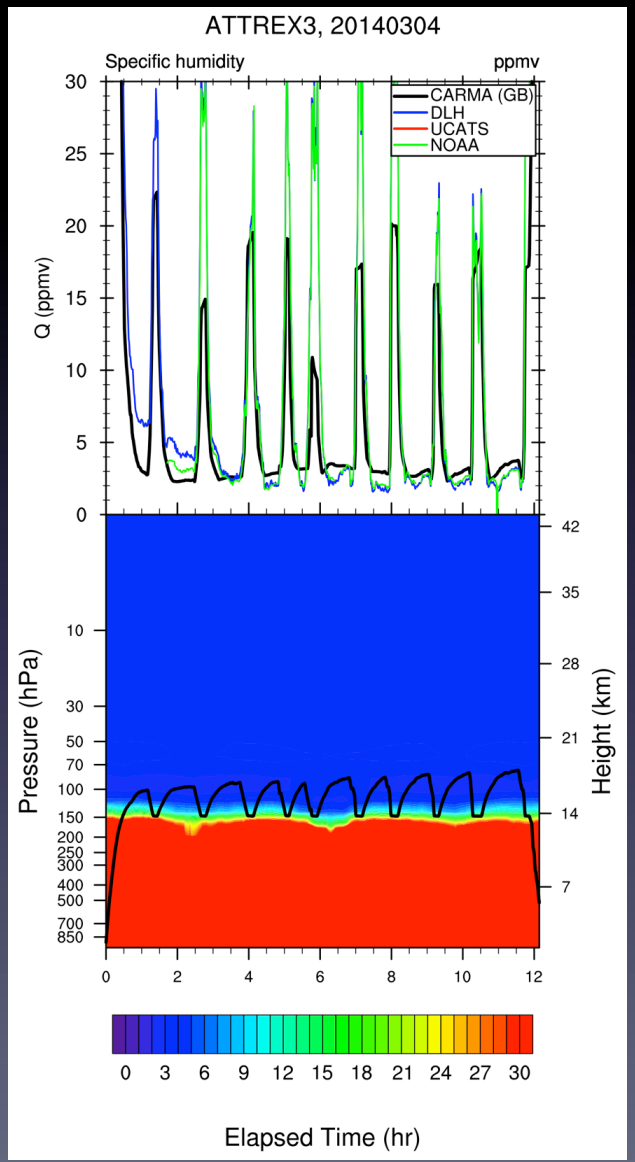


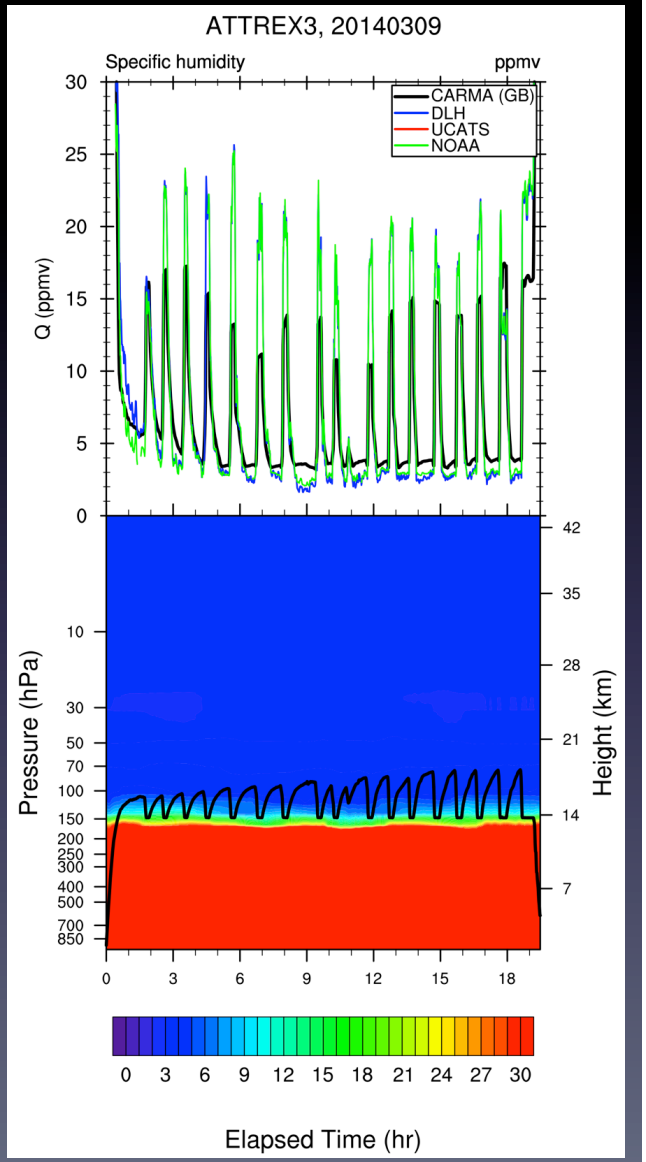




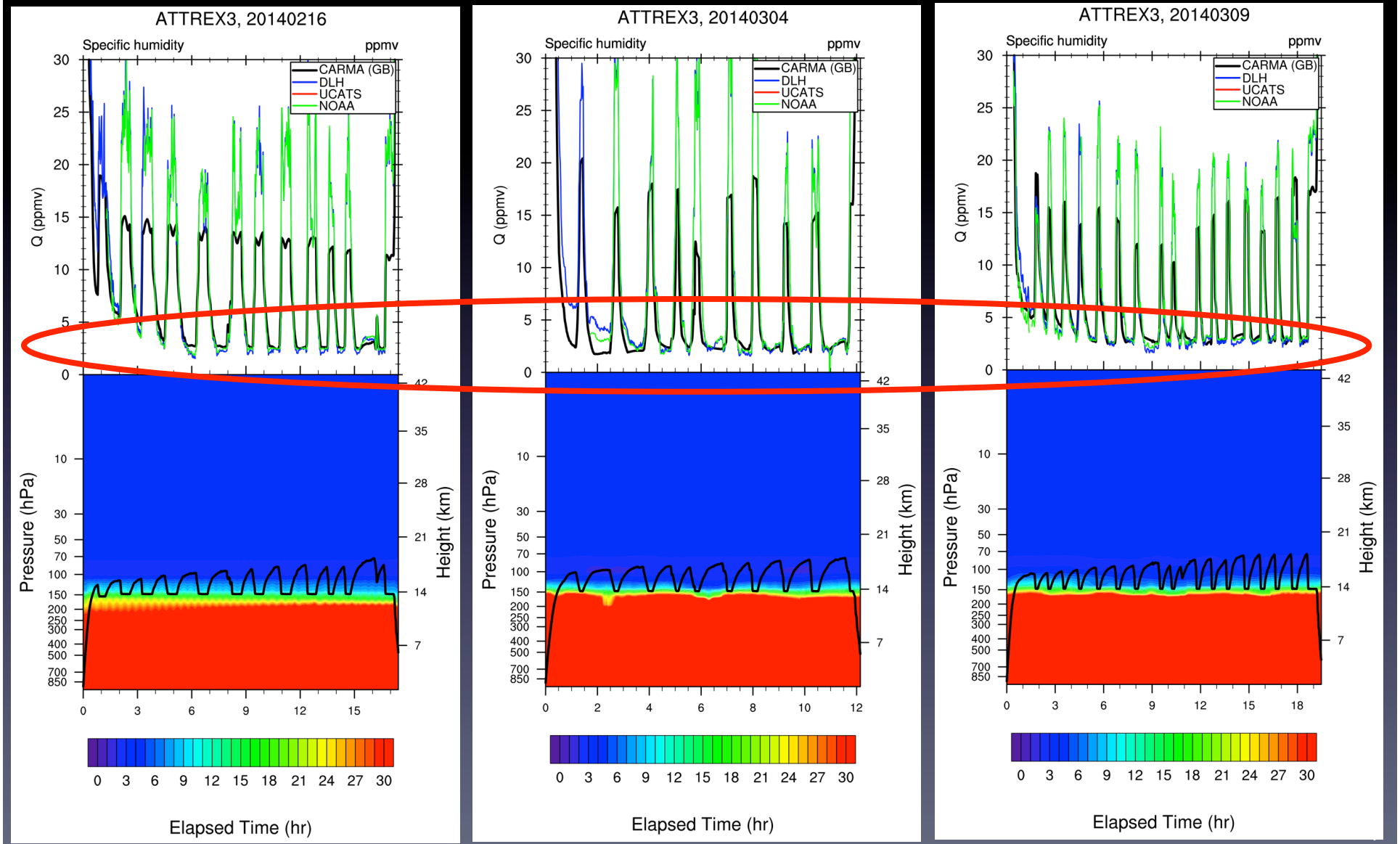
Causes Humidity Errors



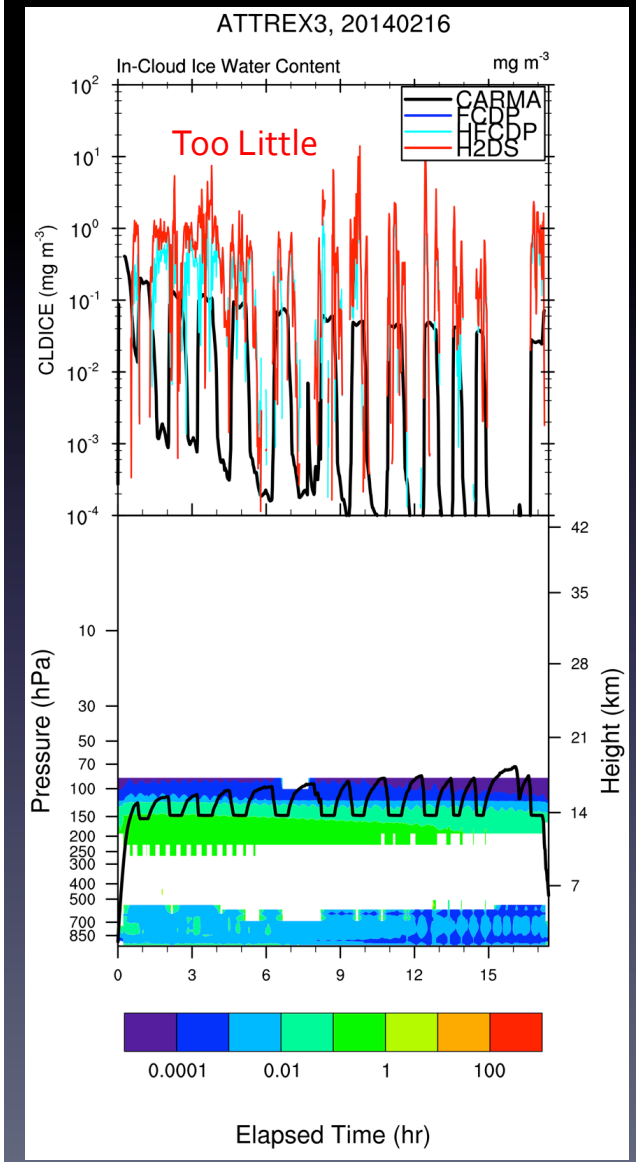


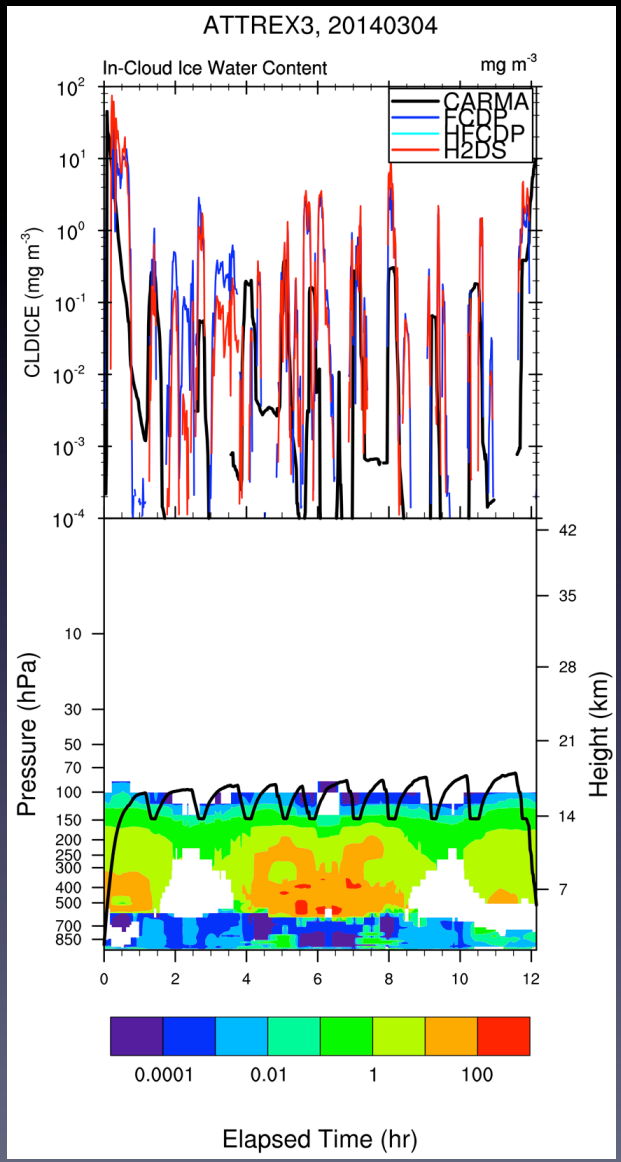


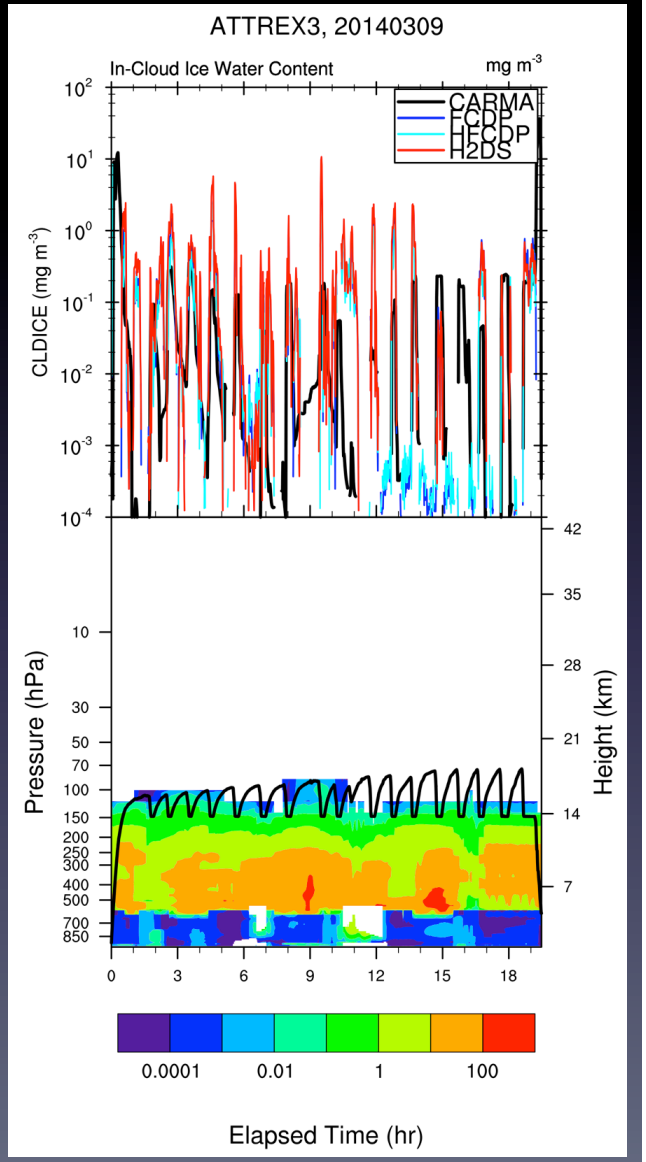
Better CP H_2O with -2K CPT



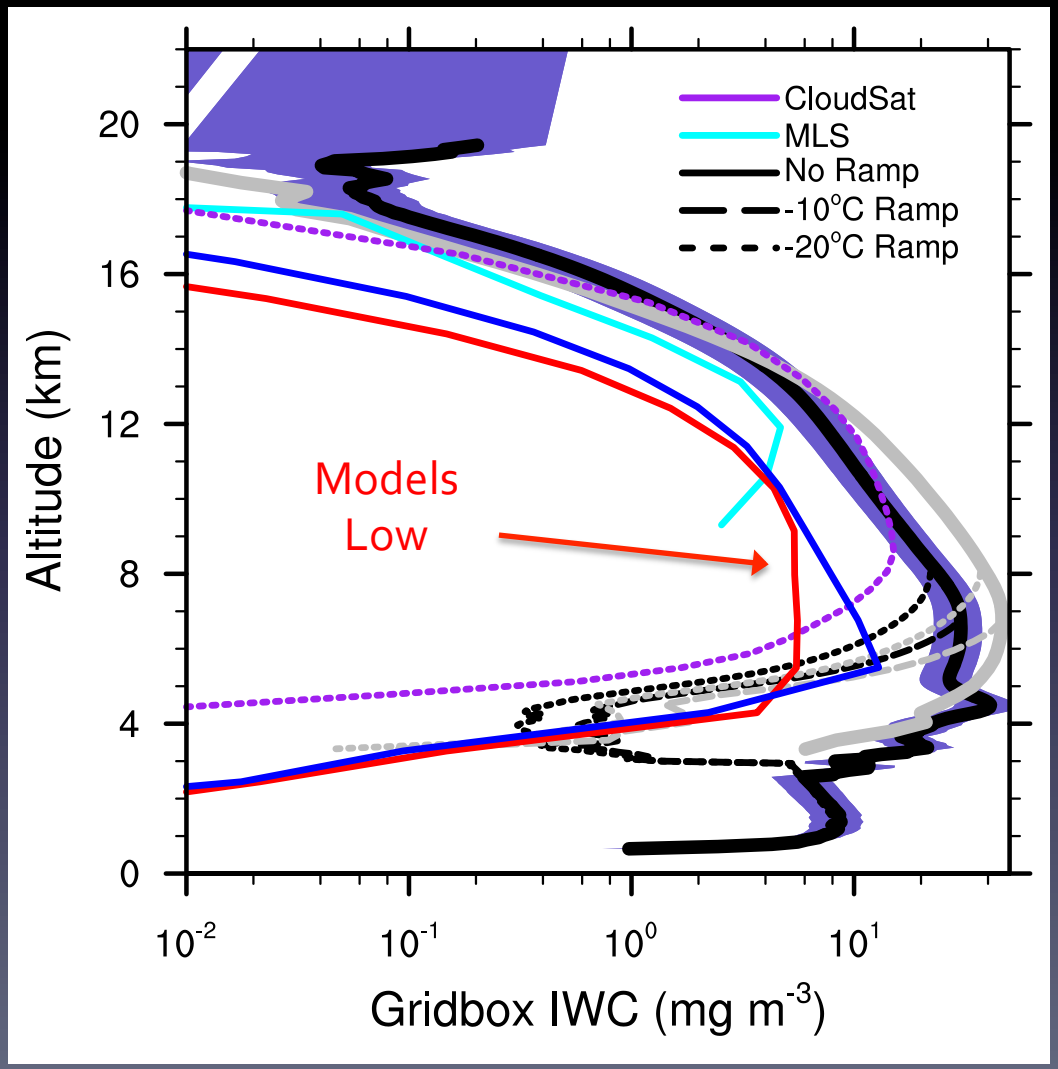
Ice Water Content Too Small





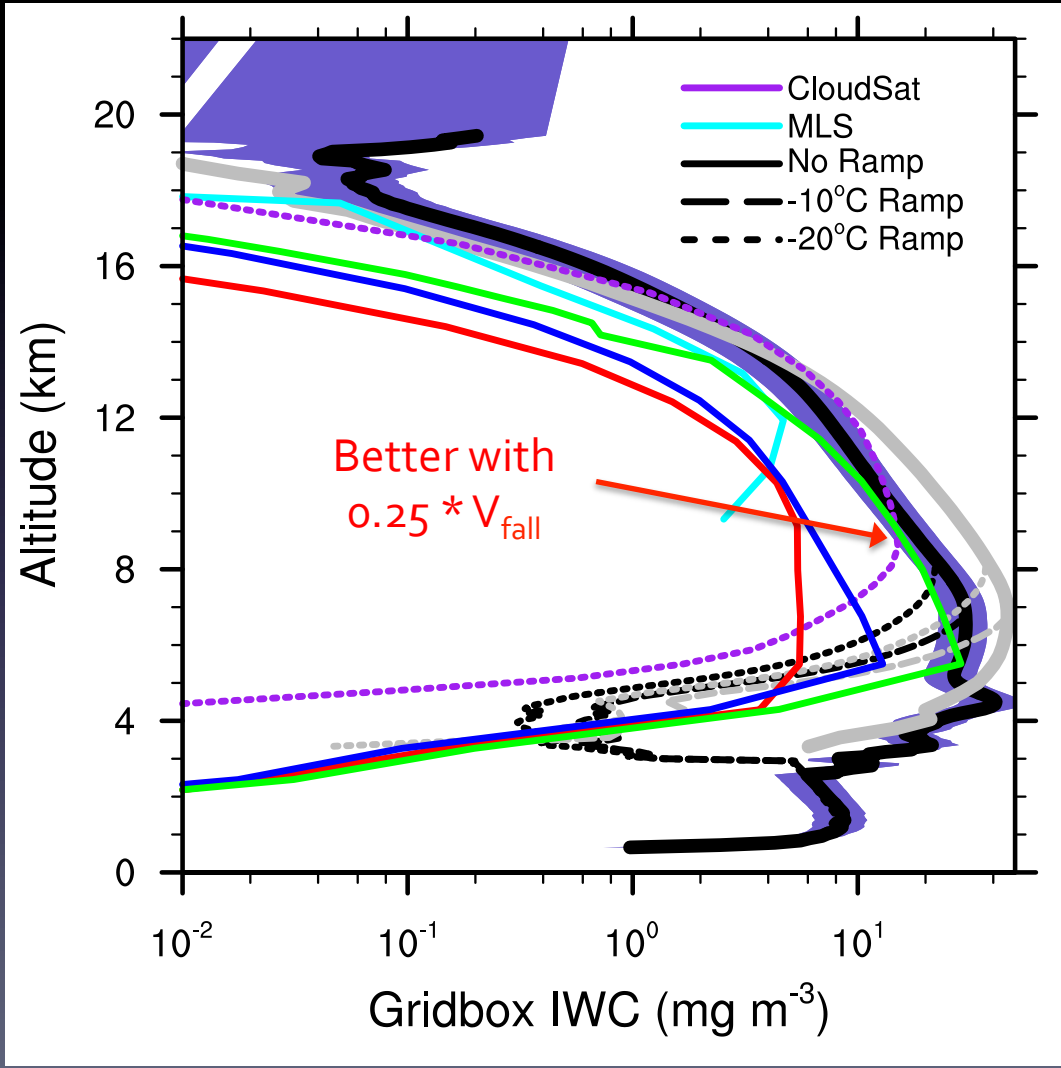


Tropical IWC Low Compared To CloudSat/CALIPSO



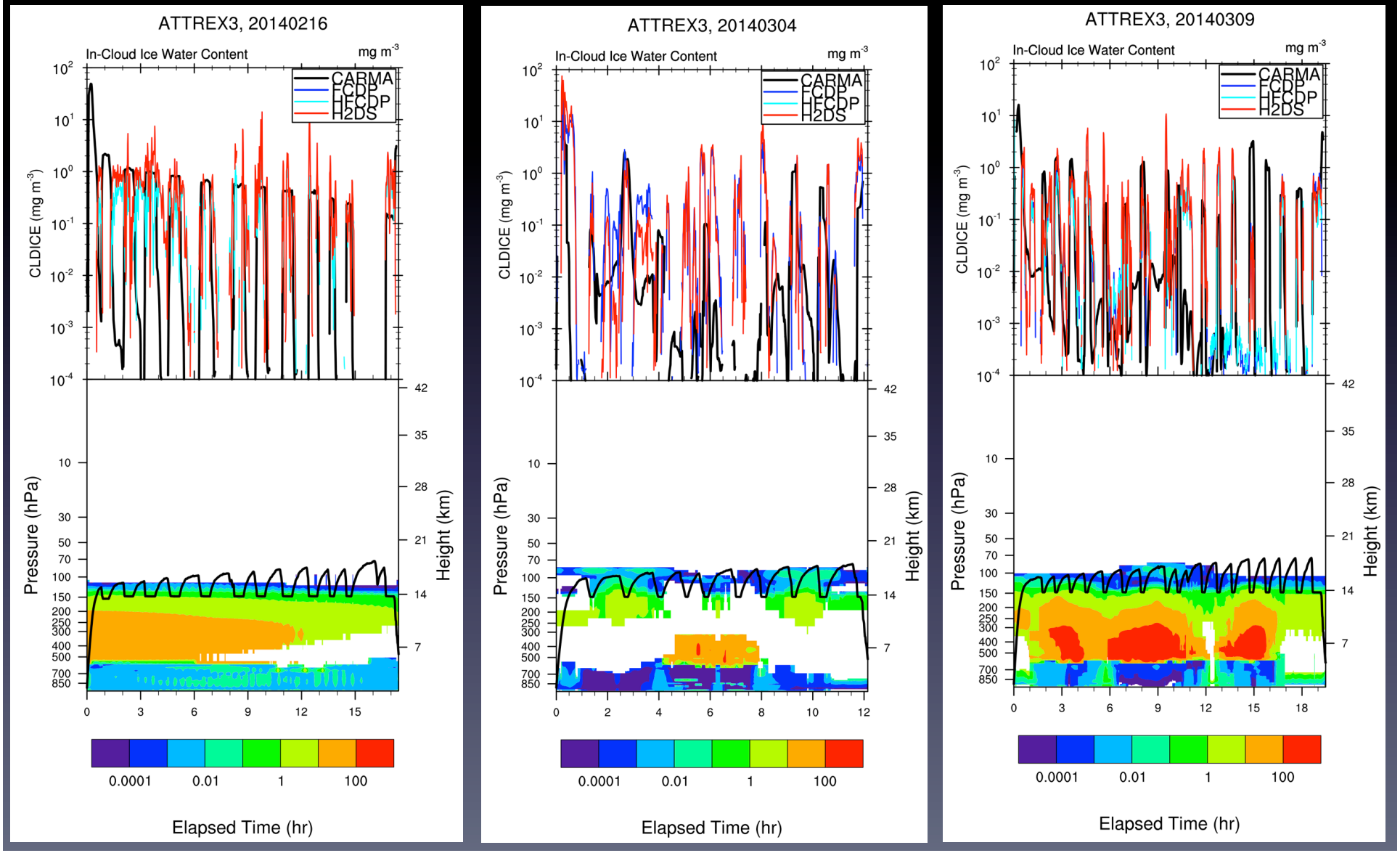
DARDAR
2C-ICE
CAM5
CAM5/CARMA

Reduced V_{fall} increases IWC

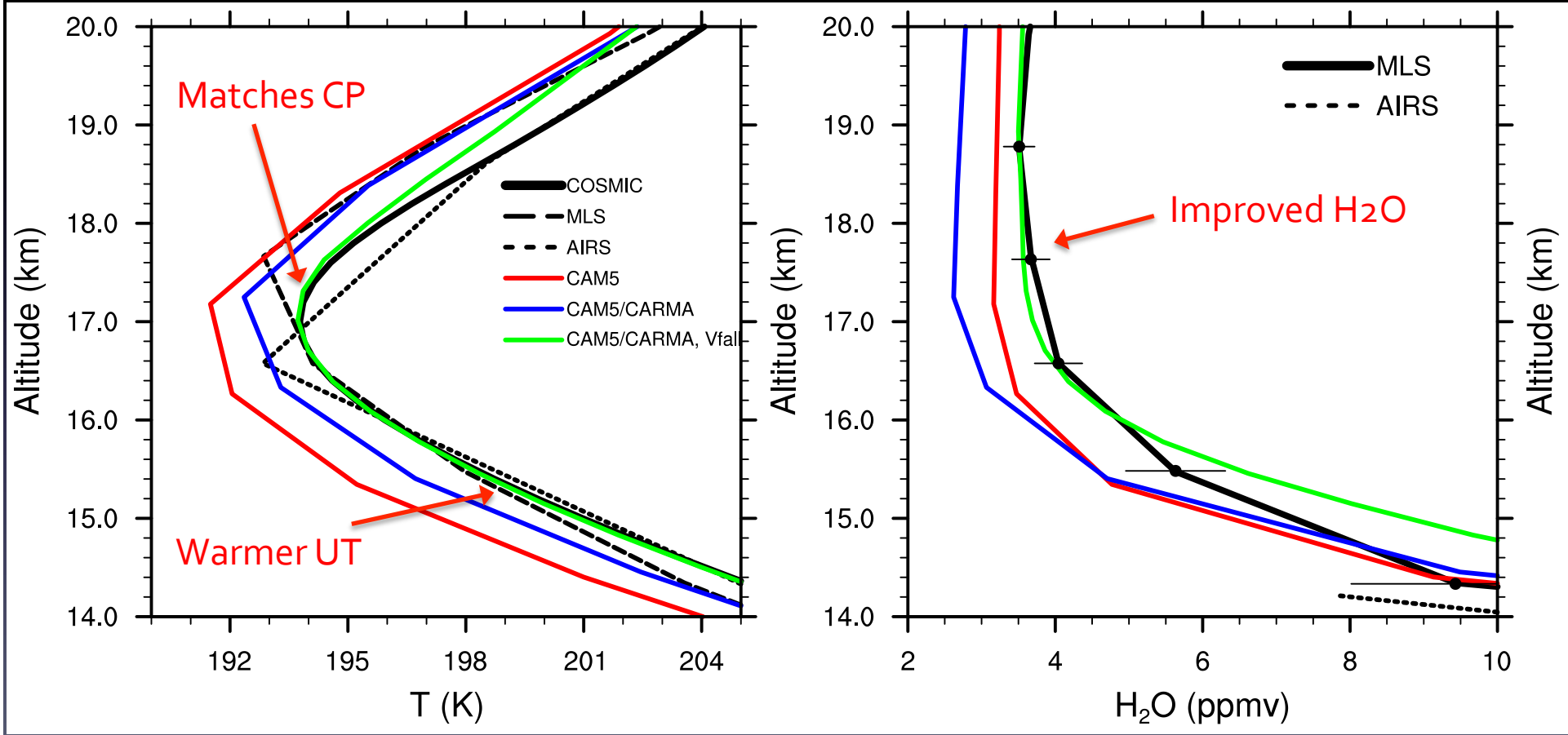


DARDAR
2C-ICE
CAM5
CAM5/CARMA
CAM5/CARMA, 0.25*Vfall

Improves IWC for ATTREX3



Improves Tropical T & H_2O



Free running V_{fall} model better than nudged?

Improves Tropical Cloud Heating

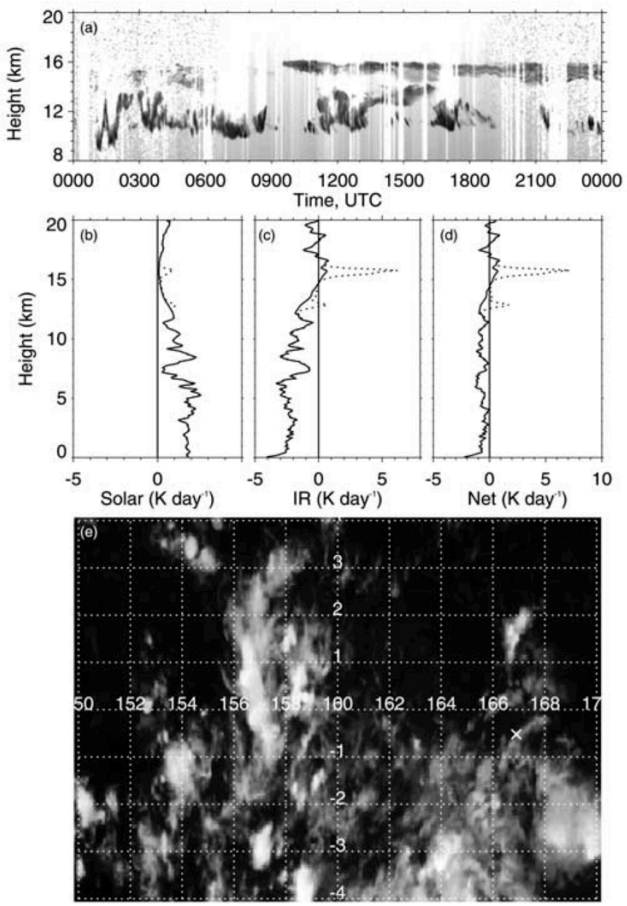
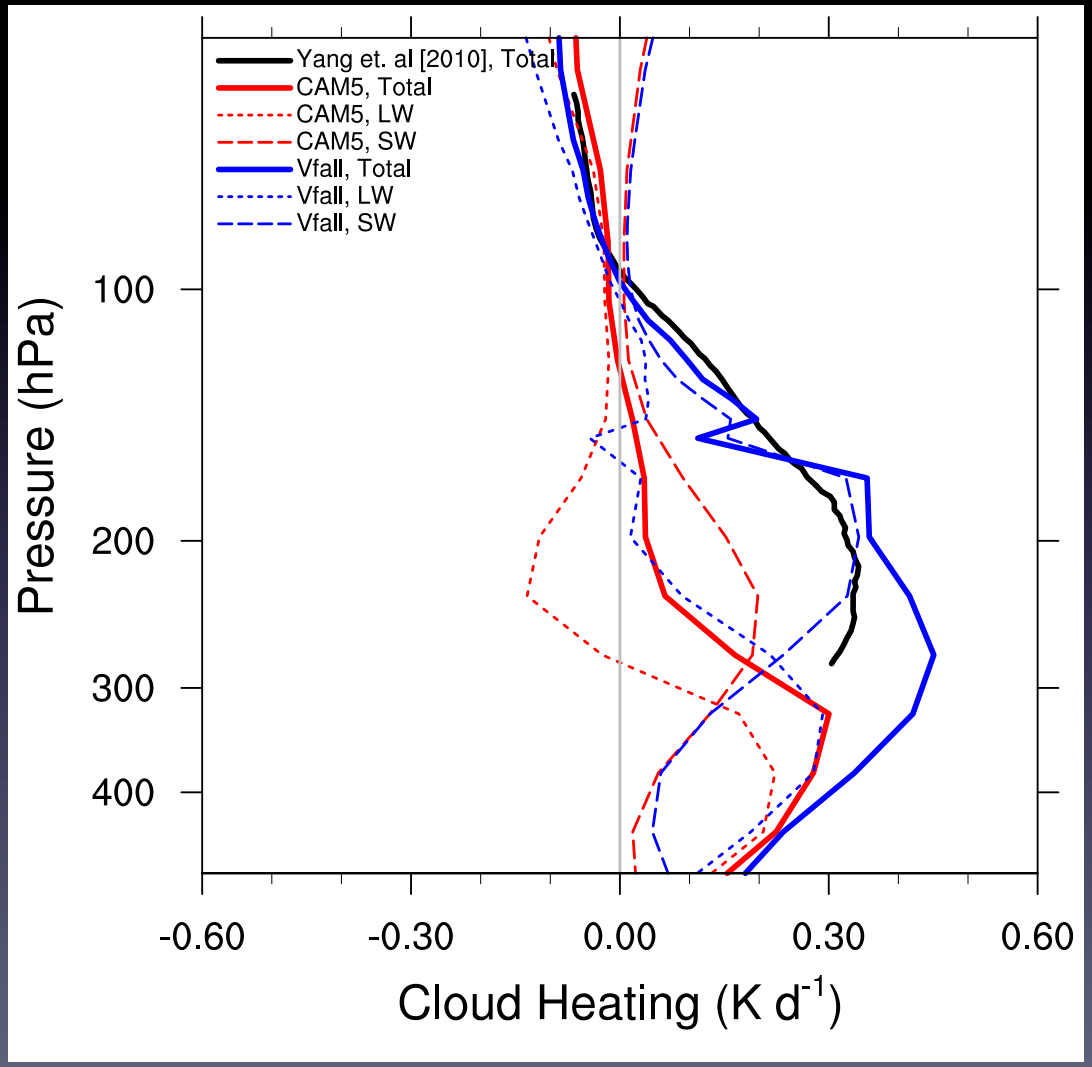


Figure 13. Same as in Figure 12 but for a multiple-layer cirrus observed on 17 June 1999. GMS-5 imagery is for 1432 UTC.



[Comstock et al., 2002]

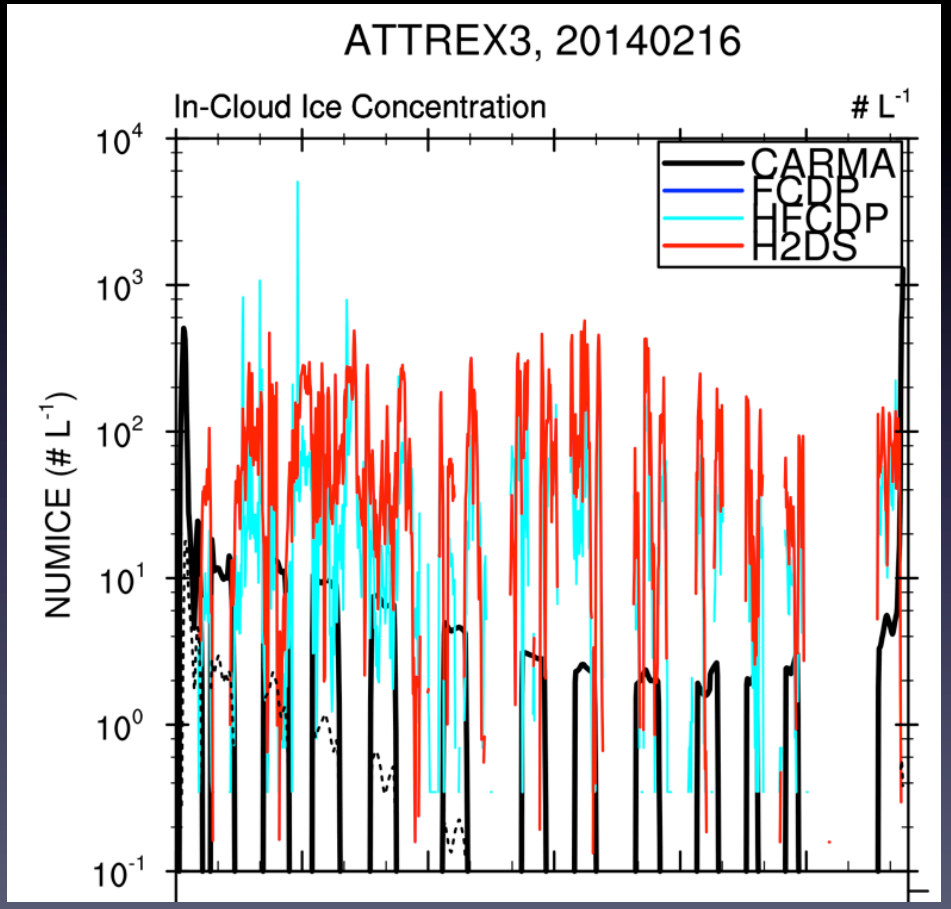
Why is Ice Concentration Low?

In Situ Ice

- Too little nucleation?
- Growth too fast?
- Missing waves & temperature variability

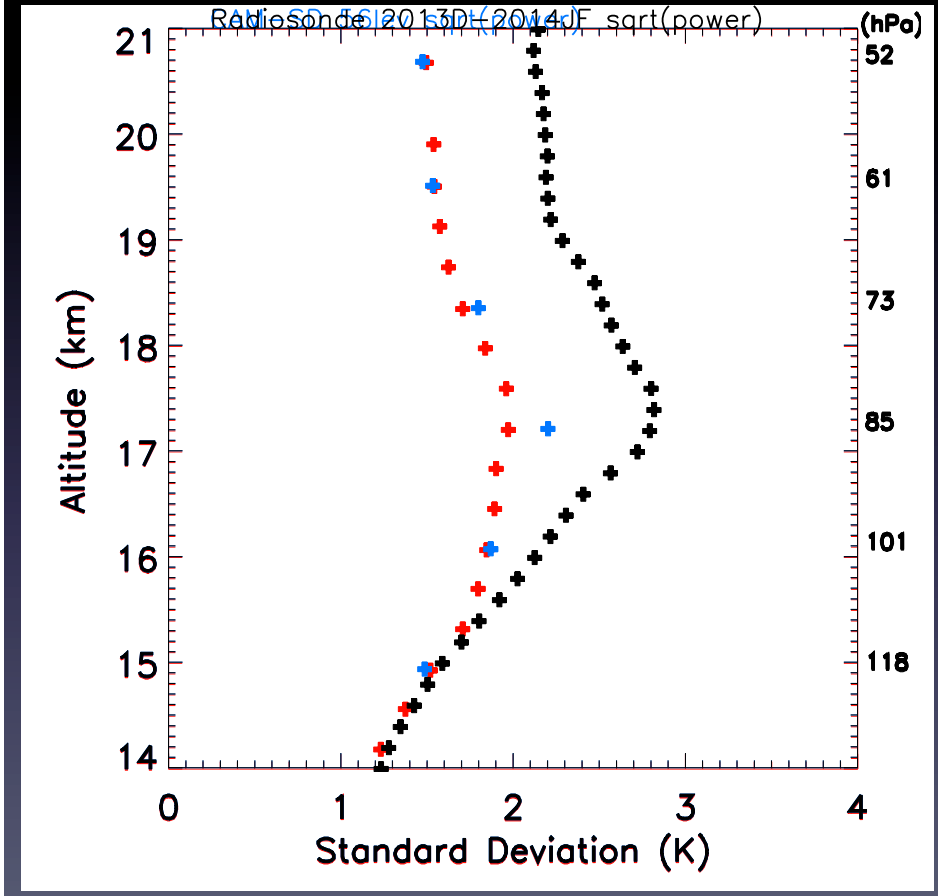
Detrained Ice

- Detrainment size too large?
- Too much coagulation?
- Wrong Mass-Diameter relationship?
- Missing waves, temperature variability, and/or convection?

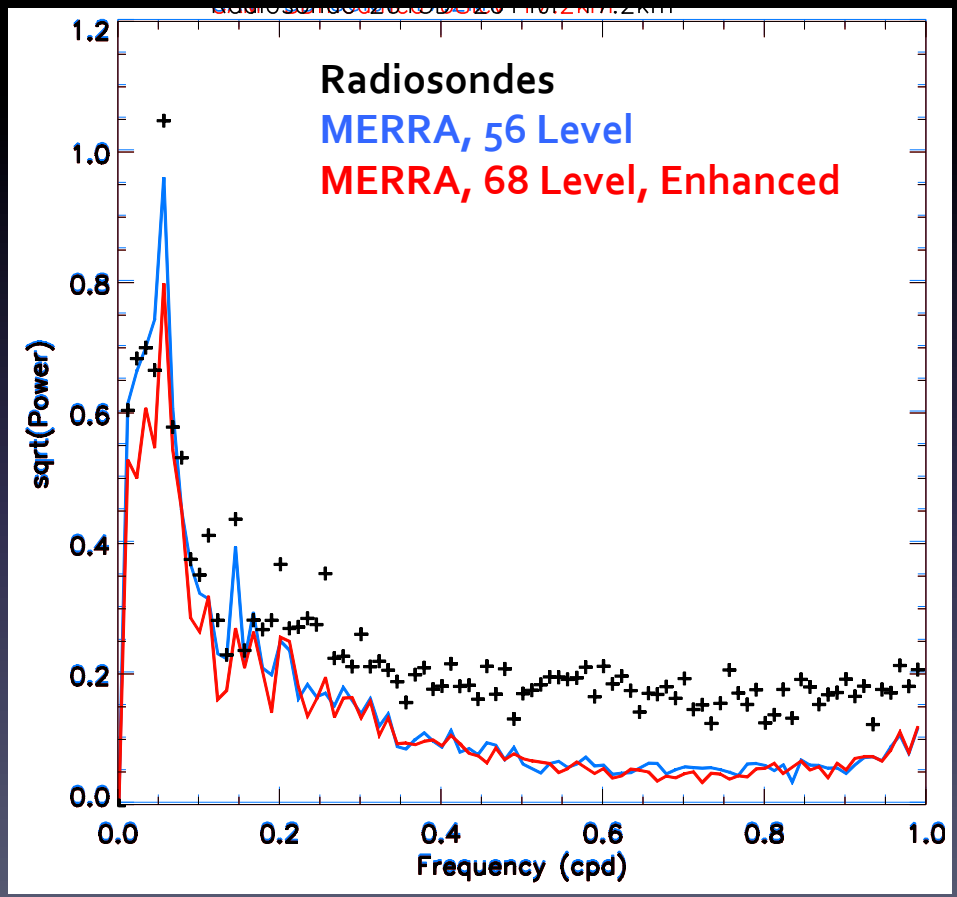


SD-CAM5 T Variability

Variability



Power Spectrum

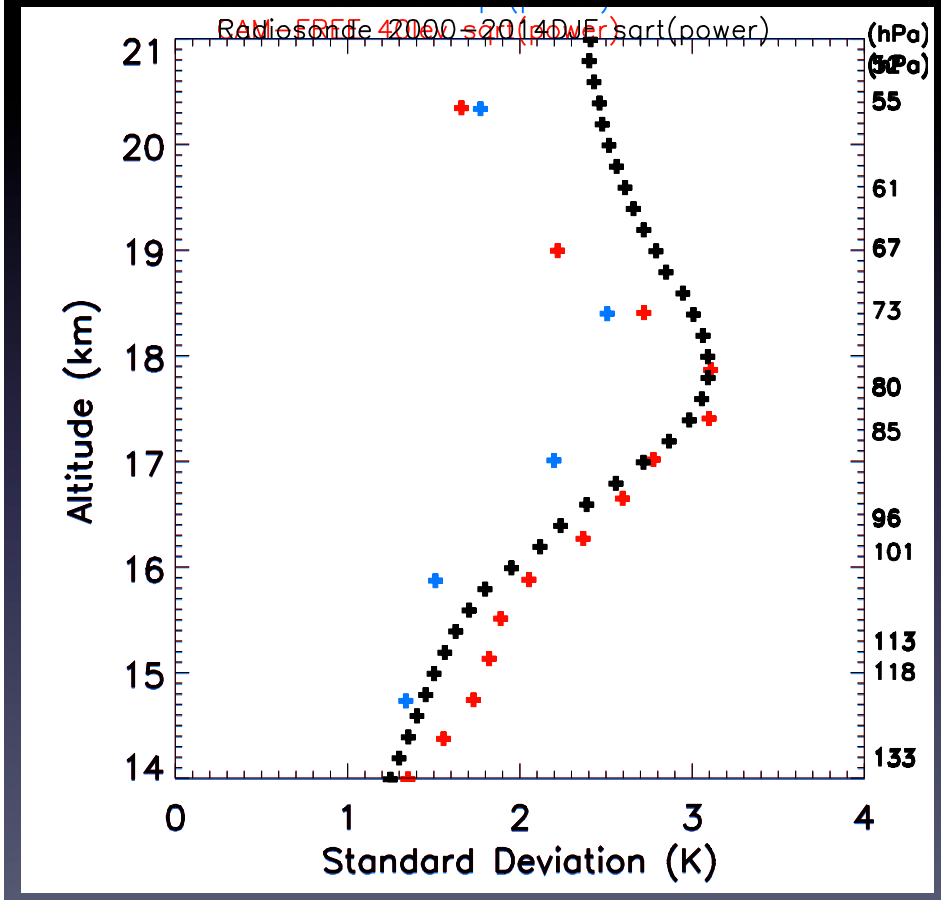


Nudging dampens variability

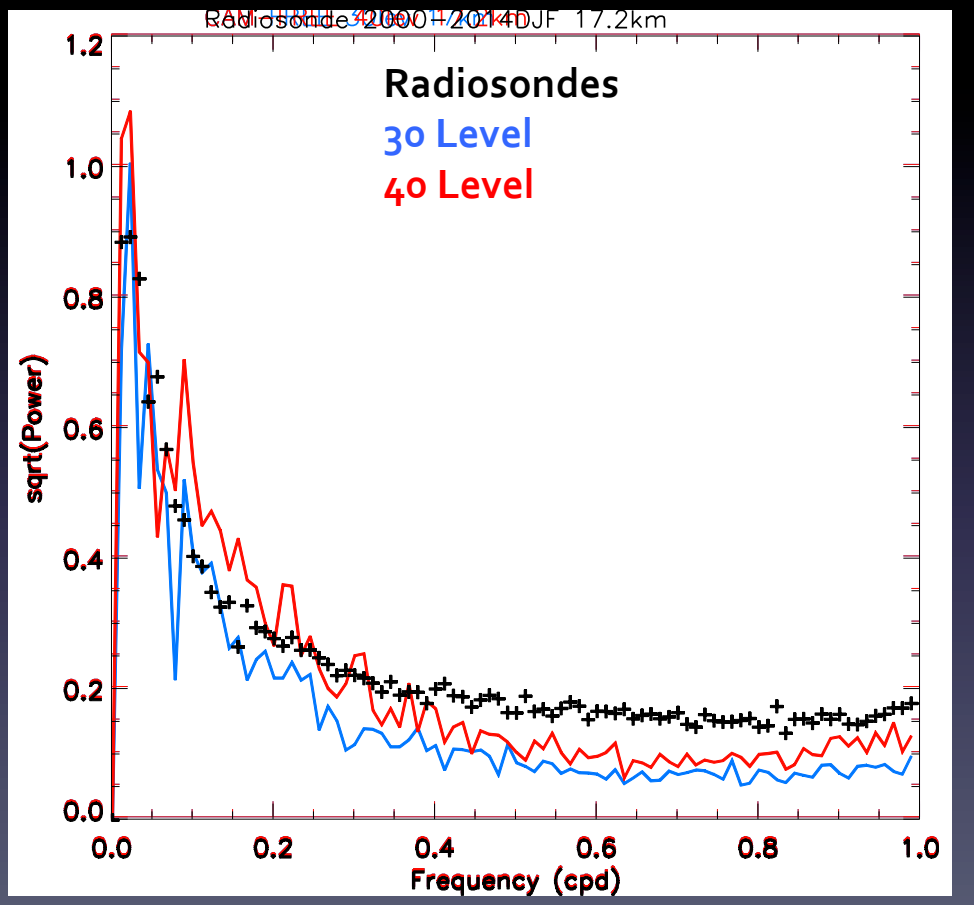
Courtesy Ji-Eun Kim

CAM5 T Variability

Variability



Power Spectrum



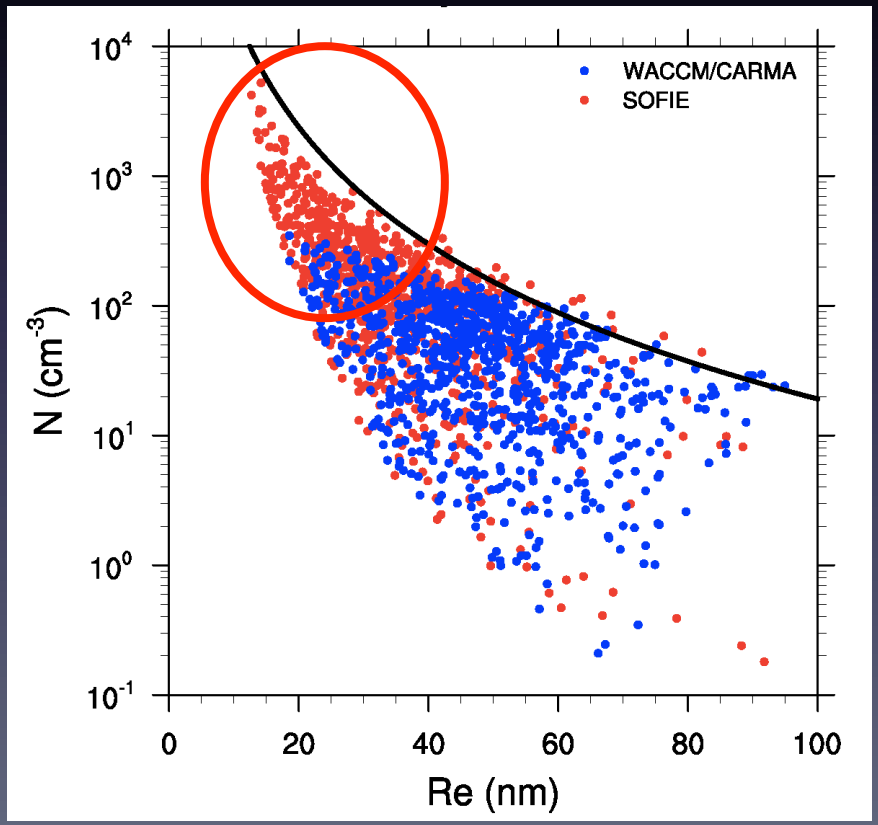
Extra levels improves variability in free running model

Courtesy Ji-Eun Kim

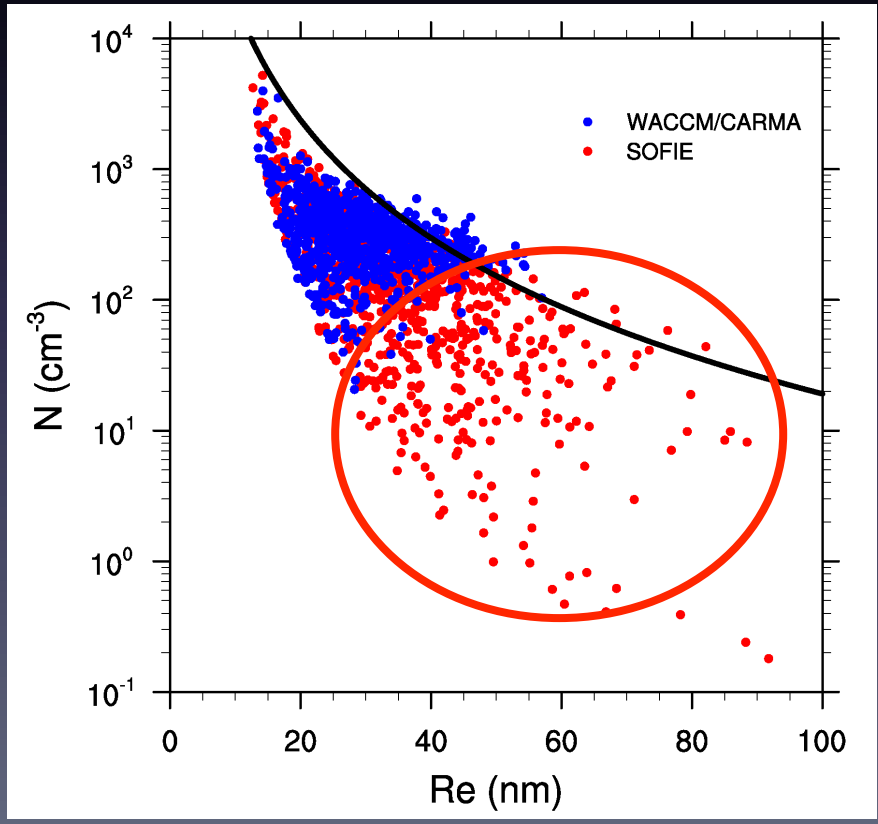
Subgrid T Variability – PMC Model

$$\Delta T = T_0(m)\sin(mz + \phi_m - \omega t)e^{z/D}$$

No Waves



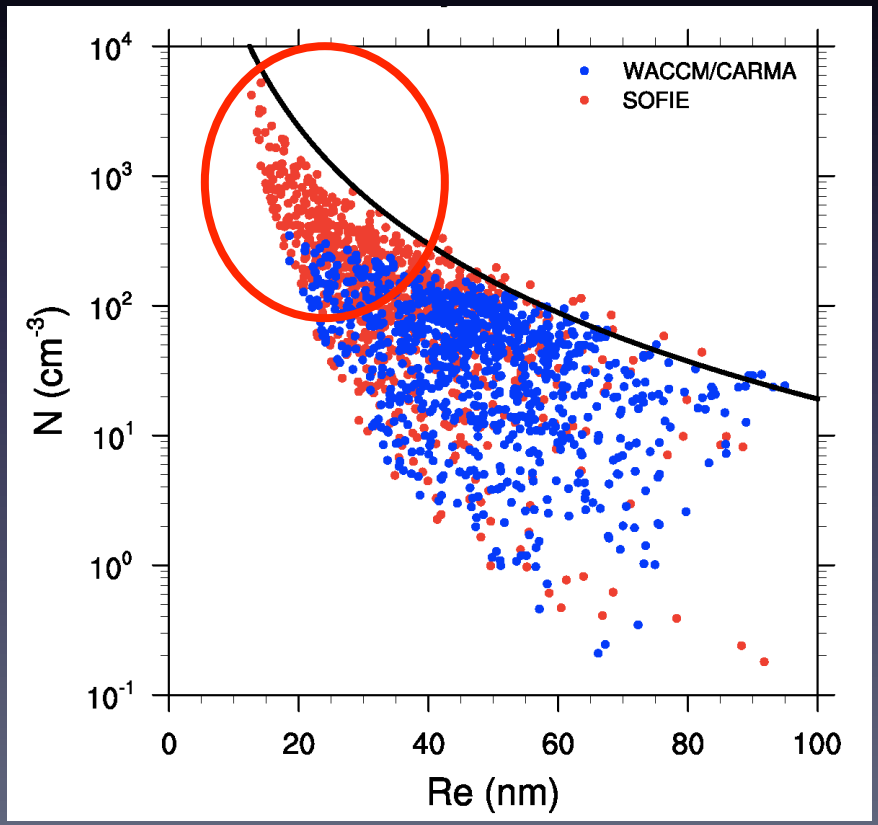
High Frequency Waves



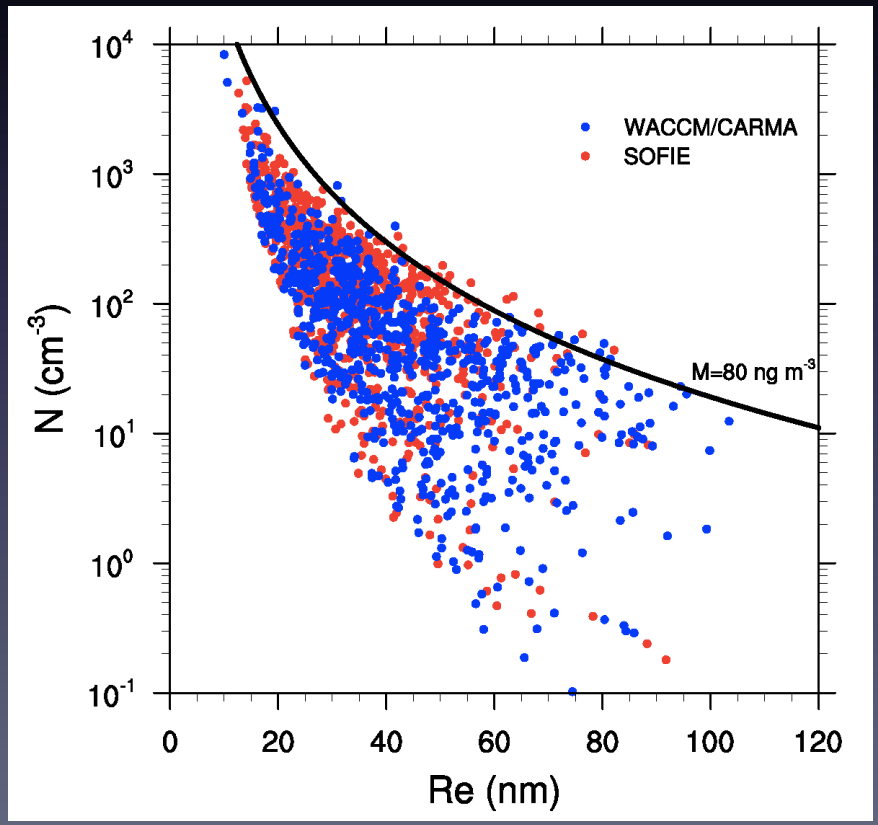
Subgrid T Variability – PMC Model

$$\Delta T = T_0(m)\sin(mz + \phi_m - \omega t)e^{z/D}$$

No Waves



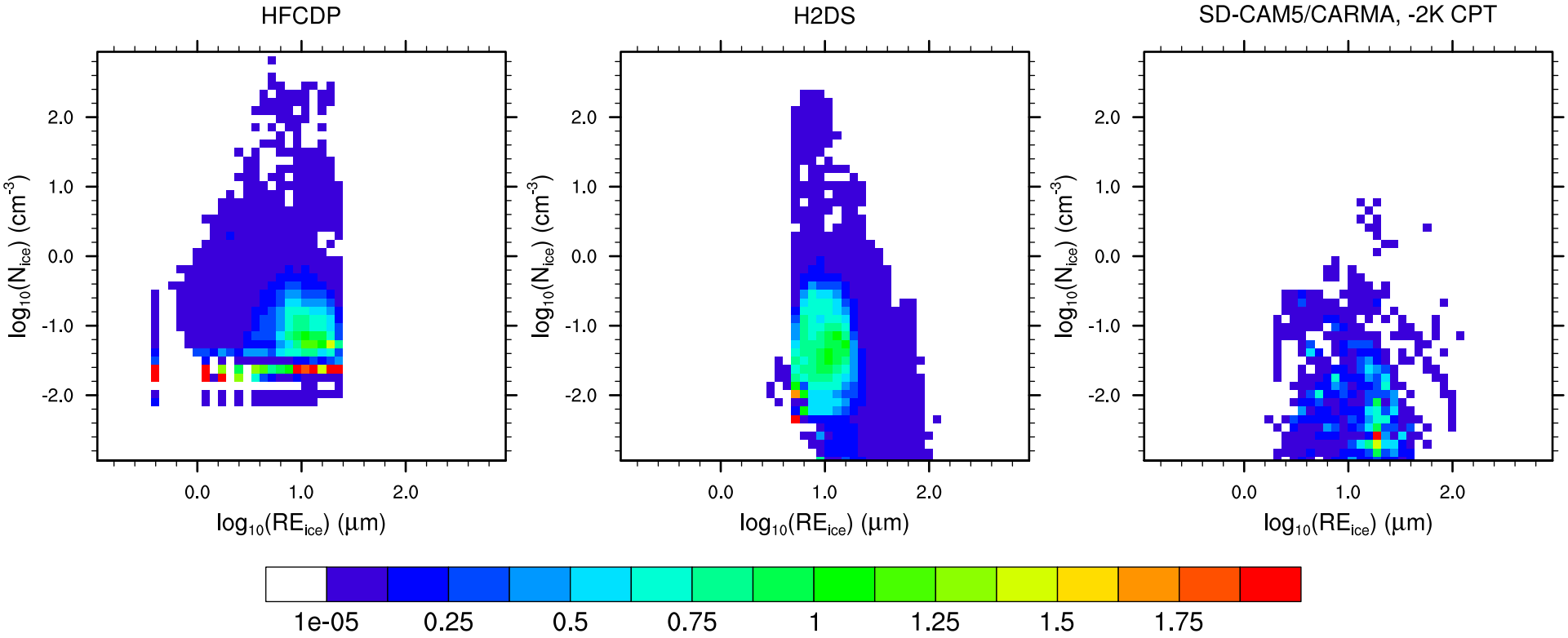
Spectrum of Waves



ATTREX3 N vs. RE

Need to be combined

Fewer & Bigger



Ncarma ~ 1/10 Nhawkeye, REhawkeye ~10 um, REcarma ~20 um

If Ncarma = Nhawkeye, then RE ~ 0.5*REcarma = REhawkeye and VF ~ ¼ VFcarma

Conclusions (So Far)

- ATTREX has been important in understanding and improving the simulation of ice clouds and water vapor in CAM5 including:
  - TTL ice cloud fraction (not shown)
  - tropical cold point and upper troposphere temperature
  - UTLS water vapor
  - cirrus mass
  - cirrus heating rates
- CAM5 is missing resolved and subgrid temperature variability that is important for ice nucleation and ice particle growth.
- Increasing ice concentration for both detrained and in situ ice should lead to improvements similar to those explored with reduced fall velocity run.
- UT cloud heating may be significantly underestimated in CAM5, which could affect model biases (IWC, T, Q, LWCF, …).

Future Work

- Explore ways to improve ice number and therefore ice mass, compared to ATTREX measurements
  - Increase temperature variability
  - Consider other nucleation schemes
  - Change detrainment size
- Evaluate new versions of the Two-Moment microphysics.
- Refine TTL macrophysics changes to be more physically based.
- Evaluate the effect of cloud heating on troposphere-stratosphere transport.

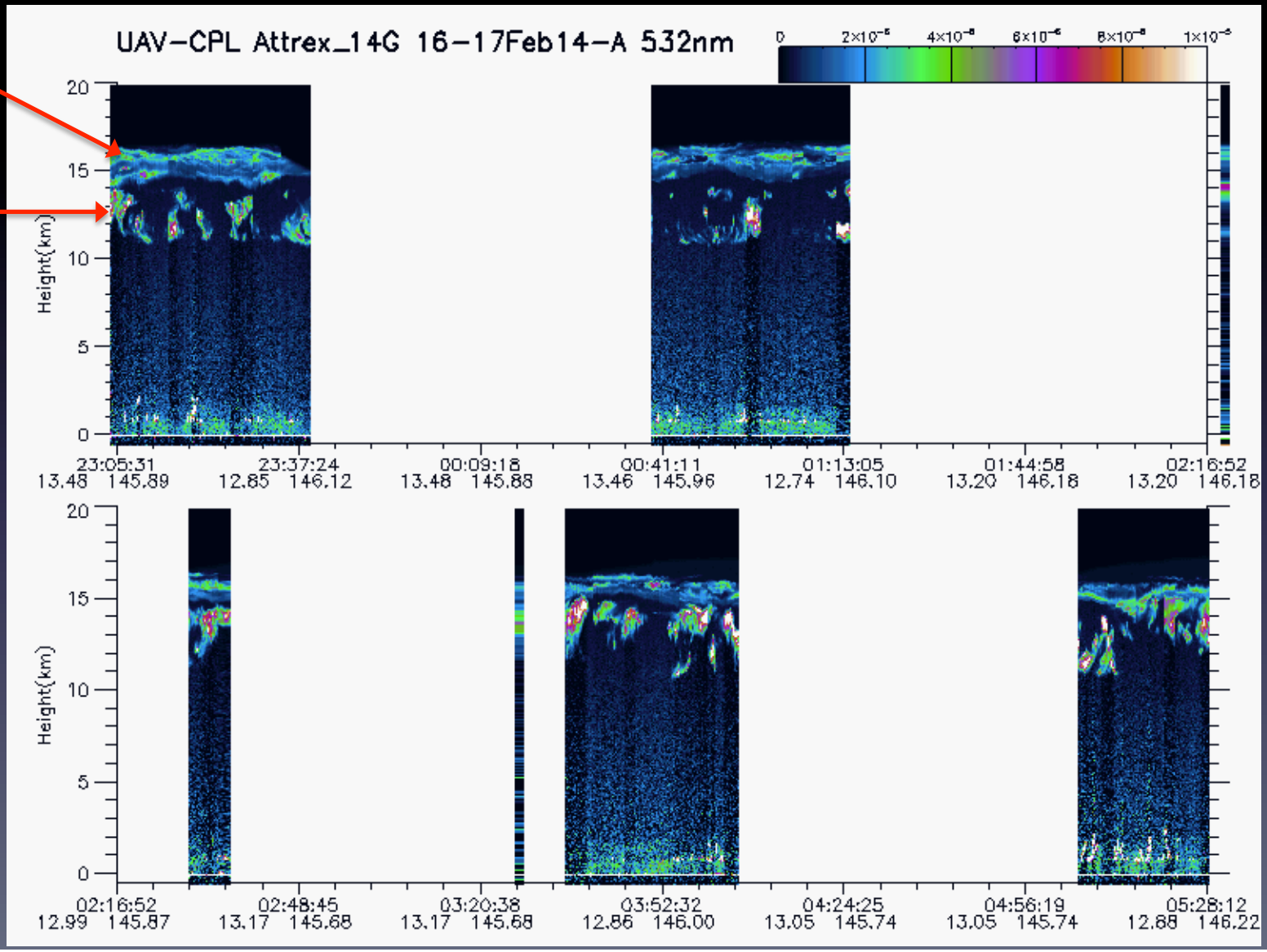
Thank You!

Photos Courtesy Dave Fratello

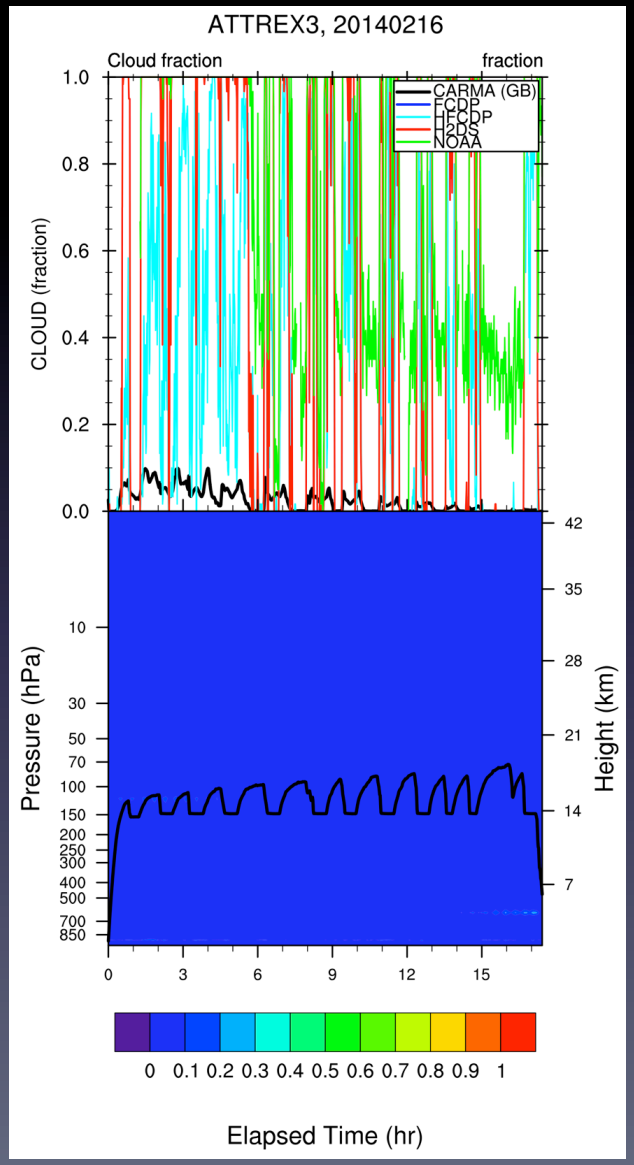
CPL, ATTREX3, 20140216

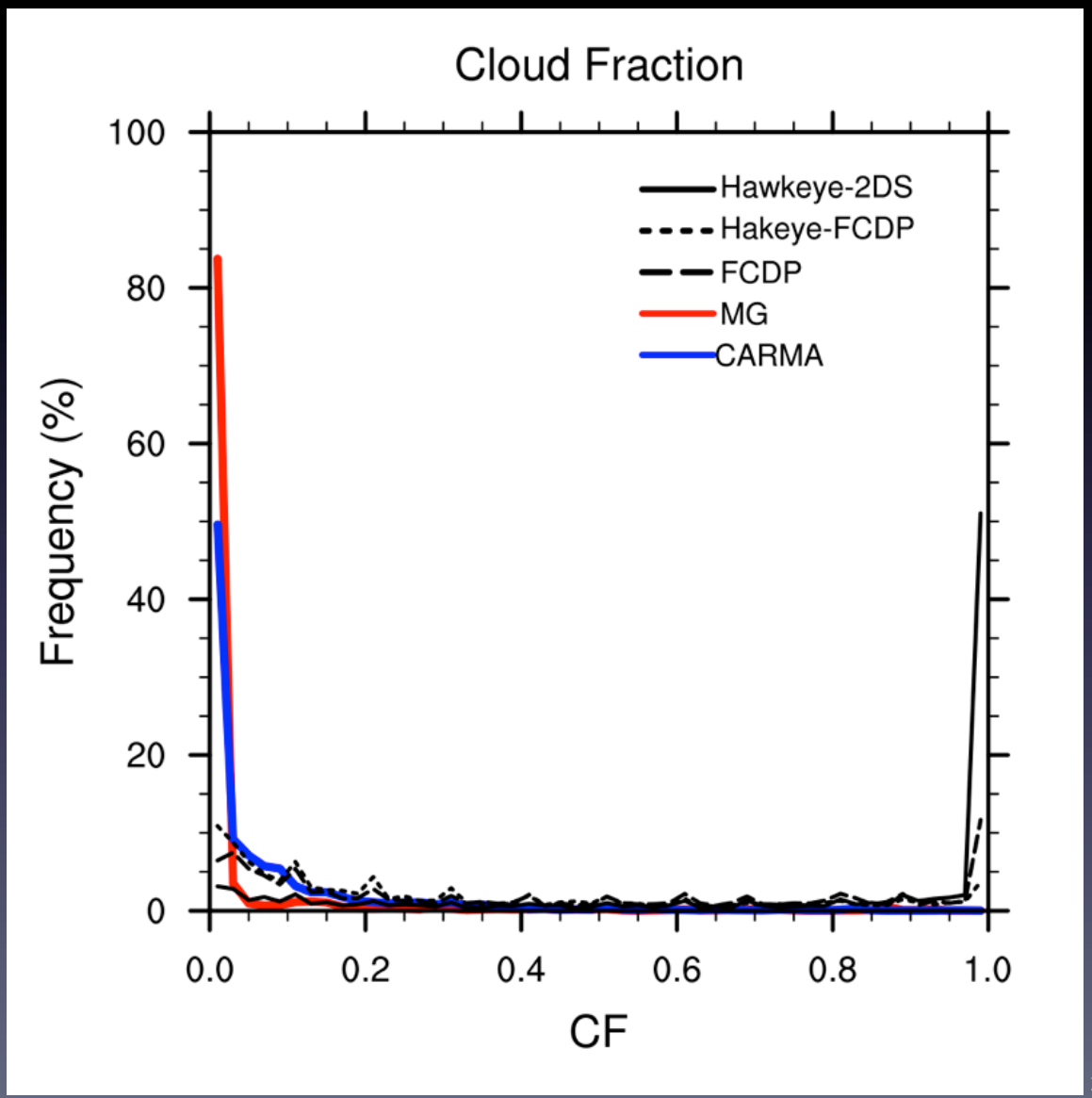
In Situ?

Convective?



Small Cloud Fraction

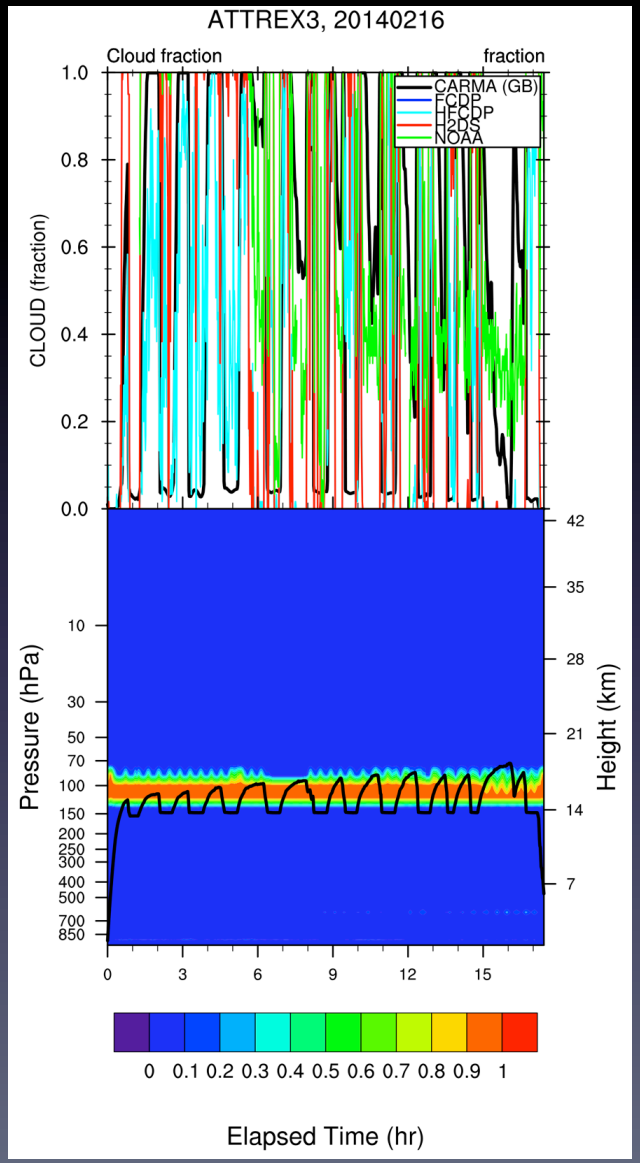


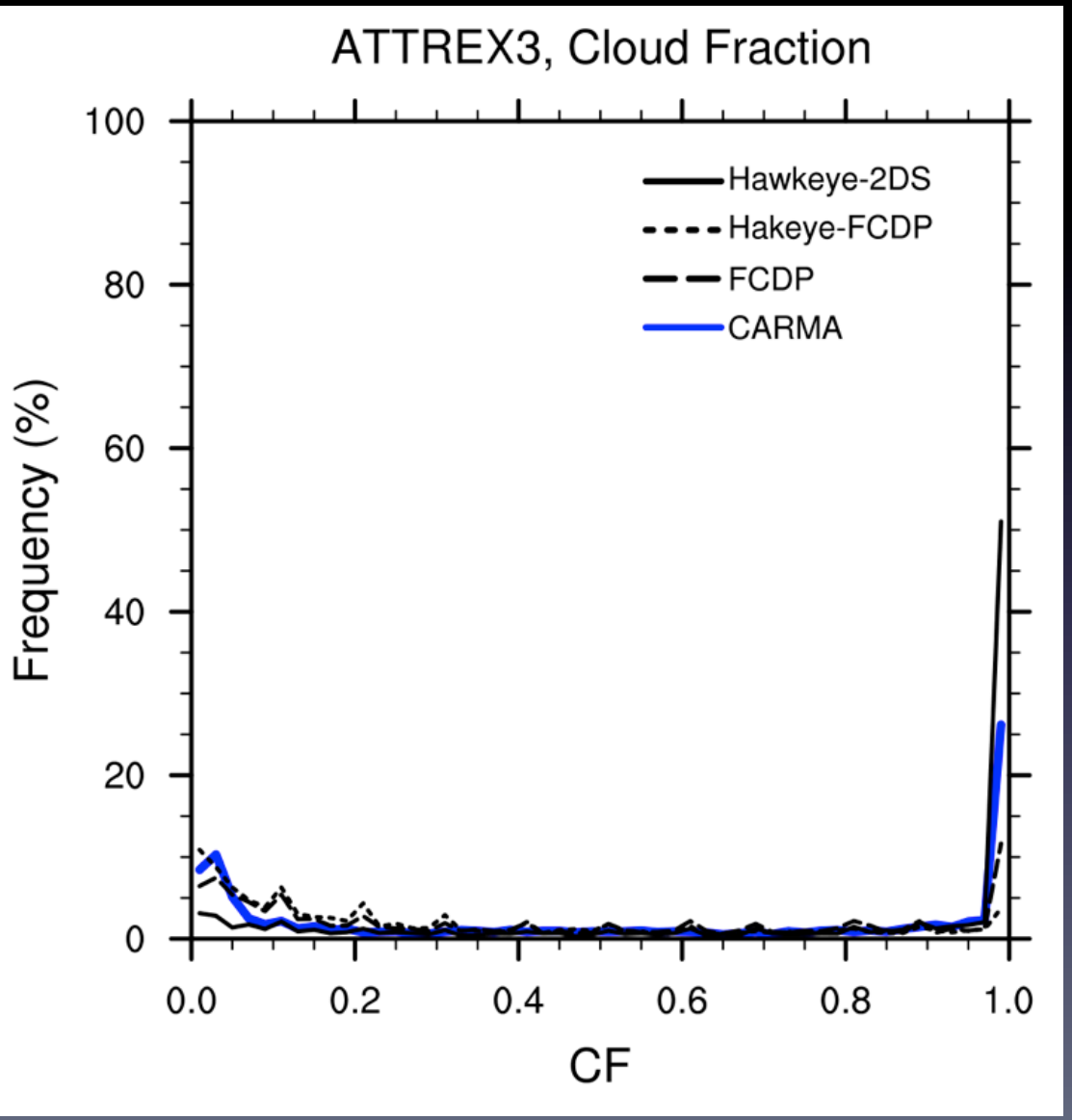


Modified Cloud Macrophysics

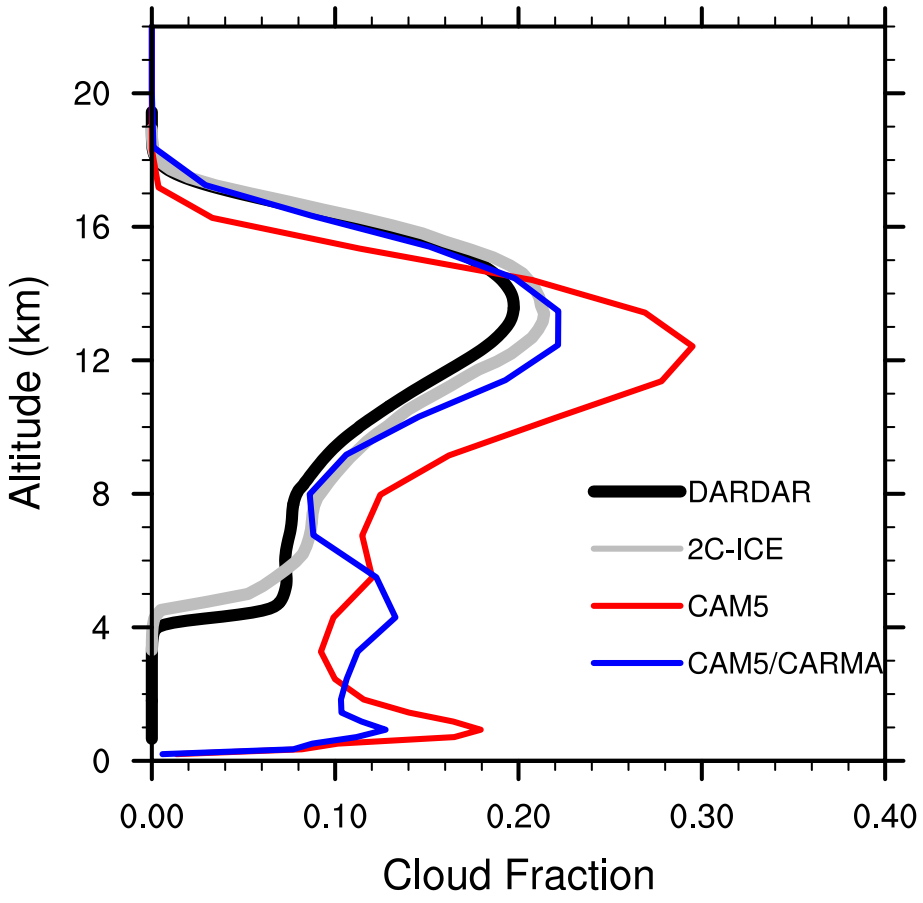
- Assume 2 Stratiform Cloud Regimes
  - Tropospheric Region (P > 140 hPa)
    - Subgrid scale
    - Patchy T, H2O, Saturation, Clouds
    - Use subgrid saturation : S α 1/CF
    - Ice Cloud Fraction : CF α IWC
  - TTL Region (P < 120 hPa)
    - Large scale
    - Uniform T, H2O, Saturation, Clouds
    - Gridbox average saturation
    - Ice Cloud Fraction : CF=1, if IWC > IWCmin

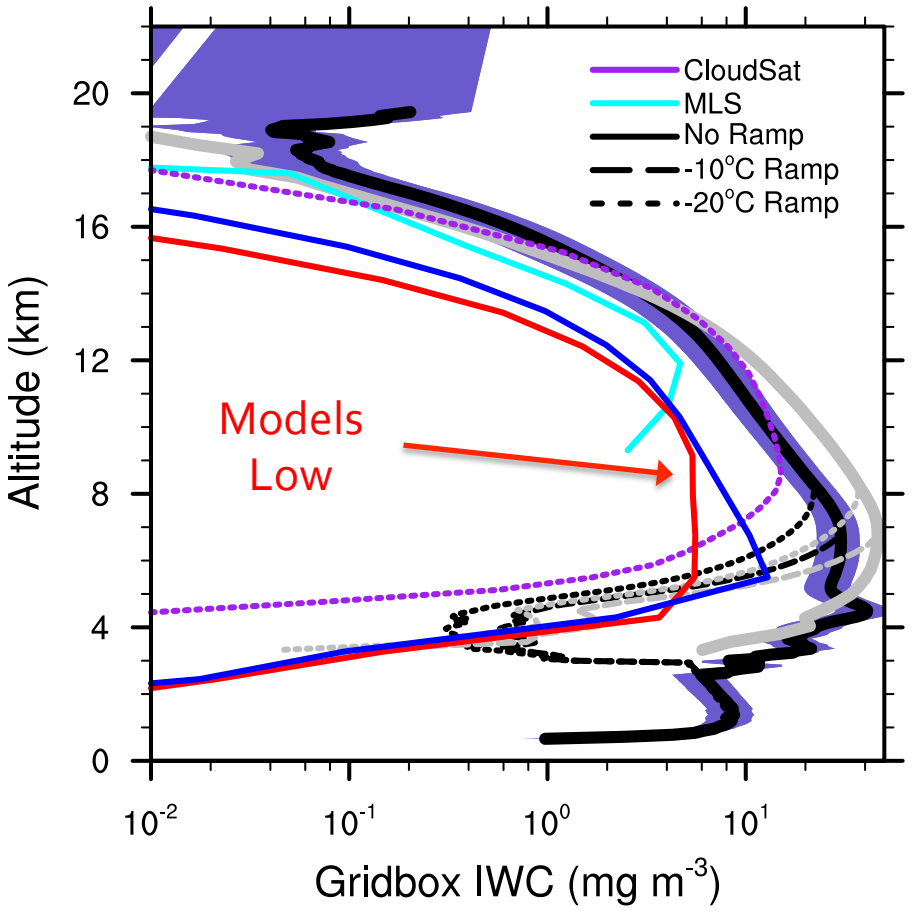
Improved Cloud Fraction





IWC Low Compared To CloudSat/CALIPSO





Reduced V_{fall} increases IWC