Incorporation of New Convective Ice Microphysics into the NASA GISS GCM and Impacts on Cloud Ice Water Path (IWP) Simulation

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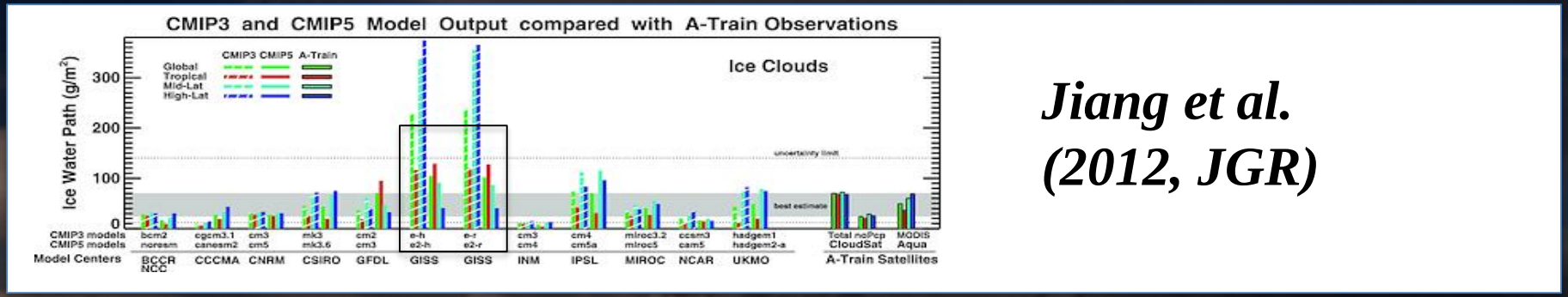
Over-Production of Cloud Ice in GISS ModelE



Jiang et al. (2012, JGR)

Decrease in IWP in ModelE from CMIP3 to CMIP5, but still near high end of uncertainty limit.

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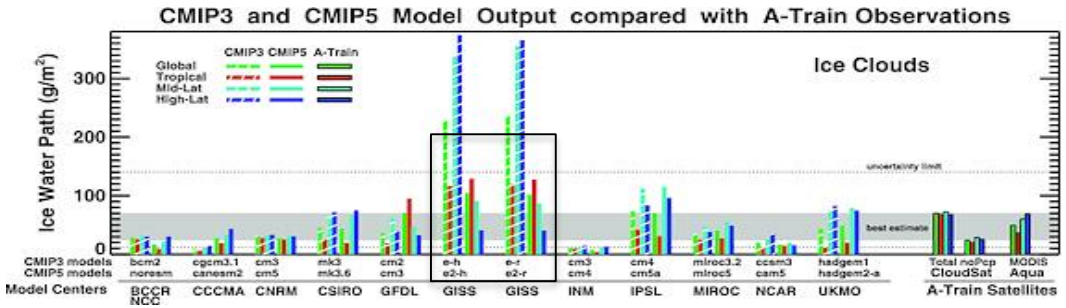

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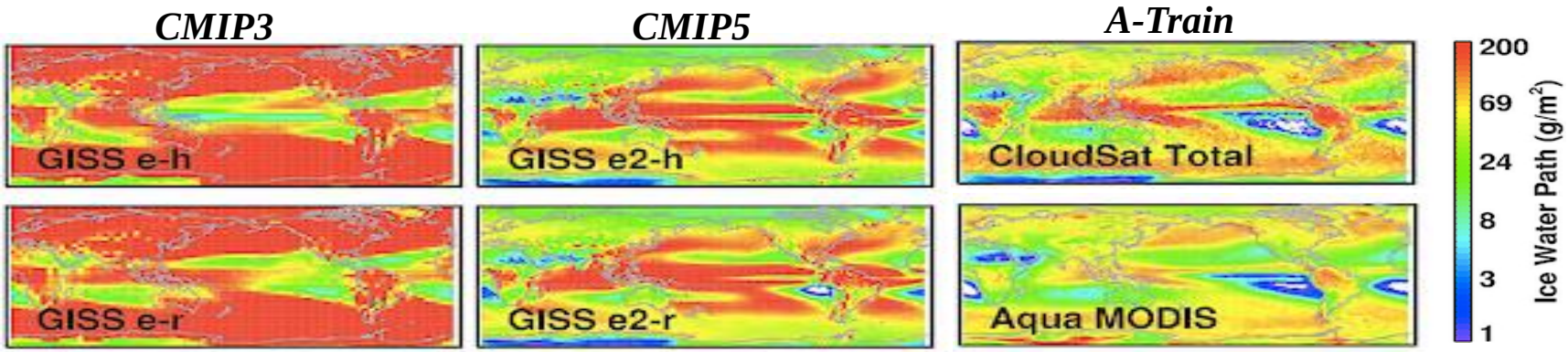


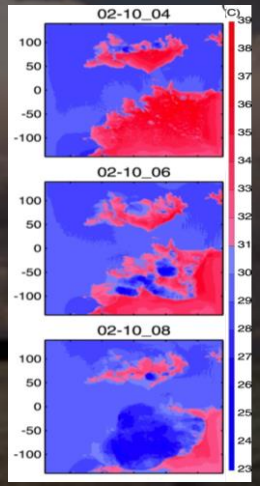
Decrease in IWP in ModelE from CMIP3 to CMIP5, but still near high end of uncertainty limit.

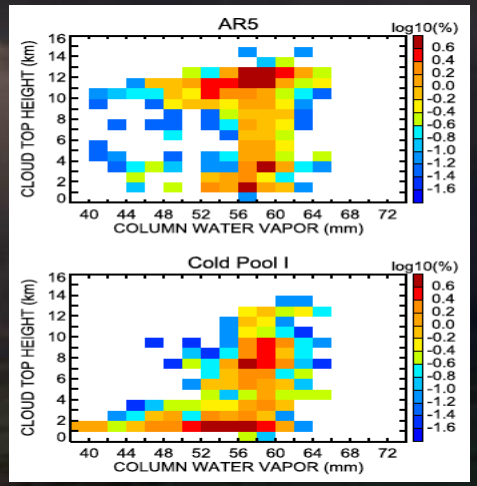
Decreases mostly driven by improvement in higher latitude clouds. It is likely that simulated tropical IWPs are still high.

Cloud Ice Simulation in the Tropics

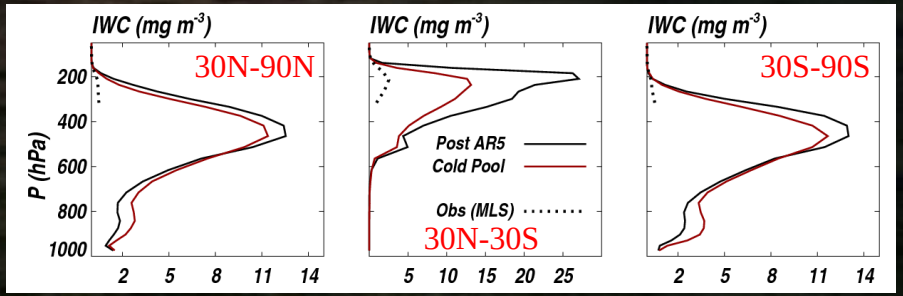
Two recent changes to the GISS convective parameterization.

1. Simple cold pool parameterization (Del Genio et al. 2015).





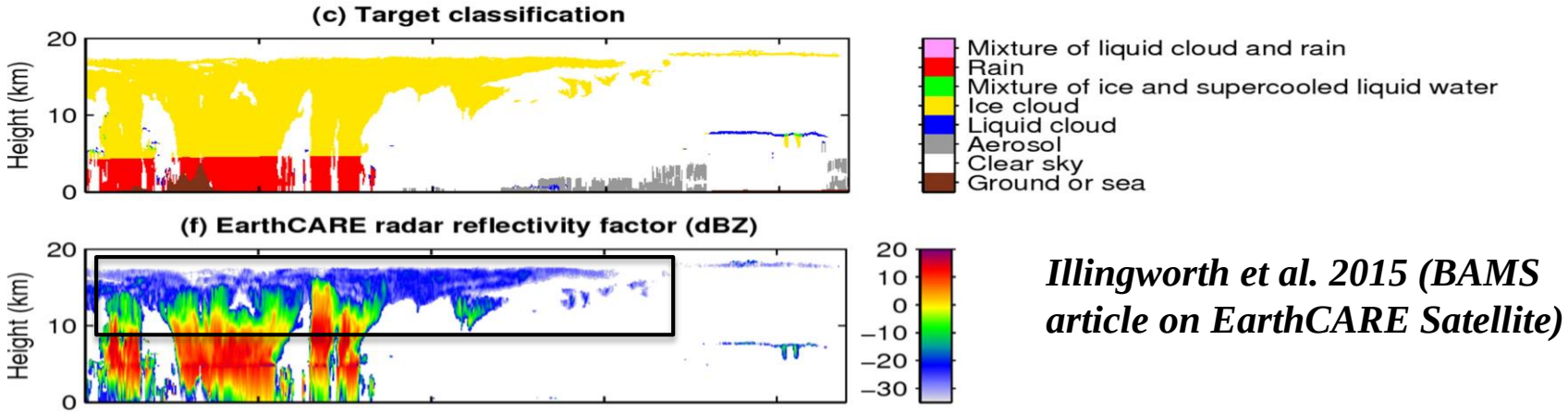
Impact on IWC:
Factor of ~2 decrease
in upper troposphere



Cloud Ice Simulation in the Tropics

Two recent changes to the GISS convective parameterization.

2. Improvements to Convective Ice Microphysics (Elsaesser et al. 2016)



Illingworth et al. 2015 (BAMS article on EarthCARE Satellite)

Previously:

> Exponential PSD Distribution, Fixed N0 and ice density.
> Fixed terminal velocity formulation from Locatelli and Hobbs (1974).

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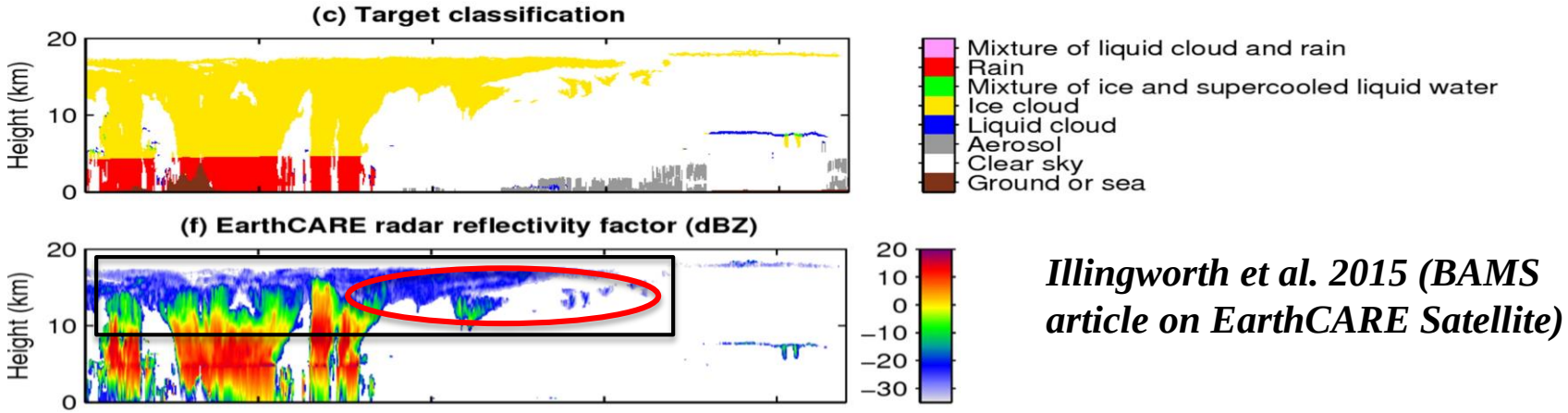

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Aircraft sampling of entire region (deep convective cores and outflow) not possible. What do ice particle size distributions (PSDs) and fall speeds look like in outflow regions?

Field Campaign Data for Cloud Ice PSDs

> Data sources: mass and number concentration distributions from TC4, SPARTICUS, MC3E near convective outflow.

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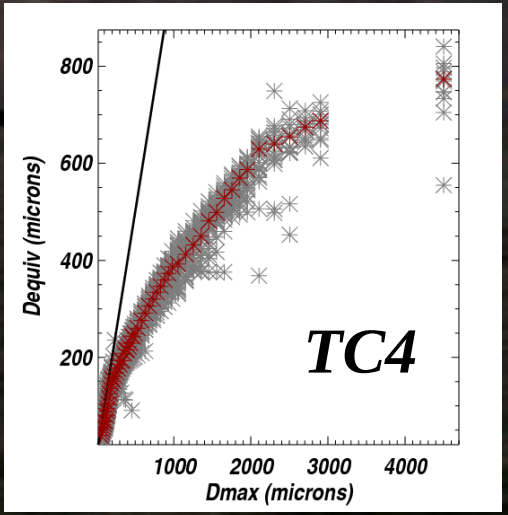

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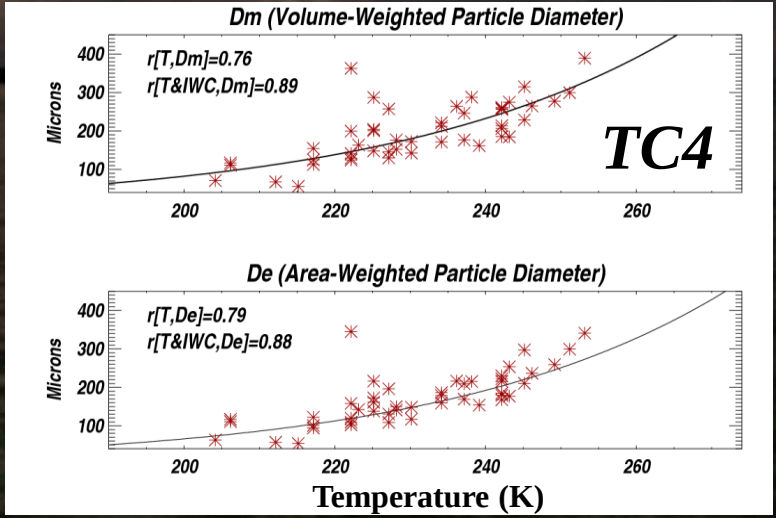


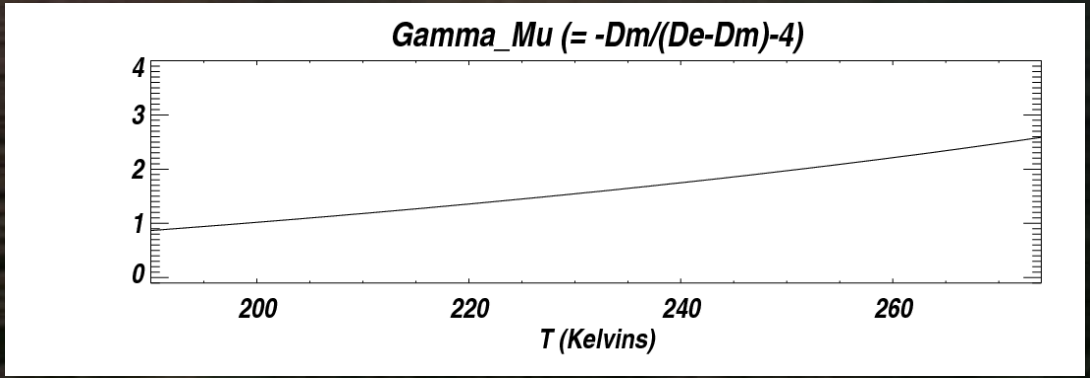
Field Campaign Data for Cloud Ice PSDs

> Data sources: mass and number concentration distributions from TC4, SPARTICUS, MC3E near convective outflow.

> Convert D_{max} to melted-sphere equivalent (D_{equiv}).

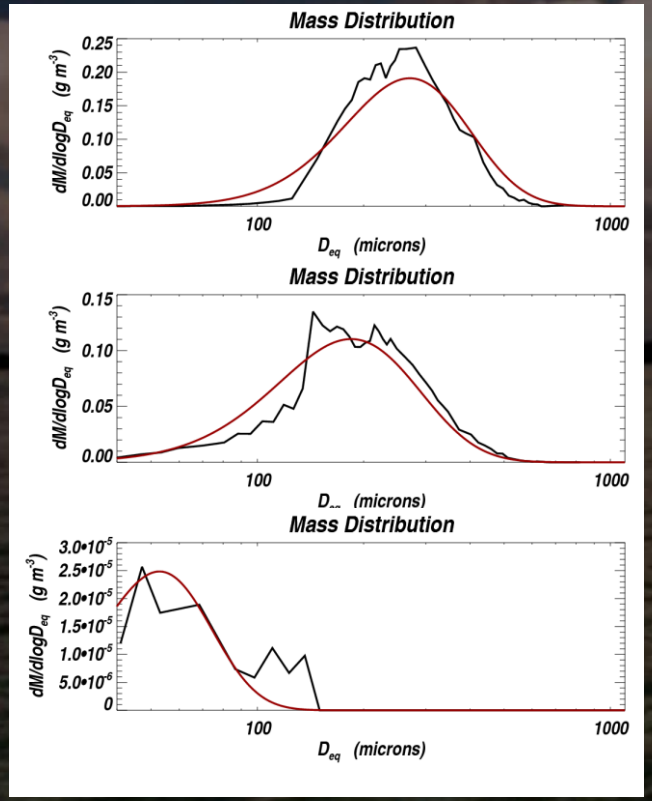
> Compute moments of the PSDs.

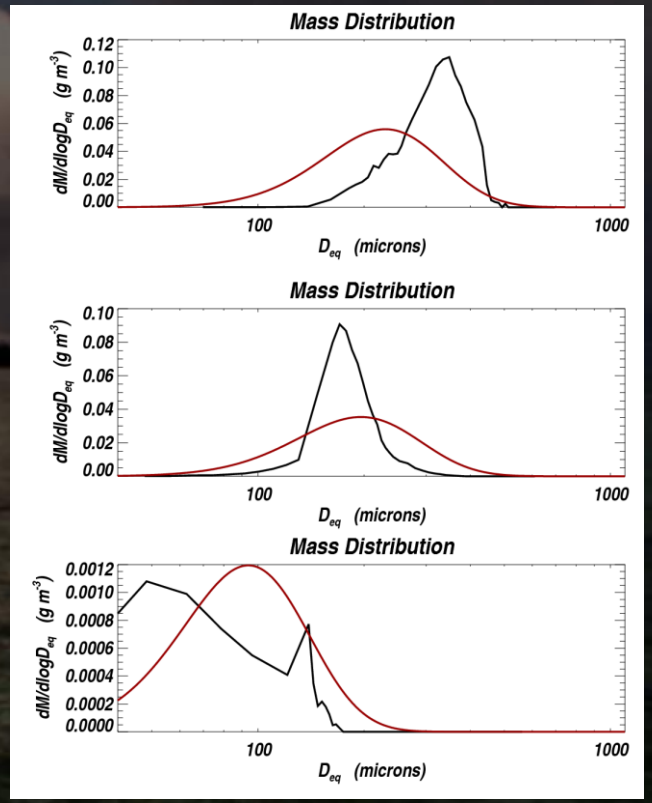
> Assume a Gamma function fit, and use normalization technique of Testud et al. (2002).



Field Campaign Data for Cloud Ice PSDs

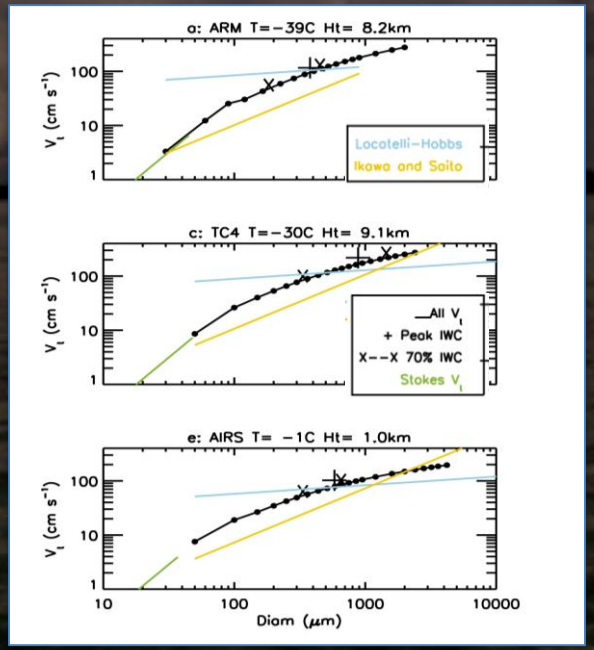
Key point: Dm, De, Temp, and IWC in convective plume are used to diagnose the mass distribution. Example fits below:

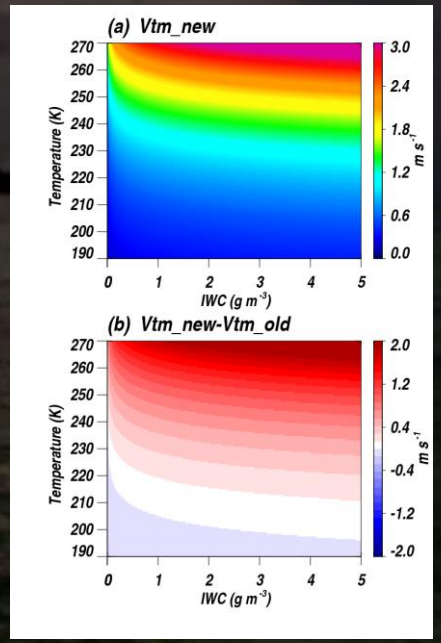




Field Campaign Data for Cloud Ice V_t Formulations

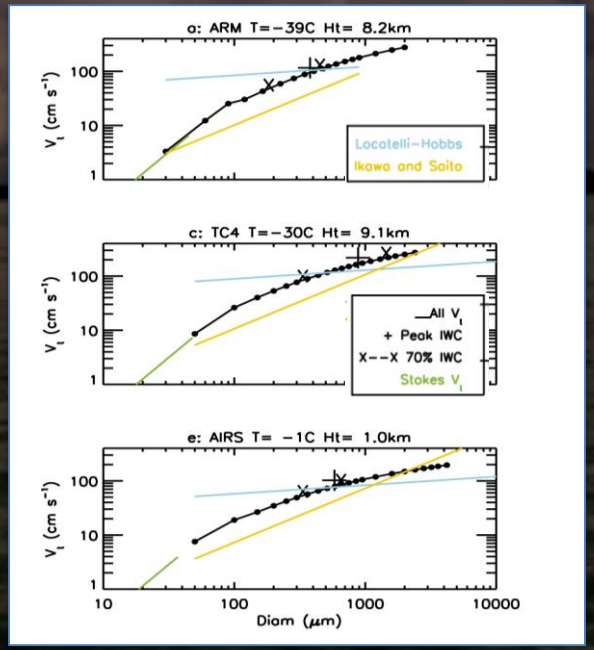
> Before conversion of D_{max} to D_{equiv} , we compute ice mass sedimentation velocities (using Heymsfield et al. 2013 formulations).

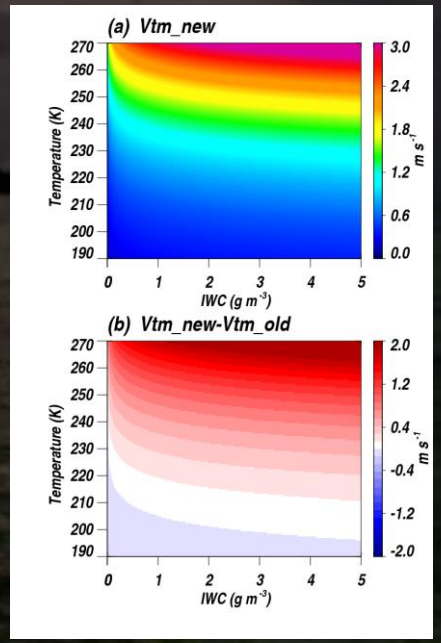




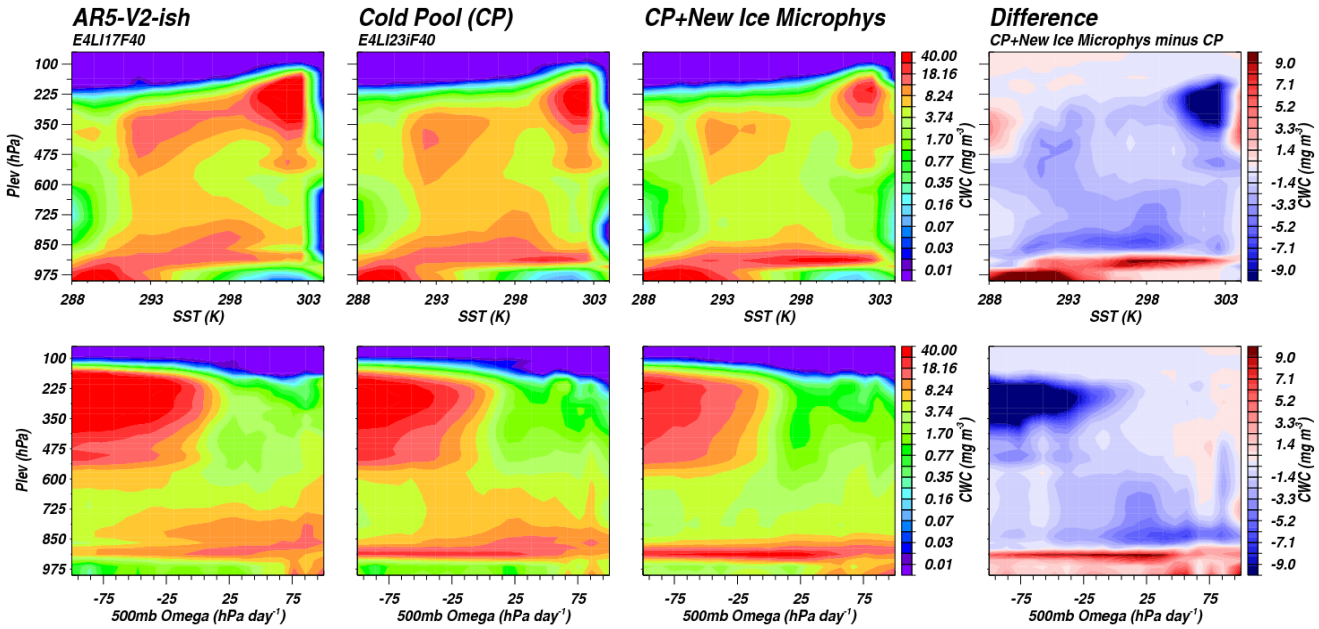
Field Campaign Data for Cloud Ice V_t Formulations

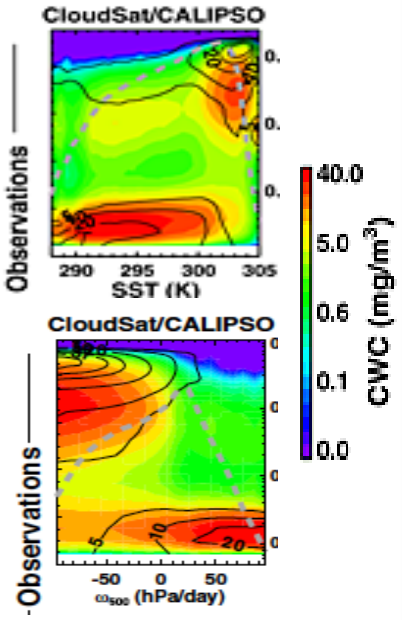
> Tricky part: Given the mass distribution, convective plume updraft velocity and ice sedimentation velocity, go back to find D_{equiv} threshold that serves to partition snow from detrained or lofted ice.





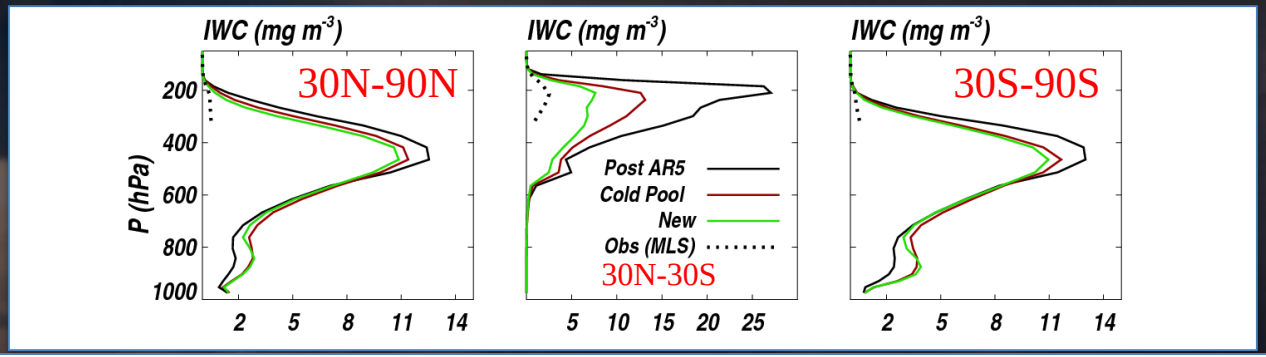
Impacts on Simulated Cloud Ice: Conditional Sampling

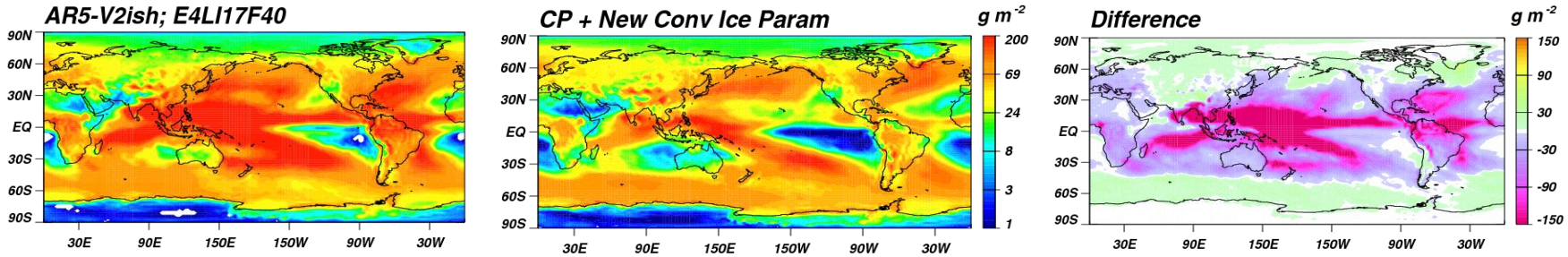


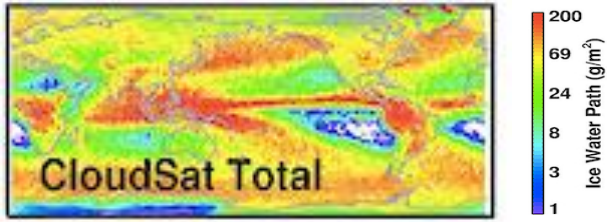


Su et al. (2013, JGR)

Impacts on Simulated Cloud Ice: Mean State







Jiang et al. (2012, JGR)

Conclusions

- We now inform our convective ice microphysics routine with field campaign data. Work will continue to incorporate new observational datasets as they become available.

- Both the cold pool parameterization and ice microphysics reduce IWC (global IWP goes from ~100 g/m2 in post-AR5 runs, to ~70-80 g/m2 in cold pool runs, to ~50-60 g/m2 when convective ice microphysics changes).

- Our dense ice/graupel species is unconstrained. What we assume affects how much ice is lofted to higher levels where we then make the snow/cloud ice partition. Future work may include addressing this.