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

Greg Elsaesser, Columbia University/NASA GISS

Anthony Del Genio, NASA GISS

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Decrease in IWP in ModelE from CMIP3 to CMIP5, but still near high end of uncertainty limit.
Over-Production of Cloud Ice in GISS ModelE

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

Image courtesy of NASA/GSFC/LaRC/JPL MISR Team
Cloud Ice Simulation in the Tropics

Two recent changes to the GISS convective parameterization.

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

Previously:

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

Illingworth et al. 2015 (BAMS article on EarthCARE Satellite)
Two recent changes to the GISS convective parameterization.

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

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?

Illingworth et al. 2015 (BAMS article on EarthCARE Satellite)
Field Campaign Data for Cloud Ice PSDs

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- Convert $D_{\text{max}}$ to melted-sphere equivalent ($D_{\text{equiv}}$).
- 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:
> Before conversion of $D_{\text{max}}$ to $D_{\text{equiv}}$, we compute ice mass sedimentation velocities (using Heymsfield et al. 2013 formulations).
> Tricky part: Given the mass distribution, convective plume updraft velocity and ice sedimentation velocity, go back to find $D_{\text{equiv}}$ 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.