Towards the next generation GFDL global atmospheric model

Presented by

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Geophysical Fluid Dynamics Laboratory Review

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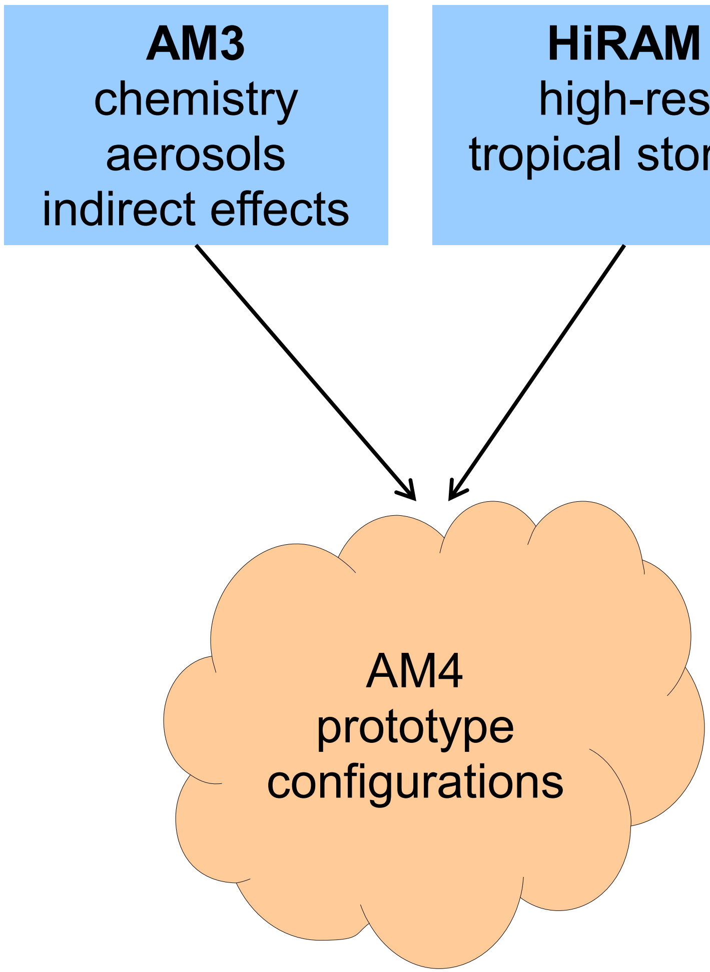
Atmosphere Working Group (AWG): first 18 months



Initial steps

- Resolution: 50 and 100 km (HiRAM)
- Aerosol cloud interactions (AM3)
- Simplified chemistry (P. Ginoux, new)
- New convection options
  - Double-plume (new)
  - Donner deep and UW shallow
- AMIP and short coupled simulations

Possible future steps

- Updated microphysics
- Unified large-scale cloud, turbulence

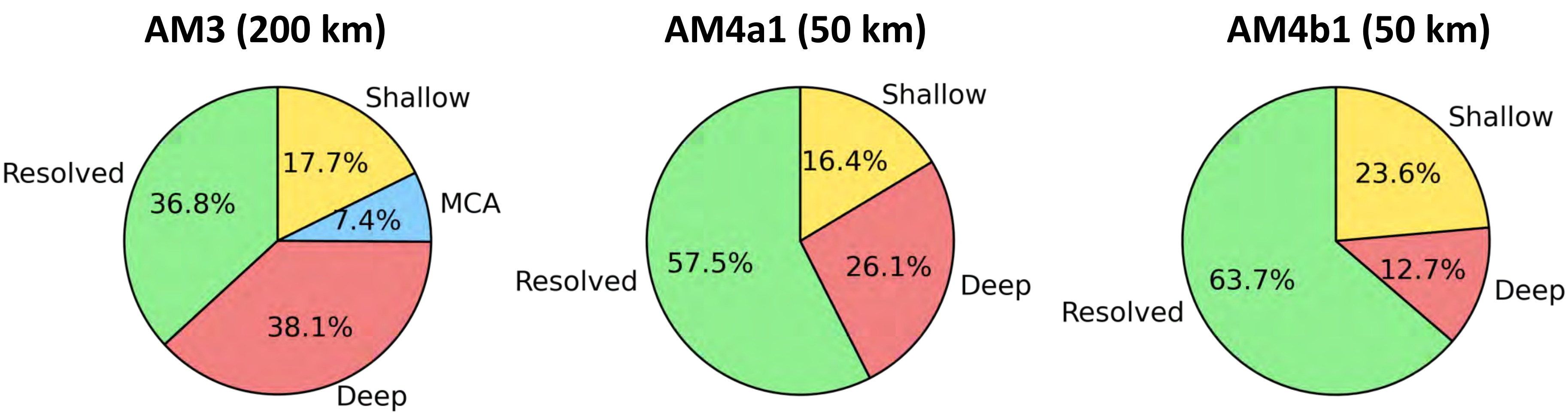
AM4 prototype configurations

- **Convective parameterization is key difference between AM4 prototype configurations**

AM4a1: "double-plume"
- Shallow plume (UW)
- Deep plume (single plume)

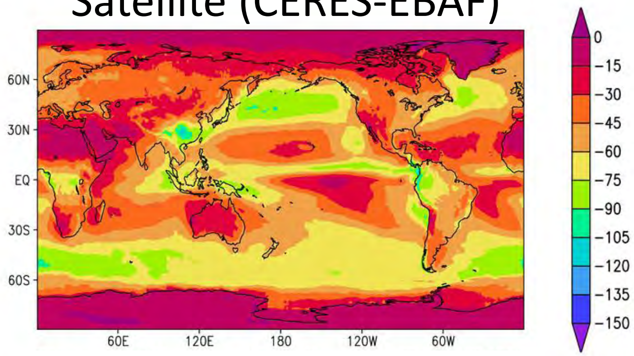
AM4b1: "alternate closure"
- Shallow plume (UW)
- Donner deep (seven plumes)
- Closure based on Benedict et al. (2013)

- **Where is the precipitation coming from?**



Cloud radiative effects: shortwave

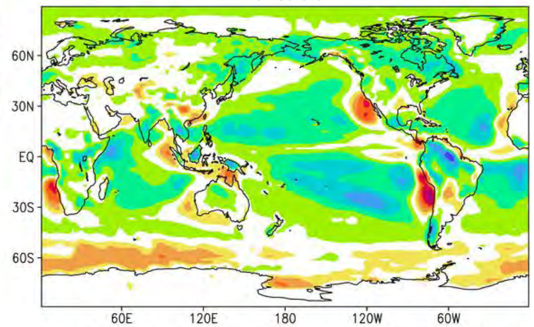
Satellite (CERES-EBAF)



mean = -47.1 W m^{-2}

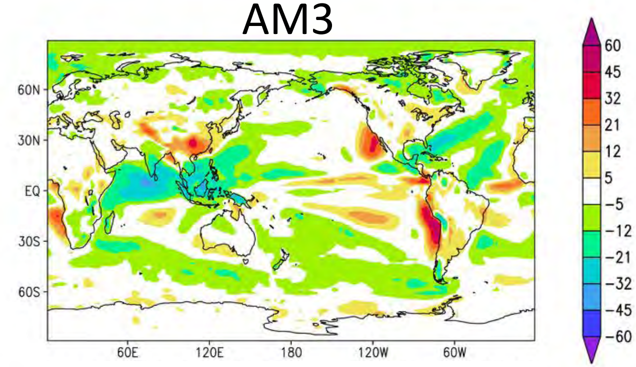
Model - Observations

AM2



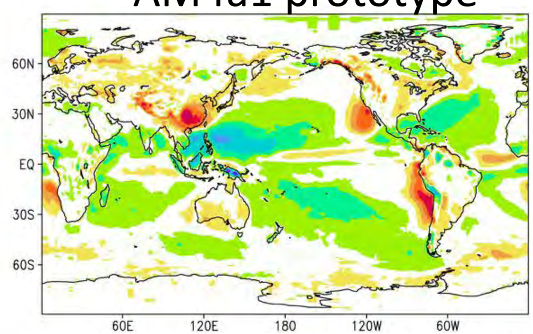
bias = -6.38; corr = 0.86; rms = 13.0

AM3



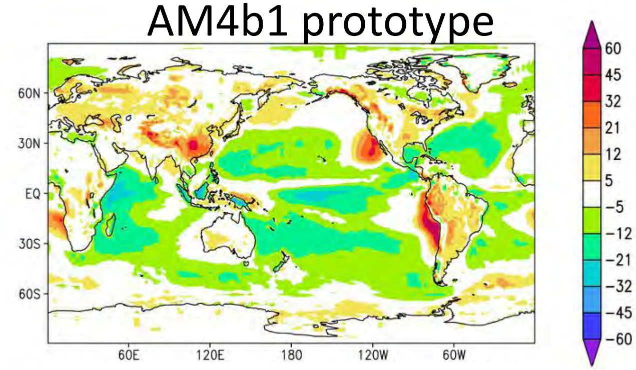
bias = -2.13; corr = 0.91; rms = 9.4

AM4a1 prototype



bias = -1.74; corr = 0.91; rms = 9.2

AM4b1 prototype

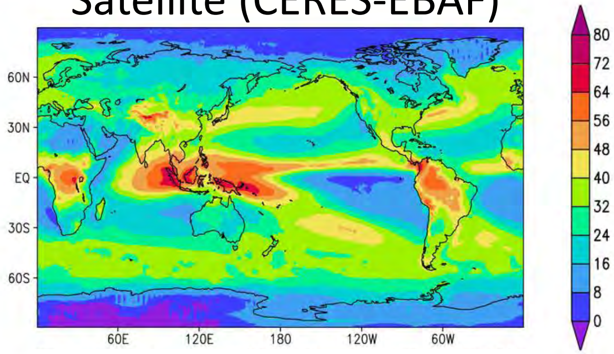


bias = -2.40; corr = 0.90; rms = 9.7

Courtesy Charles Seman

Cloud radiative effects: longwave

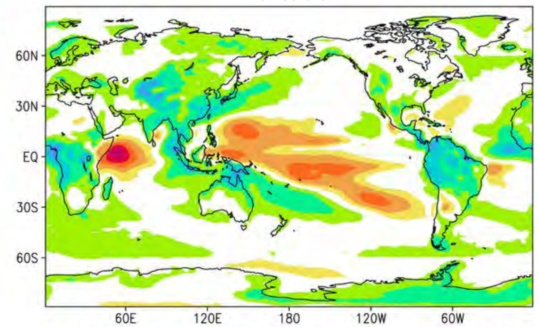
Satellite (CERES-EBAF)



mean = 29.8 W m^{-2}

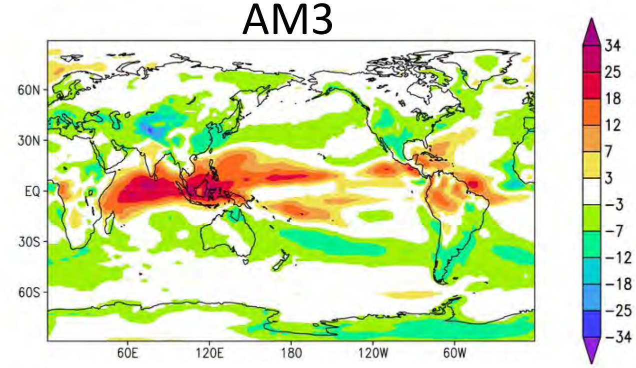
Model - Observations

AM2



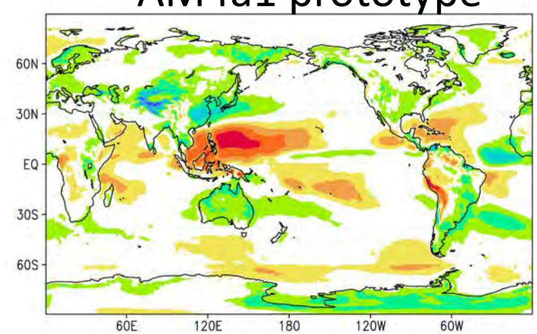
bias = -1.81; corr = 0.86; rms = 6.28

AM3



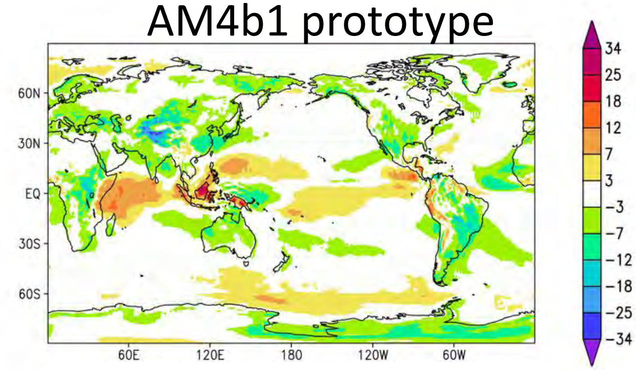
bias = -0.27; corr = 0.90; rms = 6.66

AM4a1 prototype



bias = 0.09; corr = 0.92; rms = 5.06

AM4b1 prototype

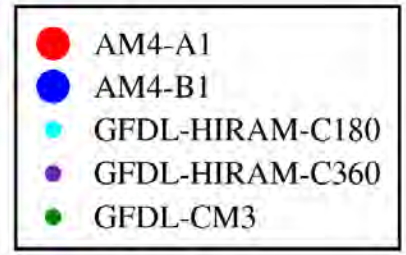


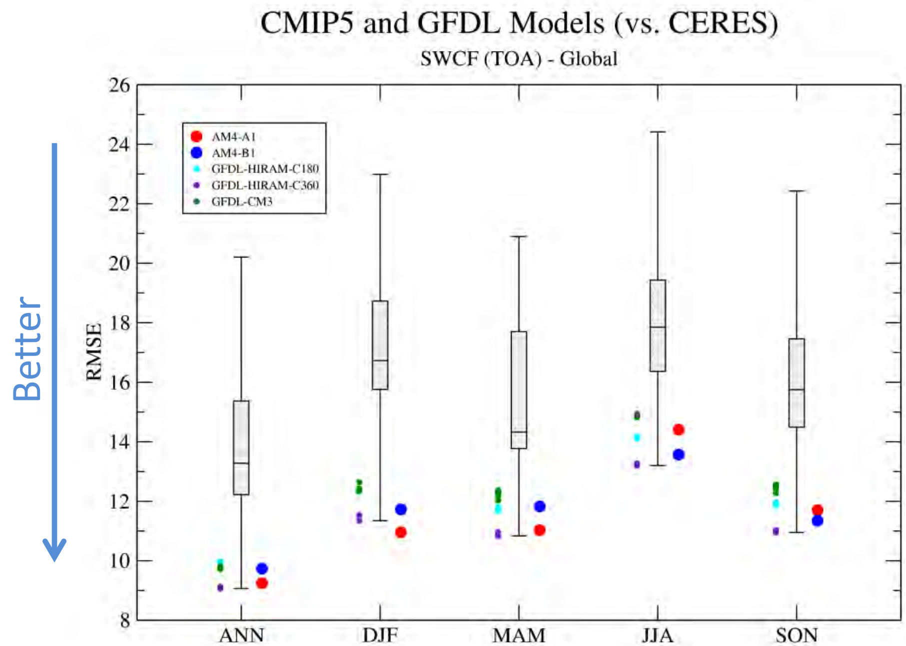
bias = -0.70; corr = 0.93; rms = 4.37

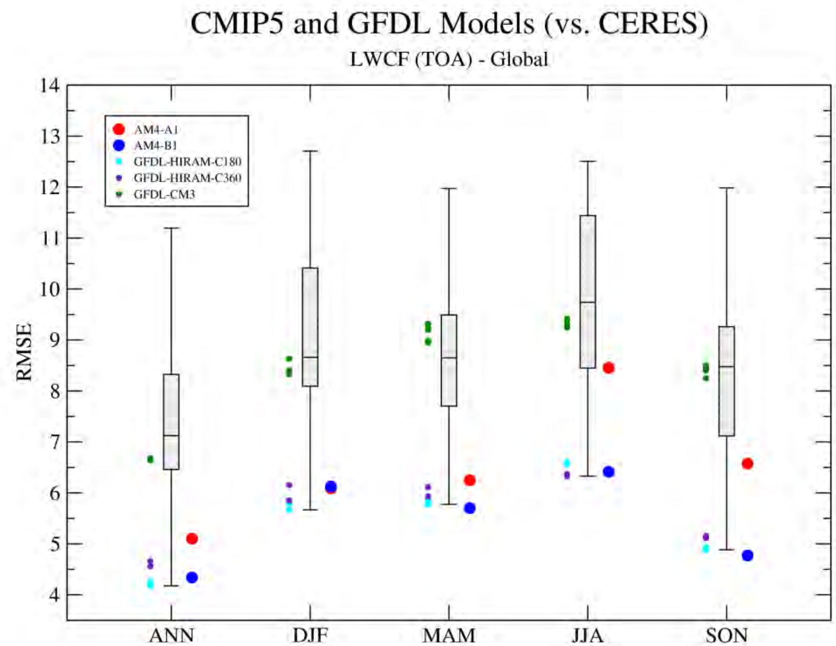
Courtesy Charles Seman

Comparison with CMIP5 models (AMIP)

Cloud radiative effects root mean square error (RMSE)







27 CMIP5 models, 84 realizations
(min, 25%, median, 75%, max)
Courtesy Bruce Wyman

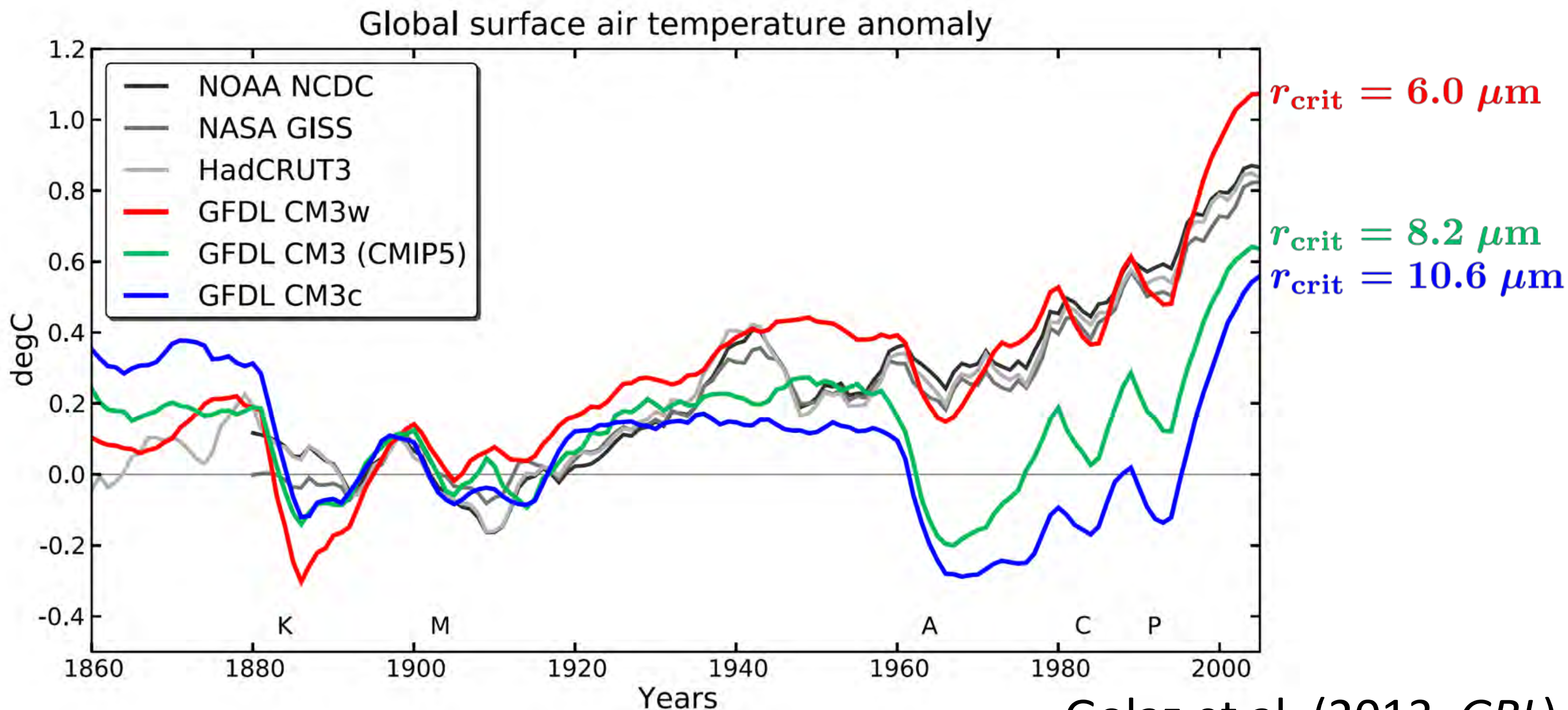
Balancing constraints

- Model development requires balancing a multiplicity of constraints

- Top-down constraints
  - Fidelity of simulation
- Bottom-up constraints
  - Fidelity of process level representation

Indirect effect and 20th century warming
Top-down constraint

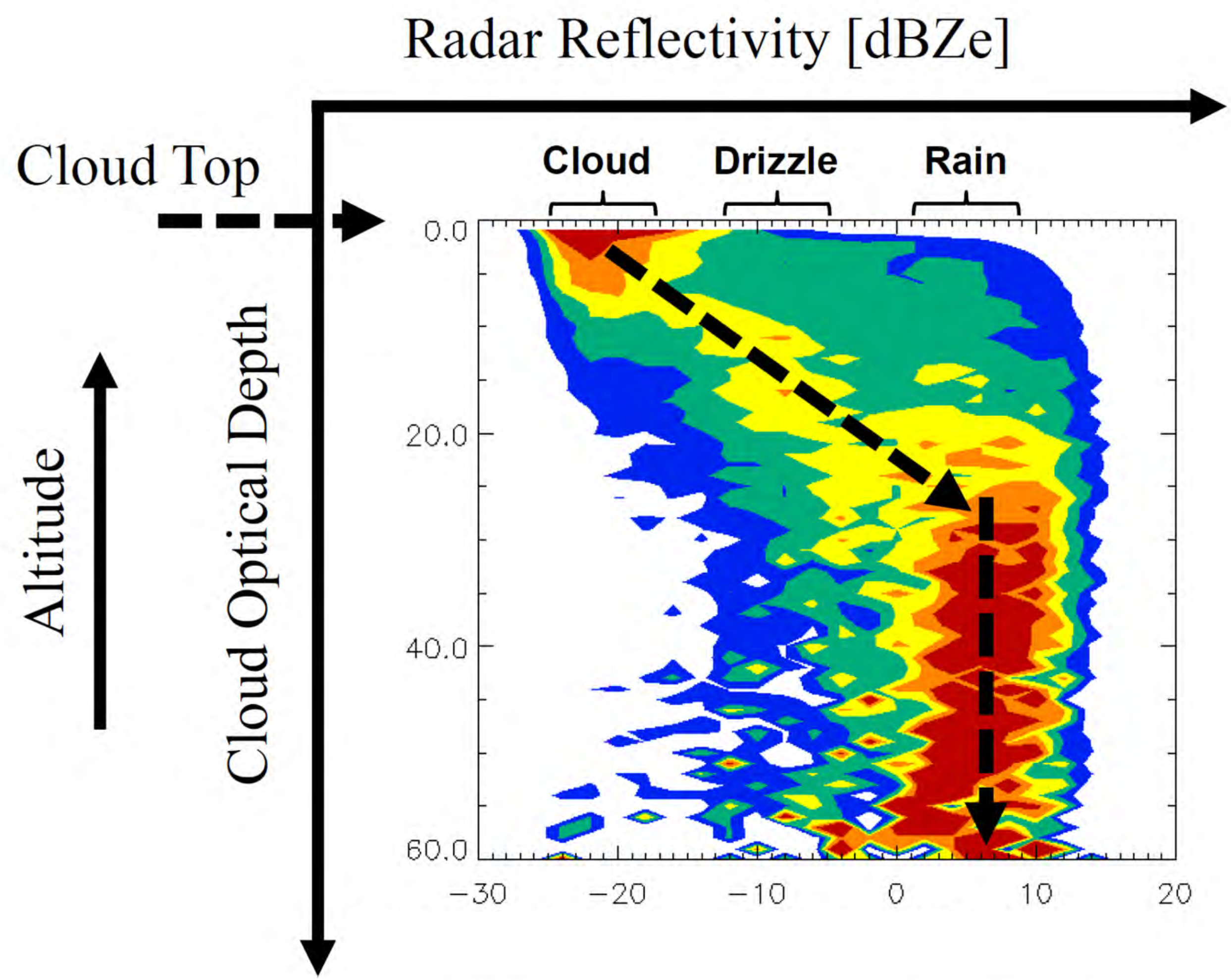
CM3 is the first GFDL model with aerosol cloud indirect effect



Golaz et al. (2013, *GRL*)

- Details of warm rain formation have large impact on magnitude of aerosol cloud indirect effect.
- 20th century warming strongly impacted by indirect effect.

Microphysical cross section



Courtesy Kentaro Suzuki

Nakajima et al. (2010); Suzuki et al. (2010)

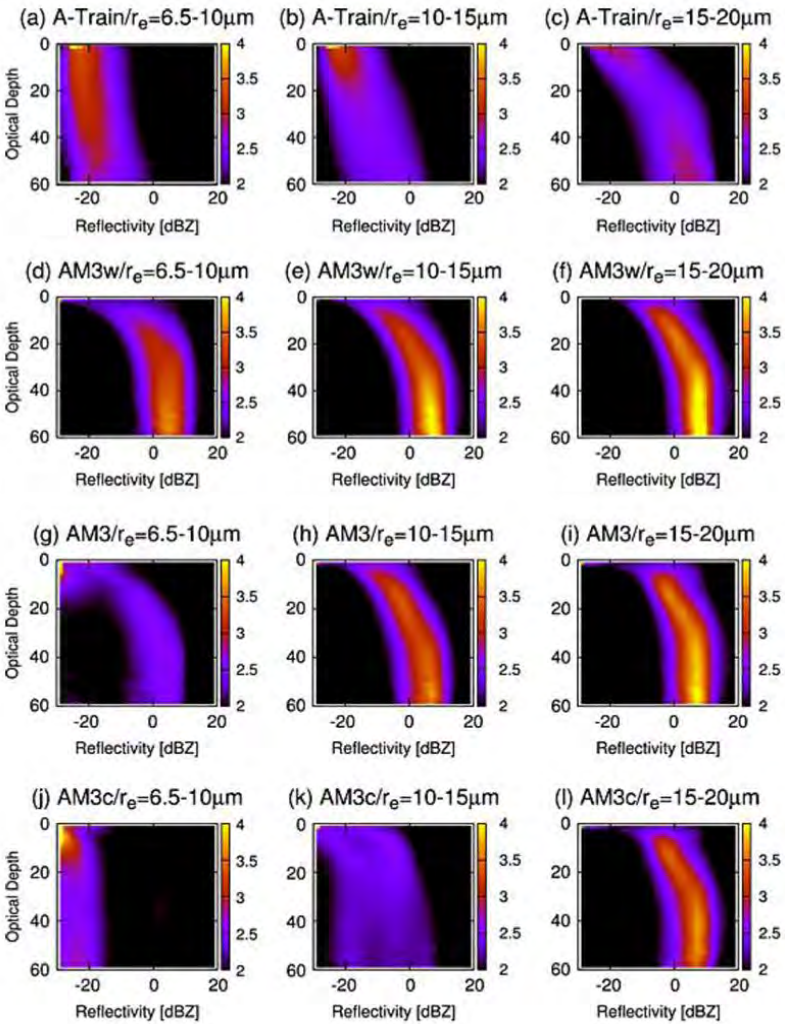
Comparisons of microphysical "fingerprints"
Bottom-up constraint

A-Train

CM3w
r_{crit}=6.0μm

CM3
r_{crit}=8.2μm

CM3c
r_{crit}=10.6μm



Transition from non-precip to precip in the real atmosphere

Always precipitating: least realistic

Always precipitating w/ hint of non-precip branch

Transition from non-precip to precip: most realistic

Suzuki, Golaz, Stephens (2013, *GRL*)

Summary and future steps

- AM4 prototype configurations
  - Consolidation of AM3 and HiRAM.
  - New convection options.
  - Quality of simulations to-date is very encouraging.
- Future steps
  - Micro-physics (e.g. double moment, prognostic precipitation, aerosol-ice interactions, ice crystal shape).
  - Unified large-scale cloud, turbulence (e.g. CLUBB or simplified PDF methods).
- Need to balance a multiplicity of constraints.