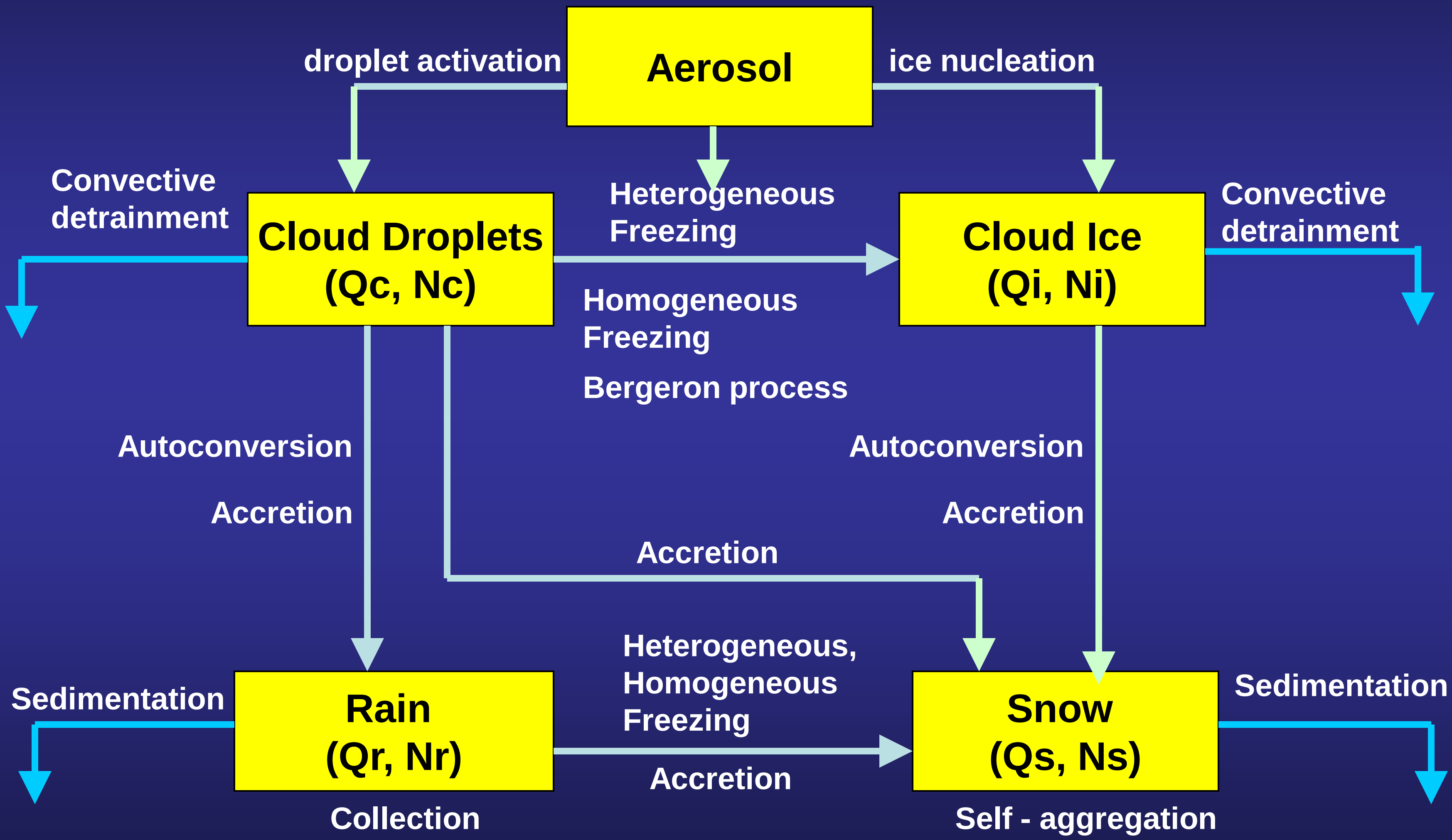
An update on Convective Microphysics Parameterization in the Zhang-McFarlane Scheme in NCAR CAM5

Guang J. Zhang and Xiaoliang Song
Scripps Institution of Oceanography,
La Jolla, CA 92093-0221

The Scheme

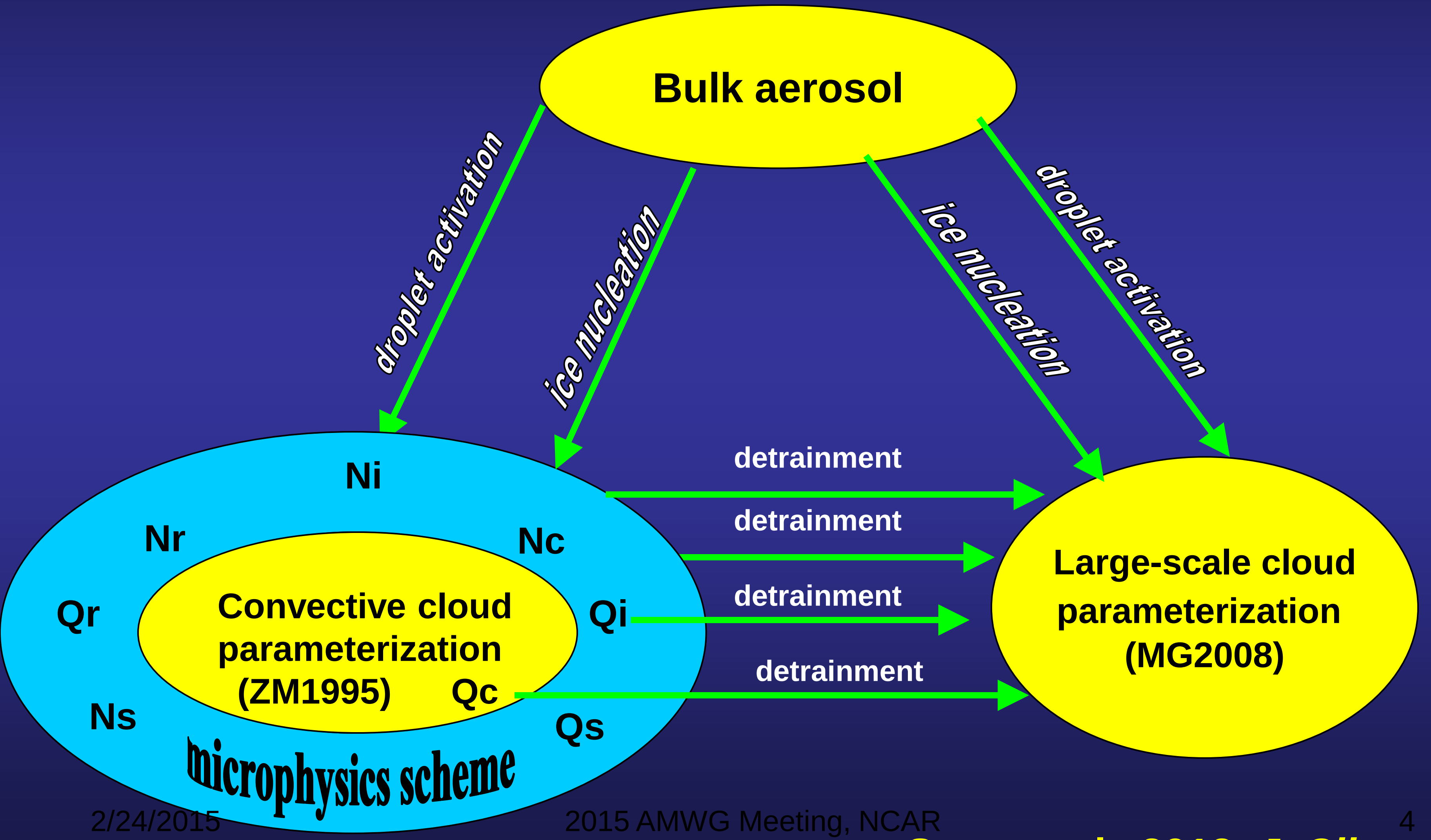
- Two-moment (mass and number concentration), 4-species (ice, liquid water, snow and rain)
- Based on the Morrison-Gettelman microphysics scheme for large-scale clouds, with heavy modifications to fit convective clouds
- No subgrid variability is considered
- Ice nucleation of Liu and Penner (2005), Liu et al. (2007), dependent on vertical velocity and nuclei number
- Contact freezing and Immersion freezing both depending on aerosol number
- Bergeron-Findeisen process: liquid water becomes ice in one time step if IWC > 0.5 mg/kg in mixed phase regime
- Updraft velocity considered in rain and snow budget equations in addition to terminal velocities
- All equations are diagnostic, same as for other thermodynamic fields in a steady-state 1-D cloud model

Two-moment microphysics scheme for convective clouds



Song and Zhang, 2011, *J. Geophys. Res.*

Implementation of the microphysics scheme in the CAM5



Song et al. 2012, *J. Climate*

New improvements

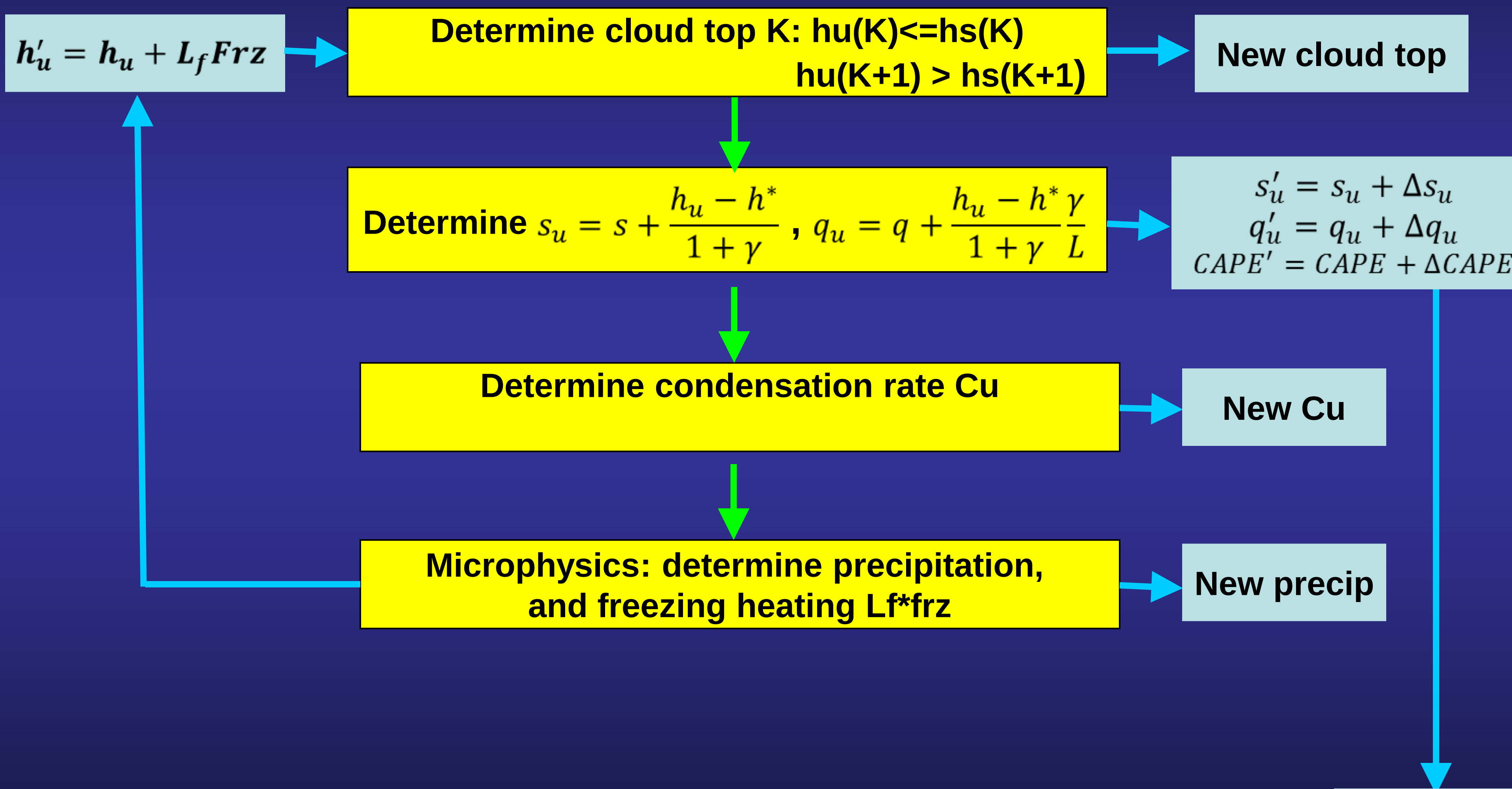
- Coupling of convective microphysics with cumulus thermodynamics (CAM5.0)
- Coupling of convective microphysics with prognostic chemistry package (CAM5.3)

Impacts of freezing heating on cumulus thermodynamics

- Influences updraft temperature, saturation specific humidity, relative humidity, condensation, and water vapor.
- Influences buoyancy, CAPE and convection intensity
- Influences altitude of convective cloud top

Key process representing the aerosol impact on convection

Representing the impact of freezing heating: A 2-step iteration



Experiments

- Three 6-yr CAM5 simulations are conducted:

  CTL: standard CAM5

  MPHY: with convective microphysics (Song et al.2012)

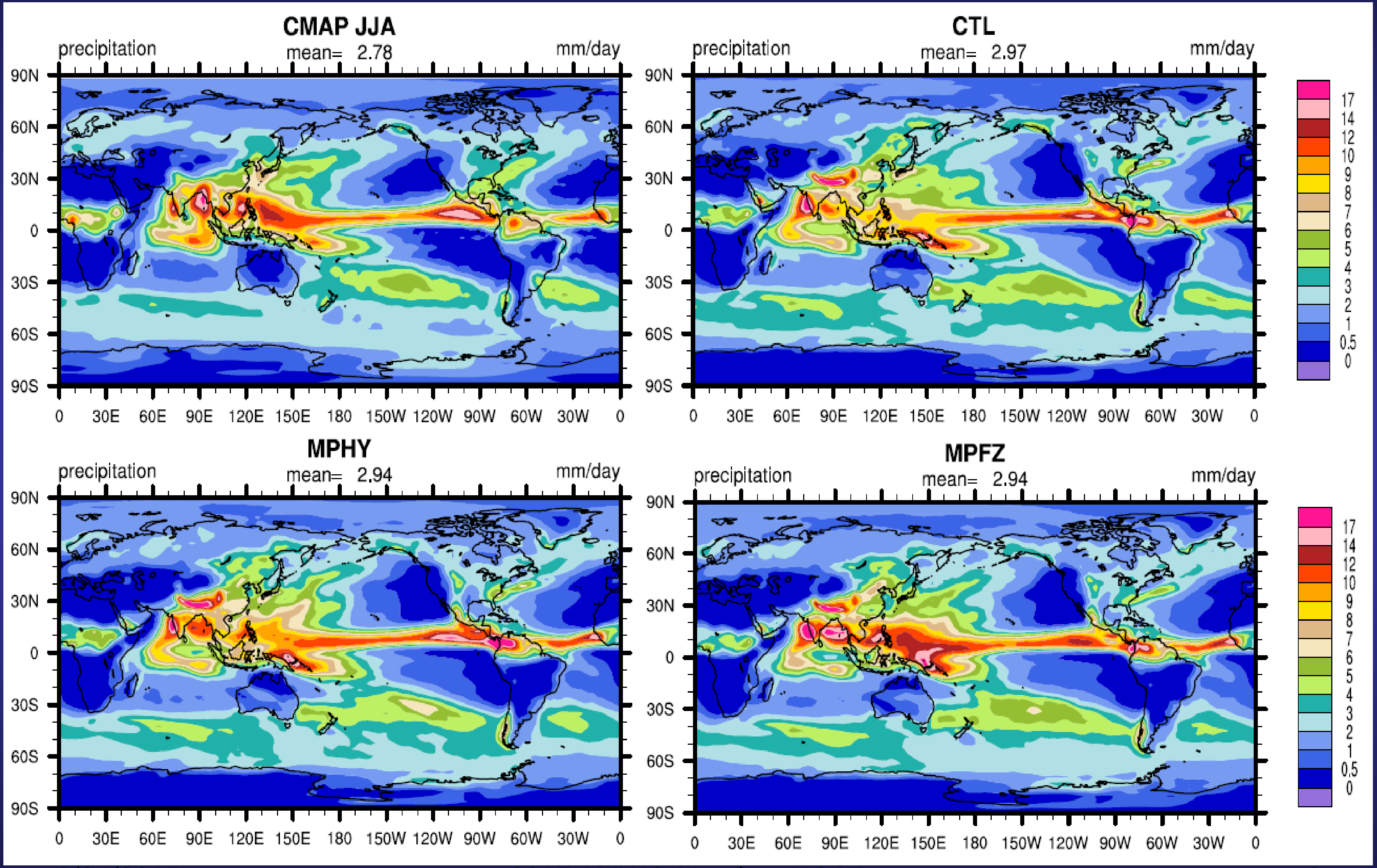
  MPFZ: same as **MPHY** but considers the impact of freezing heating on updraft thermodynamics

  Results from the last 5-year simulations are presented here

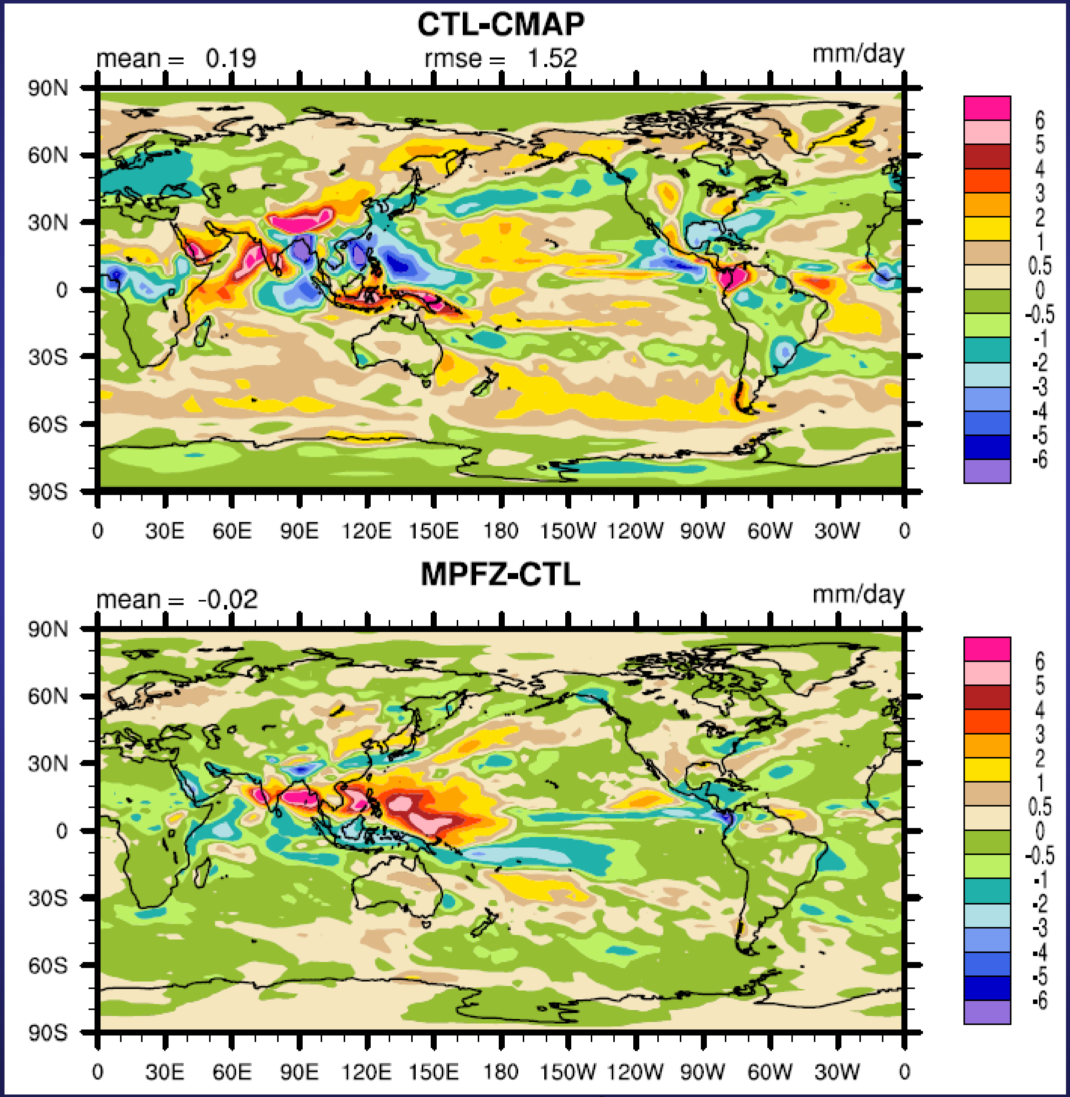
- Resolution: 1.9° X 2.5° , 30 levels

- Forcing: climatological aerosol and SST data.

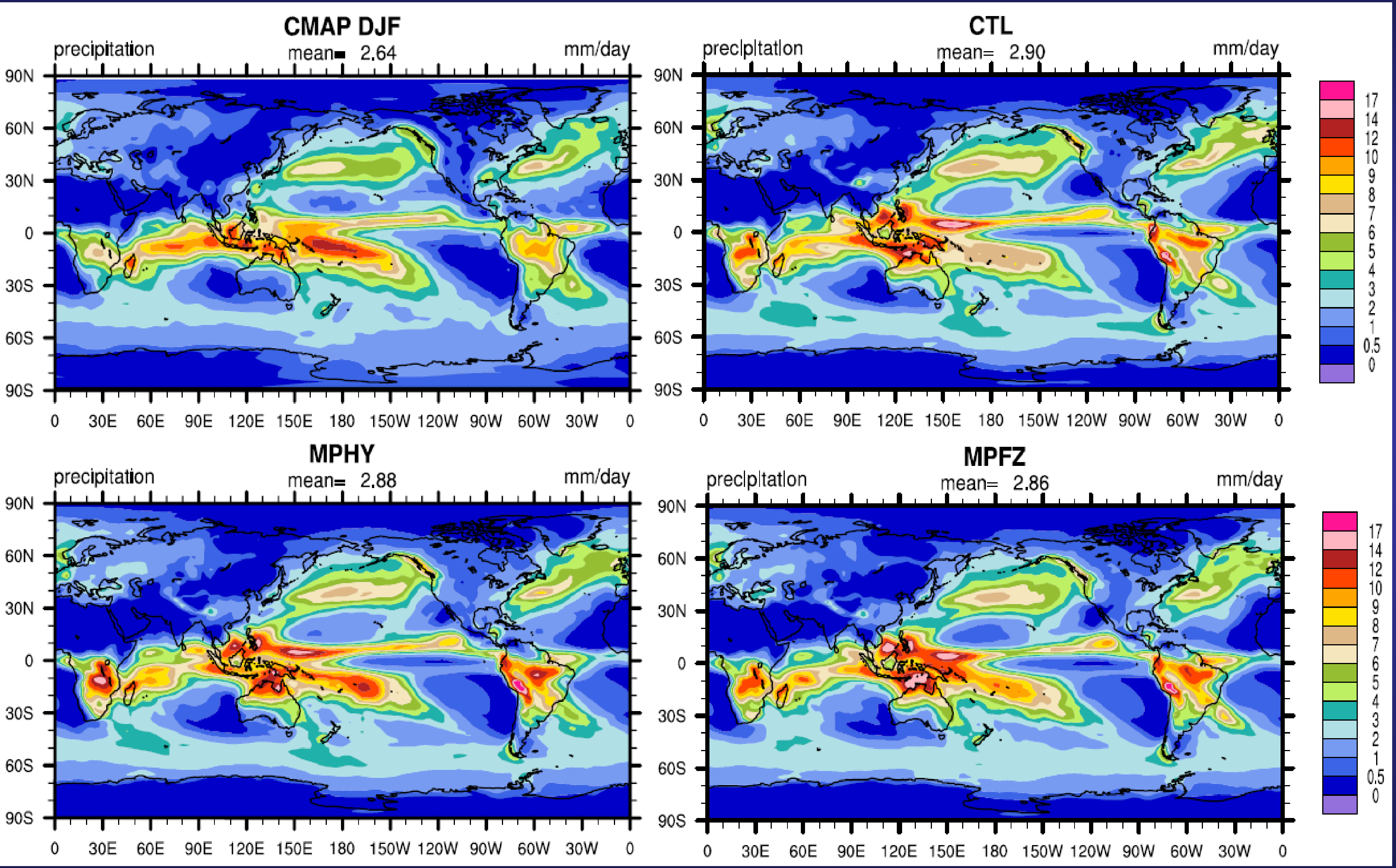
Precipitation simulation JJA



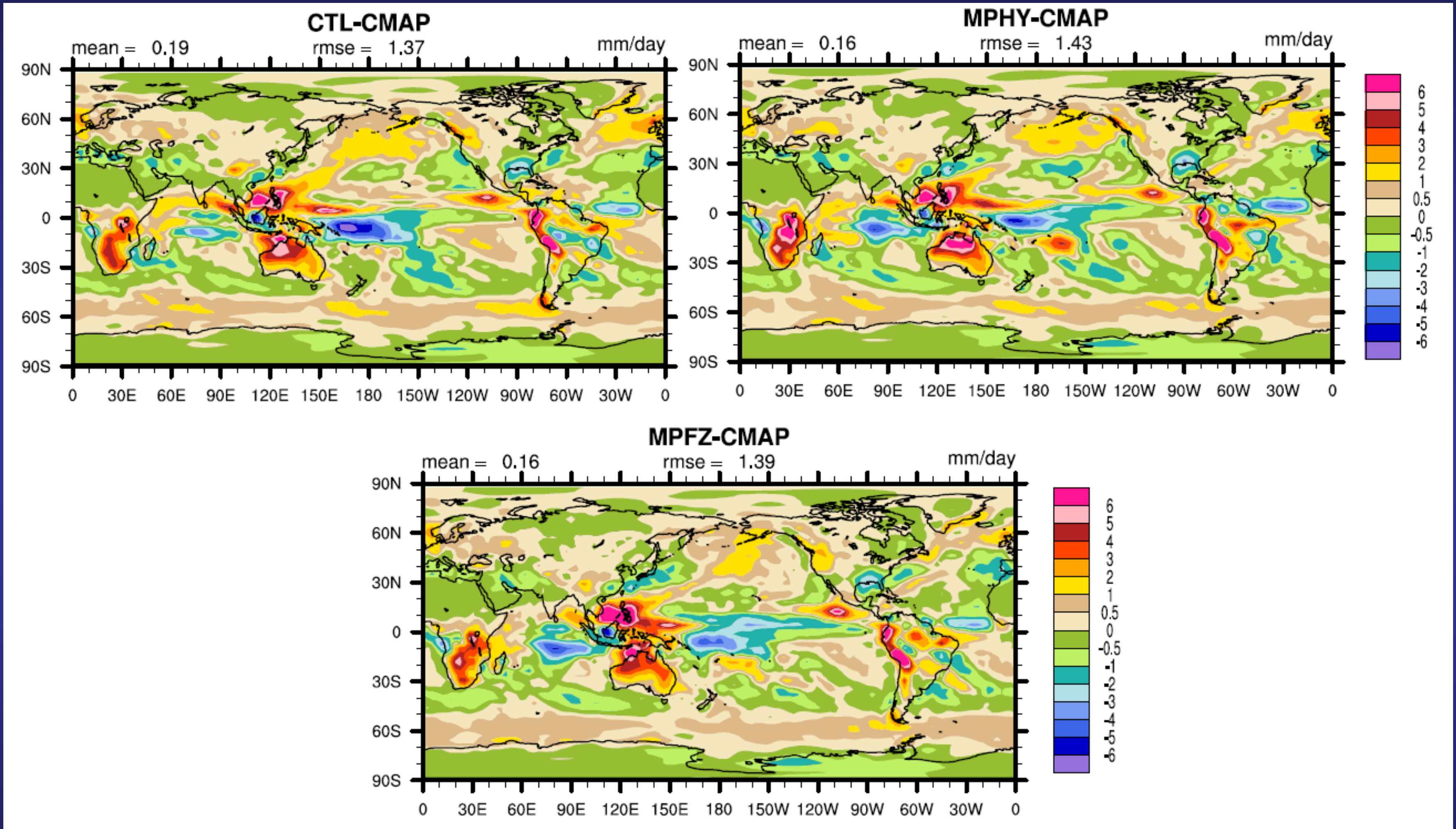
Precipitation simulation JJA



Precipitation simulation DJF

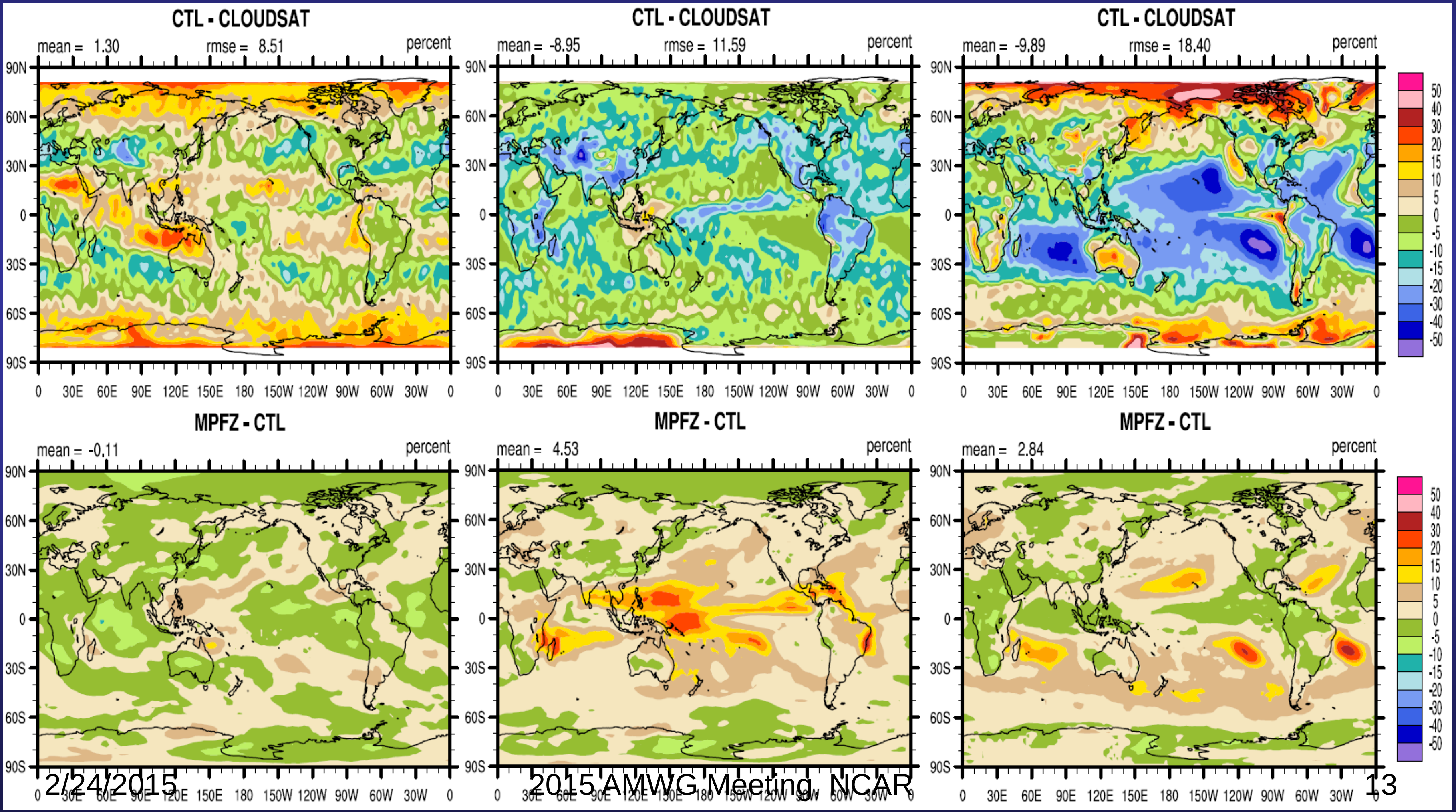


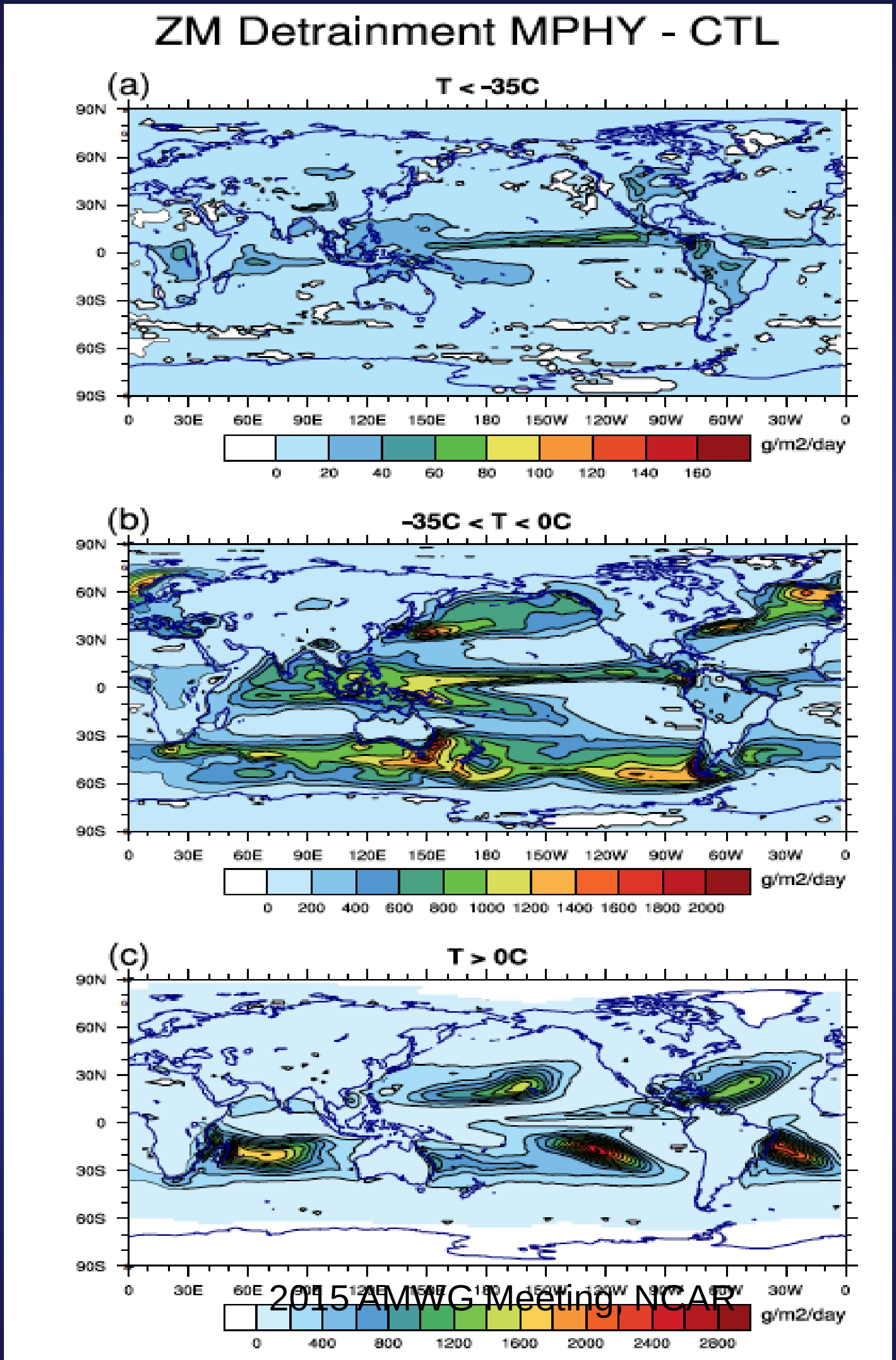
Precipitation simulation   DJF



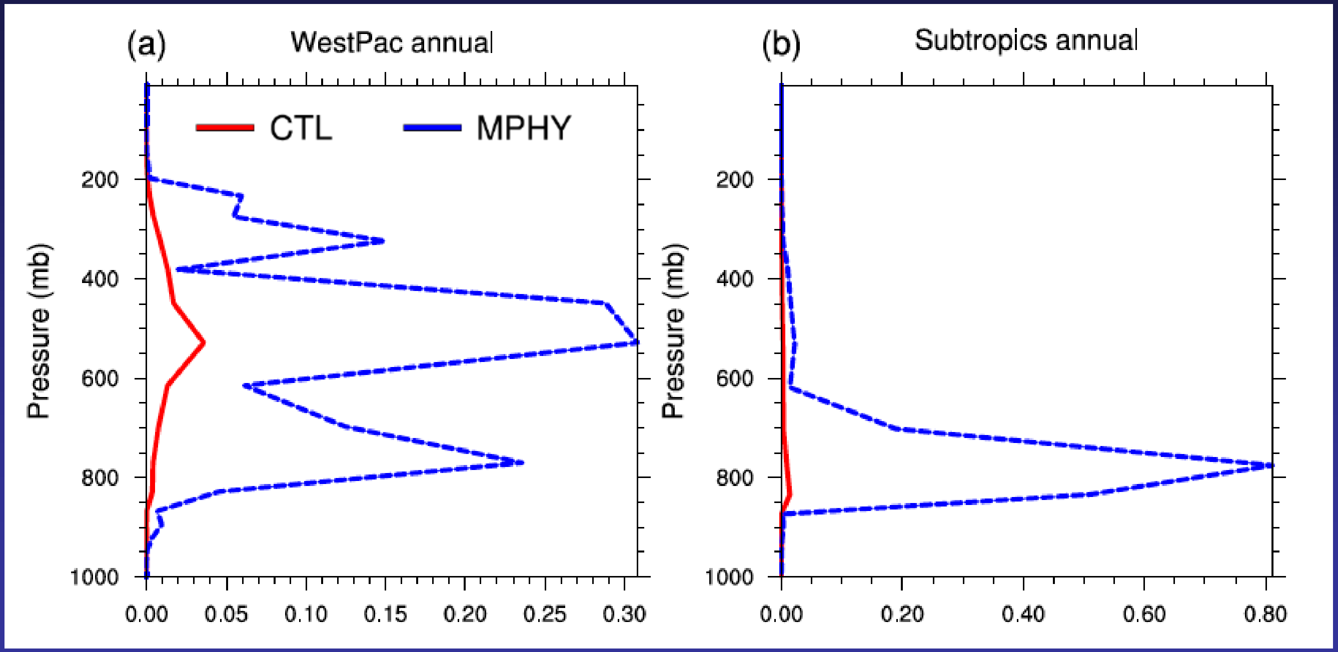
Cloud fraction

High-level | **Mid-level** | **Low-level**

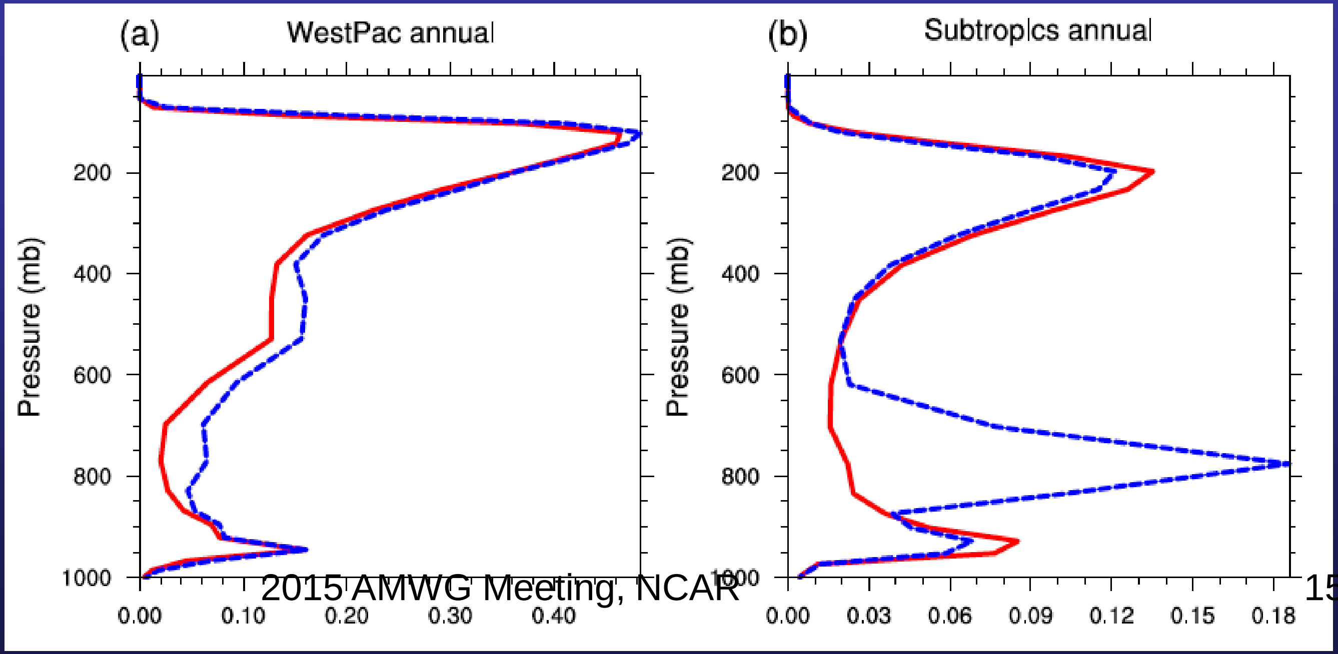



ZM Detrainment MPHY - CTL
(a)
T < -35C
g/m2/day
0 20 40 60 80 100 120 140 160
(b)
-35C < T < 0C
g/m2/day
0 200 400 600 800 1000 1200 1400 1600 1800 2000
(c)
T > 0C
g/m2/day
0 400 800 1200 1600 2000 2400 2800
90N 60N 30N 0 30S 60S 90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0

Detraintment
of cloud water/ice



Cloud fraction



Aerosol effects on deep convection

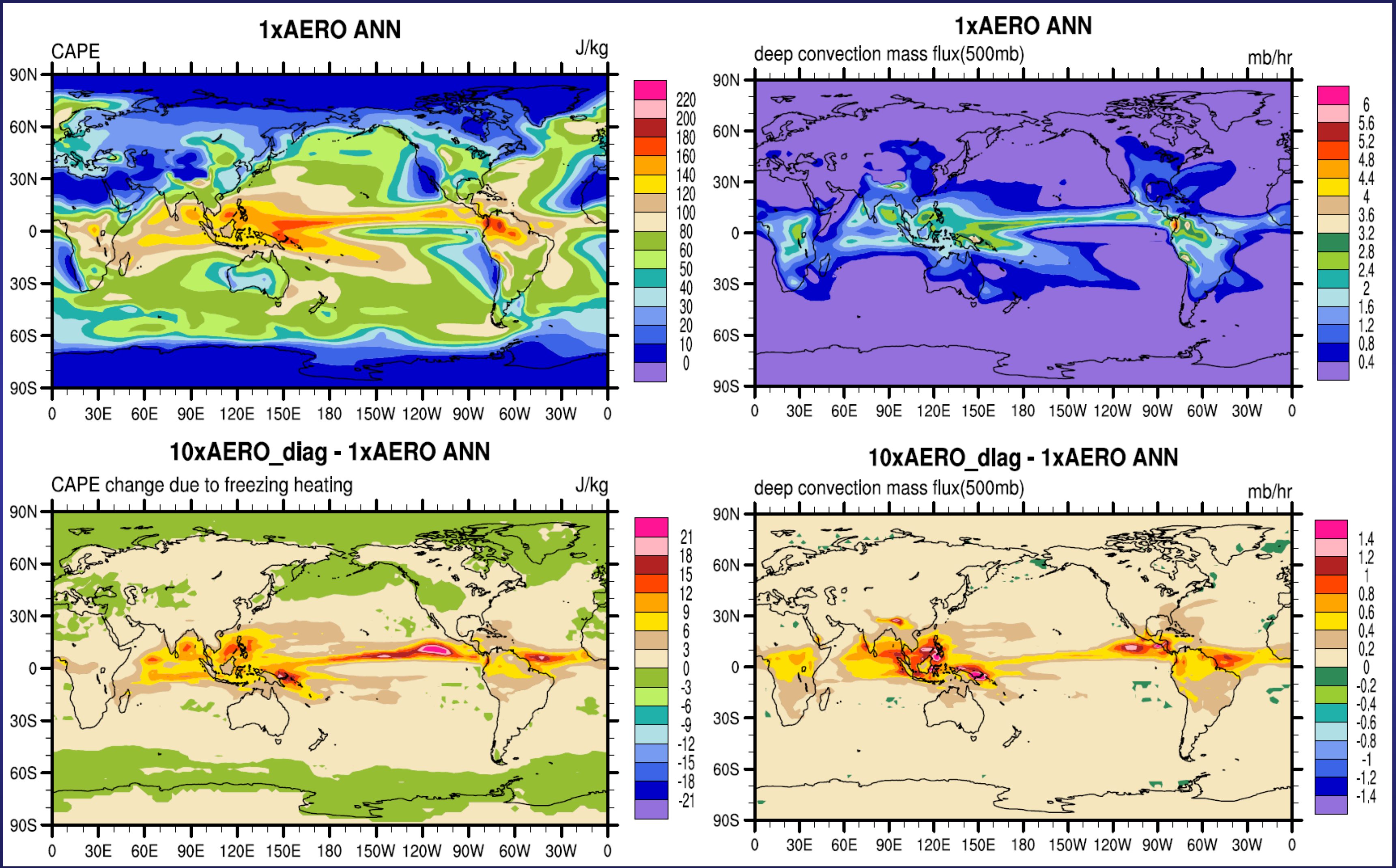
- **10xAerosol diagnostic experiment**

  Same as the **MPFZ** except one extra deep convection calculation with 10 times aerosol loading is conducted at each time step. The convective tendencies from the second calculation do not participate in the model integration. They are only for diagnostics purposes. The differences between the first and second calculations measure the aerosol effect on convection in identical dynamic and thermodynamic background conditions.

First calculation: 1xAERO

Second calculation: 10xAERO_diag

Aerosol effect on CAPE and convection intensity



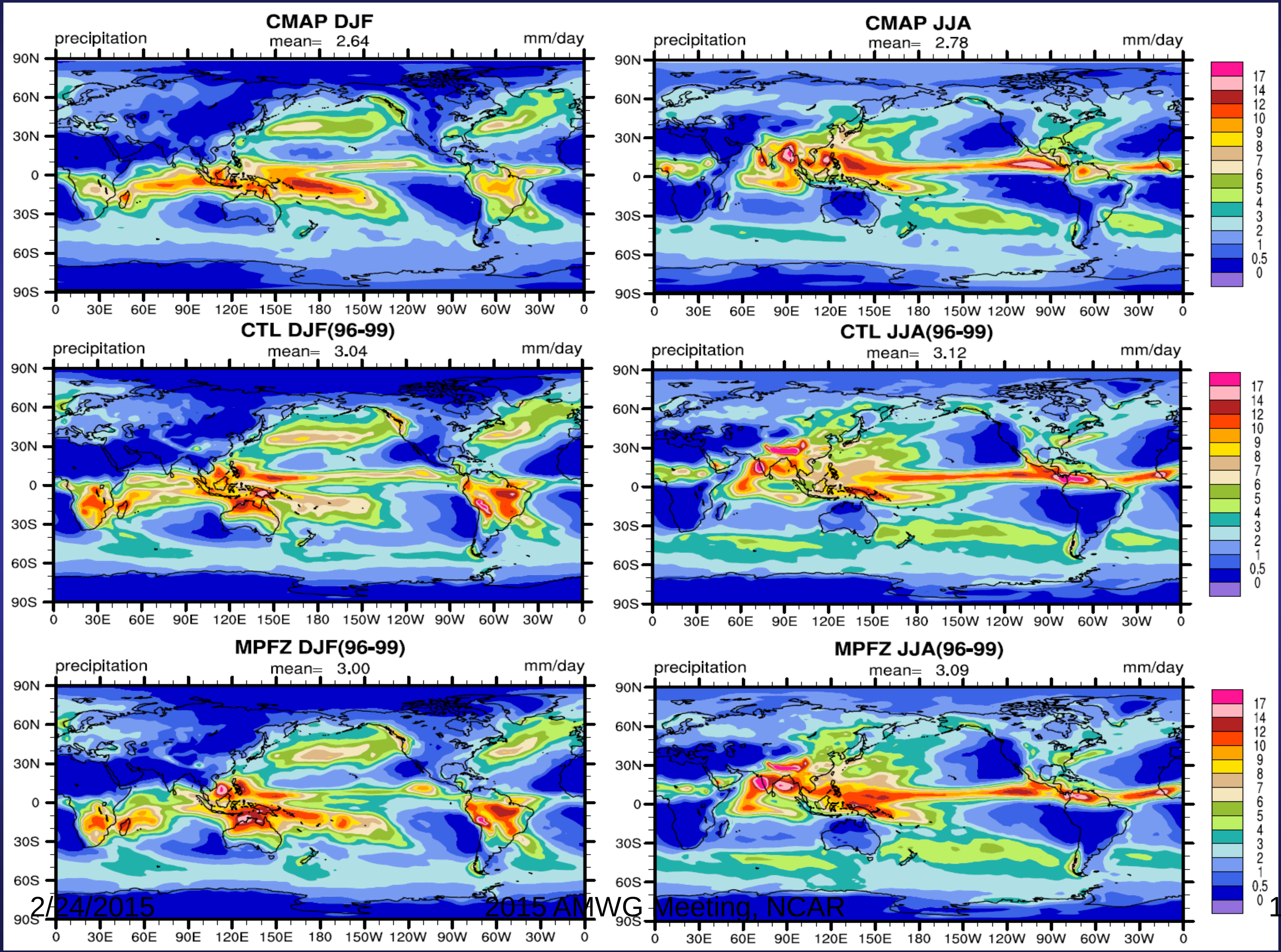
CAPE and mass flux changes due to freezing heating are enhanced when aerosol loading is increased by a factor of 10.

Invigoration

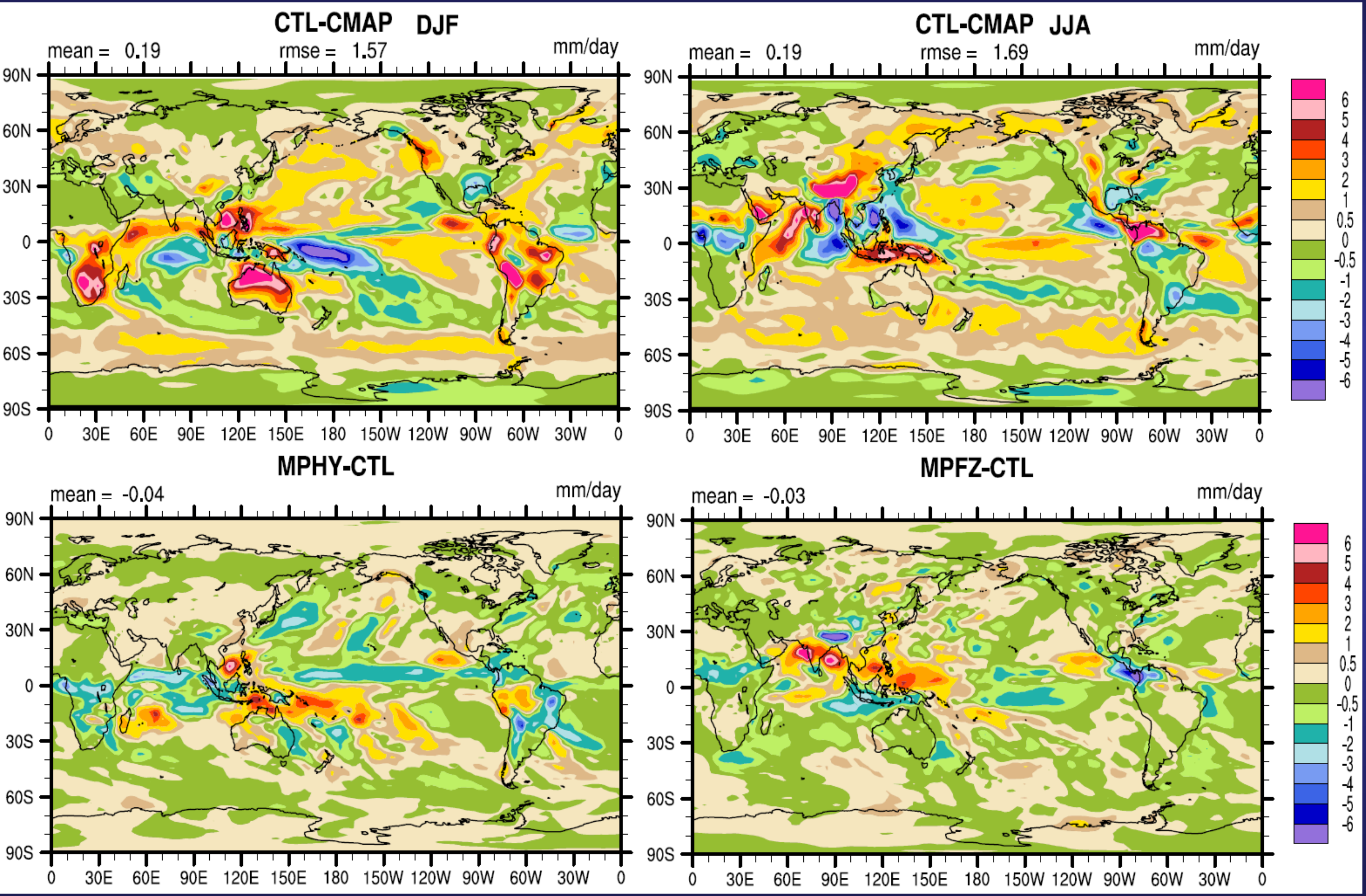
Coupling of convective microphysics with prognostic chemistry package

- The convective microphysics scheme is implemented in CAM5.3 and coupled to trop_mam3 chemistry package through cloud droplet activation and ice nucleation (modified from Brian Eaton's implementation in CAM5.1.17).
- In-cloud aerosol activation is parameterized following Steve Ghan
- Microphysics scheme works with both bulk and modal aerosols.
- Preliminary results from 4-yrs (96-99) simulations at 1.9° X 2.5° resolution are presented.

Precipitation simulation



Precipitation simulation



Summary

- A convective microphysics parameterization is implemented in CAM5
- Results from CAM5 show increased detrainment ans large-scale cloud fraction in convective regions
- Freezing heating from microphysics is now coupled with updraft thermodynamics to affect convection development
- It enables climate models to investigate aerosol-convection-climate interaction.
- For a given environmental condition, aerosols invigorate convection (more CAPE, more convection)