

Global Simulations of Cloud Phase

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Outline

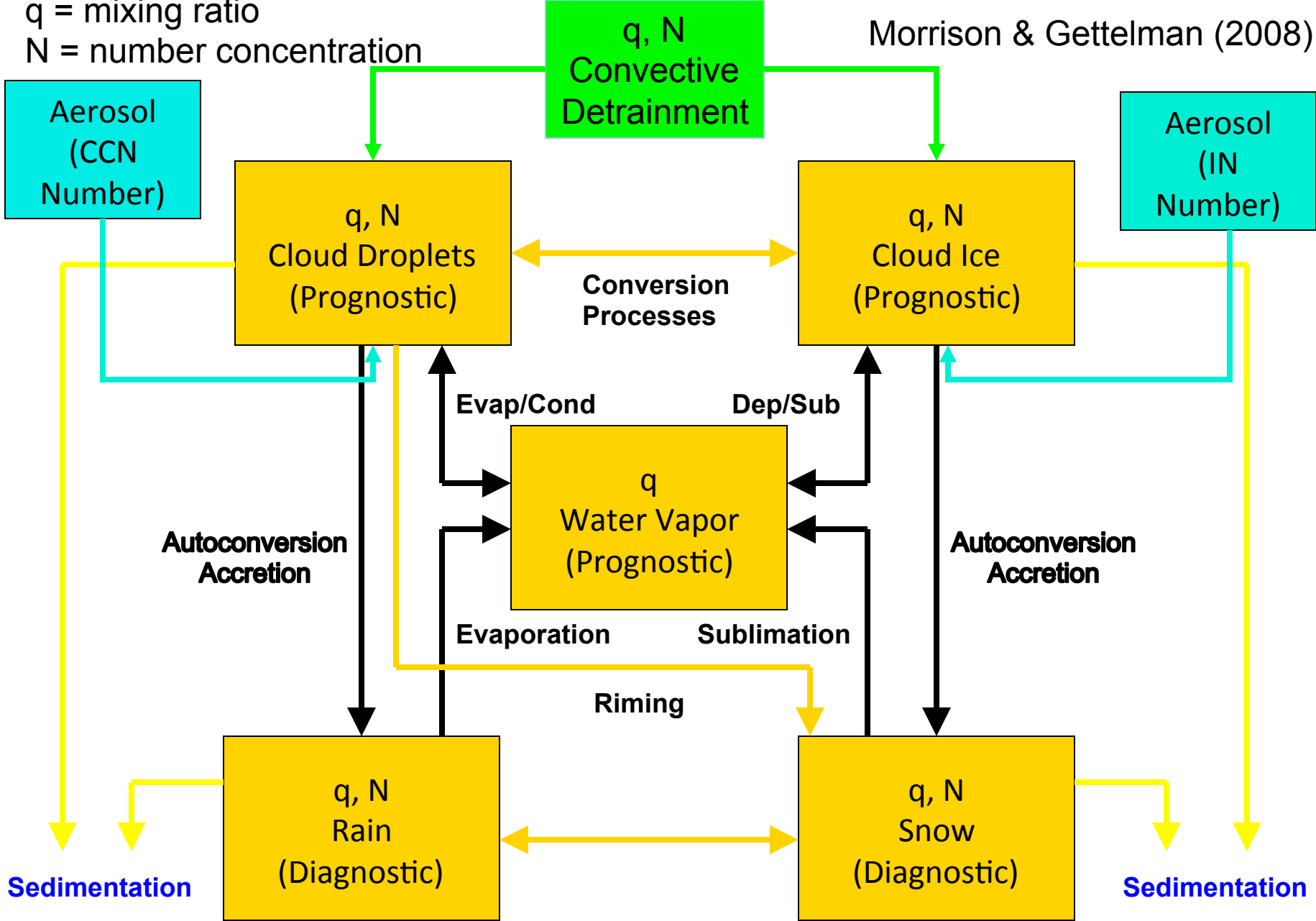
- Processes treated in advanced climate models
- Simulations of cloud phase
- Sensitivity to heterogeneous nucleation
- Sensitivity to numerics

Cloud microphysics in advanced climate models

q = mixing ratio

N = number concentration

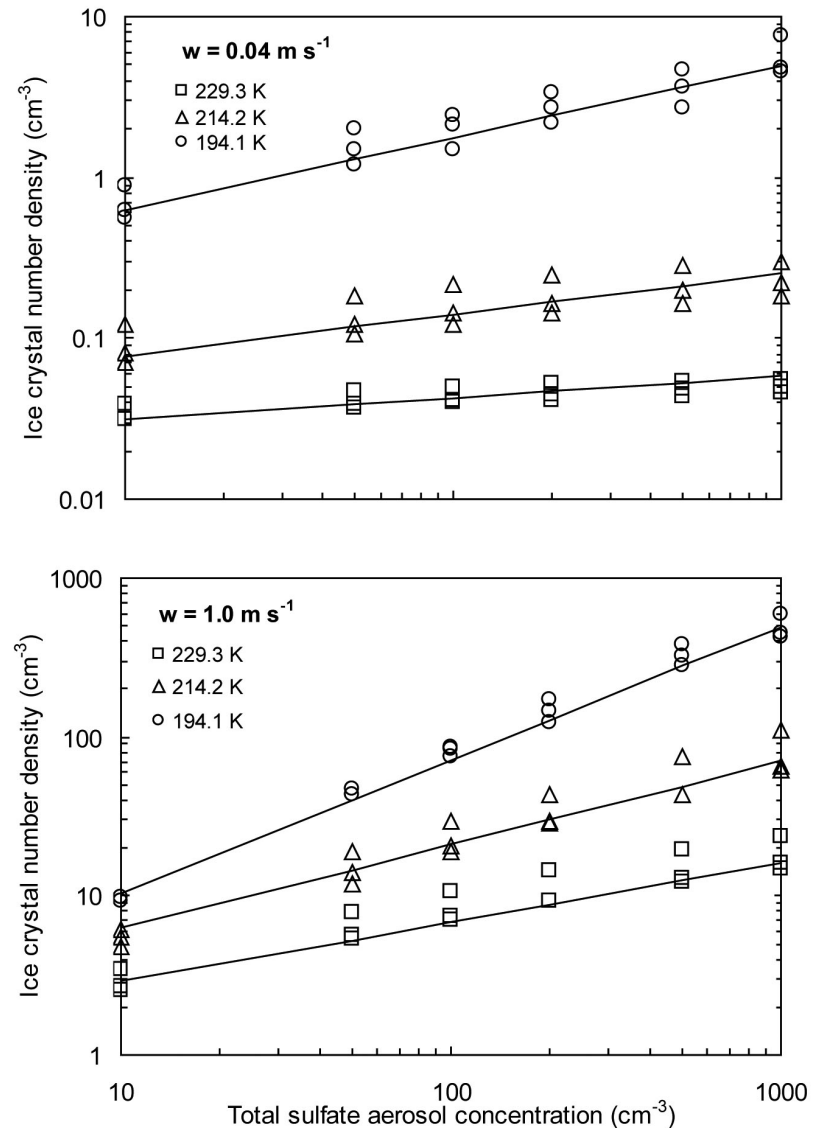
Morrison & Gettelman (2008)



Ice Nucleation in Global Models

- Homogeneous nucleation depends on temperature, aerosol number*, and updraft velocity
- Heterogeneous nucleation
 - Immersion nucleation (dust or soot). Competition with homogeneous.
 - Deposition nucleation (Meyers or Phillips)
 - Contact freezing (dust)

*larger than 0.1 micron



Liu and Penner, Met. Zeit. (2005)

Wegener-Bergeron-Findeisen (WBF) Process in Global Models

Under mixed-phase conditions $q_{vi}^* < q_v \cong q_{vl}^*$

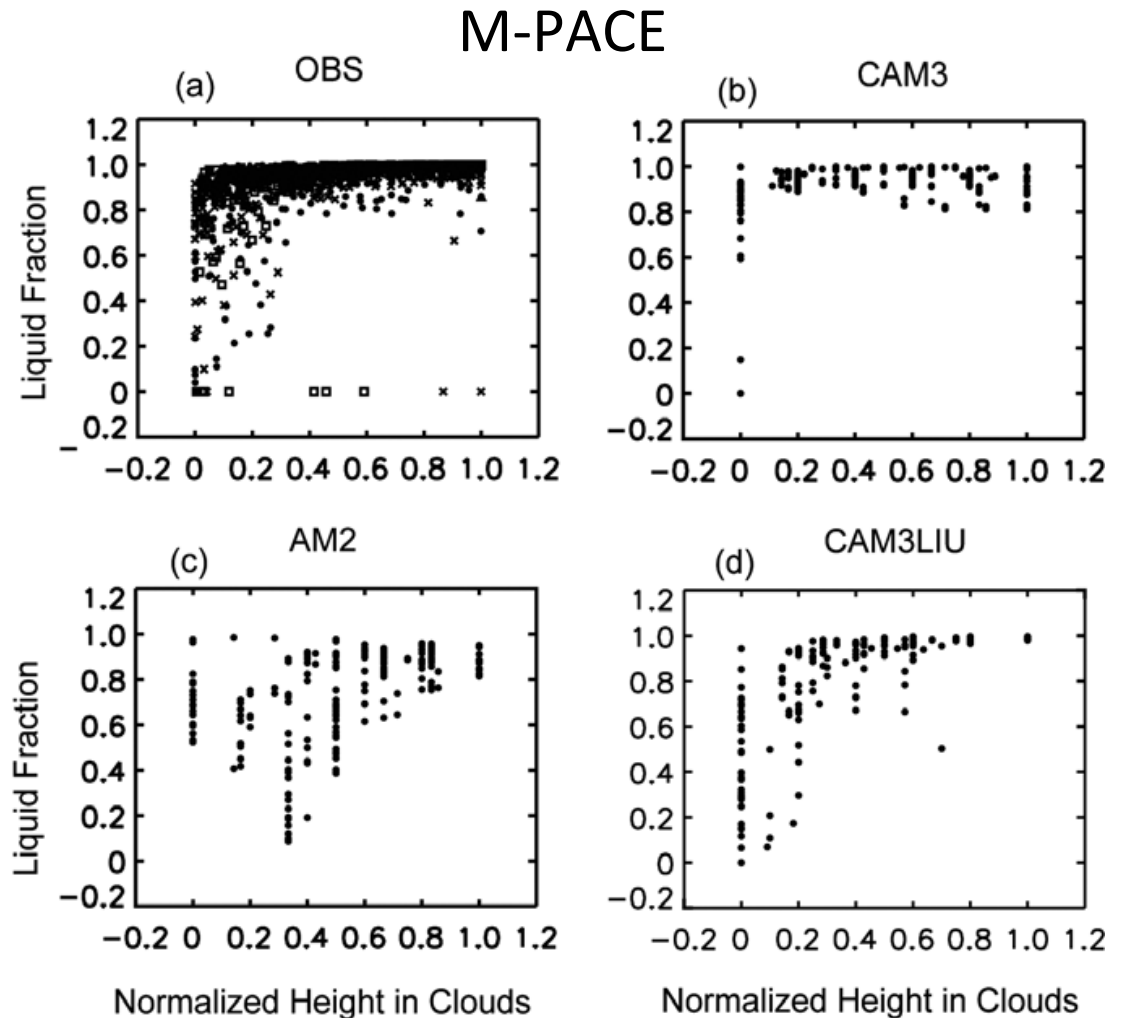
- q_{v+l} is depleted by deposition to ice crystals:

$$\left(\frac{dq_{v+l}}{dt} \right)_{dep} = \frac{q_{vi}^* - q_v}{\left(1 + \frac{L}{Cp} \frac{dq_{vi}^*}{dT} \right) \tau}$$

- q_{v+l} depletion reduces q_l assuming $RH_l=100\%$ when $q_l > 0$.

Cloud Phase

- Liquid and ice coexist in lower half of cloud
- $f(T)$ partitioning in CAM3 fails to produce low liquid fractions at observed T
- Advanced cloud schemes with WBF simulate lower liquid fractions in lower half of cloud



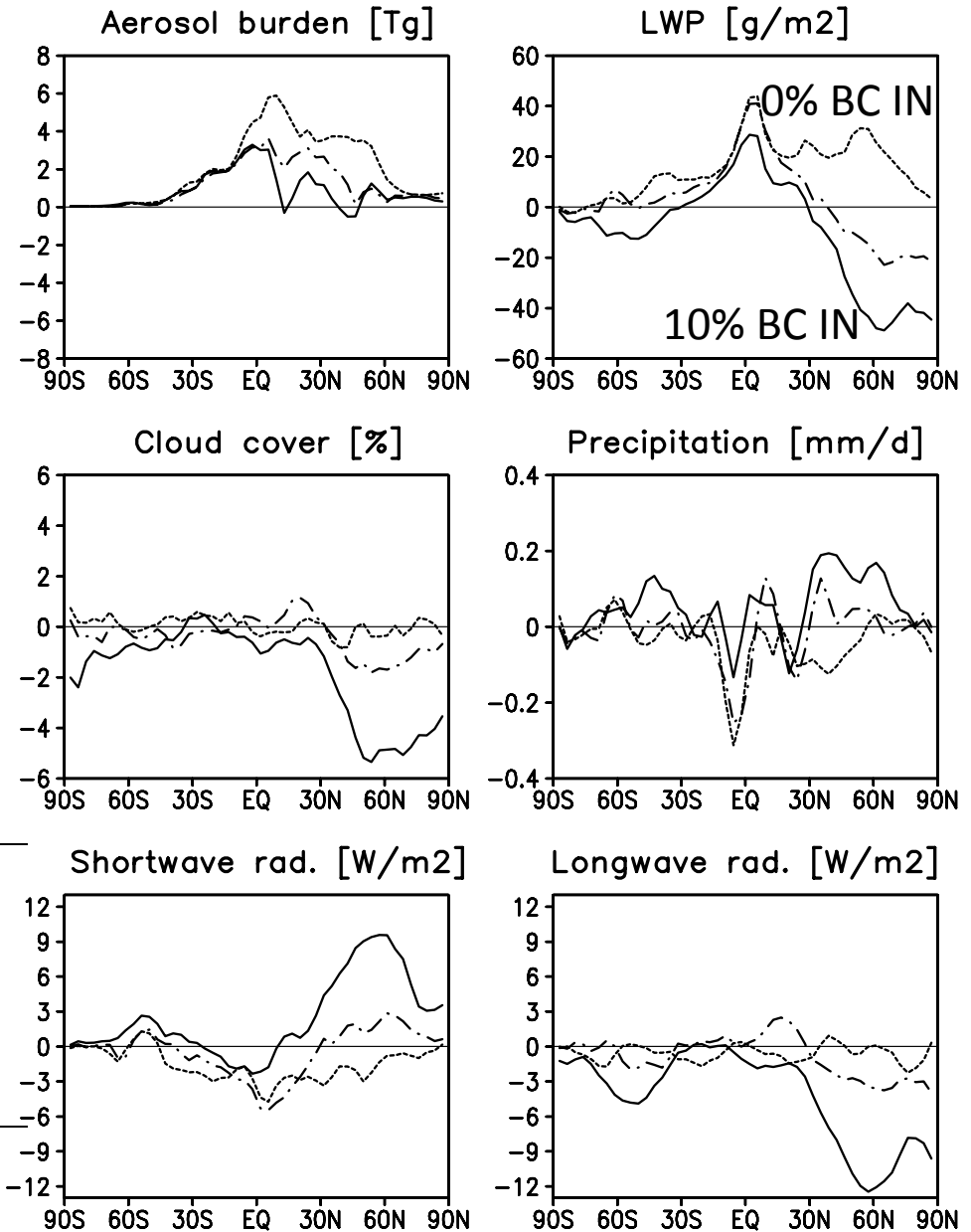
Xie et al. JGR (2008)

Glaciation Indirect Effect

Lohmann, GRL (2002)
contact nucleation dust & BC

- If 10% of BC were active as IN, enhanced glaciation would deplete LWP and cloud cover
- Impacts on SW and LW cloud forcing largely cancel
- BC is a poor IN, but other anthropogenic mechanisms are possible

Present Day – Pre-Industrial



Present Day – Pre-Industrial

Simulation	BC10%	BC1%	BC0%
ΔAB	1.1 (9)	1.6 (13)	2.6 (22)
ΔLWP $g\ m^{-2}$	-2.9 (-3)	7.9 (8)	18.5 (18)
ΔIWP $g\ m^{-2}$	0.6 (8)	0.2 (3)	0.1 (1)
ΔTCC	-1.3 (-2)	-0.3 (0)	0. (0)
ΔPR $mm\ d^{-1}$	0.05 (2)	-0.02 (-1)	-0.05 (-2)
ΔF_{SW} $W\ m^{-2}$	+1.9 (1)	-1.0 (0)	-2.0 (-1)
ΔF_{LW} $W\ m^{-2}$	-3.5 (2)	-0.5 (0)	-0.6 (-0)
ΔF_{net} $W\ m^{-2}$	-1.6	-1.5	-1.4

Subgrid Variations in WBF Process

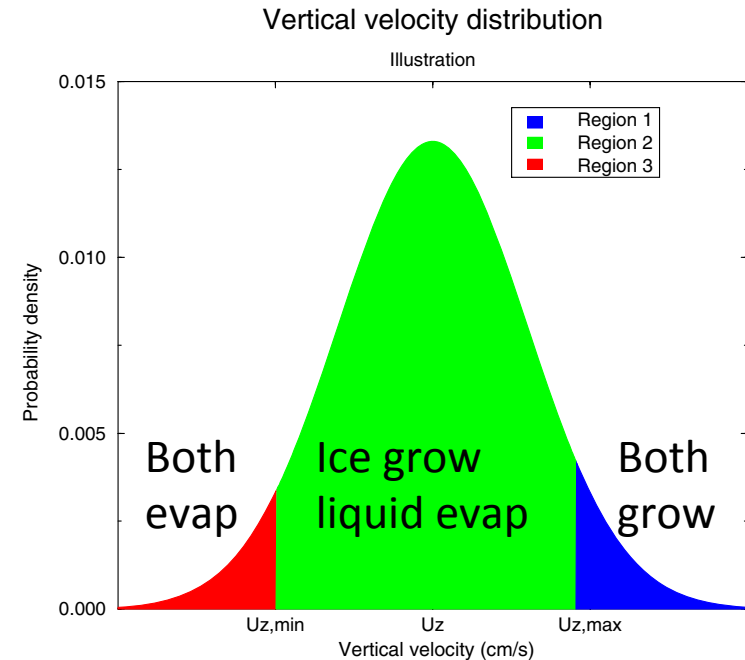
Storelvmo et al. ERL (2008)

- Subgrid variability in WBF process has a large effect on aerosol impact on LWP and SW and LW energy balance
- This estimate of sensitivity is probably excessive because of assumptions about BC as IN

AER_{LIQ} : no aerosol effects on ice

AER_{MIX} : WBF at grid-cell mean only

AER_{WBF} : subgrid WBF

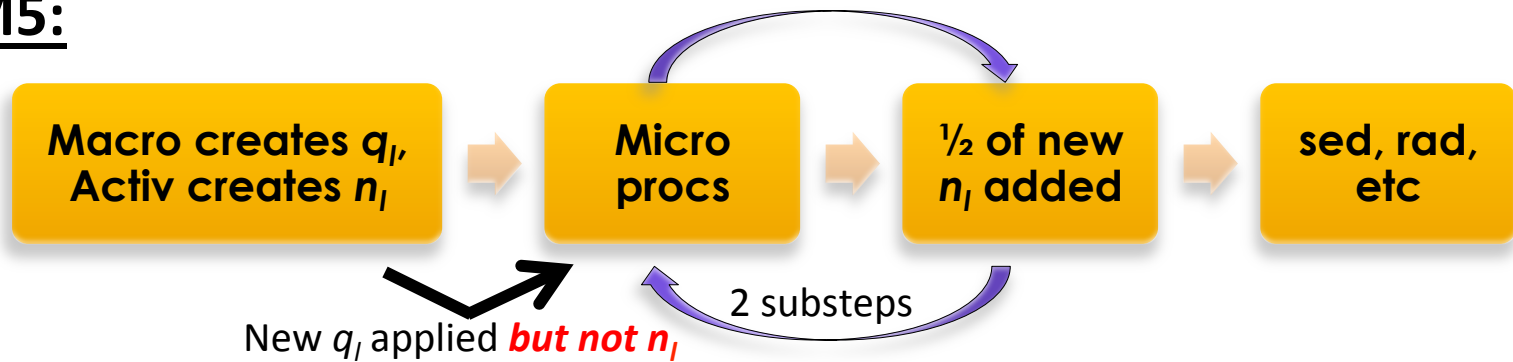


Present Day – Pre-Industrial

Simulation	AER_{LIQ}	AER_{MIX}	AER_{WBF}
Cloud cover (%)	-0.21	-0.21	-0.25
Liquid water path ($g\ m^{-2}$)	5.4	4.1	-6.9
Ice water path ($g\ m^{-2}$)	0.17	-0.28	0.20
Shortwave radiation, TOA ($W\ m^{-2}$)	-1.66	-1.11	1.13
Outgoing longwave radiation ($W\ m^{-2}$)	-0.27	-0.38	-1.08
Net radiation, TOA ($W\ m^{-2}$)	-1.93	-1.49	0.05
Effective droplet radius (μm)	-0.96	-1.01	-0.89
Precipitation (mm/day)	-0.004	-0.026	0.011

Beware Numerical Issues (Peter Caldwell)

In CAM5:



In New Scheme:

q_i AND n_i are updated before microphysics

Impact:

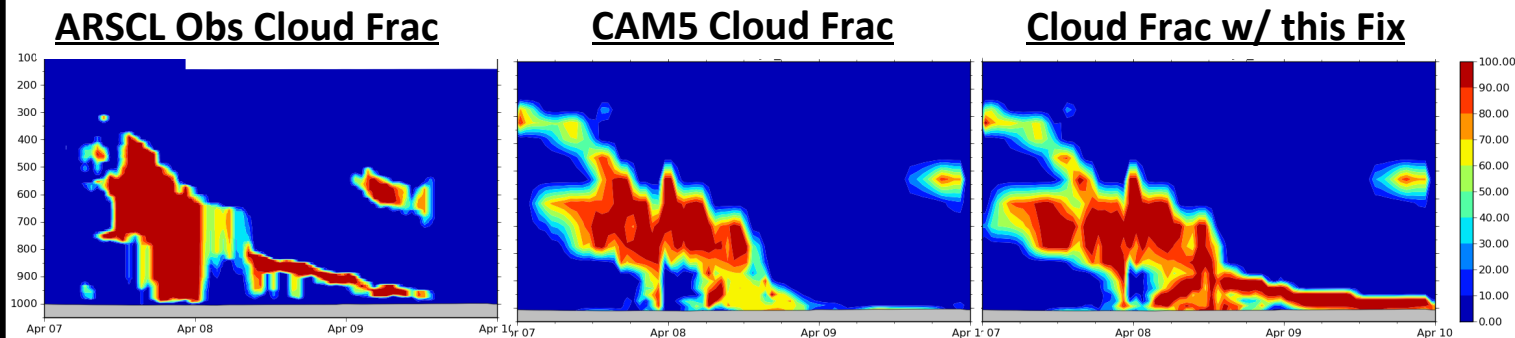


Fig: MERRA-driven 24-48 hr CAPT forecasts for ISDAC "Golden Day" (Courtesy J. Boyle)

Extra slides

Where Simulated WBF Occurs

Vertical distribution of anthropogenic impacts on liquid and ice

Storelvmo et al. ERL (2008)

