Latest Microphysics Developments & Ice Microphysics and Indirect effects for CAM4

A. Gettelman, X. Liu, H. Morrison, S. Ghan

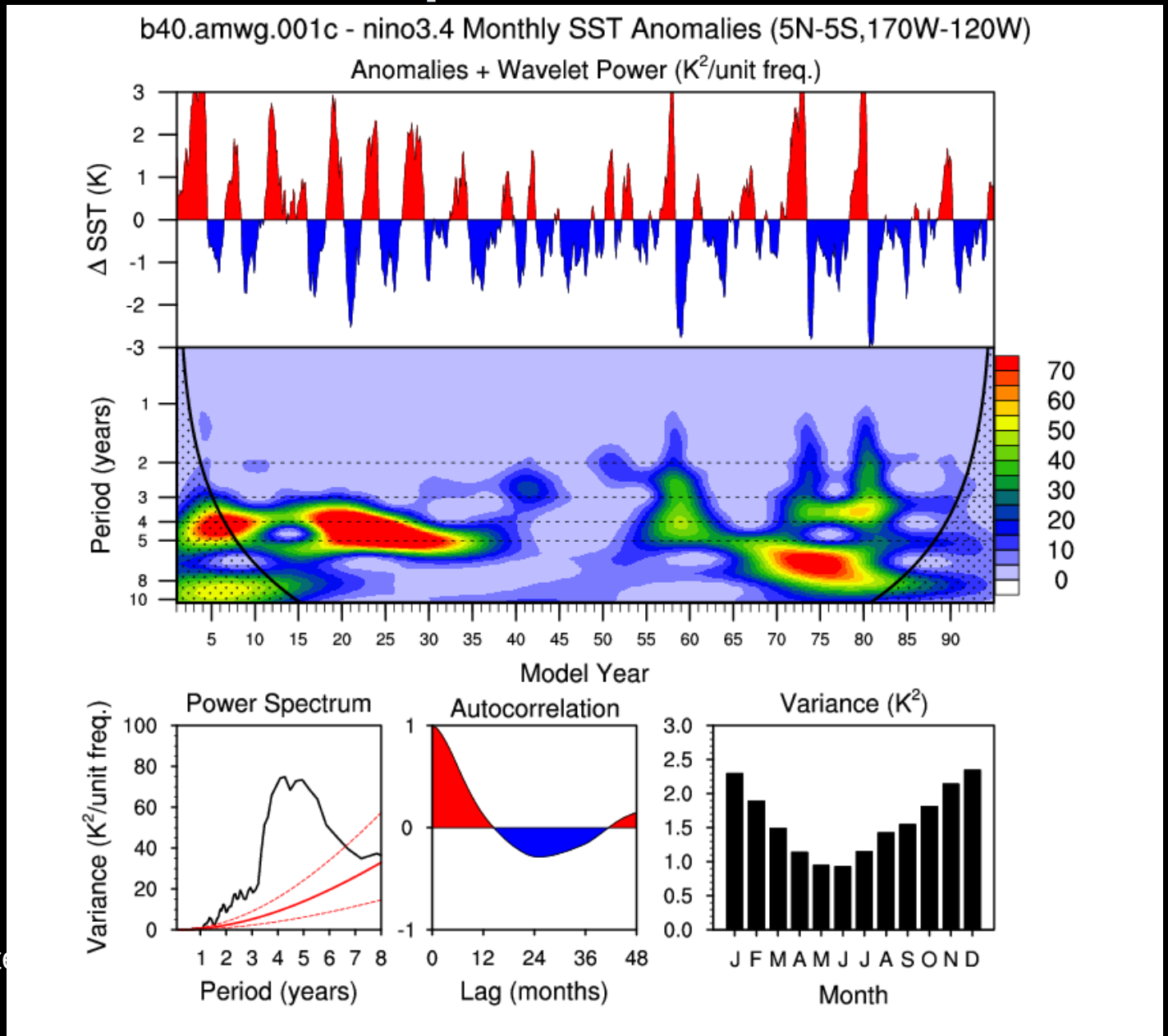
Outline

- Motivation
- CAM Microphysics Status
- New Ice Nucleation Description
- Basic Results
- Status and future plans

MG Microphysics Status

- Code Running in Coupled Model
- Produces ‘reasonable’ climate
  - Microphysics look good
- ENSO good in coupled system
- Too much sea ice in coupled run
- See R. Neale talk
- Indirect effects diagnosed
- New Optics being built for RRTM (Conley talk)

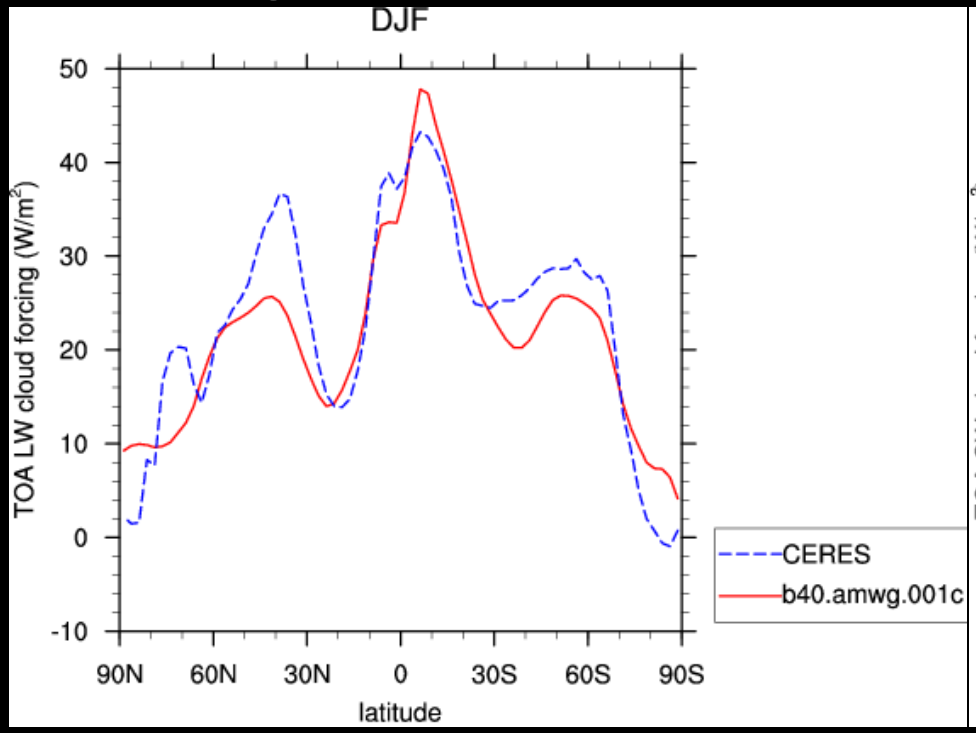
MG Coupled Run: ENSO

- 

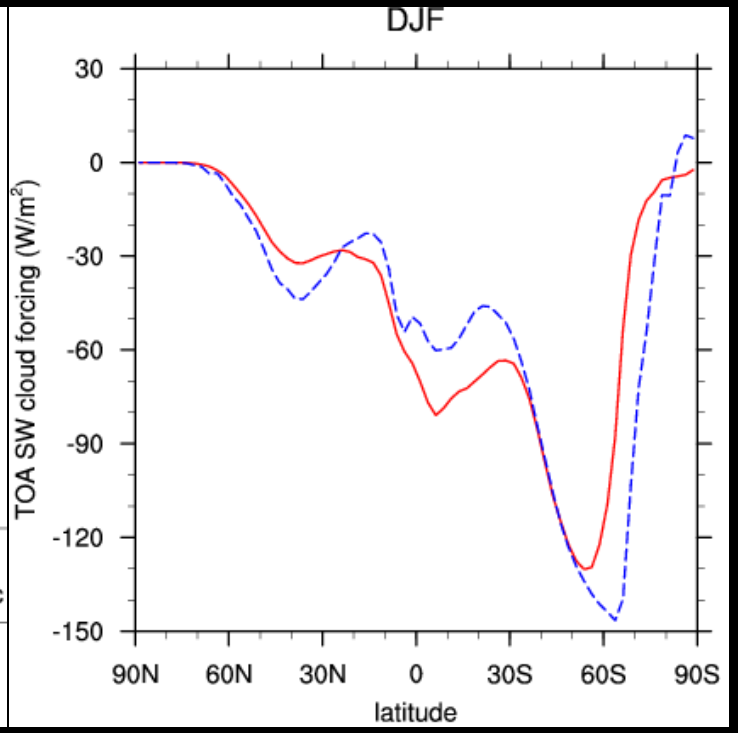
MG Coupled Run: Cloud Forcing

Cloud Forcing v. CERES Obs

Longwave

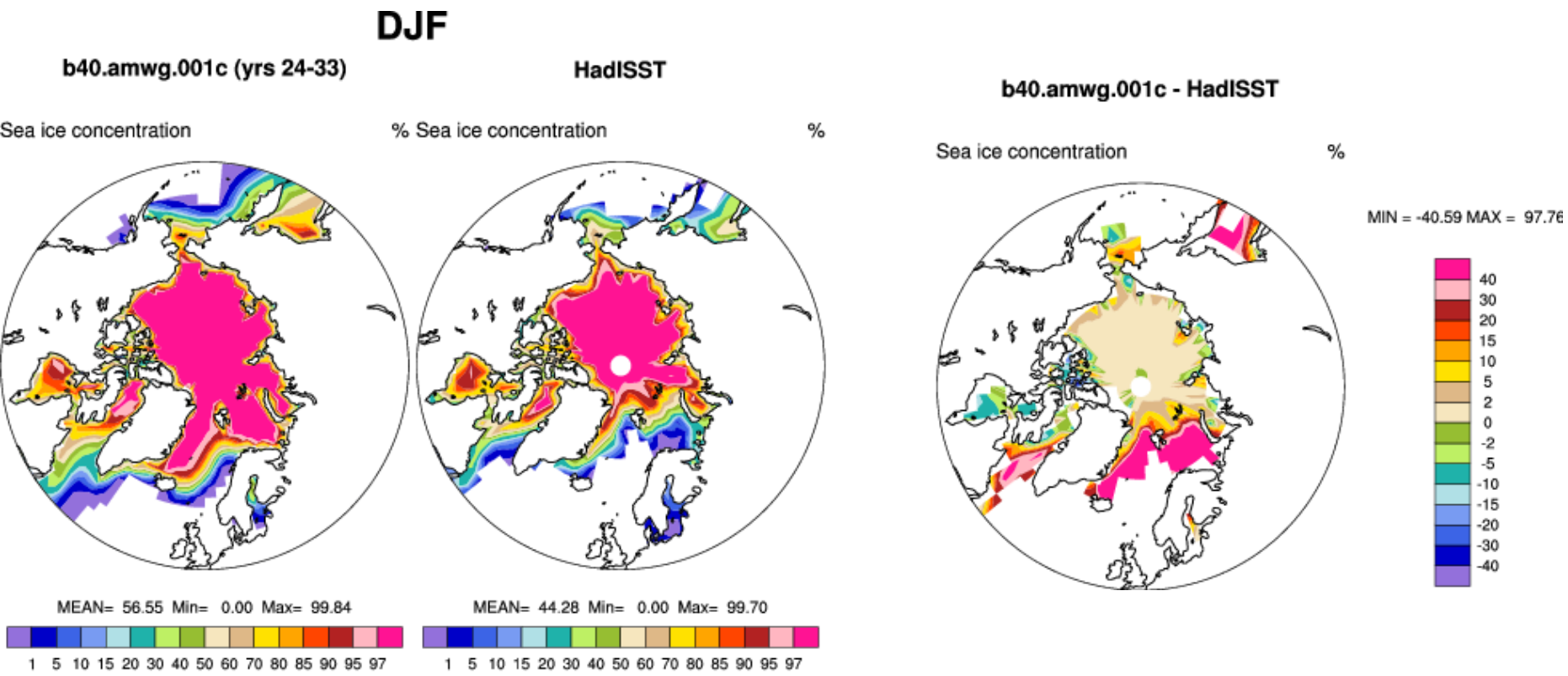


Shortwave

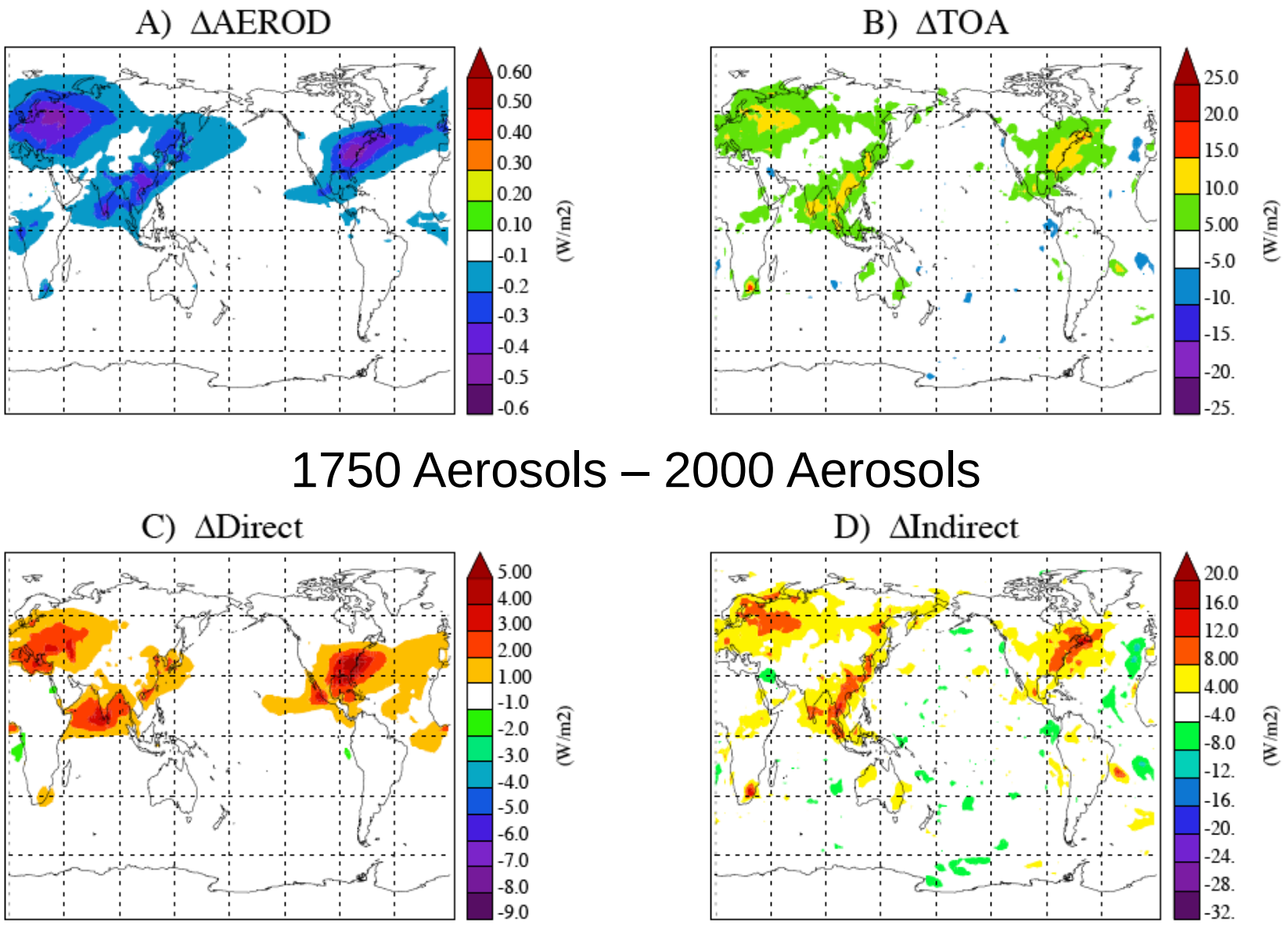


MG Coupled Run: NH Sea Ice

Sea Ice too thick/extensive



Aerosol Indirect Effects (AIE)



AIE Key Findings

- Model produces reasonable effects compared to observations
  - Not a strong global constraint
- Aerosol Indirect Effects are ~1-2 W/m2 with direct effects of 0.4-0.7W/m2
  - Depends on Pre-industrial emissions
- AIE numbers are only weakly dependent (10%) on whether aerosol mass is prescribed or prognostic
- Oxidant levels also seem to matter for AIE
  - Changes AIE by 20-30%

AIE Next Steps

- Waiting on:
  - RRTM radiation interface: more flexible
  - New Radiation and New Cloud Optics
  - Final Aerosol Code (BAM/Modal, scavenging)
- Near final Configuration
  - PBL, Macrophysics
- Options (BAM):
  - Add aerosol species (Biogenic),
  - Change size distributions
  - Minimum Droplet Number
  - Modify Microphysics (Park)

Ice Processes: Motivation

- Cirrus and ice nucleation uncertain
- Supersaturation over ice common
  - CAM does not permit it
- Cirrus radiative forcing important
- Cirrus affects stratospheric H_2O
- Better description allows process level testing with observations

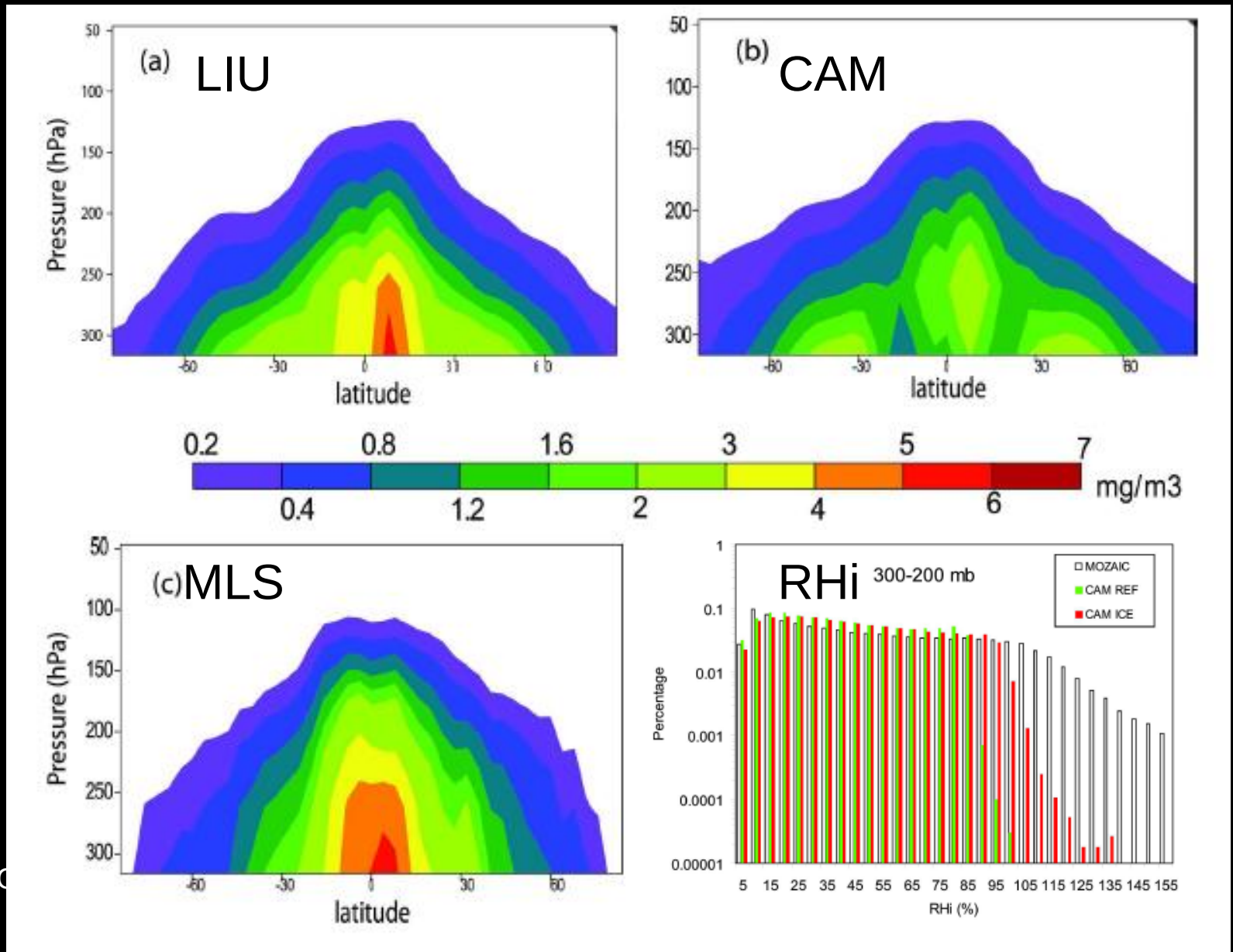
Ice Microphysics in MG Micro

- New microphysics has limited ice nucelation
  - N_i=f(T) following Cooper (1986)
  - N_i=const below -35C
- Goal
  - Explore ice processes & sensitivity
    - Bergeron
    - Hallet Mossop ice multiplication
  - Parameterize ice nucleation
  - Allow supersaturation

Ice Nucleation

- Add ice nucleation treatment of Liu & Penner 2005, following Liu et al 2007
  - Homogenous and Heterogenous immersion nucleation
  - Relax Zhang et al closure for ice to allow supersaturation (C-E w.r.t. liquid)
- Based on parameterizing nucleation results from a detailed parcel model
  - Pro: detailed model
  - Con: lots of fixed numbers

Liu et al 2007: in CAM3.0



Allowing Supersaturation

- Goal: adjust closure for supersaturation
- Principle:
  - Separate ice and liquid cloud fractions
  - Bulk condensation only w.r.t water (liquid).
  - Ice formation requires
    - Existing ice (vapor deposition onto ice)
    - Liu et al 2007 parameterized ice nucleation
  - Process rates & sedimentation govern ice
  - Ice cloud fraction closed using IWC
    - Empirical fit to mid-lat cirrus observations (Wang & Sassen 2002, JAS)

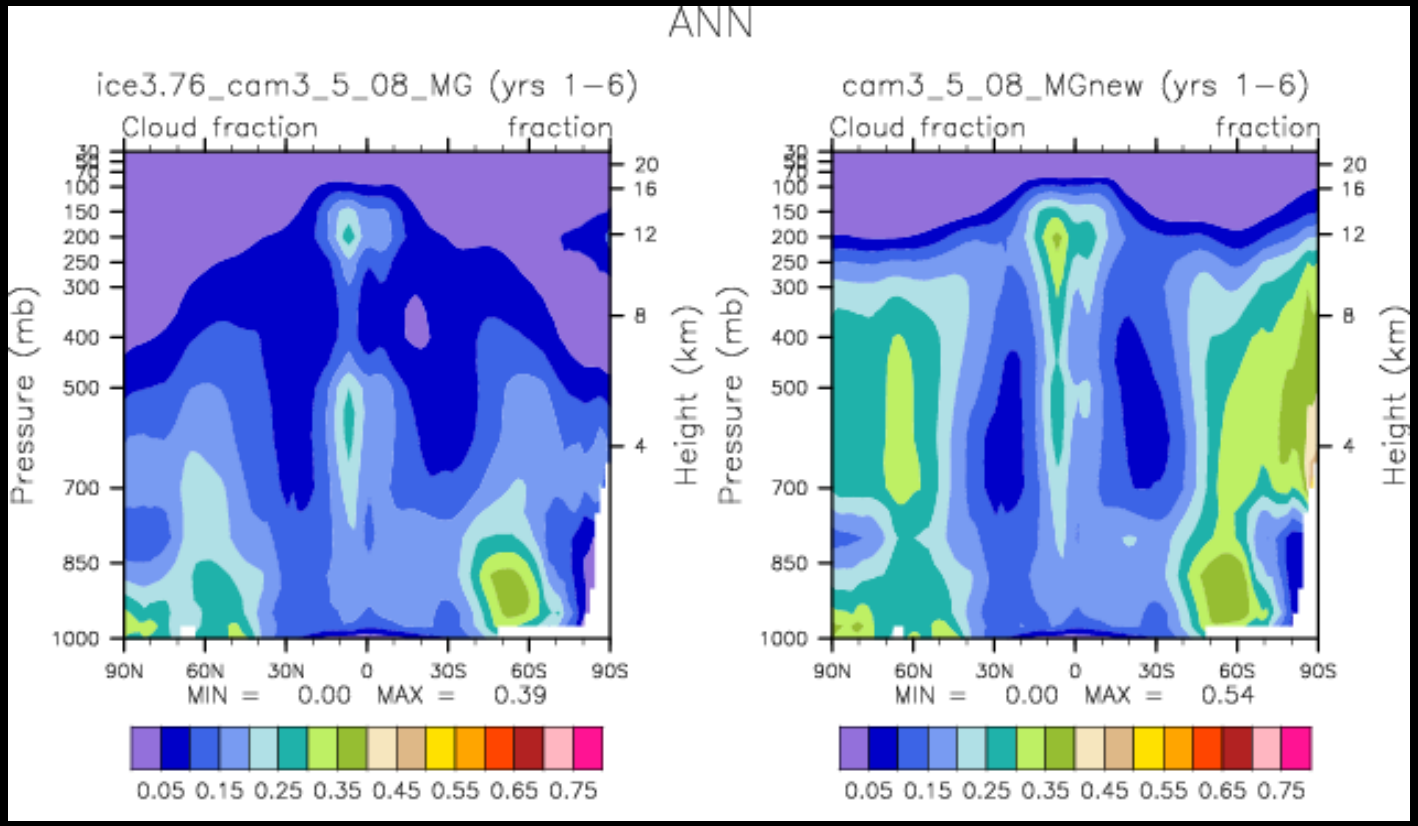
Key Results: Current Version

- Reasonable TOA distributions
- Reduction of High Latitude Cloud
  - Especially mid-high clouds
- Increased UT humidity
- SW & LW Cloud Forcing 3W/m^2 less
- 30% lower IWP

Cloud Fraction

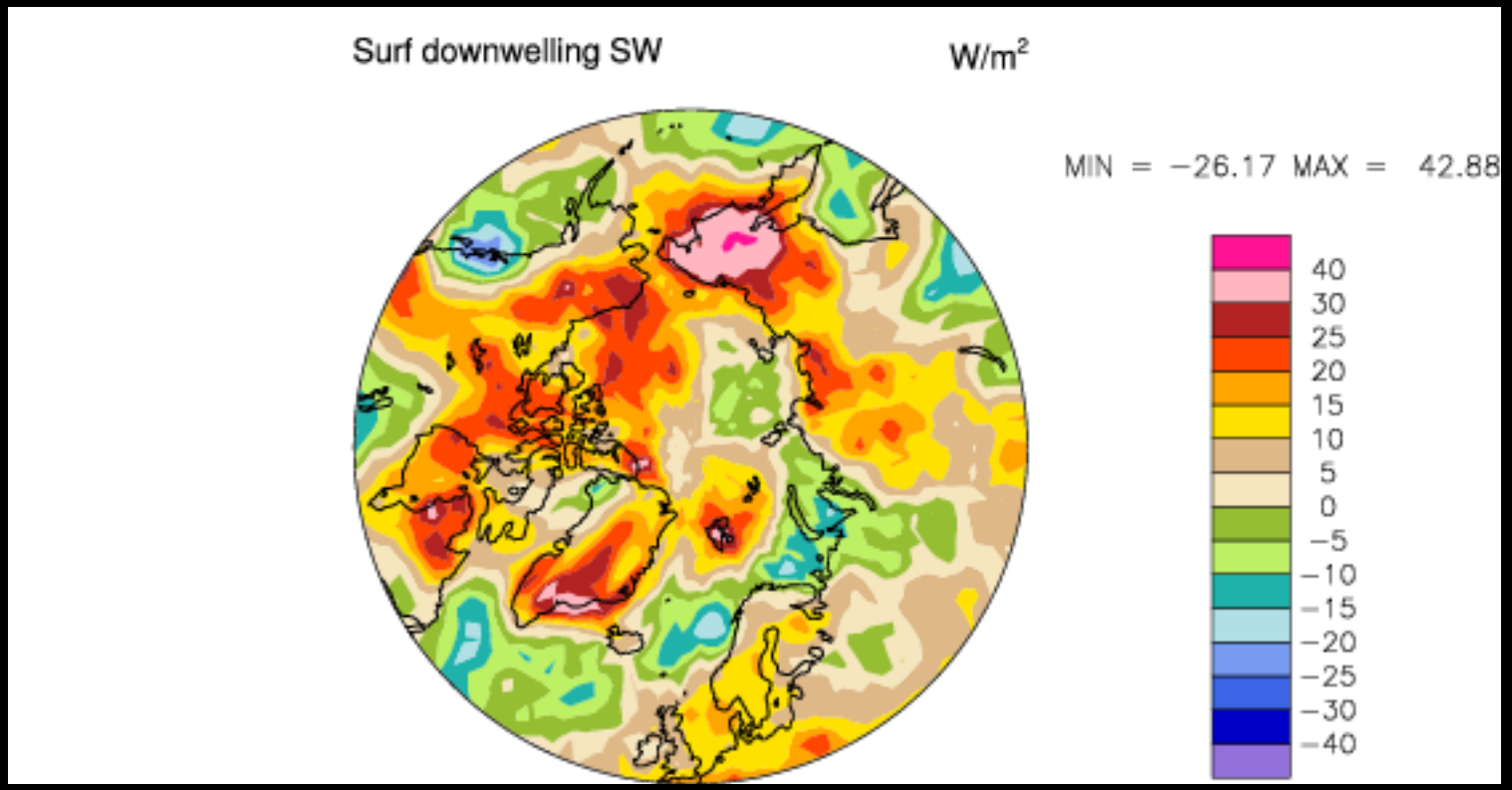
New Ice

Base Case



Downward JJA SW

New Ice - Base Case (avg +8W/m^2)



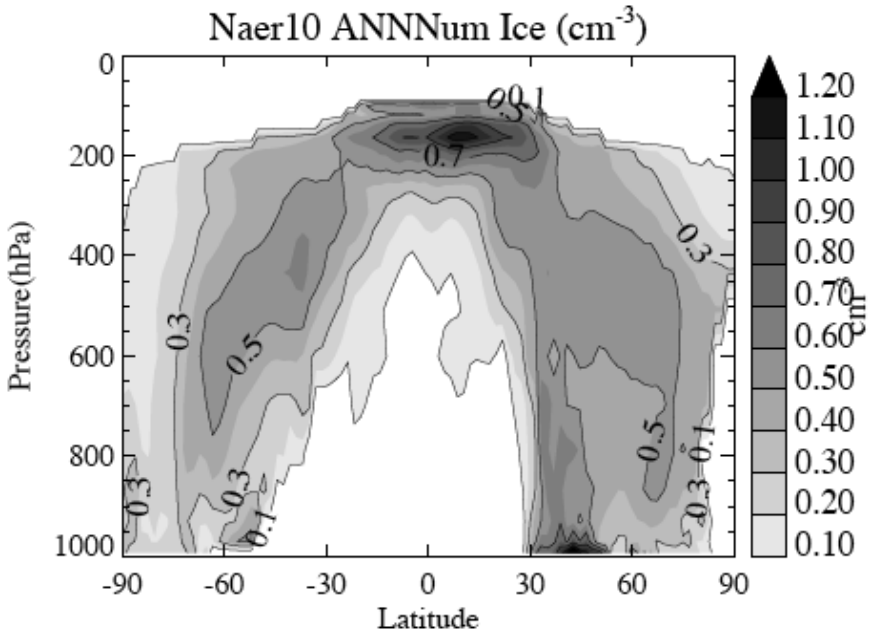
Ice Cloud Indirect Effects

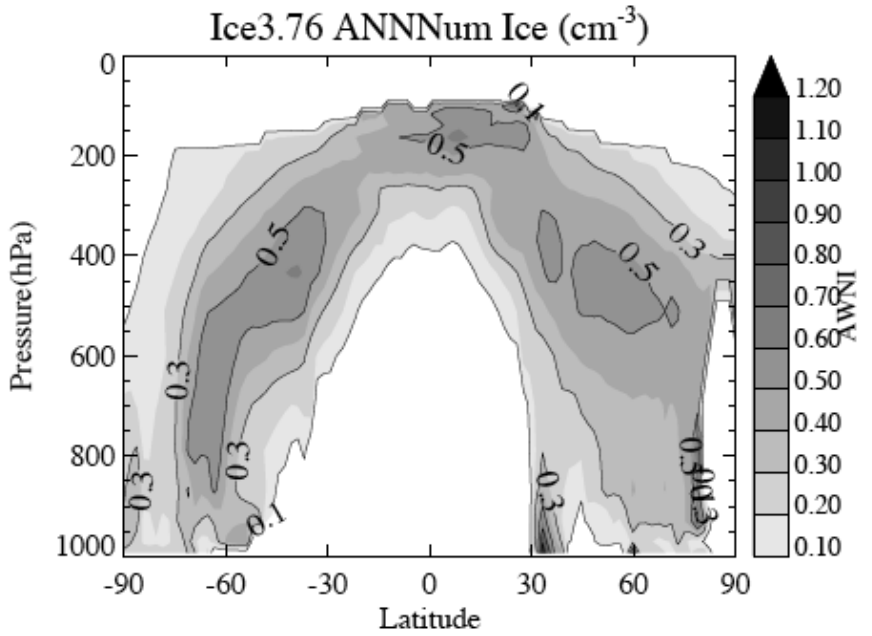
- Sensitivity Experiments
  - Increase ice nuclei by factor of 10, 100 (global)
- Results:
  - x10: IWP + 25%, tropical CF ±8-10W/m2
  - x100: IWP +100%, tropical CF ±16-20W/m2
  - X100: regional decreases in precipitation rate
- Need to explore sensitivity to aerosols
  - Vertical distribution of aerosols

Change in Ice Number

High IN (x10)

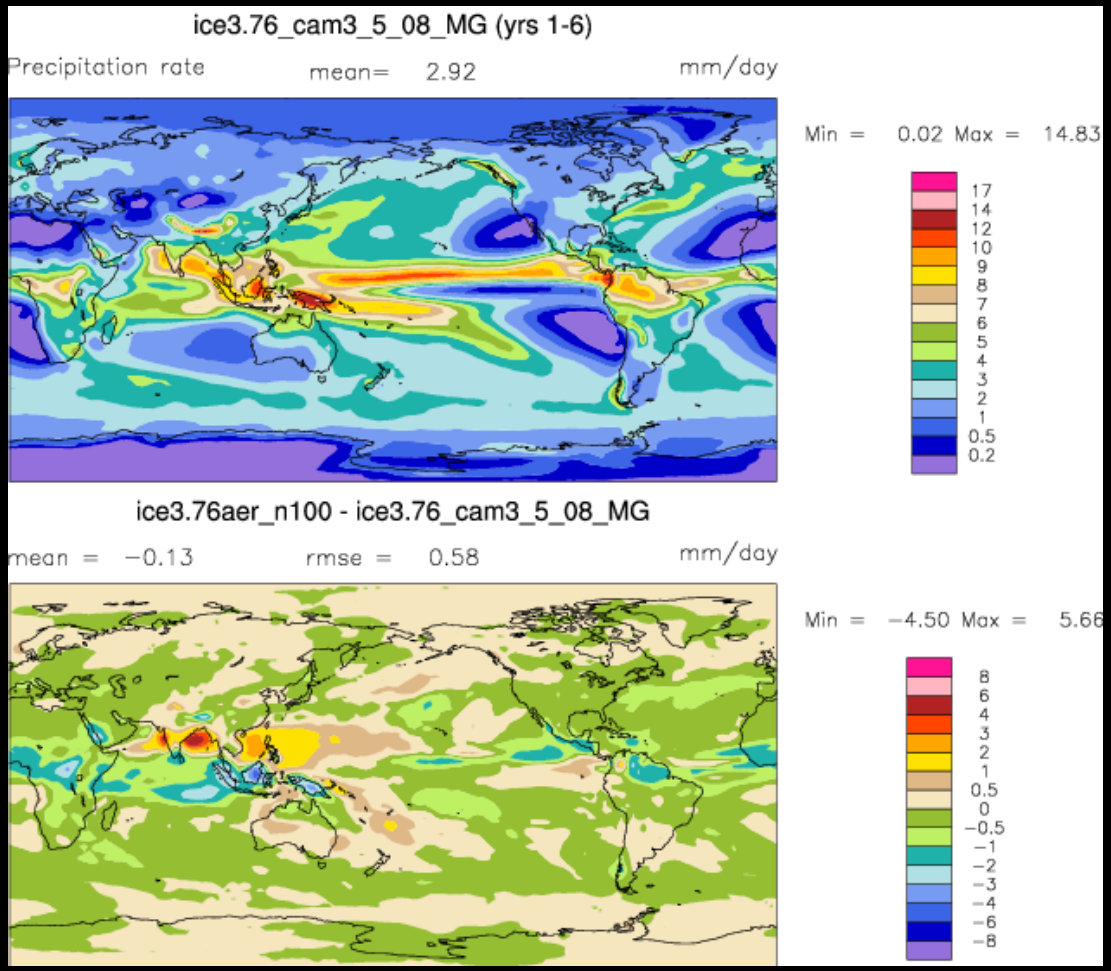
Std IN





Change in Precip

- Base
- High IN-Base
  - (x100)



Status and Plans

- Finalize and Harmonize code
  - Rewriting mixed phase code now
  - Perhaps separate process rates by individual cloud fractions
- Write up description
  - Target for end of summer
- Port to latest version of trunk
  - Harmonize macrophysics and closure with Park/Rasch work
  - Propose for CAM4