

The effects of anthropogenic aerosols as simulated by the SP-CAM with two-moment microphysics

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Center for Multiscale Modeling of Atmospheric Processes

CMMAP

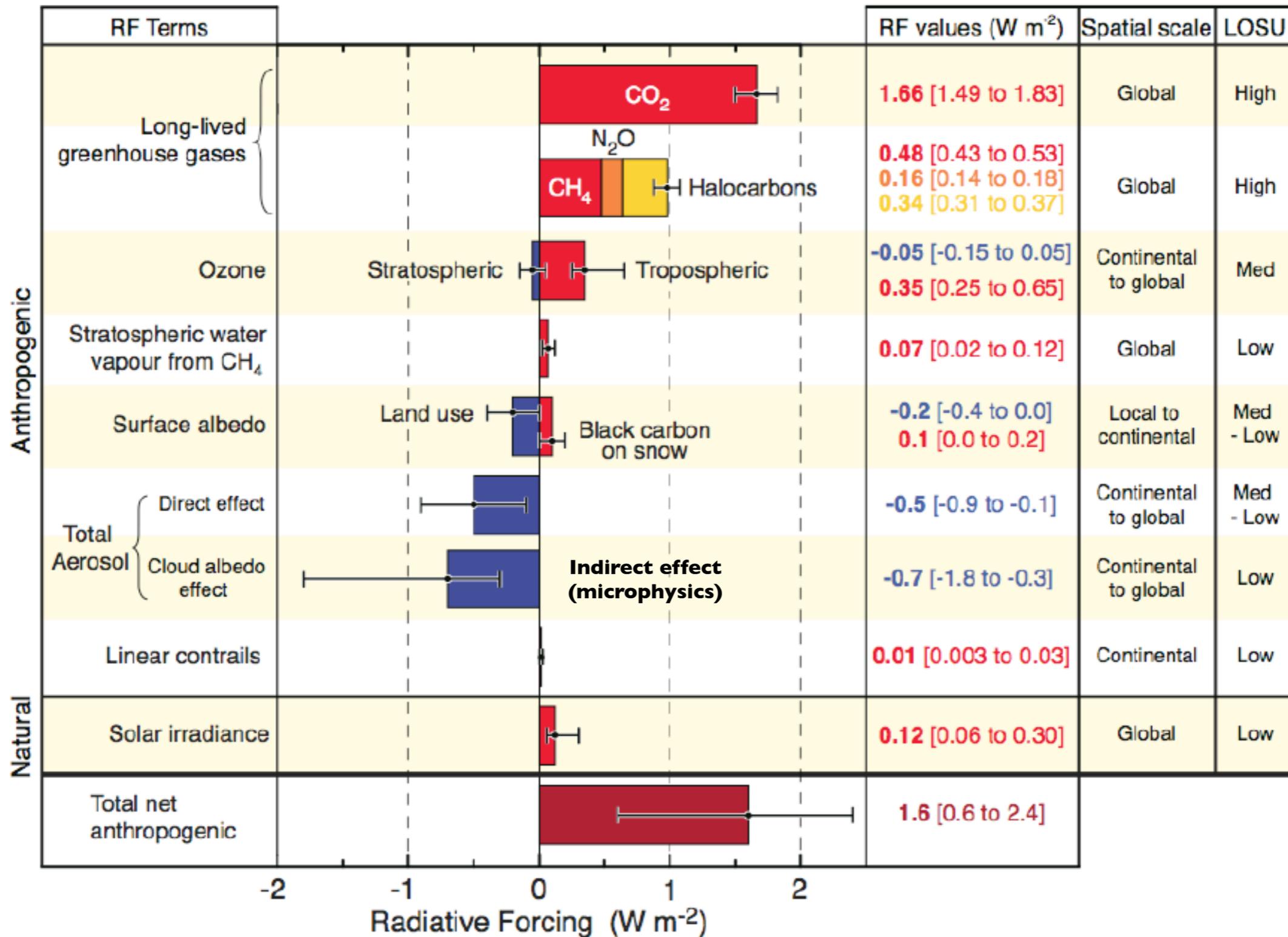
Reach for the sky.



Industrial Era Climate Change

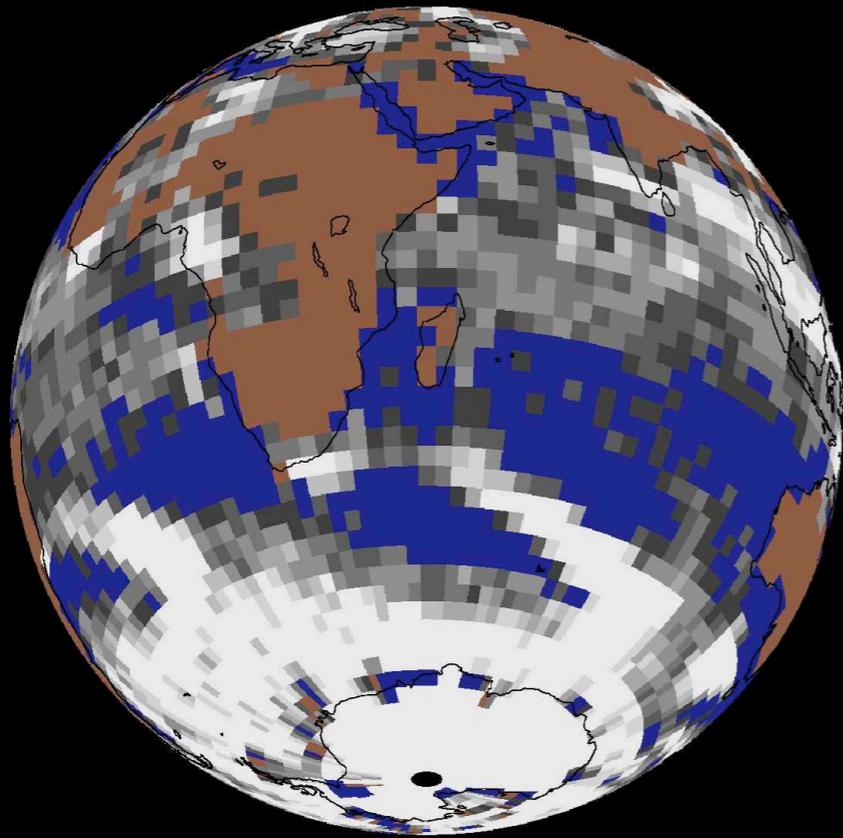
Source: IPCC 4th Assessment Report (AR4)

Radiative Forcing Components

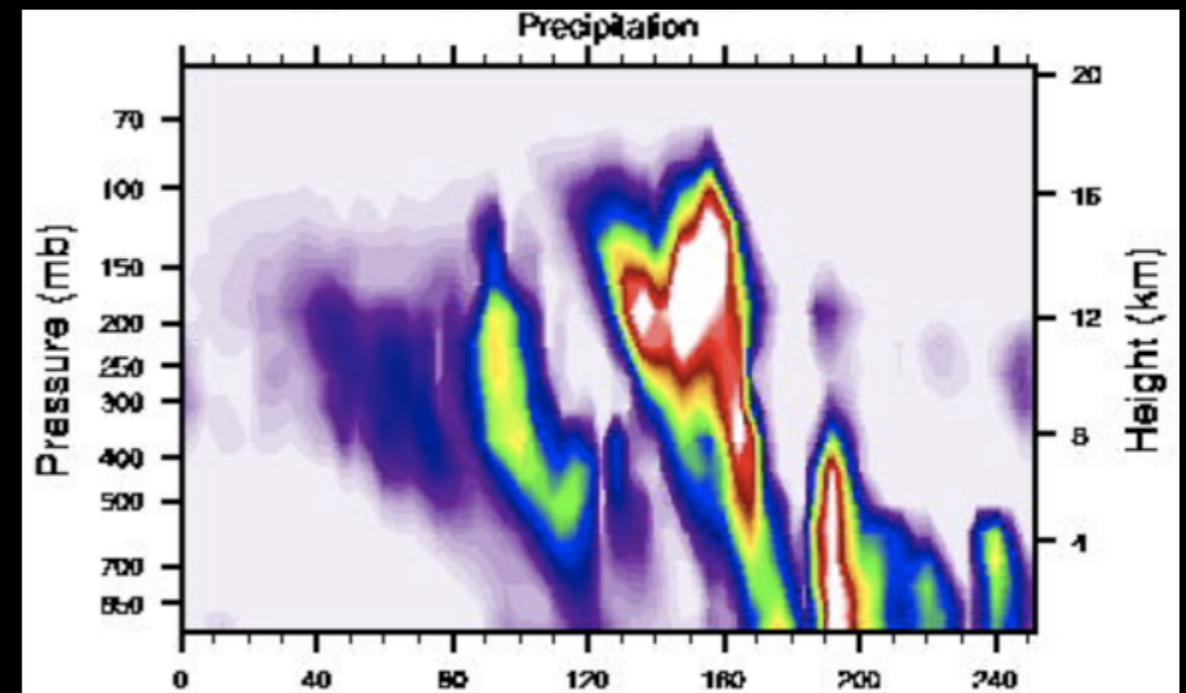
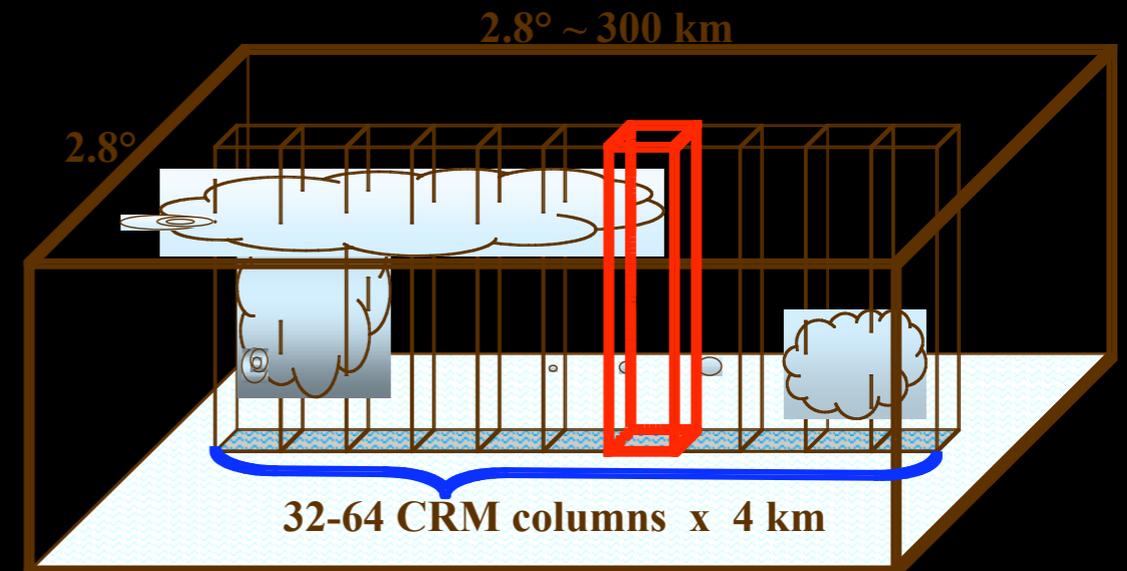


Super-parameterized CAM: SP-CAM Multiscale Modeling Framework (MMF)

A copy of a CRM (a.k.a. “super-parameterization”) is run in each column of CAM GCM.



Each column of this has this



Bulk Microphysics Schemes in System for Atmospheric Modeling - SAM CRM used as super-parameterization in SP-CAM

Original One-Moment (Khairoutdinov and Randall 2003)

- 2 prognostic microphysics variables: total non-precipitating and precipitating water mixing ratios;
- Cloud liquid and ice water, rain, graupel and snow are diagnosed as $f(T)$;
- Autoconversion to rain by simple Kessler formula;
- Cloud drop effective radius is prescribed
- **No indirect aerosol effect is included.**

Two-Moment (Morrison et al. 2005) Thanks to Peter Blossey for implementing it in SAM

- 10 prognostic microphysics variables;
- Prognostic mixing ratio and concentration for 5 categories of water;
- Autoconversion depends on water content and concentration (KK 2000);
- Cloud Condensation nuclei (CCN) spectrum is prescribed;
- Cloud droplet effective radius is computed;
- **Indirect aerosol effects are included.**

Specification of global CCN distribution

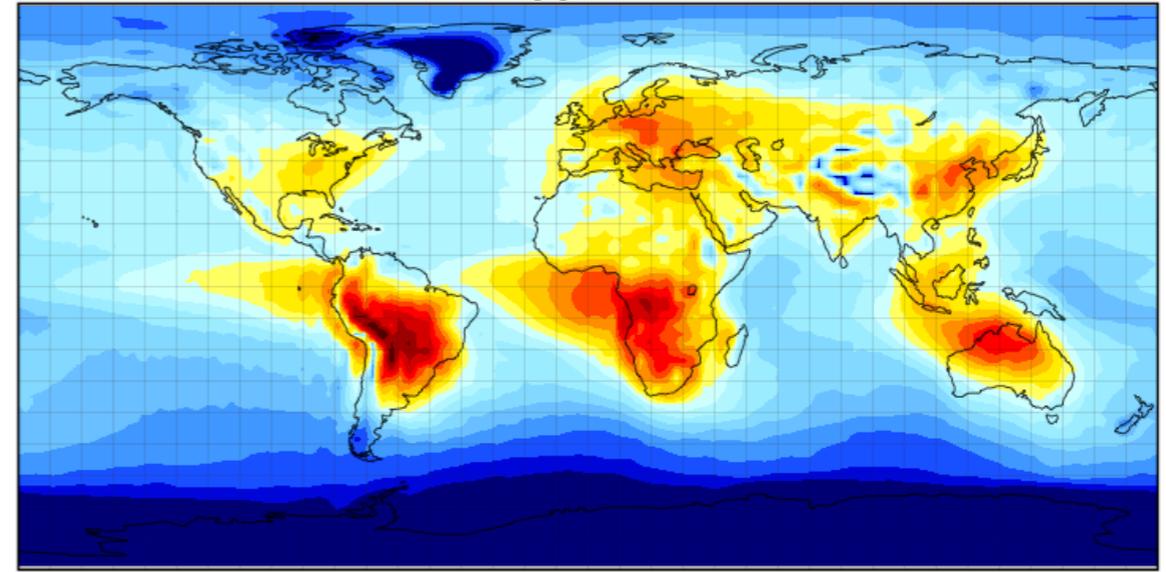
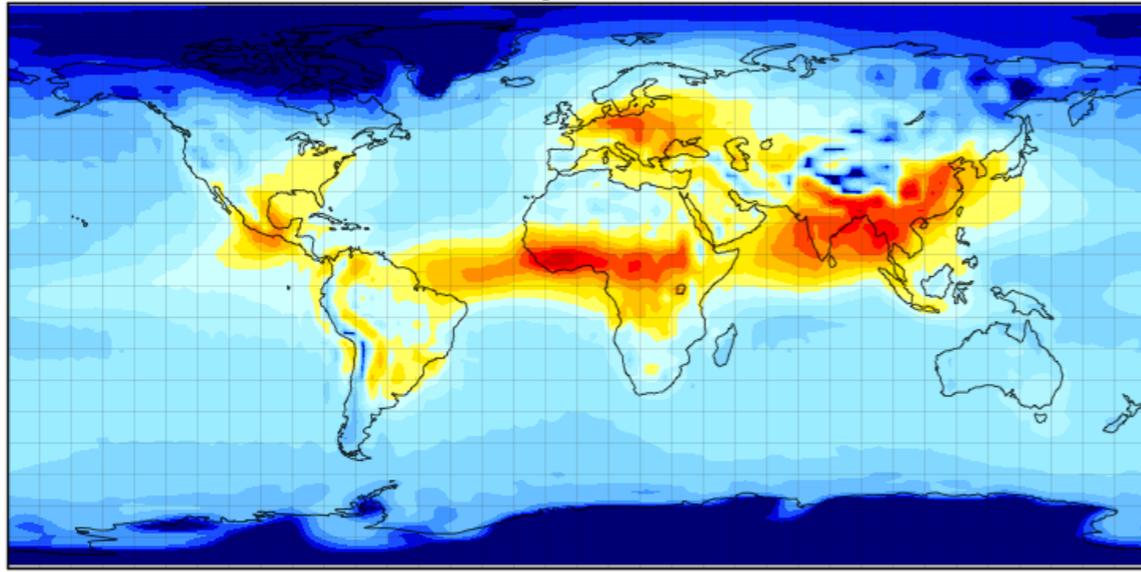
- Estimated from the present-day (PD) and preindustrial (PI; 1870) monthly climatology derived from fully coupled CCSM3 T85 runs;
- CCN consist of sulfate, organic aerosols and sea salt;
- PD > PI in the amount of sulfates;
- Sea salt, and organics are assumed unchanged: PD=PI;
- CCN activation spectrum: $N = CS^k$, where S -supersaturation; C is the CCN # active at 1% supersaturation, $k = 0.4$.
- $C = aN_a$ where N_a is the estimated mean CCN aerosol concentration below 900 mb, $a = 0.5$ in this study.

Prescribed CCN concentration at 1% supersaturation

DJF

PD

JJA



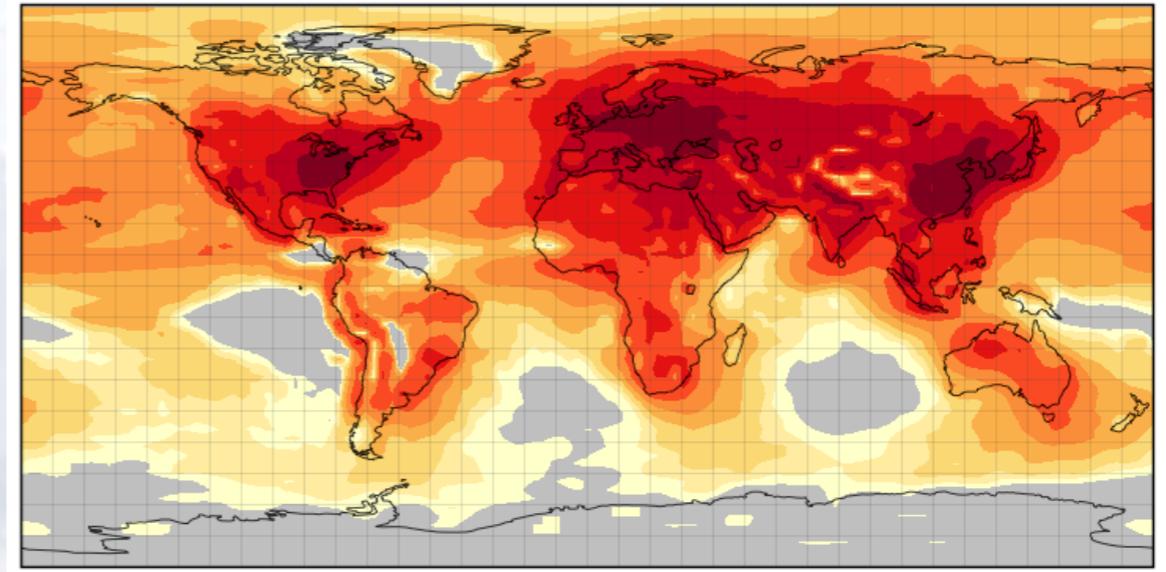
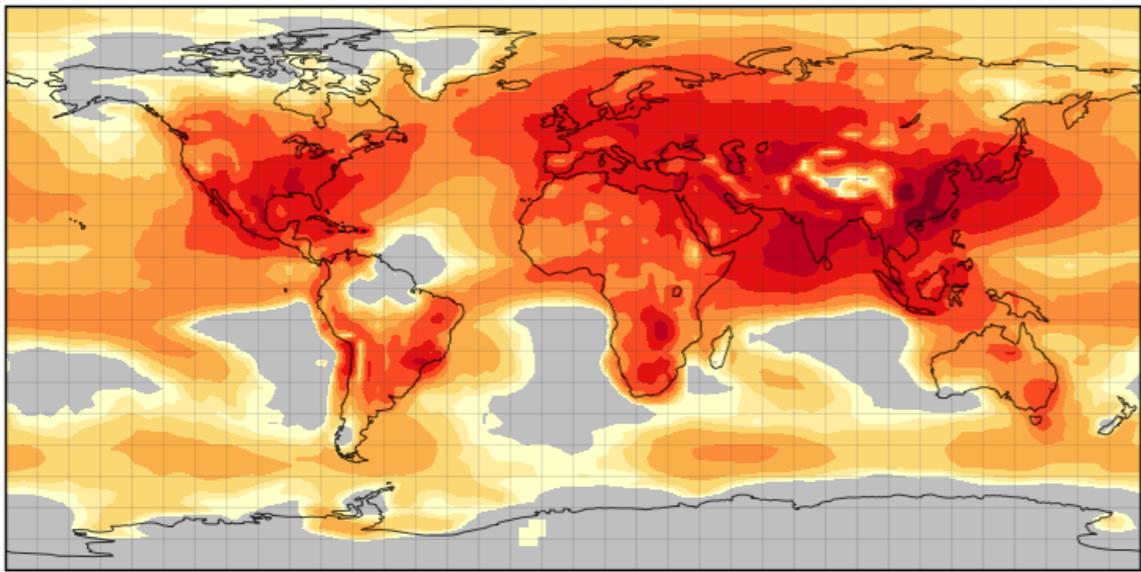
CCN conc. for CRM (#/cm³)



DJF

PD - PI

JJA



Experiments

- **3-year runs (+4-month spin-up), PD and PI CCN, 1- and 2-moment microphysics (4 is total # of runs);**
- **All runs use PD climatological monthly SSTs as BC and PD CO₂;**
- **CAM: Semi-Lagrangian dycore, T42 (1.8x1.8 deg), 30 levels, timestep=900s;**
- **CRM: 32 x 28, x-gridstep=4 km, timestep=20s;**
- **Radiation transfer is computed on CRM grid;**

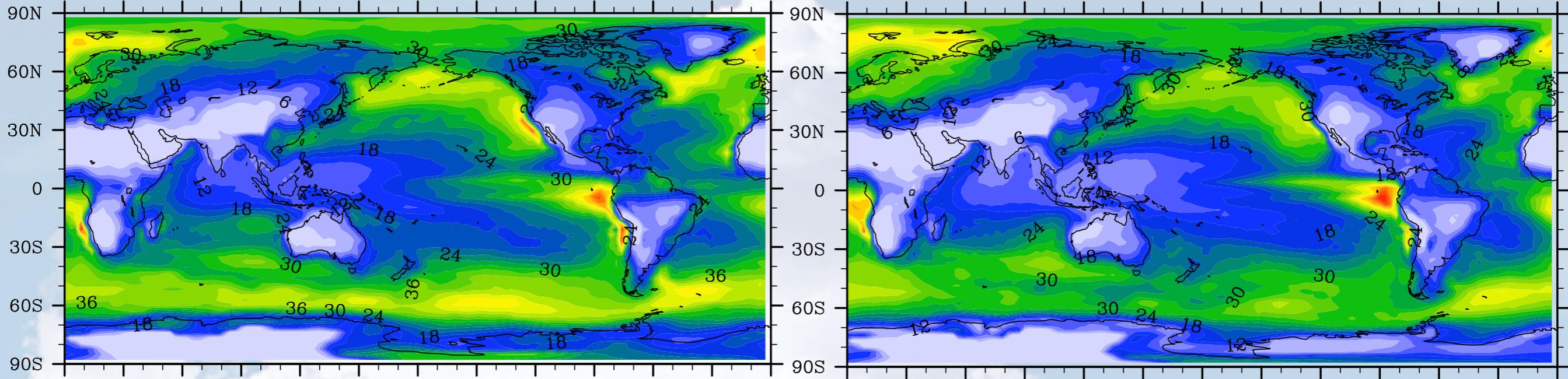
ISCCP-Simulator Low Clouds, %

SP-CAM 1-Moment

22

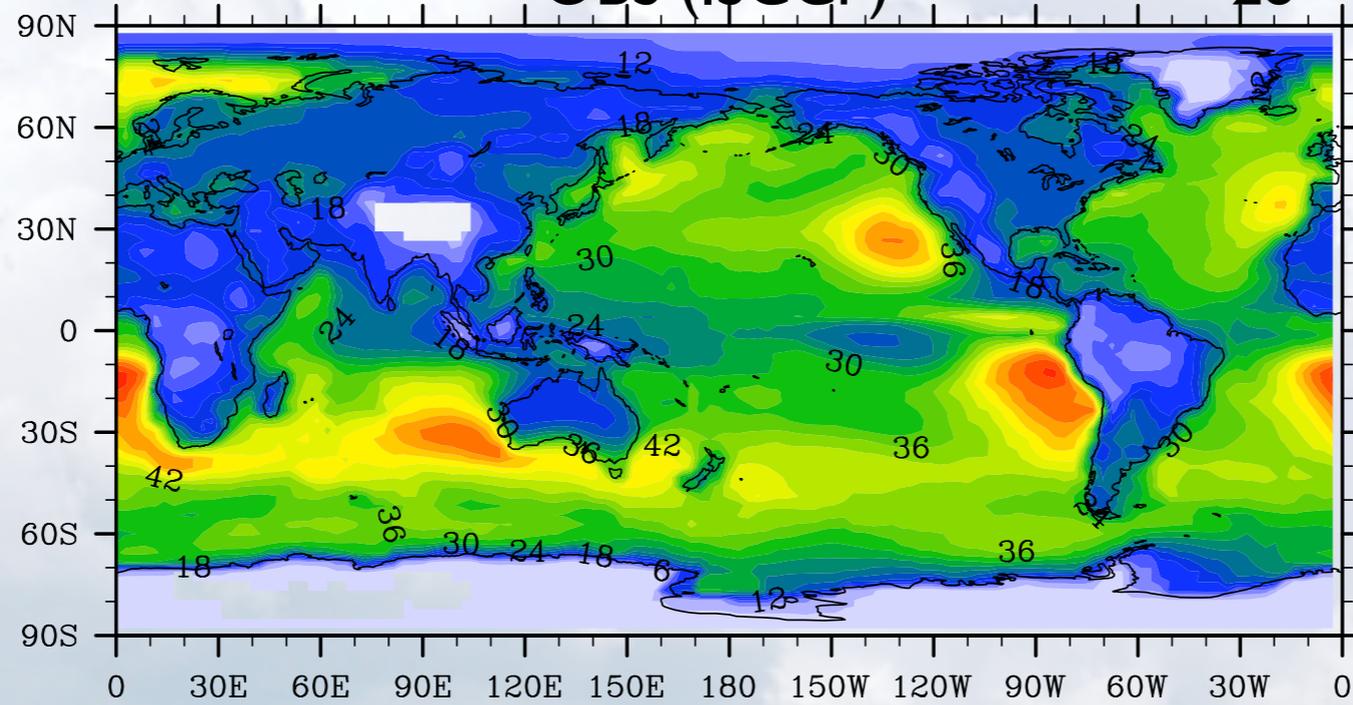
SP-CAM 2-Moment

20



OBS (ISCCP)

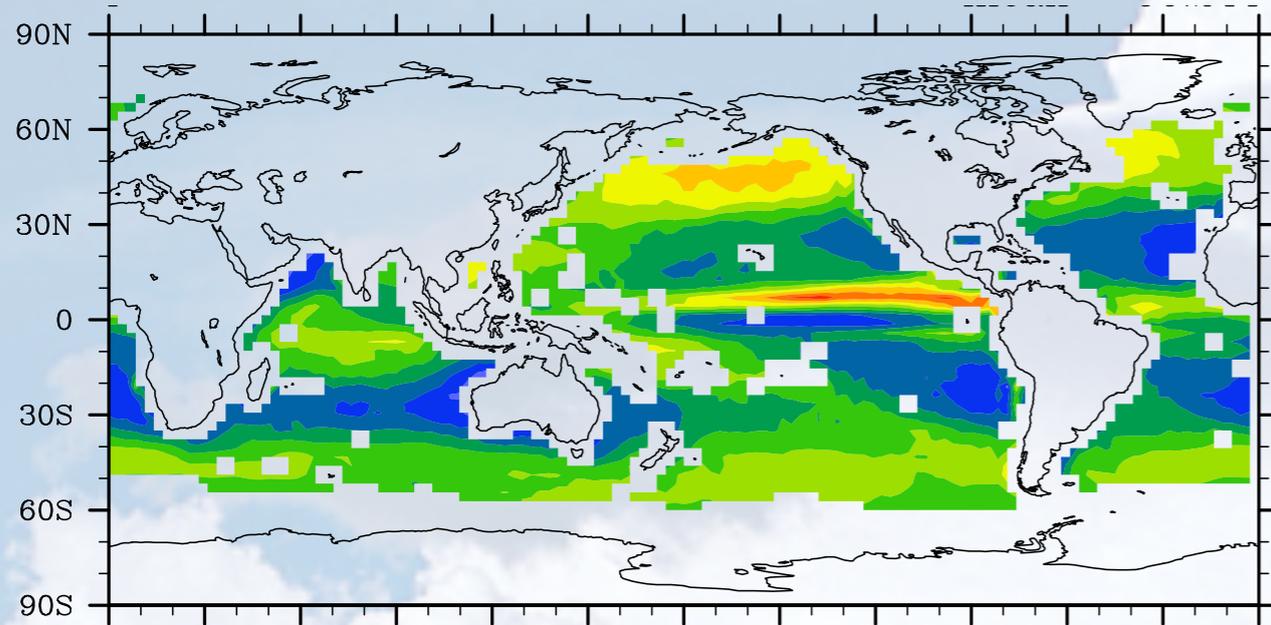
28



Column Liquid Water (Oceans)

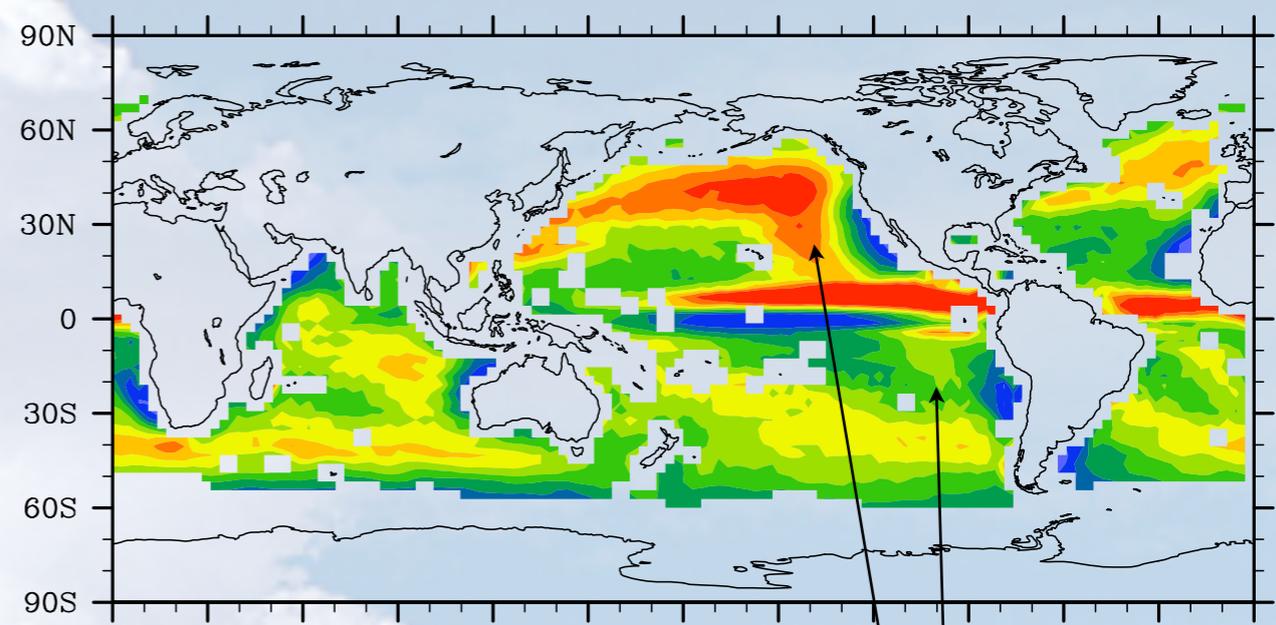
SP-CAM I-Moment

96



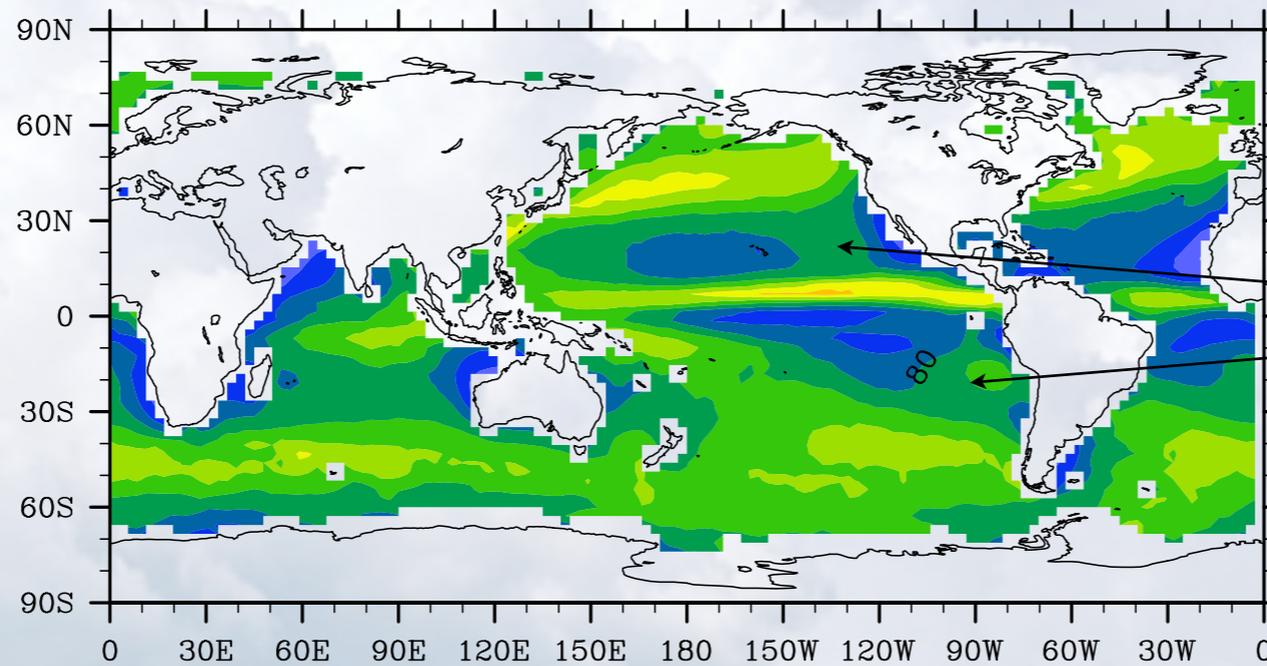
SP-CAM 2-Moment

120



OBS (SSMI)

93



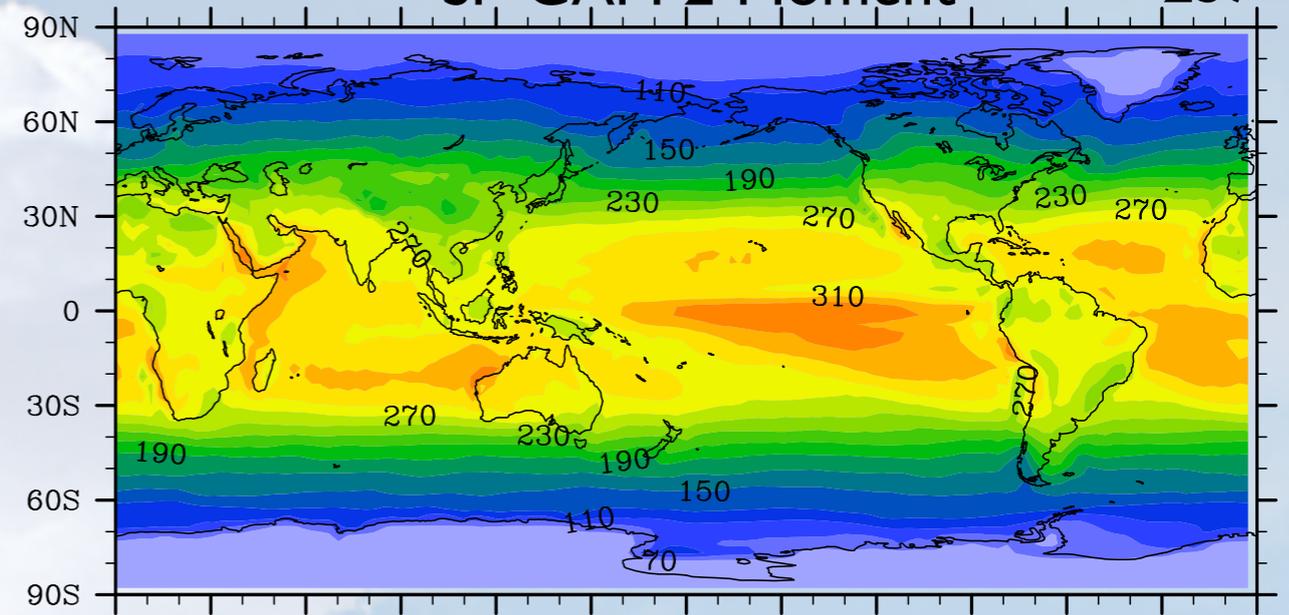
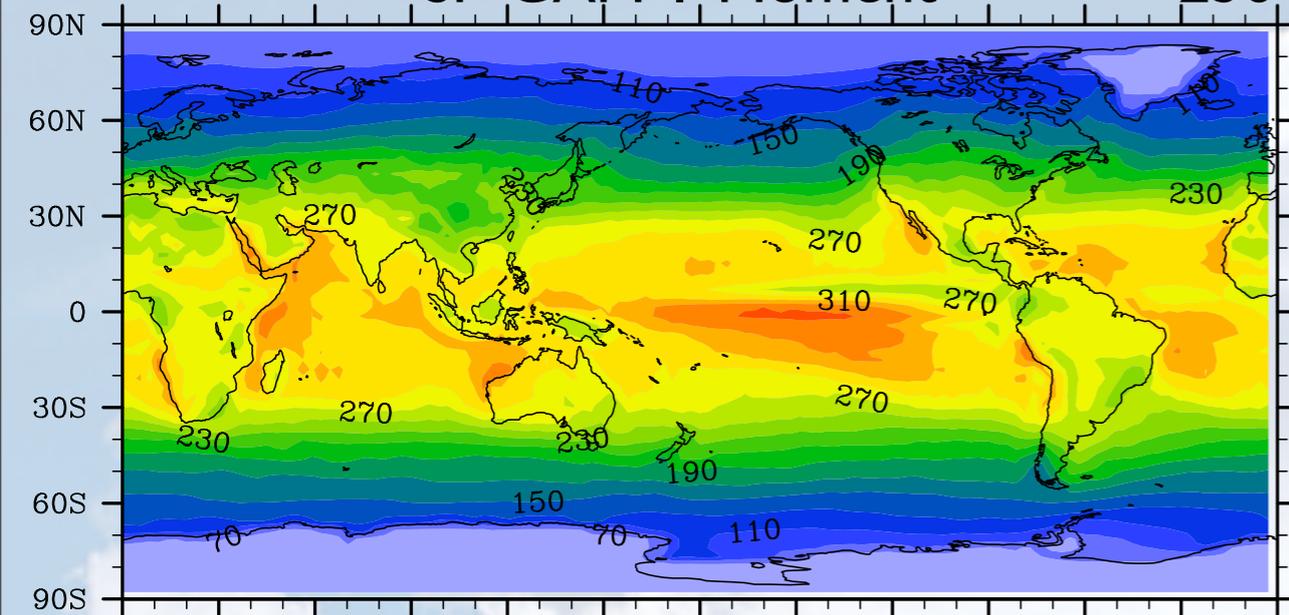
g/m^2

Geographical pattern in 2-moment case is large improvement over 1-moment

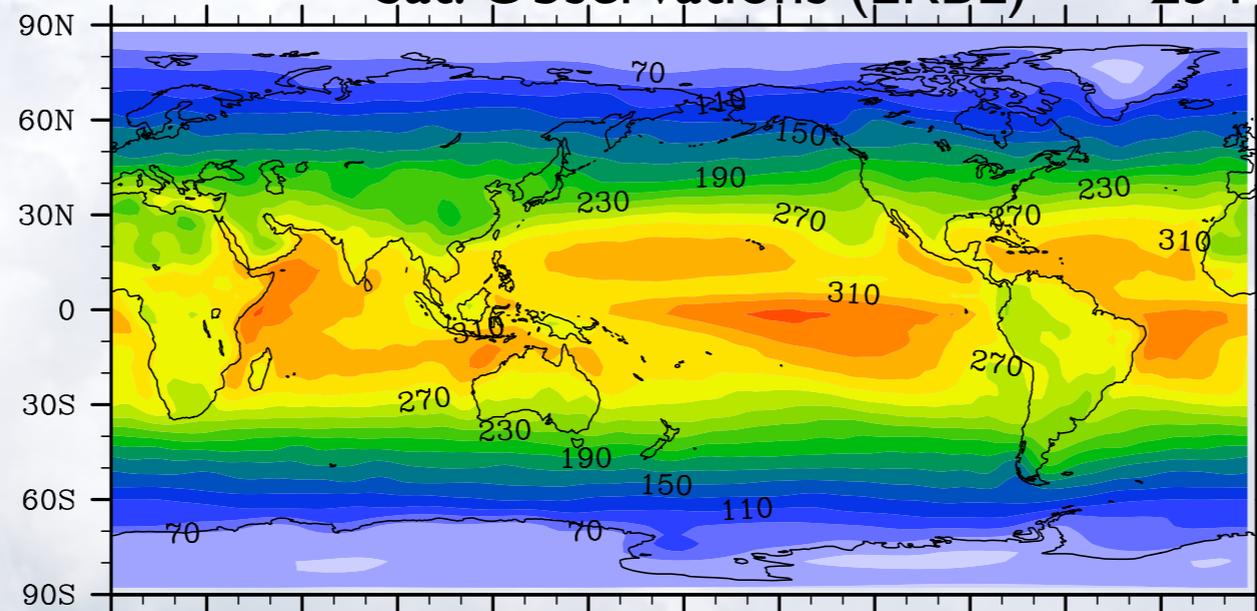
Annual mean absorbed solar radiation

SP-CAM 1-Moment 236

SP-CAM 2-Moment 237

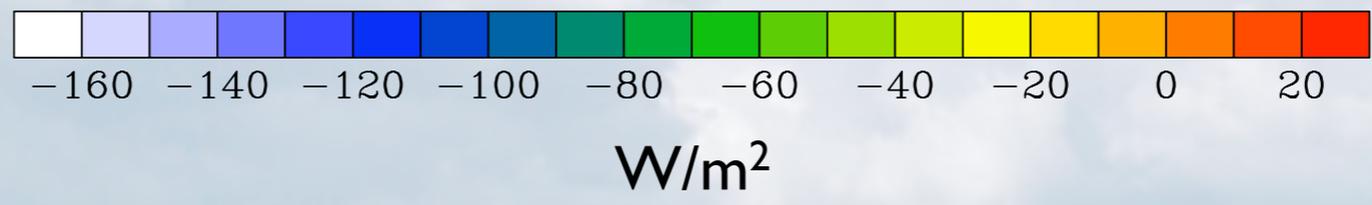
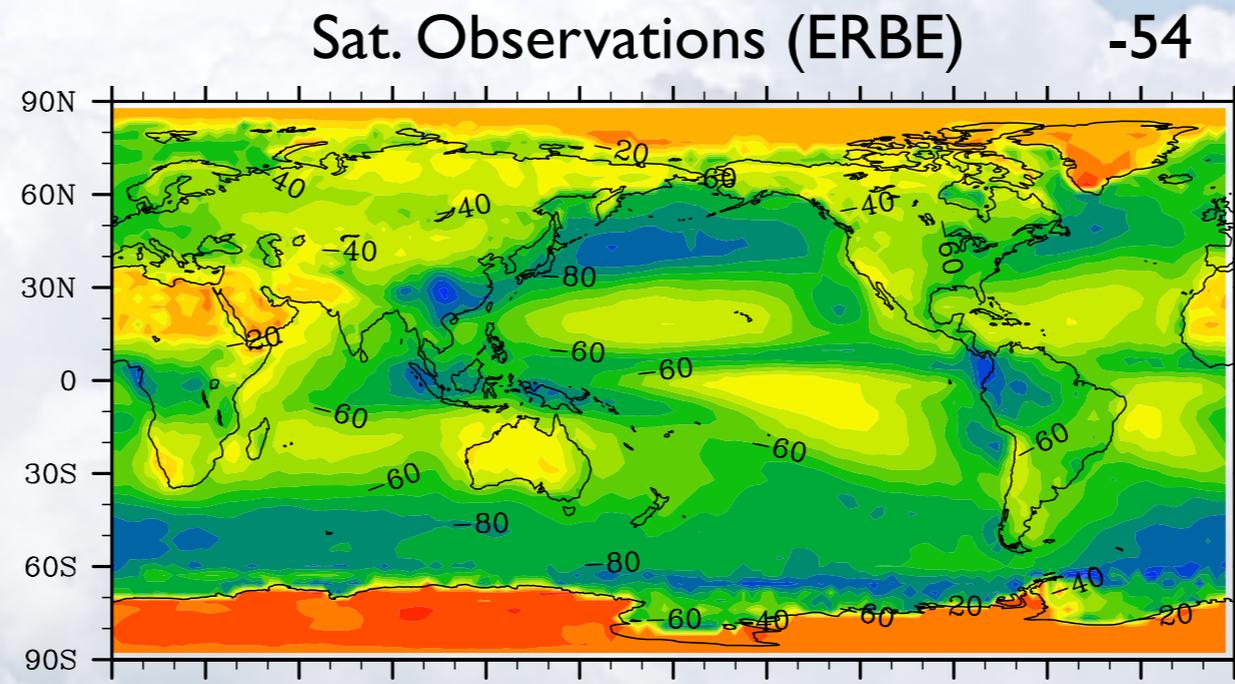
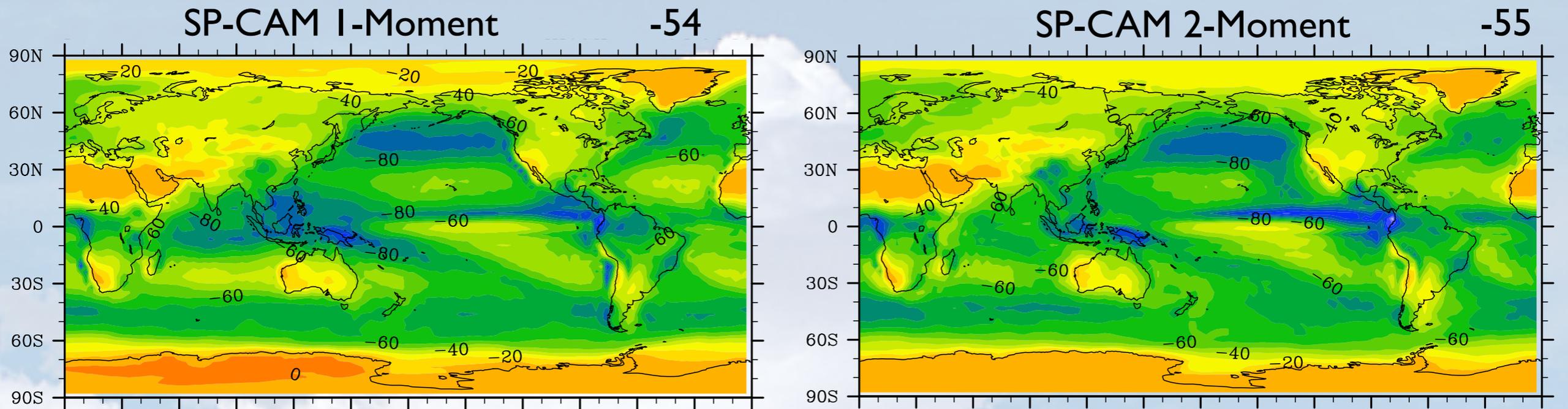


Sat. Observations (ERBE) 234



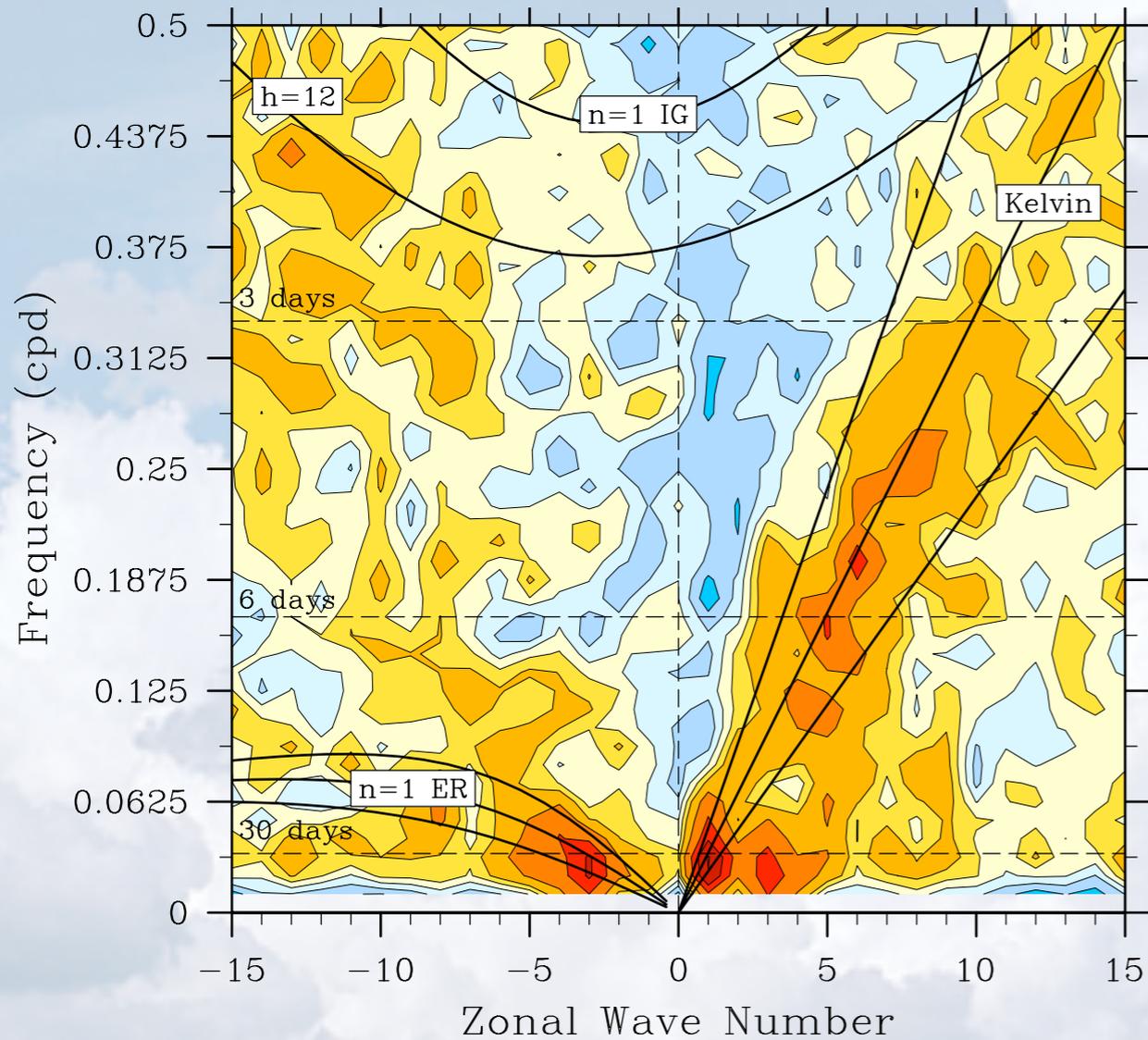
W/m²

Annual mean solar cloud effect

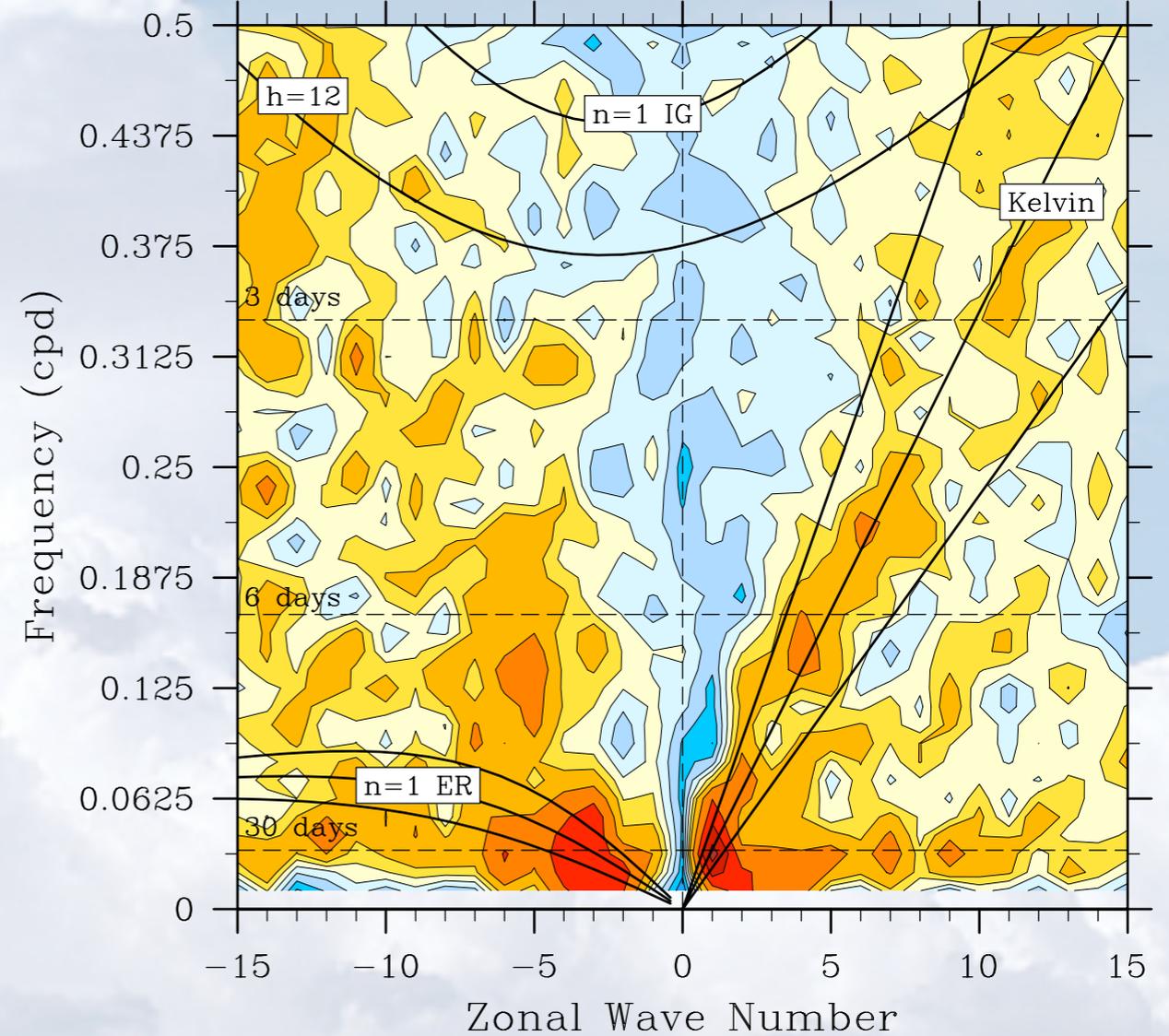


Sub-seasonal Variability in Tropics

SP-CAM I-Moment



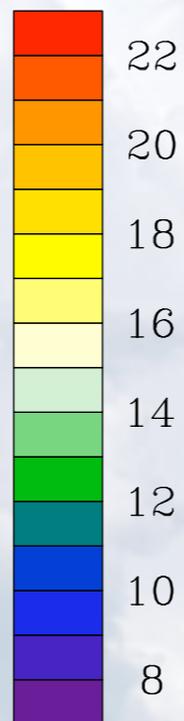
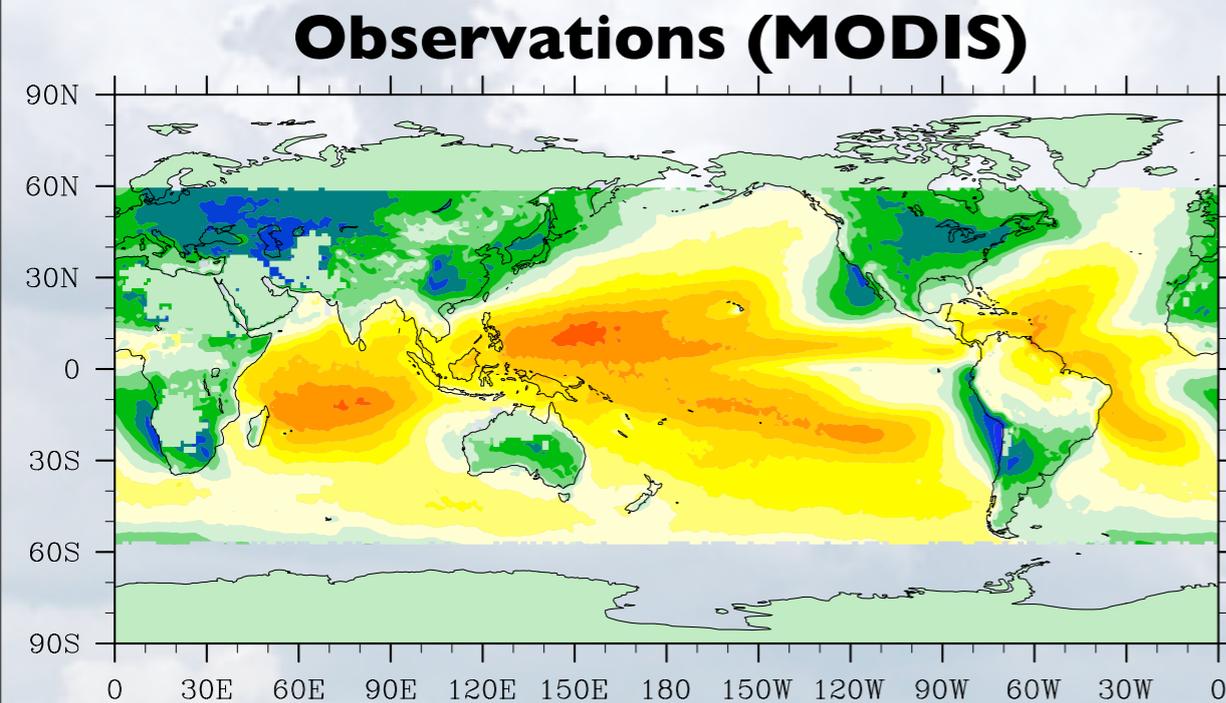
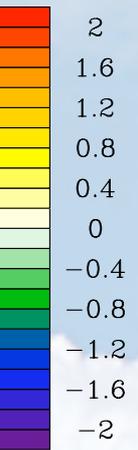
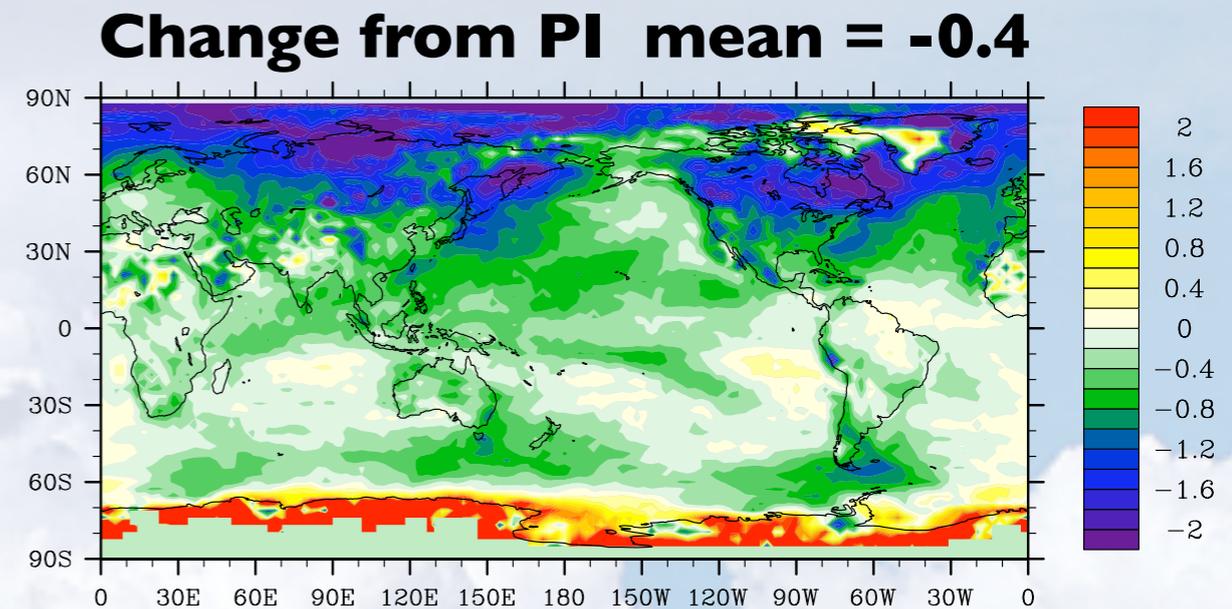
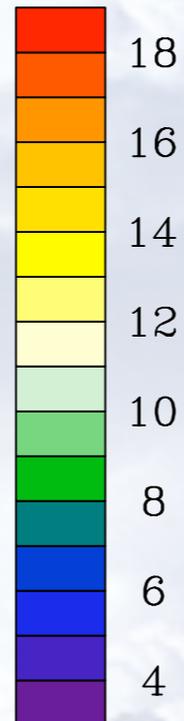
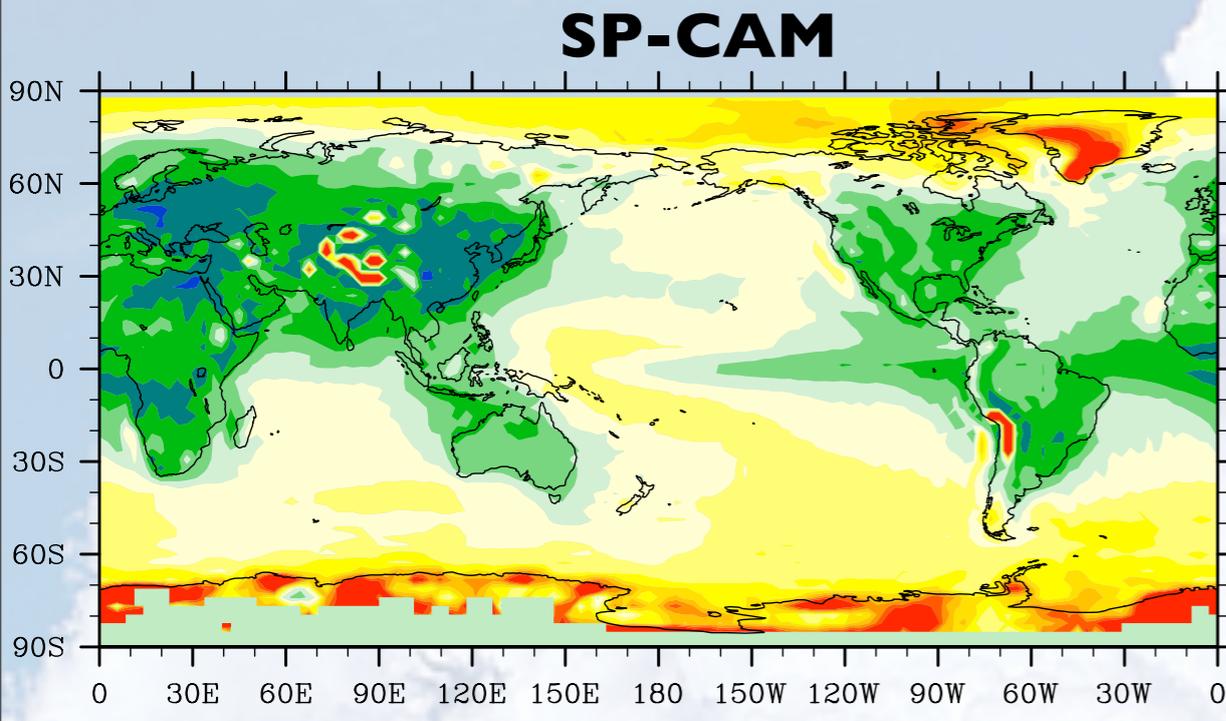
SP-CAM 2-Moment



Both simulations show robust MJO

Annual MODIS-simulator effective radius

SP-CAM with 2-Moment Microphysics



MODIS retrieved Reff seems too large.

Thanks to Robert Pincus for his help in implementing the MODIS simulator and for the MODIS data

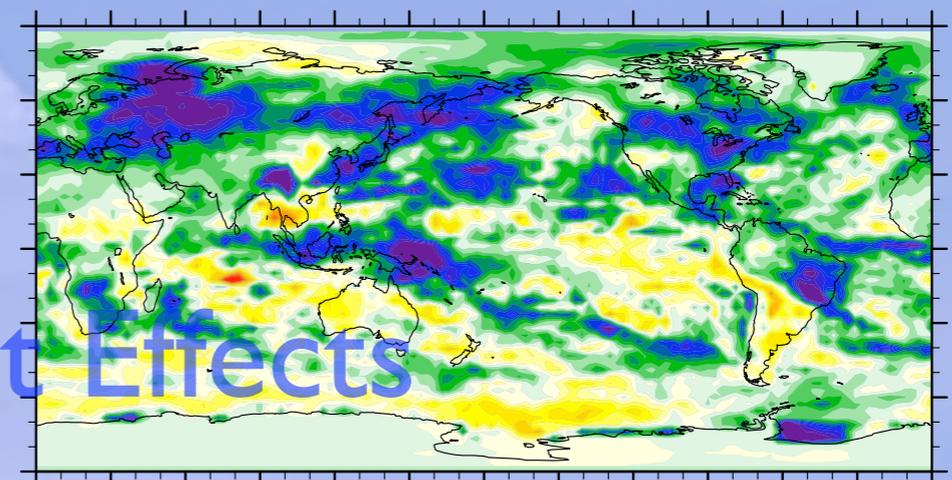
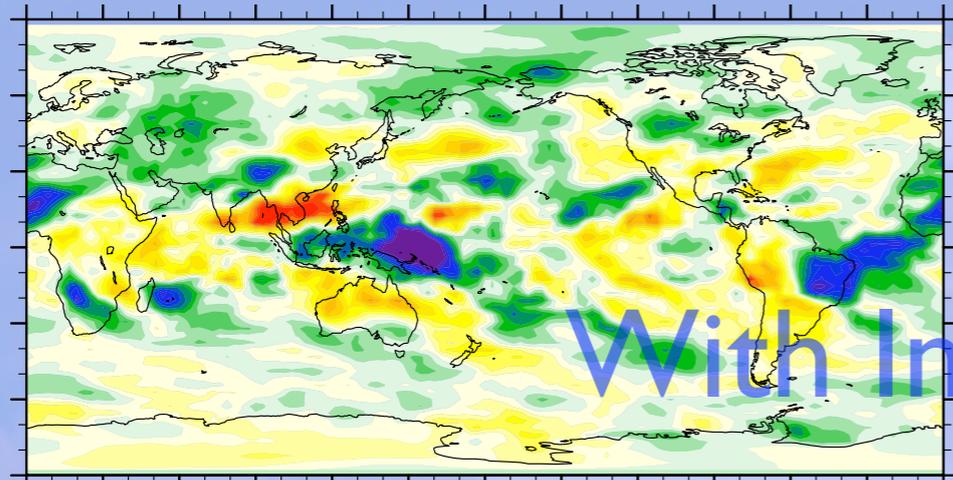
Change from preindustrial

Outgoing Longwave

Absorbed Shortwave

SPCAM 2-Moment -0.1

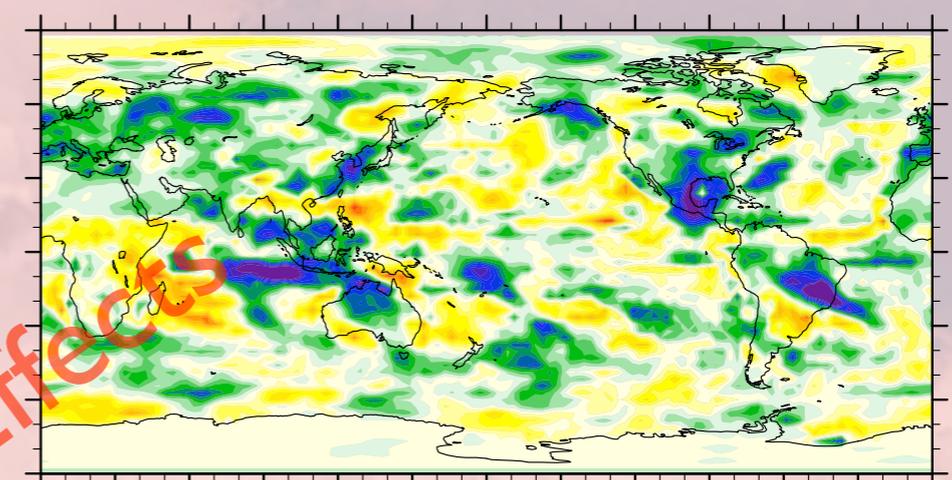
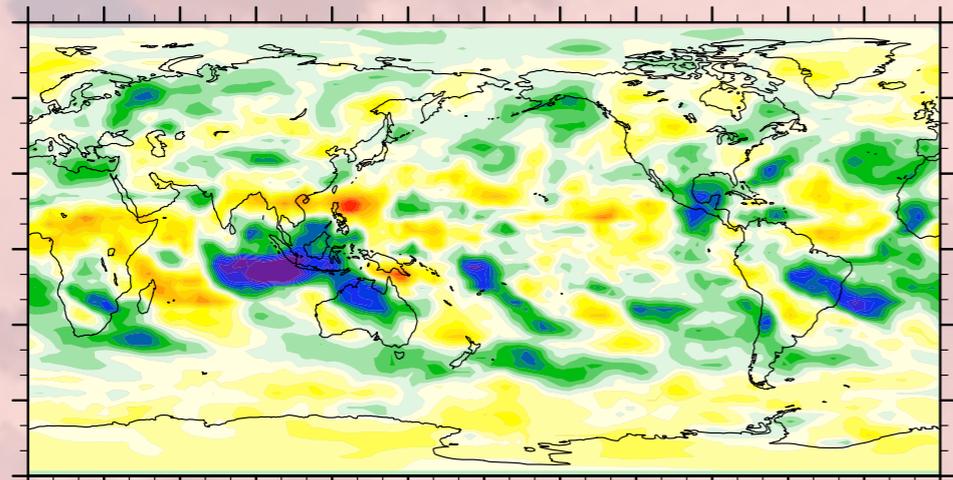
SPCAM 2-Moment -2.0



With Indirect Effects

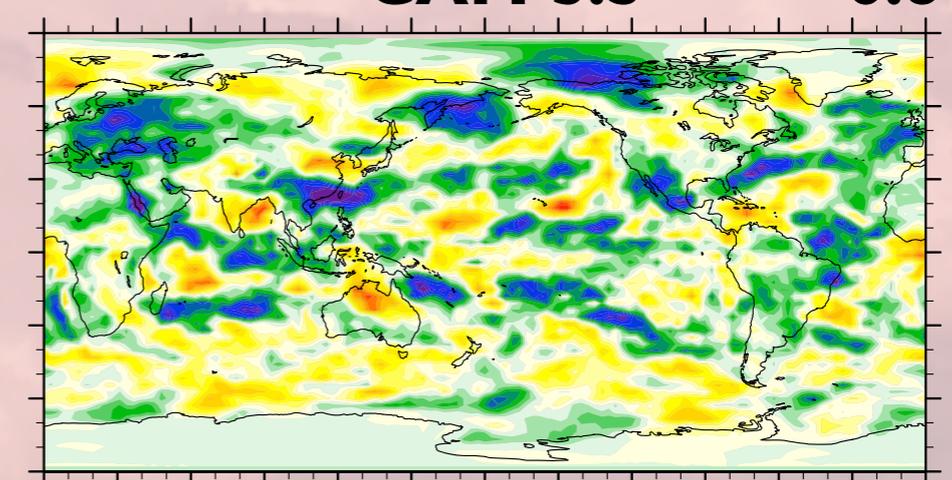
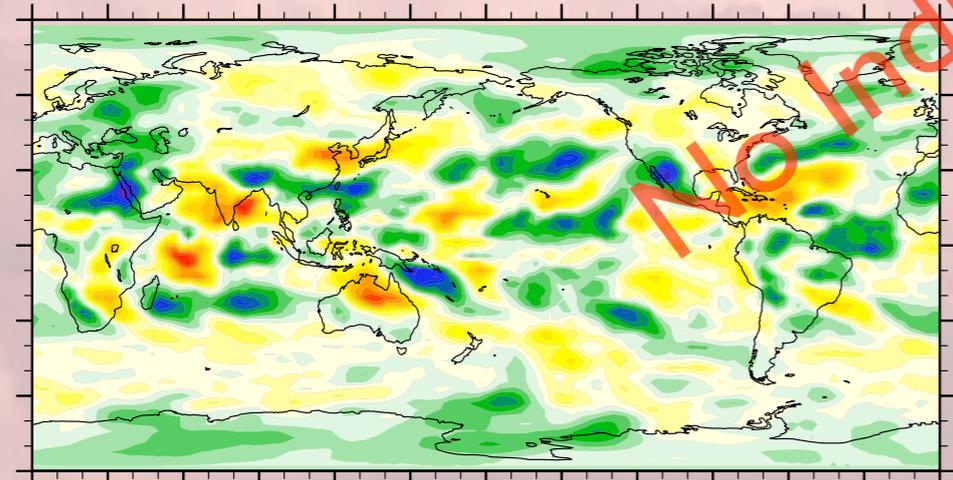
SPCAM 1-Moment -0.1

SPCAM 1-Moment -0.5



CAM 3.5 0.0

CAM 3.5 -0.6

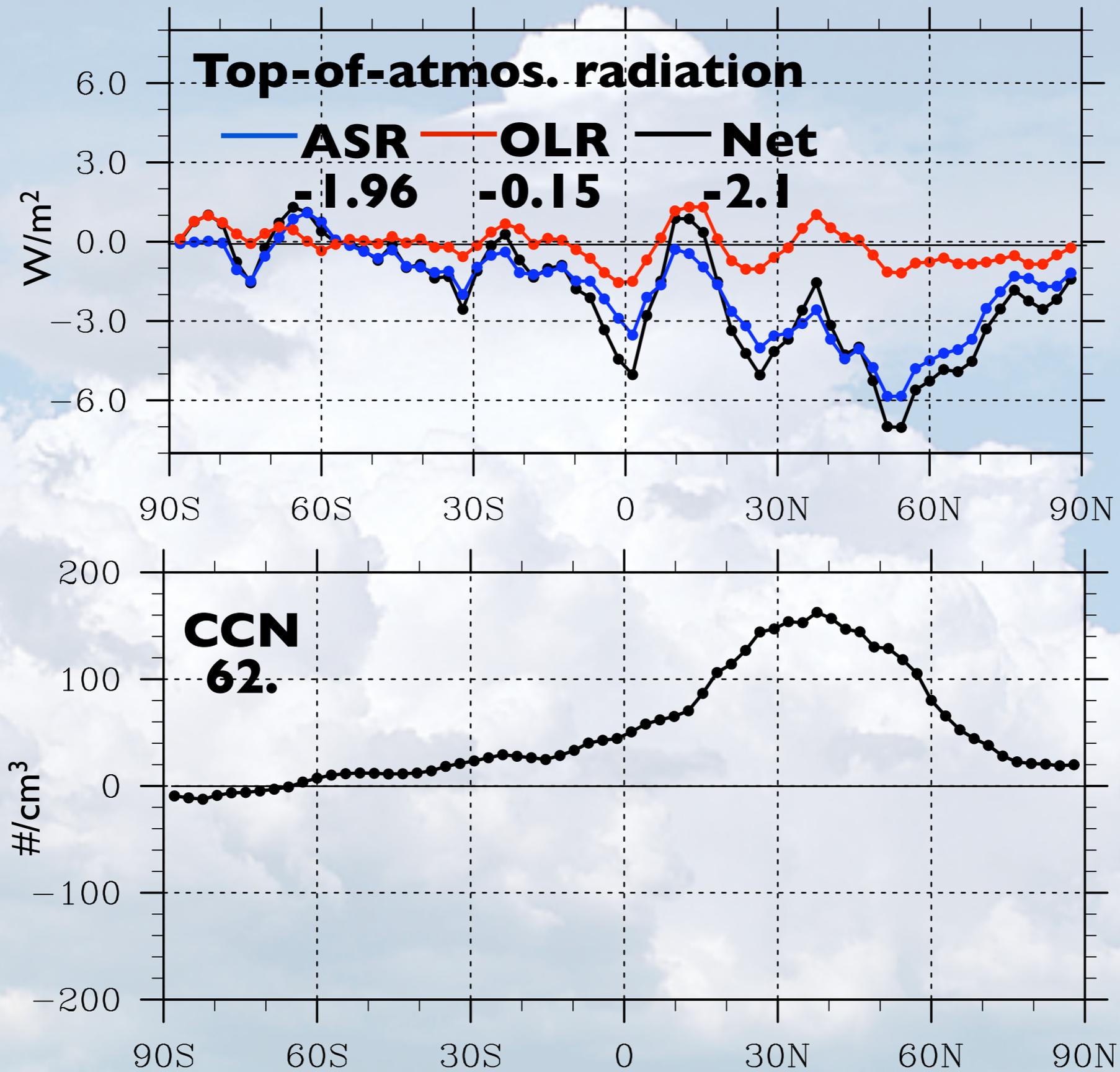


NO Indirect Effects

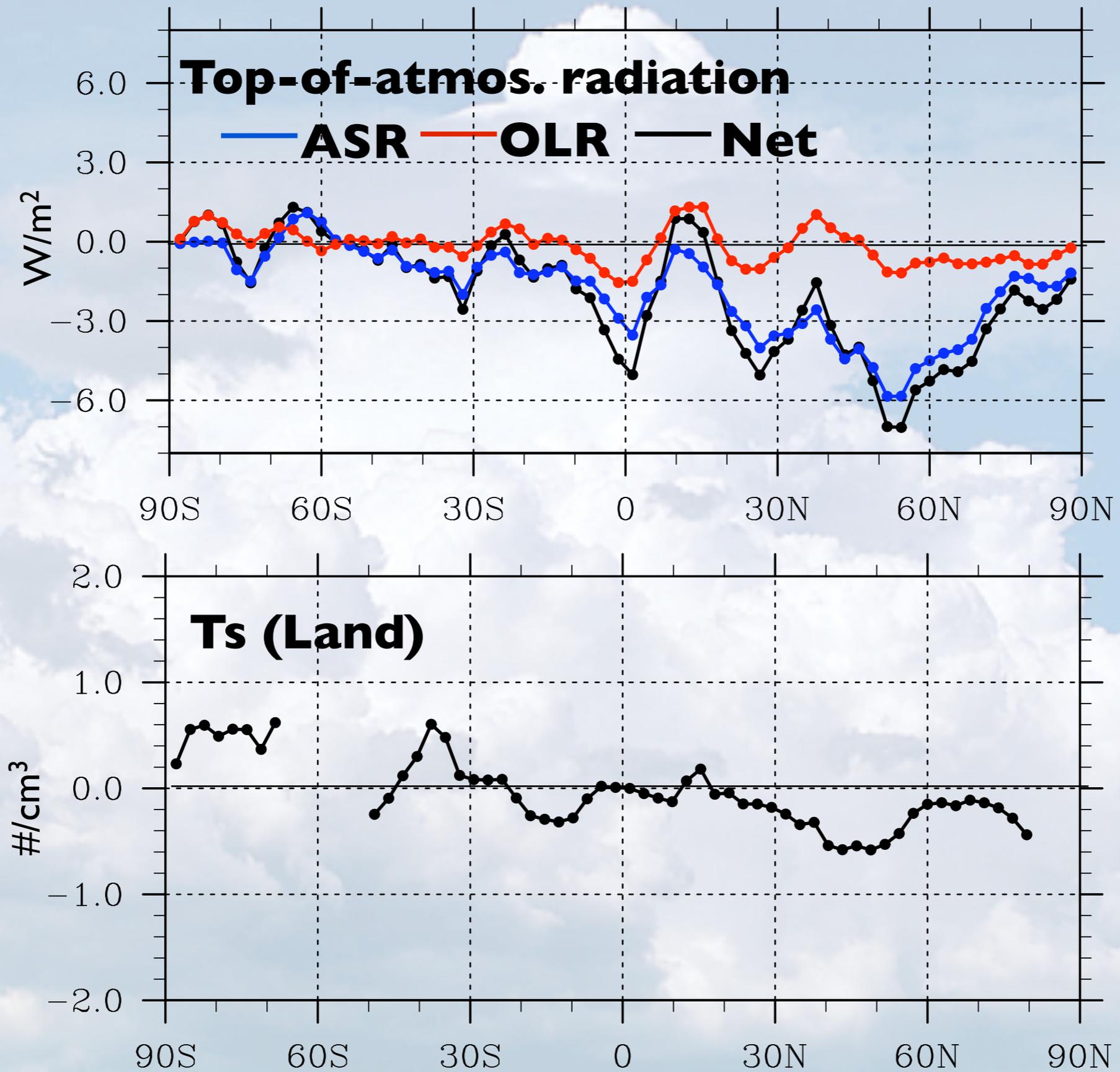
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0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0

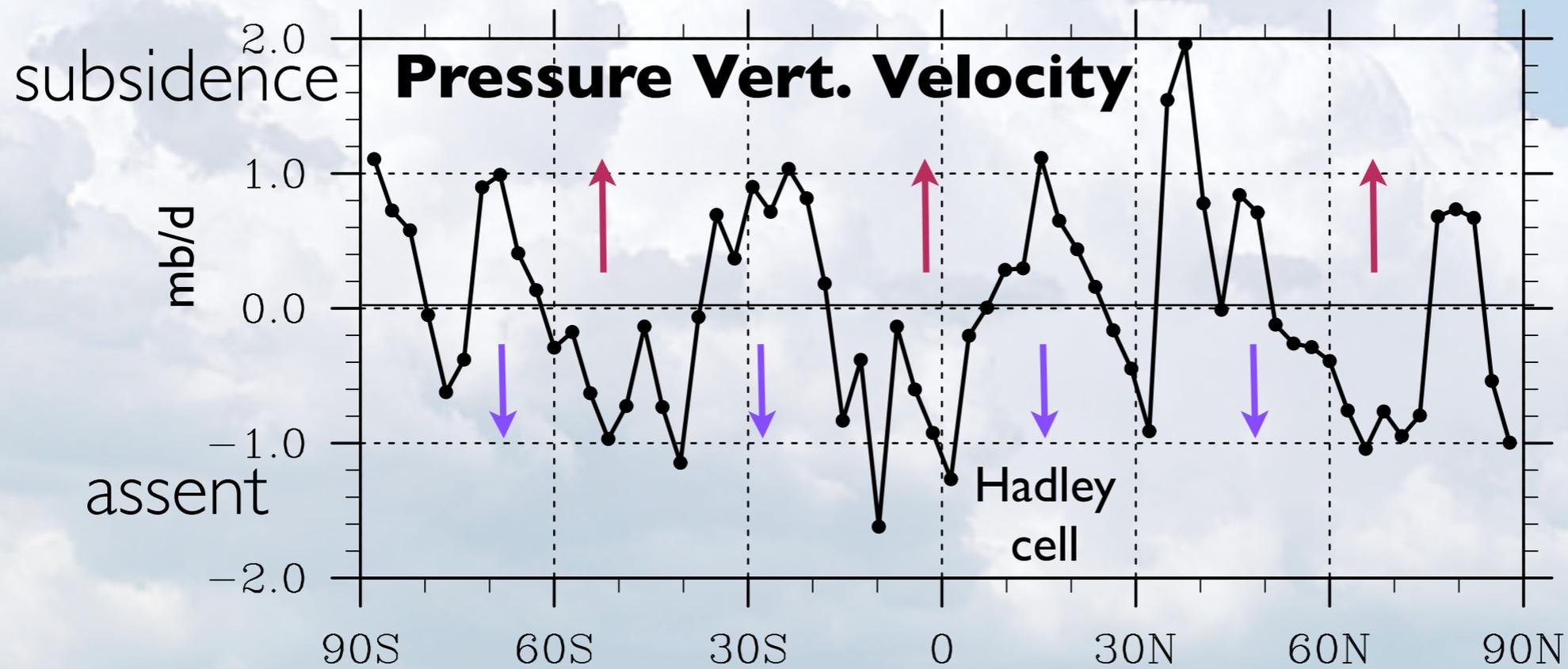
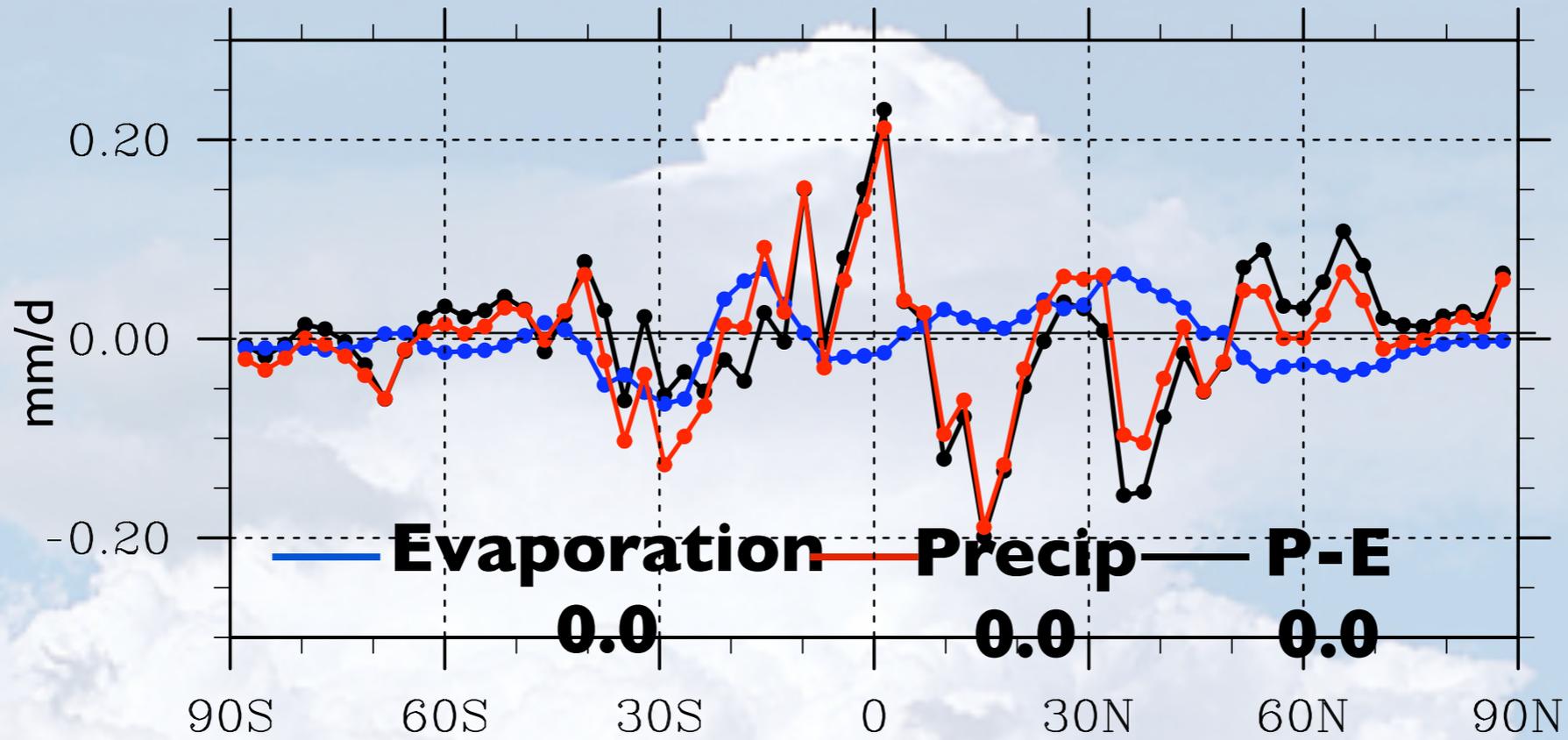
Zonal-mean changes from preindustrial



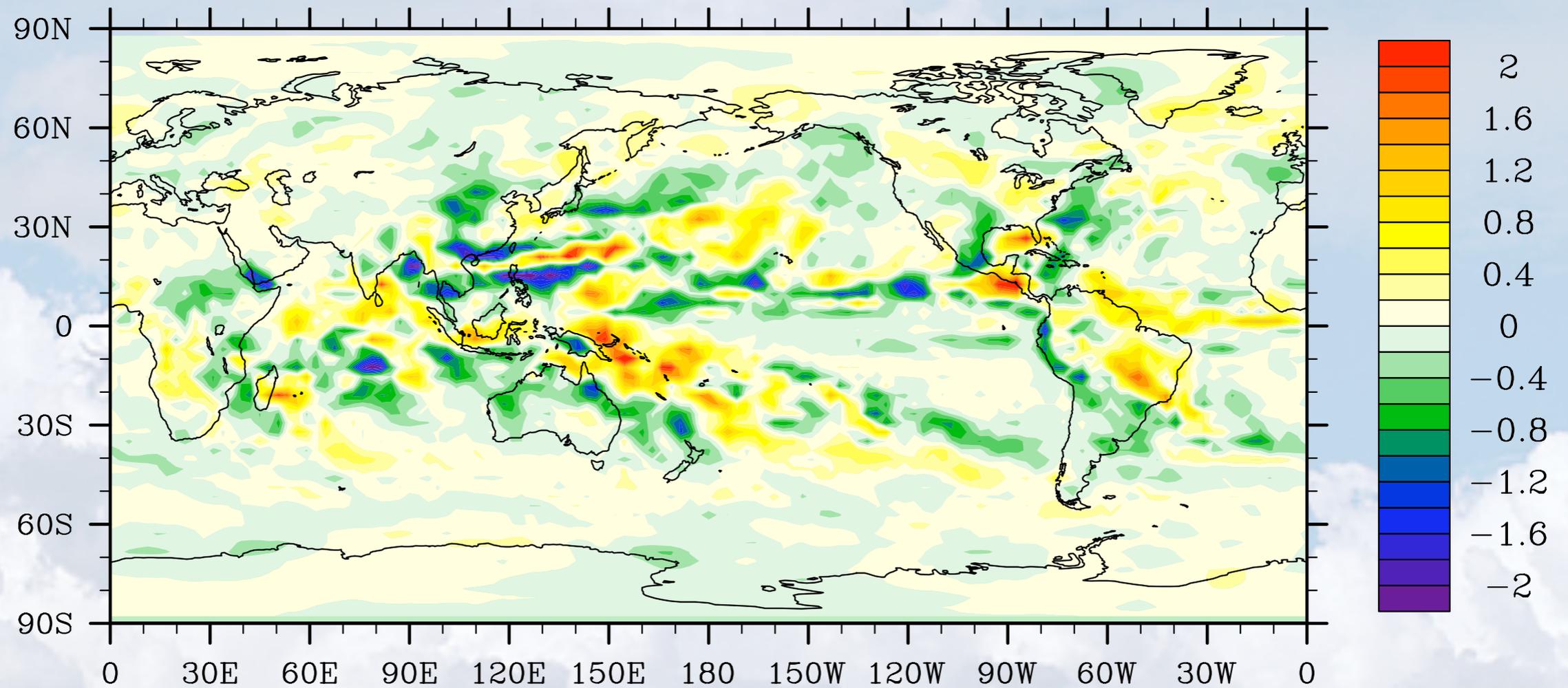
Zonal-mean changes from preindustrial



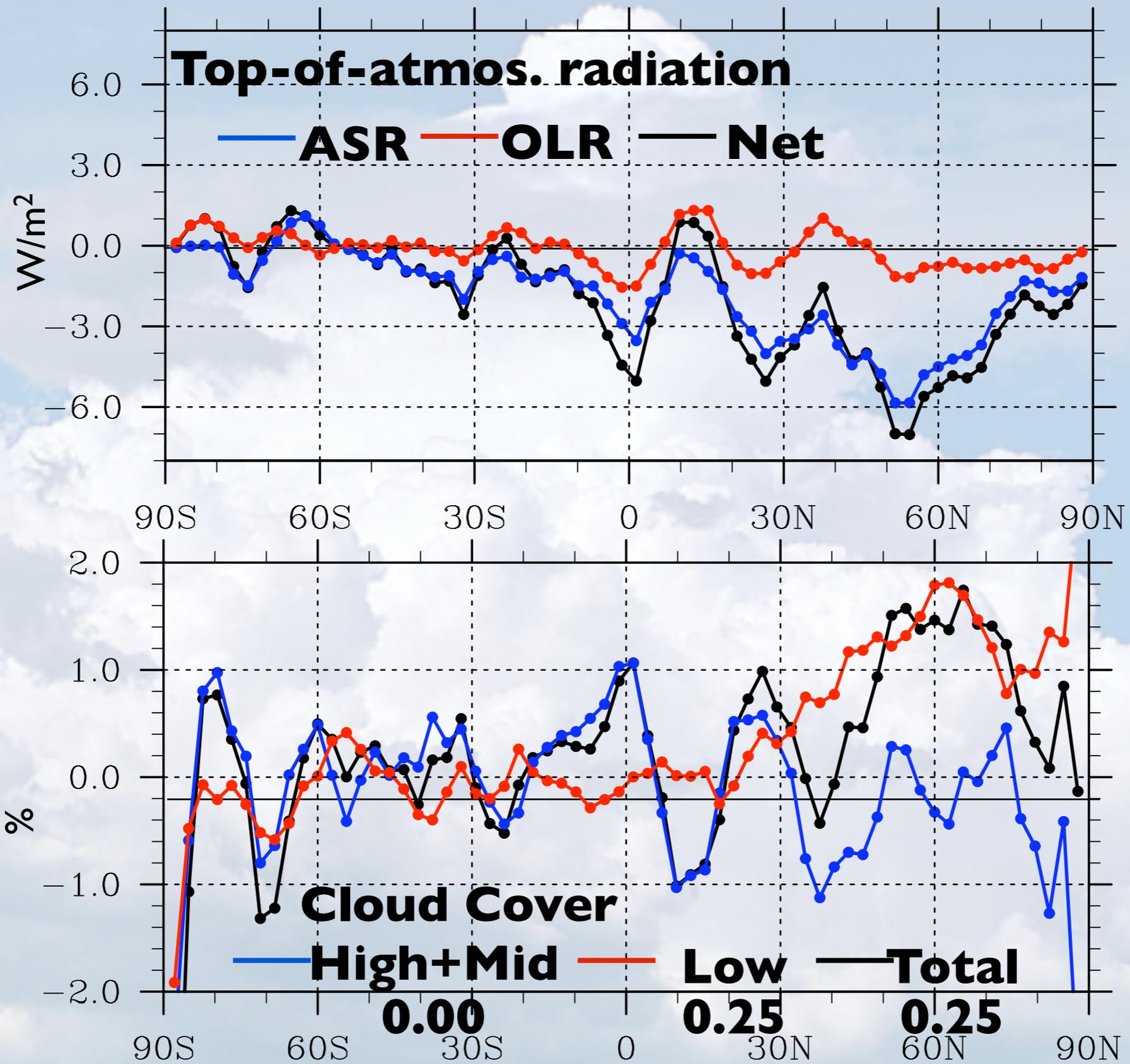
Zonal-mean changes from preindustrial



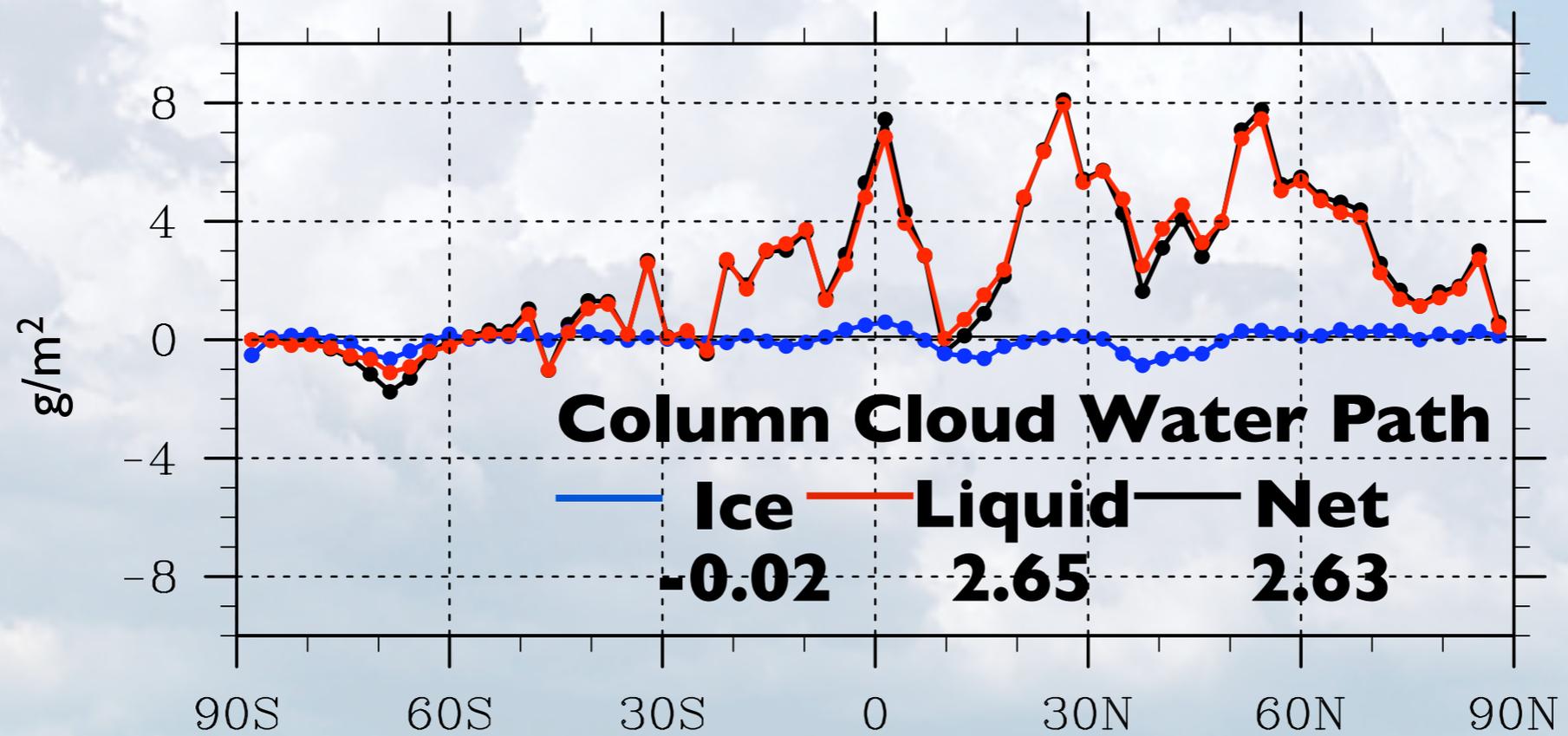
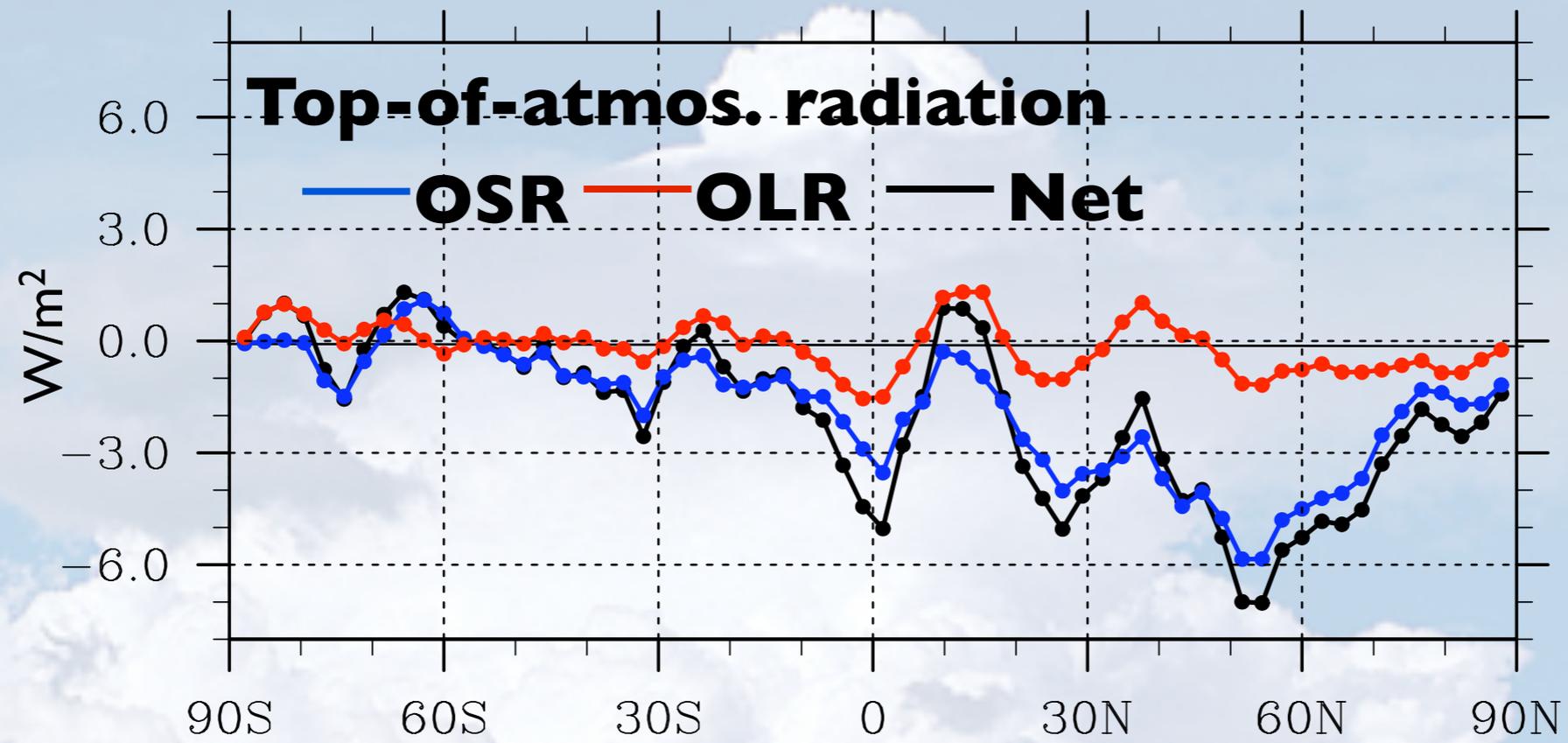
Annual precipitation changes from preindustrial



Zonal-mean changes from preindustrial



Zonal-mean changes from preindustrial



Summary

- **Two-moment microphysics capable of representing indirect aerosol effects is implemented in SP-CAM;**
- **The presence of anthropogenic sulfate aerosol tends to strengthen the Hadley cell and increase mid-latitude cyclone activity, redistributing precipitation without changing the net;**
- **Anthropogenic sulfate aerosol effect (feedback) is estimated to be**
 - **Direct: -0.6 W/m^2 ;**
 - **Indirect: -1.5 W/m^2**

IPCC 4th Assessment Report (AR4)

Industrial Era Climate Change

Radiative Forcing Components

● SPCAM

