Prototype MMF: Recent results

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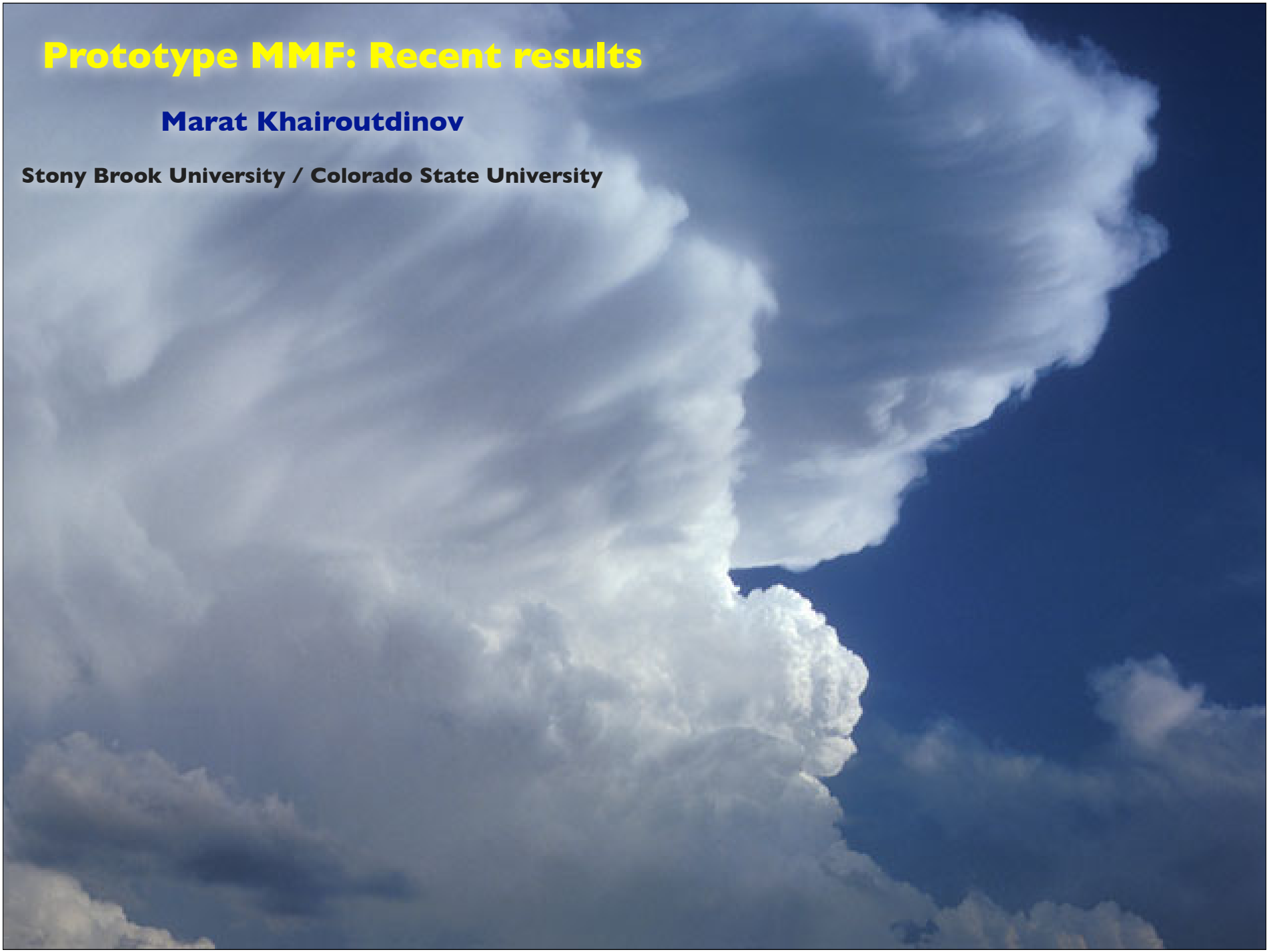
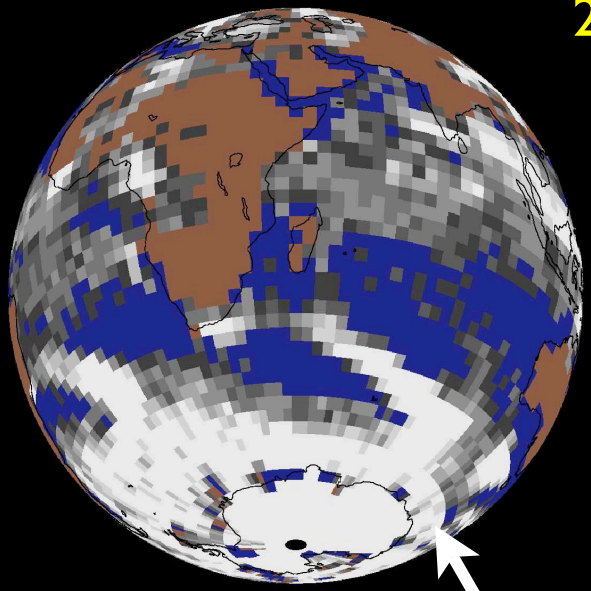


Multi-scale Modeling Framework (MMF): SP-CAM

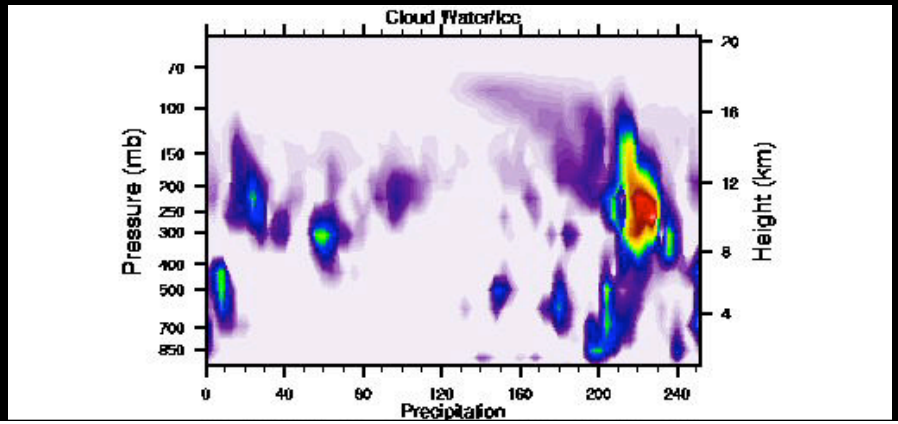
Run a copy of Cloud-Resolving Model
(CRM; a.k.a. 'Super-Parameterization')
in each column of a General Circulation Model (GCM)
(we use NCAR Community Atmosphere Model - CAM)

Super-parameterization is a small-domain cloud-resolving model that explicitly computes vertical profiles of tendencies due to sub-GCM-scale processes in response to GCM-grid-scale forcing

Total number of CRMs: 8,192
2-D CRM Domain: 32-64 columns (dx=4km)
and as many levels as the GCM (L30)



Each column of GCM has a CRM

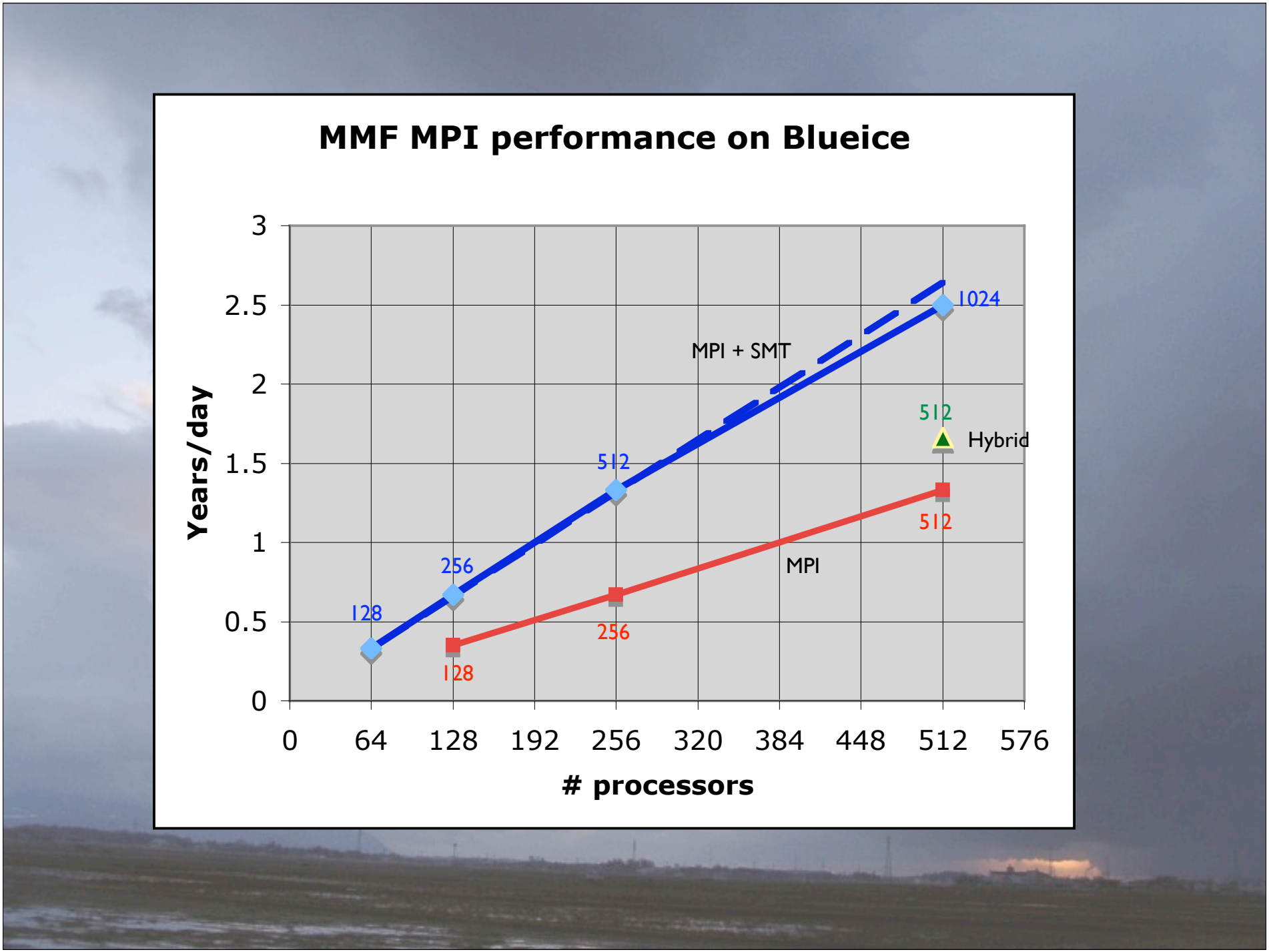


Prototype-MMF (SP-CAM) Research

- Simulations available for analysis/diagnostics/research
  - AMIP (Prescribed sea surface temperatures), 19 years
  - Climatological SST, Present, 4 years
  - Cess' Present+2K, 4 years
  - 2xCO2 SST from a CCSM run, 4 years
  - Weather-forecasting mode - CAPT framework
- Sensitivity studies
  - Short runs, few months to 1-2 years
  - Microphysics (ice)
  - CRM domain/grid configuration
  - Host GCM grid resolution
- Framework Improvements
  - Cloud model high-order closures for unresolved scales
  - 'Mini-LES' cloud resolving model for shallow clouds
  - Microphysics
- Offline CRM runs
- Software Improvements
  - MPI-only version of SP-CAM which runs on more processors than number of latitudinal circles

Pure-MPI MMF

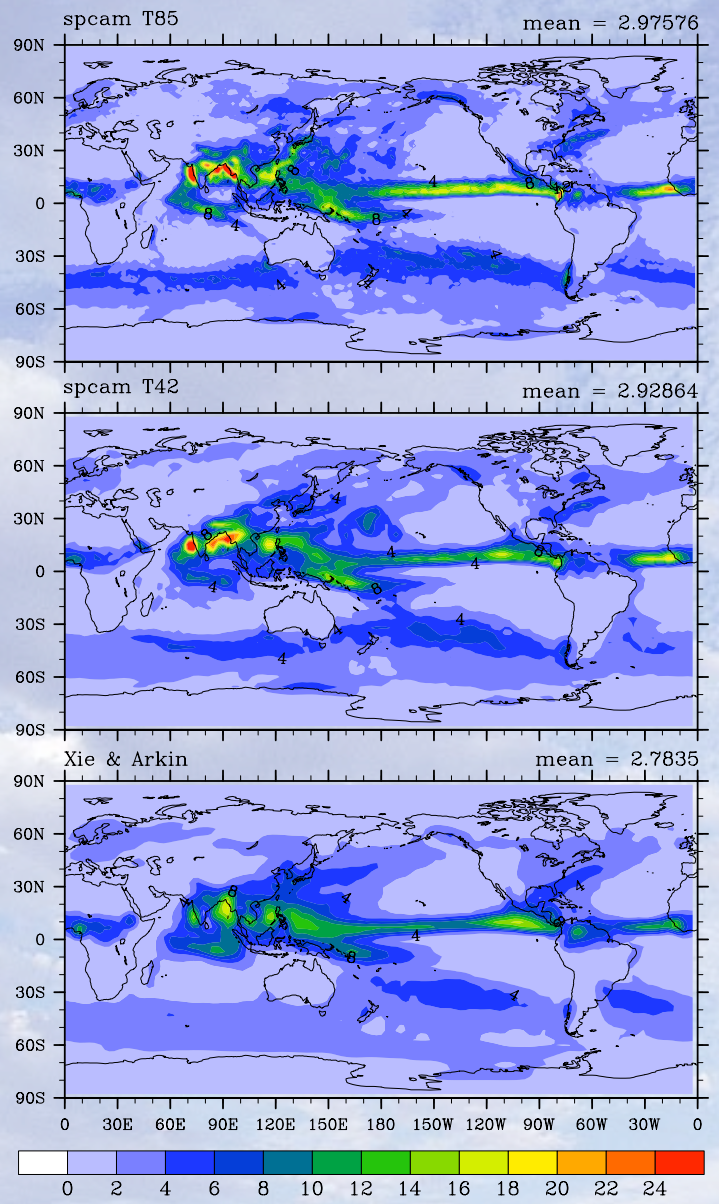
- Based on work done for standard CAM GCM by Patrick Worley (ORNL)
- Dynamical core (SLD or EUL only) is run on different number of processes than column physics
- Maximum number of MPI processes for dynamics still = number of latitudes (64 for T42; 128 for T85)
- Maximum number of MPI processes for physics = number of grid columns (8192 for T42; 32,768 for T85)
- Communication is still done for the GCM grid fields; each CRM core memory is local to a host MPI process
- Bottom line: **Pure-MPI version of MMF may scale well on BlueGene/L**


MMF MPI performance on Blueice
Years/day
processors
0
0.5
1
1.5
2
2.5
3
0
64
128
192
256
320
384
448
512
576
MPI + SMT
MPI
Hybrid
128
256
512
1024
128
256
512
512

T42 vs T85 SP-CAM
Precipitation Rate

JJA

JJA Precipitation Rate, mm/day



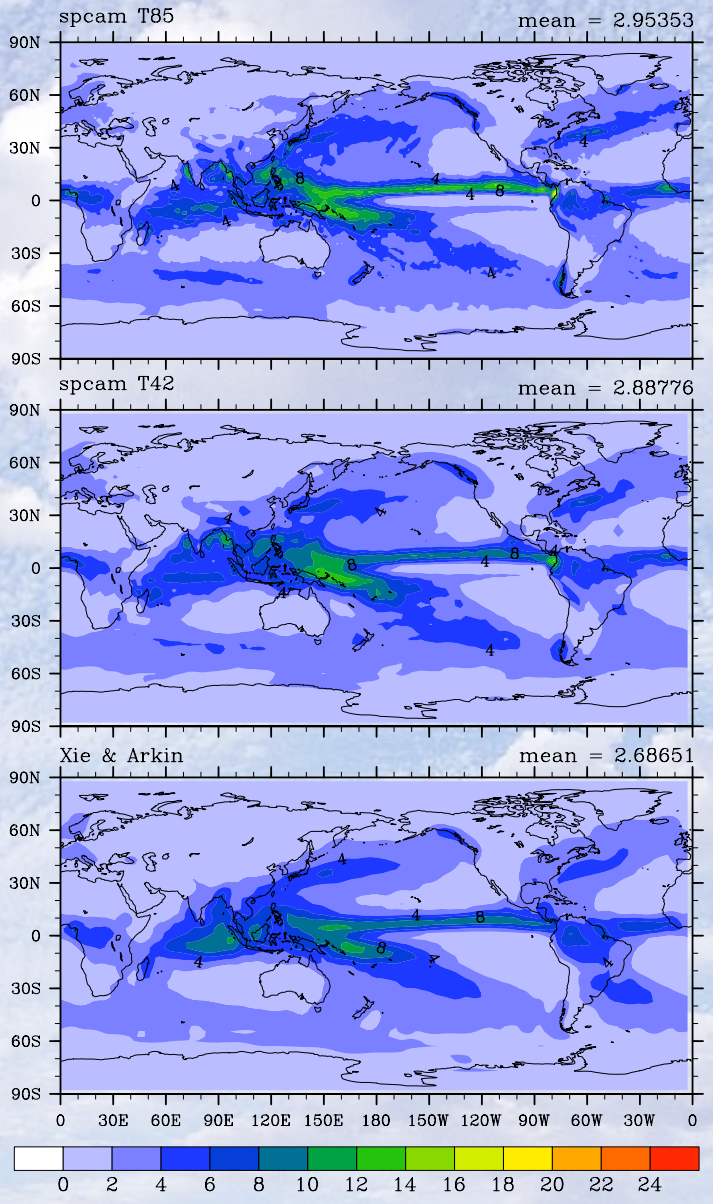
T85 1.4°x1.4°

T42 2.8°x2.8°

OBS

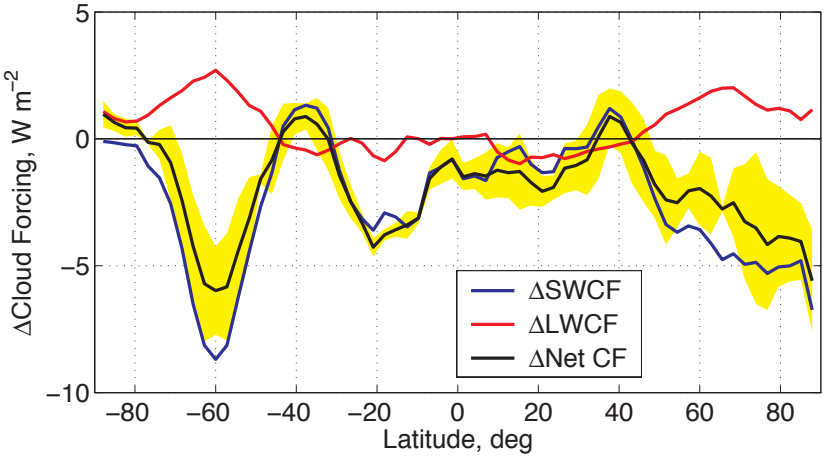
ANN

ANN Precipitation Rate, mm/day

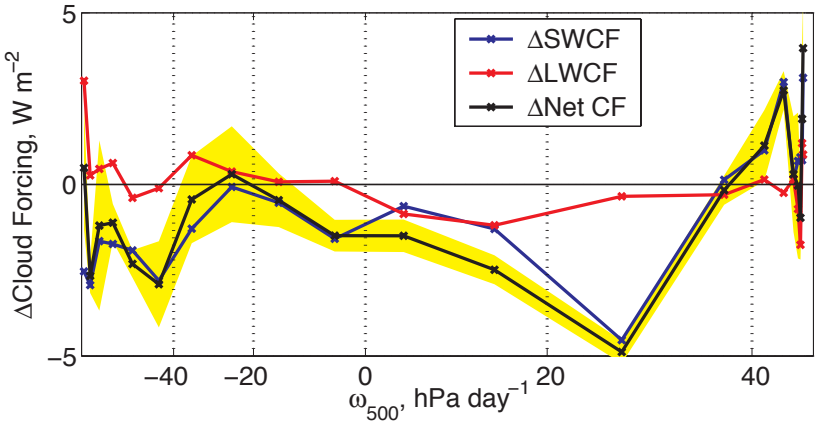


Cess-type SST+2K climate sensitivity experiment

Zonal-mean Cloud Forcing Changes
as a function of latitude

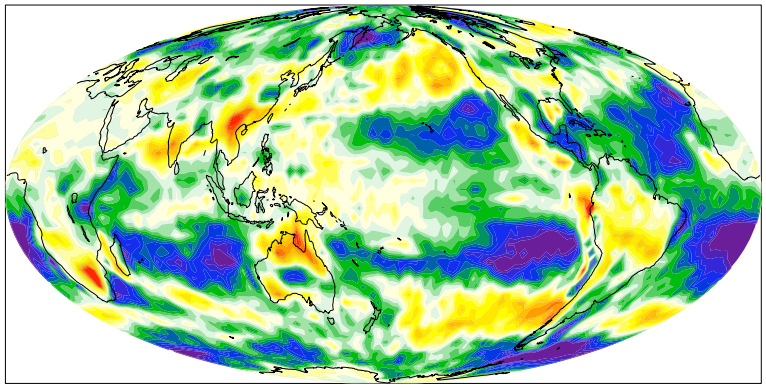


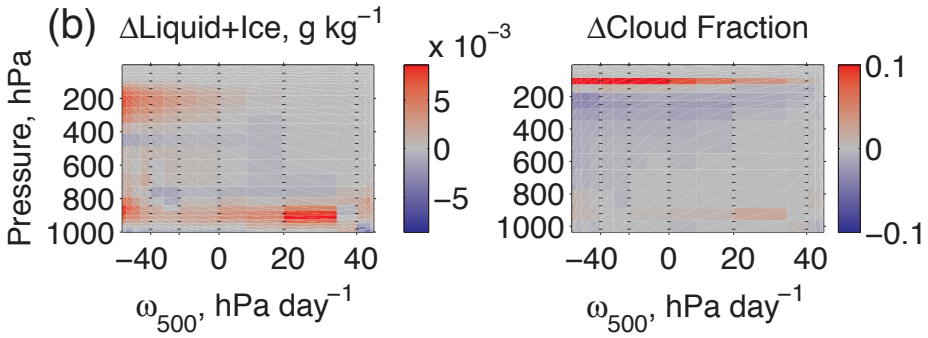
CF in Tropics sorted by 500-mb vert. velocity



Ascend ← → Subsidence

Bony diagram





d(LWCF)= 0.17 W/m^2 d(SWCF)= -1.94 W/m^2

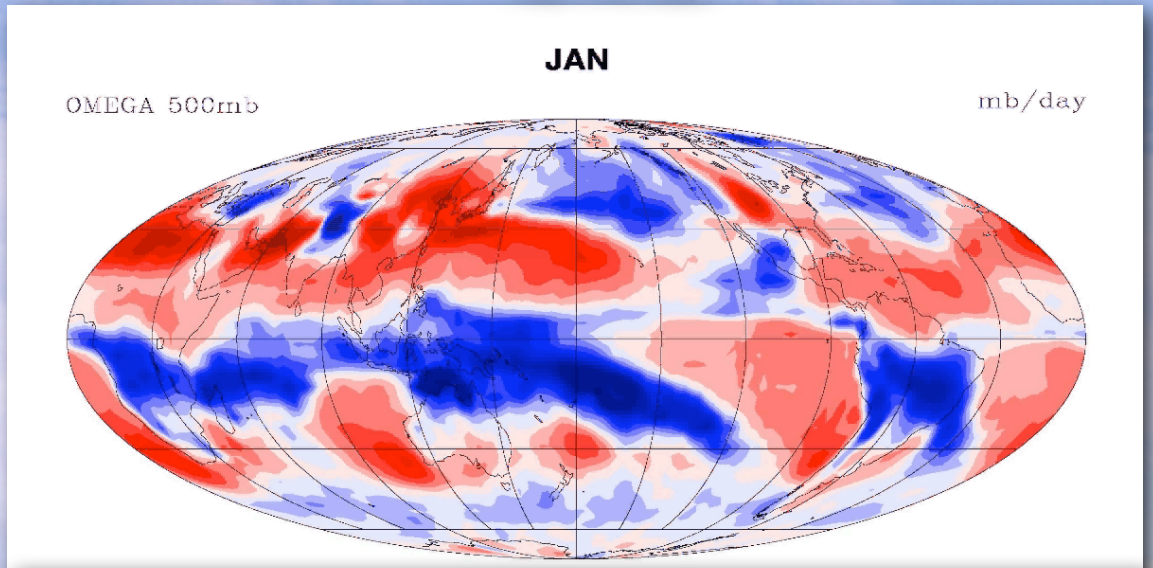
d(CF)= -1.77 W/m^2

climate sensitivity parameter $\lambda = 0.41$ Km^{2}W^{-1}

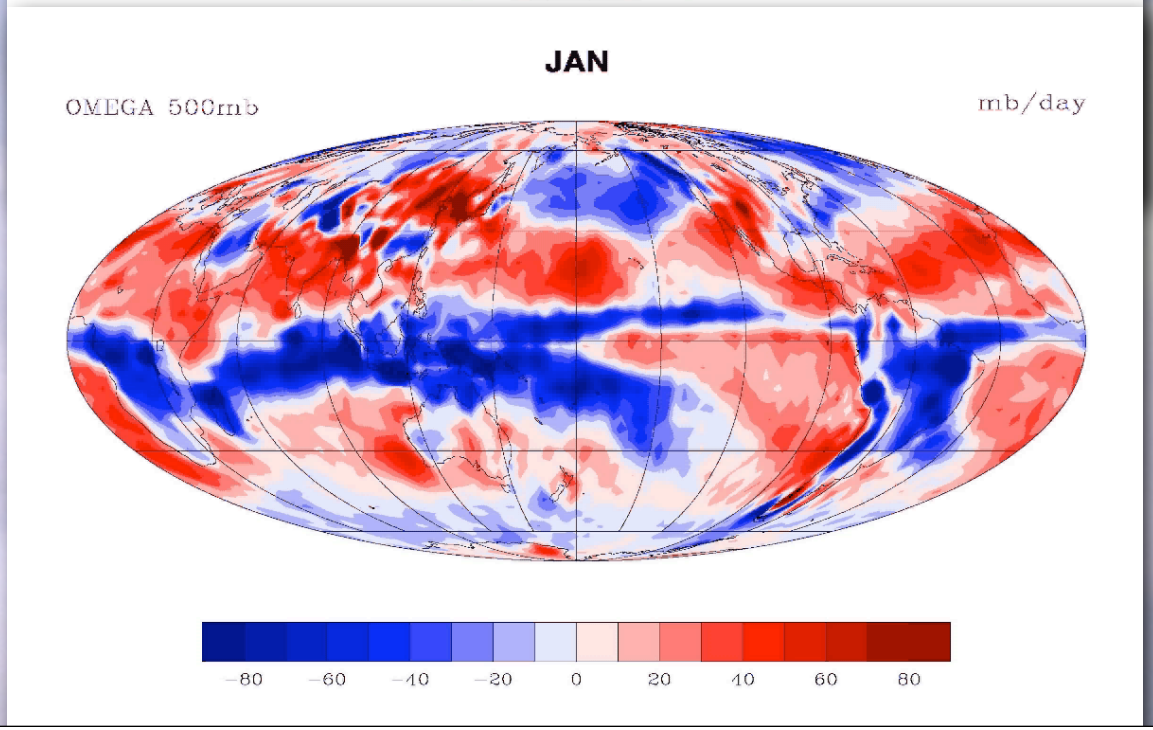
Wyant et al (2006, GRL)

Vertical velocity at 500 mb
Monthly Climate
1988-1996 mean

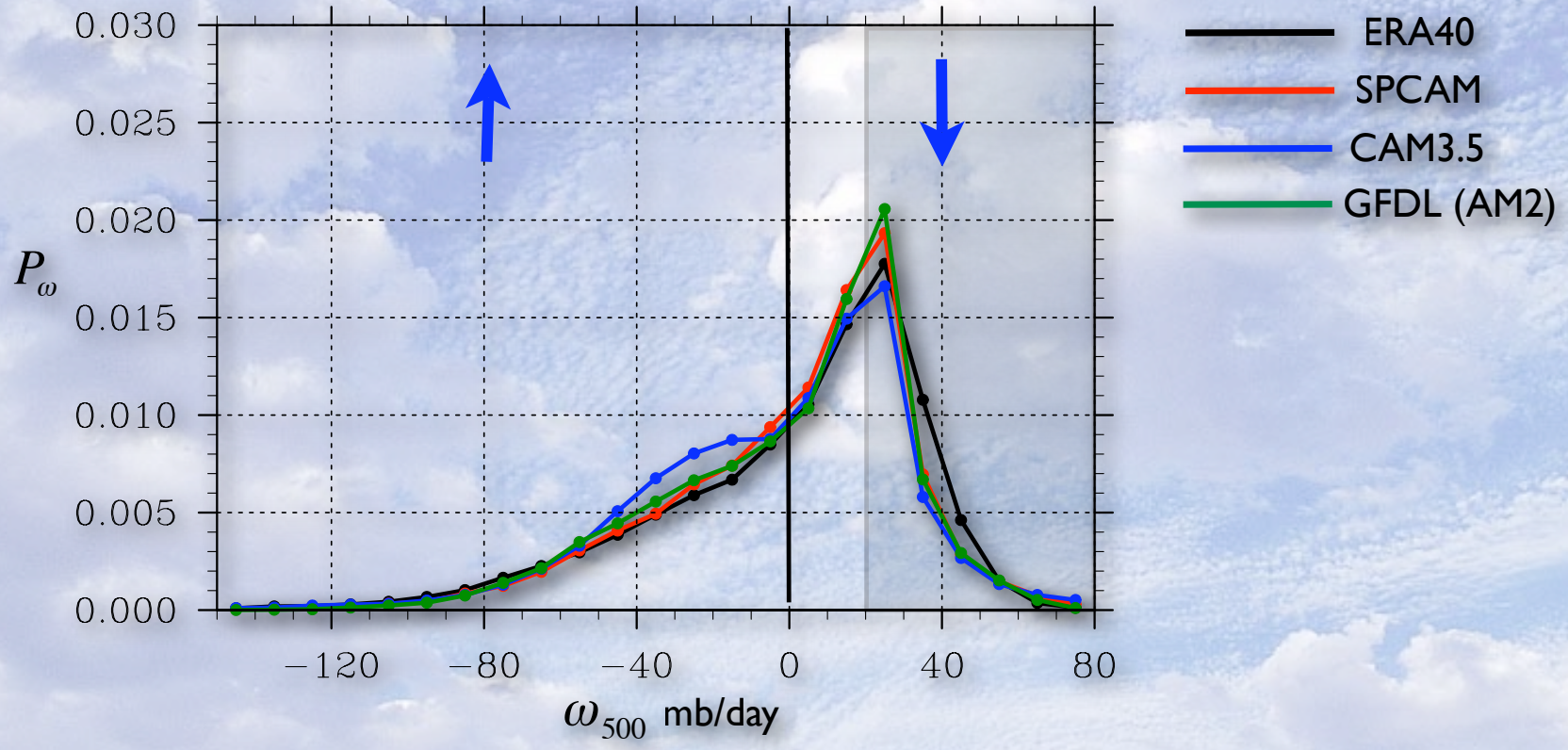
SPCAM



OBS (ERA40)



PDF of the 500 mb pressure vertical velocity in the Tropics (30°S - 30°N)



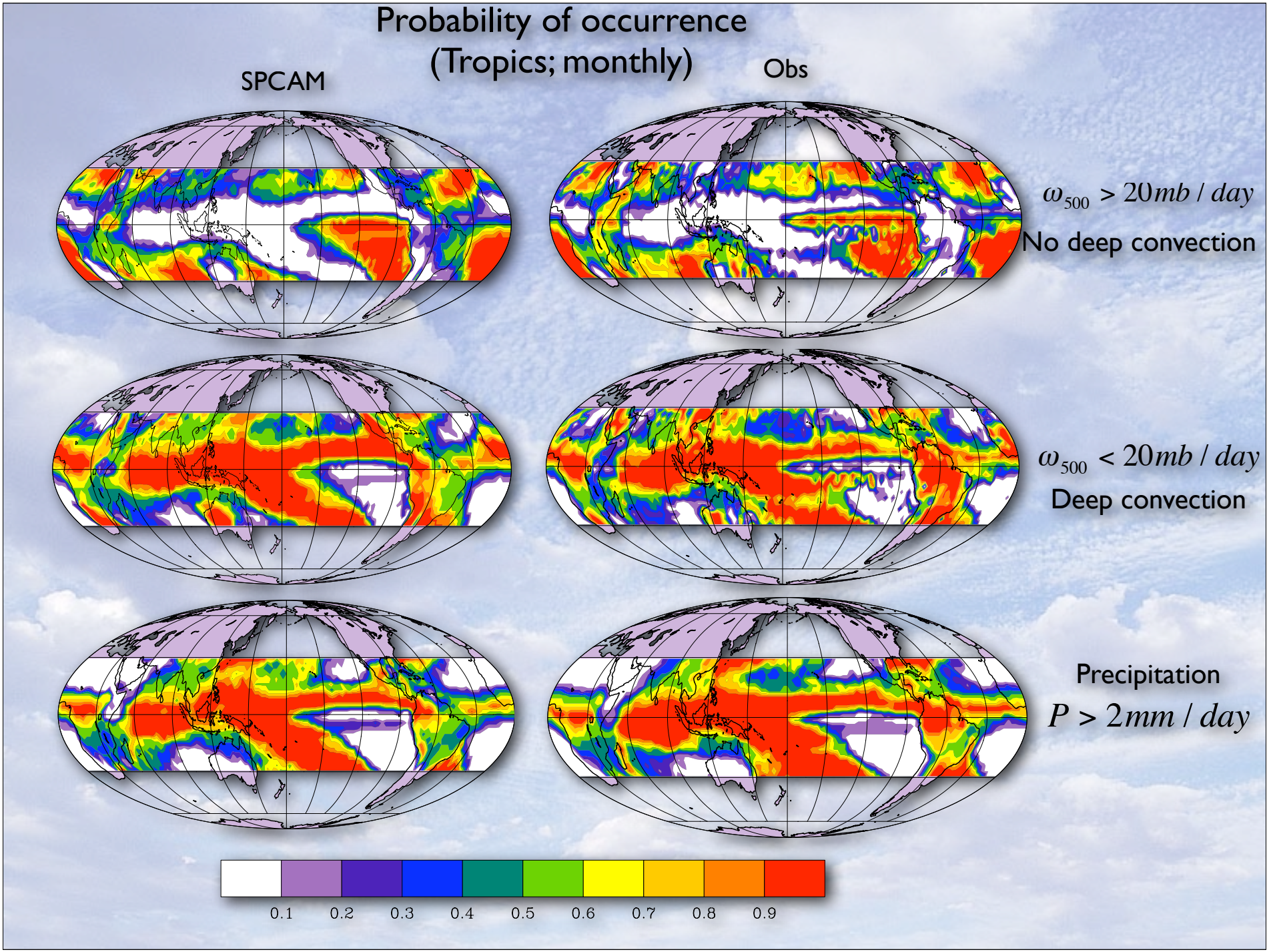
$$\omega \frac{\partial s}{\partial p} \approx R + \alpha P$$

$$\omega_0 \approx R / \frac{\partial s}{\partial p}$$

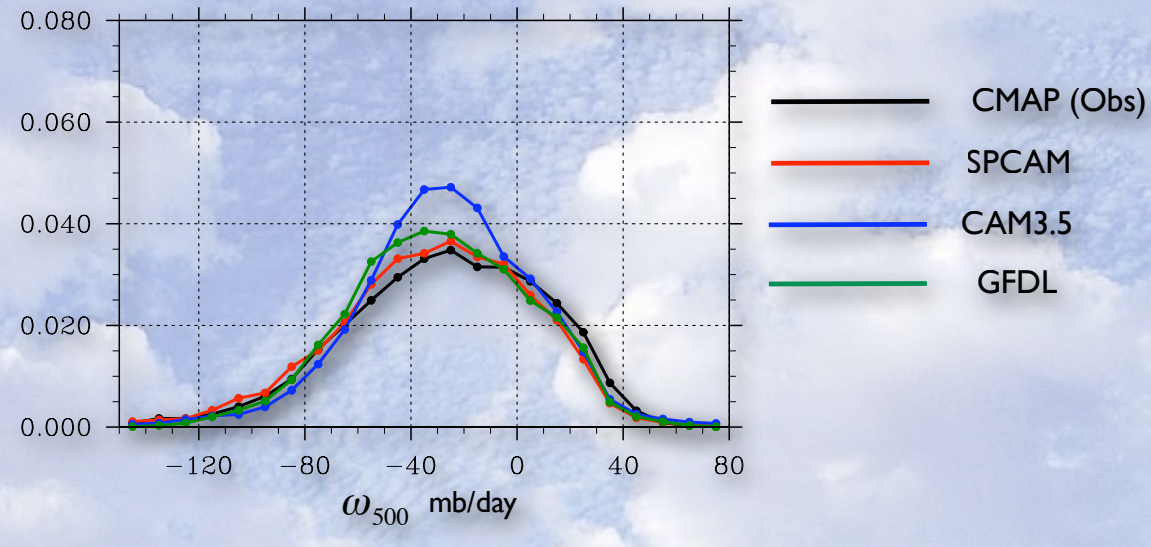
$$R \approx -1.5 K / day$$

$$\frac{\partial s}{\partial p} \approx -0.05 K / mb$$

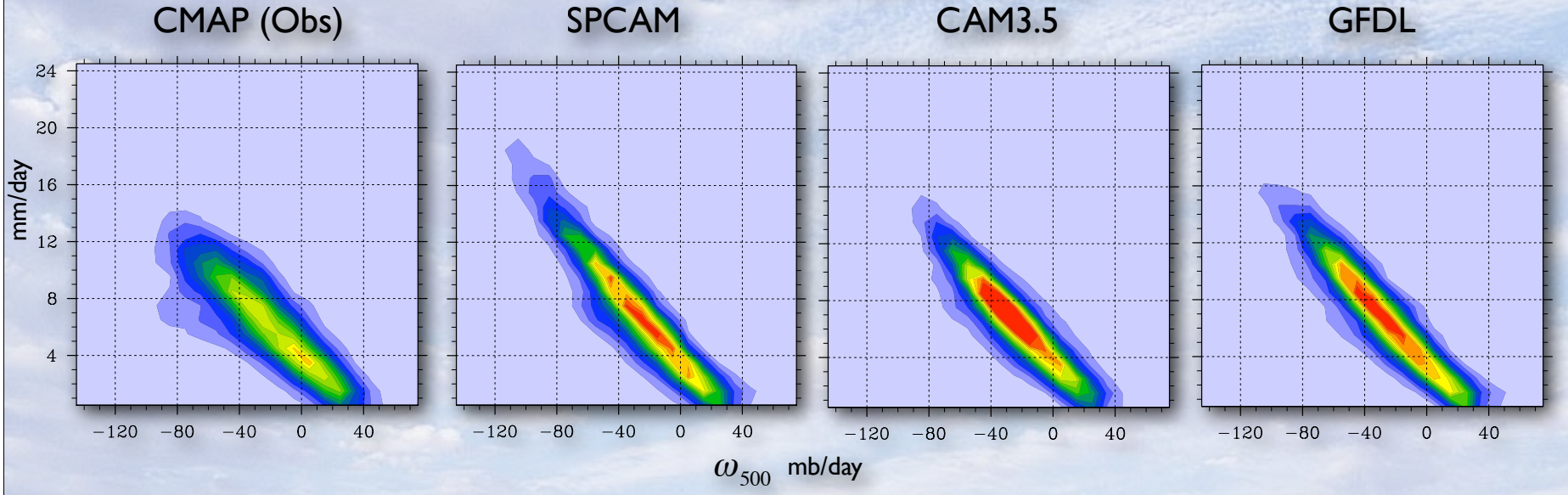
$$\omega_0 (P = 0) \approx 30 mb / day$$


Probability of occurrence
(Tropics; monthly)
SPCAM
Obs
$\omega_{500} > 20mb / day$
No deep convection
$\omega_{500} < 20mb / day$
Deep convection
Precipitation
$P > 2mm / day$
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

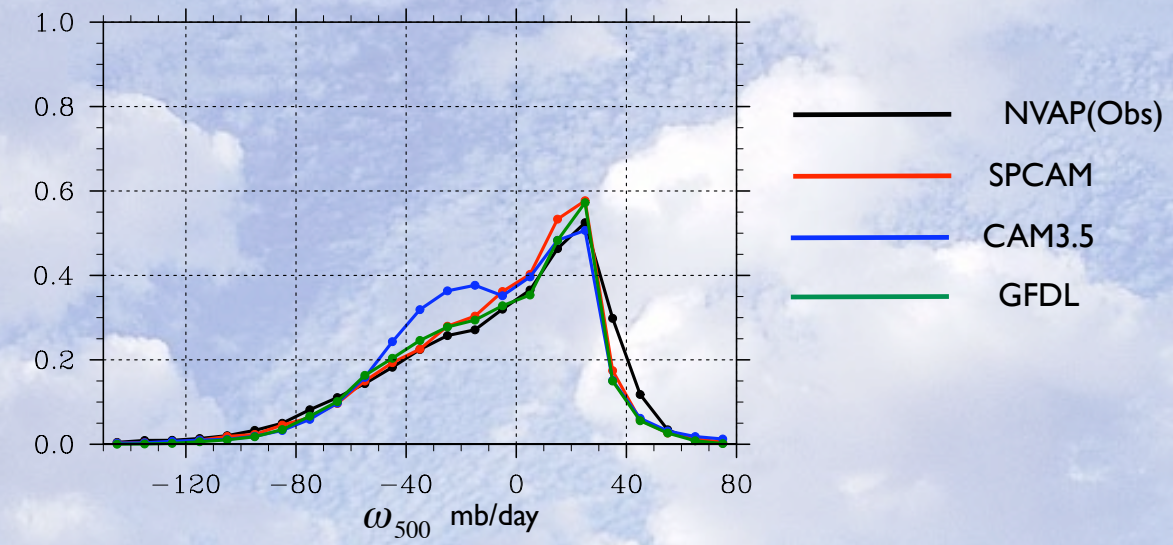
Spectrum of precipitation rate in the Tropics (30°S - 30°N)



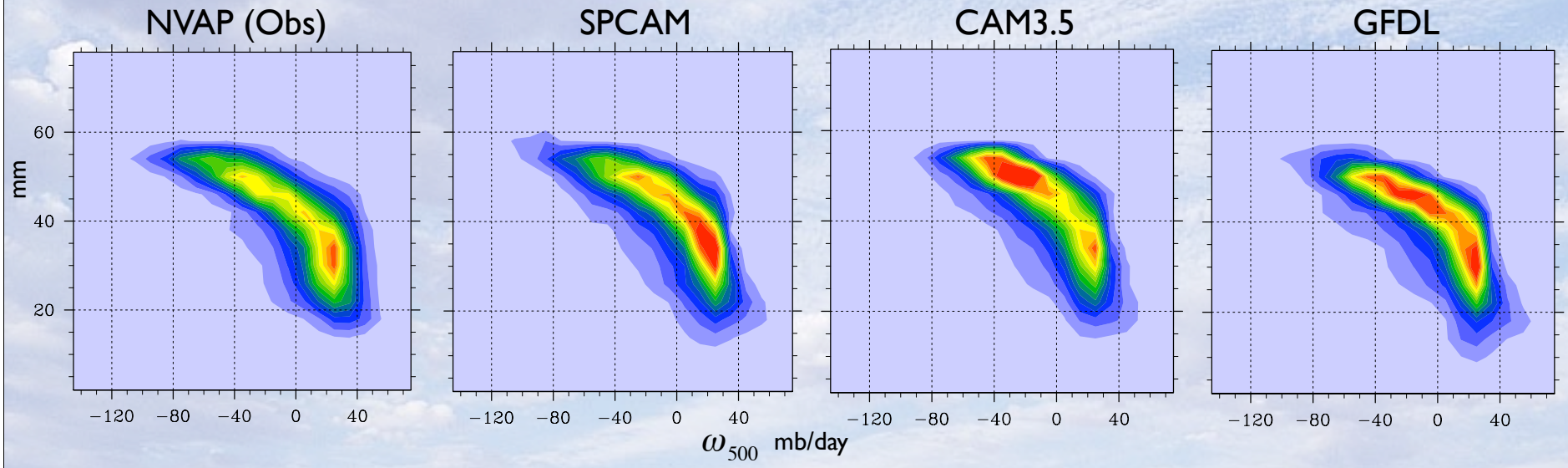
Joint PDF of the 500 mb pressure vertical velocity and precipitation rate in the Tropics (30°S - 30°N)



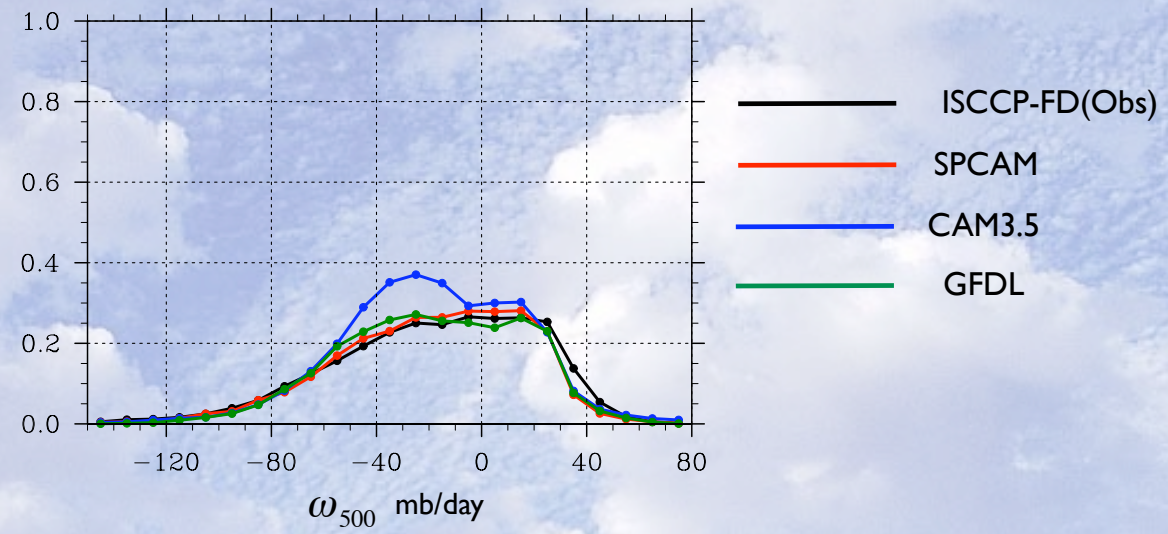
Spectrum of column-integrated water vapor (PW) in the Tropics (30°S - 30°N)



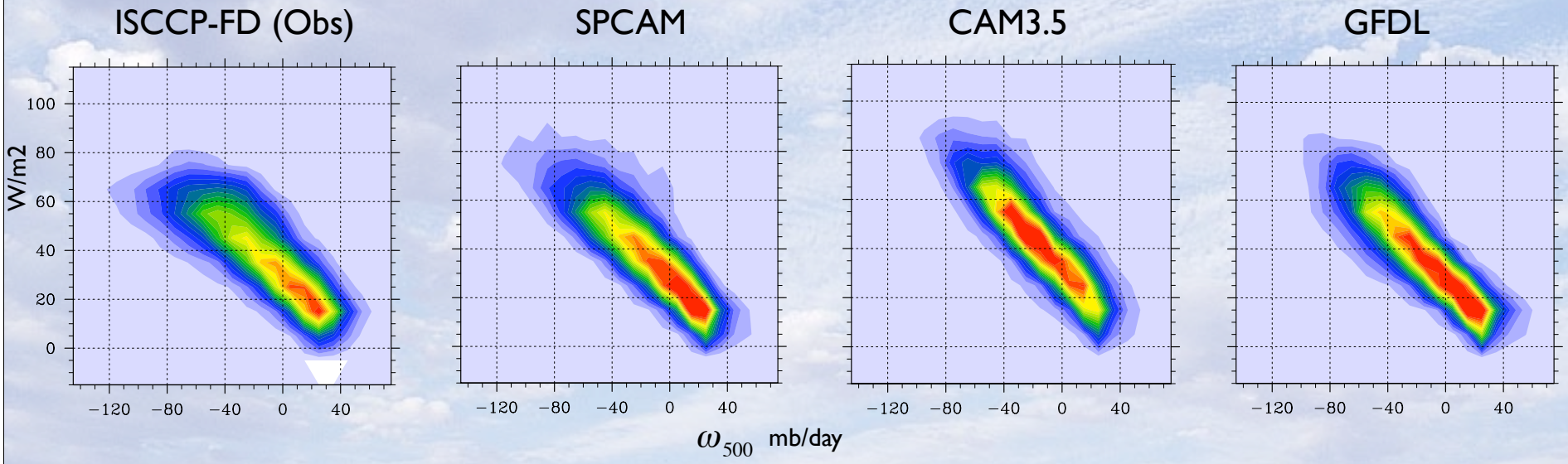
Joint PDF of the 500 mb pressure vertical velocity and PW
in the Tropics (30°S - 30°N)



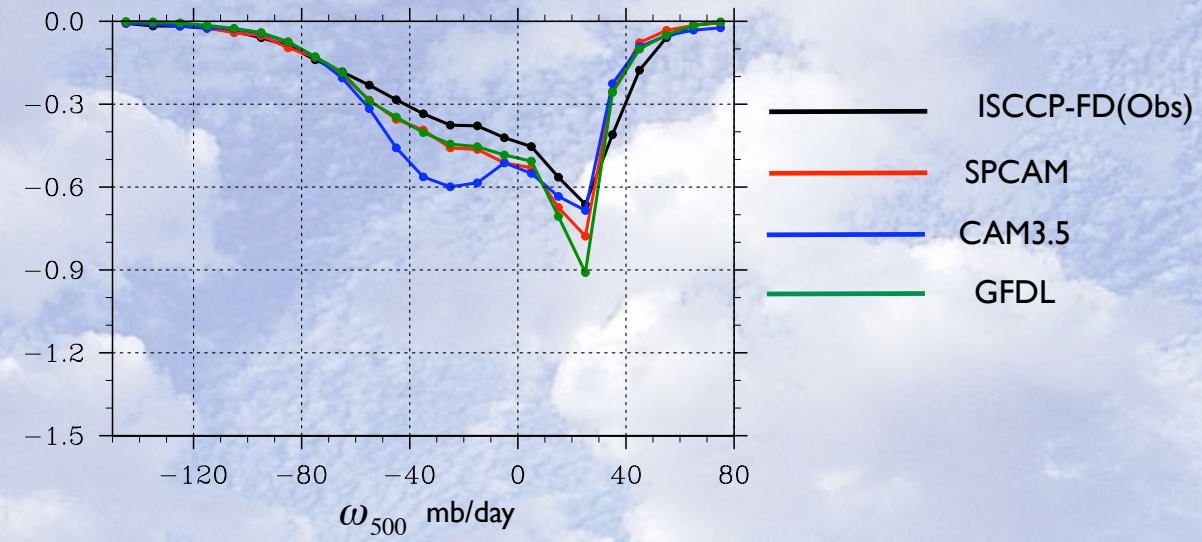
Spectrum of Longwave cloud forcing (LWCF) in the Tropics (30°S - 30°N)



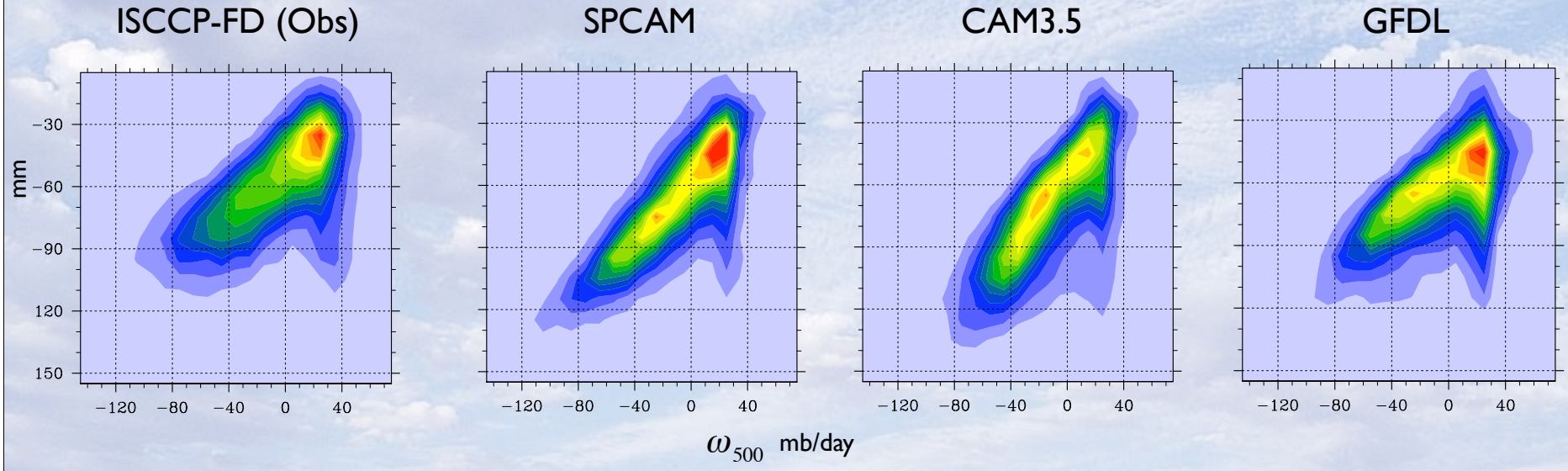
Joint PDF of the 500 mb pressure vertical velocity and LWCF in the Tropics (30°S - 30°N)



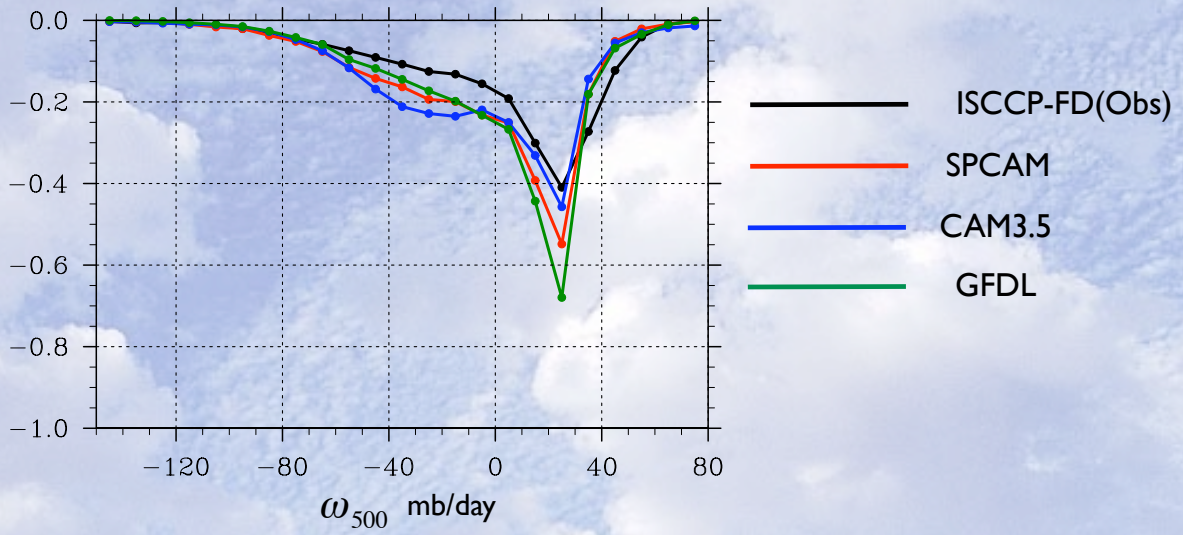
Spectrum of Shortwave cloud forcing (SWCF) in the Tropics (30°S - 30°N)



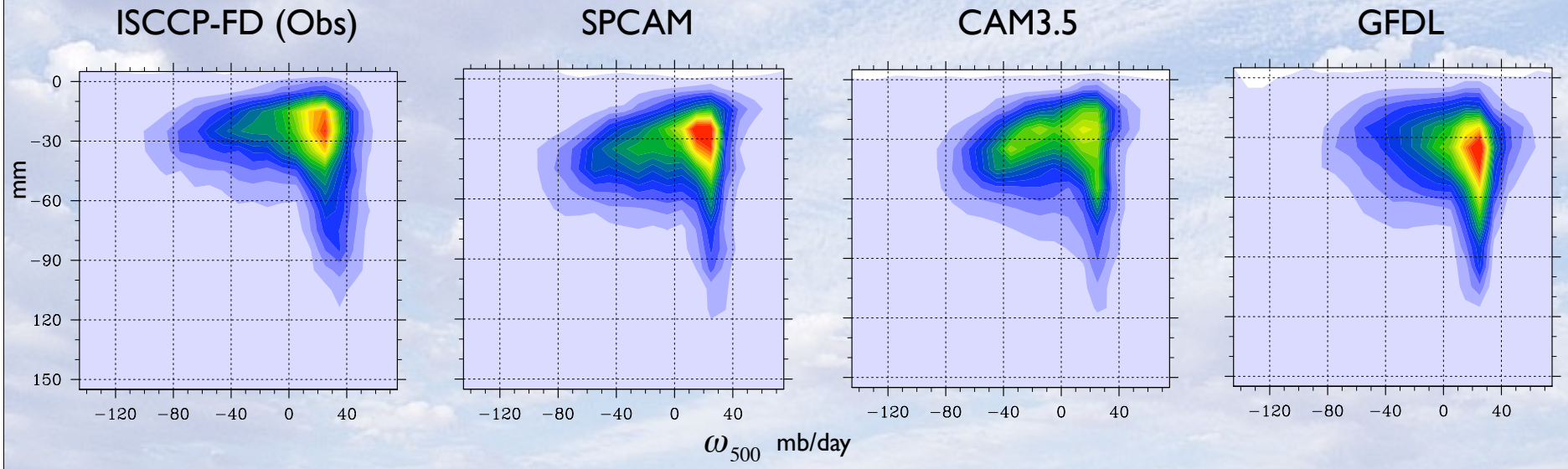
Joint PDF of the 500 mb pressure vertical velocity and SWCF in the Tropics (30°S - 30°N)



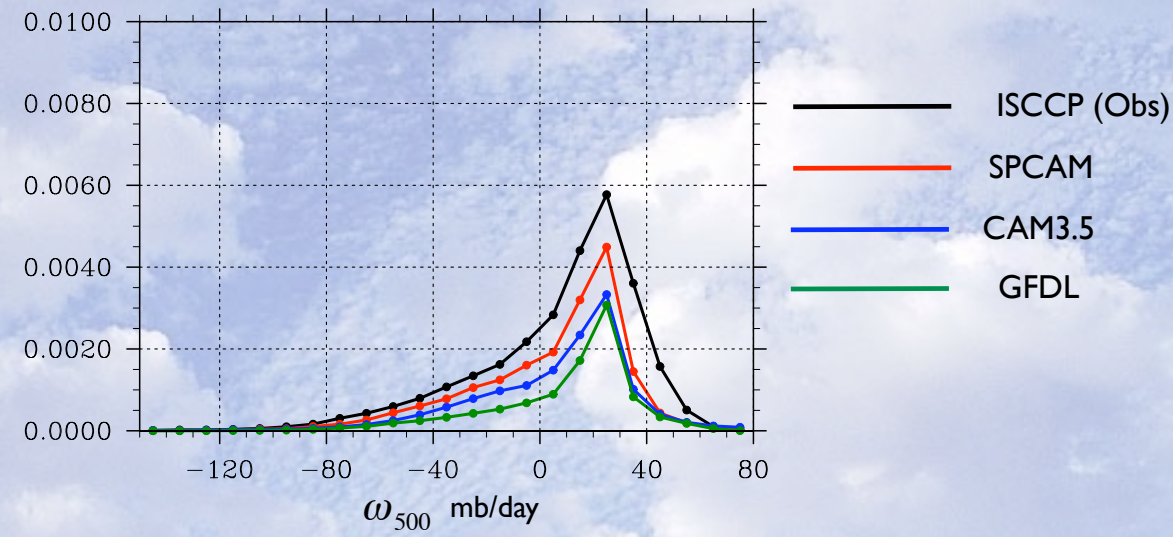
Spectrum of Cloud radiative focing (CRF) in the Tropics (30°S - 30°N)



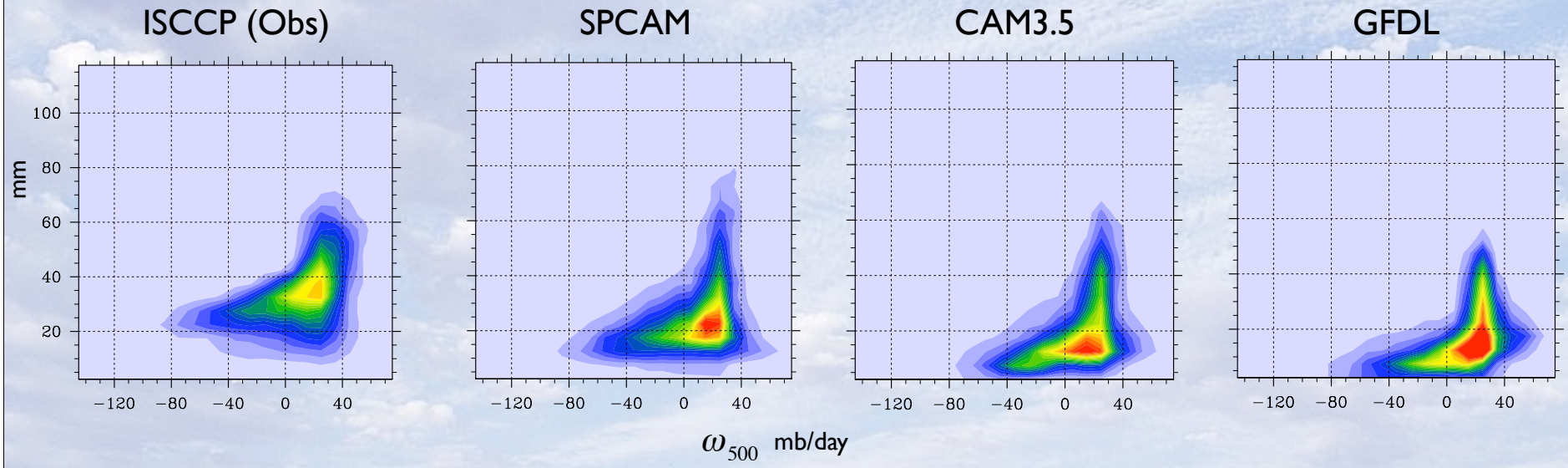
Joint PDF of the 500 mb pressure vertical velocity and precipitation rate in the Tropics (30°S - 30°N)



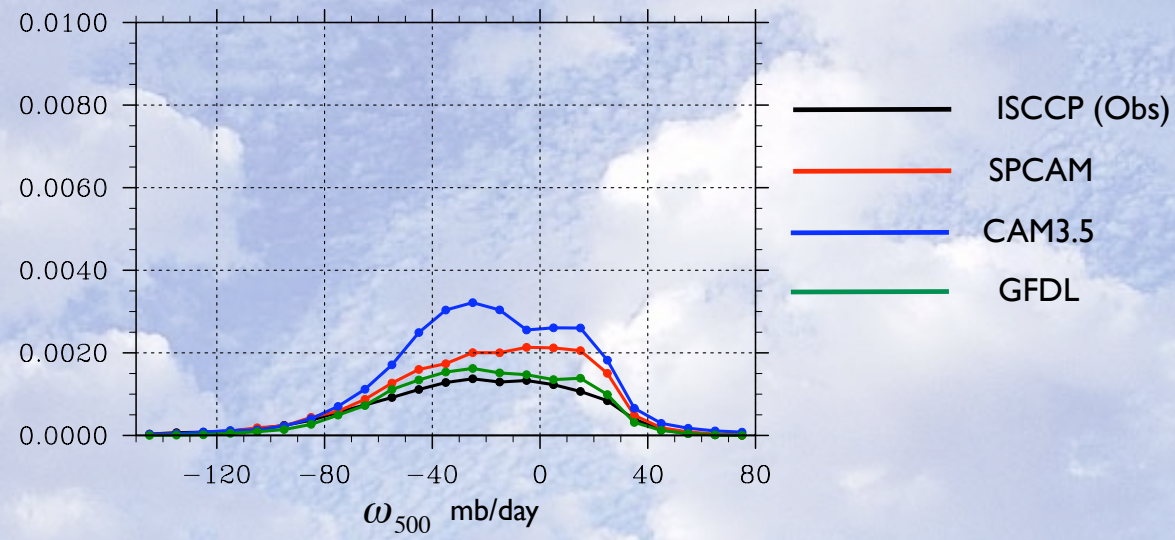
Spectrum of Low-cloud fraction (LC) in the Tropics (30°S - 30°N)



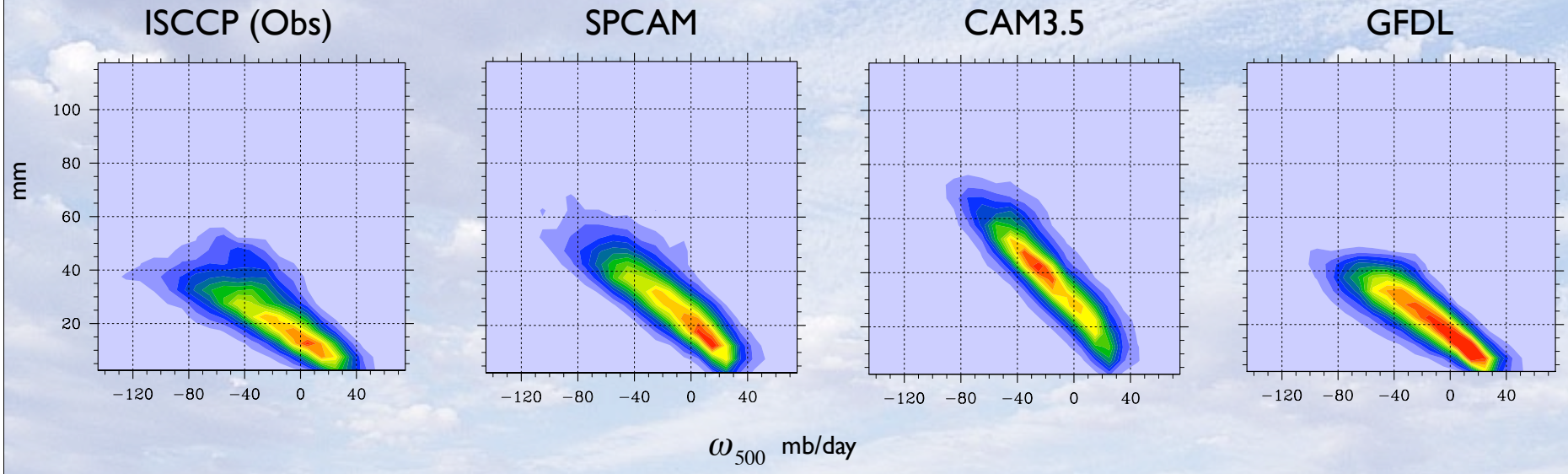
Joint PDF of the 500 mb pressure vertical velocity and LC in the Tropics (30°S - 30°N)



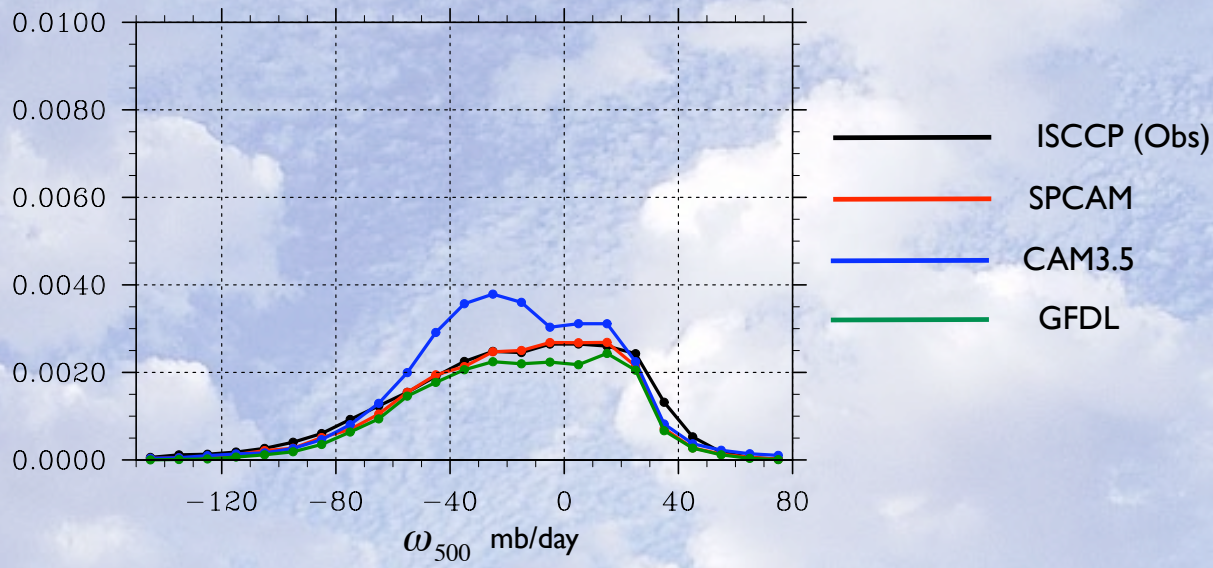
Spectrum of High-cloud fraction (HC) in the Tropics (30°S - 30°N)



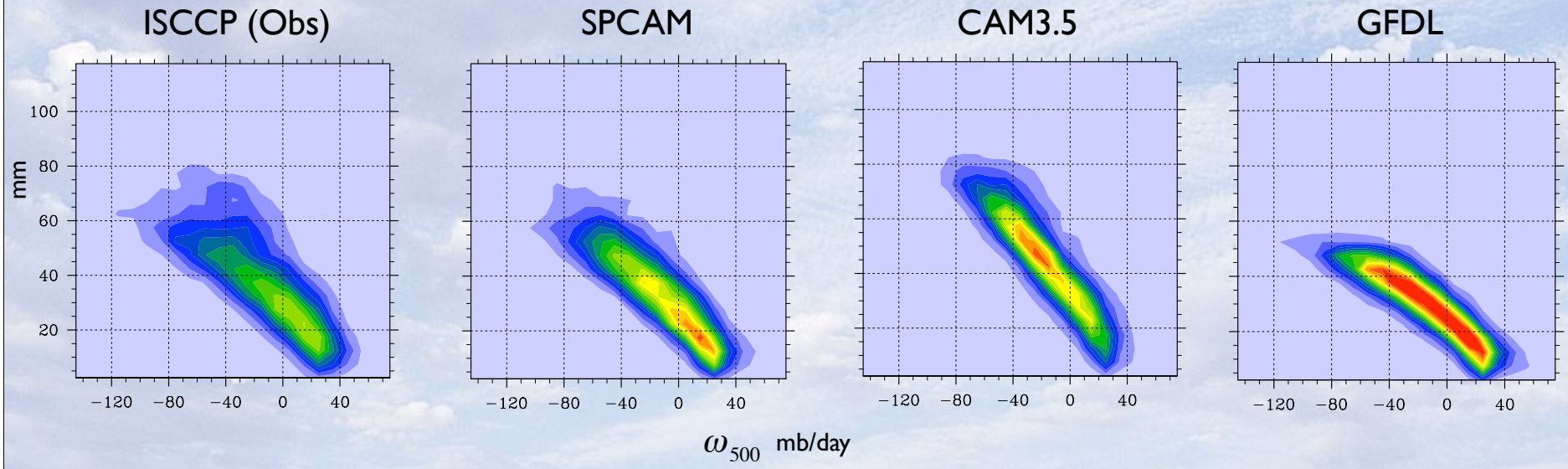
Joint PDF of the 500 mb pressure vertical velocity and HC in the Tropics (30°S - 30°N)



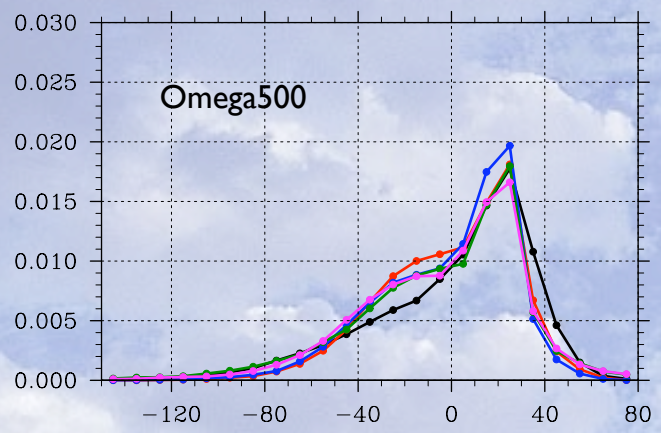
PDF of Mid + High cloud fraction (MHC) in the Tropics (30°S - 30°N)

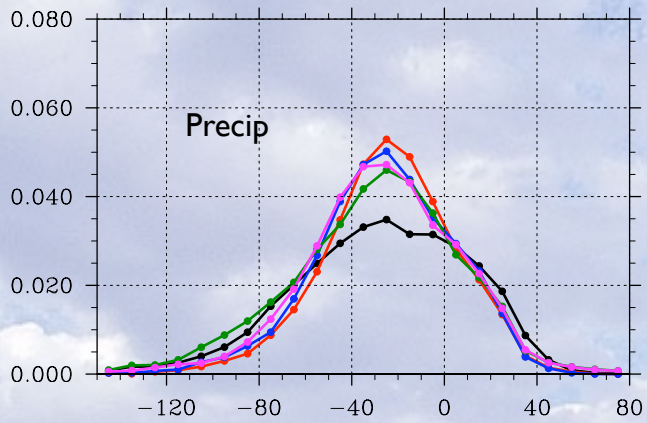


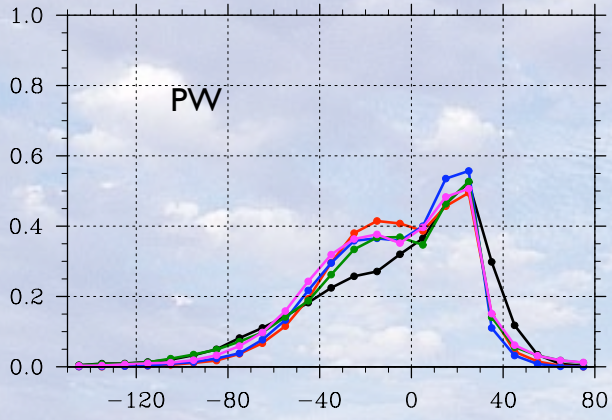
Joint PDF of the 500 mb pressure vertical velocity and precipitation rate in the Tropics (30°S - 30°N)



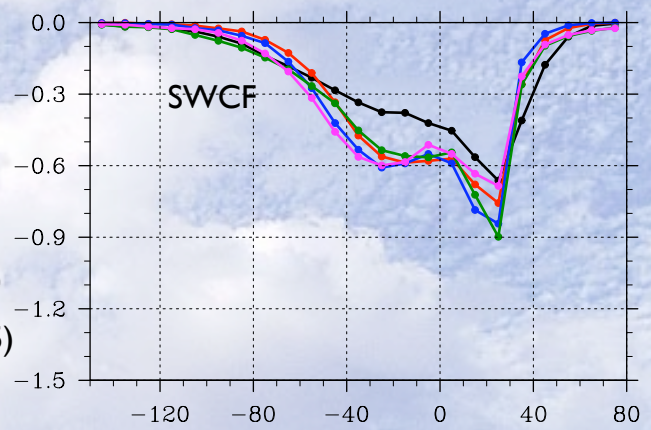
CAM PDF biases don't seem to depend on type of dynamical core or resolution.

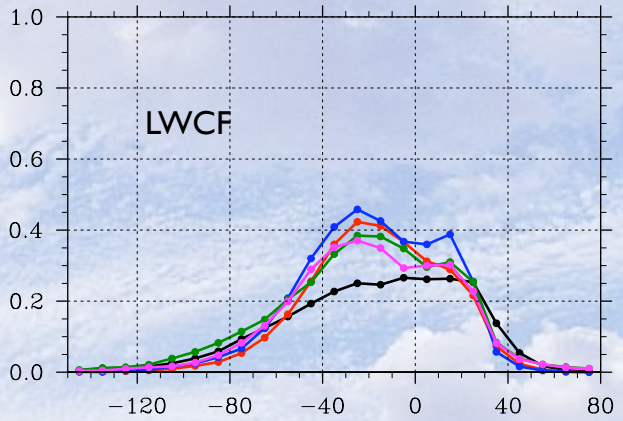


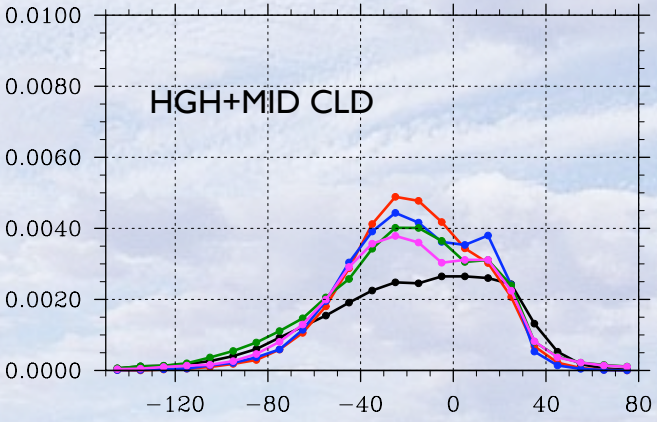




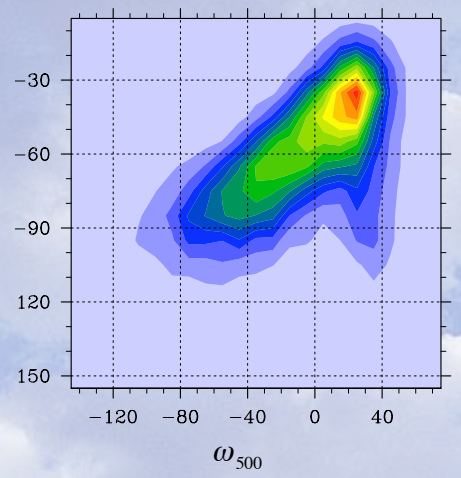
NVAP(Obs)
CAM3 (EUL T42)
CAM3 (EUL T82)
CAM3 (FV 2x2.5)
CAM3.5 (FV 2x2.5)





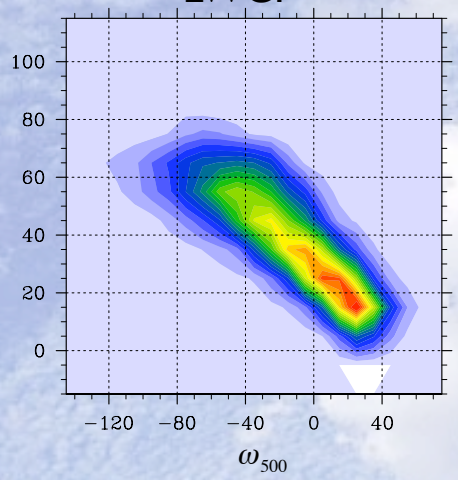


SWCF



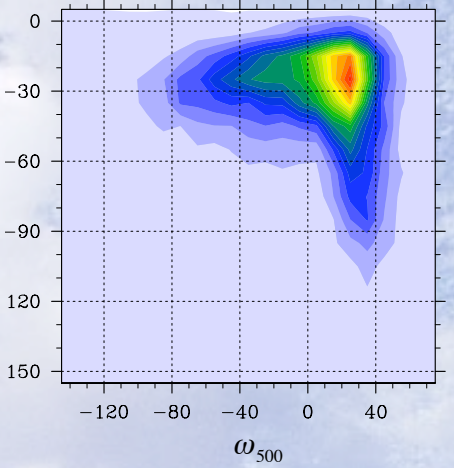
+

LWCF

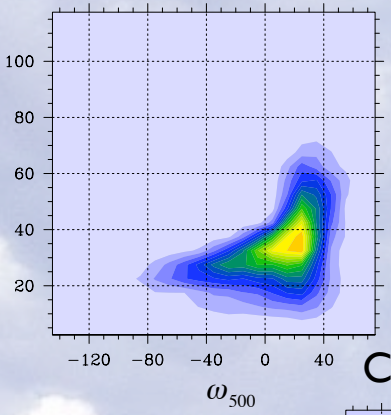


=

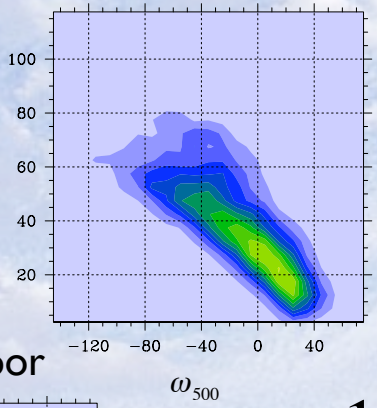
CF



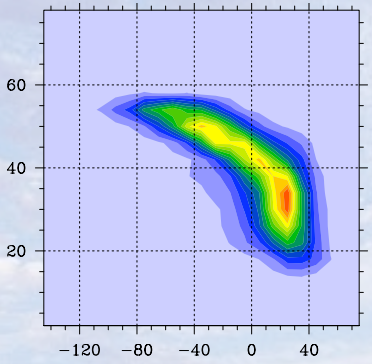
Low Clouds



High Clouds

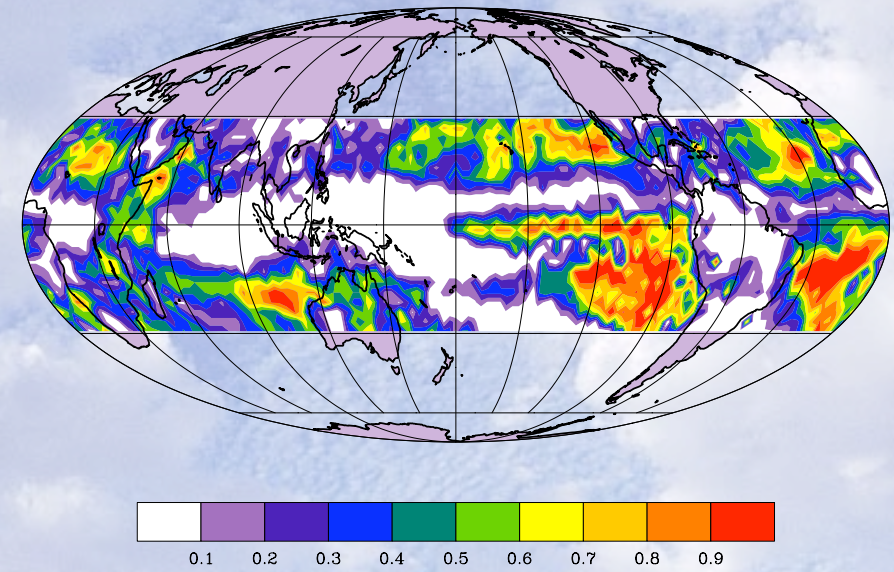


Column Vapor



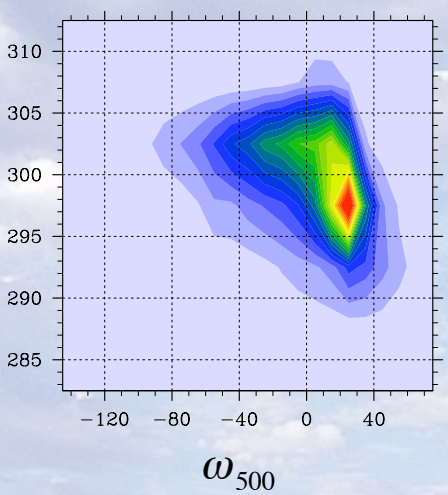
$$15 < \omega_{500} < 35(mb / day)$$

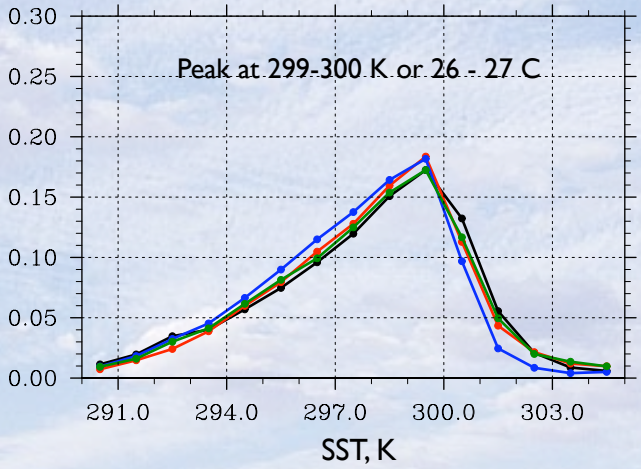
Probability of occurrence of $15 < \omega_{500} < 35(mb / day)$

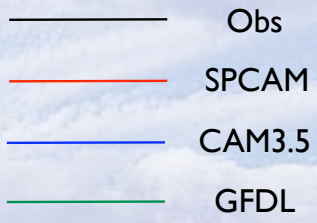


PDF of surface temperature for $15 < \omega_{500} < 35(mb / day)$ in the Tropics (30°S - 30°N)

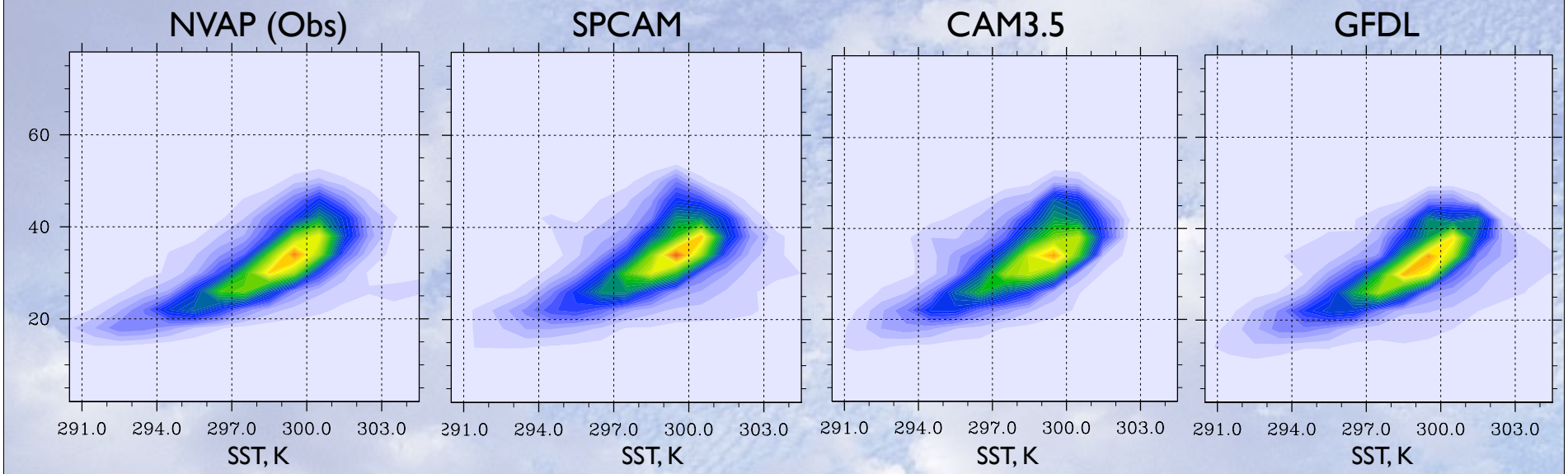
Surface Temperature



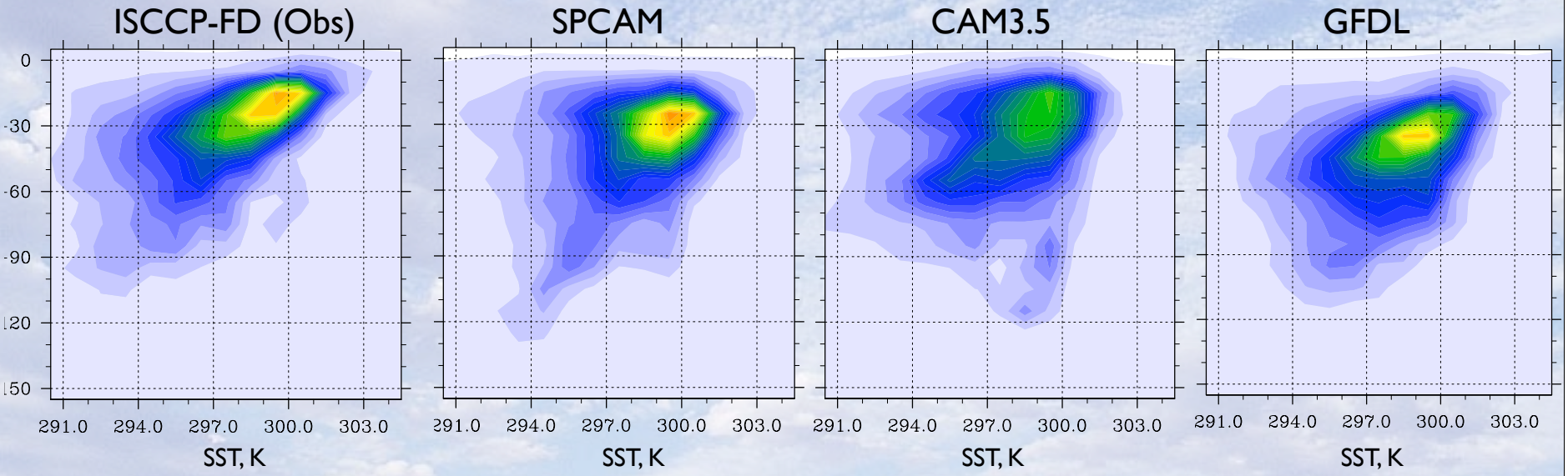




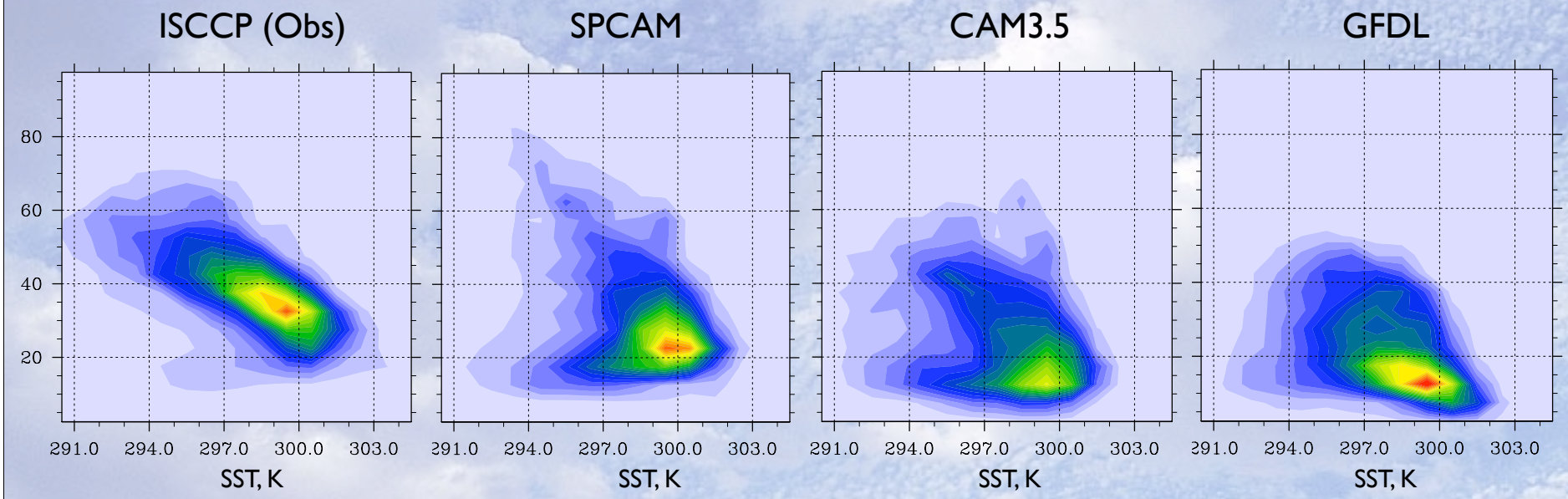
PDF of Precipitable water in the Tropics (30°S - 30°N) $15 < \omega_{500} < 35(mb/day)$



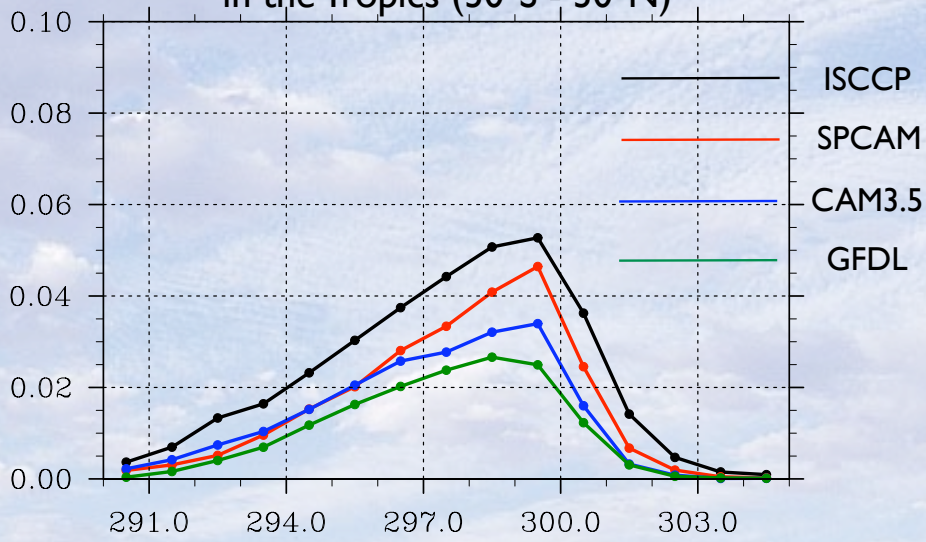
PDF of Shortwave Cloud Forcing in the Tropics (30°S - 30°N) $15 < \omega_{500} < 35(mb/day)$



PDF of Low Cloud Amount in the Tropics (30°S - 30°N) $15 < \omega_{500} < 35(mb/day)$

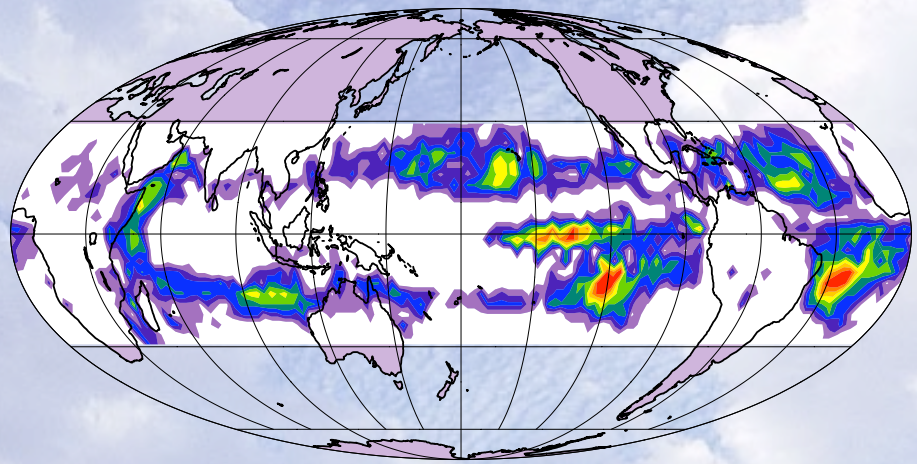


Spectrum of Low cloud amount for $15 < \omega_{500} < 35(mb/day)$ in the Tropics (30°S - 30°N)

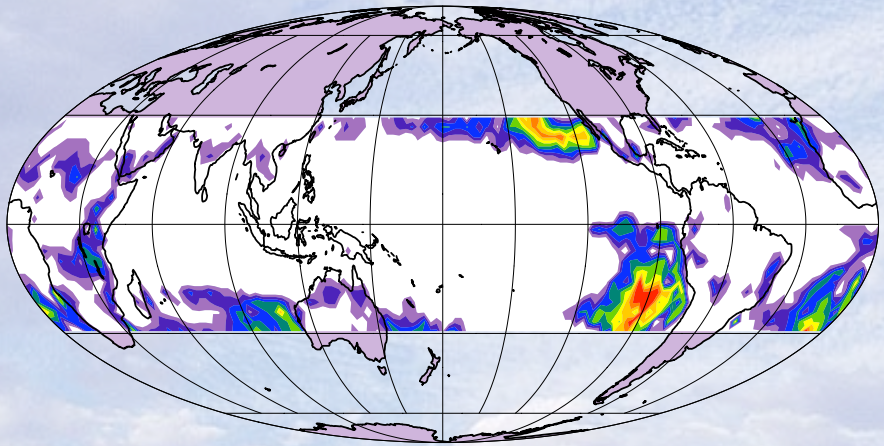


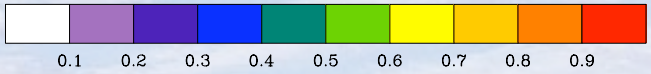
Probability of occurrence of $15 < \omega_{500} < 35(mb / day)$

298 < TS < 301 K

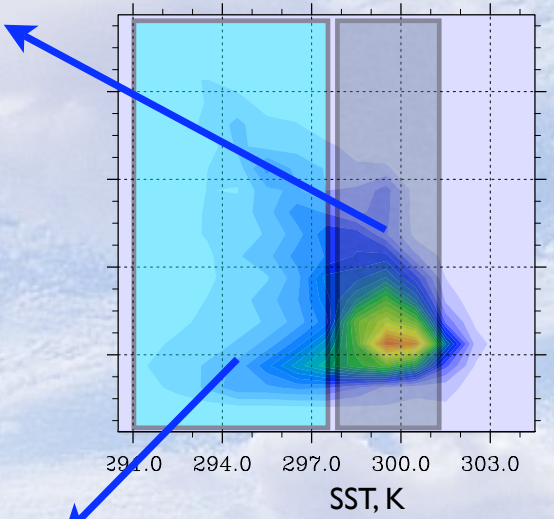


291 < TS < 297 K



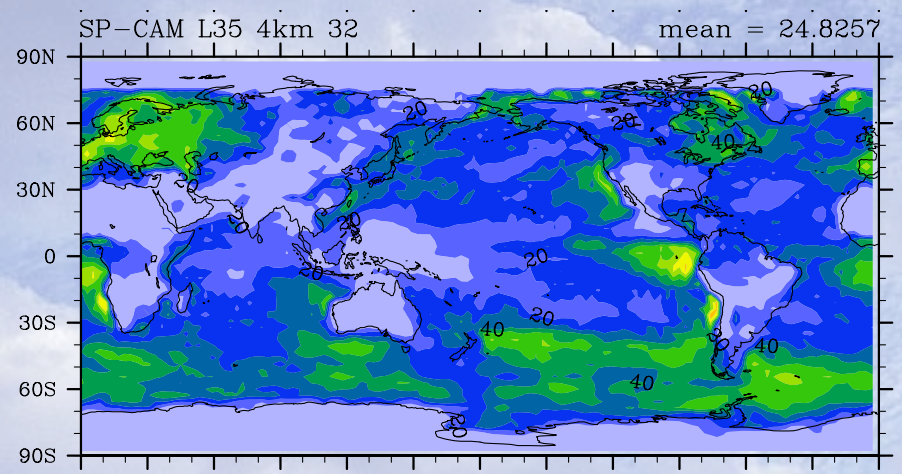


SPCAM Low Clouds

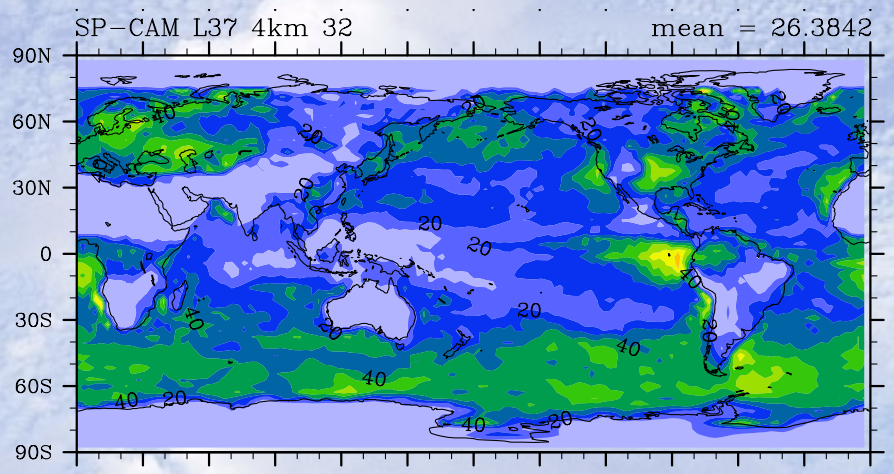


Sensitivity of low-cloud fraction to number of vertical levels

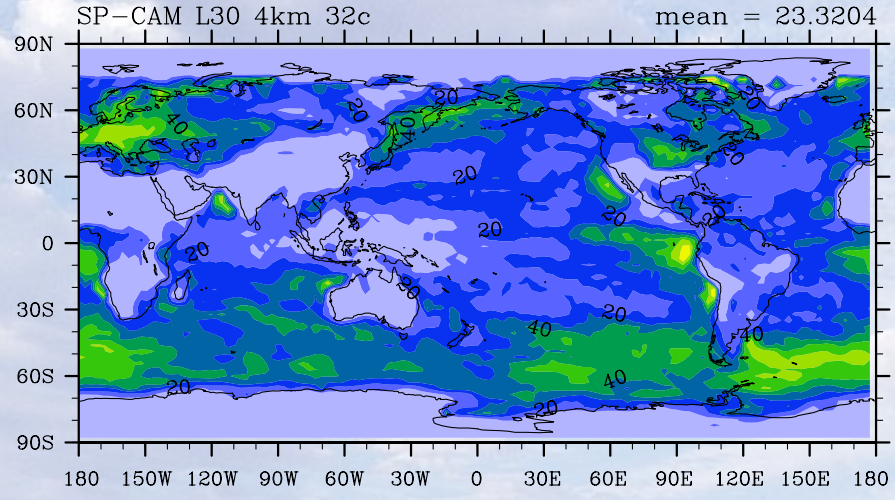
35 Levels



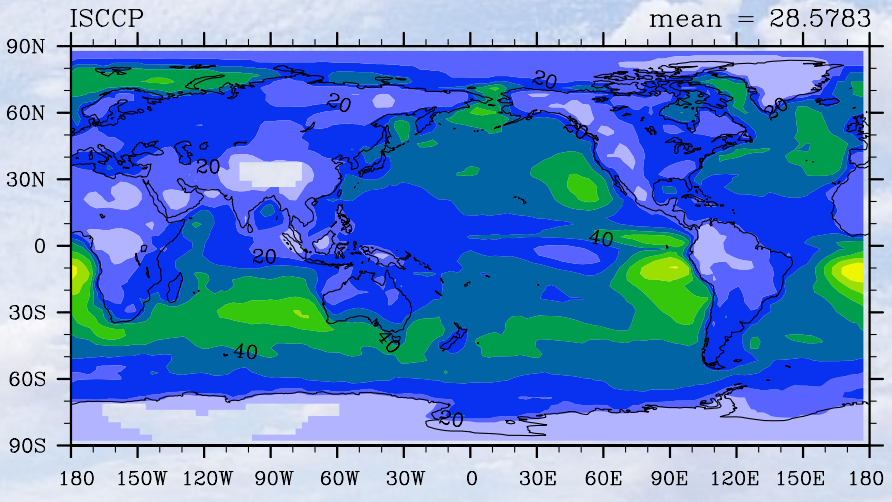
37 Levels



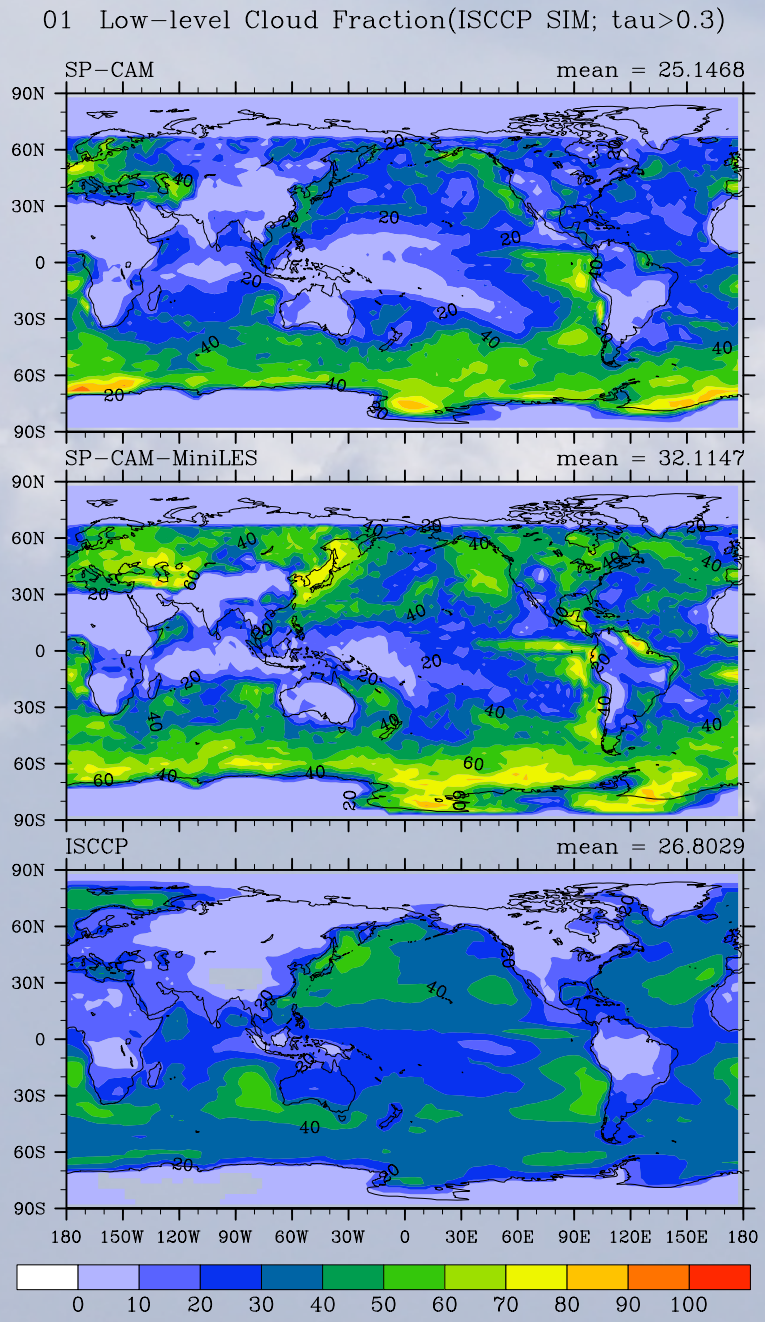
30 Levels (Control)



ISCCP (October)



Preliminary experiment with a second CRM ('MiniLES') to model low-level clouds



SP-CAM

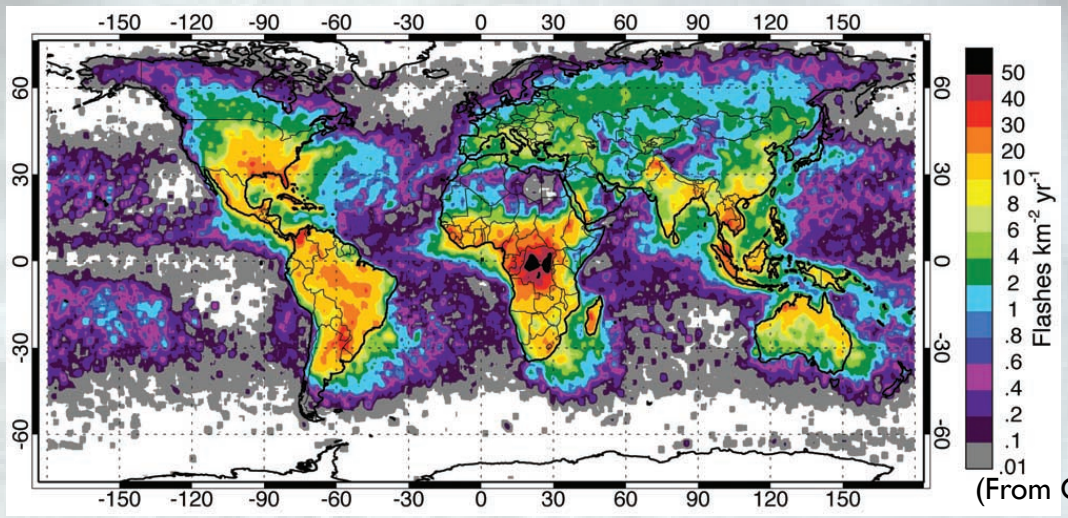
SP-CAM + MiniLES

"LES": dx=250m

Obs

Lightning as a proxy for Land vs Maritime Deep convection intensity?

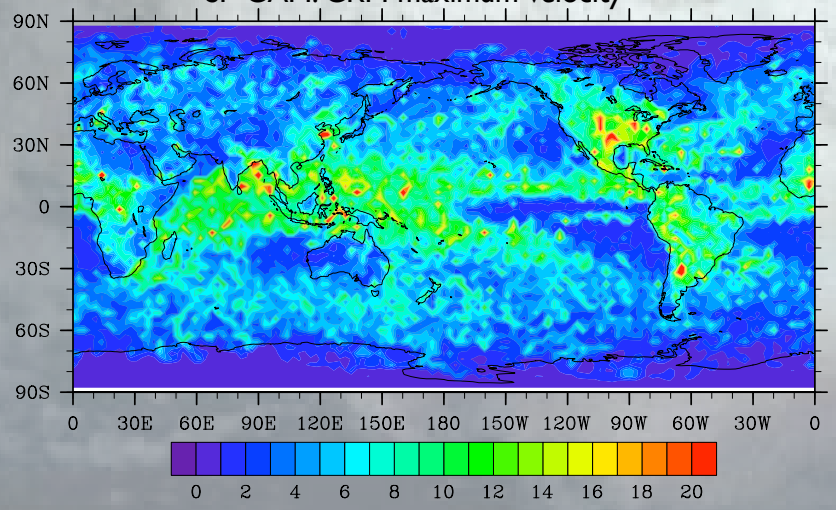
Observed Annual Number of Lightning per km2



(From Christian et al , JGR 2003)

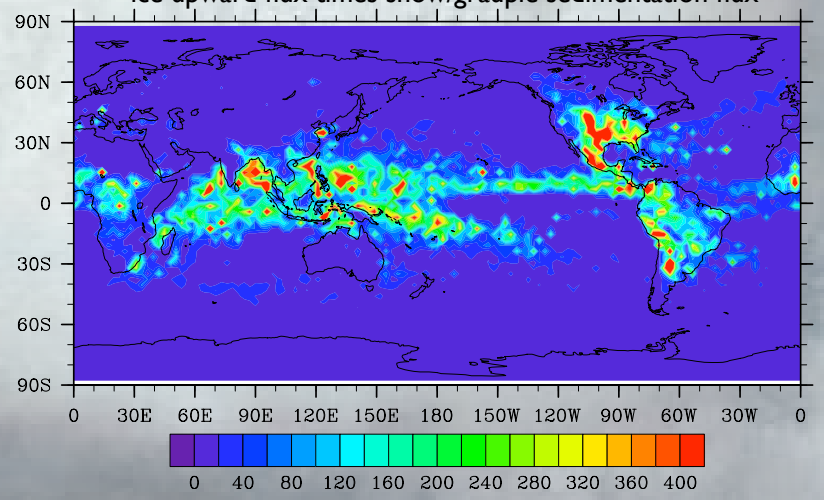
Figure 4. The annualized distribution of total lightning activity (in units of fl km^{-2} yr^{-1}).

SP-CAM: CRM maximum velocity



SP-CAM: CRM proxy for electrification rate

ice upward flux times snow/grauple sedimentation flux



Prototype-MMF (SP-CAM) Research

- Simulations available for analysis/diagnostics/research
  - AMIP (Prescribed sea surface temperatures), 19 years
  - Climatological SST, Present, 4 years
  - Cess' Present+2K, 4 years
  - 2xCO2 SST from a CCSM run, 4 years
  - Weather-forecasting mode - CAPT framework
- Sensitivity studies
  - Short runs, few months to 1-2 years
  - Microphysics (ice)
  - CRM domain/grid configuration
  - Host GCM grid resolution
- Framework Improvements
  - Cloud model high-order closures for unresolved scales
  - 'Mini-LES' cloud resolving model for shallow clouds
  - Microphysics
- Offline CRM runs
- Software Improvements
  - MPI-only version of SP-CAM which runs on more processors than number of latitudinal circles