Tropical Clouds and TOA Cloud Radiative Effects in the CMIP5 Models

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Data

- Observations
  - TOA radiative fluxes
    - CERES EBAF 2.7: 2001-2008
  - Cloudiness: Satellite simulator output
    - GOCCP:
      - 2-D low, mid and high cloud fraction: 2007-2008
    - ISCCP:
      - 3-D joint histogram of cloud fraction (CTP, τ): 1984-2007
- AMIP5 simulations
  - 1979-2008
- Focus on periods common to Obs and AMIP5

CMIP5 Models

Model	Country	Nx*ny	Lon*lat
CanAM4	Canada	128x64	2.8x2.8
CNRM-CM5	France	256x128	1.4x1.4
GFDL-CM3	US-GFDL	144x90	2.5x2.0
HadGEM2-A	UK	192x145	1.875x1.25
IPSL-CM5A-LR	France	96x96	3.75x1.9
MIROC5	Japan	256x128	1.4x1.4
MPI-ESM-LR	Germany	192x96	1.875x1.865
MRI-CGCM3	Japan	320x160	1.125x1.121

Method

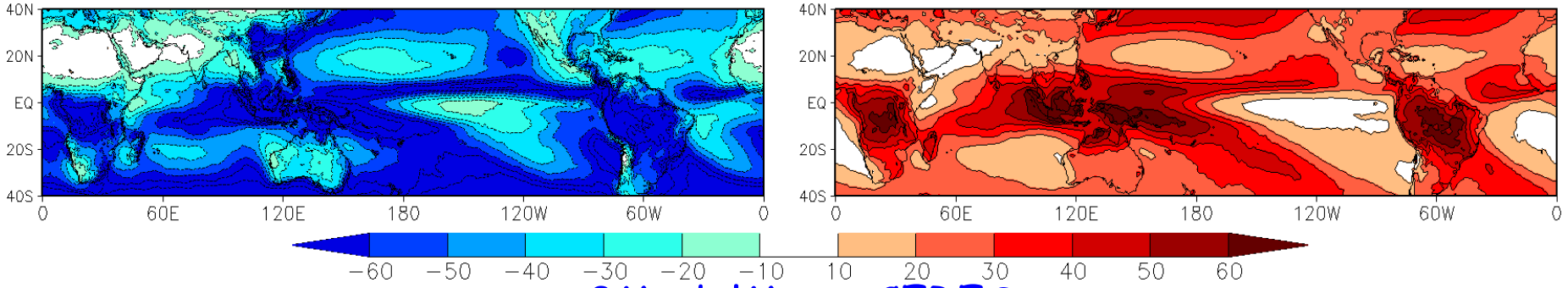
- Clim: Annual mean
- Variability: ENSO
  - Linear regression against ENSO MEI, use 12mon data
- Cloud Radiative Kernel (CRK)
  - Fu-Liou radiative transfer model (Rose and Charlock 2002)
  - Derived for each tropical lon-lat grid and each calendar month, for both obs and AMIP5 multi-model mean, using their respective monthly climatologies
- TOA_CRE(CTP, τ)
  - Anomalies due to ENSO :
    CRK(CTP, τ, mon)*deseasonalized CF(CTP, τ, mon, yr) linearly regressed against ENSO MEI

Annual Clim: TOA CRE

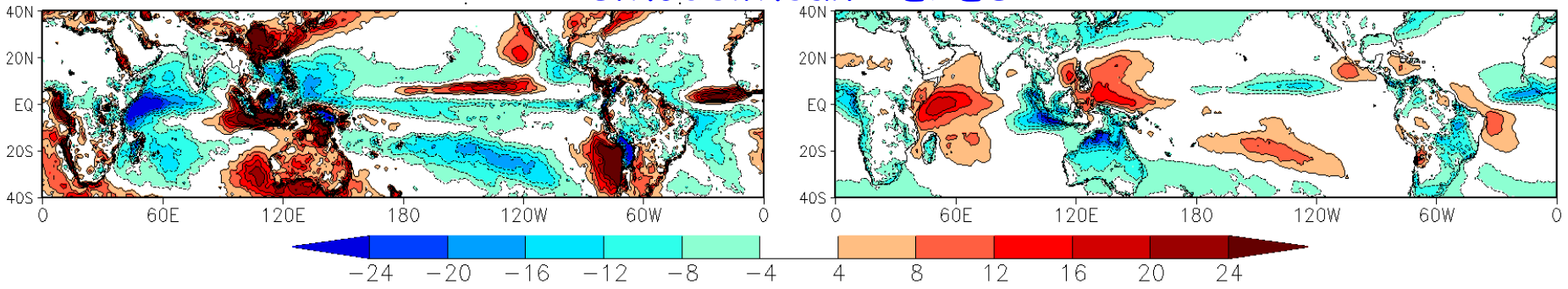
SWCRE

CERES

LWCRE



8ModelMean-CERES

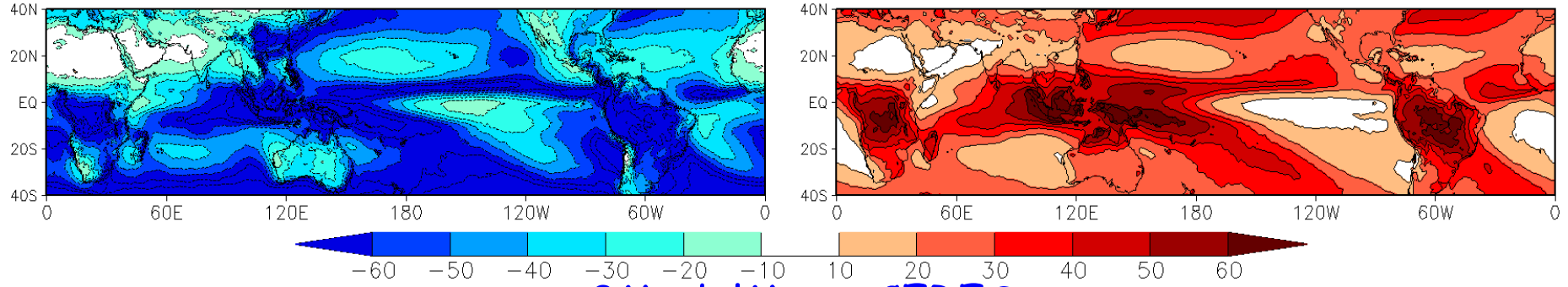


Annual Clim: TOA CRE

SWCRE

CERES

LWCRE



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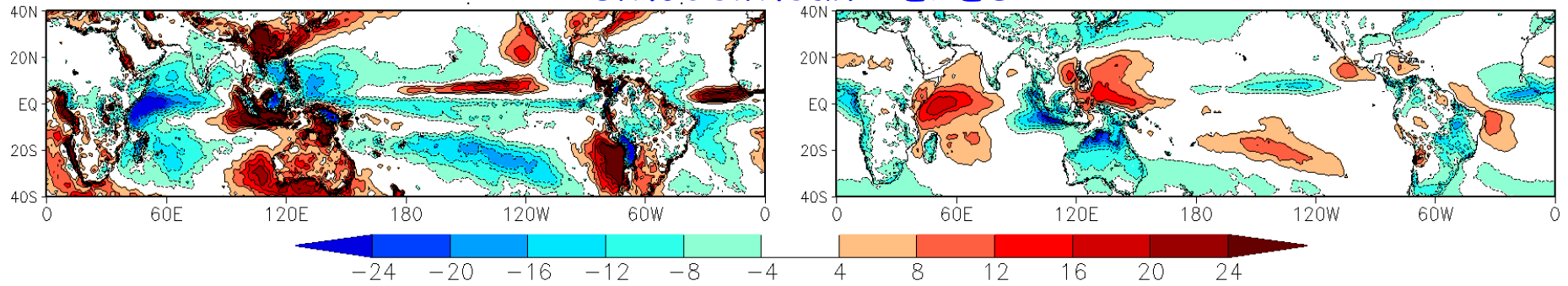
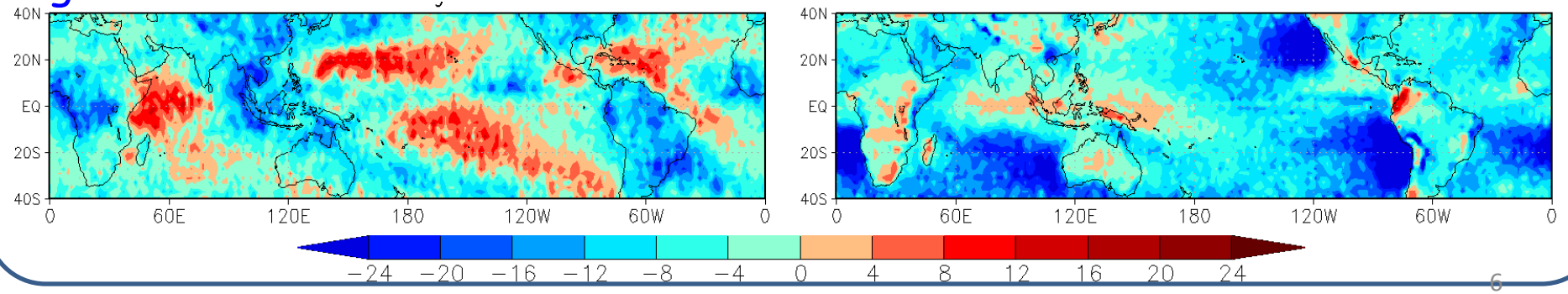


CALIPSO Cloud Fraction

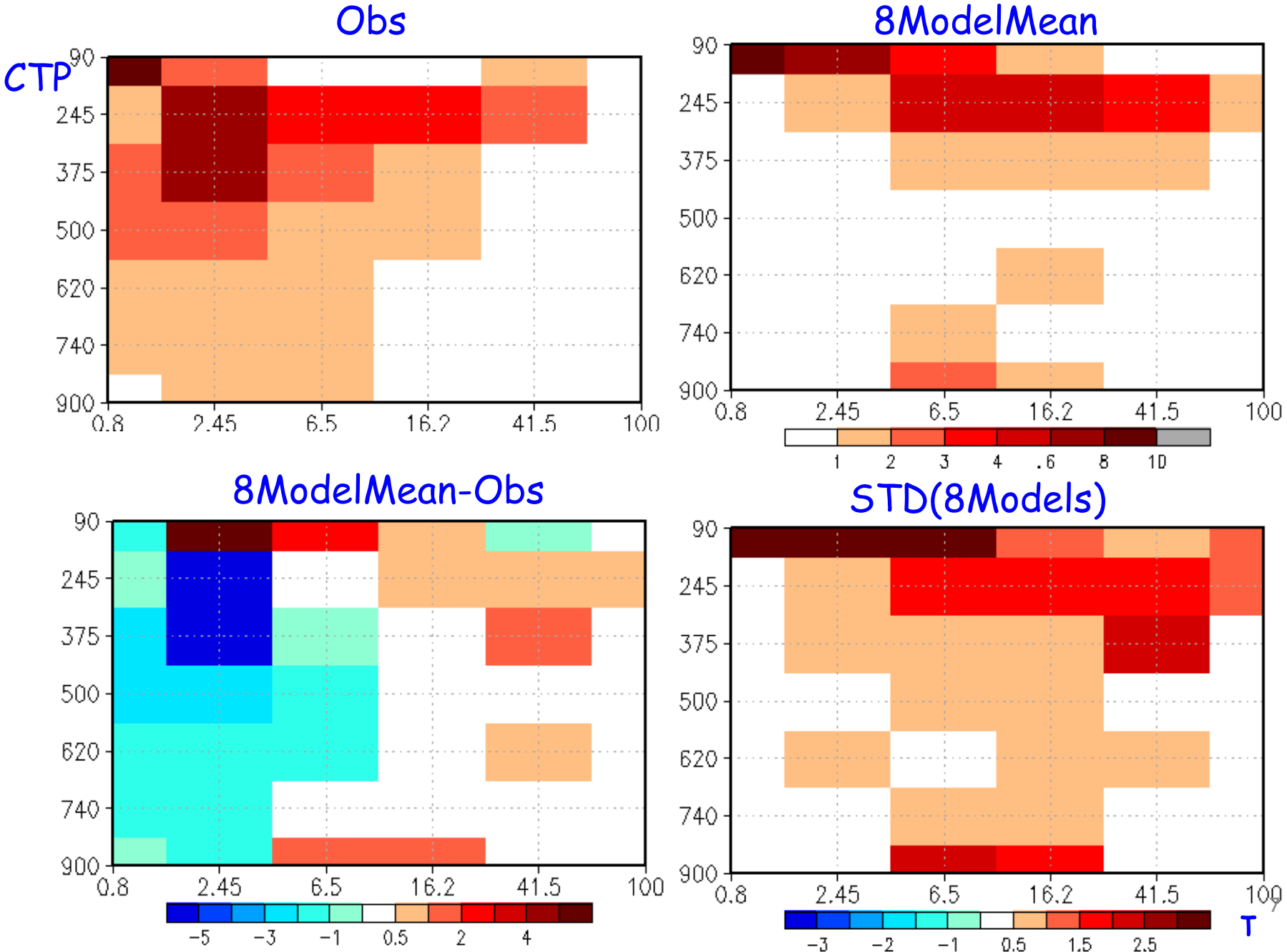
High Cloud

8ModelMean-CERES

Low Cloud



Annual Clim: ISCCP Cloud Fraction(CTP,τ)

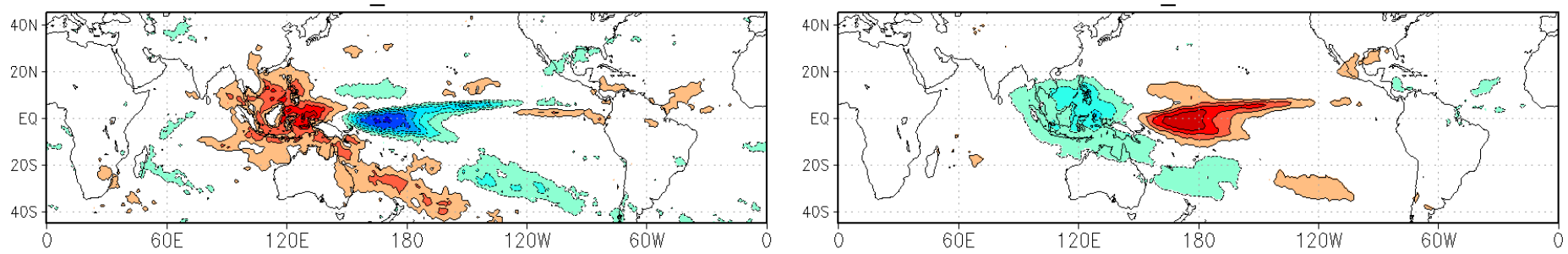


TOA CRE Anomalies associated with ENSO

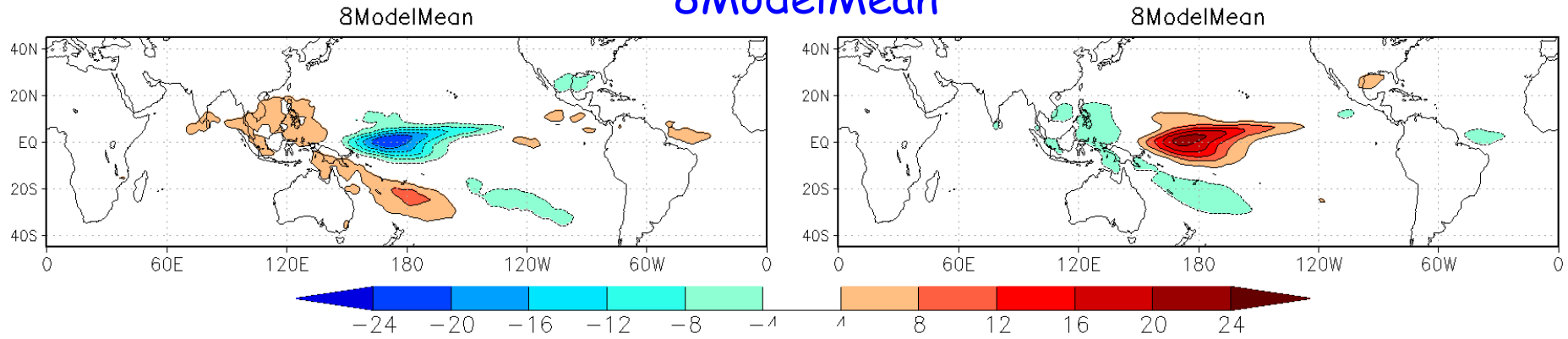
SWCRE

CERES

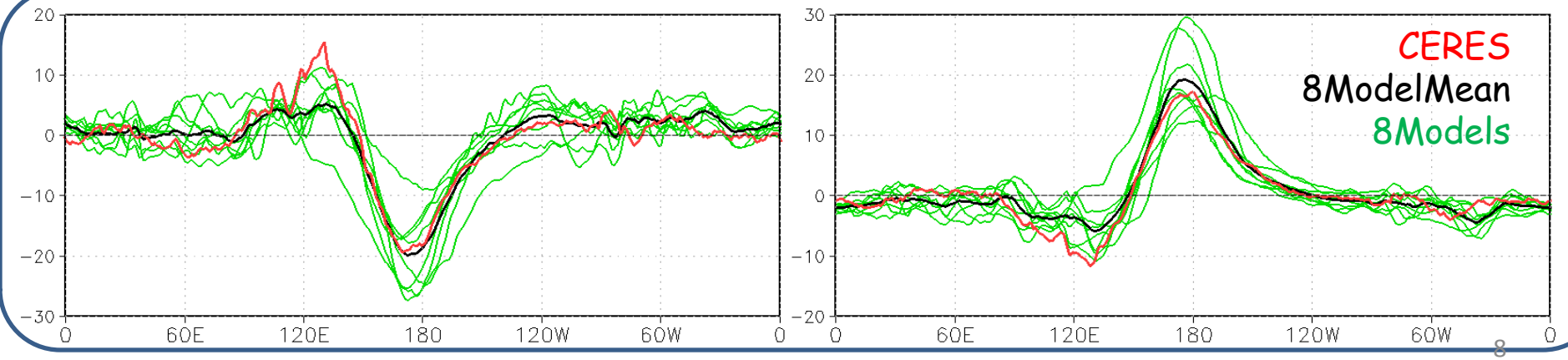
LWCRE



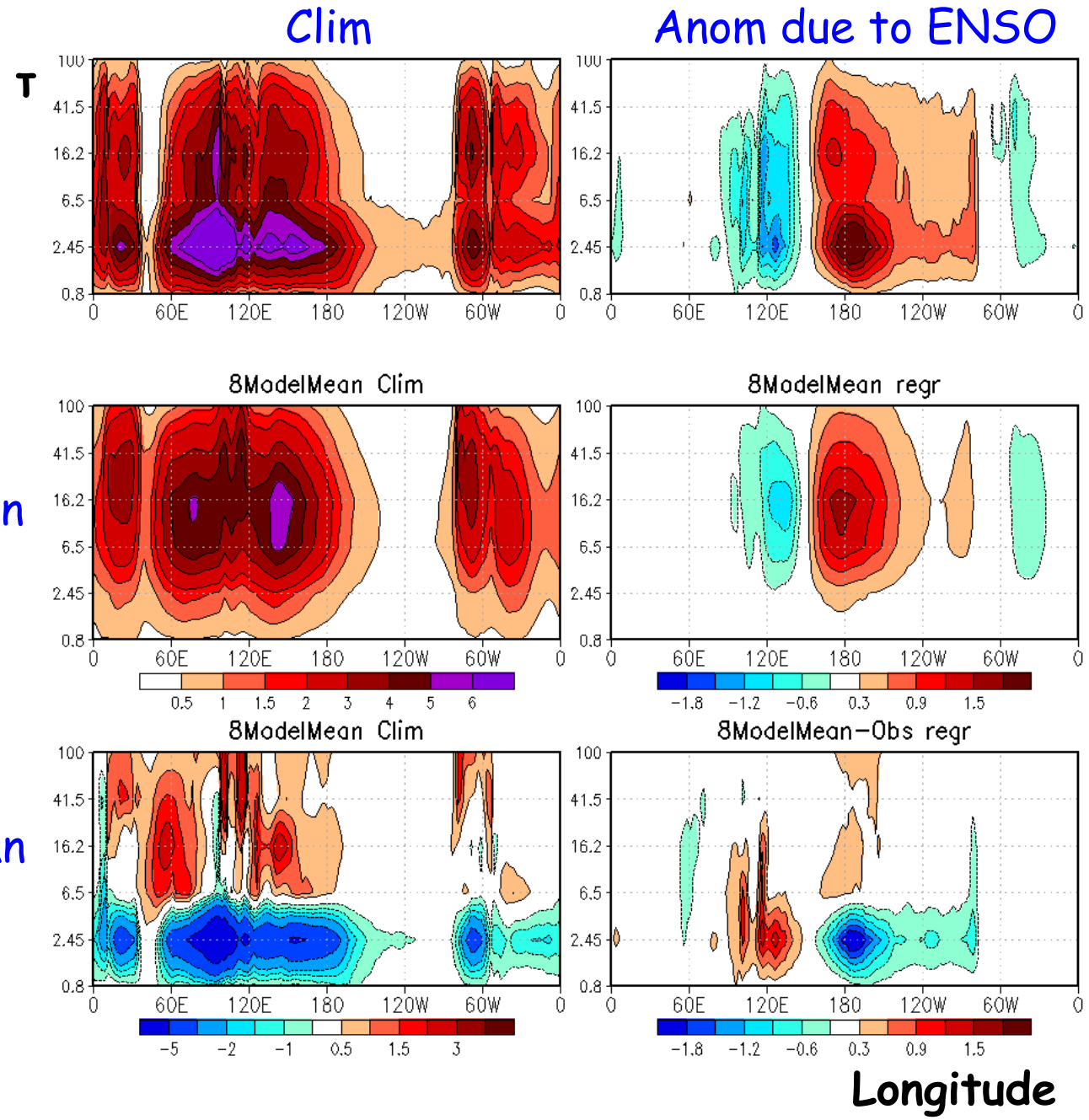
8ModelMean



5S-5N

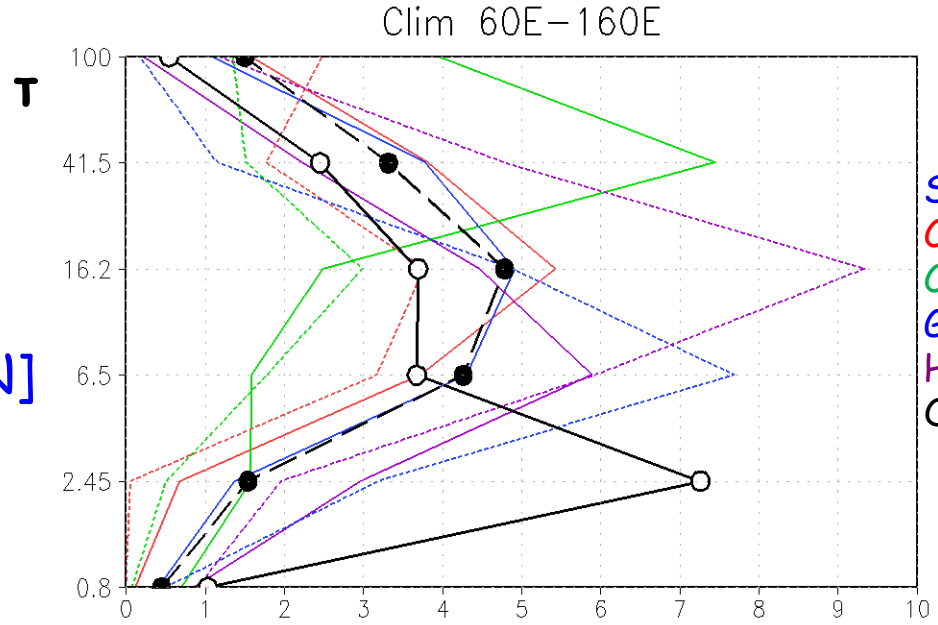


ISCCP Cloud Fraction (245mb,τ): 5S-5N



ISCCP Cloud Fraction (245mb,τ)

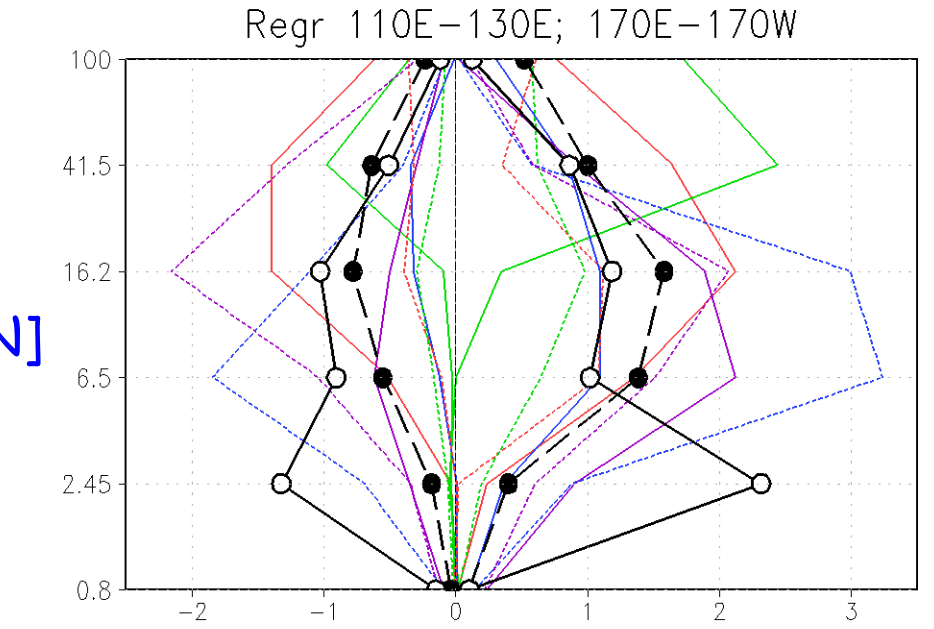
Clim
[60E-160E;5S-5N]



Solid
CanAM4
CNRM-CM4
GFDL-CM3
HadGEM2-A
Obs

Dashed
IPSL-CM5A-LR
MIROC5
MPI-ESM-LR
MRI-CGCM3
8ModelMean

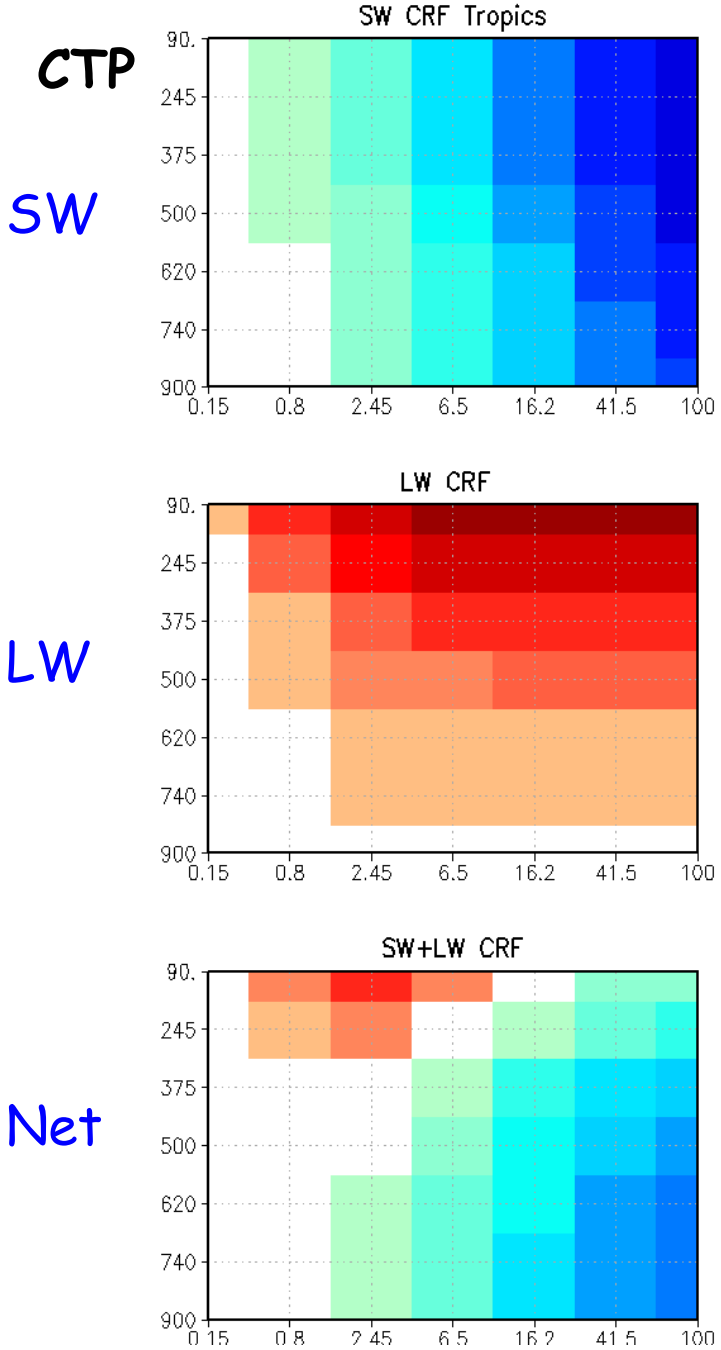
W TPac
[110E-130E;5S-5N]



E TPac
[170E-170W;5S-5N]

Considerable model diversity

Cloud Radiative Kernel (CTP,T) Annual Tropical Mean



* SW: largely zonally symmetric over tropical oceans
* LW: notable zonal dependence

* Annual tropical mean distribution consistent with annual global mean in Zelinka et al (2012) using climatology of a different set of models

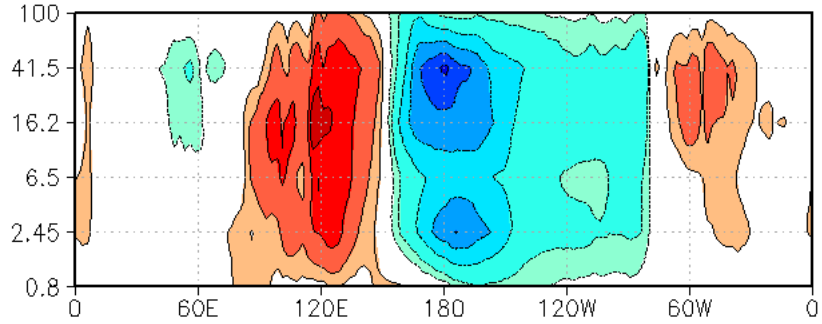
Reconstructed ΔTOA_CRE(245mb,τ): 5S-5N

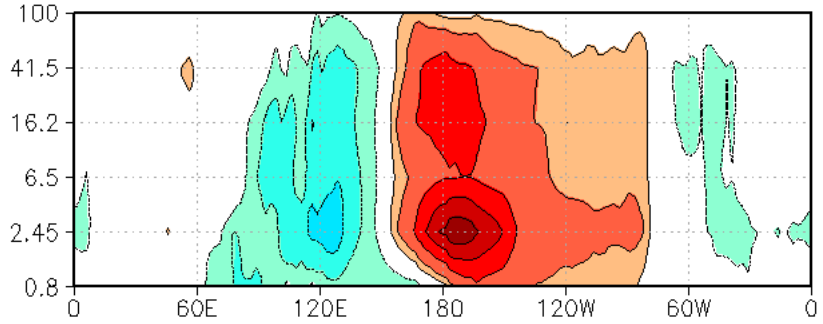
SWCRE

LWCRE

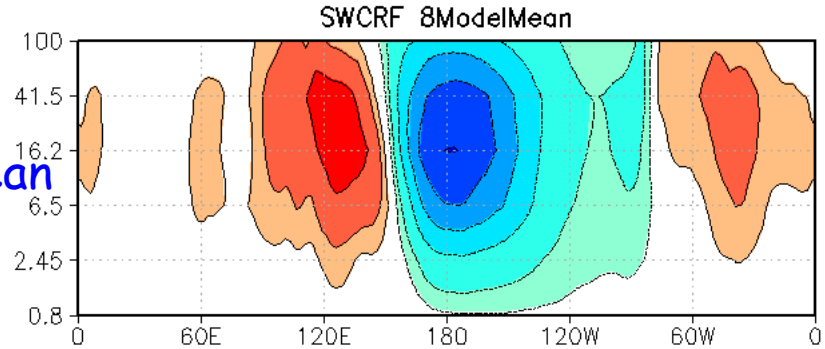
T

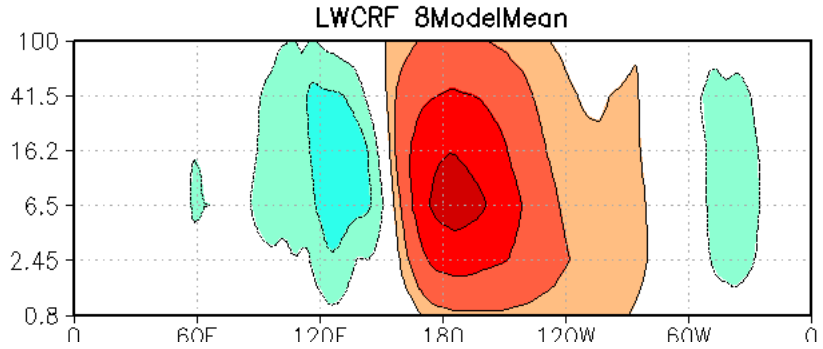
Obs

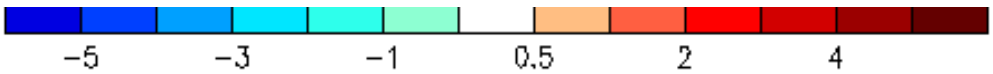




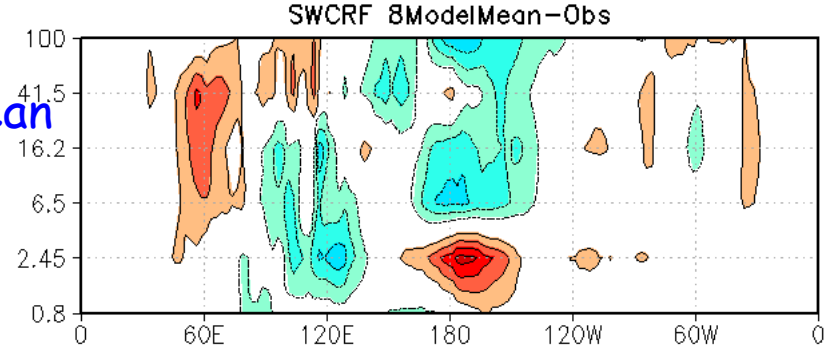
8ModelMean

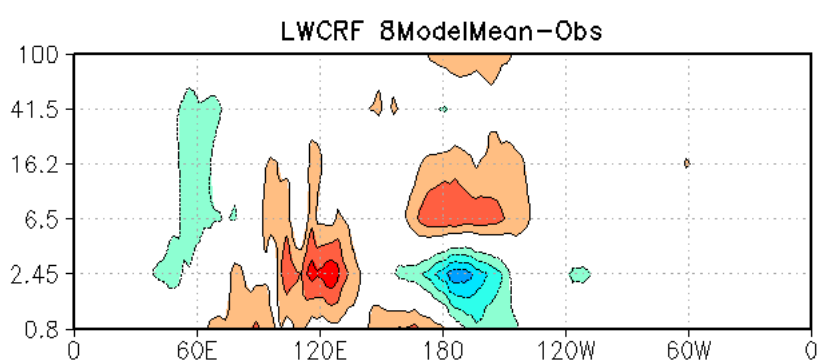


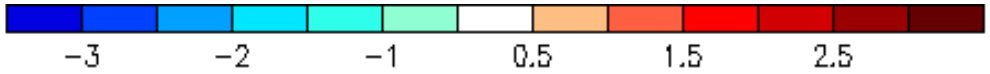




8ModelMean -Obs







Longitude

Conclusions

- CMIP5 models are problematic in simulating tropical clouds
  - Climatologically:
    - less total cloud amount; lack mid and low clouds
    - less high clouds over Maritime continent; more high clouds over western tropical Indian Ocean and Pacific trade cumulus regions
    - model clouds optically thicker than observed
    - considerable model diversity
  - Model bias in climatology strongly impacts that in variability

- AMIP5 simulations of TOA CRE anomalies due to ENSO
  - Western tropical Pacific:
    - consistently underestimate obs; due to less mean high clouds there
  - Central tropical Pacific:
    - multi-model mean resembles obs well, which is however a result of compensating errors between weaker anomaly from thin high clouds and stronger anomaly from medium and thick high clouds
  - Considerable model diversity