High resolution NASA GEOS5 model for simulating mean, variability, and extreme characteristics

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Introduction (Goal)

1. GEOS5: AGCM, resolutions from 2° to 10km with 72 layers to 0.01hPa
2. Evaluate quality of the recent high-resolution GEOS-5 model version
3. Assessment of the seasonal mean features, climate variability, and extremes (T, Prcp) focusing on winter and summer season

Model run

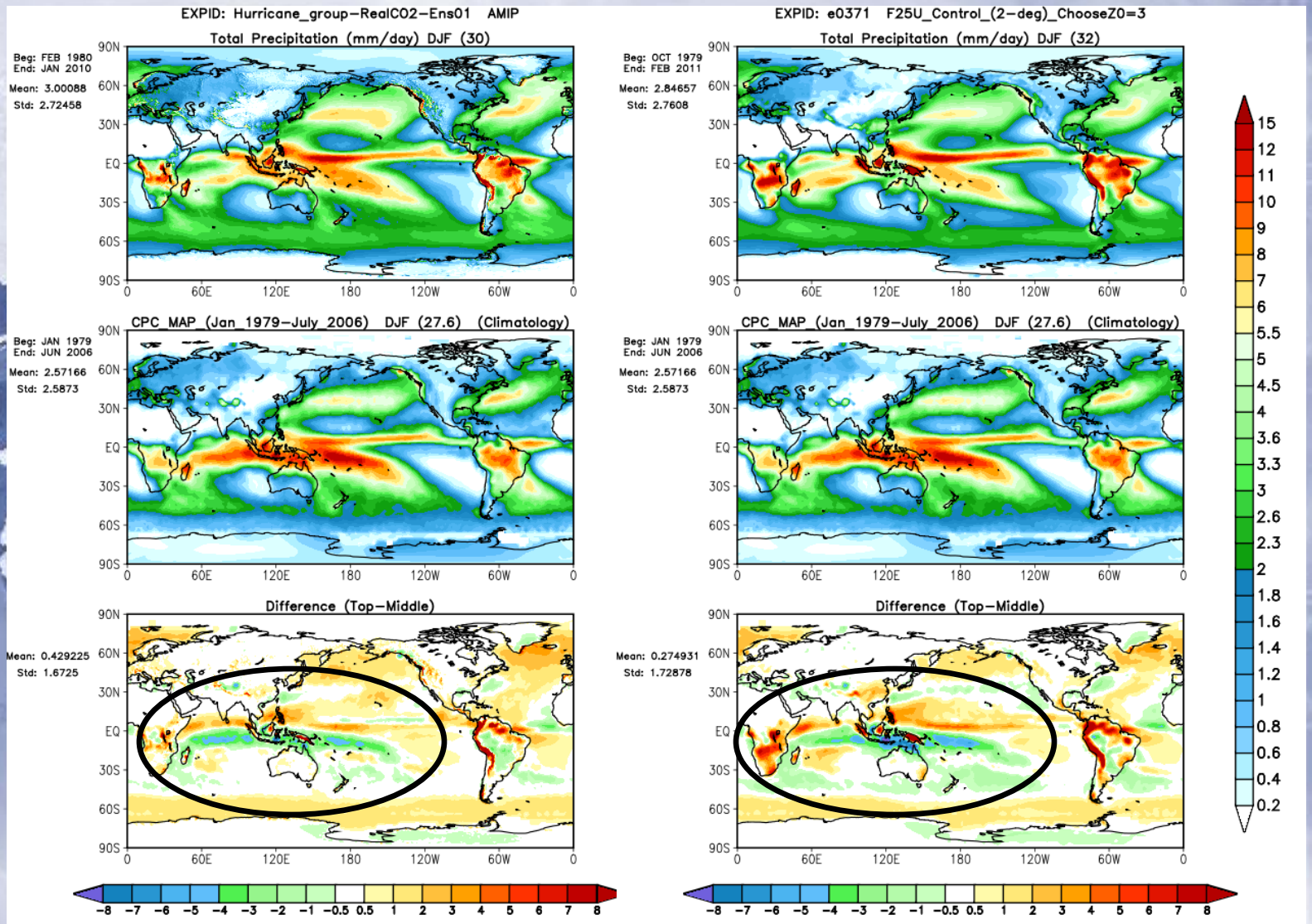
1. Resolution: 0.5 degree, Period: 30 years (1980~2009)
2. Three member ensemble starting January 1980, AMIP-type integration
3. Atmospheric IC from MERRA, SST from Hadley SST (updated monthly)

Highlights of the model

1. High-resolution input data (atmospheric IC, oceanic BC, topography, aerosol, sea ice, and so on.)
2. Modified RAS (new stochastic formulation to determine cumulus entrainment)
3. Modified near surface wind : improvement in low-level circulation and frictional convergence
4. Catchment based land-surface model (Koster et al. 2000) and a multi-layer snow model (Stieglitz et al. 2001)
5. Chemistry : Upgraded biofuel, aerosol data and new formulation of the emission process

And so on……

Precipitation (DJF)



Model

Obs.

Diff.

0.5 deg. resol.

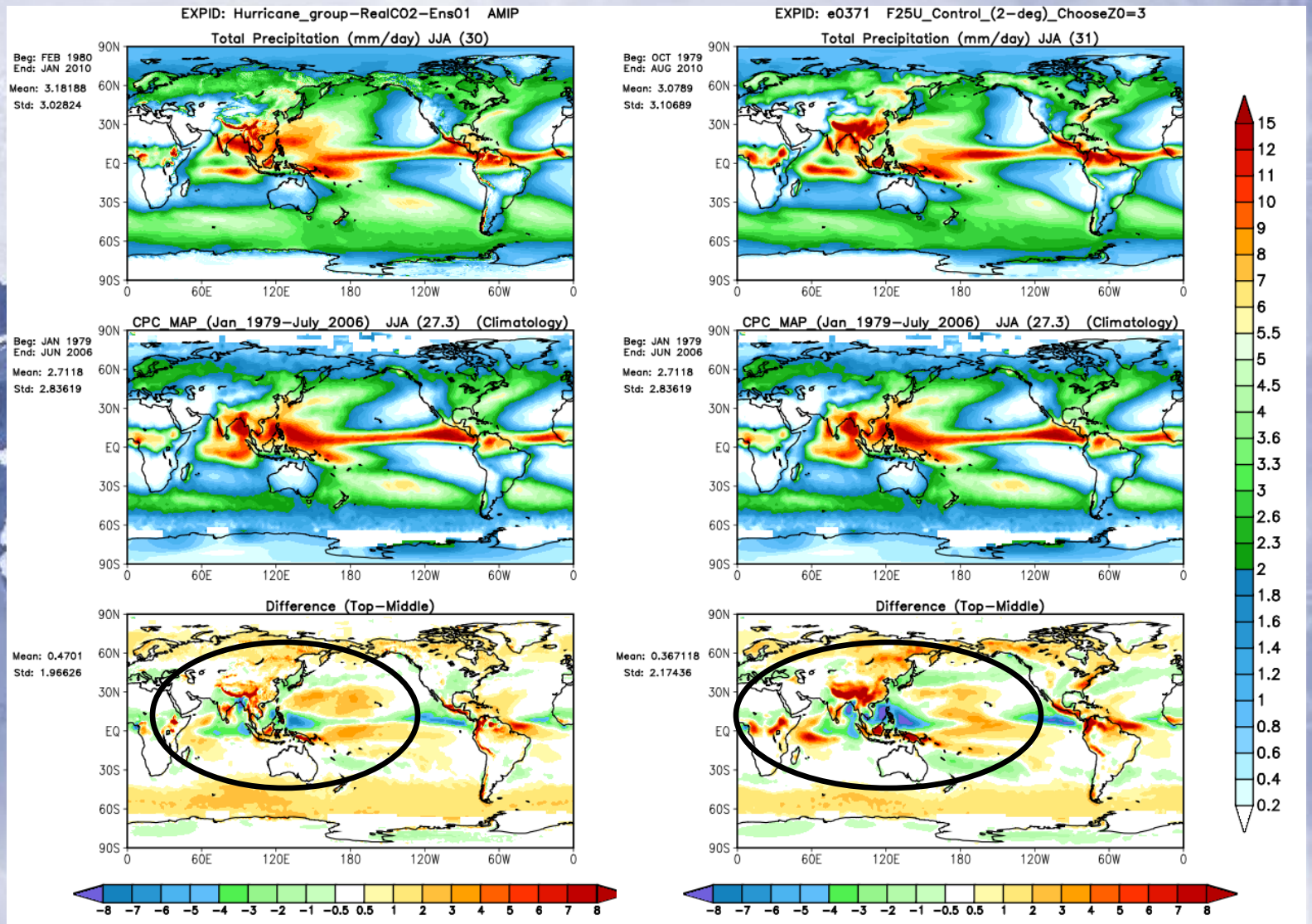
2 deg. resol.

Precipitation (JJA)

Model

Obs.

Diff.



0.5 deg. resol.

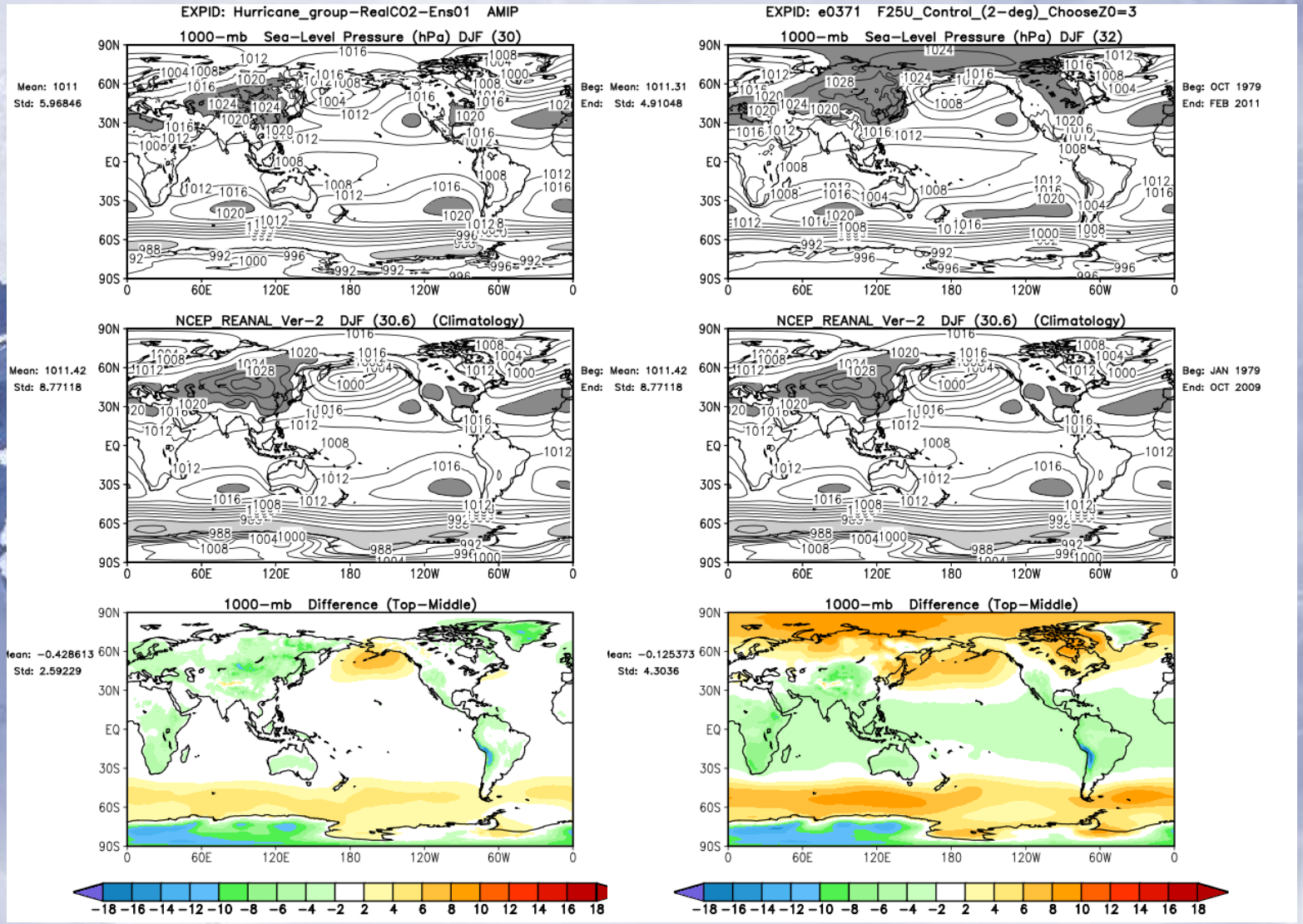
2 deg. resol.

Sea Level Pressure (DJF)

Model

Re-analysis

Diff.



0.5 deg. resol.

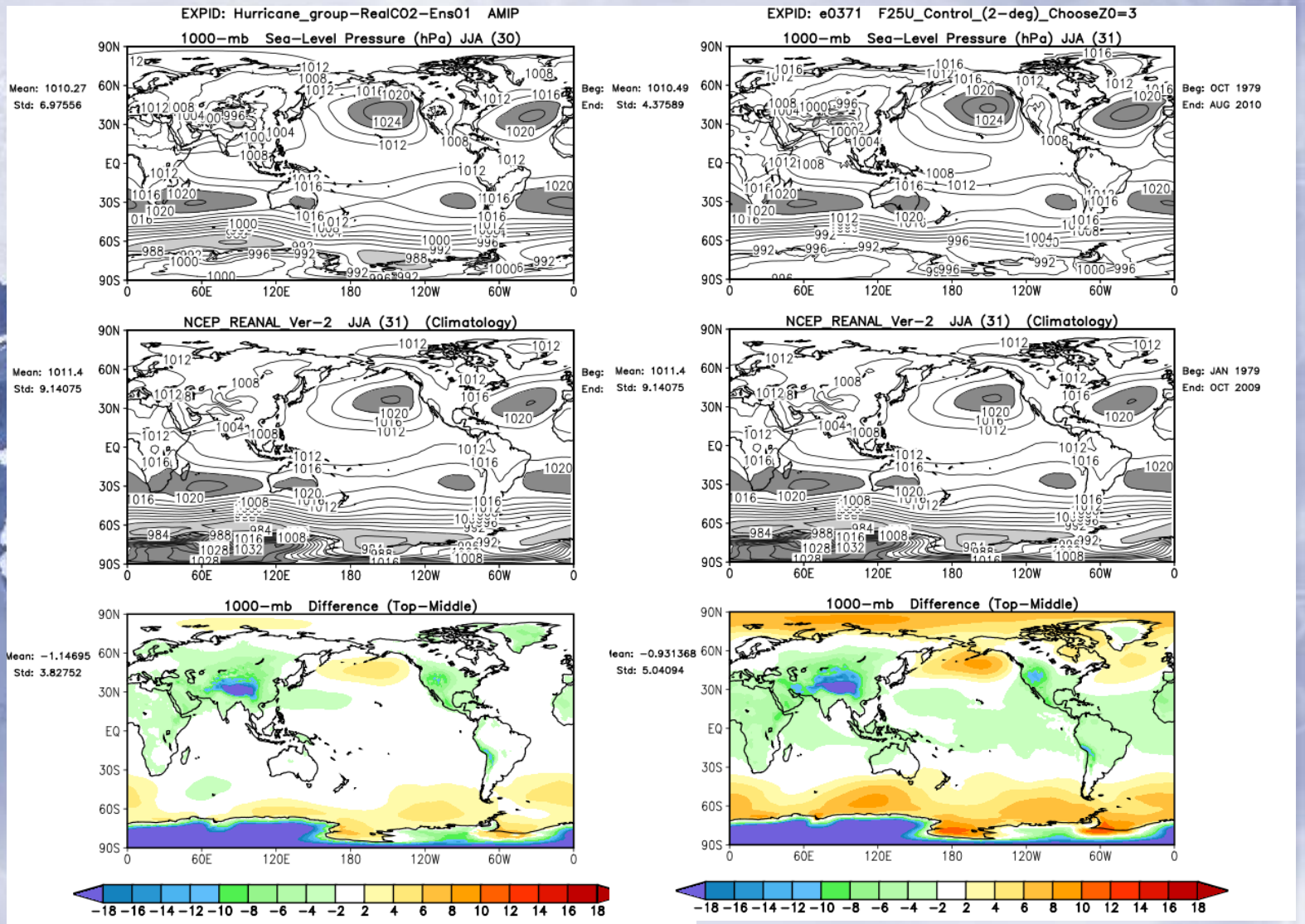
2 deg. resol.

Sea Level Pressure (JJA)

Model

Re-analysis

Diff.



0.5 deg. resol.

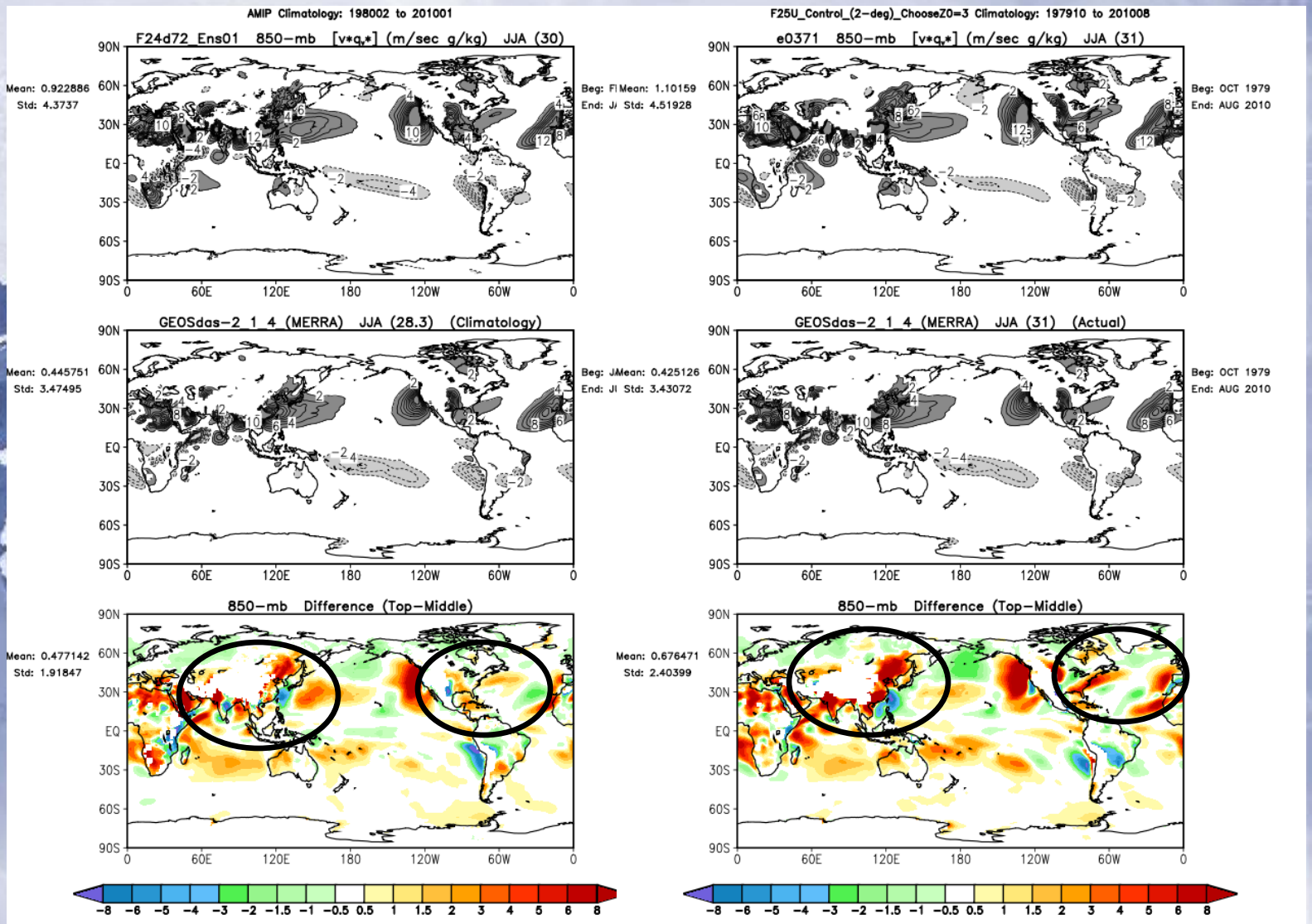
2 deg. resol.

Moisture transport by V* at 850 hPa (JJA)

Model

Re-analysis

Diff.



0.5 deg. resol.

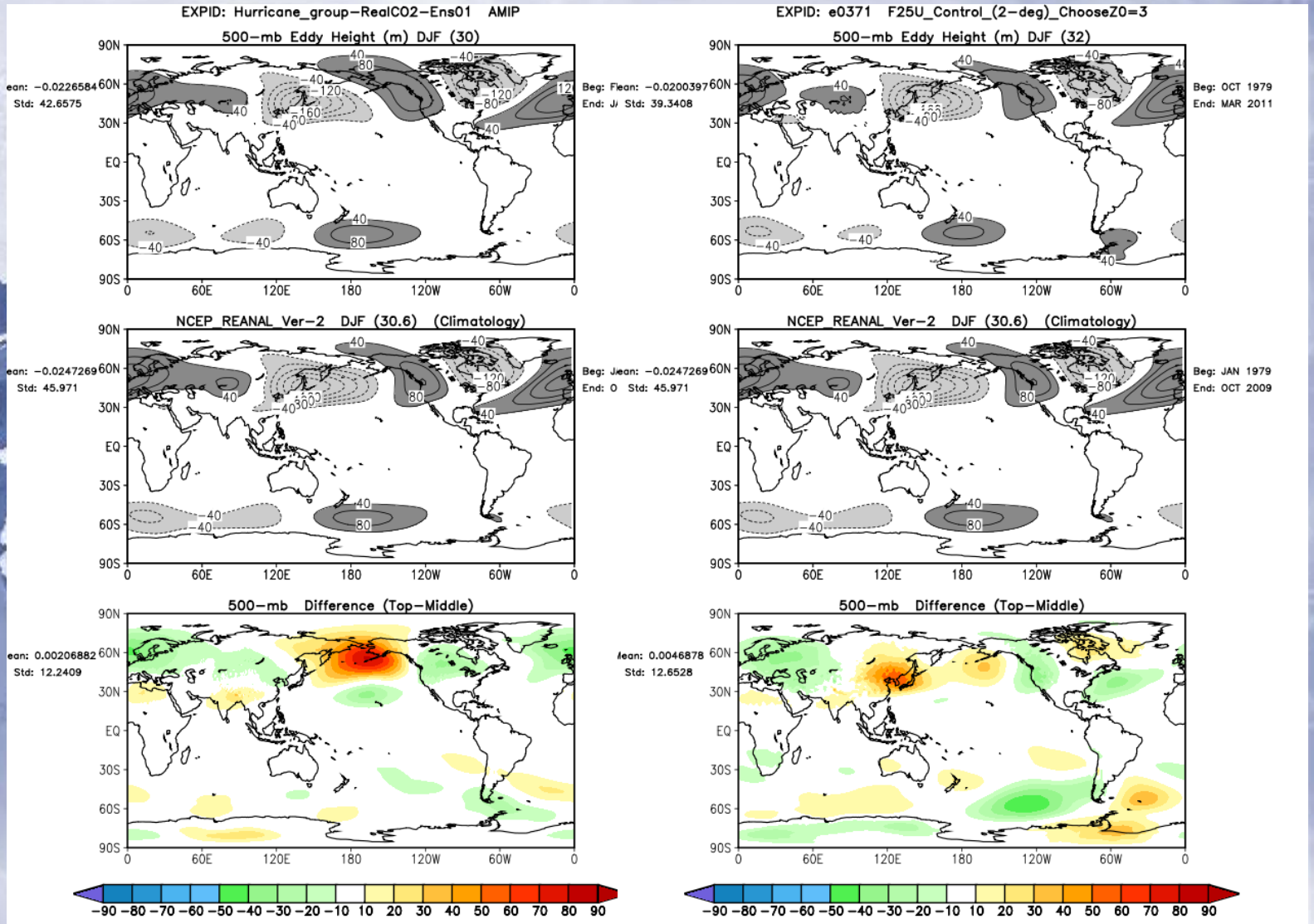
2 deg. resol.

Eddy height at 500 hPa (DJF)

Model

Re-analysis

Diff.



0.5 deg. resol.

2 deg. resol.

30-Year AMIP Simulations (—)
vs.
MERRA 0.5-deg Reanalysis(—)

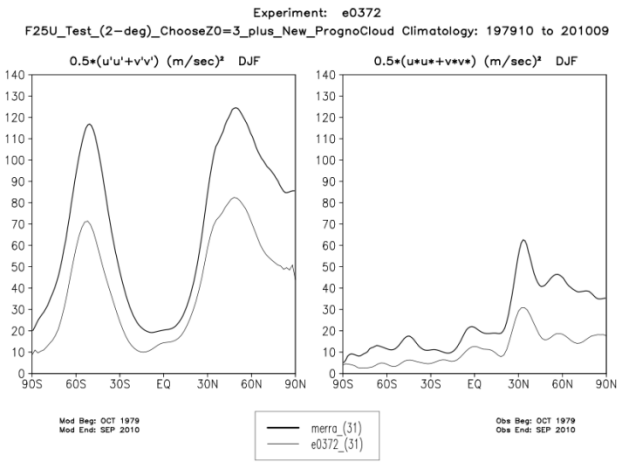
Dec-Jan-Feb

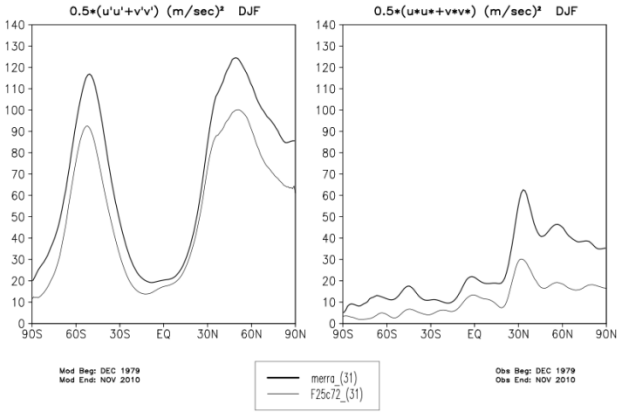
2-deg

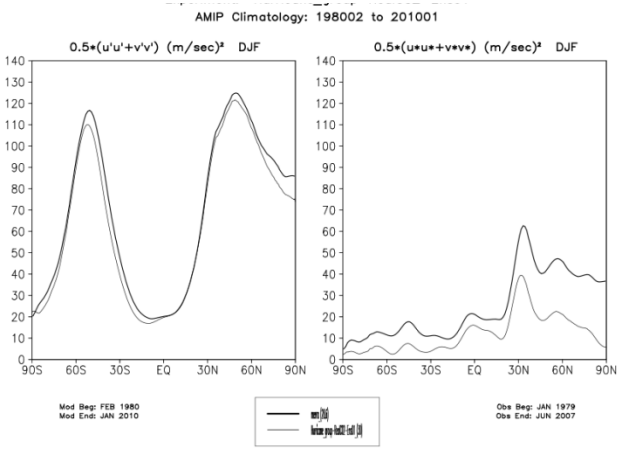
1-deg

0.5-deg

Vertically Integrated Kinetic Energy due to Transient Waves







Vertically Integrated Kinetic Energy due to Stationary Waves

30-Year AMIP Simulations (←)
vs.
MERRA 0.5-deg Reanalysis (←)

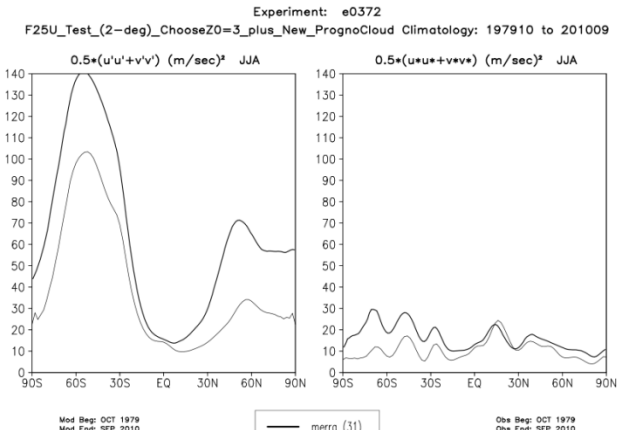
Jun-Jul-Aug

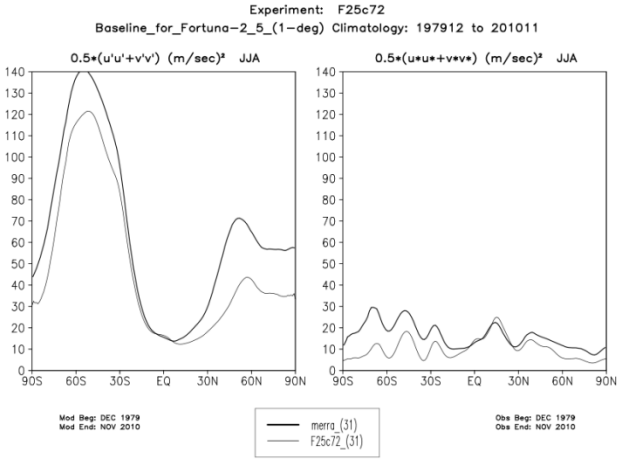
2-deg

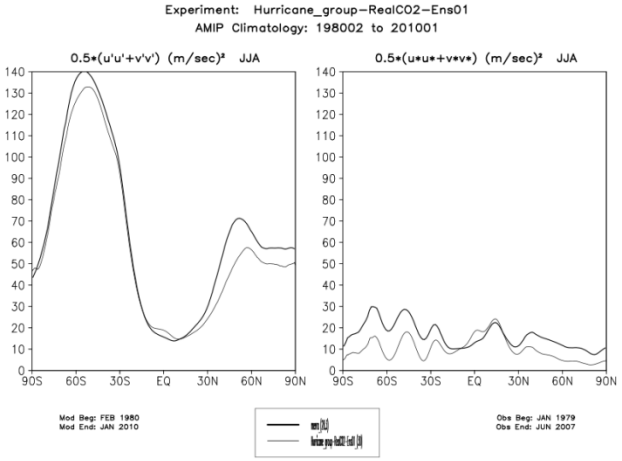
Vertically Integrated Kinetic Energy due to Transient Waves

1-deg

0.5-deg







Vertically Integrated Kinetic Energy due to Stationary Waves

Kinetic Energy due to Transient Waves

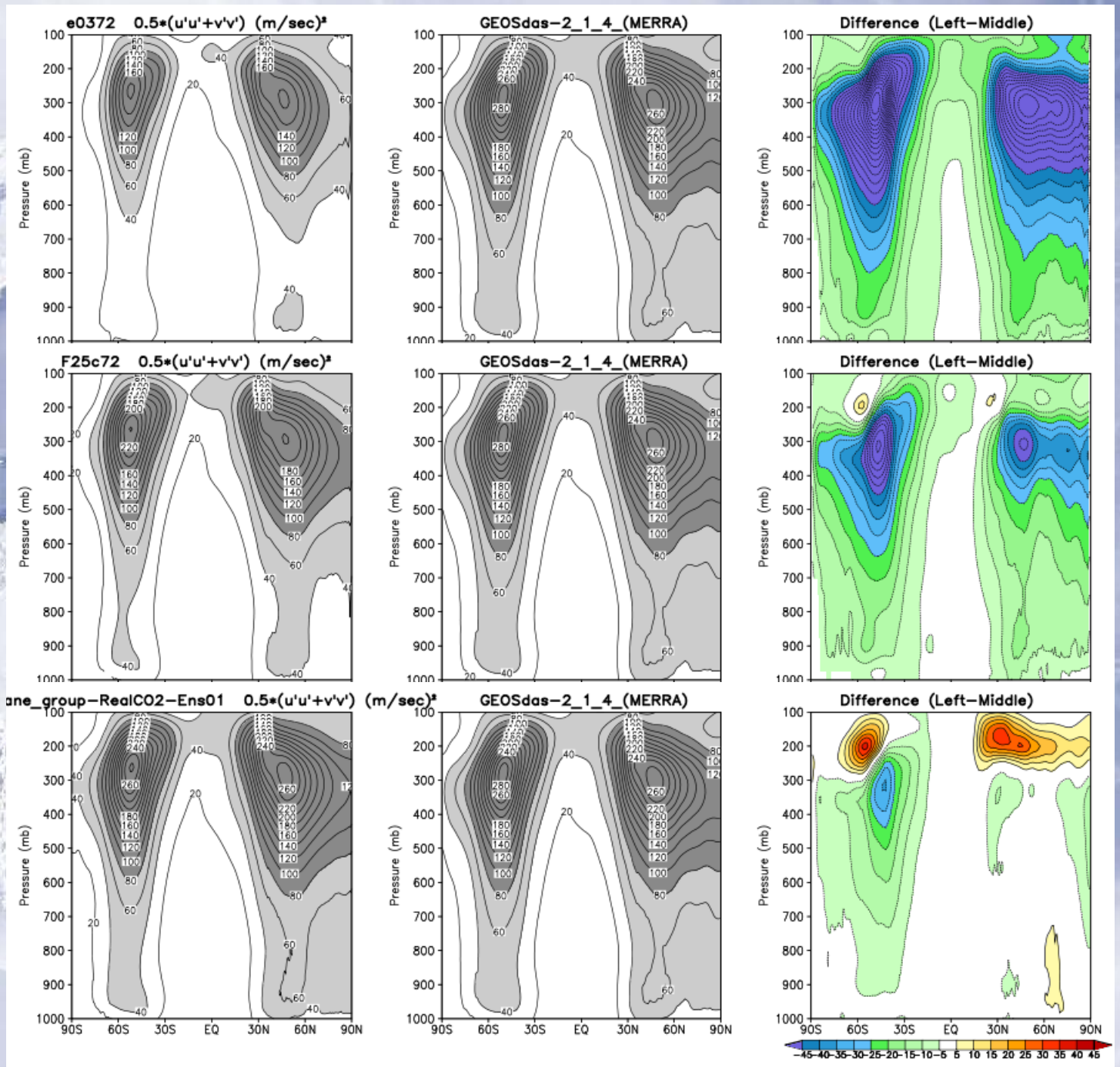
2-deg

30-Year AMIP Simulations vs. MERRA 0.5-deg Reanalysis

1-deg

Dec-Jan-Feb

0.5-deg



Moisture Flux due to Transient Waves

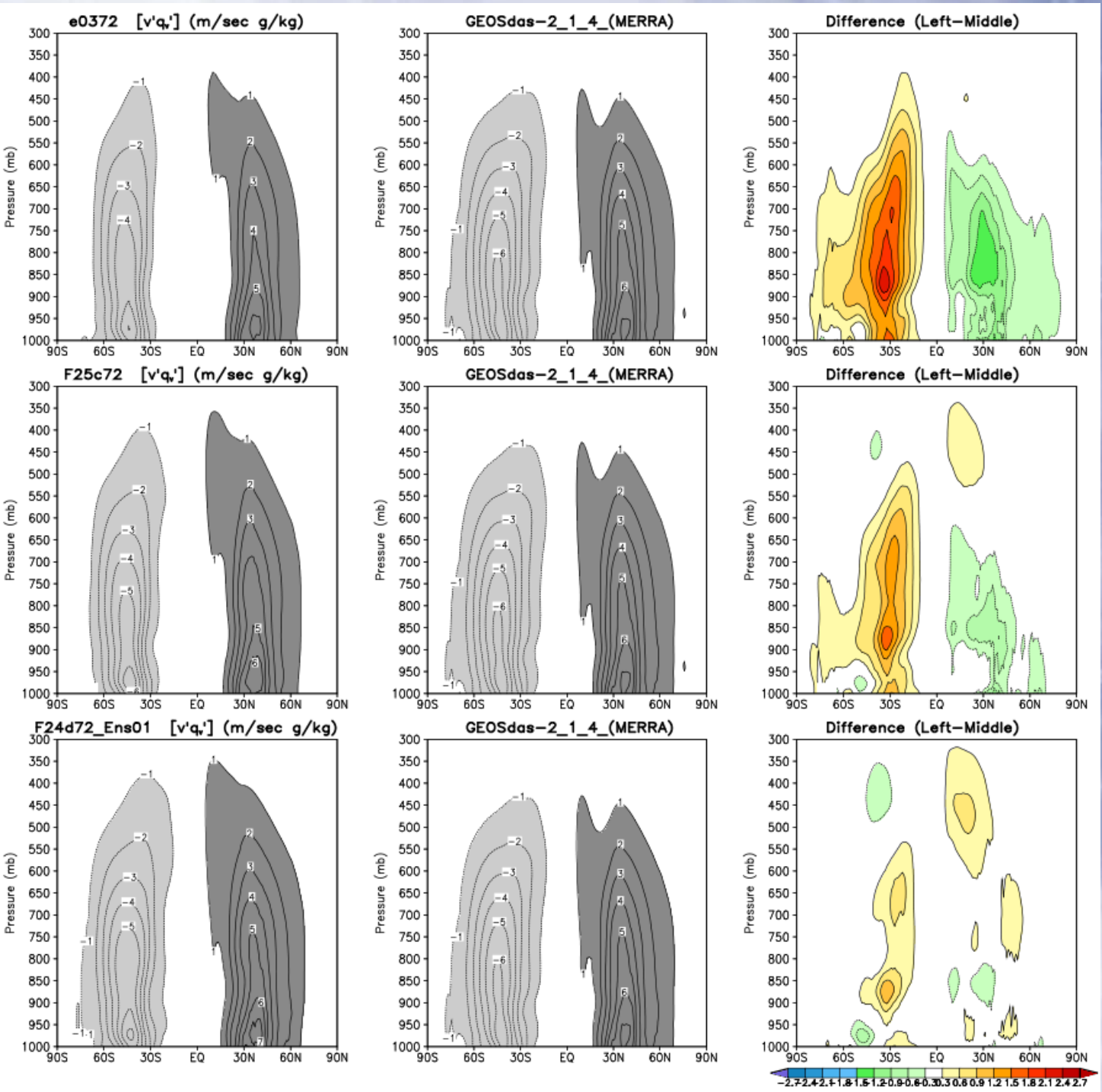
2-deg

30-Year AMIP Simulations vs. MERRA 0.5-deg Reanalysis

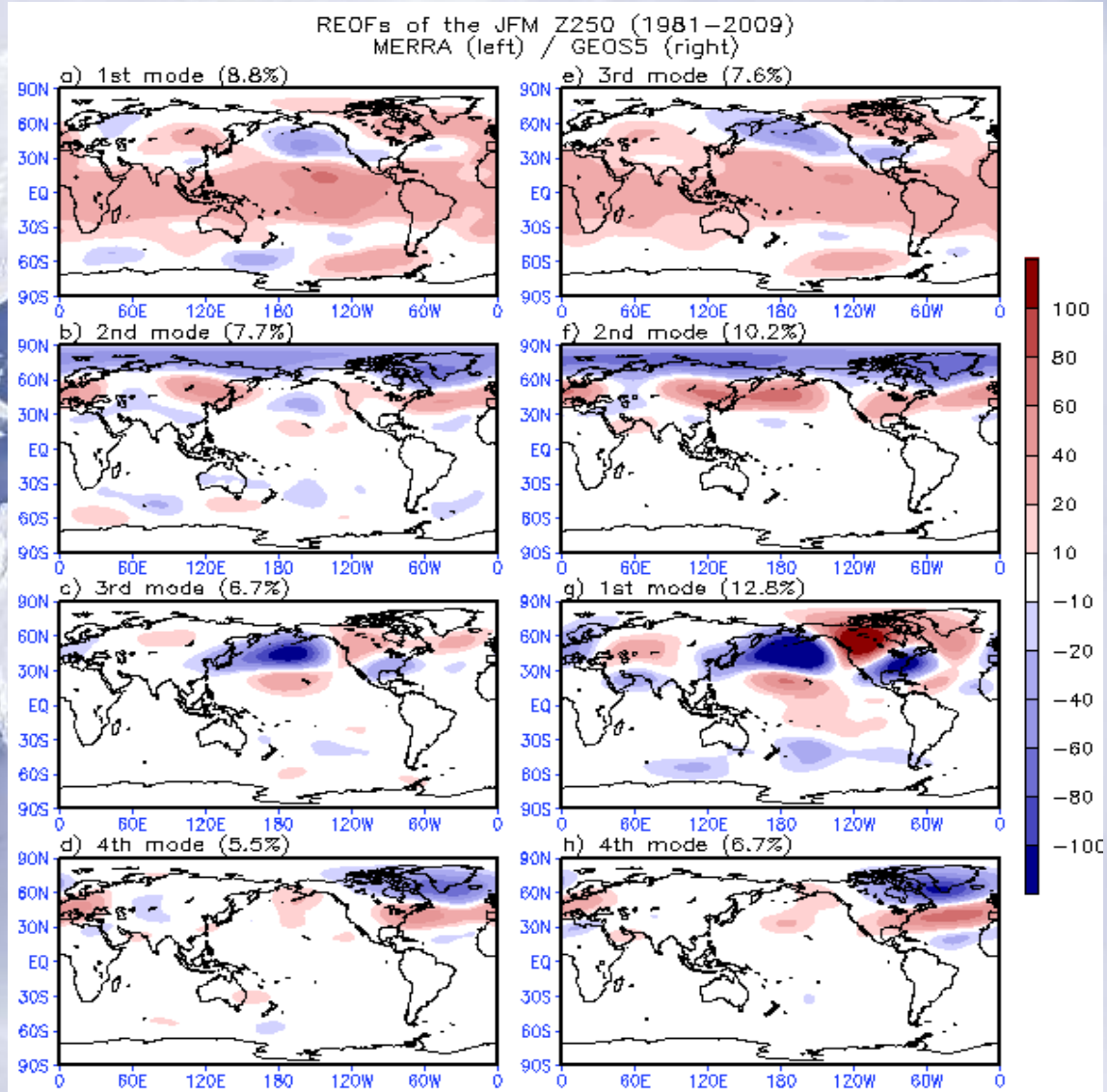
1-deg

Dec-Jan-Feb

0.5-deg



Dominant modes (JFM monthly variability) (REOF z250)



MERRA GEOS5 (0.5deg)

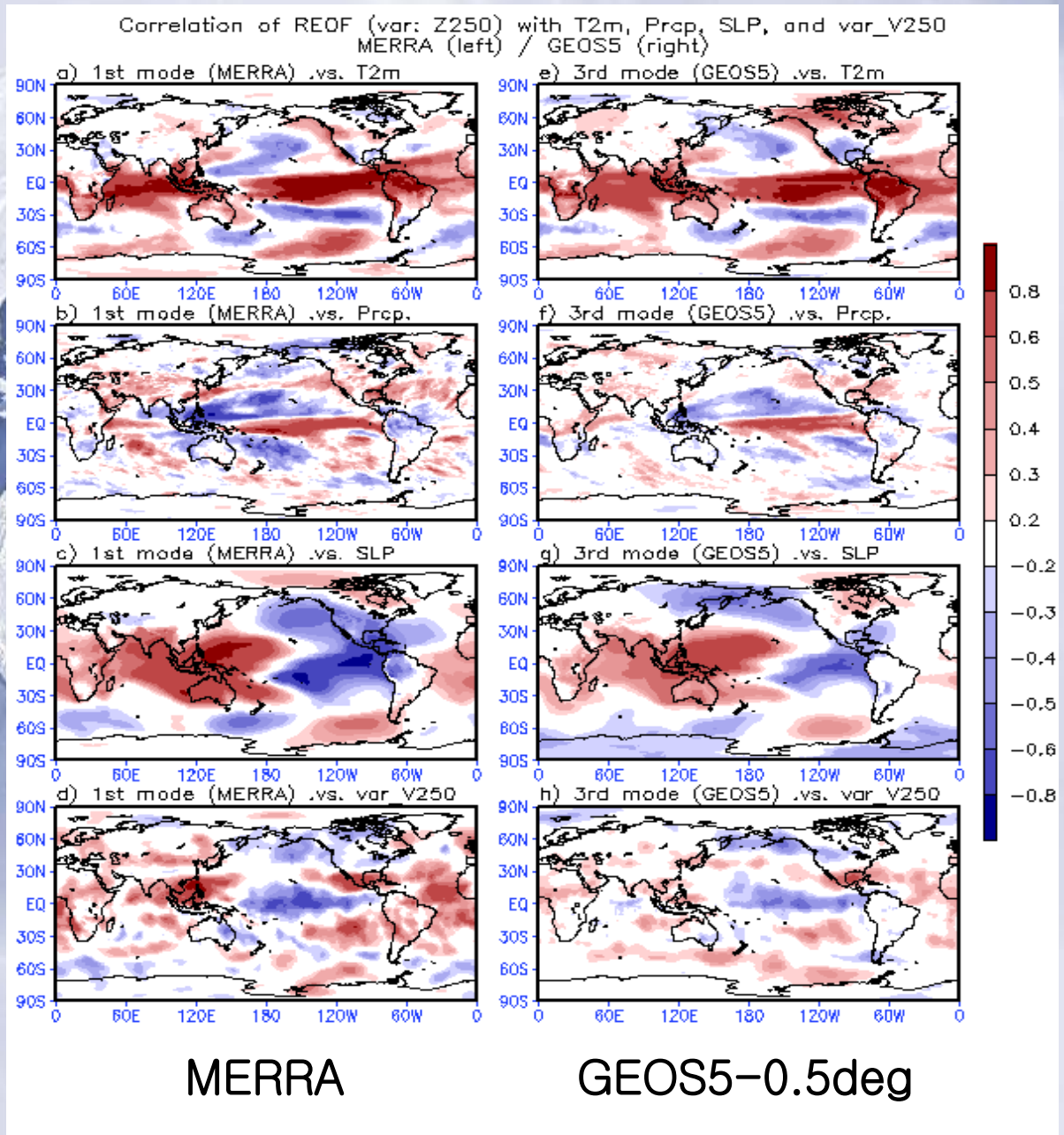
ENSO

NAM (Northern annular mode)

PNA

NAO

JFM Climate / Weather links (Corr. with ENSO REOF)



T2m

Prcp

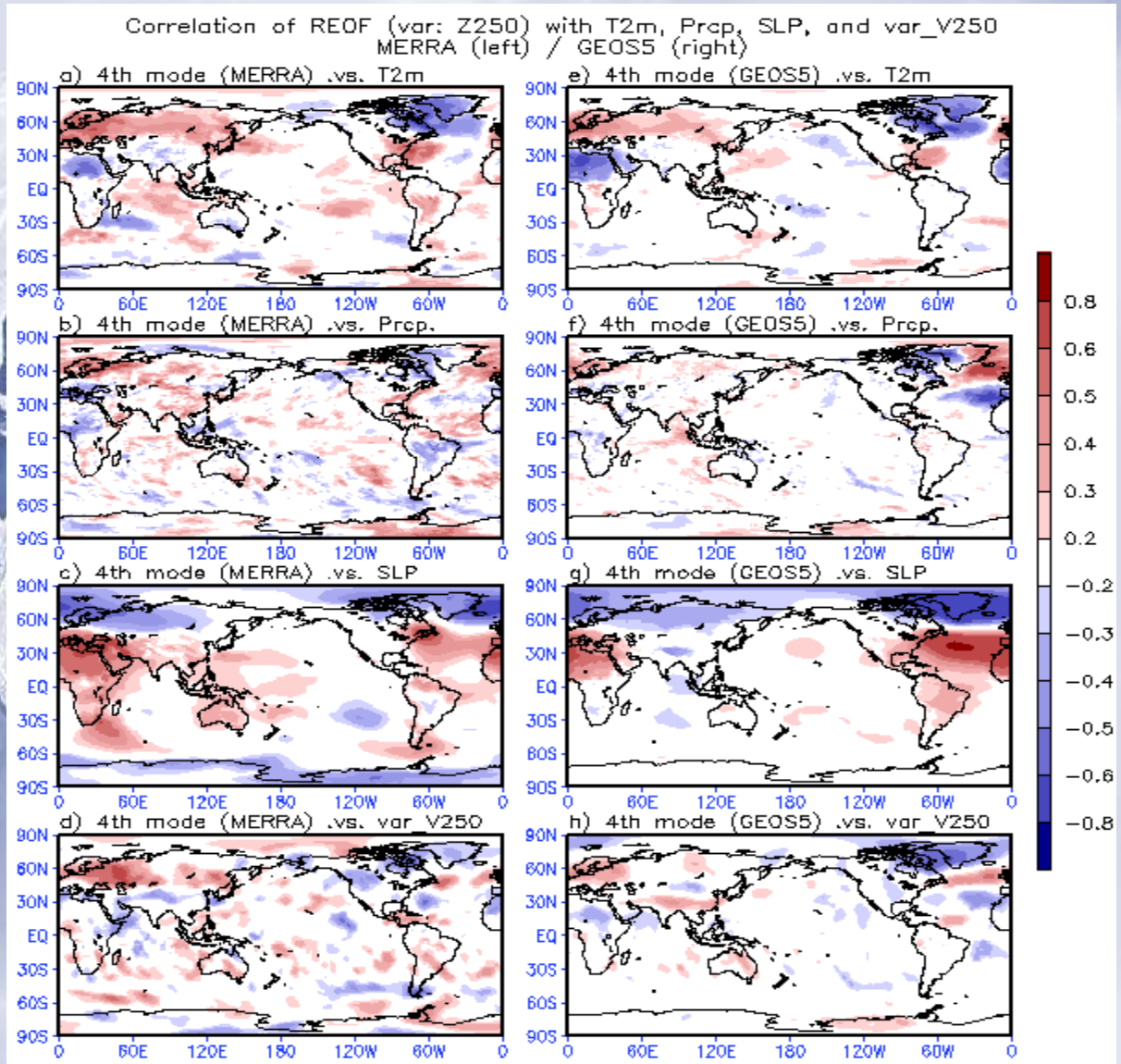
SLP

v'2

MERRA

GEOS5-0.5deg

JFM Climate / Weather links (Corr. with NAO REOF)



T2m

Prcp

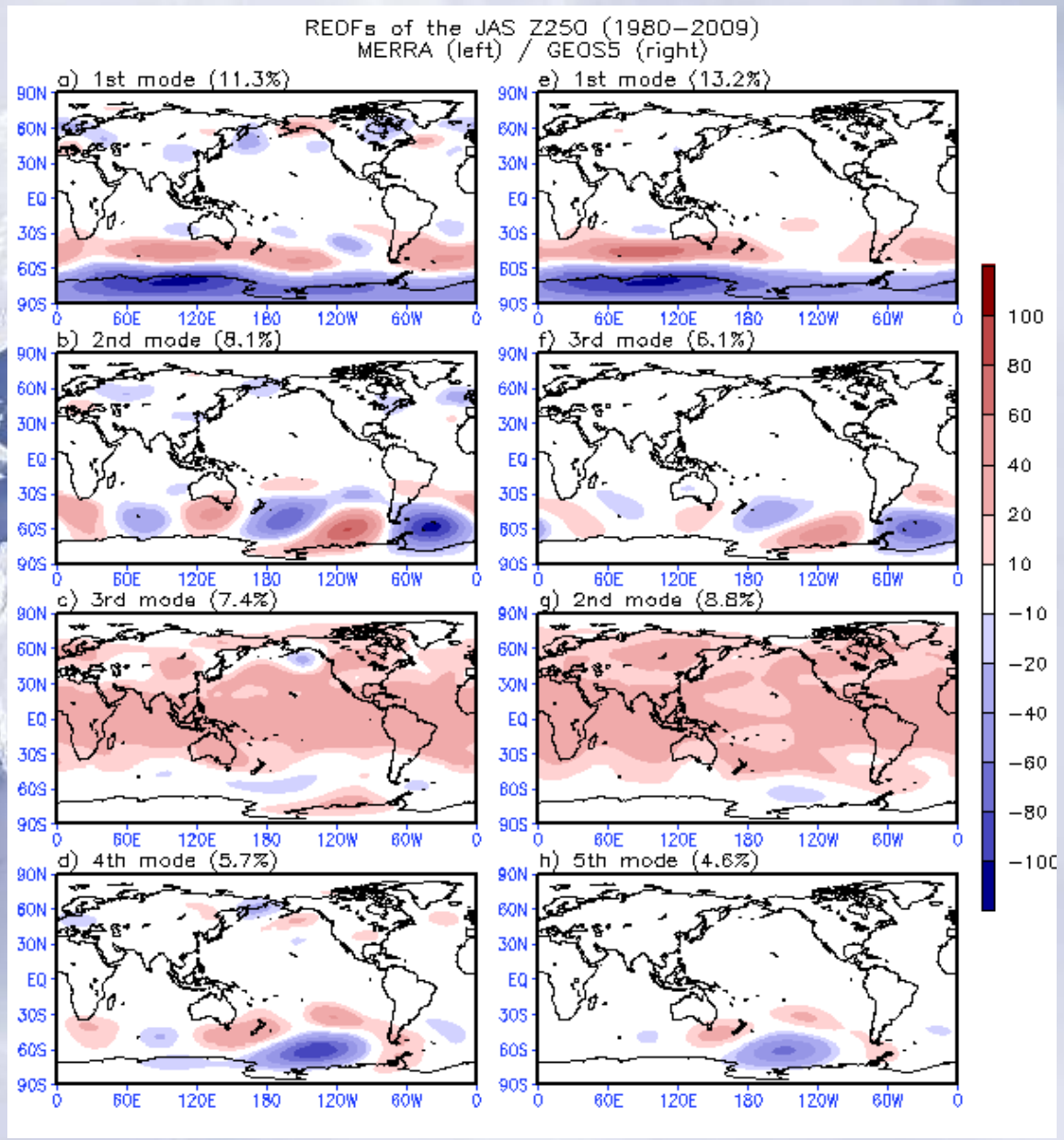
SLP

v'2

MERRA

GEOS5-0.5deg

JAS monthly variability



SAM (Southern annular mode)

PSA (Pacific South American mode) 2

Trend

PSA 1

MERRA

GEOS5 (0.5deg)

Generalized Extreme Value Distribution (GEVD)

The GEVD is used as an approximation to model the maxima of long (finite) sequences of random variables. We fit a sample of extremes to the GEVD to obtain the parameters that best explain the probability distribution of the extremes. A key advantage of GEVD is that the parameters of the GEVD provide the flexibility needed to fit to the different types of behaviors of the tails of those distributions.

The cumulative distribution function (CDF) of the GEVD

$$F(x;\mu,\sigma,\xi) = \exp\left\{-\left[1+\xi\left(\frac{x-\mu}{\sigma}\right)\right]^{-1/\xi}\right\}$$

ξ, μ, and σ represent the shape, location, and scale of the distribution

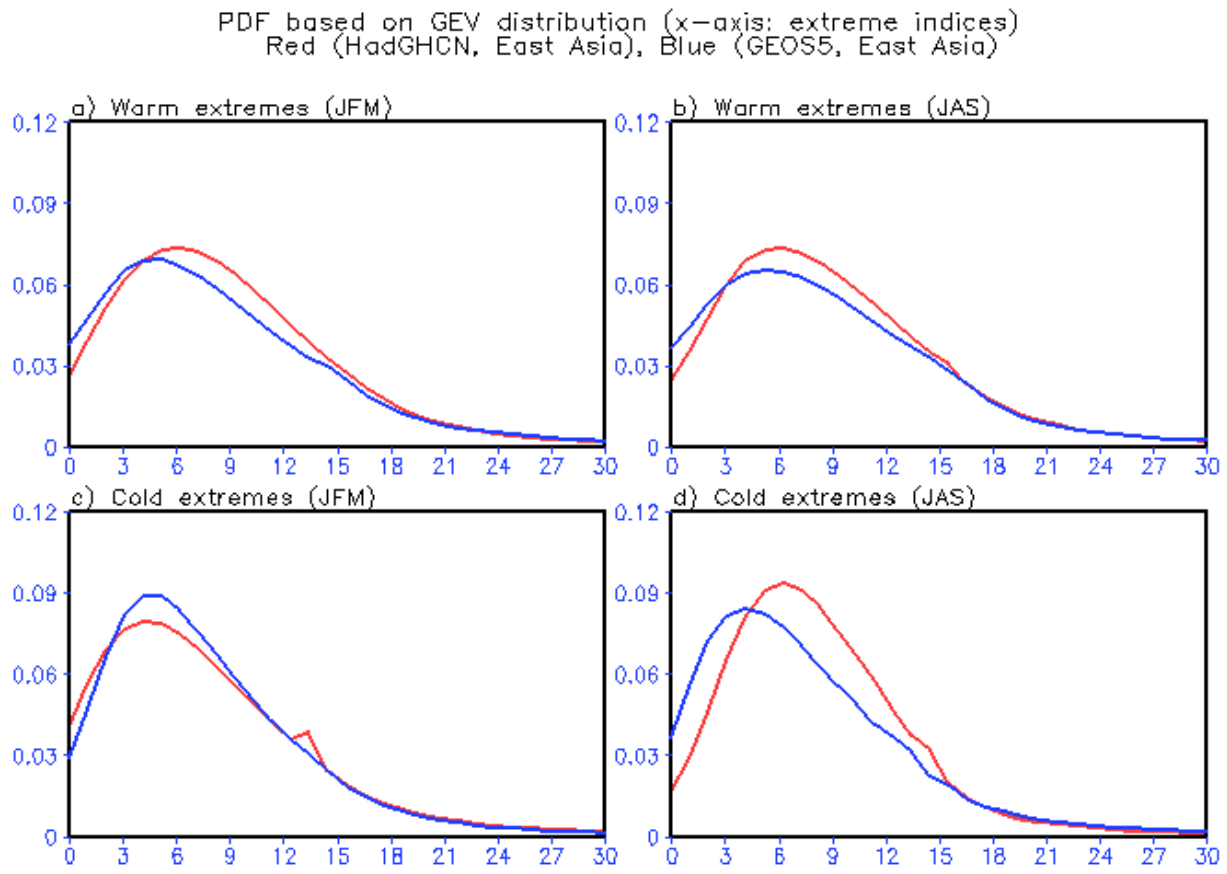
Probability distribution function (PDF)

$$\frac{1}{\sigma}\, t(x)^{\xi+1} e^{-t(x)},$$

$$t(x) = \begin{cases} \left(1+\xi\frac{x-\mu}{\sigma}\right)^{-1/\xi} & \text{if } \xi \neq 0 \\ e^{-(x-\mu)/\sigma} & \text{if } \xi = 0 \end{cases}$$

Probability distribution function for T extremes based on GEV : East Asia (90-150E, 20-60N)

Red: HadGHCN, Blue: GEOS5



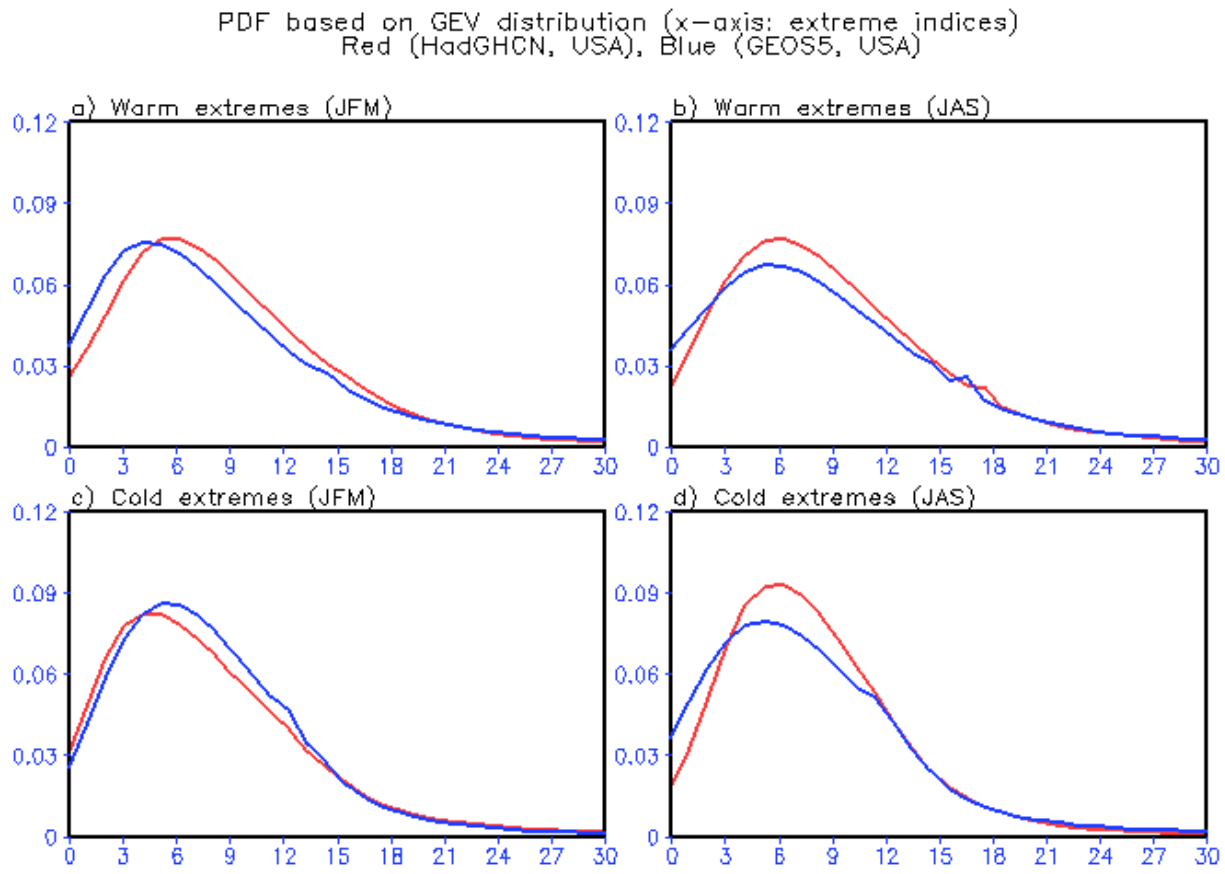
JFM **JAS**

# of Warm days: Tmax (90%)

# of Cold days: Tmin (10%)

Probability distribution function for T extremes based on GEV : USA (60-130W, 25-60N)

Red: HadGHCN, Blue: GEOS5



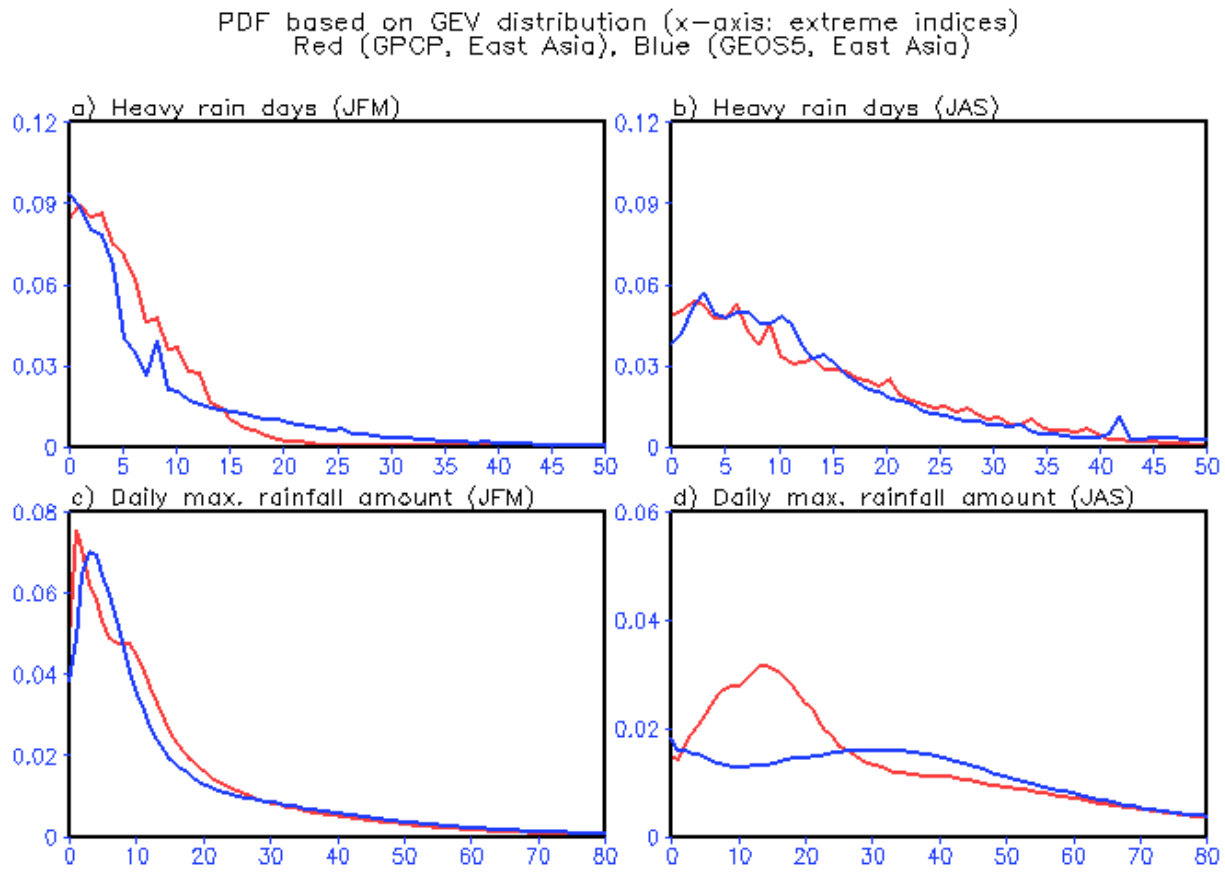
JFM **JAS**

# of Warm days: Tmax (90%)

# of Cold days: Tmin (10%)

Probability distribution function for Prcp extremes based on GEV : East Asia

Red: GPCP, Blue: GEOS5



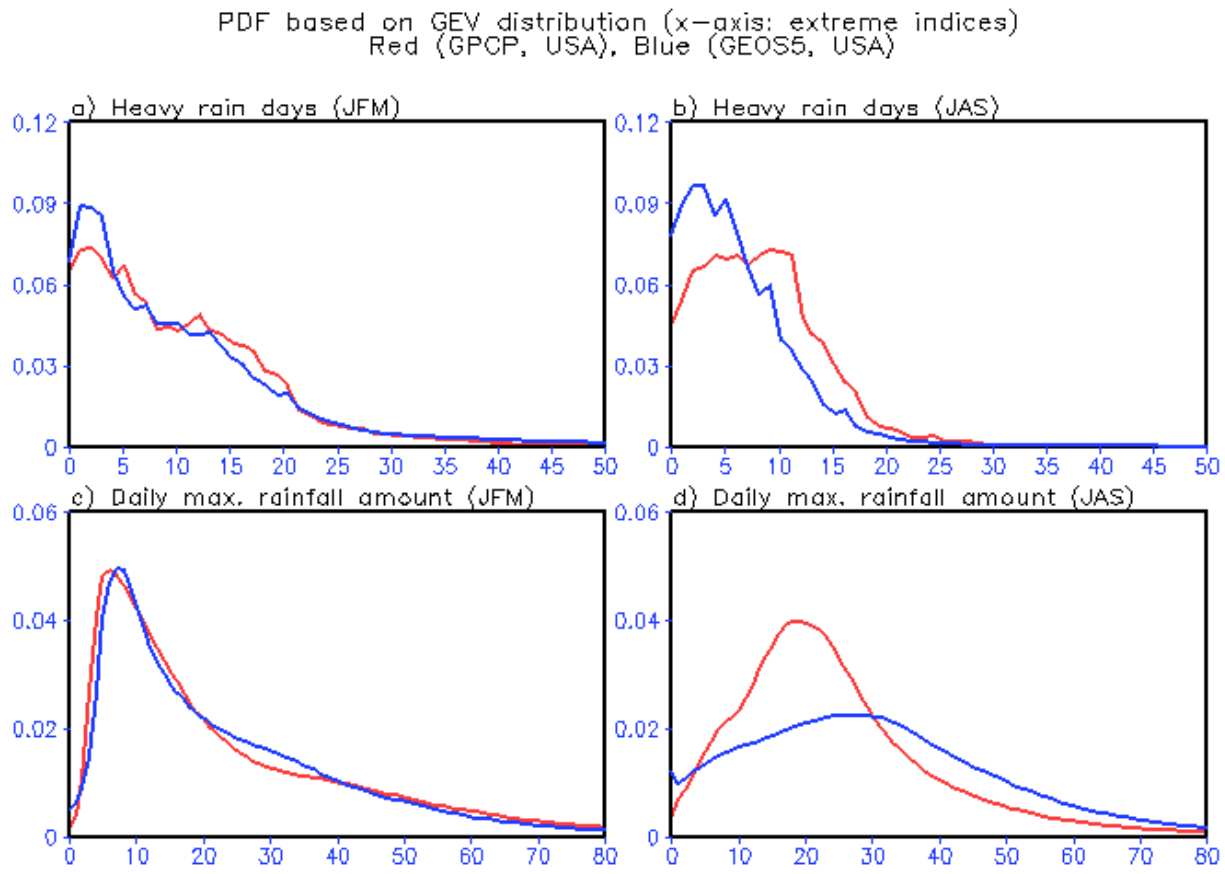
JFM **JAS**

Heavy rain days

Daily max. rain amount

Probability distribution function for Prcp extremes based on GEV : USA

Red: GPCP, Blue: GEOS5



JFM

JAS

Heavy rain days

Daily max. rain amount

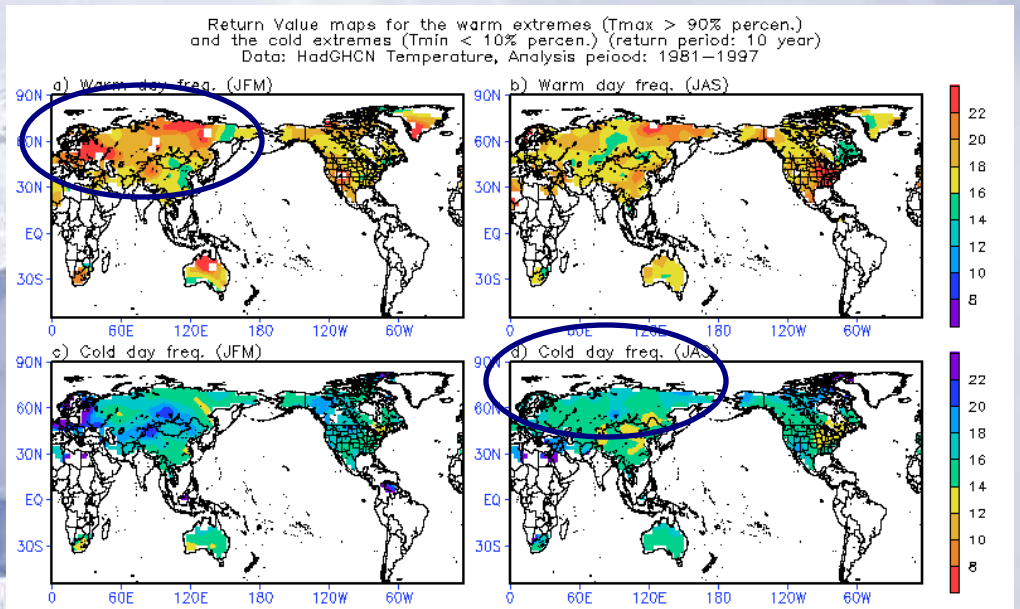
Return value based on GEVD

The *Y*-year return value is defined as the value that is expected to be equaled or exceeded once in *Y* years (*Y* is called “return period”). Here X_Y is calculated by inverting the GEVD

$$x_Y = \mu - \frac{\sigma}{\varsigma}\left\{1 - \left[-\ln\left(1 - \frac{1}{Y}\right)\right]^{-\varsigma}\right\}$$

Extremes (10-yr return values: T)

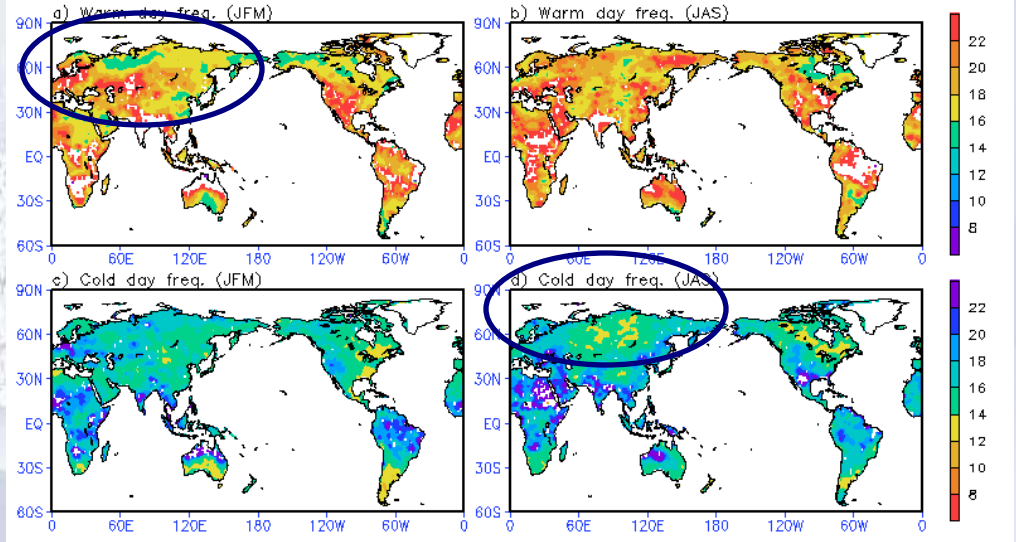
Observation (HadGHCN)



# of Warm day

# of Cold day

GEOS5 (0.5 deg.)



# of Warm day

# of Cold day

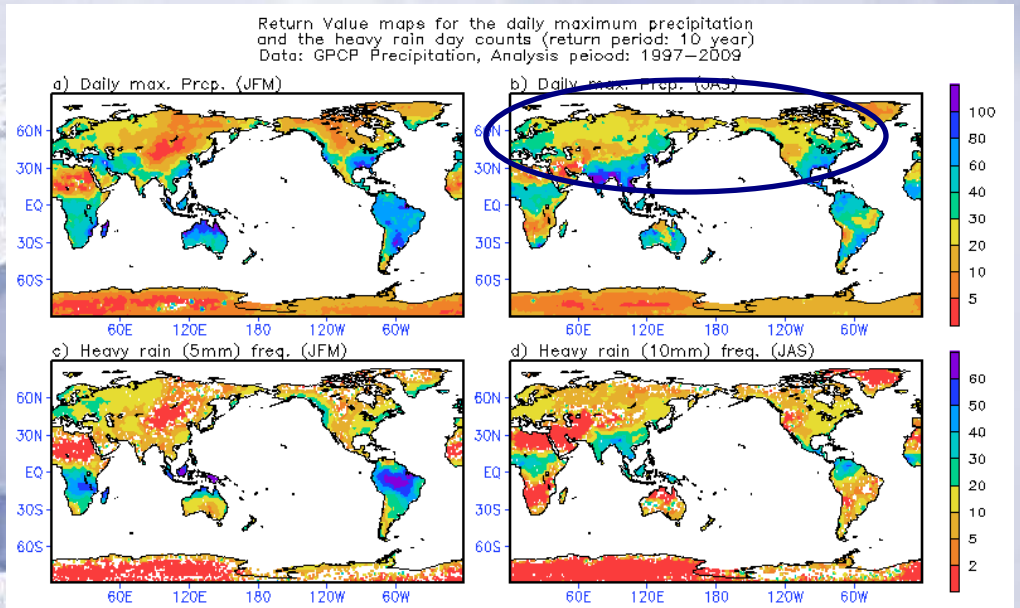
JFM

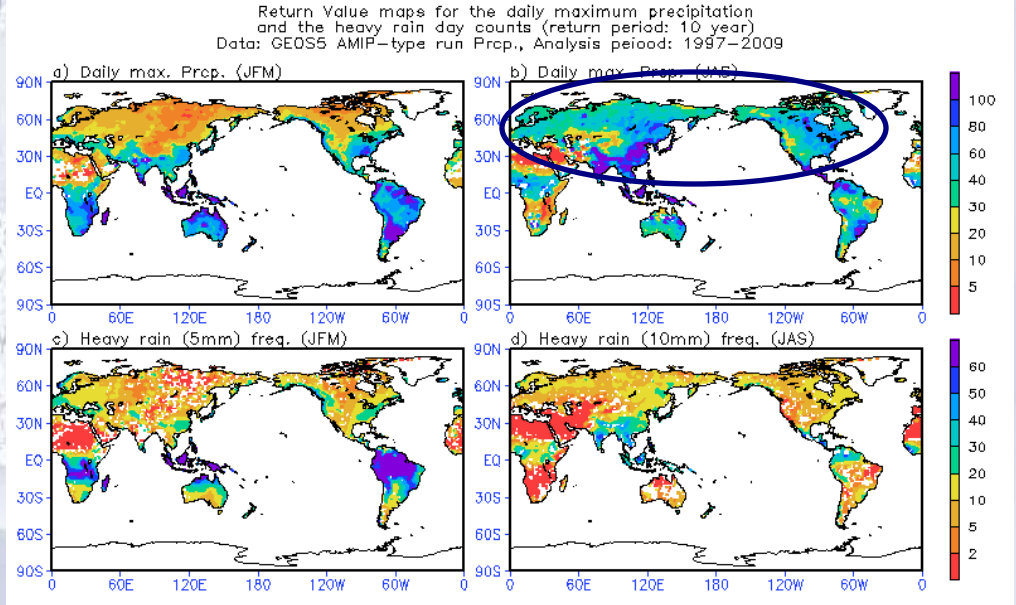
JAS

Extremes (10-yr return values: Prcp.)

Observation (GPCP)

GEOS5 (0.5 deg.)





JFM

JAS

Daily Max.

Heavy rain

Daily Max.

Heavy rain

Summary

1. High-resolution GEOS5 reasonably reproduces seasonal mean, monthly variability, the dominant independent modes, and extreme characteristics (useful tool for climate research).

2. High-resolution GEOS5 (0.5 deg. Resolution) shows the improvements in the large-scale climatological structures and energetics, compared with the coarse resolution (2 deg. Resolution) runs.

3. However, GEOS5 tends to overestimate the observed precipitation extreme characteristics specifically for daily maximum rainfall in summer (JAS)). (e.g., heavier density at the tail of the PDF and overestimated return values for this precipitation extreme)

Model configuration

	Configuration		Configuration
Grid Resol.	a half degree	**Vertical levs**	72 (sfc.~0.01mb)
Atm. forcing	MERRA	**Convection**	RAS
Ocean SST	HadSST (weekly)	**Large-scale cloud**	PDF of total water
Land (hydrology)	Koster et al. (2000) catchment	**Radiation**	Chou et al. (1999,2001)
Land model (snow)	Stieglitz et al. (2001) multi-layer	**Chemistry, Aerosol**	GOCART
Gravity wave drag	McFarlane (1987) orographic, Garcia & Boville (1994) non-orog. (stratosphere, mesosphere)	**PBL (Turbulent mixing)**	Louis et al. (1982) stable, Lock et al. (2000) unstable, Non-local