Intercomparison of observed and simulated climatic trends in the North American monsoon

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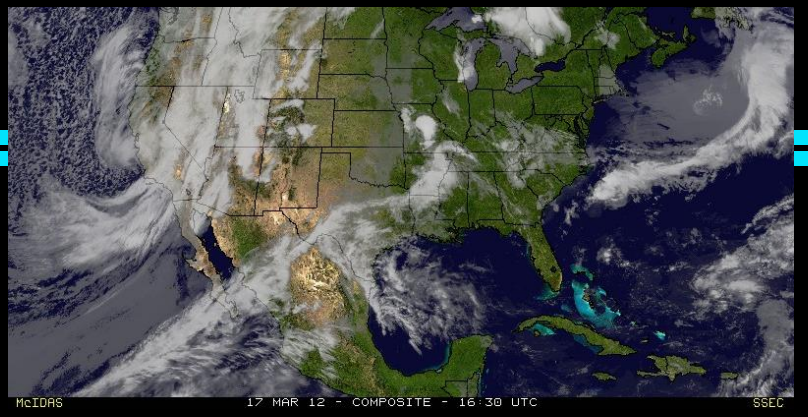
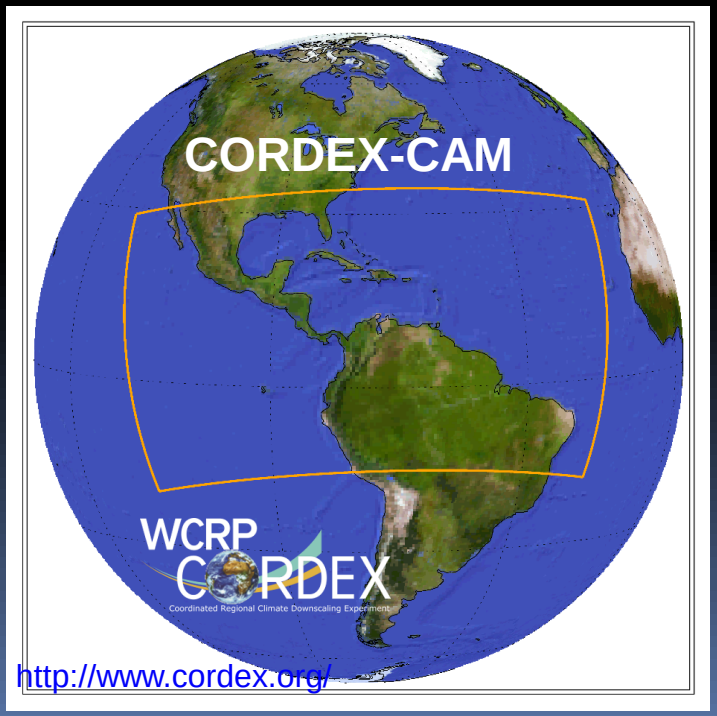
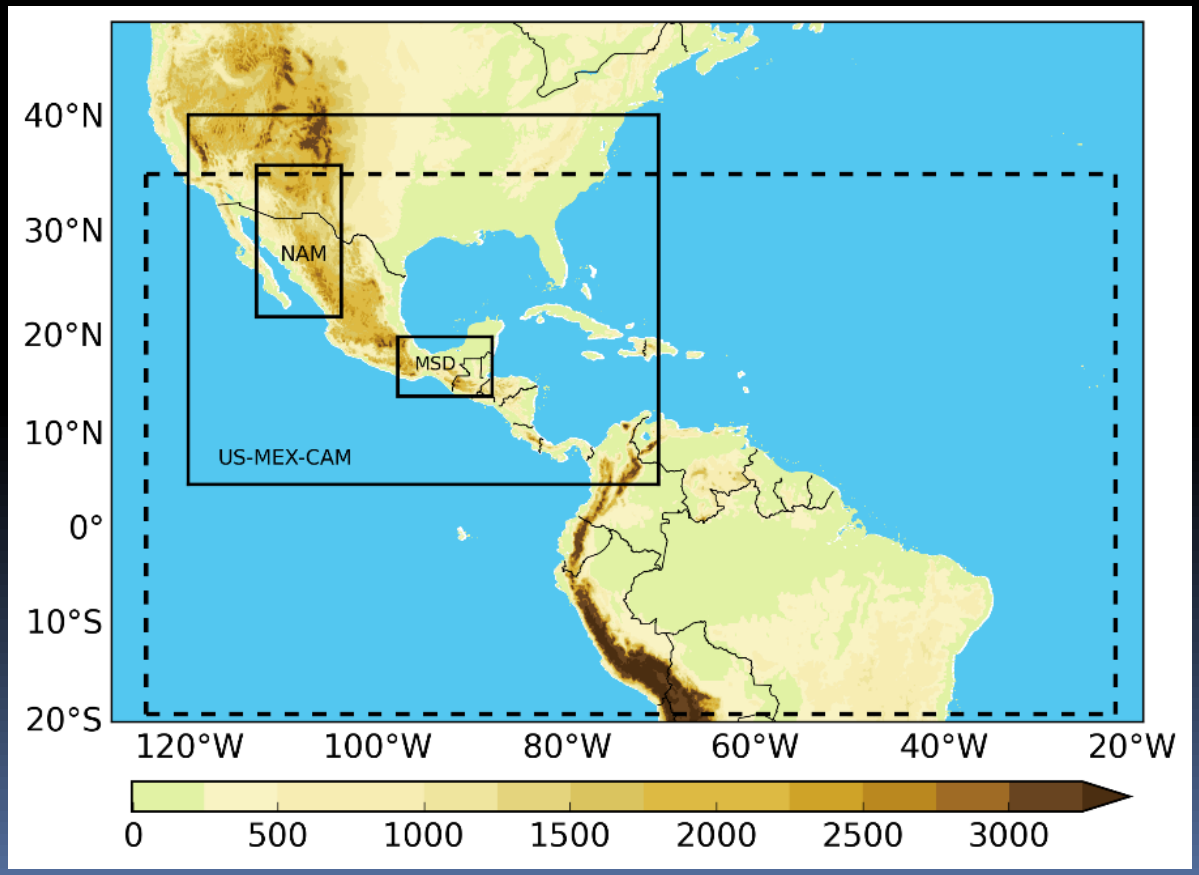


1. Introduction
2. Data and methodology
3. Evaluation of RCMs
4. Climatic trends
5. Interannual/decadal variability
6. Conclusions
7. Ongoing research



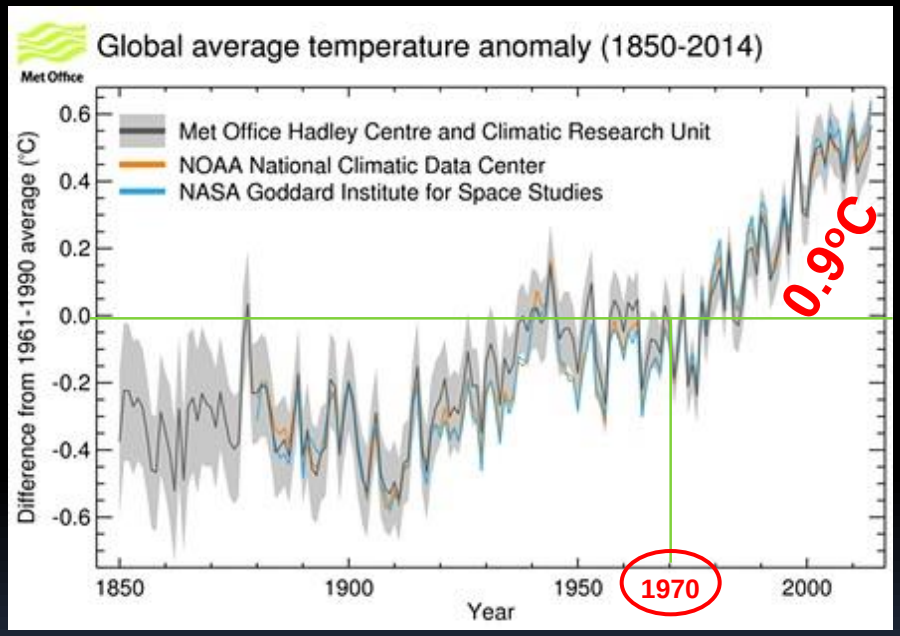
Objective

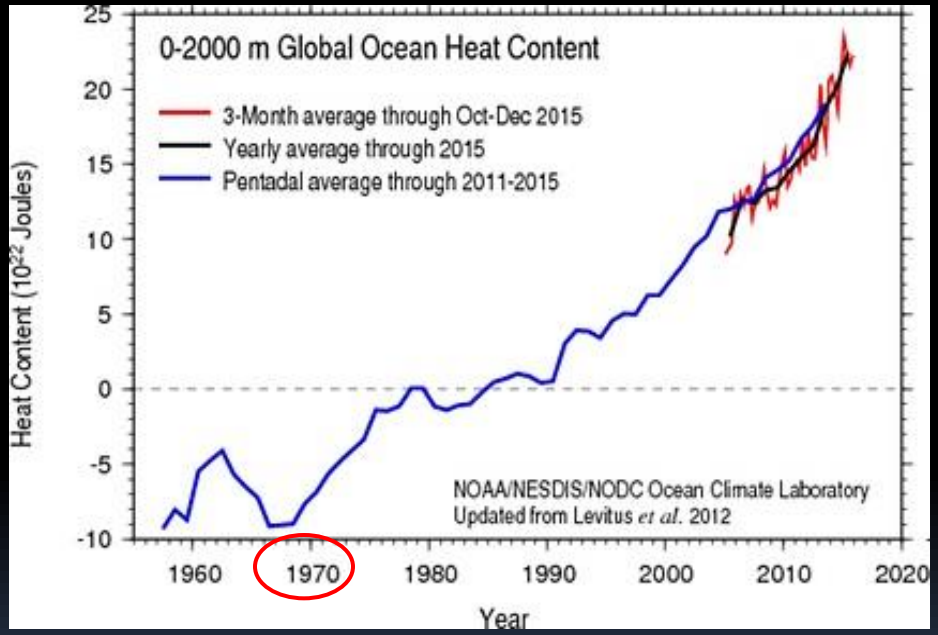
Investigate Temp y Precip trends in the CORDEX-CAM domain through a regional model intercomparison (1980-2010)



1. Introduction

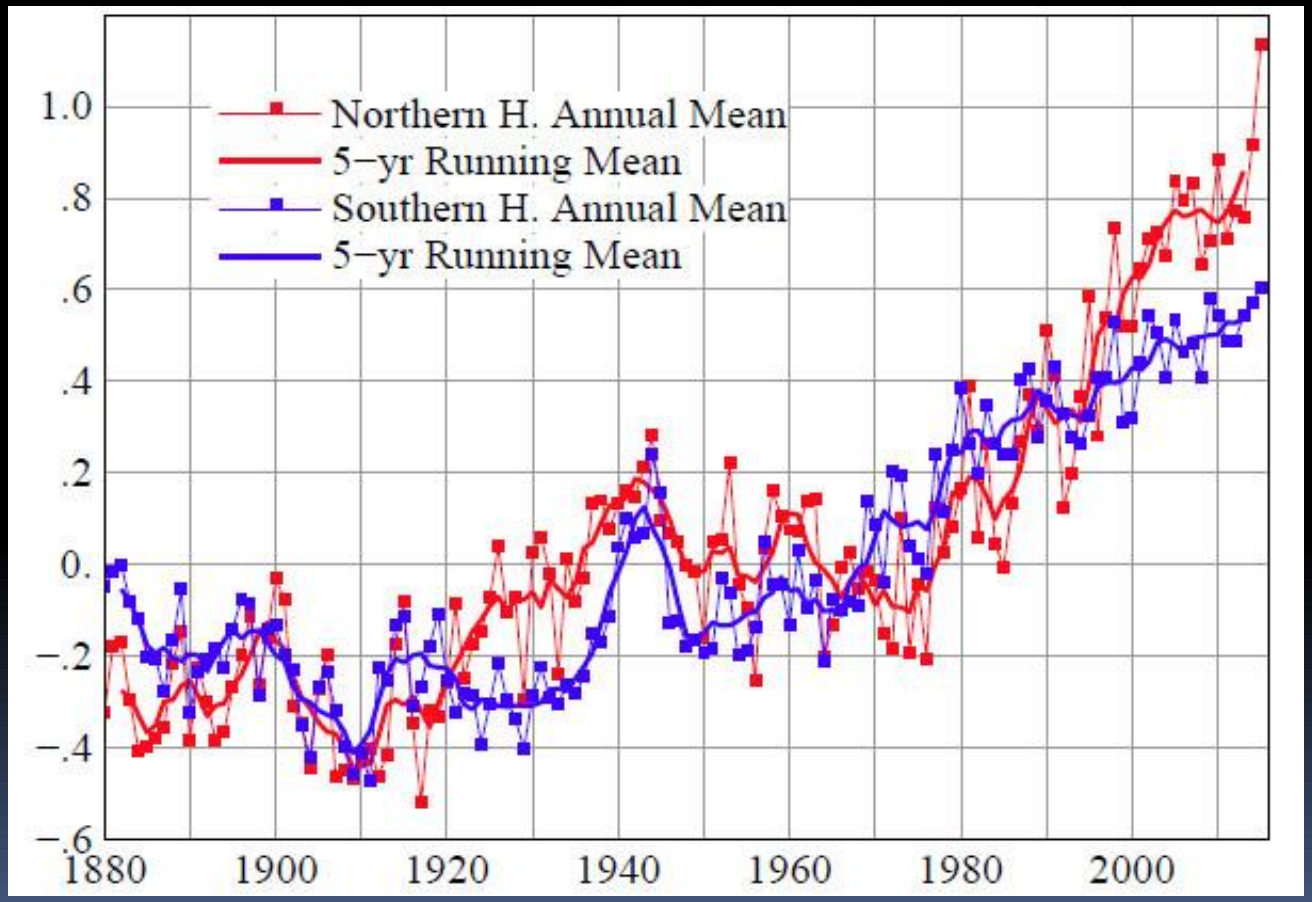
OBS: Global Air Temperature Anomaly and Global Ocean Heat Content





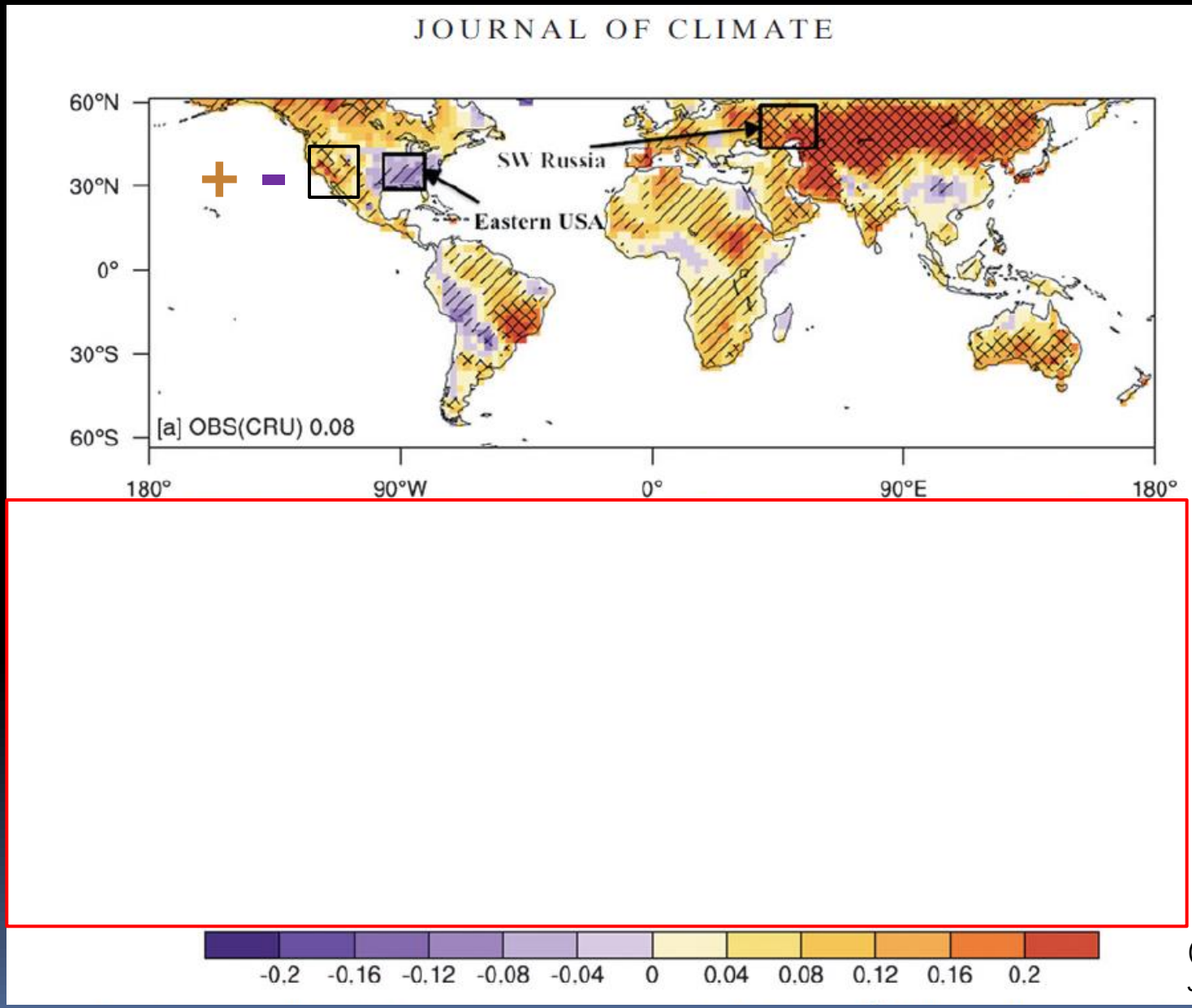
Ta global = 15°C

Observations:
NH and SH Temperature Change (°C)



NASA GISS site

Temperature Trends (°C/decade) 1930-2004



OBS: CRU

CMIP5 Ens: 19 GCMs with 79 members

(Kumar *et al.,* 2013b, *J. Clim*, **26**, 4168-4185)

Positive Temp trend in the more recent period

JJA

DJF

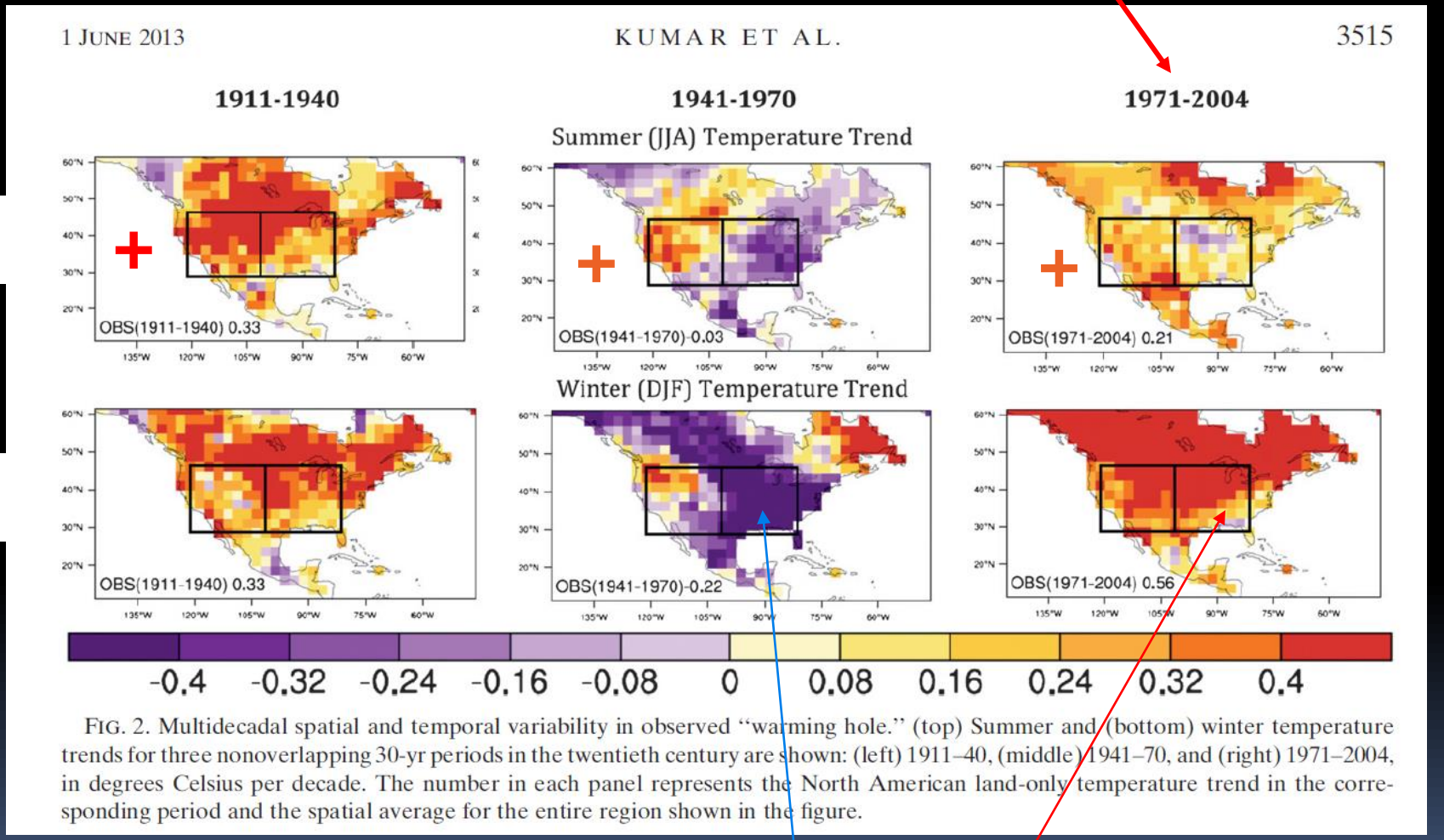


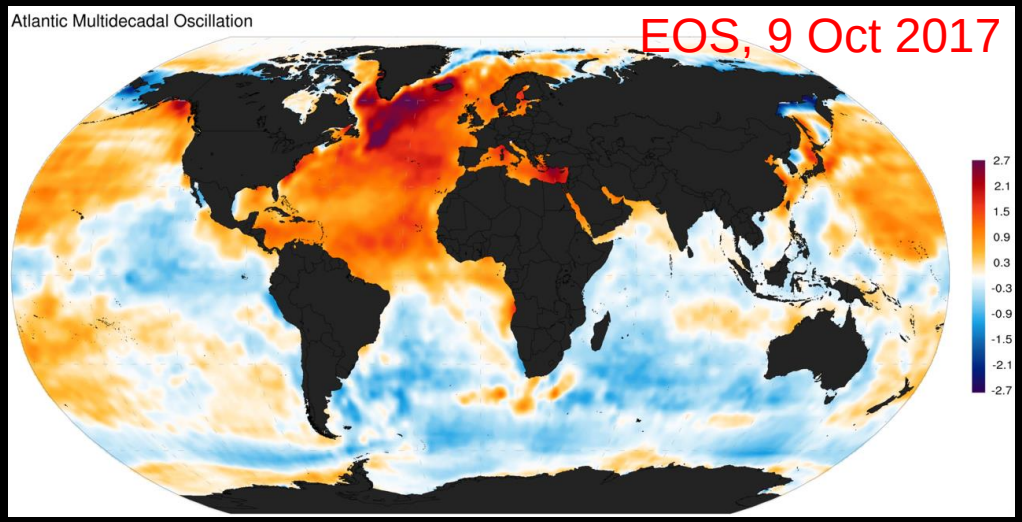
FIG. 2. Multidecadal spatial and temporal variability in observed "warming hole." (top) Summer and (bottom) winter temperature trends for three nonoverlapping 30-yr periods in the twentieth century are shown: (left) 1911–40, (middle) 1941–70, and (right) 1971–2004, in degrees Celsius per decade. The number in each panel represents the North American land-only temperature trend in the corresponding period and the spatial average for the entire region shown in the figure.

- AMO

+AMO

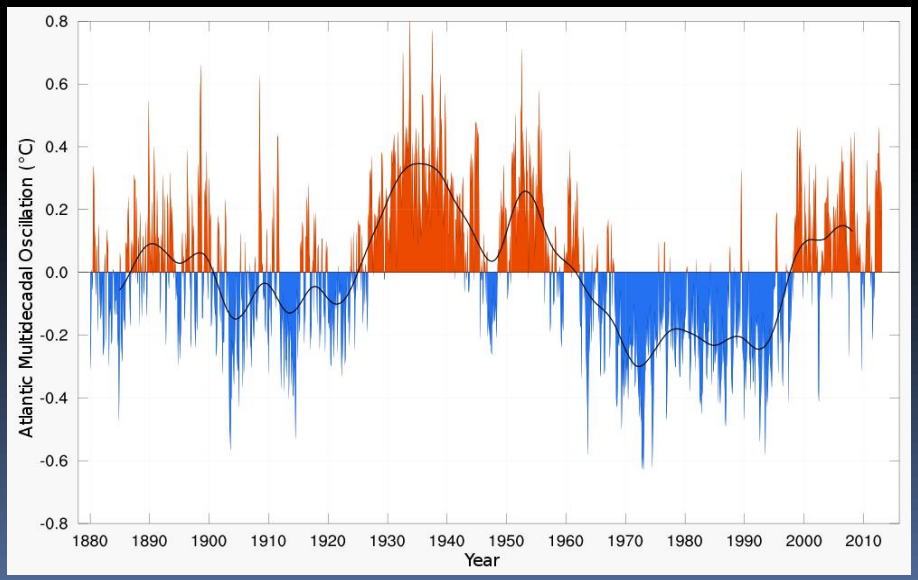
(Kumar *et al.*, 2013a, *J. Clim.*, **26**, 4168-4185)

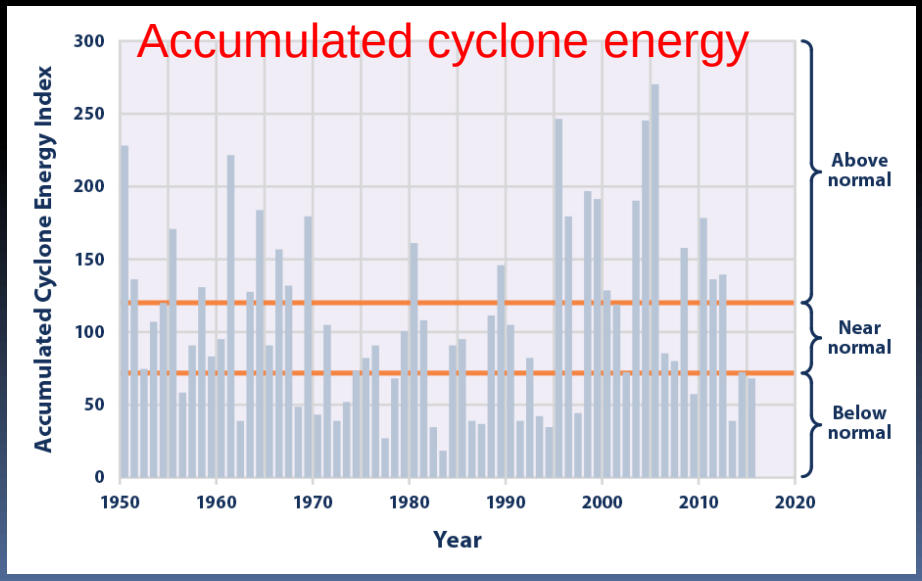
Atlantic Multidecadal Oscillation (AMO)



← **+ AMO**

1) Atl TCs more intense
2) Weakening of NASH
3) More droughts in the SW-US, NW Mexico





Precipitation Trends (mm/decade) 1930-2004

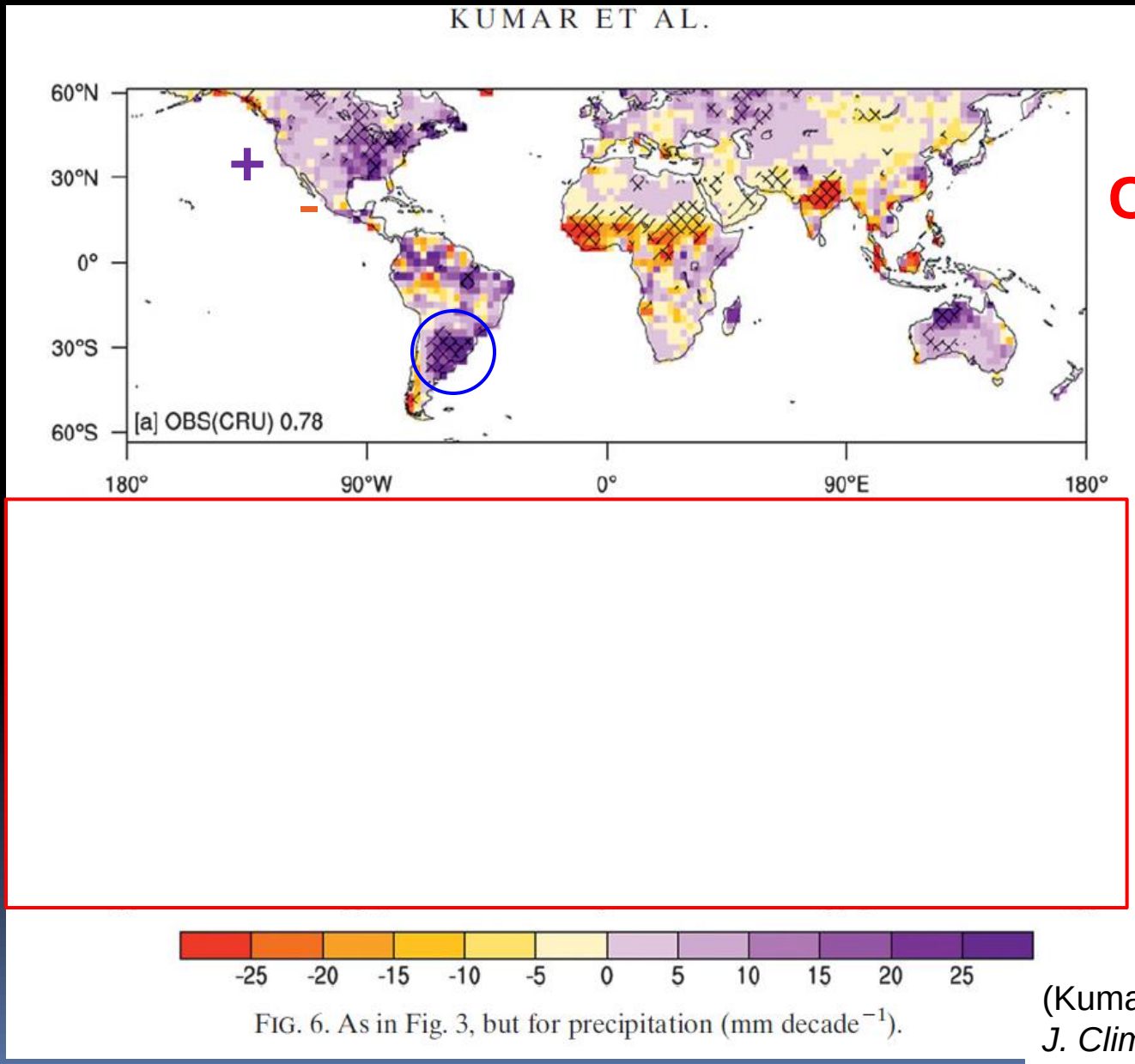


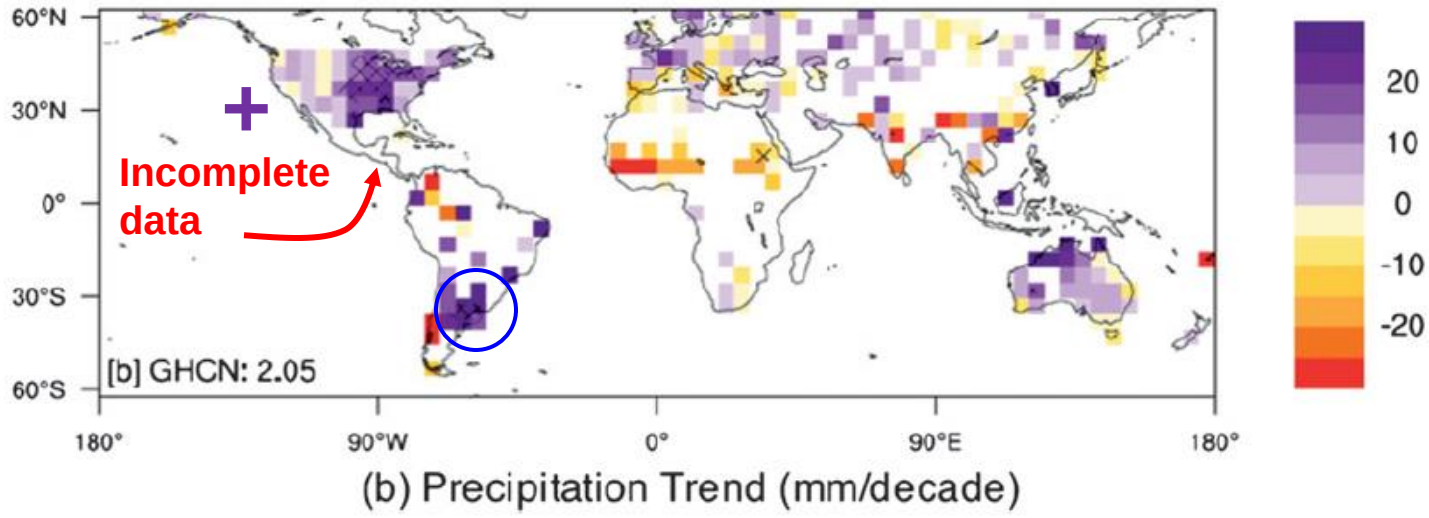
FIG. 6. As in Fig. 3, but for precipitation (mm decade^{-1}).

CRU

CMIP5 ensemble

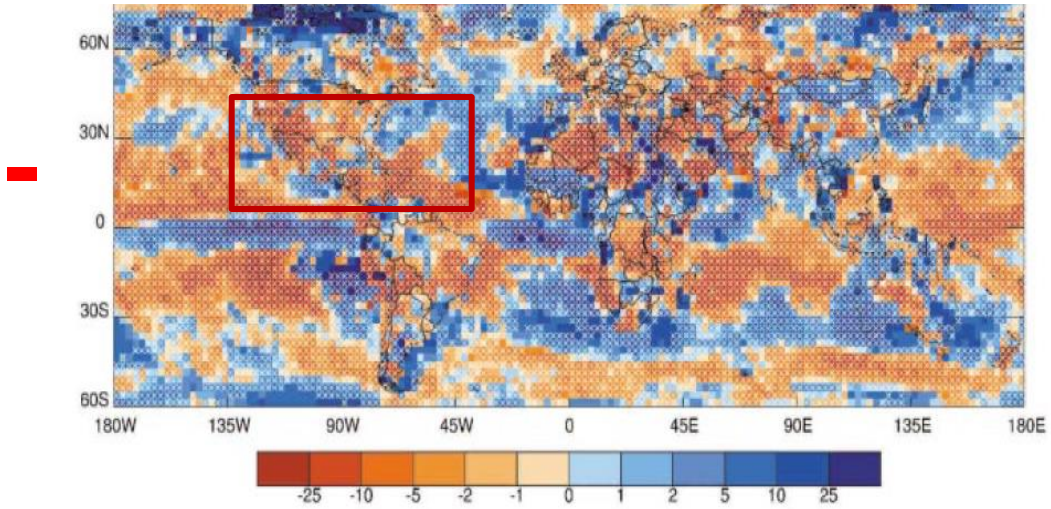
(Kumar *et al.* 2013b, *J. Clim.*, **26**, 4168-4185)

GHCN: Precipitation Trends (mm/decade) 1930-2004



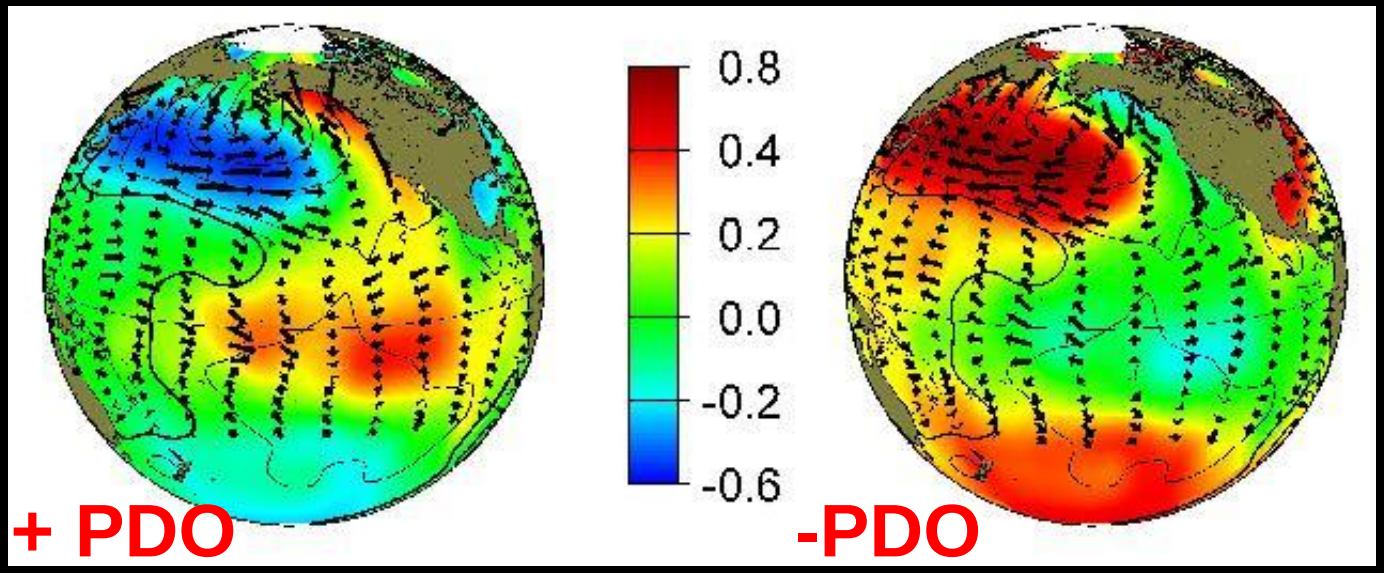
(Kumar et al. 2013b, *J. Clim*, 26, 4168-4185; consistent with New *et al*., 2001, IJOC)

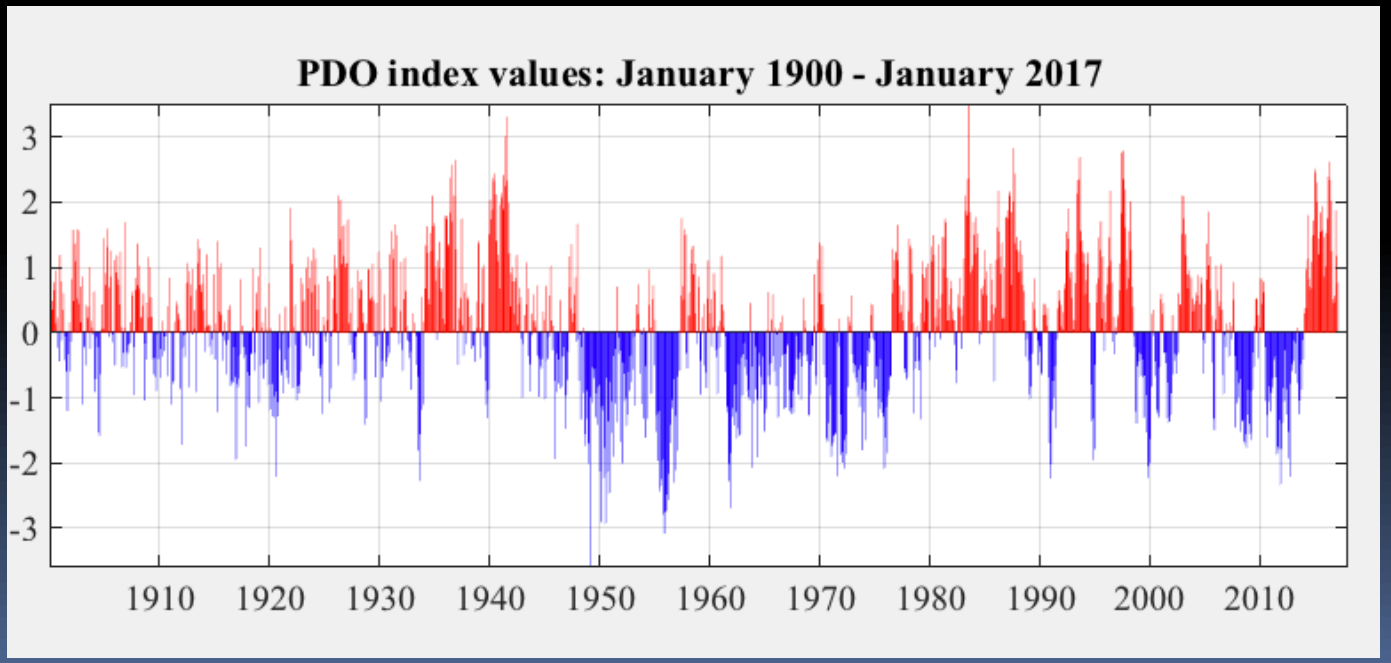
CMAP Precip trends (%/decade) 1979-1999



Negative trend in the subtropics/ tropics (New *et al*., 2001)

PDO: SST anomalies (°C)

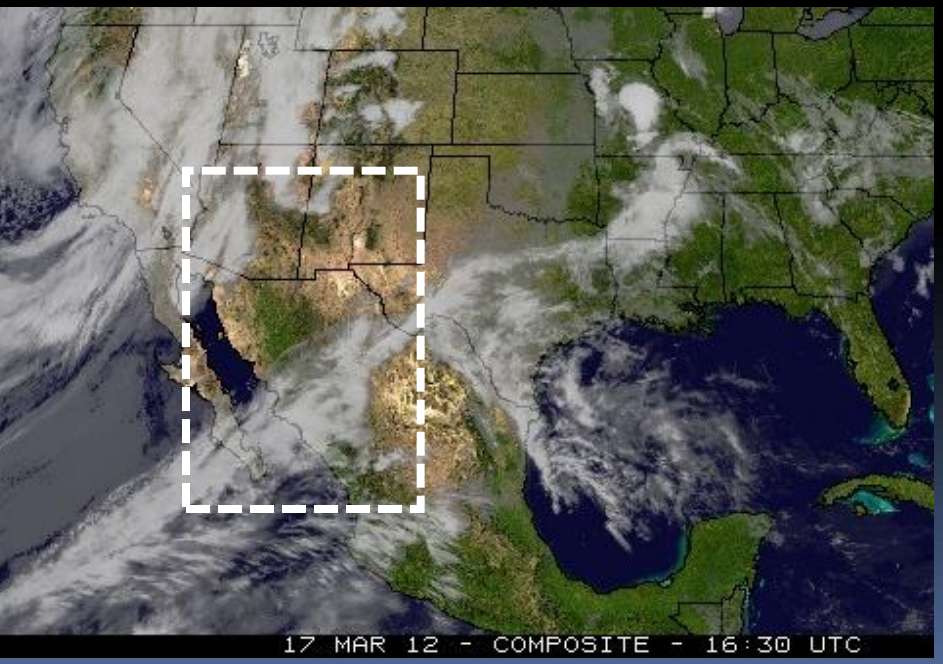


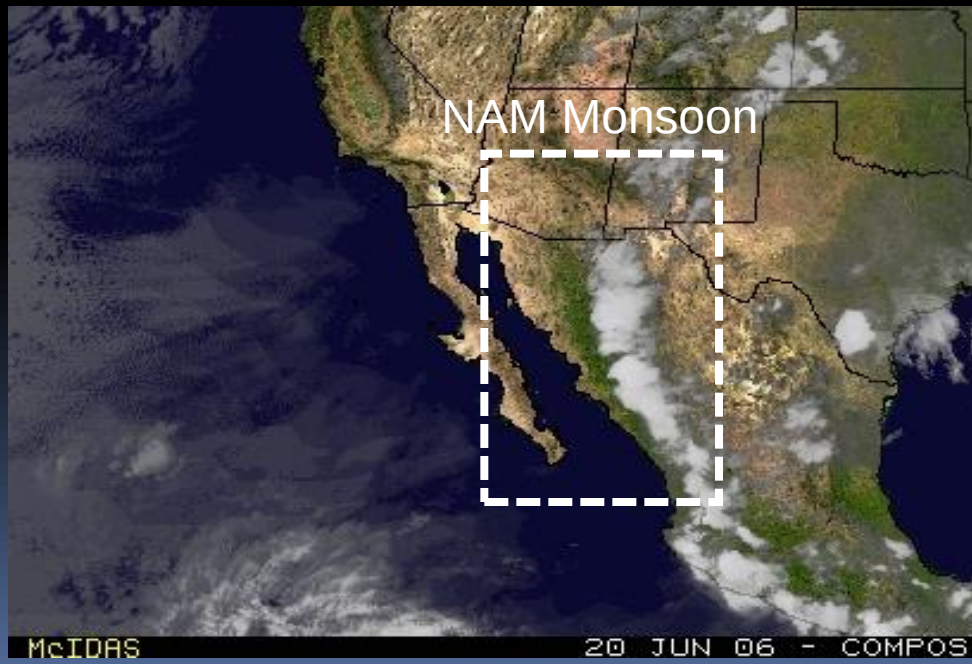


http://research.jisao.washington.edu/pdo/

Research questions

1. Does the North American monsoon region show significant Temp and Precip trends?
2. What is the ability of 3 RCMs to reproduce these trends?
3. Are the significant trends related to natural variations (ENSO, PDO, AMO)?





2. Data and Methodology

Observations	Metrics	Indices
CRU (Temp, Precip)	Dispersion	ENSO
GPCP (Precip)	Spatial bias	PDO
CHIRPS (Precip)	Annual cycles	AMO
	Trends	

Linear trends ($p<0.05$).

Regional trends with Mann-Kendall trend test and Sen's slope

Models setup

ICBC: ERAIN 75 Reanalysis

Simulation: 1979-2010

Spin up: 1979

Analysis: 1980-2010

Resolution: 50 km

Core: Hydrostatic

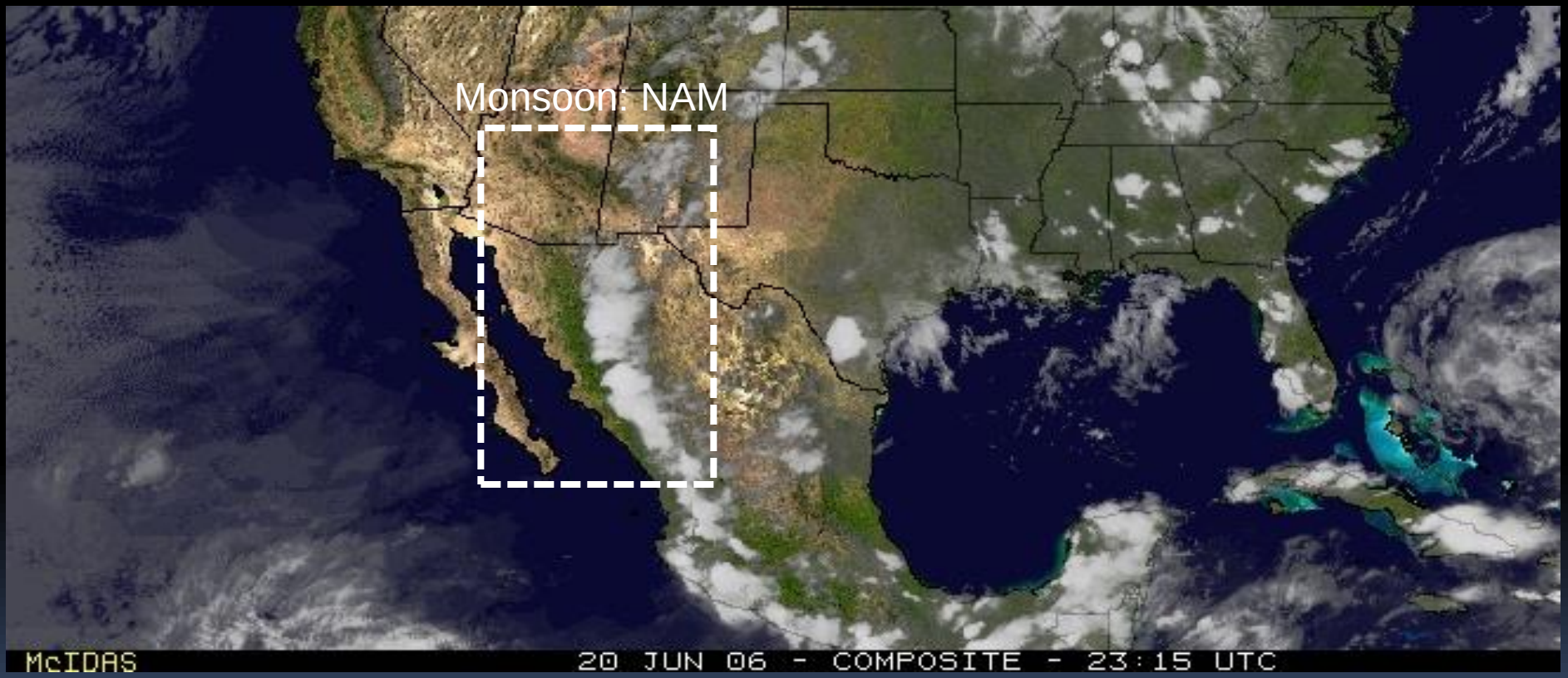
Regional Models
PRECIS
RCA4
RegCM4.0-Grell
RegCM4.5-Tiedtke

RegCM4 Emanuel ➔ ocean

Physical parameterizations

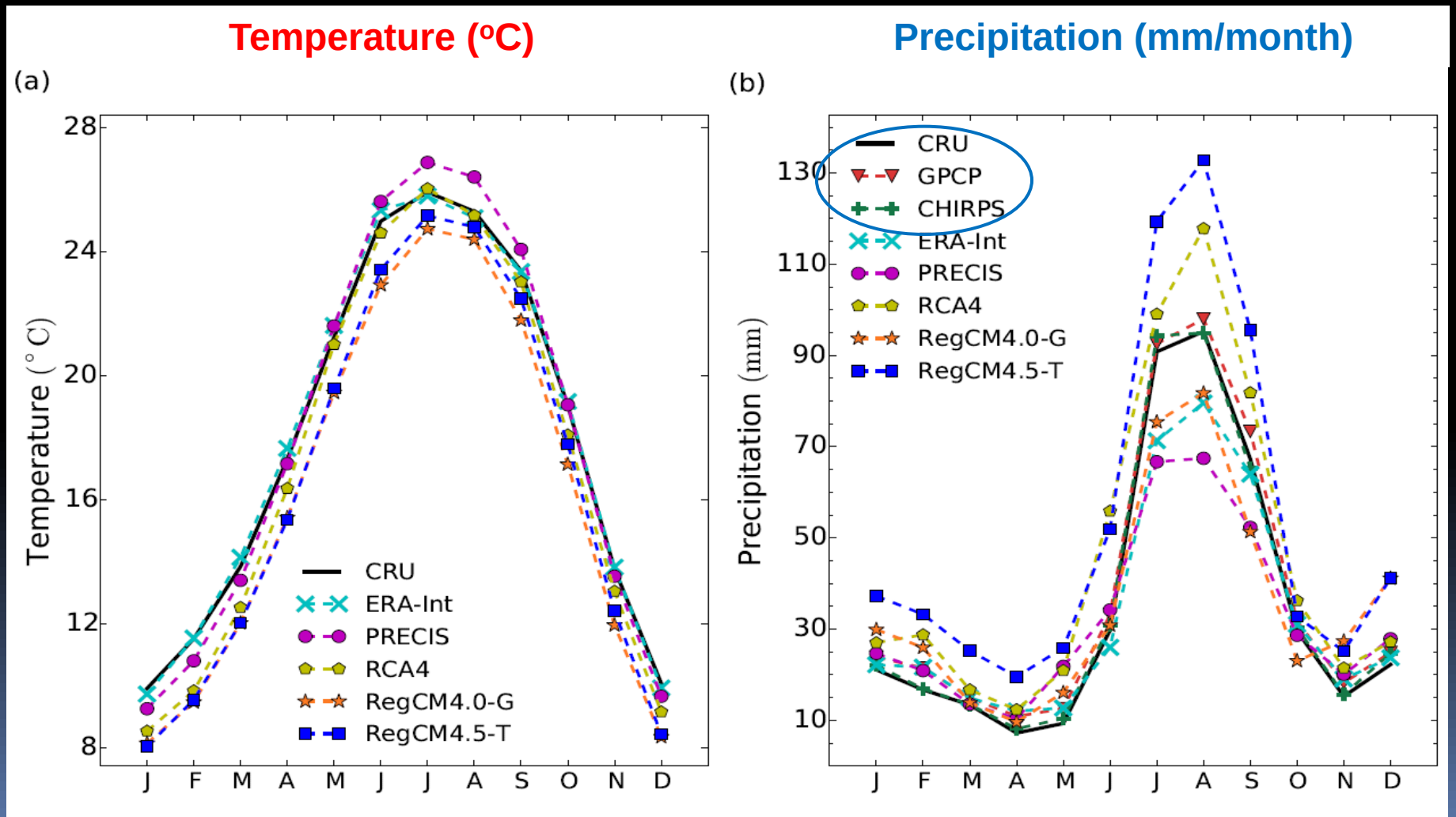
Physical Options	PRECIS (HadRM3P)	RCA4	RegCM4.0-G (Grell)	RegCM4.5-T (Tiedtke)
Convection-c (continent)	Gregory and Rowntree (1990)	Kain and Fritsch (1990, 1993), Kain (2004)	Grell (1993)	Tiedtke (1989, 1996)
Convection-o (ocean)	Gregory and Rowntree (1990)	Kain and Fritsch (1990, 1993), Kain (2004)	Emanuel (1991)	Emanuel (1991)
Microphysics or moisture scheme	Smith (1990)	Rasch and Kristjánsson (1998)	**SUBEX** (Pal *et al.* , 2000)	**SUBEX** (Pal *et al.* , 2000)
Land-surface	**MOSES2** (Essery *et al.* , 2003)	Samuelsson *et al.*, (2006)	**BATS** (Dickinson *et al.*, 1993)	**BATS** (Dickinson *et al.*, 1993)
Radiation	Edwards and Slingo (1996)	Savijarvi (1990), Sass *et al.*, (1994)	**CCM3** (Kiehl, 1996)	**CCM3** (Kiehl, 1996)
Planetary Boundary Layer (PBL)			**Holtslag** (Holtslag, 1990)	**Holtslag** (Holtslag, 1990)

3. Evaluation of RCMs



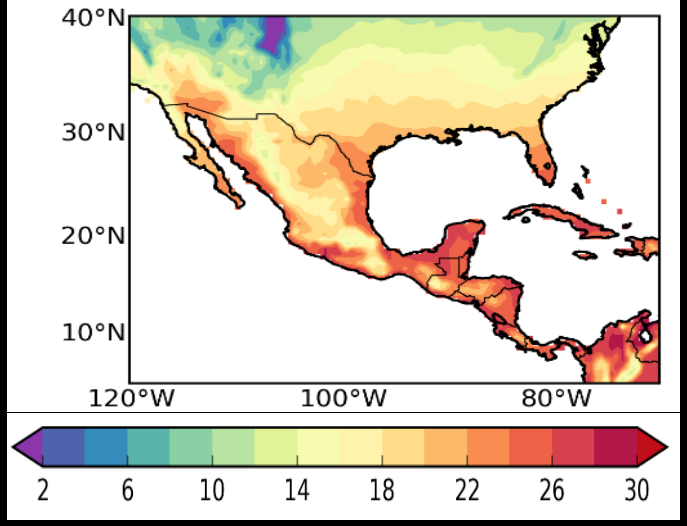
3. Metrics of evaluation (1980-2010)

NAM Region

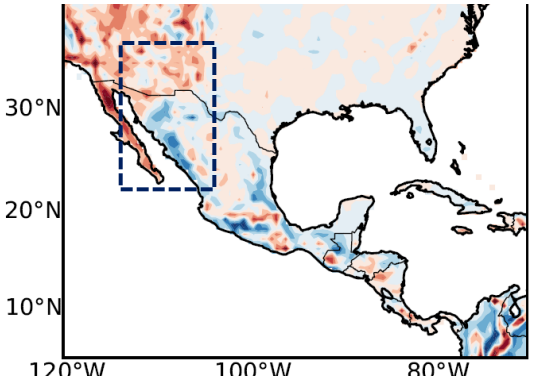


Temperature bias (ºC) with respect to CRU (1980-2010)

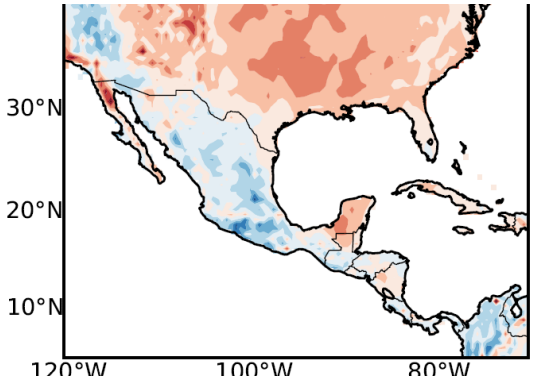
CRU Mean Annual Temperature (ºC)



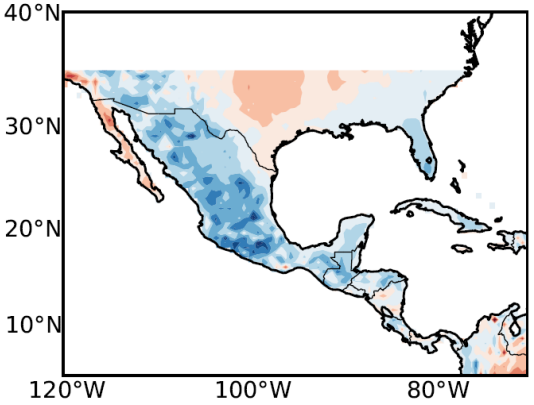
ERAIN



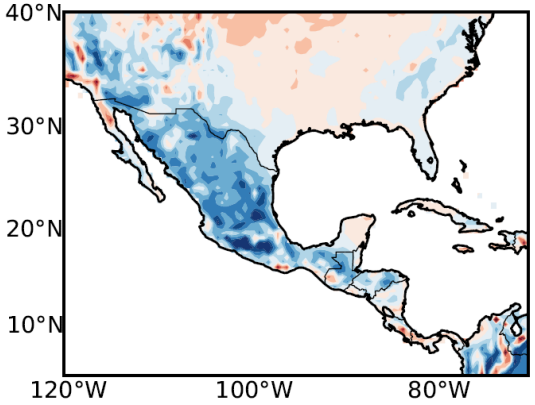
PRECIS



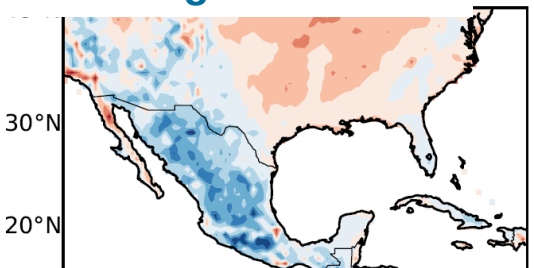
RCA4

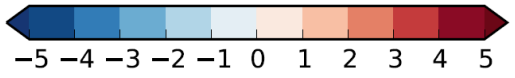


RegCM4-G



RegCM4.5-T

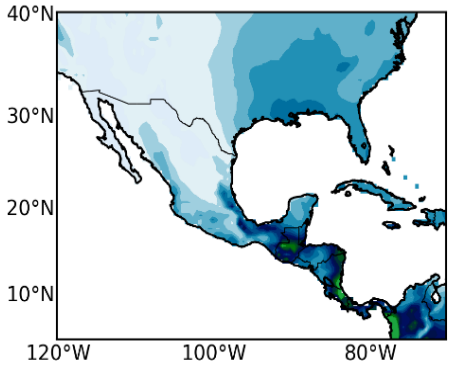




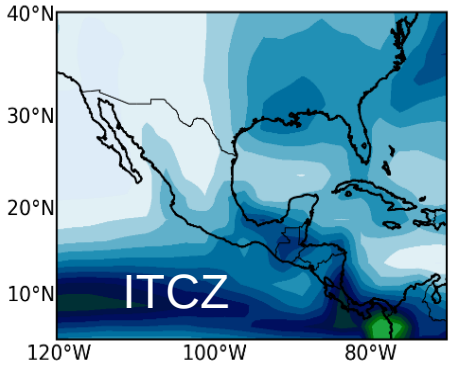
Annual precipitation bias with respect to GPCP (1980-2010)

Mean Annual Precipitation

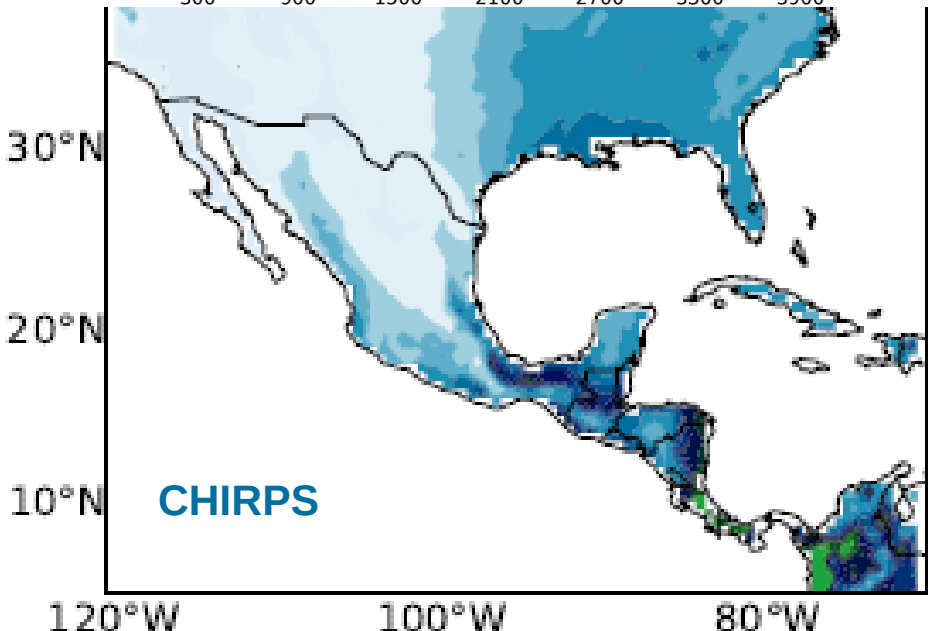
CRU



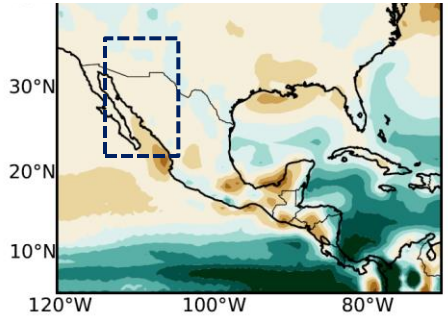
GPCP



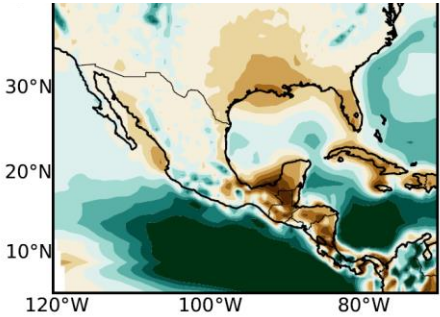
(mm)



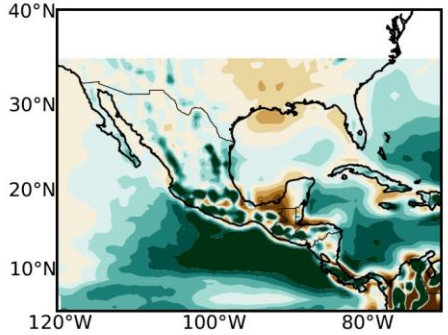
ERA-Int



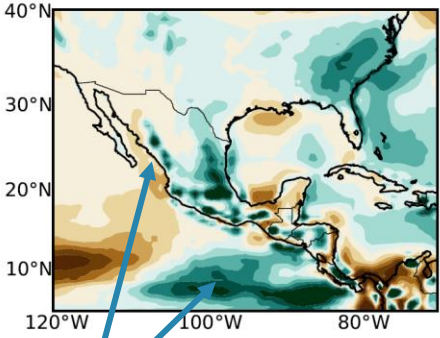
PRECIS



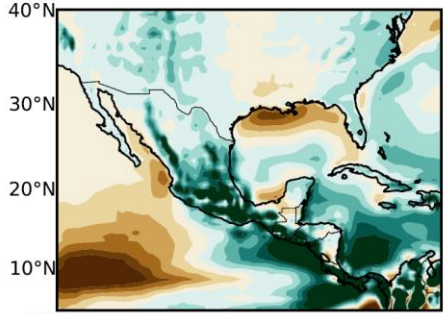
RCA4



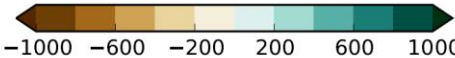
RegCM4.0-G



RegCM4.5-T



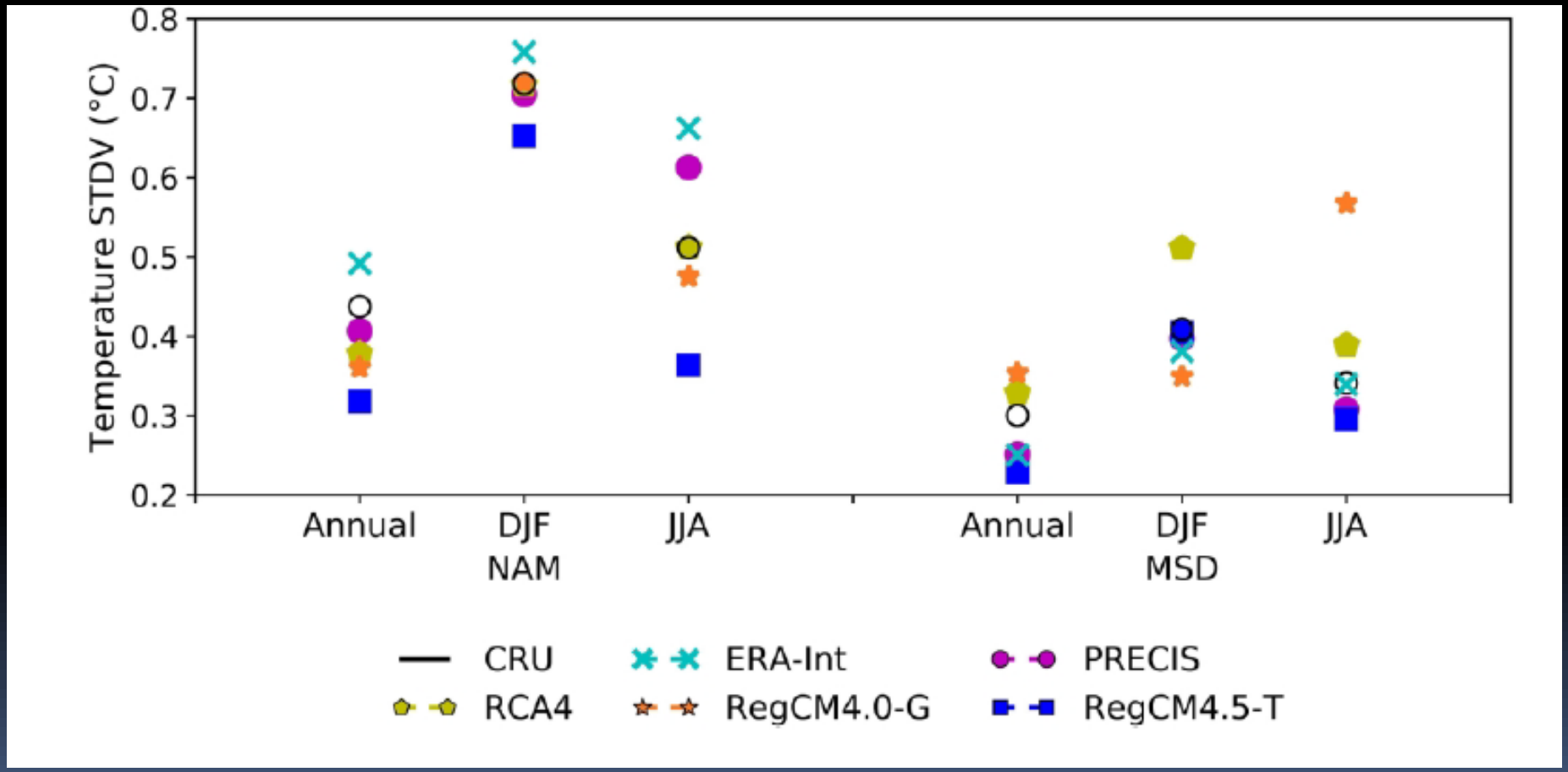
Wet bias: >3 mm/d



(mm/yr)

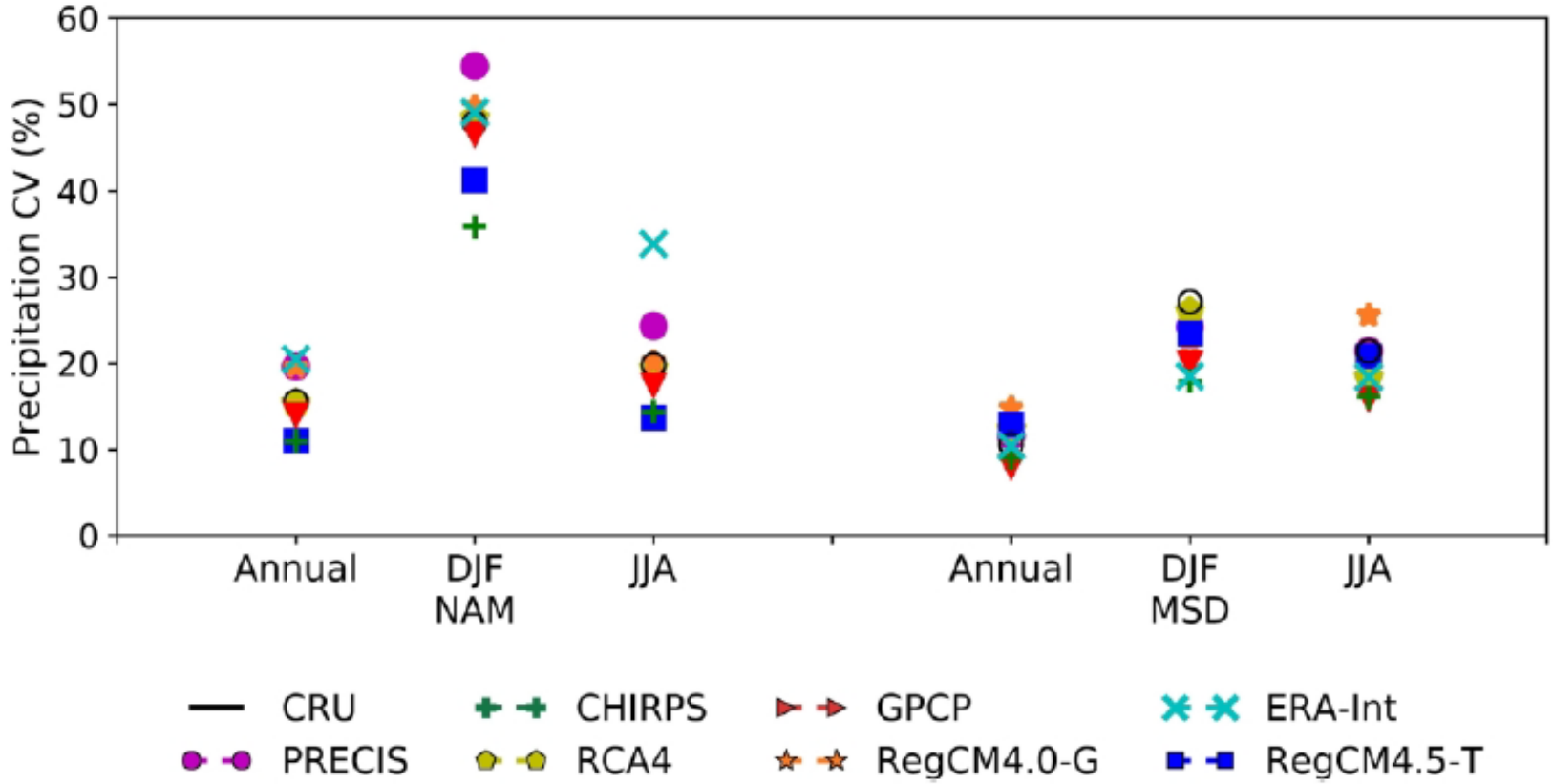
Variability of temperature (ºC) 1980-2010

NAM: Tropic/Subtropics MSD: Tropics

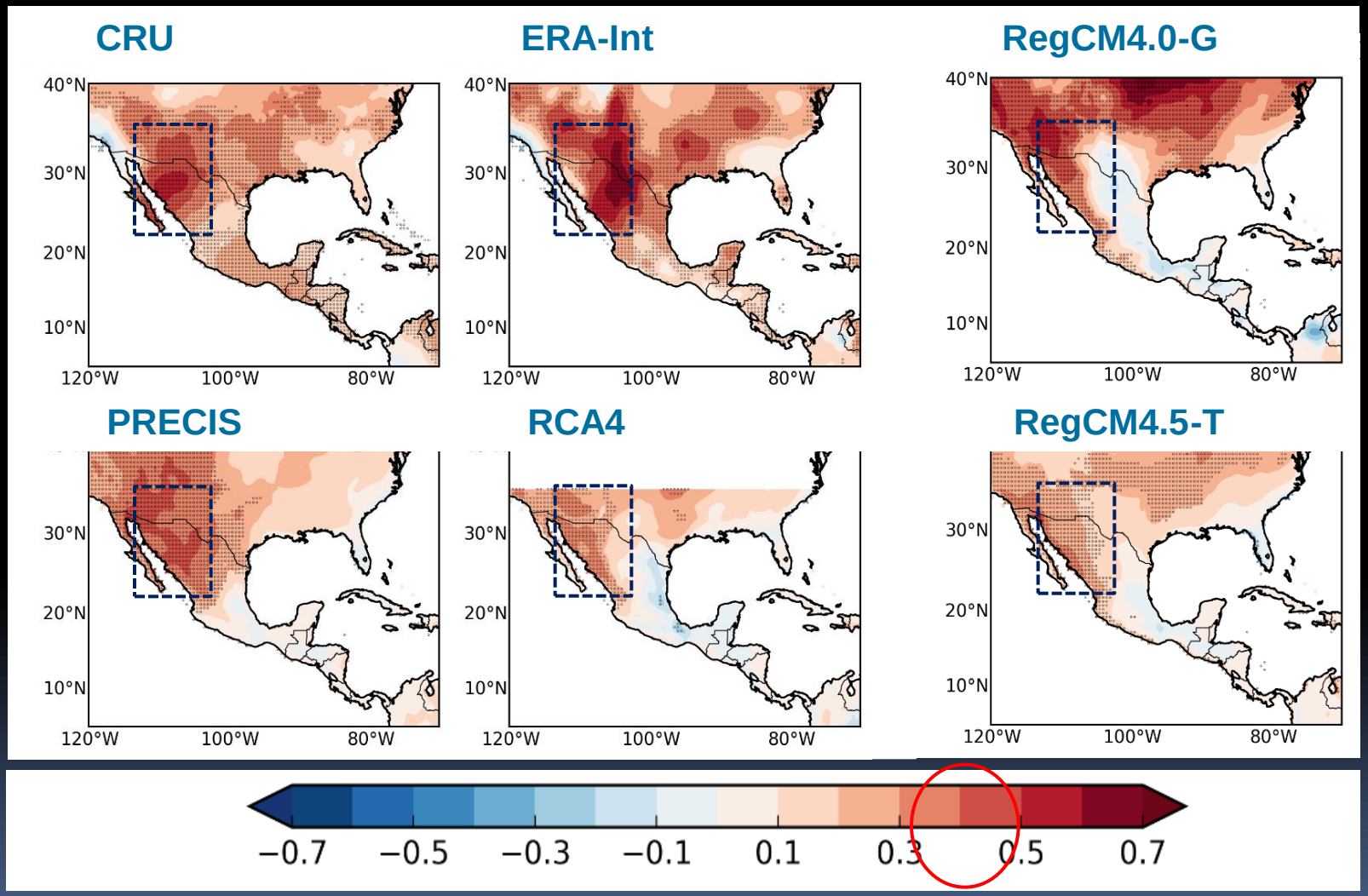


Variability of precipitation (%) 1980-2010

NAM: Tropic/Subtropics MSD: Tropics

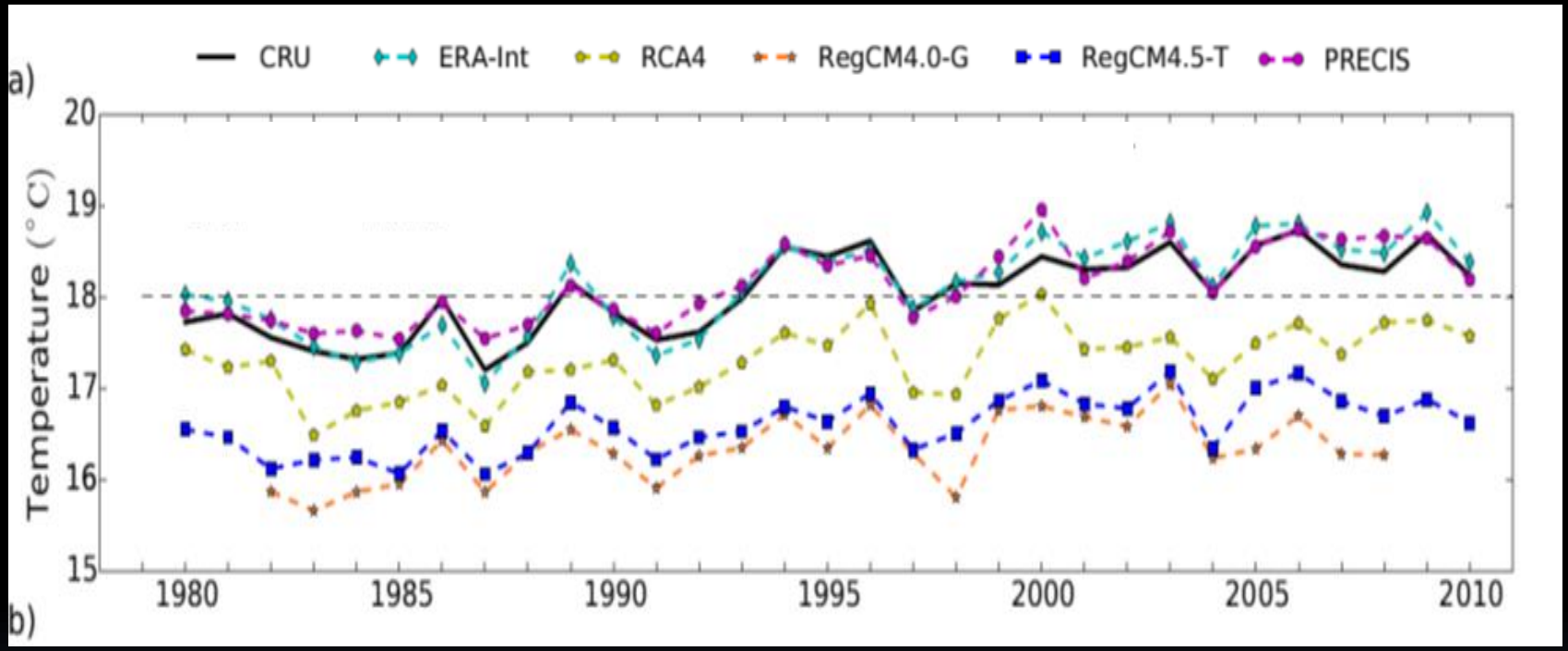


4. Decadal trends of temperature (ºC/decade) 1980-2010



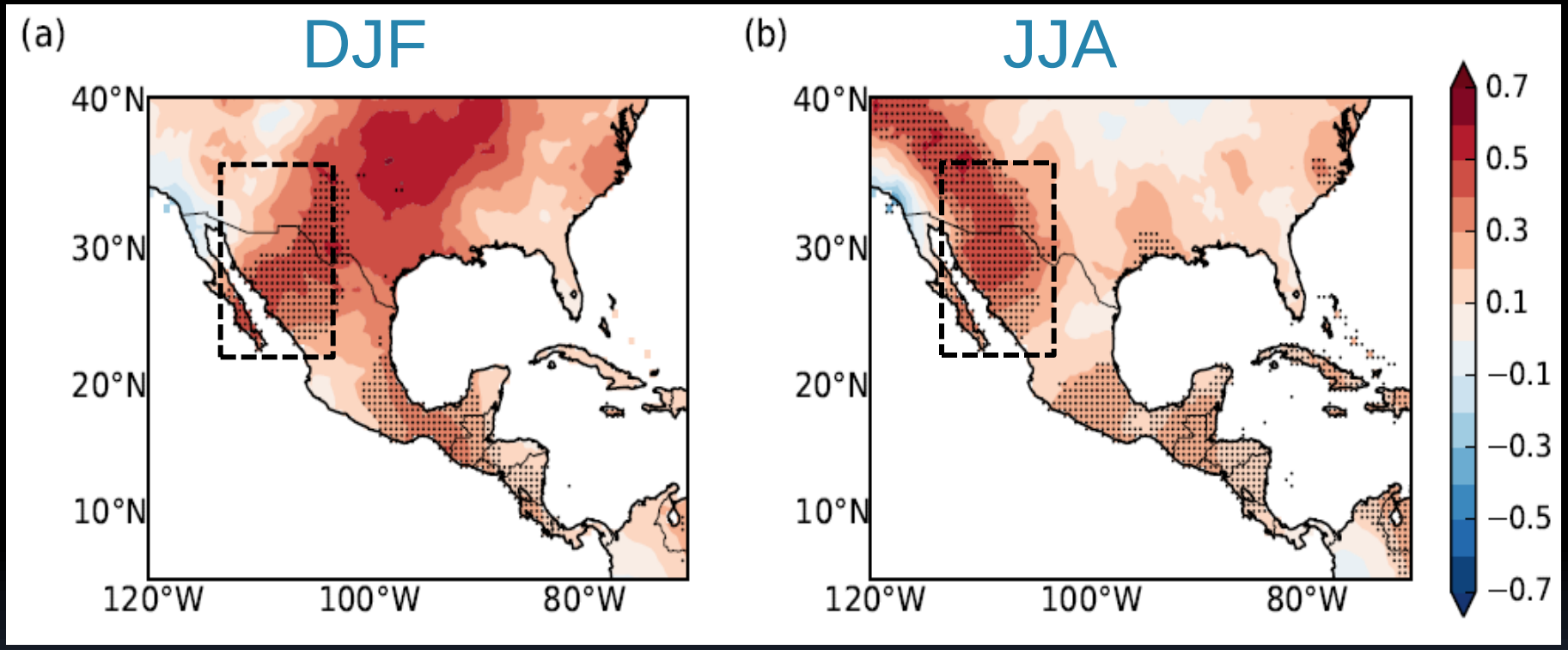
Dots: Stat significance at 95%

Mean annual temperature (ºC) in the NAM region (1980-2010)

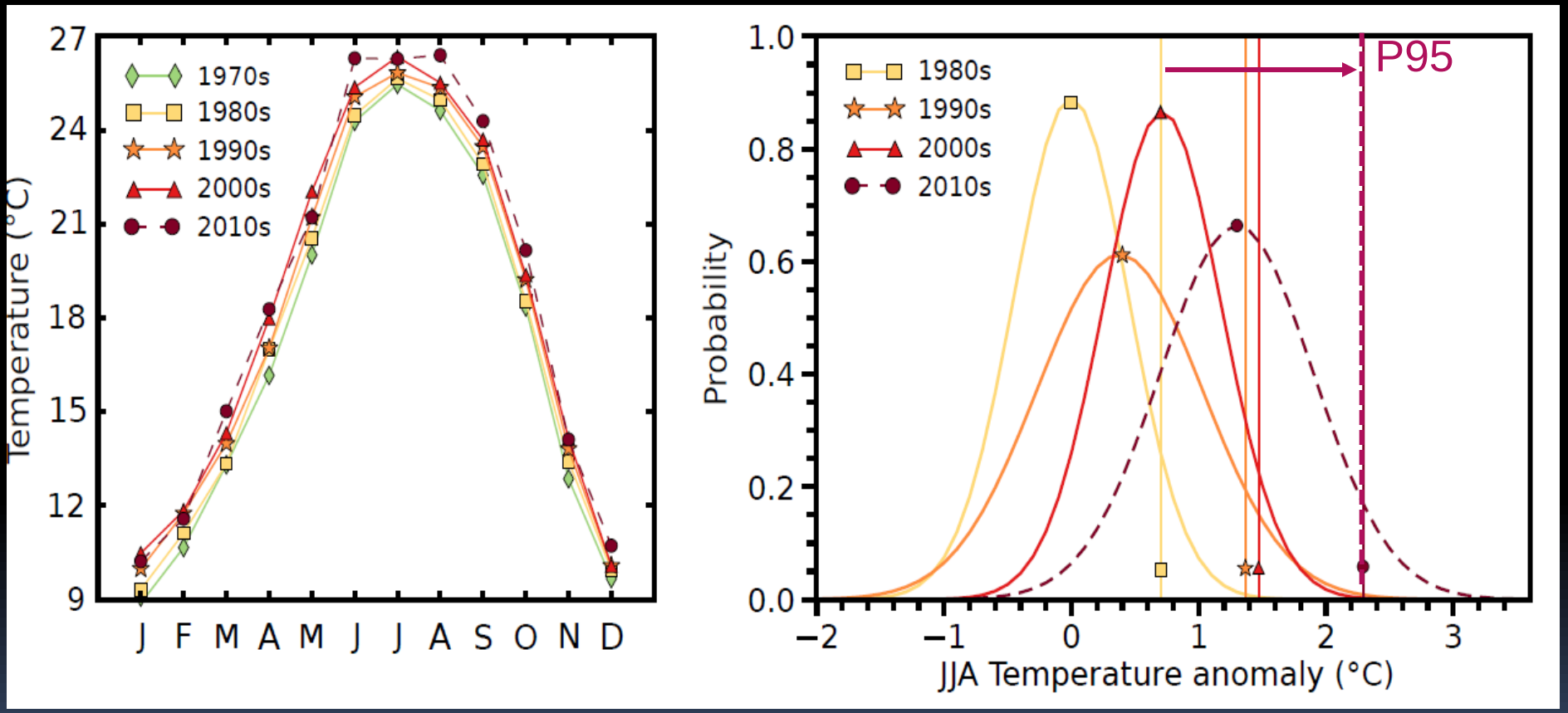


NAM Observed Temperature Trend:
0.4ºC/decade significant at the 95% level

Trends of CRU seasonal temperature (ºC/decade) 1980-2010



CRU decadal trends of seasonal temperature (ºC/decade) 1980-2010



Temperature projections based on multi-model weighted ensembles

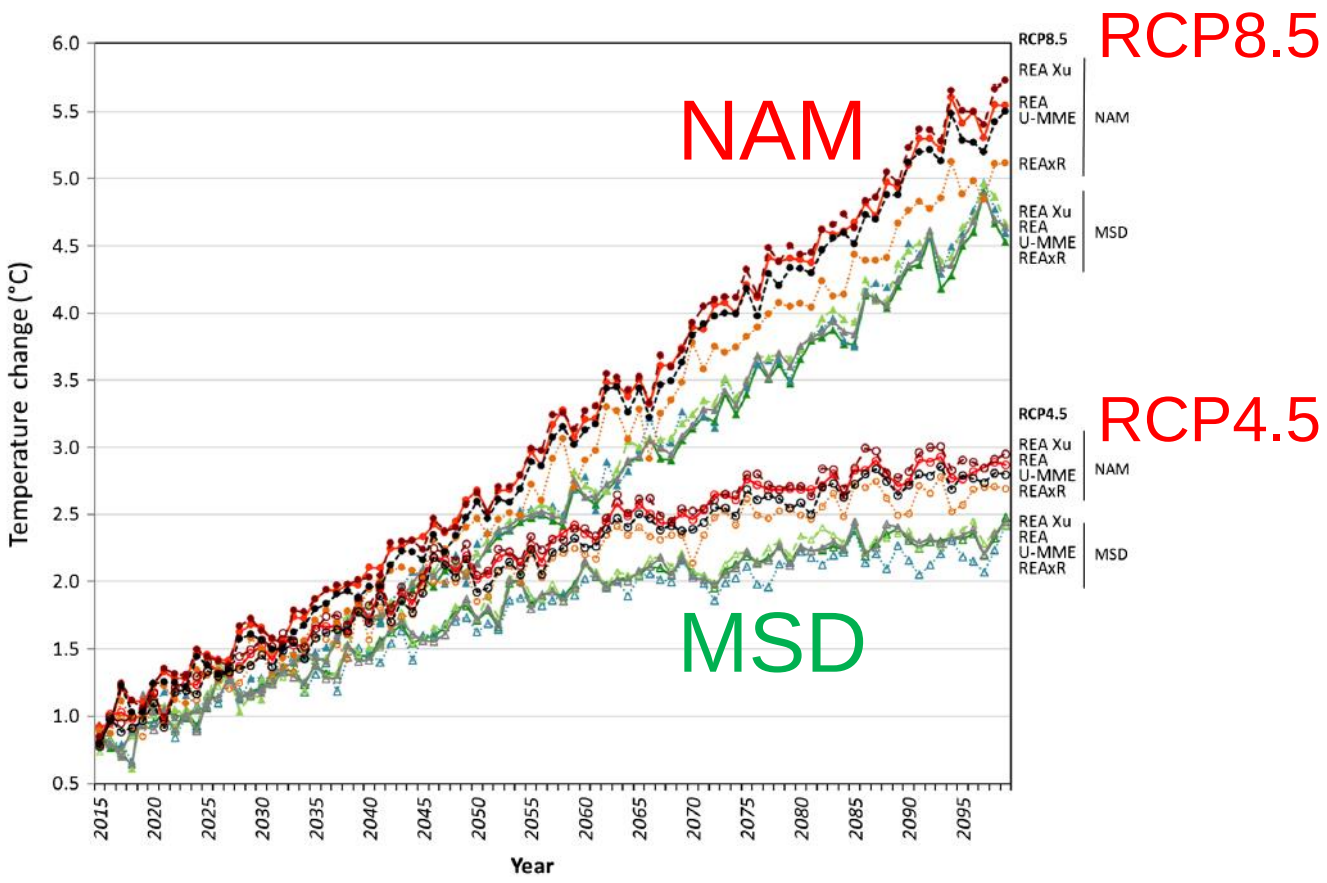
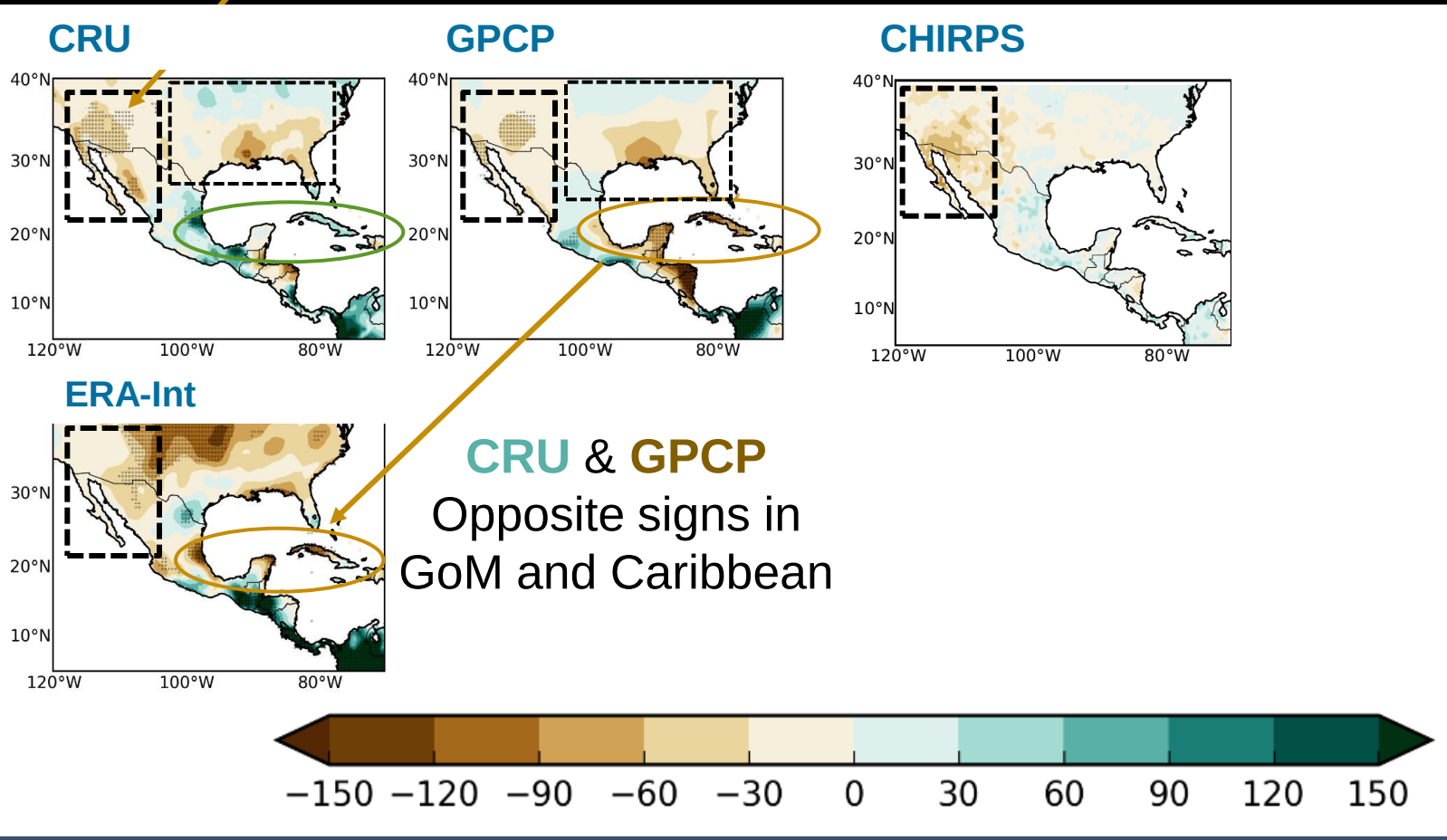


FIGURE 8 Time series of annual temperature change relative to 1971–2000 in the RCP8.5 and RCP4.5 scenarios averaged over gridpoints of the NAM and MSD regions according to REA, REAxR, REA Xu, and the U-MME. Open (solid) symbols represent the RCP4.5 (RCP8.5) scenarios [Colour figure can be viewed at wileyonlinelibrary.com]

Colorado-Ruiz, Cavazos, *et al*., *Int. J. Climatol*, 2018, https://doi.org/10.1002/joc.5773

5. OBS trends of Precip (mm/decade) 1980-2010

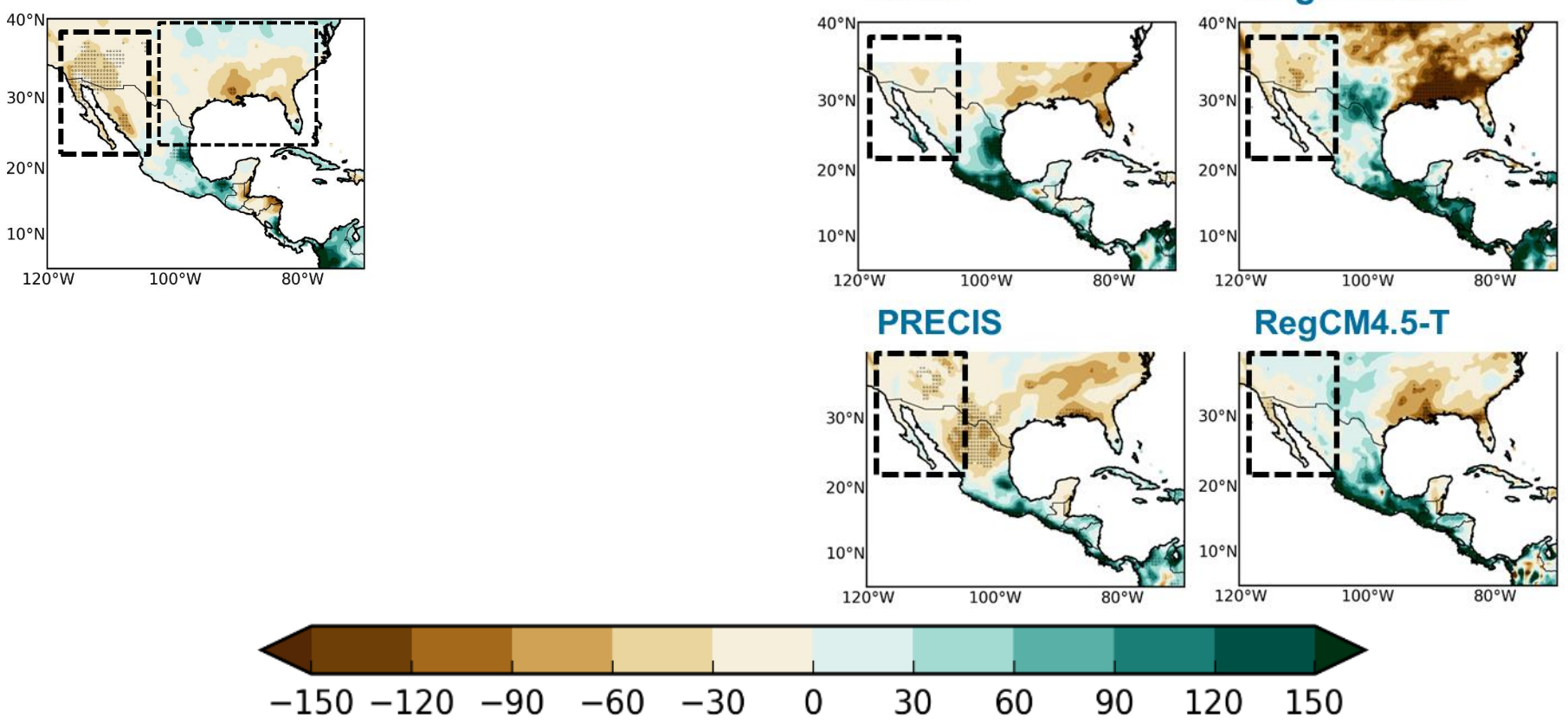
Dots: Stat signif at 95%



Color scale can be deceiving as in the tropics it rains a lot!

Decadal trends of precipitation (mm/decade) 1980-2010

Regional Models

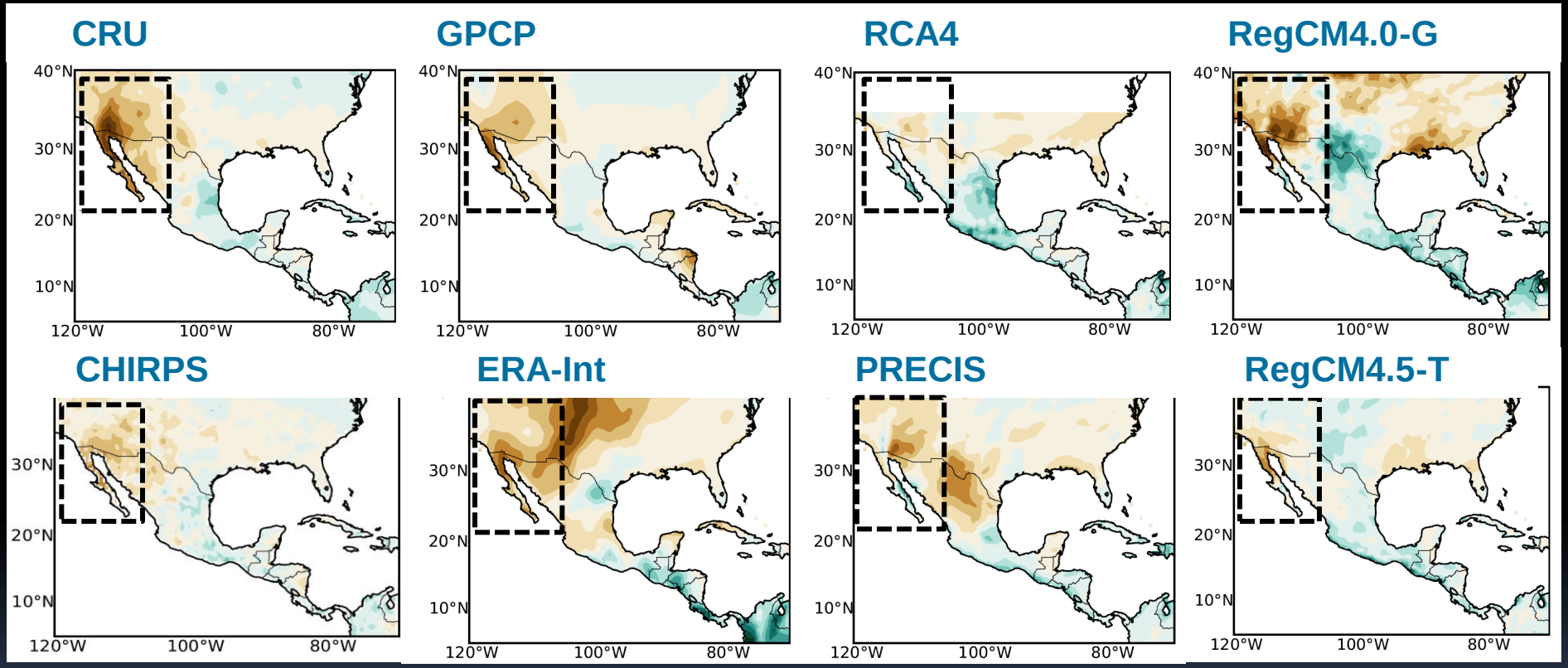


Color scale can be deceiving as in the tropics it rains a lot!

Decadal trends of precipitation (%/decade) 1980-2010

Observations

Regional Models



Correlations with teleconnection índices

Table 4. (a) and (c) Correlation coefficients of CRU mean annual area-averaged temperature (Temp) and precipitation (Precip) in the NAM and the MSD regions with the annual timeseries of AMO, PDO, and ONI during the 1980-2010 and 1950-2017, respectively. (b) and (d) Same as in (a) and (c) but for detrended Temp and Precip. One (two) asterisk indicates statistical significance at 95% (99%).

(a) 1980-2010

	NAM	
Index	**Temp**	**Precip**
AMO	**0.53****	**-0.43****
PDO	**-0.37***	**0.32***
ONI	-0.26	0.09

(c) 1950-2017

	NAM	
	Temp	**Precip**
AMO	**0.55****	**-0.24***
PDO	0.17	**0.47****
ONI	0.03	0.23

(b) Detrended 1980-2010

	NAM	
Index	**Temp**	**Precip**
AMO	-0.09	-0.25
PDO	0.05	0.16
ONI	-0.17	0.01

(d) Detrended 1950-2017

	NAM	
	Temp	**Precip**
AMO	**0.50****	**-0.28***
PDO	-0.10	**0.42****
ONI	0.06	**0.24***

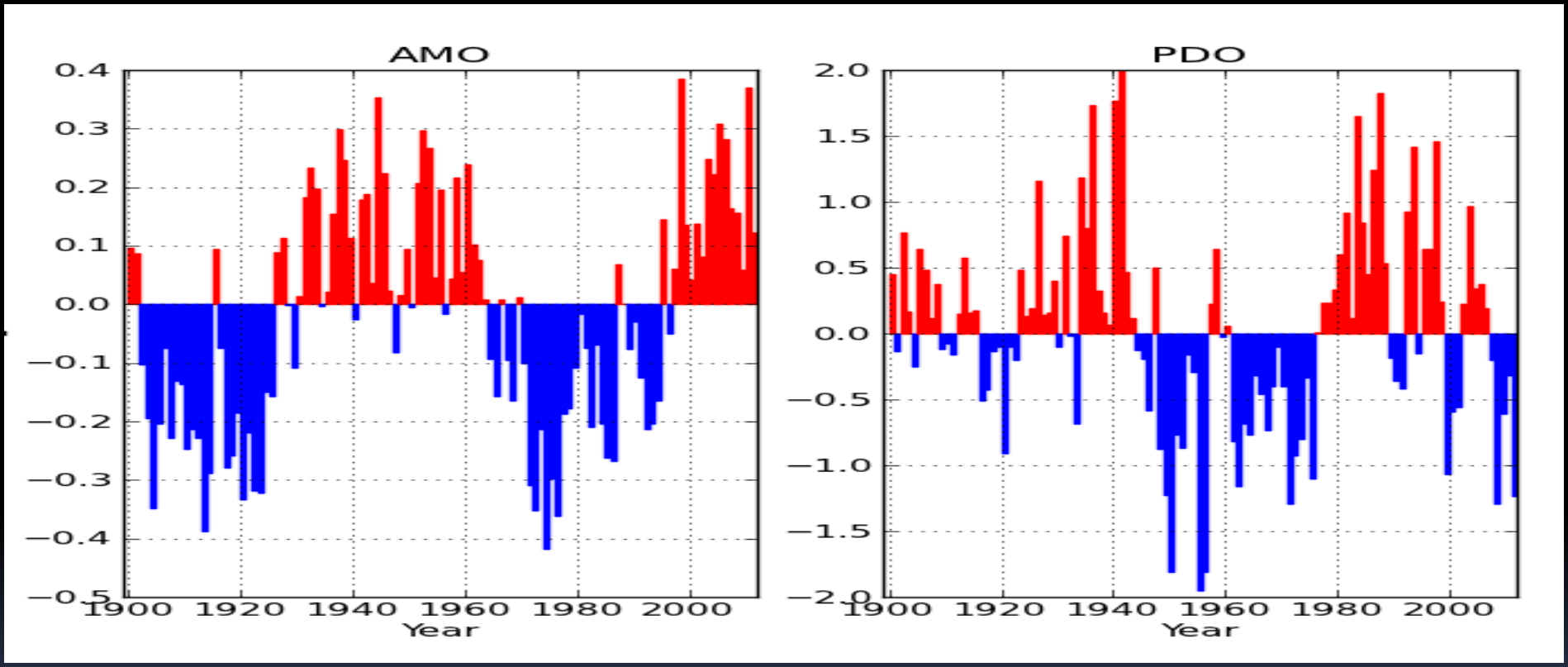
+ Prec

- AMO

+ PDO

EN

AMO and PDO Indices

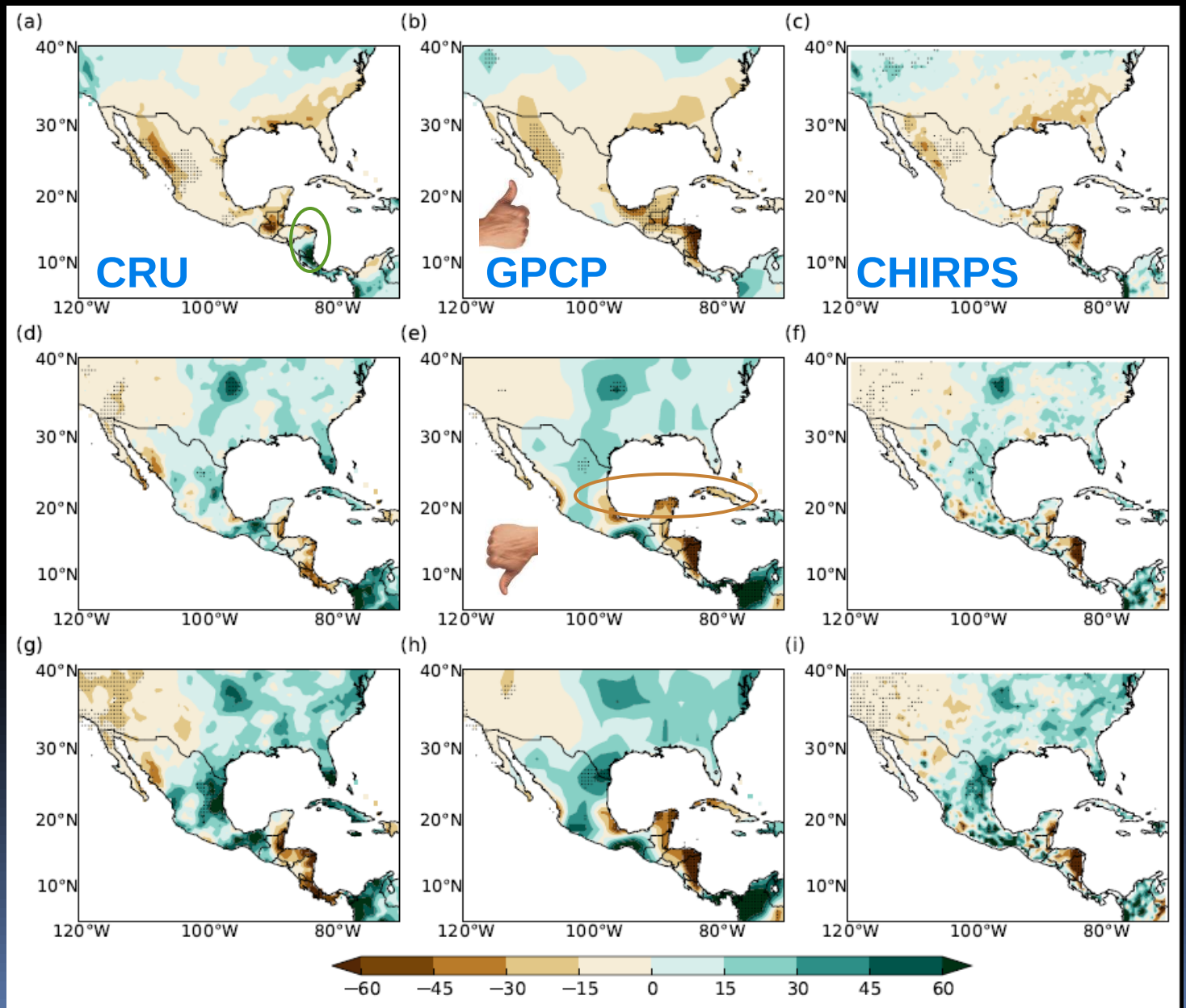


Obs Seasonal Precip Trends (%/decade) 1980-2010

DJF

JJA

JJAS



DJF Dry:
-PDO
LN, STJ,
Hadley C

JJAS -/+
-PDO,
+AMO /
+ AMO
NASH,
TCs

Conclusions

- **Evaluation:** RCMs capture the annual cycles and the interannual and seasonal variability, but tend to be cooler and drier than observed.

- **Trends:** Observations show significant warming (0.4^{o}C/decade) and drying (10%) trends in the NAM region that appear to be related to +AMO (-AMO and + PDO) ➔ NAM region is already a hotspot.

- Winter negative Precip trends in the subtropics are captured by the RCMs, but not summer's.

- CRU and GPCP show opposite Precip trends over the Gulf of Mexico and Cuba. Uncertainties: resolution, data avialbility, satellite problems.

- Obs datasets contain important biases over mountain areas due to lack of observations, thus model simulations may have lower biases than they appear

Unsolved research questions

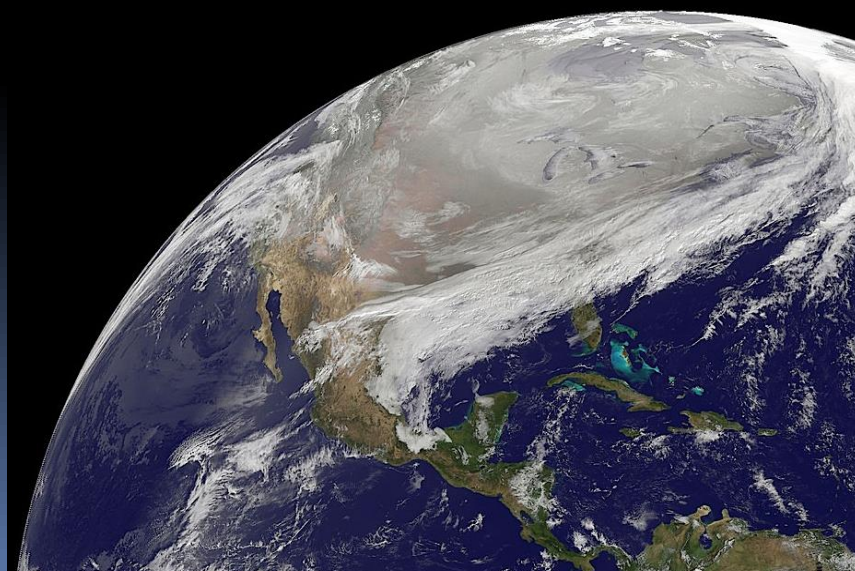
- Can the warming trend in the NAM region be partially attributed to climate change or other factors?
- What is the role of the subtropical jet stream and the Hadley cell in the winter drying trends in the subtropics?
- What is the combined impact of the AMO and NASH on the positive summer precipitation trends in the GoM region?
- How are extreme events changing in the region and why?
- Period of analysis…
- Data uncertianties (Obs, reanlayisis, and models)…

Ongoing Research

Rosa B. Luna, PhD student:

Changes in the subtropical winter circulation of North America under climate change conditions and their influence in Mexico using RegCM4.7

- **Subtropical jet stream**
- **Cold fronts and Norte winds**

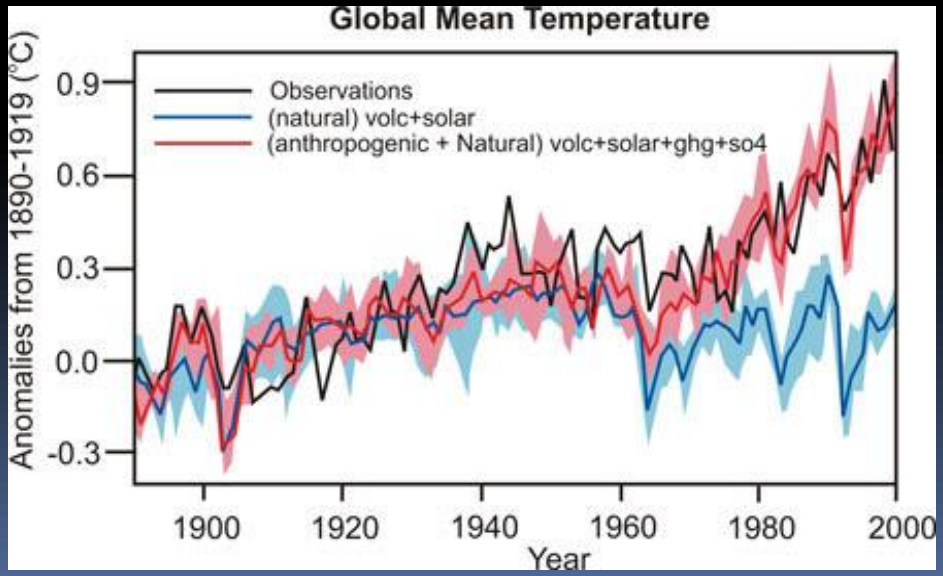


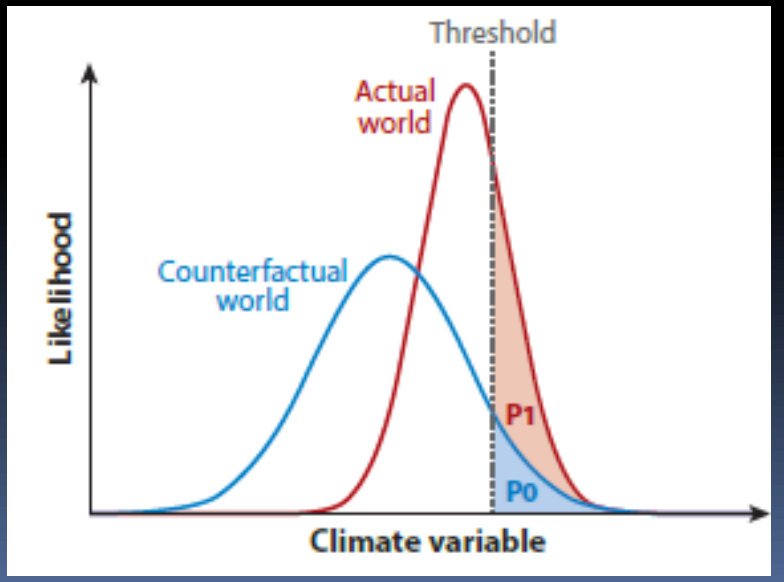
Ongoing Research

Gabriela Colorado-Ruiz, PhD student:

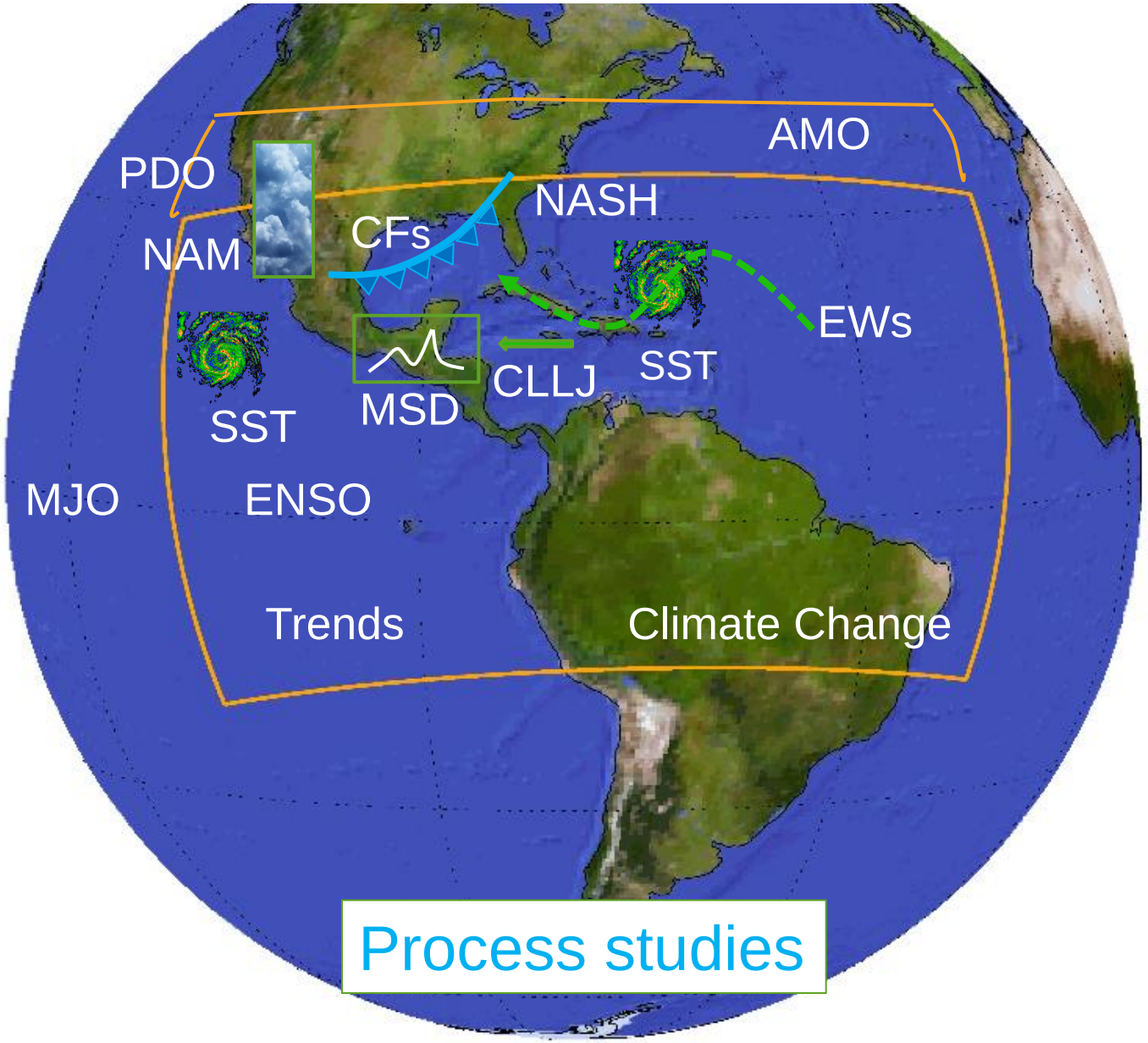
Detection and attribution of extreme precipitation events in Mexico

- Self-organizing maps – detection of circulation patterns
- Extreme value theory – characterize regional extremes
- GCMs (natural and anthropogenic forcings for attribution)





CORDEX-CAM Domain



Interactive trend analysis in the domain is available at:

http://cordexcam-unam.cicese.mx/

Obrigada / Gracias / Thank you

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