CORDEX and NARCCAP: Foundations in Reanalyses

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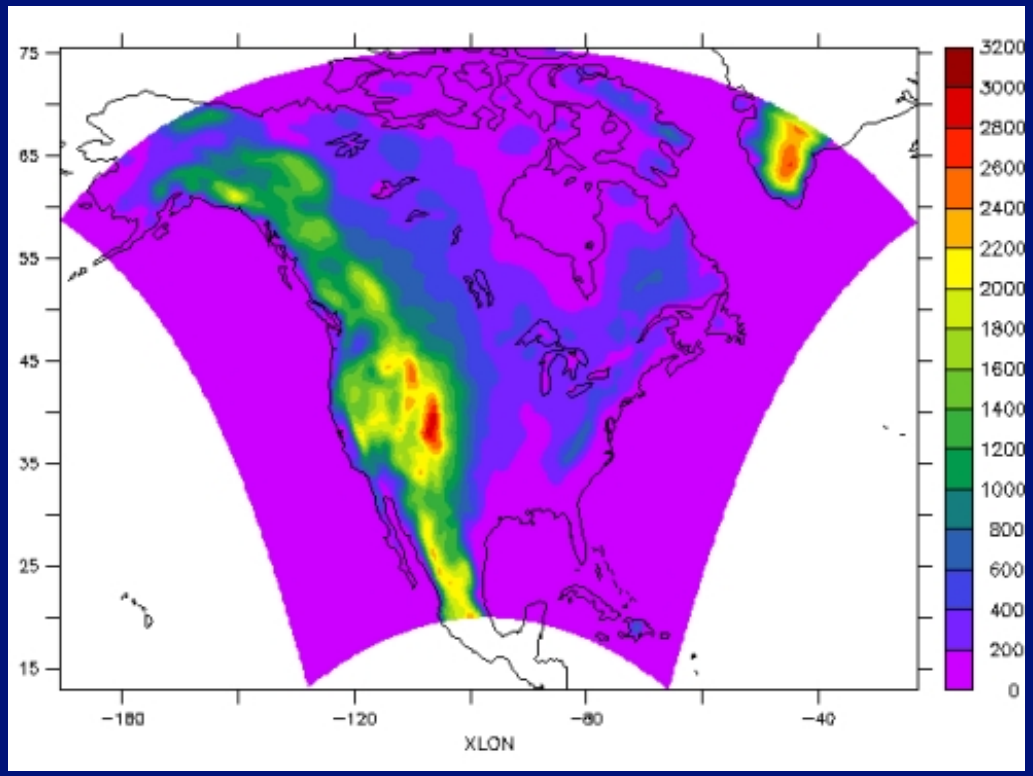
Coordinated Regional Downscaling Experiment (CORDEX)
North American Regional Climate Change Assessment Program (NARCCAP)

1. Overview of NARCCAP & CORDEX
2. General results – multiple regions
3. Sensitivity to reanalysis
4. Summary

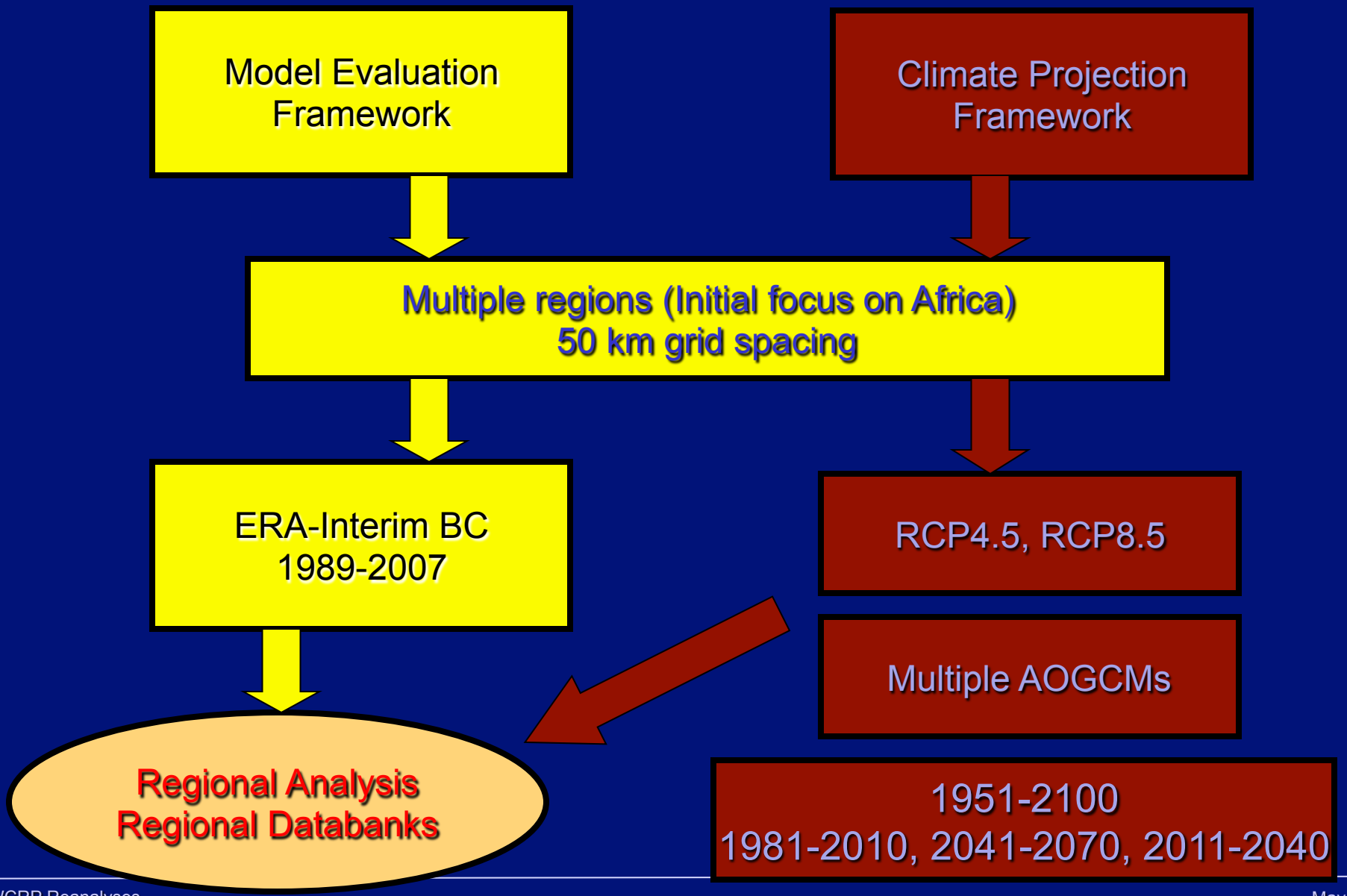
NARCCAP

MM5	RegCM3	CRCM	HADRM3	RSM	WRF
Iowa State/ PNNL	UC Santa Cruz ICTP	Quebec, Ouranos	Hadley Centre	Scripps	NCAR/ PNNL

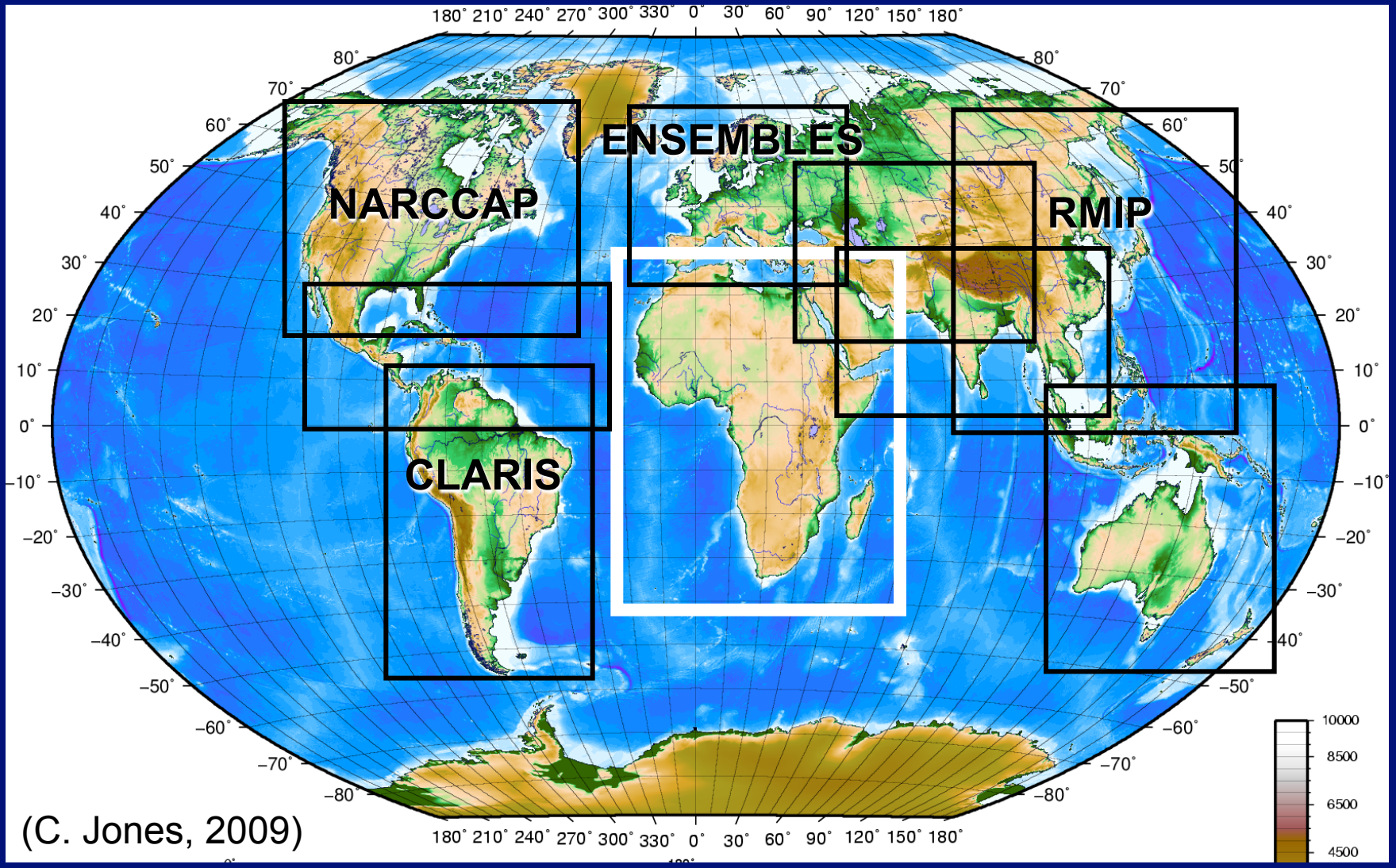
- Domain
  - **Most of North America**
- Period
  - **1980-2004**
- Boundary Conditions
  - **NCEP/DOE reanalysis**
- Resolution
  - **50 km**



CORDEX Phase I experiment design

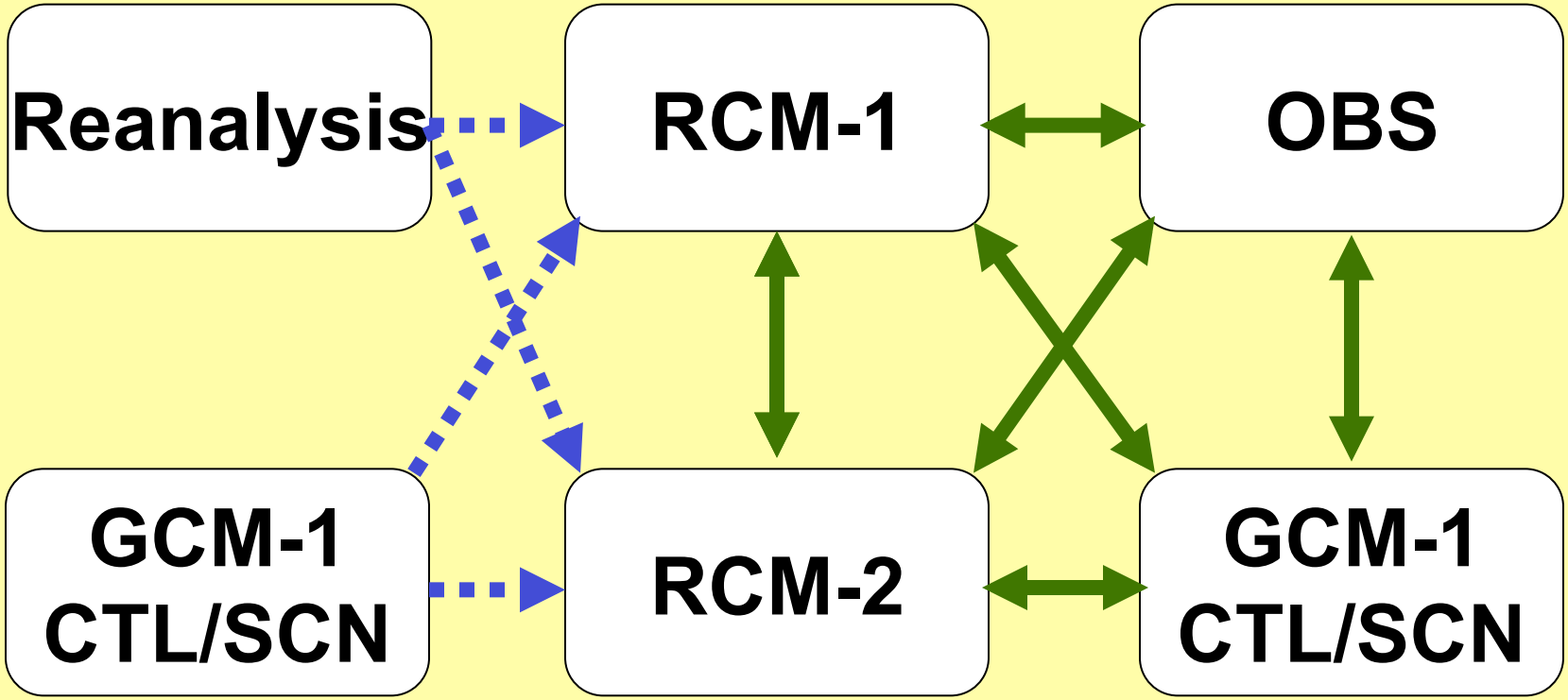


Coordinated Regional Downscaling Experiment (CORDEX)
~ Regions ~



Possible Comparisons?

(Pan et al. 2001)



- A simple spatial ANOVA model:

$$\begin{array}{lccccccc} \text{NCEP} & \mathbf{X}_{0k} & = & \boldsymbol{\mu} & & + & \boldsymbol{\epsilon}_{0k} & \\ \text{RCM}_i & \mathbf{X}_{ik} & = & \boldsymbol{\mu} & + \boldsymbol{\alpha}_i + & & \boldsymbol{\epsilon}_{ik} & i = 1, \ldots, 5,\ k = 1, \ldots, 20 \end{array}$$

  - $\boldsymbol{\mu}$ represents common effect
  - $\{\boldsymbol{\alpha}_i\}$ represents model-specific effects

- Spatial priors for $\boldsymbol{\mu}$, $\{\boldsymbol{\alpha}_i\}$, $\{\boldsymbol{\epsilon}_{0k}\}$, $\{\boldsymbol{\epsilon}_{ik}\}$

- Inference focuses on posterior distribution of $\boldsymbol{\mu}$ and $\{\boldsymbol{\alpha}_i\}$.

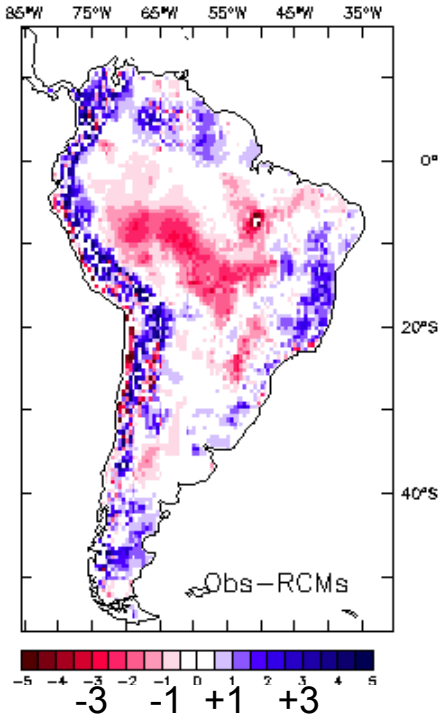
(S. Sain, 2008, 2012)

South America

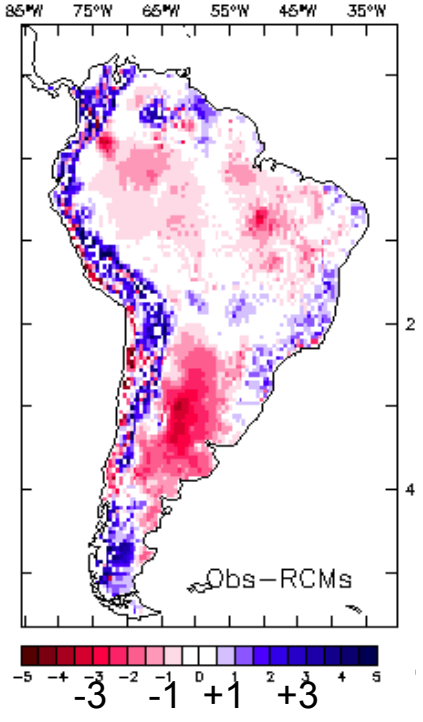
7 RCMs using ERA-Interim boundary conditions (1990-2008)

Temperature Bias (ºC)

JJA

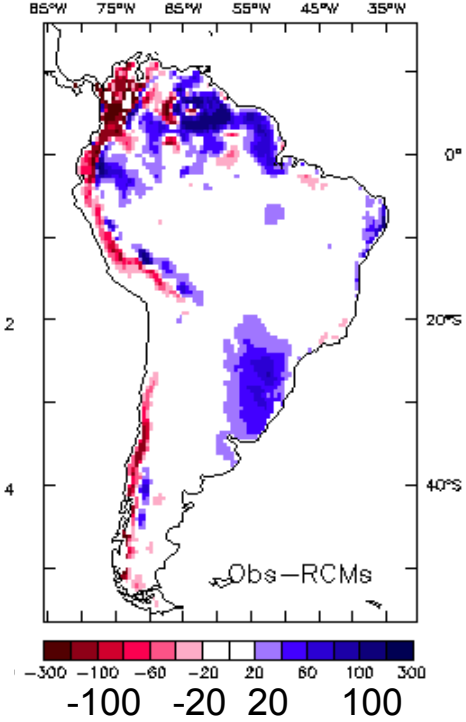


DJF

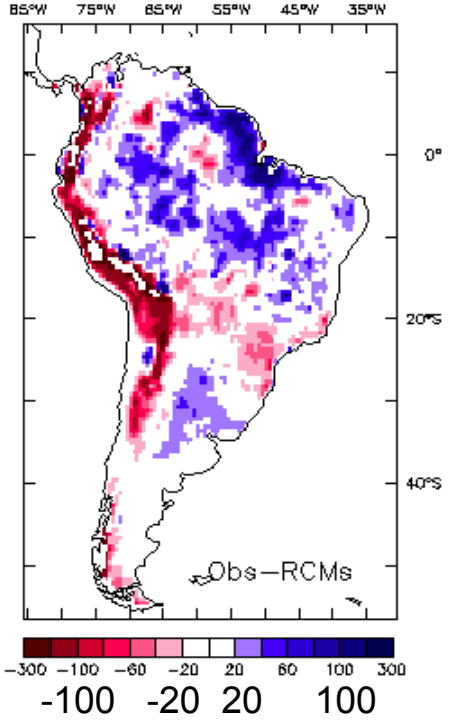


Precipitation Bias (mm/month)

JJA



DJF



Ensemble vs. (CRU & UDEL)

Ensemble vs. (GPCC, CRU, UDEL & CPC)

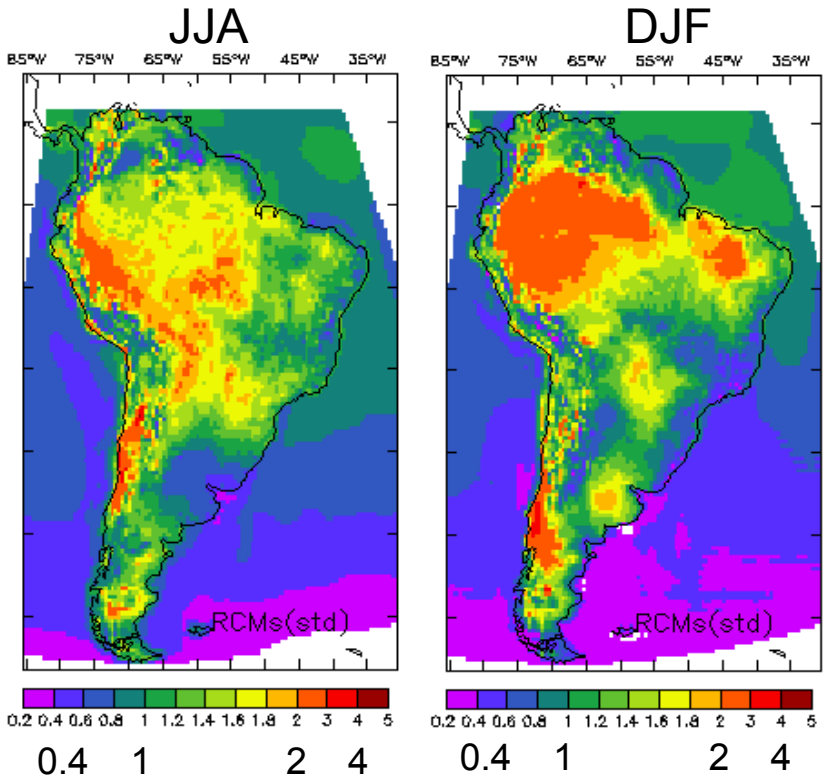
(Solman et al., 2012 - submitted)

South America

7 RCMs using ERA-Interim boundary conditions (1990-2008)

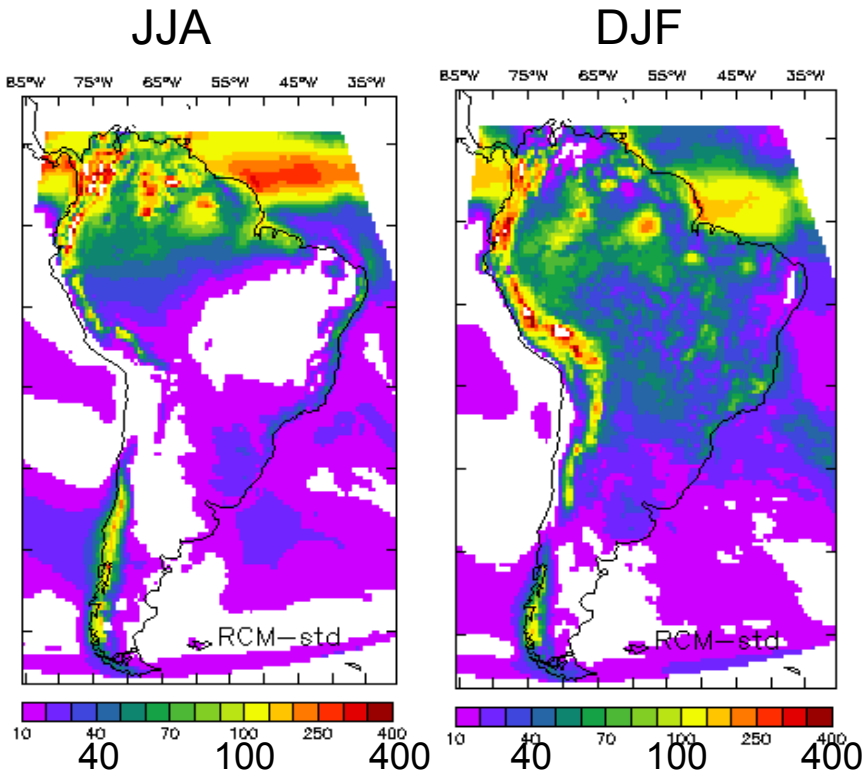
Intermodel spread

Temperature (ºC)



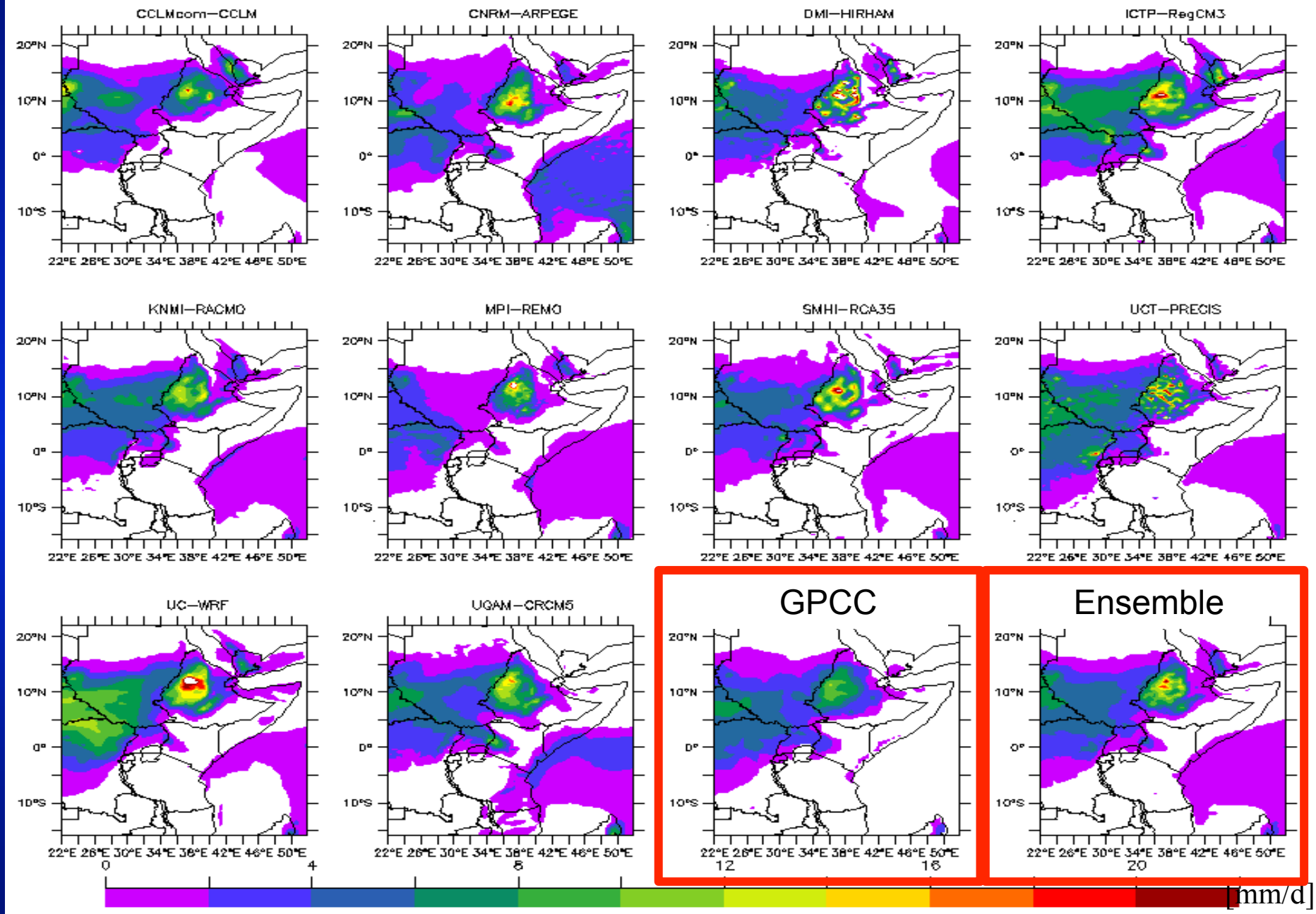
Intermodel spread

Precipitation (mm/month)

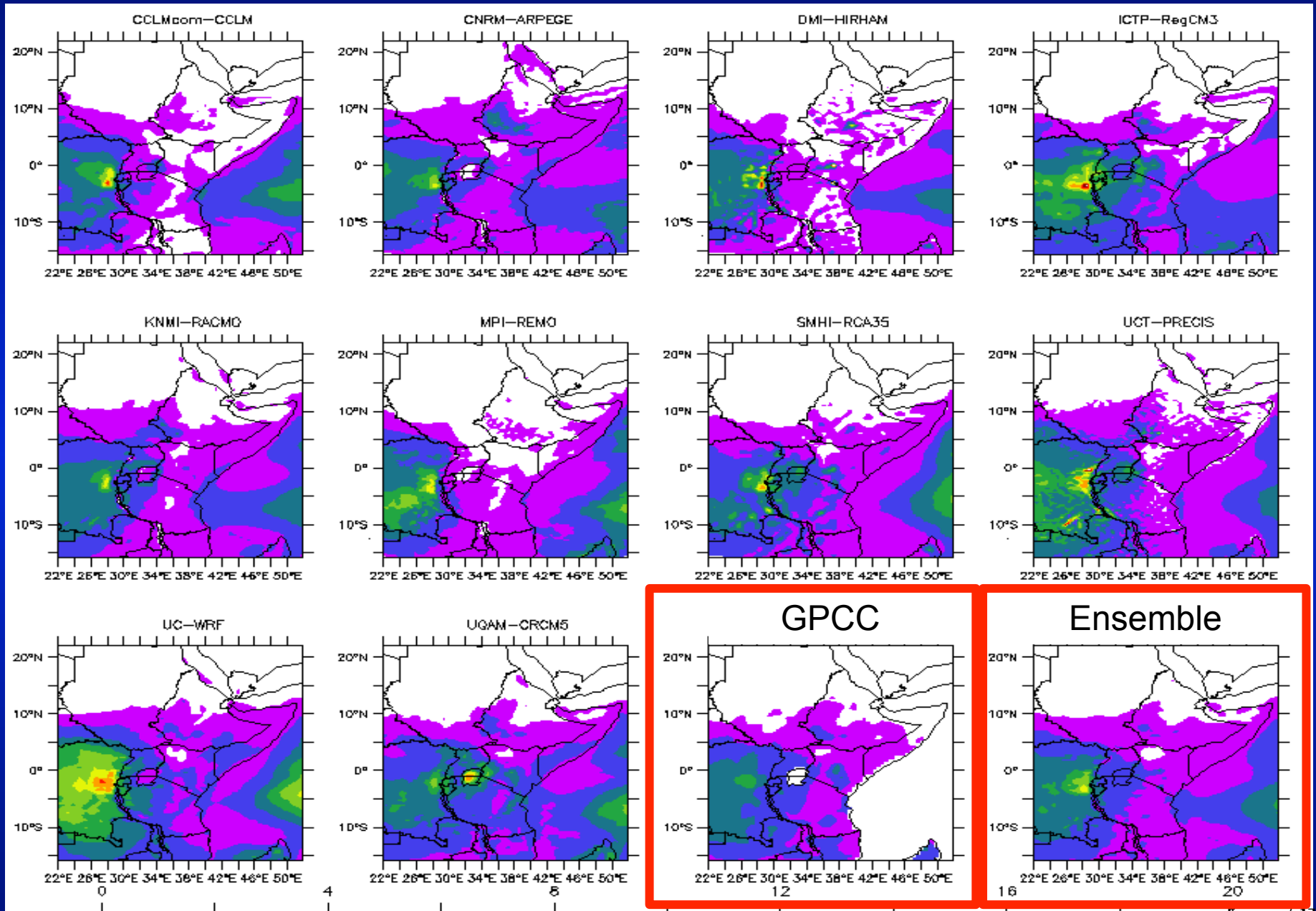


(Solman et al., 2012 - submitted)

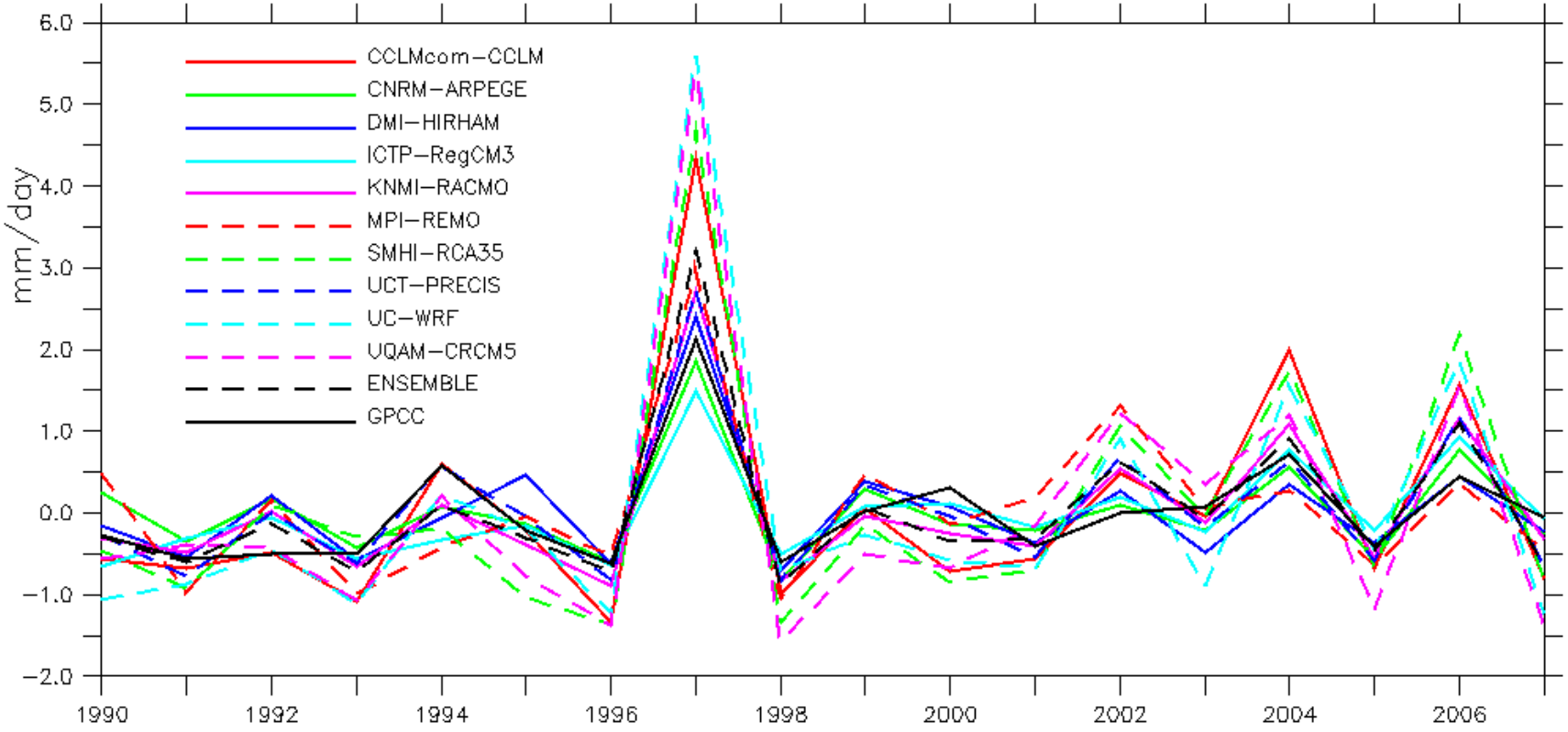
CORDEX Africa : East Africa Rainfall (1990-2008 ; JAS)



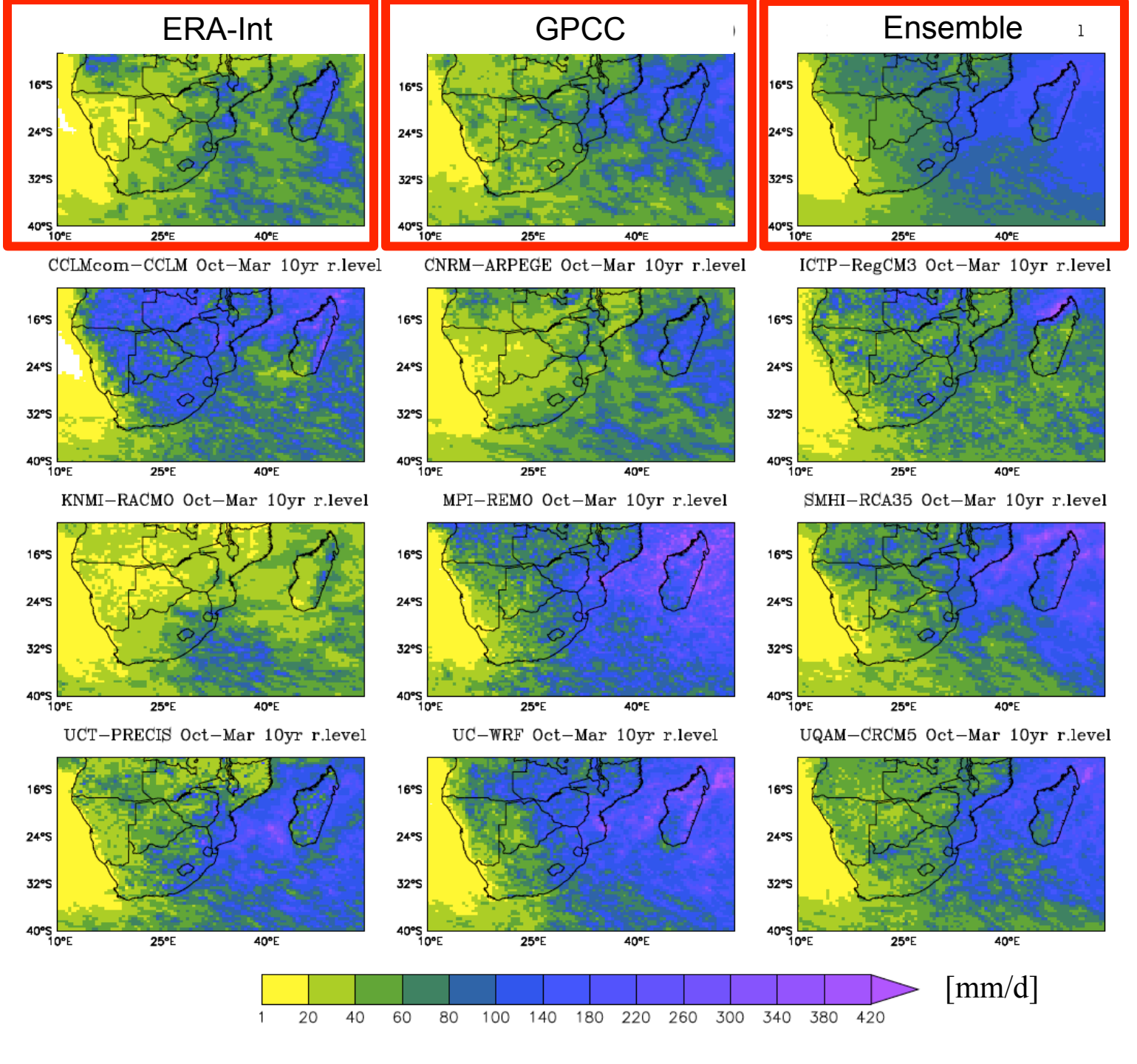
CORDEX Africa : East Africa Rainfall (1990-2008 ; OND)



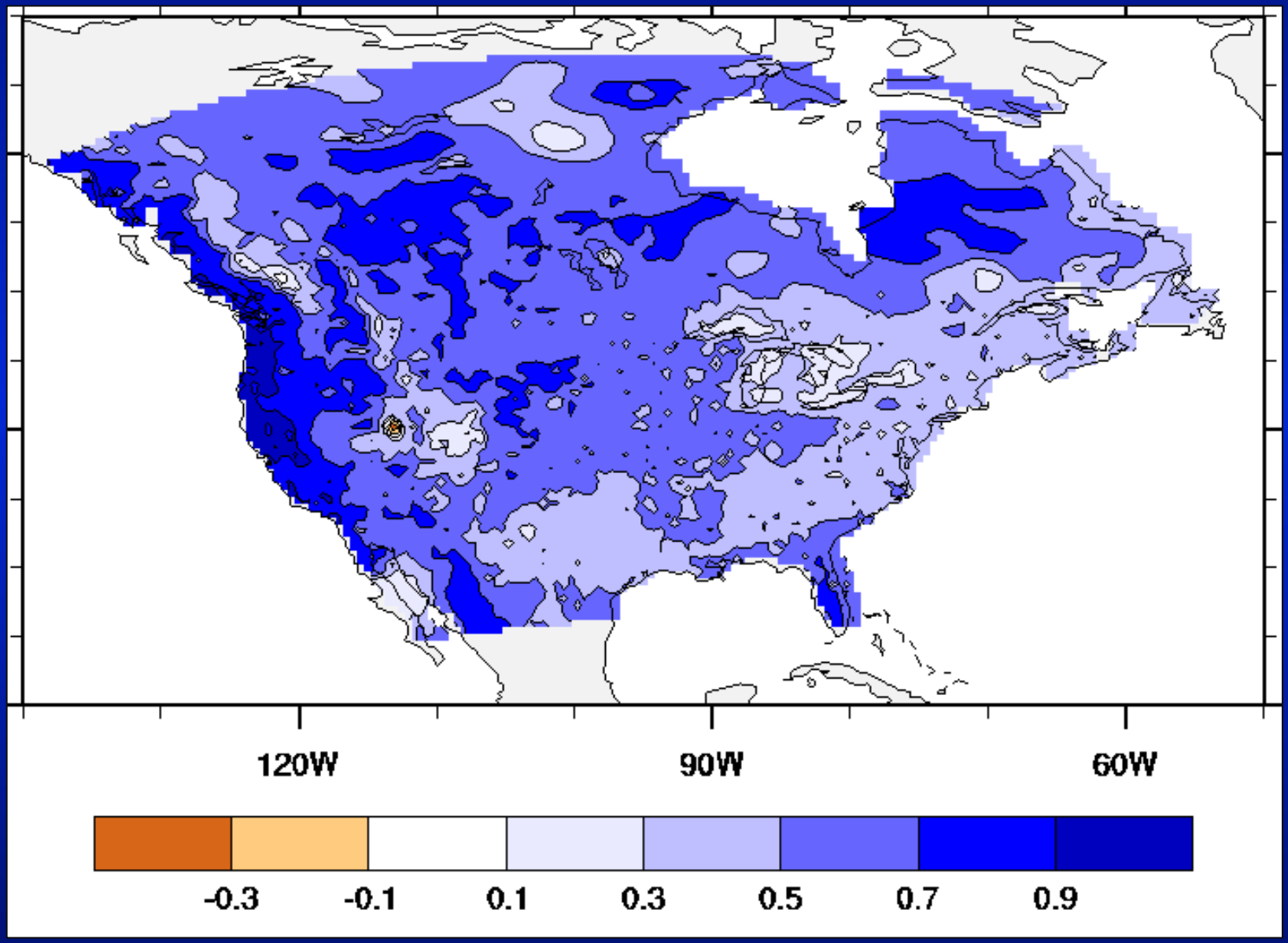
Interannual Rainfall Variability during OND in CORDEX sub region 5(Figure2)



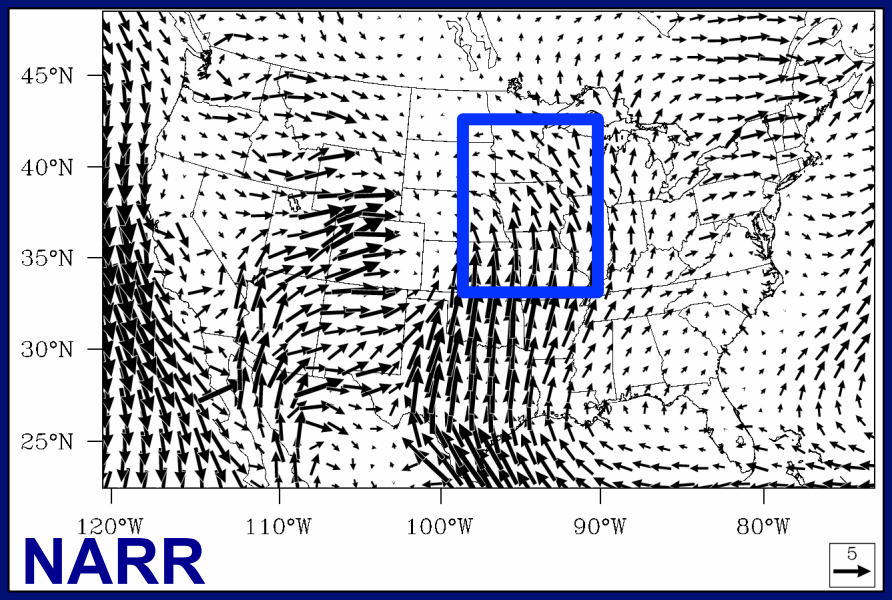
CORDEX Africa: 10-Yr Return Values of Daily Precipitation - Southern Africa (1990-2006 ; Oct-Mar)

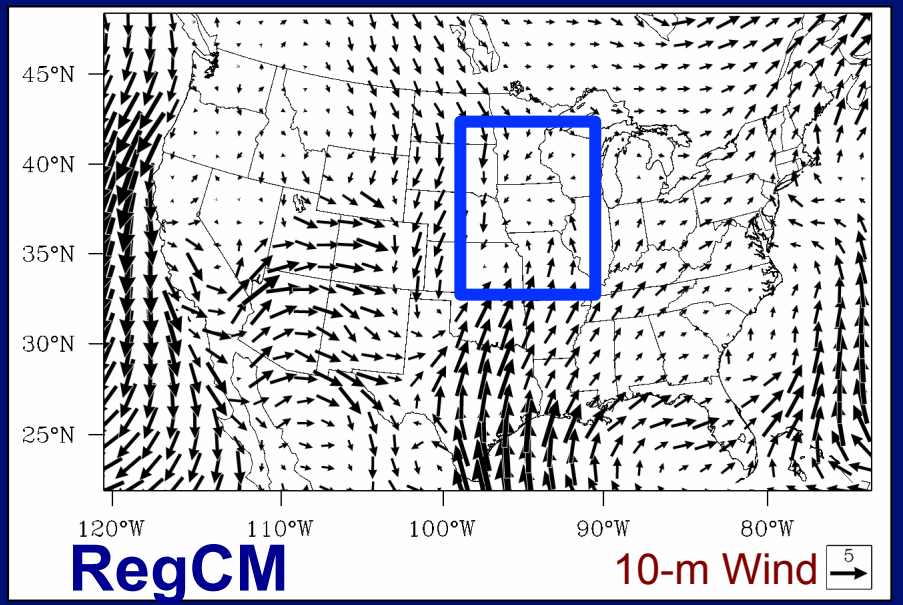


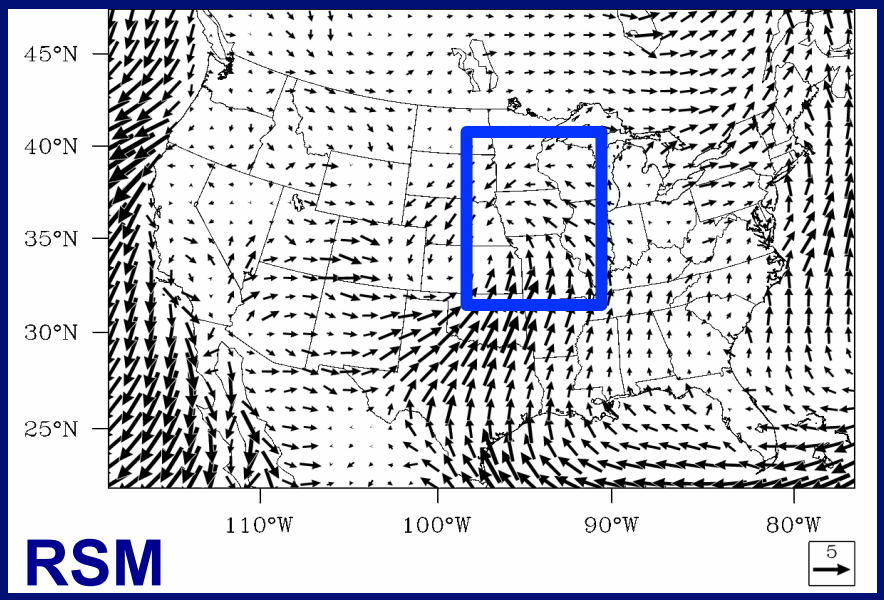
NARCCAP:
Correlation of Monthly Precipitation Time Series

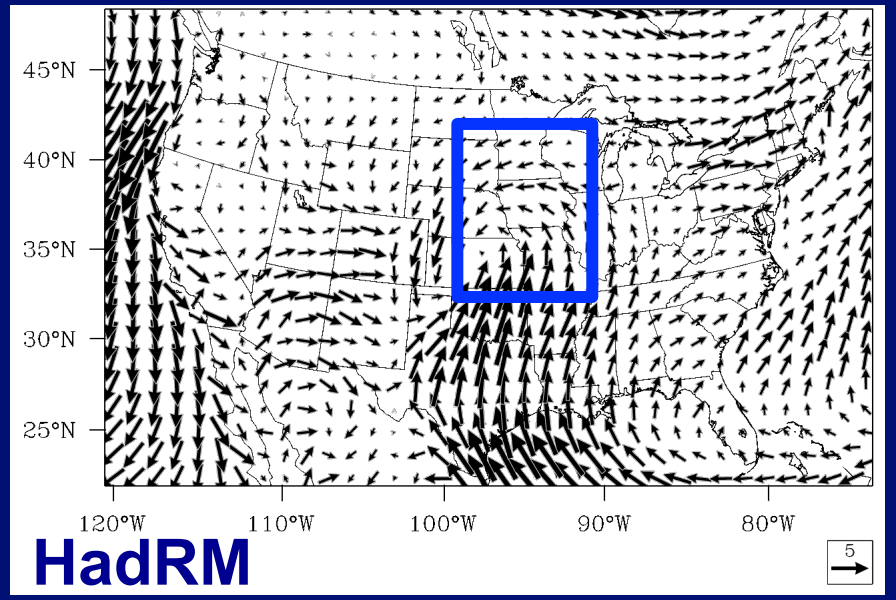


NARCCAP: Composite Structure Extreme Prec Events - JJA





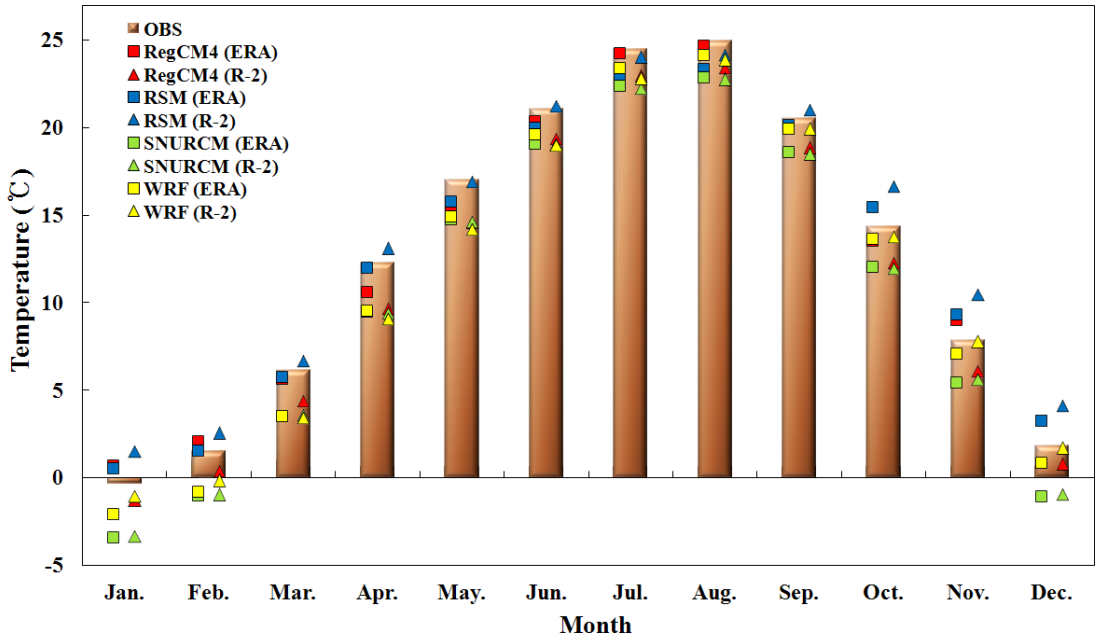


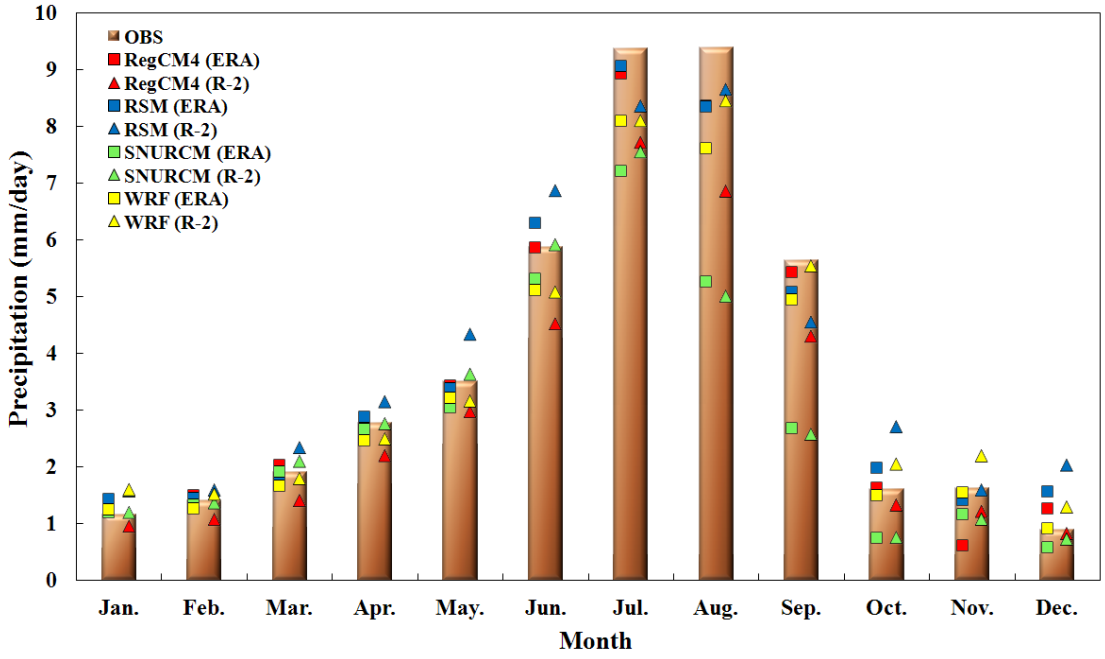


Temperature

CORDEX: East Asia

- WRF, SNURCM(MM5), RegCM4, RSM
- NCEP/DOE & ERA-interim Forcing
- 20 years (1989-2008)



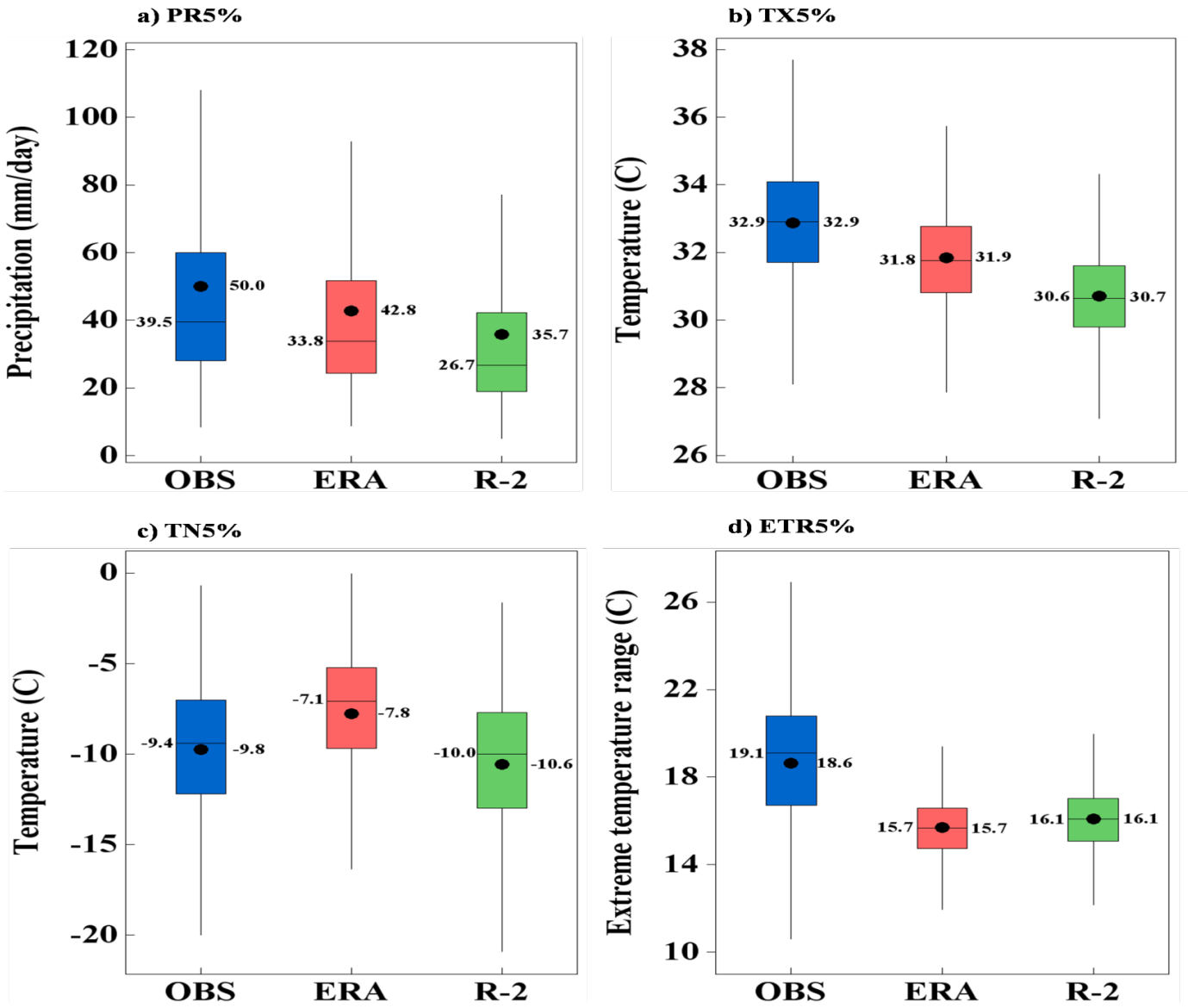


Precipitation

Kang (2012)

Extreme Climate Indices

(RegCM4 : Korea sub-region)



Kang (2012)

NARCCAP: HadRM3P T Biases

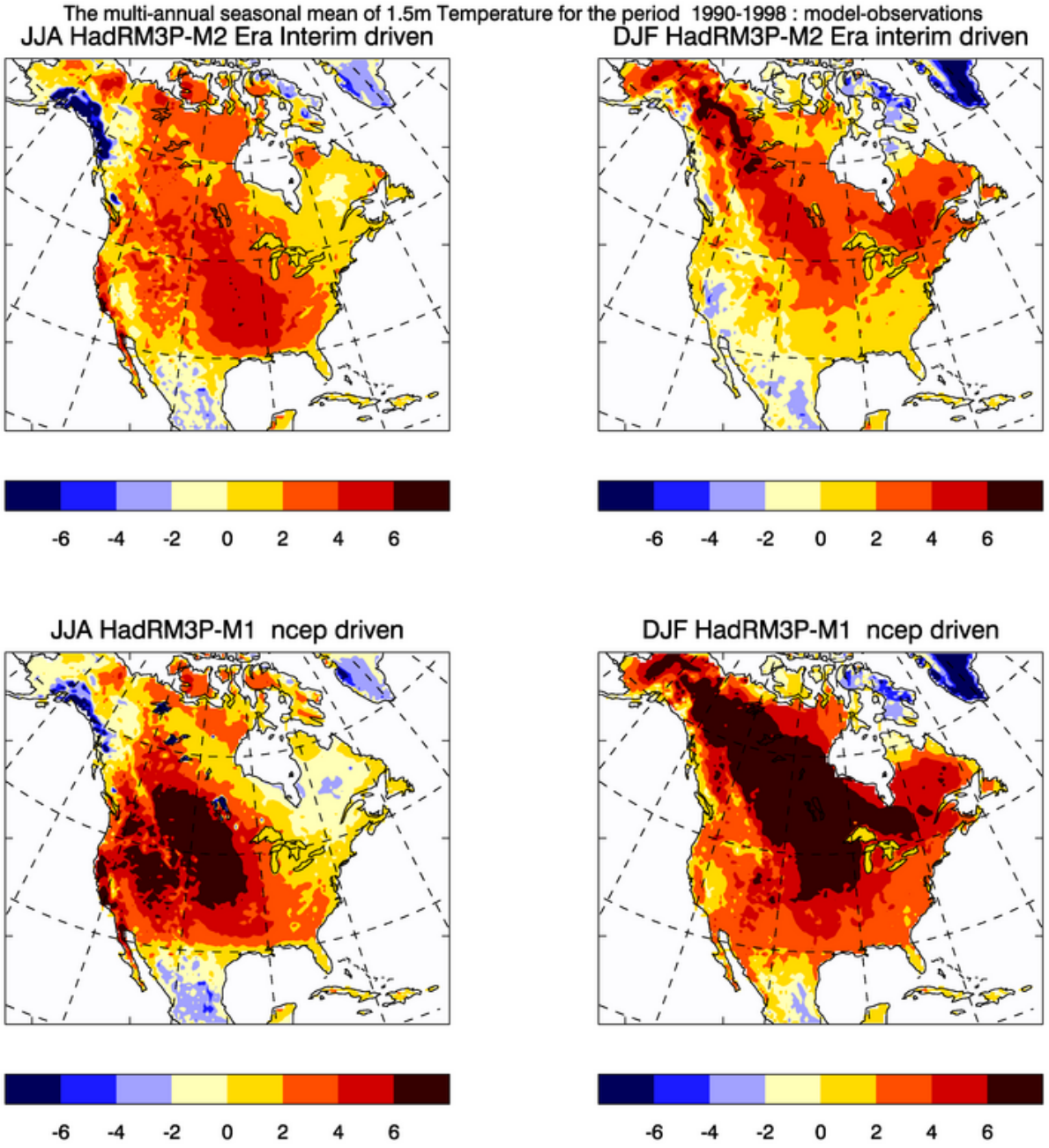
Met Office Hadley Centre

HadRM3P JJA/ DJF temperature biases:

Top – ERA-In boundaries

Bottom – NCEP boundaries

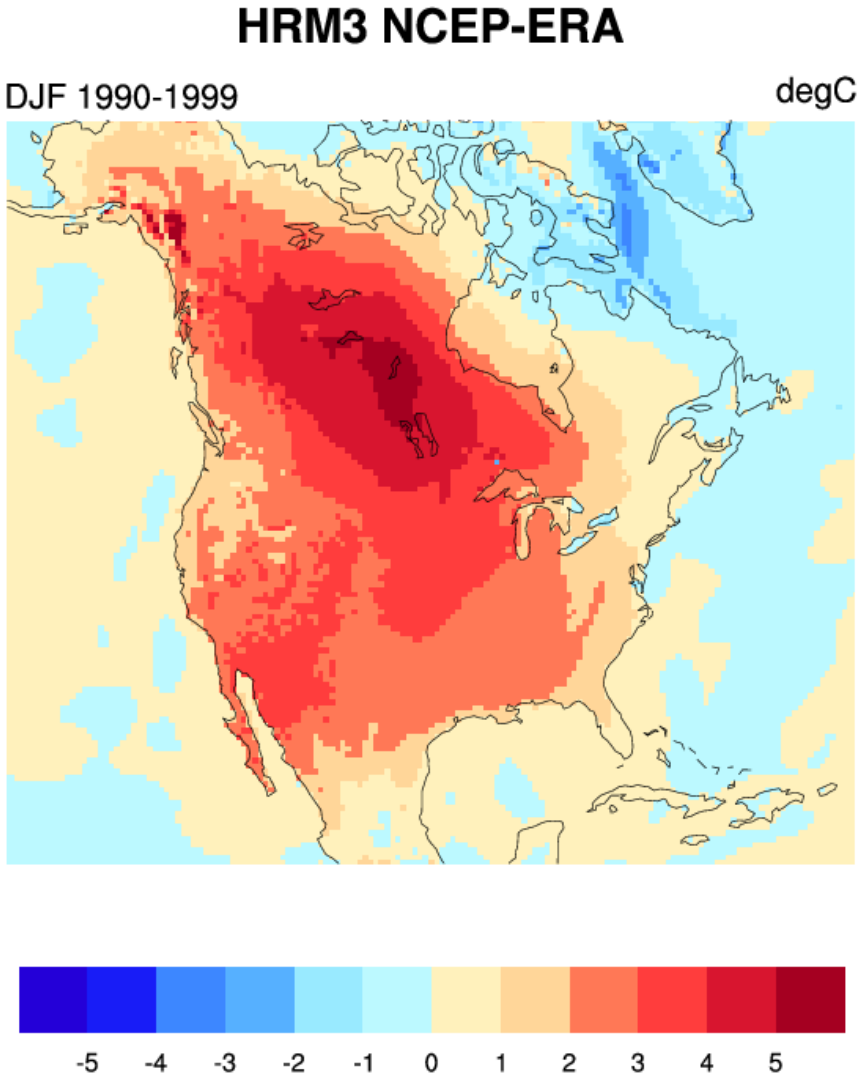
Bias pattern similar – magnitude much greater with NCEP boundaries



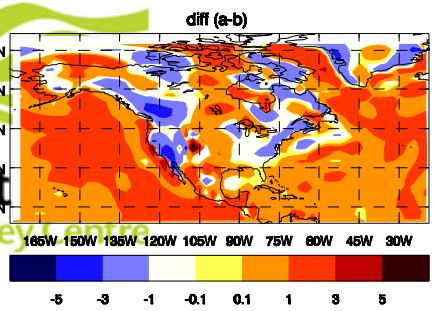
Difference in DJF surface temperature simulation when using NCEP rather than ERA-Interim boundaries

HadRM3P DJF temperature bias reduced by >5K when using ERA-Interim boundary conditions

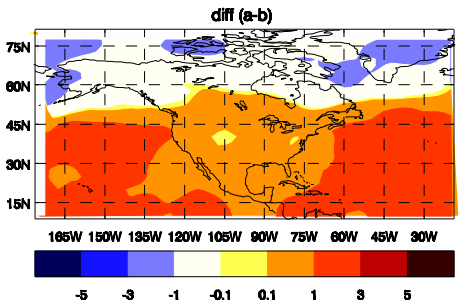
Similar signal seen in summer



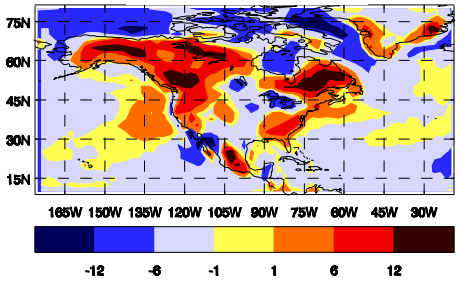
1000hPa



200hPa

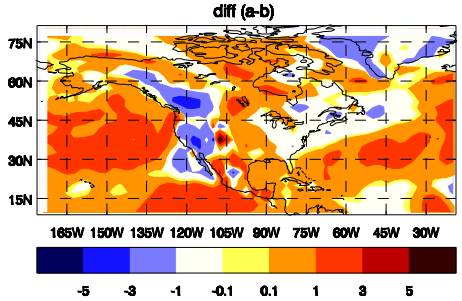


1000hPa

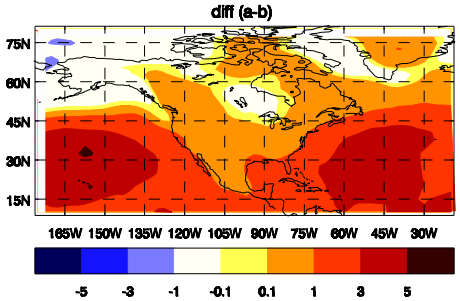


NCEP–ERA-Interim temperature (left and middle) and Rh

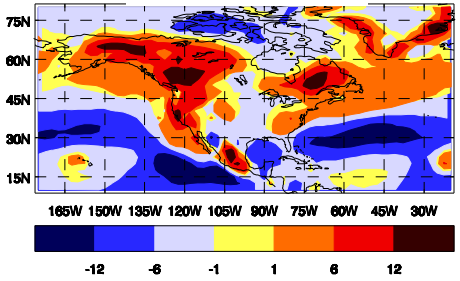
925hPa



150hPa

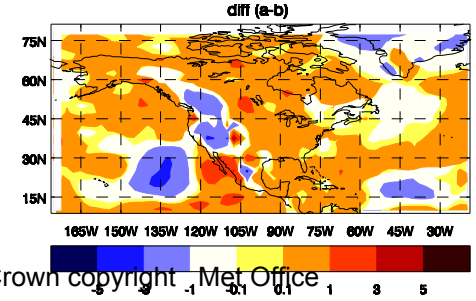


925hPa

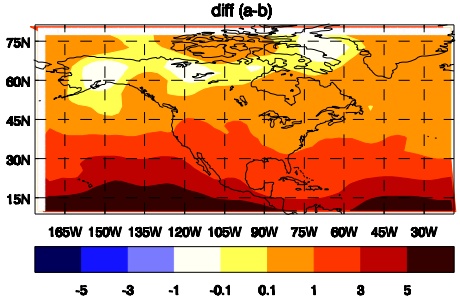


NCEP warmer and moister on western inflow boundary

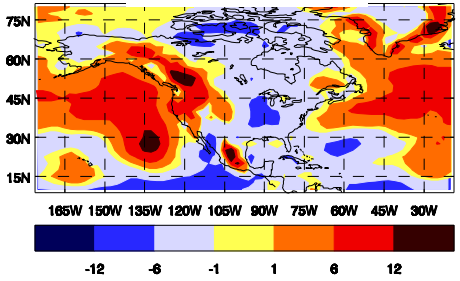
850hPa



100hPa



850hPa



Some reasons for differences in the downscaled reanalyses

- At western boundary, NCEP reanalysis both warmer and moister in the lower troposphere and in the upper troposphere/ stratosphere
  - increases temperature and downward longwave radaiation (from higher atmospheric humidities and, in winter, by increased cloud cover)
- In winter, warmer temperatures lead to
  - reduced snow cover and enhanced solar radiation absorption at the surface
- In spring/summer lead to
  - drier soils, lower evaporative cooling and lower cloud amounts enhancing surface solar radiation

Summary

- Reanalyses are central part of evaluation of dynamic downscaling:
  - provide “real world” BCs
  - provide basis for model evaluation

- Using reanalyses allows extensive testing of models against observations
  - ensembles especially important for this

- Reanalyses are not identical esp. away from well-observed regions, which can impact downscaling.

EXTRA SLIDES

NARCCAP

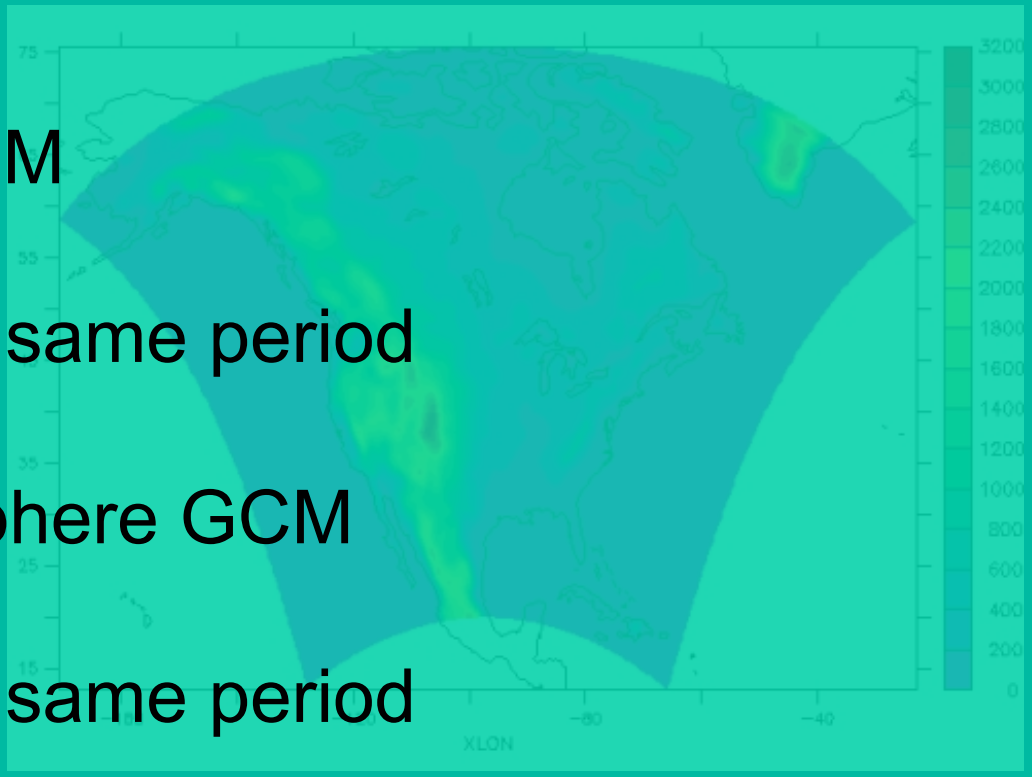
MM5	RegCM3	CRCM	HADRM3	RSM	WRF
Iowa State/ PNNL	UC Santa Cruz ICTP	Quebec, Ouranos	Hadley Centre	Scripps	NCAR/ PNNL

- Domain
  - Most of North America
- Resolution
  - ~50 km
- Analysis Period
  - 1968-2000
- Boundary Conditions
  - NCEP/DOE Reanalysis

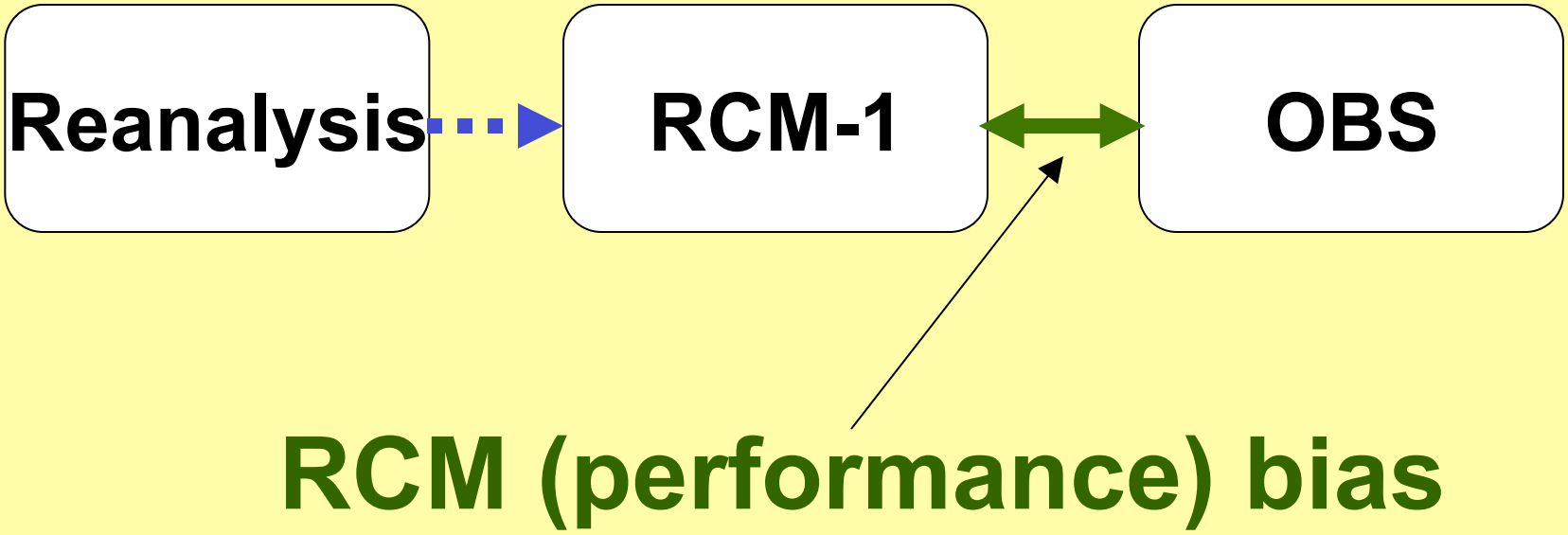
PLUS:

GFDL Atmosphere GCM
- 0.5° resolution
- specified SST/ice for same period

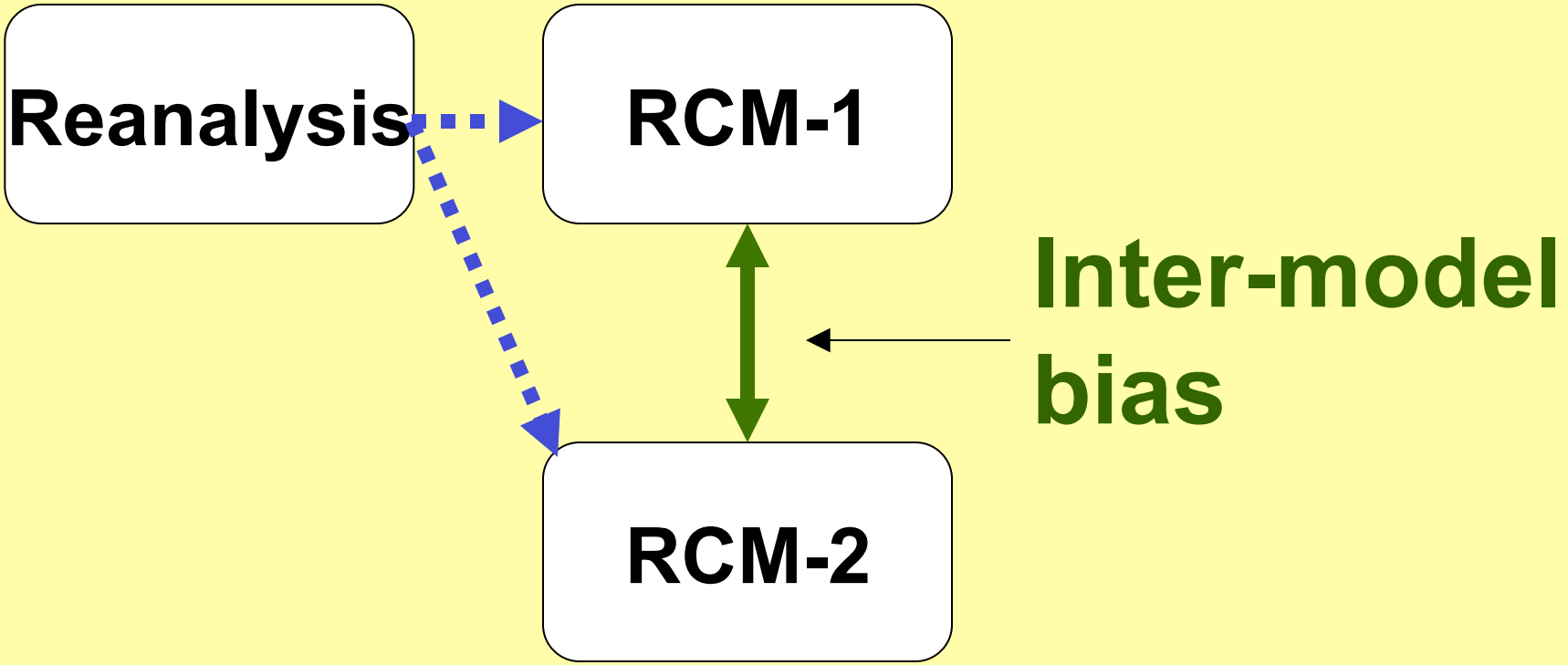
NCAR CAM3 - Atmosphere GCM
~ 0.5° resolution
- specified SST/ice for same period



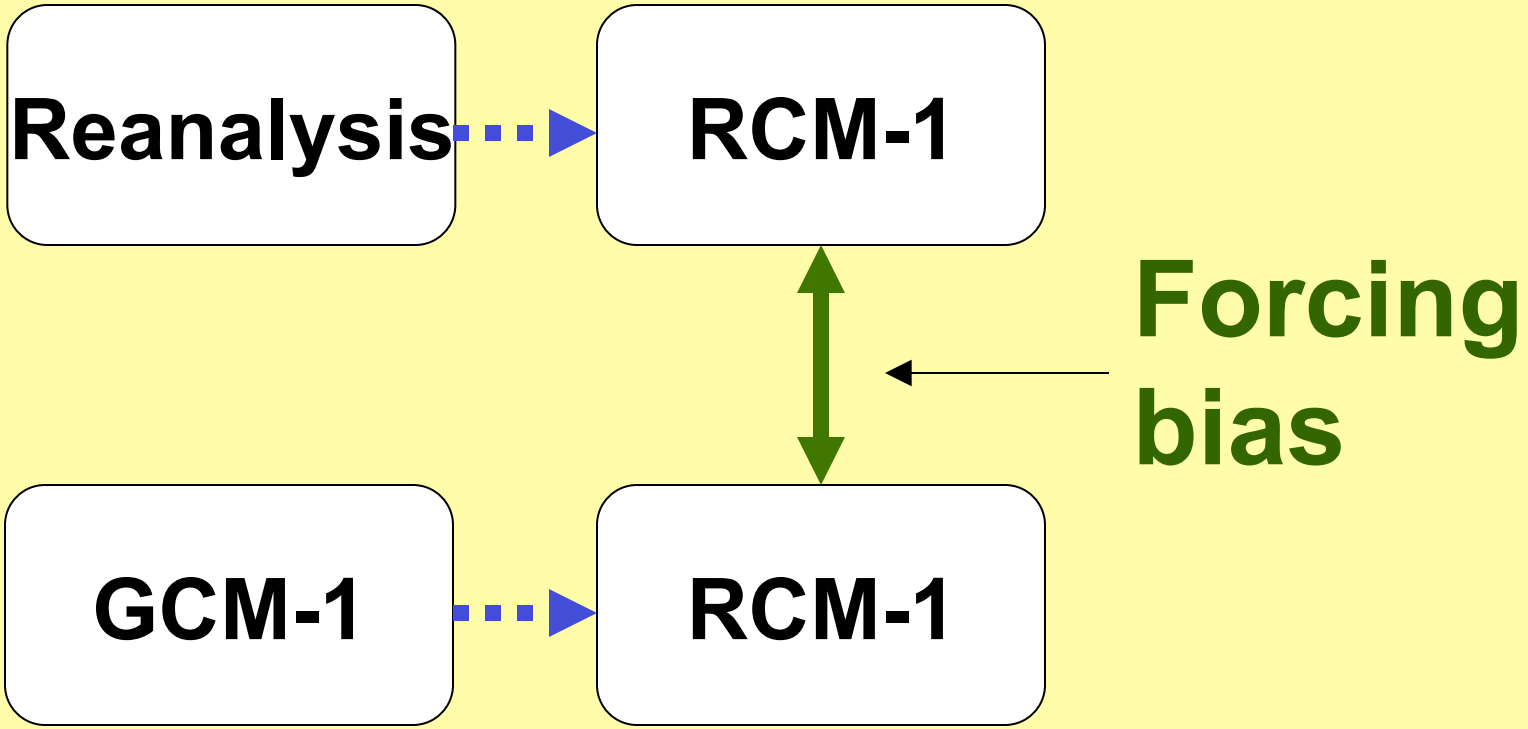
Definition of Biases



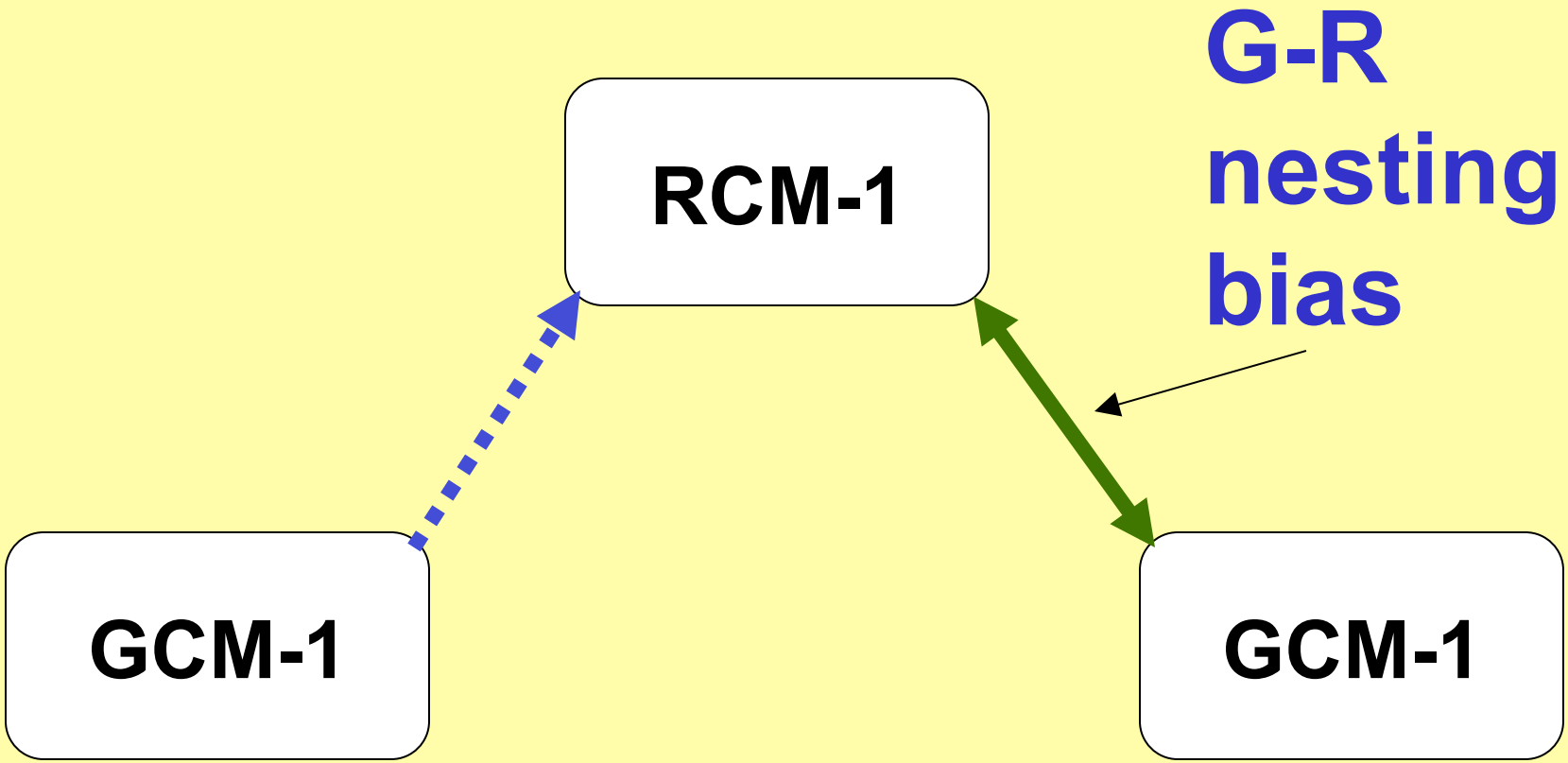
Definition of Biases



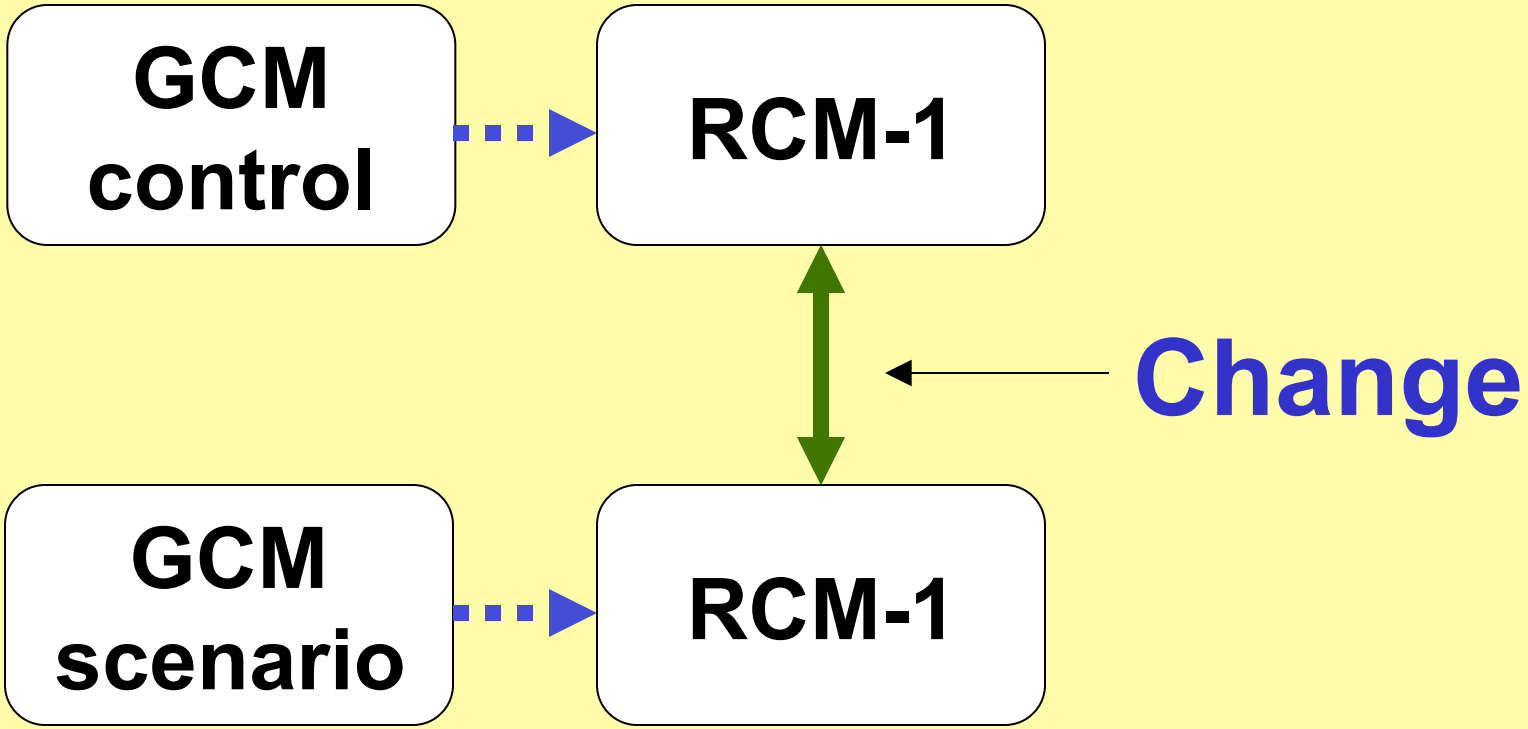
Definition of Biases

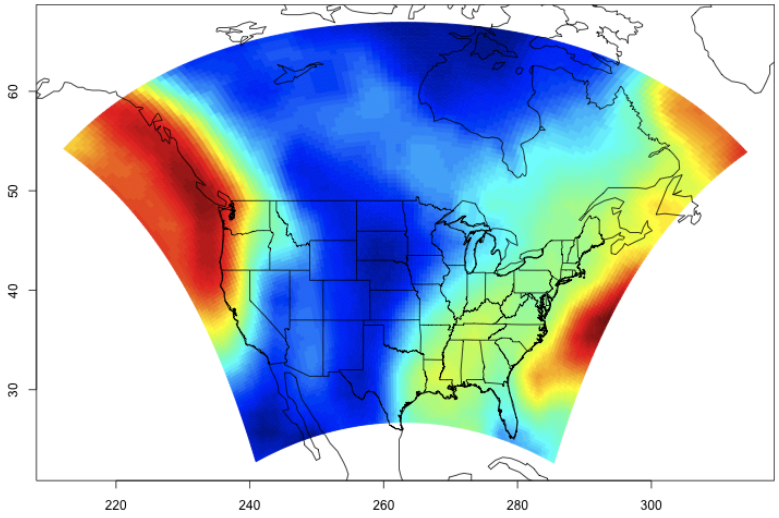


Definition of Biases

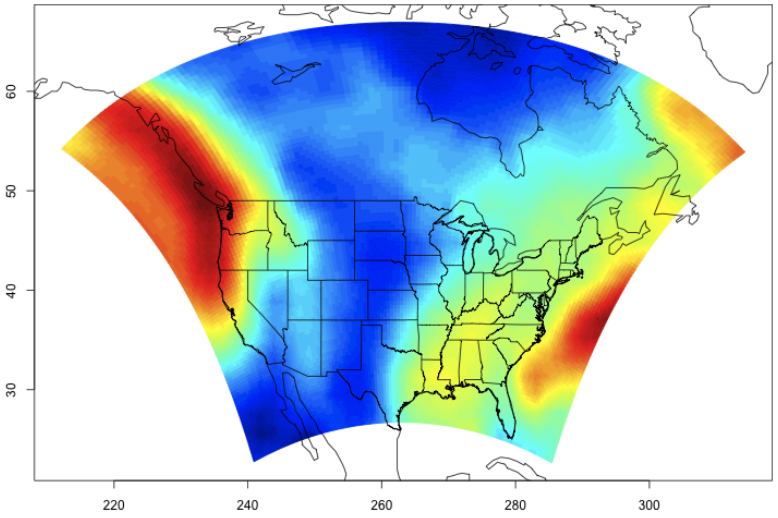


Climate Change

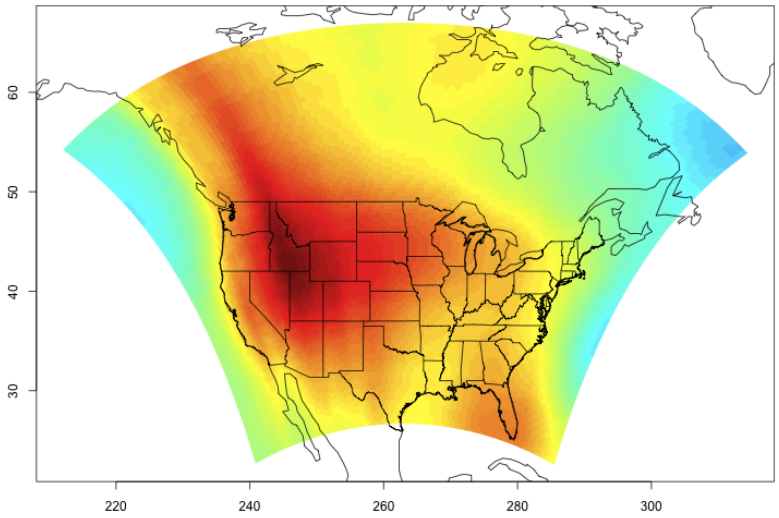




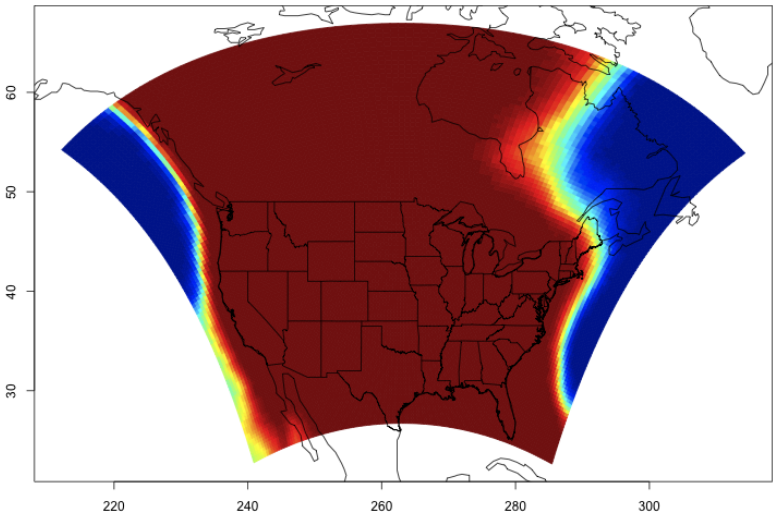
$\overline{\text{NCEP}}$



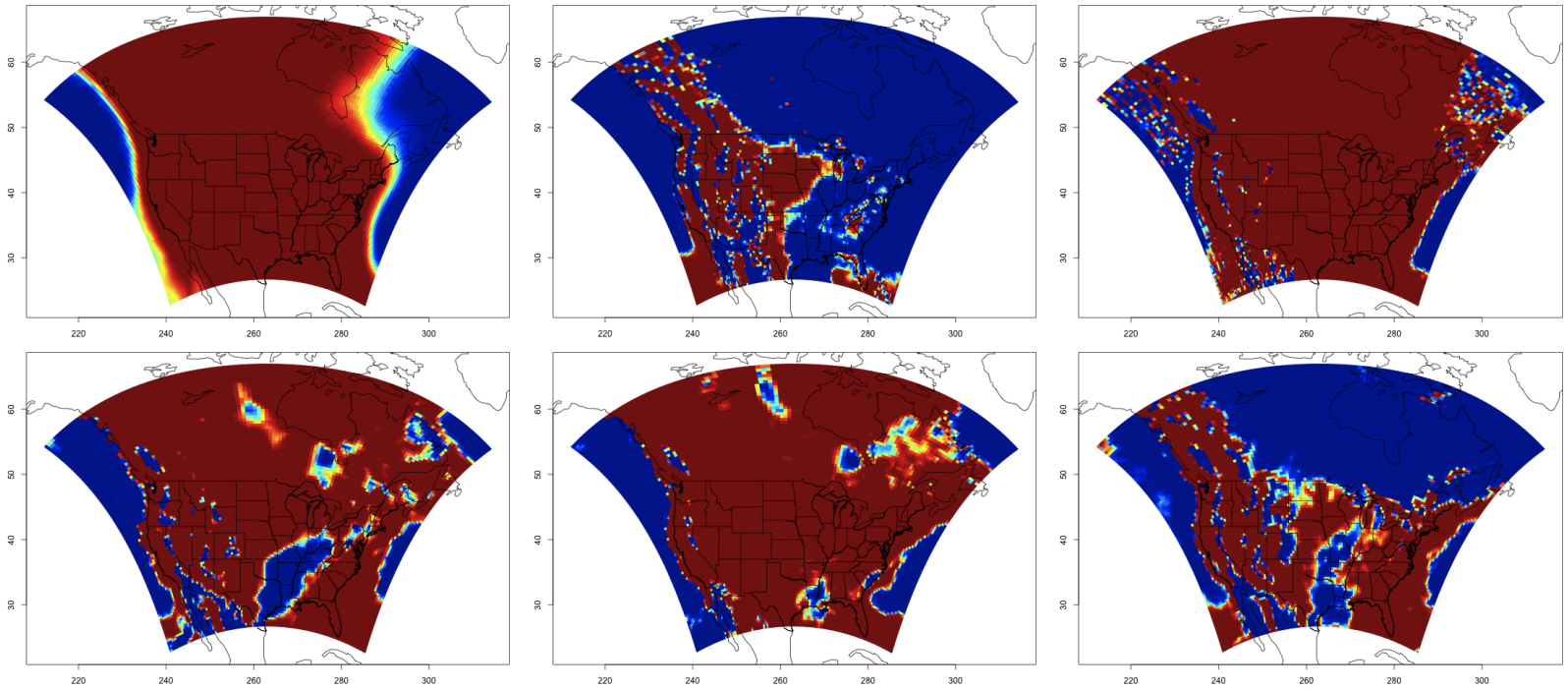
$\bar{\mu}$



$\bar{\mu} - \overline{\text{NCEP}}$



$P[\mu > \overline{\text{NCEP}}]$



ALL CRCM ECPC
MM5 RCM3 WRFP

Performance of CORDEX RCMs in Simulating East African Rainfall

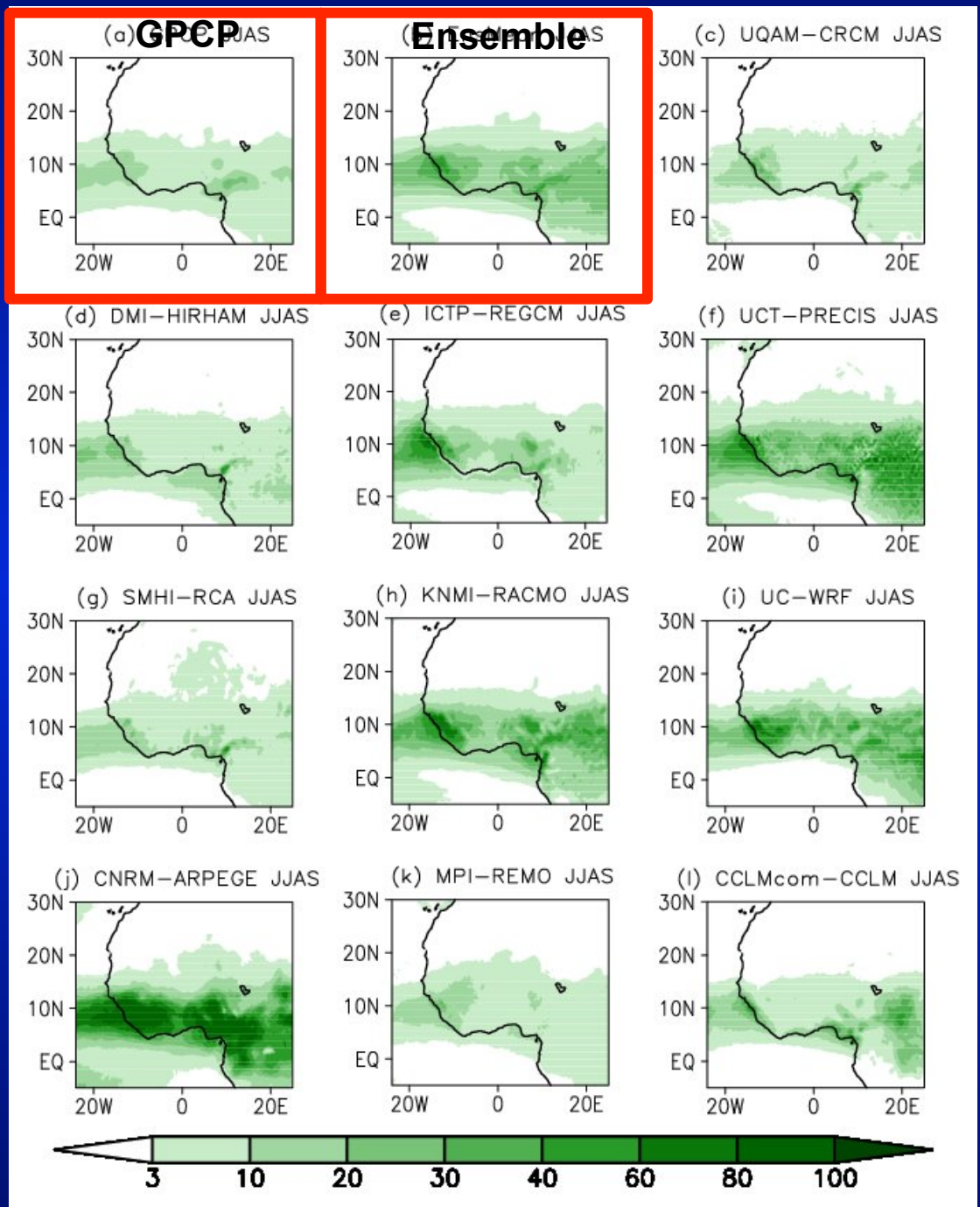
The first two figures below show the spatial distribution of rainfall for seasons JAS (fig1 a) and OND (fig1 b) averaged from 1990 to 2008 for the RCMs simulations and GPCC observation over the East Africa. The seasonal choice was based on the rainy season in the region. The maximum rainfall is located in north of equator during JAS(fig1a), and south of the equator during OND (fig1b) which is in association with the movement of ITCZ.

The results shows that most of the RCMs simulated the realistic rainfall belt well along the ITCZ except overestimation the magnitude. The ensemble is found to be more close to observation in representing spatial rainfall distribution over the region.

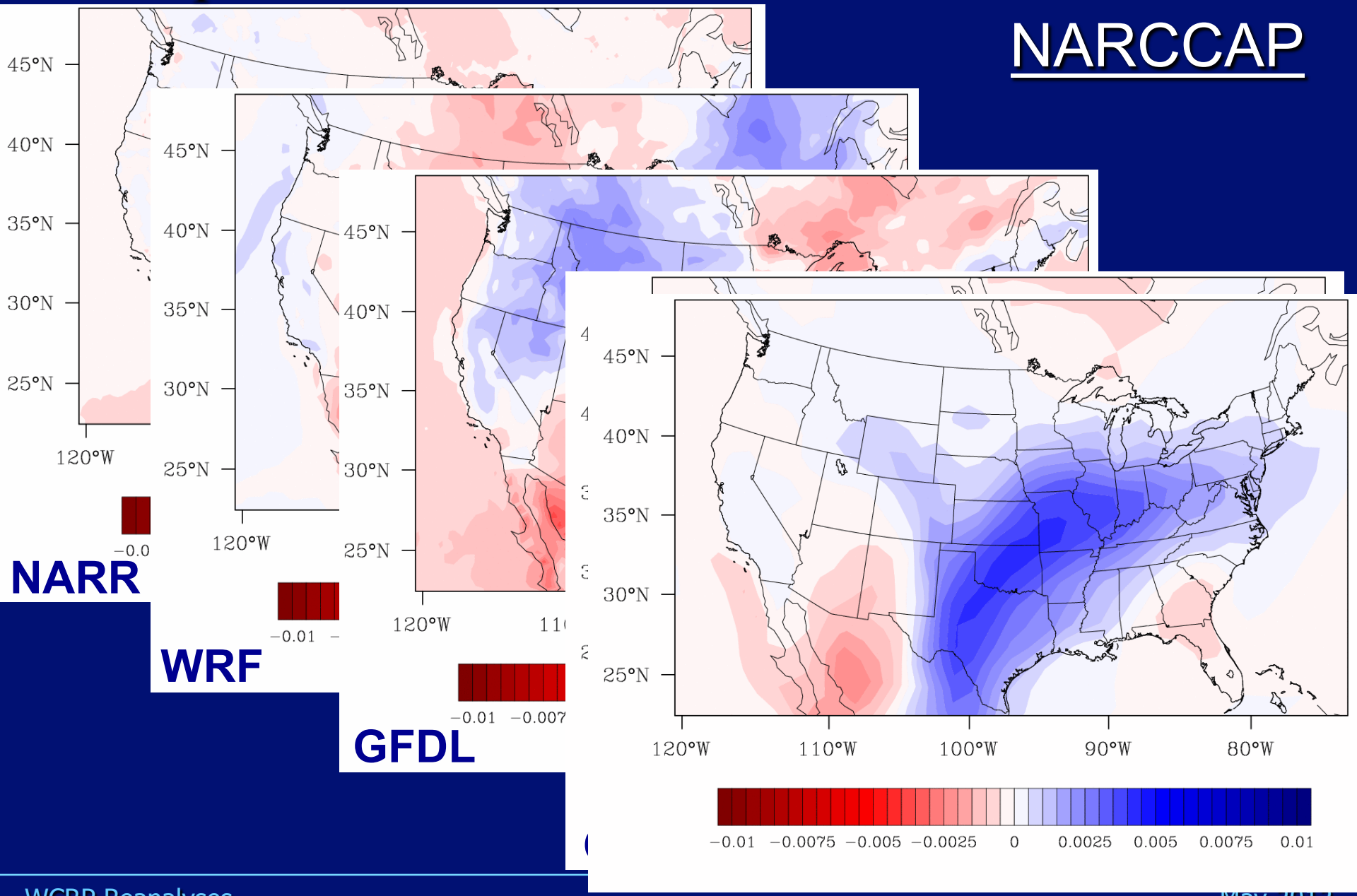
Fig2 shows the comparison between CORDEX-RCMs simulation and observed(GPCC) spatial averaged seasonal mean rainfall anomaly during OND in CORDEX Africa sub-region 5. Most of the RCMs realistically simulate the inter-annual rainfall variability in agreement with the observation, except overestimation in some of the RCMs. All the RCMs capture the 1997 high rainfall event which is associated with strong El Nino occurrence.

In general, the analysis indicating that the CORDEX RCMS are useful in providing many regional details that GCMs fail to capture due to the limited resolution. The first notable problem in most of the CORDEX RCMs is the overestimation of rainfall.

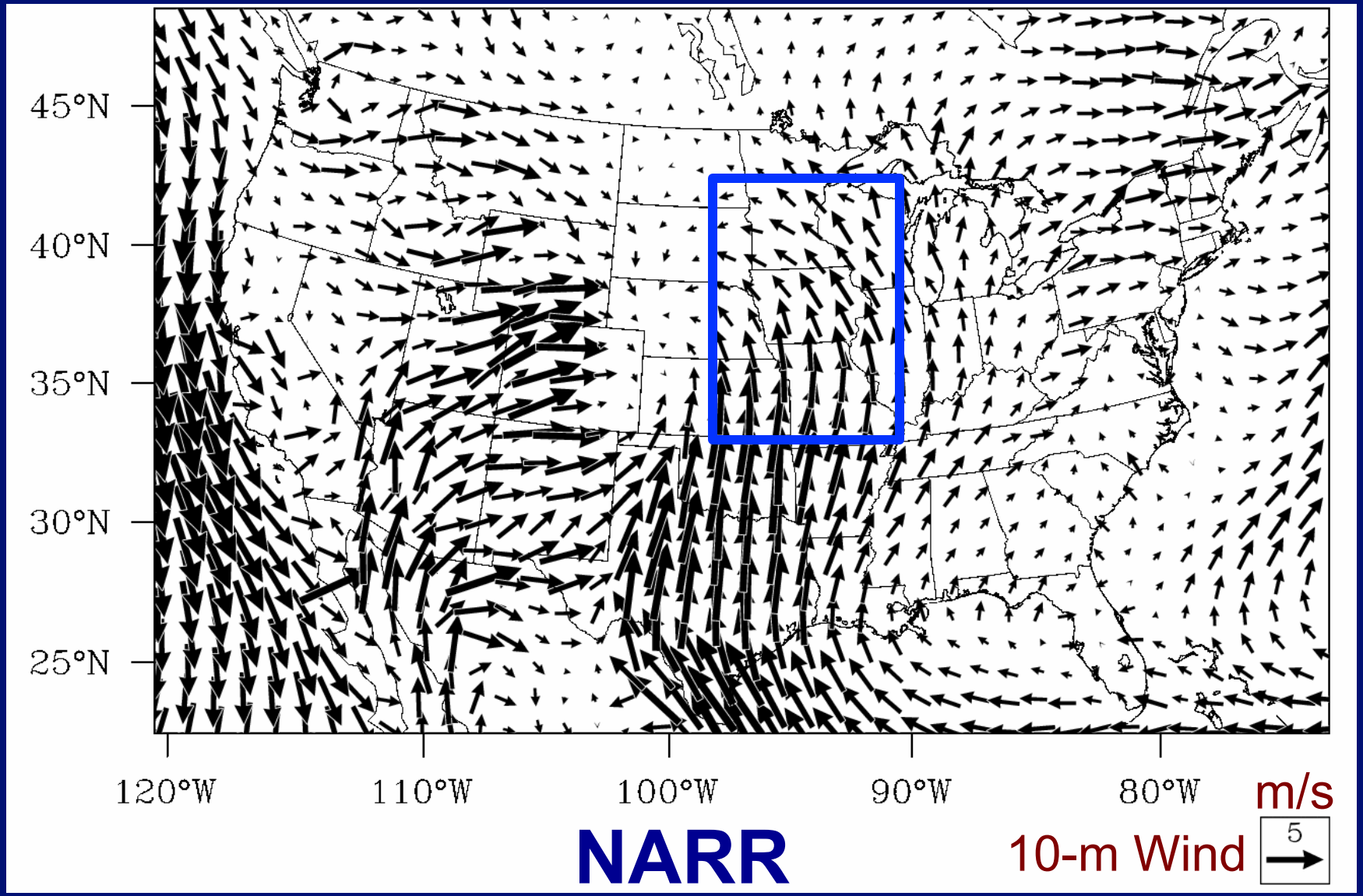
CORDEX Africa: Frequency of West Africa Wet Spells (1989-2008 ; JJAS)



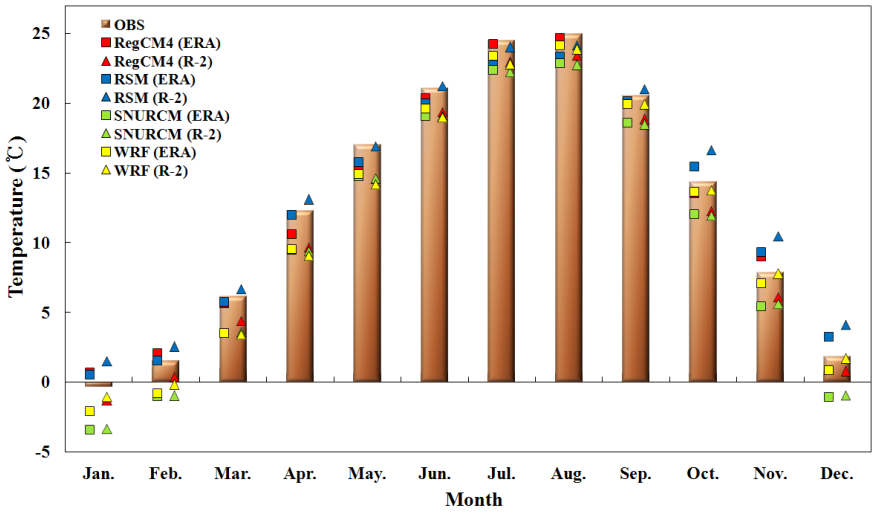
Composite Structure of Extreme Events - JJA

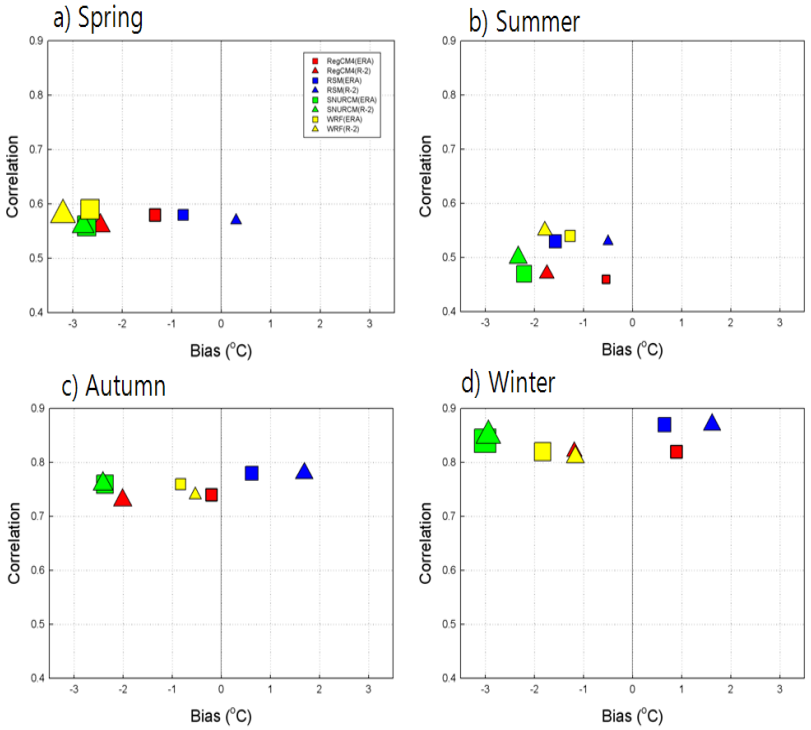


Composite Structure of Extreme Events - JJA

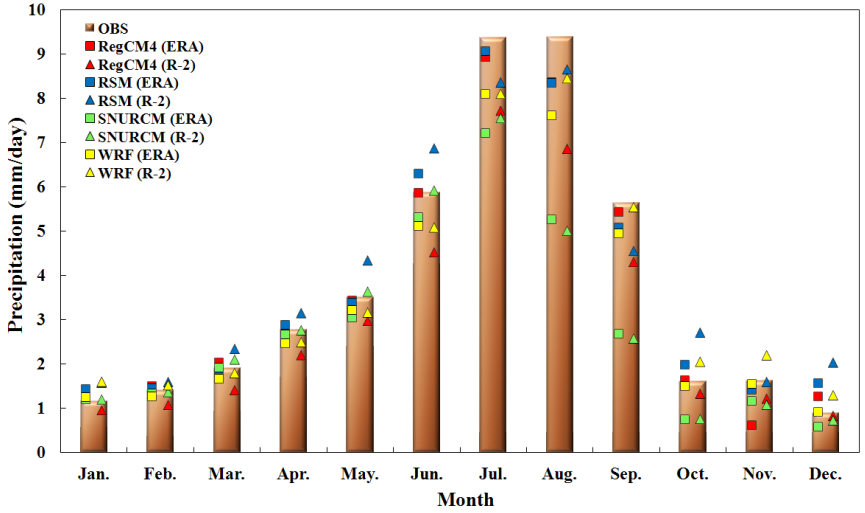


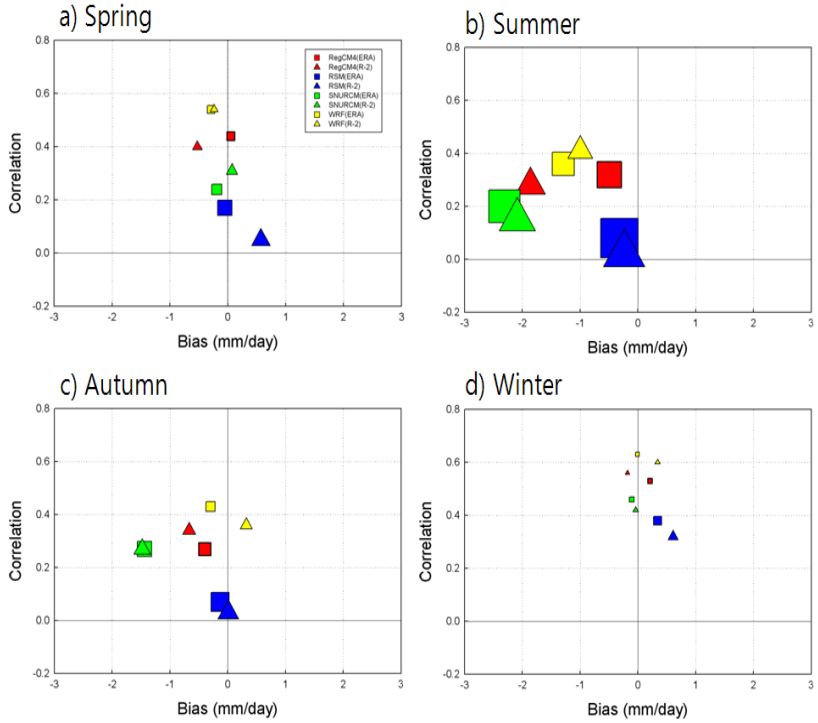
Temperature



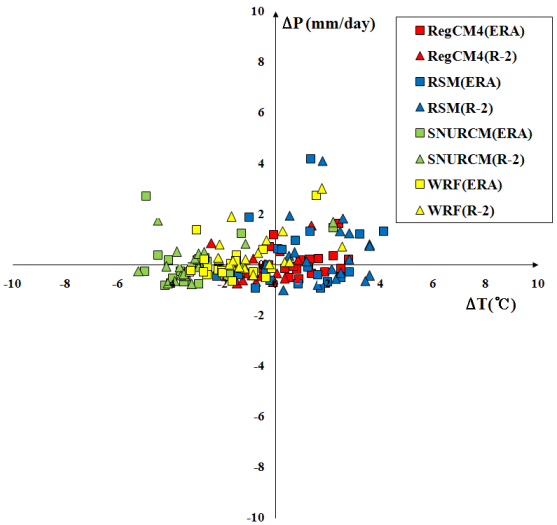


Precipitation

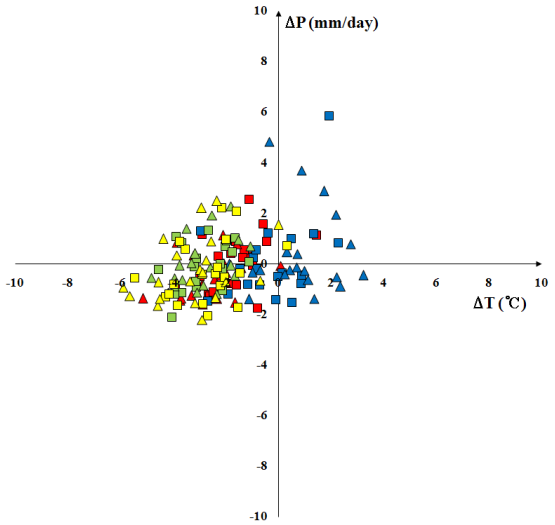




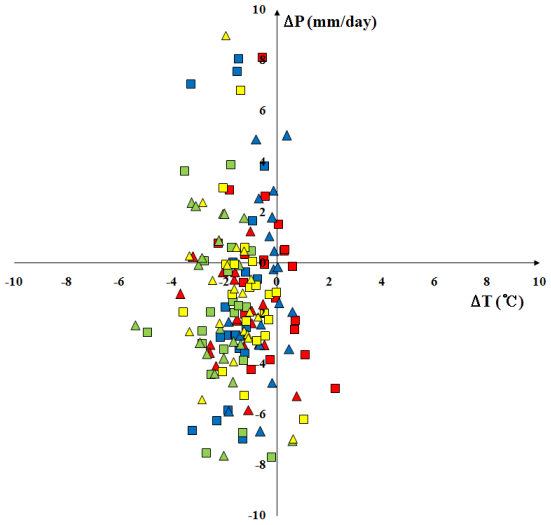
a) Jan.



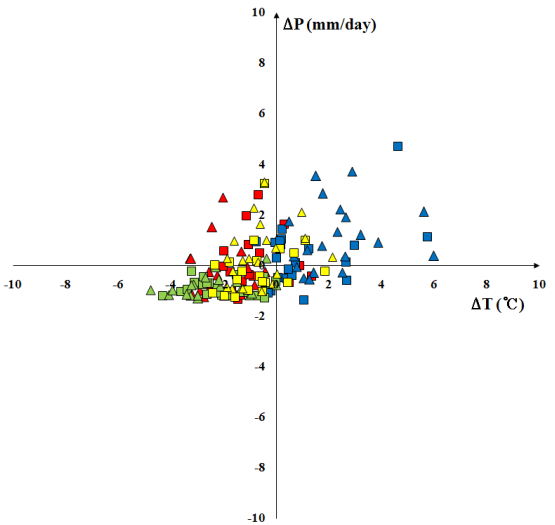
b) April

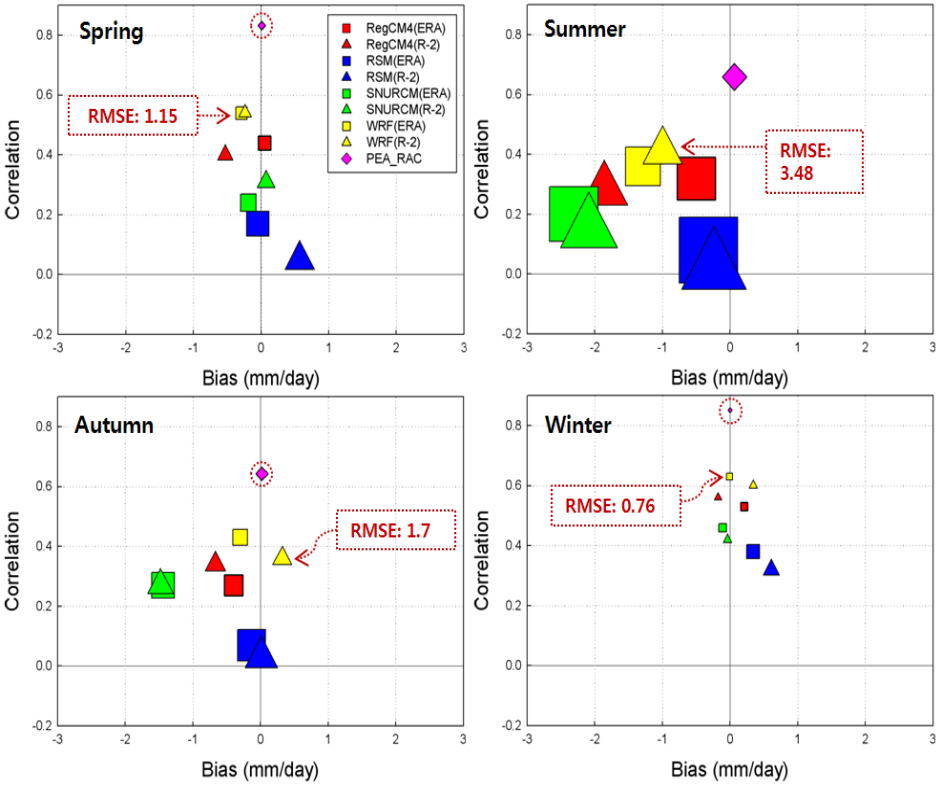


c) July



d) Oct.

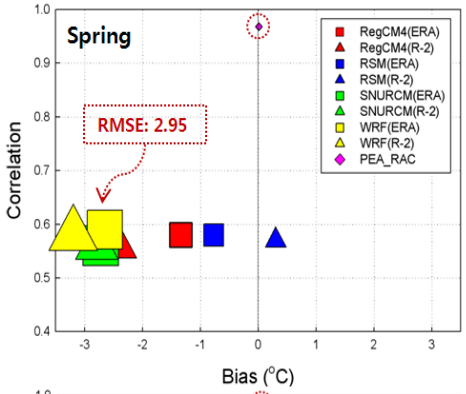


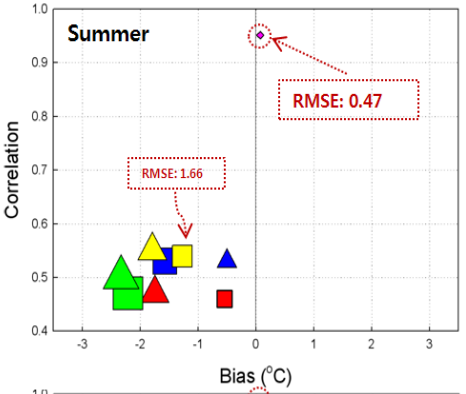

Spring
RMSE: 1.15
RegCM4(ERA)
RegCM4(R-2)
RSM(ERA)
RSM(R-2)
SNURCM(ERA)
SNURCM(R-2)
WRF(ERA)
WRF(R-2)
PEA_RAC
Correlation
Bias (mm/day)

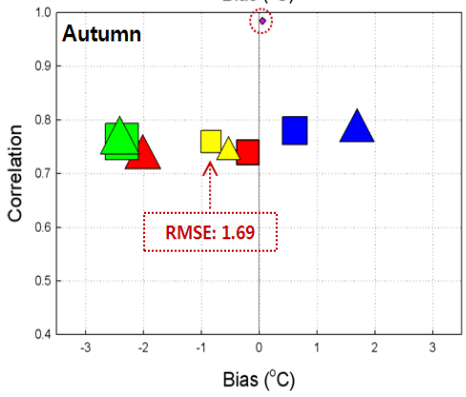
Summer
RMSE: 3.48
Correlation
Bias (mm/day)

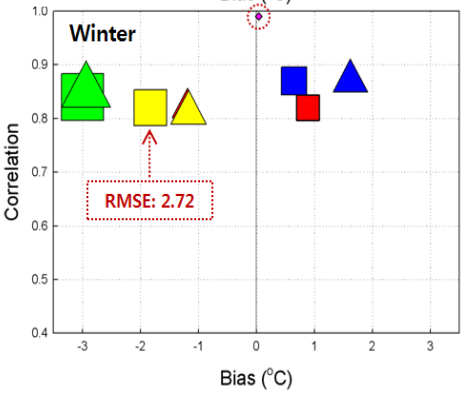
Autumn
RMSE: 1.7
Correlation
Bias (mm/day)

Winter
RMSE: 0.76
Correlation
Bias (mm/day)


Spring
RMSE: 2.95
RegCM4(ERA)
RegCM4(R-2)
RSM(ERA)
RSM(R-2)
SNURCM(ERA)
SNURCM(R-2)
WRF(ERA)
WRF(R-2)
PEA_RAC
Correlation
Bias (°C)


Summer
RMSE: 0.47
RMSE: 1.66
Correlation
Bias (°C)


Autumn
RMSE: 1.69
Correlation
Bias (°C)


Winter
RMSE: 2.72
Correlation
Bias (°C)

Summary of reanalysis downscaling analysis

- HadRM3P-NCEP has by far the largest seasonal temperature biases (see BAMS article)
- HadRM3P has no systematic tendency for significant positive temperatures biases (Xu et el., 2006 over China, Marengo et al., 2009 over South America, Kamga et Buscalet, 2006, over Africa)
- Previous studies have used ECMWF boundary conditions, ERA-15, ERA-40 or ERA-Interim reanalyses
- HadRM3P-ERA-Interim data produces significantly lower (5K) temperature biases - and similar in magnitude to the other RCMs.

Some reasons for differences in the downscaled reanalyses

- At the boundary of the NARCCAP domain the NCEP data are both warmer and moister in the lower troposphere and in the upper troposphere/stratosphere – directly increasing temperature and increasing downward longwave radaiation (from higher atmospheric humidities and, in winter, by increased cloud cover)
- In winter the warmer temperatures lead to reduced snow cover thus enhanced solar radiation absorption at the surface and in spring/summer lead to drier soils, lower evaporative cooling and lower cloud amounts enhancing surface solar radiation