On Recent Research Developments at NC State University Relevant to the MSU NSF Biocomplexity Project

'An Integrated Analysis of Regional Land-Climate Interactions'

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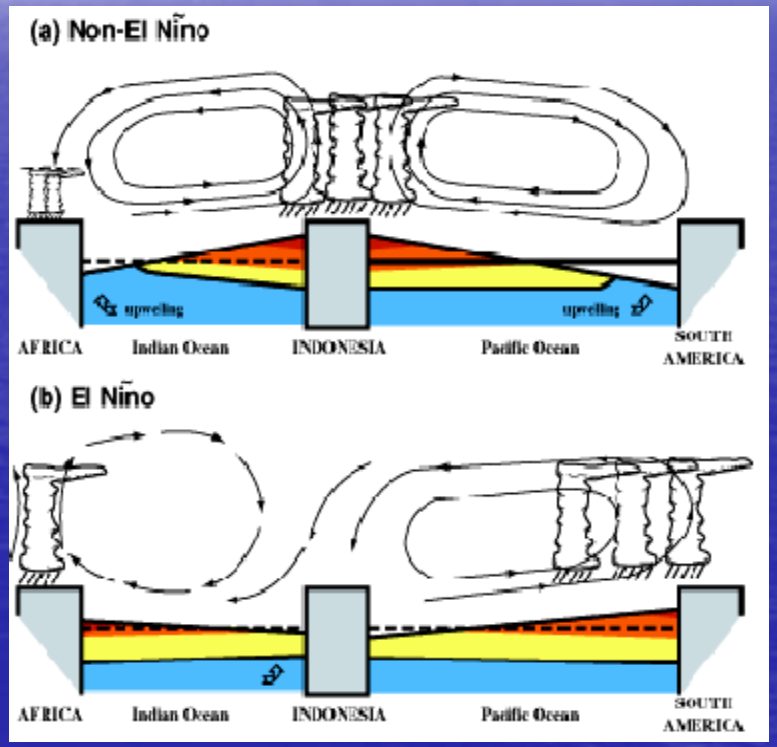
More Details

http://climlab4.meas.ncsu.edu

Climate Modeling Laboratory
NC State University

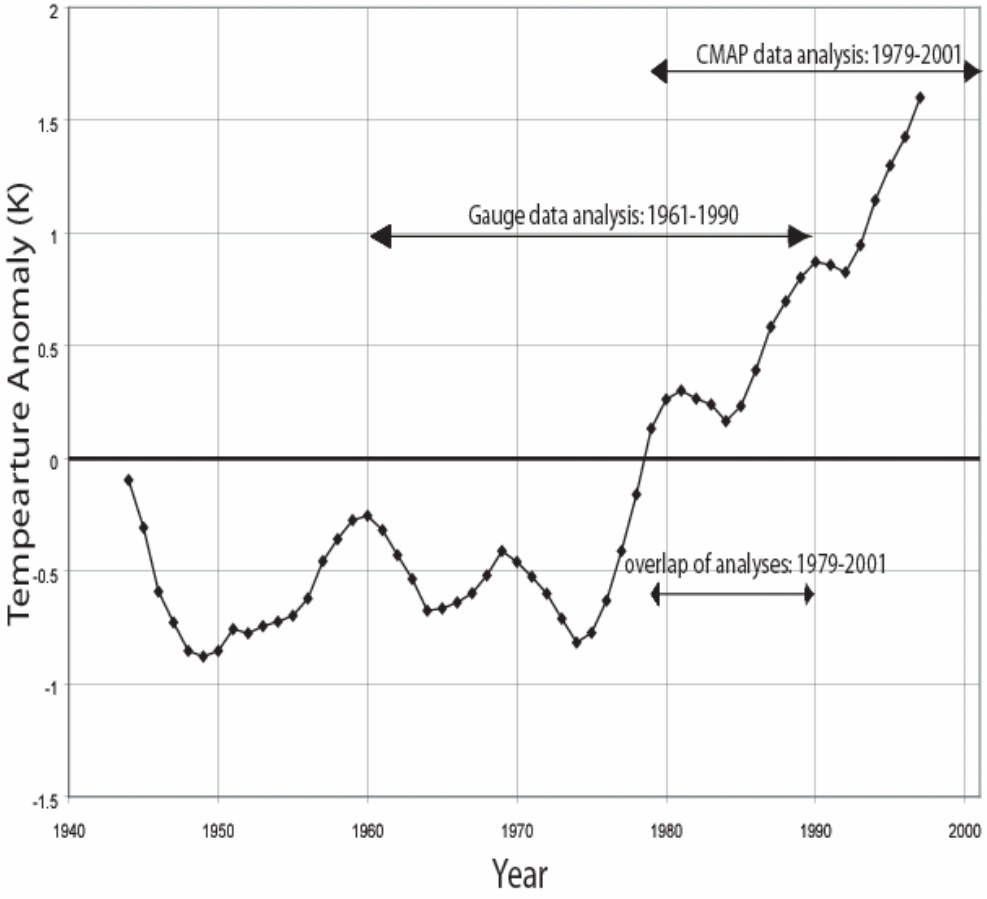
Demonstration of ENSO

- Dominant air/sea process of the tropical oceans
- Creates a shift in the Walker Circulation with an associated shift in Indian Ocean SST
- Greater Horn of Africa generally becomes wetter during a warm ENSO event
- Not all anomalous rainfall events are associated with ENSO.



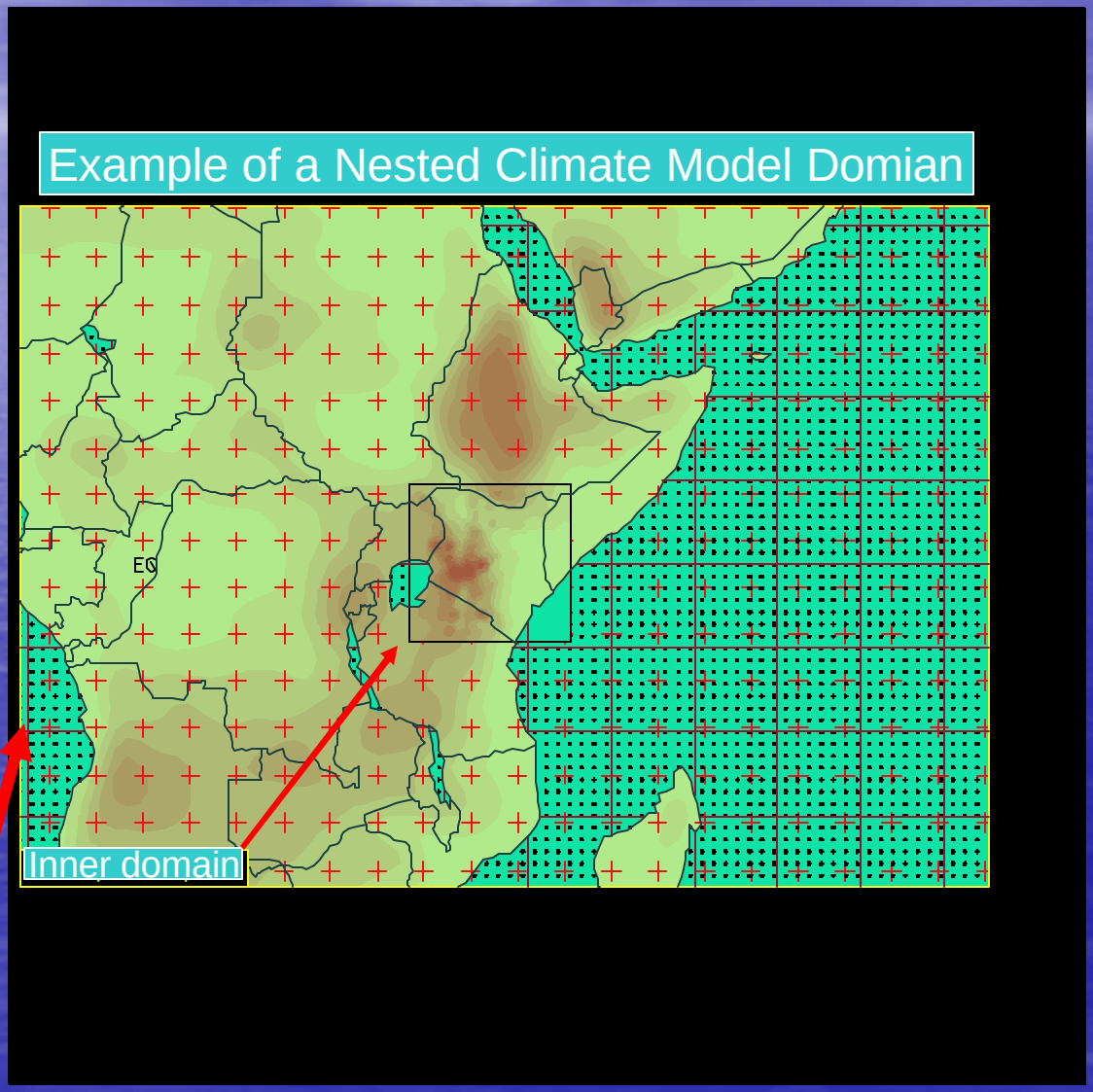
(Webster, http://dao.colorado.edu/~webster/mw/paper/naturepaper.html)

Global Warming Trend

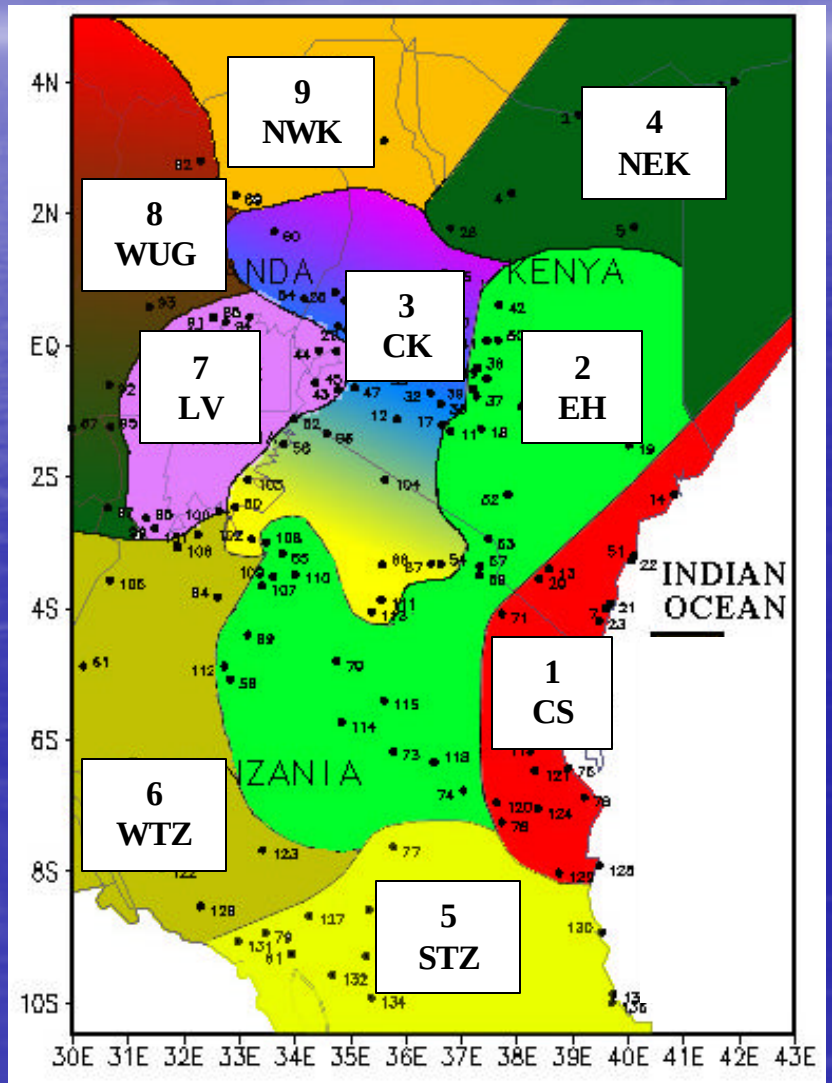


Customization of RCMs for Downscaling

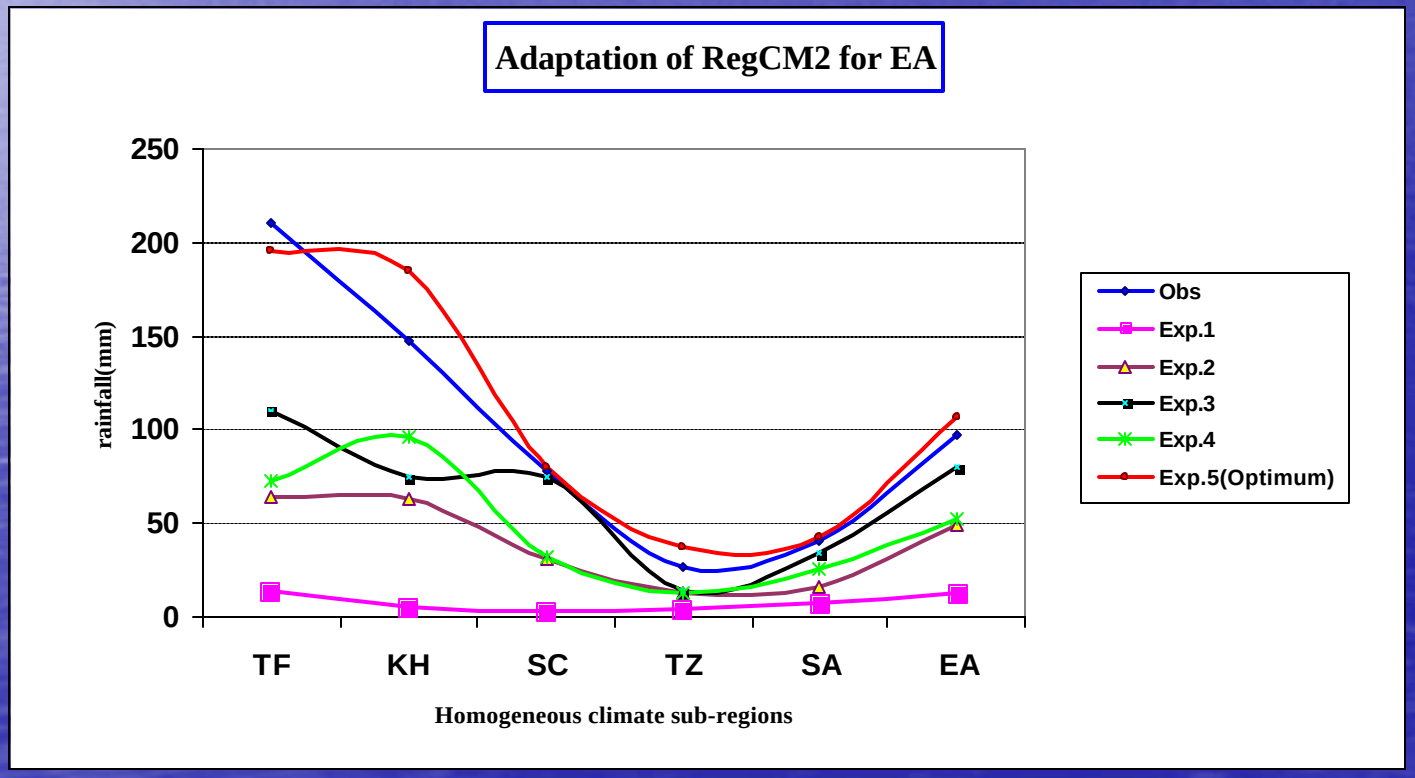
MODEL NUMERICAL DOMAIN



Eastern Africa Homogeneous Climatic Zones (Matayo & Semazzi, 1999)

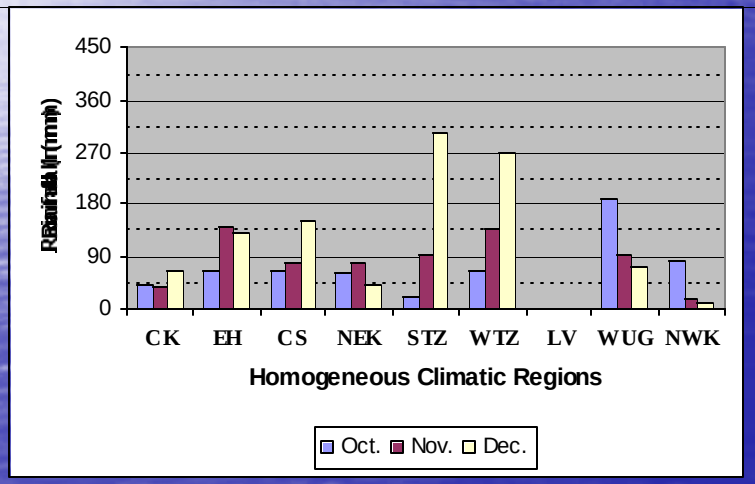


Optimization of Regional Numerical Models

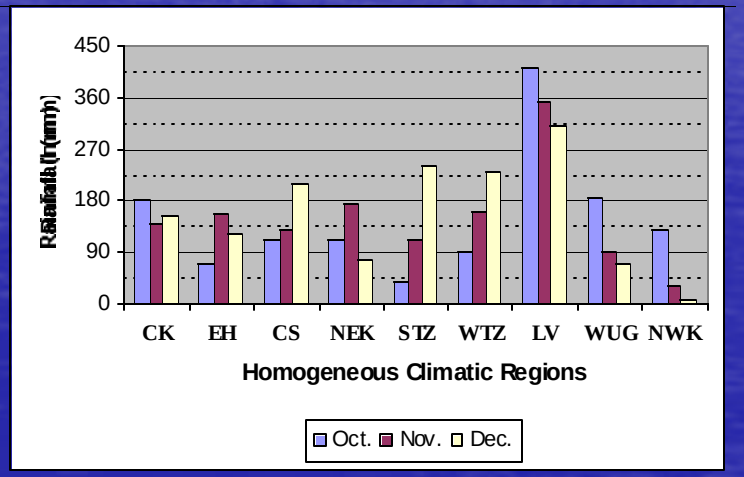


PERFORMANCE IN SIMULATING INTERA-SEASONAL VARIABILITY (RegCM2-NCSU Version – Semazzi et al, 1999)

Observations

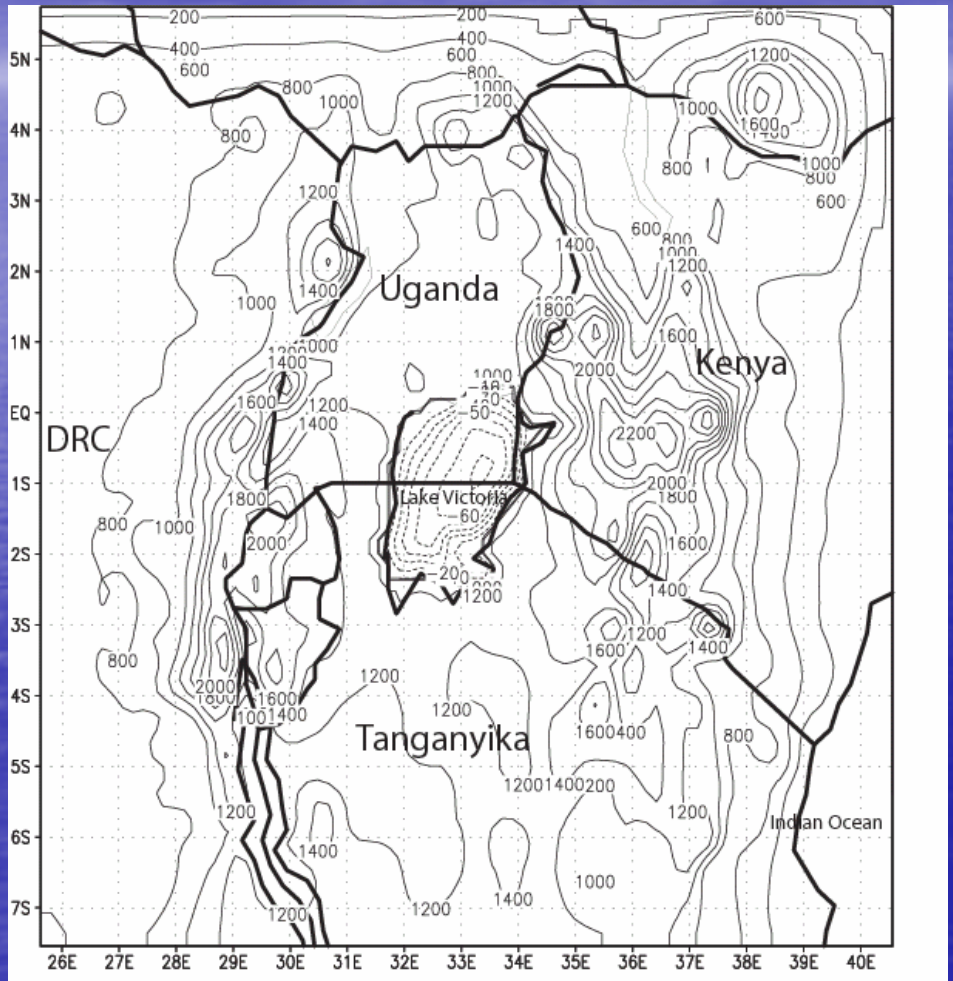


NCSU-RegCM2 Model



Importance of large lakes over Eastern Africa

Orography & Large Lakes



Model domain topography with horizontal resolution of 20 km (combined from NCAR dataset, and Johnson's Bathymetry data). unit: m.

PERFORMANCE IN SIMULATING VARIABILITY AT WATERSHED SCALES – Semazzi et al (2002)

- Coupled POM-RegCM2 model for Lake Victoria Basin-

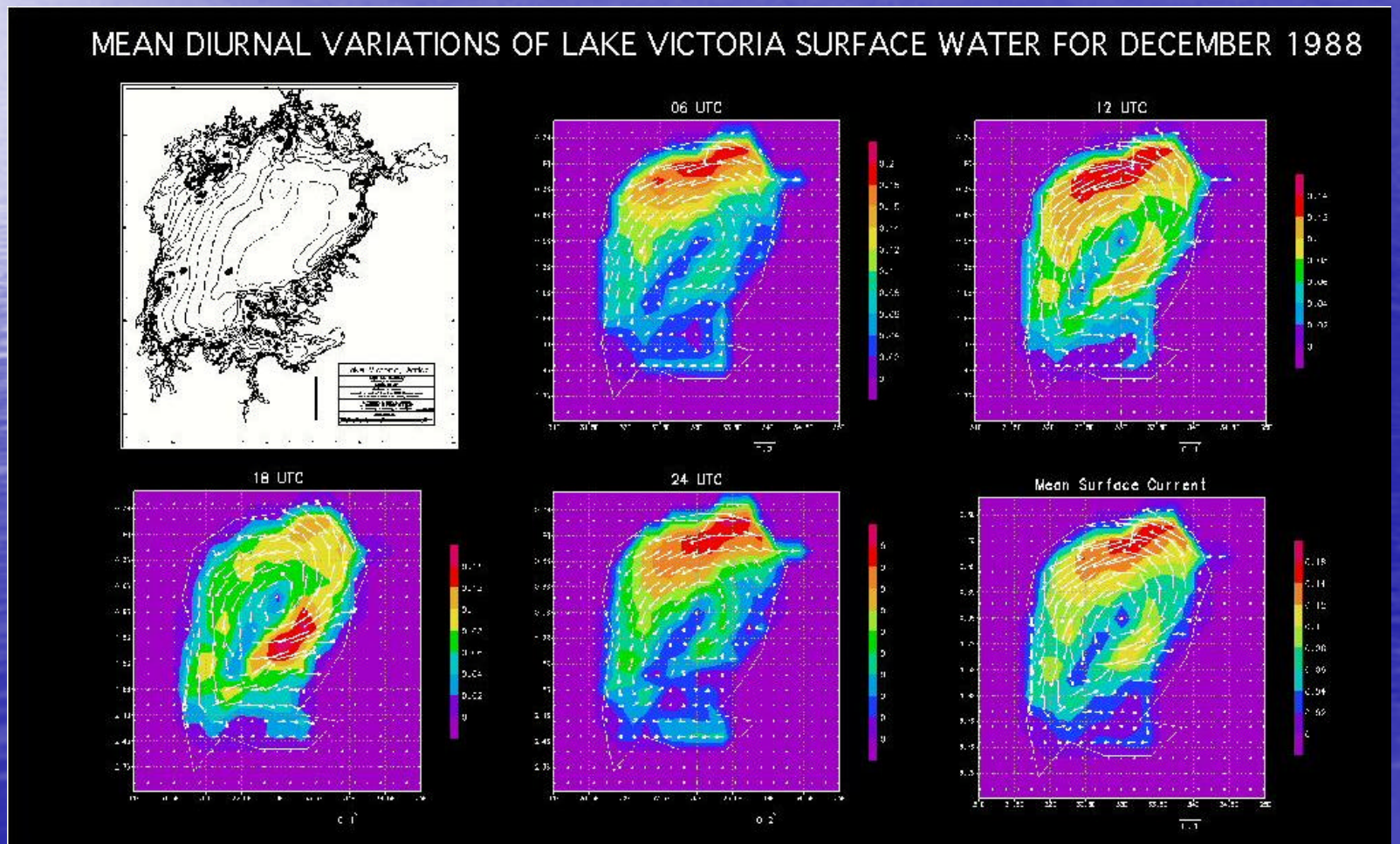


Table-1

Lake	Area (sq. Km)	Volume (cu. Km)	Maximum depth (m)
Victoria	69,463 (2nd)	2,700 (8th)	92 (not among top)
Malawi	28,878 (10th)	7,725 (5th)	706 (4th)
Tanganyika	31,986 (7th)	18,900 (3rd)	1,464 (2nd)
Michigan	57,800 (6th)	4,910 (6th)	180 (not among top)

Table-3

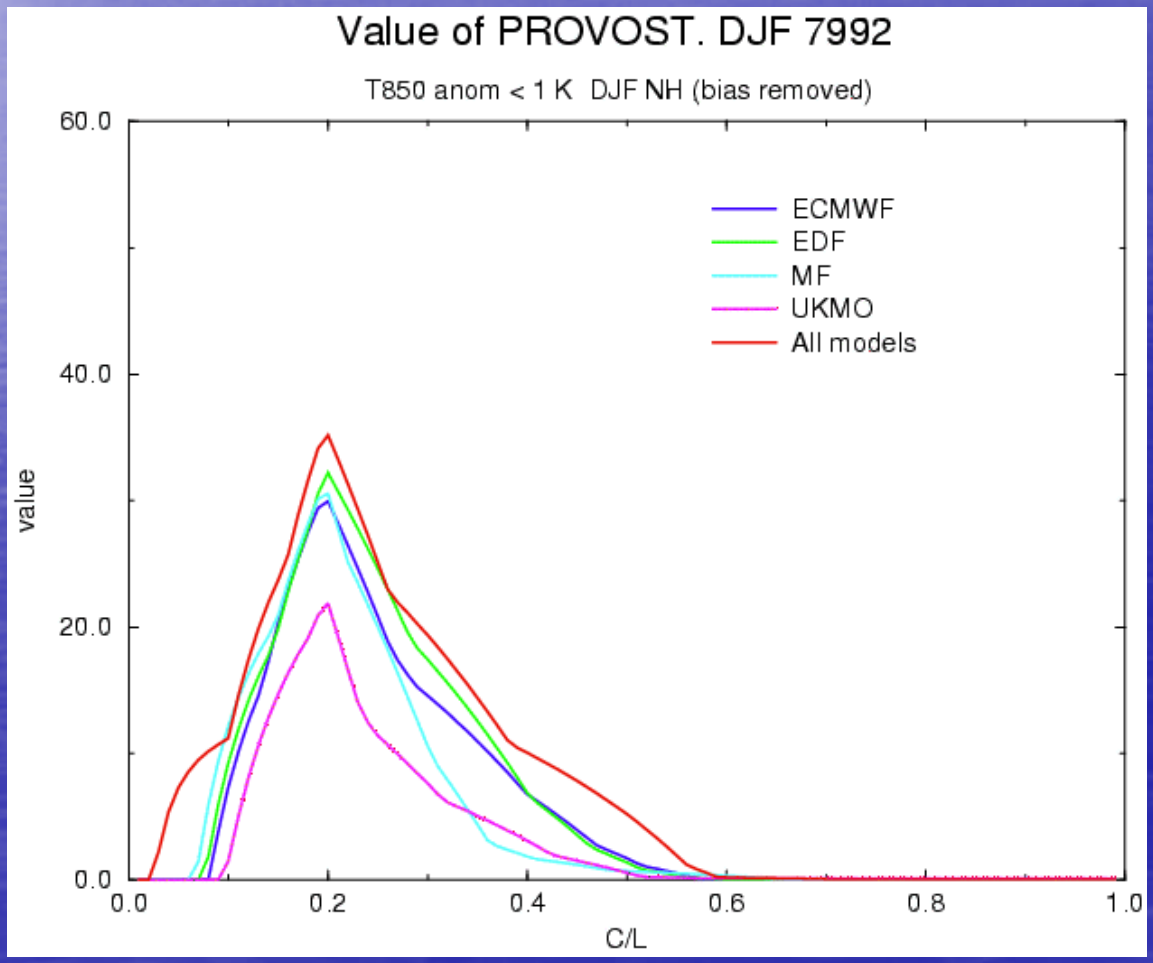
	RegCM2-POM	POM	RegCM2-1D	Observed
Mean LST	24.4 °C	22.4 °C	23.3°C	25.2°C
Difference (model-observed)	-0.8 °C	-2.8 °C	-1.9 °C	0
Difference (%)	-3.17%	-11.11%	-7.54%	0

Table-2

	RegCM2-POM Coastal (C) entire lake basin (EB)	RegCM2/1-D Coastal (C) entire lake basin (EB)	Observed Coastal(C) entire lake basin (EB)
Actual (mm)	143.5 (C) 140.0 (EB)	157.75 (C) 146.7 (EB)	130 (C) 135 (EB)
Difference (mm) (simulation-observed)	13.5 (C) 5.1 (EB)	27.75 (C) 11.7 (EB)	0 (C) 0 (C)
Difference (%)	10.38% (C) 3.77% (EB)	21.35% (C) 8.67% (EB)	0 % (C) 0 % (EB)

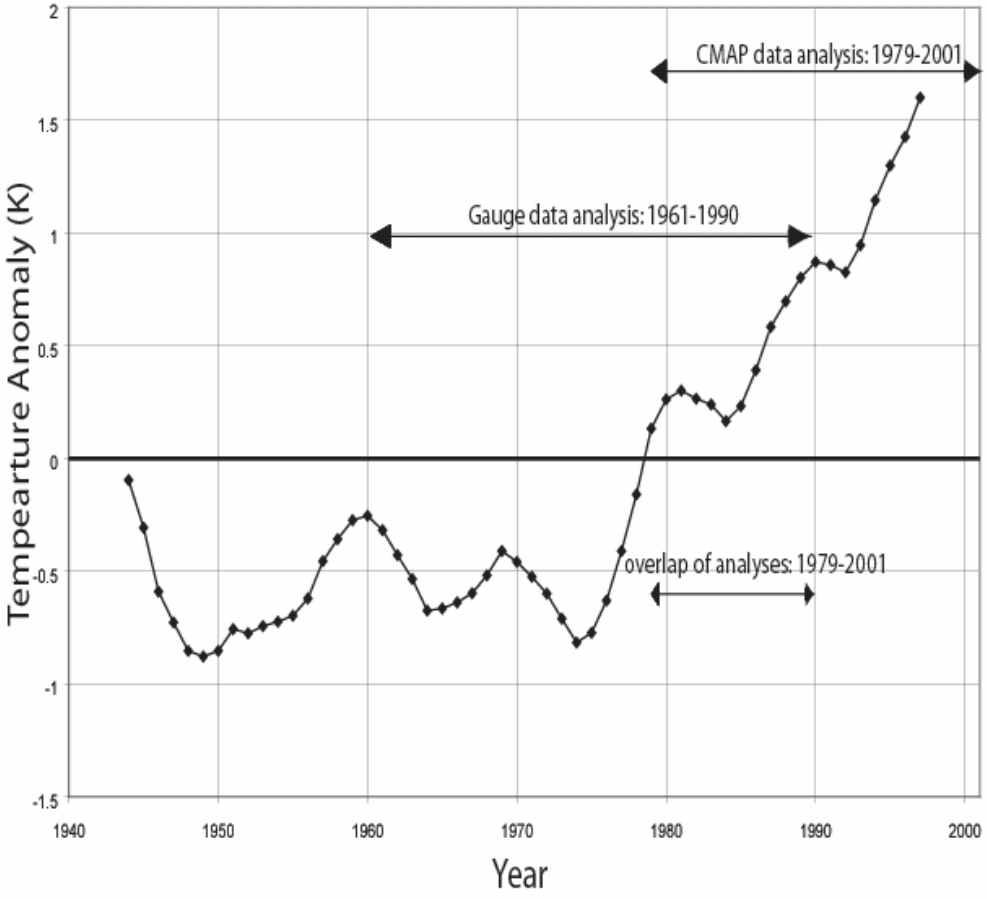
Ensemble Model Prediction Research

Advantages of Ensemble Climate Model Projections
(Palmer et al, 1999)

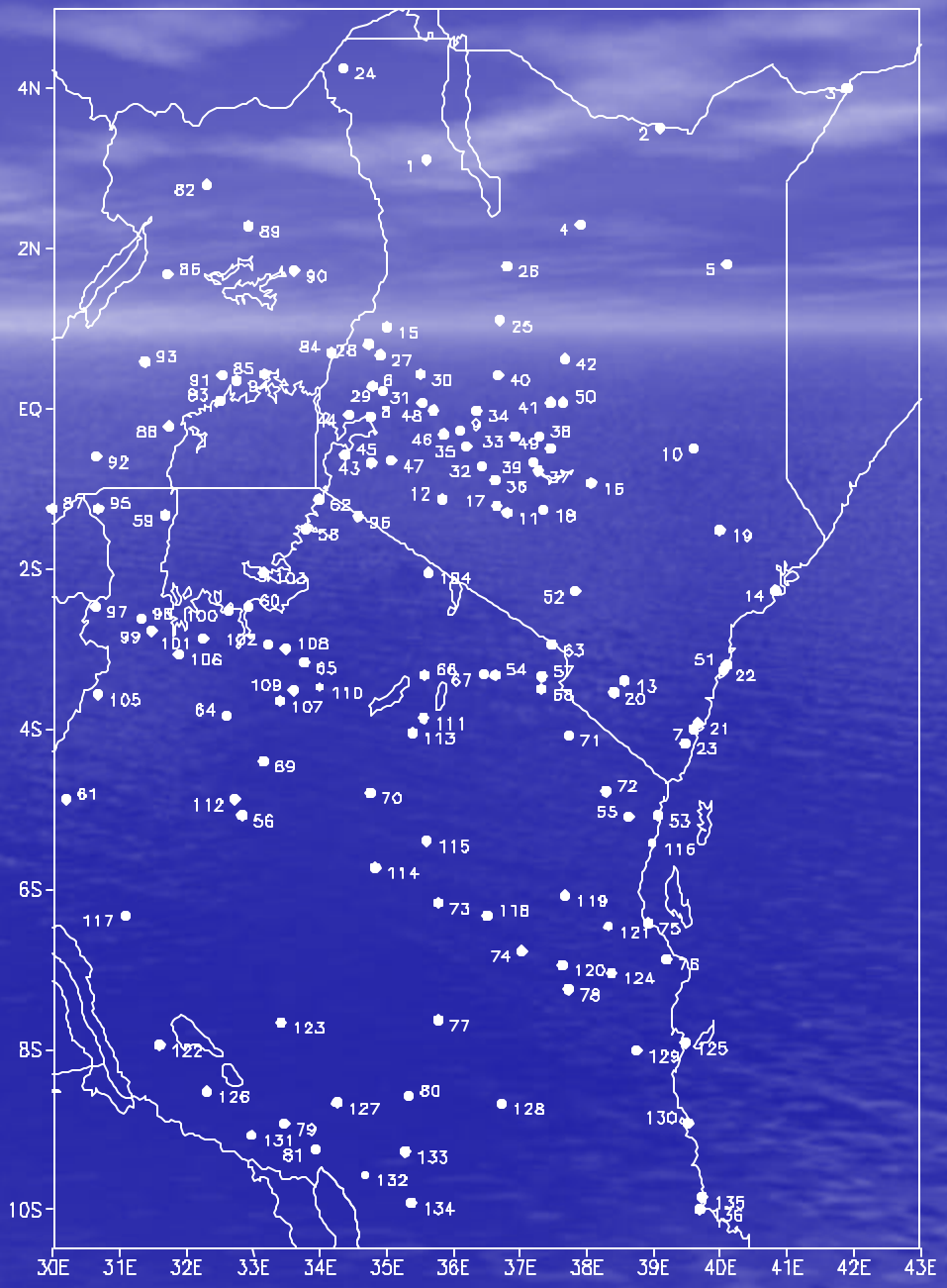


Dominant Modes of Climate Variability Over Eastern Africa

Global Warming Trend



- Rain Gauge Data comes from 144 stations (1961-90)
- CMAP has a 2.5° Resolution (1979-2001)
- Averaged for OND



Construction of EOF Time Series

Correlation = Matrix $\begin{bmatrix} 1 \cdots & r_{p1} \\ \vdots & \vdots \\ r_{p1} \cdots & 1 \end{bmatrix}$

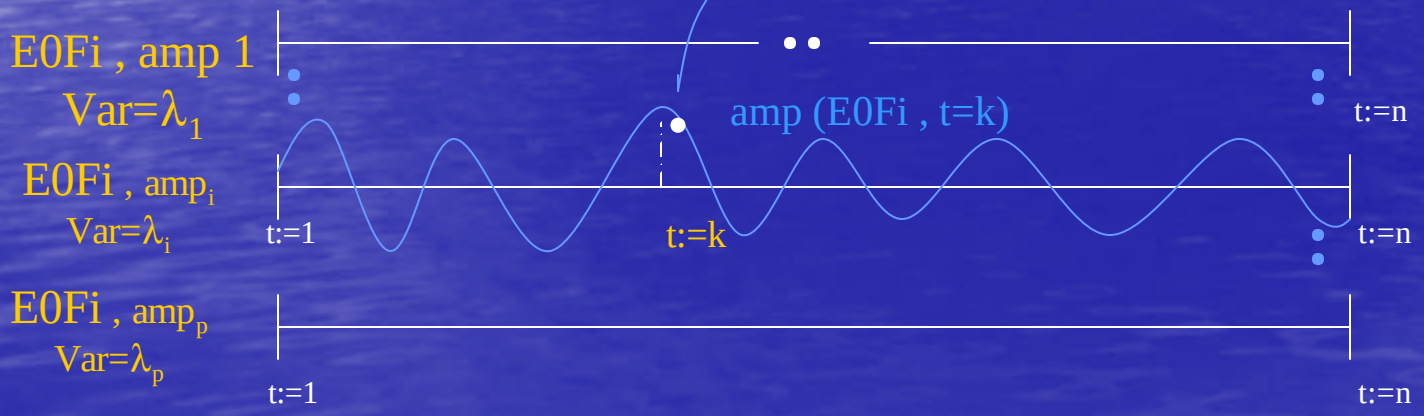
$\begin{bmatrix} Z_{11} \cdots & Z_{1k} \cdots & Z_{1n} \\ \vdots & \vdots & \vdots \\ Z_{p1} \cdots & Z_{pk} \cdots & Z_{pn} \end{bmatrix}$ =Data

data map at $t=kth$ Column

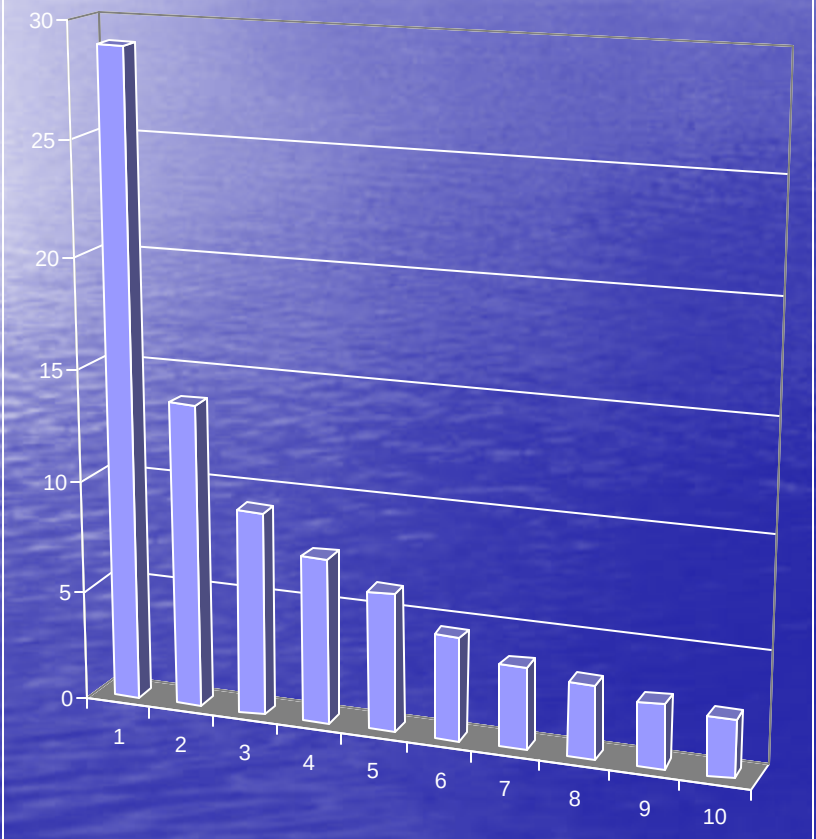
i^{th} eigen vector of R Matrix

$$[e_{i1}, e_{i2}, \ldots, e_{ip}] \bullet \begin{bmatrix} Z_{1k} \\ \vdots \\ Z_{pk} \end{bmatrix} = \text{amp}(\text{E0F}i\ t=k)$$

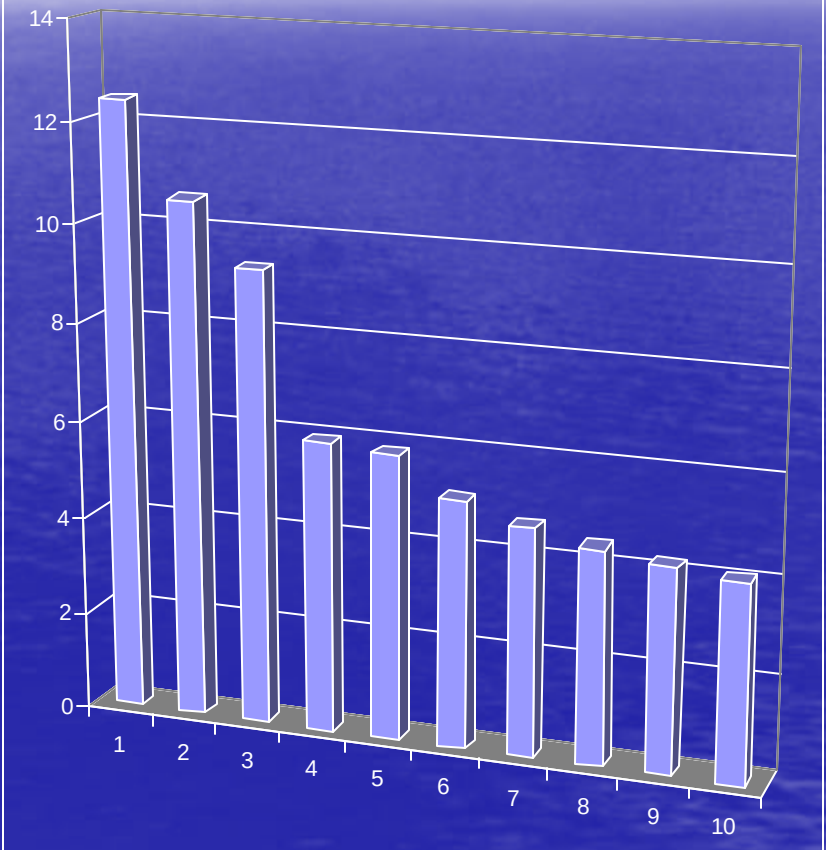
$$e_{i1}Z_{1k} + e_{i2}Z_{2k} + e_{i3}Z_{3k} + \cdots + e_{ip}Z_{pk}$$

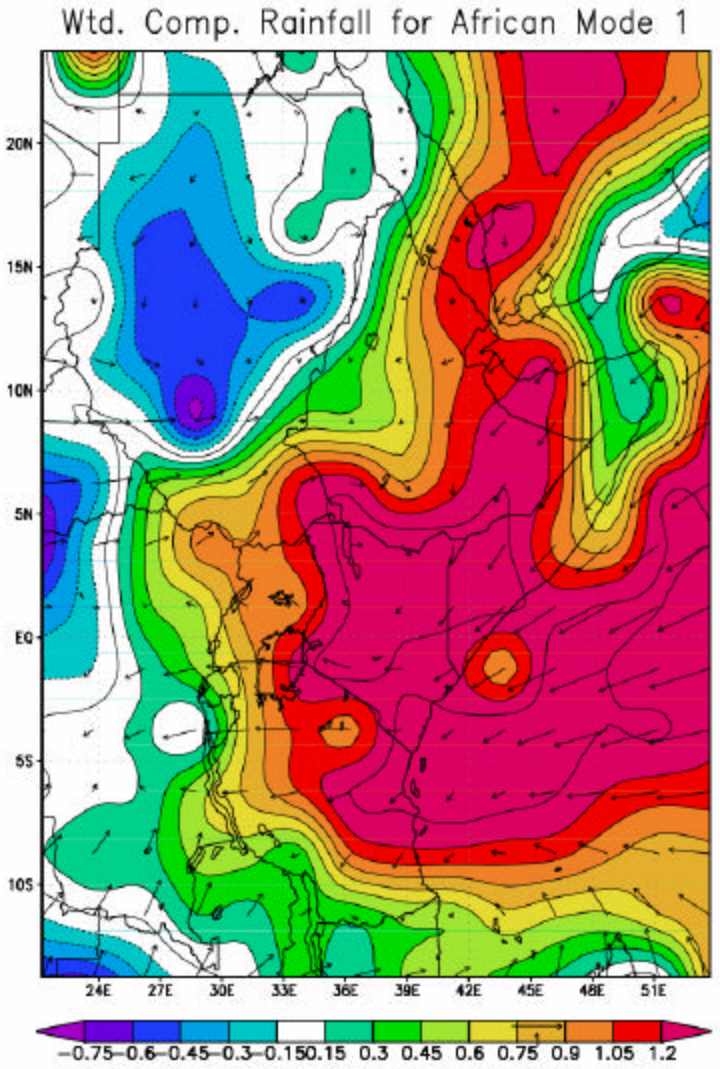


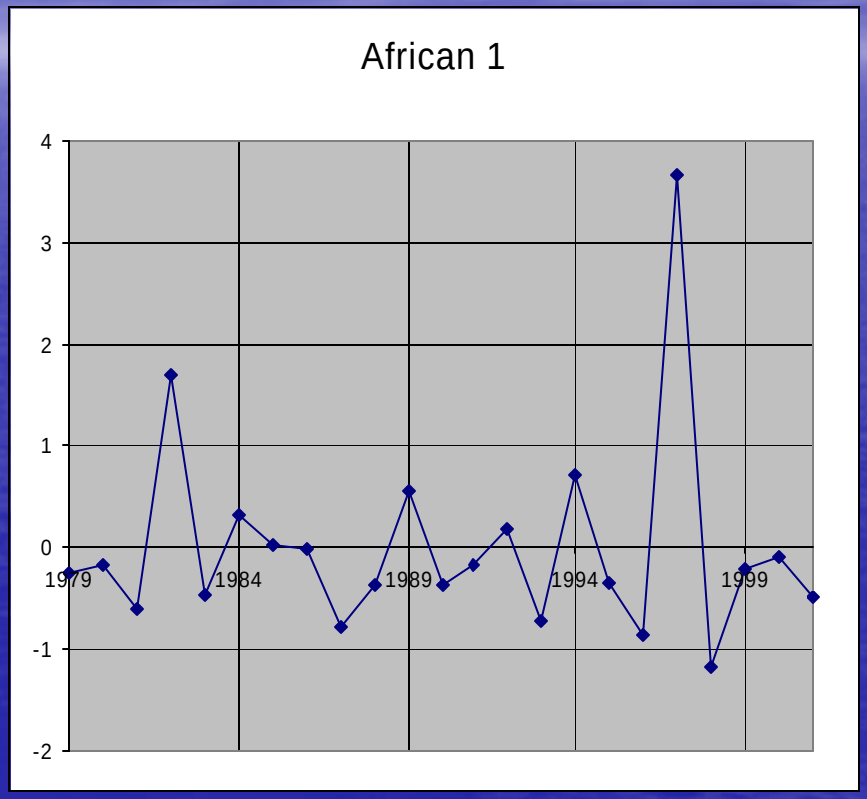
East African Rainfall EOF % Variance

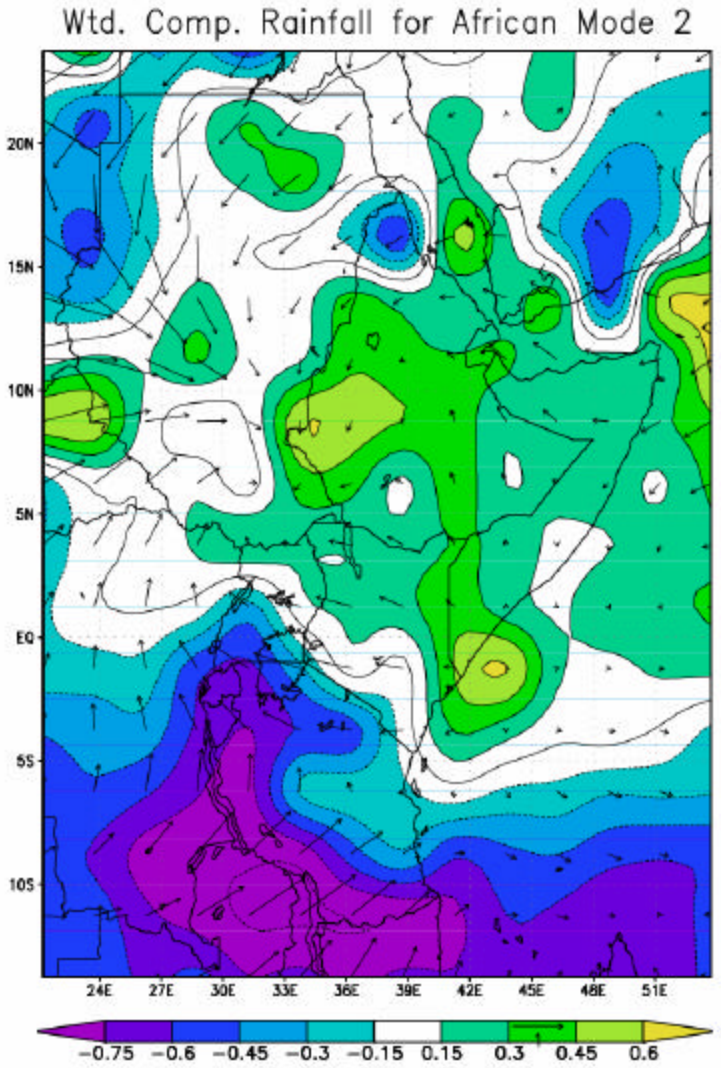


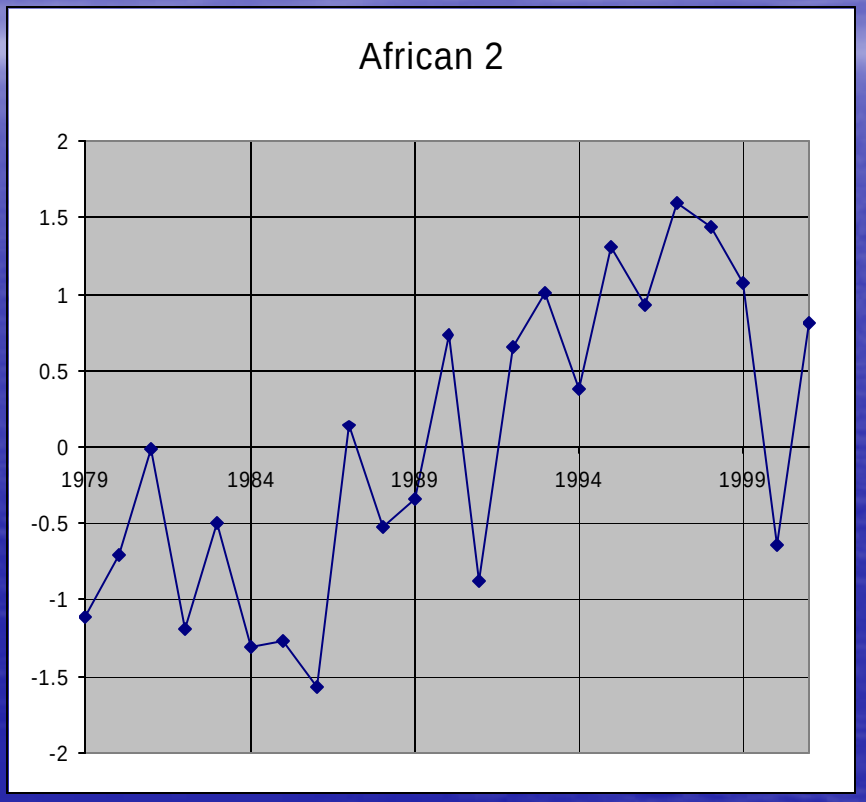
Global Rainfall EOF % Variance

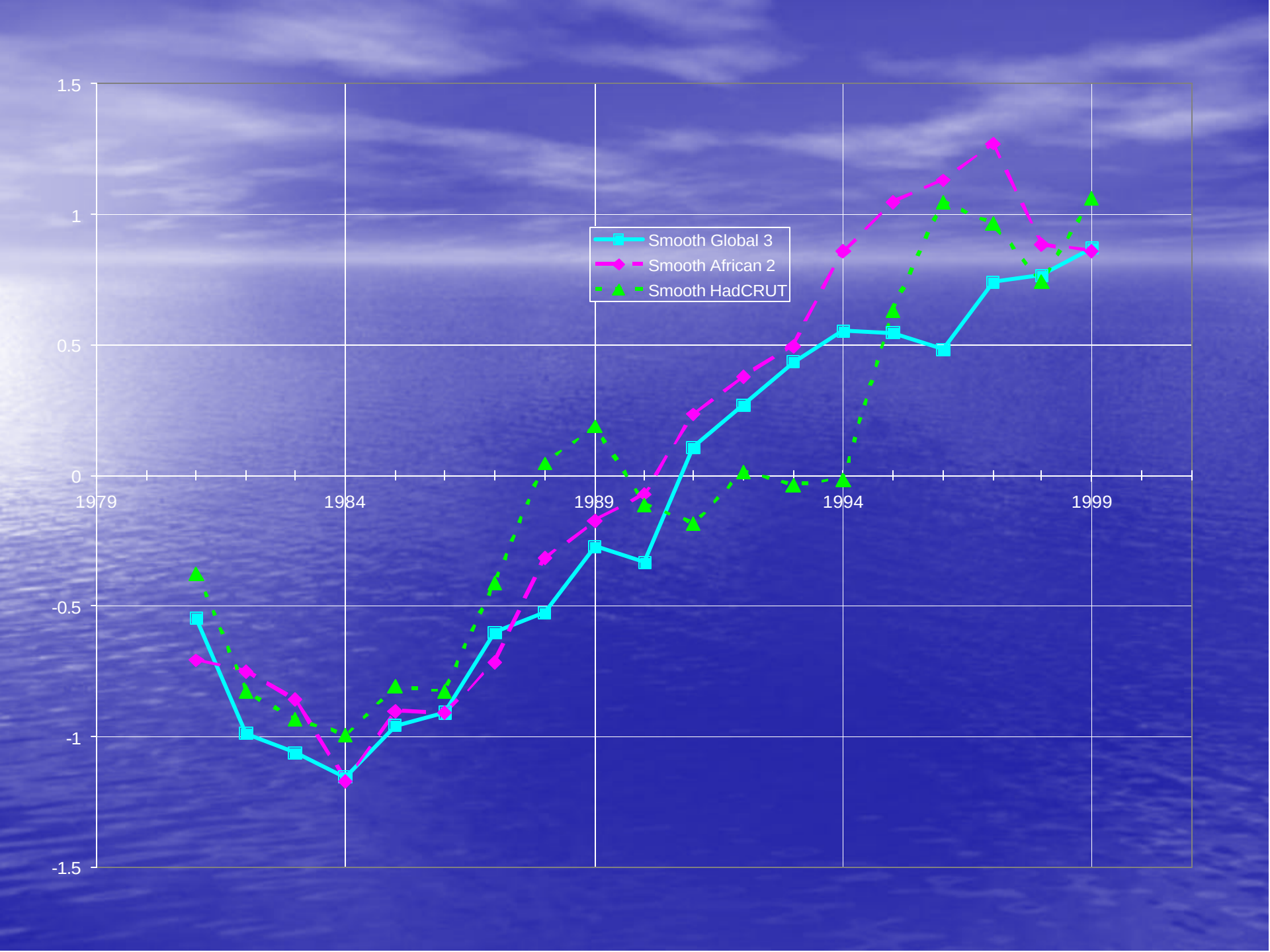


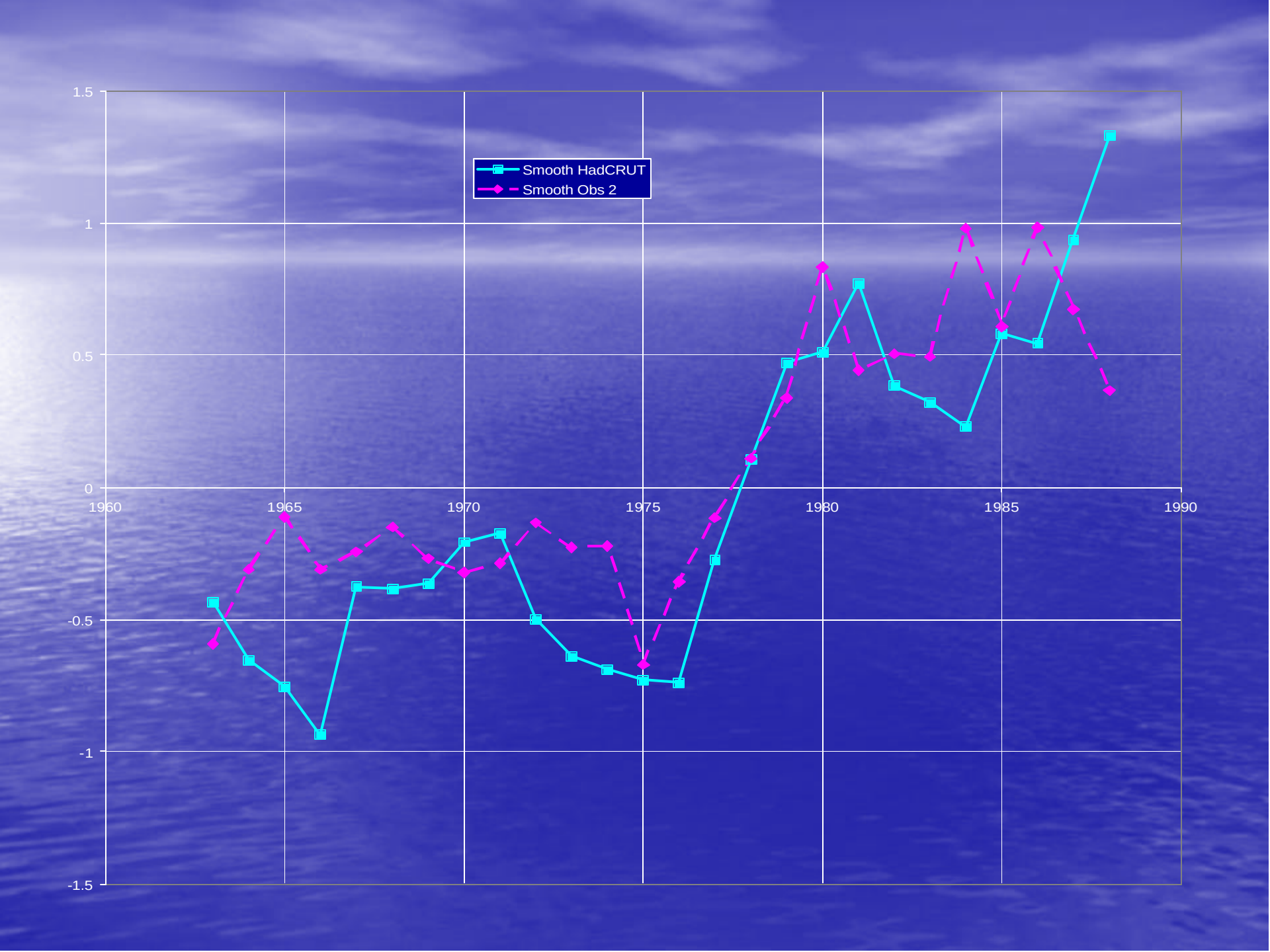

Wtd. Comp. Rainfall for African Mode 1
20N
15N
10N
5N
EQ
5S
10S
24E
27E
30E
33E
36E
39E
42E
45E
48E
51E
−0.75 −0.6 −0.45 −0.3 −0.15 0.15 0.3 0.45 0.6 0.75 0.9 1.05 1.2


African 1
4
3
2
1
0
-1
-2
1979
1984
1989
1994
1999


Wtd. Comp. Rainfall for African Mode 2
20N
15N
10N
5N
EQ
5S
10S
24E
27E
30E
33E
36E
39E
42E
45E
48E
51E
-0.75
-0.6
-0.45
-0.3
-0.15
0.15
0.3
0.45
0.6


African 2
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1979
1984
1989
1994
1999


1.5
1
0.5
0
-0.5
-1
-1.5
1979
1984
1989
1994
1999
Smooth Global 3
Smooth African 2
Smooth HadCRUT


Smooth HadCRUT
Smooth Obs 2
1.5
1
0.5
0
-0.5
-1
-1.5
1960
1965
1970
1975
1980
1985
1990

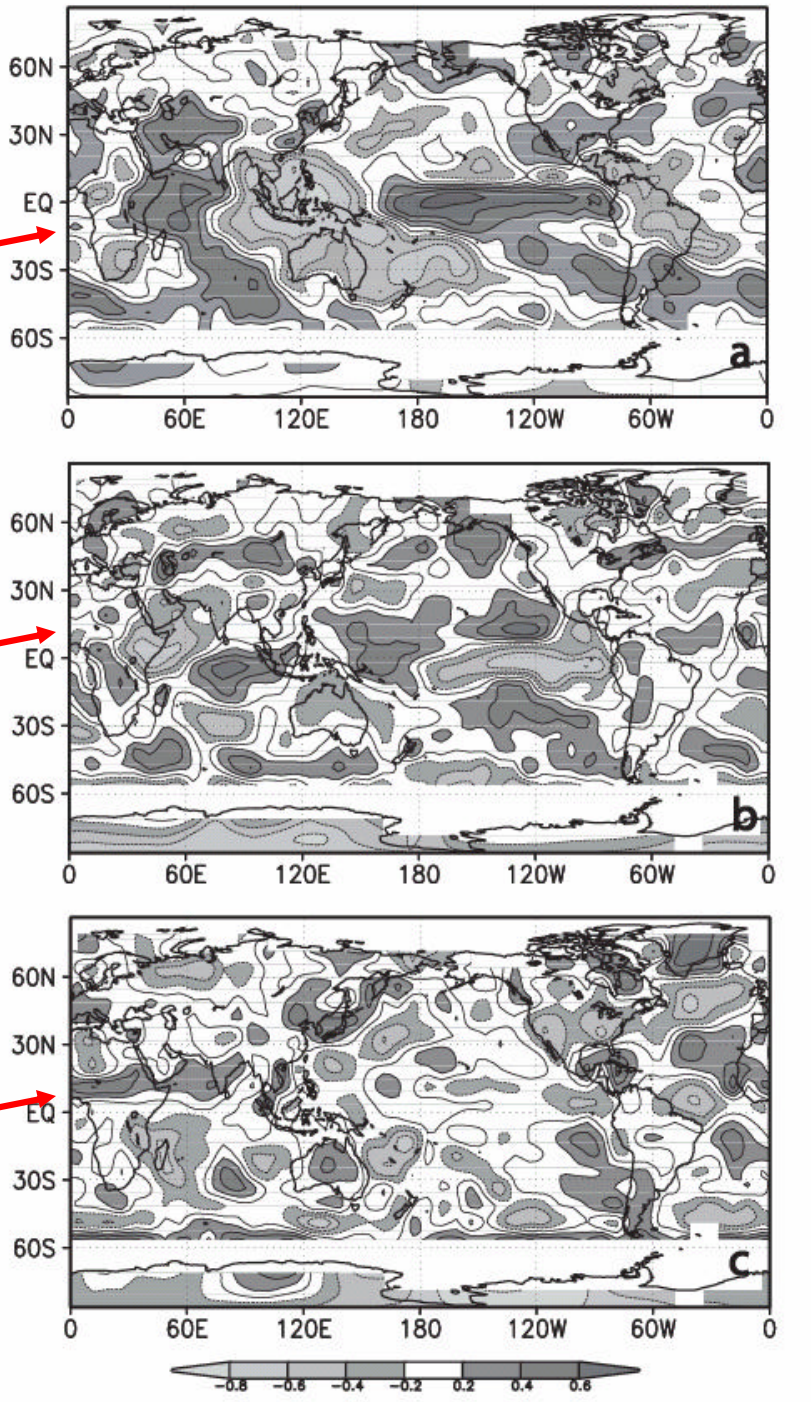
CMAP RAINFALL ANALYSIS

1979-2003

El-Nino Climate

Indian Ocean/El Nino

Climate Change Mode

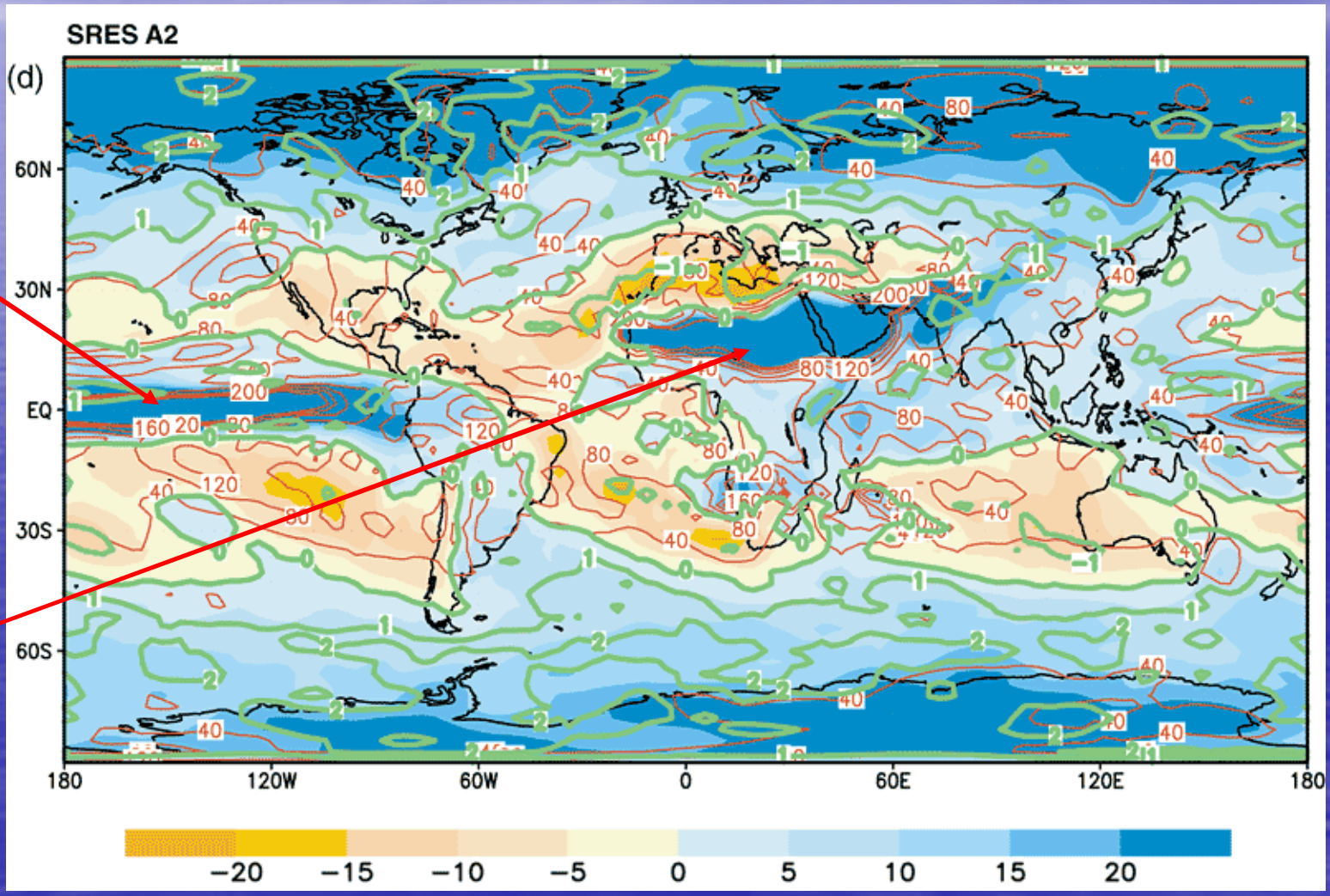


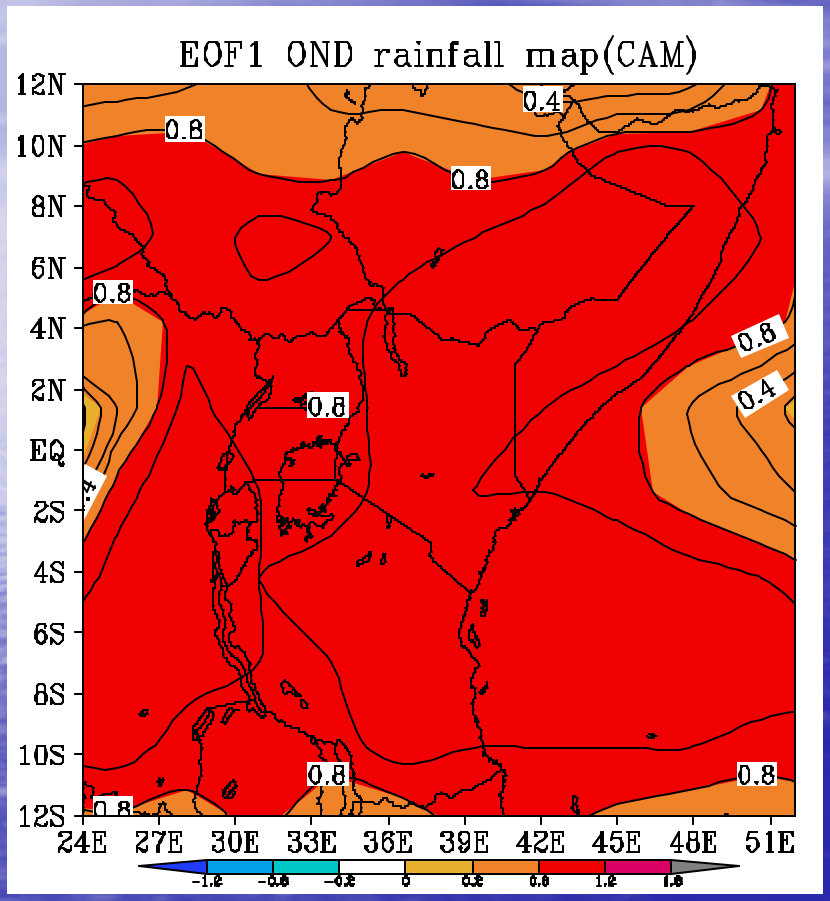
Rainfall Project: Period 2071 to 2100 relative to the period 1961 to 1990

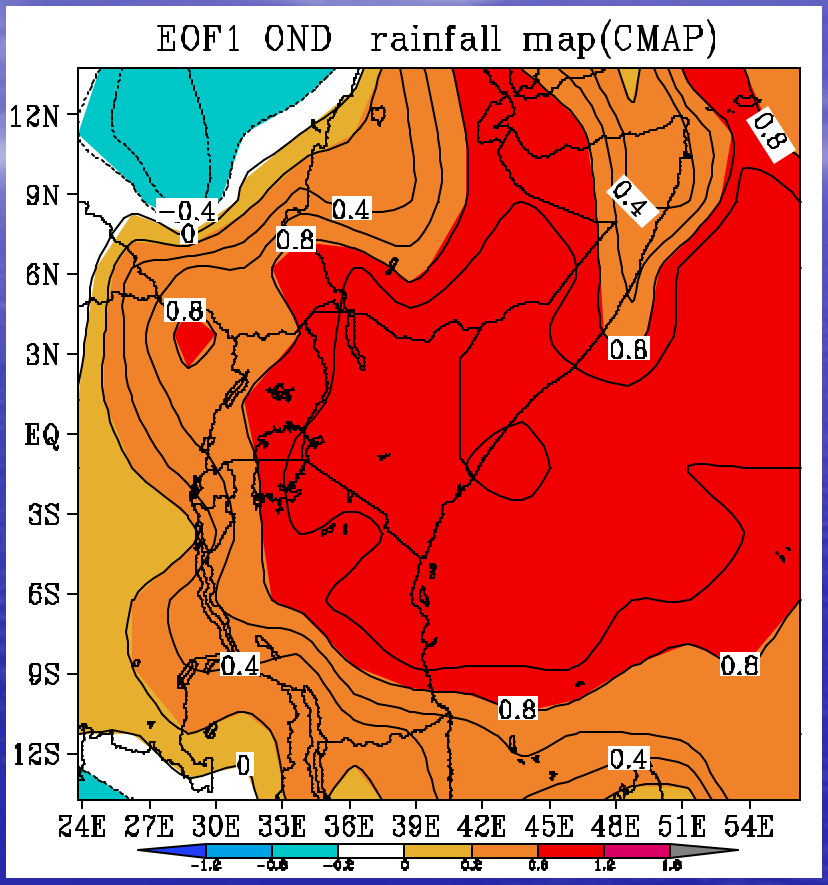
(SRES scenario B2)

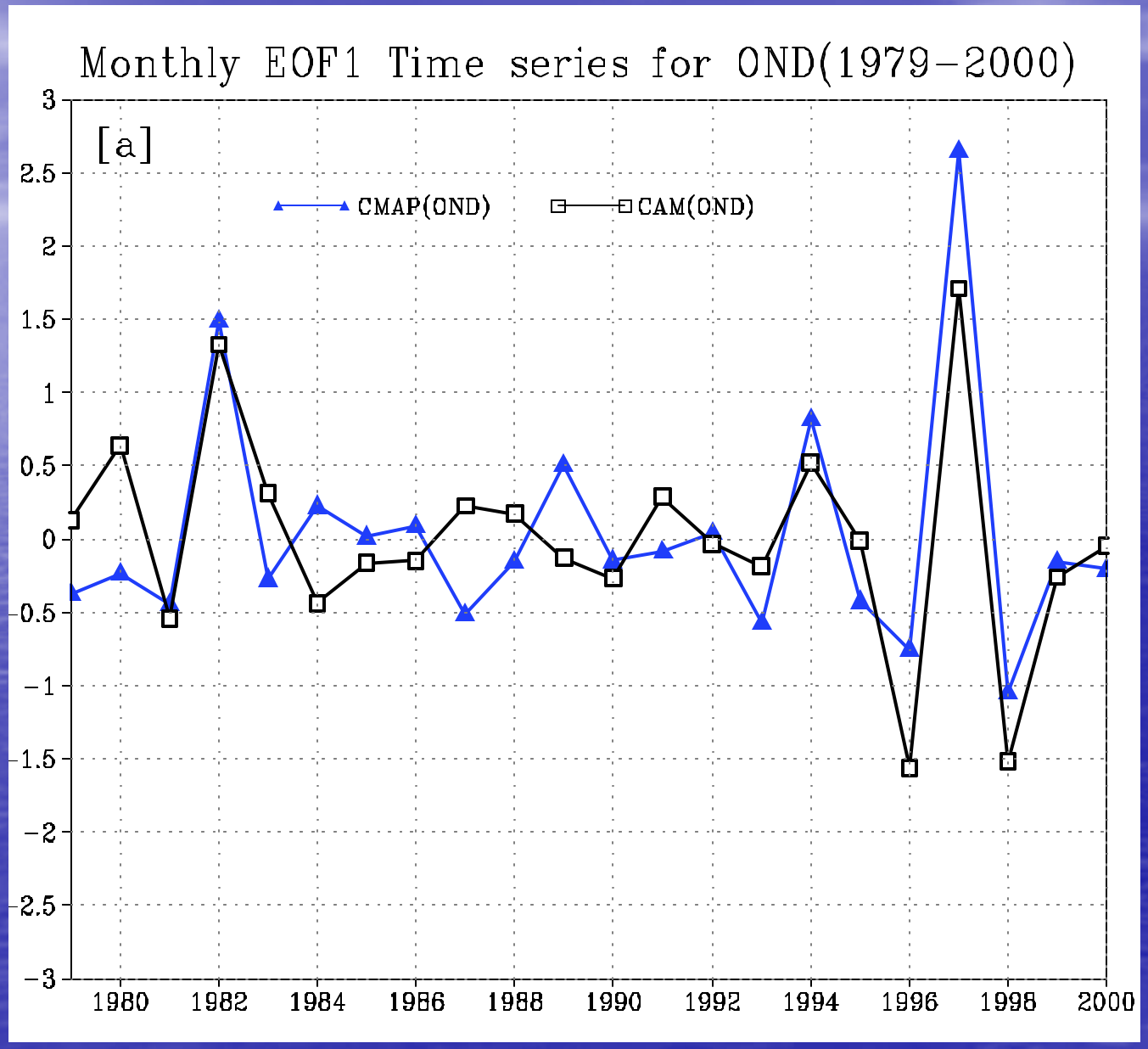
Enhanced El-Nino Climate activity

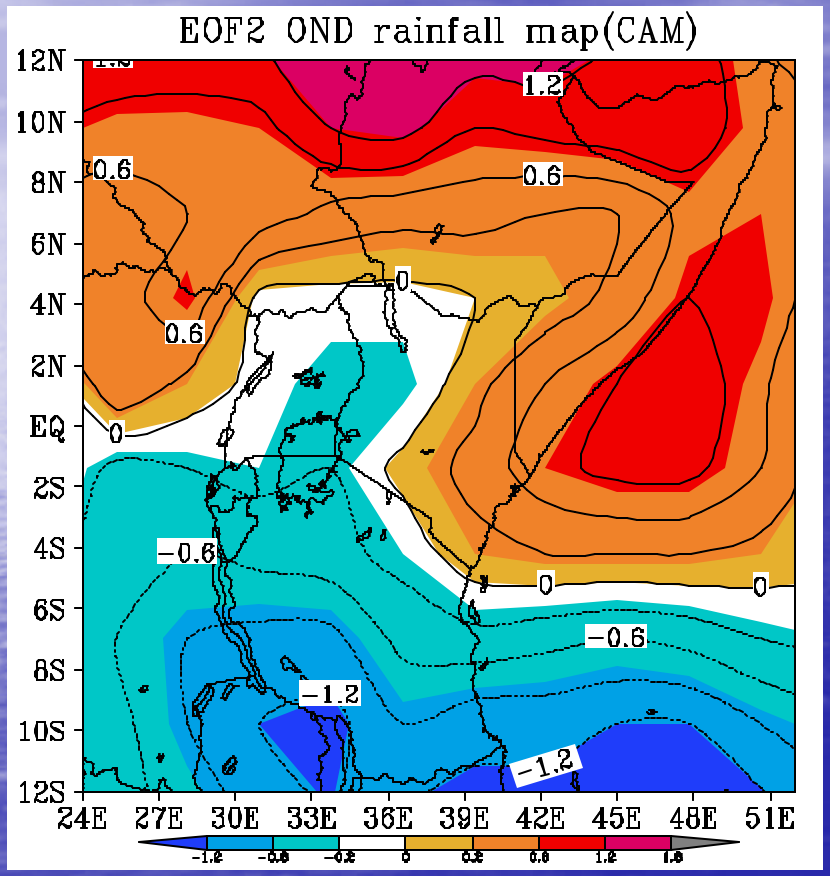
Similar to current changes

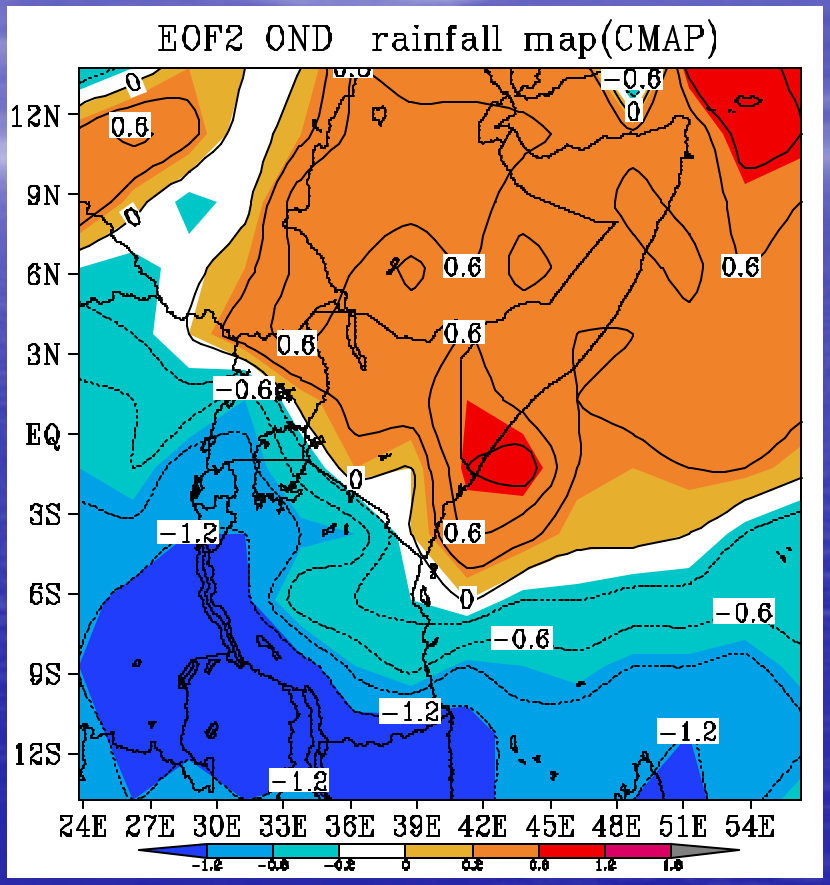


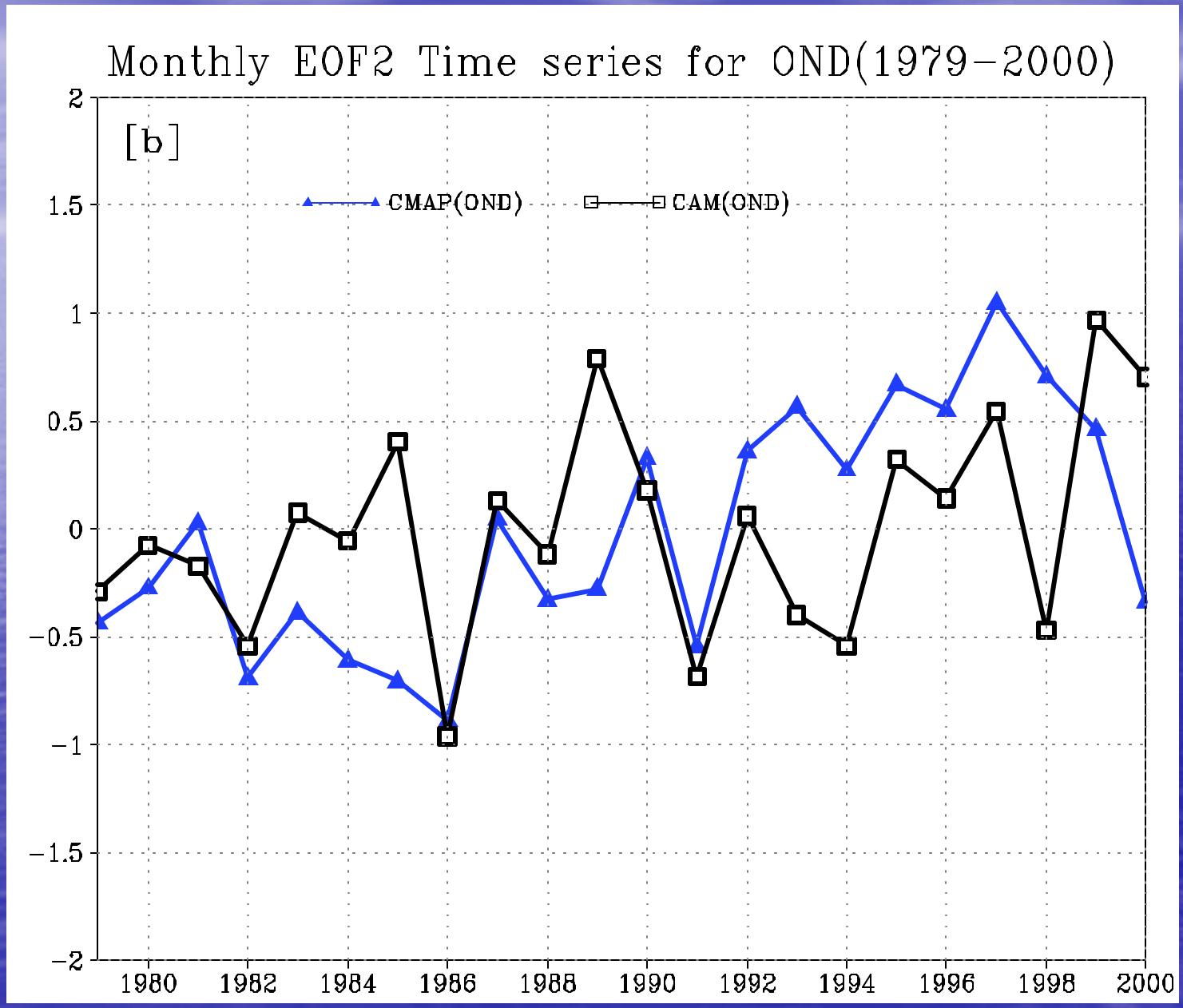

EOF1 OND rainfall map(CAM)
12N
10N
8N
6N
4N
2N
EQ
2S
4S
6S
8S
10S
12S
24E
27E
30E
33E
36E
39E
42E
45E
48E
51E
0.8
0.4
-1.2
-0.8
-0.2
0
0.2
0.8
1.2
1.6

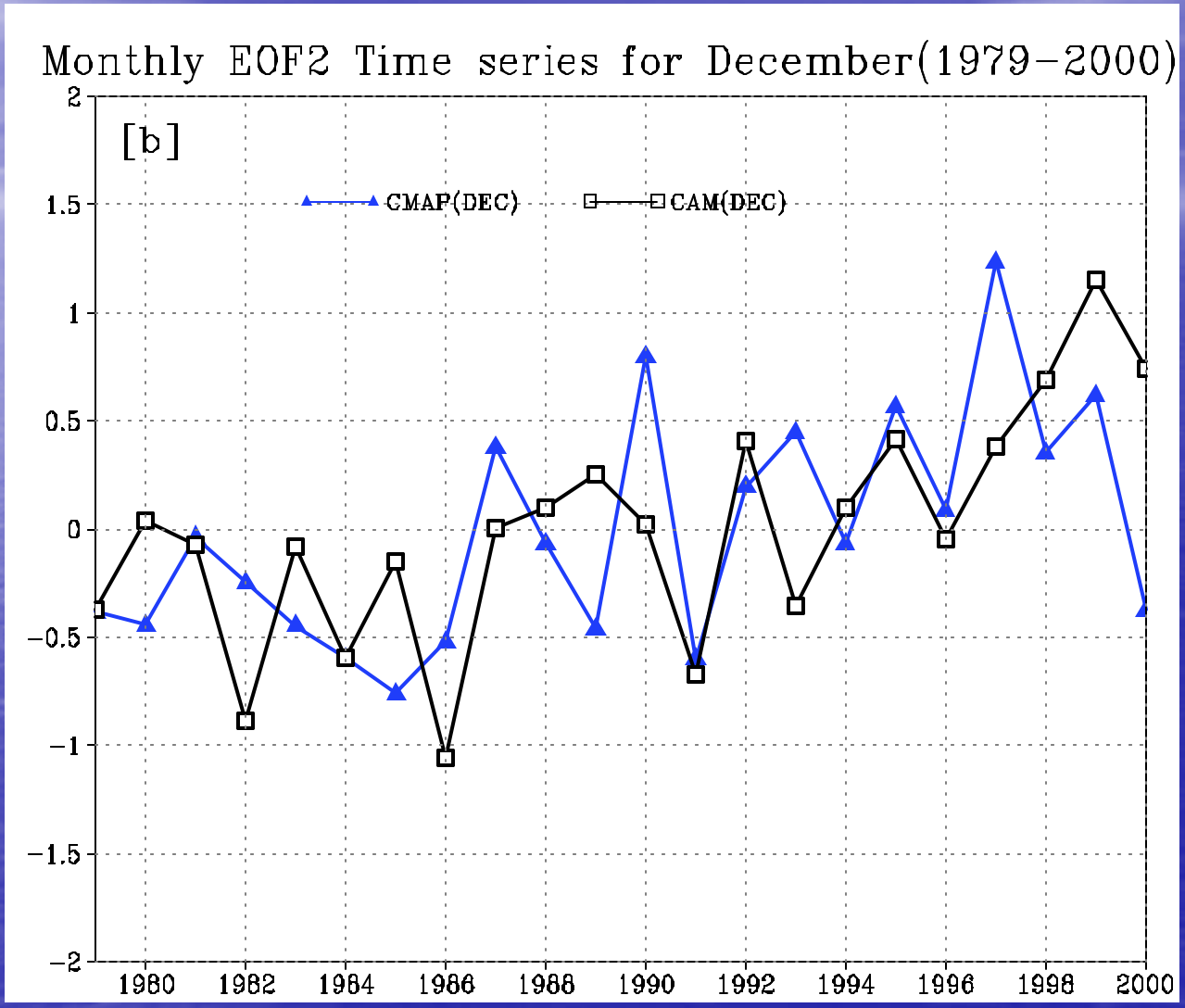

EOF1 OND rainfall map(CMAP)
12N
9N
6N
3N
EQ
3S
6S
9S
12S
24E
27E
30E
33E
36E
39E
42E
45E
48E
51E
54E
0.8
0.4
-0.4
0
-1.2
-0.8
-0.2
0
0.2
0.8
1.2
1.6


Monthly EOF1 Time series for OND(1979-2000)
[a]
CMAP(OND)
CAM(OND)
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000


EOF2 OND rainfall map(CAM)
12N
10N
8N
6N
4N
2N
EQ
2S
4S
6S
8S
10S
12S
24E
27E
30E
33E
36E
39E
42E
45E
48E
51E
1.2
0.6
0
−0.6
−1.2


EOF2 OND rainfall map(CMAP)
12N
9N
6N
3N
EQ
3S
6S
9S
12S
24E
27E
30E
33E
36E
39E
42E
45E
48E
51E
54E
0.6
0
−0.6
−1.2


Monthly EOF2 Time series for OND(1979-2000)
[b]
CMAP(OND)
CAM(OND)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000


Monthly EOF2 Time series for December(1979-2000)
[b]
CMAP(DEC)
CAM(DEC)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000

Conclusions

- ENSO and the Indian Ocean dipole have the strongest influence on rainfall in the East Africa
- Both have the similar effect on the region, so they are indistinguishable in our analysis
- The next strongest influence comes from Global Warming
- GCM reasonably reproduce both ENSO and Global warming modes over Eastern Africa.
- We should expect the regional climate models to improve over the regional simulations produced by GCMs
- **Ensemble Model Prediction produces superior results**