How Good are Model Operational forecasts?

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University of Oxford
UK

Outline

- Recap on Climate Models
  - Modelling approaches to seasonal forecasting
  - AGCM or AOGCM: Prescribed SSTs Vs Coupling
  - Ensemble Forecasting….
- Model Climatology
- Climate Variability in Models
  - CCM3, NCEP, ECHAM
  - ECMWF PROVOST Integrations
  - UKMO HadAM3
- Conclusions

Routes to Seasonal Forecasting

- Empirical / Statistical
- Dynamic Modelling (GCMs, Numerical Models, Climate Models)

Routes to Seasonal Forecasting

- Empirical / Statistical
  - Computationally cheap
  - Not physically based
- Dynamic Modelling (GCMs, Numerical Models, Climate Models)
  - Computationally very expensive
  - Physically based

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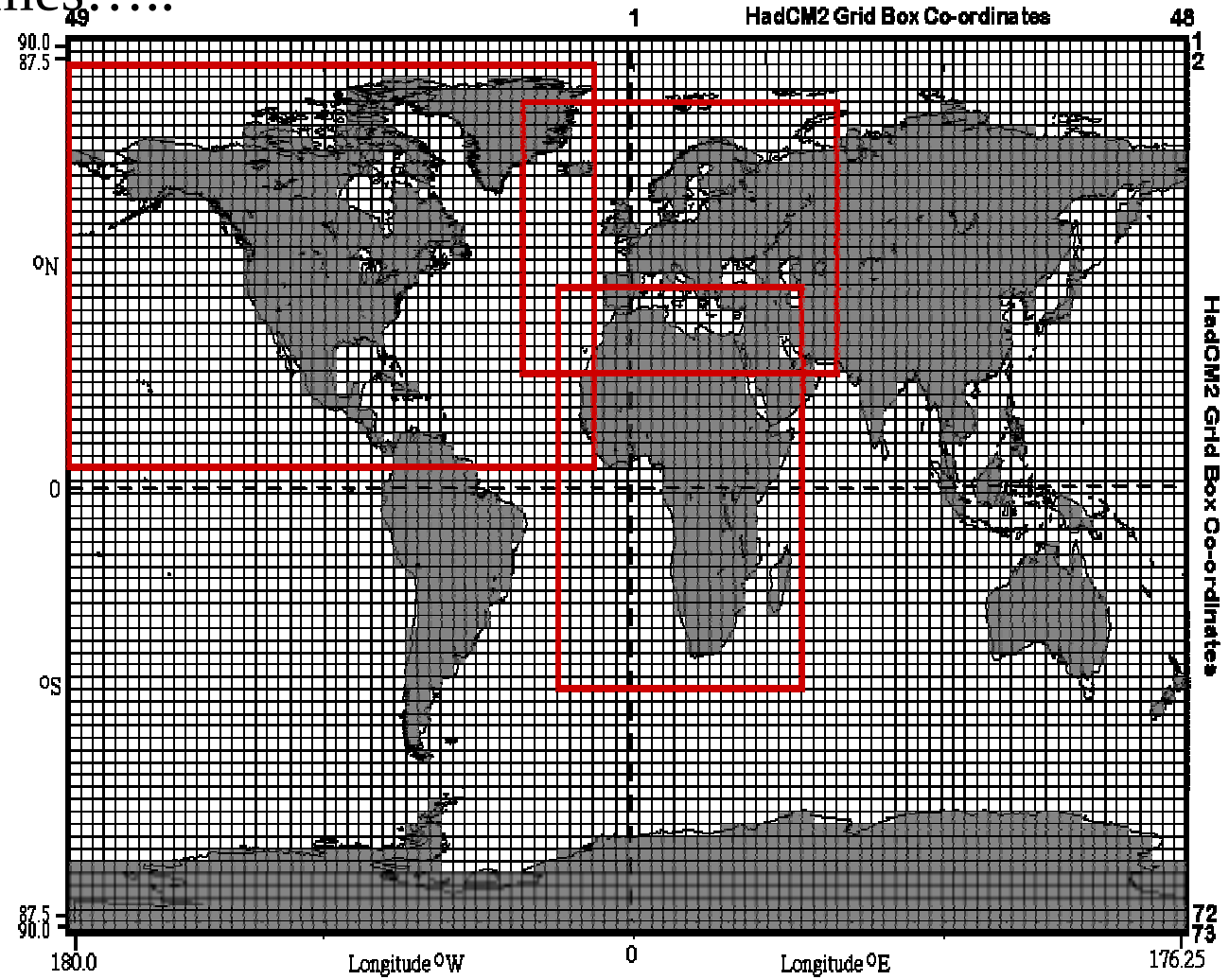
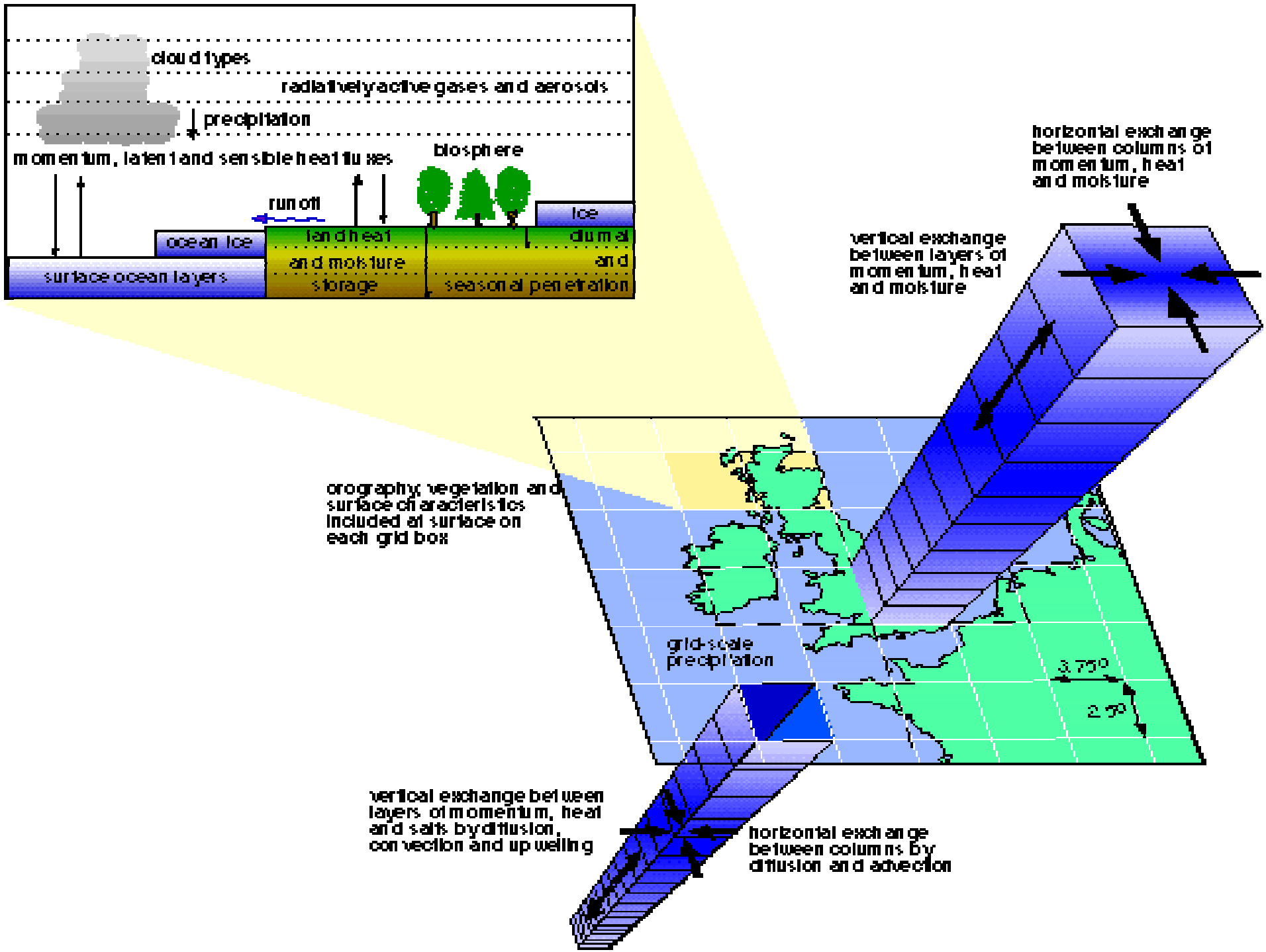
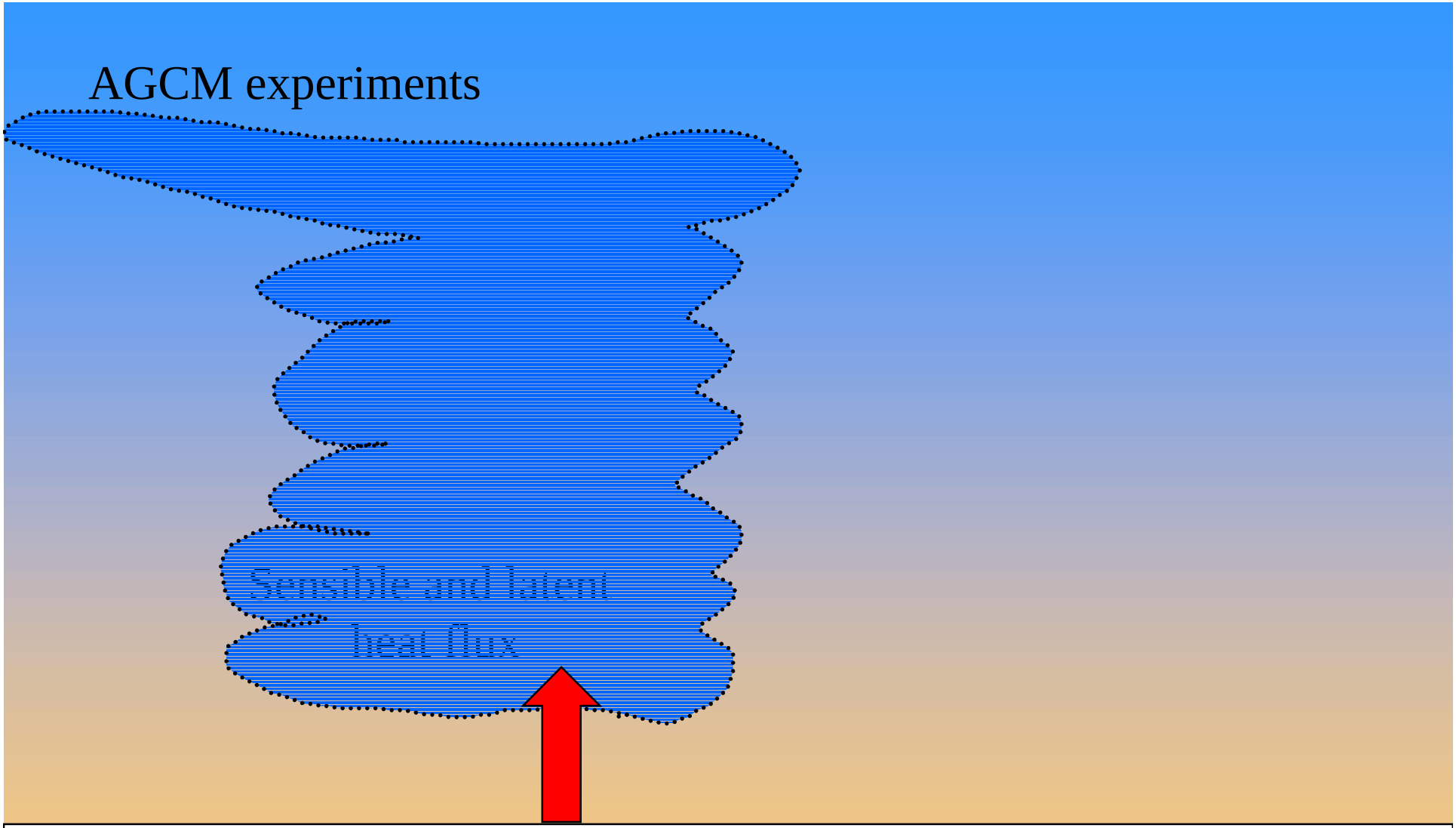
Primitive Equations
Finite difference scheme
Finite element approach
Paramterisation schemes…..



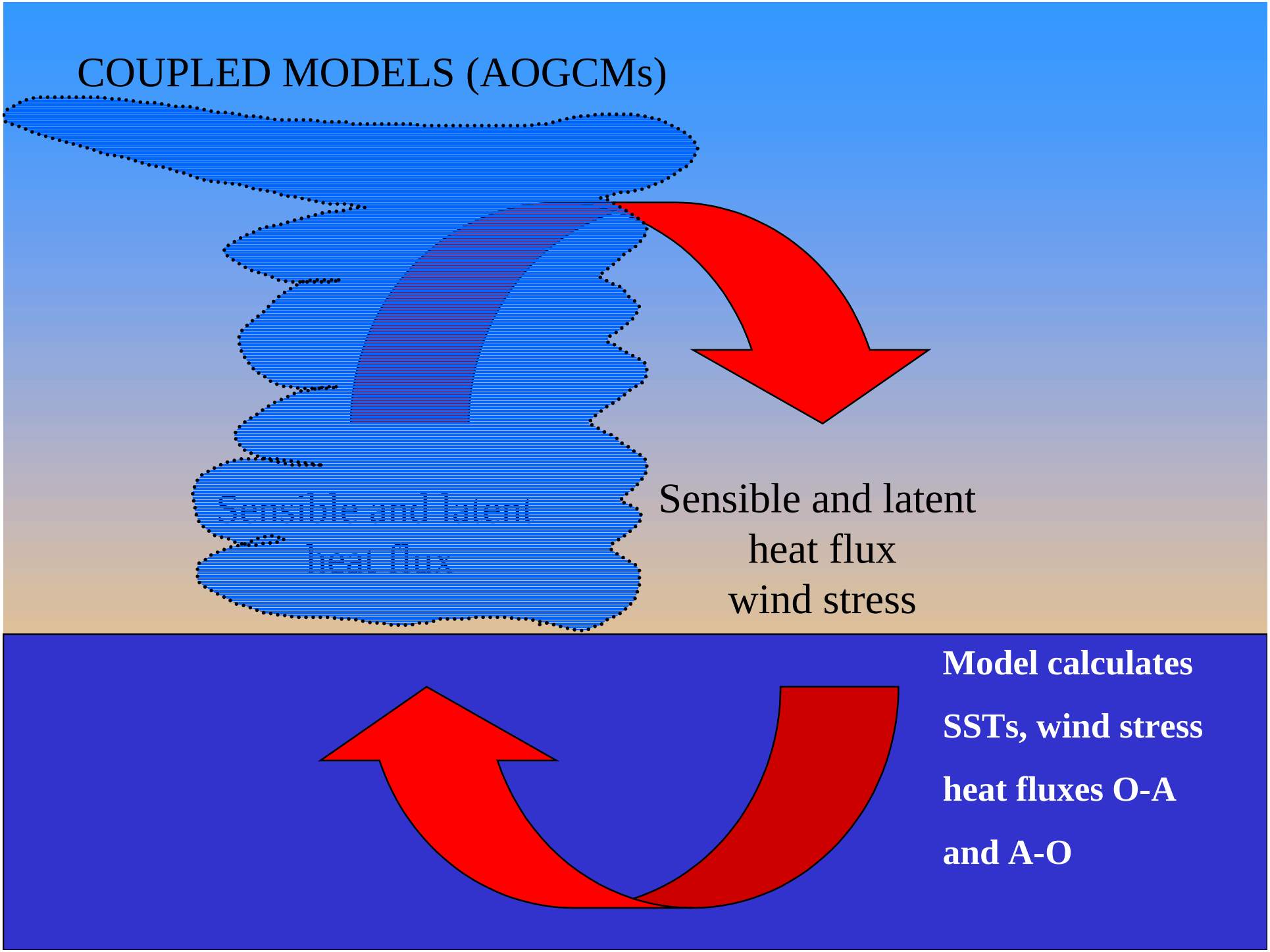

cloud types
radiatively active gases and aerosols
precipitation
momentum, latent and sensible heat fluxes
biosphere
runoff
ice
ocean ice
land heat
and moisture
storage
diurnal
and
seasonal penetration
surface ocean layers
horizontal exchange between columns of momentum, heat and moisture
vertical exchange between layers of momentum, heat and moisture
orography, vegetation and surface characteristics included at surface on each grid box
grid-scale precipitation
3.75°
2.5°
vertical exchange between layers of momentum, heat and salts by diffusion, convection and upwelling
horizontal exchange between columns by diffusion and advection

Dynamical Modelling

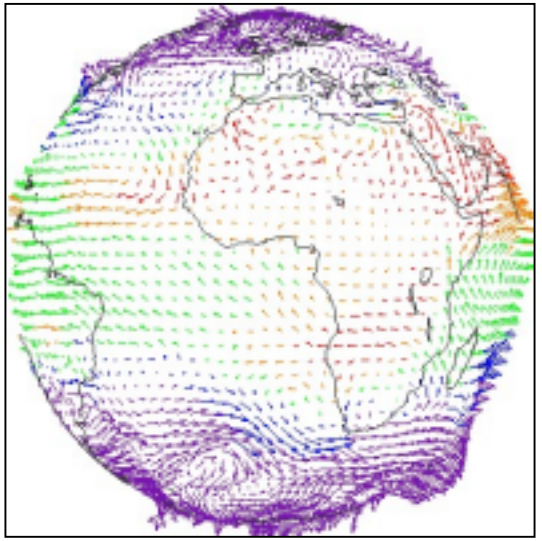
- Atmosphere only Models (AGCMs)
  - Model forced with observed (usually persisted) SSTs
  - e.g. 3 month forecast for July 2002 made with observed April SSTs which do not change over the 3 months
- Coupled Models (AOGCMs)
  - Model provided with observed SSTs at the start of the experiment
  - Model calculates SSTs



SSTs (and therefore heat fluxes to atmosphere)
prescribed by observed SSTs
BUT
Heat fluxes and wind stress from atmosphere are ignored


COUPLED MODELS (AOGCMs)
Sensible and latent heat flux
Sensible and latent heat flux
wind stress
Model calculates
SSTs, wind stress
heat fluxes O-A
and A-O

Process of seasonal forecasting….



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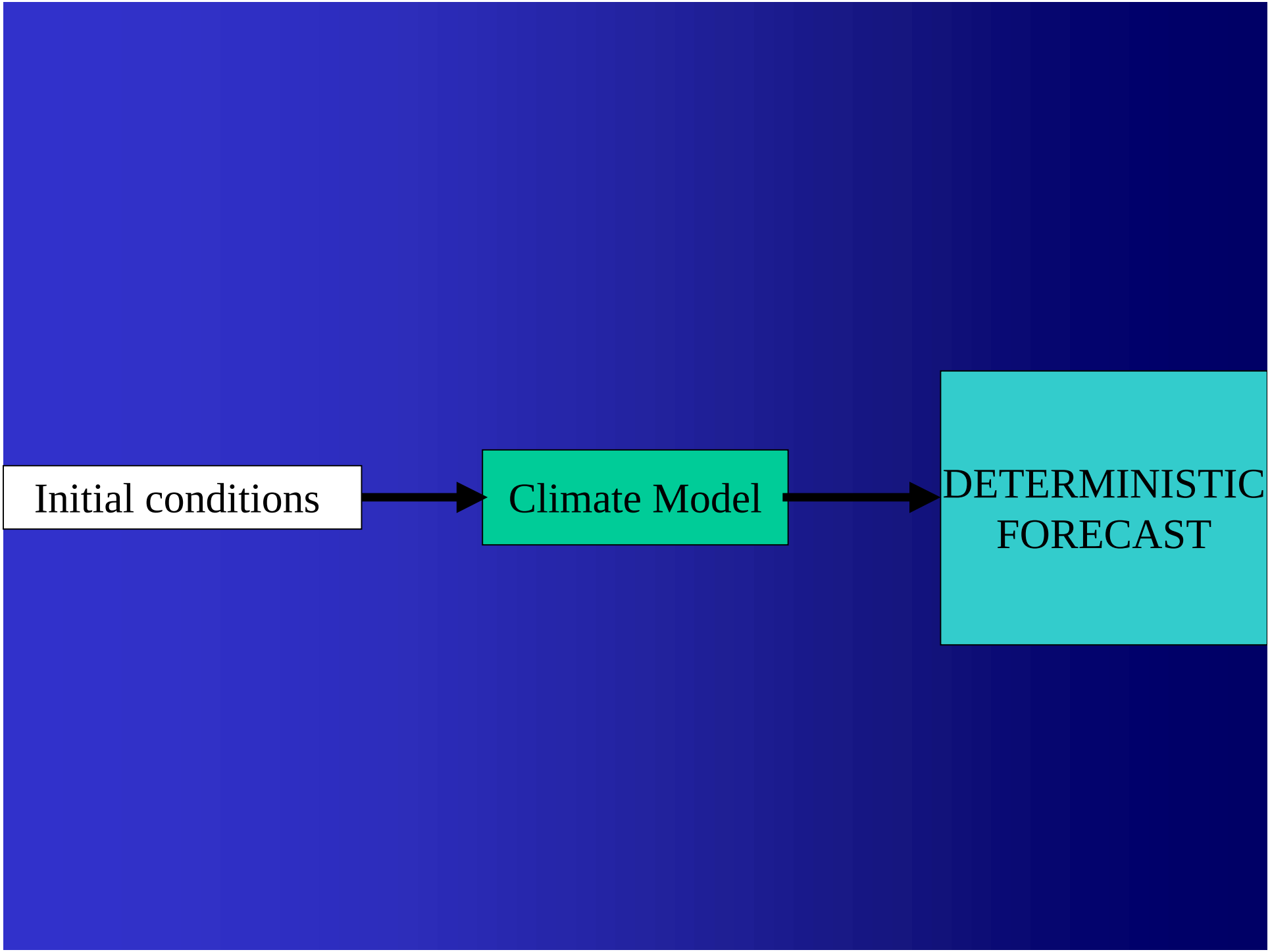
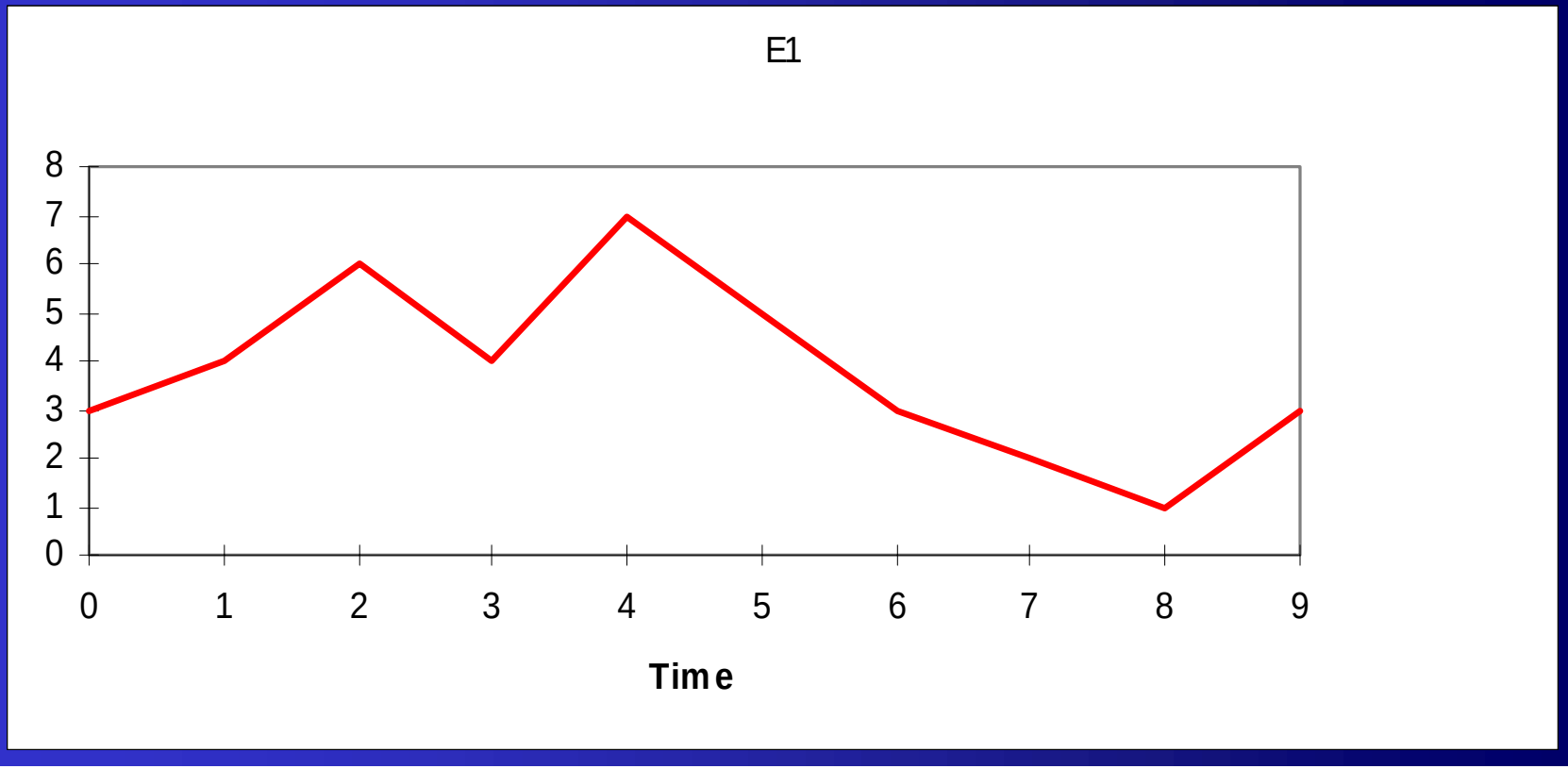
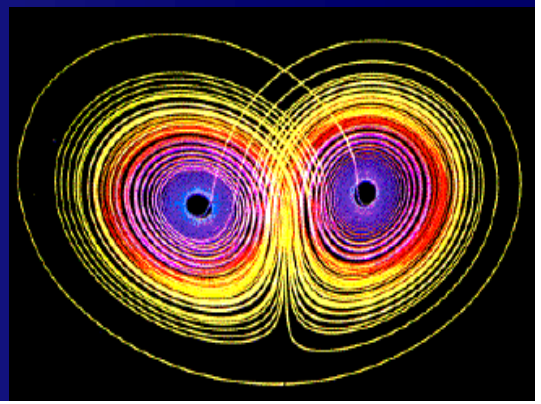

Initial conditions
Climate Model
DETERMINISTIC
FORECAST

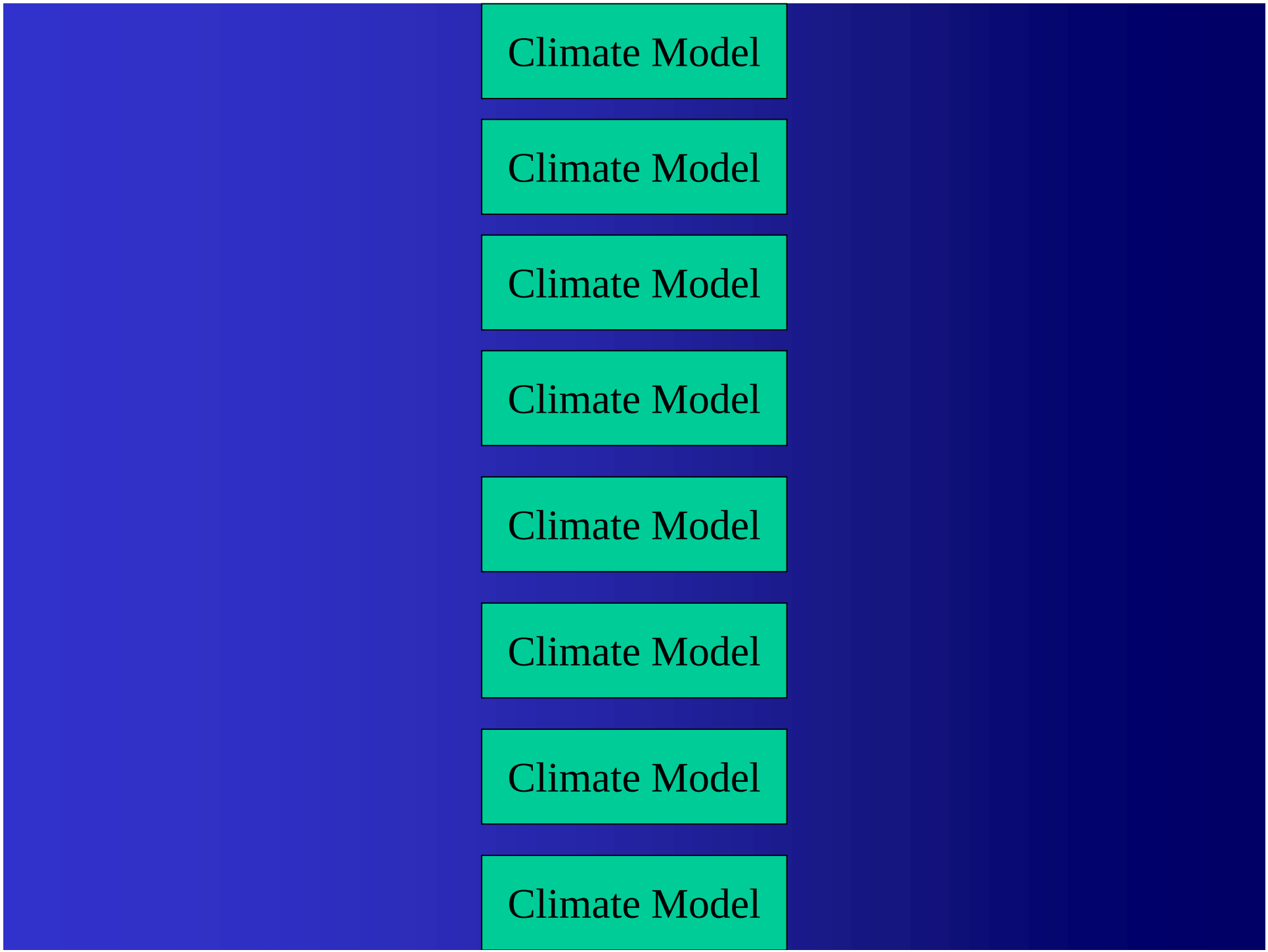
Initial conditions → Climate Model → DETERMINISTIC FORECAST



Initial conditions → Climate Model → DETERMINISTIC FORECAST



BEWARE THE BUTTERFLY!


Climate Model
Climate Model
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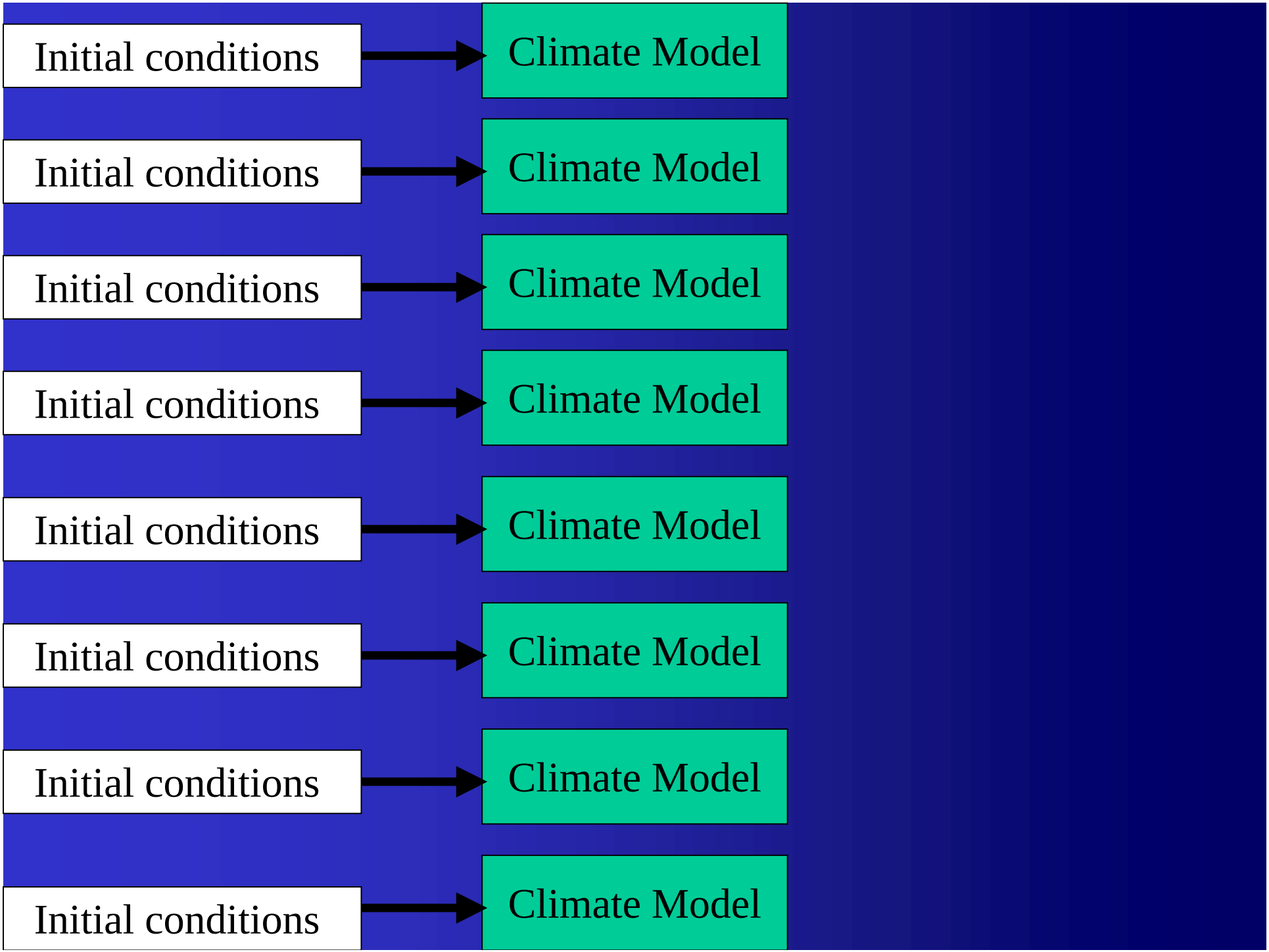
Initial conditions
Climate Model
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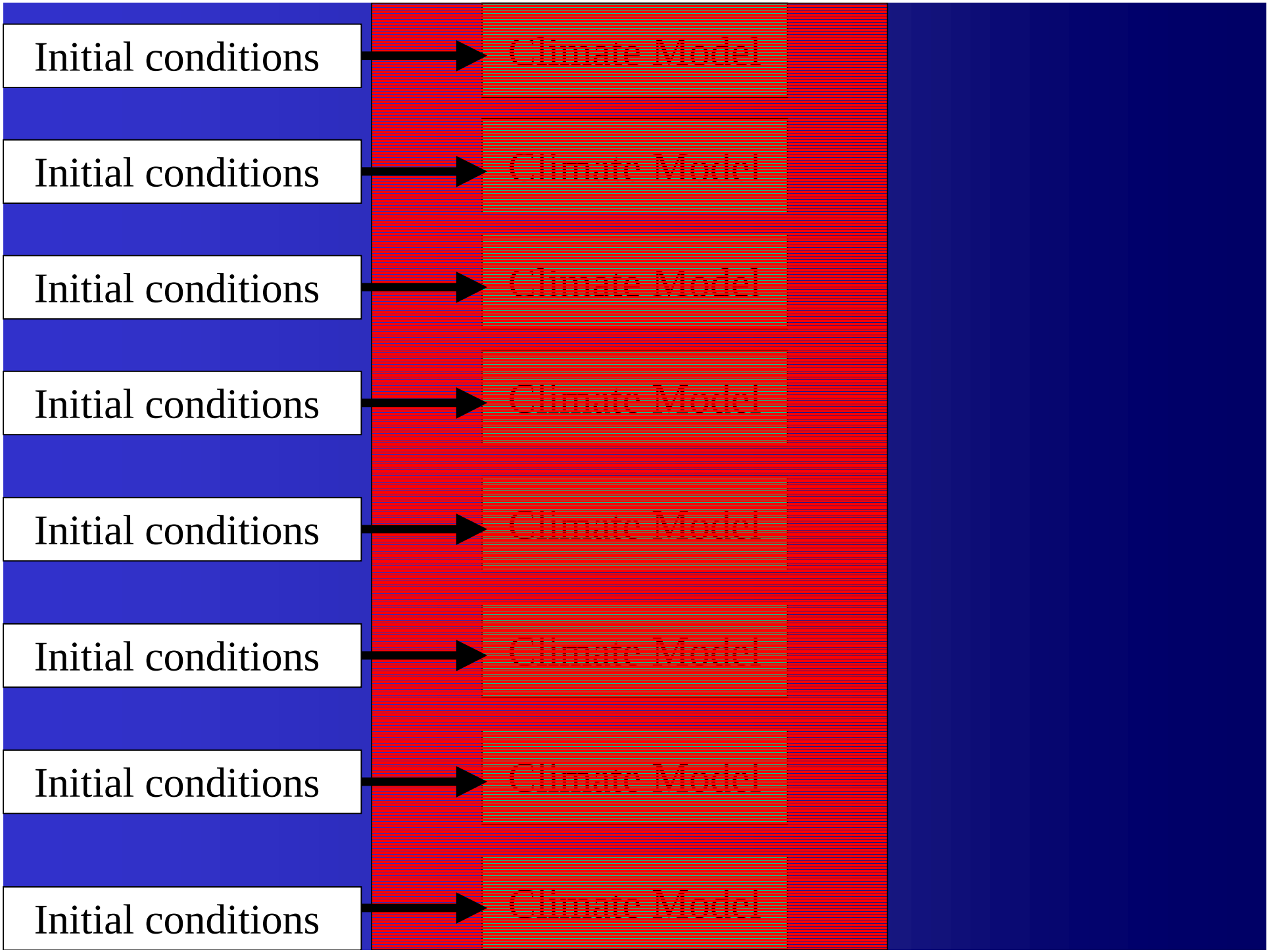
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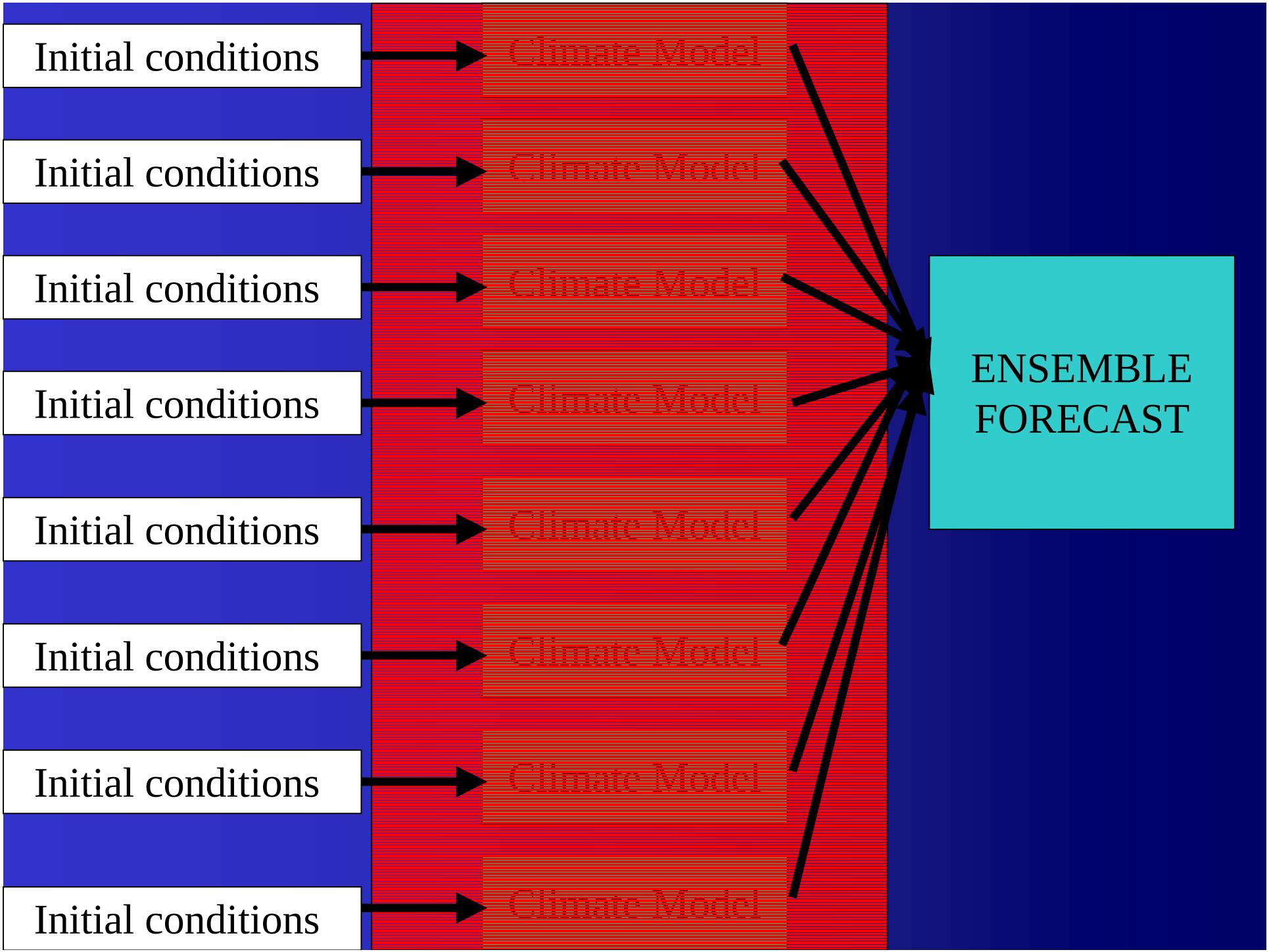
Initial conditions
Initial conditions
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Initial conditions
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Initial conditions
Initial conditions
Climate Model
Climate Model
Climate Model
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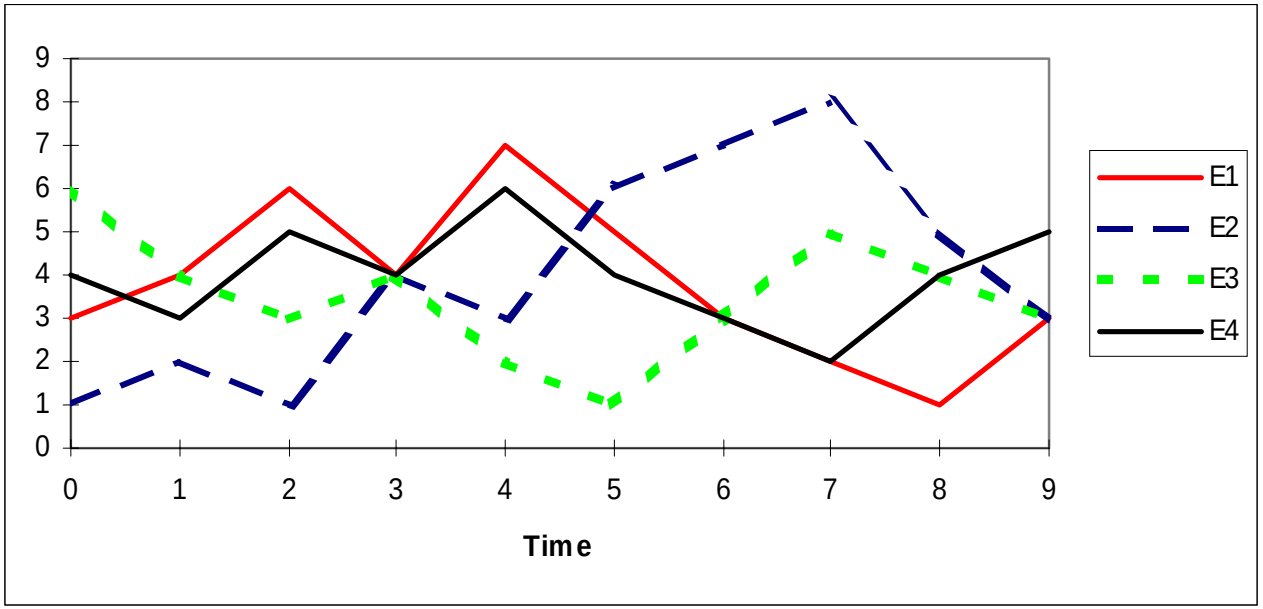
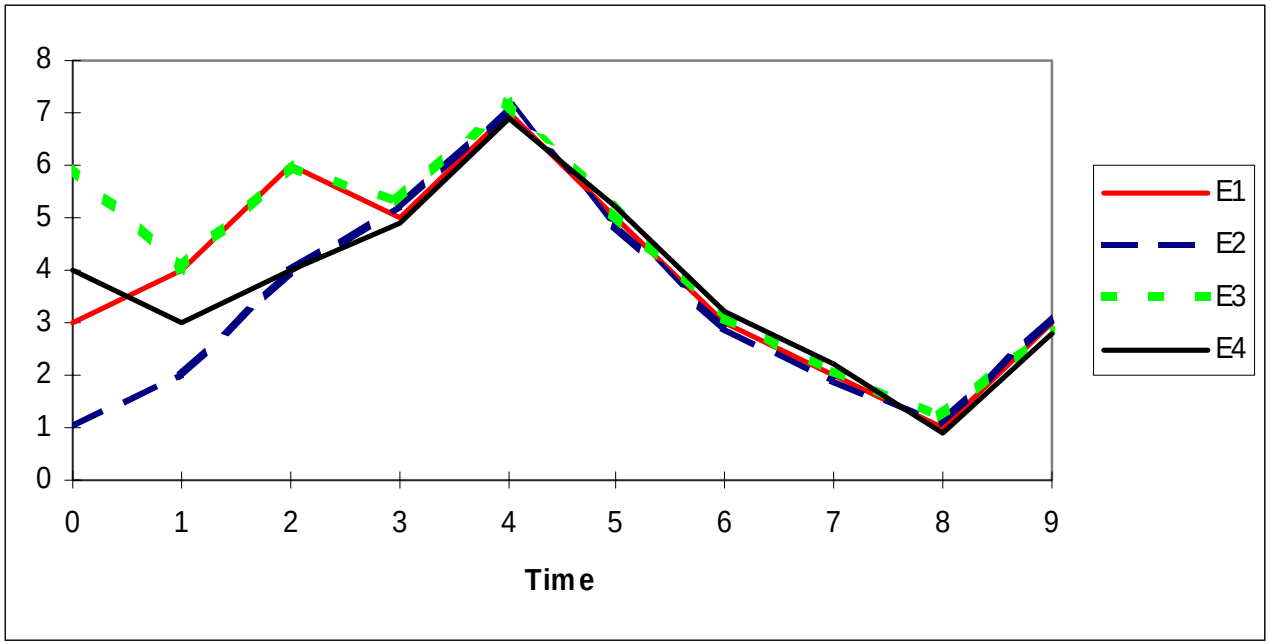
Climate Model
Climate Model
ENSEMBLE FORECAST

Very Low Skill



Very High Skill



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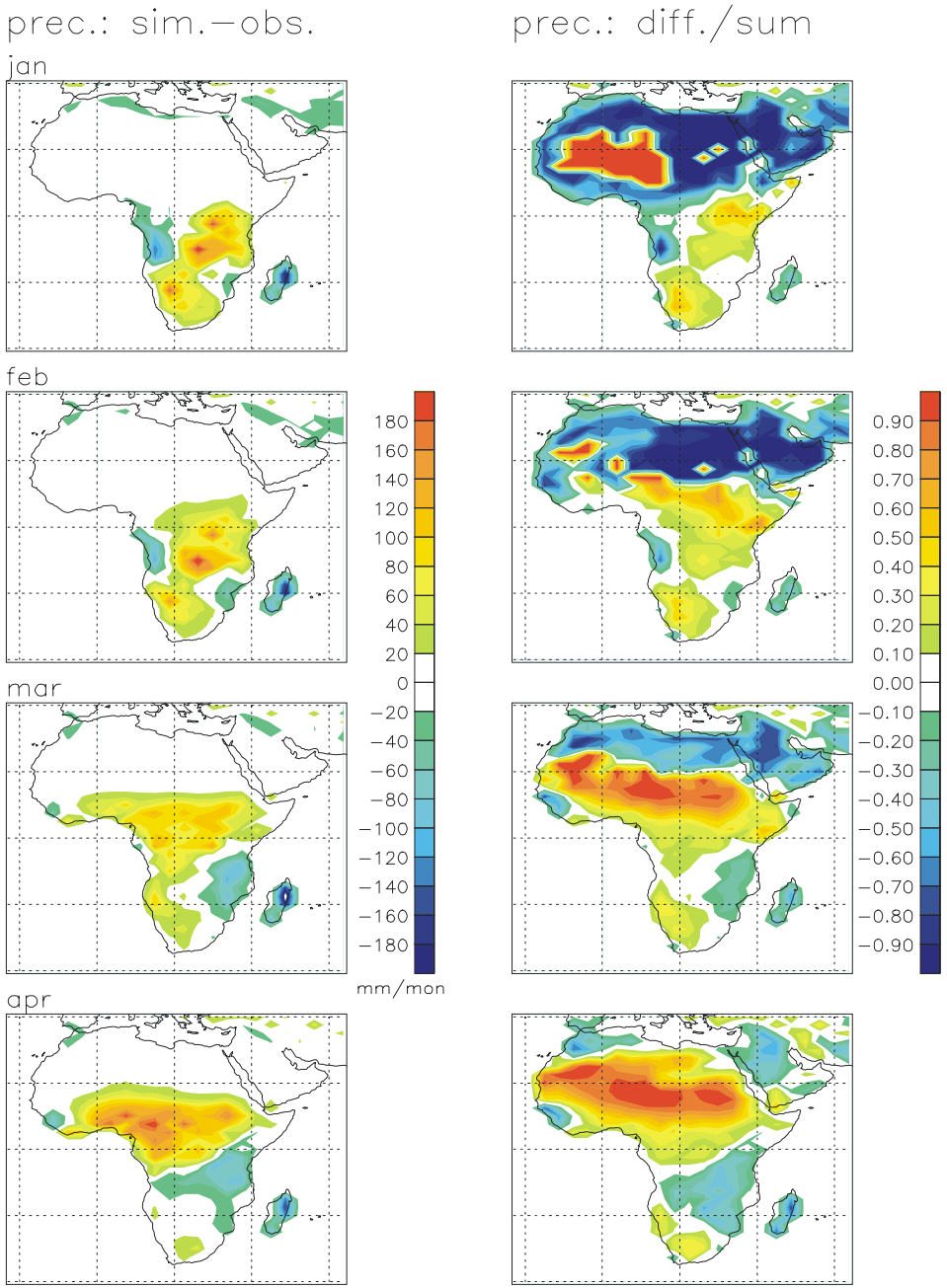
Dynamic Models: Caution…..

- Does model climatology match the observed climatology?
- Does model variability match observed climate variability where the model is forced with observed (historical) SSTs?

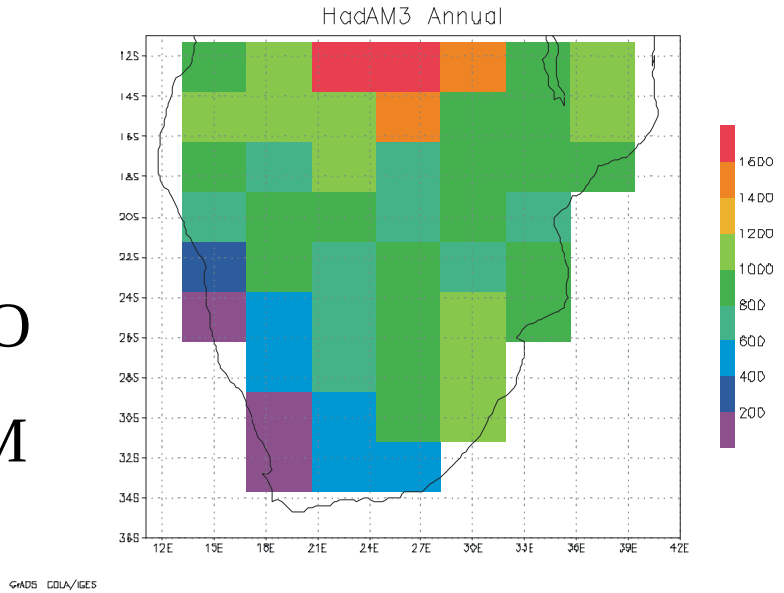
Model Climatology

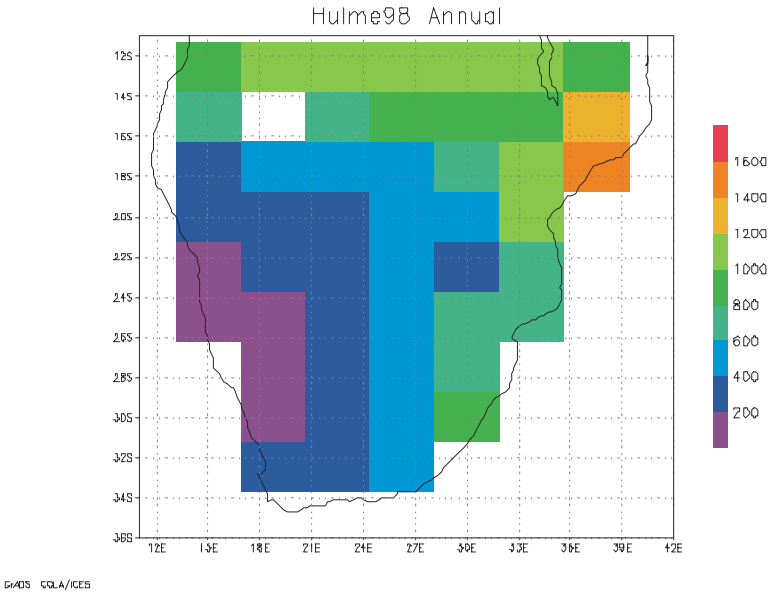
UKMO
AGCM
1950-1998

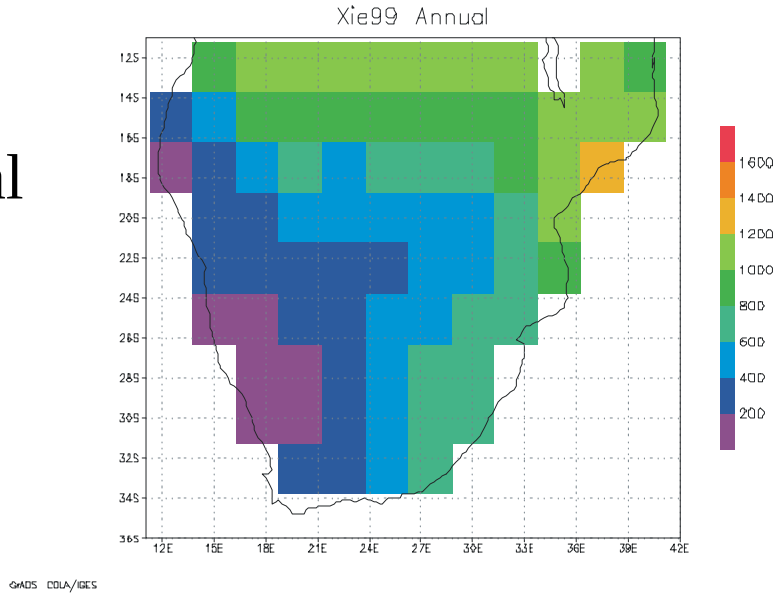
Model Rain
Minus
Observed Rain

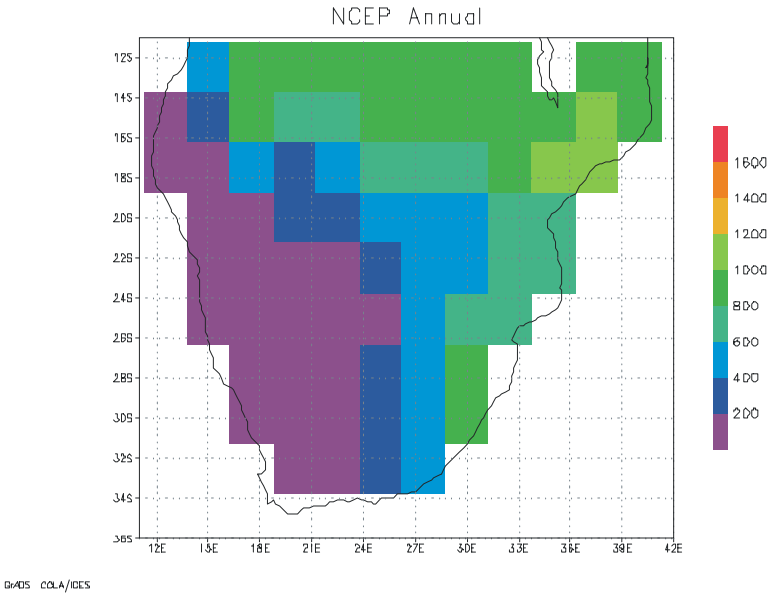


UKMO AGCM 1979-1998 Annual









East-west rainfall gradient is a good test!

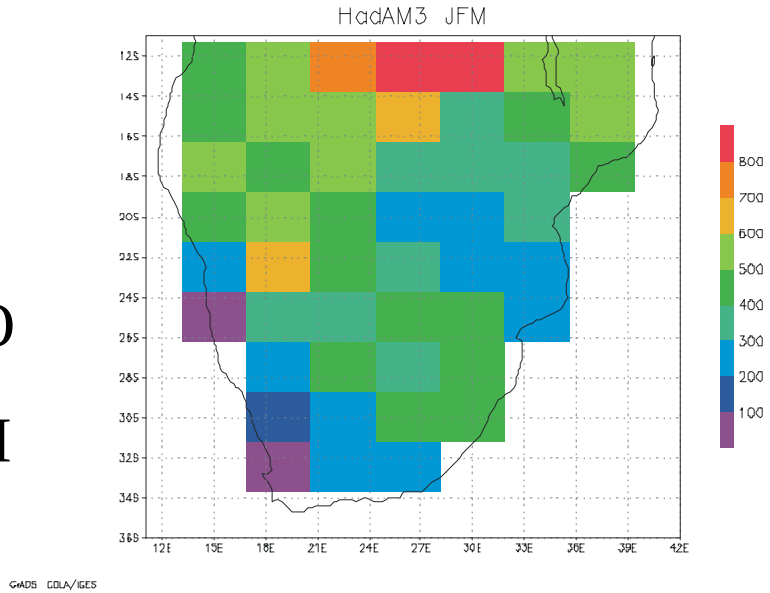
UKMO

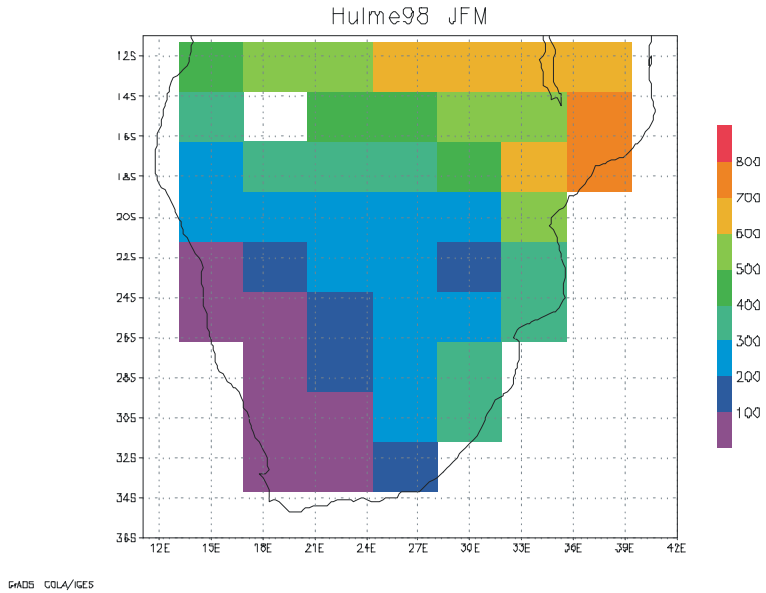
AGCM

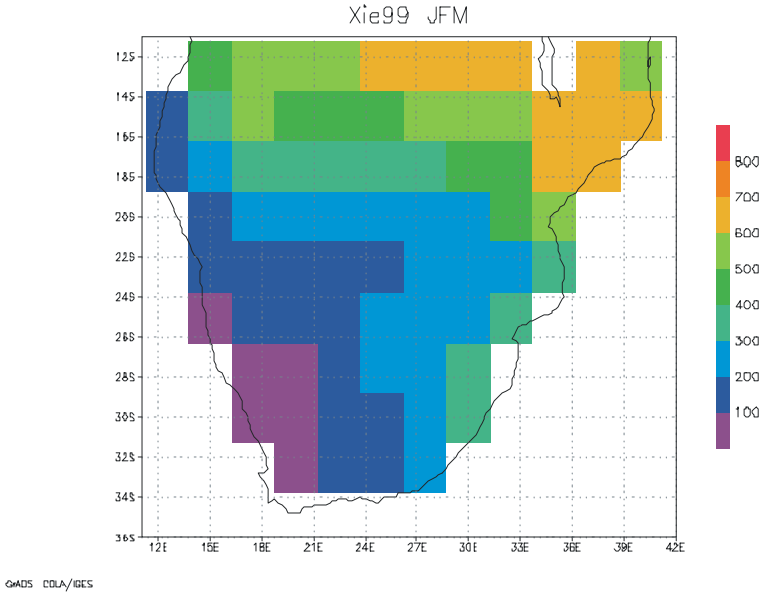
1979-

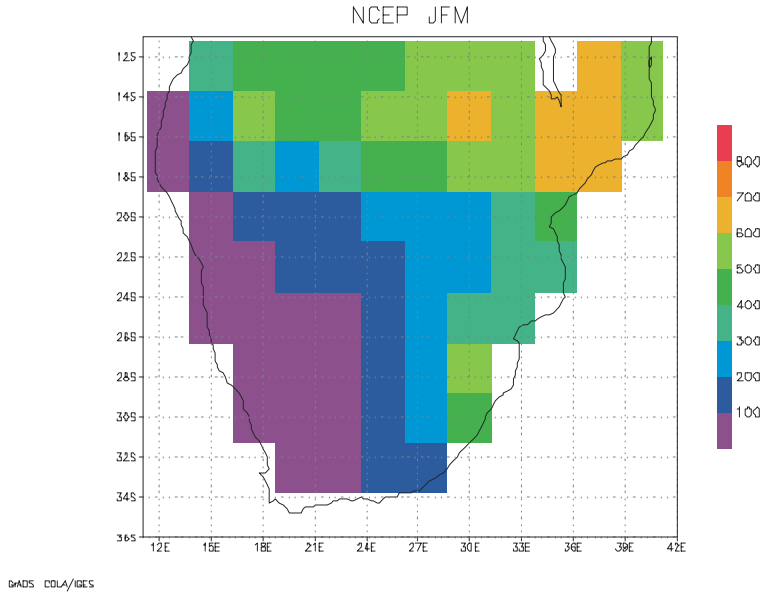
1998

JFM

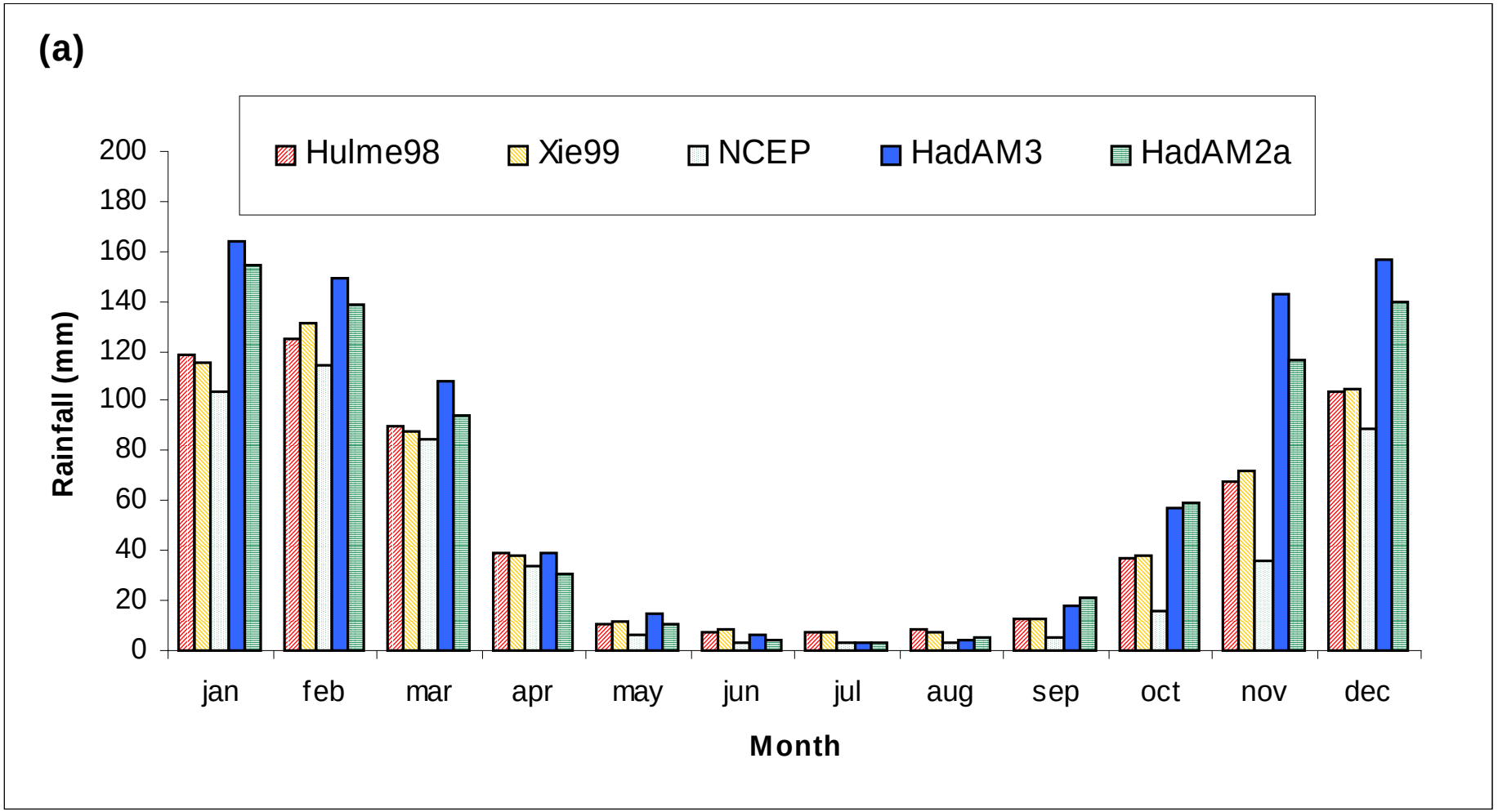




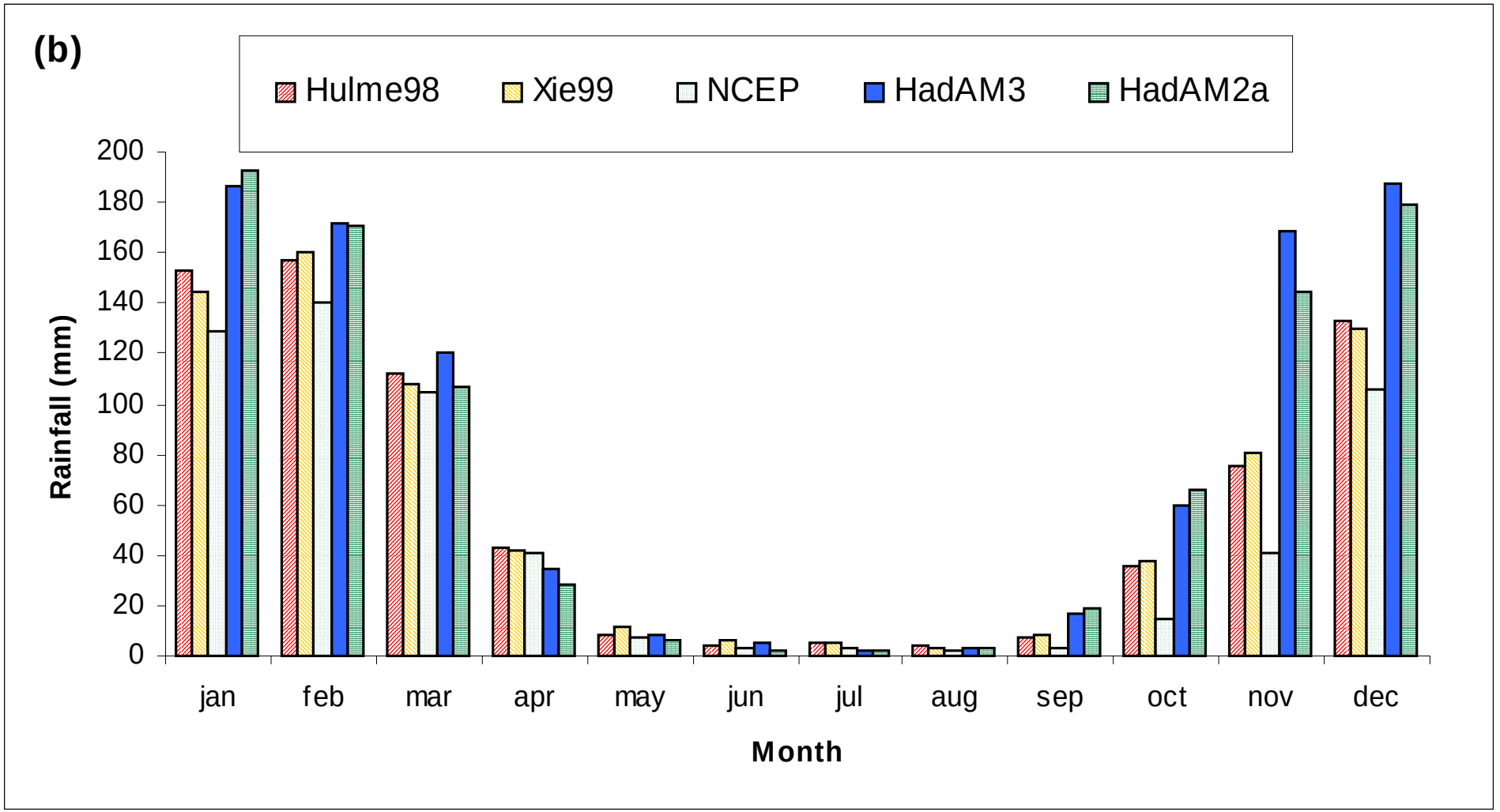




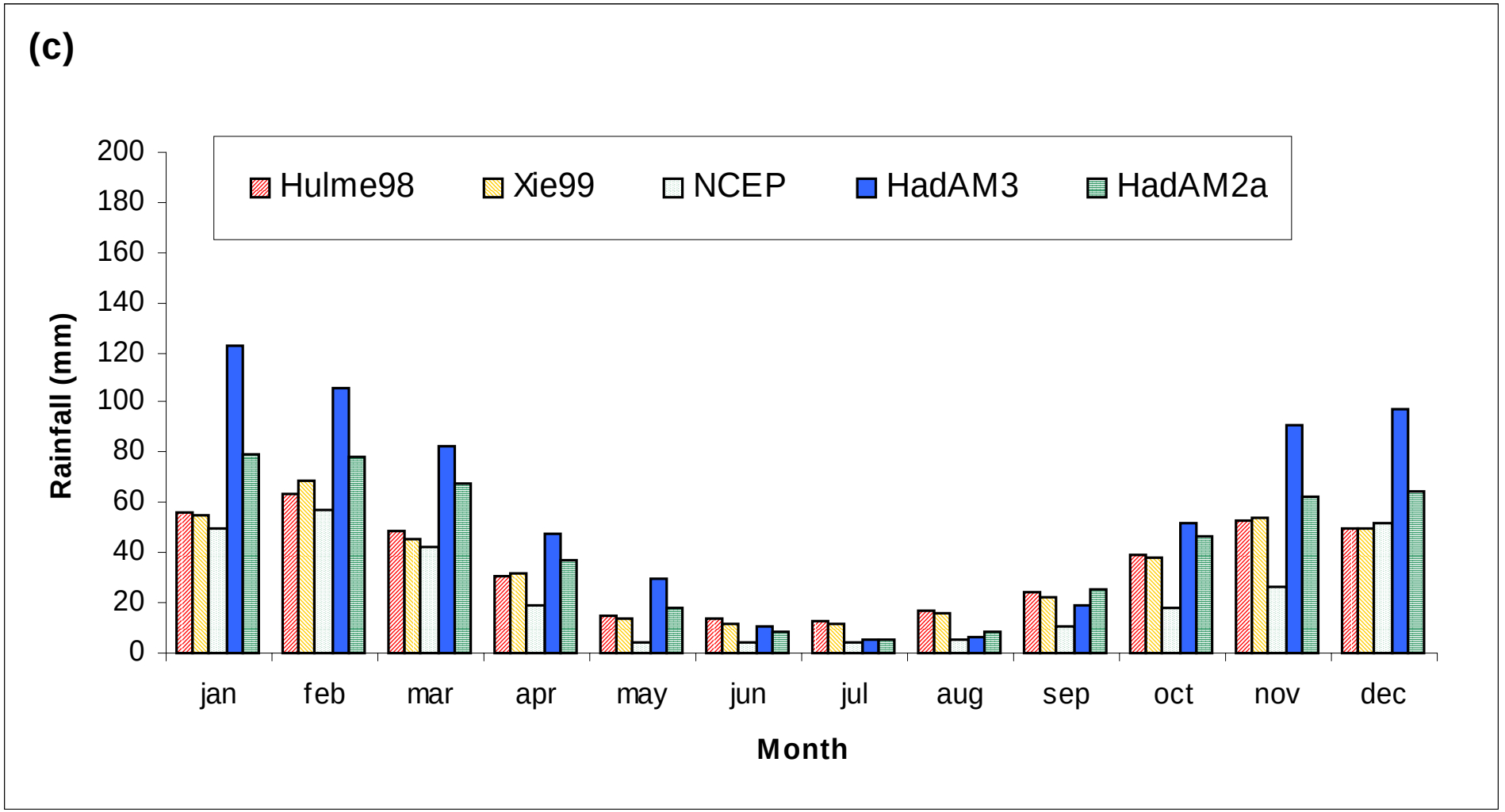
12° - 32.5° S


(a)
Hulme98
Xie99
NCEP
HadAM3
HadAM2a
Rainfall (mm)
200
180
160
140
120
100
80
60
40
20
0
jan
feb
mar
apr
may
jun
jul
aug
sep
oct
nov
dec
Month

12.5° – 22.5° S


(b)
Hulme98
Xie99
NCEP
HadAM3
HadAM2a
Rainfall (mm)
200
180
160
140
120
100
80
60
40
20
0
jan
feb
mar
apr
may
jun
jul
aug
sep
oct
nov
dec
Month

25° – 32.5° S


(c)
Hulme98
Xie99
NCEP
HadAM3
HadAM2a
Rainfall (mm)
200
180
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Does the bias in model climatology matter?

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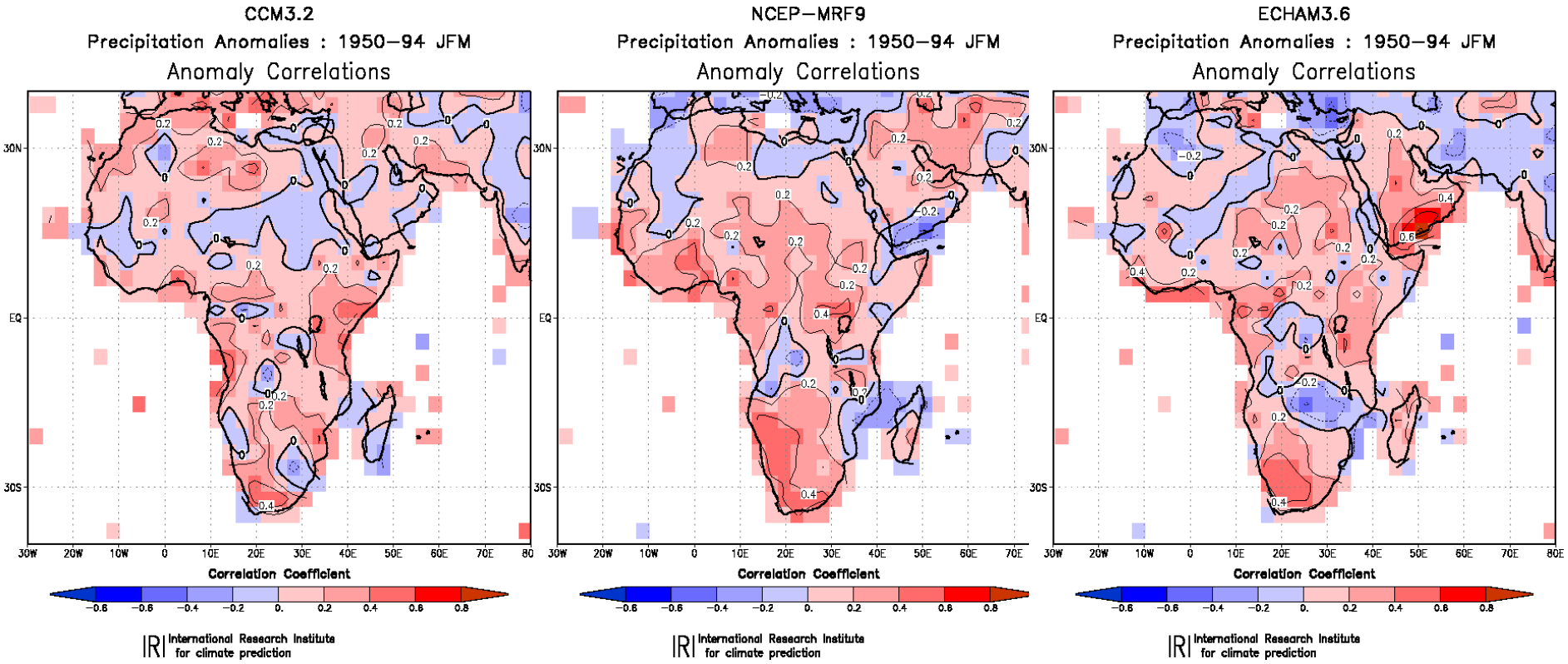
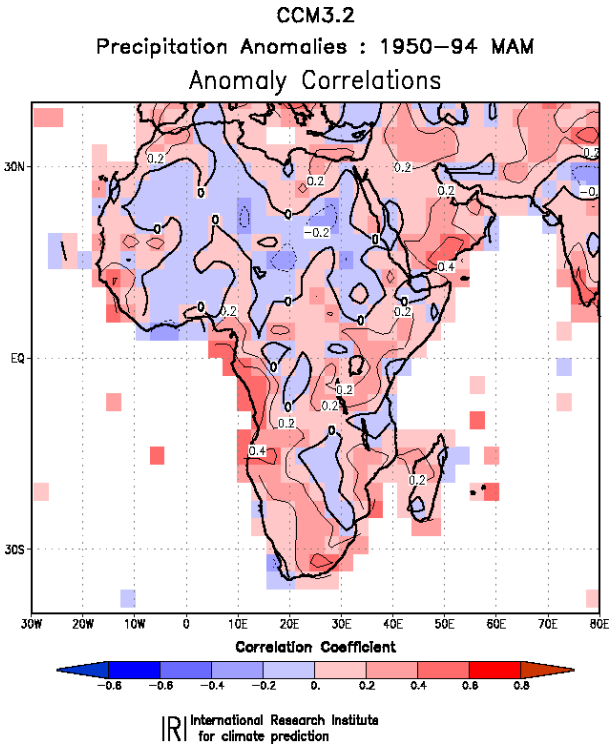
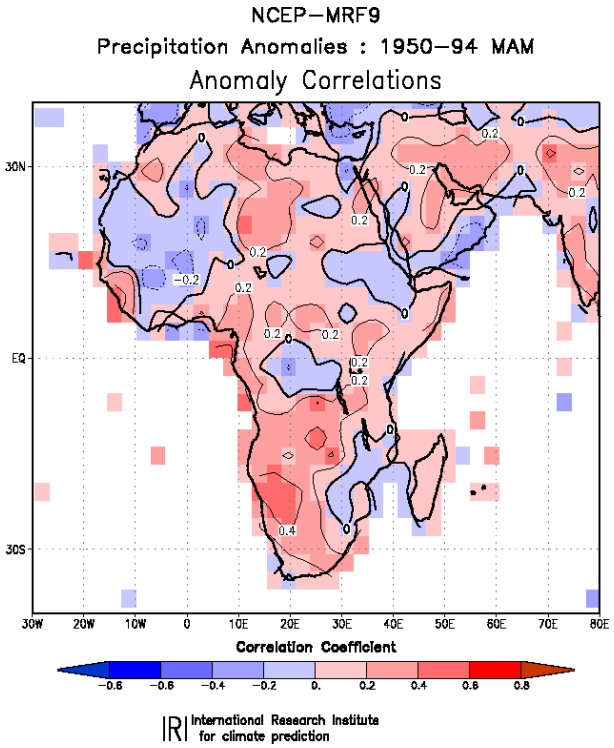
Model Vs Observed Precip JFM 1950-1994
'Perfect' (known) SSTs
http://iripred.ldeo.columbia.edu

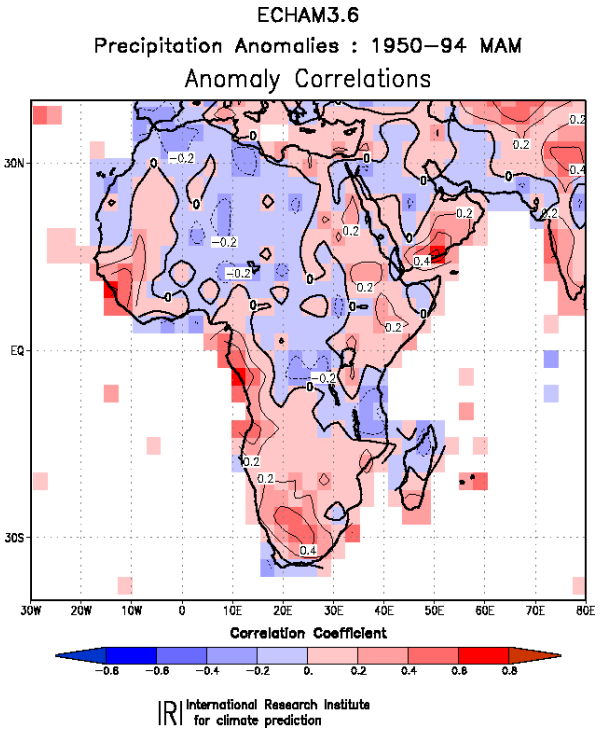


Maps available for JFM, MAM, MJJ, JAS, SON, OND, DJF
For 1950-1994, 1950-1972, 1973-1994
For CCM3, NCEP, ECHAM

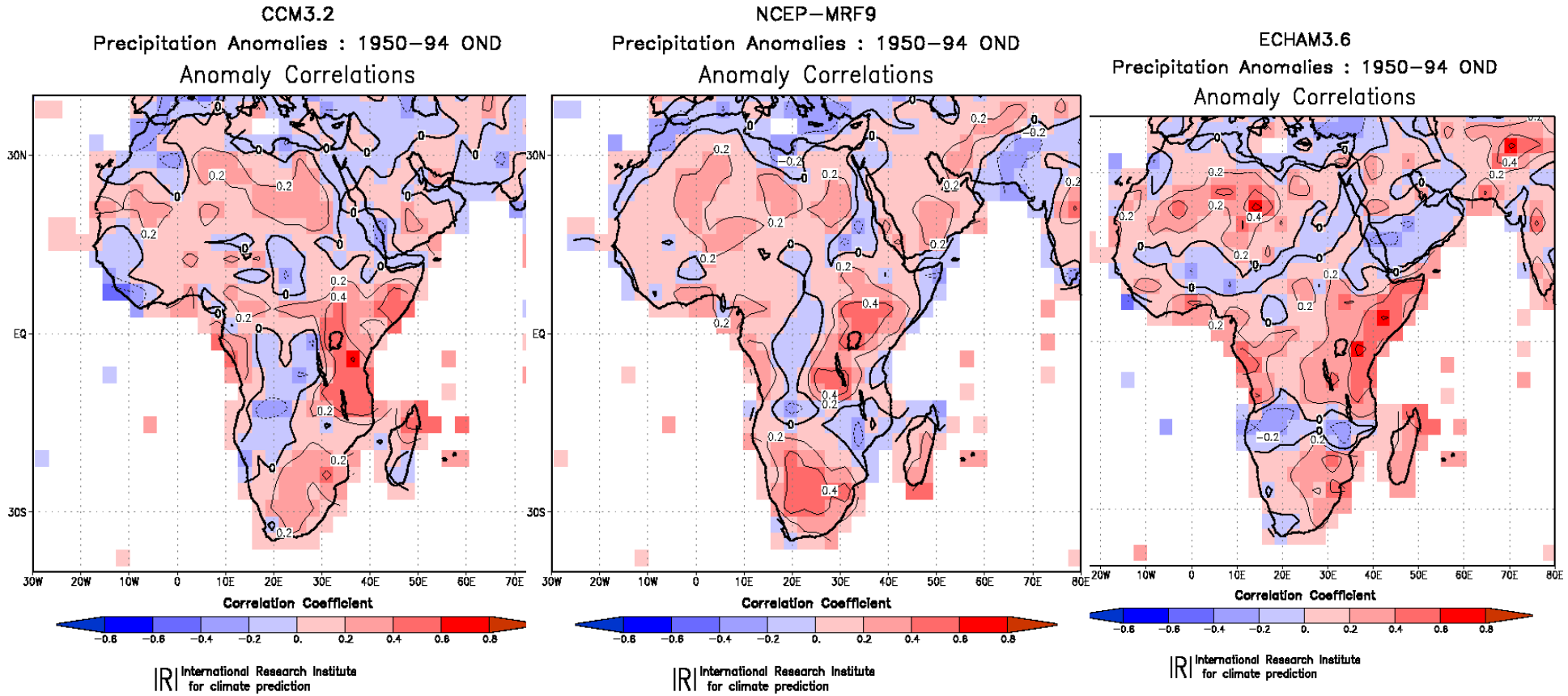
Model Vs Observed Precip MAM 1950-1994
‘Perfect’ (known) SSTs







Model Vs Observed Precip OND 1950-1994
'Perfect' (known) SSTs



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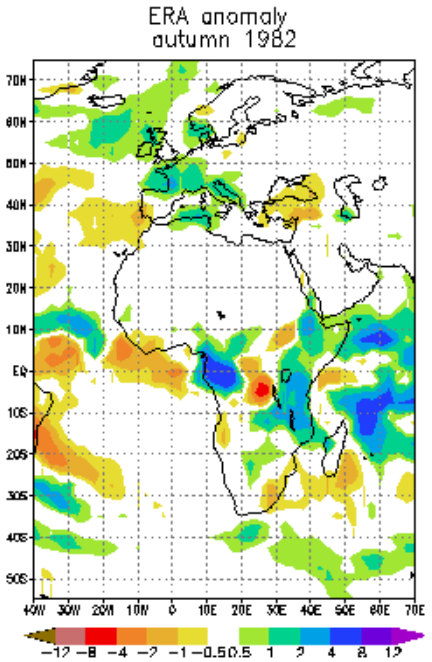
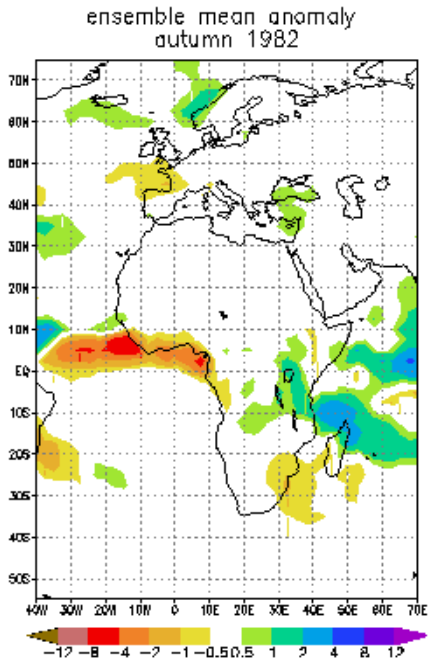
ECMWF PROVOST INETGRATIONS

- 9-member ensembles of 120-day integrations
- run over all seasons for the ERA-15 period, 1979-1993
- initiated from consecutive ERA-15 analyses, from 1 to 9 days preceding the season of interest

- Model details: ECMWF cycle 13R4 with semi-Lagrangian dynamics at T63L31 resolution
- run with observed prescribed SSTs taken from ERA-15 and updated daily

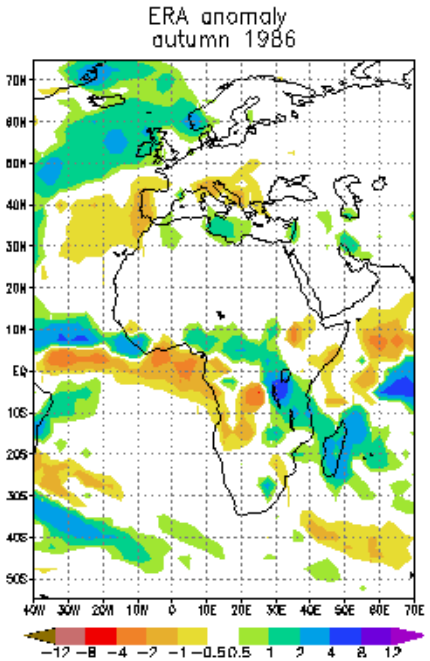
October-December Precip

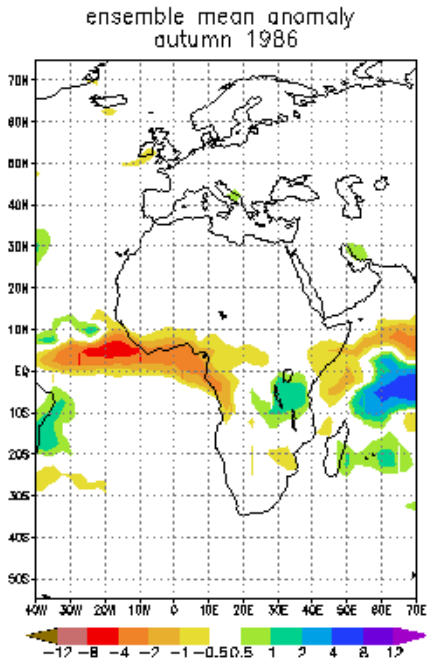




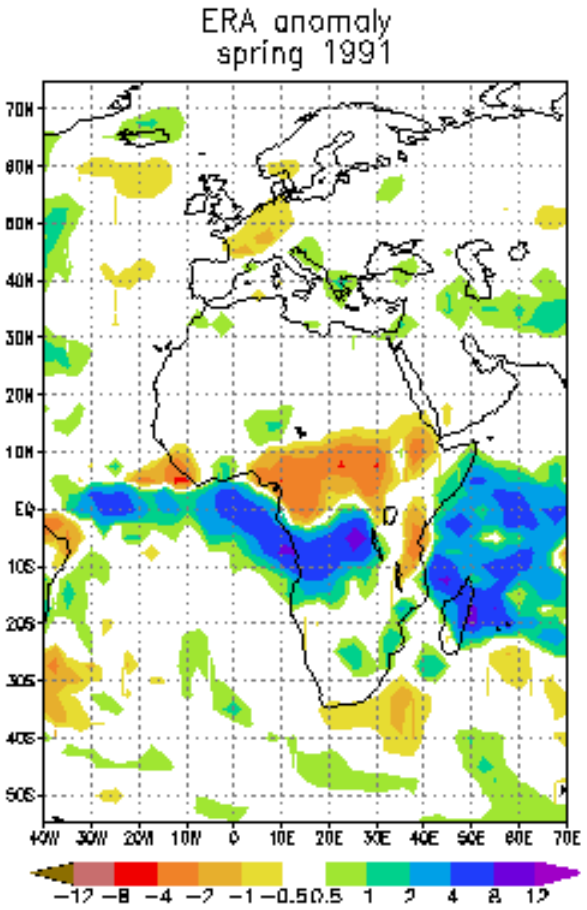
OBS MODEL

OBS MODEL

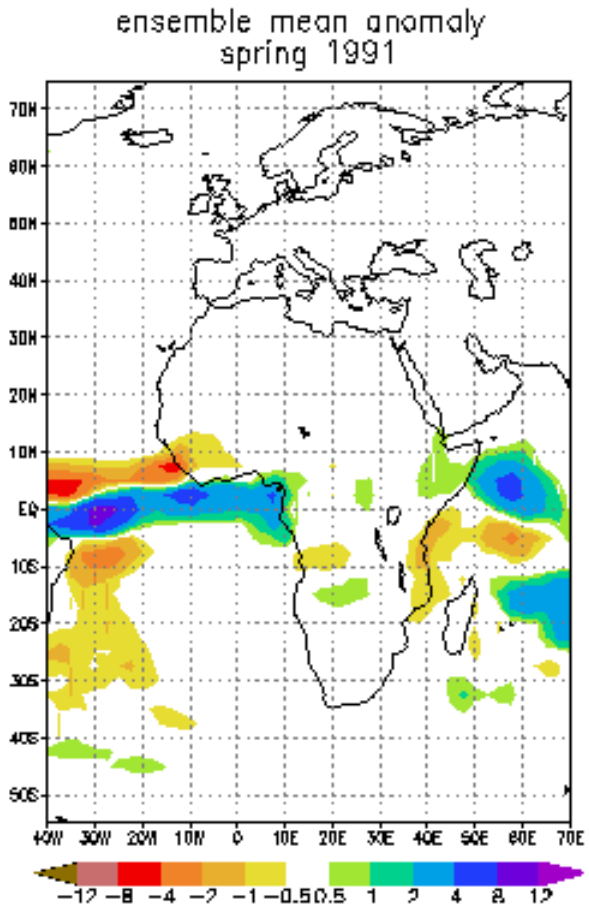




MAM Precip (problem over land)

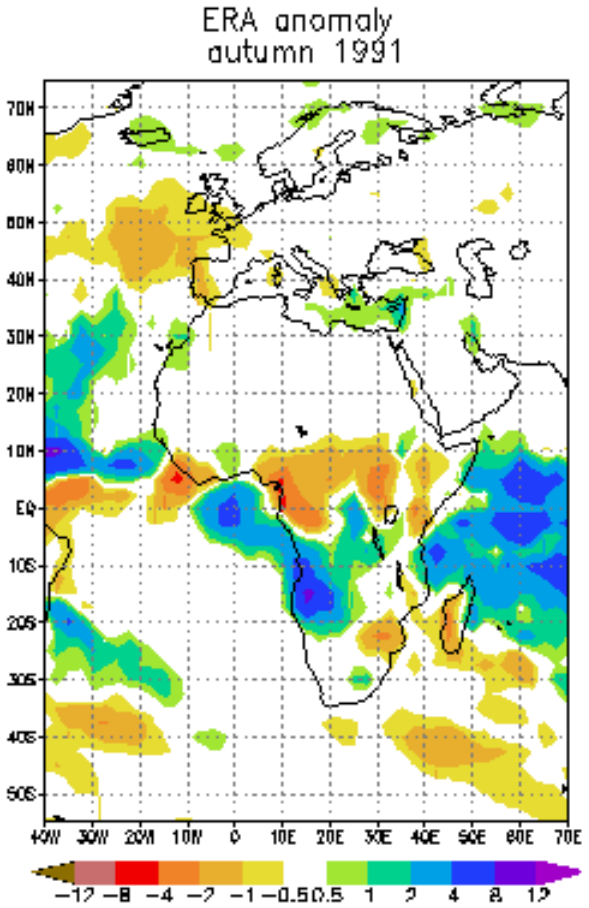


OBS

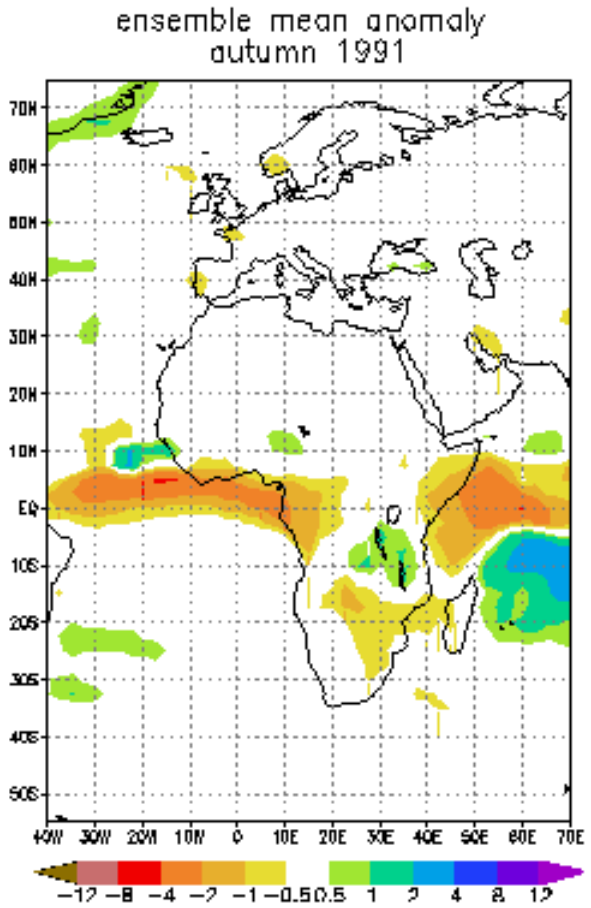


MODEL

OND Precip (poor simulation)

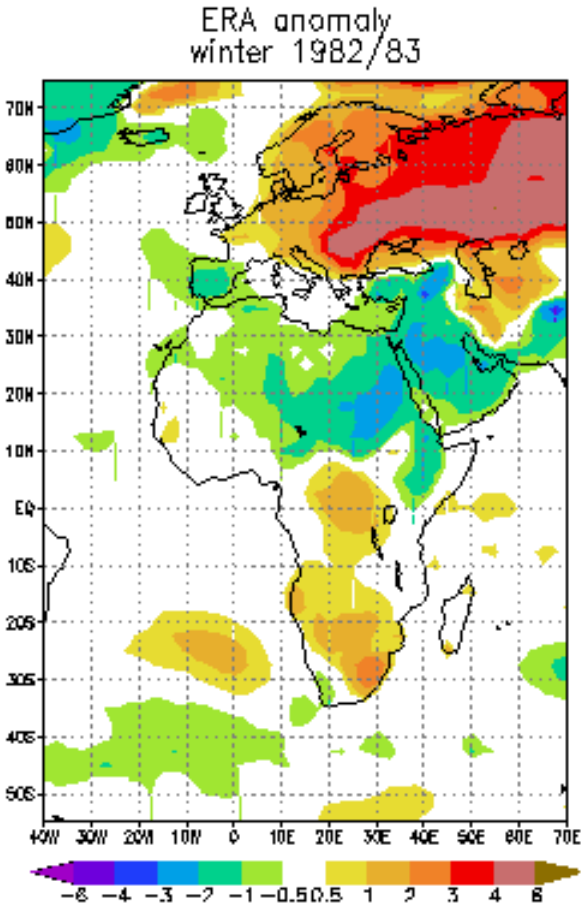


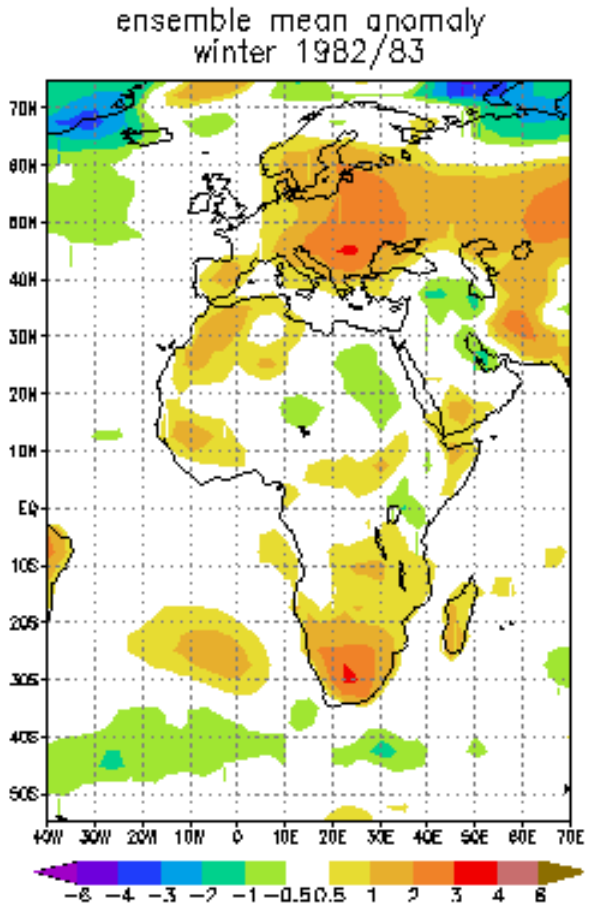
OBS



MODEL

DJF Surface Temperature

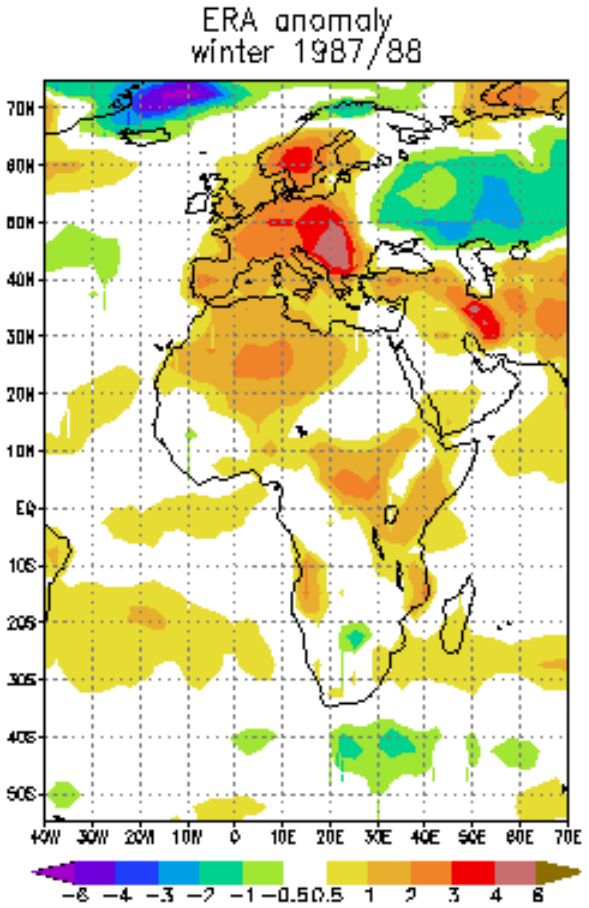


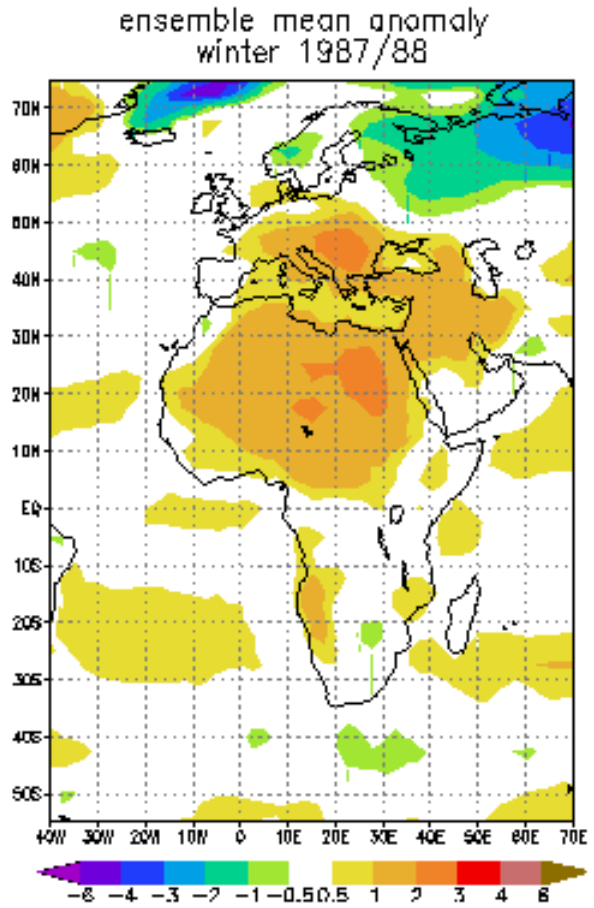


OBS

MODEL

DJF Surface Temperature…….WOW!

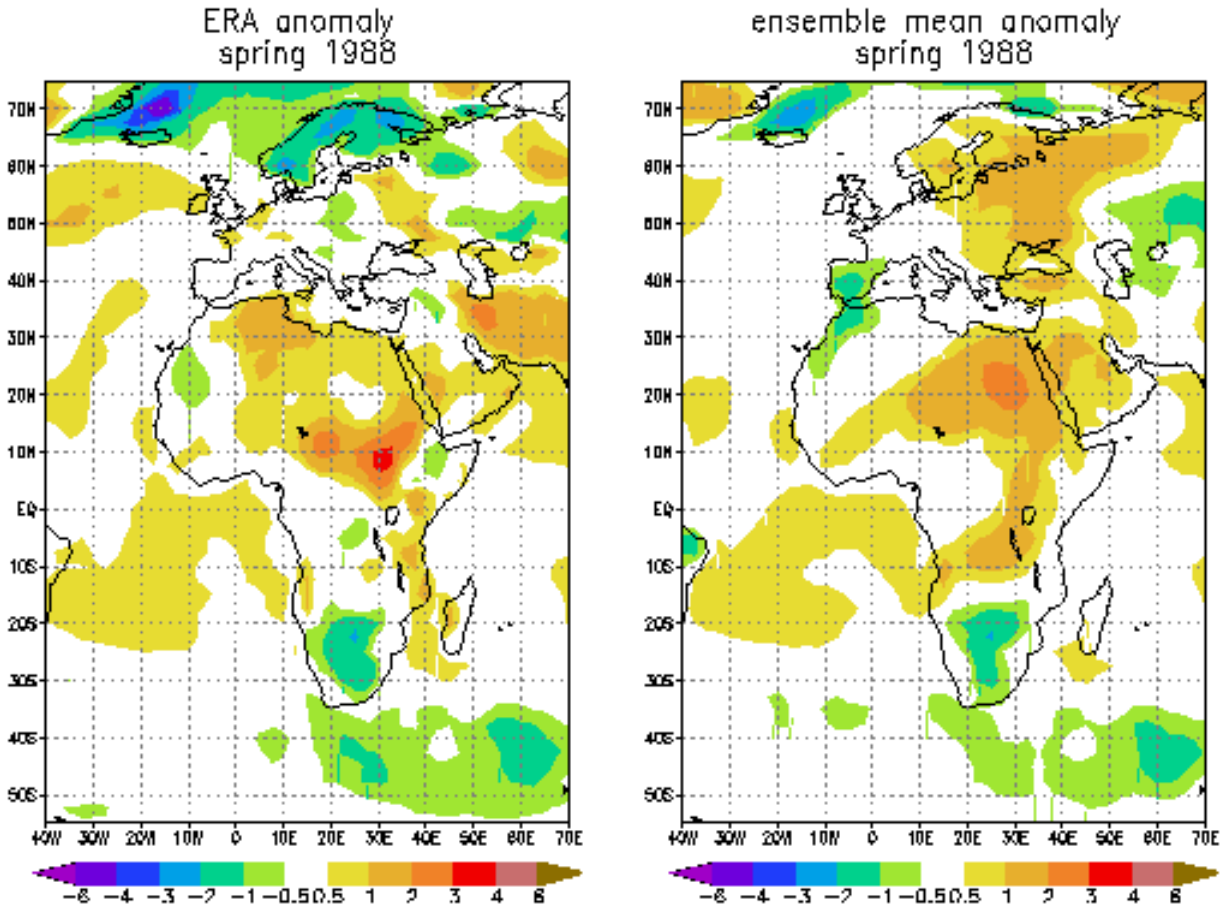




OBS

MODEL

MAM Surface Temperature…….WOW Again!



ECMWF PROVOST

- Library of Maps available to CLIPS workshop
- DJF, MAM, JAS, OND, March
- 1980, 82, 83, 86, 87, 88, 91, 92, 93
- Precip, surface temperatures

- Precip Skill modest
- Temperature skill better (why do you think this is true?
- Oceans better than land
- Model underestimates amplitudes over land overestimates amplitudes over oceans
- Large scale Vs convective rainfall problem

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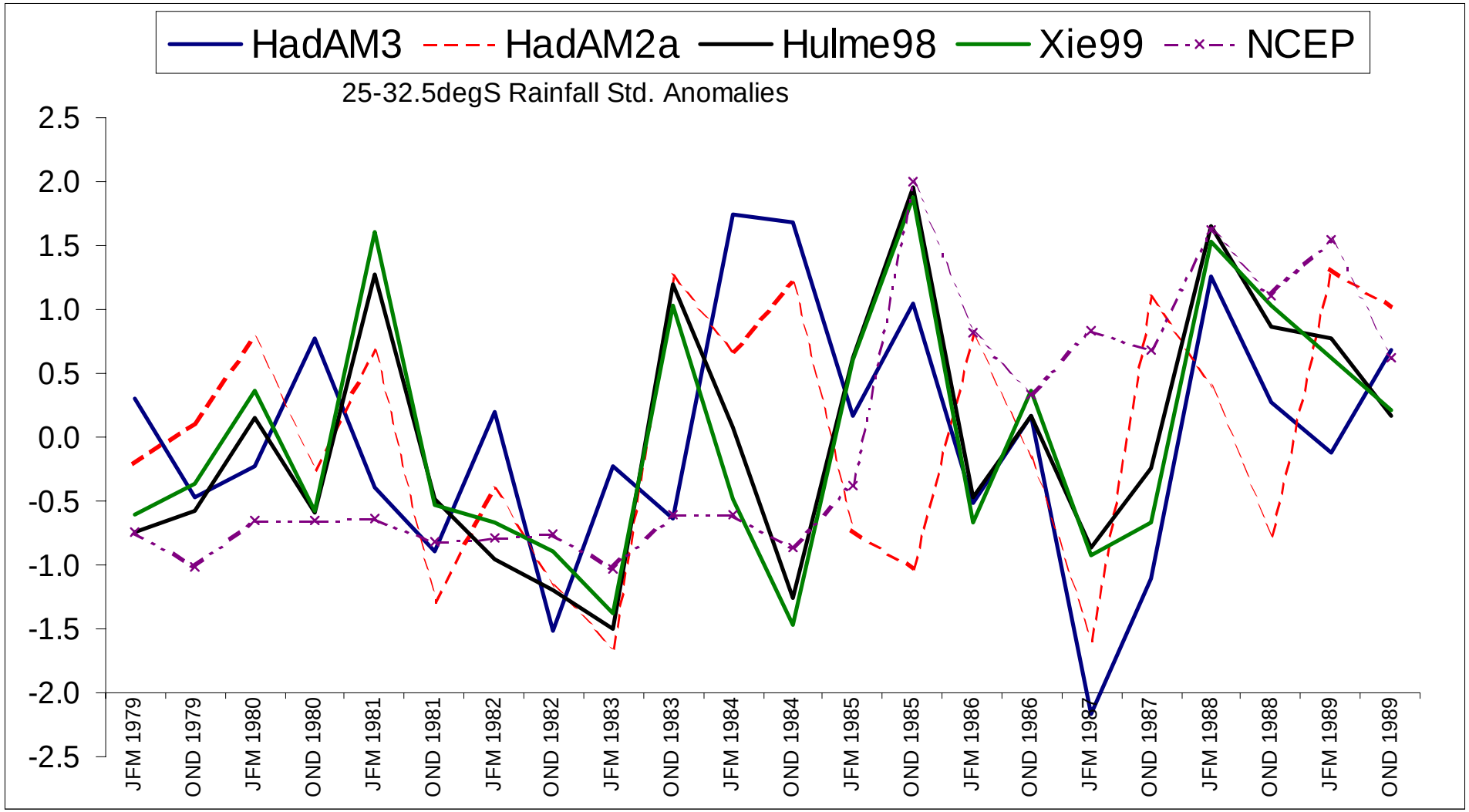
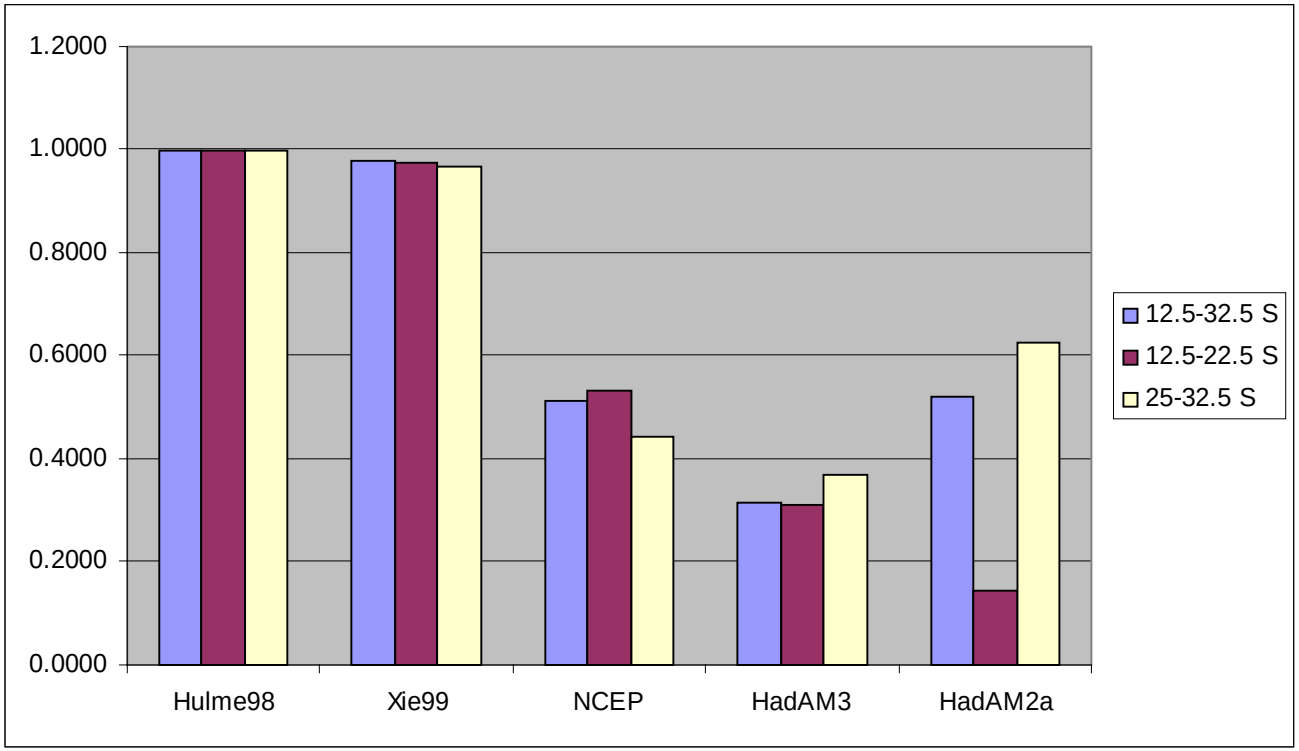
  - UKMO HadAM3
- Conclusions


HadAM3
HadAM2a
Hulme98
Xie99
NCEP
25-32.5degS Rainfall Std. Anomalies
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
JFM 1979
OND 1979
JFM 1980
OND 1980
JFM 1981
OND 1981
JFM 1982
OND 1982
JFM 1983
OND 1983
JFM 1984
OND 1984
JFM 1985
OND 1985
JFM 1986
OND 1986
JFM 1987
OND 1987
JFM 1988
OND 1988
JFM 1989
OND 1989

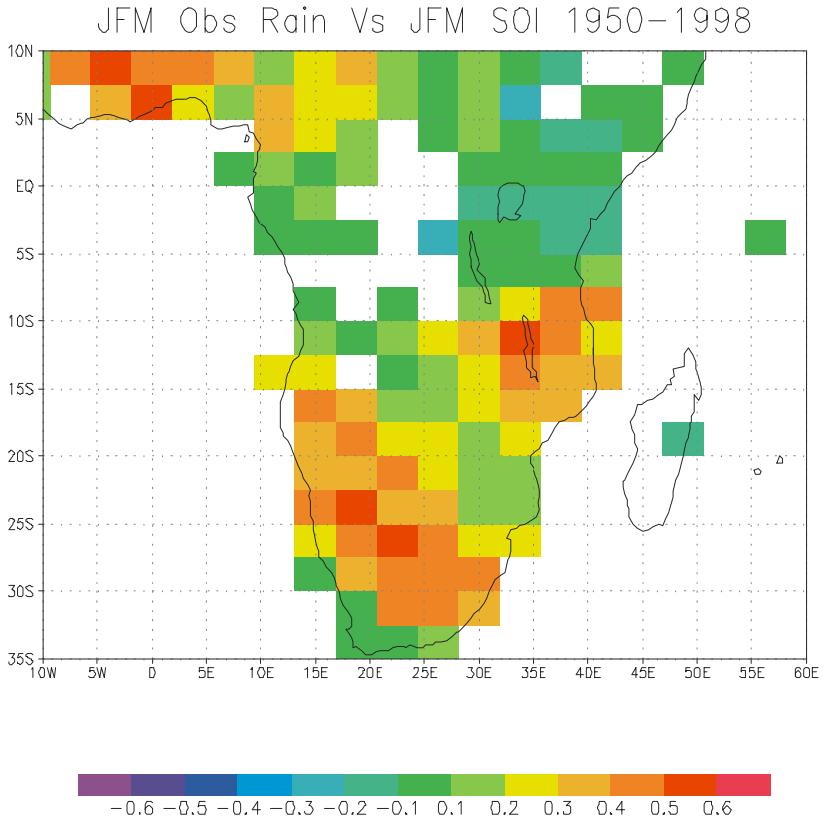
Obs JFm precip (Hulme) Correlated with satellite and model precip 1979-1993

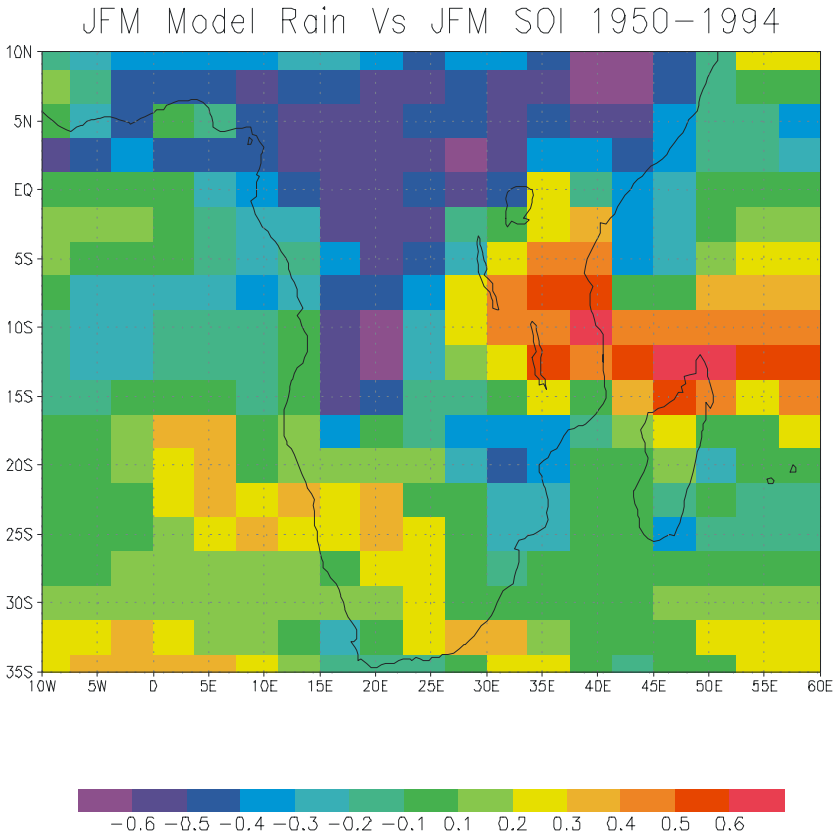


	Hulme98	Xie99	NCEP	HadAM3	HadAM2a
12.5-32.5 S	1.0000	0.9797	0.5136	0.3155	0.5216
12.5-22.5 S	1.0000	0.9753	0.5305	0.3095	0.1441
25-32.5 S	1.0000	0.9674	0.4412	0.3682	0.6239

Obs

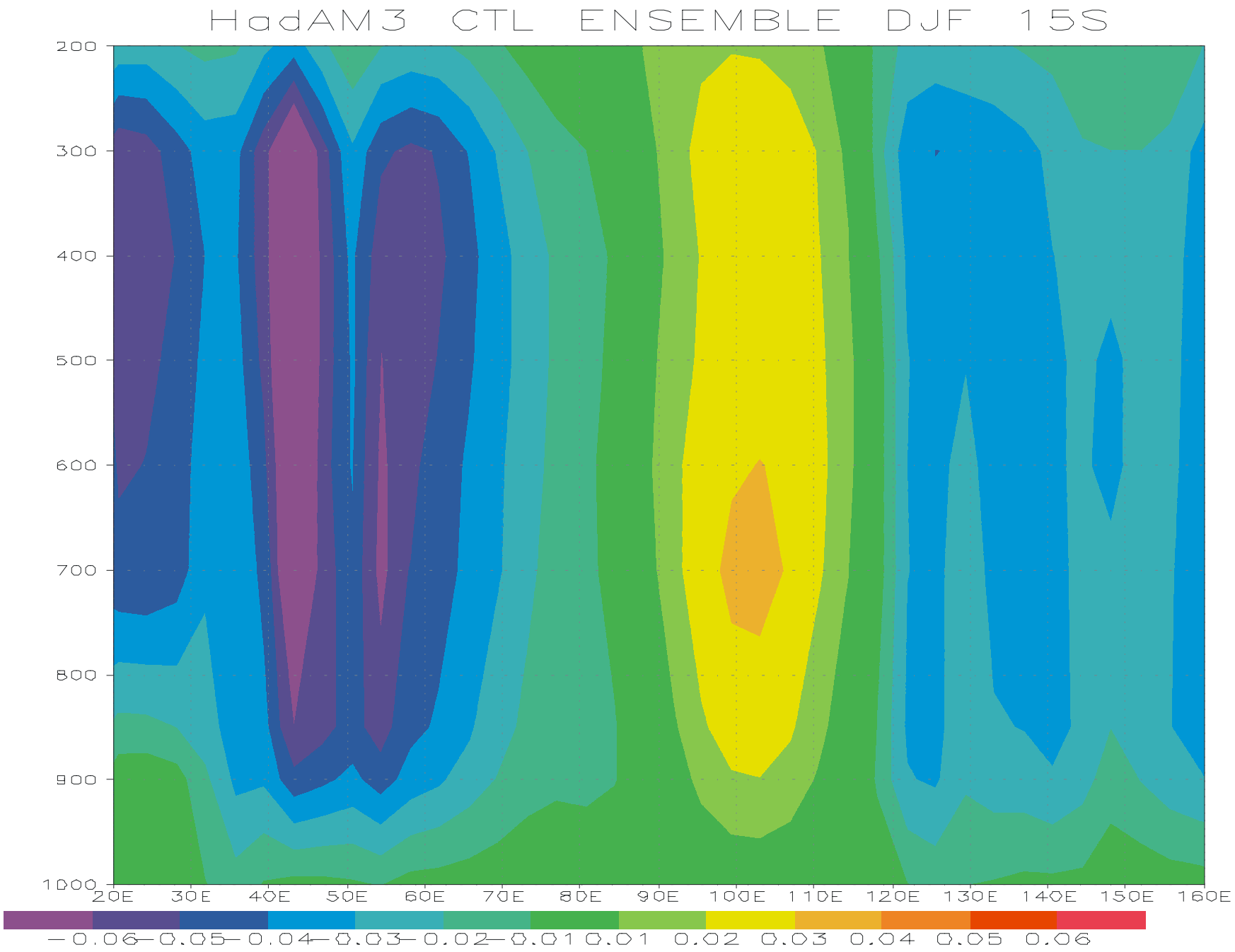
HadAM3

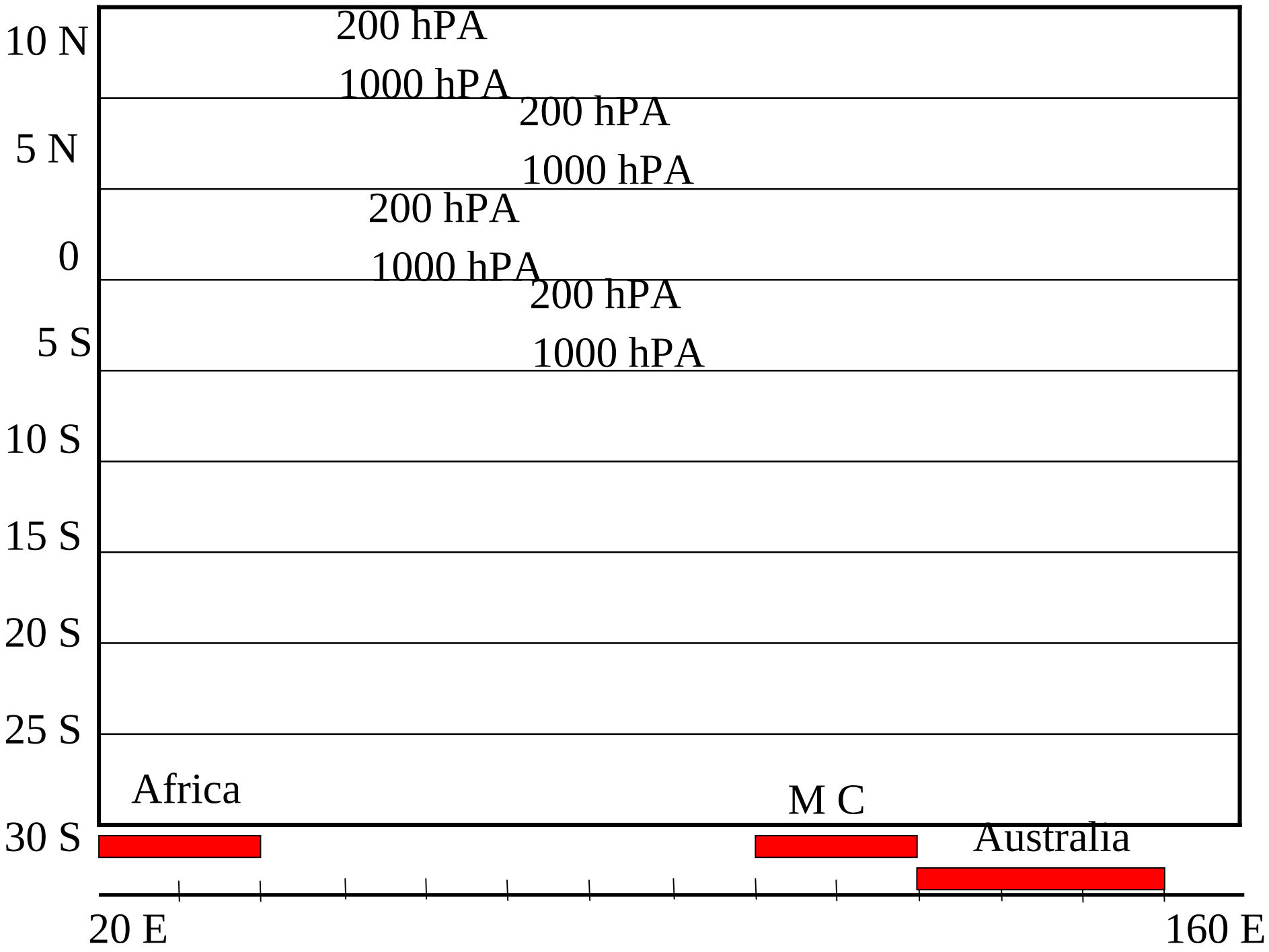

JFM Obs Rain Vs JFM SOI 1950-1998
10N
5N
EQ
5S
10S
15S
20S
25S
30S
35S
10W 5W 0 5E 10E 15E 20E 25E 30E 35E 40E 45E 50E 55E 60E
-0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0.1 0.2 0.3 0.4 0.5 0.6

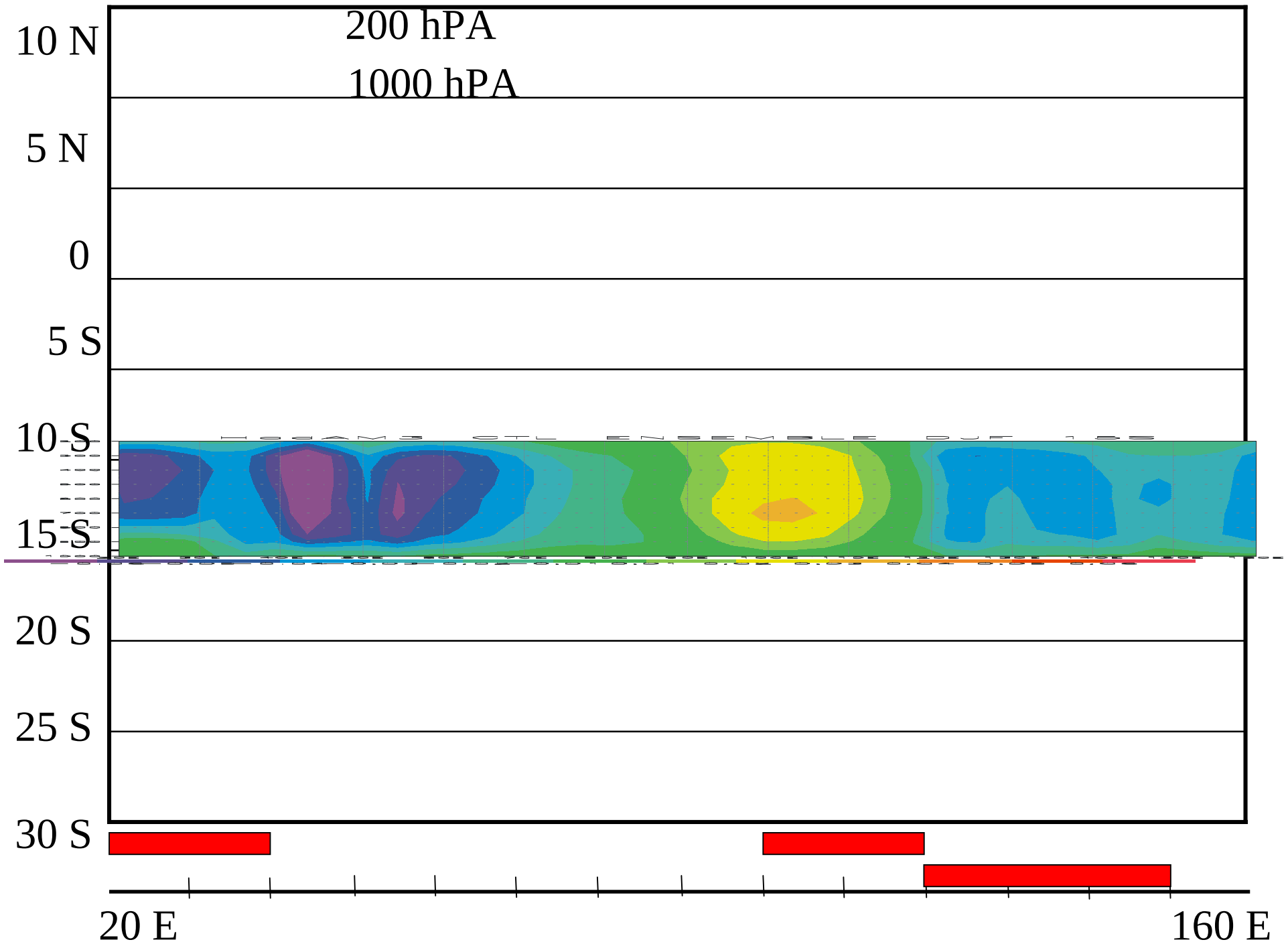

JFM Model Rain Vs JFM SOI 1950-1994
10N
5N
EQ
5S
10S
15S
20S
25S
30S
35S
10W 5W 0 5E 10E 15E 20E 25E 30E 35E 40E 45E 50E 55E 60E
-0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0.1 0.2 0.3 0.4 0.5 0.6

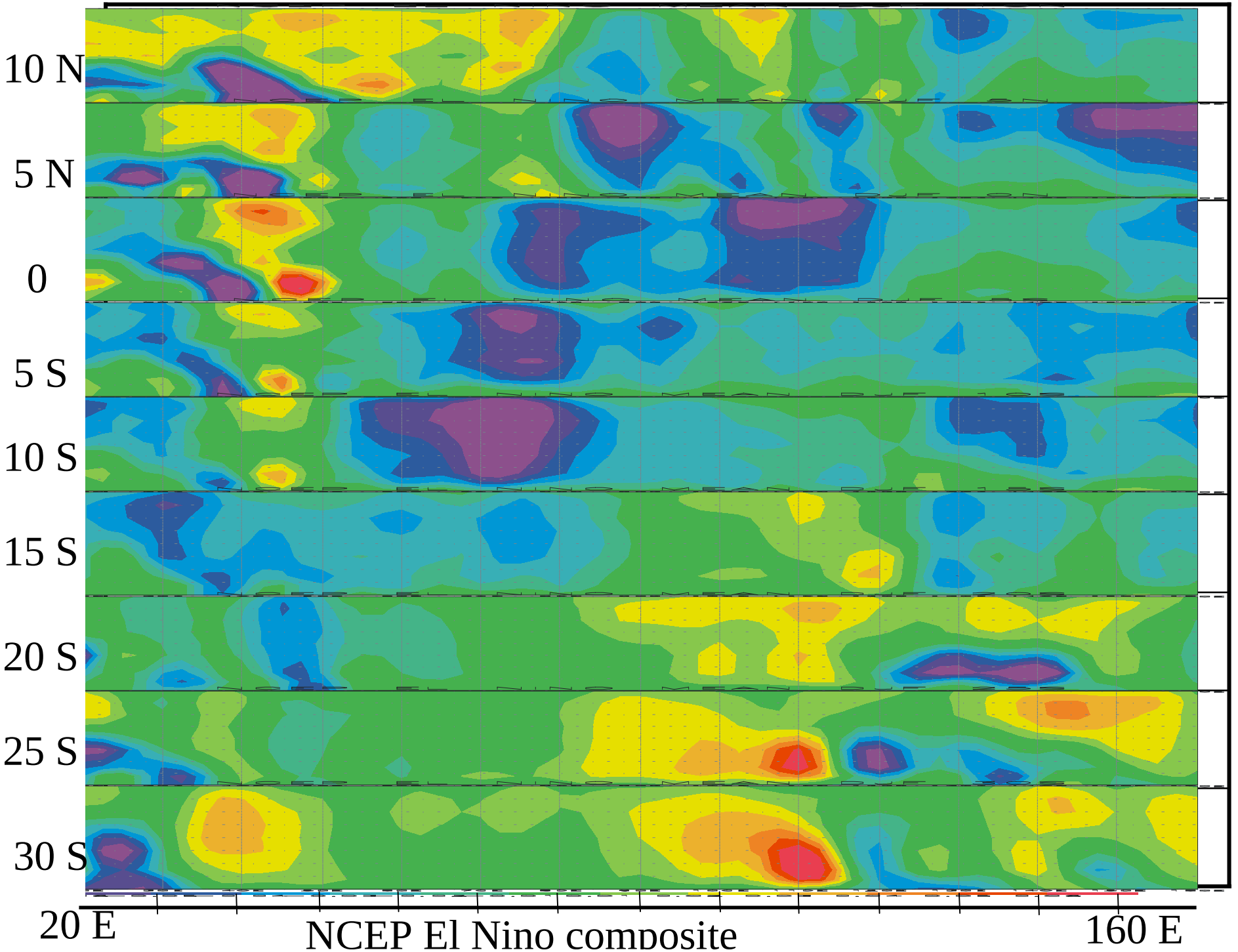
Omega DJF X Sections

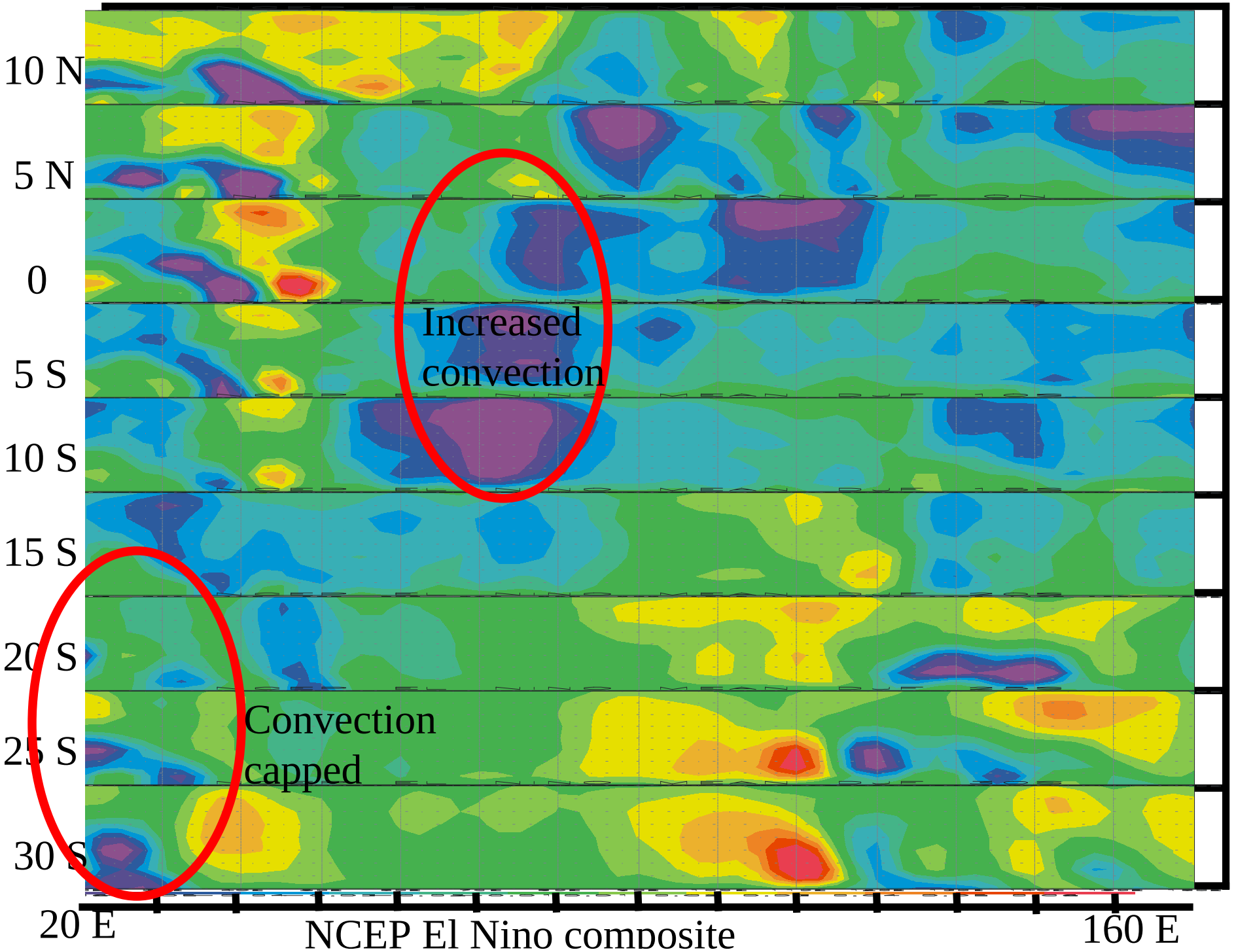
- El Nino Composites
  - NCEP and HadAM3
- Climatology
  - NCEP and HadAM3


HadAM3 CTL ENSEMBLE DJF 15S
200
300
400
500
600
700
800
900
1000
20E
30E
40E
50E
60E
70E
80E
90E
100E
110E
120E
130E
140E
150E
160E
−0.06 −0.05 −0.04 −0.03 −0.02 −0.01 0.01 0.02 0.03 0.04 0.05 0.06

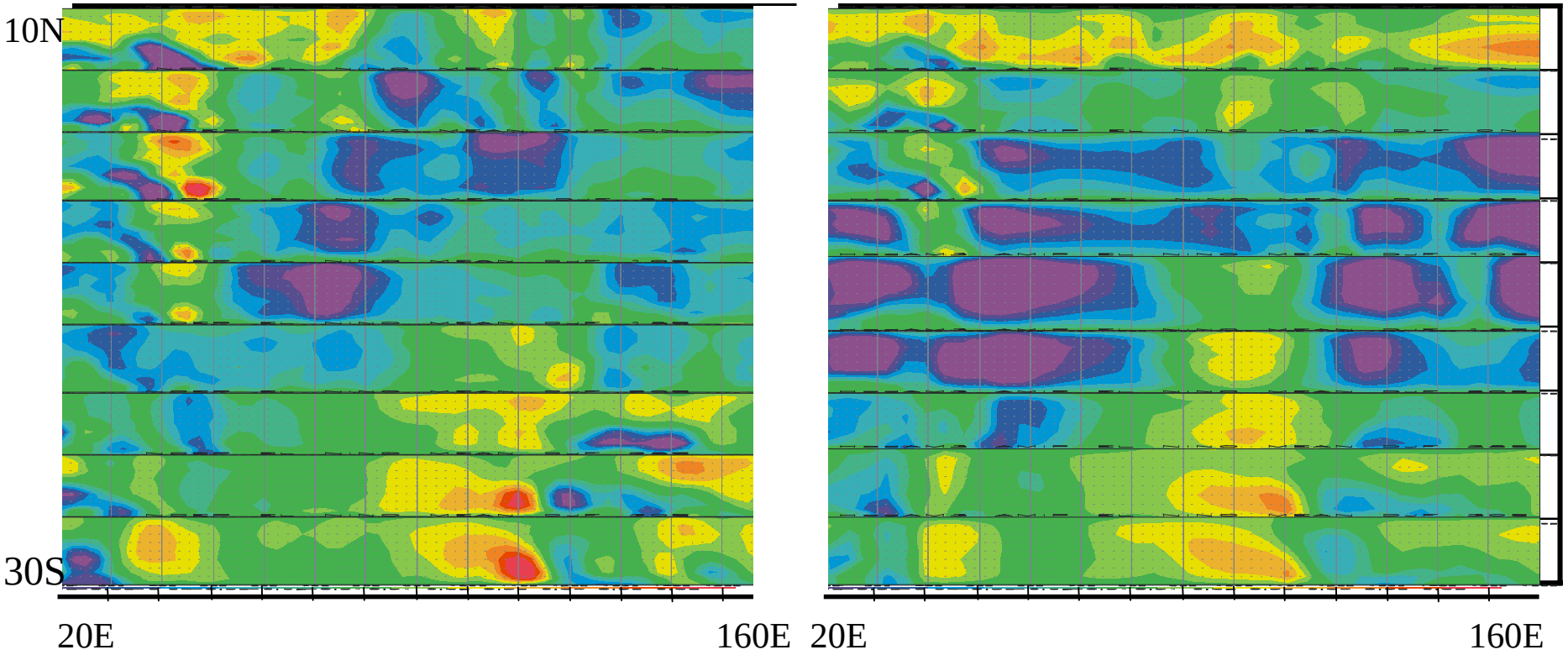

10 N
5 N
0
5 S
10 S
15 S
20 S
25 S
30 S
200 hPA
1000 hPA
200 hPA
1000 hPA
200 hPA
1000 hPA
200 hPA
1000 hPA
Africa
M C
Australia
20 E
160 E


200 hPA
1000 hPA
10 N
5 N
0
5 S
10 S
15 S
20 S
25 S
30 S
20 E
160 E


10 N
5 N
0
5 S
10 S
15 S
20 S
25 S
30 S
20 E
160 E
NCEP El Nino composite


10 N
5 N
0
5 S
10 S
15 S
20 S
25 S
30 S
20 E
160 E
Increased
convection
Convection
capped
NCEP El Nino composite

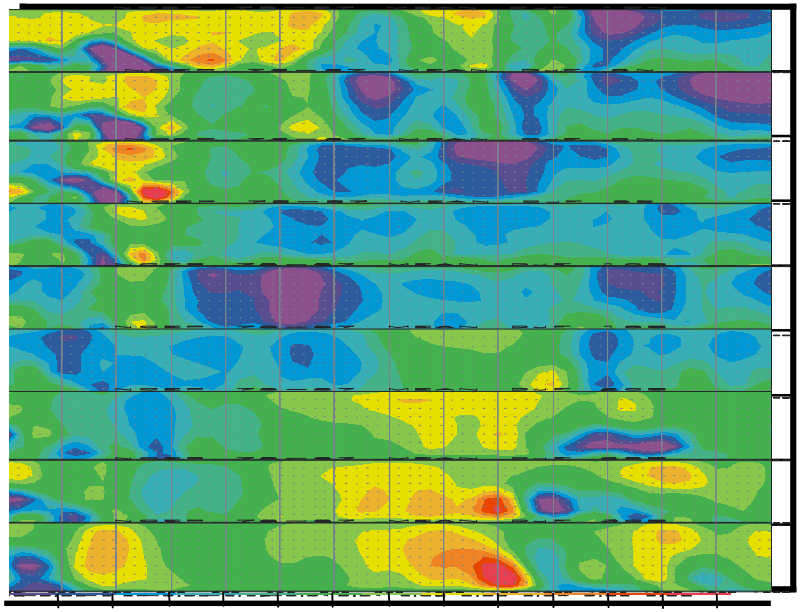
El Nino



NCEP

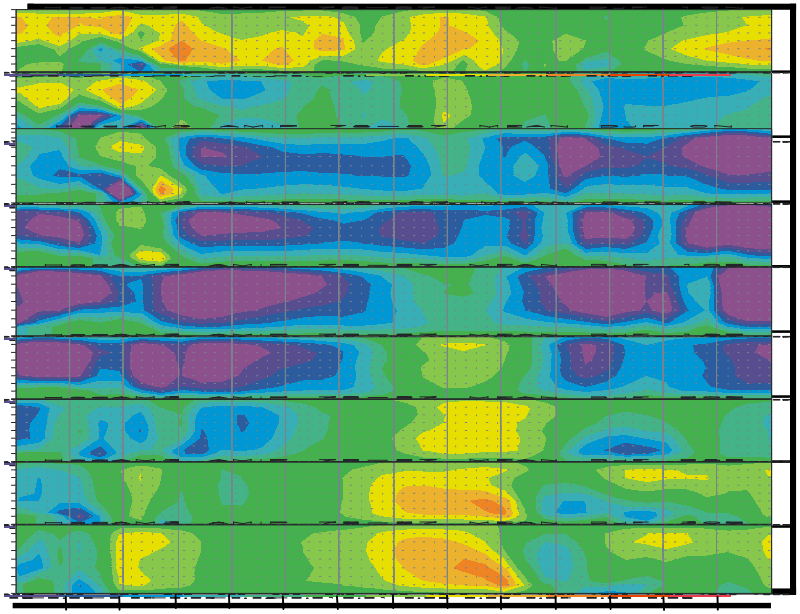
HadAM3

LTM



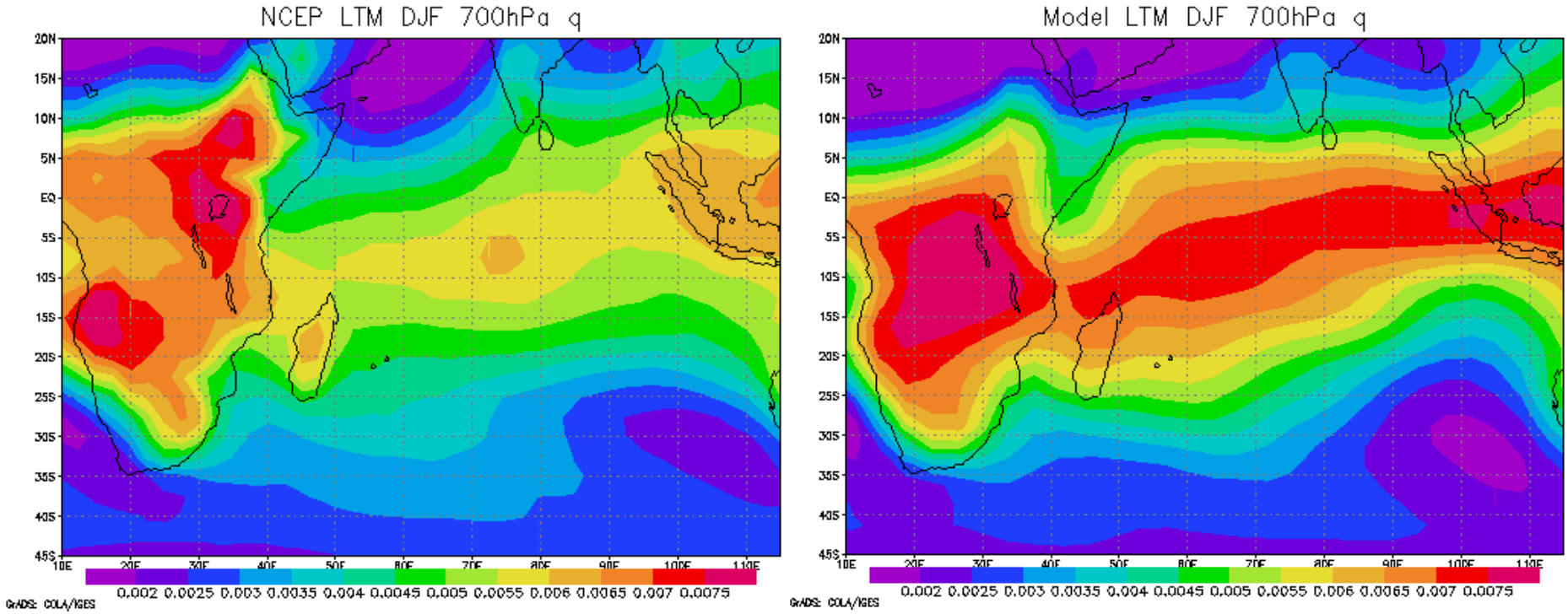
20E 160E

NCEP

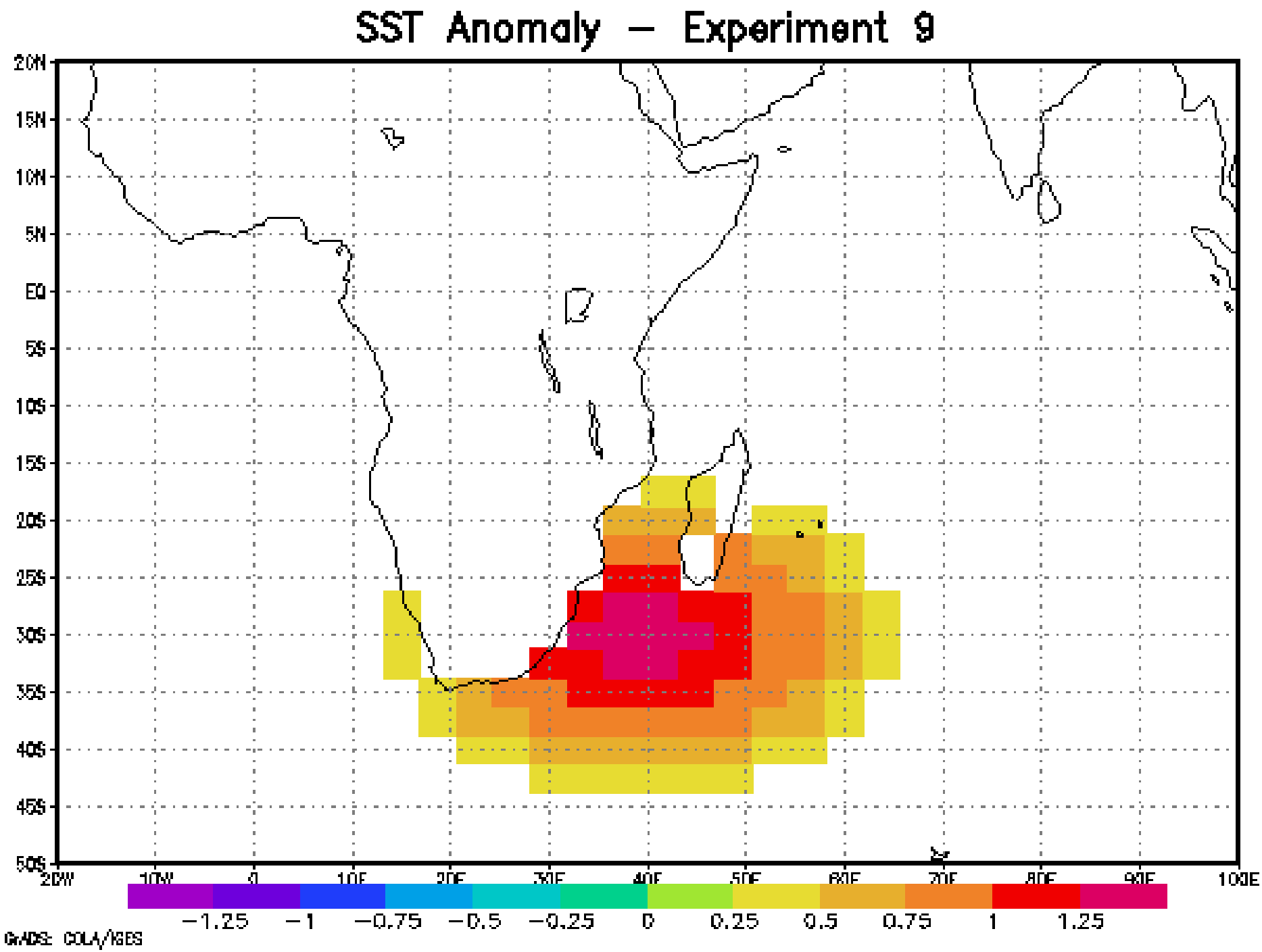


20E 160E

HadAM3


NCEP LTM DJF 700hPa q
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
35S
40S
45S
10E
20E
30E
40E
50E
60E
70E
80E
90E
100E
110E
0.002 0.0025 0.003 0.0035 0.004 0.0045 0.005 0.0055 0.006 0.0065 0.007 0.0075
GrADS: COLA/IGES

Model LTM DJF 700hPa q
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
35S
40S
45S
10E
20E
30E
40E
50E
60E
70E
80E
90E
100E
110E
0.002 0.0025 0.003 0.0035 0.004 0.0045 0.005 0.0055 0.006 0.0065 0.007 0.0075
GrADS: COLA/IGES


SST Anomaly – Experiment 9
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
35S
40S
45S
50S
20W
10W
0
10E
20E
30E
40E
50E
60E
70E
80E
90E
100E
−1.25
−1
−0.75
−0.5
−0.25
0
0.25
0.5
0.75
1
1.25
GrADS: COLA/IGES

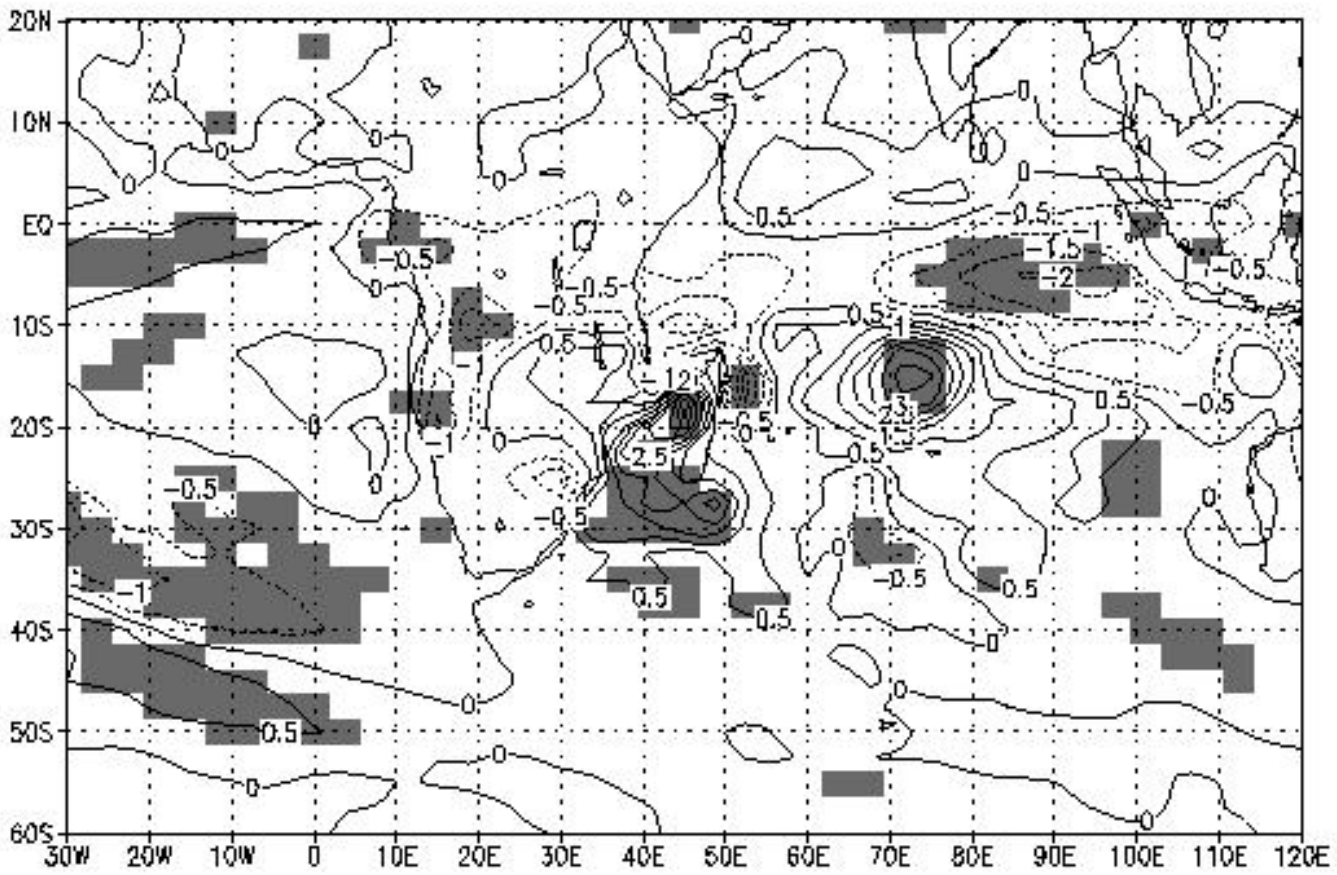
Expt 9

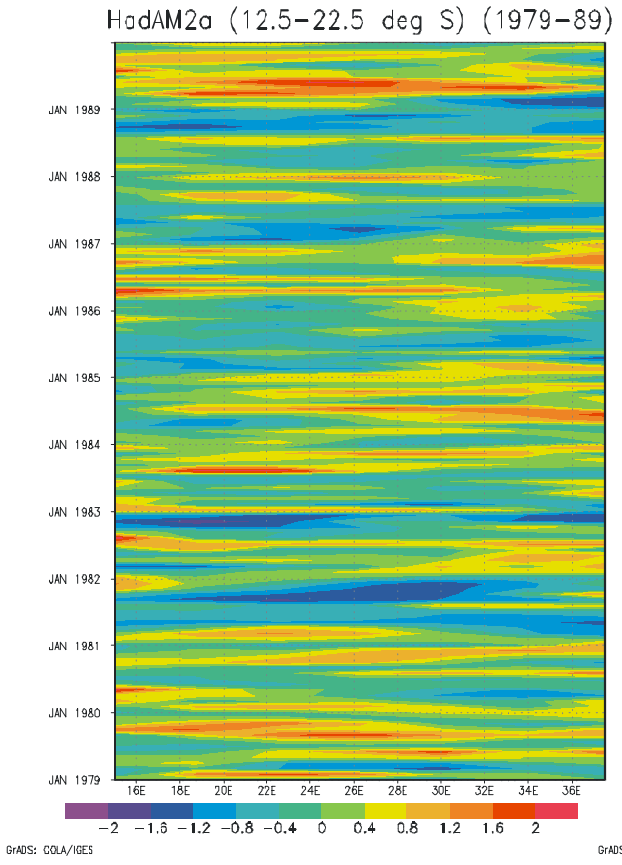
Rain Rate

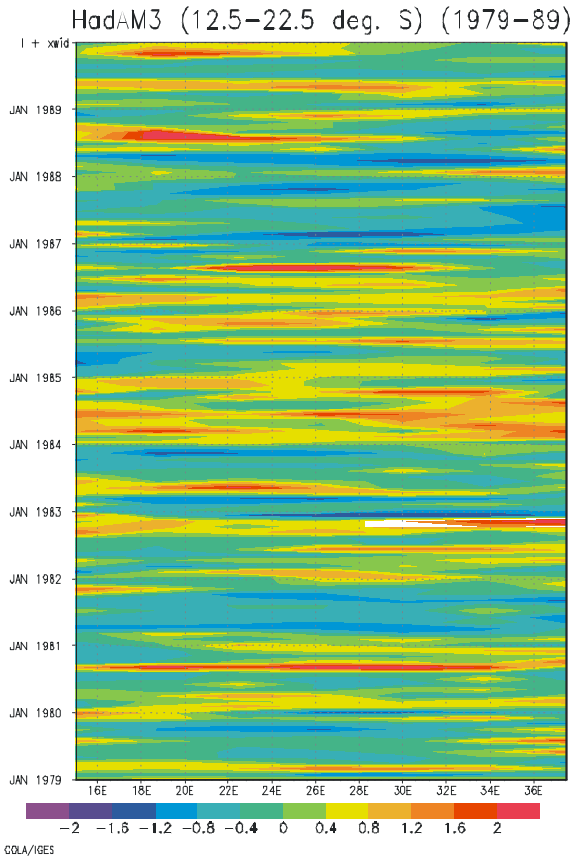
Experiment

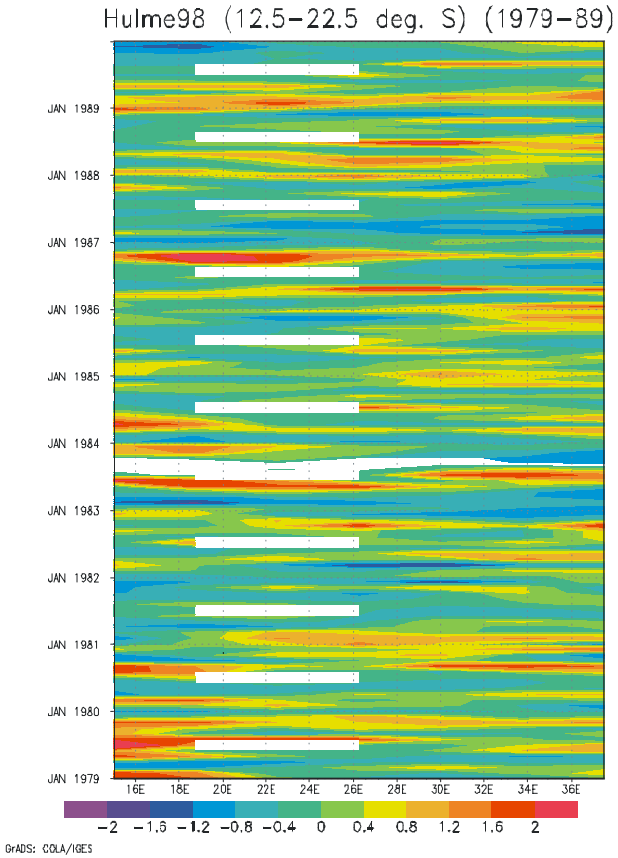
Minus

control

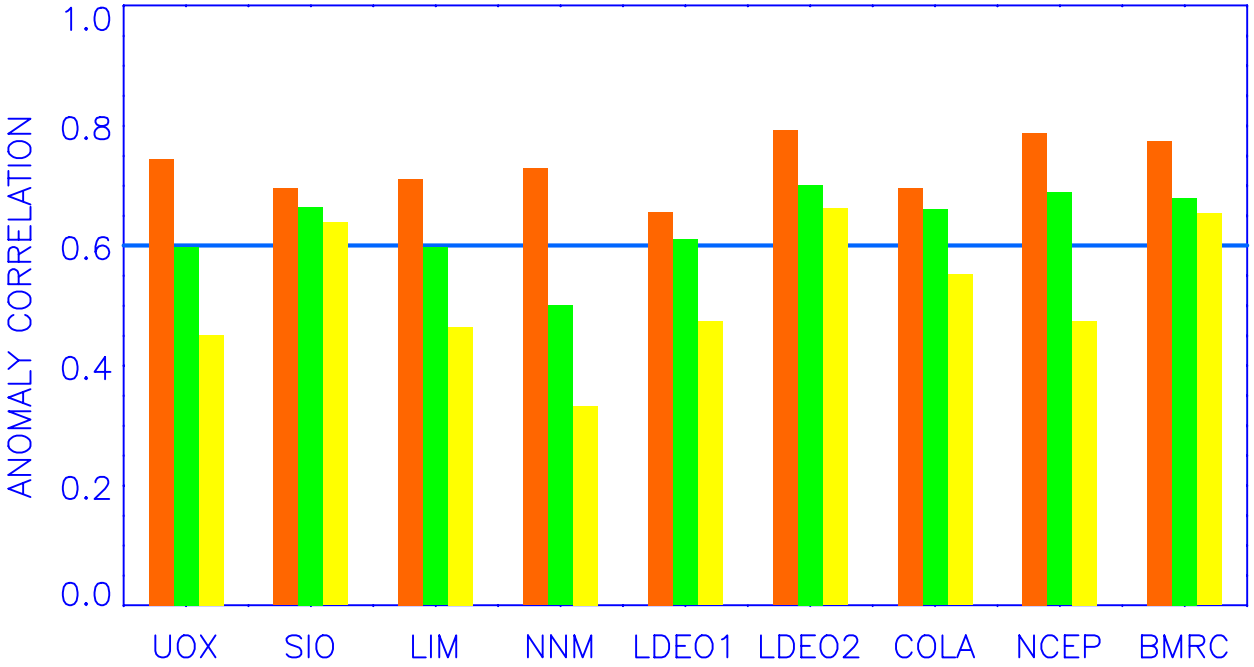



HadAM2a (12.5-22.5 deg S) (1979-89)
JAN 1989
JAN 1988
JAN 1987
JAN 1986
JAN 1985
JAN 1984
JAN 1983
JAN 1982
JAN 1981
JAN 1980
JAN 1979
16E 18E 20E 22E 24E 26E 28E 30E 32E 34E 36E
−2 −1.6 −1.2 −0.8 −0.4 0 0.4 0.8 1.2 1.6 2
GrADS: COLA/IGES


HadAM3 (12.5-22.5 deg. S) (1979-89)
1 + xwid
JAN 1989
JAN 1988
JAN 1987
JAN 1986
JAN 1985
JAN 1984
JAN 1983
JAN 1982
JAN 1981
JAN 1980
JAN 1979
16E 18E 20E 22E 24E 26E 28E 30E 32E 34E 36E
−2 −1.6 −1.2 −0.8 −0.4 0 0.4 0.8 1.2 1.6 2
GrADS: COLA/IGES


Hulme98 (12.5-22.5 deg. S) (1979-89)
JAN 1989
JAN 1988
JAN 1987
JAN 1986
JAN 1985
JAN 1984
JAN 1983
JAN 1982
JAN 1981
JAN 1980
JAN 1979
16E 18E 20E 22E 24E 26E 28E 30E 32E 34E 36E
−2 −1.6 −1.2 −0.8 −0.4 0 0.4 0.8 1.2 1.6 2
GrADS: COLA/IGES

Comparison of Models



Nino3 SSTA correlation coefficients for lead times of six (red), 9 (green) and 12 (yellow) months based on a (common) sub-sample for each prediction model. The sub-sample consists of forecasts 3 months apart for the BMRC model and one month for the other models for 1982-84, 1986-89 and 1991 (Kirtman and Shukla 1998). The models are University of Oxford (UOX), Scripps (SIO), Linear Inverse Model (LIM), Neural Network (NNM), LDEO models version1 and 2 (LDEO1,2), COLA and NCEP.

Summary

- Skill Scores vary with time of year and location
- Temperature is generally better than Precipitation
- Problems in simulating variability relate to problems with climatology
- Problems with climatology relate to model physics
- Empirical models still have an important role!!!

- What info should end user be given?
  - Include areas of no skill?
- Skill # Accuracy # Value