"I GET ALL THE NEWS I NEED ON THE WEATHER REPORT"

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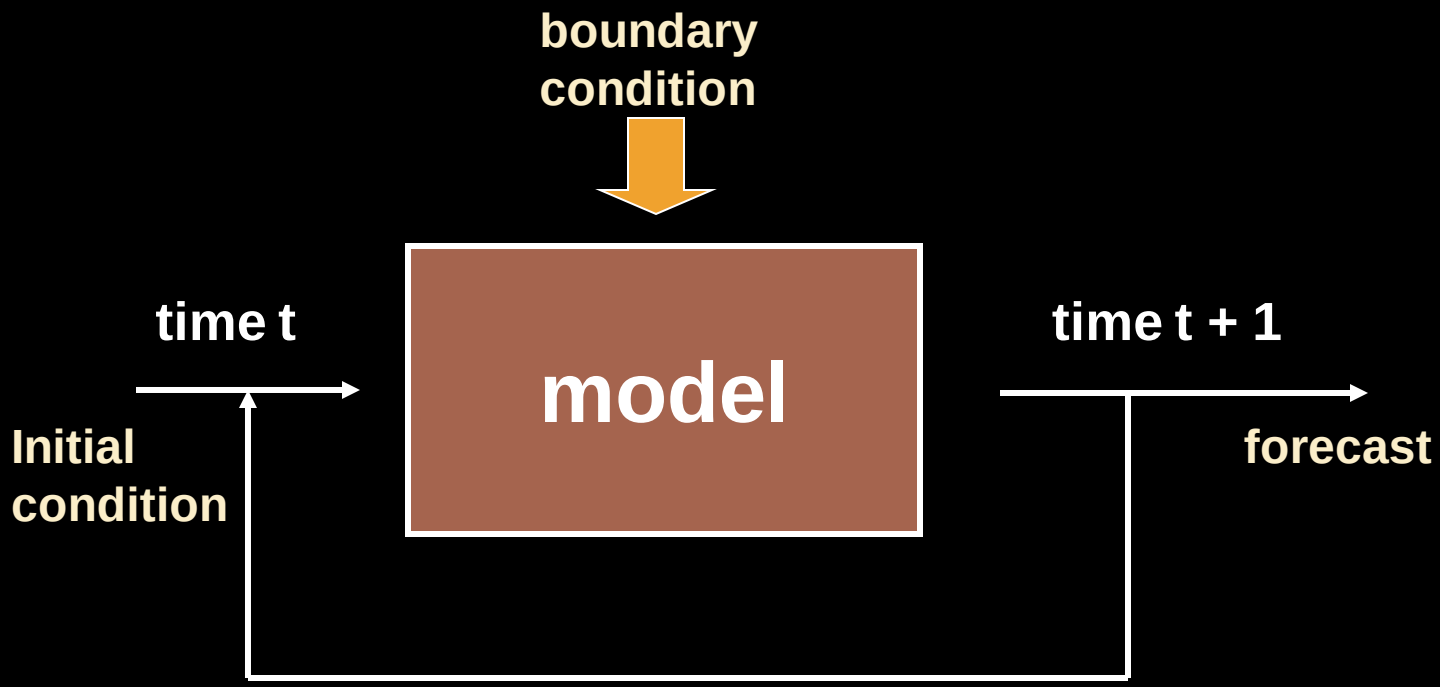
Francois Engelbrecht
Stephanie Landman

WMO FORECAST TIME RANGES

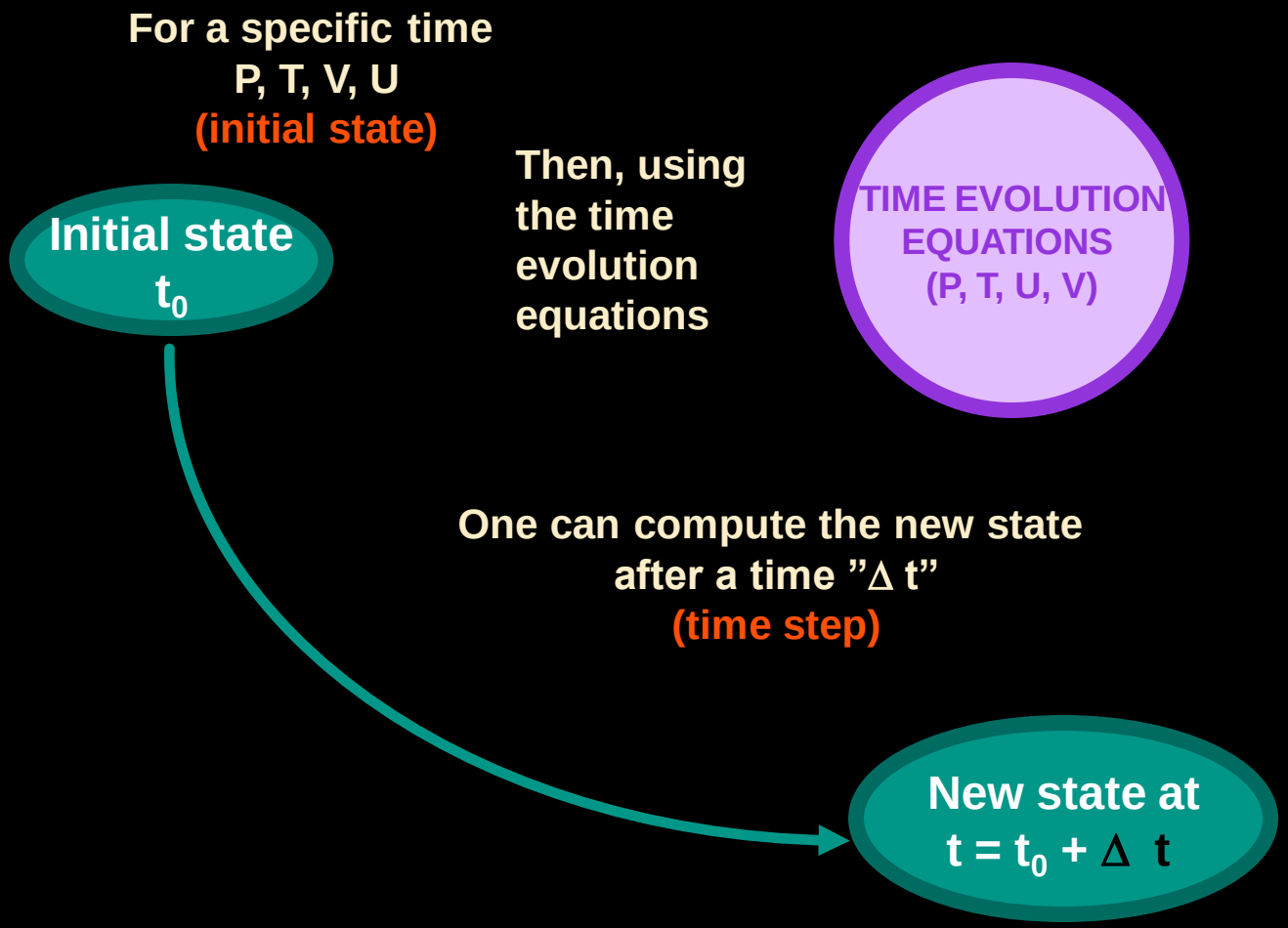
- **Nowcasting:** A description of current weather parameters and 0 to 2 hours' description of forecast weather parameters
- **Very short-range weather forecasting:** Up to 12 hours' description of weather parameters
- **Short-range weather forecasting:** Beyond 12 hours' and up to 72 hours' description of weather parameters
- **Medium-range weather forecasting:** Beyond 72 hours' and up to 240 hours' description of weather parameters
- **Extended-range weather forecasting:** Beyond 10 days' and up to 30 days' description of weather parameters. Usually averaged and expressed as a departure from climate values for that period
- **Long-range forecasting:** From 30 days up to two years
  - **Month forecast:** Description of averaged weather parameters expressed as a departure (deviation, variation, anomaly) from climate values for that month at any lead-time
  - **Seasonal forecast:** Description of averaged weather parameters expressed as a departure from climate values for that season at any lead-time
- **Climate forecasting:** Beyond two years
  - **Climate variability prediction:** Description of the expected climate parameters associated with the variation of interannual, decadal and multi-decadal climate anomalies
  - **Climate prediction:** Description of expected future climate including the effects of both natural and human influences

A NUMERICAL MODEL: OPERATIONAL ORGANIZATION (1)

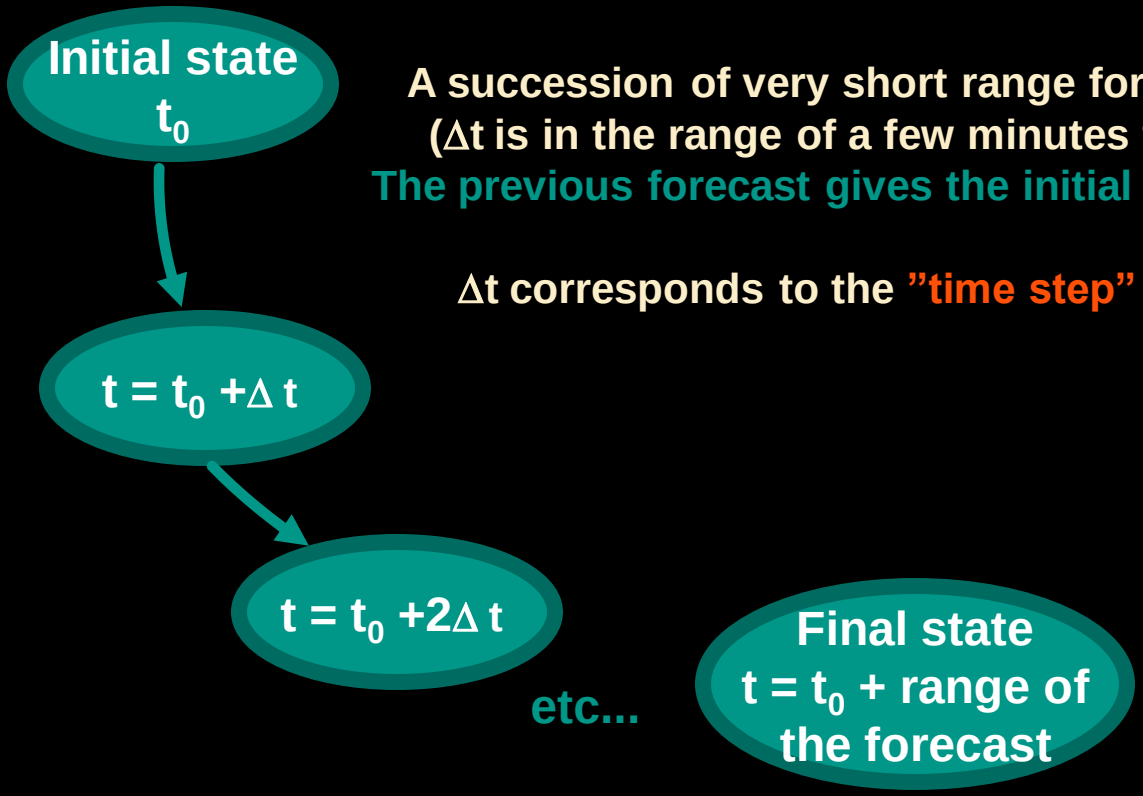
A typical run:



A NUMERICAL MODEL: OPERATIONAL ORGANIZATION (2)



A NUMERICAL MODEL: OPERATIONAL ORGANIZATION (3)



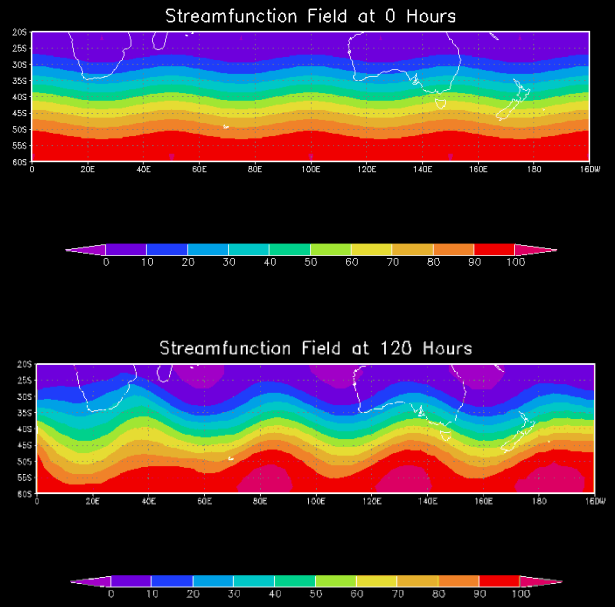
A succession of very short range forecast are made
(Δt is in the range of a few minutes to 30 minutes)
The previous forecast gives the initial state for the next

Δt corresponds to the "time step" of the model

NOT SO LONG AGO...

1940s

$$\frac{\partial}{\partial t}\nabla^2\psi = -\mathbf{V}_\psi \cdot \nabla\left(\nabla^2\psi + f\right)$$



1980s

Sonale momentumvergelyking

$$\frac{U}{a\cos\phi}\frac{\partial u^*}{\partial\lambda} + \frac{v^*}{a}\frac{\partial U}{\partial\phi} + \omega^*\frac{\partial U}{\partial p} - fv^* + \frac{1}{a\cos\phi}\frac{\partial\Phi^*}{\partial\lambda} - F^*_{(x)} = 0$$

Meridionale momentumvergelyking

$$\frac{U}{a\cos\phi}\frac{\partial v^*}{\partial\lambda} + fu^* + \frac{1}{a}\frac{\partial\Phi^*}{\partial\phi} - F^*_{(y)} = 0$$

Kontinuïteitsvergelyking

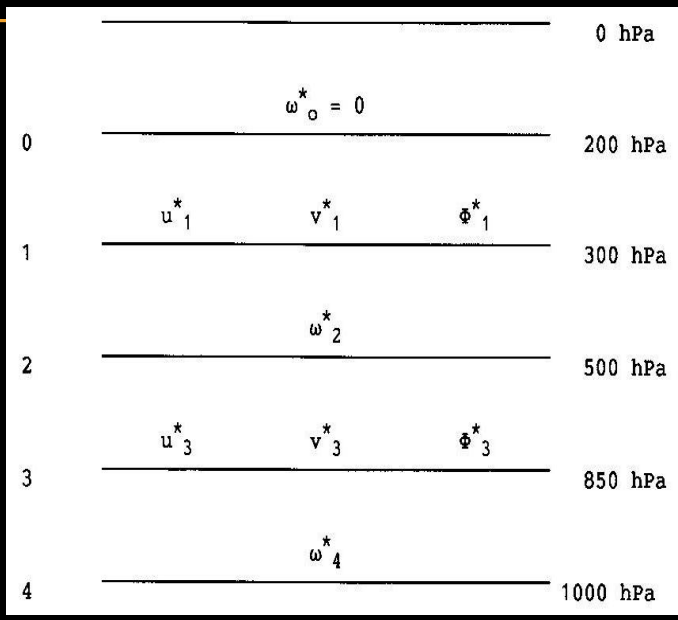
$$\frac{1}{a\cos\phi}\frac{\partial u^*}{\partial\lambda} + \frac{1}{a\cos\phi}\frac{\partial(v^*\cos\phi)}{\partial\phi} + \frac{\partial\omega^*}{\partial p} = 0$$

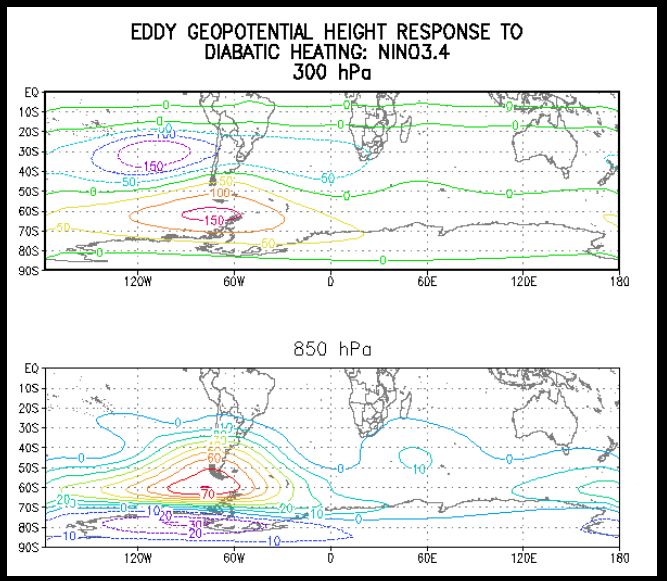
Hidrostatiese vergelyking

$$\frac{\partial\Phi^*}{\partial p} + \frac{RT^*}{p} = 0$$

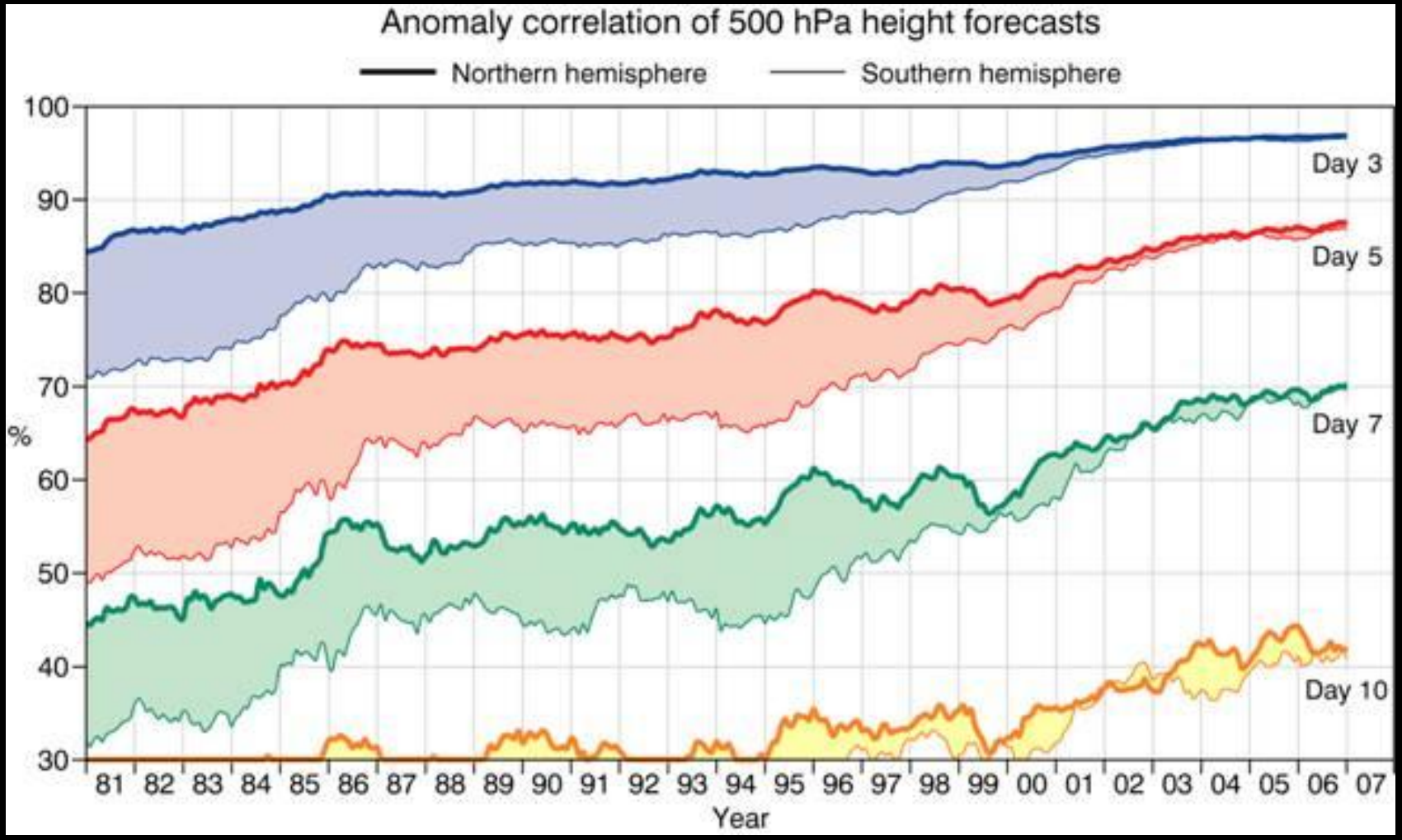
Termodinamiese vergelyking

$$\frac{U}{a\cos\phi}\frac{\partial T^*}{\partial\lambda} + \frac{v^*}{a}\frac{\partial[\bar{T}]}{\partial\phi} - S_p\omega^* = \frac{Q^*}{c_p}$$



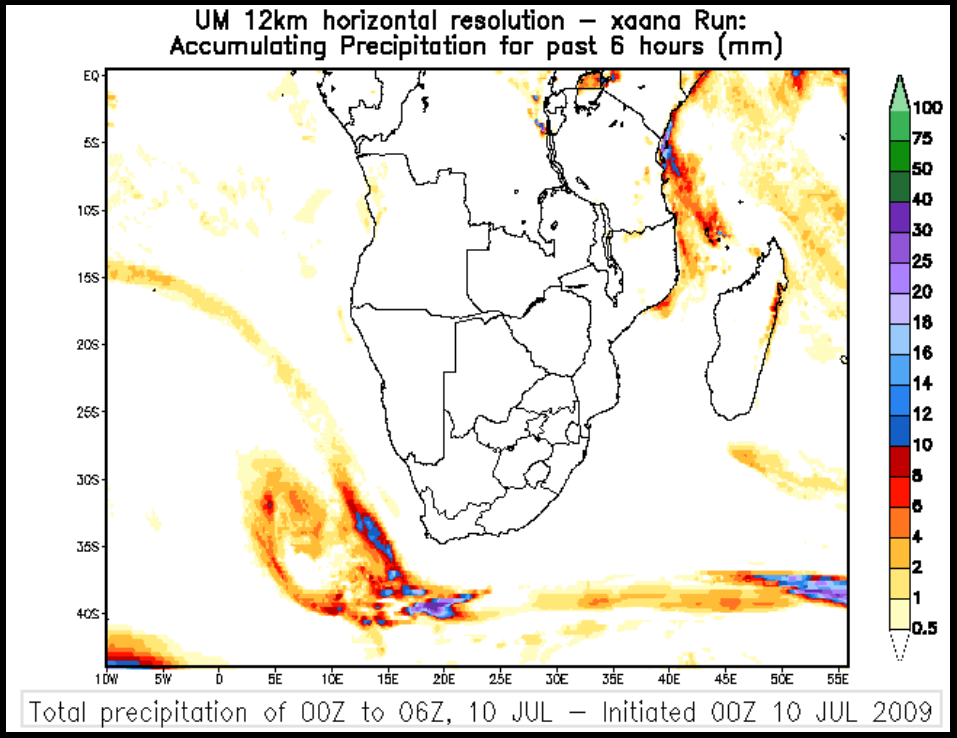


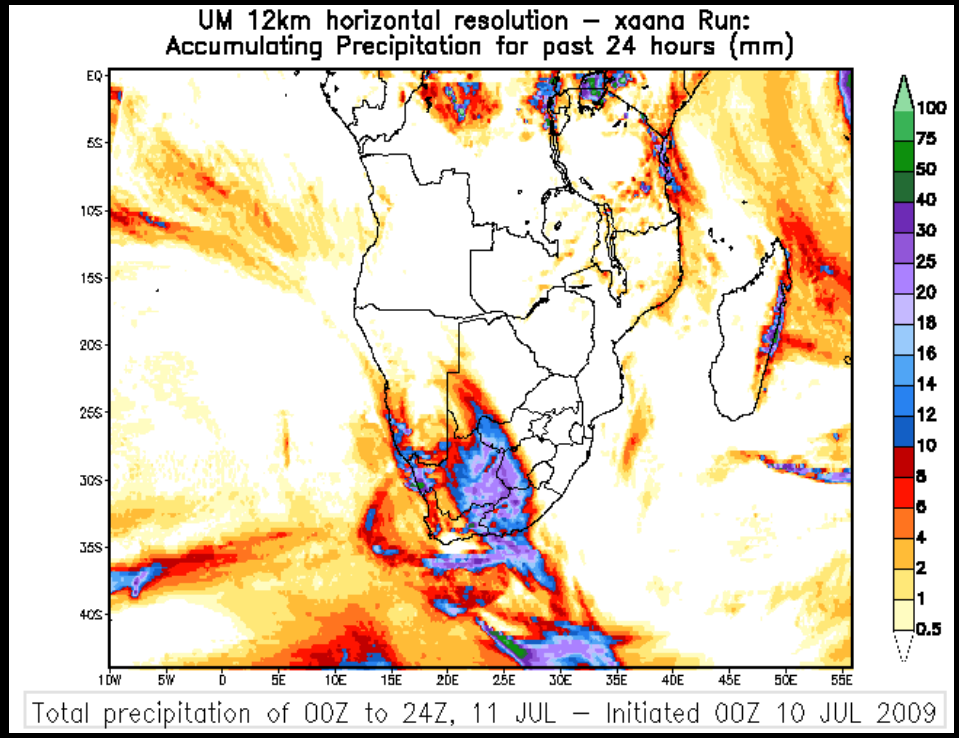
CONVERGENCE OF NWP SKILL



ECMWF

SHORT-RANGE WEATHER FORECAST MODELS





EFFECTS OF SMALL ERRORS IN THE INITIAL CONDITIONS

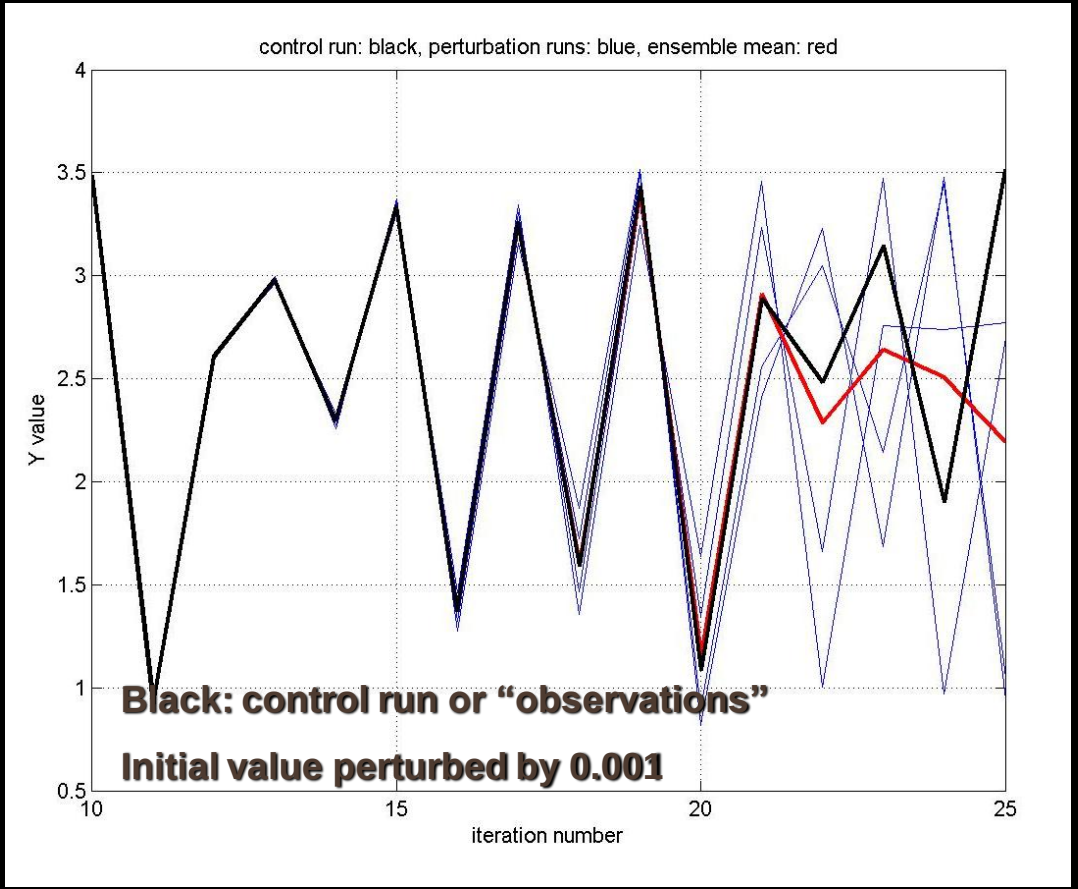
- There will always be atmospheric motions whose scales are too small to be properly observed and represented in a model
- Thus, there is an unavoidable level of error in the determination of the initial state
- The nonlinearity and instability of the atmospheric flow will inevitably cause the small inherent errors in the initial data to grow and gradually affect the larger scales of motion so that the forecast flow field will eventually evolve differently from the actual flow

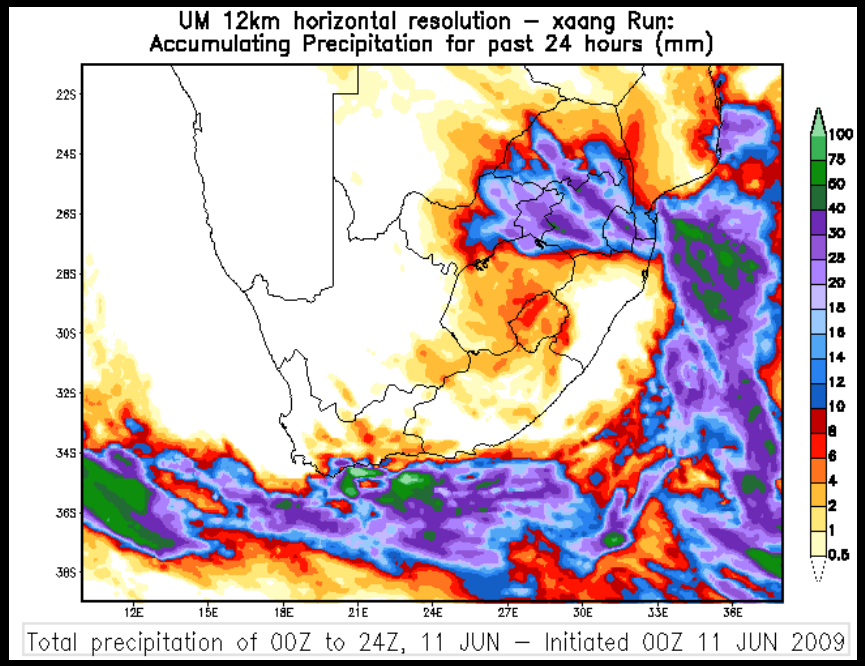
FIRST-ORDER QUADRATIC DIFFERENCE EQUATION

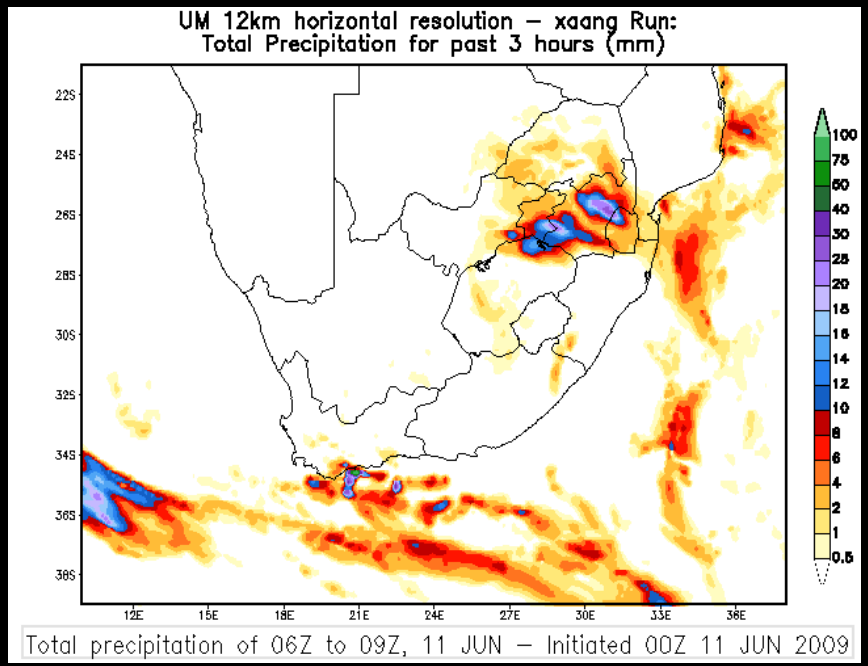
- Lorenz illustrated the general problem of predictability by considering the first-order quadratic difference equations:

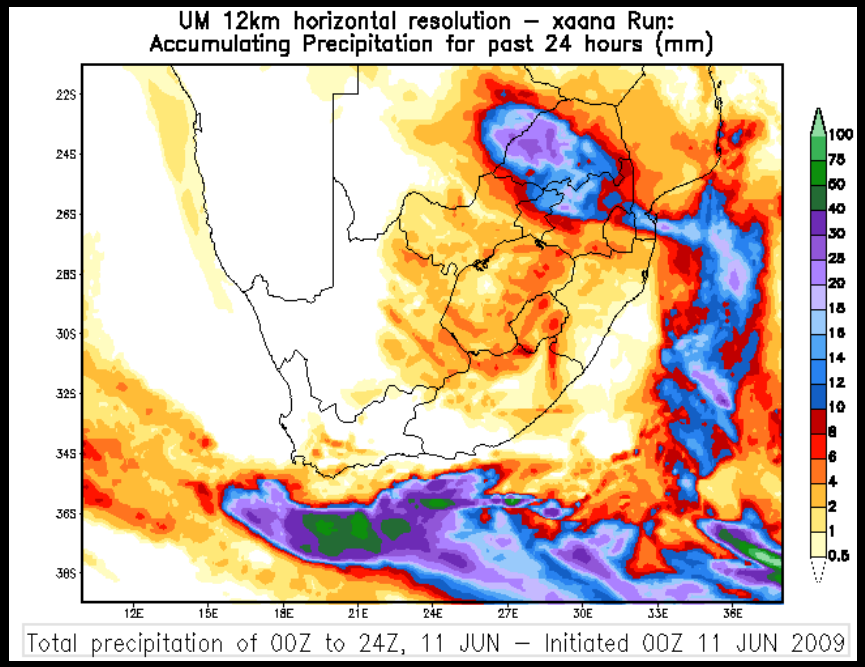
$$Y_{s+1} = aY_s - Y_s^2$$

- Figure is for Y(0) = 1.5; a = 3.75




UM 12km horizontal resolution – xaang Run:
Accumulating Precipitation for past 24 hours (mm)
22S
24S
26S
28S
30S
32S
34S
36S
38S
12E
15E
18E
21E
24E
27E
30E
33E
36E
100
75
50
40
30
25
20
17
16
14
12
10
8
6
4
2
1
0.5
Total precipitation of 00Z to 24Z, 11 JUN – Initiated 00Z 11 JUN 2009


UM 12km horizontal resolution – xaang Run:
Total Precipitation for past 3 hours (mm)
22S
24S
26S
28S
30S
32S
34S
36S
38S
12E
15E
18E
21E
24E
27E
30E
33E
36E
100
75
50
40
30
25
20
17
16
14
12
10
8
6
4
2
1
0.5
Total precipitation of 06Z to 09Z, 11 JUN – Initiated 00Z 11 JUN 2009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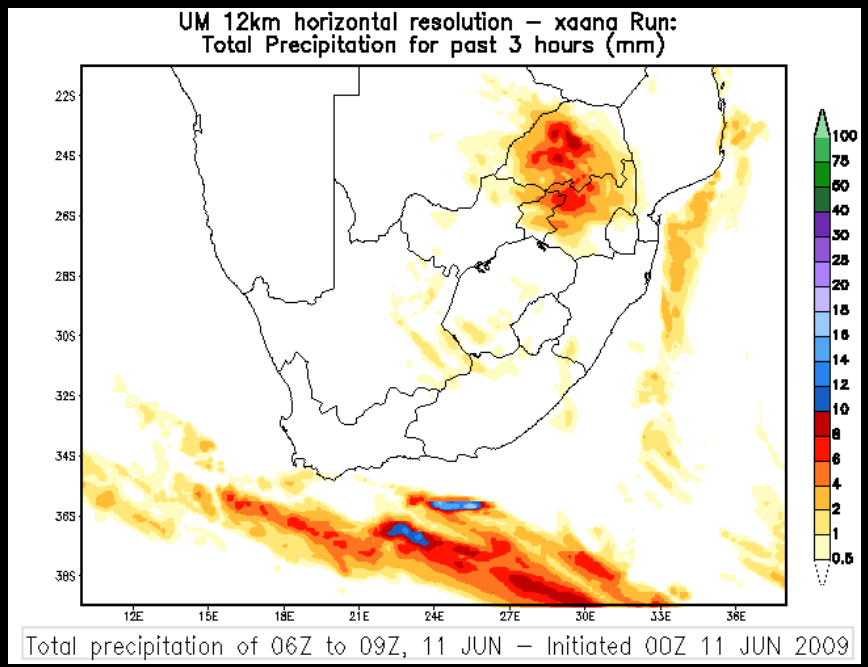
UM 12km horizontal resolution – xaang Run:
Total Precipitation for past 3 hours (mm)
22S
24S
26S
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30S
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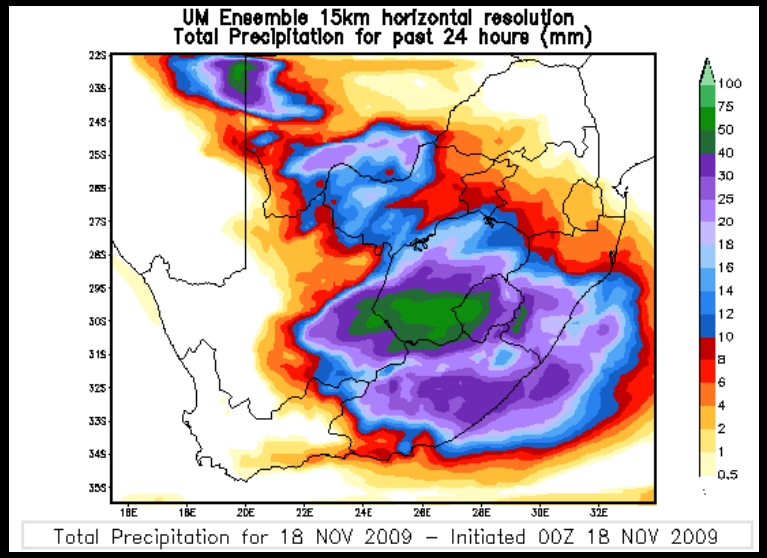
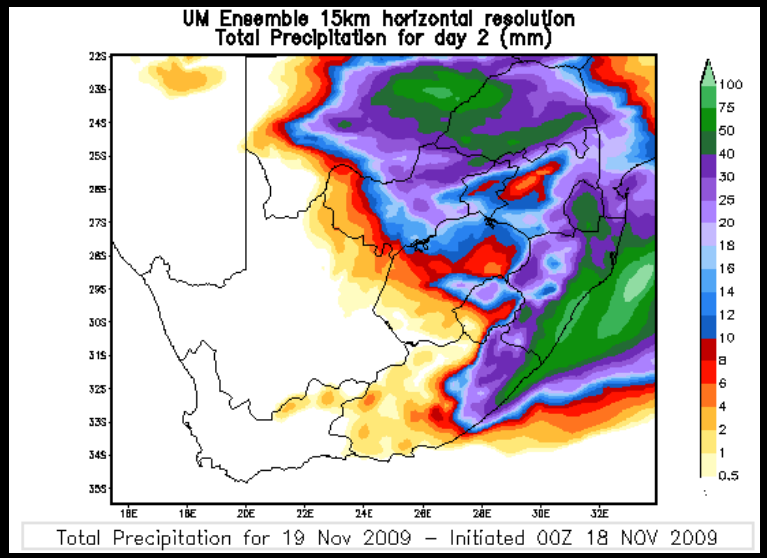
1
0.5
Total precipitation of 06Z to 09Z, 11 JUN – Initiated 00Z 11 JUN 2009

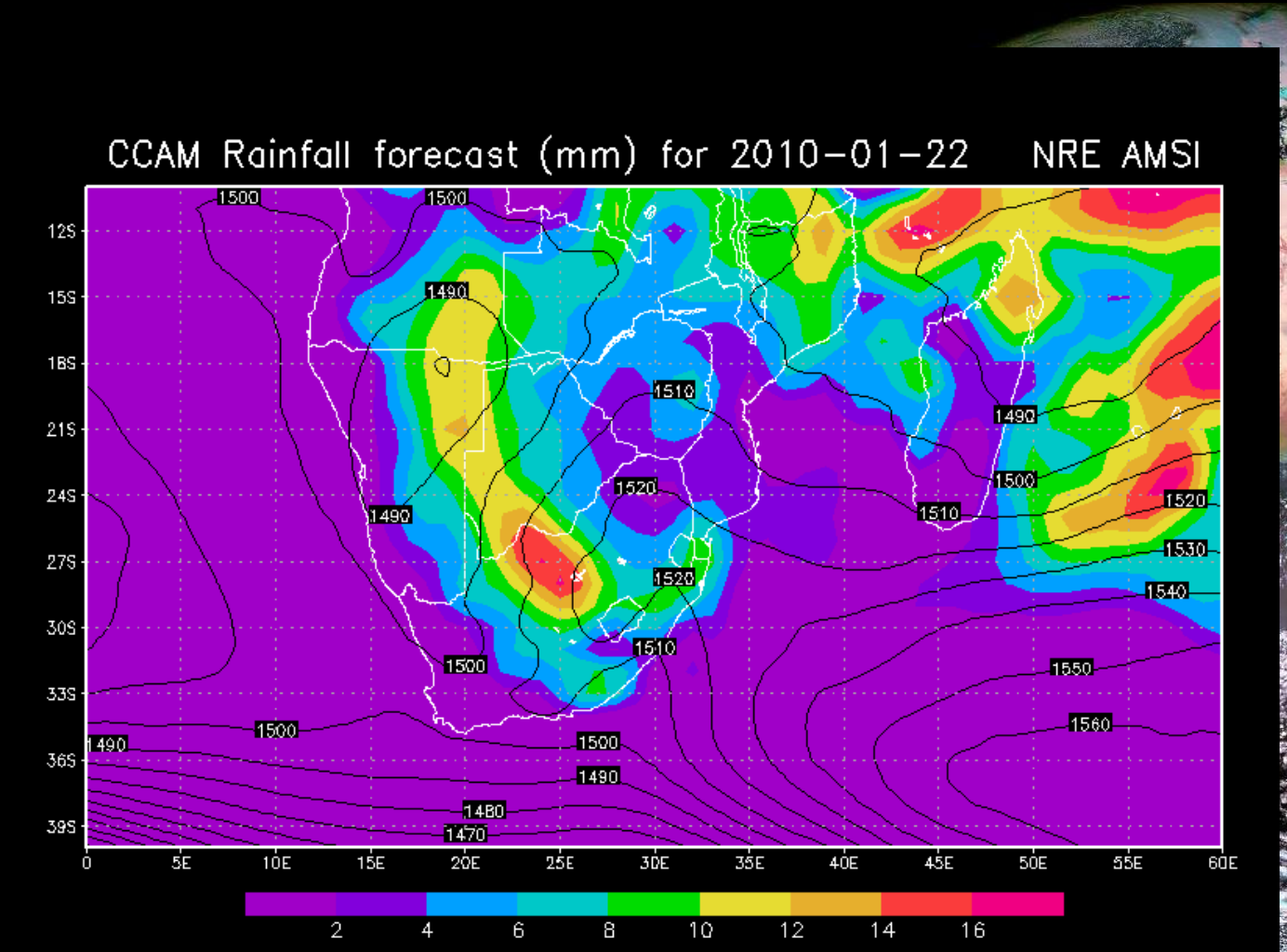
NEW MULTI-MODEL SHORT-RANGE ENSEMBLE SYSTEM (PRECIPITATION)

- 24hour totals for:
  - day1 (14 members) and
  - day2 (6 members)
- Unified Model (different configurations and resolutions)
  - 10 members:
    - 12km (xaana/ng/nj)
    - 15km (xaaha/hc)
- WRF model
  - 2 members:
    - 12km
    - Non-hydrostatic mesoscale core
  - 2 members:
    - 15km
    - Advanced Research WRF core

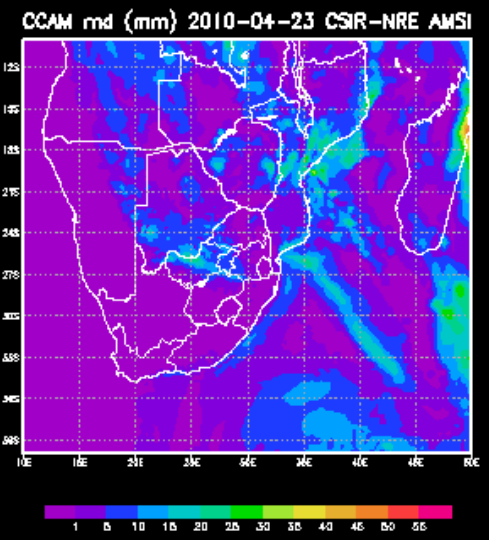


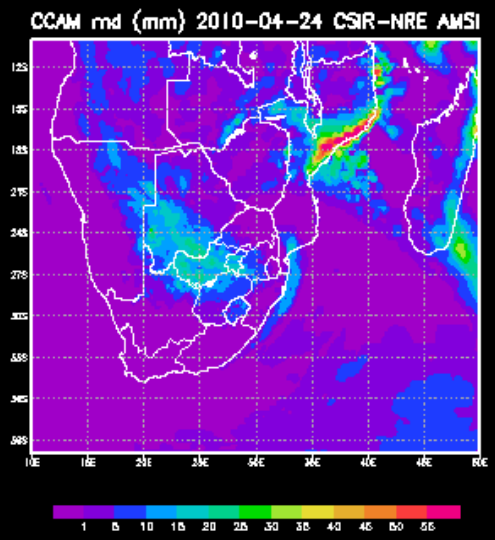


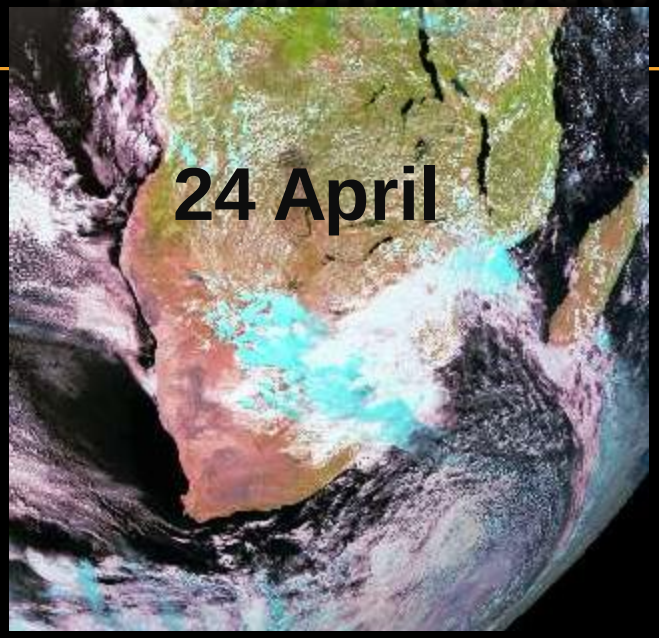
RAINFALL FORECAST FOR 22 JAN 10

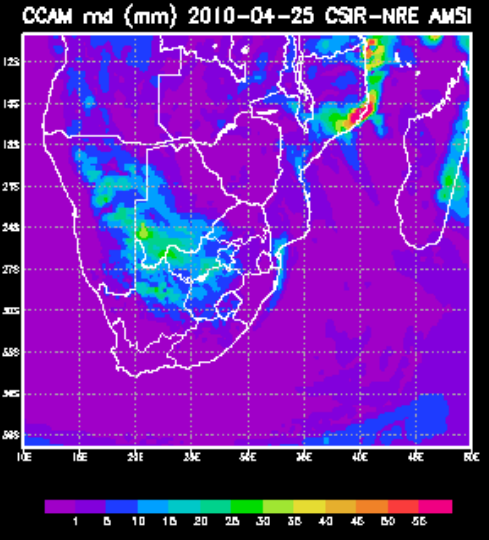


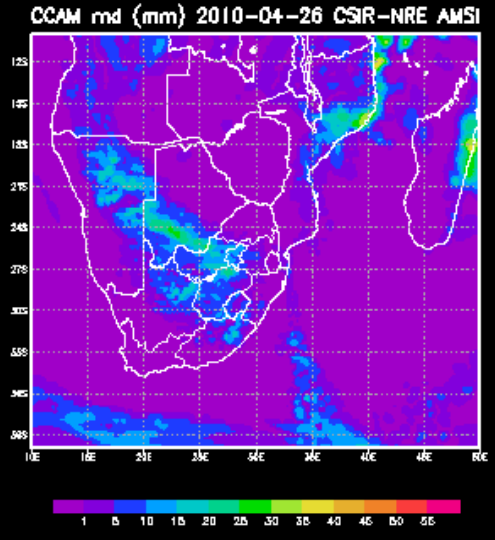
RECENT COLD/WET SPELL IN APRIL 2010

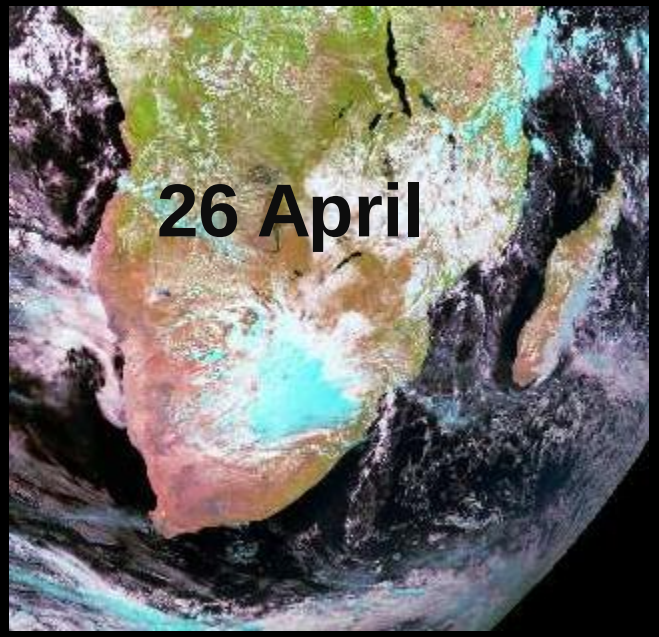


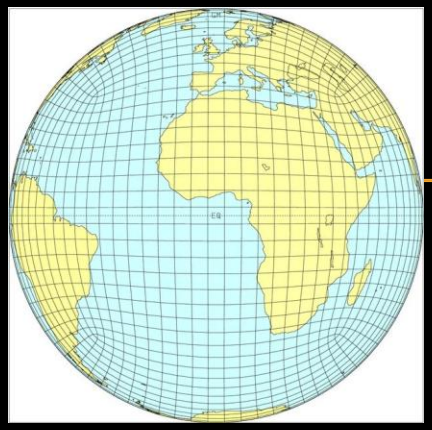


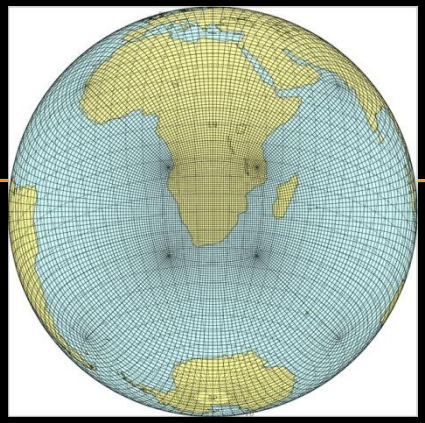


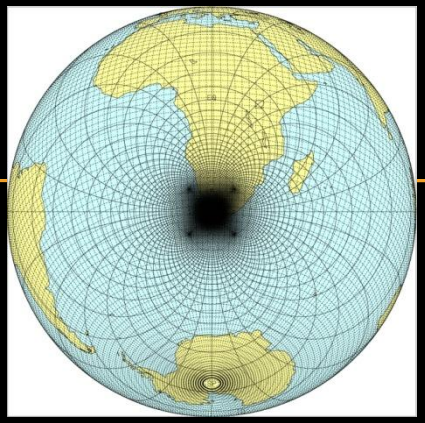


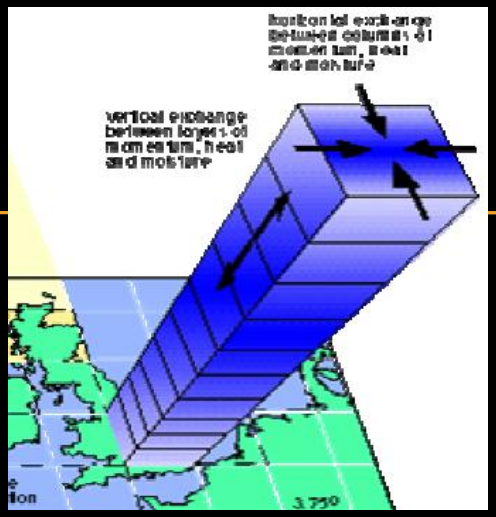










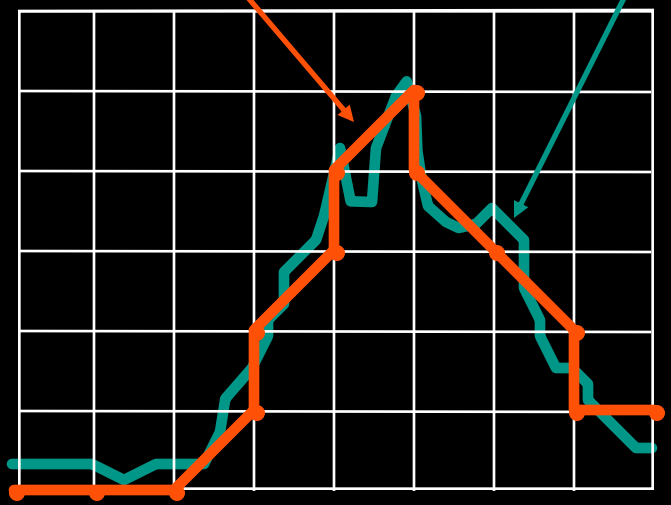


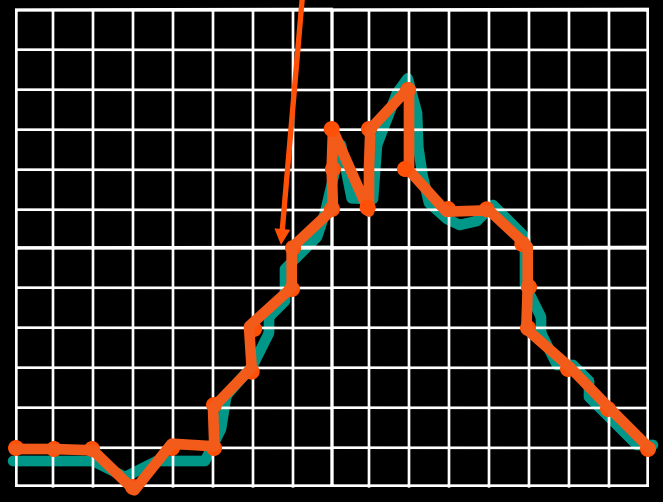
An example for the topography of the model

Real topography profile

Topography profile in the model

Topography profile in the model using a doubling of horizontal and vertical resolution



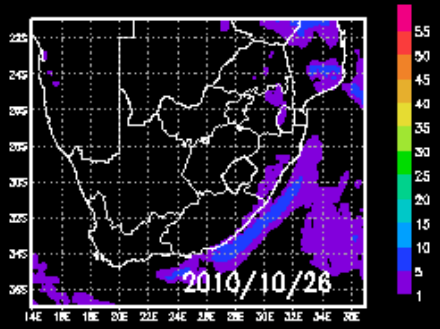


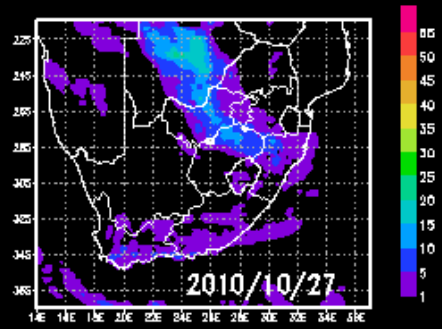
Latest weather forecast

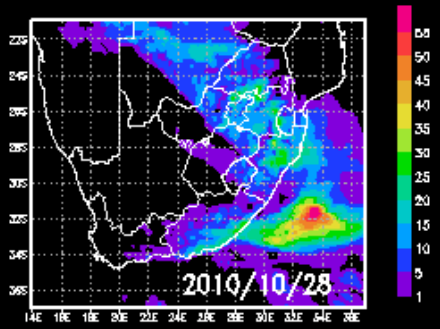
CCAM rainfall (mm)

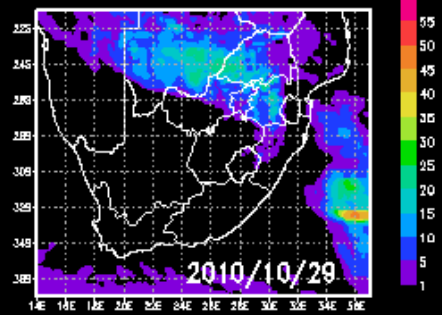
Produced by:

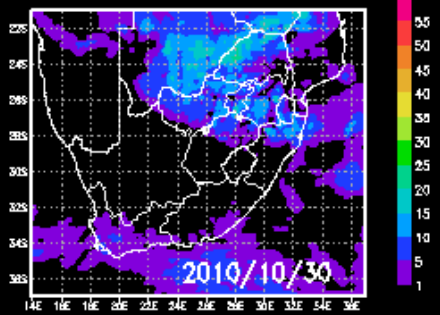
The Climate Studies and Modelling Group (CSM) of the CSIR.

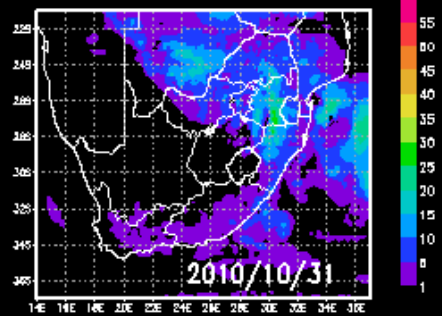


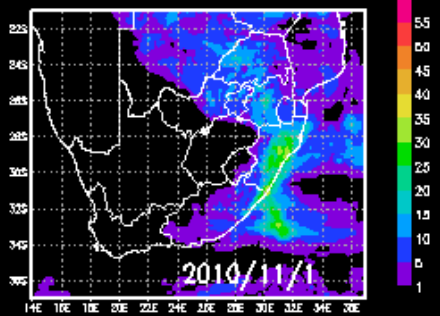










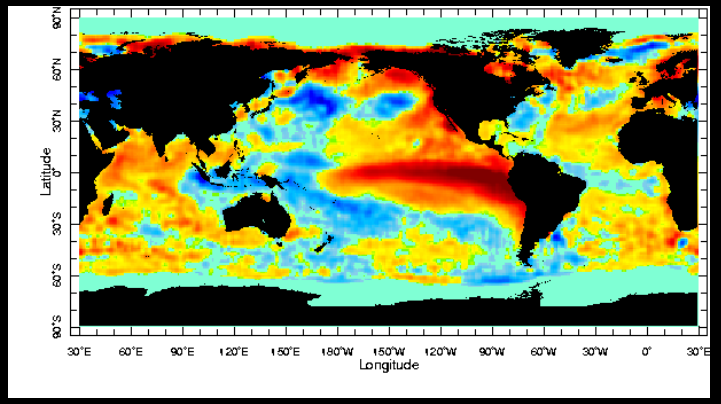


LIMITS OF LONGER RANGE FORECASTS

- Great progress has been made to predict the day-to-day state of the atmosphere (e.g., frontal movement, winds, pressure)
- However, day-to-day fluctuations in weather are not predictable beyond two weeks
- Beyond that time, errors in the data defining the state of the atmosphere at the start of a forecast period grow and overwhelm valid forecast information
- This so called "chaotic" behaviour is an ***inherent property*** of the atmosphere

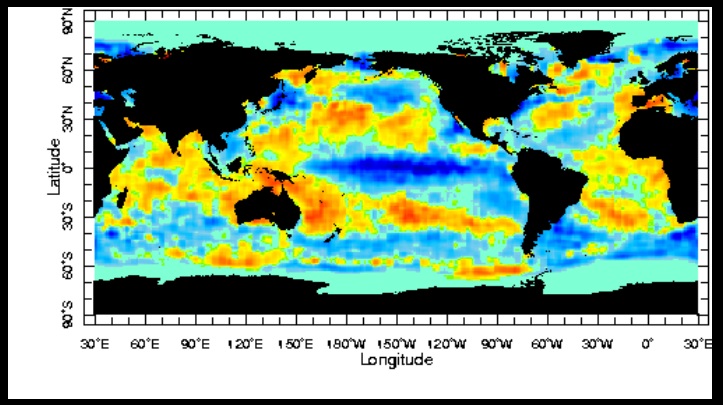
HOW IS IT THEN POSSIBLE TO PREDICT *SEASONAL CLIMATE ANOMALIES*?

Predictions of rainfall, frontal passages, etc. for a particular day at a certain location several months ahead has no usable skill. However, there is some skill in predicting anomalies in the **seasonal average** of the weather. The predictability of seasonal climate anomalies results primarily from the influence of **slowly evolving boundary conditions**, and most notably SSTs (i.e., El Niño and La Niña), on the atmospheric circulation.



Sea-surface temperature (SST) anomalies of September 1997 (El Niño of 1997/98)

Anomaly: departure from the mean or average



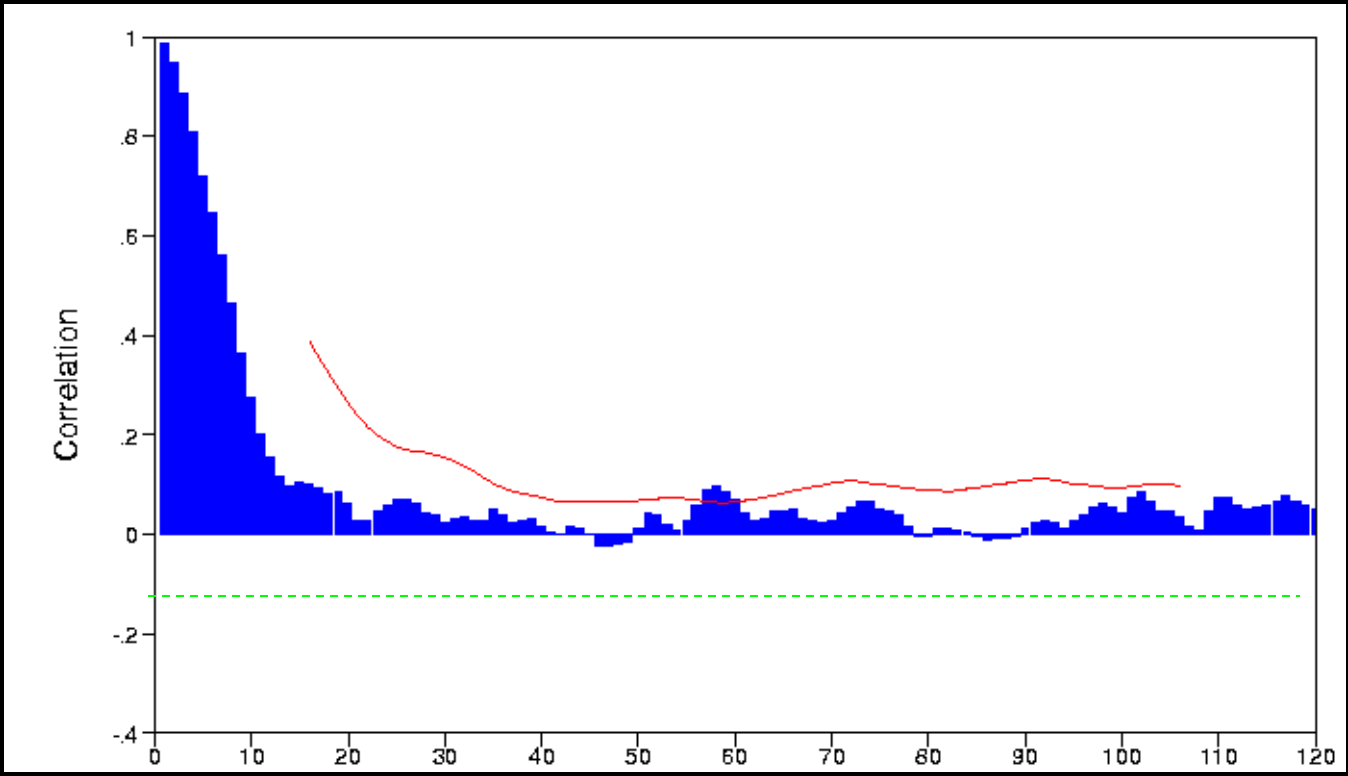
Sea-surface temperature (SST) anomalies of November 1988 (La Niña of 1988/89)

DYNAMICAL FORECASTS: SEASONAL FORECASTS

Daily Scores

+

Monthly running mean Scores

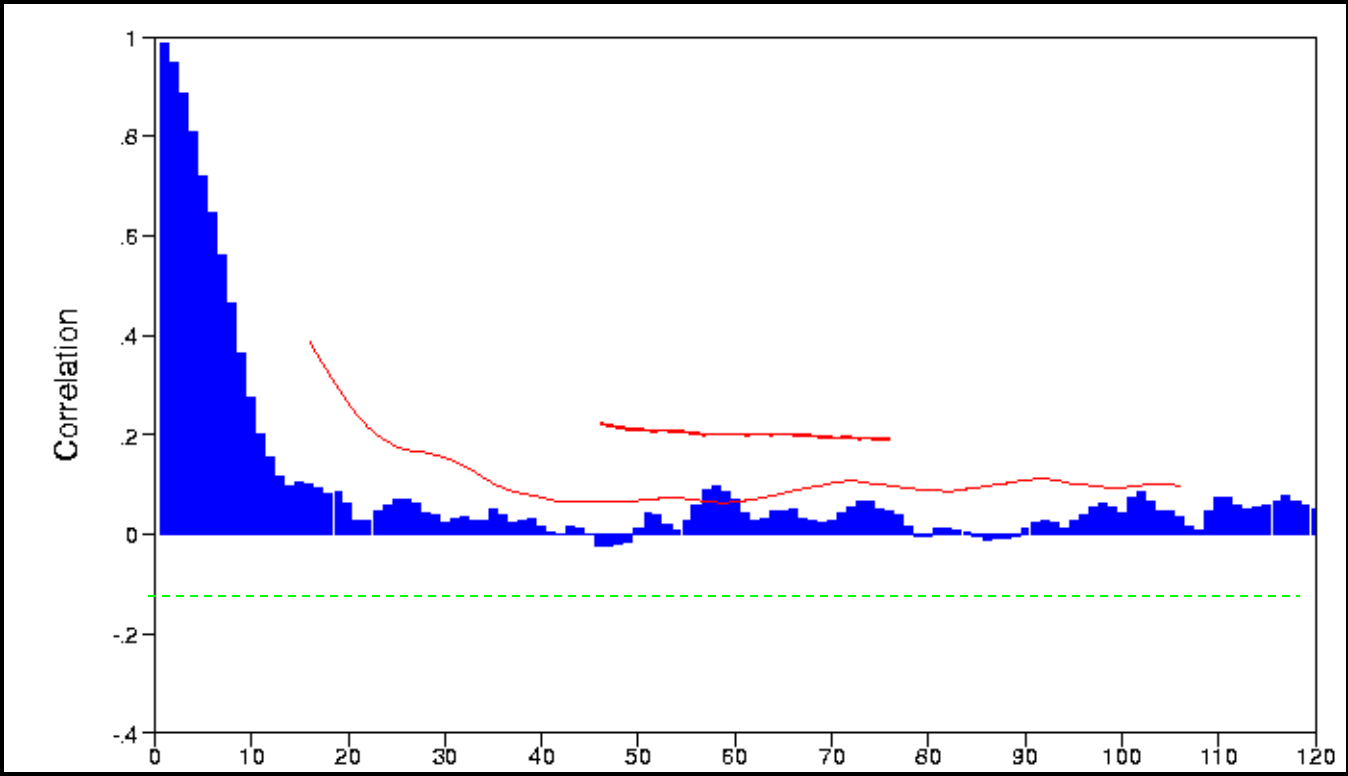


DYNAMICAL FORECASTS: SEASONAL FORECASTS

Daily Scores

+

Seasonal running mean Scores



DYNAMICAL FORECASTS: SEASONAL FORECASTS

Daily Scores

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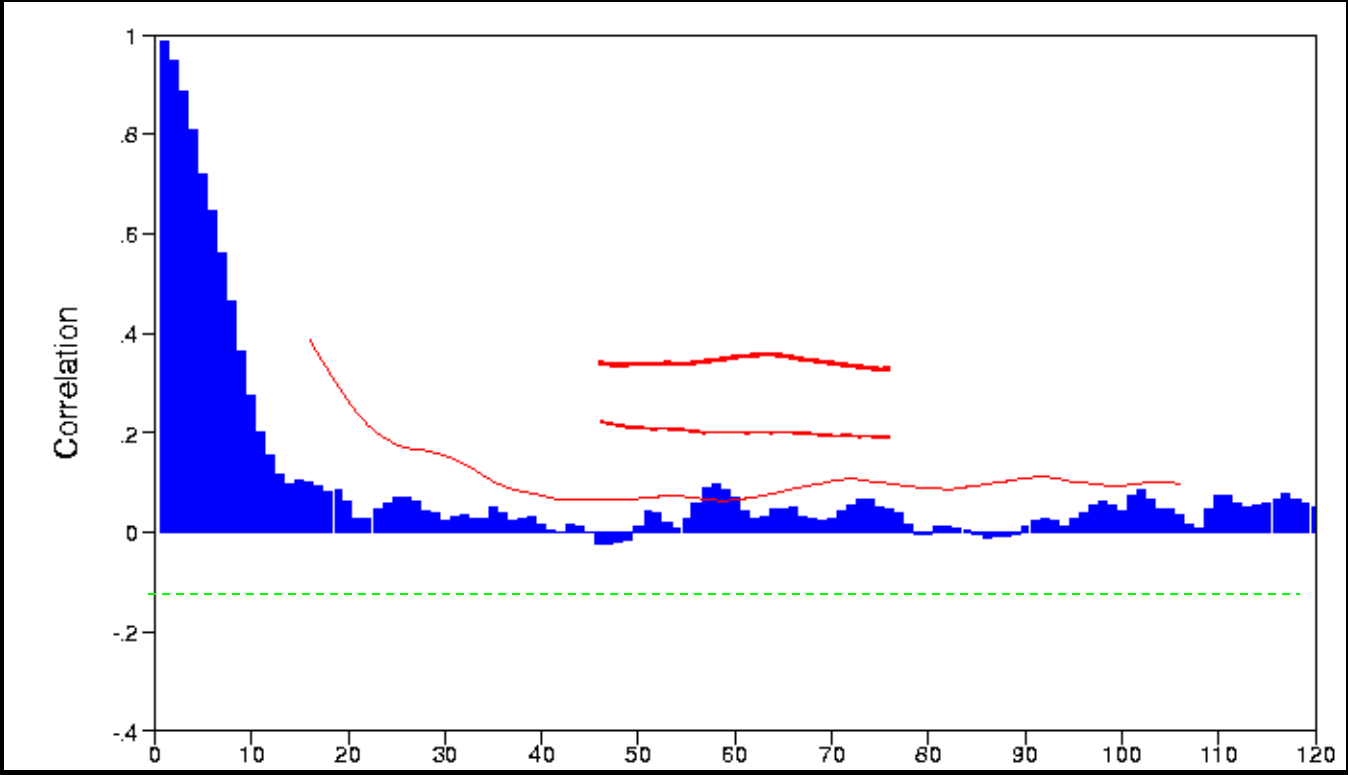
Ensemble forecast, Seasonal running mean and SST forecast



DYNAMICAL FORECASTS: SEASONAL FORECASTS

Daily Scores

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Ensemble forecast, Seasonal running mean and SST forecast

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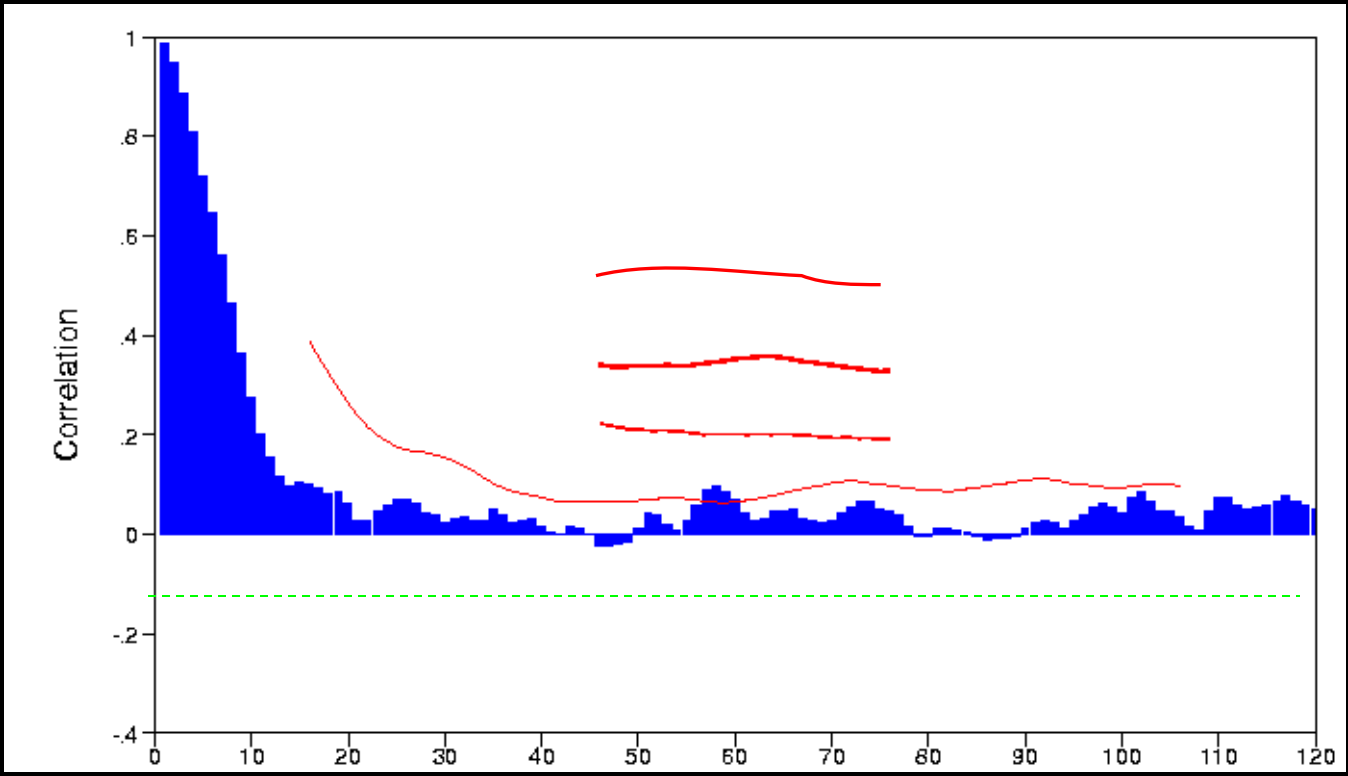
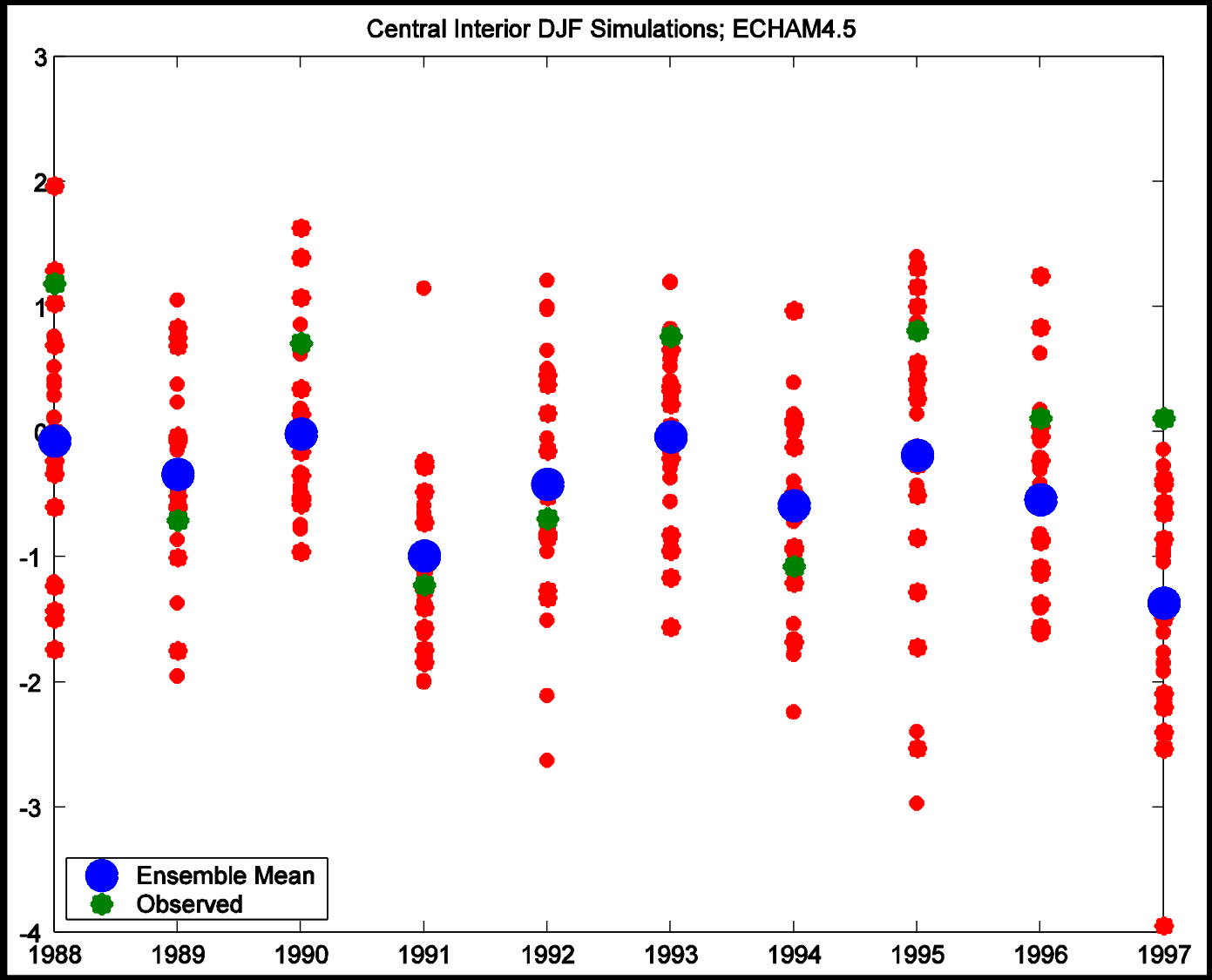
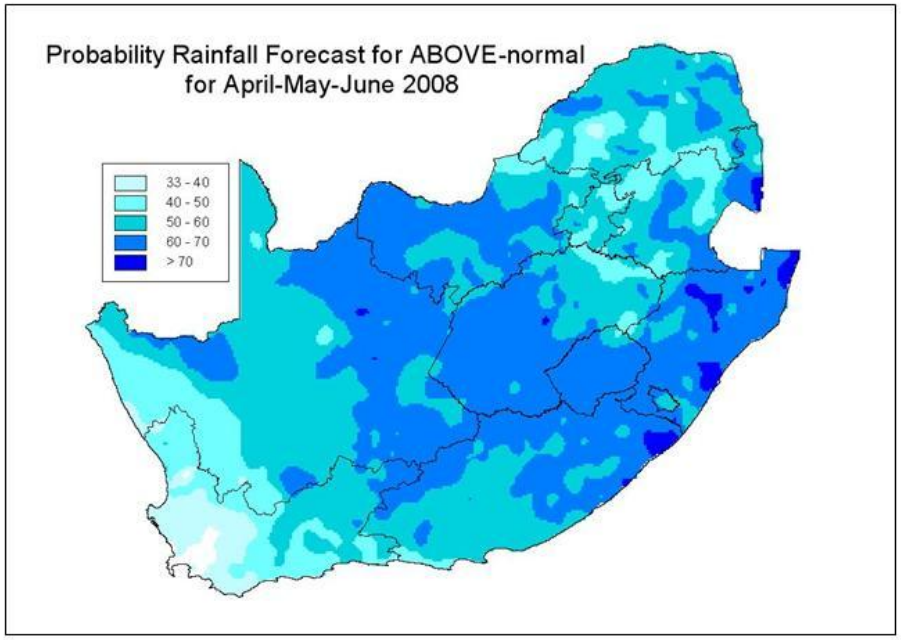
MOS

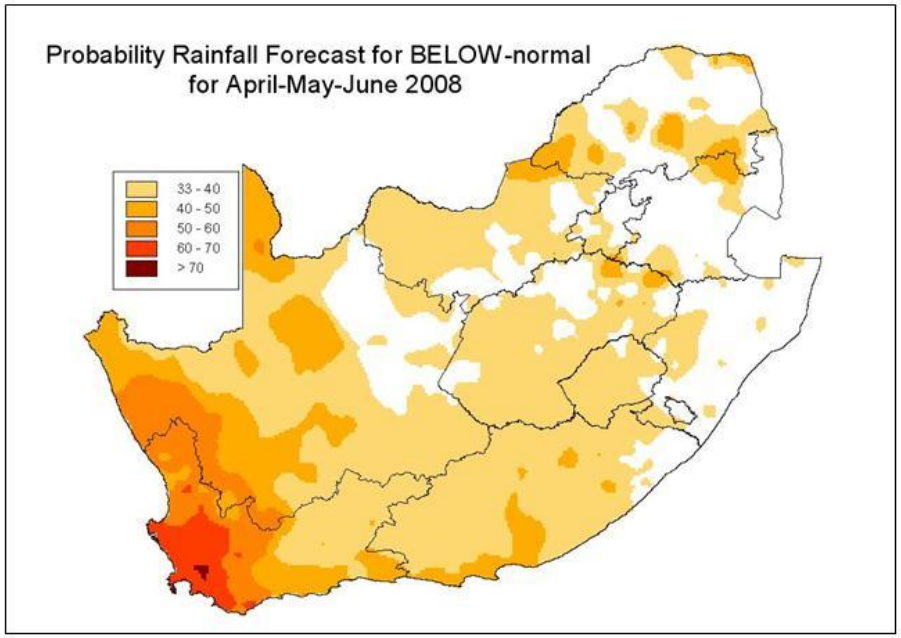


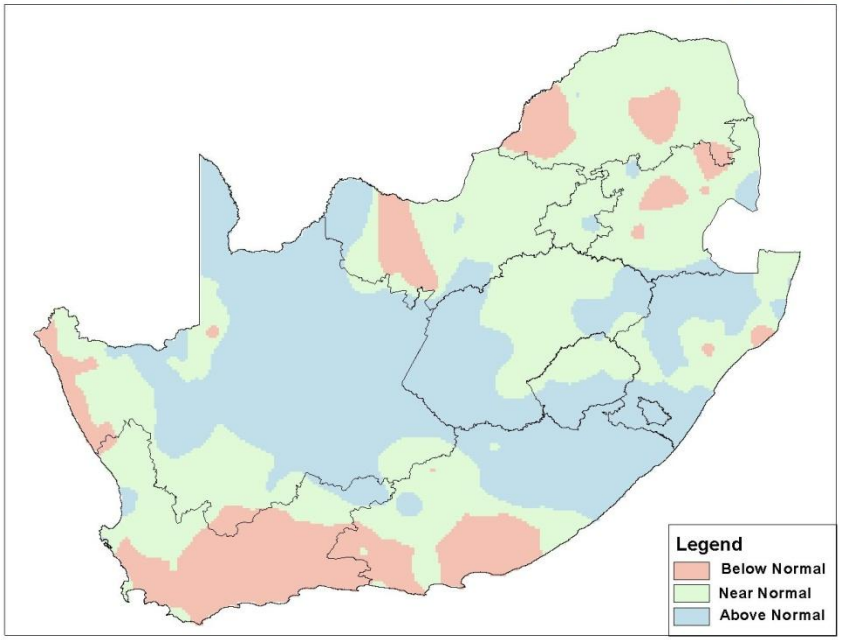
ENSEMBLE OF FORECASTS



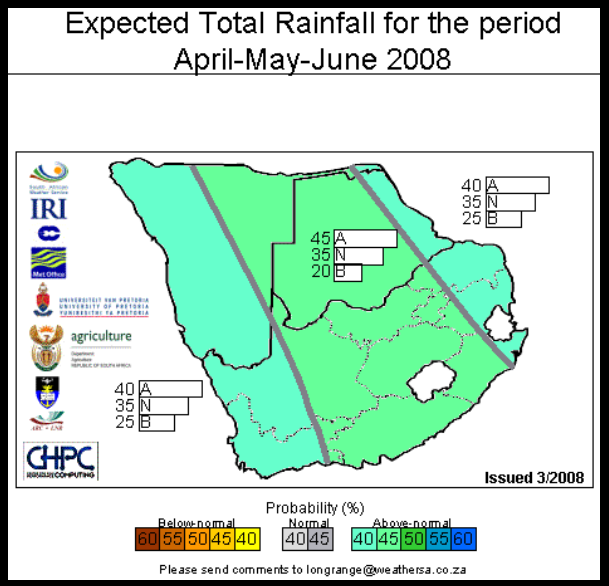
Objective multi-model forecast

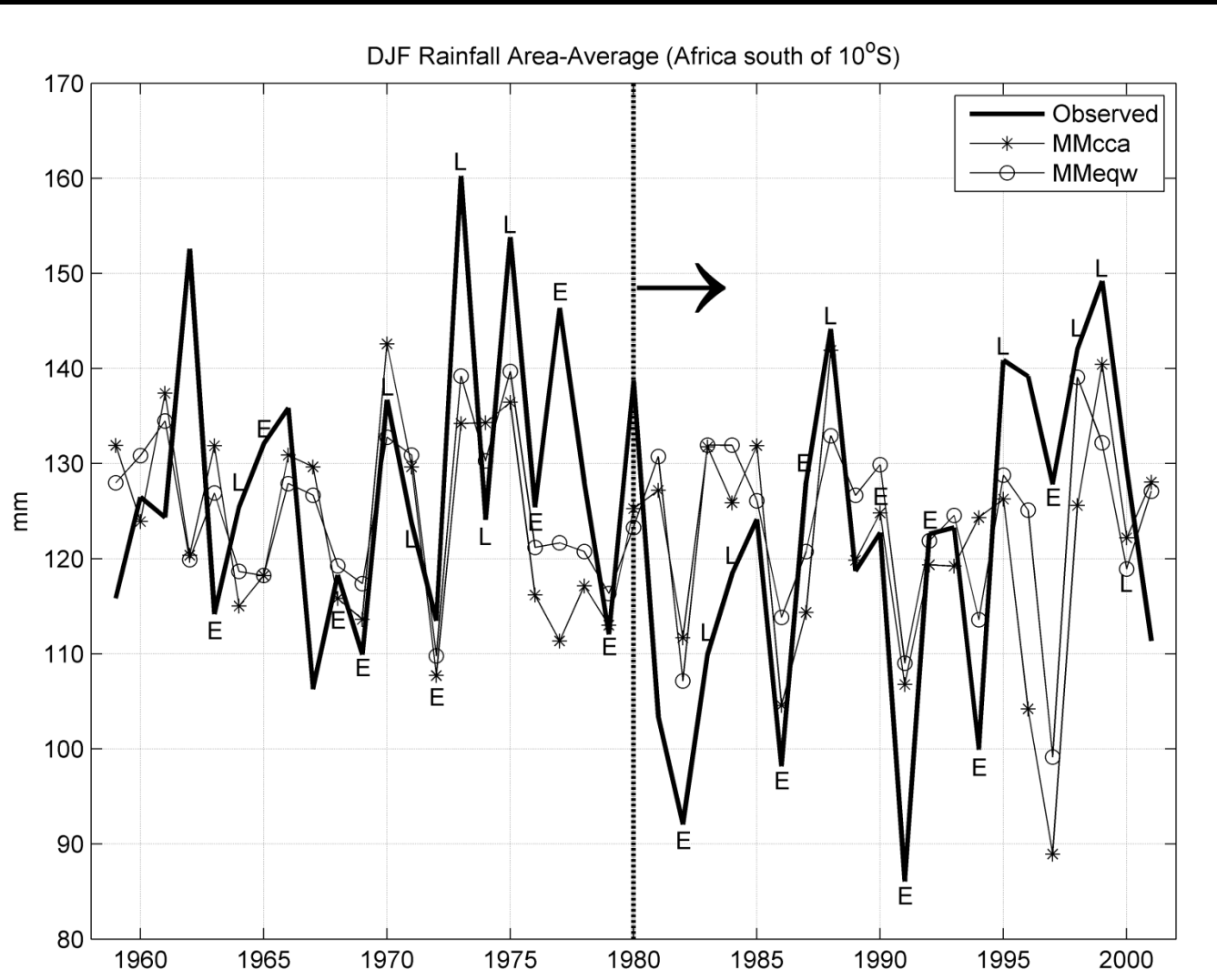






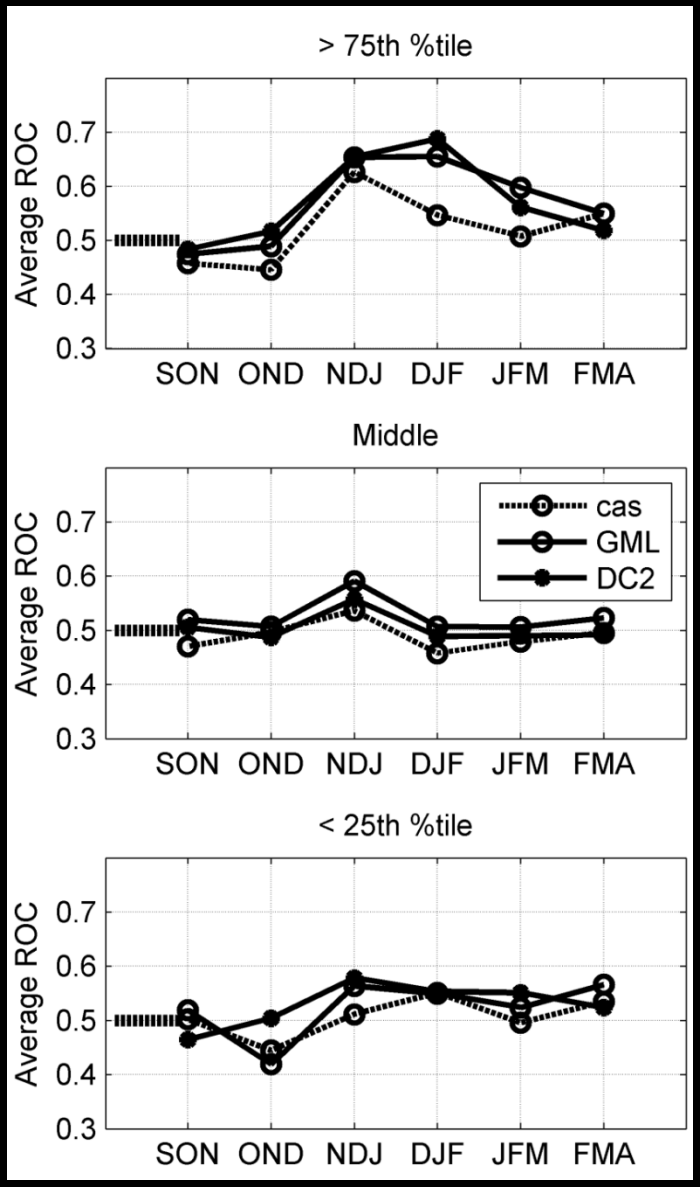
Subjective consensus forecast

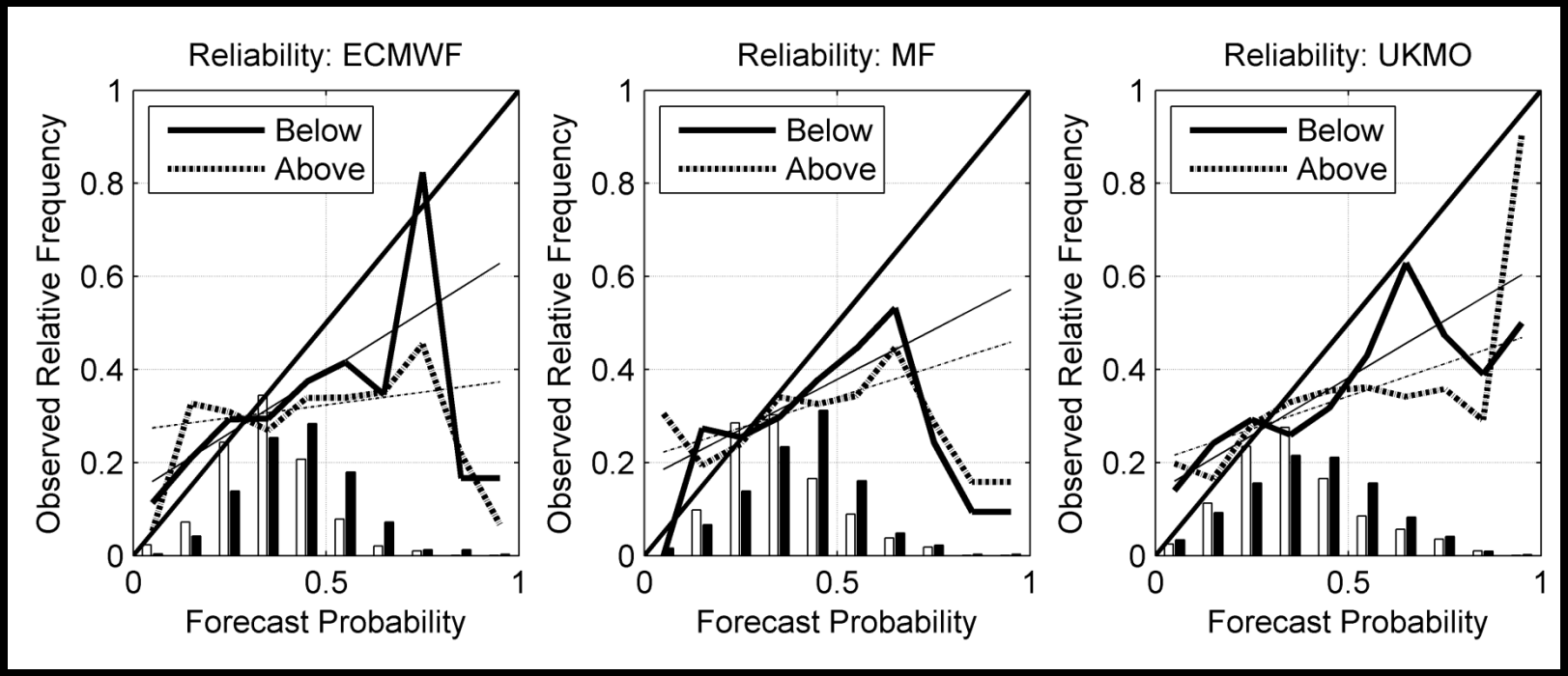


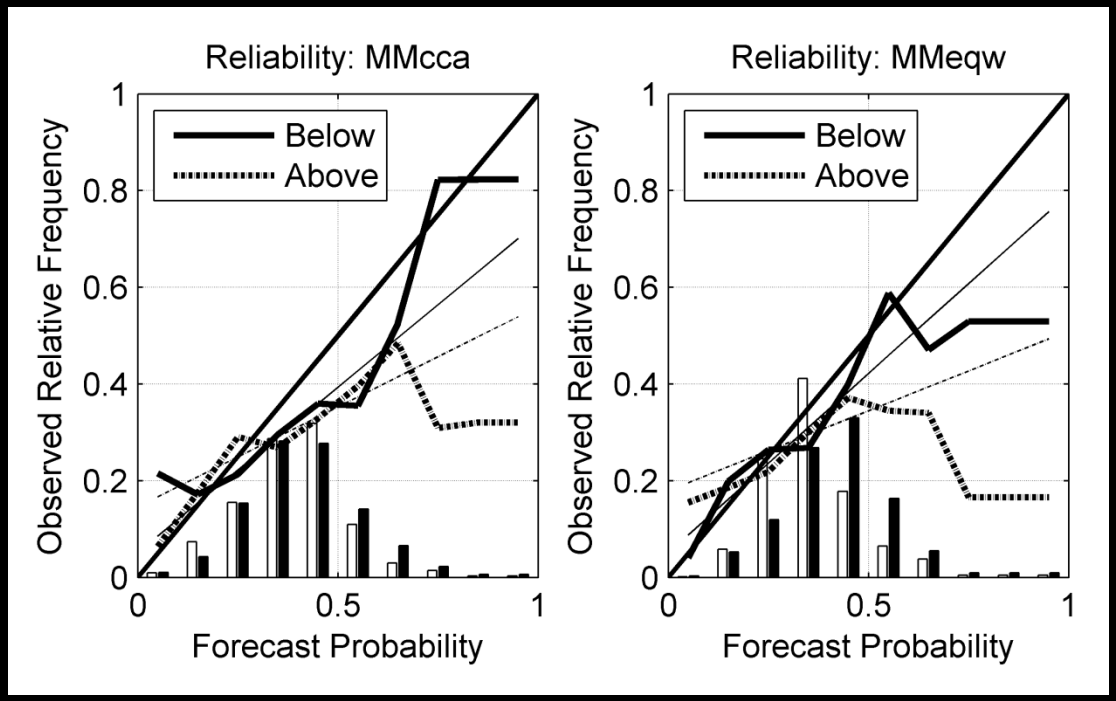

DJF Rainfall Area-Average (Africa south of 10°S)
Observed
MMcca
MMeqw
mm
170
160
150
140
130
120
110
100
90
80
1960
1965
1970
1975
1980
1985
1990
1995
2000
L
E

COUPLED MODELS AND SEASONAL FORECASTING

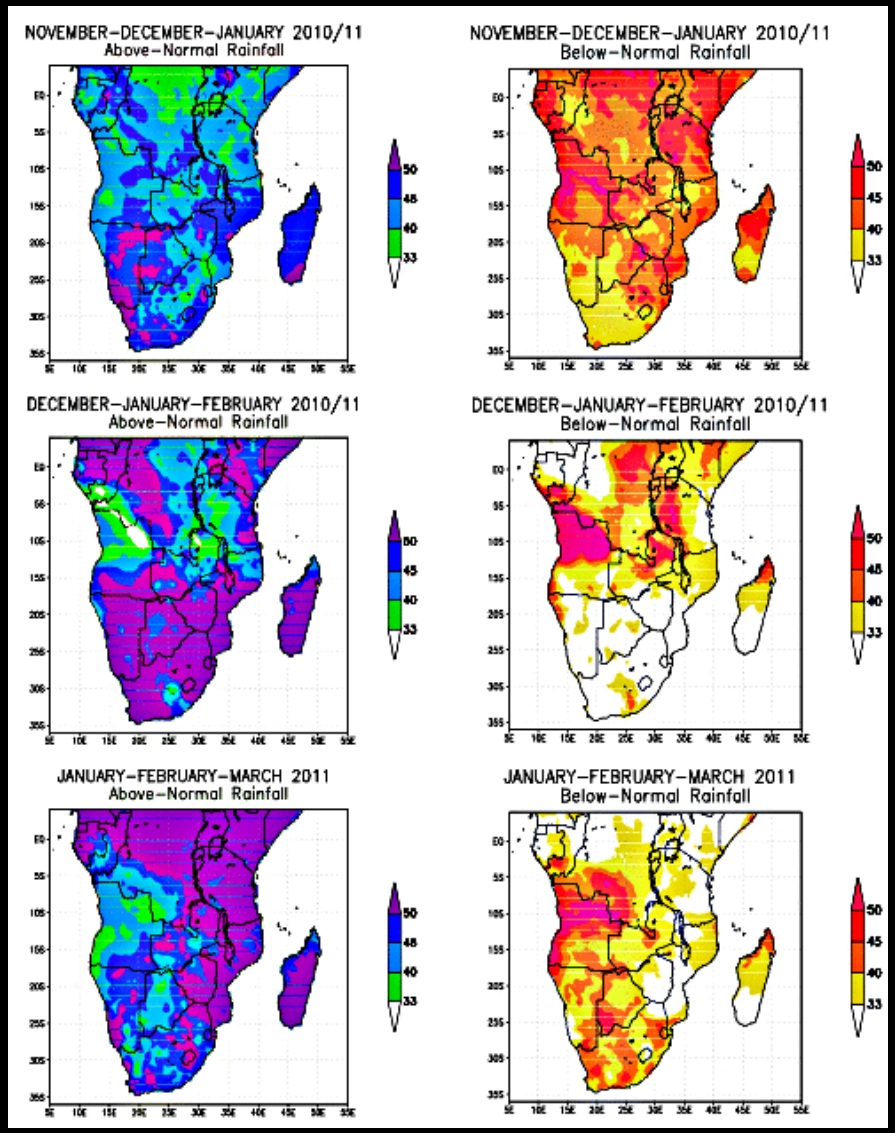
- ECHAM4.5
  - Constructed analogue SST
  - MOM3
  - GML (slab)
- 850 hPa gp height fields downscaled to 94 districts
- Initial training period
  - 1982/83 – 1995/96
- Retro-active test period
  - 1996/97 – 2008/09

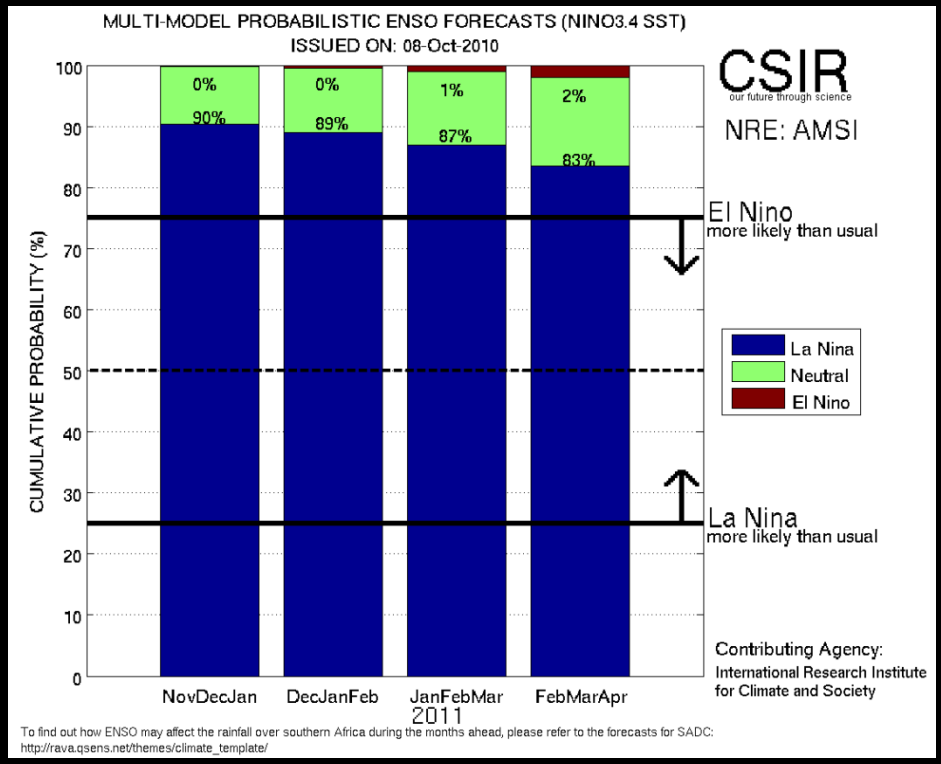



Reliability: ECMWF
Reliability: MF
Reliability: UKMO
Below
Above
Observed Relative Frequency
Forecast Probability
0
0.2
0.4
0.6
0.8
1
0.5

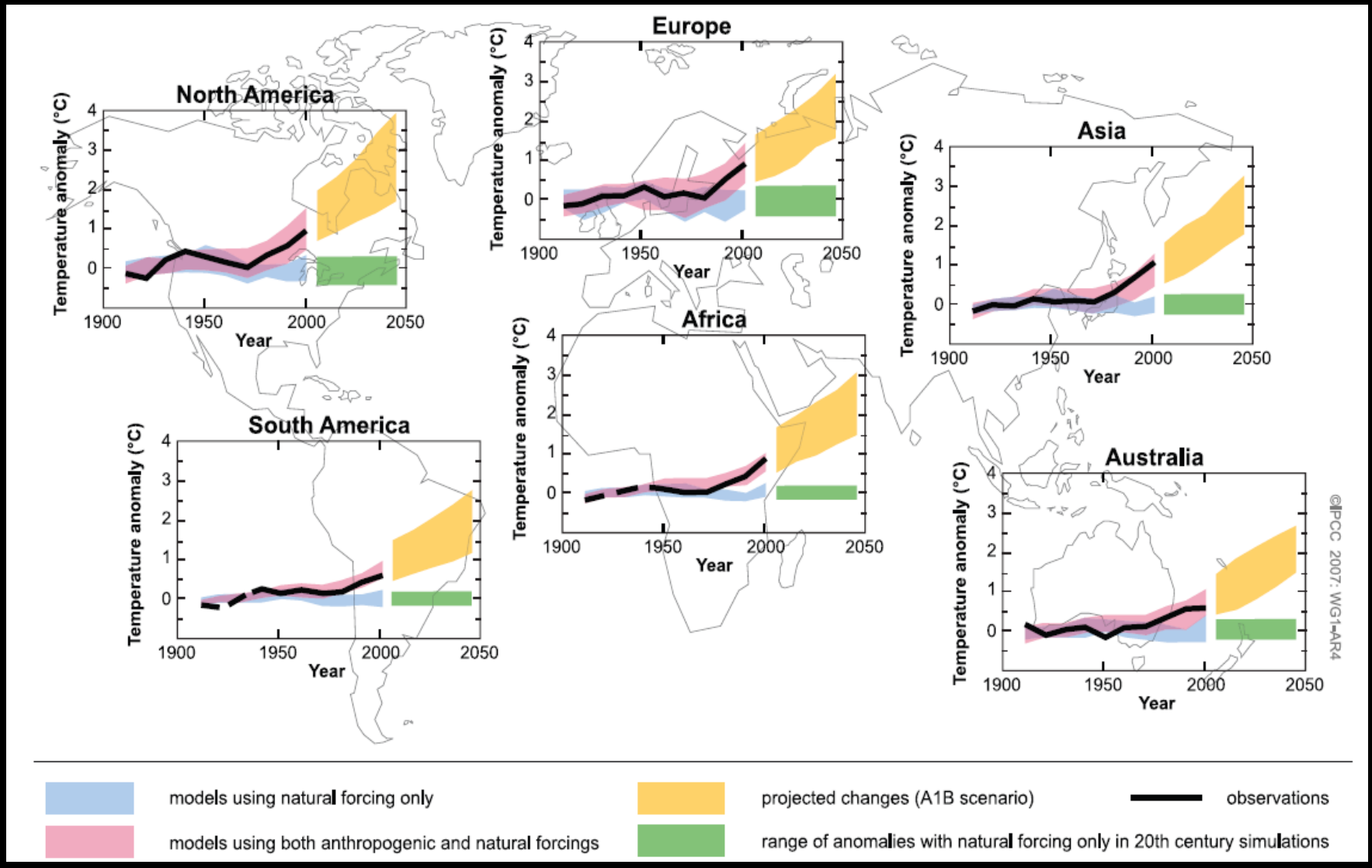

Reliability: MMcca
Reliability: MMeqw
Below
Above
Observed Relative Frequency
Forecast Probability
0
0.2
0.4
0.6
0.8
1
0.5

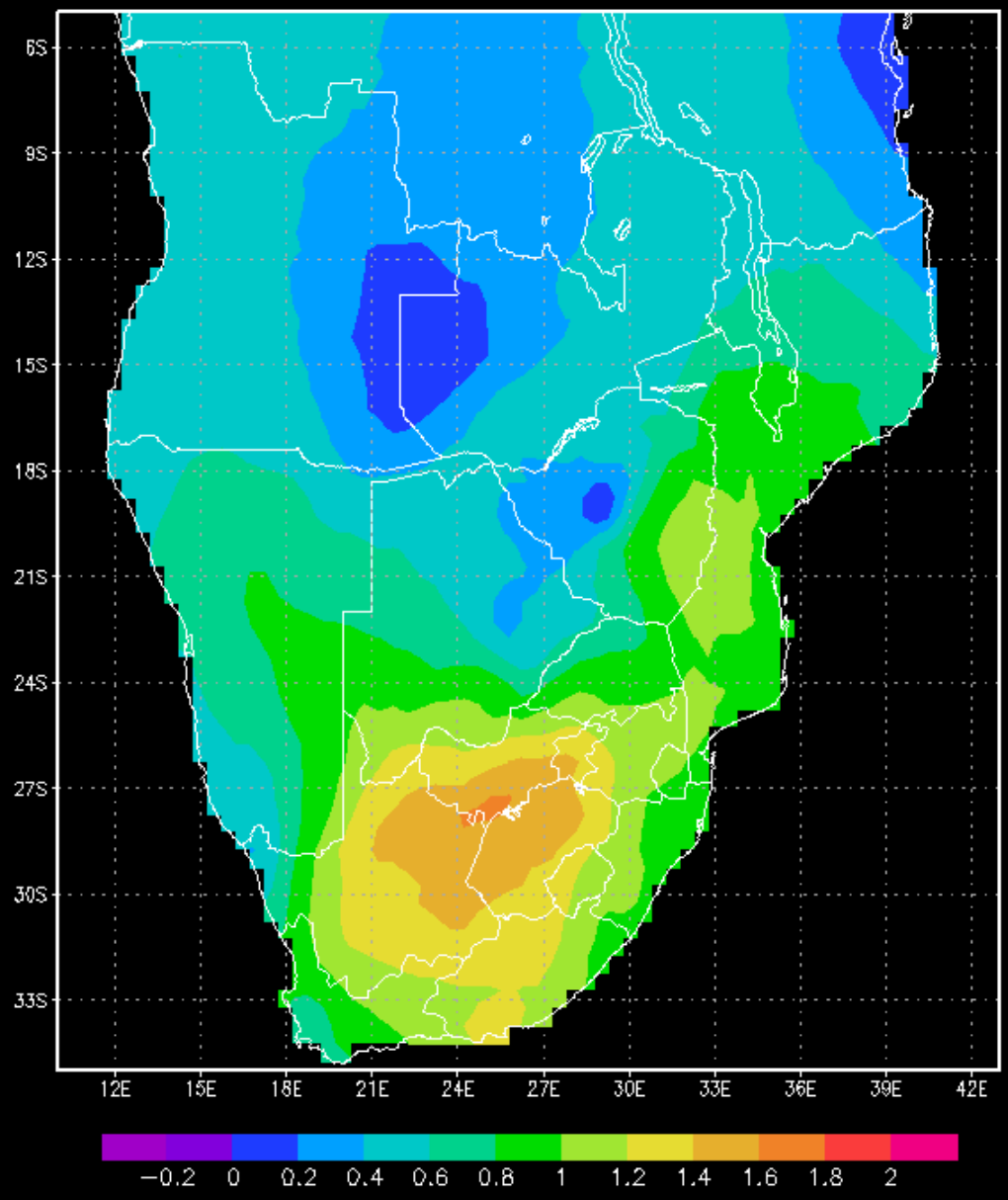
LATEST SEASONAL FORECASTS





CLIMATE CHANGE PROJECTIONS





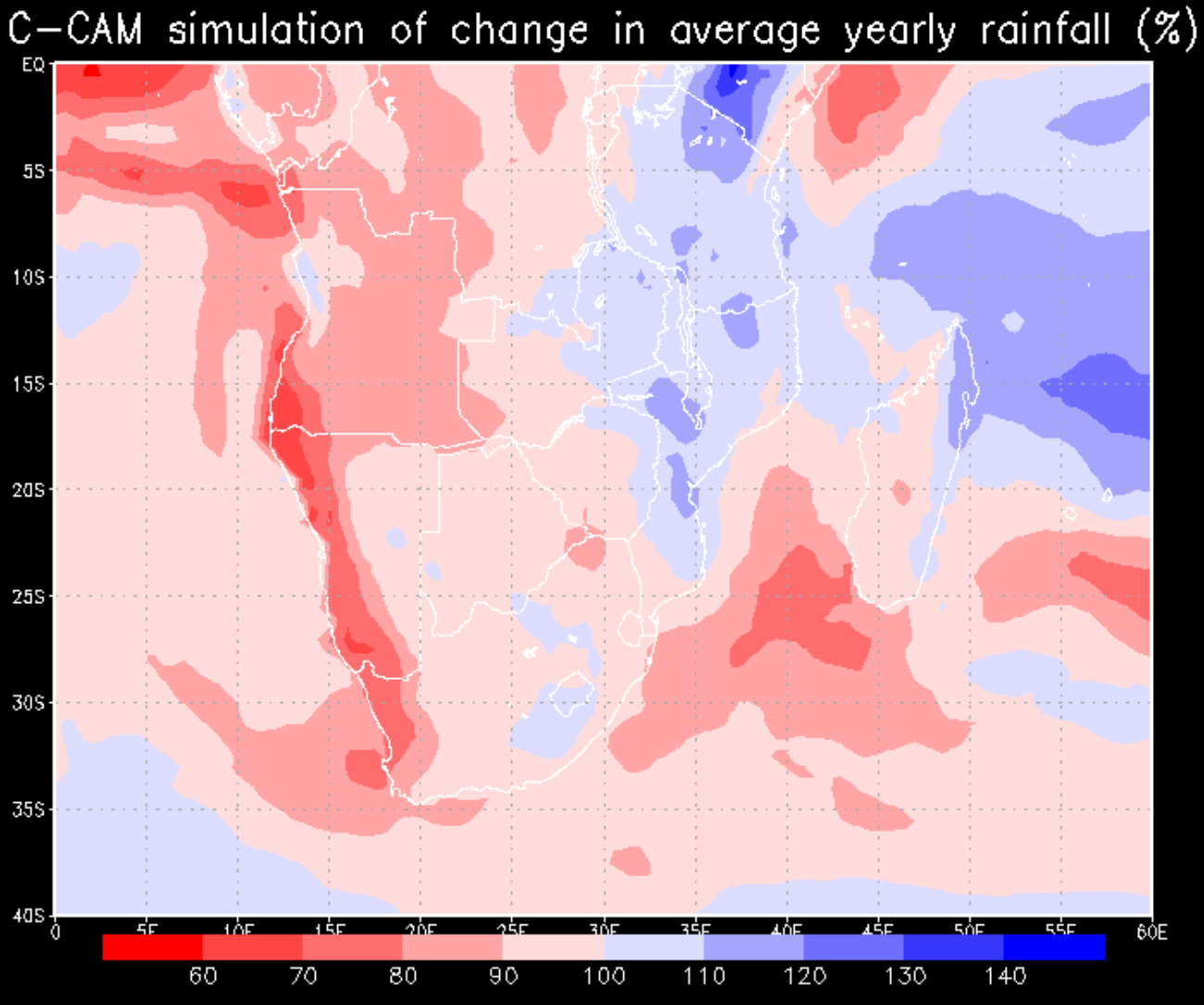
Yearly temperature trends 1901-2002 (CRU)

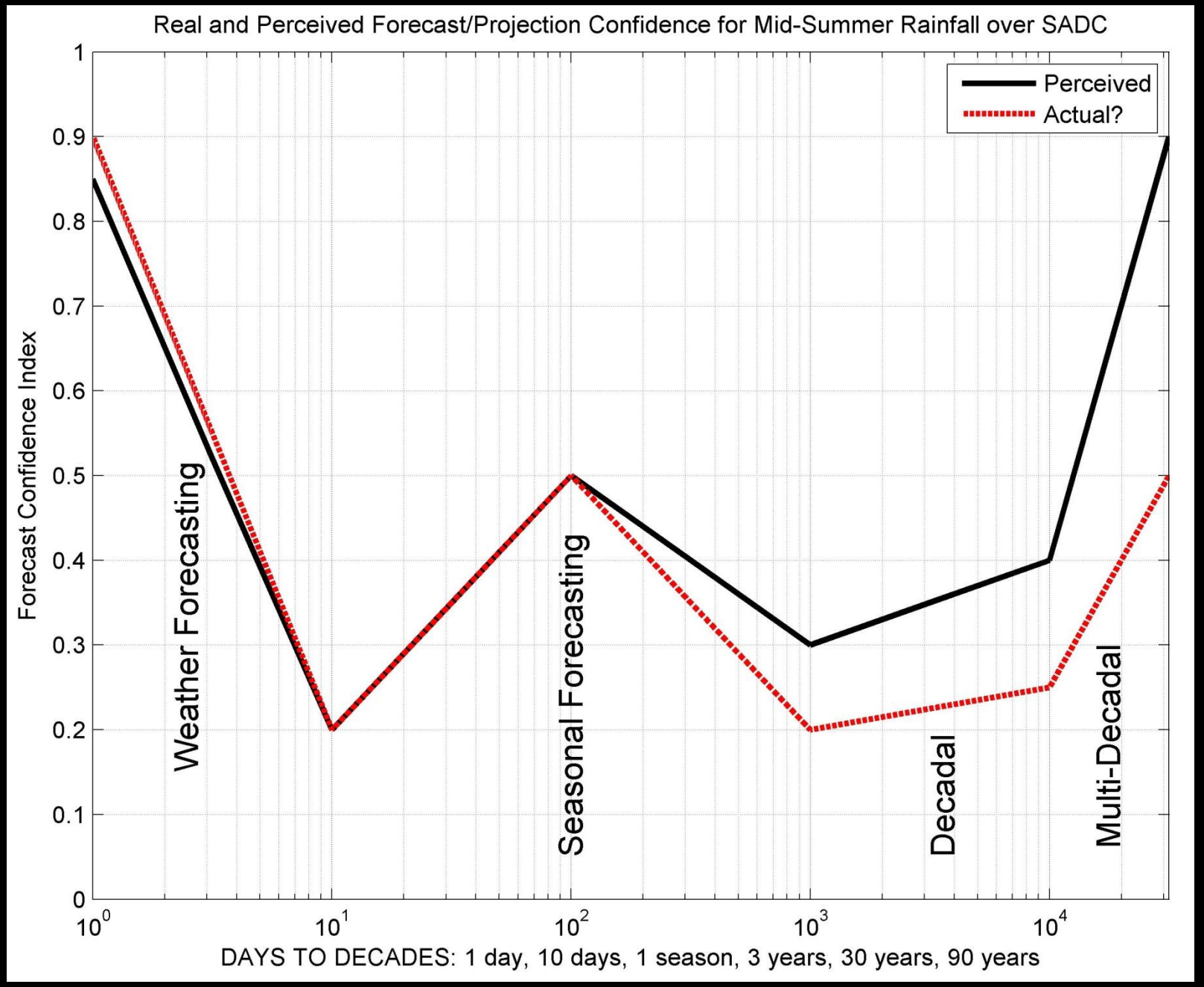
* The largest trends occur over the central interior of South Africa – temps rising at more than twice the global average temp increase

•Warming trend weaker over coastal areas

Change in yearly rainfall totals (%) over southern Africa

- A generally warmer and drier climate
- A shorter and more intense summer rainfall season
- Cloud bands displaced westwards in spring and autumn
- Drier winter rainfall region




Real and Perceived Forecast/Projection Confidence for Mid-Summer Rainfall over SADC
Perceived
Actual?
Forecast Confidence Index
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Weather Forecasting
Seasonal Forecasting
Decadal
Multi-Decadal
10^0
10^1
10^2
10^3
10^4
DAYS TO DECADES: 1 day, 10 days, 1 season, 3 years, 30 years, 90 years

Weather and Climate Modelling at the NRE

Climate Studies and Modelling (CSM)

Component 1

High-resolution Weather Forecasting

(1-10 days)

Component 2

Long-Range Forecasting

(Weeks to months)

Component 3

Climate Change Projections

(Decadal and multi-decadal)

Component 4

Model Development

Operational Forecasting

SEAMLESS FORECASTING: Using common forecast systems to predict for multiple time scales

FINAL THOUGHTS

- Forecasts for various time-ranges are subject to different forcings and have different skill levels
- Forecast models can provide useful forecasts
- Forecast model development has resulted in improved forecasts, also of extreme events
- The South African modelling community, in partnership with international modellers, is constantly improving on operational forecast systems