Fundamentals of Seasonal Forecasting

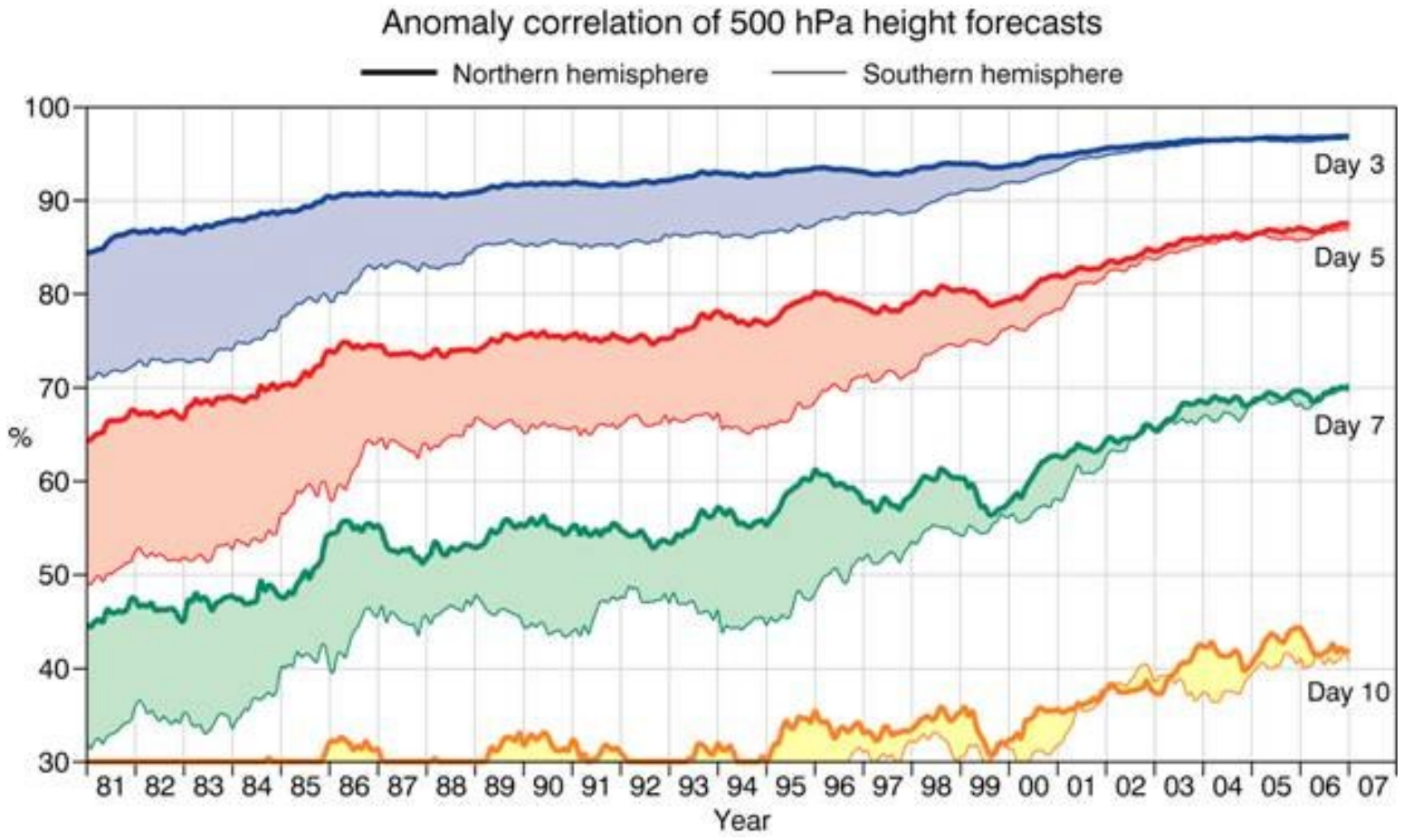
Willem A. Landman

Lecture 1

WMO Forecast time ranges

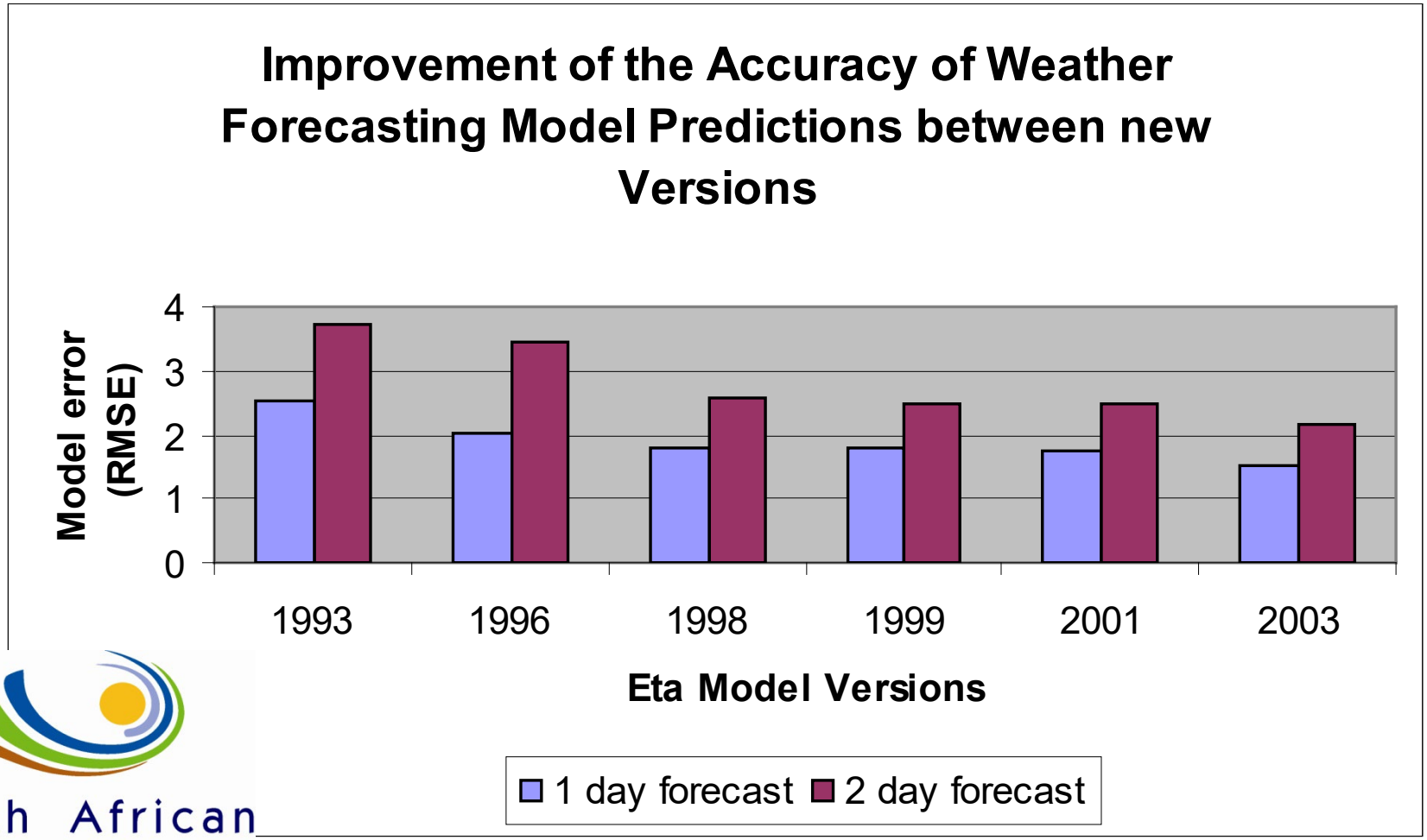
- **Nowcasting:** A description of current weather parameters and 0 to 2 hours' description of forecast weather parameters
- **Very short-range weather forecasting:** Up to 12 hours' description of weather parameters
- **Short-range weather forecasting:** Beyond 12 hours' and up to 72 hours' description 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

Convergence of NWP skill



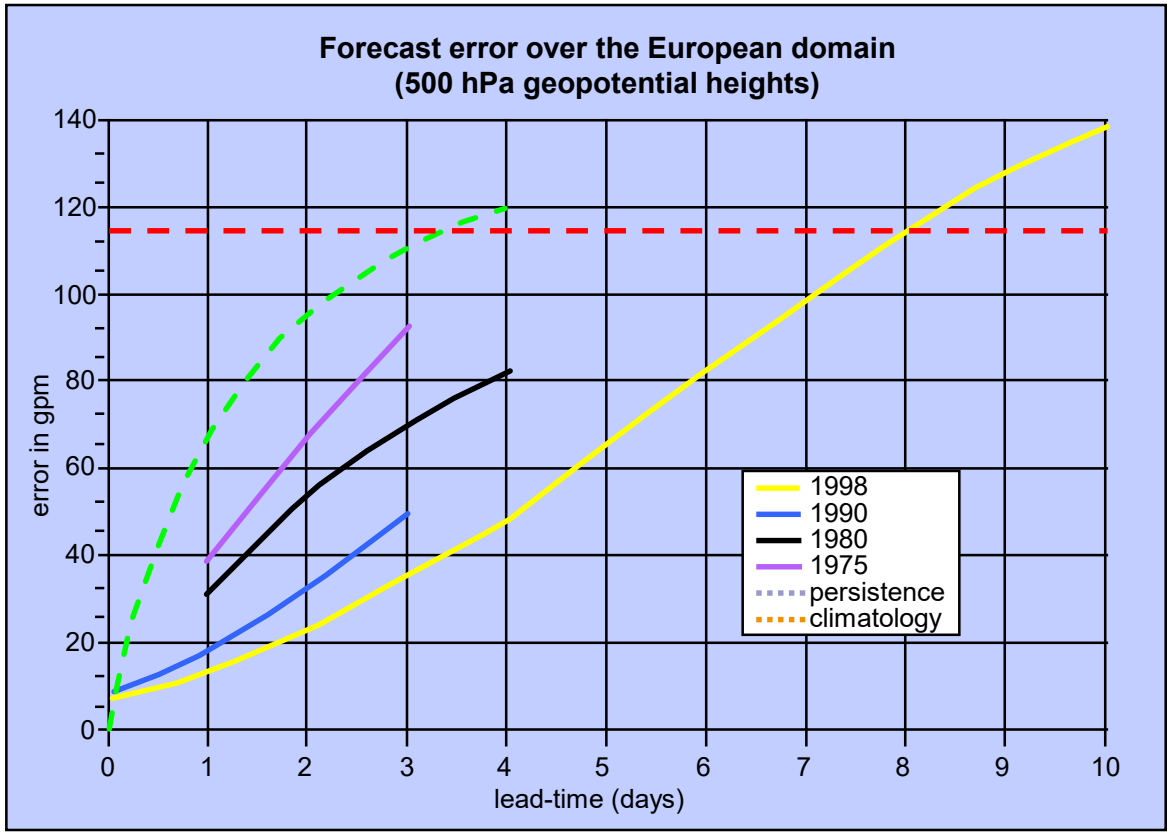
ECMWF

Improvement of Eta model skill



South African Weather Service

Typical performances of weather forecast models and their improvement over time



climatology:
average taken over a long time; the forecast is that the average value will happen.

persistence:
'today's weather is what will happen tomorrow'.

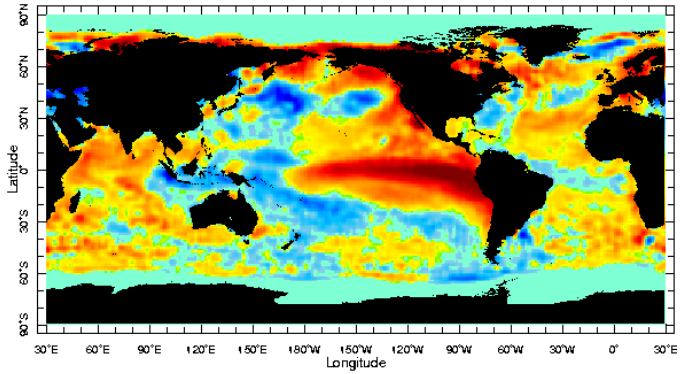
Progress! Forecast errors made by a 1998 model after 5 days, are similar to errors made after 2 days by a 1975 model.

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

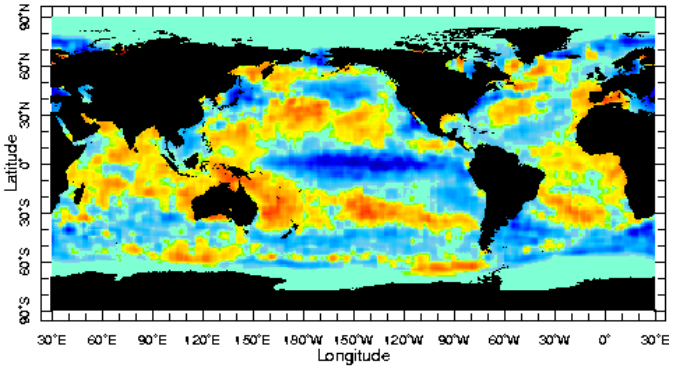
How is it then possible to predict ***seasonal*** *climate anomalies*?

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



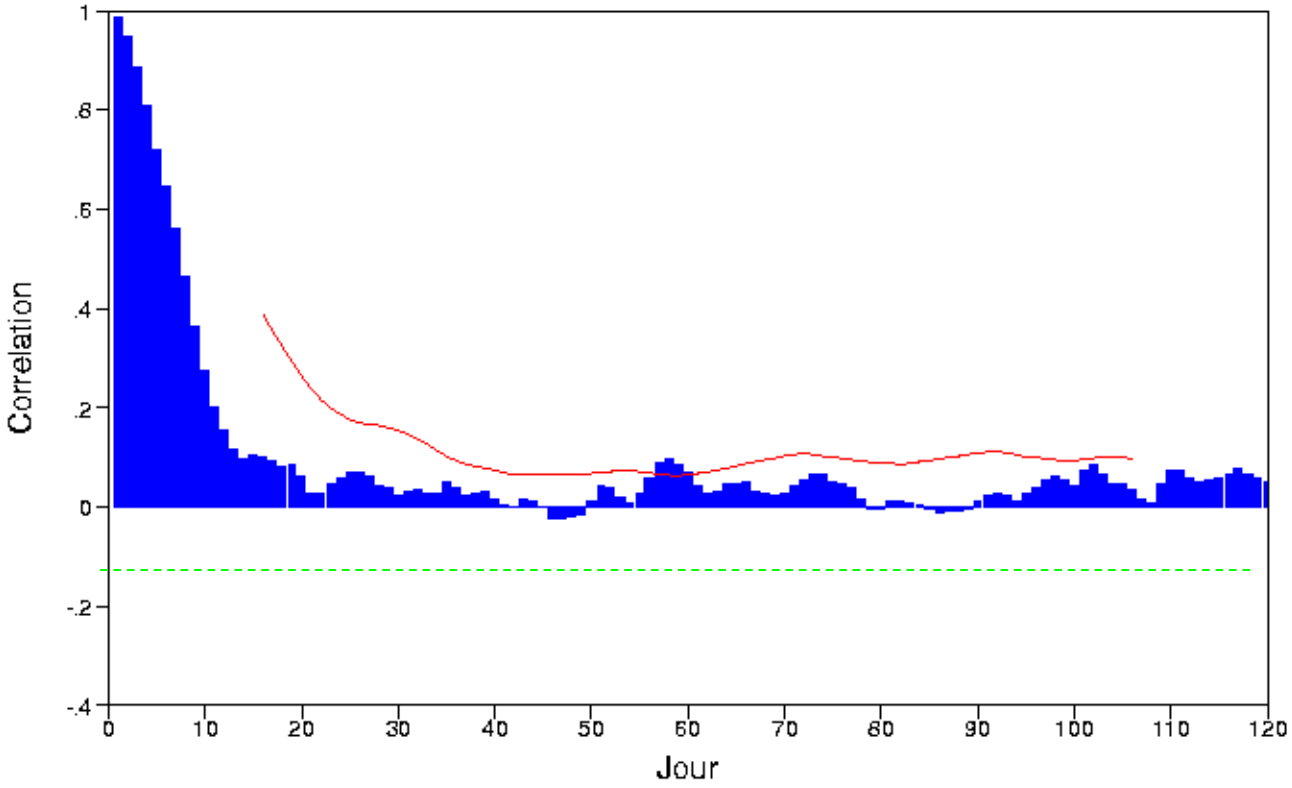
Sea-surface temperature (SST) anomalies of November 1988 (La Niña of 1988/89)

Dynamical Forecasts: Monthly Forecasts

Daily Scores over Northern Hemisphere

+

Monthly running mean Scores

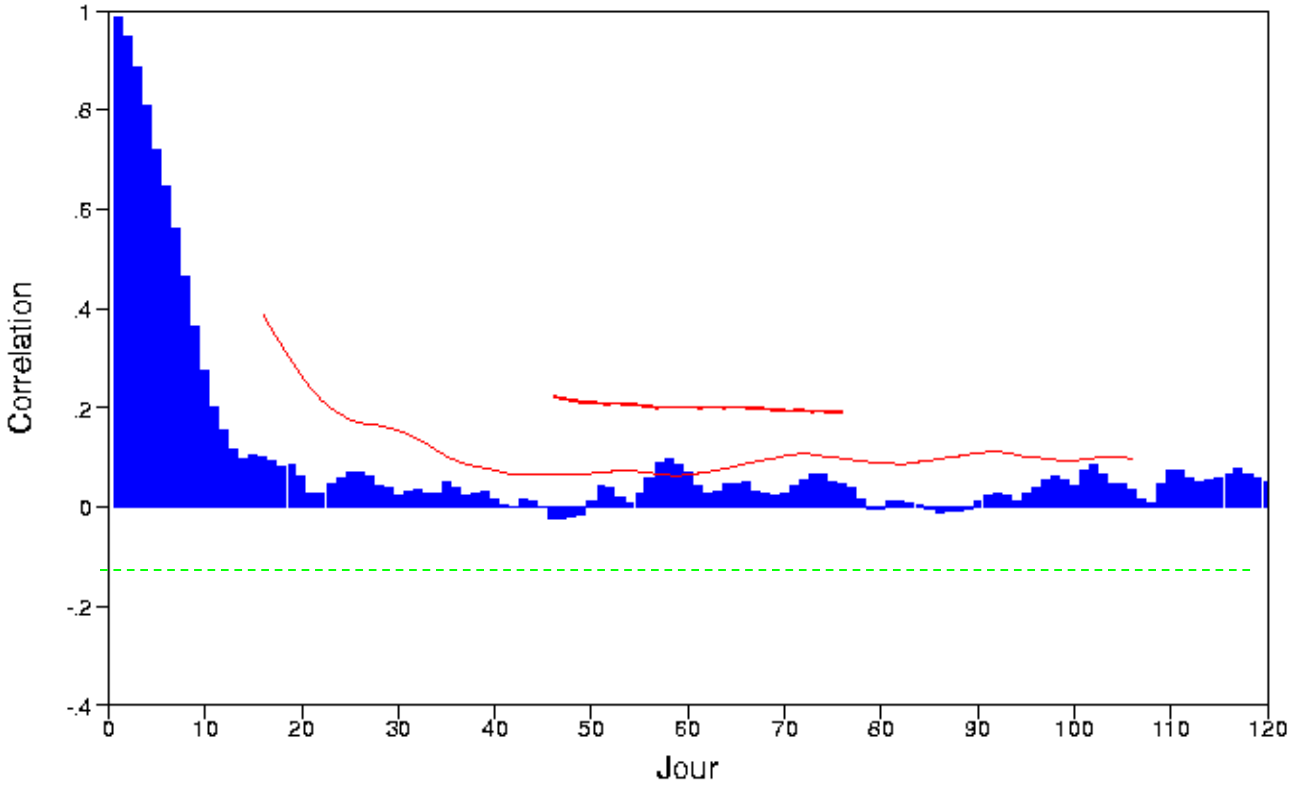


Dynamical Forecasts: Seasonal Forecasts

Daily Scores over Northern Hemisphere

+

Seasonal running mean Scores

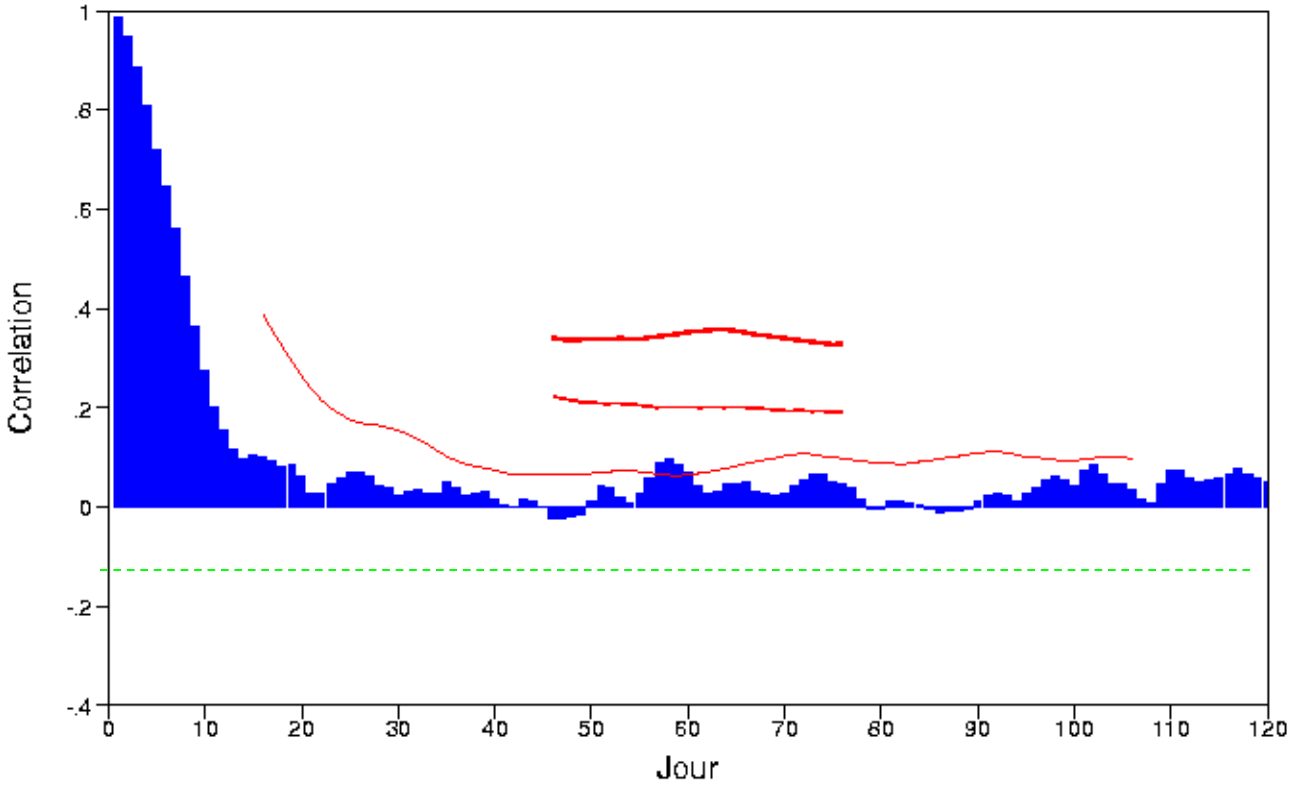


Dynamical Forecasts: Seasonal Forecasts

Daily Scores over Northern Hemisphere

+

Ensemble forecast, Seasonal running mean and SST forecast



Dynamical Forecasts: Seasonal Forecasts

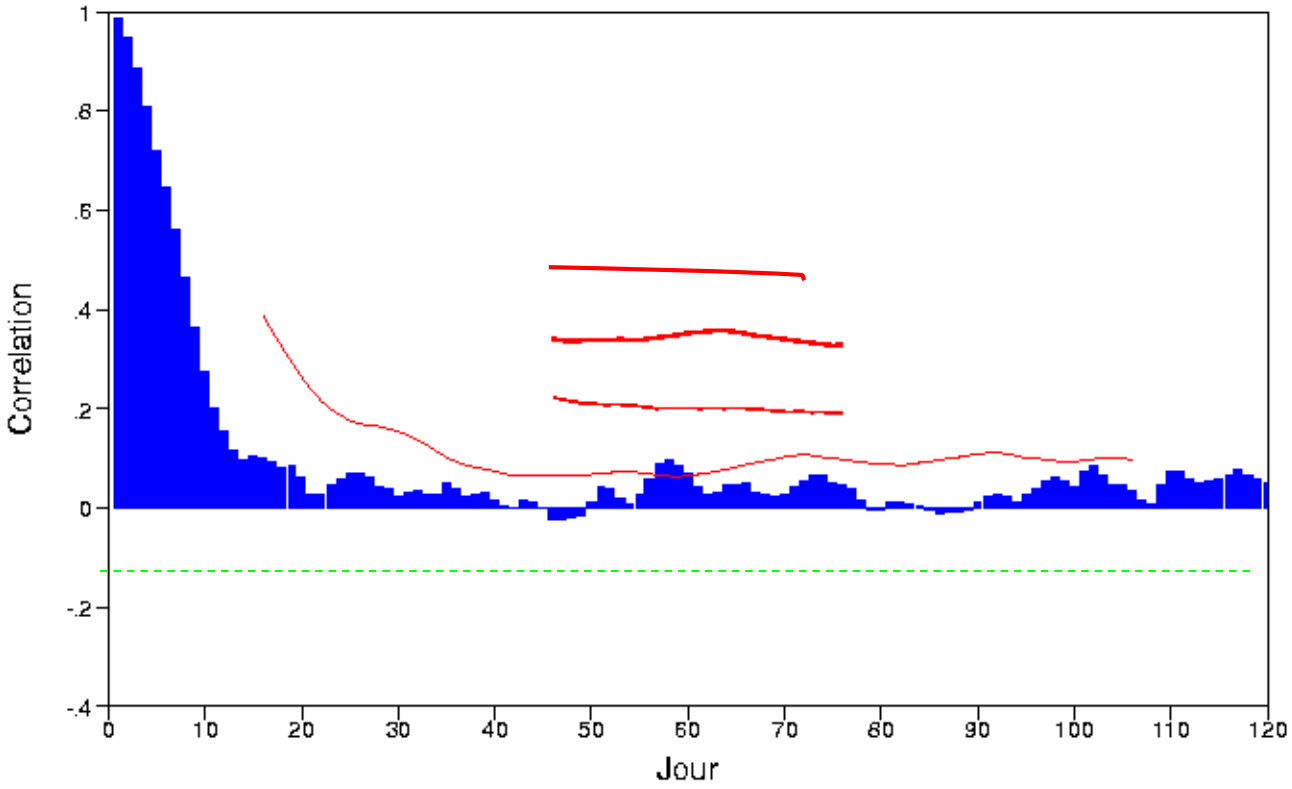
Daily Scores over Northern Hemisphere

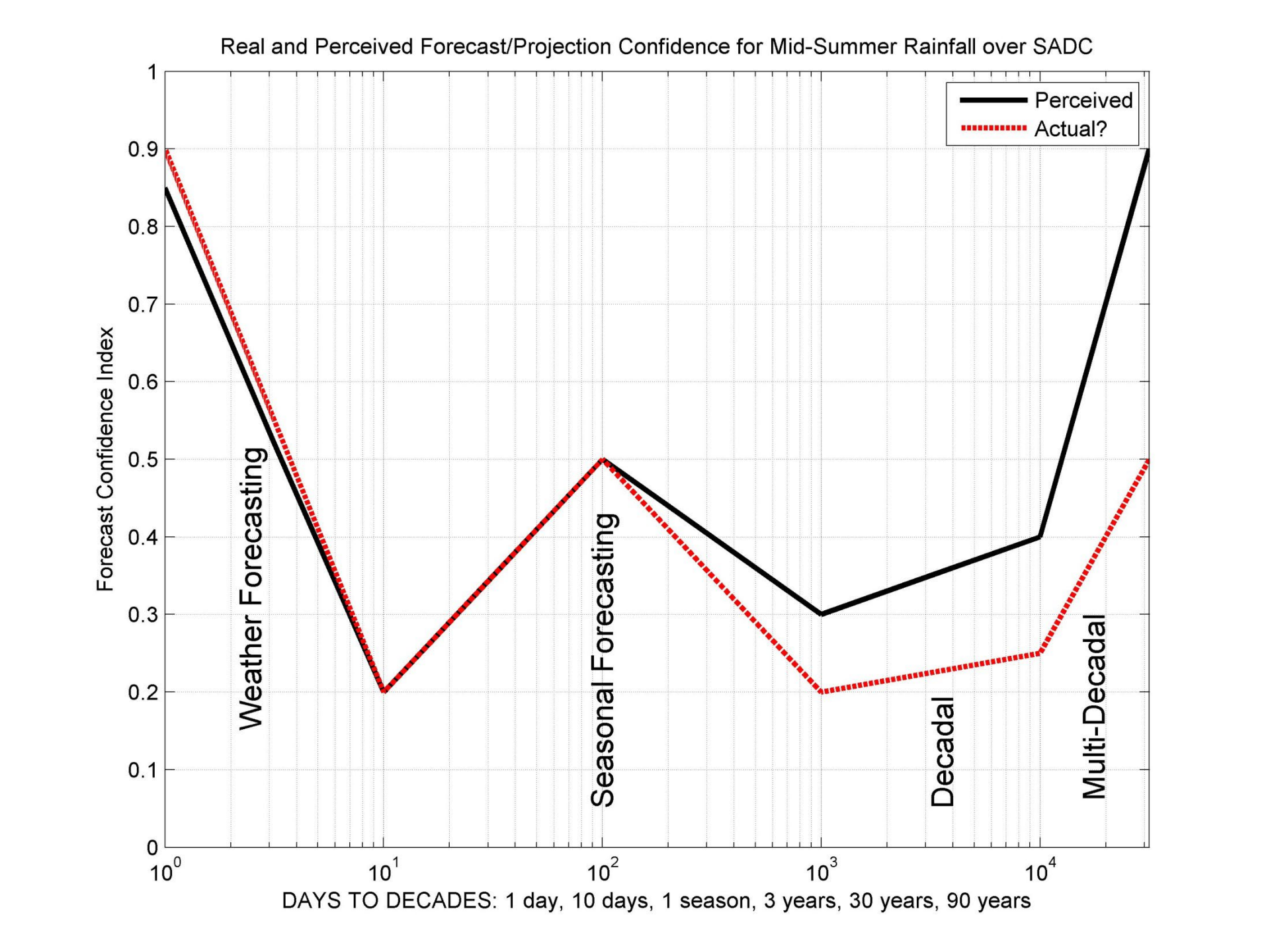
+

Ensemble forecast, Seasonal running mean and SST forecast

+

Post-processing



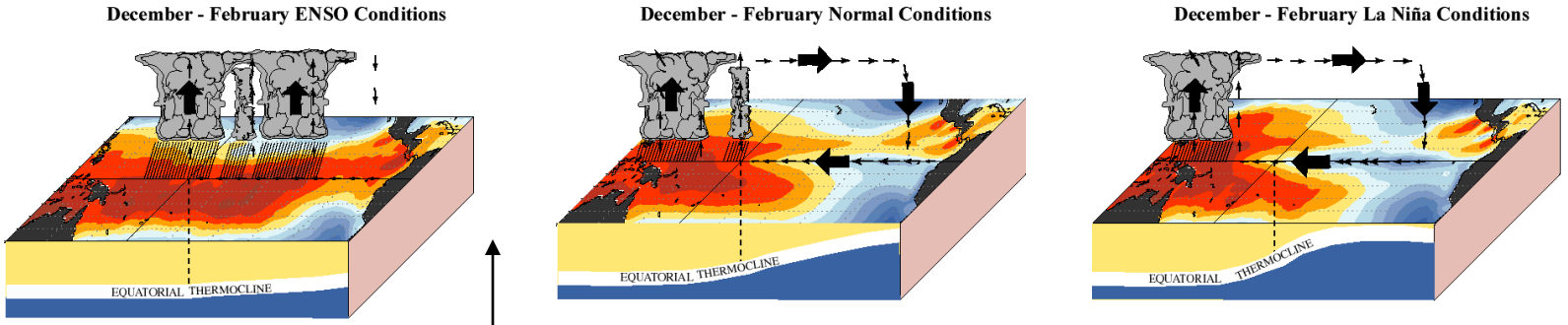

Real and Perceived Forecast/Projection Confidence for Mid-Summer Rainfall over SADC
Perceived
Actual?
Forecast Confidence Index
Weather Forecasting
Seasonal Forecasting
Decadal
Multi-Decadal
DAYS TO DECADES: 1 day, 10 days, 1 season, 3 years, 30 years, 90 years

El Niño and La Niña events occur over the equatorial Pacific Ocean

El Niño year

Normal year

La Niña year



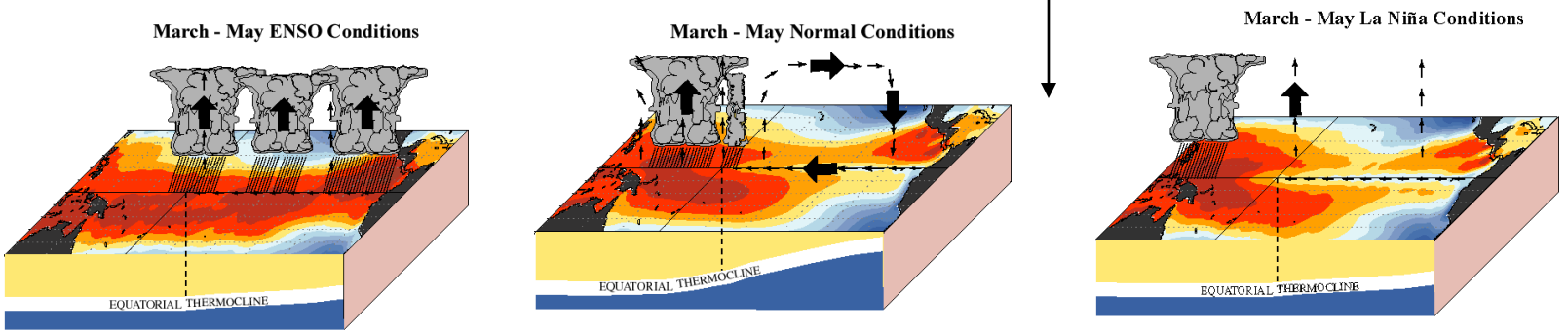
Surface:

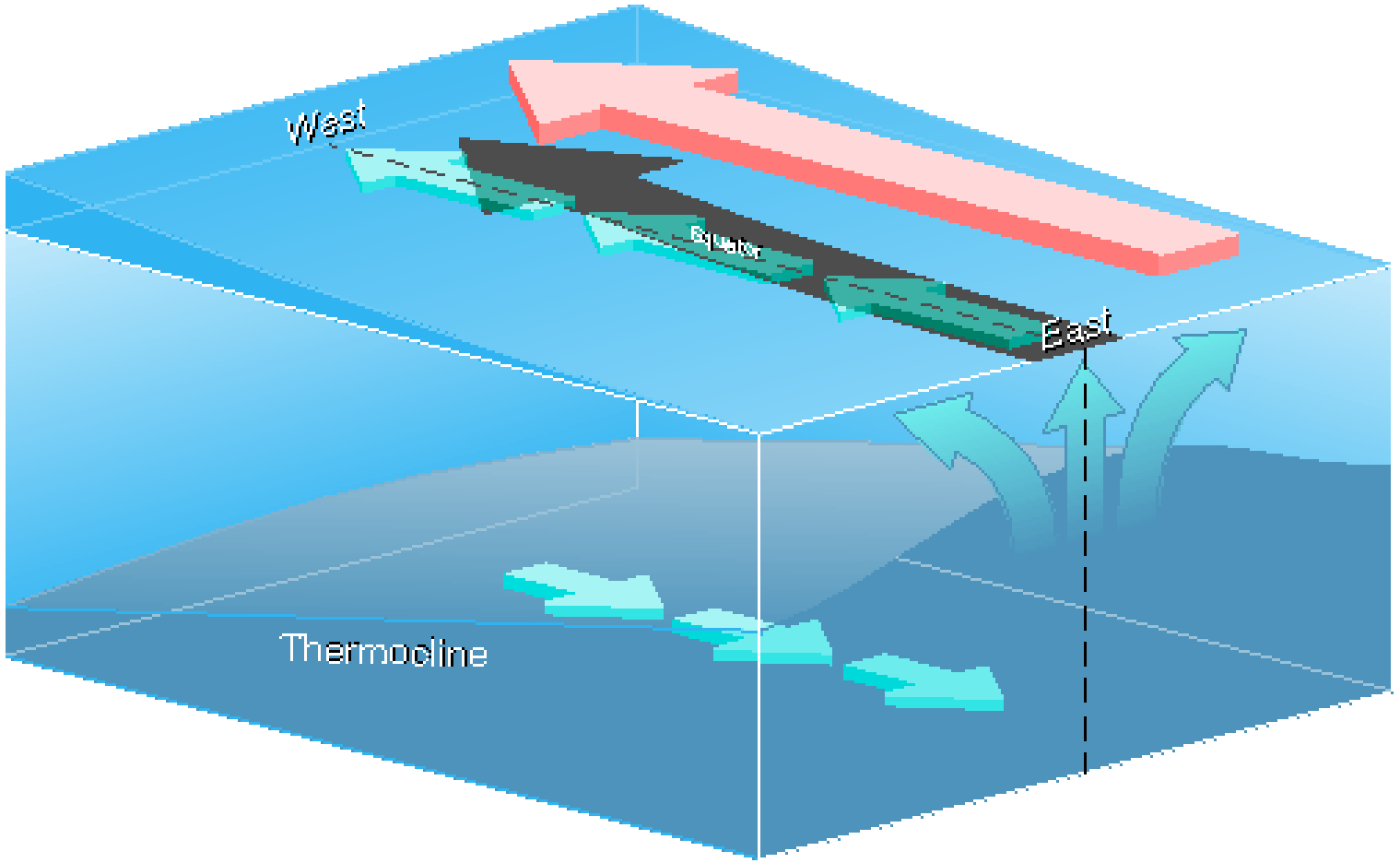
Red: warm anomalies

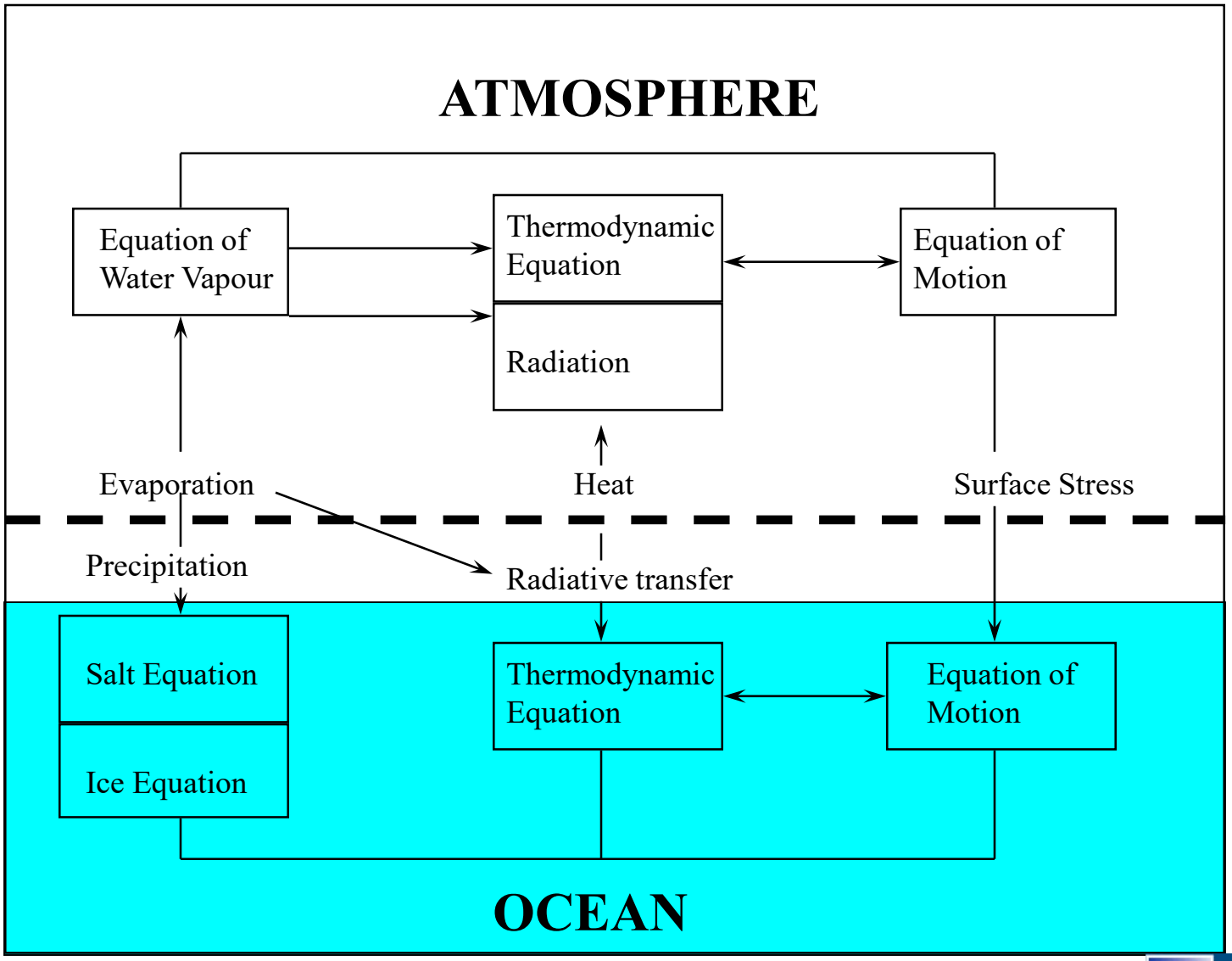
Blue: cold anomalies

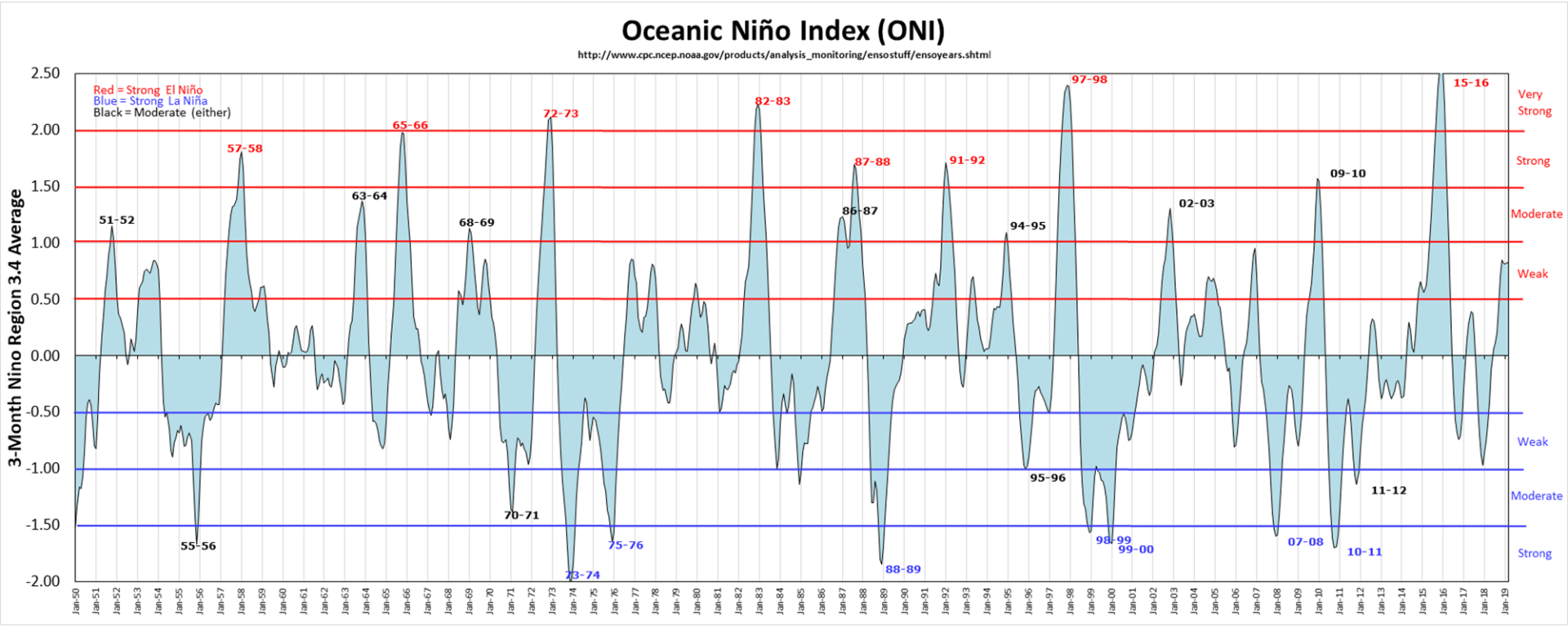
summer

autumn

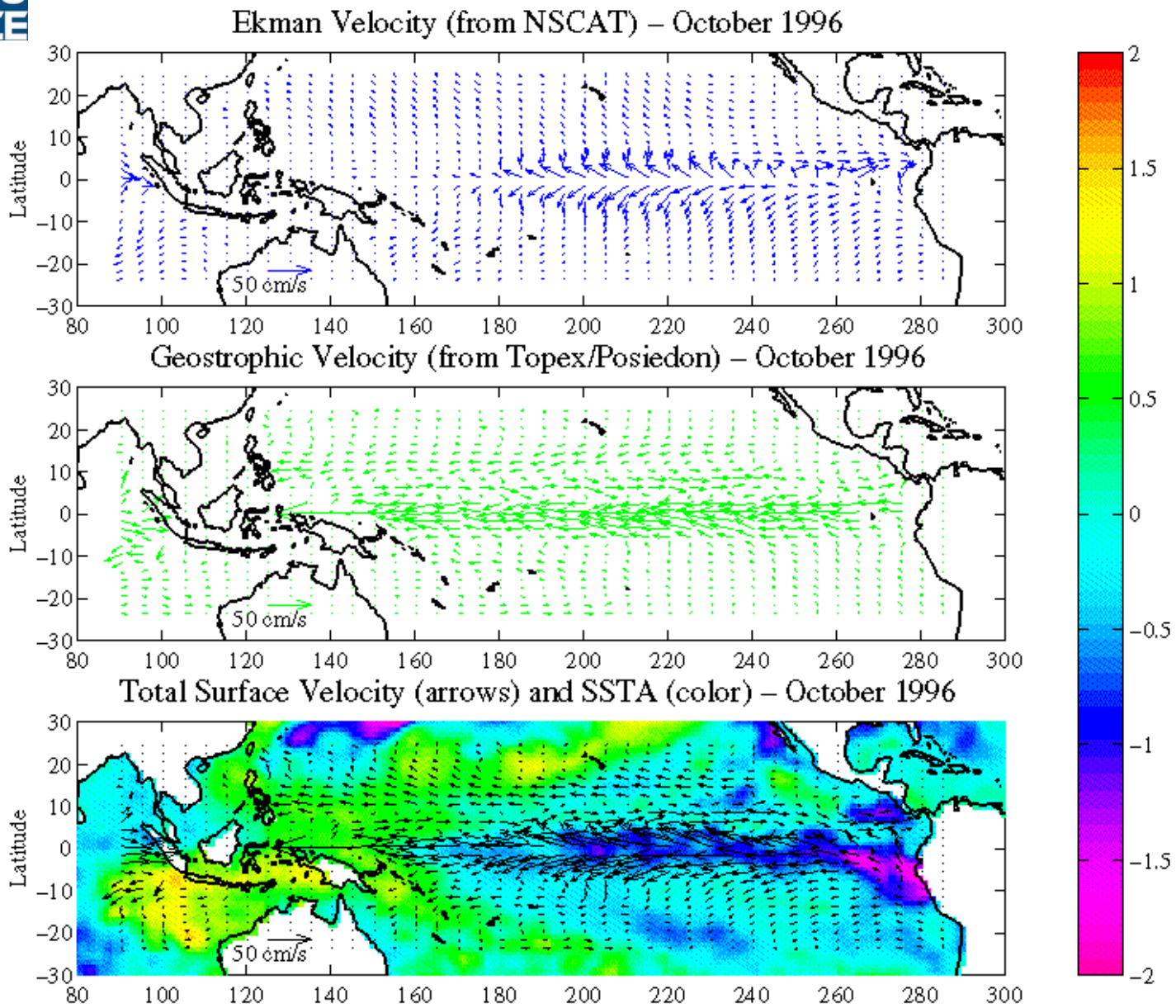



West
East
Thermocline


ATMOSPHERE
Equation of Water Vapour
Thermodynamic Equation
Radiation
Equation of Motion
Evaporation
Heat
Surface Stress
Precipitation
Radiative transfer
Salt Equation
Ice Equation
Thermodynamic Equation
Equation of Motion
OCEAN

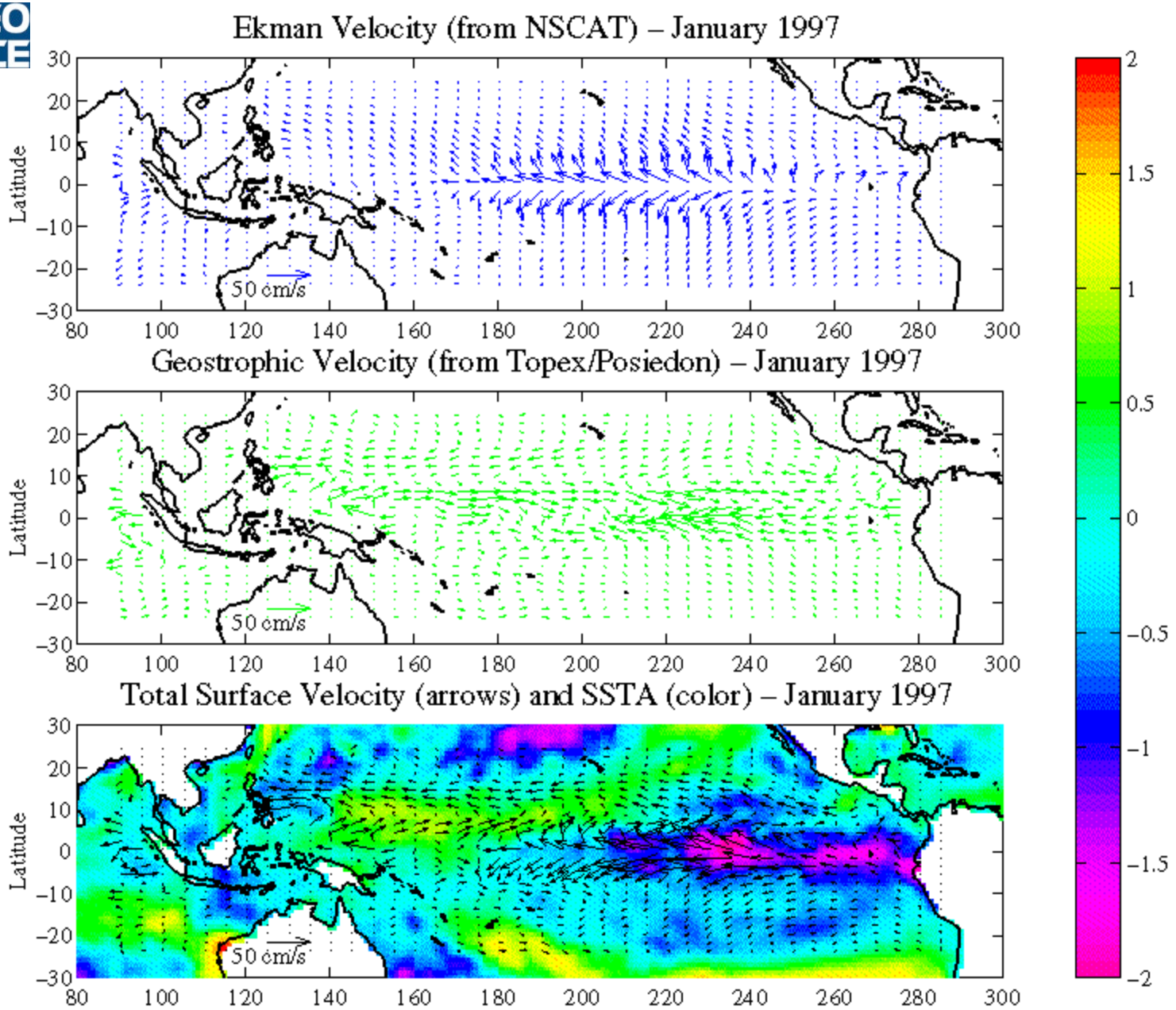


https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php



NSCAT data courtesy of W. Tang/JPL
Topex/Posiedon SSHgt analysis courtesy of Univ. of Texas
SST data courtesy of R. Reynolds/NOAA

Surface Velocity calculation: G. Lagerloef & J. Gunn
Earth & Space Research
Internet: www.esr.org



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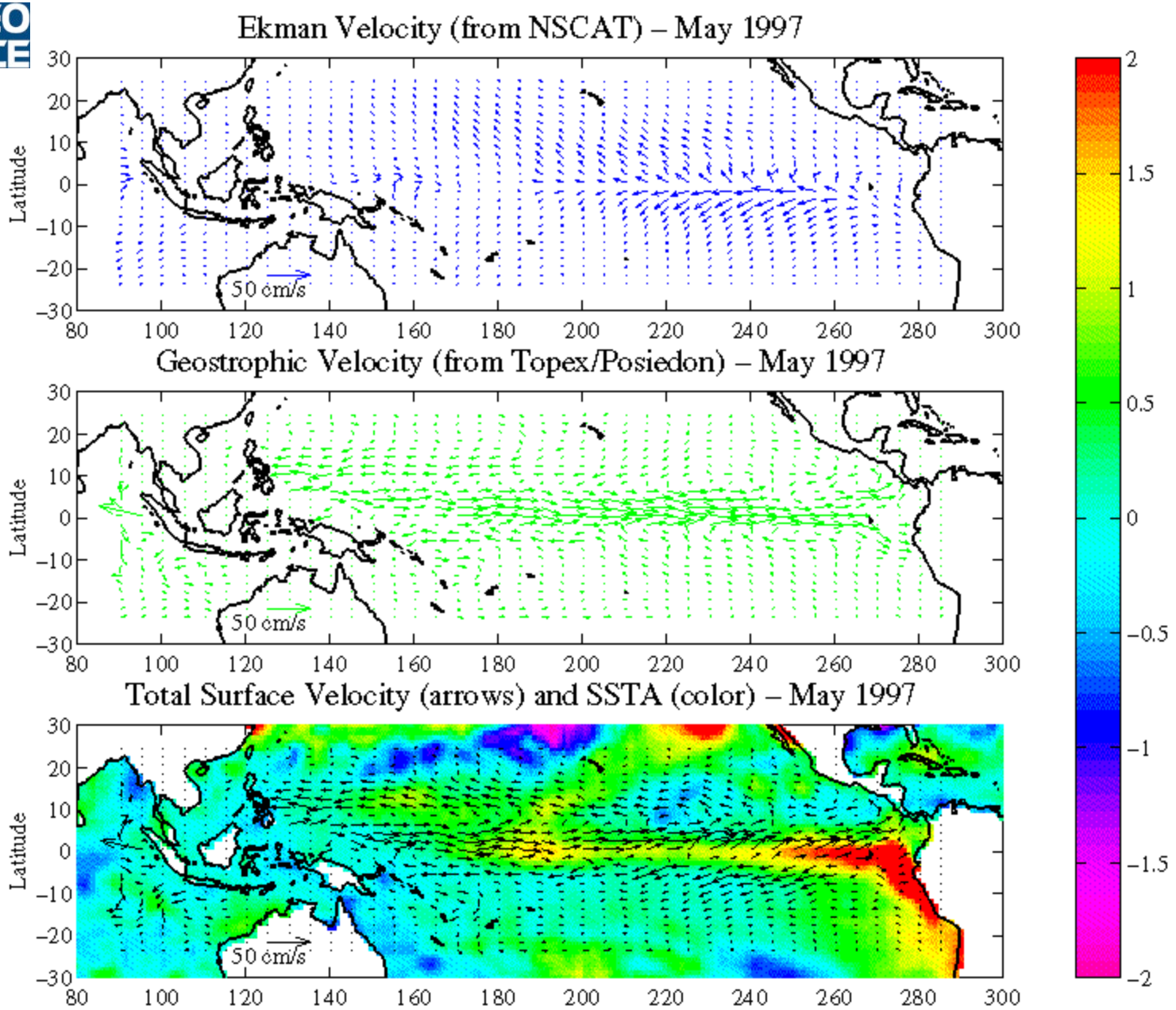

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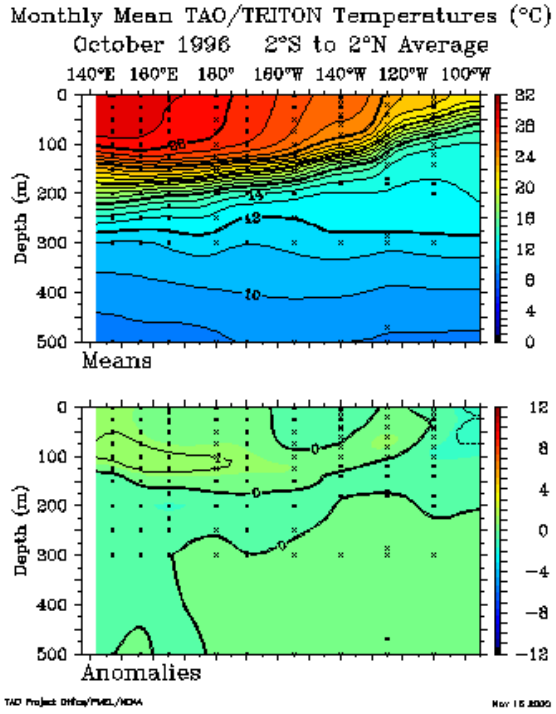
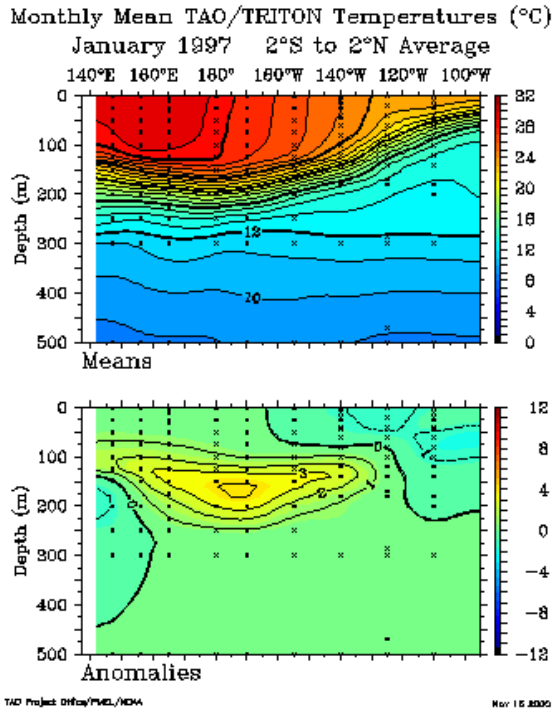
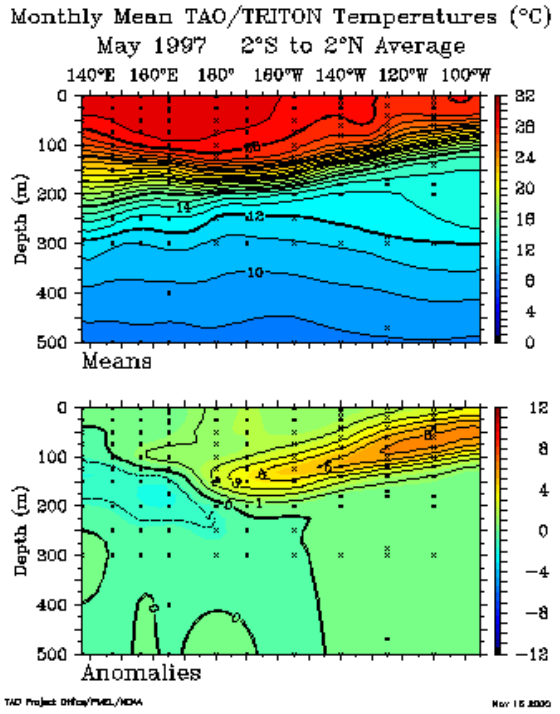
ENSO

- The deep Oceanic structure and its evolution







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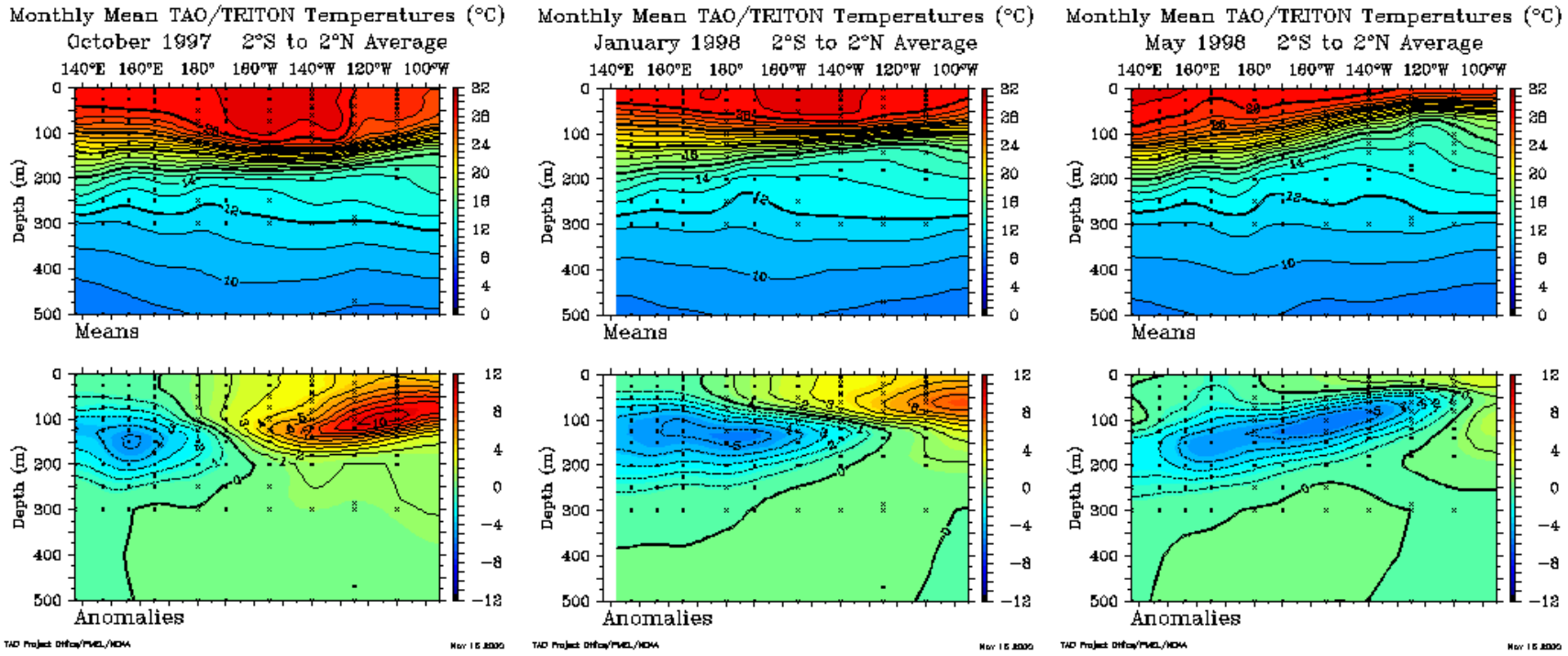

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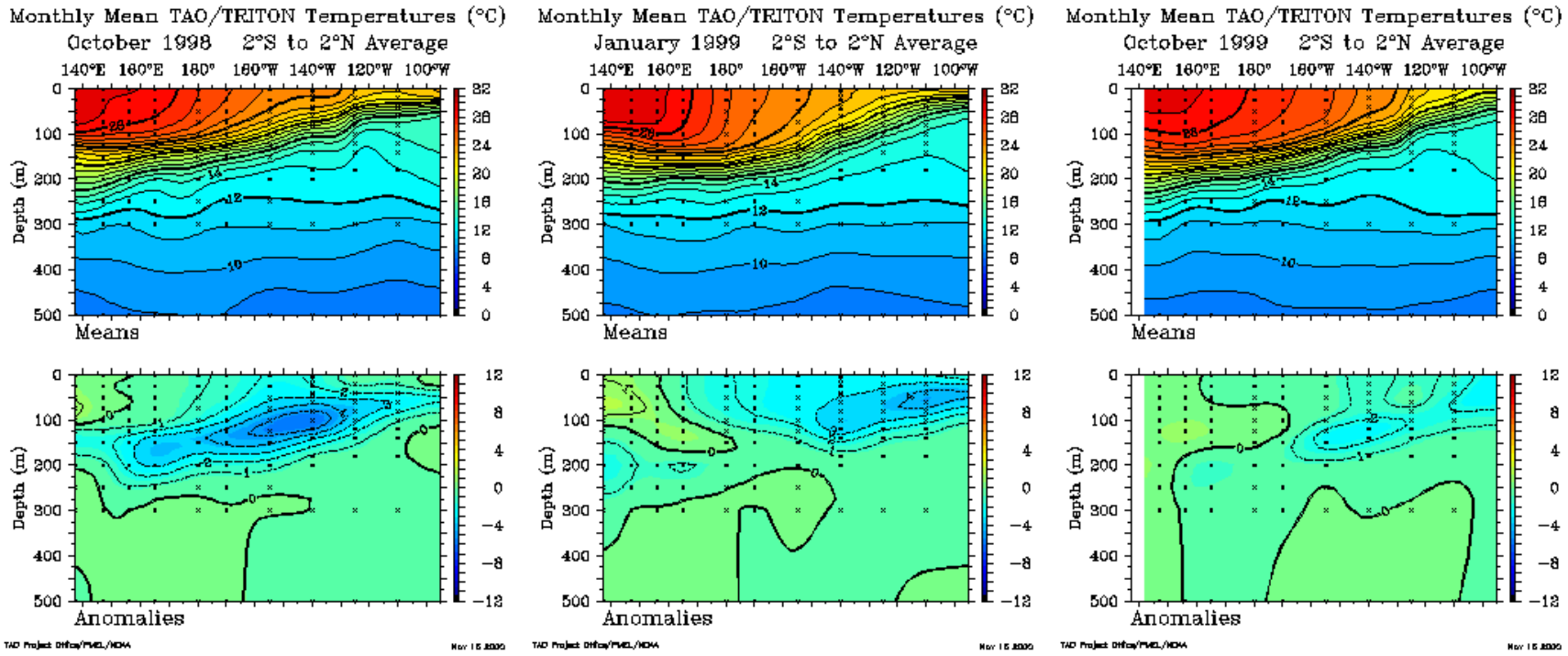
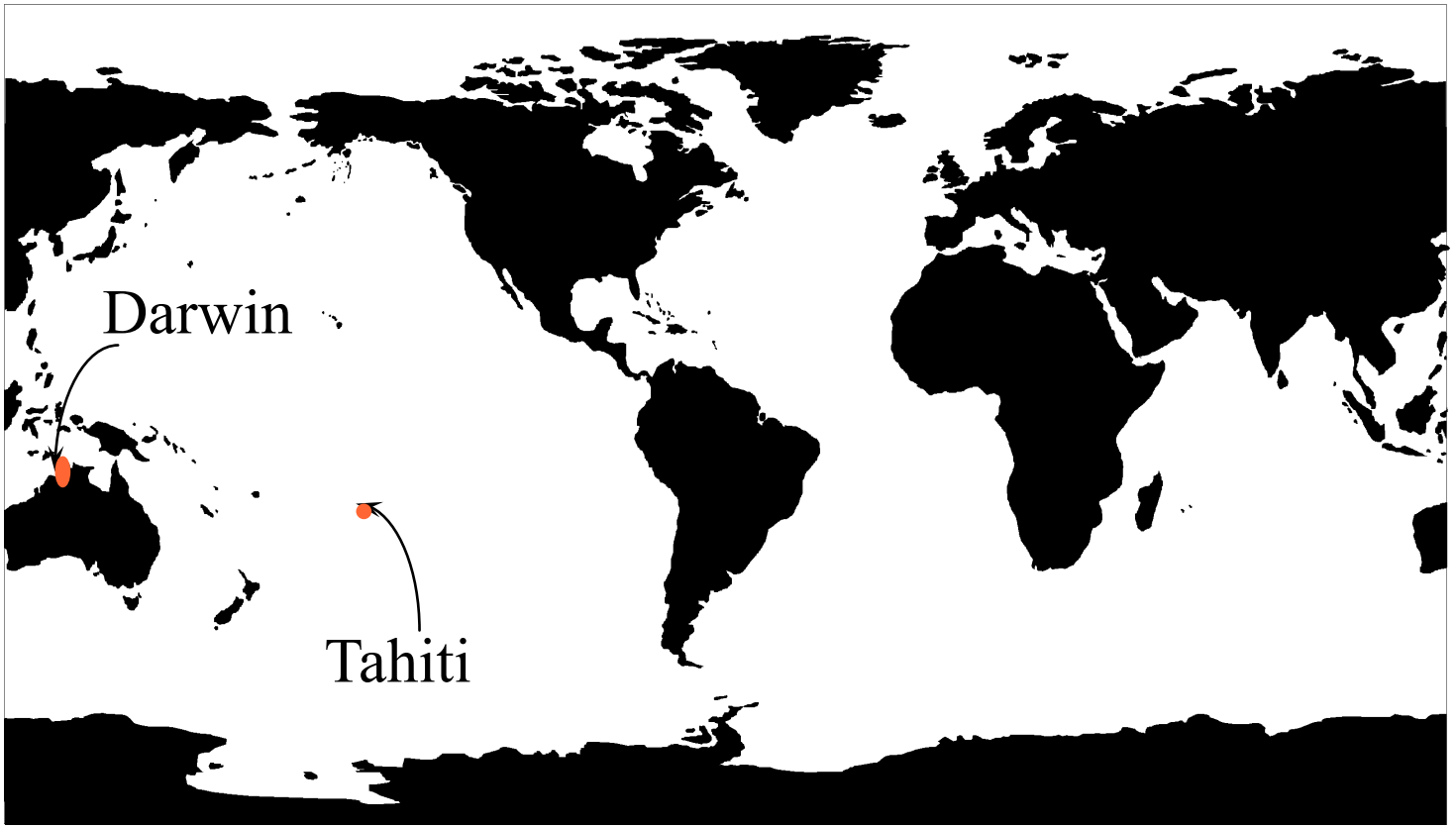
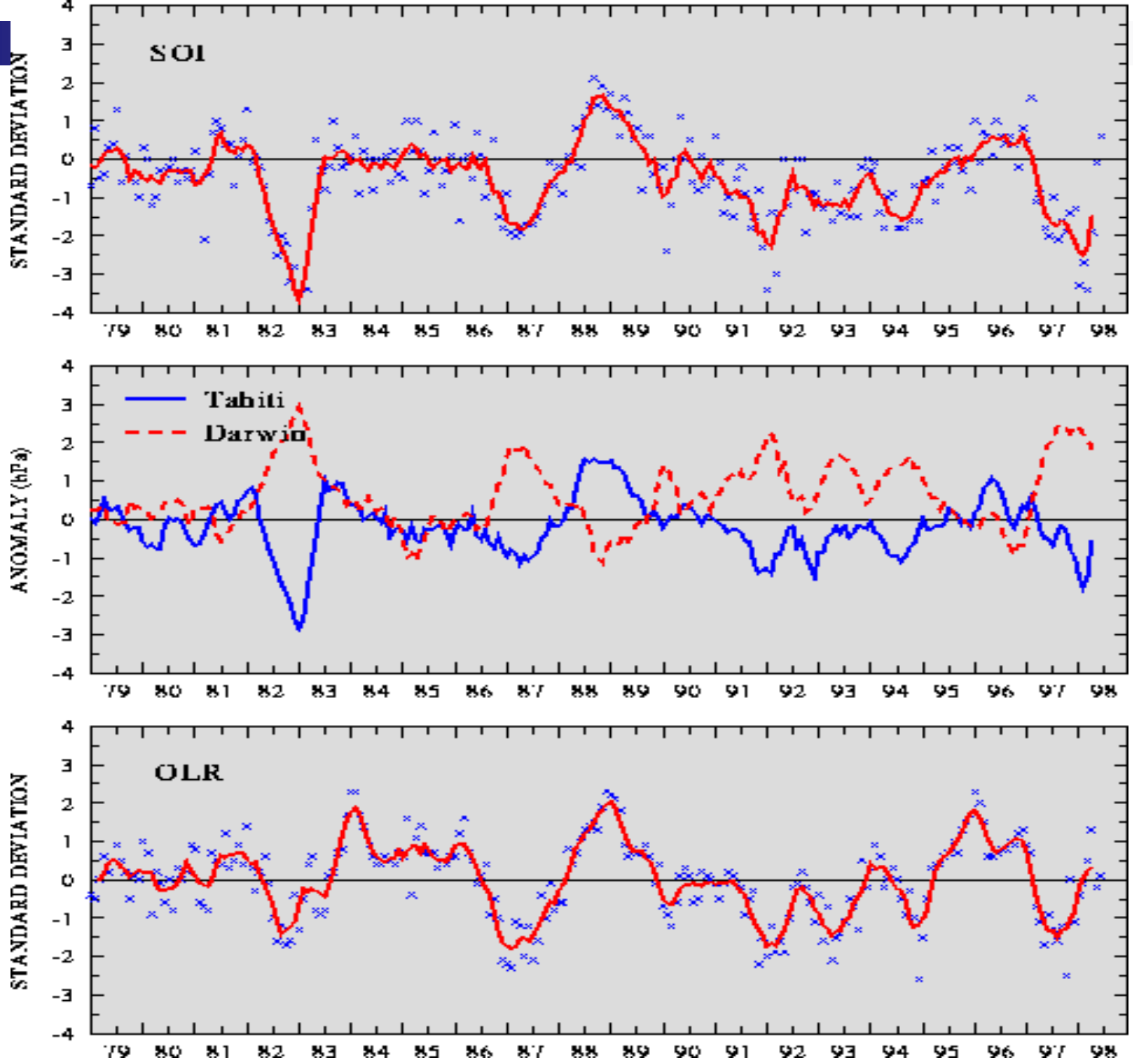
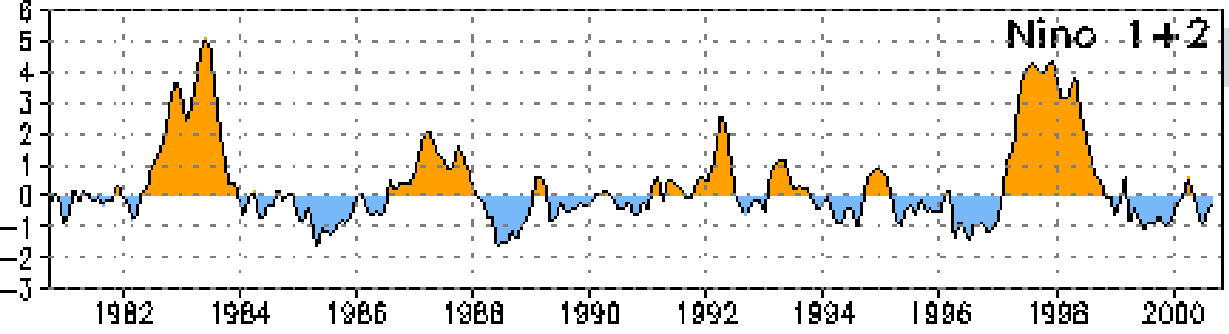


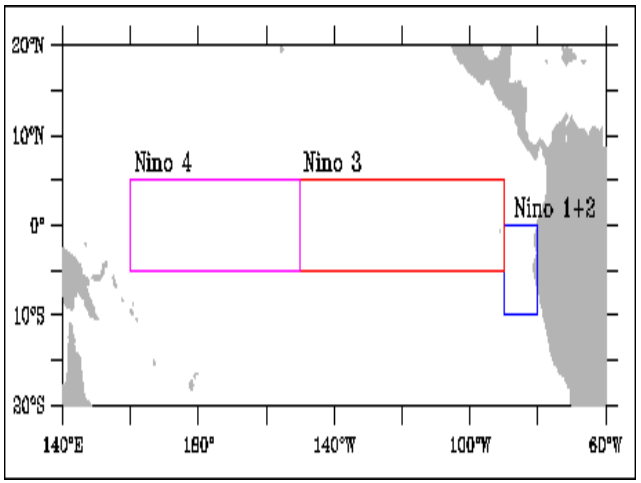
ENSO

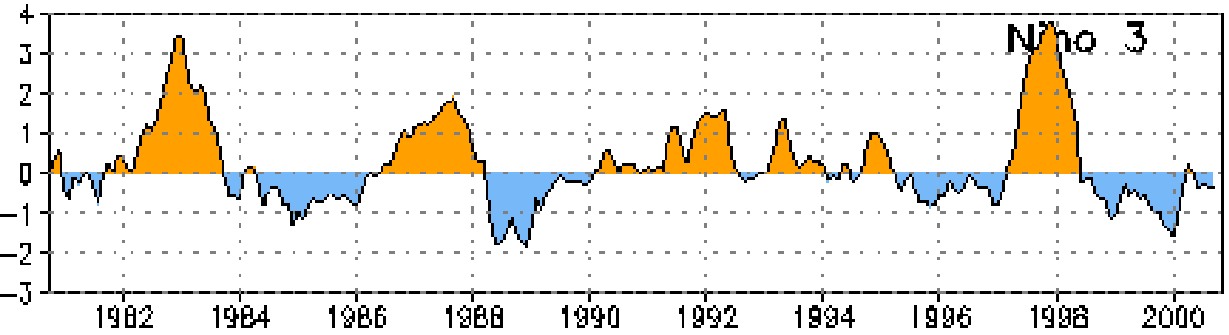
- Southern Oscillation Index

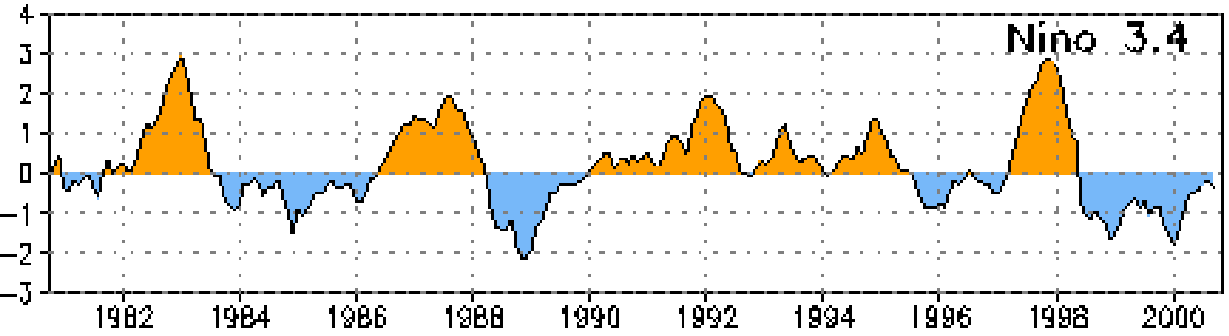


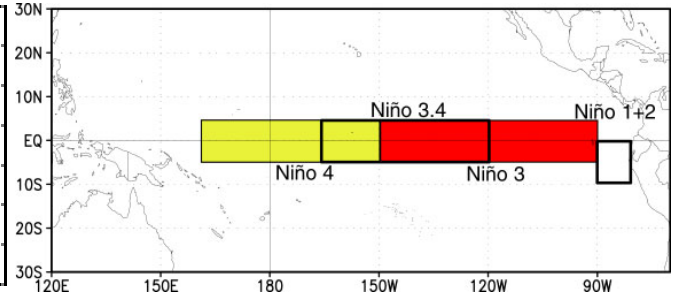

SOI
STANDARD DEVIATION
Tahiti
Darwin
ANOMALY (hPa)
OLR
STANDARD DEVIATION
4
3
2
1
0
-1
-2
-3
-4
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98

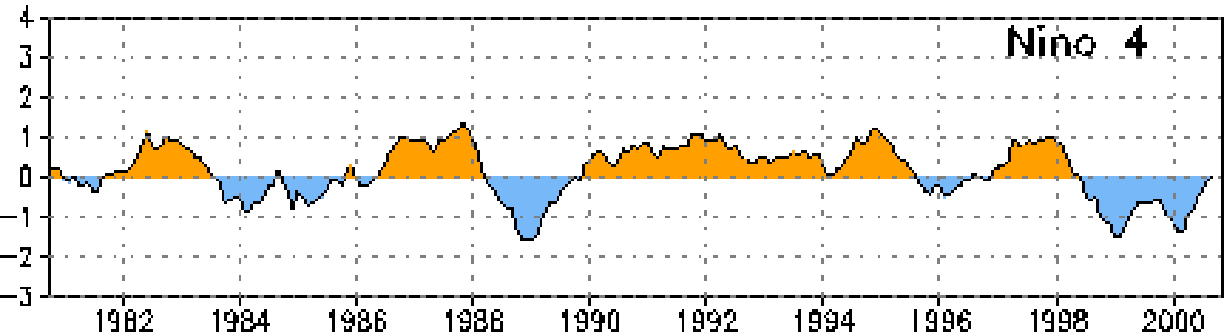

Nino 1+2
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000


20°N
10°N
0°
10°S
20°S
140°E
180°
140°W
100°W
60°W
Nino 4
Nino 3
Nino 1+2

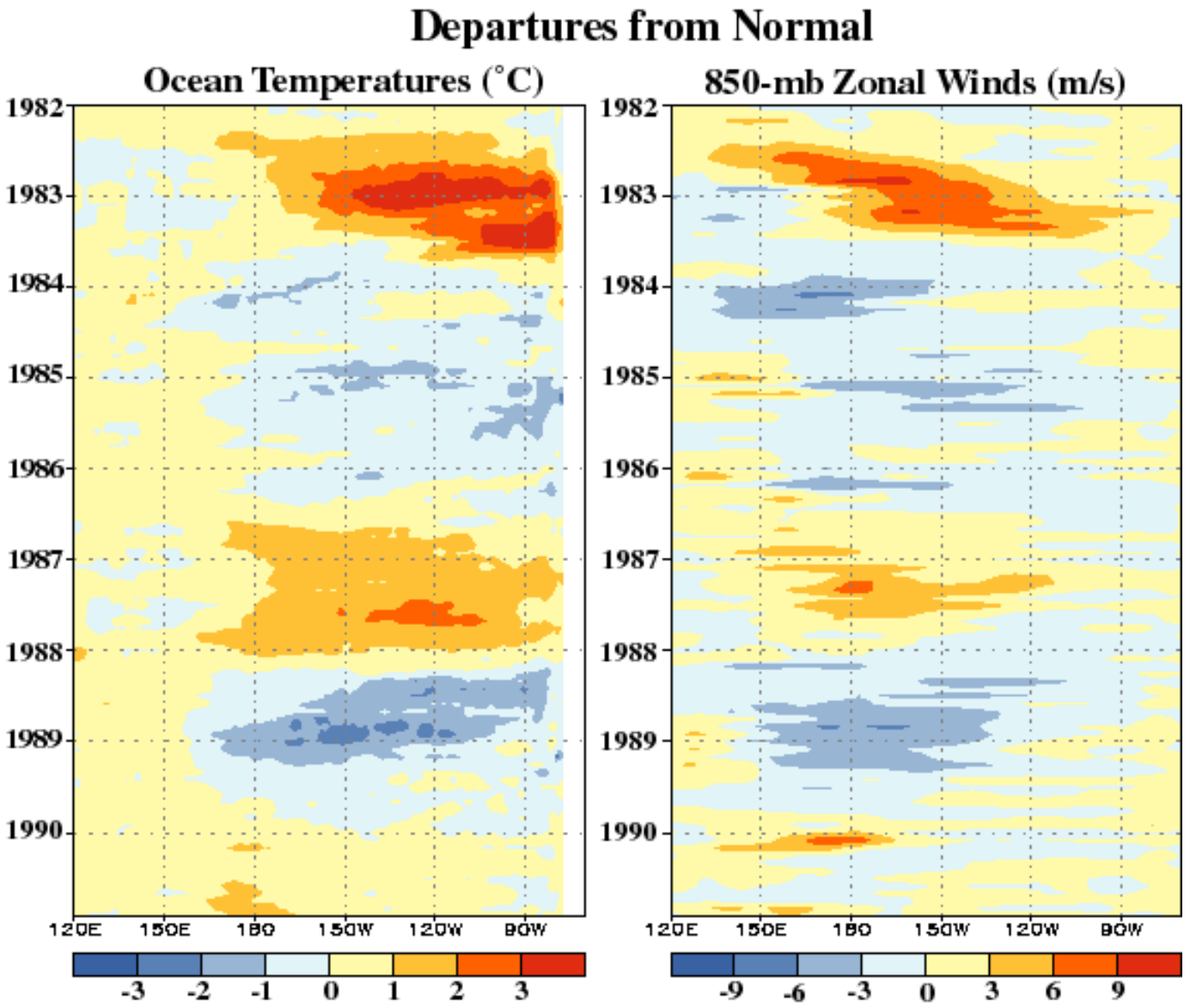

Nino 3
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000


Nino 3.4
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000

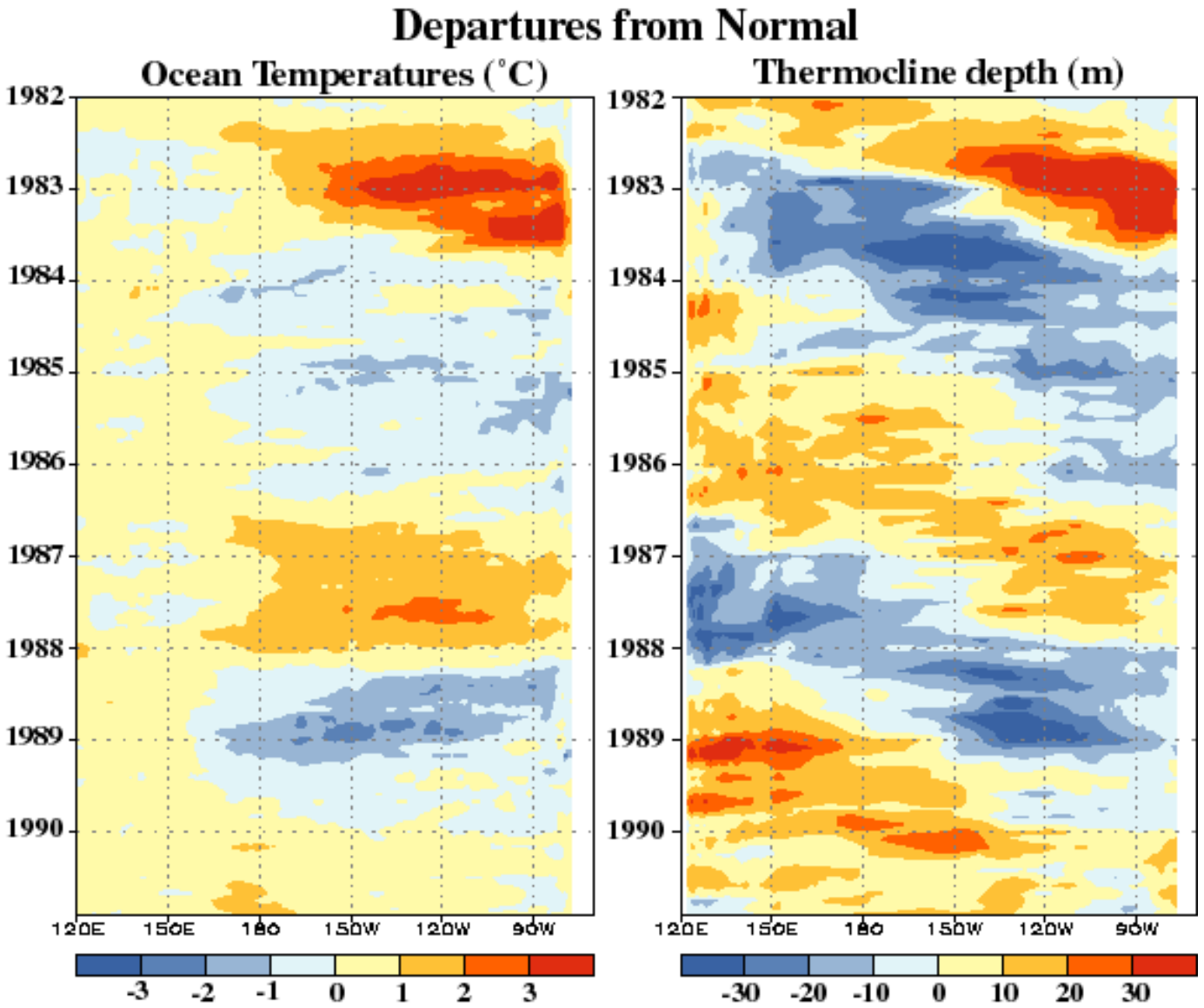

30N
20N
10N
EQ
10S
20S
30S
120E
150E
180
150W
120W
90W
Niño 3.4
Niño 1+2
Niño 4
Niño 3


Nino 4
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000

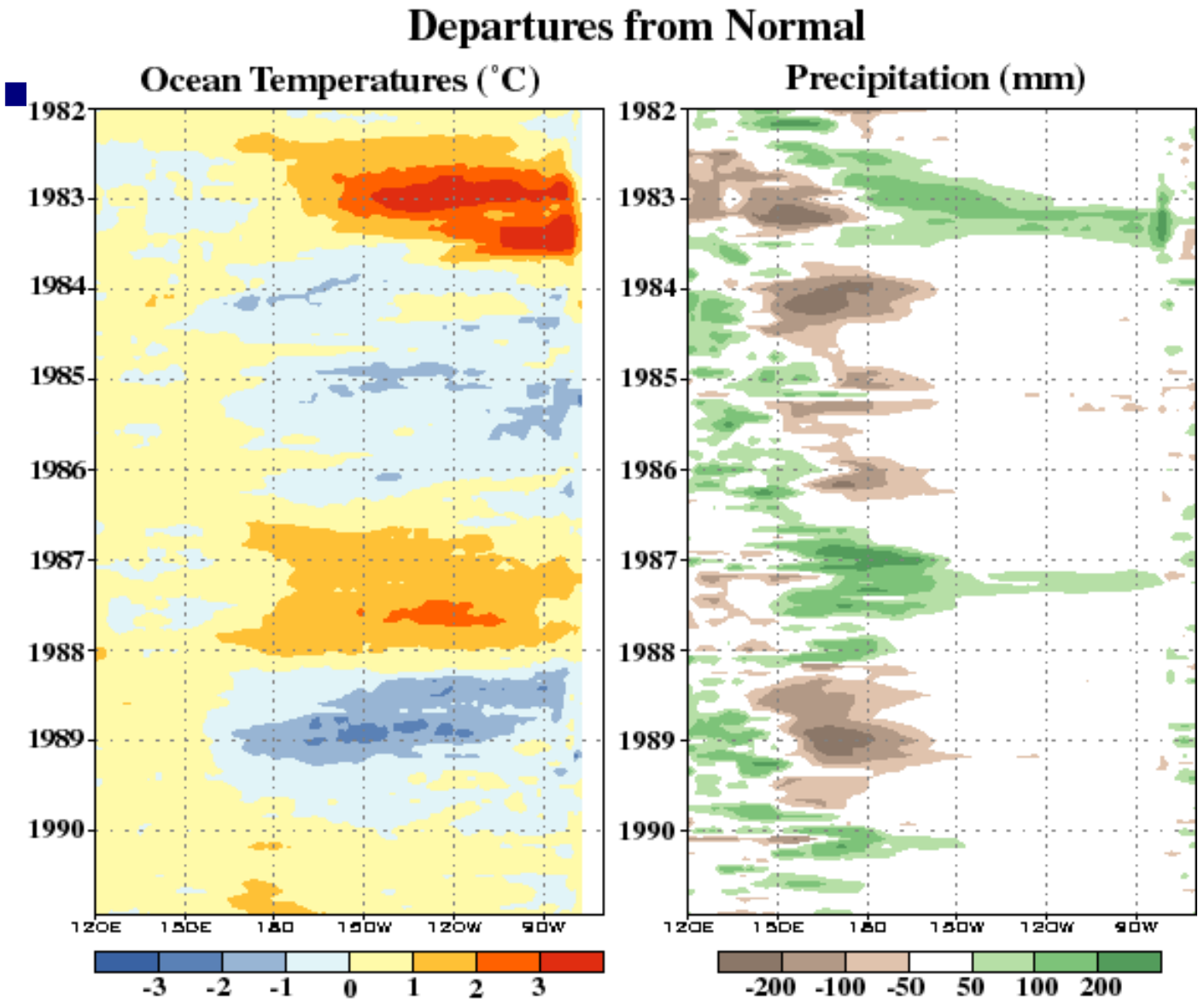
ENSO


Departures from Normal
Ocean Temperatures (°C)
850-mb Zonal Winds (m/s)
1982
1983
1984
1985
1986
1987
1988
1989
1990
120E
150E
180
150W
120W
90W
-3
-2
-1
0
1
2
3
-9
-6
-3
0
3
6
9

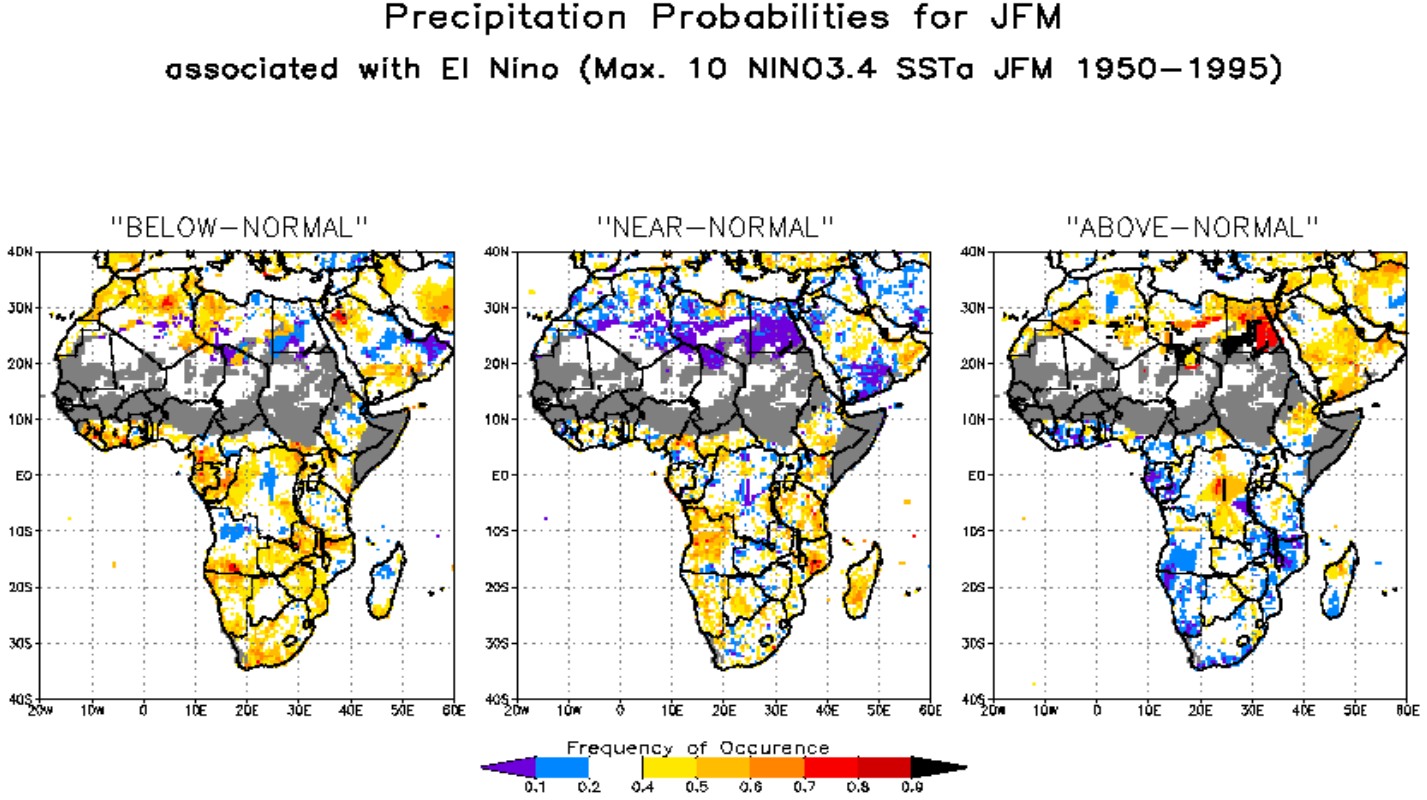
ENSO


Departures from Normal
Ocean Temperatures (°C)
Thermocline depth (m)
1982
1983
1984
1985
1986
1987
1988
1989
1990
120E
150E
180
150W
120W
90W
-3
-2
-1
0
1
2
3
-30
-20
-10
0
10
20
30

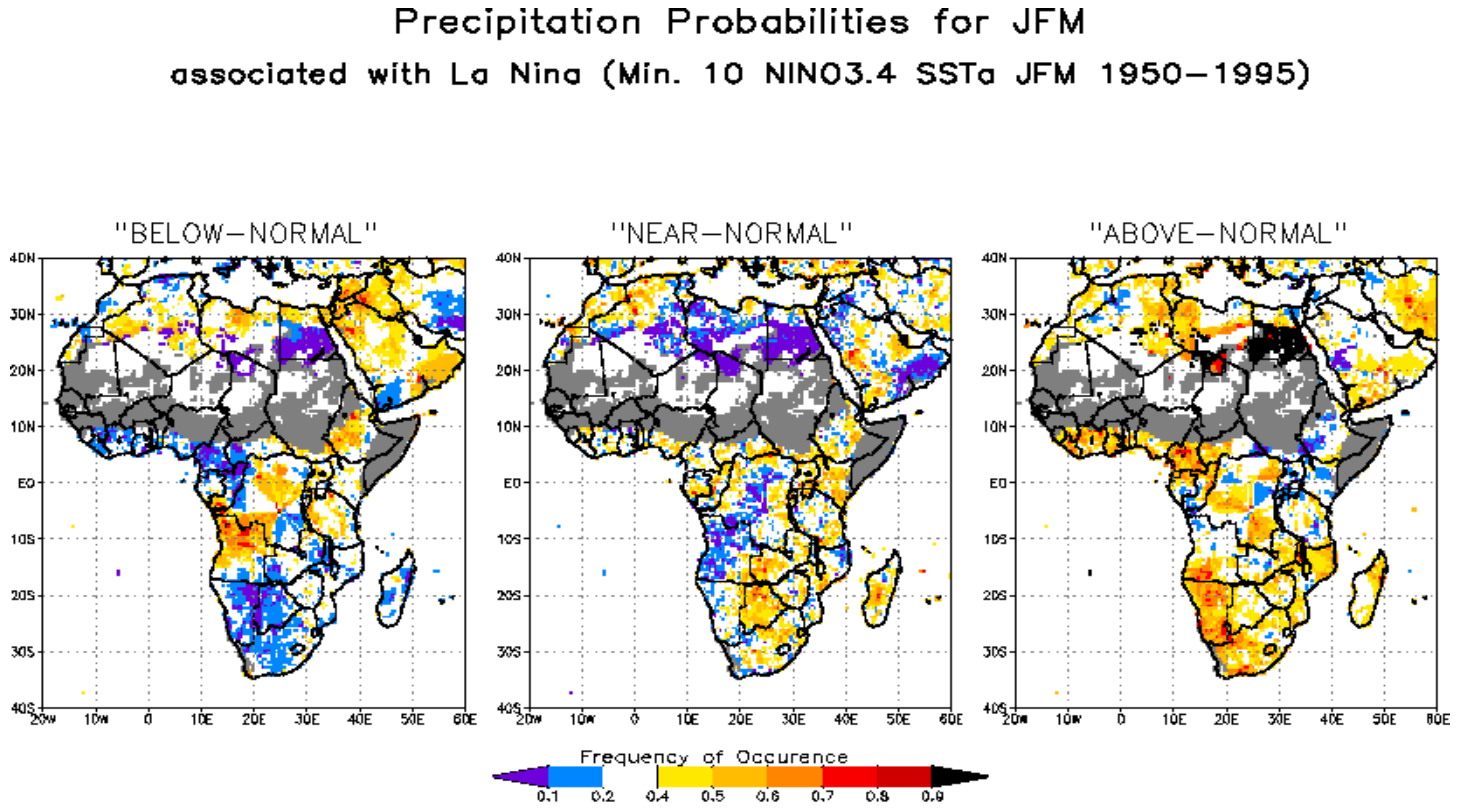
ENSO

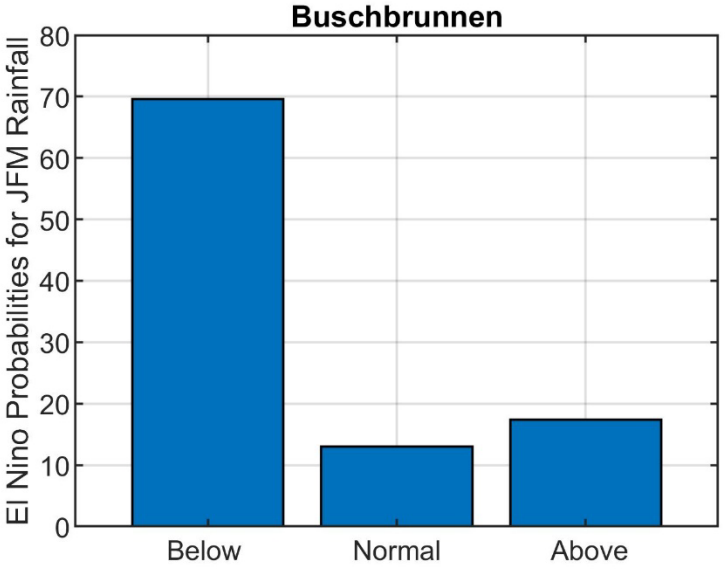

Departures from Normal
Ocean Temperatures (°C)
Precipitation (mm)
1982
1983
1984
1985
1986
1987
1988
1989
1990
120E
150E
180
150W
120W
90W
-3
-2
-1
0
1
2
3
-200
-100
-50
50
100
200

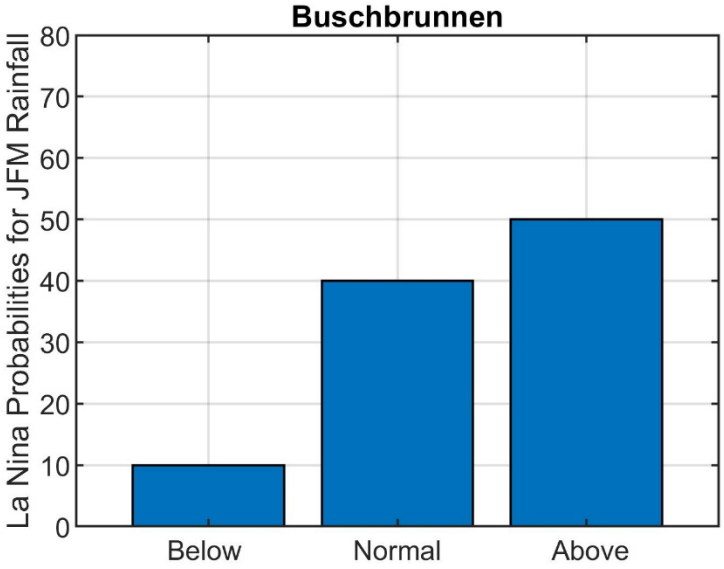
JFM Rainfall during El Niño

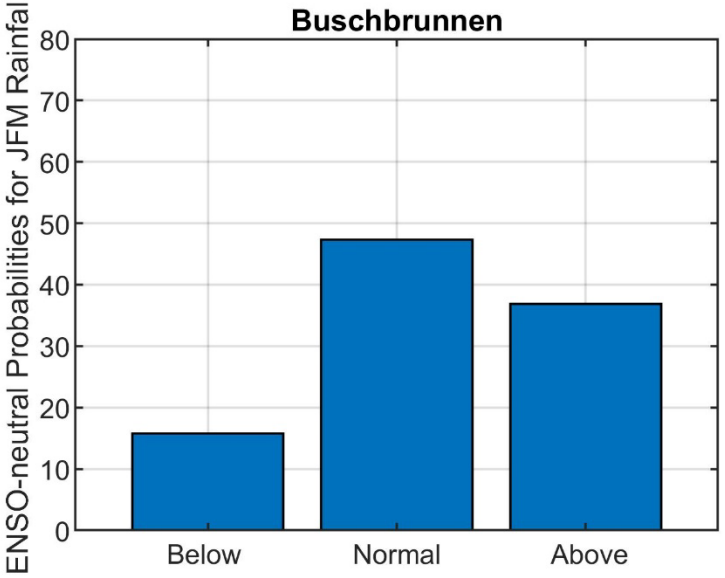


JFM Rainfall during La Niña

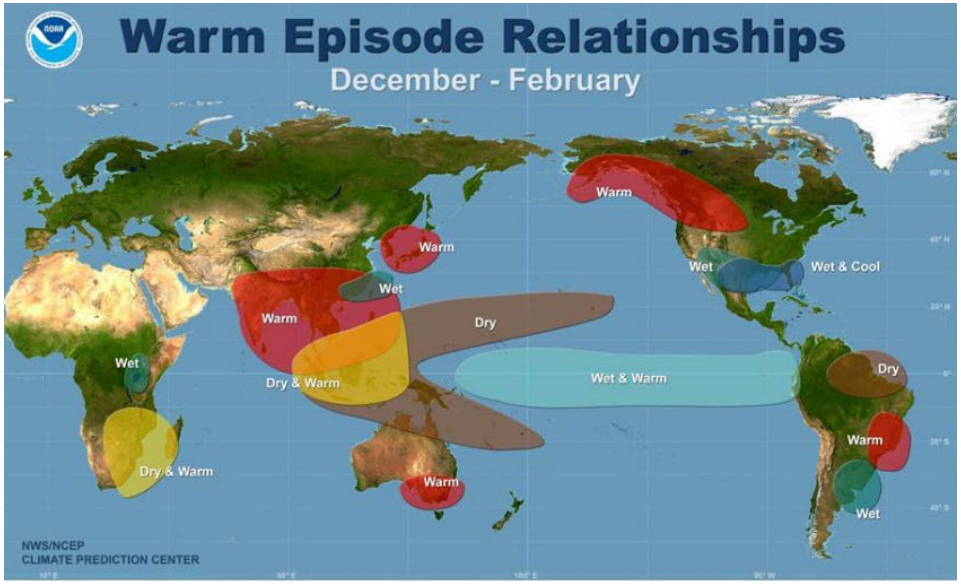



Buschbrunnen
El Nino Probabilities for JFM Rainfall
80
70
60
50
40
30
20
10
0
Below
Normal
Above


Buschbrunnen
La Nina Probabilities for JFM Rainfall
80
70
60
50
40
30
20
10
0
Below
Normal
Above

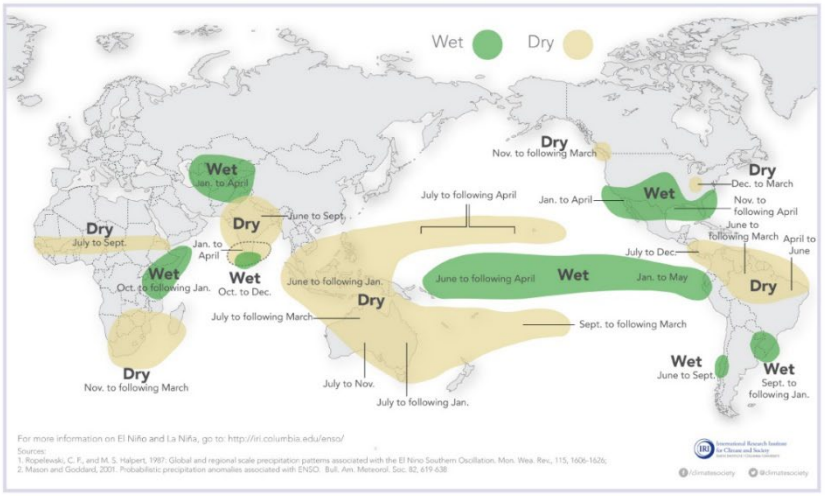

Buschbrunnen
ENSO-neutral Probabilities for JFM Rainfall
80
70
60
50
40
30
20
10
0
Below
Normal
Above

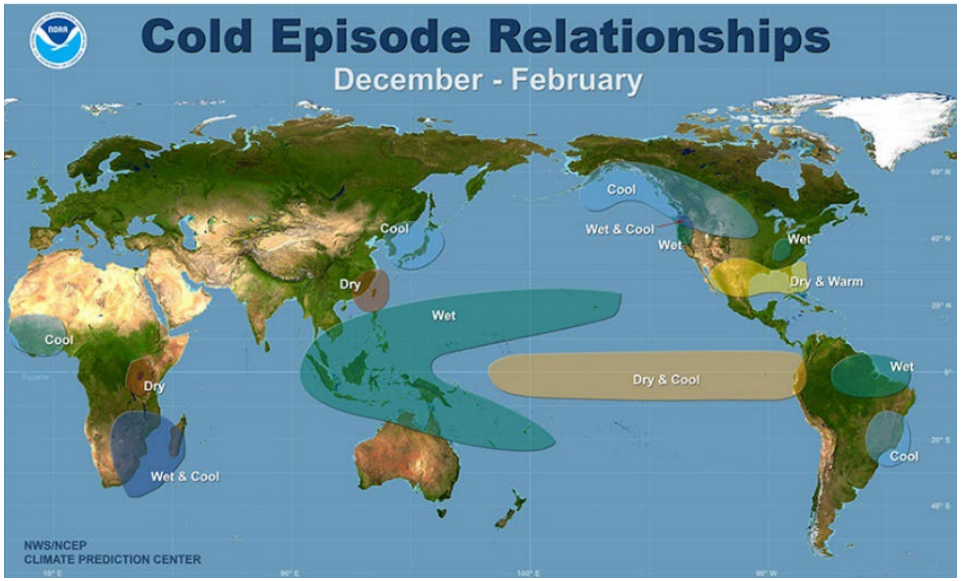

Angola
Zambia
Zimbabwe
Botswana
South Africa
Atlantic Ocean
Kunene
Omusati
Oshana
Oshikoto
Kavango West
Kavango East
Zambezi
Otjozondjupa
Omaheke
Erongo
Hardap
Karas
Windhoek
Khomas
Swakopmund
Walvis Bay
Henties Bay
Otjiwarongo
Rundu
Gobabis
Mariental
Keetmanshoop
Lüderitz
Namibia
National Capital
Region Capital
City or town
2020 Copyright © Ontheworldmap.com



El Niño and Rainfall

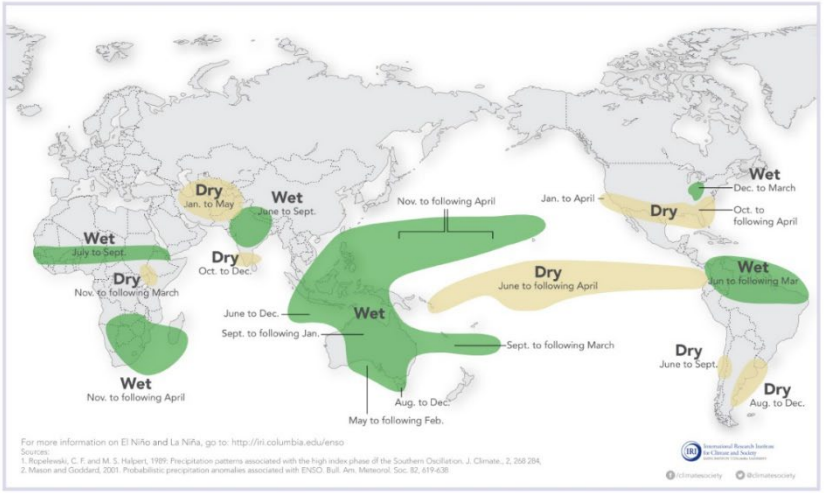
El Niño conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. Although they vary somewhat from one El Niño to the next, the strongest shifts remain fairly consistent in the regions and seasons shown on the map below.

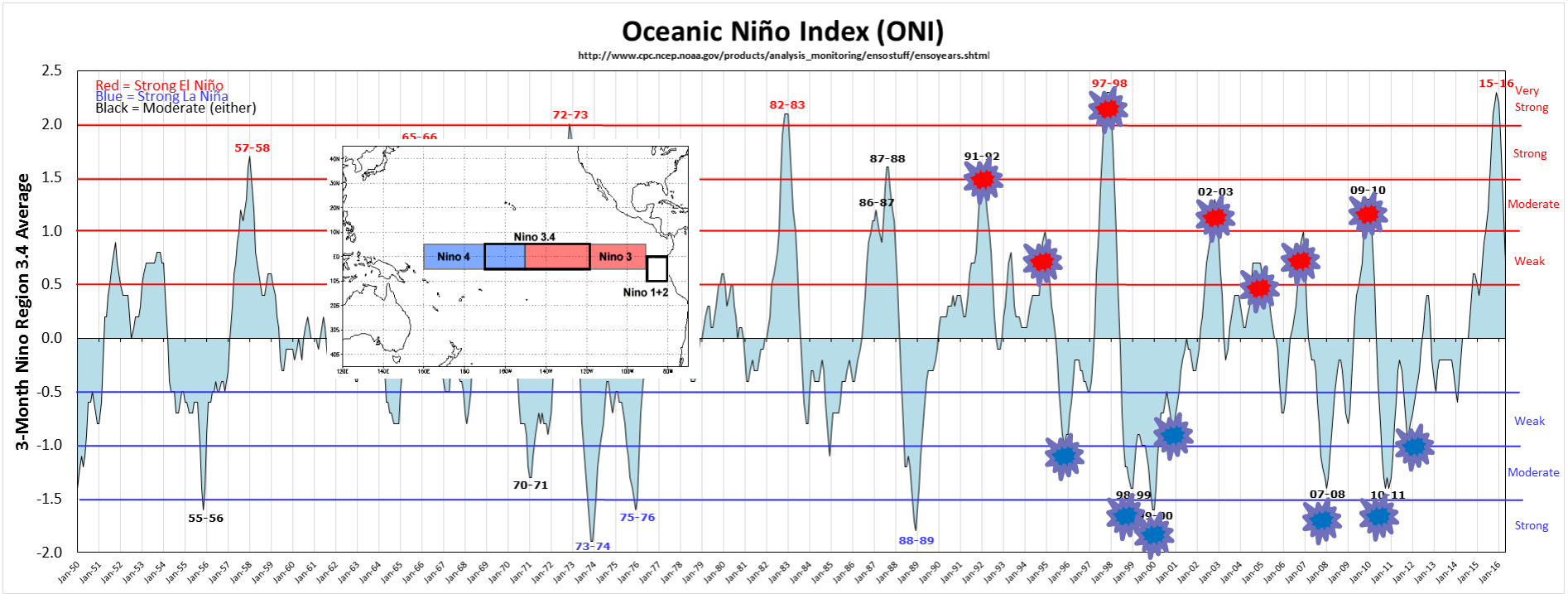




La Niña and Rainfall

La Niña conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. Although they vary somewhat from one La Niña to the next, the strongest shifts remain fairly consistent in the regions and seasons shown on the map below.





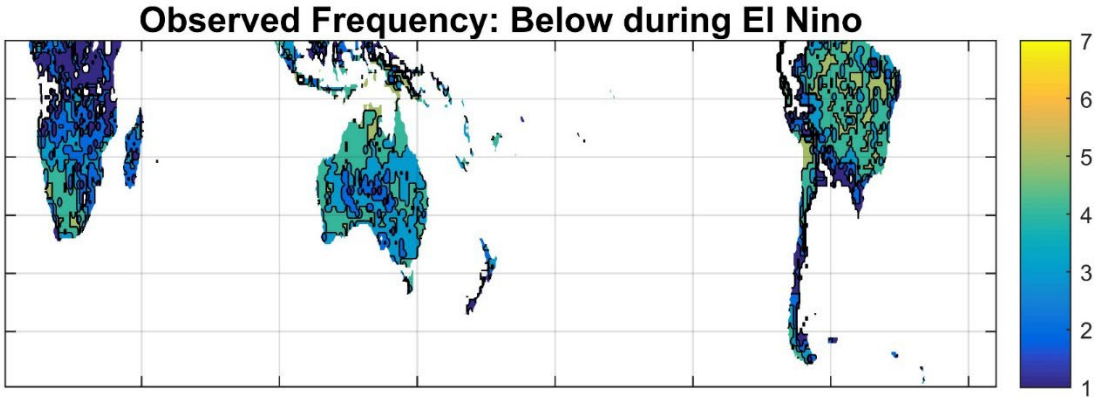
Hindcasts from each coupled model are interpolated to the nearest GPCC grid-point after which the mean and variance biases of each model's data are corrected

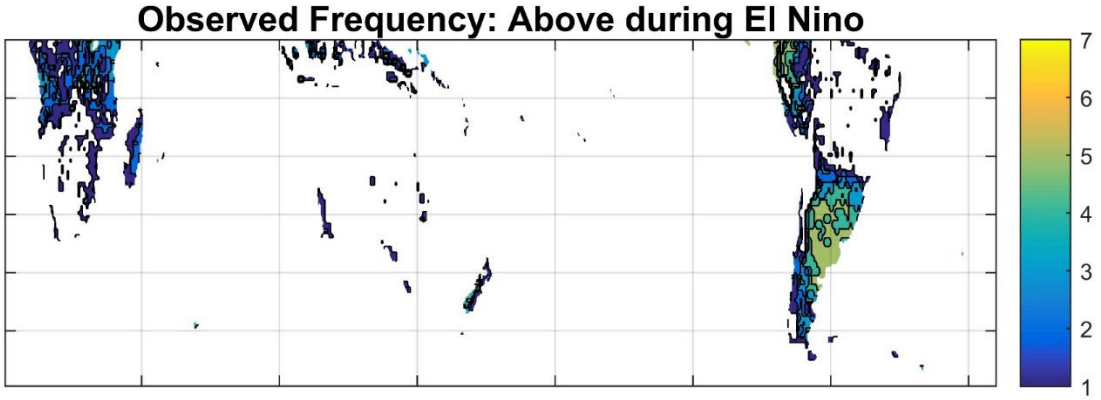
1980 to present:
COLA-RSMAS-CCSM4 (10)
GFDL-CM2.5-FLOR-B01 (12)
NASA-GMAO-062012 (12)
[equal weights in multi-model]

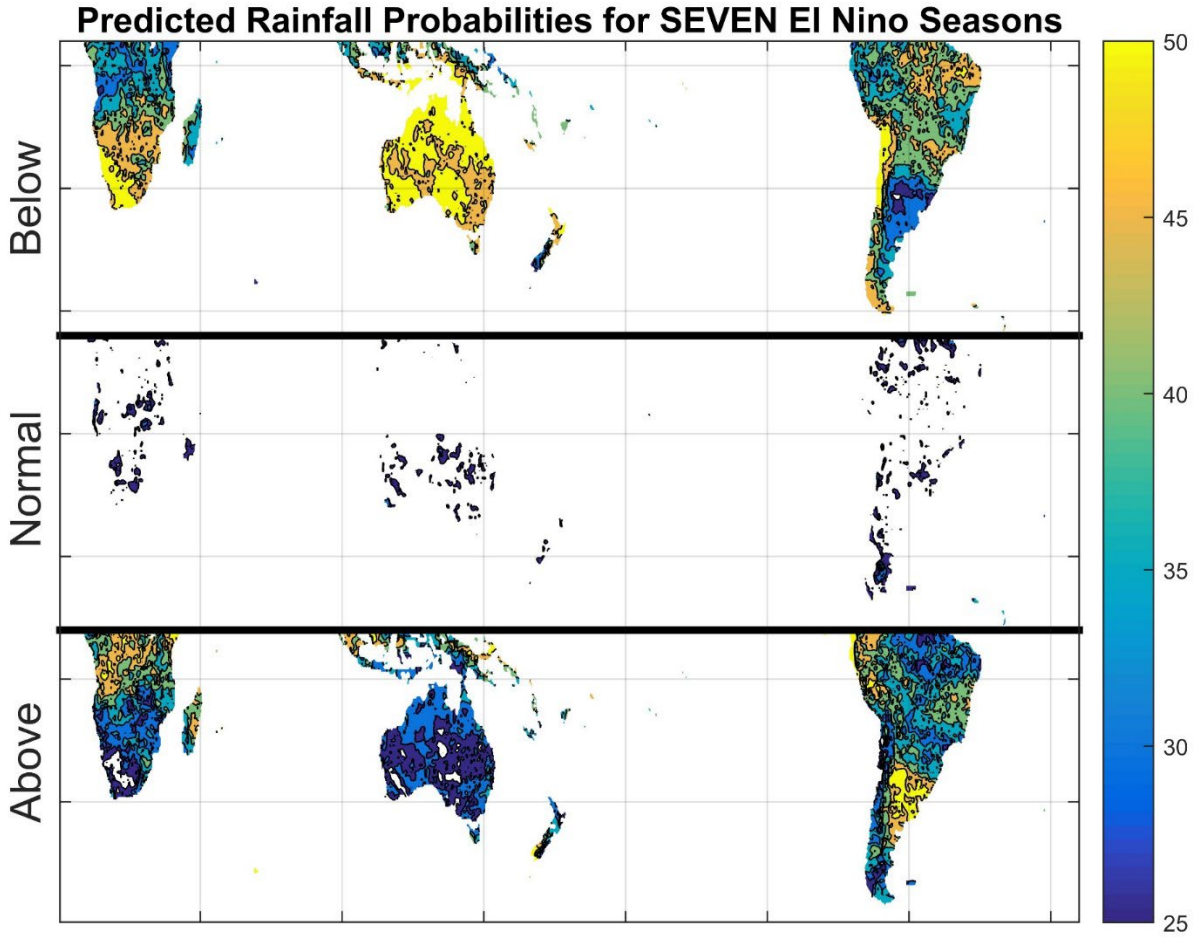
- Initialisation: November
- Dec-Jan-Feb hindcasts (re-forecasts)

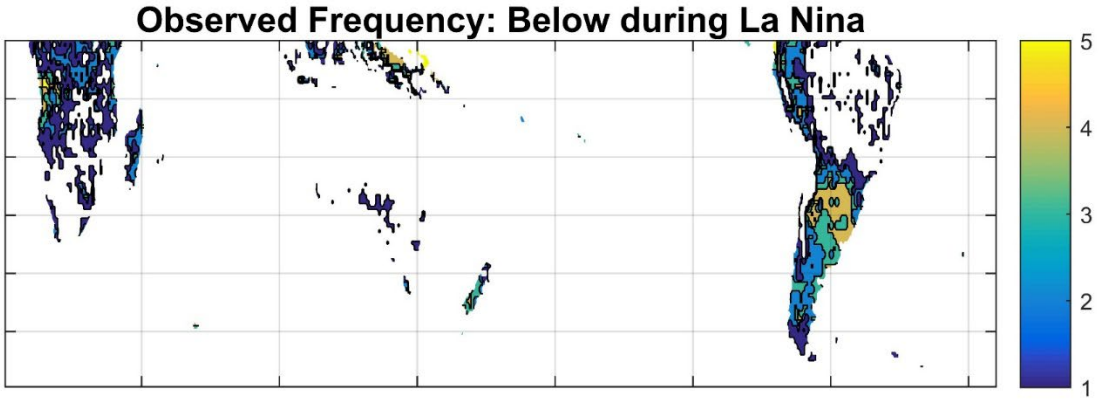
WCRP GCOS GPCC FDP version 7
(0.5° lat-lon resolution)

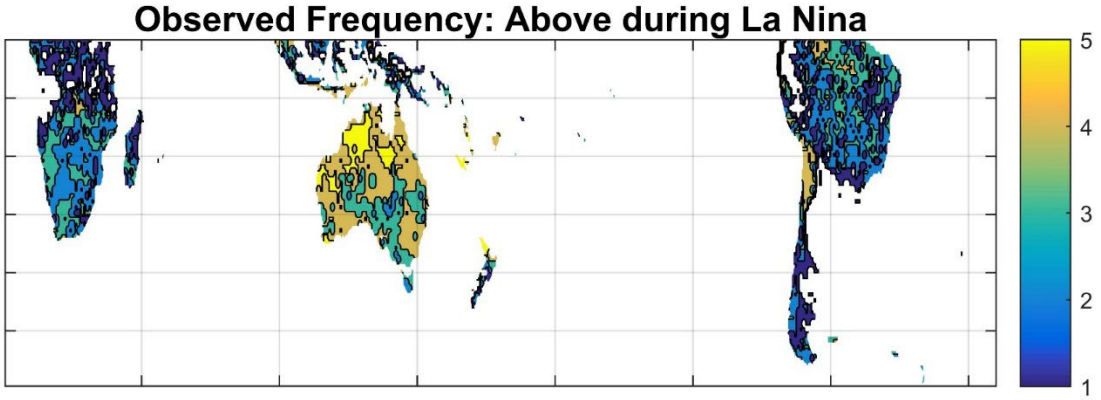
For three categories with thresholds defined by respectively the 25th (dry category) and 75th (wet category) percentile values of the climatological record – seasonal ***extremes***

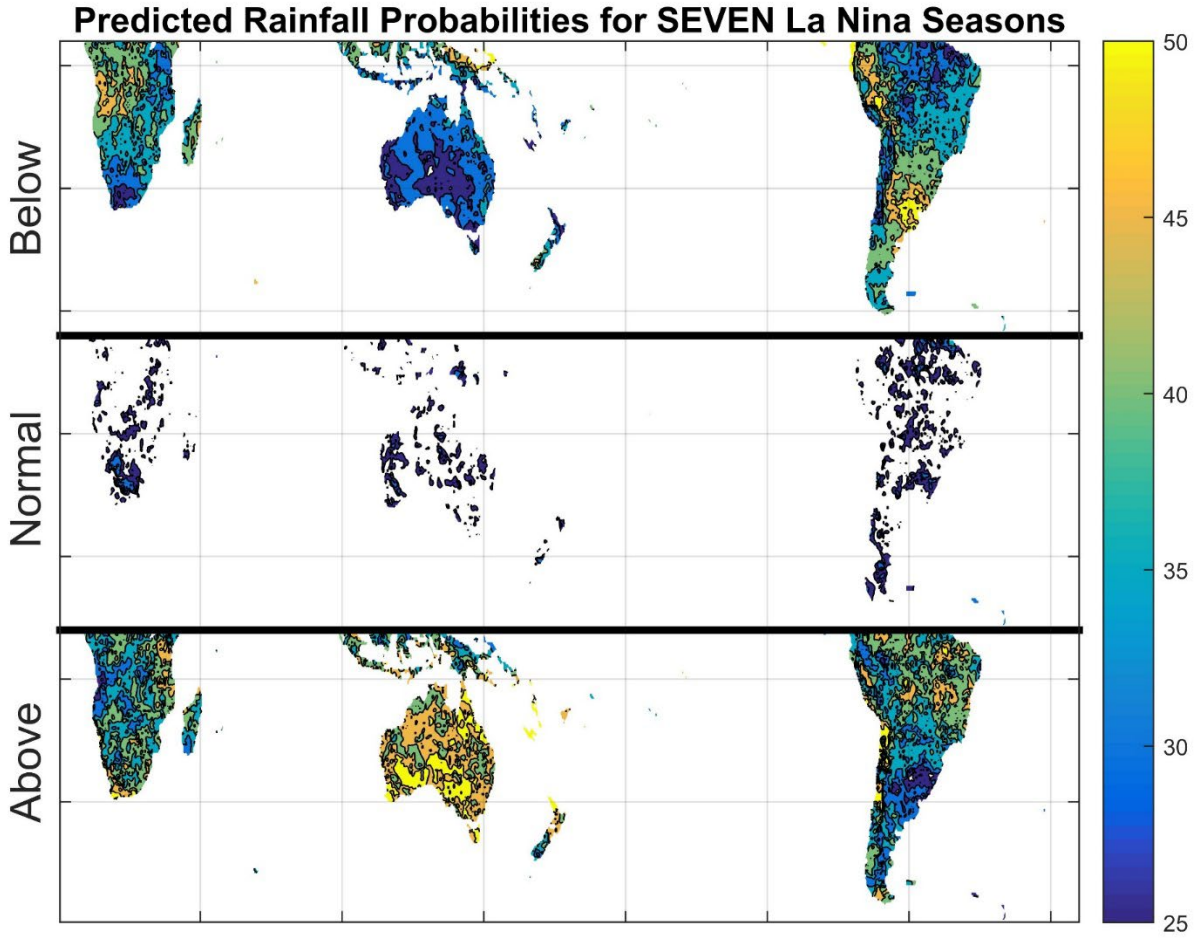

Observed Frequency: Below during El Nino
7
6
5
4
3
2
1


Observed Frequency: Above during El Nino
7
6
5
4
3
2
1

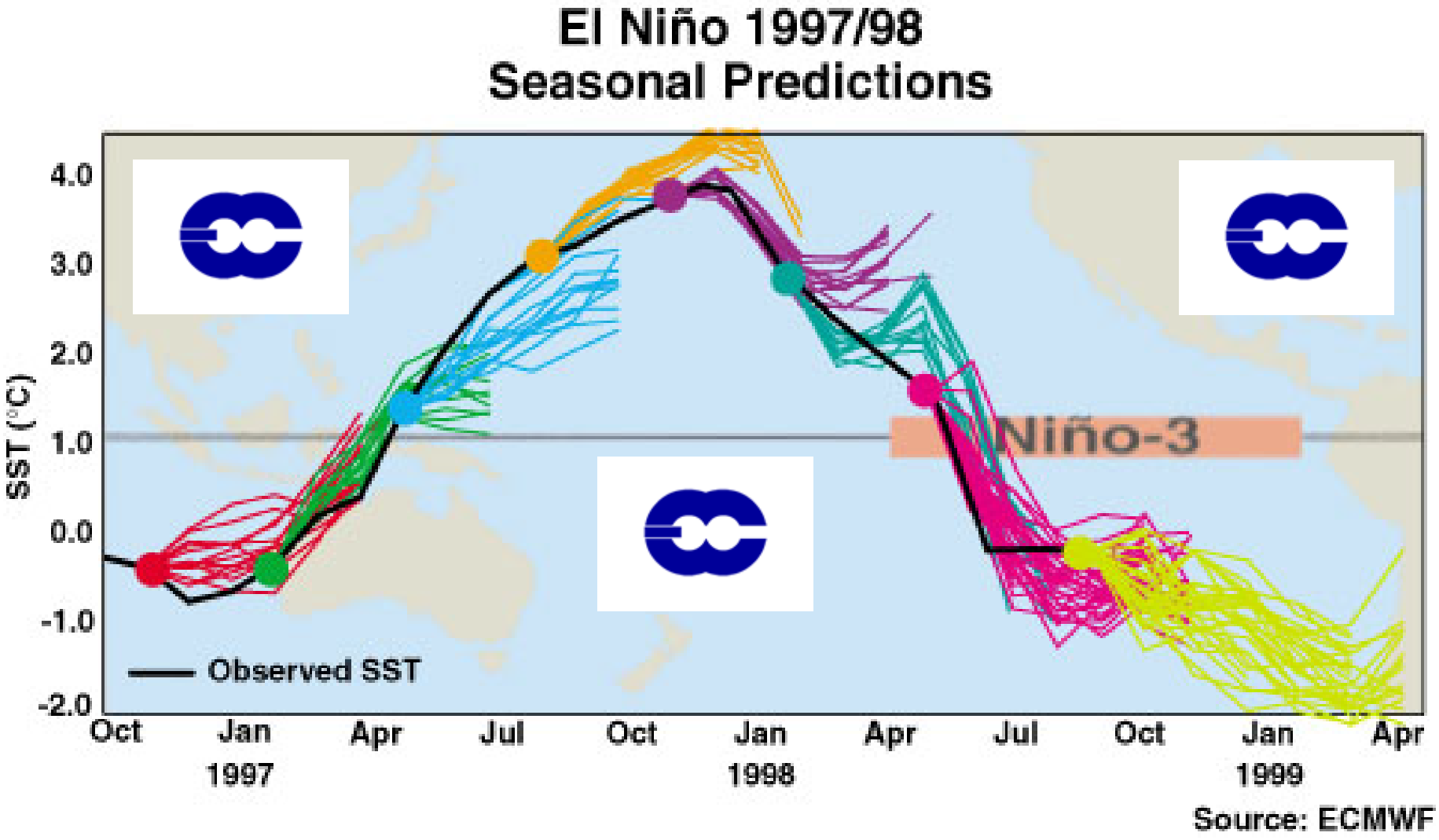

Predicted Rainfall Probabilities for SEVEN El Nino Seasons
Below
Normal
Above
50
45
40
35
30
25


Observed Frequency: Below during La Nina
5
4
3
2
1


Observed Frequency: Above during La Nina
5
4
3
2
1

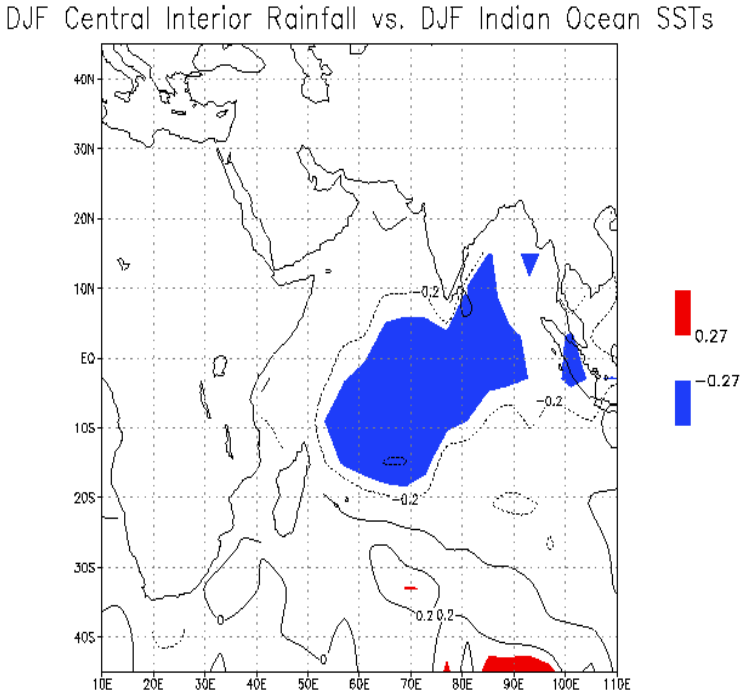

Predicted Rainfall Probabilities for SEVEN La Nina Seasons
Below
Normal
Above
50
45
40
35
30
25

Some ENSO forecasts are probabilistic



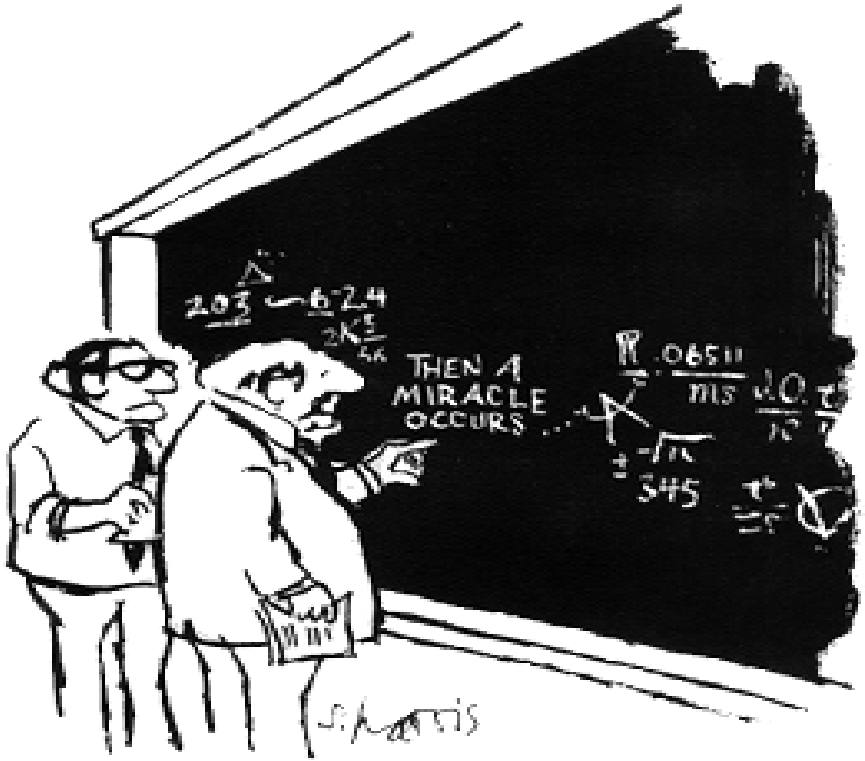
But El Niño and La Niña events are not the only factors influencing southern African seasonal rainfall…

- The map shows a very simplistic view on the association between the Indian Ocean and central interior summer rainfall
- However, the association is complex, and best simulated using physical models, e.g., General Circulation Models (GCMs)



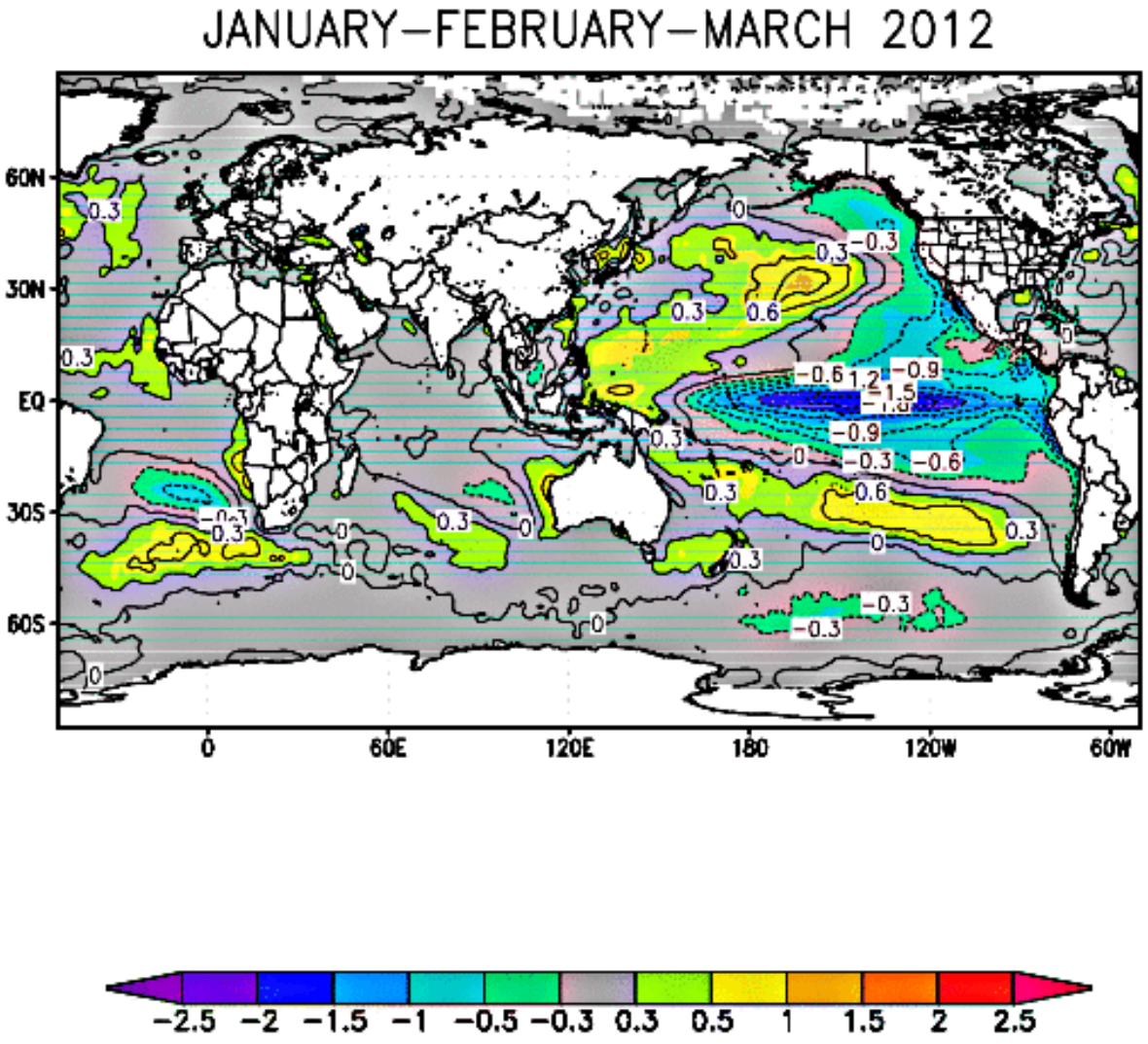
Correlation map showing the areas over the Indian Ocean most strongly associated with our summer rainfall

The evolution of El Niño and La Niña events and also other factors, like Indian Ocean SSTs, need to be taken into consideration when making a seasonal forecast... so how is a seasonal forecast compiled?



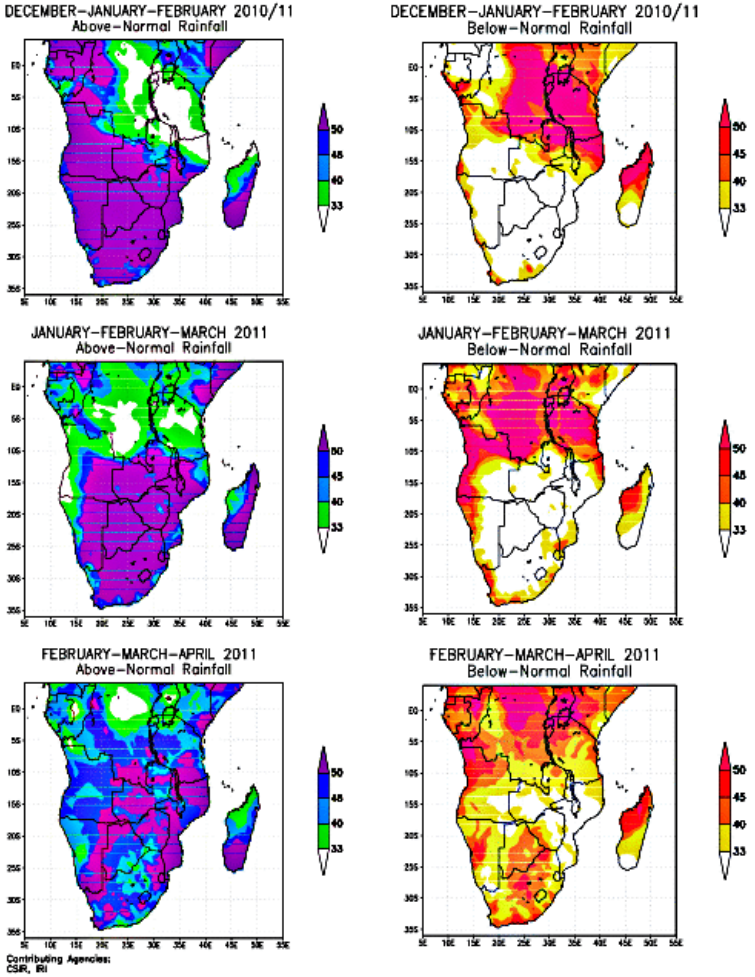
"I think you should be more explicit here in step two."

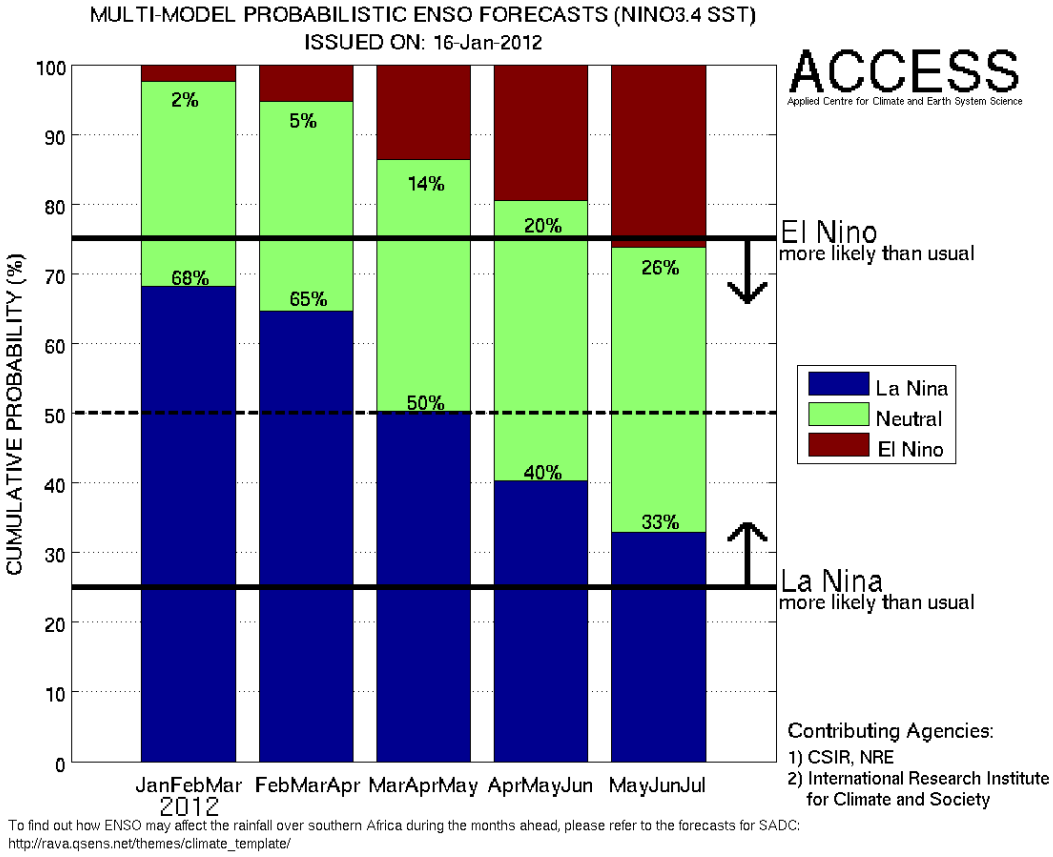
Step 1: Global SSTs



We need to form a clear understanding what the latest global SST anomaly patterns look like, and also what is to be expected in their evolution. Such prior knowledge of the global SSTs should lead to improved interpretation of a particular atmospheric GCM's behaviour, since the GCMs are forced with persisted and/or forecast global SST anomalies.

Step 2: Obtaining forecast output

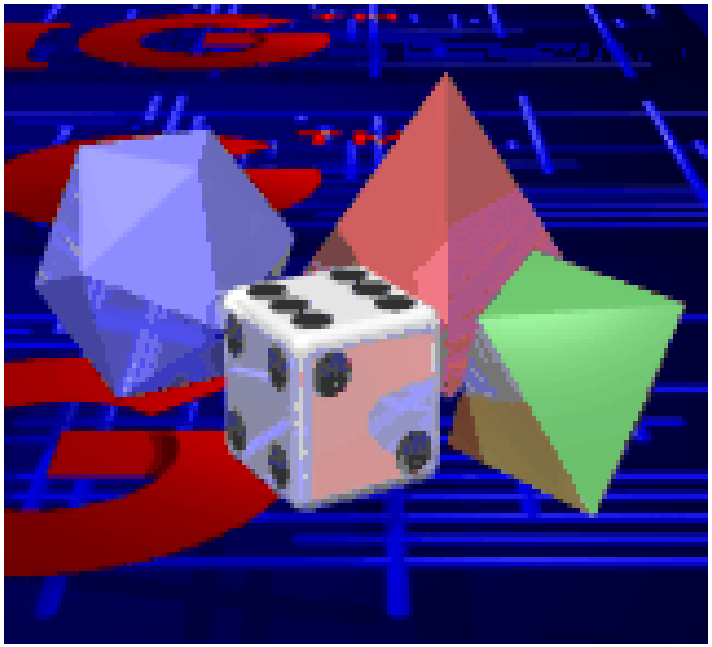




Forecast Format

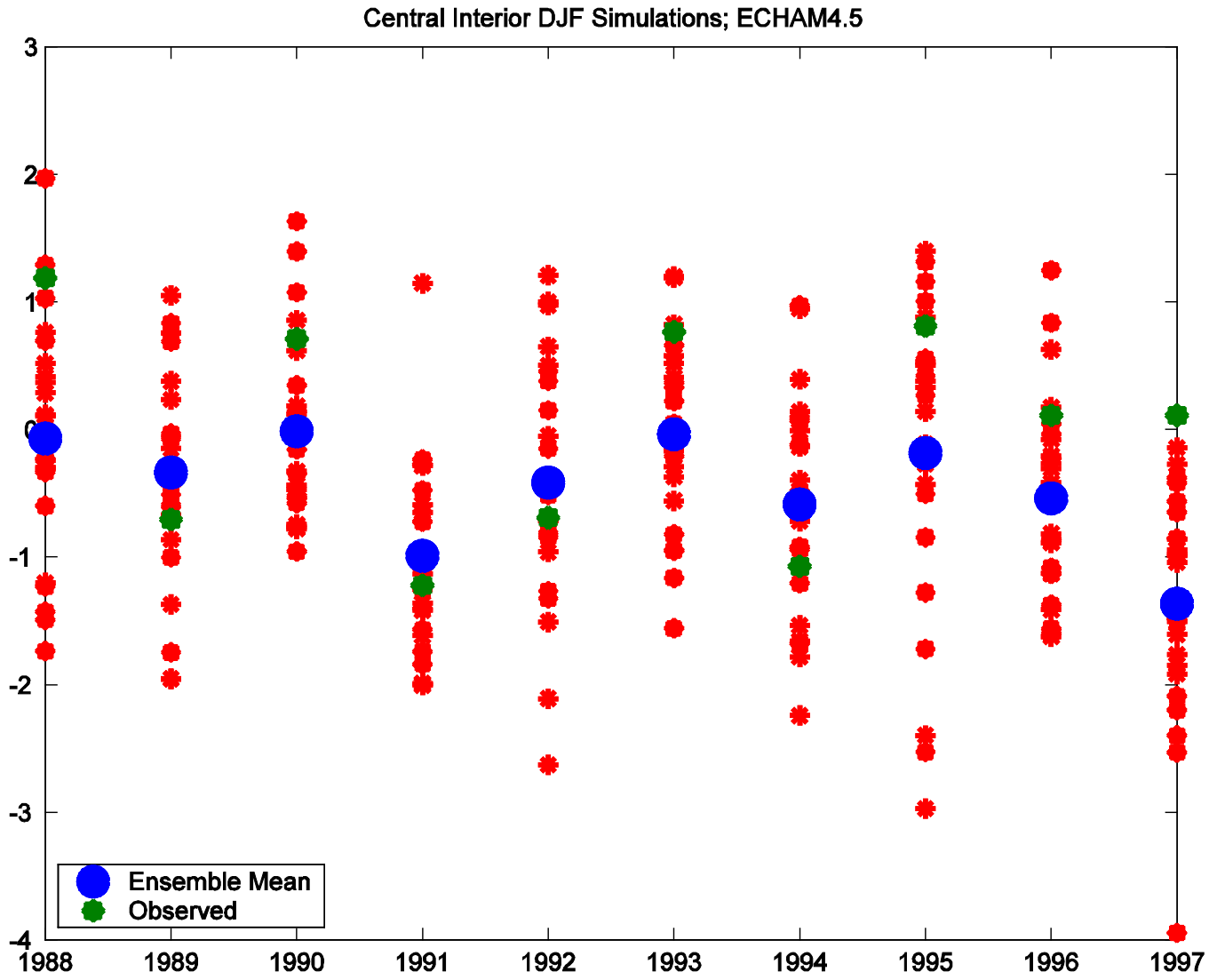
The inherent variability of the atmosphere (weather noise) and the lack of understanding of all of the components of the climate system ***require*** seasonal climate forecasts to be expressed…

probabilistically



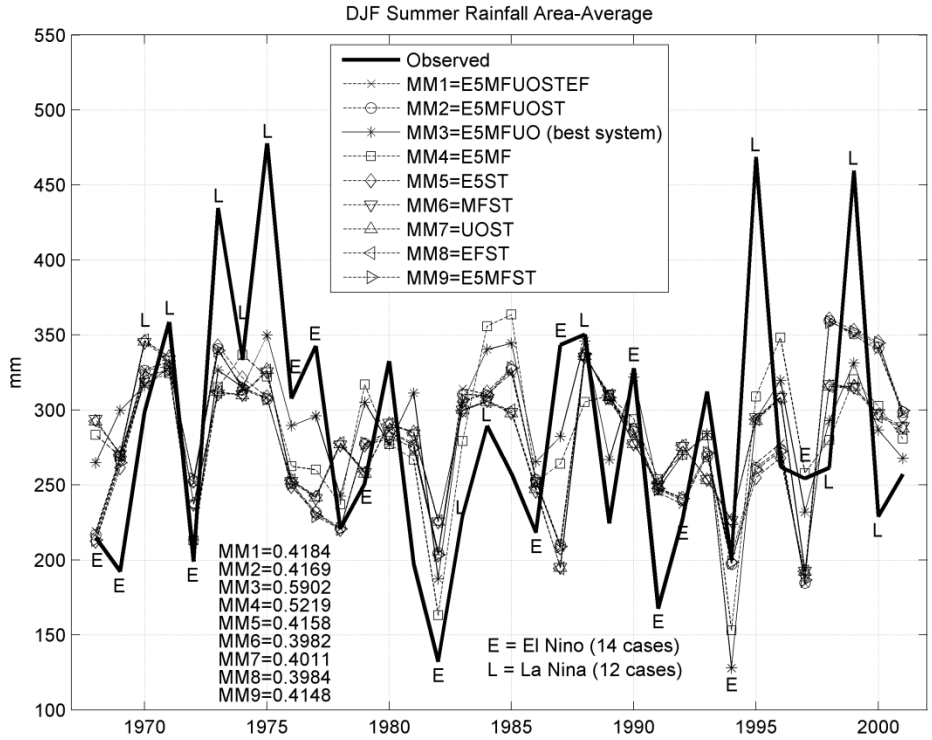
Forecasts are made for three *equi-probable* categories of below-normal (dry conditions), near-normal (around the average), and above-normal (wet conditions). A *probability* is assigned to each category, indicating the *chance* of the particular category to occur during the target season

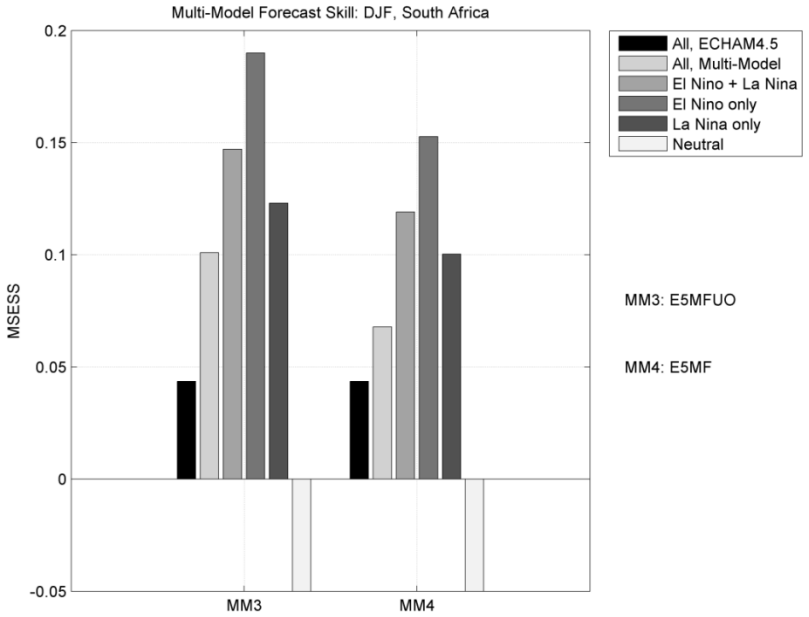
Ensemble of forecasts

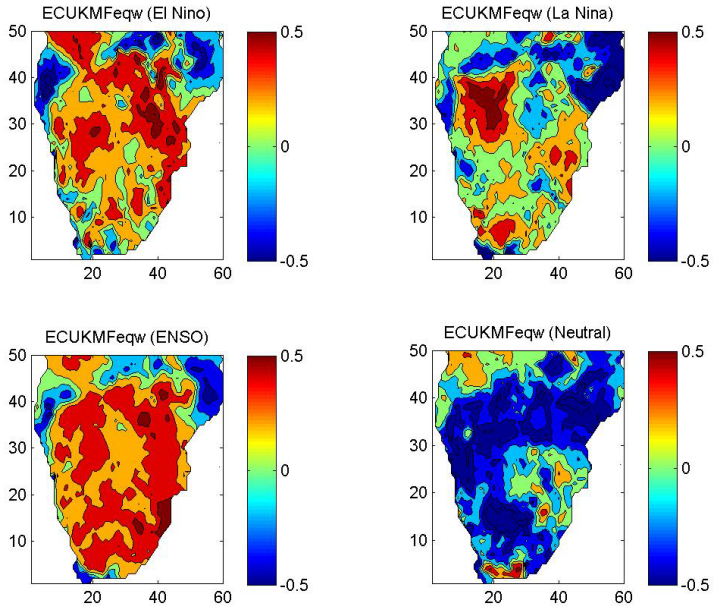


Step 3: Interpretation

- Forecasts are ***PROBABILISTIC***
- The forecast probabilities indicate
  - the ***direction*** of the forecast
  - as well as the amount of ***confidence*** in the forecast
- Forecast users should be particularly aware of the probabilities of the non-favoured categories, as these probabilities are never small enough to disregard







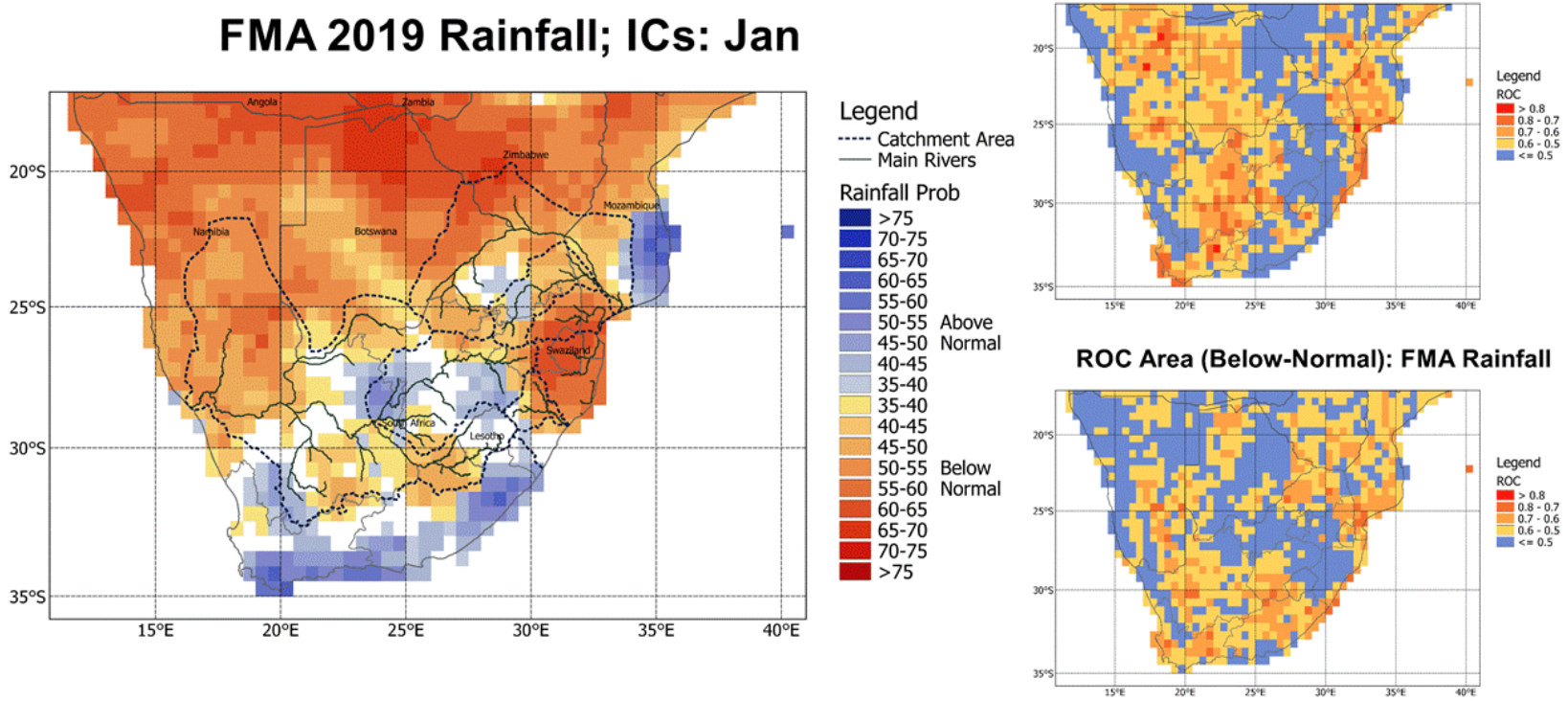
No ENSO no skill?

How reliable are the models used in the seasonal forecast?

- ***Estimates of model skill*** are produced by assessing the models' performance over an ***independent*** forecast test period.

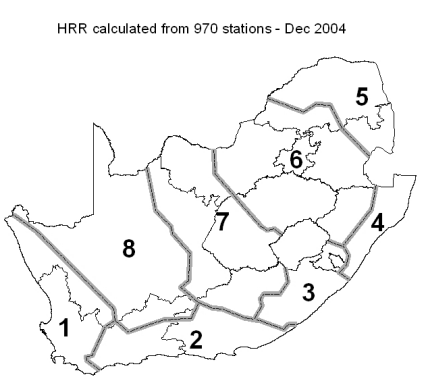
- The skill estimates provide ***evidence*** of the ***regions***, and ***time of the year (season)***, in which a given model gives ***reliable*** forecasts

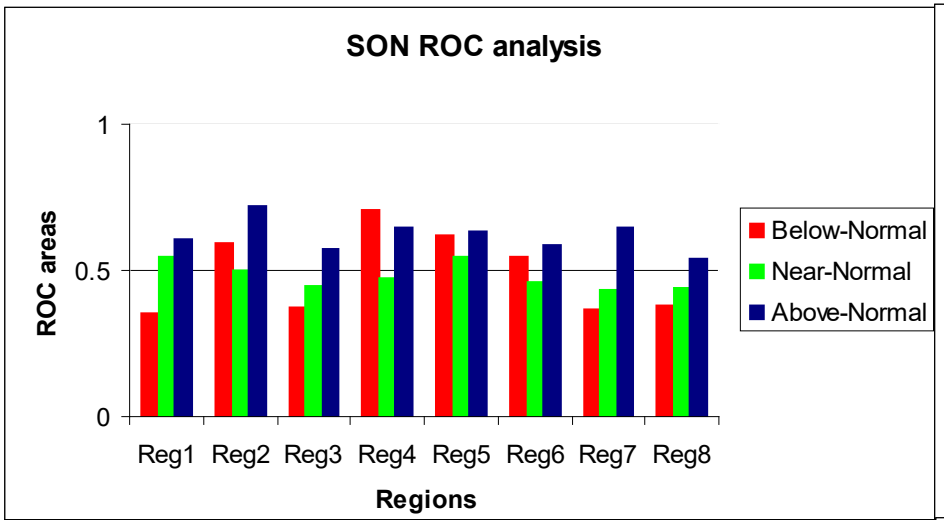
Example of real-time forecast and associated skill maps

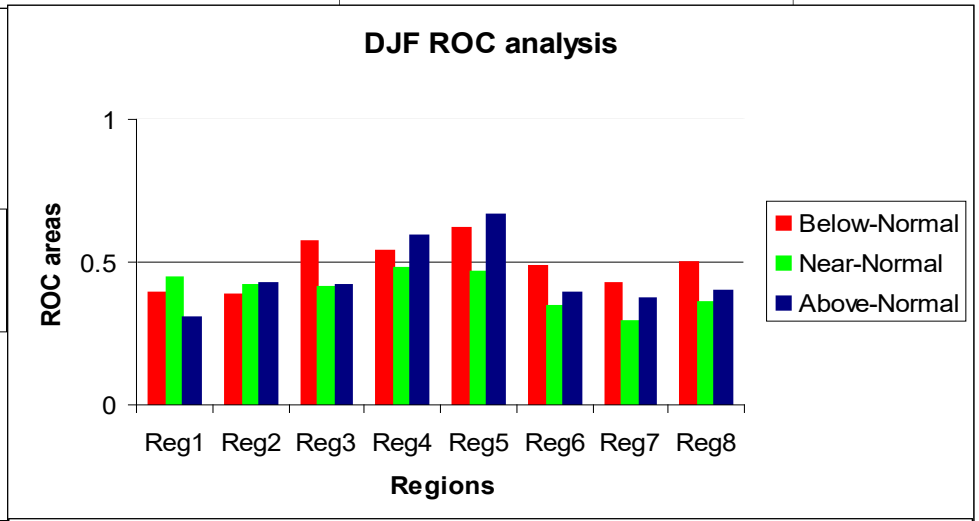


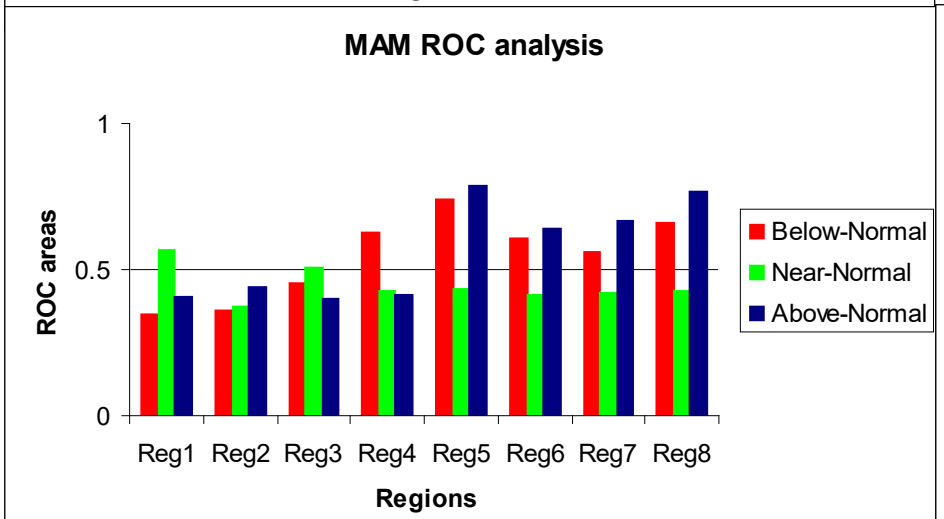
https://tinyurl.com/ForecastProf

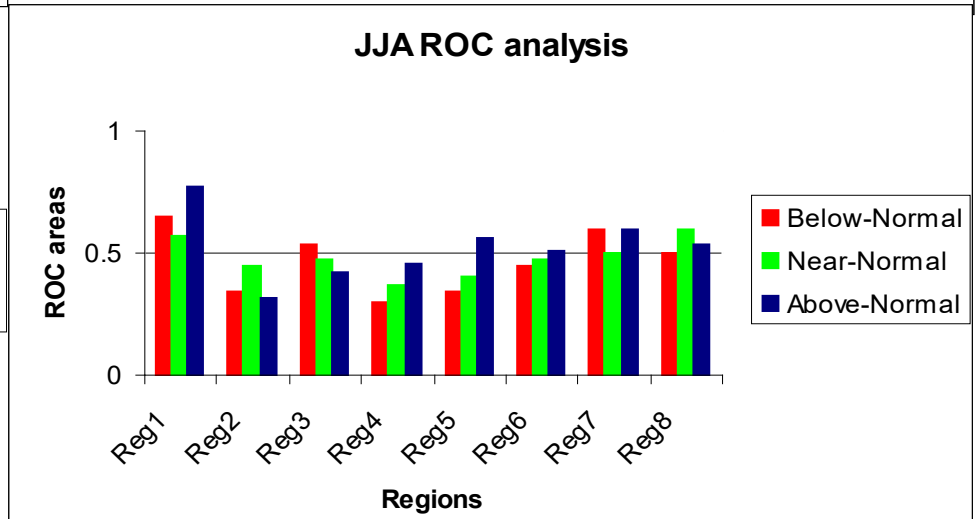
Operational Forecast Skill











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http://www.earth-perspectives.com/1/1/22

Earth Perspectives
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REVIEW Open Access

How the International Research Institute for Climate and Society has contributed towards seasonal climate forecast modelling and operations in South Africa

Willem A Landman

Abstract

The production of seasonal forecasts on a routine basis in South Africa started in the early 1990s. Most of the modelling then was based on linear statistical approaches. The subsequent evolution of the seasonal forecasting enterprise in South Africa included the development of seasonal forecasting expertise and the enhancement of complex modelling systems which include the implementation and administration of atmospheric global and regional circulation models, empirical downscaling, multi-model ensembles, ocean-atmosphere coupled model development, and applications of forecasts. The International Research Institute for Climate and Society has made telling contributions to this evolution over the past 20 years and these will be highlighted here.