Helping Users Derive Value from Seasonal Forecast Information

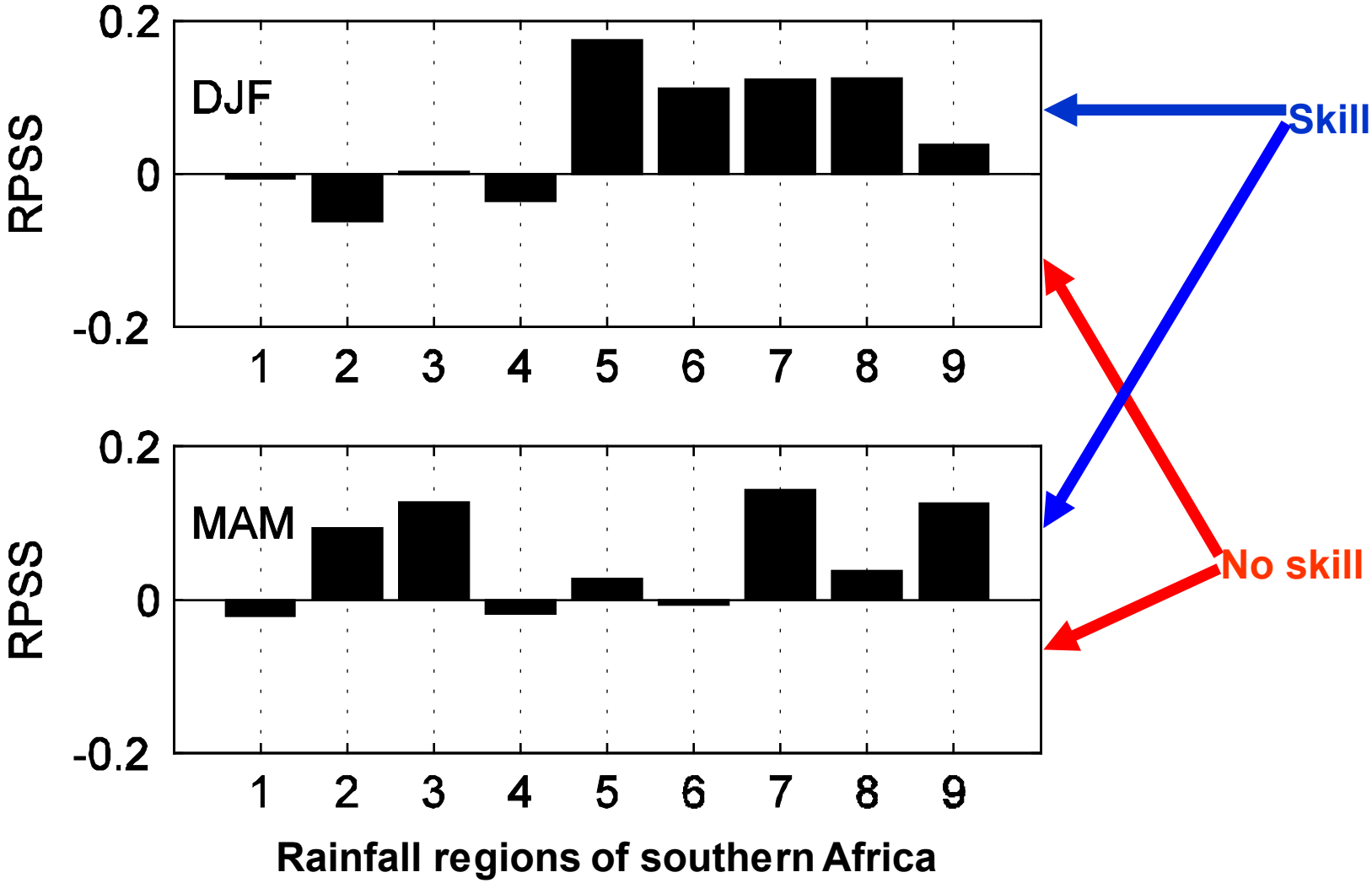
Willem A. Landman

Lecture 8

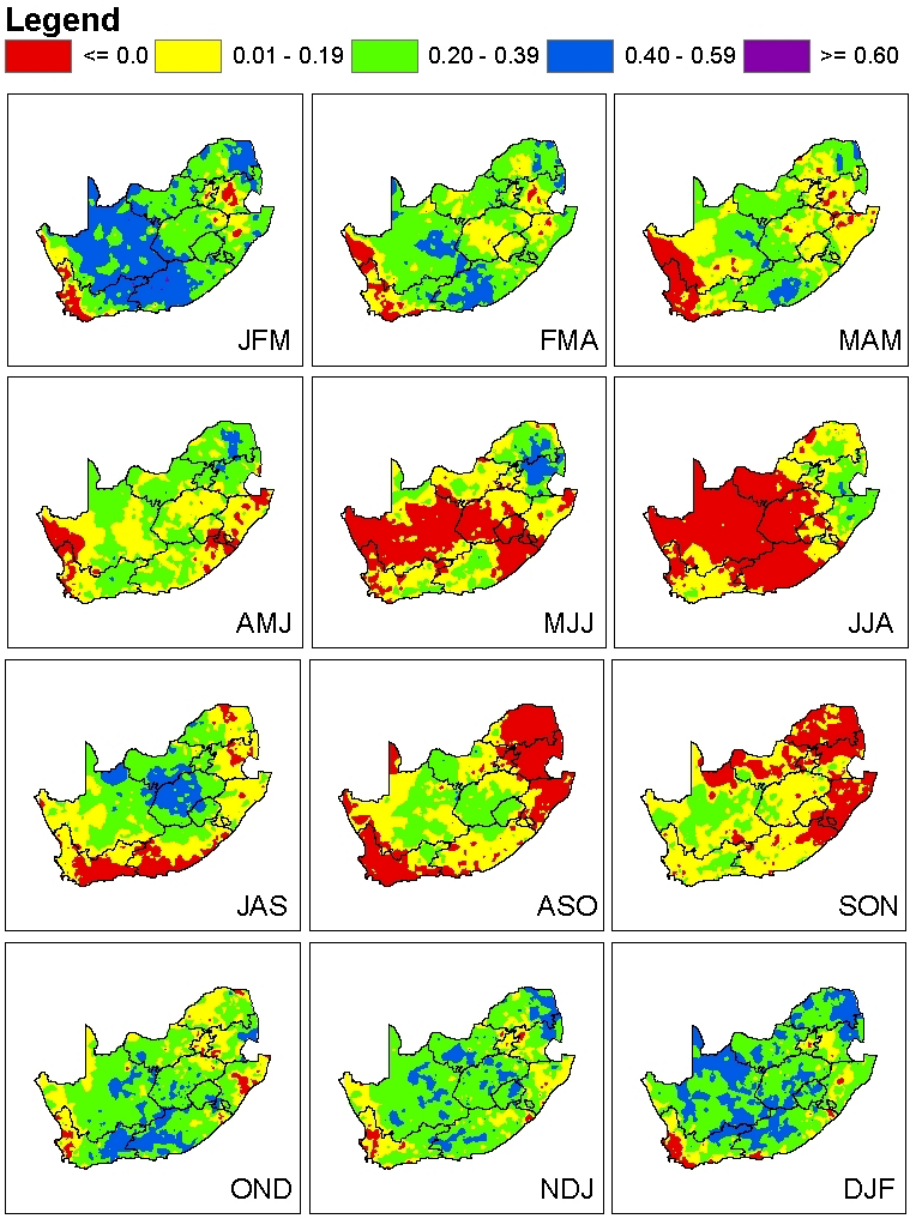
Do we make useful forecasts?

- Need to demonstrate:
  - Models are skilful
  - We are improving our understanding
  - Operational forecasts are skilful
- Can we demonstrate usefulness?

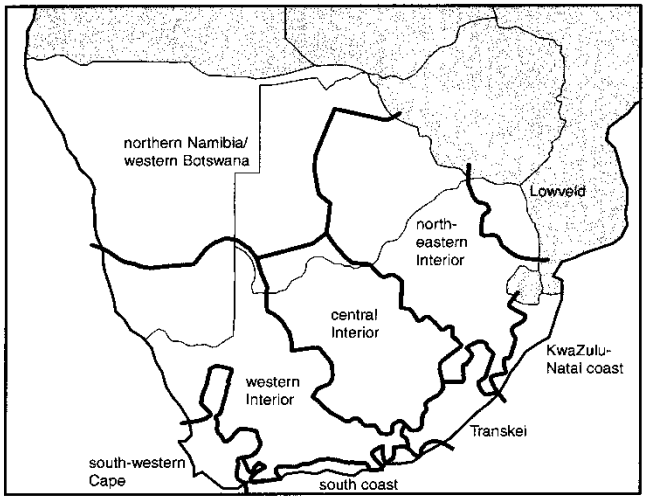
Demonstration of model skill

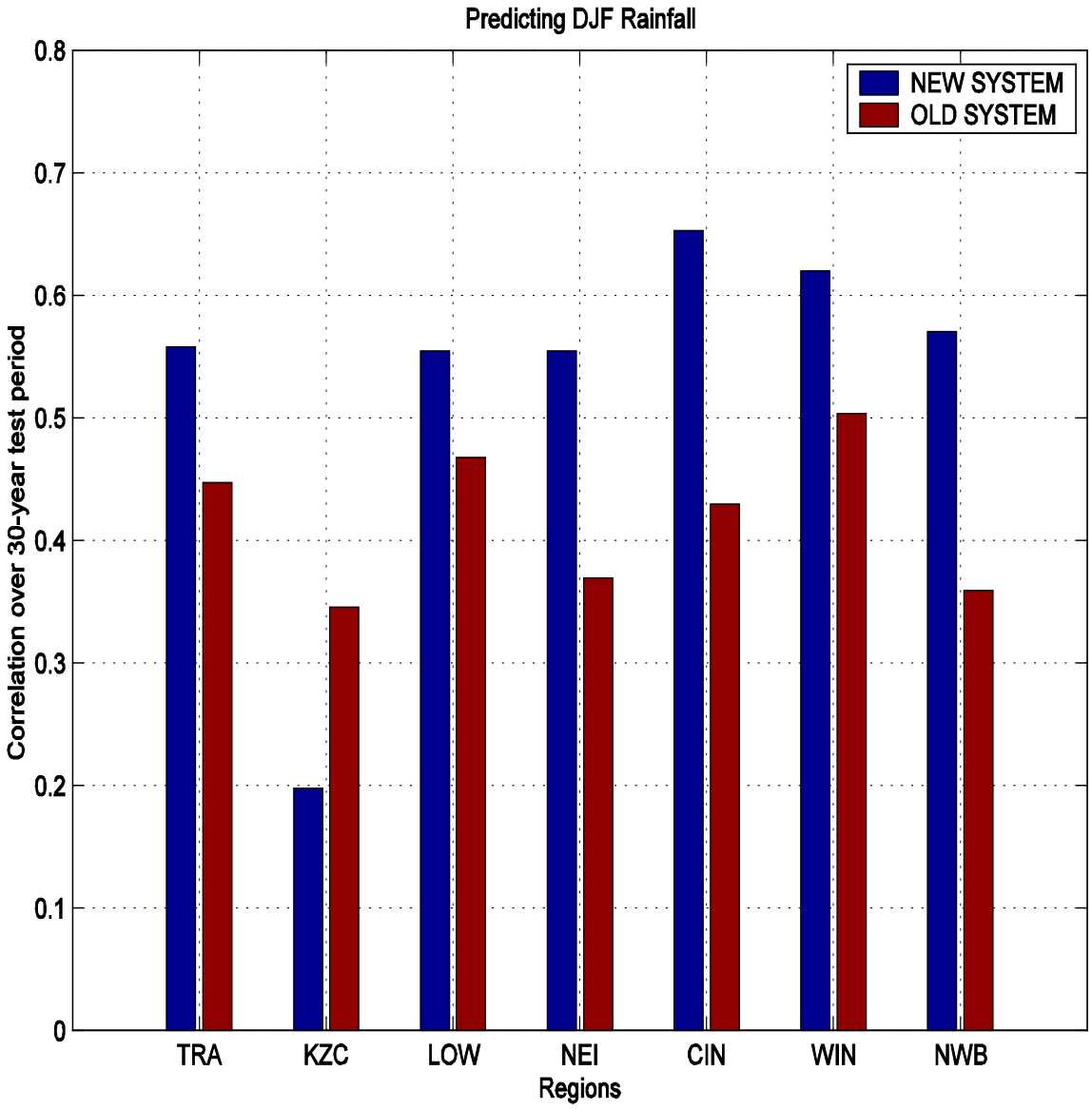


Simulation Skill for Seasons



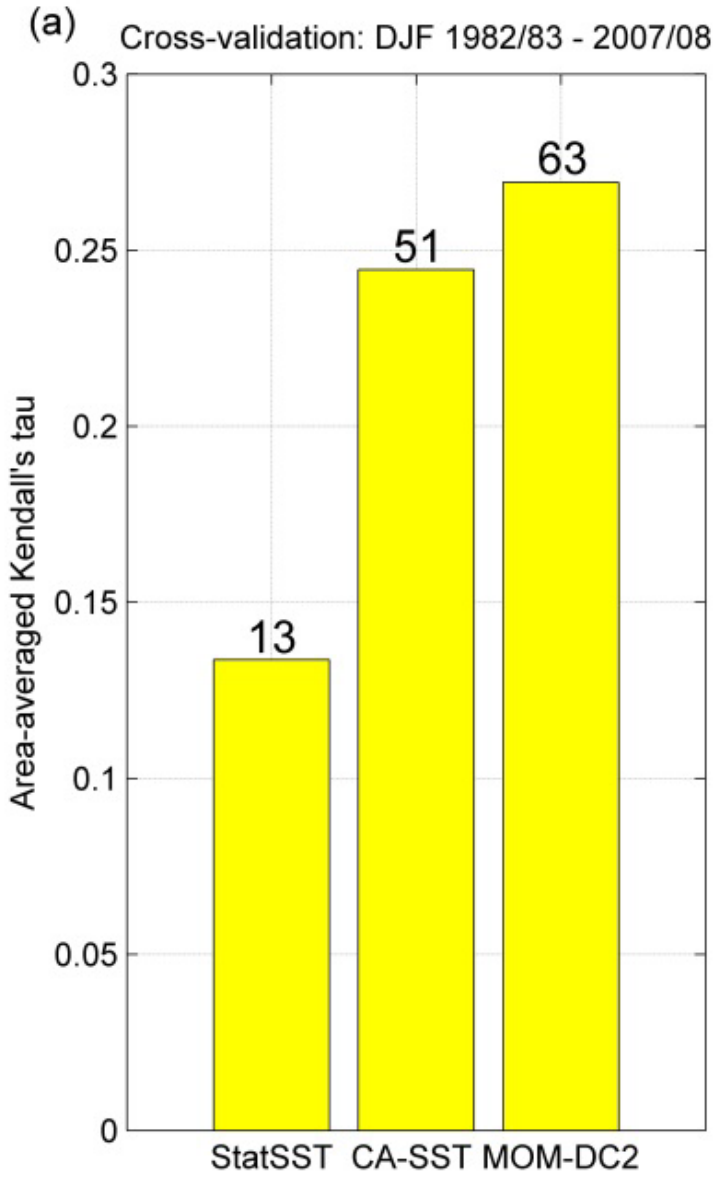
The seasonal forecast systems of the SAWS use the slow evolution of SSTs to make forecasts. In fact, improvements in the forecast systems have occurred owing to the better understanding of the coupled ocean-atmosphere system obtained through research at the SAWS and elsewhere.

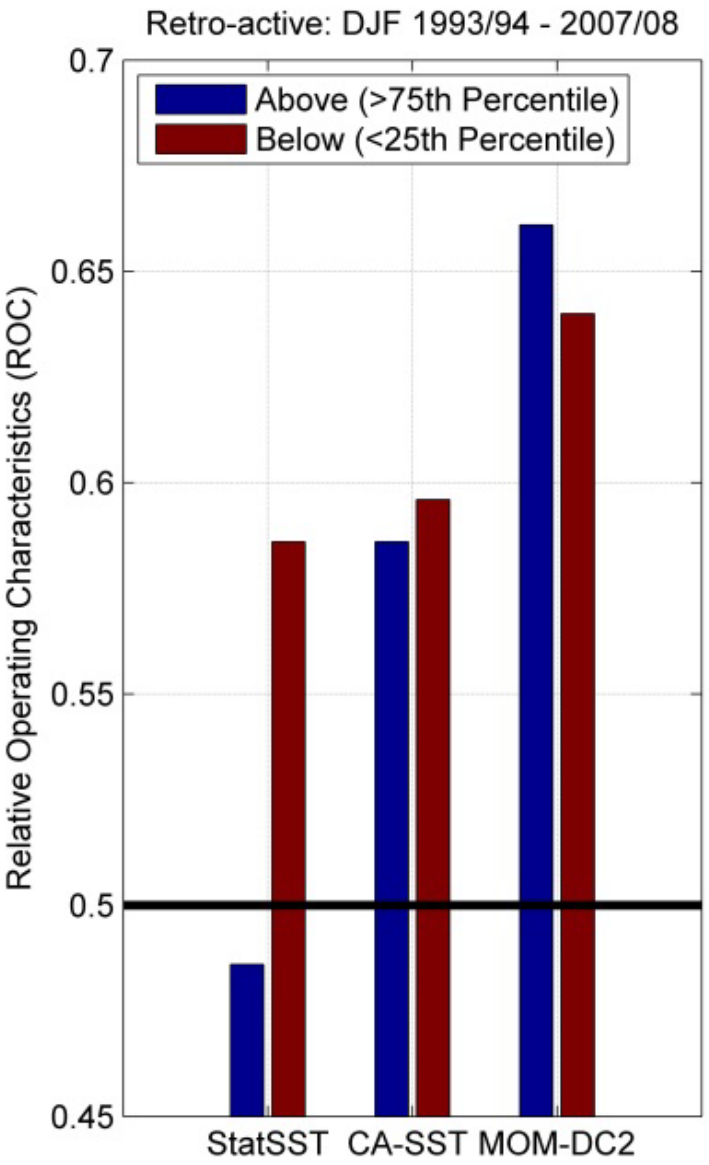




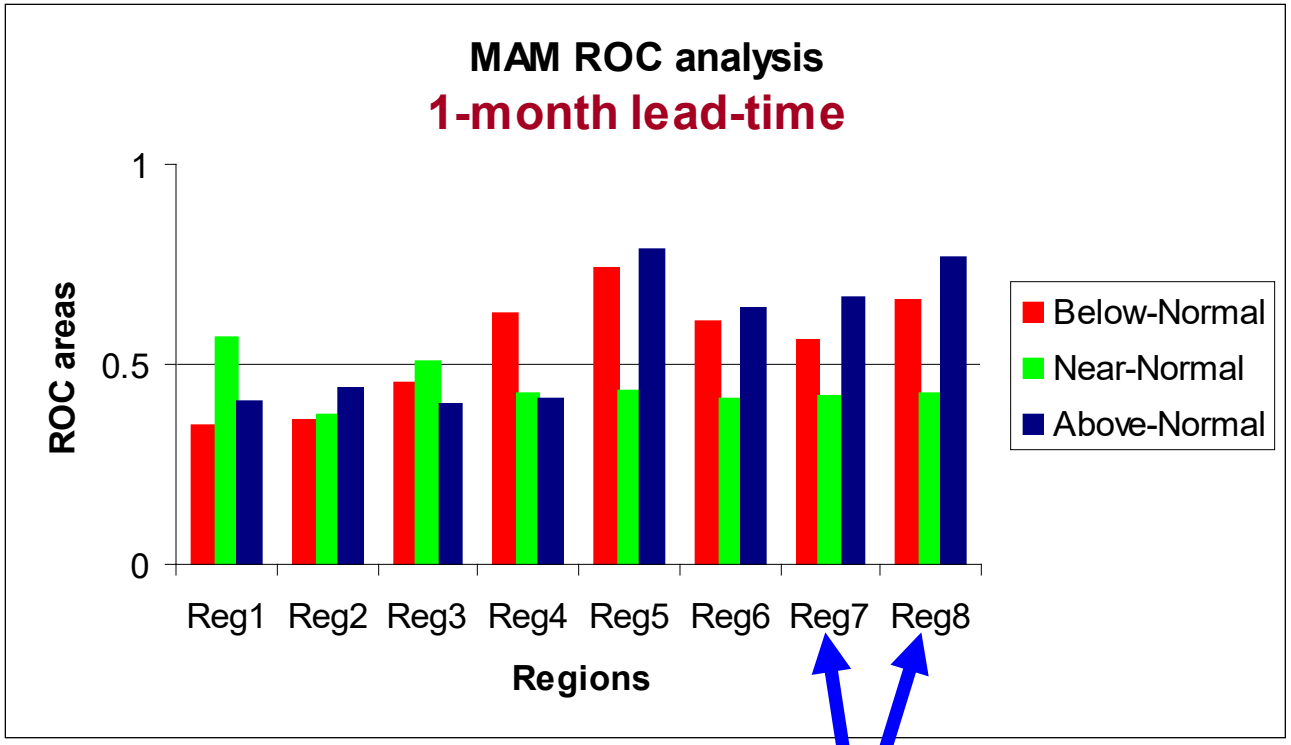
One of the reasons why seasonal forecast skill for South Africa has increased is our improved understanding of the effect El Niño and La Niña events have on our observed and modelled seasonal climate variability

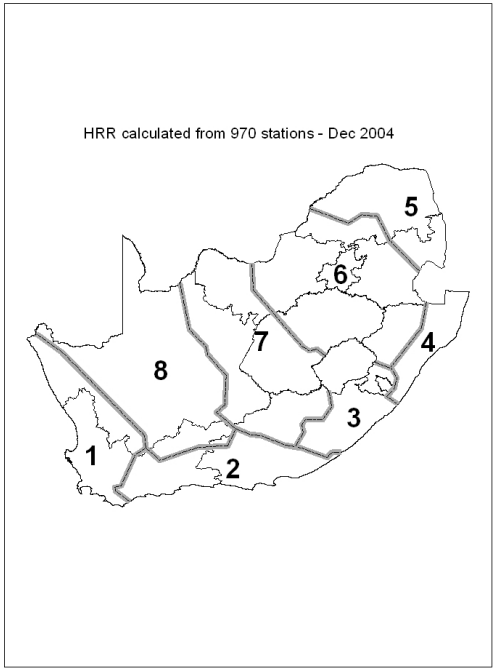
More on forecast system improvement





Operational forecasts are skilful





Important rainfall season for these regions

Forecast Quality and Forecast Value

- Value: the economic (or societal) worth of forecasts
  - Forecasts only have value if people use them
- Quality: the correspondence between forecasts and observations
  - accuracy, skill, reliability, ...
  - "use" - make a decision or take an action which would not otherwise have been made
- Quality and value are not the same. There is not even a simple relationship between them
  - a forecast may have high skill, but no value
  - a low skill forecast could give high value to some users

http://www.wmo.ch/web/wcp/clips2001/html/index_curriculum.htm

IMPROVING OUTREACH IN ATMOSPHERIC SCIENCES

Assessment of Users of Climate Products

BY DAVID CHANGNON

Opportunities to enhance climate information and to integrate it into decisions continue to expand; however, successful transfer of this knowledge requires frequent interactions between atmospheric scientists and users.

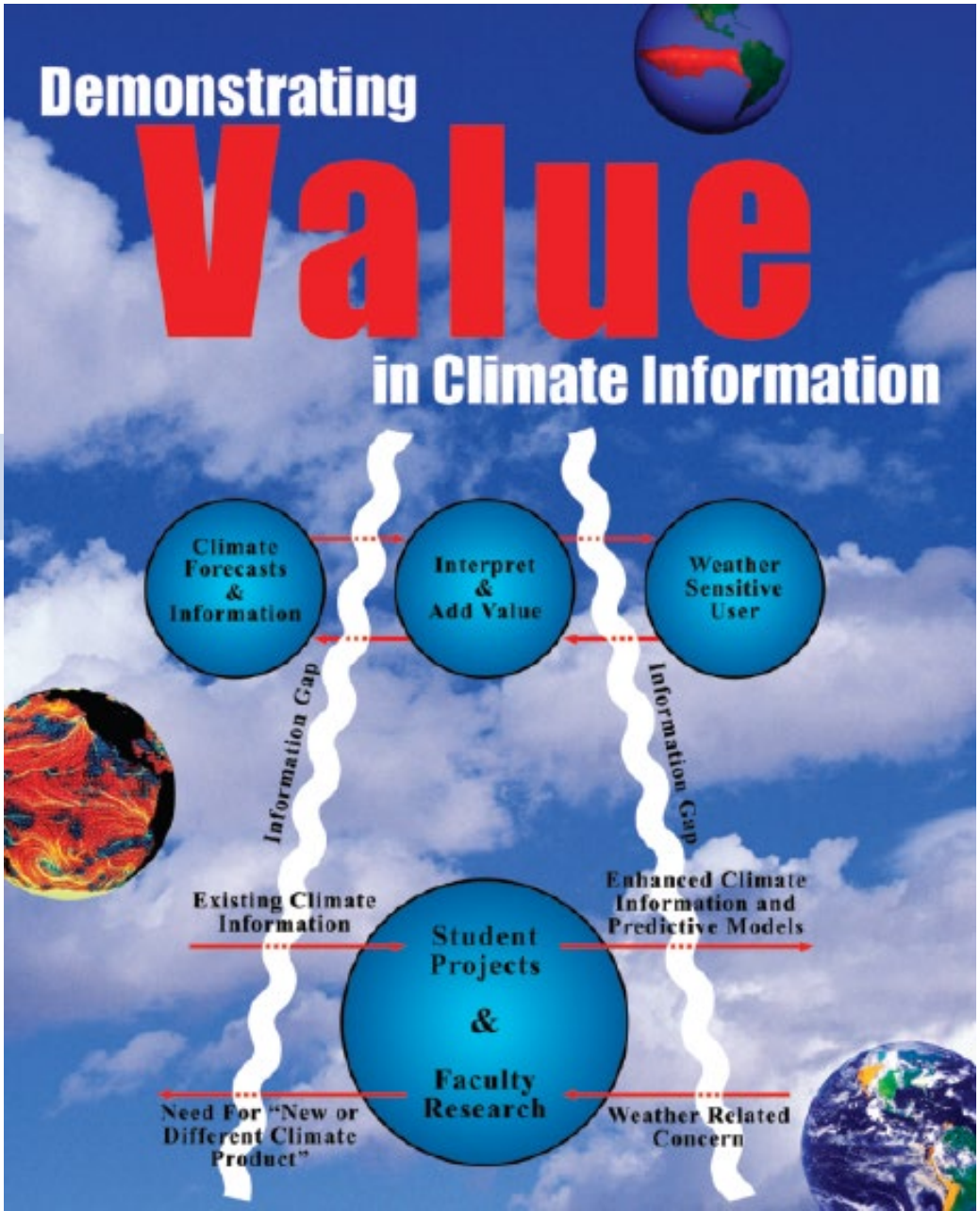


FIG. 1. A schematic illustrating the transfer of information required by weather-sensitive decision makers and climatologists if climate information is to be effectively integrated into decision processes.

Approaching commercial farmers

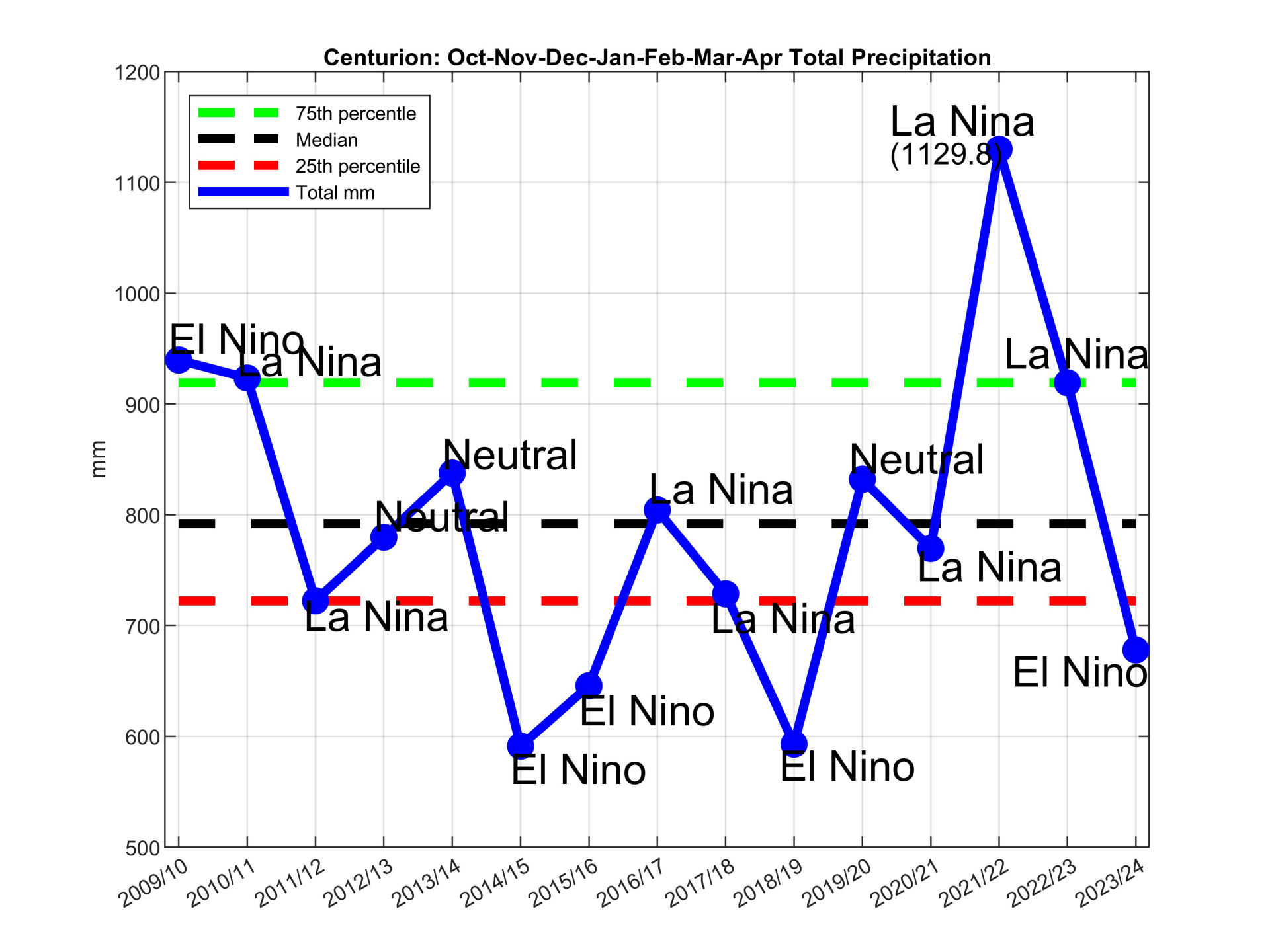
Table 1 Factors that influences the decisions taken by commercial crop farmers.

RESPONDENT	FACTORS INFLUENCING DECISIONS	FACTORS LIMITING EXECUTION
1	Seasonal rainfall forecast Market prices (SAFFEX) Available capital	Available capital Availability of land to rent Availability of workers Status of machinery (are they new, old, need to be replaced, serviced etc.)
2.	Seasonal rainfall forecast Financial position Forage needs	Onset of rainy season
3.	Seasonal rainfall forecast Market prices Water quota	Market prices
4	Seasonal rainfall forecast Start of rainy season Area prepared during winter Market prices and tendencies	Available soil moisture
5	Market prices Financial position Seasonal rainfall forecast Quality and cost of labour	Risk of drought Status of machinery Fuel prices Available capital
6	Seasonal rainfall forecast Market prices	Financial position
7	Seasonal rainfall forecast Available moisture Market prices	Labour risk

Klopper, E., Vogel, C.H. and Landman, W.A. (2006). Seasonal climate forecasts – potential agricultural-risk management tools? *Climatic Change*, **76**, 73-90.

User may ask what El Niño is…

- Is El Niño Spanish for *DROUGHT?*
- Does El Niño always mean *DROUGHT* for my region?
- When there is a *DROUGHT*, is it *always* a consequence of El Niño?
- What about **La Niña**, the opposite phase of El Niño?


Centurion: Oct-Nov-Dec-Jan-Feb-Mar-Apr Total Precipitation
75th percentile
Median
25th percentile
Total mm
mm
1200
1100
1000
900
800
700
600
500
2009/10
2010/11
2011/12
2012/13
2013/14
2014/15
2015/16
2016/17
2017/18
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El Nino

How do El Niño (or La Niña) events affect our seasonal climate?

- Can we be a 100% certain that every El Niño will be causing droughts and every La Niña be causing floods over my region?
- Let us try to explain how El Niño (or La Niña) affects our summer season through the example of one of our soccer heroes…

RONALDO!!!!!

Will my favourite soccer team definitely win the league???

- No guarantees!!!
- HOWEVER, with Ronaldo on my soccer team, the ***probability*** of them winning the league is enhanced…
- Because…

…for the most part…

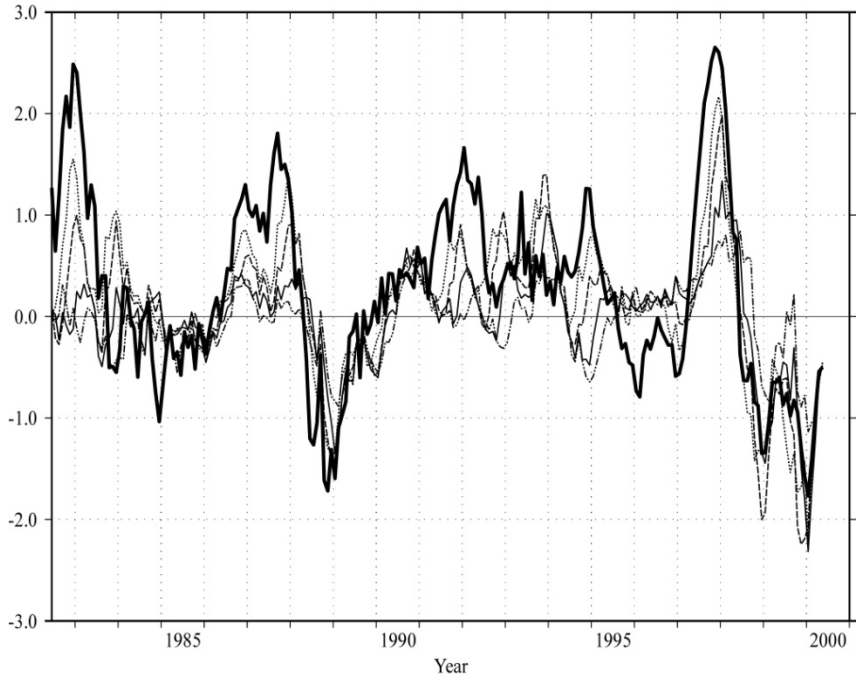
…but occasionally…

Analogous to Ronaldo's influence on a soccer game…

- When there is an El Niño (La Niña) event taking place, the **CHANCES** of drought (floods) over my region **INCREASE** (Ronaldo is fit and in top form – however, there are **no guarantees** that he WILL lead his team to victory)
- It may happen that we do not experience severe drought (floods) conditions during an El Niño (La Niña) event (Ronaldo misses the goal or the goalkeeper is having the game of his life – other overriding external influences prevail)

Can we know ahead of a coming season whether or not that season will be associated with an El Niño or a La Niña event?

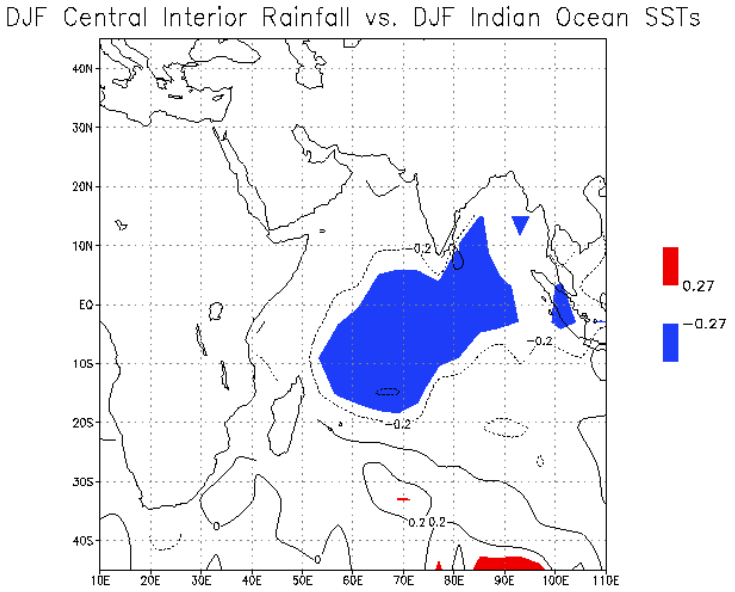
The SAWS has developed a model that can skilfully predict the SST anomalies of the eastern equatorial Pacific Ocean (where El Niño and La Niña events are observed)

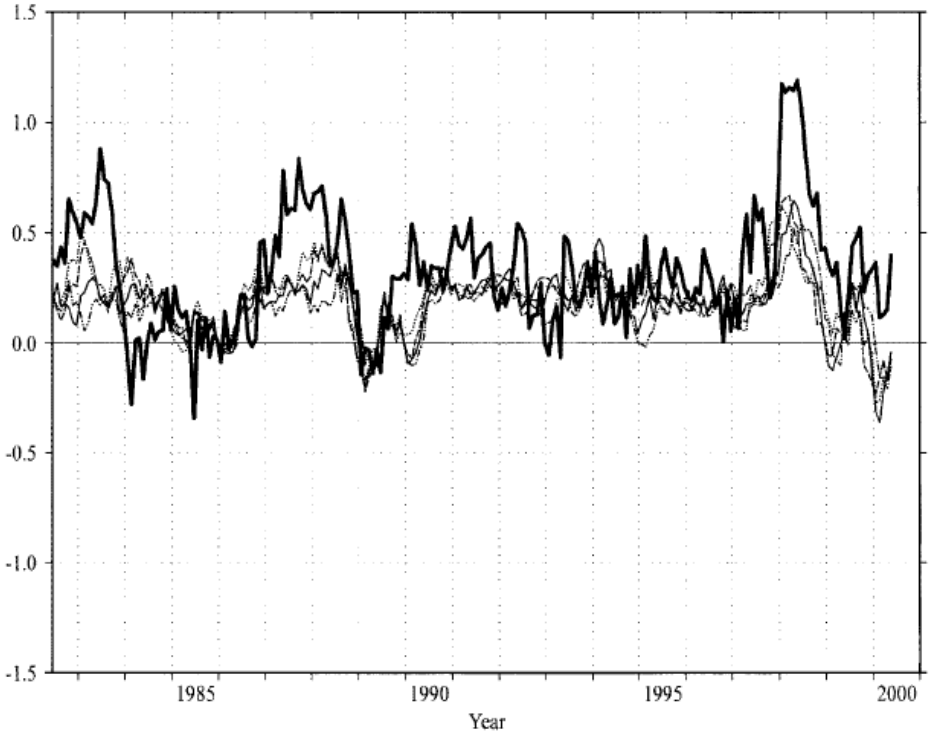


Operational-like forecasts of the eastern equatorial Pacific Ocean SSTs, made at lead-times up to 9 month ahead. Solid line: observed

There are actually quite a large number of forecast models of equatorial Pacific Ocean SST variability and we need to also consider these forecasts. However, the SAWS model also has the ability to make skillful forecasts for other ocean areas such as the equatorial Indian Ocean

Users should also be made aware of the fact that other factors, such as Indian Ocean SSTs, influence the seasonal rainfall variability…

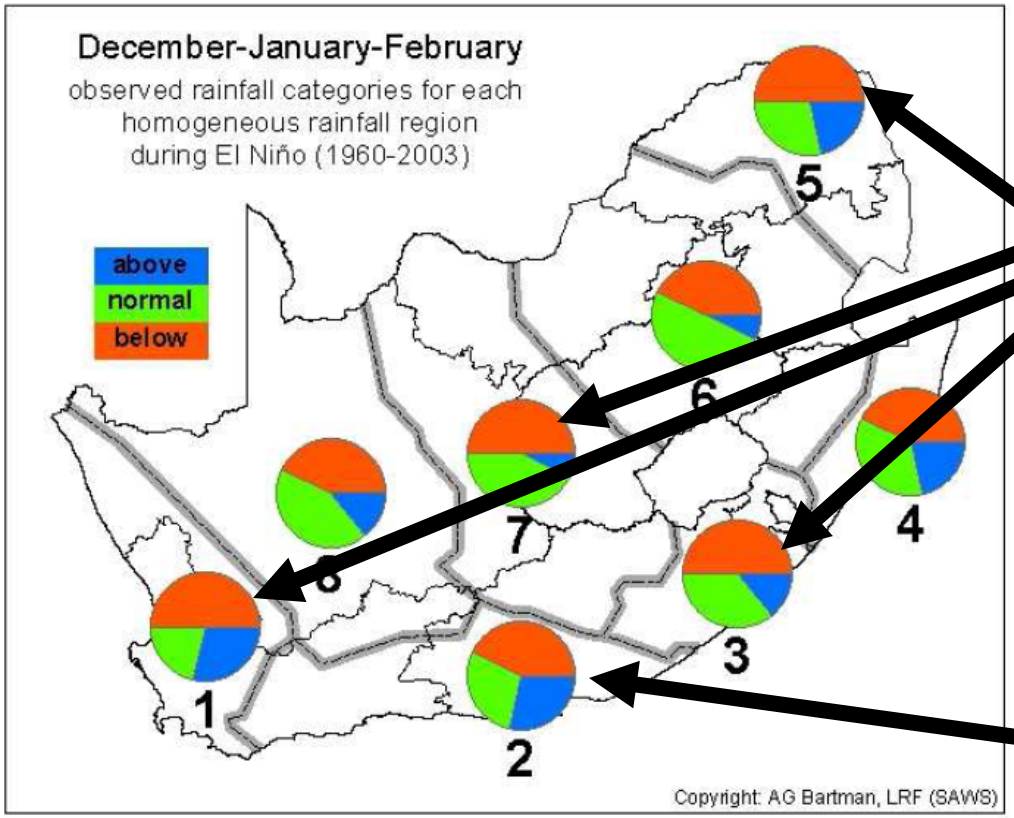




Operational-like forecasts of the equatorial Indian Ocean SSTs, made at lead-times up to 9 month ahead. Solid line: observed

…and there is some skill in predicting these SSTs

From observed data, one can determine the likelihood of certain rainfall outcomes associated with, for example, El Niño events



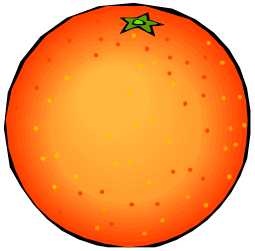
[Maps like this one can also be made showing Indian Ocean SSTs' influence on seasonal rainfall]

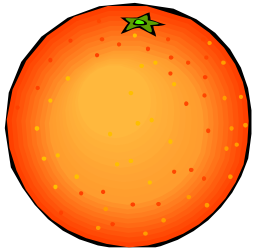
During DJF when there is an El Niño, there is about a 50% chance of it being a below-normal rainfall season

An outcome of "climatology" is probably the most likely [each category about the same chance of occurring]

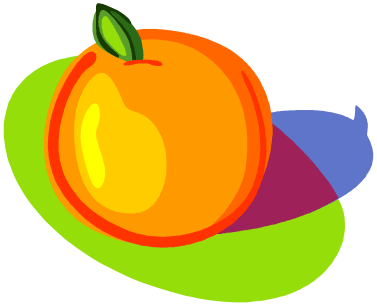
Interpreting forecast probabilities

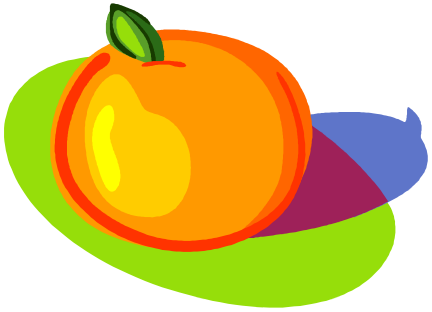
A 33.3%



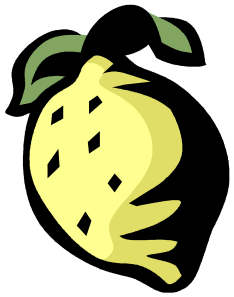


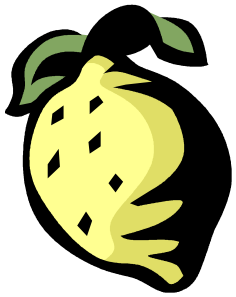
N 33.3%





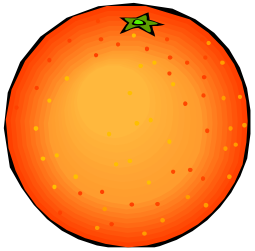
B 33.3%



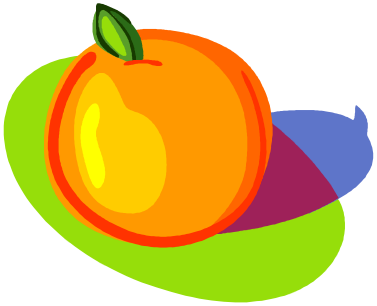


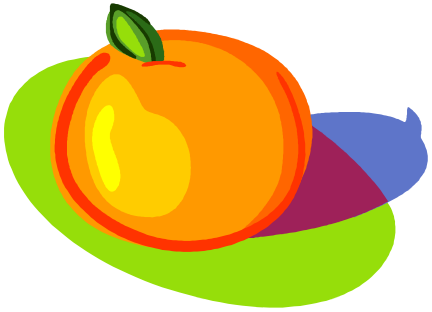
Interpreting forecast probabilities

A 16.7%

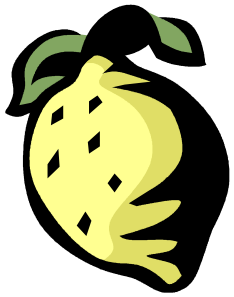


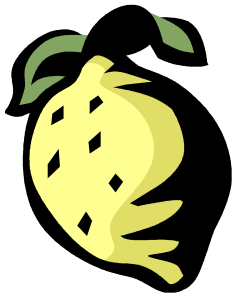
N 33.3%

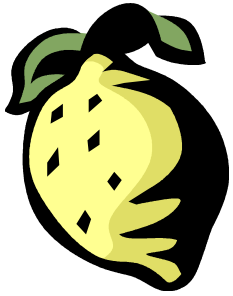




B 50.0%







Introducing ***LEAD-TIME***…

Forecasts are made at different ***lead-times***, ranging from one month so several seasons. How does lead-time relate to the confidence we have in seasonal forecasts?

Enter Ronaldo again…

Ronaldo gets injured…

Will he be fit again soon…?

- Prognosis: no surgery required, but can take 1 to 2 months to recover
- Will he be ready for the all important game against *Bafana Bafana* in 6 weeks time?

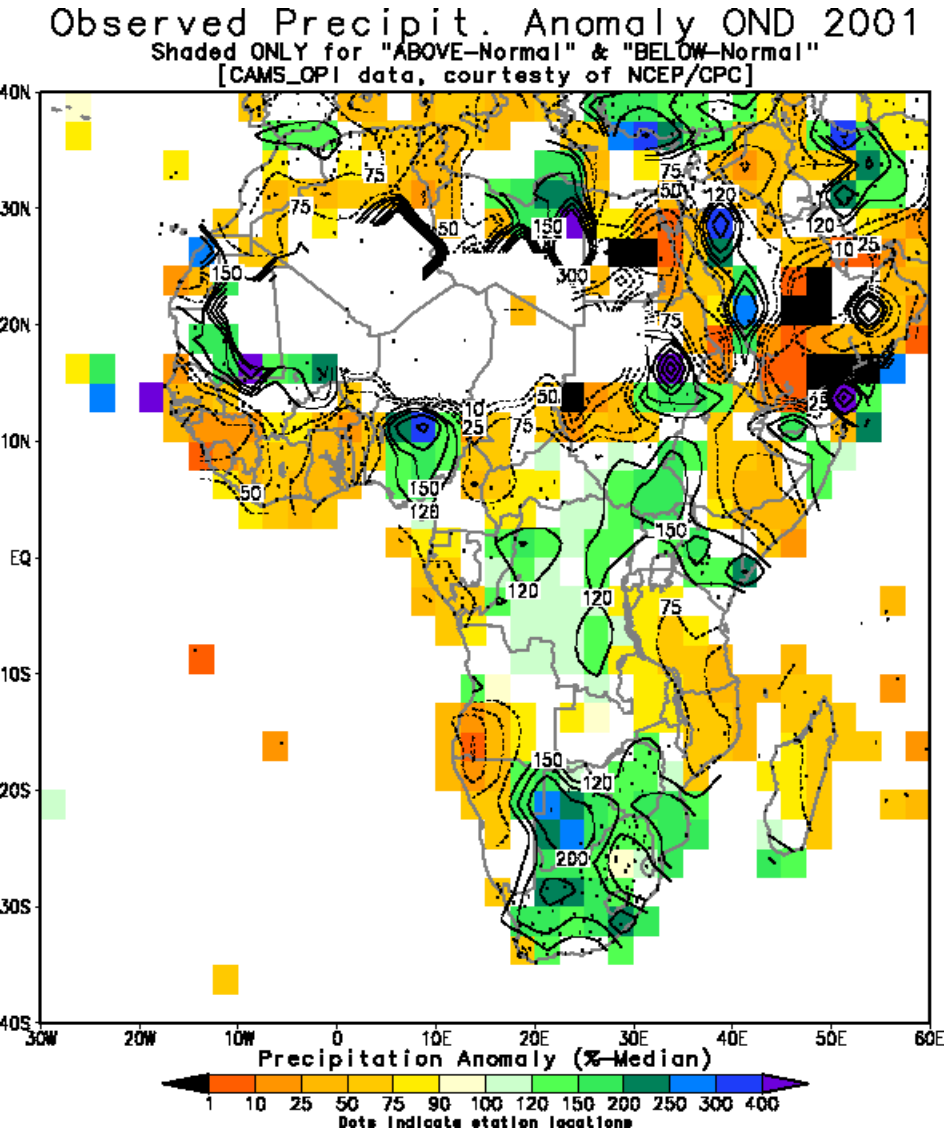
Match day approaches…

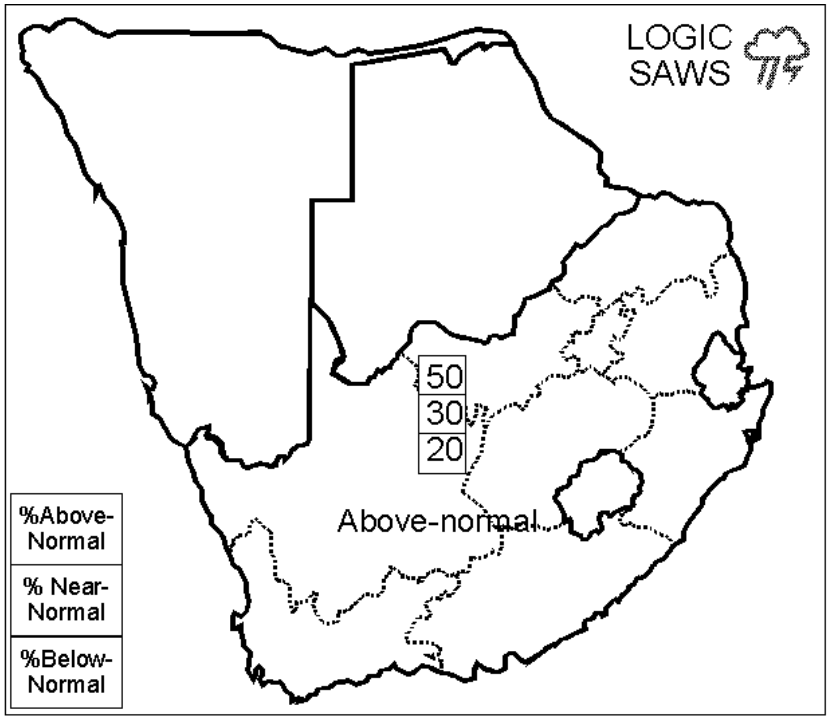
- Now it is 3 weeks before the big match and Ronaldo is still injured
- He should be recovered fully in 2 to 4 weeks…

- The big match is next week…
- …and Ronaldo has been seen doing light training with the Brazilian team…
- Who will win?

Similar to day-to-day weather forecasting, we also have a lot more confidence in the forecast probability distribution of rainfall (or temperature) when we get closer to the season being forecast. However, our forecasts can never be a 100% certain, that is, never be made deterministically – there will always be some uncertainty in the forecast

OND 2001 (issued Jul 01)



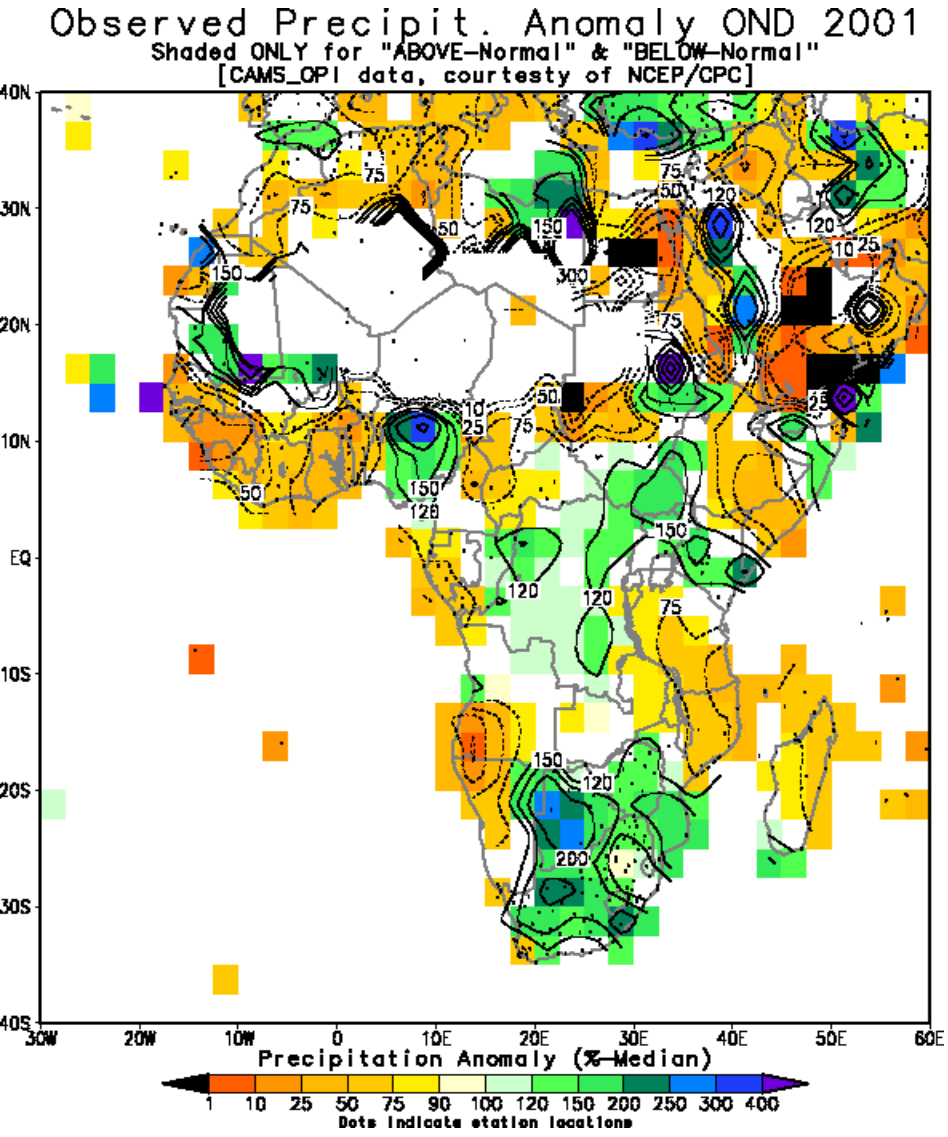


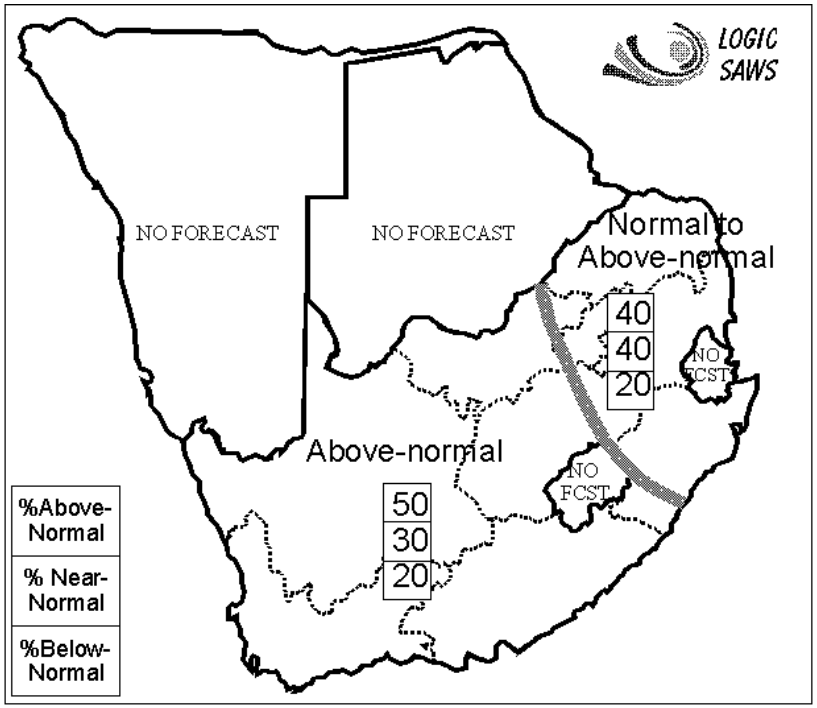
Expected total rainfall for
October + November + December 2001

Forecast made at a three-month lead-time

The largest forecast probability is for wet conditions to occur, which is in agreement with the large area of observed positive rainfall anomalies – hence a *useful* forecast was made

OND 2001 (issued Sep 01)





Expected total rainfall for
October + November + December 2001

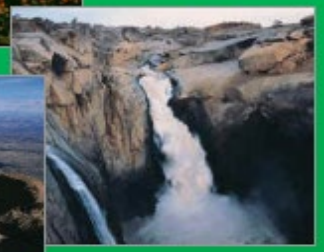
Note the improved forecast information at this shorter lead-time as opposed to the forecast for the same season shown on the previous slide: the forecast makes a distinction between the north-eastern interior and the remainder of the region

ARID ECO-ZONES

www.weathersa.co.za

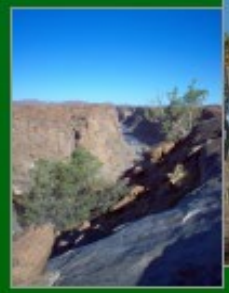
Tourism is a major contributor to the economy of South Africa. The arid western regions or eco-zones of South Africa provide an amazing variety of fauna and flora that are quite distinct.

The South African National Parks (SANParks) authorities are aware of the need to better understand the impacts of extreme weather and climate events and to make use of available forecasts.

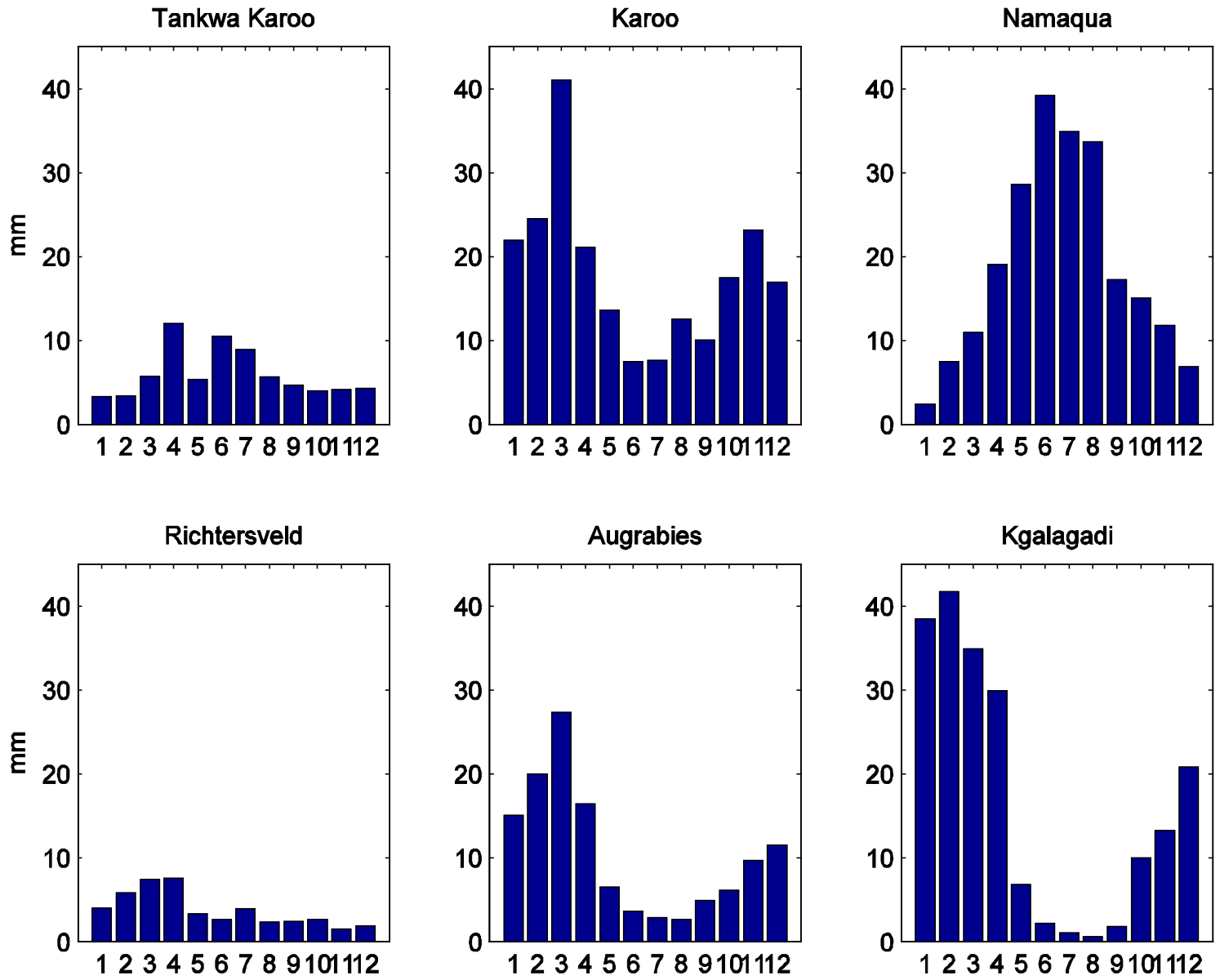


Early warnings of extreme seasons are likely to be beneficial to small parks, which have less flexibility and may be more sensitive than larger parks.

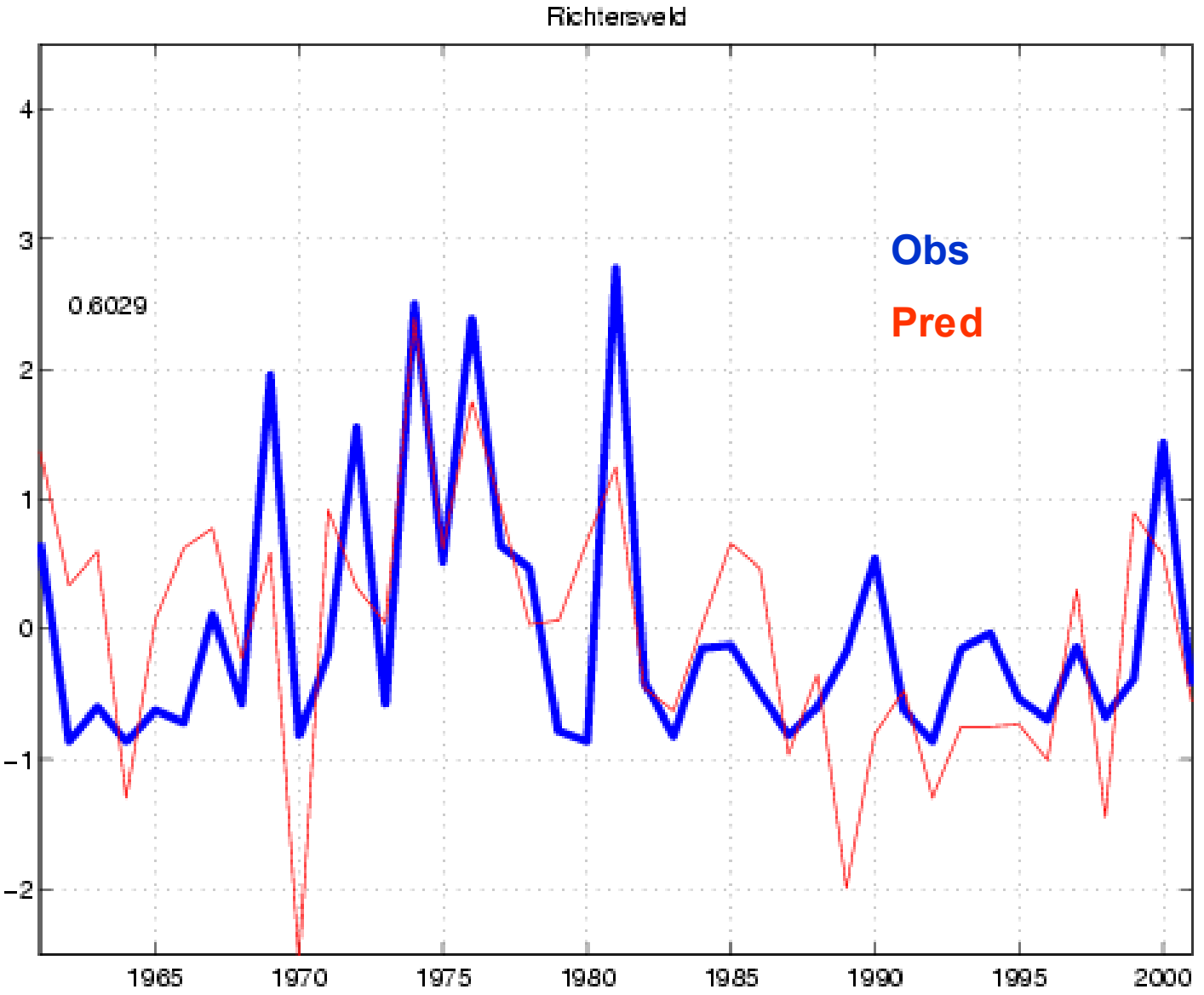
Small parks can make use of tailored forecasts in anticipation of a big natural die-off of wildlife caused by flooding or severe drought.



Rainfall seasonal cycle of arid parks



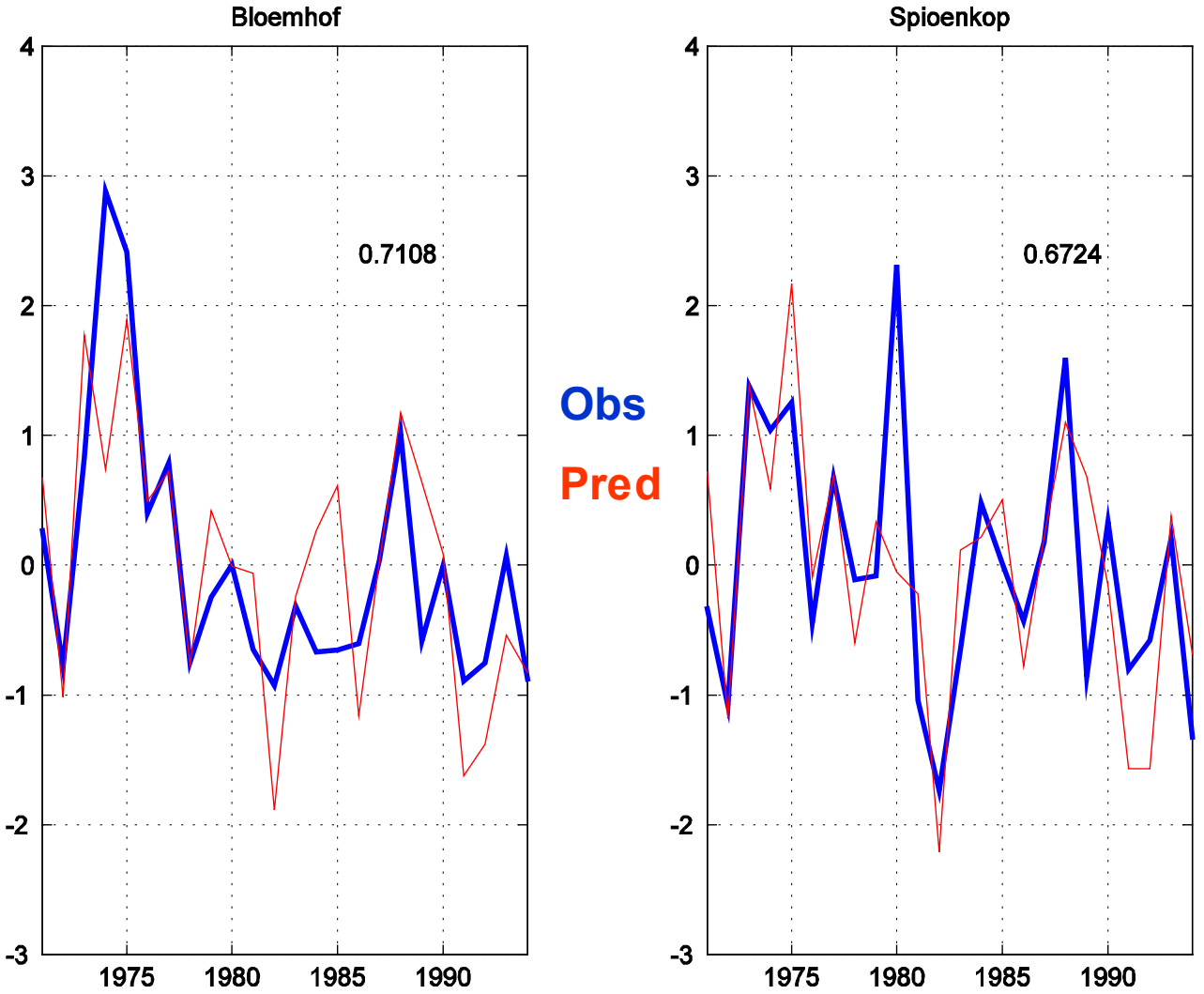
Rainfall simulation for an arid park:

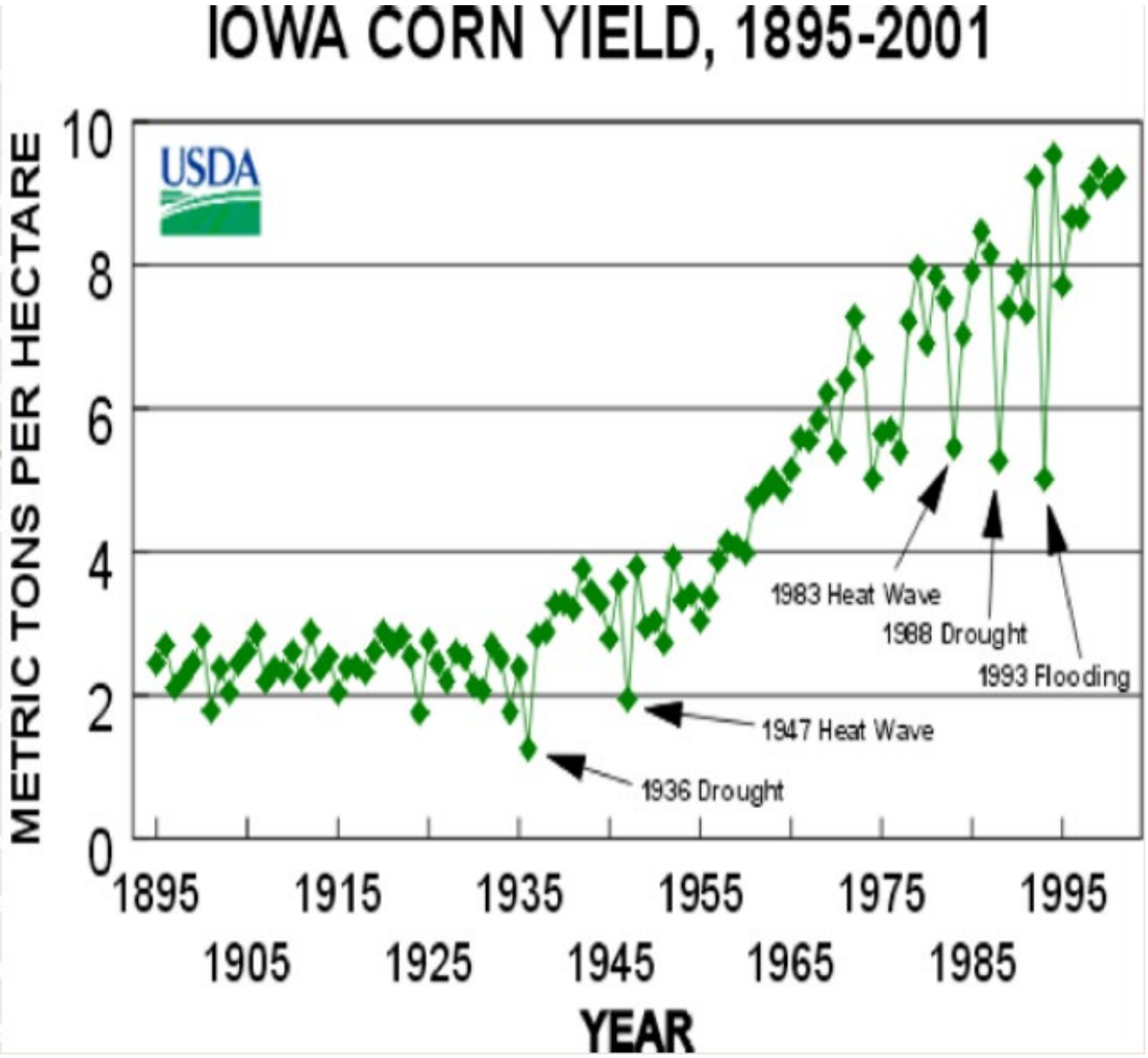


Downscaled from GCM simulations

GCM-downscaled forecasts: (Naturalised) **Streamflow**

DJF at 1-month lead-time





Although an upward trend in yields is evident from 1950s, more recent drought AND flooding as well as intense heat (extremes) caused lower yields

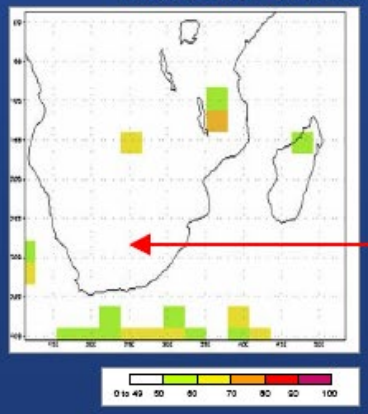
http://www.wmo.ch/web/wcp/clips2001/html/index_curriculum.htm

Extreme Dry events: The 1991/92 Drought

The 1991/92 drought was one of the most severe meteorological droughts of the 20th century in southern Africa.

- 49 000 agricultural jobs lost
- 20 000 non-agricultural jobs lost
- 70% of crops failed
- Associated with 27% decline in agricultural gross domestic product

Extreme: Above

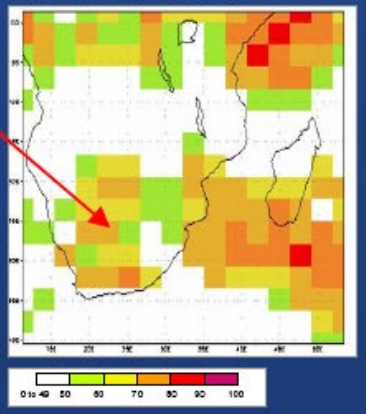


Probability of Extreme Above-normal Rainfall during Dec to Feb 1991/92

Note the areas indicating a high chance (above 50%) for extreme below-normal rainfall over South Africa.

Note the white areas showing a small chance for extreme above-normal rainfall.

Extreme: Below



Probability of Extreme Below-normal Rainfall during Dec to Feb 1991/92

South African Weather Service

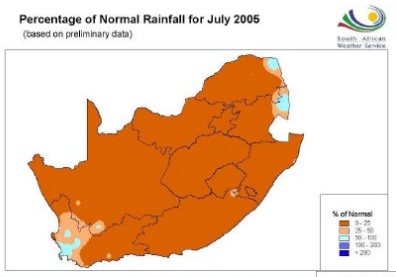
Compiled by Annelise du Piesanie, Long-Range Forecasting Group, South African Weather Service.
For more information email longrange@weathersa.co.za

Information package for commercial clients

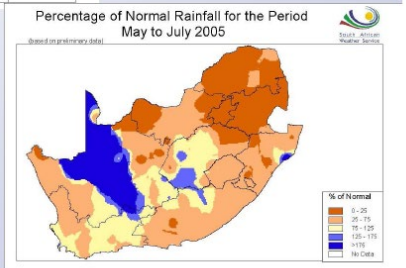
South African Weather Service

Long - Range Forecasting Group

Forecast Issued August 2005



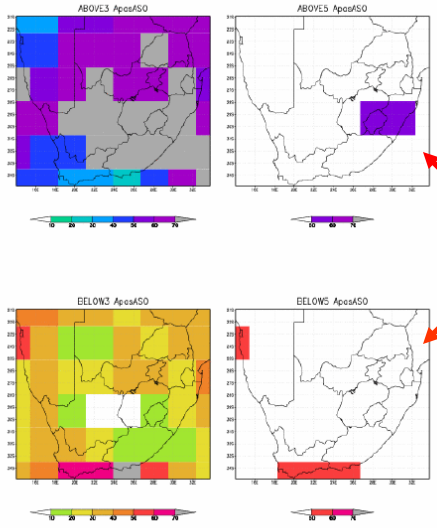
Observed Rainfall



Forecast Format

- Forecasts are presented as probabilities for
  - the below- and above-normal categories, and
  - extremes
- A season is defined here as *extreme* when its rainfall anomalies fall within the top and bottom 15th percentile of the climate records, leaving a 70% probability that the rainfall will not be extreme

ASO



Extremes

Are seasonal forecasts for *everyone*?

- Although seasonal forecasts are expected to be useful more frequently than not, the cost of taking precautions (based on the forecast) must be weighed against the savings that the precautions would bring if the unwanted climate event occurred.
- Users of seasonal forecasts should do cost-loss analyses to get an idea of the potential rewards and penalties involved.
- The best way for a user to determine whether action should be taken is for the user to set a probability threshold for the most likely category. Cost-benefit analysis should be able to give guidance on what this threshold should be.
- When the forecast probability exceeds this threshold, the choice of the threshold translates into a deterministic forecast. For example, a farmer who may realize that he should only act when the forecast probability of the below-normal category exceeds 50%, will translate a forecast of A=20%; N=25%; and B=55% into a statement of "it will be dry".

Cost/Loss Ratio

Action taken	Event occurs: DROUGHT	
	Yes	No
Yes	Cost to perform protective action	Cost to perform protective action
No	Loss incurred if drought occurs	0

Richardson, D. S., 2000: Skill and relative economic value of the ECMWF ensemble prediction system. *Quarterly Journal of the Royal Meteorological Society*, **126**, 649-667.

WEATHER AND FORECASTING VOLUME 14

Conditional Probabilities, Relative Operating Characteristics, and Relative Operating Levels

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(Manuscript received 21 July 1998, in final form 19 April 1999)

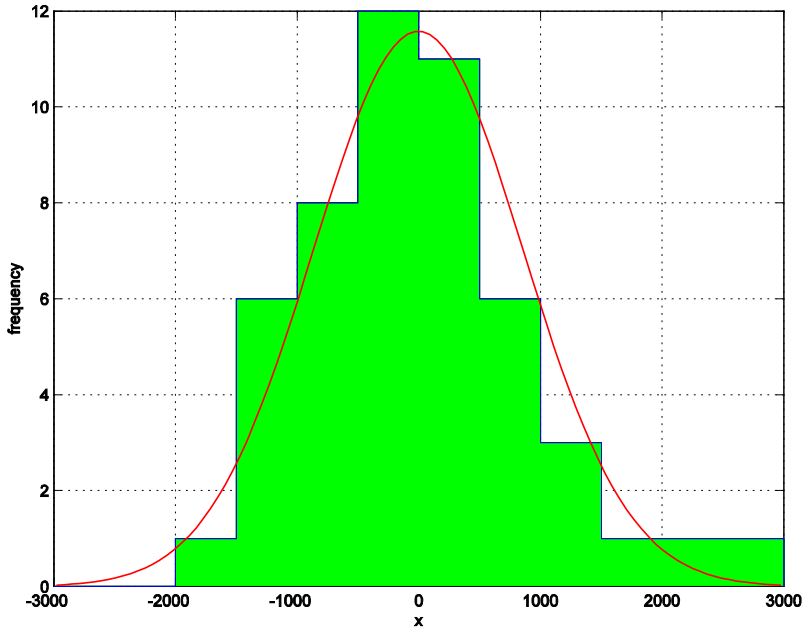
ABSTRACT

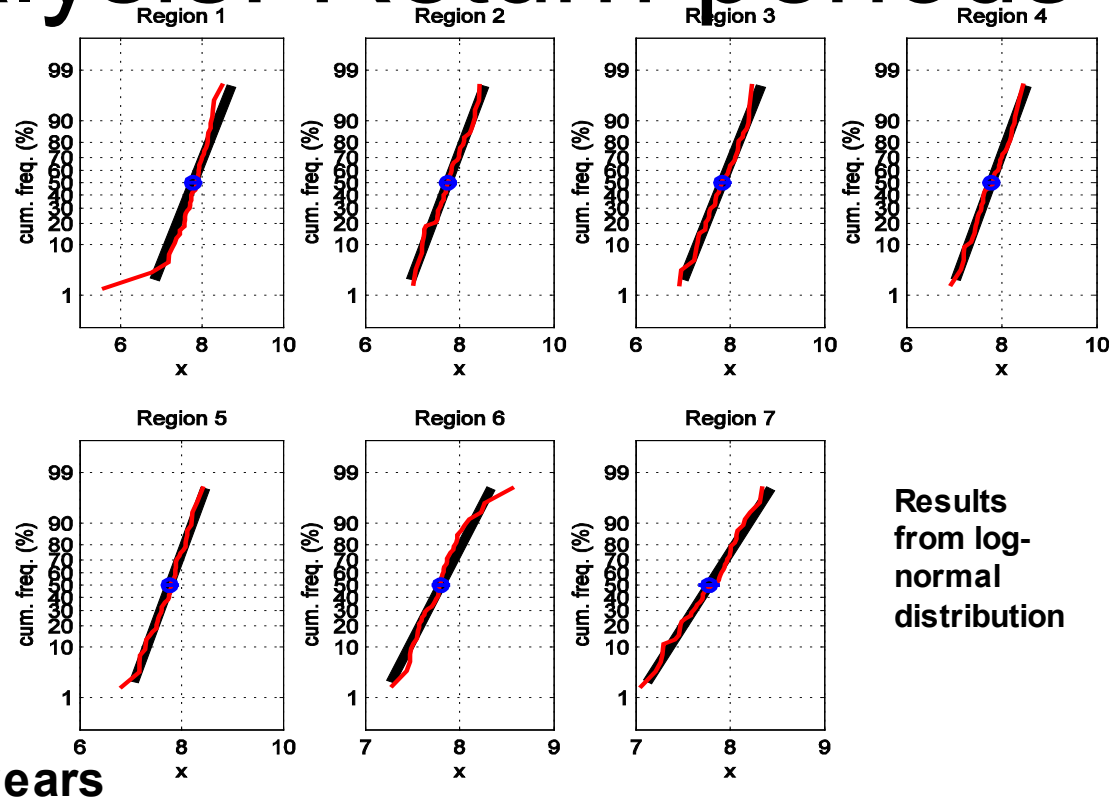
The relative operating characteristic (ROC) curve is a highly flexible method for representing the quality of dichotomous, categorical, continuous, and probabilistic forecasts. The method is based on ratios that measure the proportions of events and nonevents for which warnings were provided. These ratios provide estimates of the probabilities that an event will be forewarned and that an incorrect warning will be provided for a nonevent. Some guidelines for interpreting the ROC curve are provided. While the ROC curve is of direct interest to the user, the warning is provided in advance of the outcome and so there is additional value in knowing the probability of an event occurring contingent upon a warning being provided or not provided. An alternative method to the ROC curve is proposed that represents forecast quality when expressed in terms of probabilities of events occurring contingent upon the warnings provided. The ratios used provide estimates of the probability of an event occurring given the forecast that is issued. Some problems in constructing the curve in a manner that is directly analogous to that for the ROC curve are highlighted, and so an alternative approach is proposed. In the context of probabilistic forecasts, the ROC curve provides a means of identifying the forecast probability at which forecast value is optimized. In the context of continuous variables, the proposed relative operating levels curve indicates the exceedence threshold for defining an event at which forecast skill is optimized, and can enable the forecast user to estimate the probabilities of events other than that defined by the forecaster.

Assisting commercial clients: *Crop insurance*

- Insurance issue: how to treat major droughts
  - The premium rates are based around the reduction in crop yields
  - The policies have quite a high excess, most of the claim payments come from years of severe loss during intense droughts
  - The way in which the drought years are treated therefore has a big impact on projected claims over a long period of time
- Severe droughts might have a lower frequency than once every, say, 30 years and that the value of those losses should in fact be spread over a longer period
  - That would reduce the value of projected claims in the 30 year period
  - Premium rates charged to farmers could therefore be too high
  - Alternatively, if the droughts occur more often than once every 30 years, then premium rates are too low
  - This becomes a critical issue in the setting of premium rates
- Return periods calculation required

Statistical analysis: Return periods



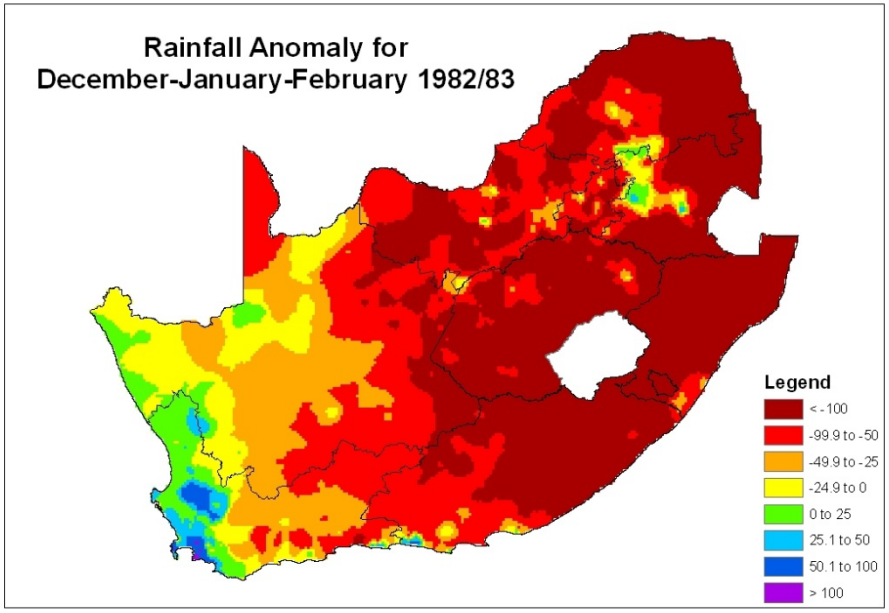


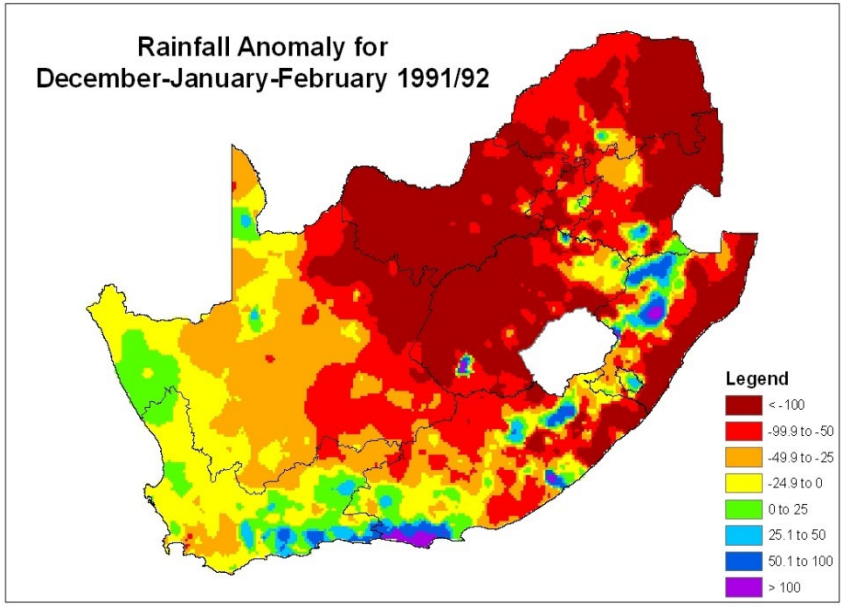
Results from log-normal distribution

Return periods in years

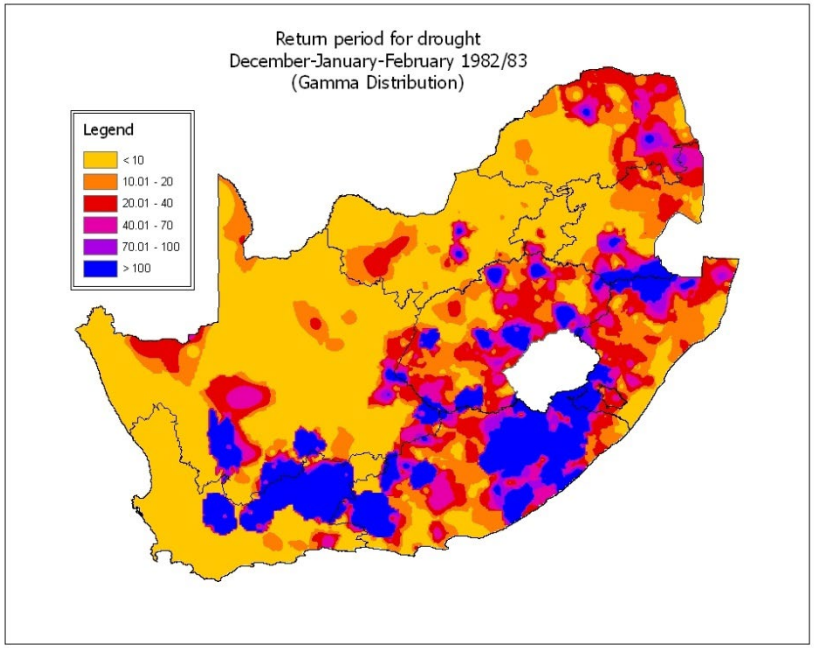
Regions	DJF 1982/83	DJF 1991/92
Transkei	>10000	2.9334
Kw aZulu-Natal coast	33.2779	9.9731
Low veld	75.7002	60.2773
North-eastern interior	83.9631	17.1792
Central interior	20.2143	21.9732
Western interior	8.9904	4.3545
Northern Namibia / w estern Botsw ana	6.0234	5.76

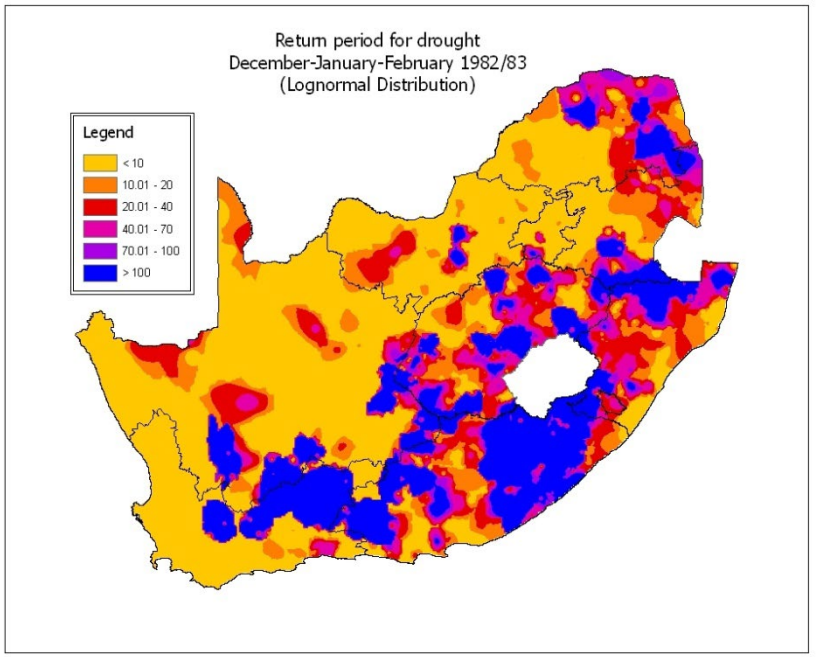
Rainfall anomaly (mm) of DJF 1982/83 and 1991/92



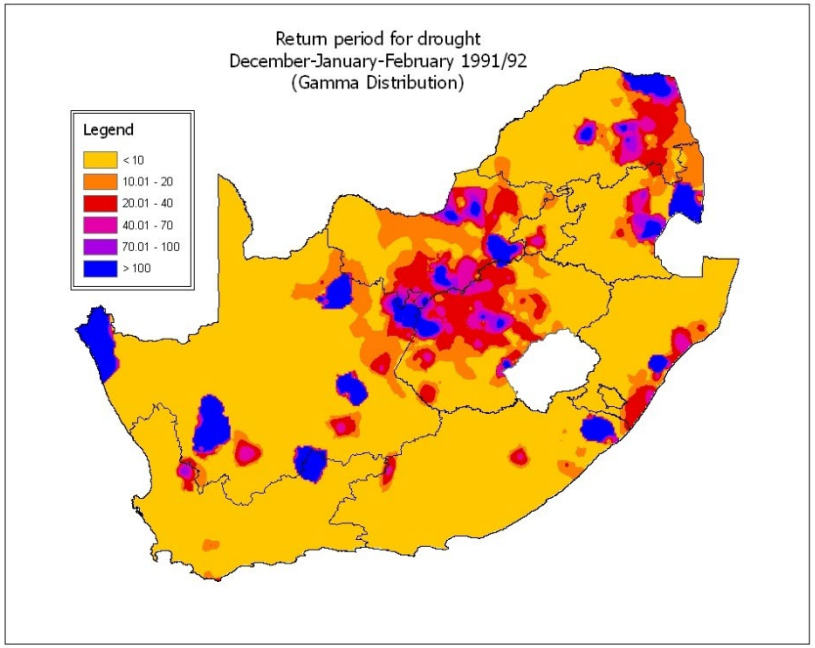


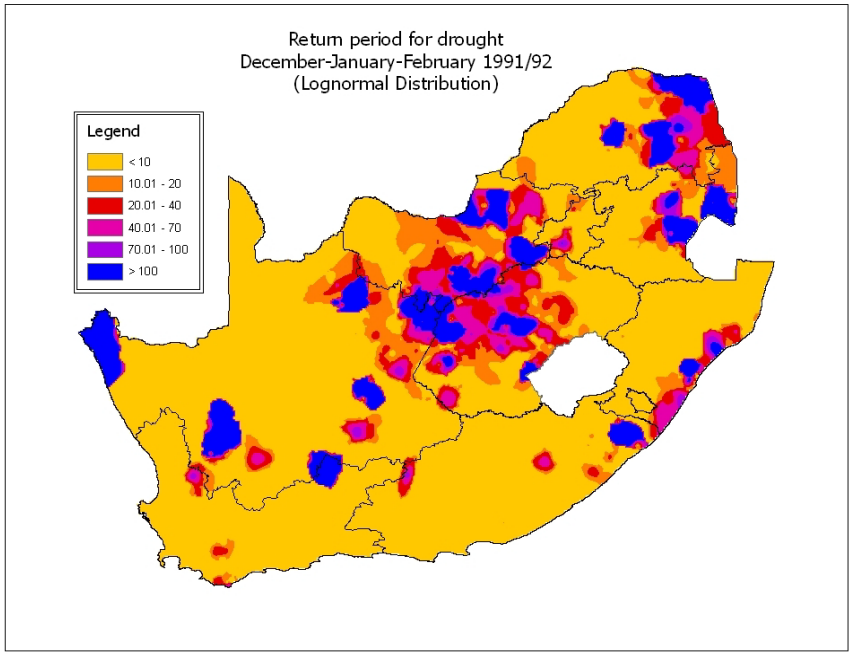
Return periods (years): DJF 1982/83



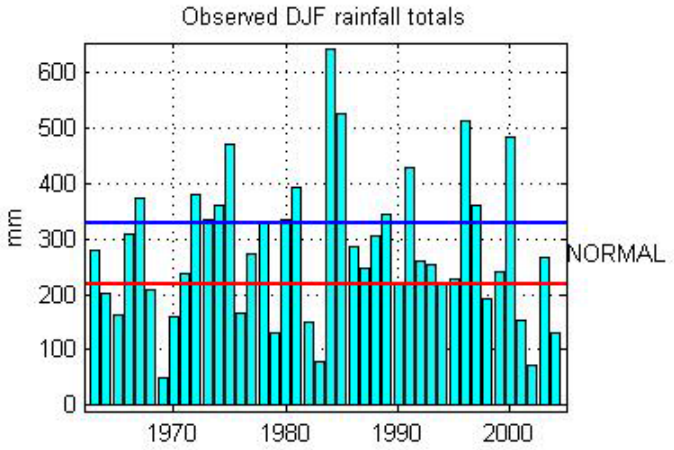


Return periods (years): DJF 1991/92





Information for users. Is it useful?

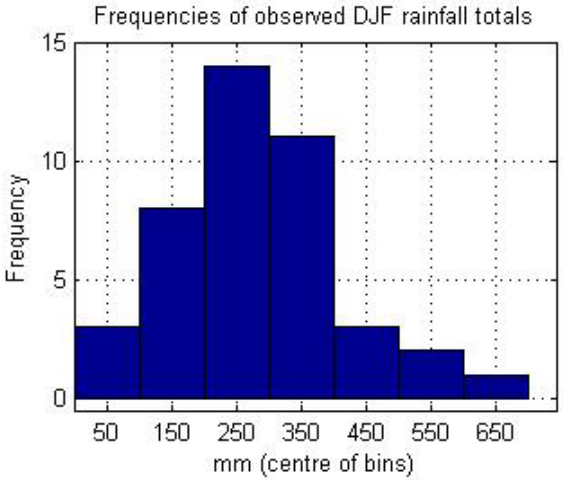


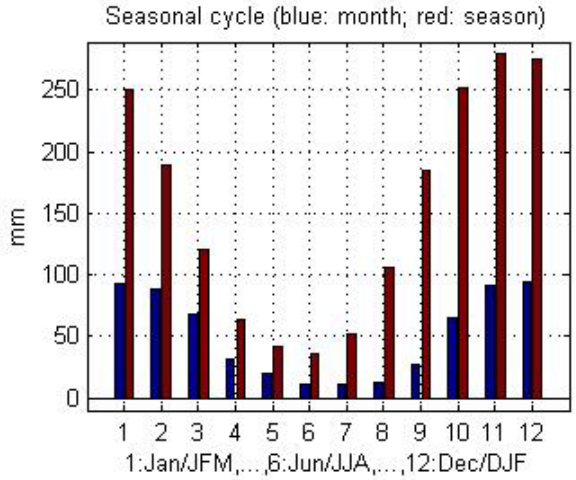
PONGOLA

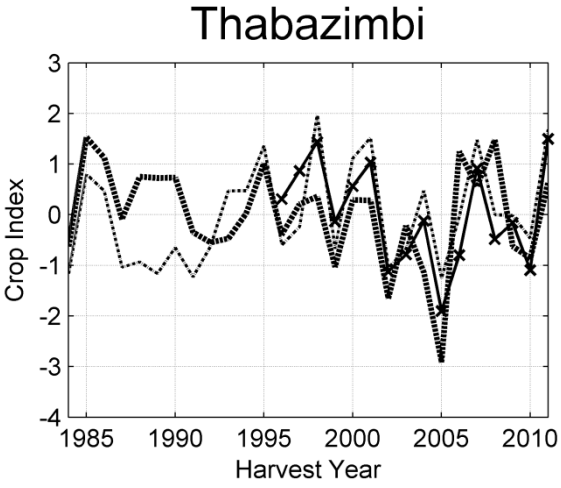
Normal category = 219-328 mm
Below-normal < 219 mm
Above-normal > 328 mm

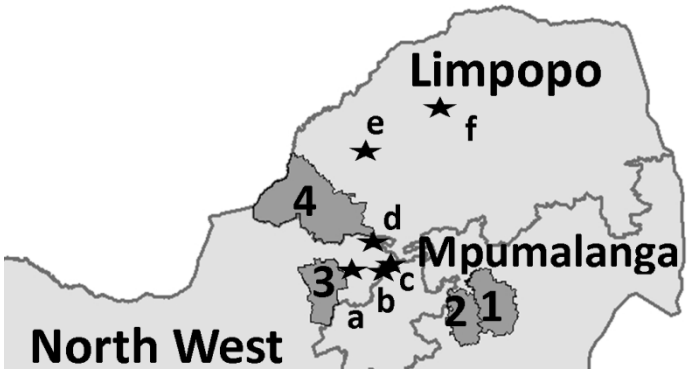
Mean = 280 mm
Median = 263 mm
Standard deviation = 130

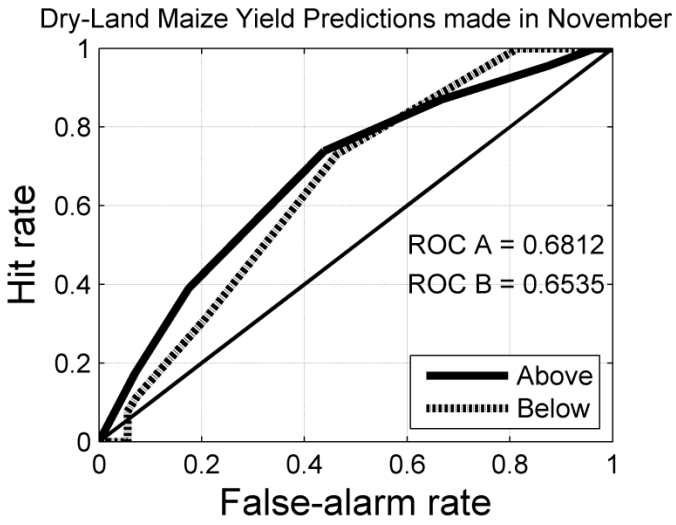
Driest year = 1969 (50 mm)
Return period = 207 years
Wettest year = 1984 (643 mm)
Return period = 61 years

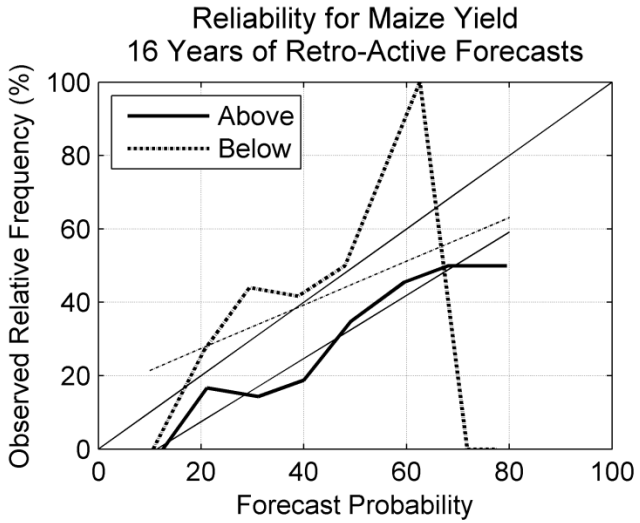


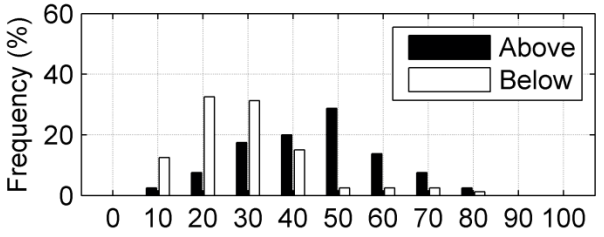



Thabazimbi
Crop Index
Harvest Year
3
2
1
0
-1
-2
-3
-4
1985
1990
1995
2000
2005
2010

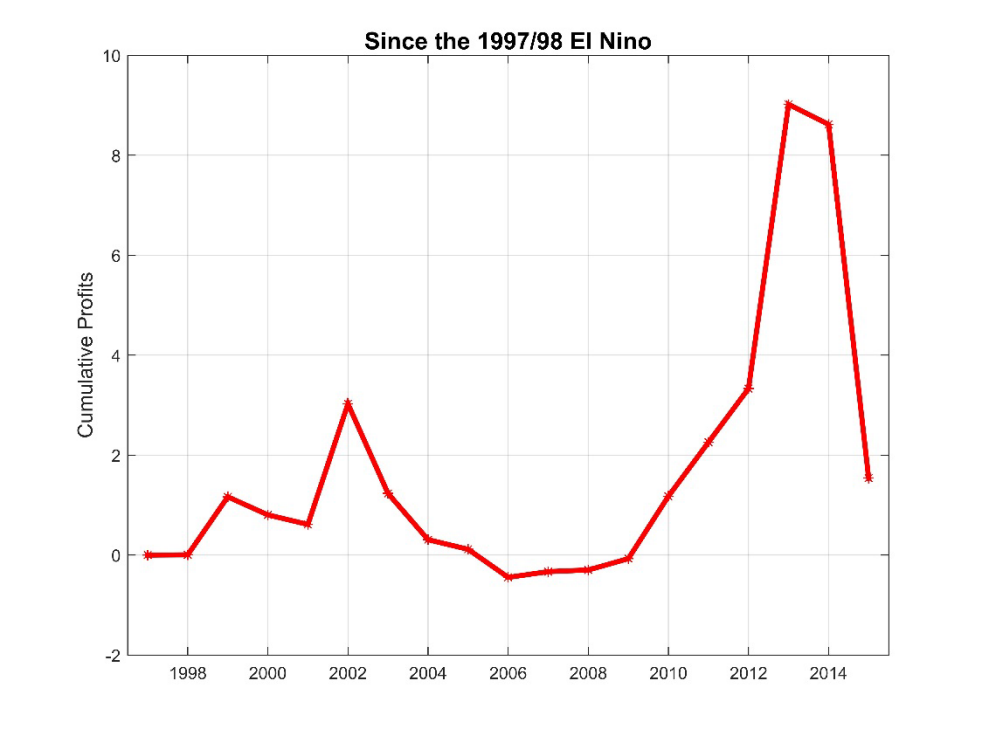

Limpopo
Mpumalanga
North West
e
f
d
c
b
a
4
3
2
1

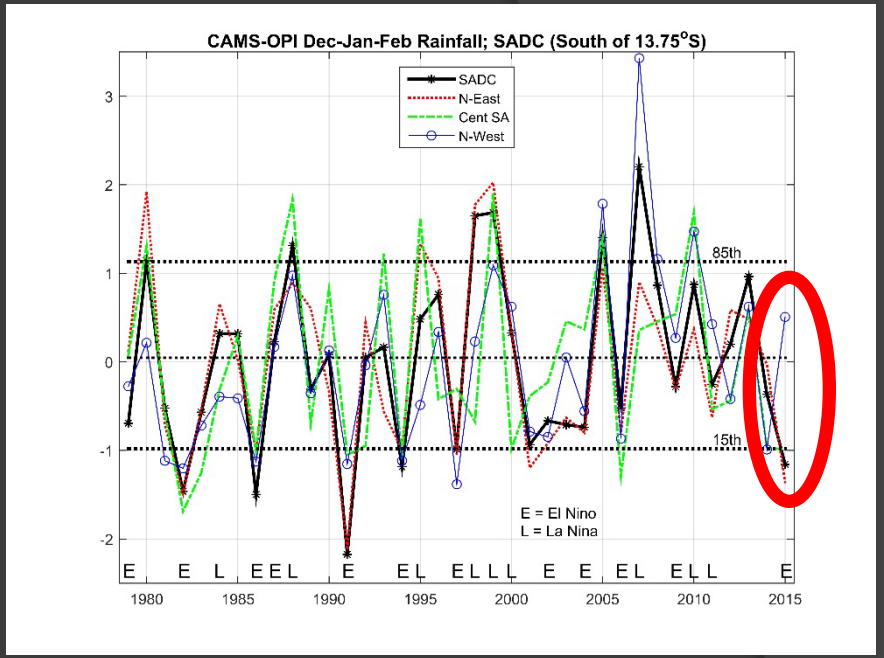

Dry-Land Maize Yield Predictions made in November
Hit rate
False-alarm rate
ROC A = 0.6812
ROC B = 0.6535
Above
Below
0
0.2
0.4
0.6
0.8
1

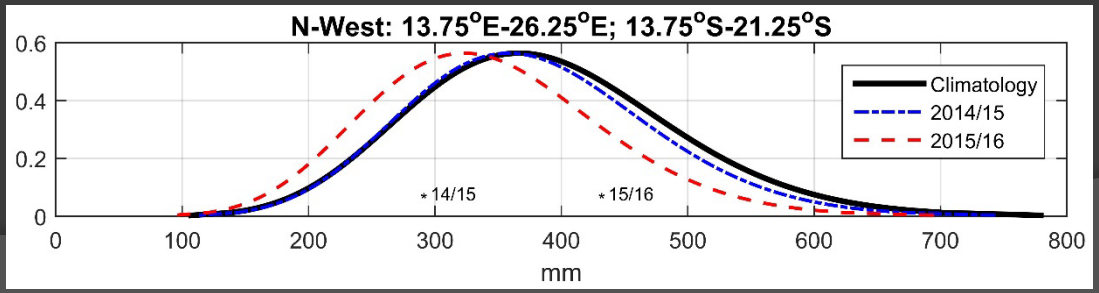

Reliability for Maize Yield
16 Years of Retro-Active Forecasts
Observed Relative Frequency (%)
Forecast Probability
Above
Below
0
20
40
60
80
100

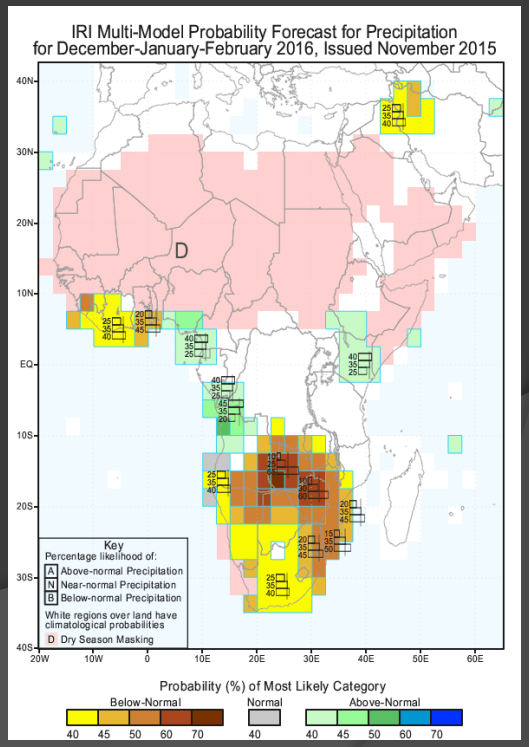

Frequency (%)
Above
Below
0
10
20
30
40
50
60
70
80
90
100

Impact if forecast goes “wrong”…

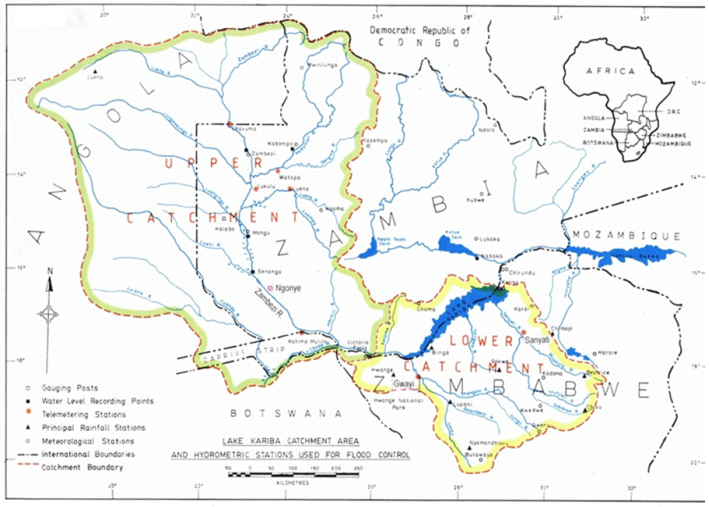


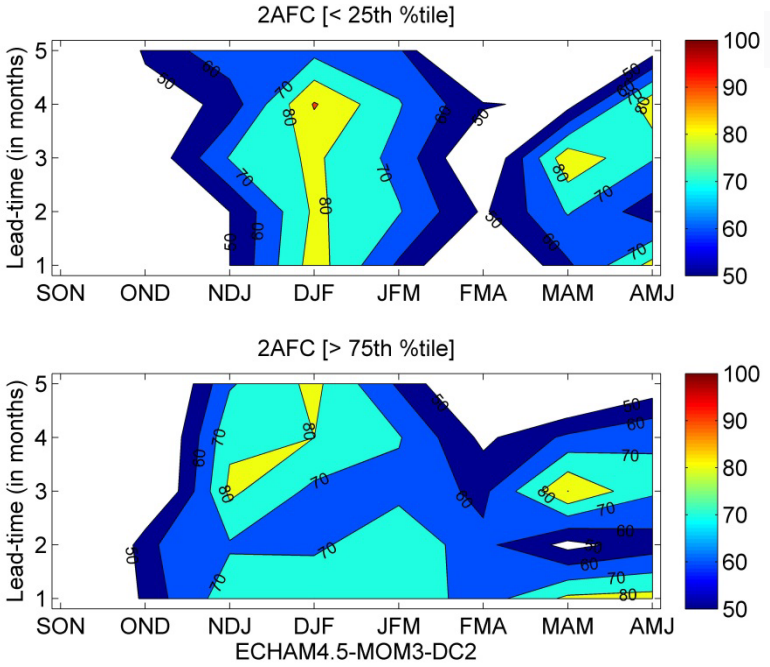




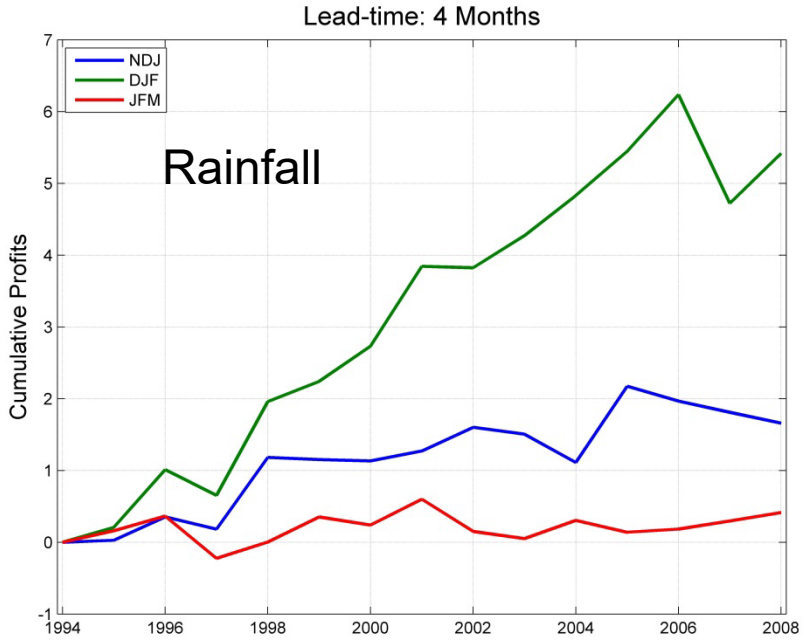


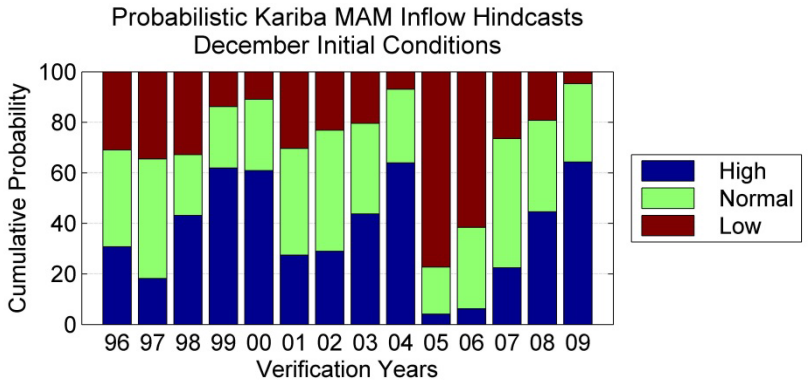
Kariba

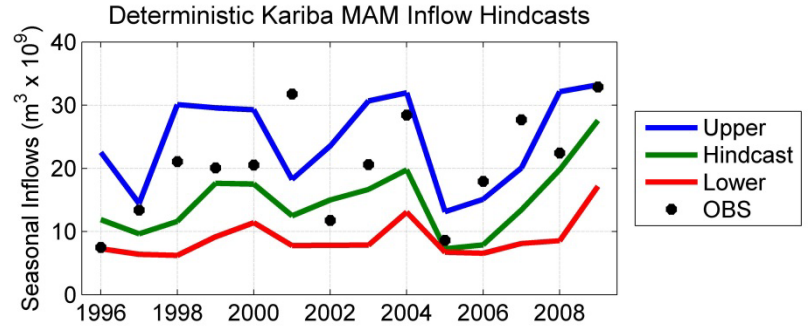




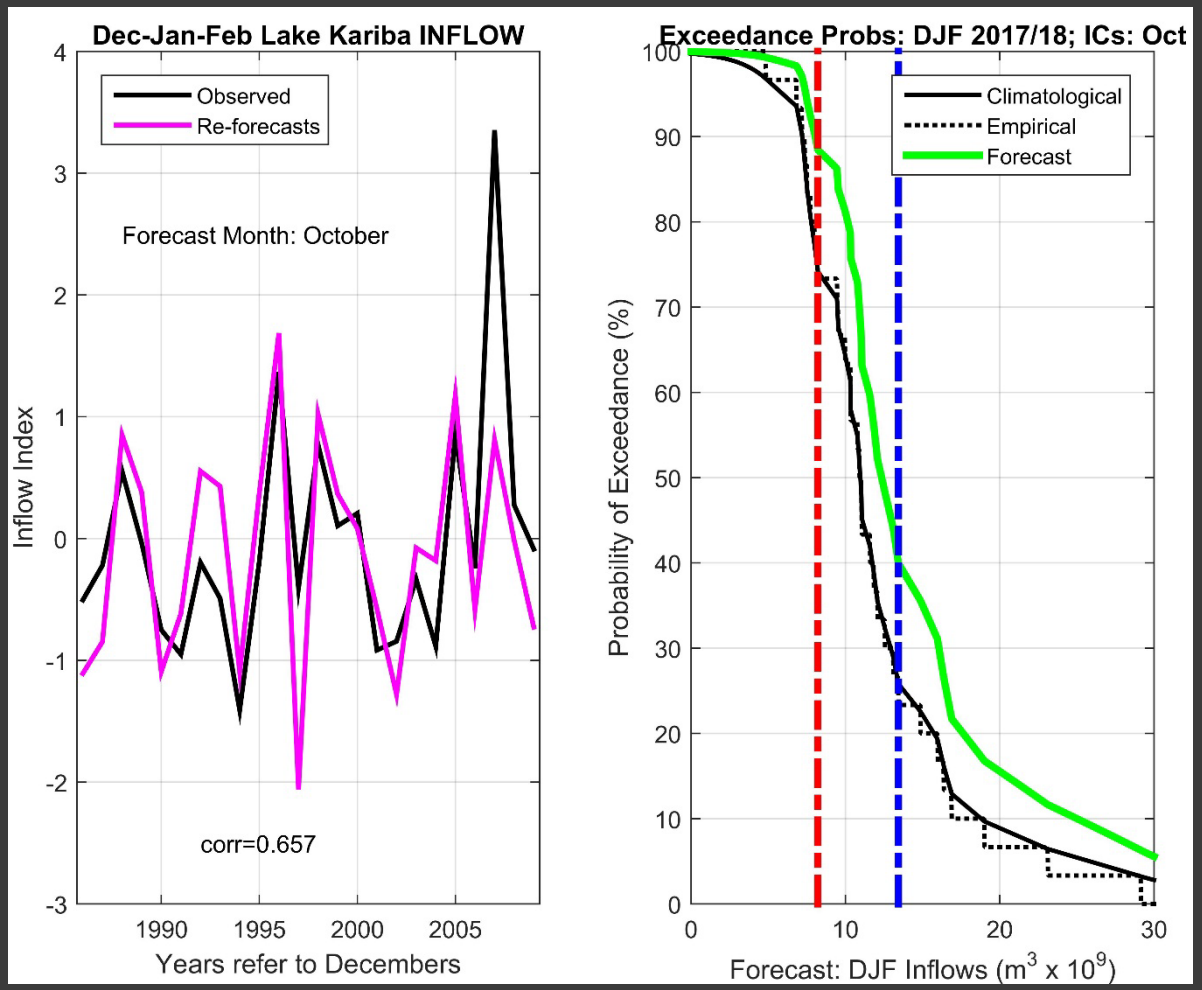
two-alternative forced choice (2AFC) score: probability of a correct decision

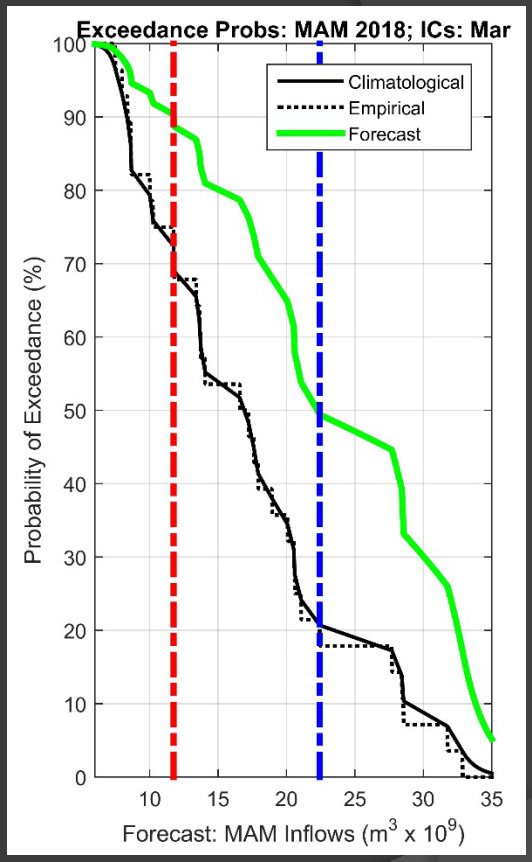






…if forecast is not used…





First 1/3 of April
2016 ~20%
2017 ~40%
2018 ~60%

Dam Levels as at 29-March-2018

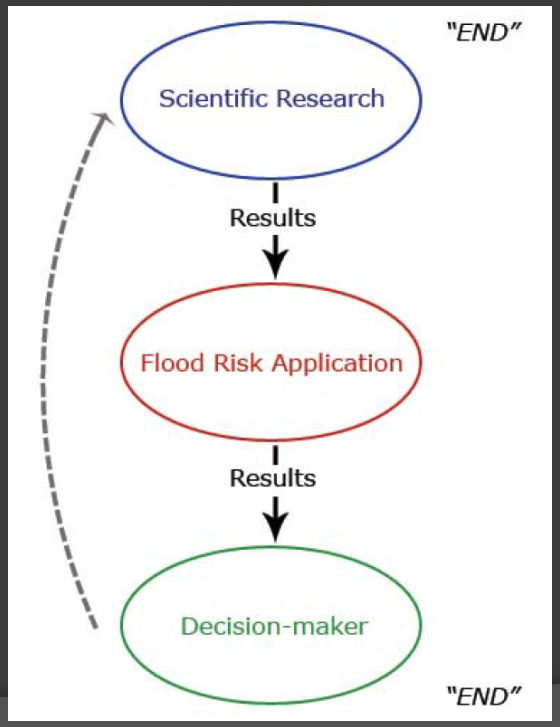
DAM NAME	FULL SUPPLY CAPACITY (millions of cubic metres)	CURRENT CAPACITY (millions of cubic metres)	% FULL	DAILY TREND
Kariba	64800.00	37216.6	57.4	↑

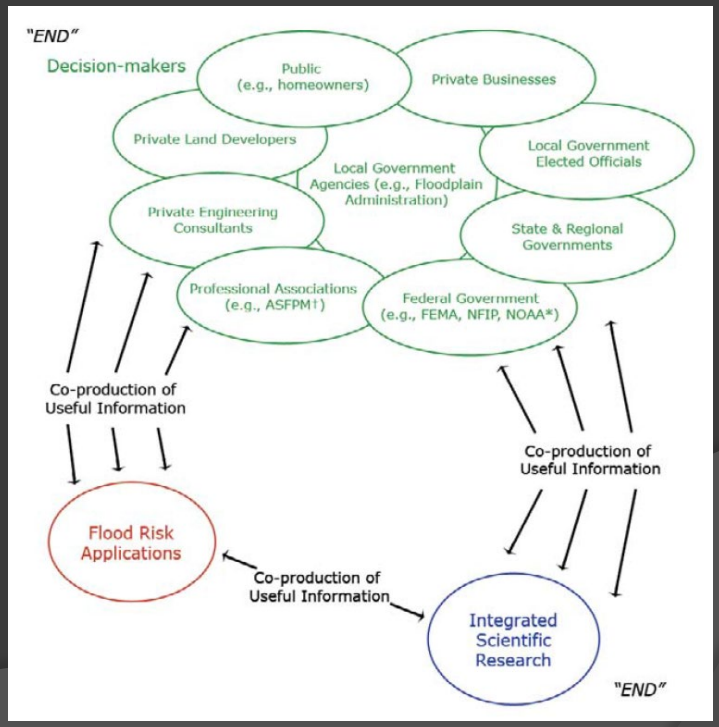
FLOOD RISK, UNCERTAINTY, AND SCIENTIFIC INFORMATION FOR DECISION MAKING

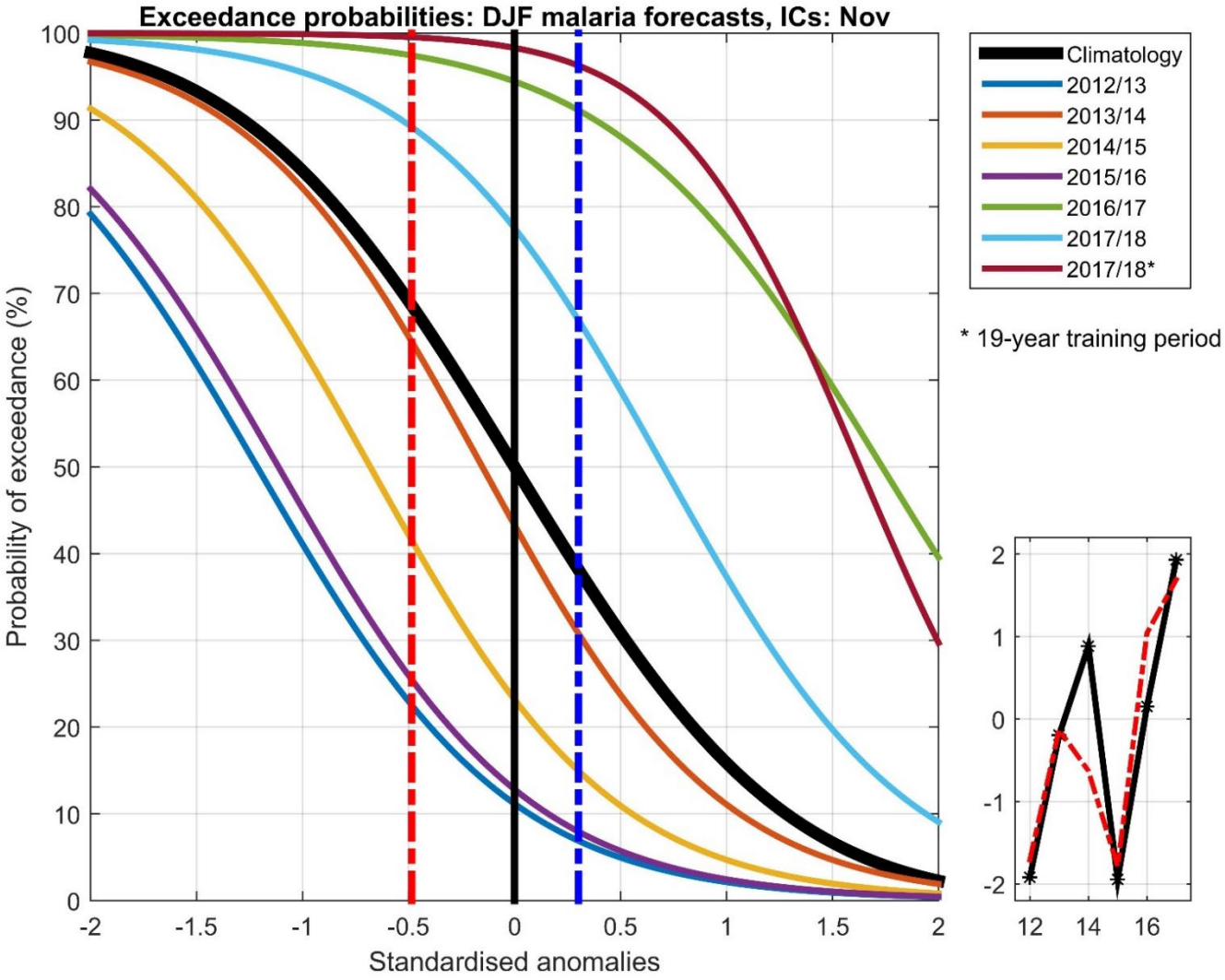
Lessons from an Interdisciplinary Project

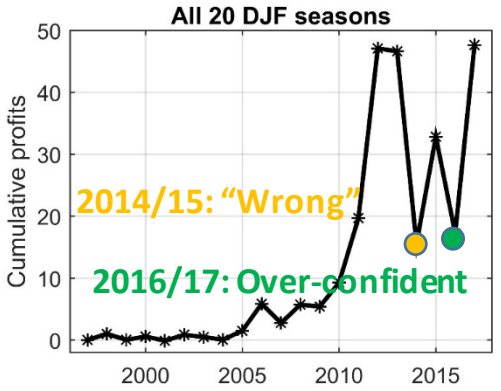
BY REBECCA E. MORSS, OLGA V. WILHELMI, MARY W. DOWNTON, AND EVE GRUNTFEST

This essay discusses the complex ways in which scientific information and uncertainty can interact with societal decision making, and proposes a collaborative, integrated approach to societally useful scientific research.









1. DJF malaria model **trained on 14 years** of data – then produced forecasts for the **next 6 years**
2. For **2017/18**, model trained on **19 years**
3. In general the forecasts seem to have been useful, **except for the 2014/15** when its PoE curve is predicted to be on the left of the climatological curve, while the observed outcome is for malaria cases to be close to one standard deviation above average

- One of four new climate-based malaria incidence/outbreak prediction models
- Developed as part of the iDEWS project that included a number of modelling institutions as well as the Limpopo Department of Health