South African Seasonal Rainfall Prediction Performance by a Coupled Ocean-Atmosphere Model

Occam's razor:
Of two equivalent theories or explanations, all other things being equal, the simpler one is to be preferred

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CSIR
our future through science

IRI The International Research Institute for Climate and Society

South African Weather Service

Research questions

#1: Should available seasonal forecast modelling research and development in South Africa be directed towards coupled ocean-atmosphere models?

#2: Will AGCMs become redundant soon?

#3: With our latest modelling advances, have we reached the forecasting promised land yet? (what is it anyway?)

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Recent trends in sea level pressure in the Indian Ocean region

Dan Copsey,[1] Rowan Sutton,[1] and Jeff R. Knight[2]

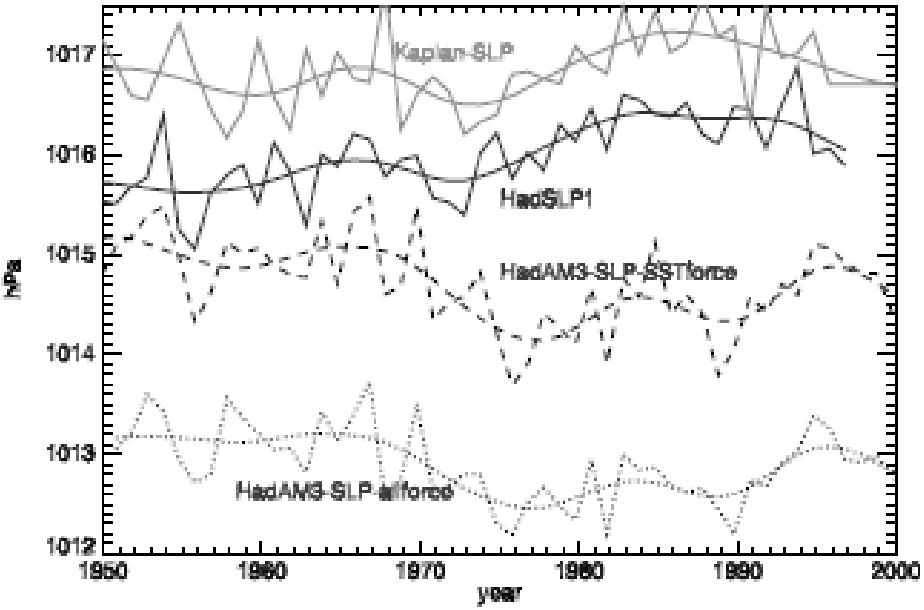

Figure 4. Timeseries of SLP in the southwest Indian Ocean (45°E–80°E, 10°S–30°S) from the ensemble means of HadAM3 forced with just SSTs (dashed), HadAM3 with all the forcings (dotted), HadSLP1 (black) and Kaplan (grey). The annual means are shown plus those computed using a low pass filter (19 point Henderson filter).

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Impact of the Indian Ocean on ENSO variability in a hybrid coupled model

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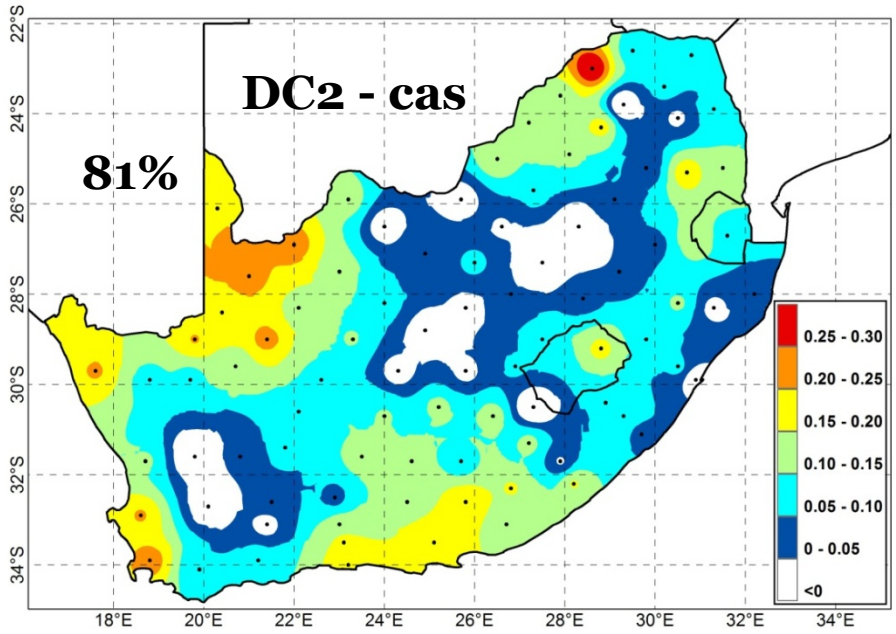
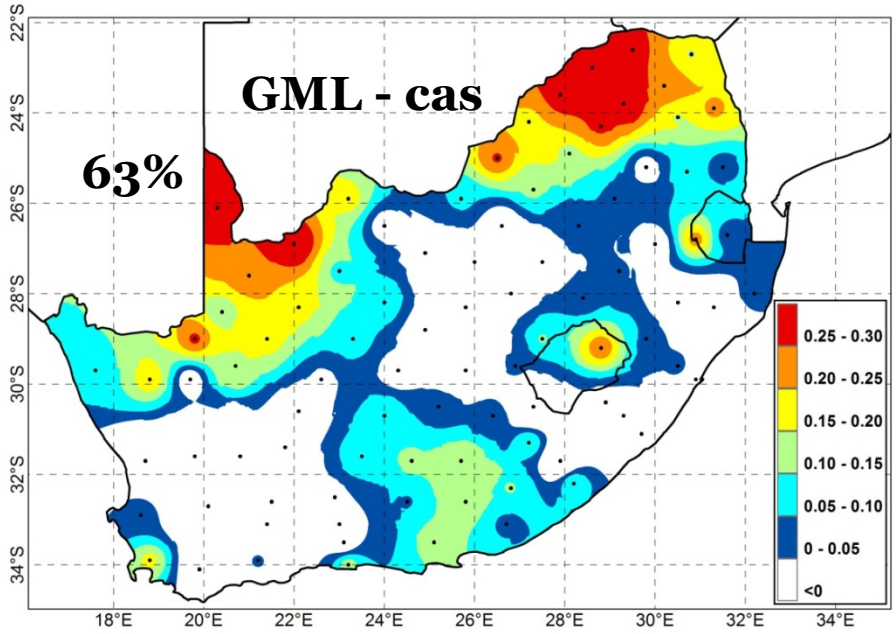
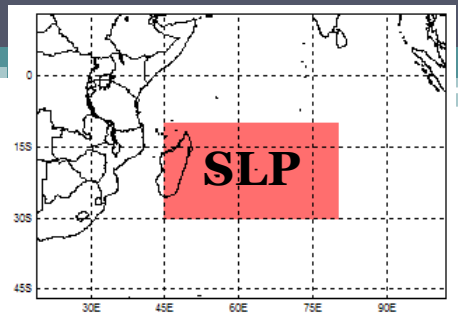
"...air-sea coupling in the Indian Ocean is necessary for simulating the Indian monsoon-ENSO relationship and for studying the influence of the Indian Ocean on the ENSO variability".







A statistical model used Indian Ocean SLP as PREDICTOR field, forecast (cross-validated over 27 years) by

1. An AGCM (2-tiered)
2. Two CGCMs (1-tiered)

at a 1-month lead-time

To predict DJF district rainfall…

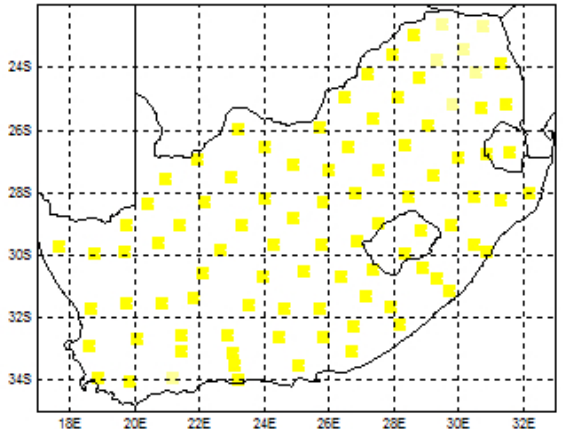
The map shows the Kendall's tau differences:

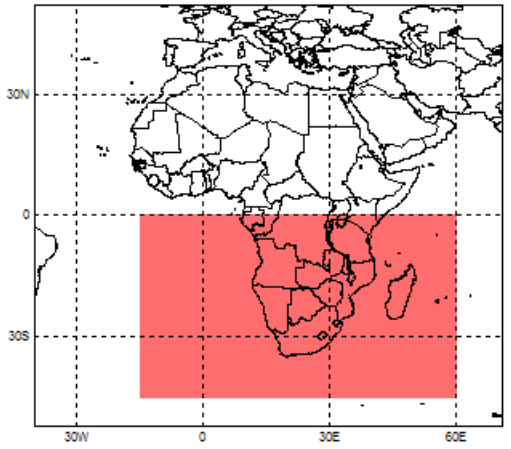
CGCMs – AGCM

Conclusion:
CGCMs' IO SLP is a better predictor (larger area covered) of SA's mid-summer rainfall variability than AGCM IO SLP

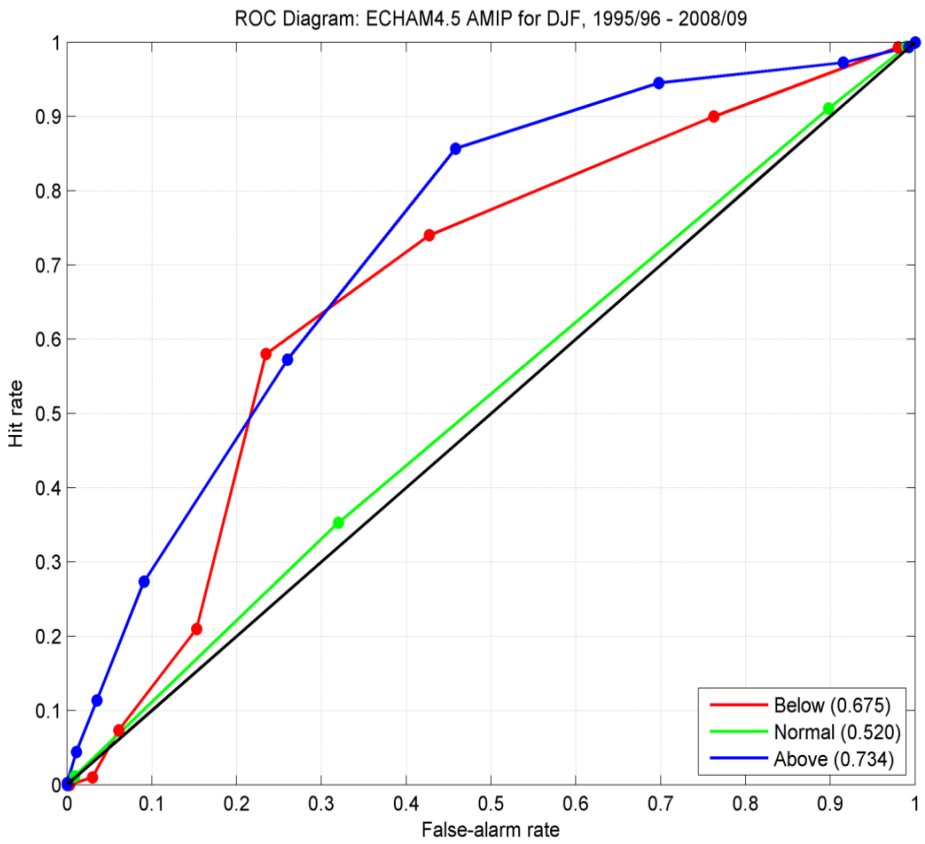
Experimental design

- ECHAM4.5
  - AGCM1: AMIP (24 members)
  - AGCM2: Constructed analogue SST (24 members)
  - CGCM1: MOM3-DC2 (12 members)
  - CGCM2: GML (slab) (12 members)
- 850 hPa geopotential height fields downscaled to 93 rainfall districts
- Initial training period
  - 1982/83 – 1995/96 (13 or 14 years)
- Retro-active test period
  - 1996/97 – 2008/09 (14 years)
  - SON, OND, NDJ, DJF, JFM and FMA





Relative operating characteristics – a measure of discrimination



ROC applied to probabilistic forecasts indicates whether the forecast probability was higher when an event such as a flood season occurred compared to when it did not occur, and therefore identifies whether a set of forecasts has the attribute of discrimination

If forecasts are good, the hit rate will accumulate faster than the FAR, and so the graph will curve towards upper left

ROC = 0.734 for above-normal: There is a greater than 70% probability that the forecasts can successfully discriminate an above-normal season from other seasons

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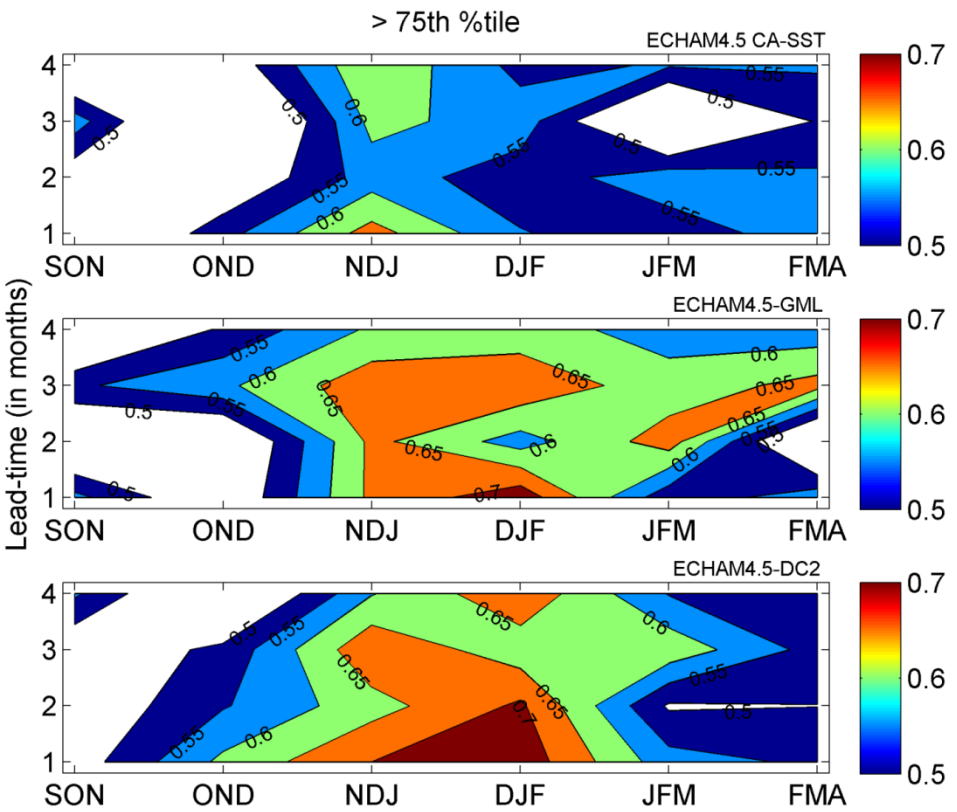

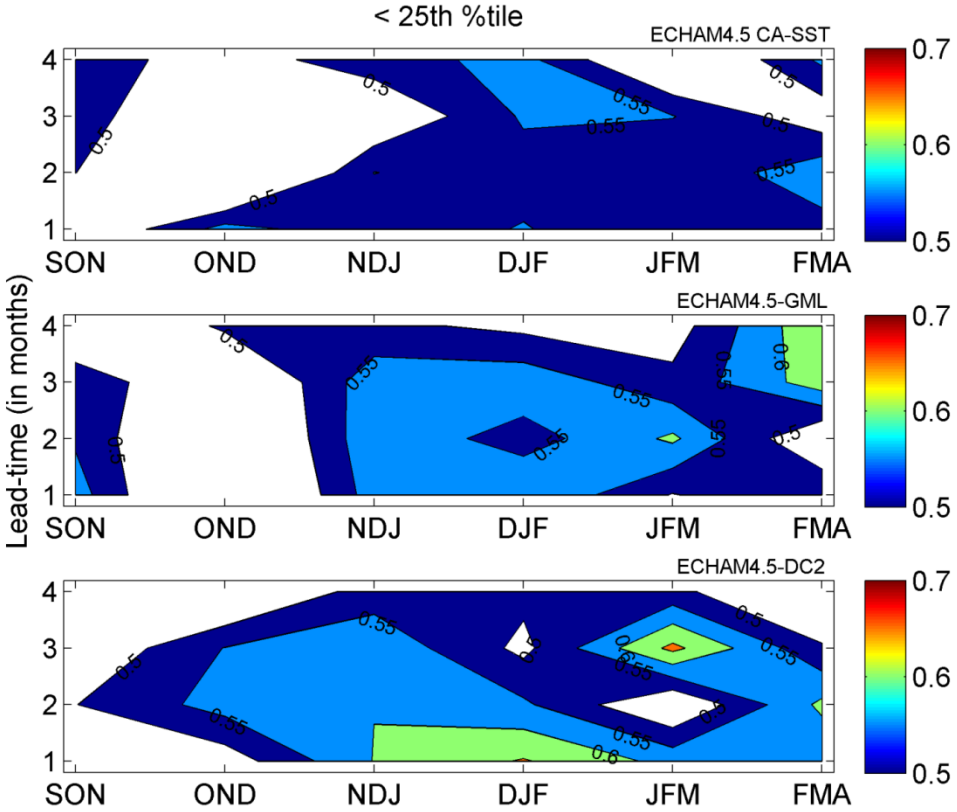

ROC scores for 6 seasons at various lead-times

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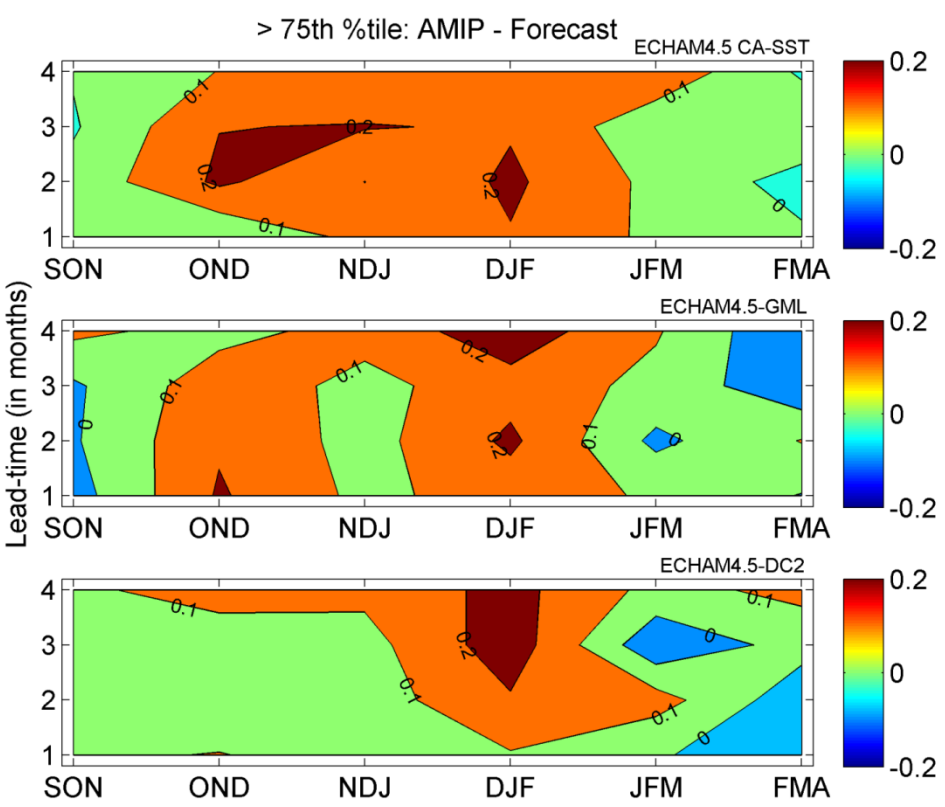
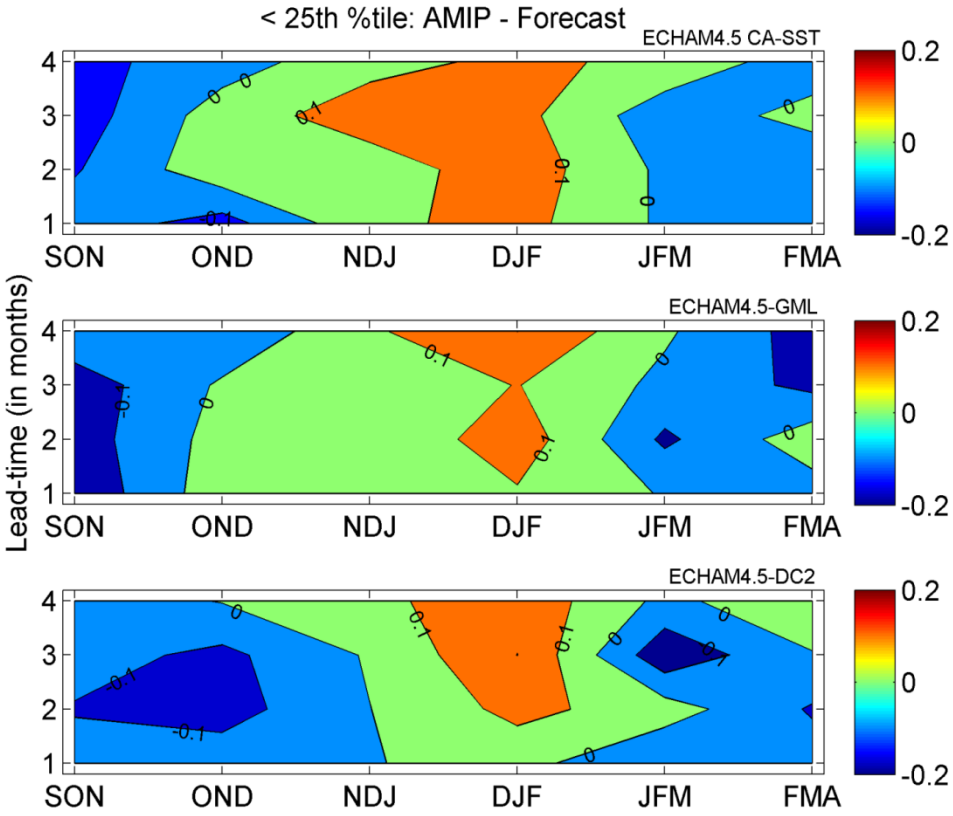


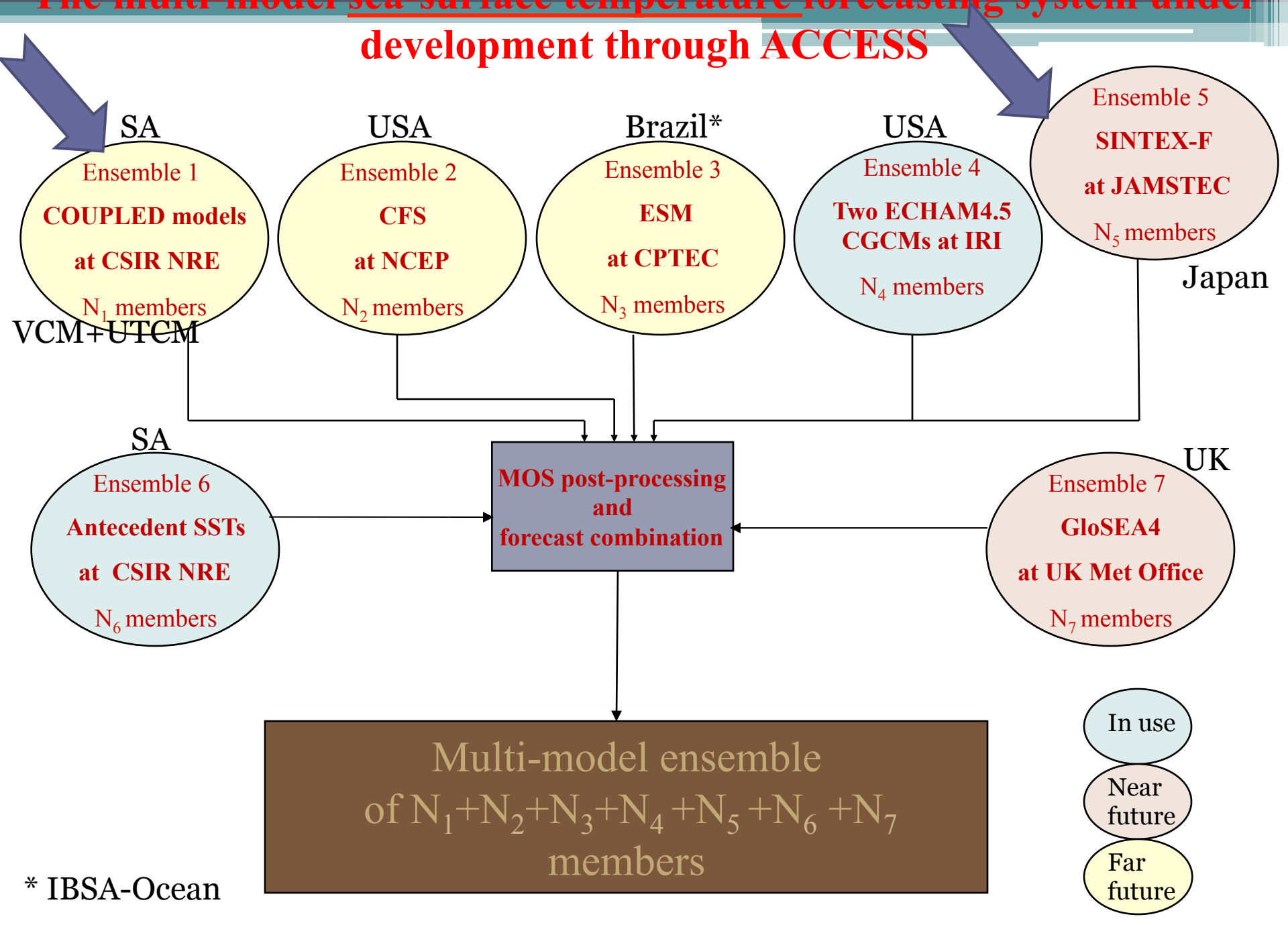


ROC score differences between AMIP and forecasts

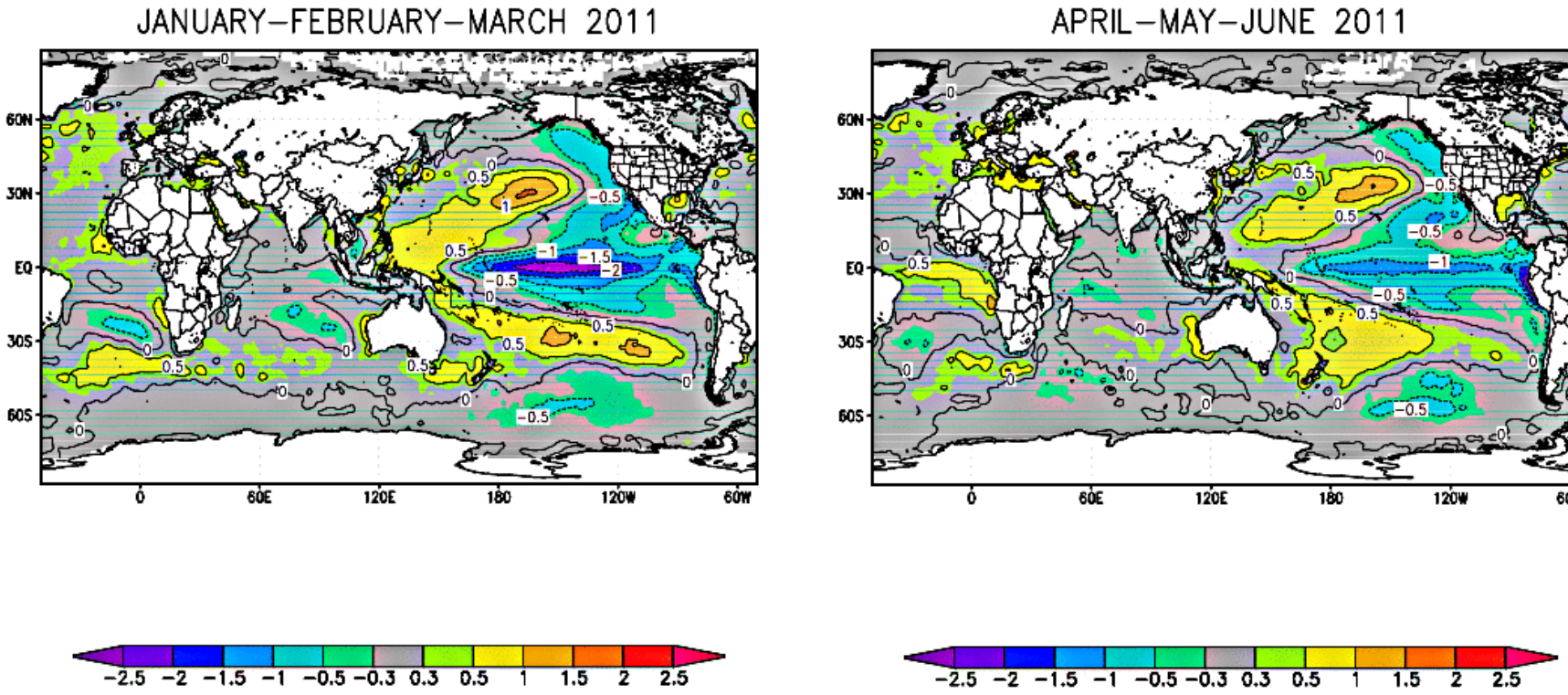
Answering the questions… (#1&#2)

- In general, the *forecast* systems that use coupled model forecasts outscore the atmosphere-only system that uses predicted SST
- However, for the season of highest predictability (DJF), AMIP-type simulations are the best
  - This means that AGCM mid-summer rainfall forecast skill can be further improved by improving the SST forecasts – and to achieve this we are developing MME SST forecasts…

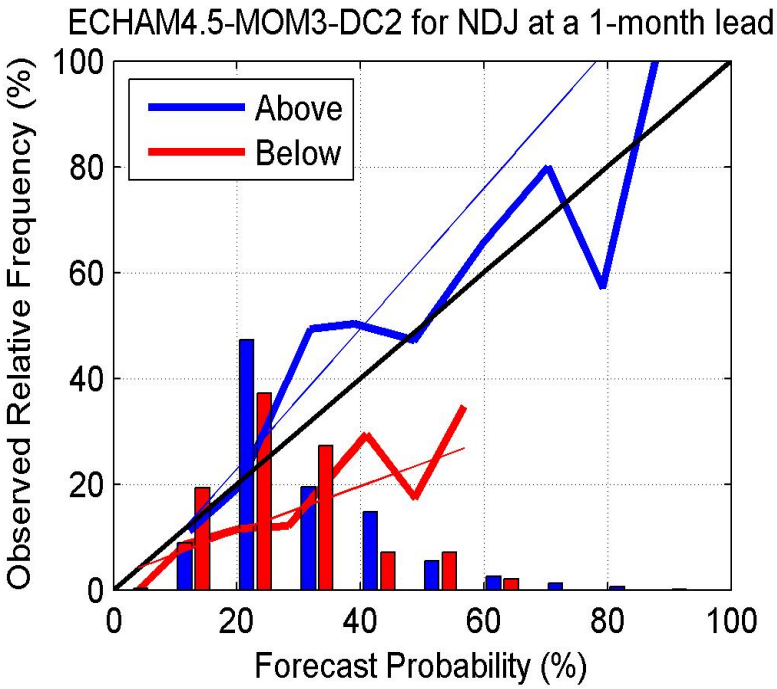
The multi-model sea-surface temperature forecasting system under development through ACCESS



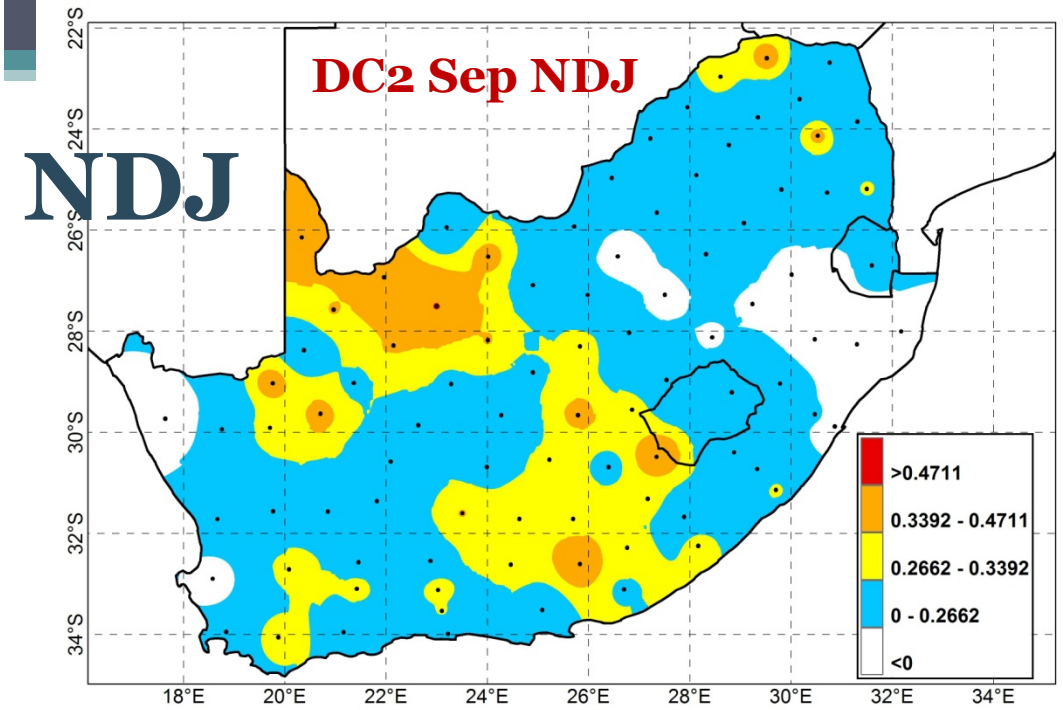
Current global SST anomaly forecasts



With improved SST forecasts, the ECHAM4.5 AGCM could perform just as well as its coupled versions. AGCMs are therefore here to stay for quite a while longer, also because they are cheaper to run than CGCMs and can therefore, by utilizing the same computational resources, be used for higher resolution runs and for the generation of more ensemble members


ECHAM4.5-MOM3-DC2 for NDJ at a 1-month lead
Above
Below
Observed Relative Frequency (%)
Forecast Probability (%)
0
20
40
60
80
100

NDJ


DC2 Sep NDJ
>0.4711
0.3392 - 0.4711
0.2662 - 0.3392
0 - 0.2662
<0
22°S
24°S
26°S
28°S
30°S
32°S
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18°E
20°E
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24°E
26°E
28°E
30°E
32°E
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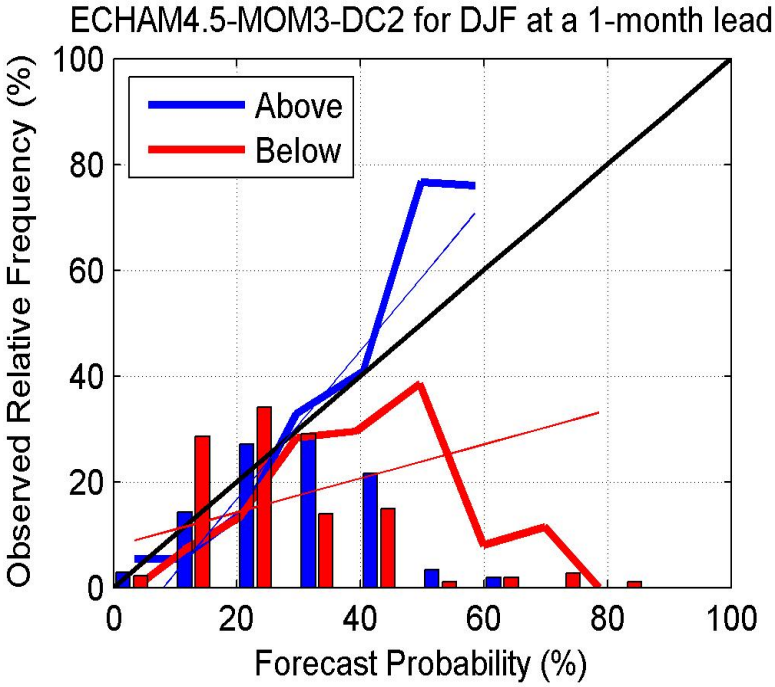
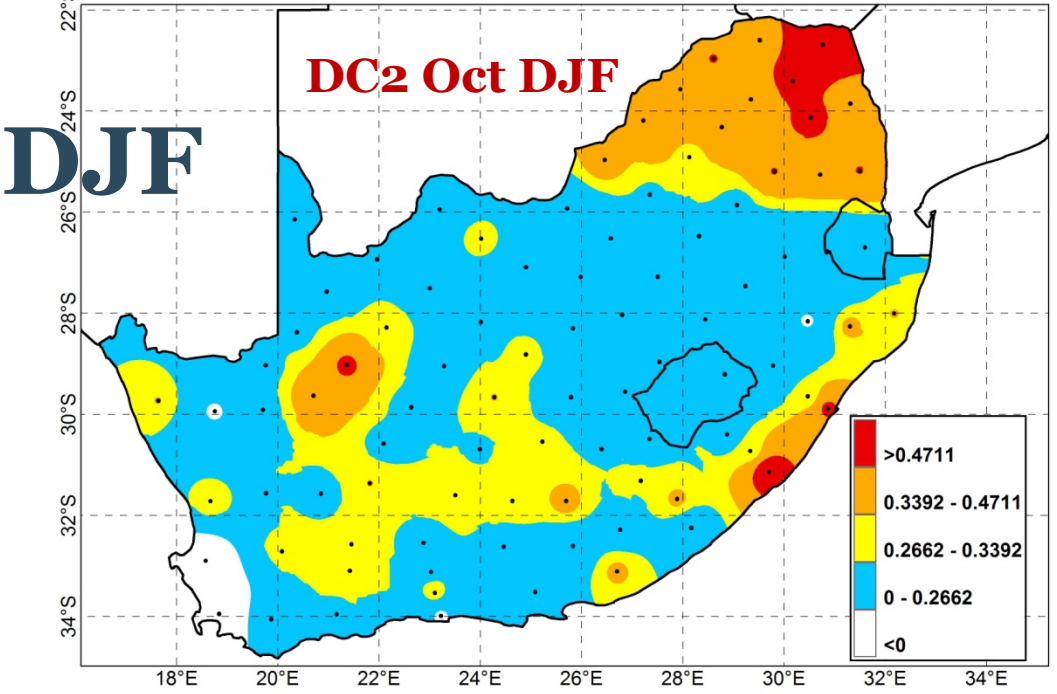
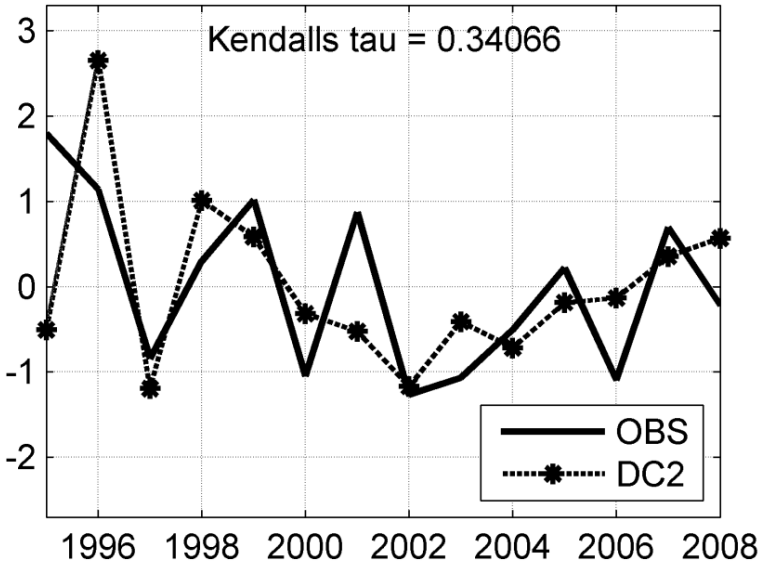

ECHAM4.5-MOM3-DC2 for DJF at a 1-month lead
Above
Below
Observed Relative Frequency (%)
Forecast Probability (%)
0
20
40
60
80
100

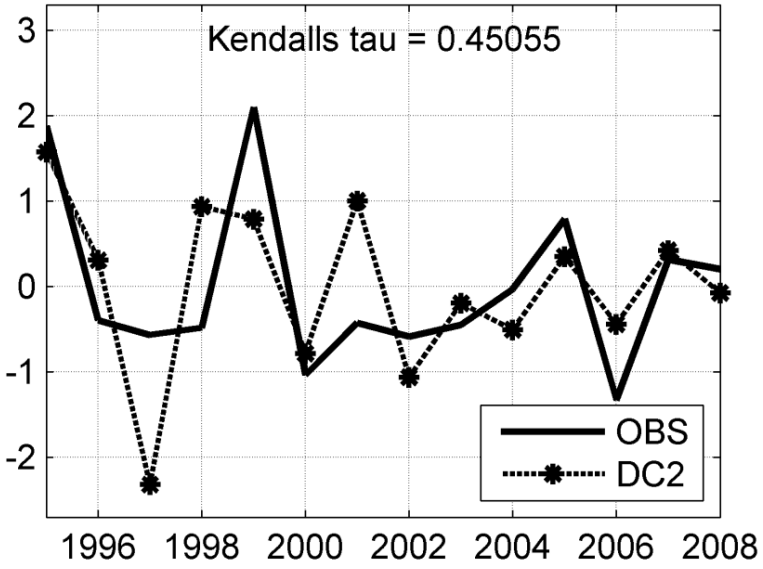
DJF


DC2 Oct DJF
>0.4711
0.3392 - 0.4711
0.2662 - 0.3392
0 - 0.2662
<0
22°S
24°S
26°S
28°S
30°S
32°S
34°S
18°E
20°E
22°E
24°E
26°E
28°E
30°E
32°E
34°E

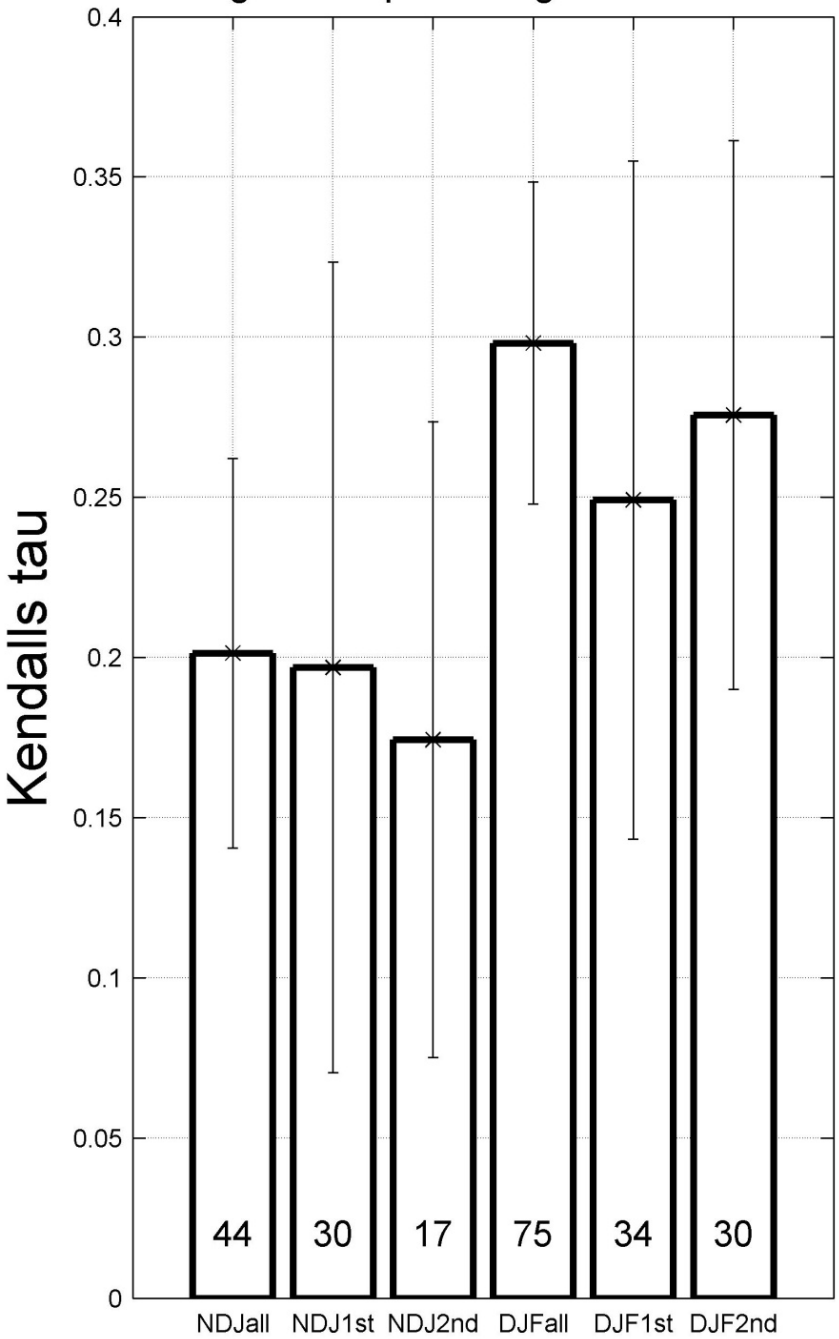
November-December-January



December-January-February



Area-averaged skill predicting NDJ and DJF rainfall



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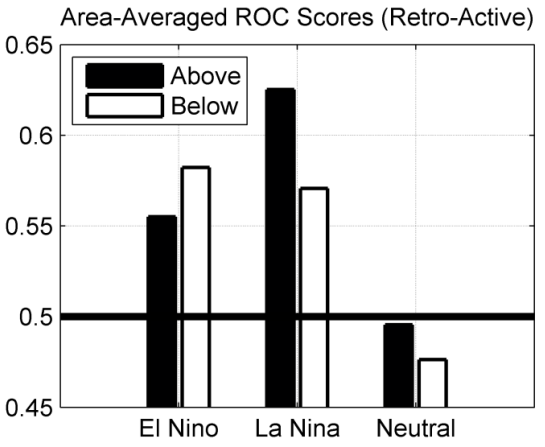
Significant forecast skill most likely to be found only for mid-summer rainfall variability

Large forecast errors are still occurring, notwithstanding

Forecast skill a function of location

Poor predictability during spring and autumn seasons, making seasonal onset and cessation forecasting challenging (to say the least!)

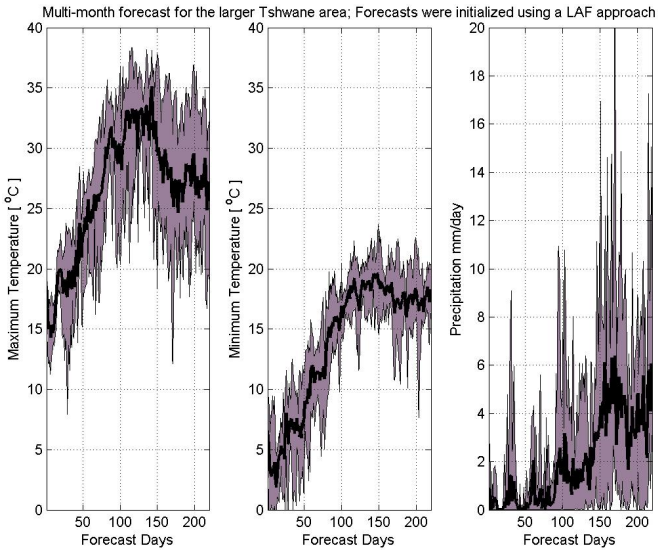
From previous work (Landman & Beraki, 2011 IJoC):
Predictability mostly assoc. with ENSO seasons

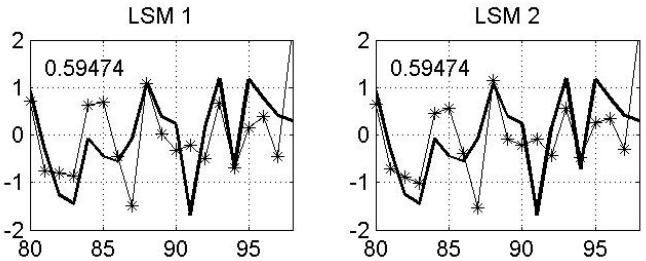


With the limitations of seasonal forecasting in mind and the large emphasis on climate change modelling in the region, how can funding agencies be convinced that more funds should be directed towards this time scale?

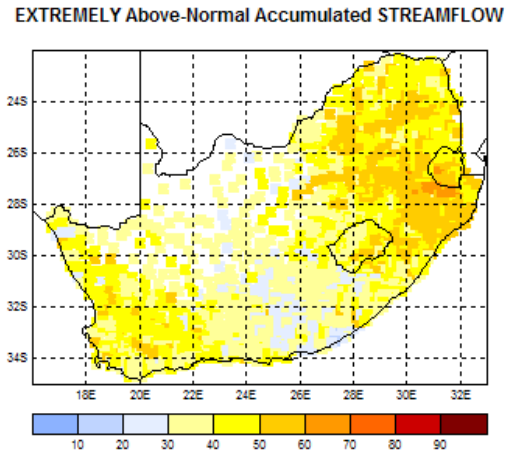
Answering the questions… (#3)

- Although further improvements are possible, seasonal forecasts may never be as skilful as weather forecasts, but that should not stop us to use them in order to:
  - Predict for intra-seasonal characteristics
  - Applications modelling, for example:
    - Agricultural production
    - Streamflow





Simulated crop production for the growing season



DJF 1999/2000 flooding; ECHAM4.5-MOM3-DC2 fully coupled model forecast late October 1999

The multi-model seasonal rainfall and surface temperature forecasting system for SADC under development through ACCESS