Operational Seasonal Forecast System Development in South Africa

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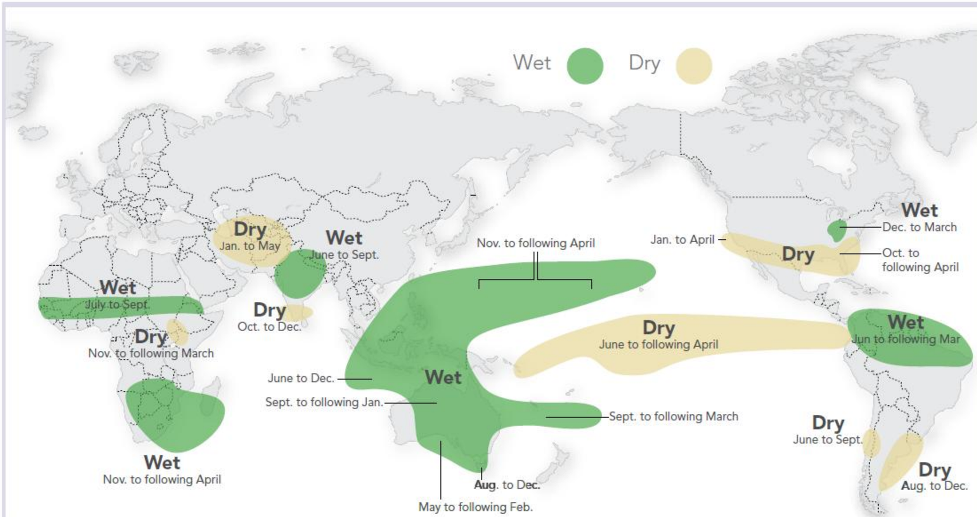
Asmerom Beraki

our future through science

South African Weather Service

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 varying somewhat from one La Niña to the next, the strongest shifts are fairly consistent in the regions and seasons shown on the map below.



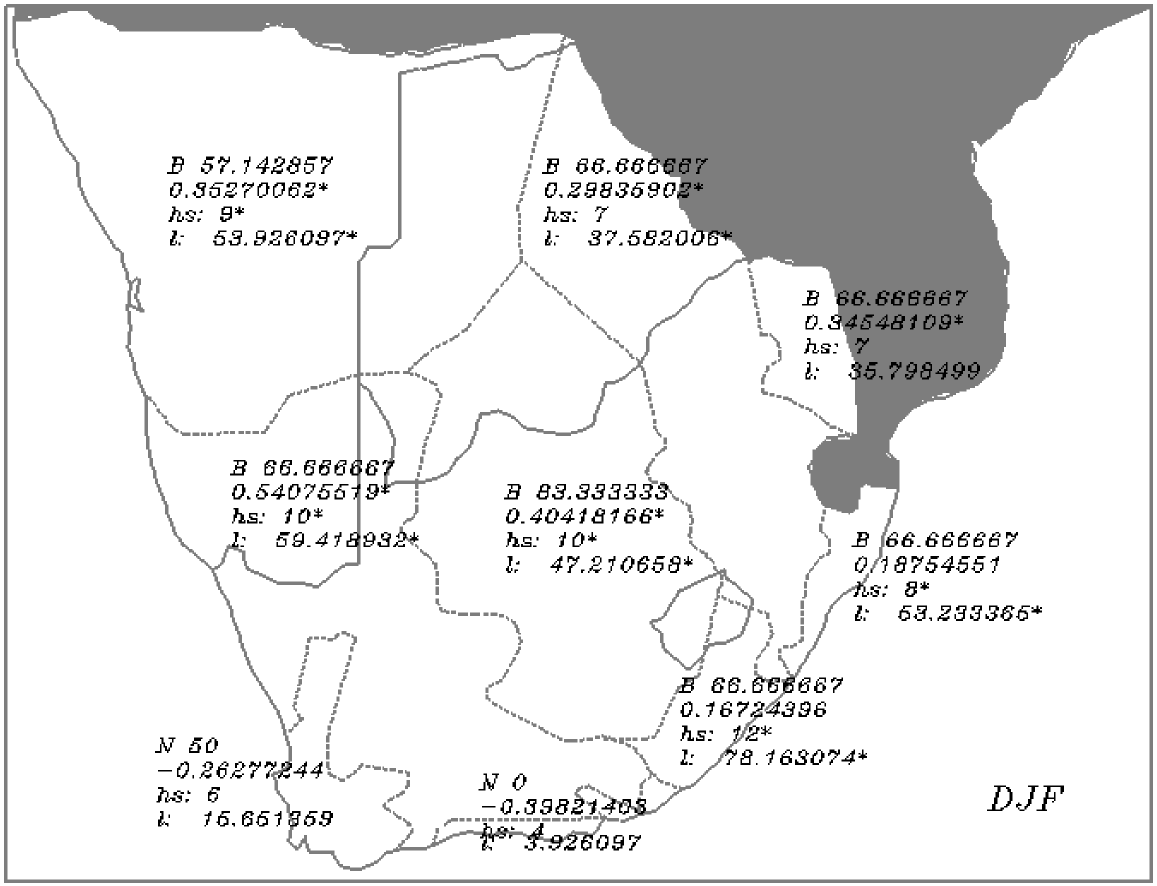
For more information on La Niña and EL Niño, go to: http://iri.columbia.edu/ENSO

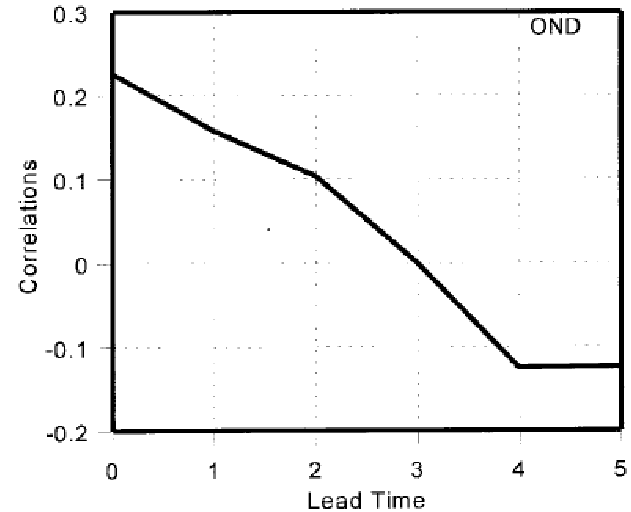
Sources: Ropelewski, C. F. and M. S. Halpert, 1989: Precipitation patterns associated with the high index phase of the Southern Oscillation. J. Climate., 2, 268 284,
Mason and Goddard, 2001. Probabilistic precipitation anomalies associated with ENSO. Bull. Am. Meteorol. Soc. 82, 619-638

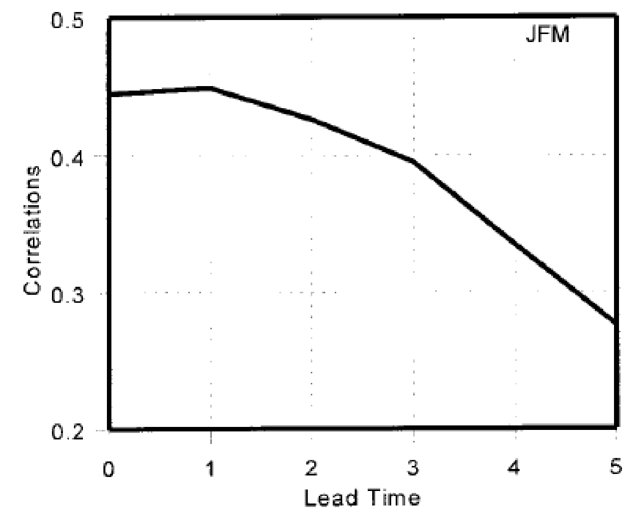
The evolution of the science of seasonal forecasting in southern Africa

- Model/system development started in early 1990s – SAWS, UCT, UP, Wits (statistical forecast systems)
- South African Long-Lead Forecast Forum
- SARCOF started in 1997 – consensus through discussions
- Late 1990s – started to use AGCMs and post-processing
  - At SAWS (COLA T30, then ECHAM4.5)
  - At UCT (HadAM3)
  - At UP (CSIRO-II/III, then CCAM)
- Global Forecasting Centre for Southern Africa – 2003
- Objective multi-model forecast systems – 2008
- Coupled model considerations – 2010 onwards

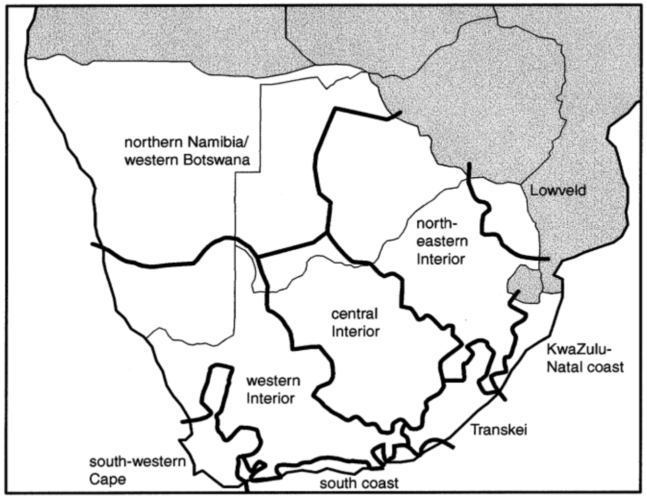
Deterministic statistical model (antecedent SST as predictor):

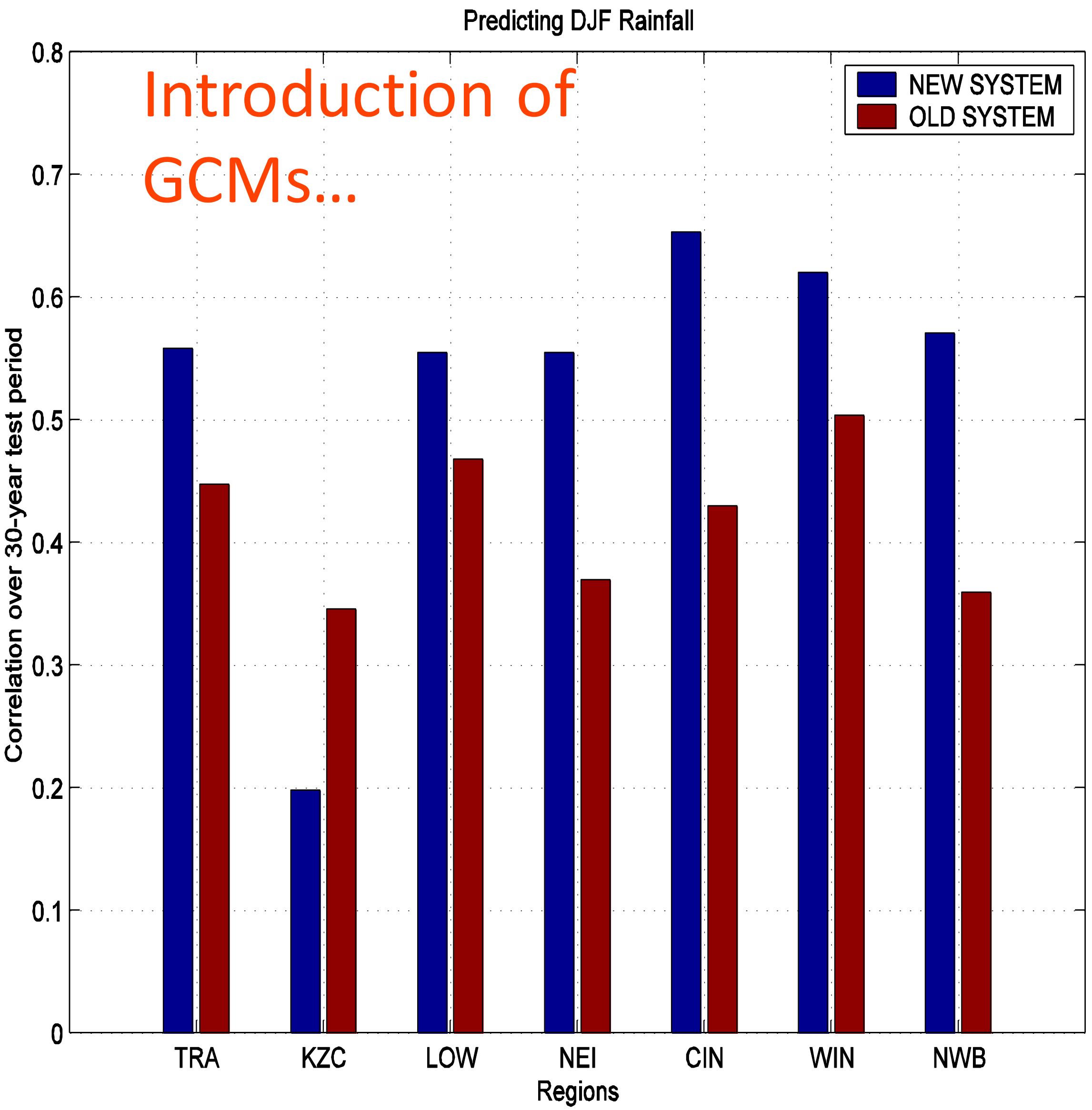




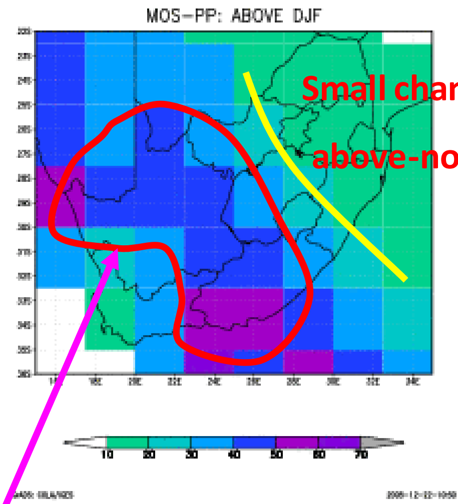


The seasonal forecast systems of the SAWS use the slow evolution of SSTs to make forecasts. In fact, improvements in the forecast systems have occurred owing to the better understanding of the **coupled ocean-atmosphere system** obtained through research at the SAWS and elsewhere.

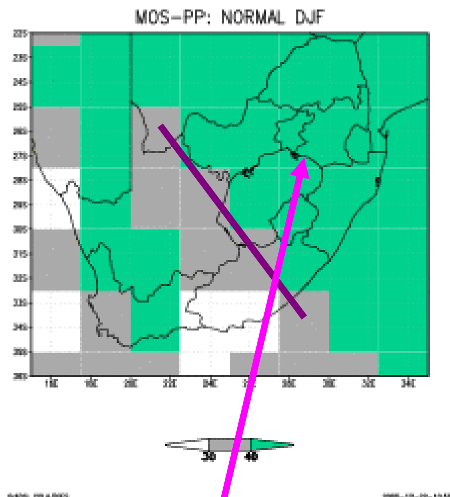


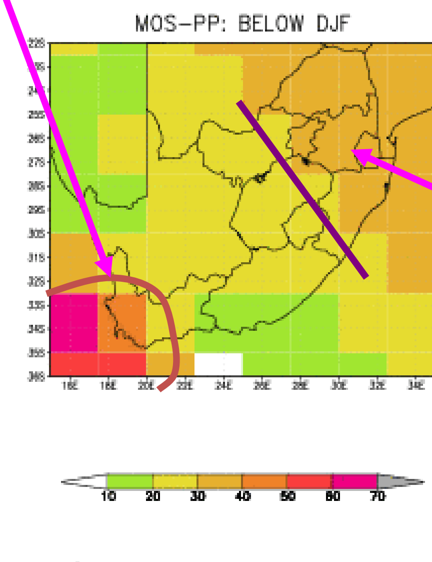


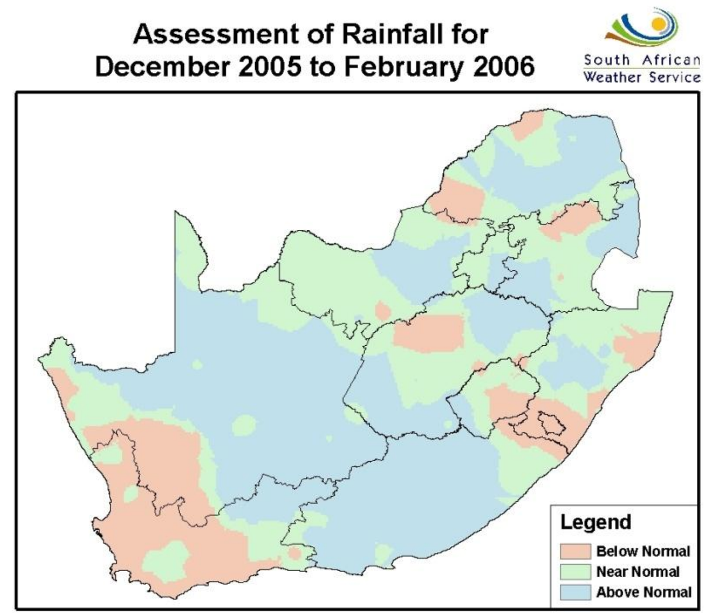
DJF 2005/06 forecast made early December



Enhanced probabilities



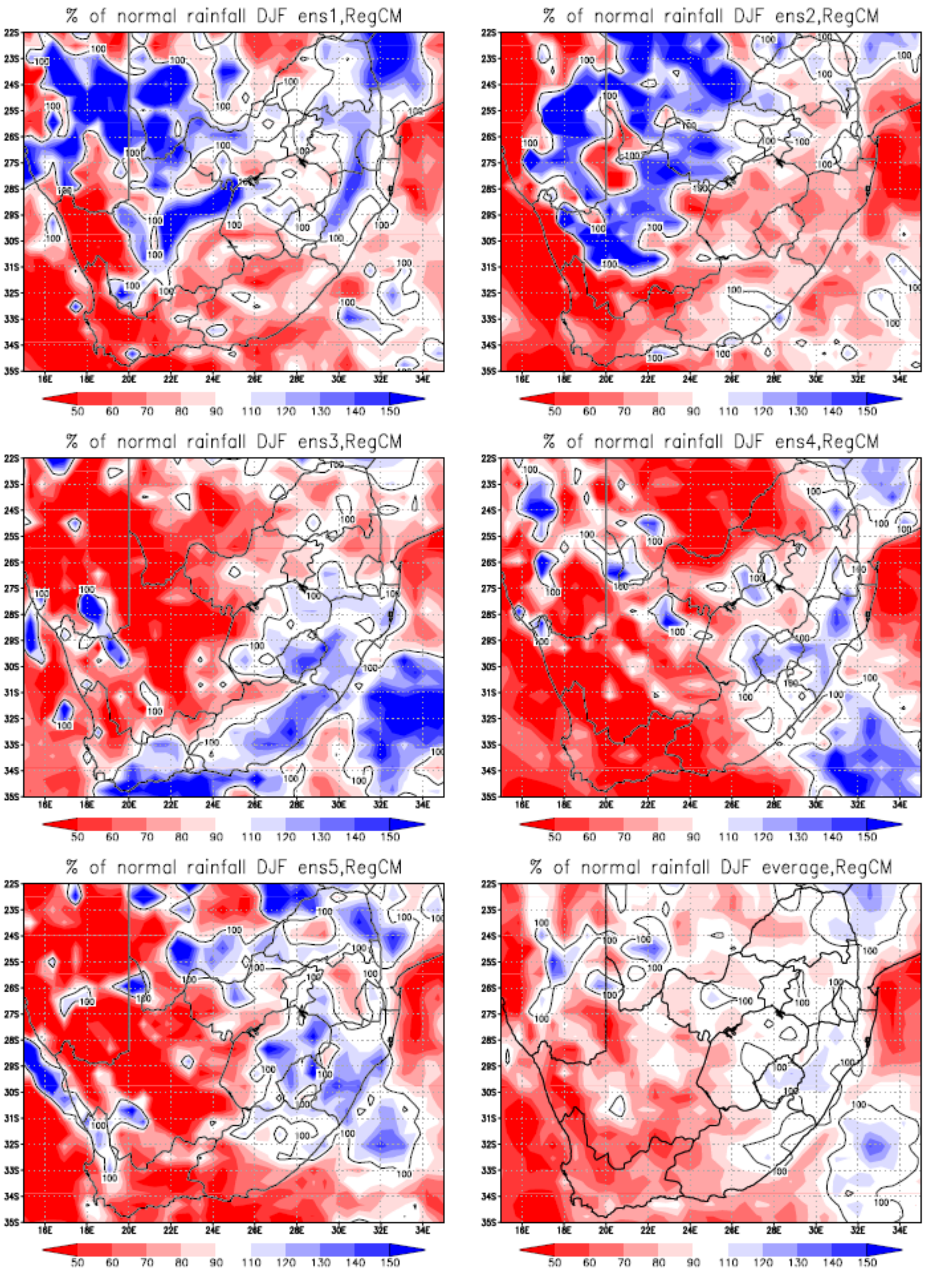




"Normal to below-normal" most likely

The MOS-PP-ECHAM4.5 system was successful in predicting enhanced probabilities of above-normal over the central-western parts and enhanced probabilities in below-normal over the south-western parts, but predicted only small probabilities of above-normal over the north-eastern parts

DJF forecasts using RCM



- First ever <u>operational</u> *regional climate model* forecast for southern Africa
- ECHAM4.5-RegCM3

Initiative lead by Mary-Jane Bopape and Maluta Mbedzi

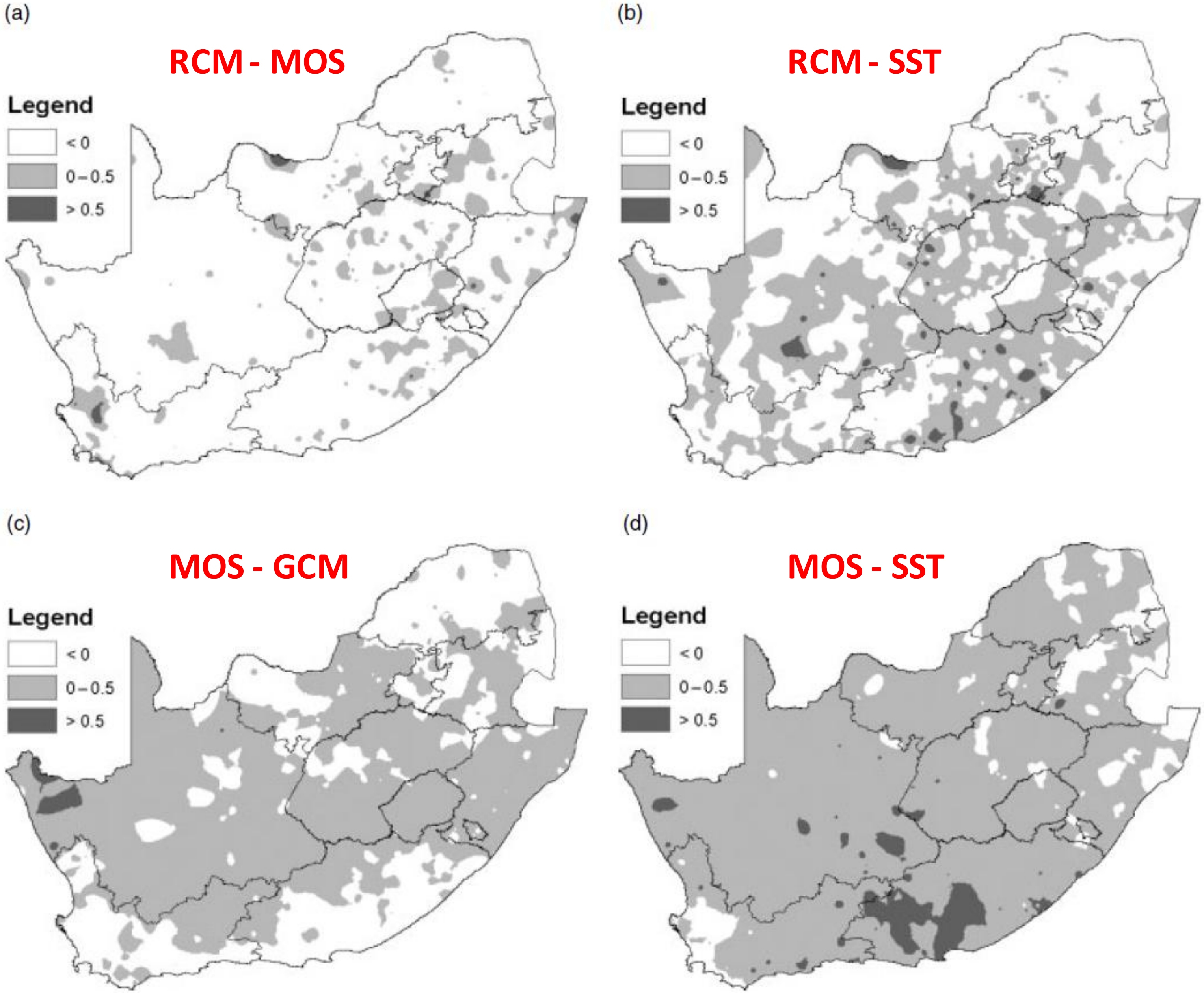


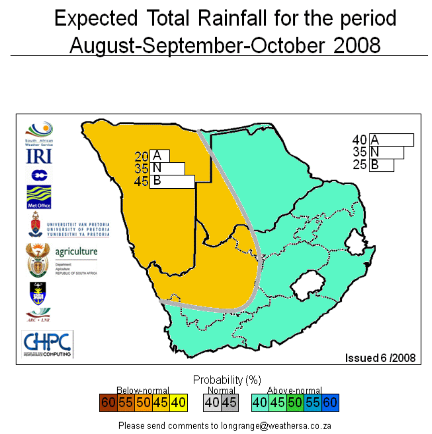
Figure 12. Correlation differences between the (a) ECHAM4.5-RegCM3 system and the ECHAM4.5-MOS system (24-member mean), the (b) ECHAM4.5-RegCM3 system and the baseline model (using SSTs to simulate rainfall), the (c) ECHAM4.5-MOS and the raw ECHAM4.5 systems (24-member mean), and the (d) ECHAM4.5-MOS (24-member mean) and the baseline system (using SSTs to simulate rainfall) over the 10-year test period. Negative values are masked out.

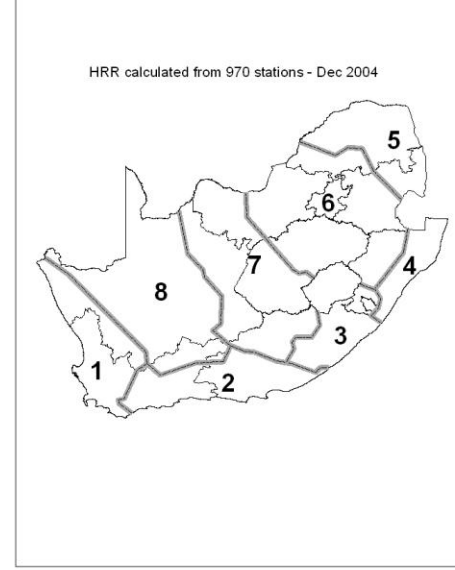
Operational Forecast Skill

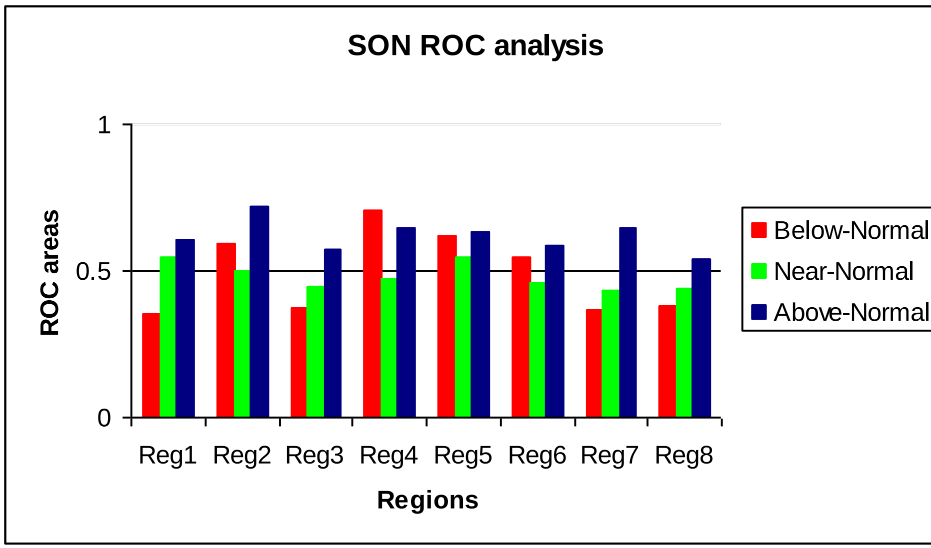
From CONSENSUS discussions

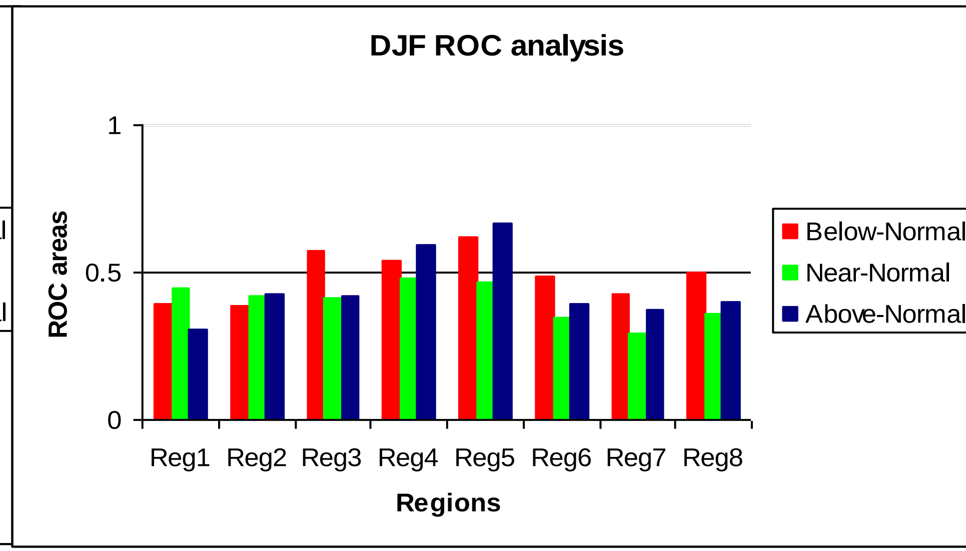
Verification work by Peggy Moatshe

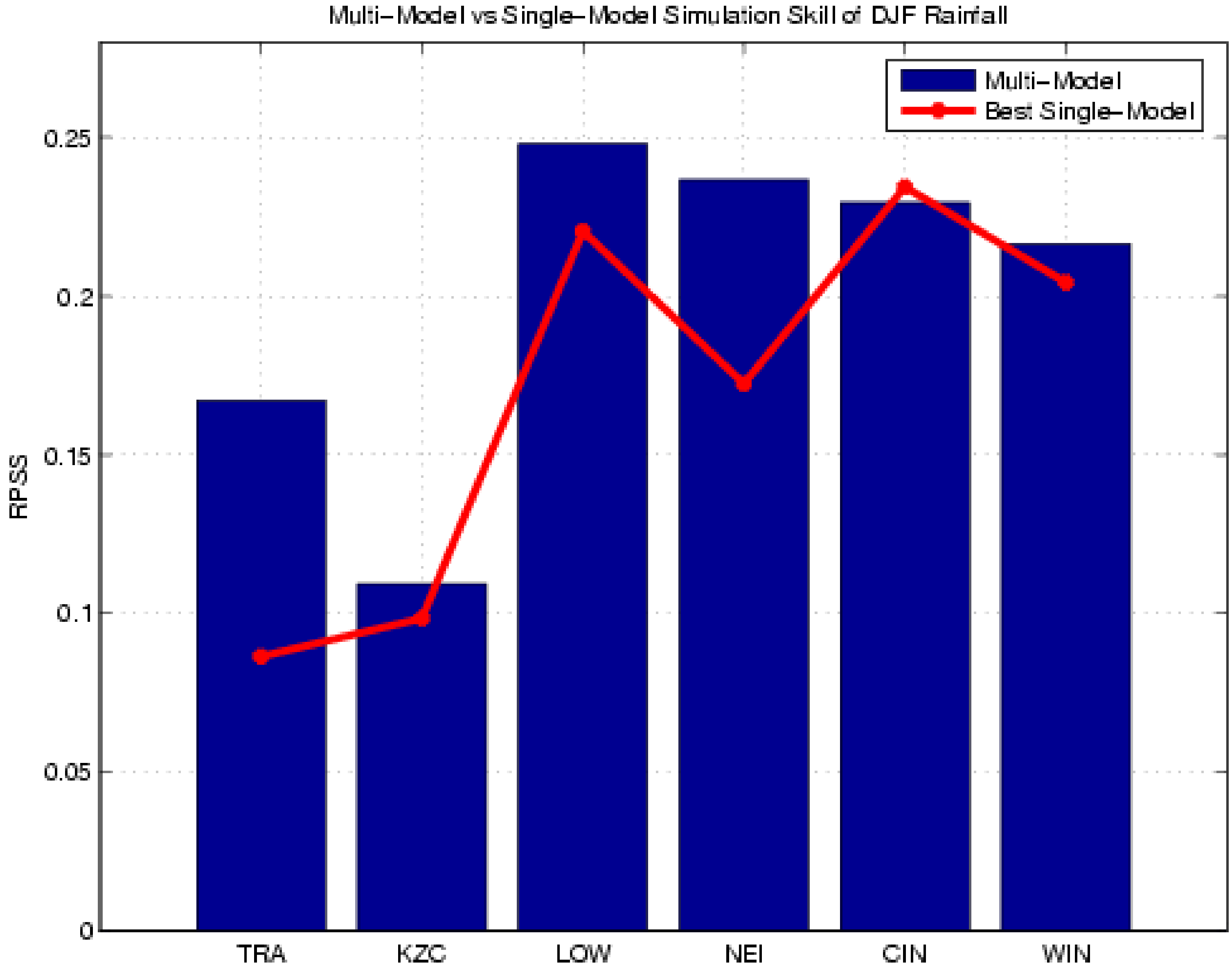
Verification over 7 years of consensus forecast production



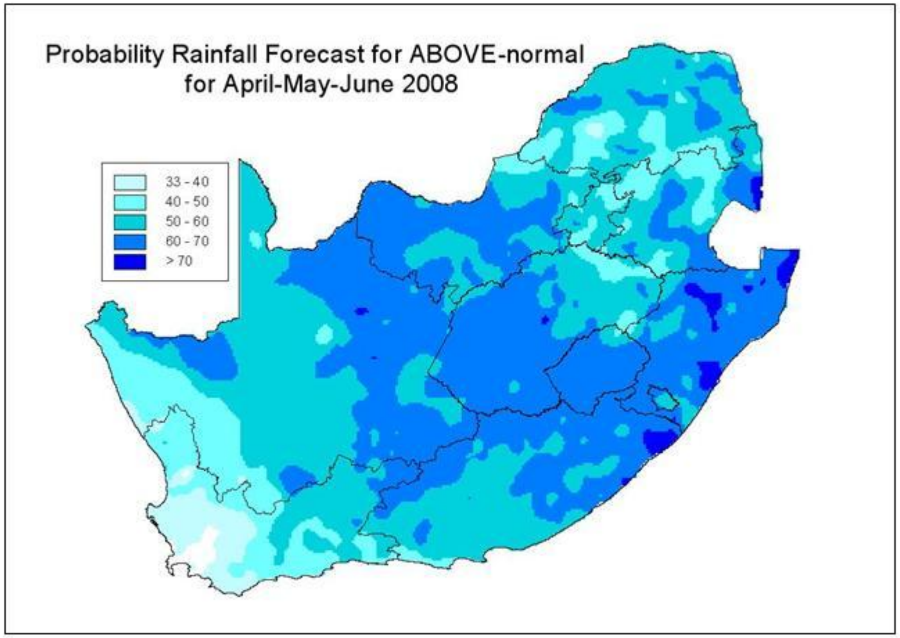




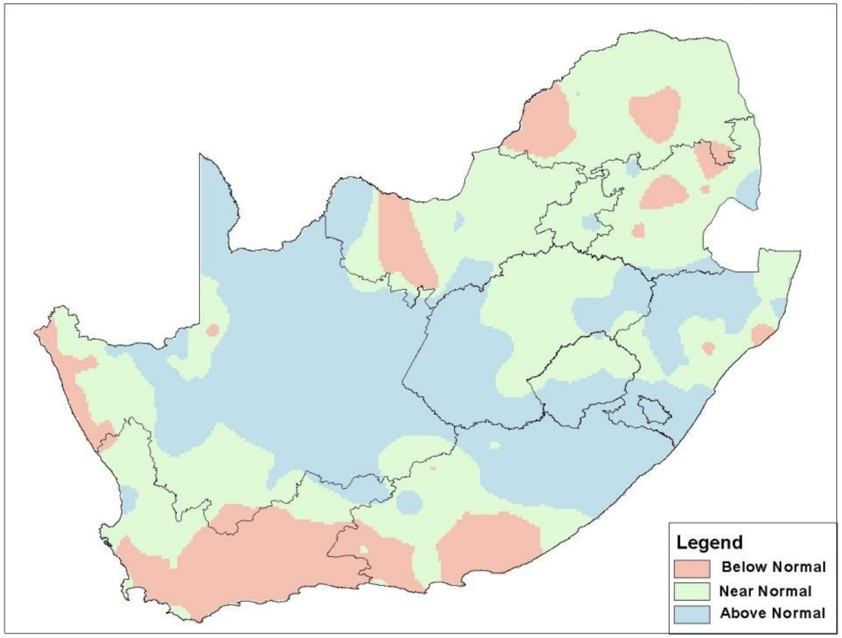


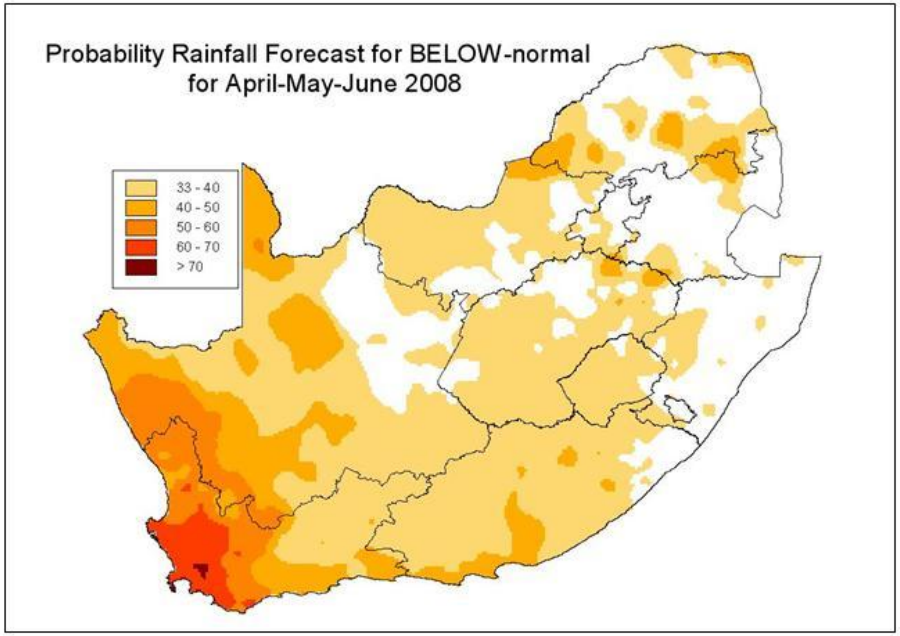

Multi−Model vs Single−Model Simulation Skill of DJF Rainfall
Multi−Model
Best Single−Model
RPSS
0.25
0.2
0.15
0.1
0.05
0
TRA
KZC
LOW
NEI
CIN
WIN

New objective multi-model forecast



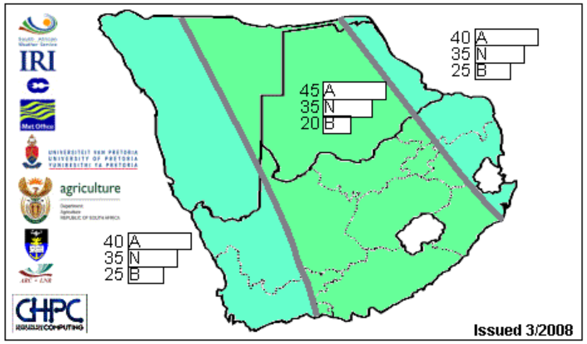
Assessment of Rainfall for
April to June 2008





Old subjective consensus forecast

Expected Total Rainfall for the period
April-May-June 2008



Probability (%)
Below-normal 60 55 50 45 40 Normal 40 45 Above-normal 40 45 50 55 60

Please send comments to longrange@weathersa.co.za

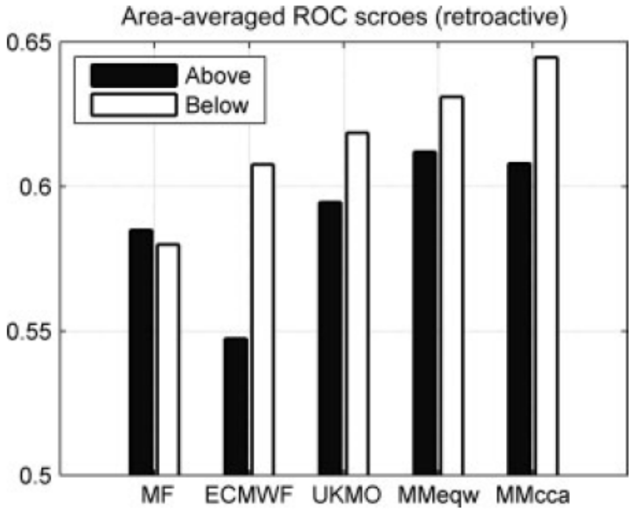


Figure 3. ROC scores, averaged over the southern African domain, for the above-normal and below-normal rainfall categories. Scores for the single models and for the two multi-models are shown.

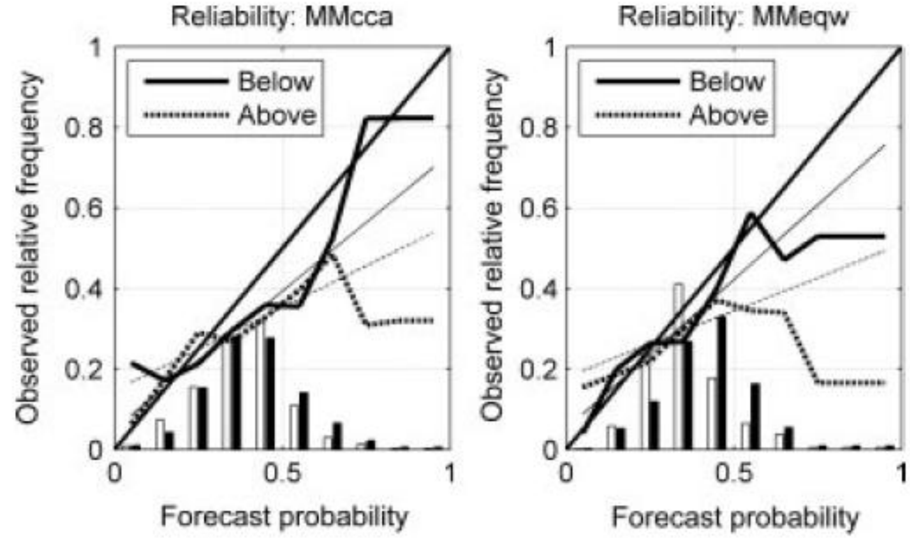


Figure 6. As in Figure 5, but for the two multi-models.

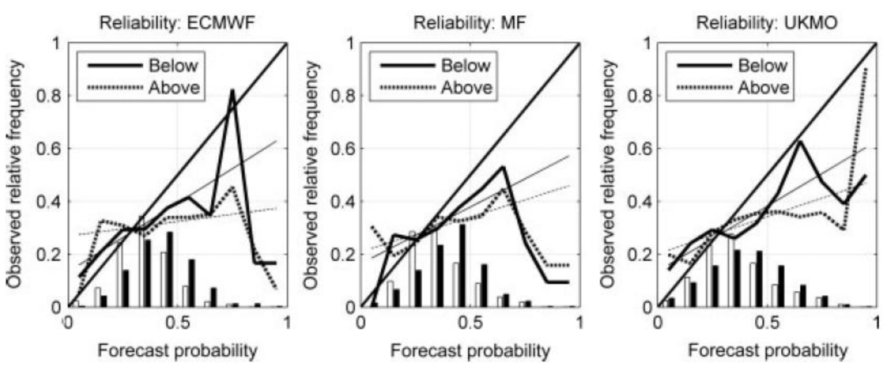


Figure 5. Reliability diagrams and frequency histograms for above- and below-normal DJF rainfall forecasts produced by the single models. The thick black curves and black bars of the histogram represent the below-normal rainfall category, while the thick black dotted curves and white bars of the histogram represent the above-normal rainfall category. For perfect reliability the curves should fall on top of the thick black diagonal line. The thin solid and dotted lines are respectively the weighted least-squares regression lines of the above-normal and below-normal reliability curves.

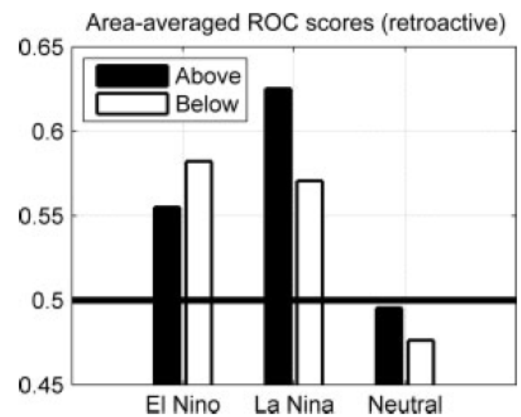
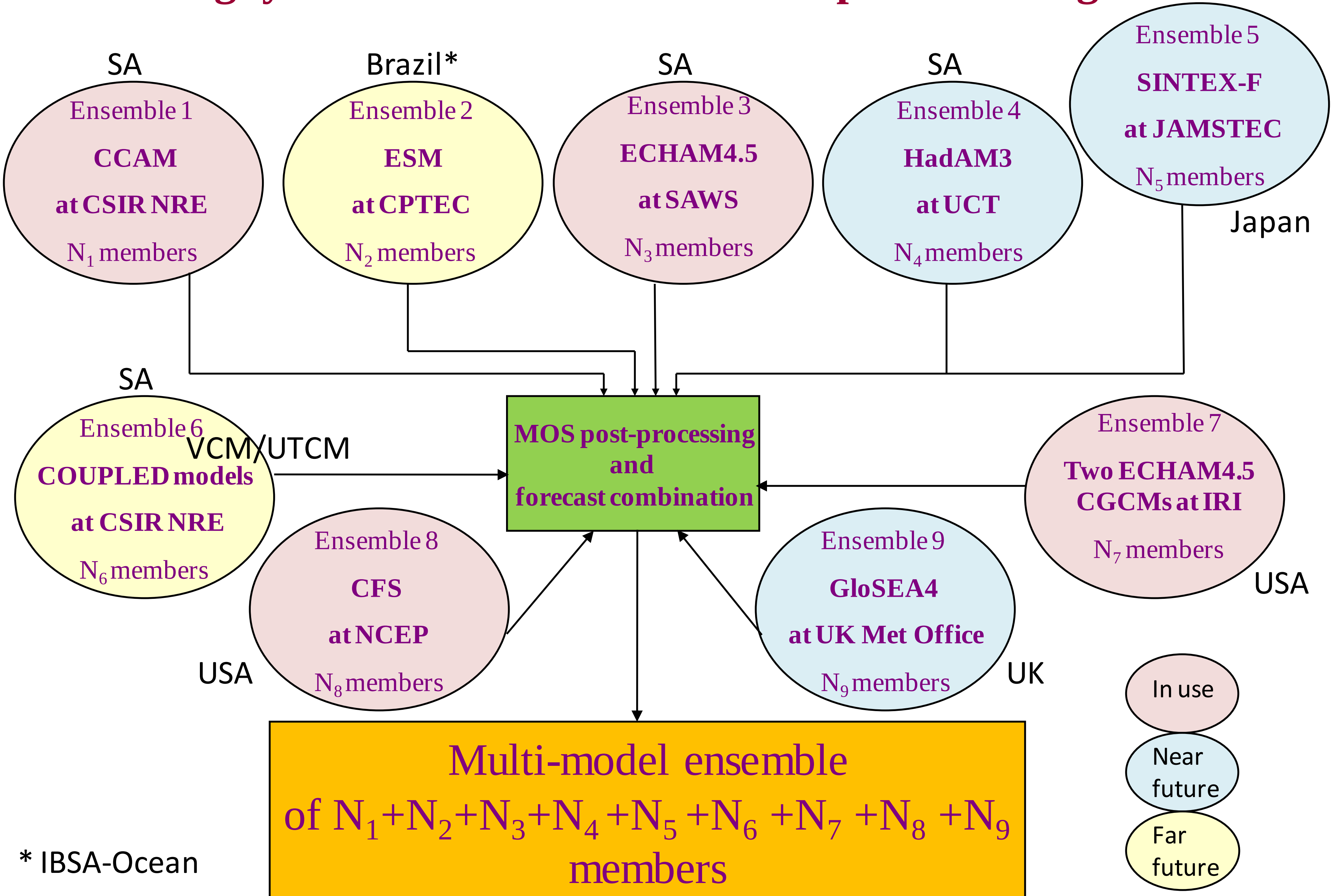
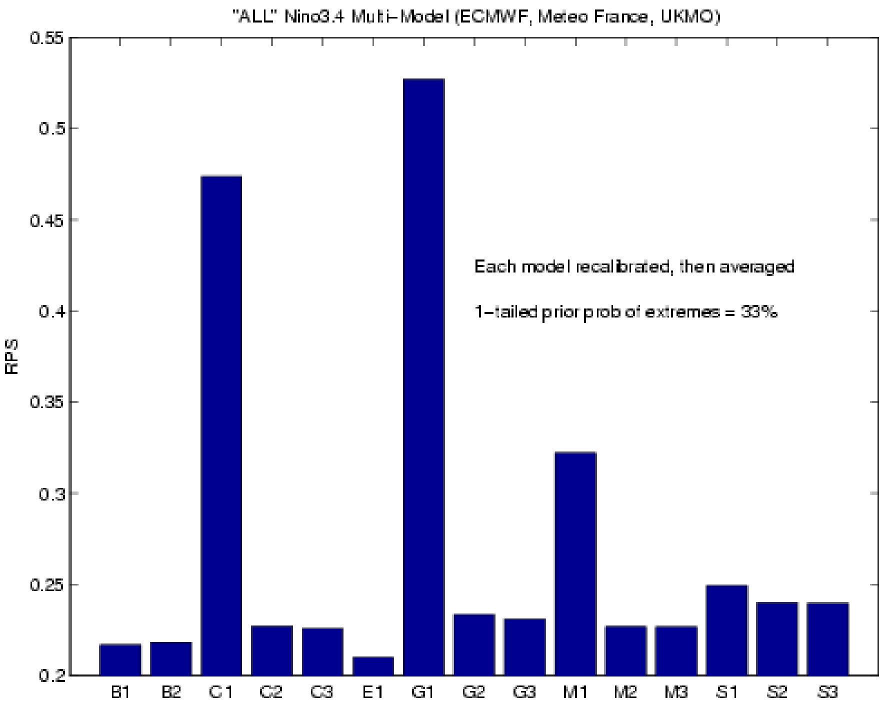


Figure 7. ROC scores, averaged over the southern African domain, for the above-normal and below-normal rainfall categories during El Niño, La Niña and neutral seasons. Scores for the MMcca multi-model are shown.

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



Some MM Combination Schemes

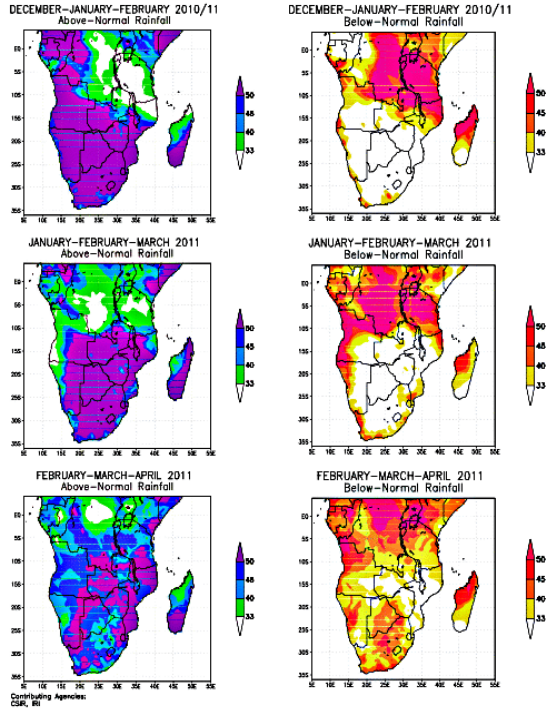


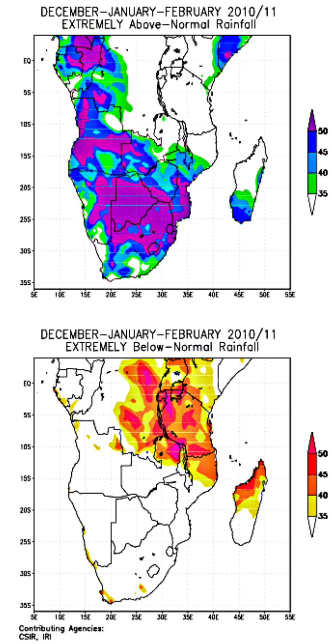
- Bayesian optimal weighting (B1)
- Bayesian sequential optimal weighting (B2)
- Canonical variate analysis
  - using members (C1)
  - using PCs (C2)
  - using moments (C3)
- Equal weighting (E1)
- Generalized linear model
  - using members (G1)
  - using PCs (G2)
  - using moments (G3)
- Multiple linear regression
  - using members (M1)
  - using PCs (M2)
  - using moments (M3)
- Stepwise regression
  - using members (S1)
  - using PCs (S2)
  - using moments (S3)

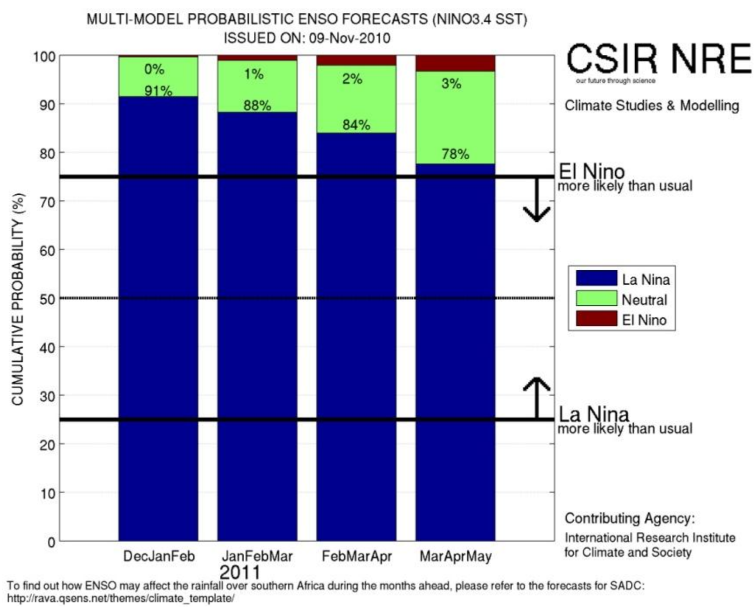
1. **Models recalibrated and combined at the same time**
2. **Each model recalibrated, then averaged**

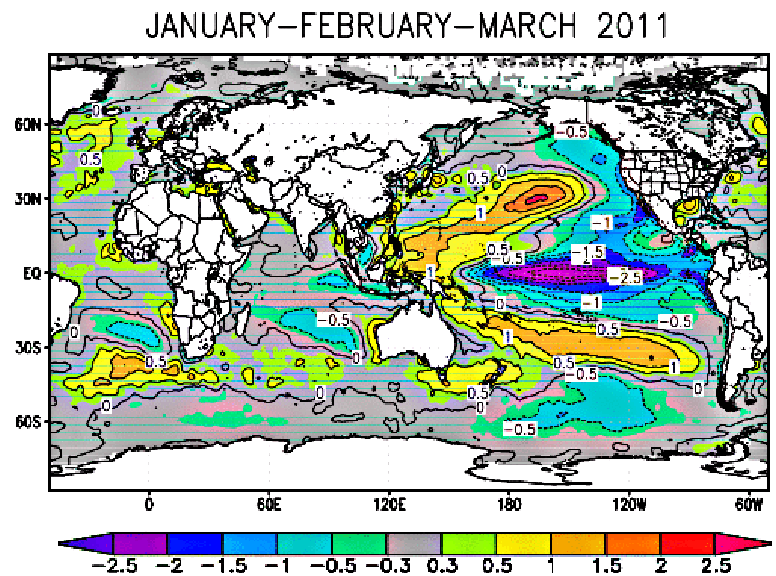
With assistance from Simon Mason

Seasonal forecast examples: *Issued Nov 2010*









www.GFCSA.net (Est. 2003)

ToR 1: To facilitate cooperation between the centres within southern Africa that run an operational global scale long-range forecasting (LRF - from 30 days up to 2 years) system

ToR 2: To produce global forecasts from dynamical forecasting systems

ToR 3: To establish a web based environment for non commercial product dissemination

ToR 4: The consortium will be managed by a committee

ToR 5: To compile archived hindcasts

ToR 6: To apply standard verification tools

ToR 7: To assist in training and capacity building for LRF

ToR 8: To actively pursue the development and improvement of global scale LRF techniques

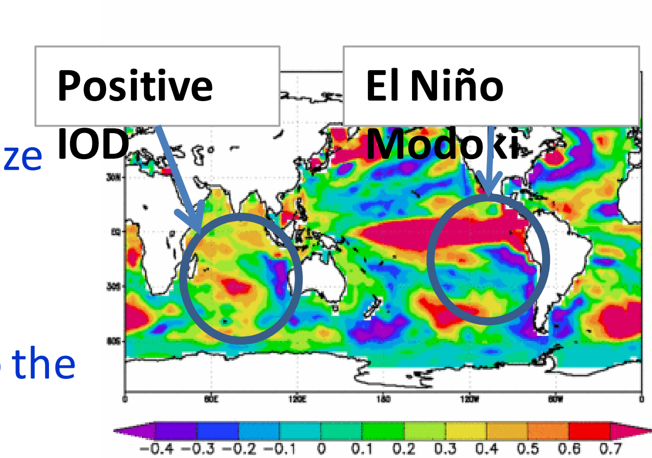
UCT: HadAM3
SAWS: ECHAM4.5 (AGCM and CGCM)
CSIR: CCAM, VCM, UTCM

"ToshioGeorge" (multi-node machine)

Example of coupled model work:
The state-of-the-art

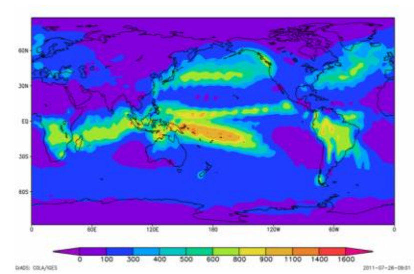
Coupled GCM Implementation:

- **ECHAM4.5-MOM3** running at the CHPC with 10 ensemble size
- Ready for operational use (pending for suitable HPC)



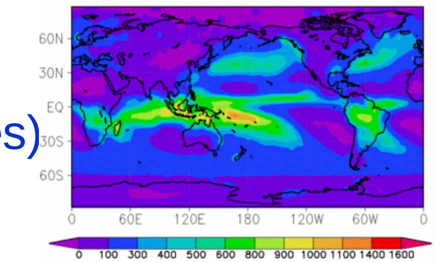
Coupling procedure:

- Anomalously coupled to the AGCM side and fully coupled to the OGCM side
- OGCM SST relaxed toward climatology at high latitudes in order to suppress spurious ice (no sea-ice model)
- AGCM and OGCM are coupled using the ***multiple-program multiple-data (MPMD)*** paradigm.
- Exchange information via data files ***every model simulation day.***



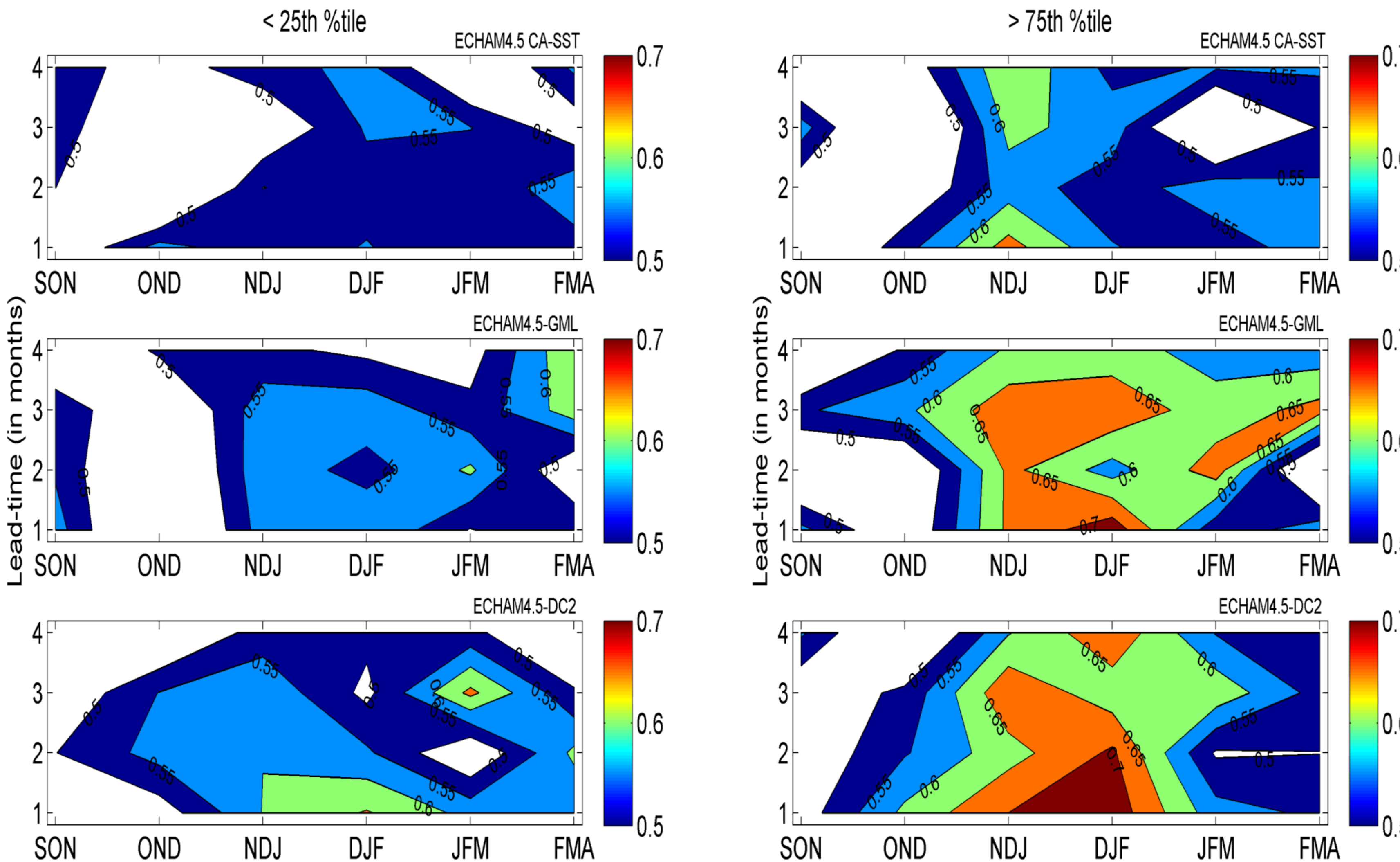
Initialization strategy:

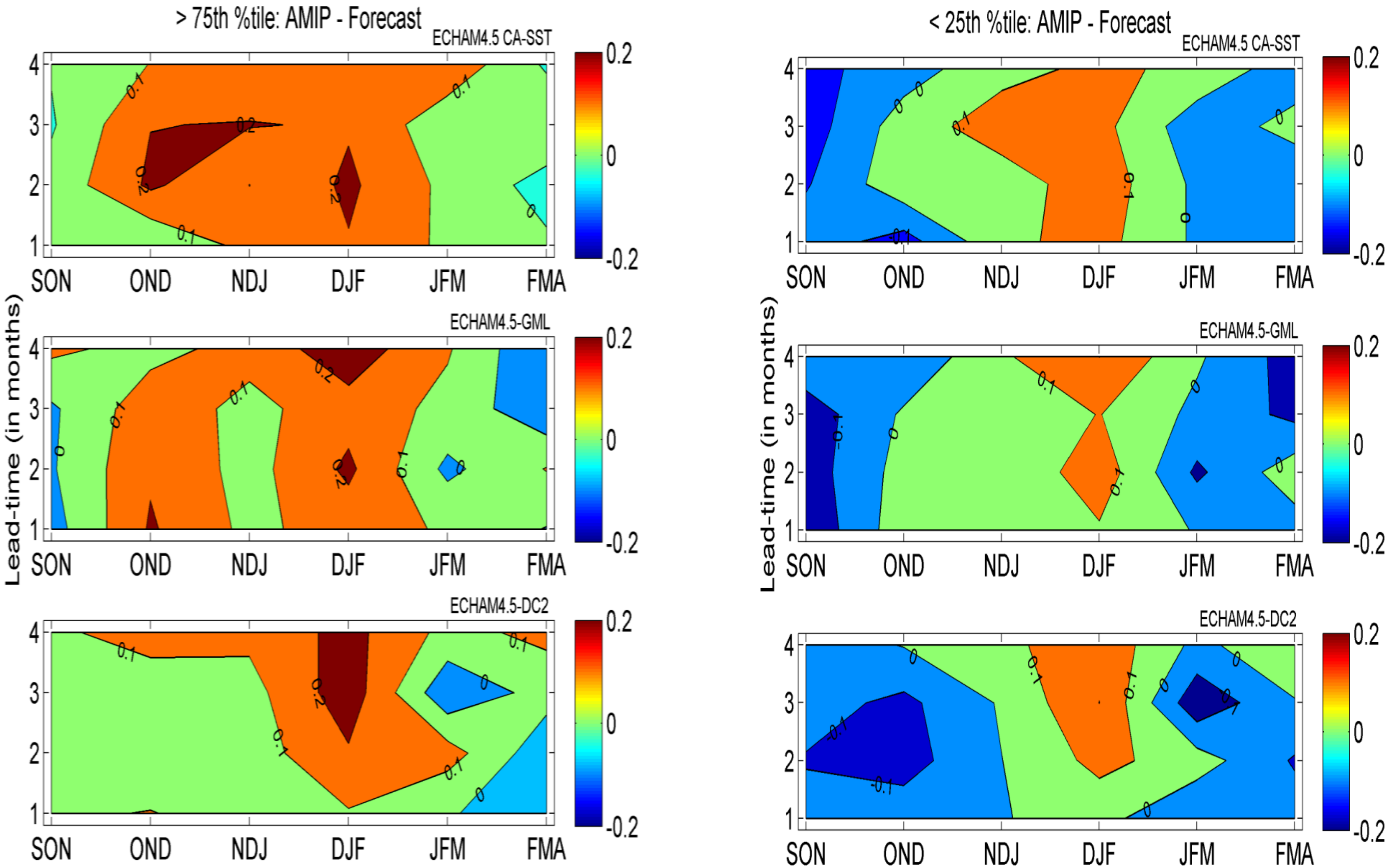
- Initialized using best available information of the ocean and atmosphere state
- Each hindcast run involves 9 months integration (0-8 lead times) and mimics truly **operational** set-up



Significant support from Dave DeWitt

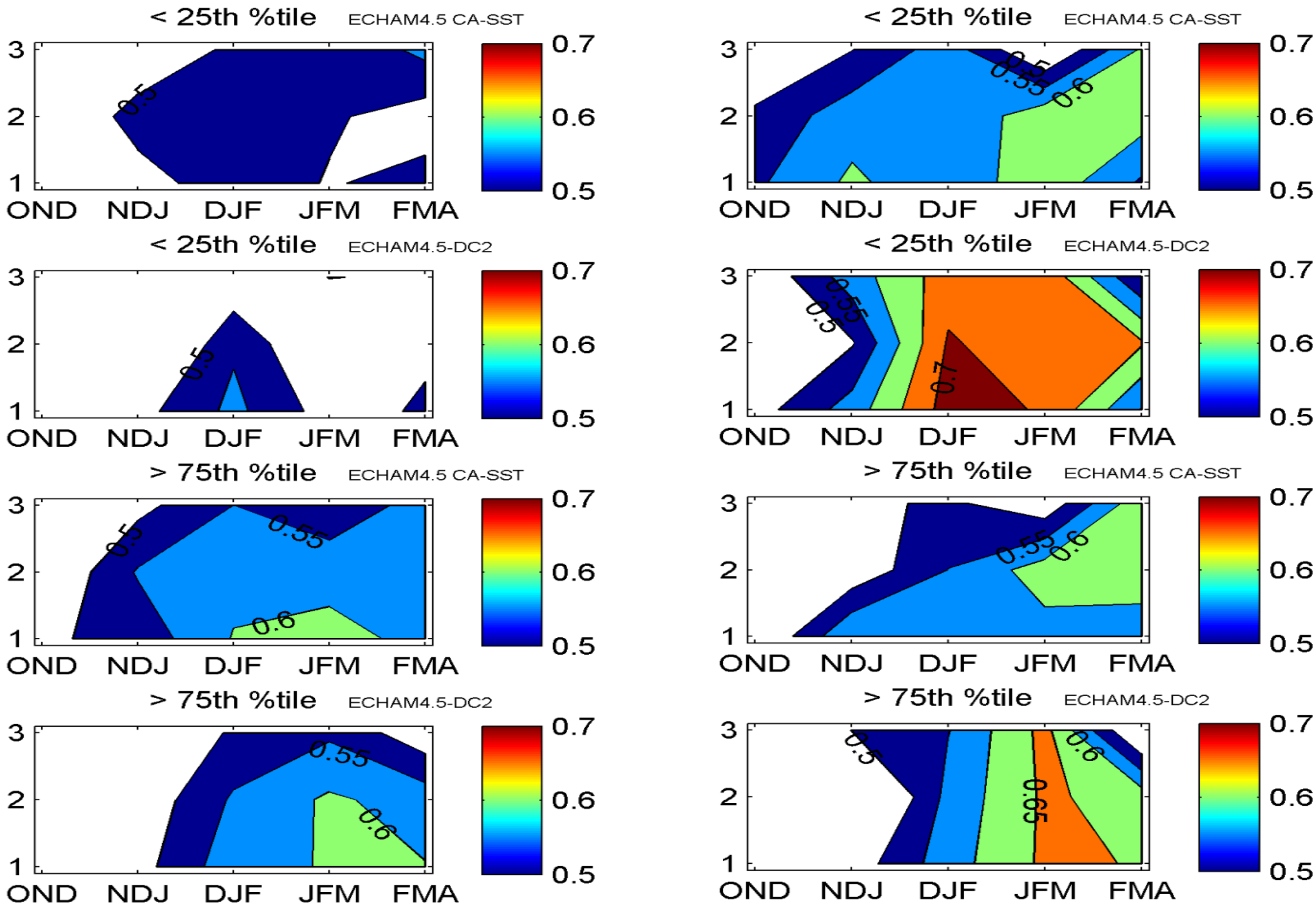
ROC Scores: Coupled vs. 2-tiered systems





> 75th %tile: AMIP - Forecast
< 25th %tile: AMIP - Forecast
ECHAM4.5 CA-SST
ECHAM4.5-GML
ECHAM4.5-DC2
Lead-time (in months)
SON
OND
NDJ
DJF
JFM
FMA
0.2
0
-0.2

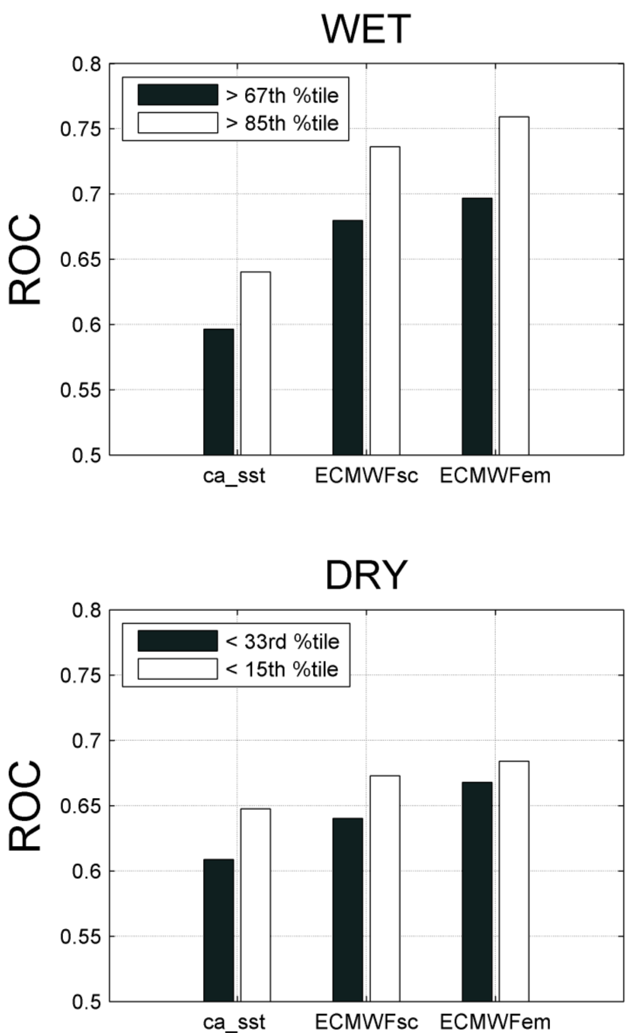
Minimum temperatures ROC Scores Maximum temperatures

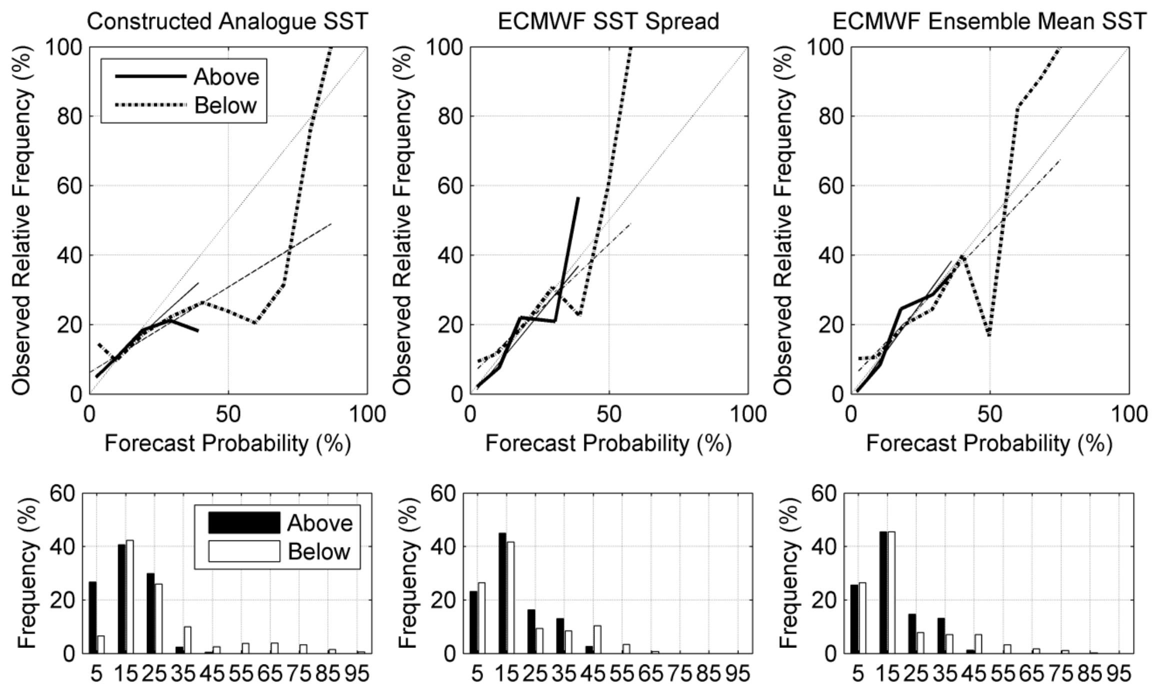


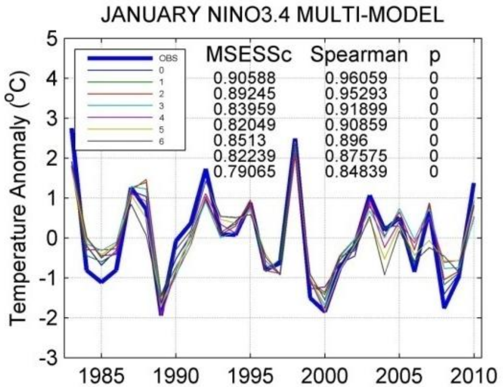
Initiative lead by Melissa Lazenby

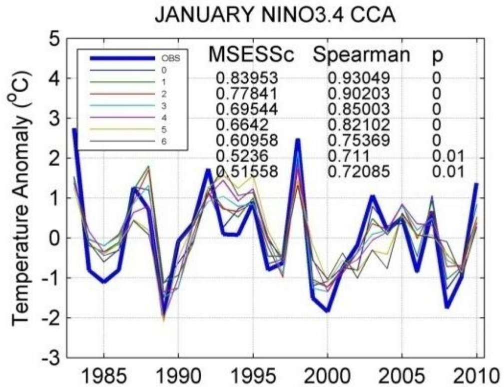
Model data supplied by Dave DeWitt

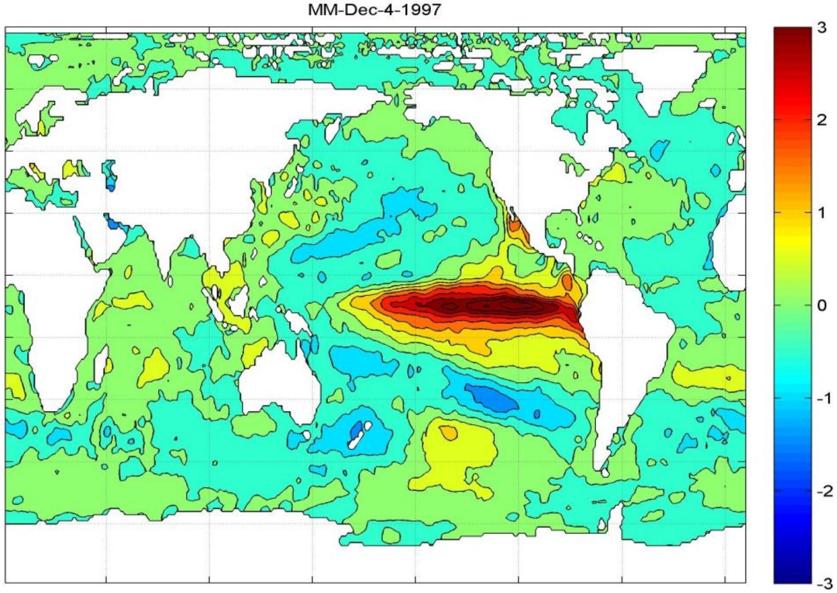
SST configuration strategy

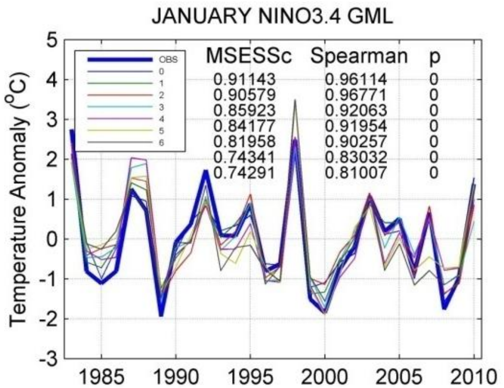


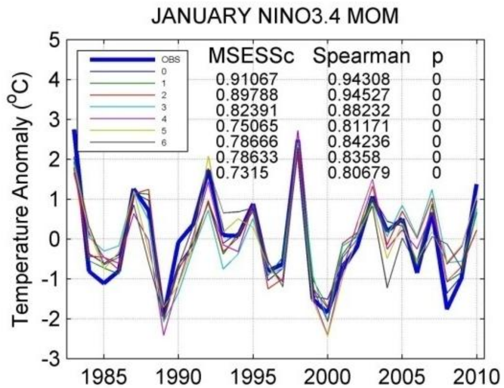


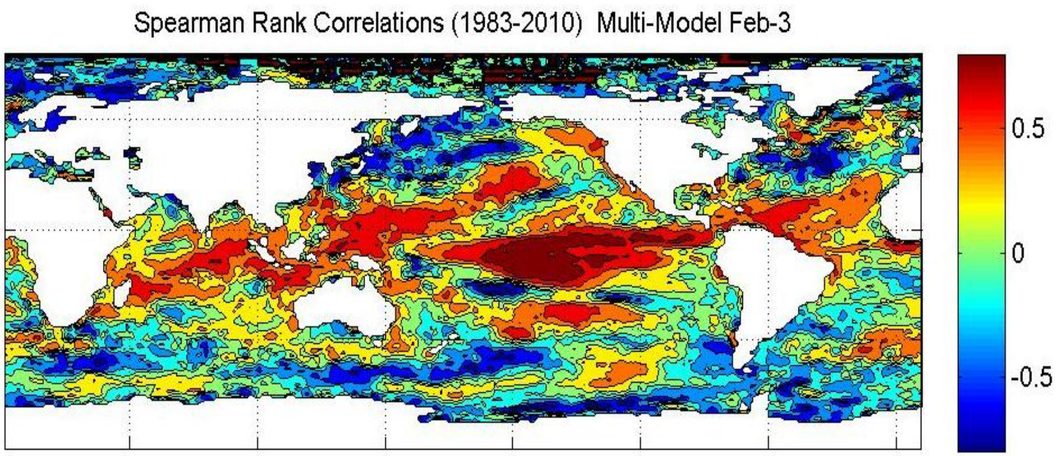

JANUARY NINO3.4 MULTI-MODEL
Temperature Anomaly (°C)
OBS 0 1 2 3 4 5 6
MSESSc Spearman p
0.90588 0.96059 0
0.89245 0.95293 0
0.83959 0.91899 0
0.82049 0.90859 0
0.8513 0.896 0
0.82239 0.87575 0
0.79065 0.84839 0
1985 1990 1995 2000 2005 2010

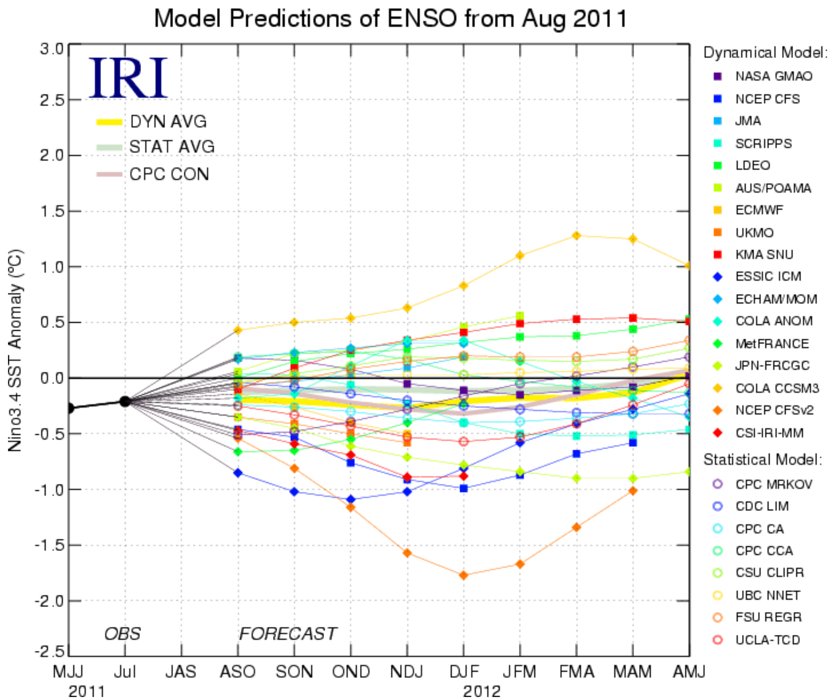

JANUARY NINO3.4 CCA
Temperature Anomaly (°C)
OBS 0 1 2 3 4 5 6
MSESSc Spearman p
0.83953 0.93049 0
0.77841 0.90203 0
0.69544 0.85003 0
0.6642 0.82102 0
0.60958 0.75369 0
0.5236 0.711 0.01
0.51558 0.72085 0.01
1985 1990 1995 2000 2005 2010

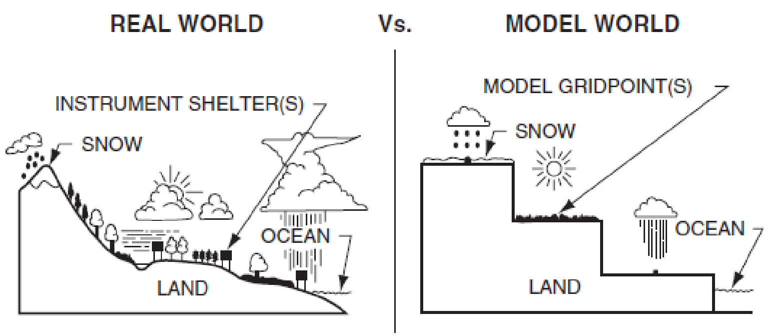

MM-Dec-4-1997

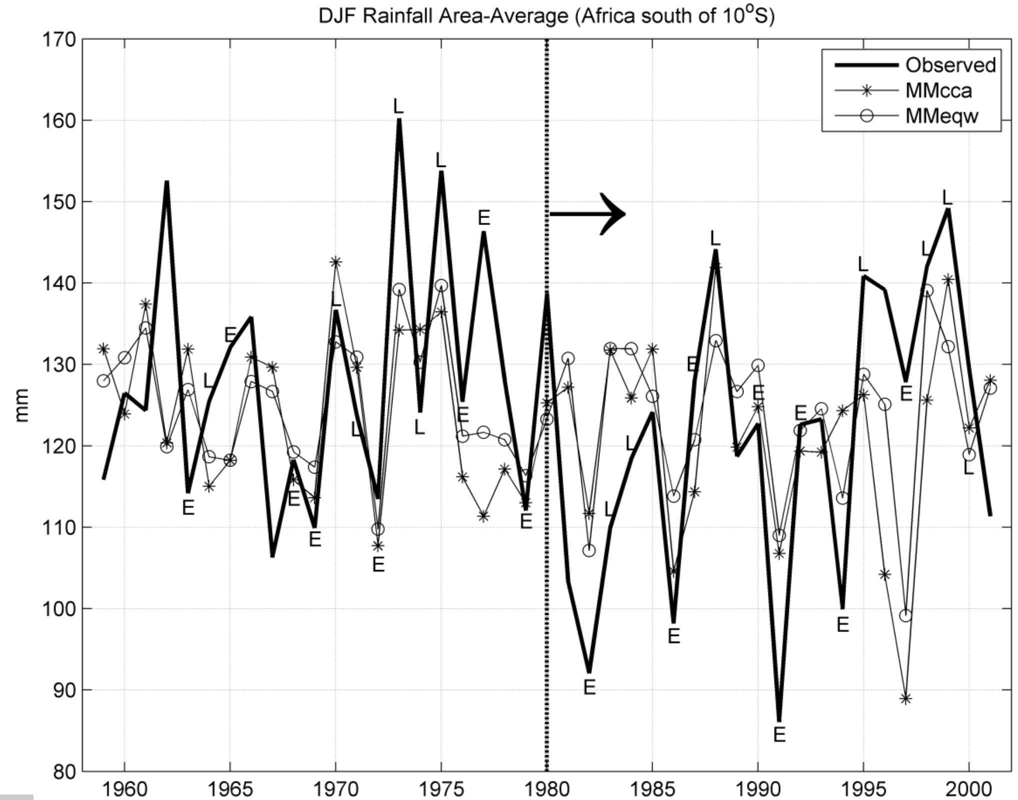

JANUARY NINO3.4 GML
Temperature Anomaly (°C)
OBS 0 1 2 3 4 5 6
MSESSc Spearman p
0.91143 0.96114 0
0.90579 0.96771 0
0.85923 0.92063 0
0.84177 0.91954 0
0.81958 0.90257 0
0.74341 0.83032 0
0.74291 0.81007 0
1985 1990 1995 2000 2005 2010


JANUARY NINO3.4 MOM
Temperature Anomaly (°C)
OBS 0 1 2 3 4 5 6
MSESSc Spearman p
0.91067 0.94308 0
0.89788 0.94527 0
0.82391 0.88232 0
0.75065 0.81171 0
0.78666 0.84236 0
0.78633 0.8358 0
0.7315 0.80679 0
1985 1990 1995 2000 2005 2010

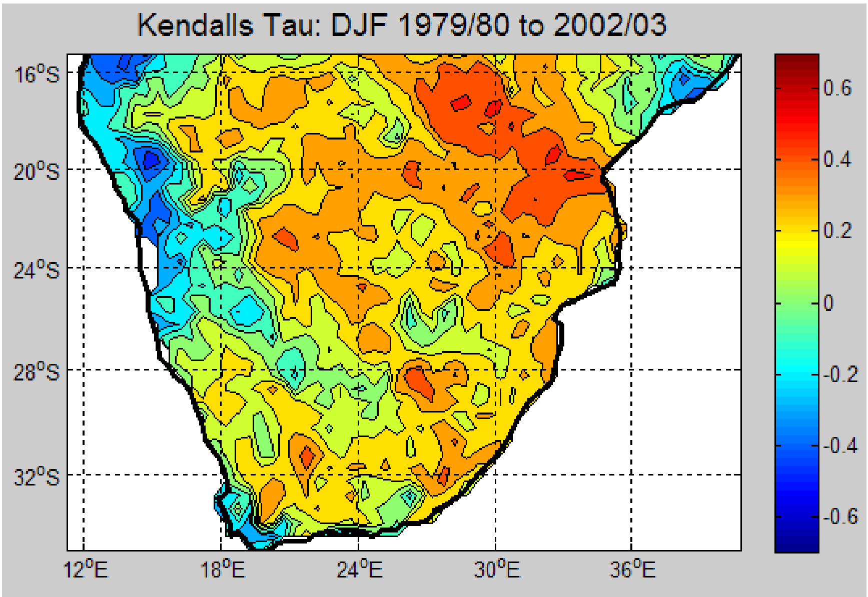

Spearman Rank Correlations (1983-2010) Multi-Model Feb-3
0.5
0
-0.5

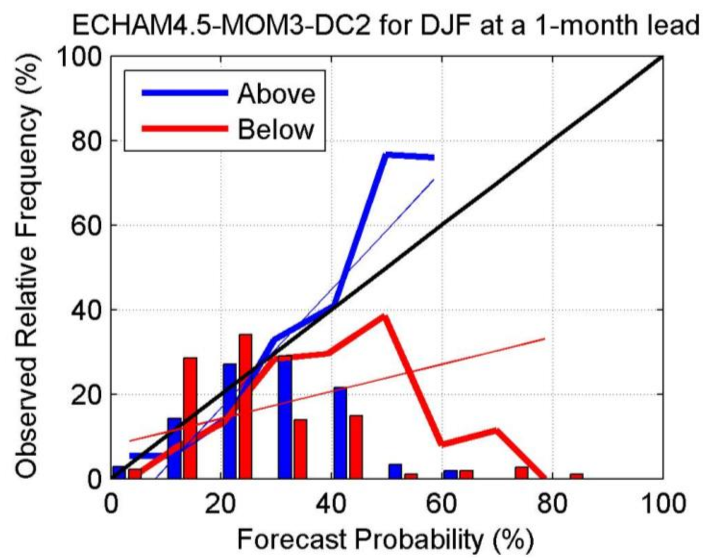

Model Predictions of ENSO from Aug 2011
IRI
DYN AVG
STAT AVG
CPC CON
Nino3.4 SST Anomaly (°C)
OBS
FORECAST
MJJ 2011 Jul JAS ASO SON OND NDJ DJF 2012 JFM FMA MAM AMJ
Dynamical Model:
NASA GMAO
NCEP CFS
JMA
SCRIPPS
LDEO
AUS/POAMA
ECMWF
UKMO
KMA SNU
ESSIC ICM
ECHAM/MOM
COLA ANOM
MetFRANCE
JPN-FRCGC
COLA CCSM3
NCEP CFSv2
CSI-IRI-MM
Statistical Model:
CPC MRKOV
CDC LIM
CPC CA
CPC CCA
CSU CLIPR
UBC NNET
FSU REGR
UCLA-TCD



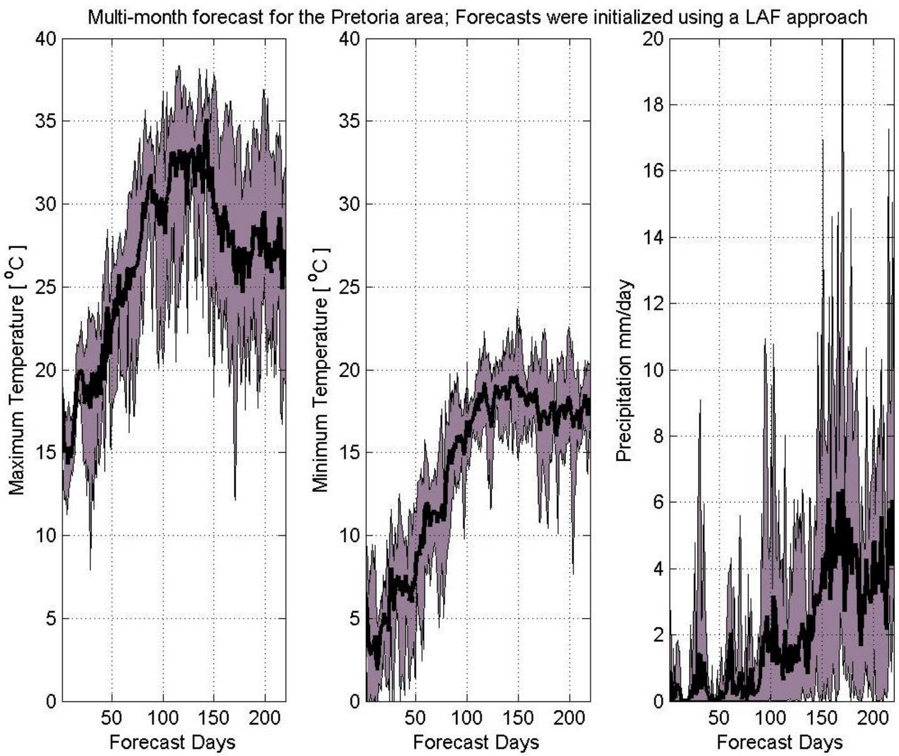


Empirical correction and verification should be part of the forecast system





Seamless forecast products



40 Years of Excellence
WATER RESEARCH COMMISSION

CCAM long-range forecasts are to be updated daily

	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
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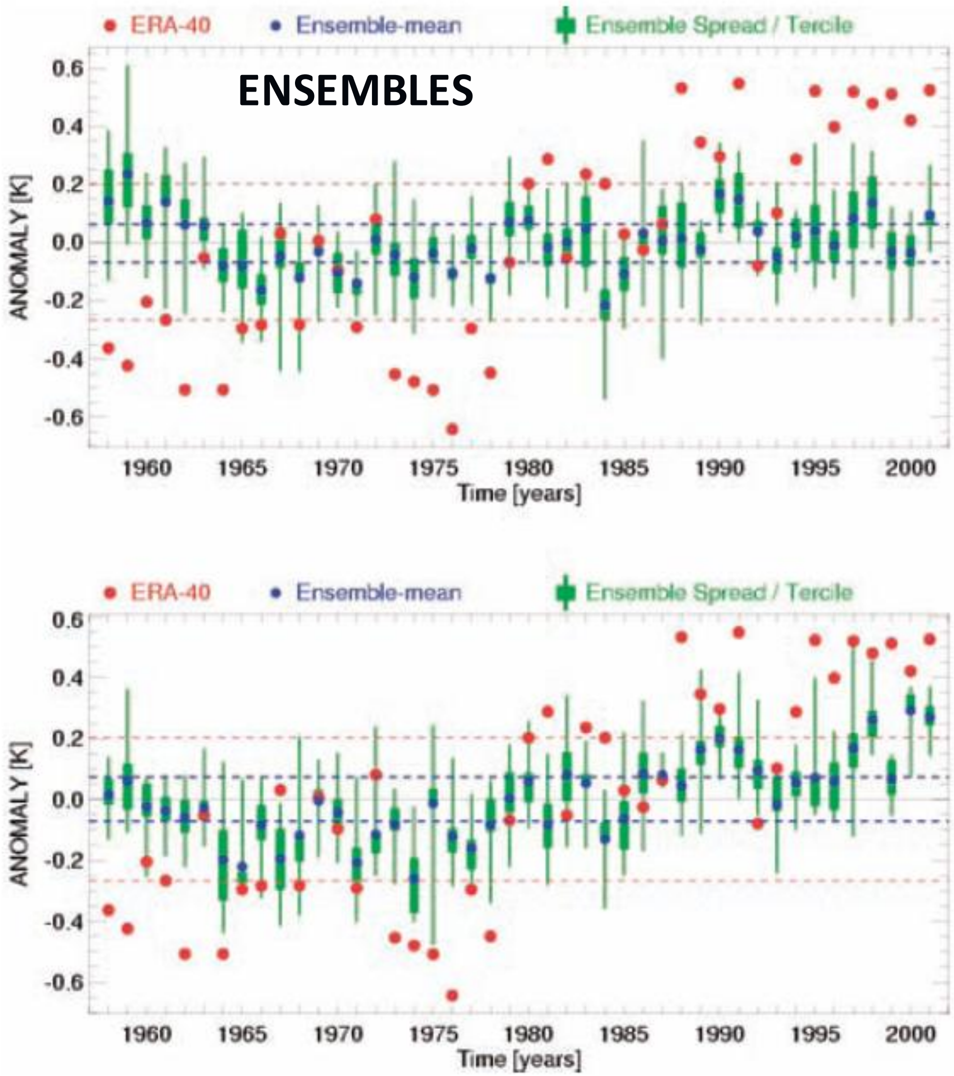
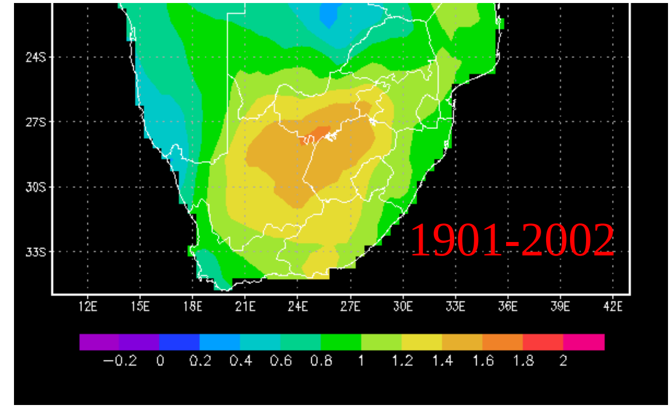
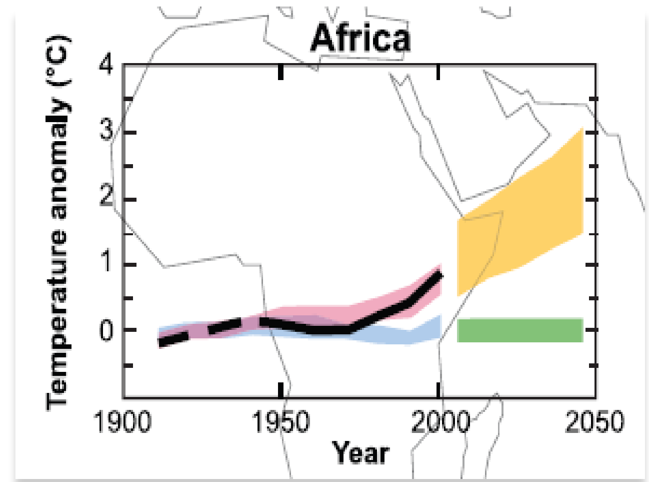


Figure 7.17: ECMWF 3-month lead time hindcasts of global 2 m temperature for August–October without (upper panel) and with (lower panel) time-varying anthropogenic greenhouse gases (GHG). In the upper panel the correlation between the ensemble mean and the observations is only 0.29, whereas this increases to 0.68 with variable GHGs, indicating that including variable greenhouse gas concentrations improves the seasonal forecast/hindcast skill of global mean surface air temperature (after Doblas-Reyes et al., 2006).



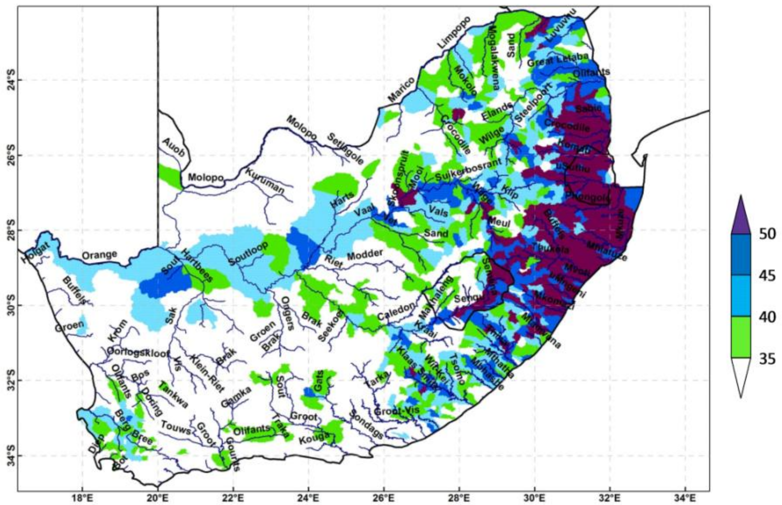


Strong anthropogenically forced warming trends have been observed over southern Africa and are projected to continue to rise, consequently justifying the investigation into how the annual update of greenhouse gas (GHG) concentrations in a global model may affect seasonal forecast performance over the region.

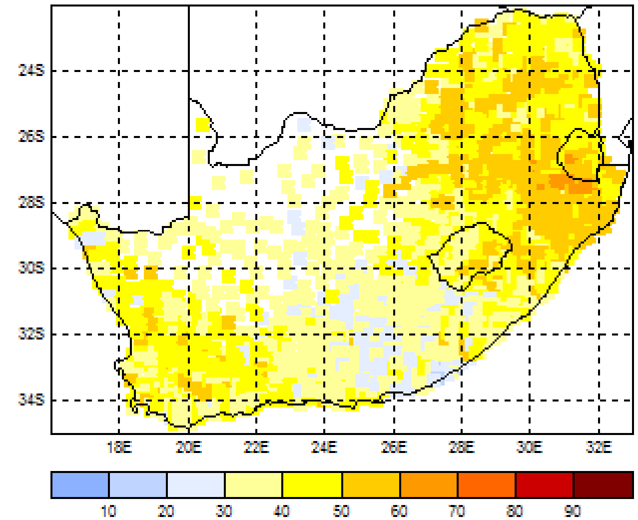
Applications Modelling

FEBRUARY – MARCH - APRIL 2011

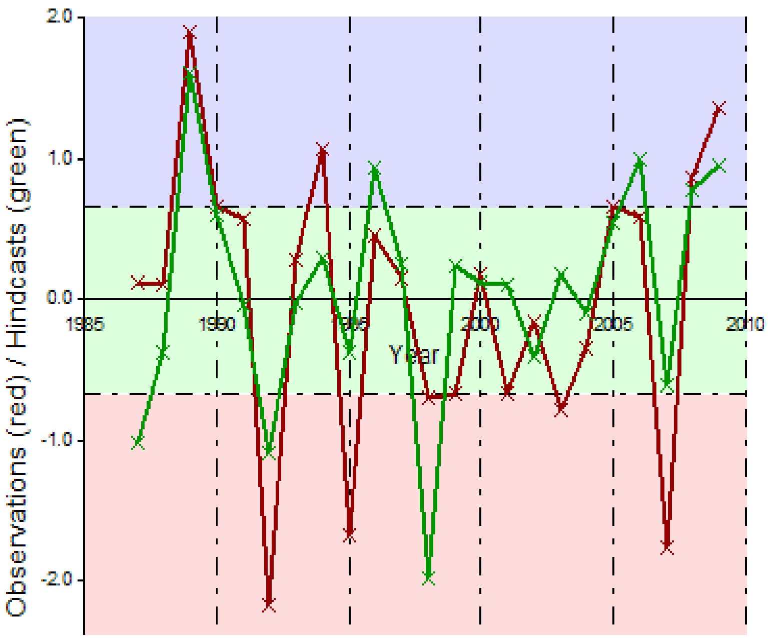
EXTREMELY Above – Normal Accumulated Streamflow

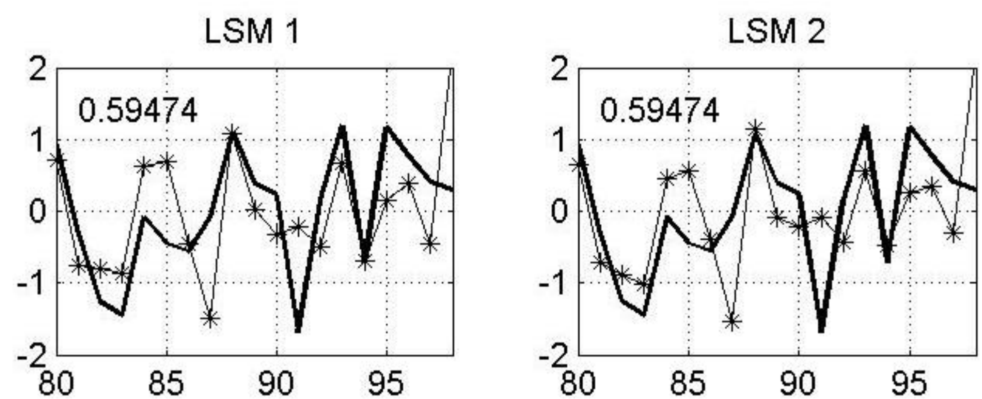


EXTREMELY Above-Normal Accumulated STREAMFLOW



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





Simulated crop production for growing season

To summarize

- From empirical to physical
- MOS > RCM
- Objective combination > subjective consensus
- CGCMs have great potential
- AGCMs should continue to be optimized
- Downscaling and verification important components of forecast system
- System improvement still continuing, including applications model development