Operational Seasonal Forecast System Development in South Africa

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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://mil.columbia.edu/ENSO

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.

Introduction of GCMs...
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 operational 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
**New objective multi-model forecast**

Probability Rainfall Forecast for ABOVE-normal for April-May-June 2008

**Old subjective consensus forecast**

Expected Total Rainfall for the period April-May-June 2008
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 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 6. As in Figure 5, but for the two multi-models.

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
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

< 25th %tile

> 75th %tile

ECHAM4.5 CA-SST

ECHAM4.5-GML

ECHAM4.5-DC2

Lead-time (in months)

SON OND NDJ DJF JFM FMA
Minimum temperatures

ROC Scores

Maximum temperatures

Initiative lead by Melissa Lazenby

Model data supplied by Dave DeWitt
SST configuration strategy
Empirical correction and verification should be part of the forecast system.
Seamless forecast products

CCAM long-range forecasts are to be updated daily

Multi-month forecast for the Pretoria area; Forecasts were initialized using a LAF approach
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

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

Simulated crop production for growing season

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