The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1934-18

Fourth ICTP Workshop on the Theory and Use of Regional Climate Models: Applying RCMs to Developing Nations in Support of Climate Change Assessment and Extended-Range Prediction

3 - 14 March 2008

Regional climate models and seasonal forecasting over southern Africa.

TADROSS Mark

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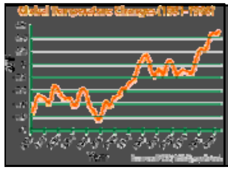
Cape Town
SOUTH AFRICA



Regional climate models and seasonal forecasting over southern Africa

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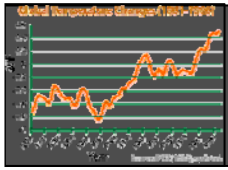
[2] South African Weather Service
[3] University of Pretoria, South Africa
[4] Danish Meteorological Institute



Structure of the talk

1. Regional climate models over southern Africa

   - physics choice, biases, diurnal cycle, rainfall frequency, land surface interactions

2. Seasonal forecasting

   - statistical and dynamical methods

3. Providing useful climate information

   - tailored information, trends in observations, thresholds of change

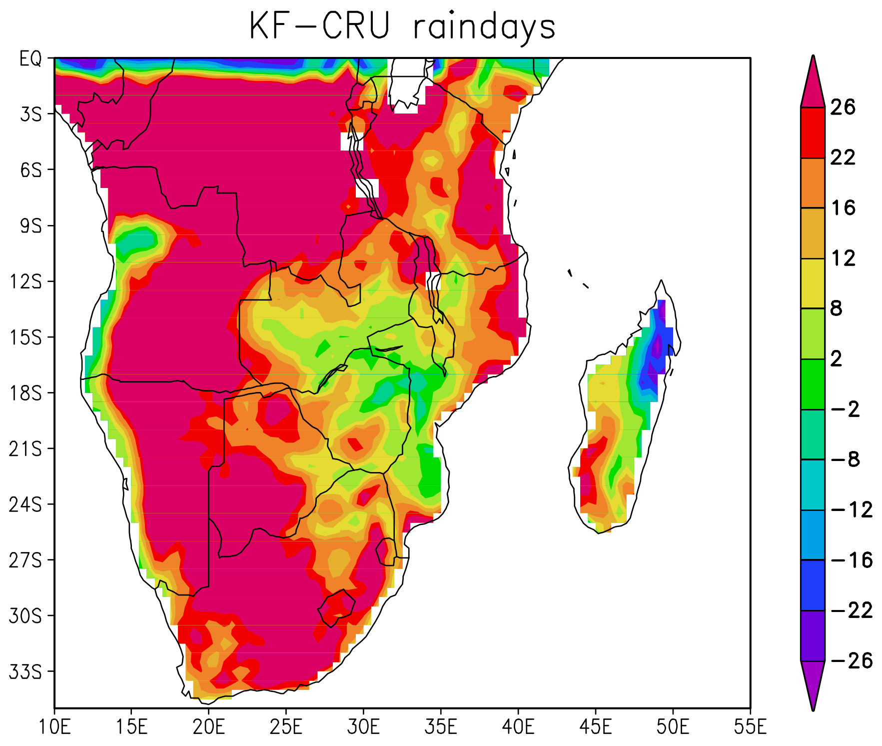
4. Climate change downscaling

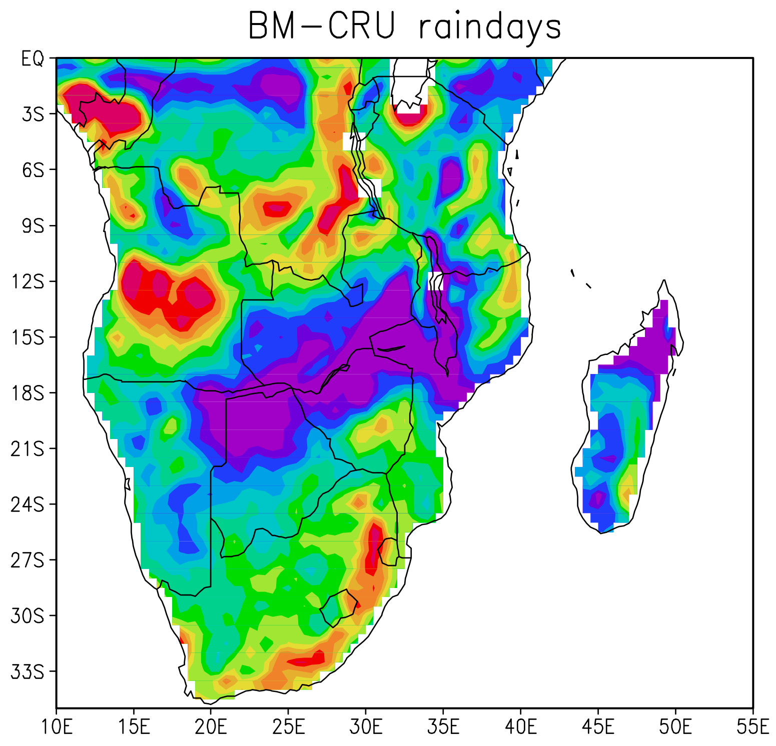
   - statistical vs. dynamical

Rainfall frequency bias depends on convection scheme (MM5)

Kain Fritsch scheme rains more frequently wrt CRU

Betts-Miller scheme rains less frequently wrt CRU





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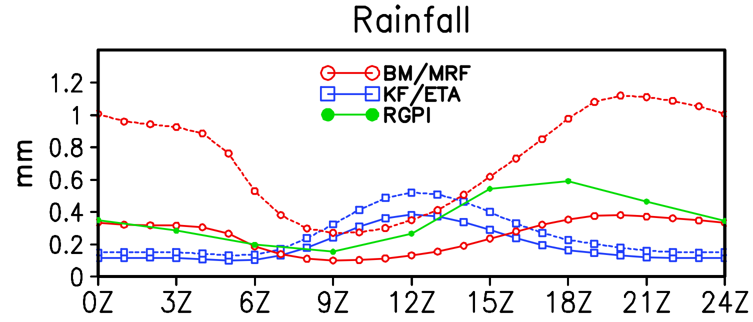
Diurnal cycle of rainfall, short wave and cloud liquid water

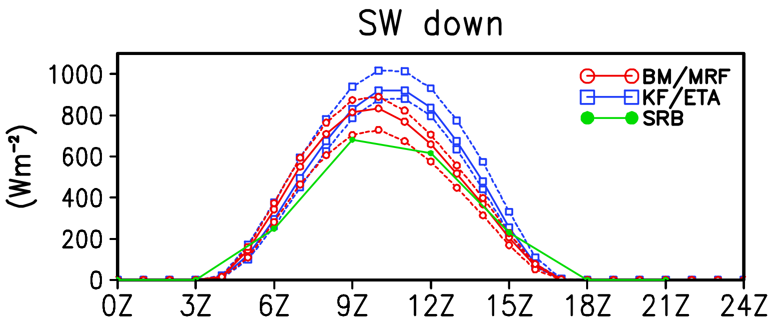
Rainfall:

Kain Fritsch rains too early
Betts-Miller rains too late



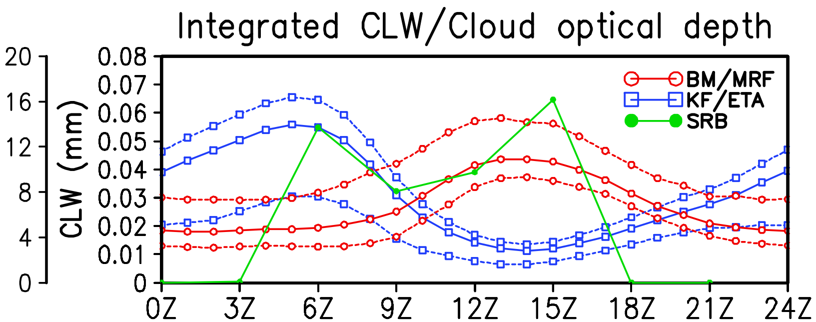
Incident short wave at surface:

Kain Fritsch peaks too late
Betts Miller peaks earlier



Integrated cloud liquid water (CLW):

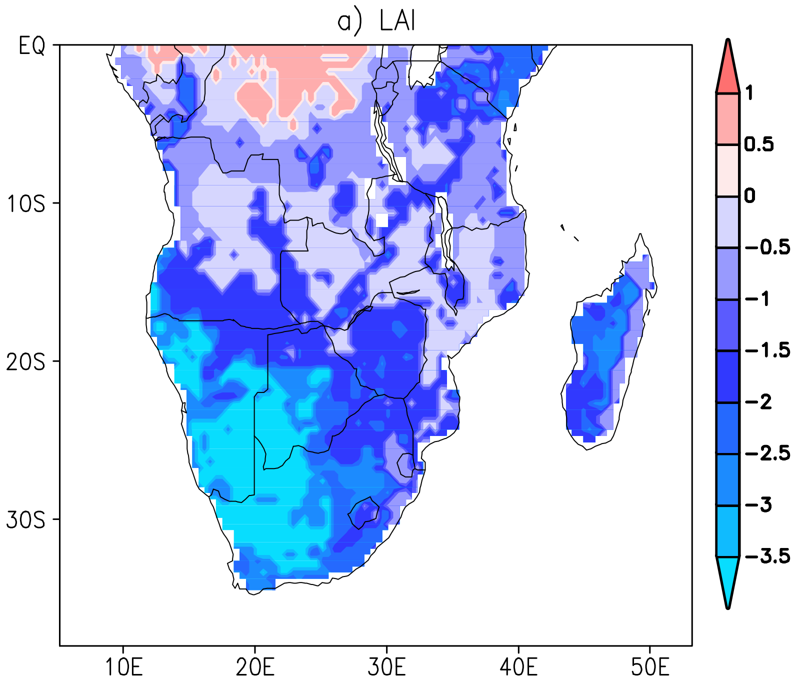
Kain Fritsch peaks early morning
Betts Miller peaks in afternoon



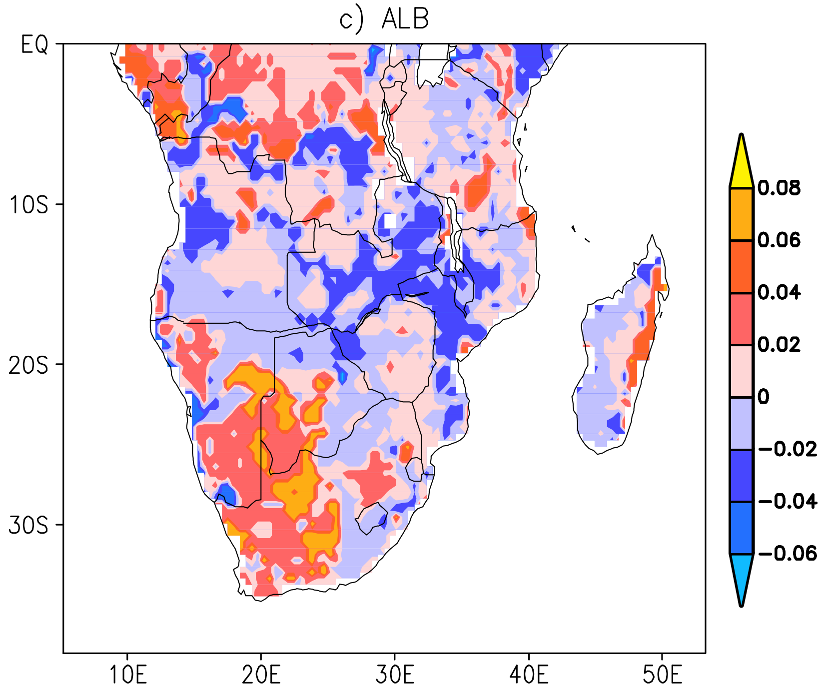
Uncertainty due to 2 different representations of land surface

Difference between Ecoclimap and USGS

Difference in Leaf Area Index



Difference in Albedo



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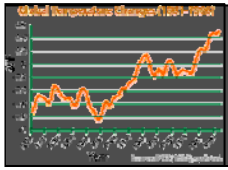
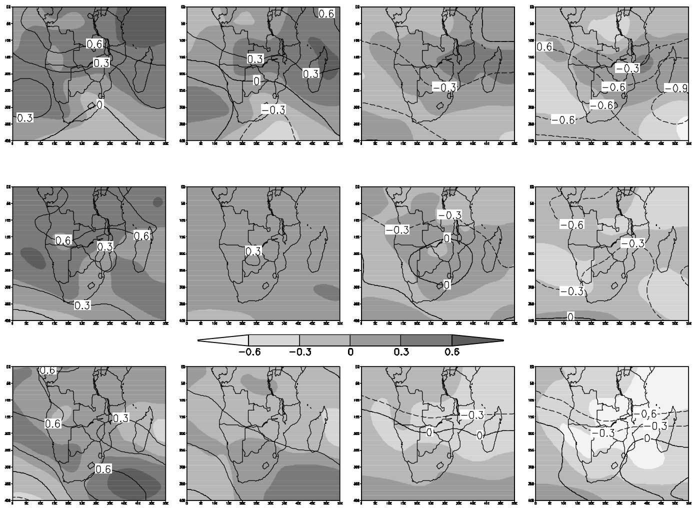
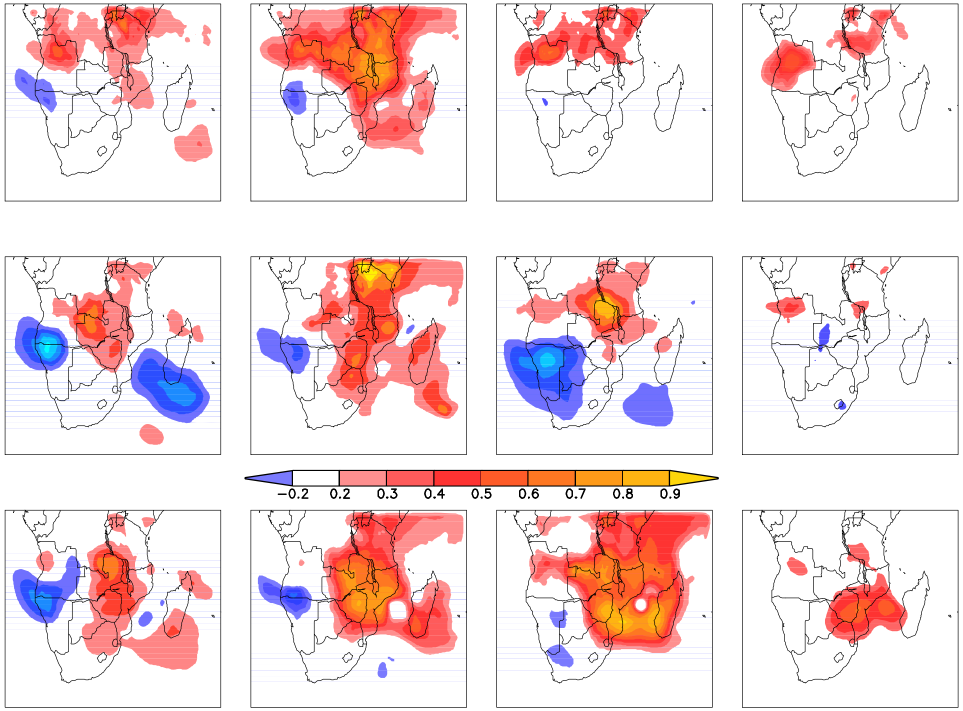


Strength of atmospheric response to surface change depends on synoptic forcing of MM5



Upper-atmosphere high

Upper-atmosphere low



Lower-atmosphere high

Lower-atmosphere low

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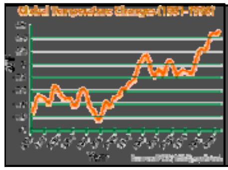
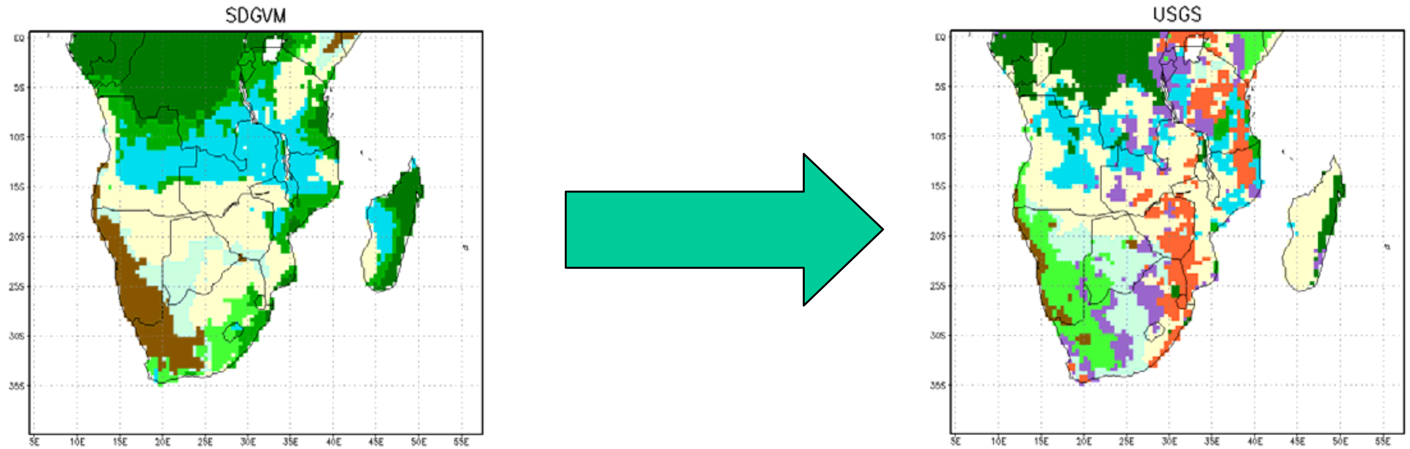
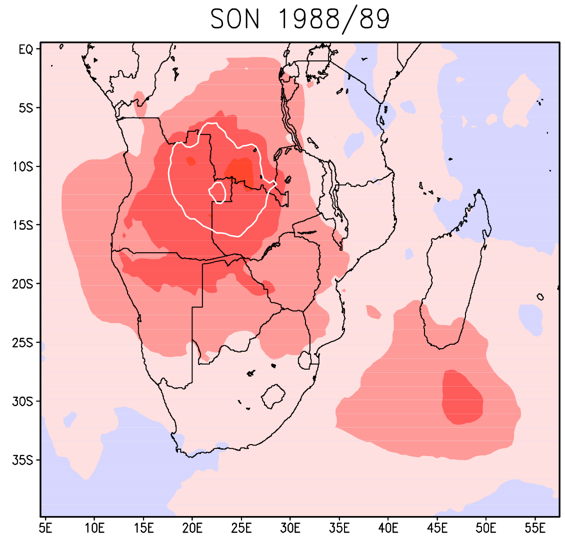
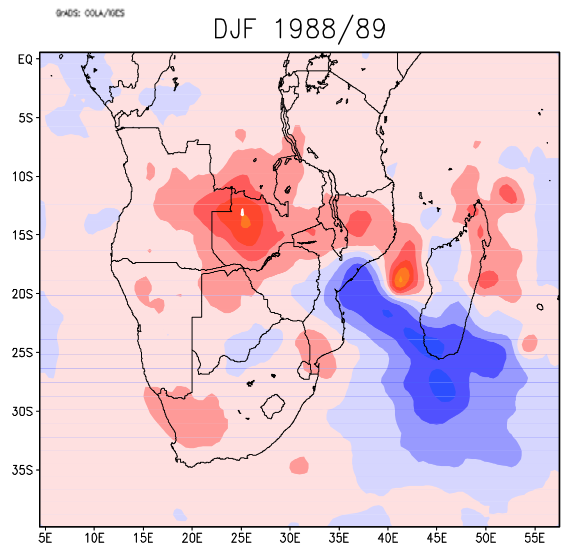


Land-use change affects regional climate







Changes more widespread during spring

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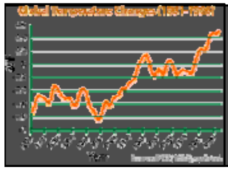
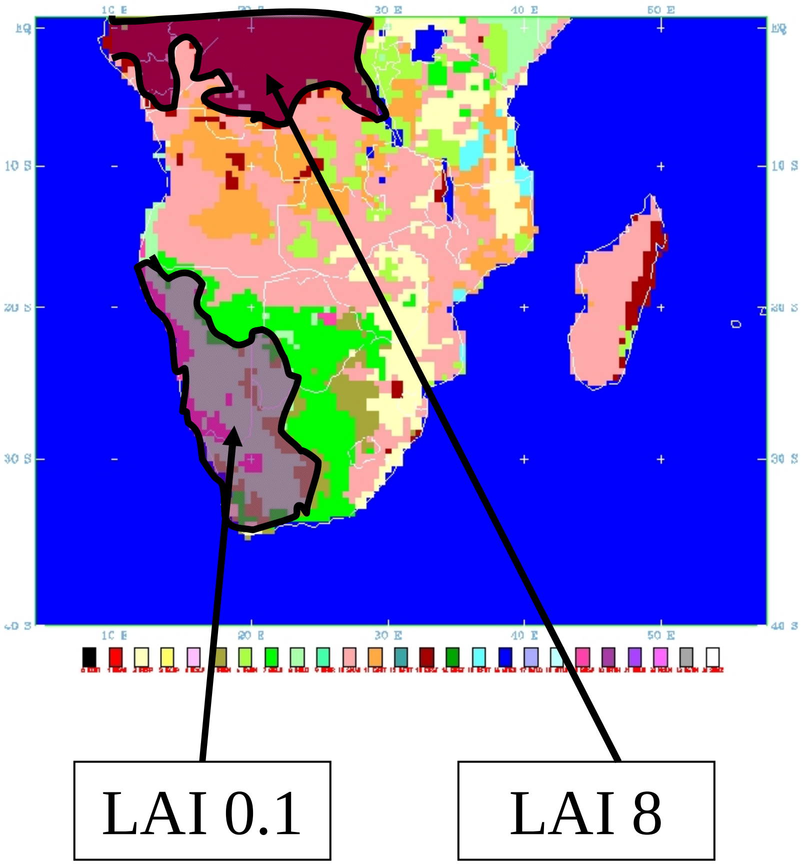


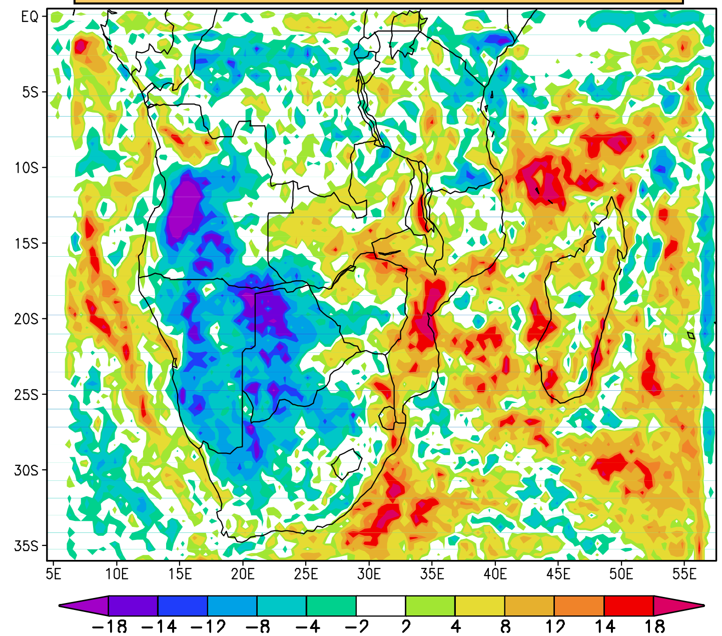
LAI – rainfall feedback greater in arid region

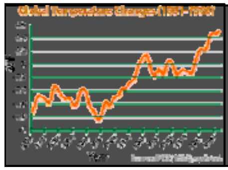
- Reduction of vegetation in semi-arid areas may reduce local rainfall
- Non-linear feedbacks with synoptic circulation

Vegetation classes



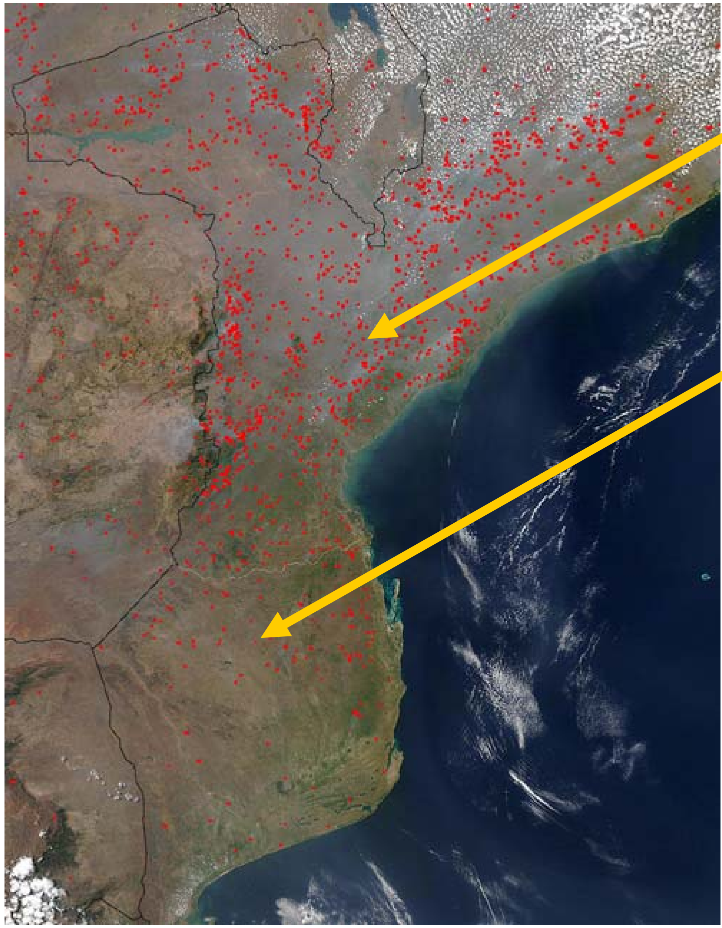
Change in Rain Days





Biomass burning during winter and spring

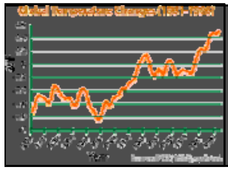
Potential feedbacks not included in current climate forecasts



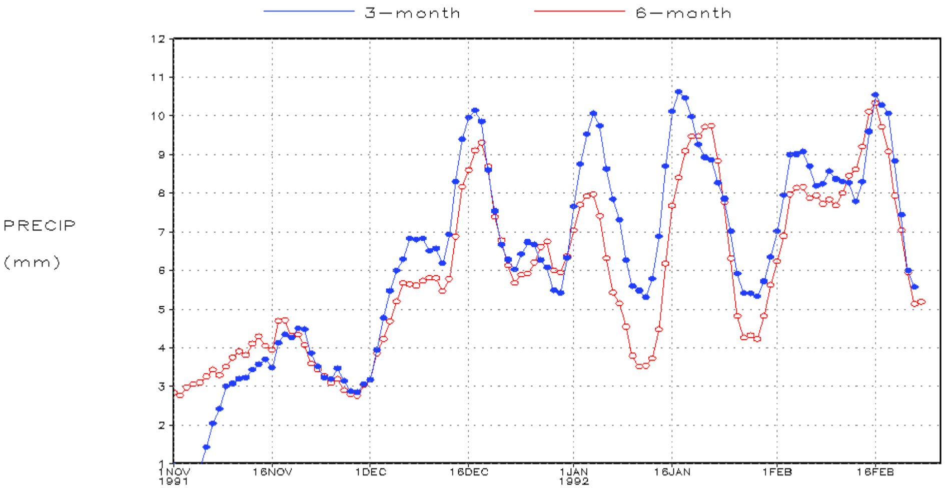
Reduced cloud cover (indirect effect)

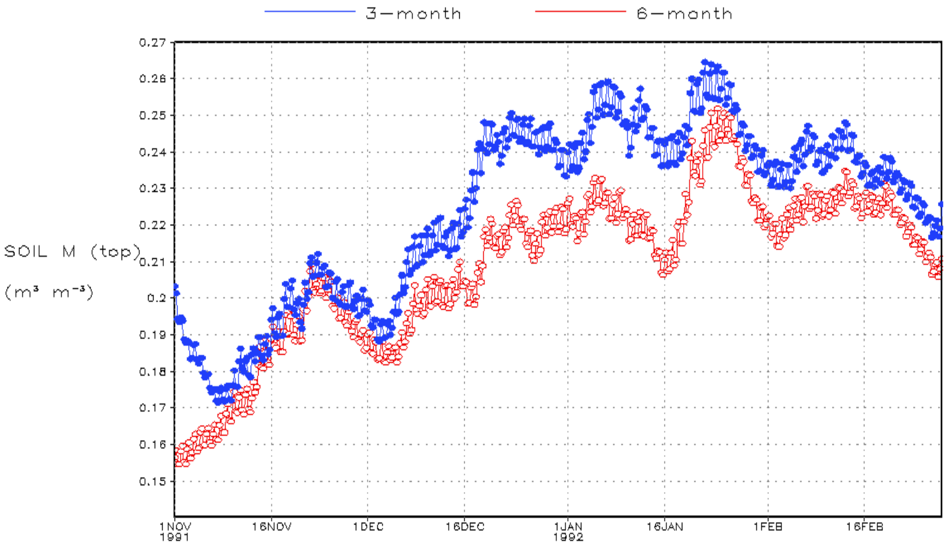
Reduced sunlight at surface

Reduced albedo & vegetation



Soil moisture important for model initialisation

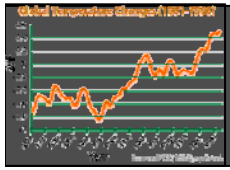




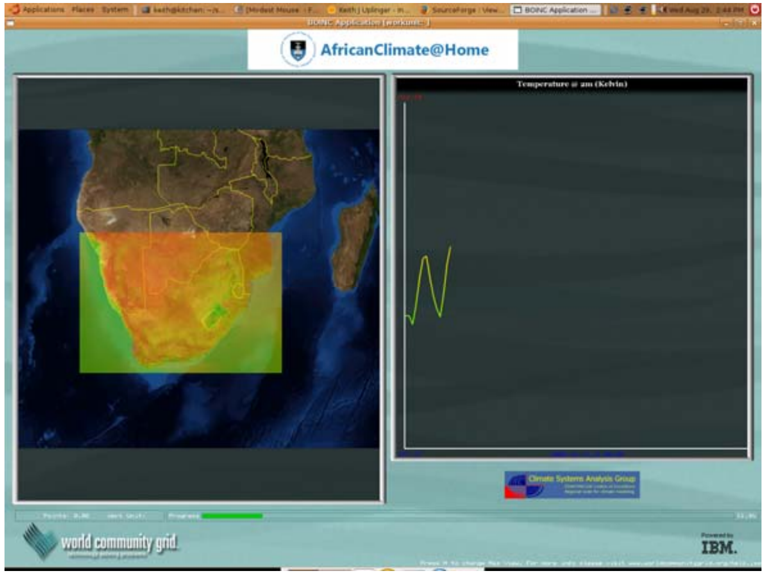
MM5 initialised with NCEP on 1 August (dry winter) and 1 November (spring period of early rains); compare the November-February (peak summer) climate in each case

Rainfall remains higher in the 1 November NCEP initialised run

Soil moisture remains higher in the 1 November NCEP initialised run



Grid computing to investigate WRF parameterisations

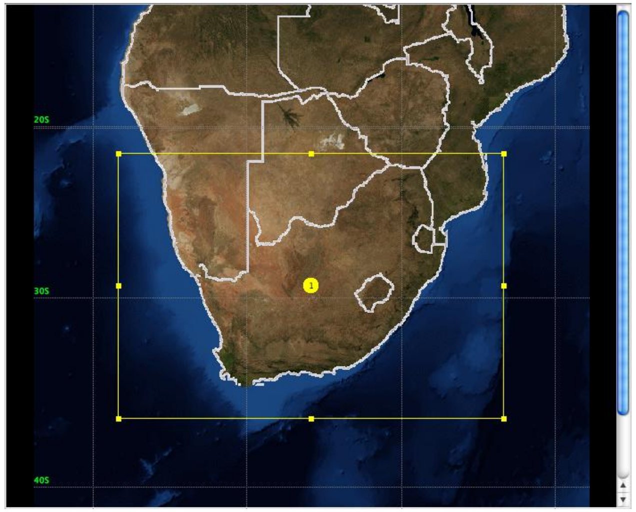


Initial Phase 1 experiment:

- 4 parameters from the Land Surface Model being analyzed (34+1=82 simulations)
  - LAI, Stomatal Resistance, Wilting Point, Porosity
- Domain over South Africa
- 1-year simulation
- Simplified output

Phase 2 testing parameters of other physical schemes:

- Convection: triggers, entrainment etc.
- Boundary layer: e.g. diffusion



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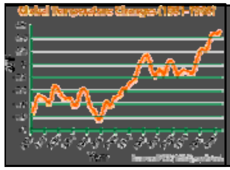

Seasonal forecasting

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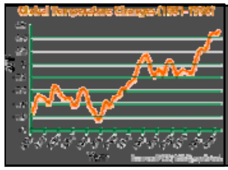

Some seasonal forecasting efforts in southern Africa

Institutions:

South African Weather Service (SAWS) – ECHAM4.5 + output from other centres

Drought Monitoring Centre (DMC) – forecast dissemination

International Research Institute (IRI) – SARCOF process with regional Met services

University of Pretoria (UP) – CCAM stretched grid model

University of Cape Town (UCT) – CAM and HadAM3

Computing resources (South Africa):

NEC at SAWS – used for running PUM (regional model used for short-range operational forecasts)

Centre for High Performance Computing (CHPC) – IBM nodes; cluster and SMP

UCT currently porting seasonal forecasts to local cluster and IBM 4-way SMP compute nodes

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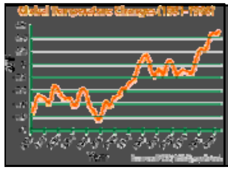
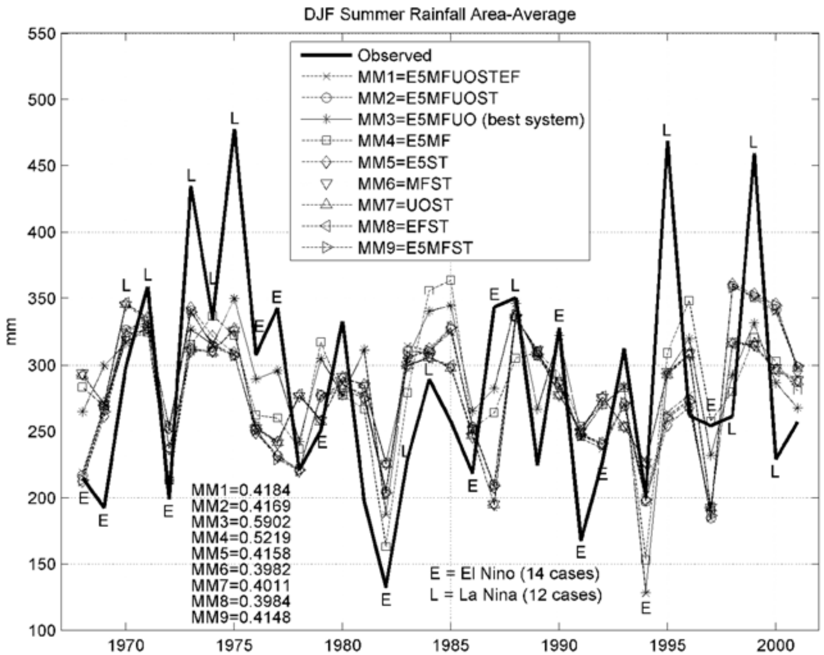
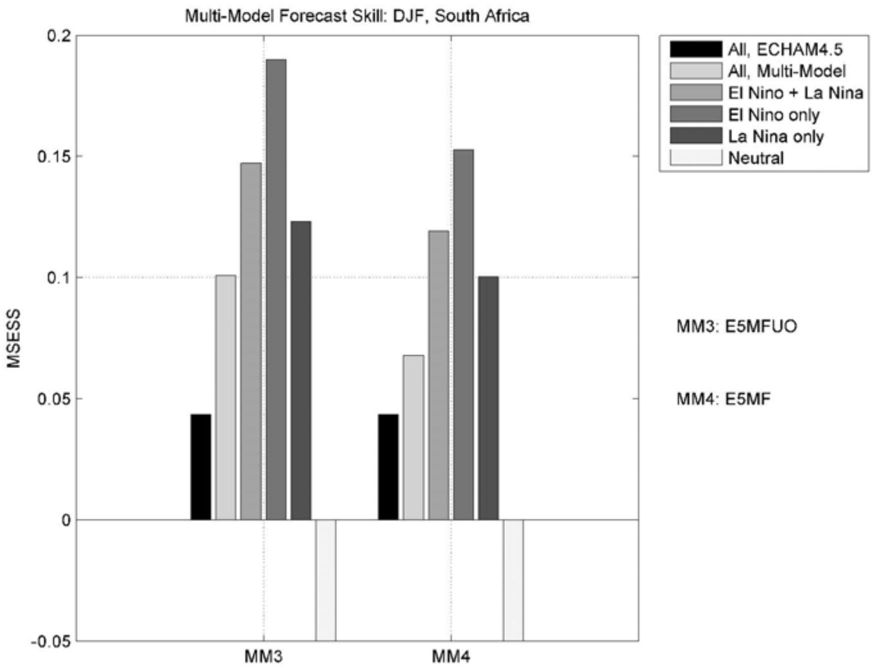


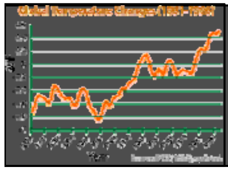
Forecasts for summer rainfall South Africa



Forecasts only feasible during ENSO years !!

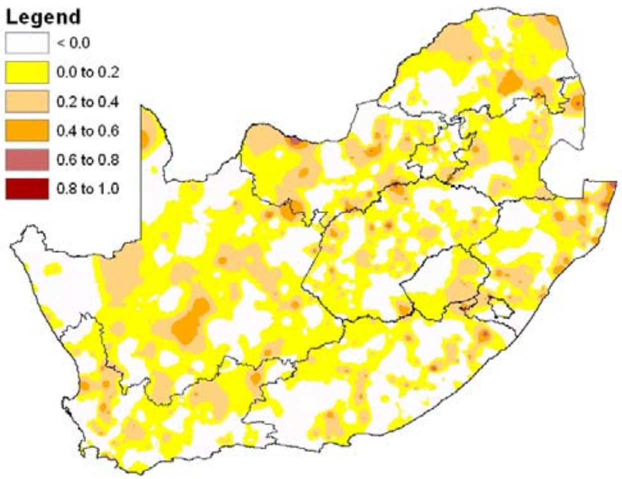


Source: Willem Landman, (South African Weather Service)

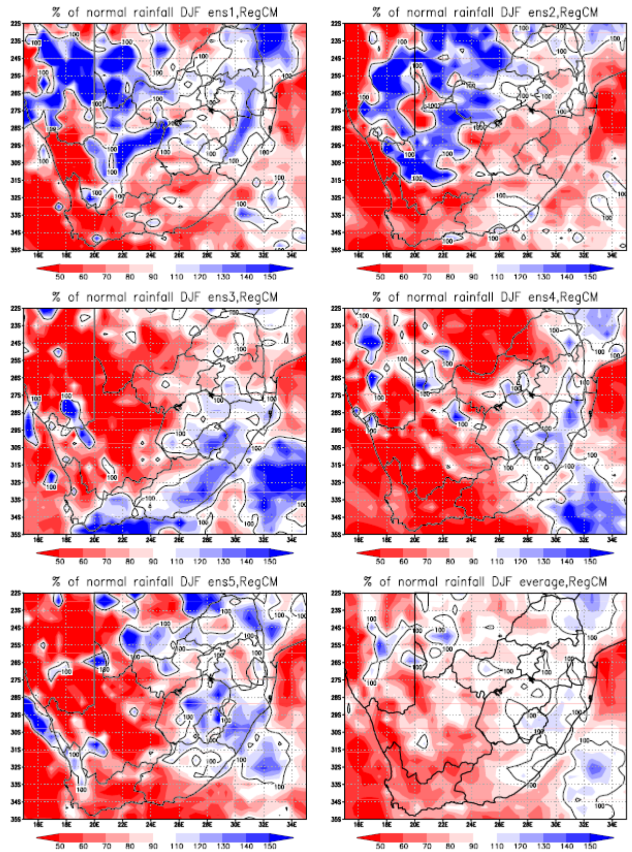


RCM (RegCM3) forecasts

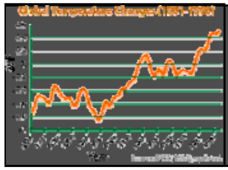
Anomaly correlation 10 years DJF (summer) rainfall



Example 5 member ensemble forecast

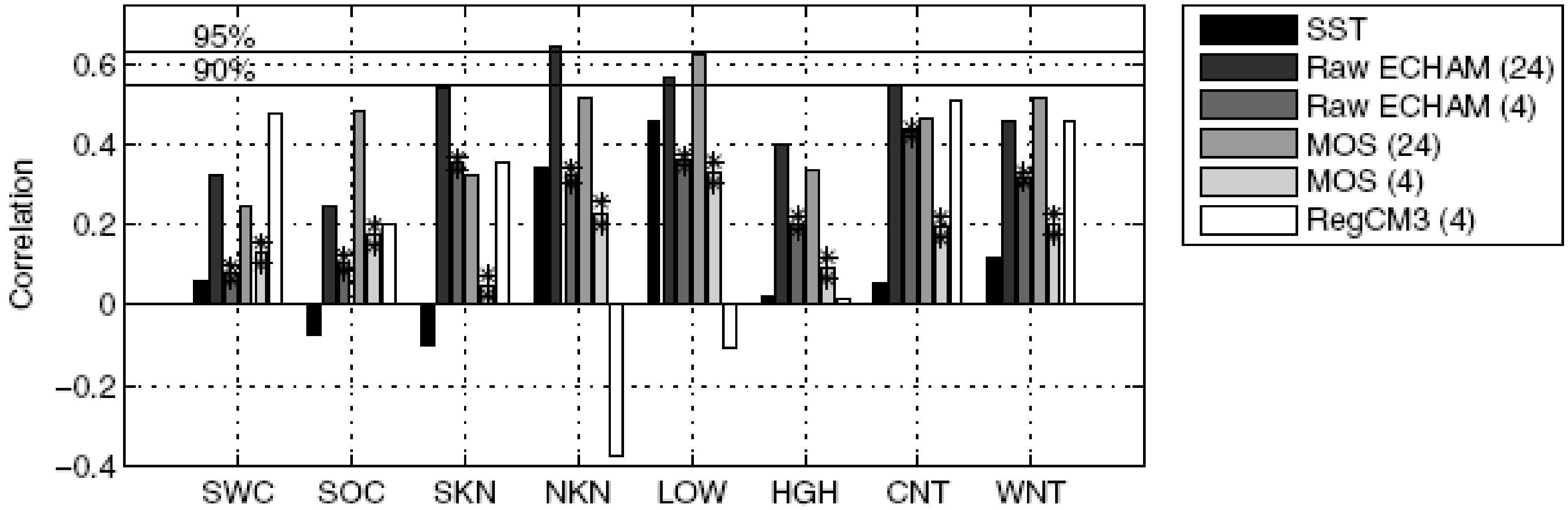


Source: Mary Jane Kgatuke, (South African Weather Service)

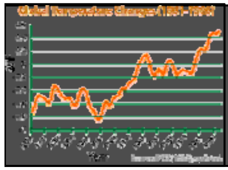


Regional skill of MOS, RCM and SST forecasts

Generally GCM post-processed MOS (model output statistics) outscores RCM which outscores SST-based statistical forecasts



Source: Willem Landman, (South African Weather Service)

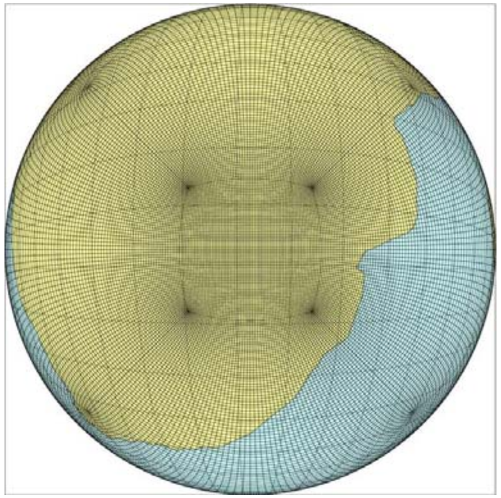


Extended range and seasonal forecasts at University of Pretoria using CCAM stretched grid model:

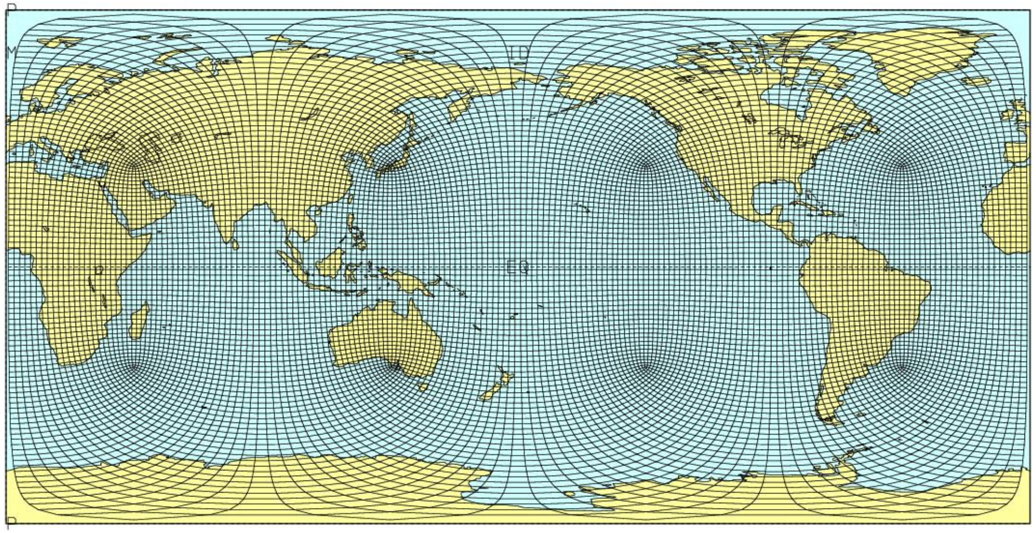
- 5x25 year AMIP simulations completed to define model climatology
- A 40 day forecast is issued weekly
- Three month forecast issued each month
- All simulations performed on the Velocity cluster at UP

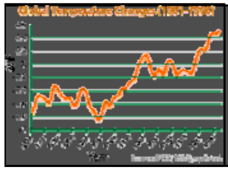
Operational forecasts:

- From 4 day to 8 day forecasts
- From 60km down to 8 km in highly stretched format



Quasi-uniform C48 grid with resolution about 210 km



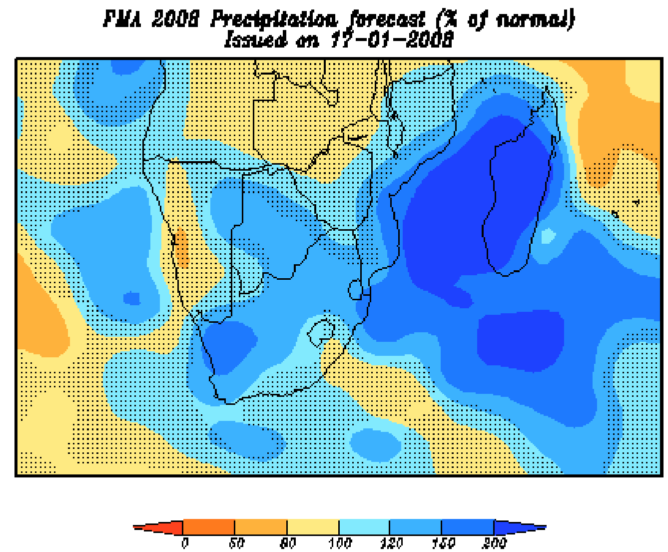


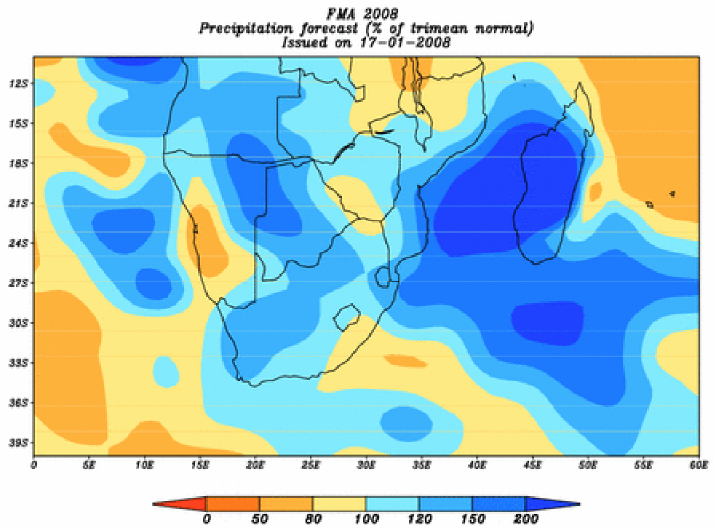
Global forecasting centre for southern Africa

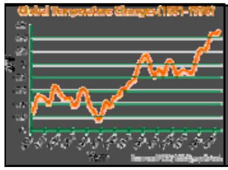
http://www.gfcsa.net/

NOTE - Fri. 22 Feb: As a result of multiple air conditioner failures which necessitated the emergency shutdown of the computers producing the forecast, we will be late in issuing the March, April, May, June, July forecast. Please check back on Wed. 27 Feb. We apologise for the inconvenience.

Global forecasts	Regional forecasts
Rainfall Anomalies	Rainfall Anomalies
Surface Temperature Anomalies	Surface Temperature Anomalies
700hPa Geopotential height anomalies	700hPa Geopotential height anomalies
	Vorticity Anomalies



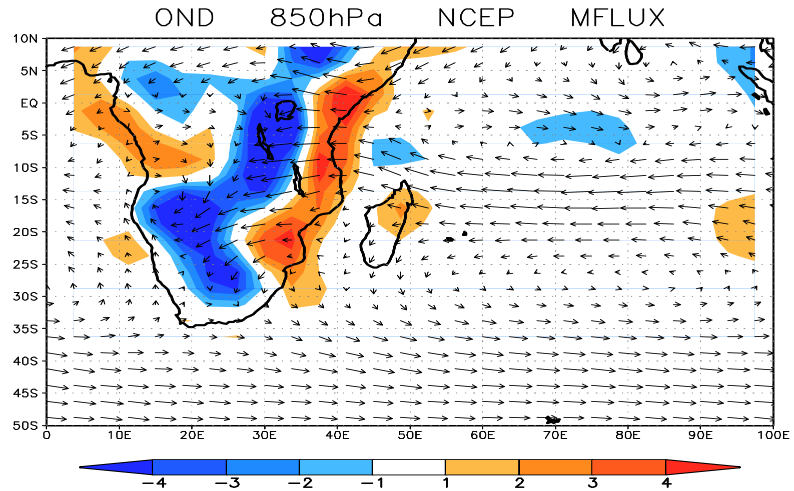




NCEP and HadAM3 moisture flux climatology

OND – early summer

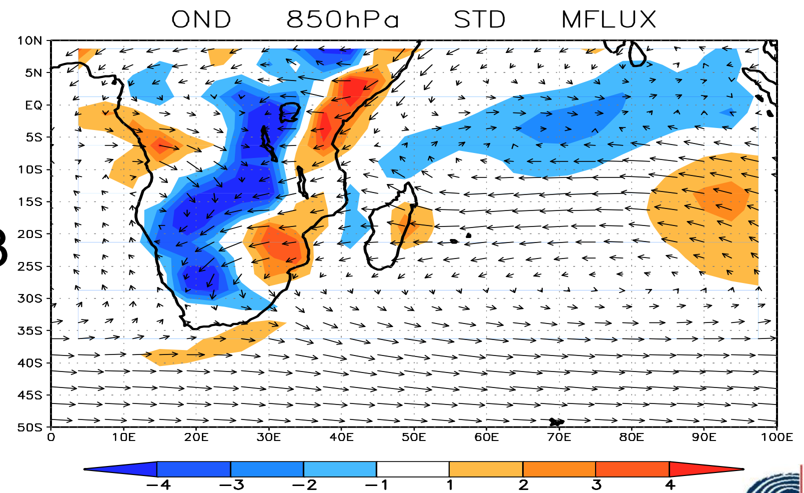
NCEP



Indian Ocean easterly flow more zonal over Madagascar in HadAM3 than NCEP

Convergence is further westwards in HadAM3

HadAM3



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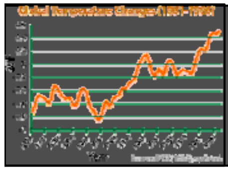
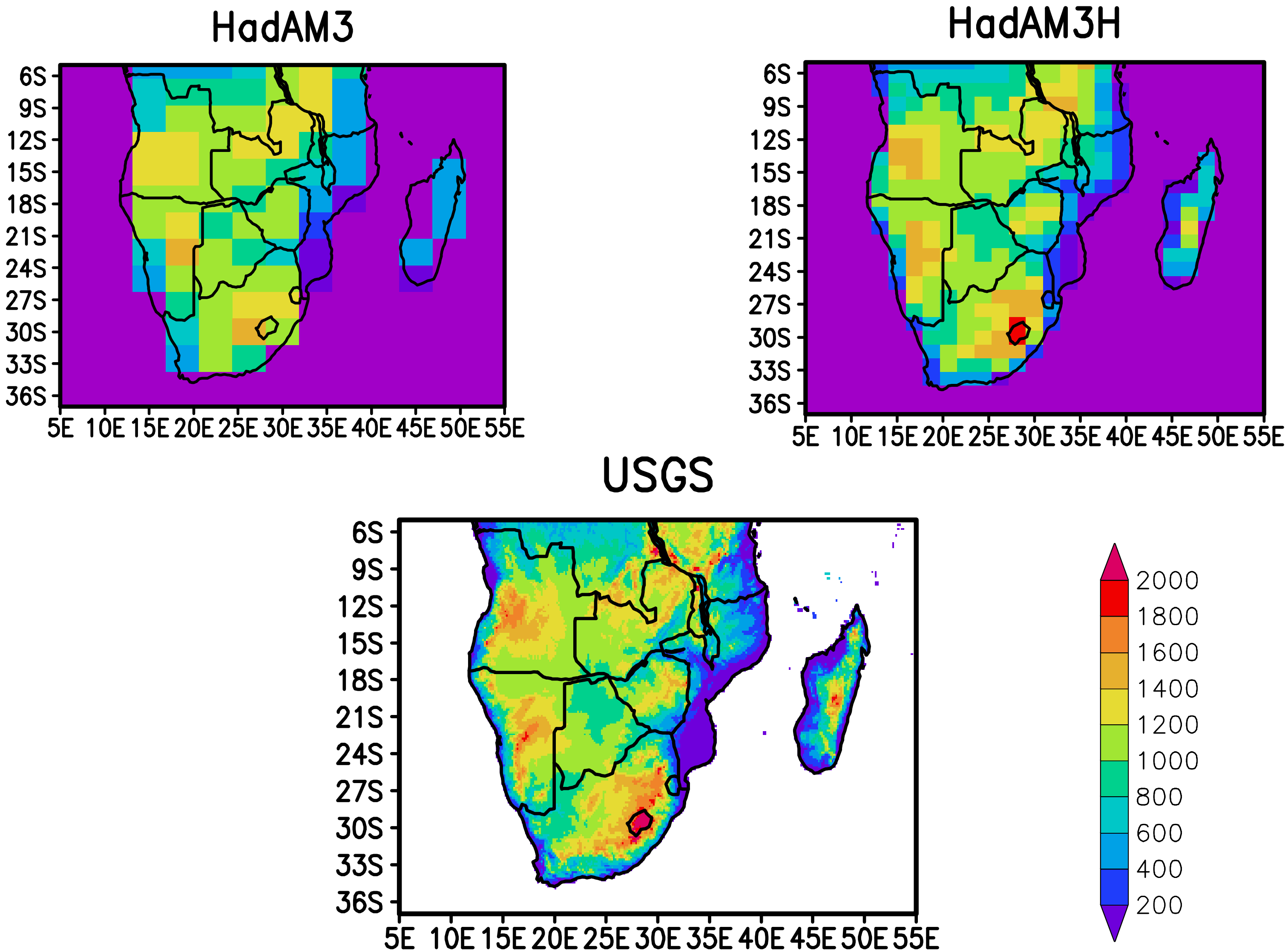


Importance of topography ?



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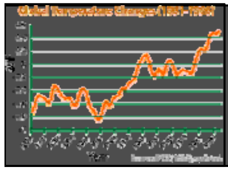
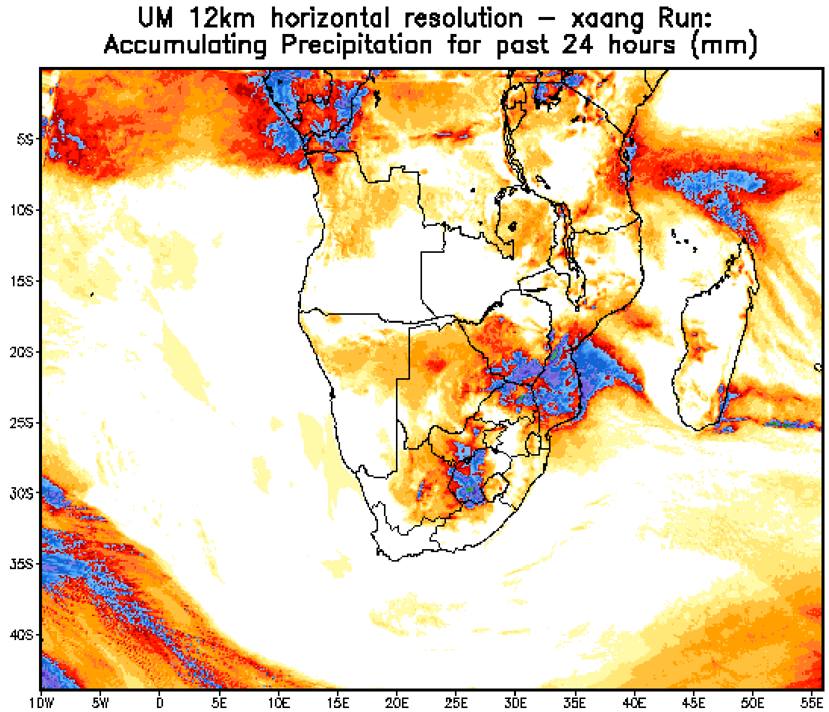
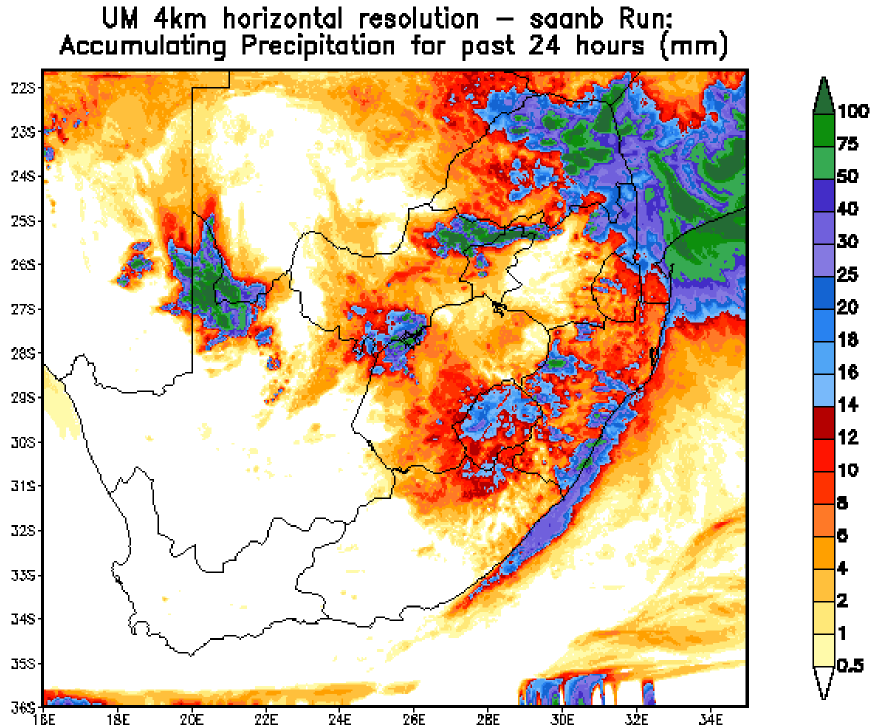


2 day forecasts with PUM at SAWS



Total precipitation of 24Z to 48Z, 30 MAR – Initiated 00Z 29 MAR



Total precipitation of 00Z to 24Z, 30 MAR – Initiated 18Z 29 MAR 2007

Source: Warren Tennant, (South African Weather Service)

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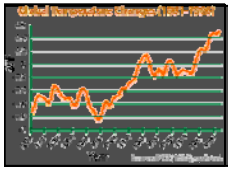
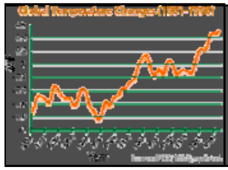


Providing useful climate information



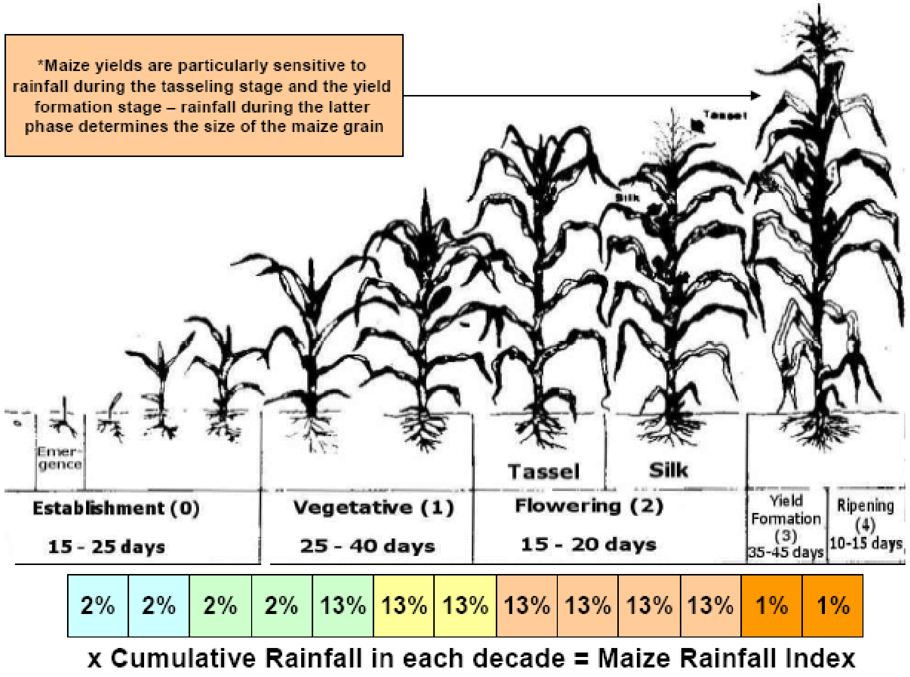
What information can potentially be forecast ?

Calculate indices based on rainfed maize crop

- Assume 3 potential planting criteria:

1. **25 mm in 10 days** (early planting)
2. **25 mm in 10 days with no dry spell > 10 days** (early planting without false start)
3. **45 mm in 4 days** (late planting)

- Assume rainfall *cessation* when: **3 consecutive dekads each < 20 mm**
- Calculate seasonal duration, dry spell frequency, number of rain days etc. based on above definitions for the start and end of season and assuming a **130-day** maturing maize varietal



Weights and diagram taken from the FAO's maize water requirement report*

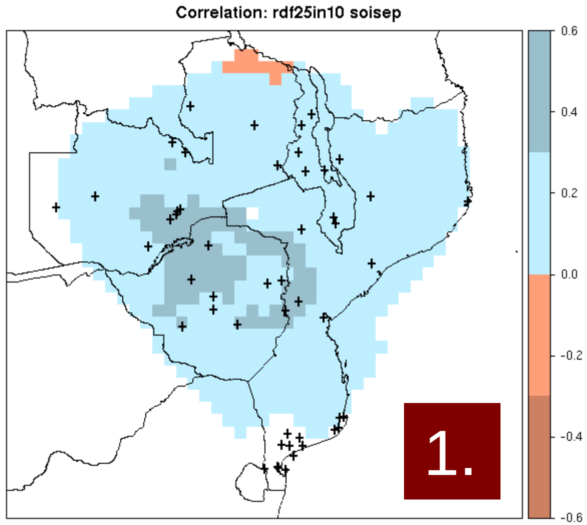
From Ibarra et al. – ARD, World Bank

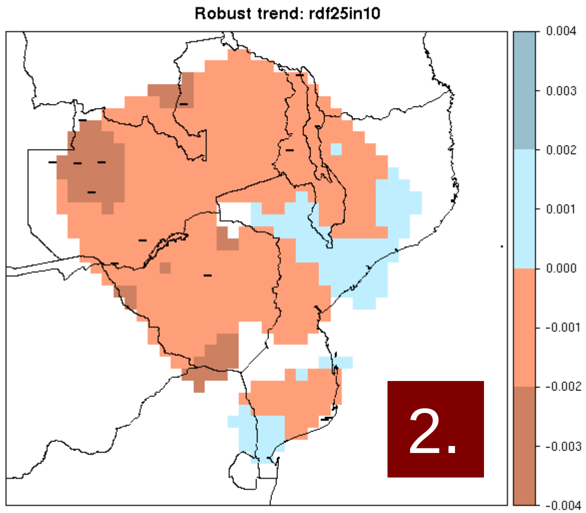
ENSO and long term change (1960-2005)

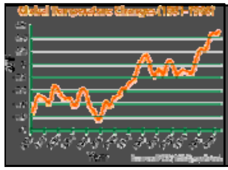
- **Both ENSO and long-term change affect intra-seasonal rainfall characteristics**

1. SOI significantly correlated with rain day frequency and dry spell duration

2. Trend for less rain days between planting and cessation

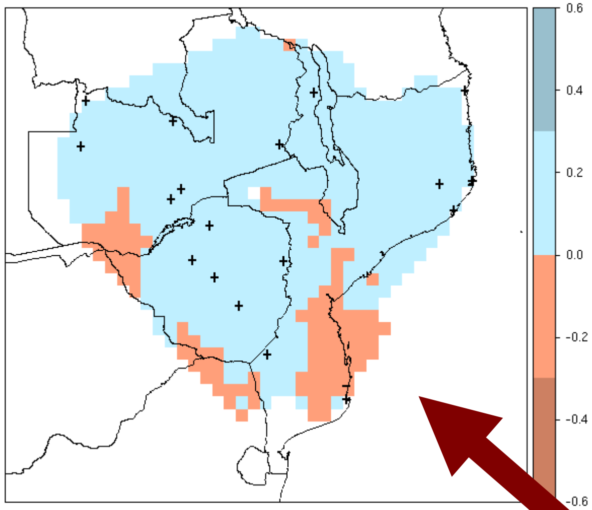






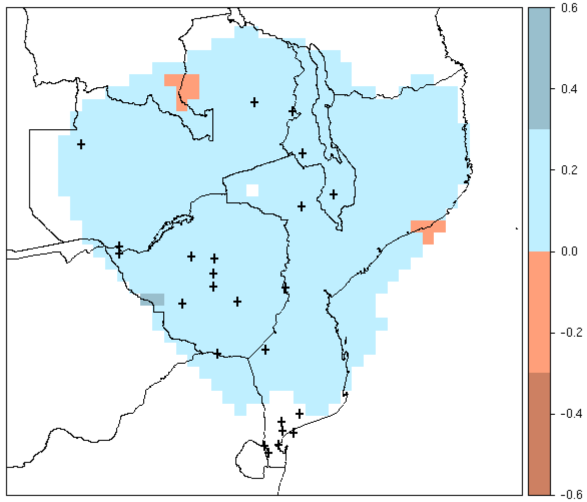
Correlation of seasonal boundaries with SOI

Correlation: st25in10 soisep

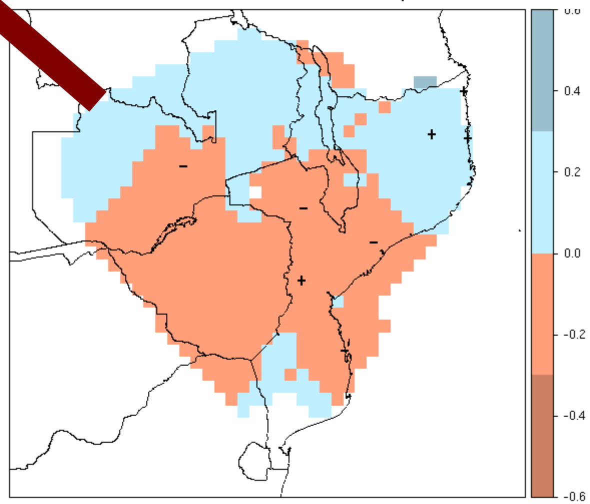


Both early planting and cessation +vely correlated with SOI $\Rightarrow$ earlier start and end of season during El Nino

Correlation: cessation soioct



Correlation: st25in10ds soisep

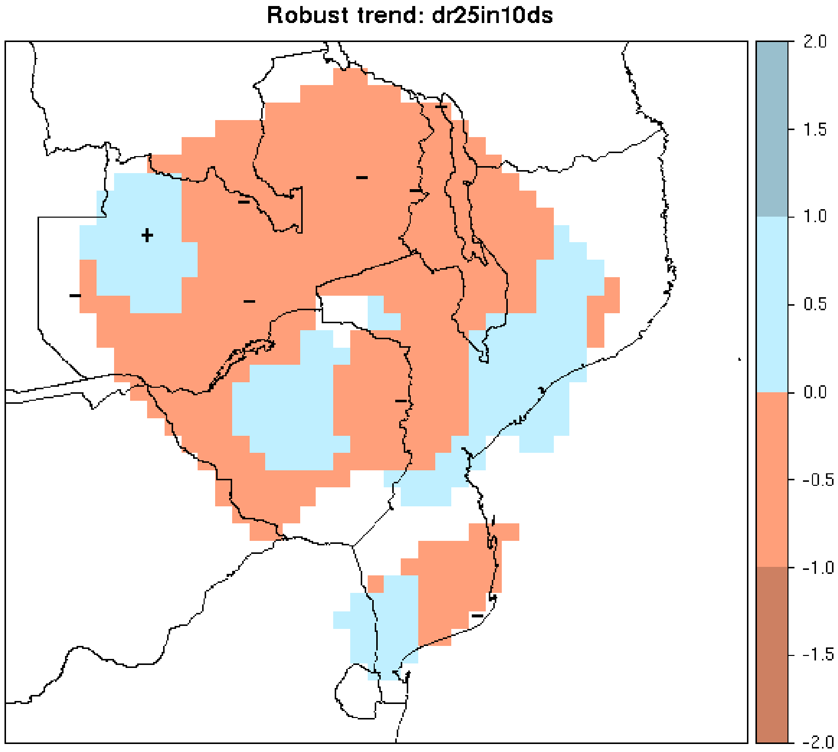


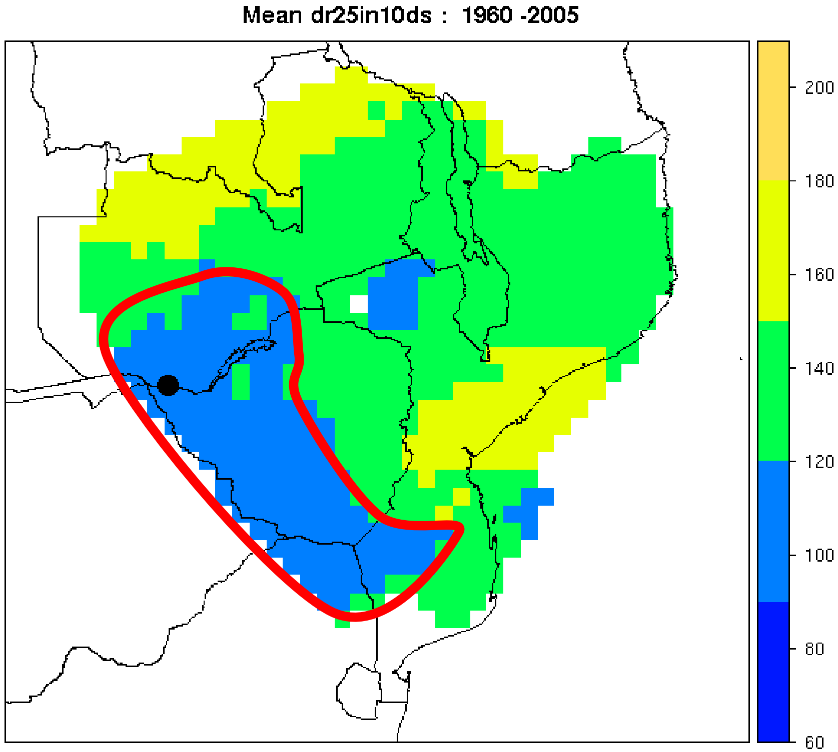
However early planting, avoiding a false start, does not necessarily come earlier !

Observed trends for seasonal duration (1960-2005)

Robust trend in seasonal duration (Planting – cessation)

Where is the mean seasonal duration close to critical thresholds for growing maize ?





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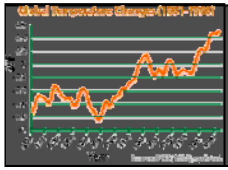
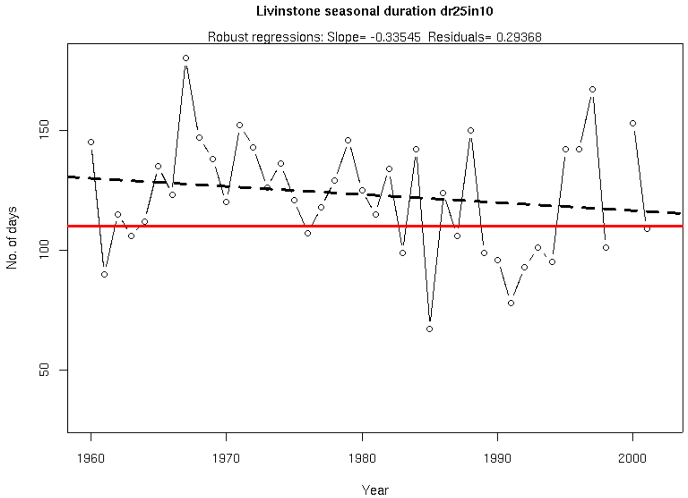
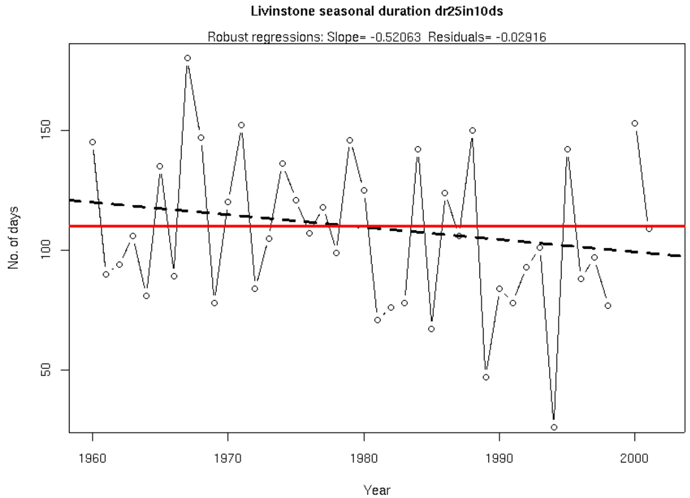


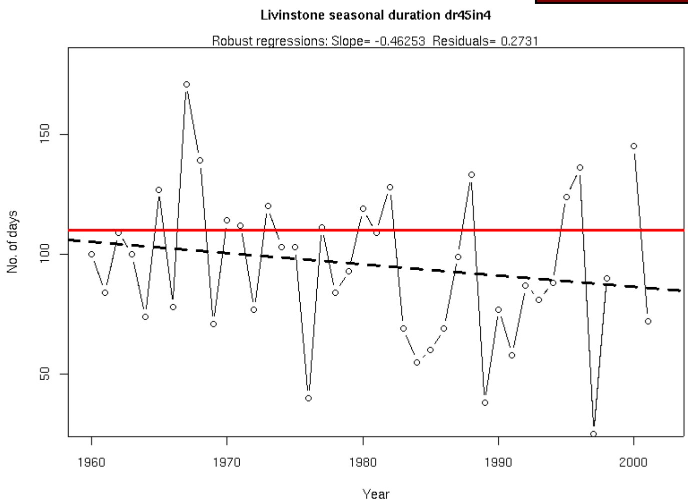
Livingstone (Zambia): increased risk of shorter seasons



Seasonal duration: EARLY planting



Seasonal duration: EARLY planting (+ no dry spell)



Seasonal duration: LATE planting

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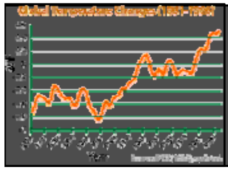
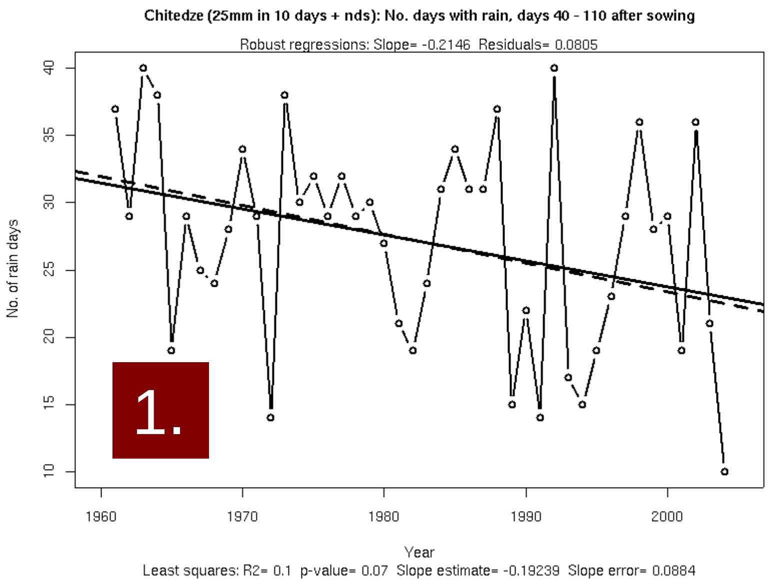


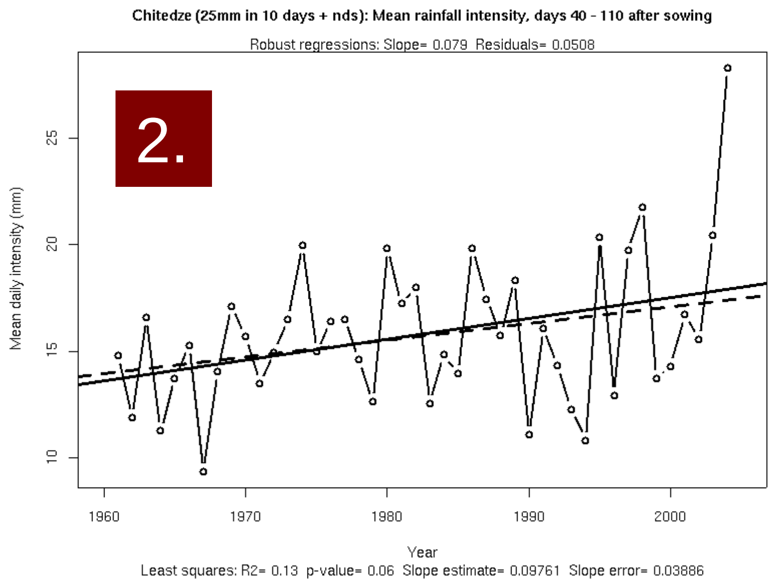
Chitedze (Malawi): intensification of rainfall season

- Trends for later planting dates reduce the length of the growing season

1. During days 40-110 after planting there is a trend for **less days with rain**
2. During days 40-110 after planting there is a trend for **increased rainfall intensity**



Number of days with rain



Mean daily rainfall intensity

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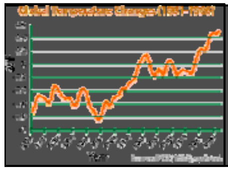
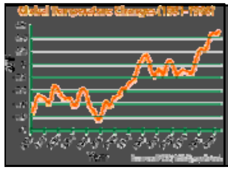


Climate change downscaling

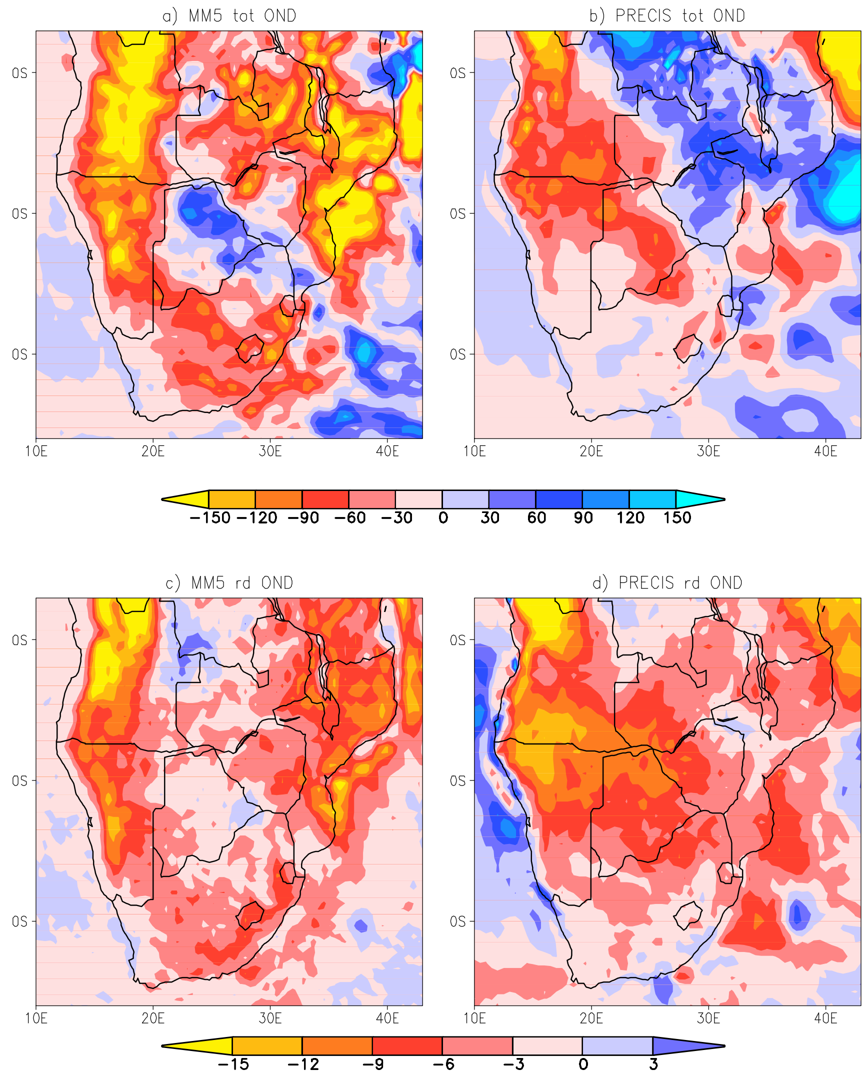


2 RCM (PRECIS + MM5) downscaling of HadAM3P

A2 scenario for late 21st century

Different changes in total rainfall during early spring (though both project increases during late summer)

More consistency between RCMs in projecting changes in the number of dry days



Change in total spring (OND) rainfall

Change in number of spring (OND) rain days

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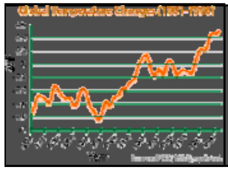
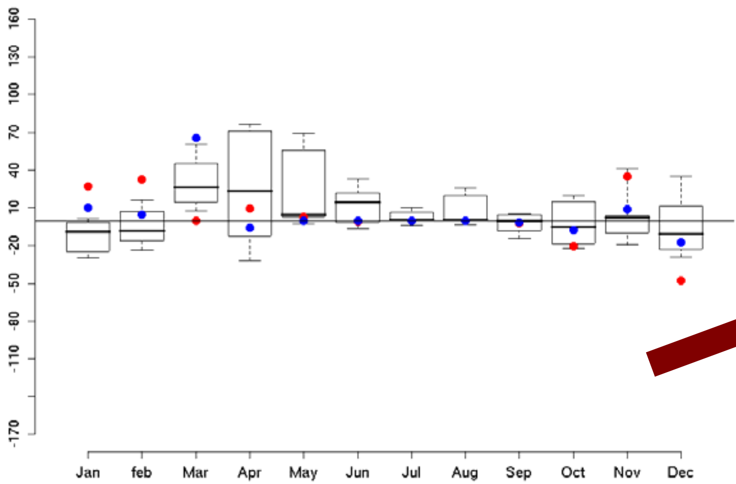
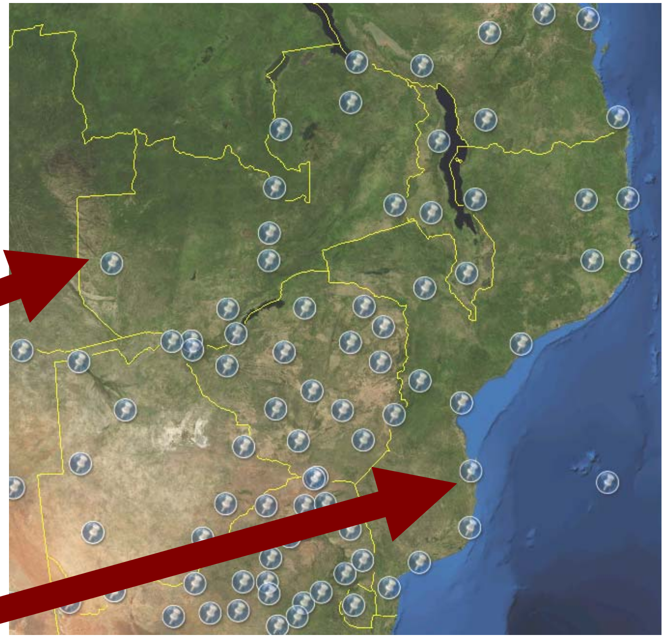


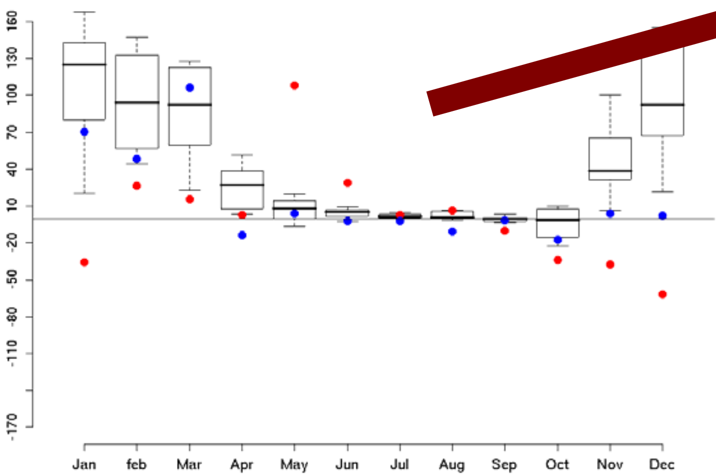
Projected change using Statistical models and RCMs

00067633 - Change in total monthly rainfall (mm)

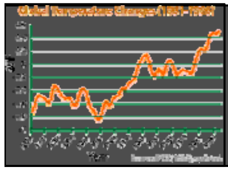




00067315 - Change in total monthly rainfall (mm)



CSAG



Summary:

- RCMs are valuable tools for investigating the regional response to environmental and climate changes over southern Africa. However it is important to understand how their biases may affect how they model change e.g. RCM that rains every day is not going to indicate increases in rain days given a perturbation to the system

- Currently MOS and statistical techniques for post-processing GCM data offer more skill for seasonal forecasting. However their inability to forecast ENSO neutral years suggests that other local environmental conditions may have a role to play.

- There are indications that forecast information, relevant to particular sectors and locations, could be provided for local decision makers. However, long-term change is evident and forecasting methodologies need to take this into account e.g. changing climatologies.