

Exchanges

- Scientific Contributions -

Tropical oceans and the predictability of southern African rainfall in the HadCM3 coupled climate model*

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Introduction

The relationship between variability in the Indian and tropical Pacific Oceans, and summer (JFM) rainfall in southern Africa is studied using transient climate change simulations of the Met Office Hadley Centre coupled climate model HadCM3, forced by the IPCC Special Report on Emissions Scenarios (SRES) greenhouse gas levels. (Nakicenovic and Swart, 2000).

The aim of the study is to investigate the role of ENSO in the forcing of southern African summer rainfall over the 20th and 21st centuries, with a view to assessing whether future predictive skill for seasonal forecasts is variable on decadal timescales.

Background

Southern Africa has one of the most interesting rainfall regimes with respect to forcing mechanisms, and timescales of variability. ENSO is currently an important control on observed precipitation variability in southern Africa, and the recent development of seasonal forecasting techniques for southern Africa have come to rely on ENSO related predictability. It is now recognised, however, that the remote forcing of southern African rainfall is not always present, and that for sustained periods in the observed record, regional forcing has been much more important (Fauchereau et al., 2003). We explore these relationships in the HadCM3 model first to evaluate the model representation of these processes, and secondly to explore the possible outlooks for southern African rainfall over the 21st century. The relative roles of ENSO and regional forcing mechanisms are compared in the model.

Model runs and data

Eight different integrations of HadCM3 are used. These include seven climate change runs forced with SRES greenhouse gas emissions, and one control run. The SRES storylines used are: A2 (3 runs); B2 (2 runs);

A1f (1 run); B1 (1 run). Each of these comprises 140 years of monthly resolution data, from 1960 to 2099, on a 2.5 latitude by 3.75 longitude grid. The control run comprises 100 years of data on the same grid. Total precipitation and sea surface temperatures (SSTs) are studied. Observed SSTs are from the GISST 2.3b dataset (Rayner et al., 1996). Rainfall data is from the CRU dataset (Hulme, 1992 and Hulme et al., 1998). All the SST and precipitation timeseries have been detrended using the best-fit linear function for each gridbox. We focus on the January - March (JFM) season.

ENSO-southern African rainfall relationships

The observed record shows significant variation in the correlation between ENSO and southern African rainfall on decadal timescales. During the period 1931-1960 this correlation was generally weak and insignificant (e.g. Richard et al., 2001), and is identified as coincident with a less active ENSO system in the tropical Pacific, as measured by the standard deviation of the Niño3 SST index. Figure 1 shows the relationship between 21-year running standard deviations of Niño3 and 21-year running Niño3/rainfall correlations for a selection of 10 gridboxes centred on Northern Province, South Africa, for the observed record, and for one of the model runs (A1f). We identify this relationship in a number of the model runs, using the same set of rainfall gridboxes. Note that while the shape of the distribution is the same, the modelled correlations in most cases are more positive than observed (and less significant as a result). There is non-linearity in both the modelled and observed relationships.

To gain a spatial sense of these teleconnections, Niño3 timeseries for JFM were correlated with global JFM precipitation for 30-year slices for each model run, starting 1961-1990, and advancing 10 years for each 30-year slice. Each of these plots (not shown) was examined, and considerable variability in the ENSO/southern African rainfall relationship was identified. We explored whether – as in the observed – this seems to be coincident with the variability of ENSO in the Pacific. In order to quantify decadal variability in the activity of ENSO, 21-year running standard deviations of the Niño3 timeseries were created. Any of the 30-year periods (starting 1961-1990) with a Niño3 timeseries wholly above or below the full

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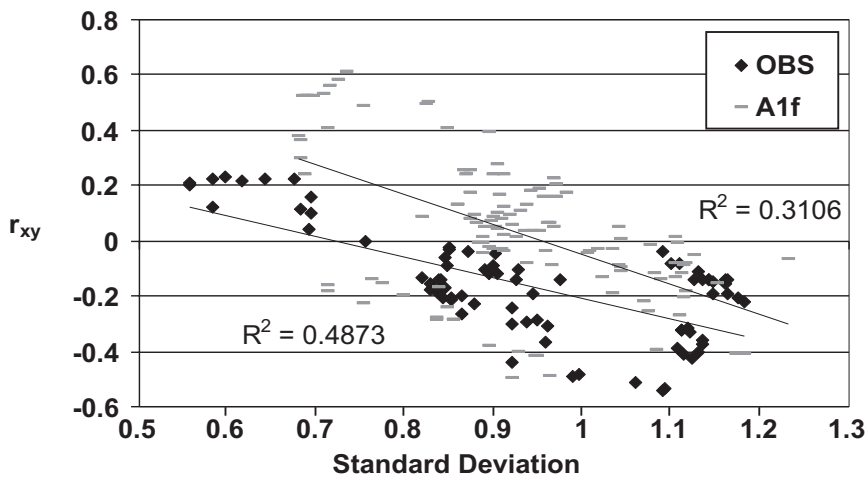


Figure 1: Scatter plot of 21-year JFM Niño3 running standard deviation against 21-year JFM running correlation between Niño3 and southern African (Northern Province) rainfall. Observed (OBS) data from 1900-1998 (GISST 2.3b SSTs and CRU/Hulme rainfall), and modelled (A1f scenario) data from 1960-2099 (HadCM3) are shown.

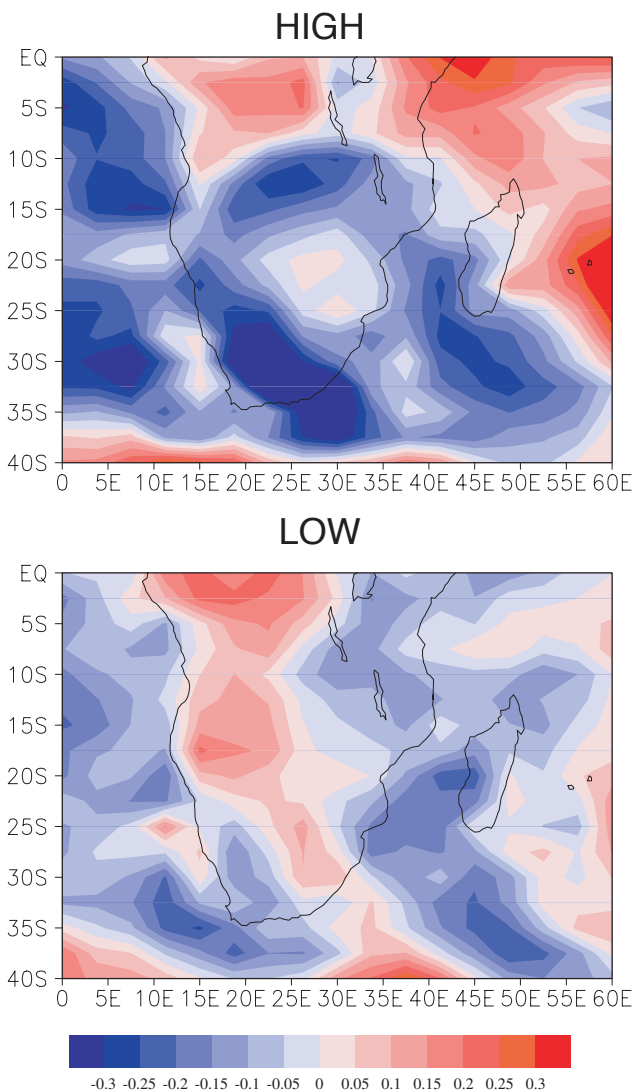


Figure 2: Averaged correlations between JFM Niño3 and rainfall over southern Africa for composite active (HIGH) and inactive (LOW) periods of ENSO activity (selected HadCM3 runs).

period standard deviation were identified as active or inactive ENSO periods respectively. A total of six active and nine inactive 30-year periods were identified. For each gridbox globally, the mean correlation coefficient for the six active periods, and for the nine inactive periods was calculated. The same was done for the correlations between Niño3 and global SSTs. Figure 2 shows the mean Niño3/precipitation correlations over southern Africa for the averaged active (HIGH) and inactive (LOW) periods. There is good agreement between the model and the observed. Whether there is a causal mechanism, and what the mechanism is, is a matter for further research. We explore here the relationship between ENSO and global SSTs, as the first step to understanding the causes of this variability.

The ENSO relationship with other tropical ocean basins is well documented (e.g. Tourre and White, 1997; Nicholson, 1997), and it is possible that the ENSO connection with southern African rainfall is driven by a link with the Indian Ocean and South Atlantic Ocean. The average correlations between Niño3 and global SSTs for active and inactive ENSO periods respectively show some interesting differences in the oceans surrounding southern Africa. The oceans surrounding southern Africa show some of the most notable differences between active and inactive ENSO periods globally. This could be pertinent to the marked decadal variability in southern African summer rainfall. Figure 3 shows the Niño3/SST averaged correlations for active (high) and inactive (low) periods. It is clear that during the active ENSO periods, correlations with the south Atlantic centred on 40°S 20°W are much more negative, and that the same band of negative correlations that comprises this area, extends more strongly into the southern Indian Ocean, to the area south of Madagascar. The correlations with the rest of the Indian Ocean are generally weaker during the inactive periods, although positive throughout. This suggests that the ENSO relationship with southern African rainfall may be modulated in some way by the intervening ocean basins on multi-annual timescales.

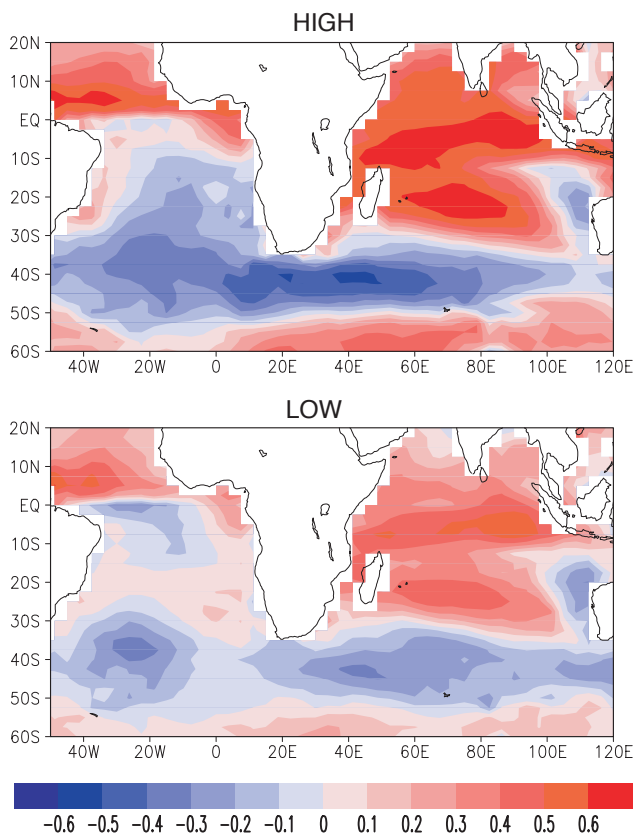


Figure 3: Averaged correlations between JFM Niño3 and SSTs in oceans surrounding southern Africa for composite active (HIGH) and inactive (LOW) periods of ENSO activity (selected HadCM3 runs).

Indian Ocean-southern African rainfall relationships.

To explore the role of the Indian Ocean SSTs in more detail, a timeseries of JFM rainfall from 10 gridboxes centred on Northern Province, South Africa, was correlated with global SSTs for each model run, and for the observed. The most significant feature of this analysis is a dipole of correlations, with negative and positive centres close to the north and south of Madagascar respectively. This is similar to the boundary between positive and negative SST correlations with Niño3, and is similar to the pattern in the observed. The pattern is robust throughout the model runs, although it varies somewhat in structure and strength over time. These figures are not included here. A further examination of the Indian Ocean SSTs reveals that the decadal variability of Niño3 standard deviations is synchronous with variability in the correlation between ENSO and the Indian Ocean SSTs. It seems, therefore, that there are important local influences on precipitation, but that these are modulated by ENSO.

Summary

There are significant periods in the observed record, and in HadCM3, where ENSO derived predictability of southern African rainfall is much lower than at present. This has important implications for seasonal forecasting in the region. The active and inactive periods of ENSO are not synchronous between the model runs. The intervening ocean basins could well modulate the variability in the ENSO-southern African rainfall relationship. As yet, we have not identified any significant global warming-related trends in this relationship in the model.

These results are of potential significance to those affected by seasonal forecasts in southern Africa. An important next step is to look at individual El Niño and La Niña events within each active and period, and identify the different effects they have on southern African rainfall.

Acknowledgements

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