4.1 NORTH EAST BRAZIL RAINFALL: INFLUENCES OF SEA SURFACE TEMPERATURE ON SEASONAL TO CENTURY TIME SCALES

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1. INTRODUCTION

The variability of wet season northeast Brazil (NEB) rainfall and its relationship with sea surface temperature (SST) has been studied on seasonal to century timescales using observed data and models. The observed rainfall data is due to Hastenrath, as described by Folland et al (2001). The seasonal to decadal model data is derived from an ensemble mean of 6 integrations of the HadAM2b atmospheric model, as described in the same paper. The century time scale model rainfall and SST data derive from 500 years of a 1400 year control simulation of the HadCM3 coupled model (Knight et al, 2003).

2. INTERANNUAL INFLUENCES OF SST

Fig. 1 shows time series of standardised simulated and observed March-May wet season NEB rainfall for 1912-1998 using the HadAM2b model forced with GISST3 SSTs. Standardisation was done separately on modelled and observed rainfall for the period 1951-1980. The correlation between observed and modelled rainfall is very high, being 0.78 over 1912-1947 and 0.81 for the rather better observed period 1948-1998. This result shows that SST is the dominant interannual influence on wet season rainfall. Figs 2a and 2b show examples of the spatial correlation of modelled (HadAM2b) and observed NEB rainfall with observed worldwide SST.

A more detailed observational analysis shows that the SST gradient across the tropical Atlantic on average most strongly affects NEB rainfall, followed by variations in Tropical Pacific SST associated with El Nino-La Nina (ENSO) (Ward and Folland, 1991). There is also some evolution of the patterns of the most influential SSTs through the seasonal cycle.

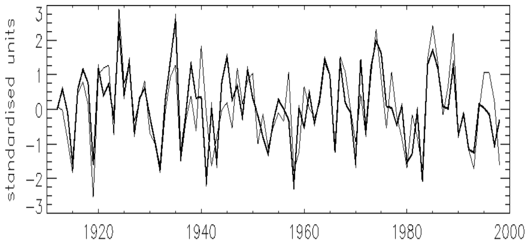

Figure 1 Time series of simulated (thick line) and observed (thin line) March-May rainfall, 1912-1998.

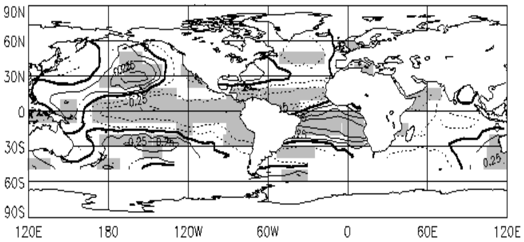

Figure 2a Simultaneous correlations between observed EB rainfall in April-May and worldwide GISST3 SST, 1948-1997.

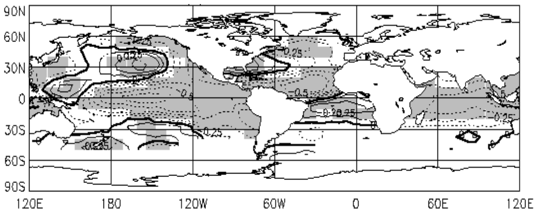

Figure 2b Simultaneous correlations between ensemble mean (6 members) HadAM2b rainfall in April-May and GISST3, 1948-1997.

The high predictability of wet season NEB rainfall from SST alone is shown by the generally very good skill of 11 seasons of real-time seasonal forecasts issued by the Met Office over 1987-1998 (Folland et al, 2001). Good skill has been maintained up to 2002, though some details of the forecasts have changed.

On interannual time scales the fluctuation of the north-south gradient of SST across the tropical Atlantic is particularly strong in the NEB wet season. However there is no coherent dipole of SST variation on such time scales, even though eigenvector analysis suggests otherwise. Nevertheless, the results of eigenvector analysis are still very useful for measuring the cross-equatorial Atlantic SST gradient for statistical forecasting (Ward and Folland, 1991).

3. DECADAL INFLUENCES OF SST

On decadal time scales there is a weakly coherent dipole of north-south SST variability, at least over the period 1912-1998 (Chang et al, 1997). This leads to a small peak in the skill of modelled March-May rainfall at these time scales (Fig. 3) with a dip in skill between ENSO and decadal timescales. Note that the statistically simulated rainfall depends on a

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simultaneous multiple regression relationship between NEB rainfall and both ENSO SSTs and the tropical Atlantic SST gradient (Folland et al, 2001 give details). The slightly higher skill of HadAM2b may reflect model responses to other aspects of the GISST3 SST patterns.

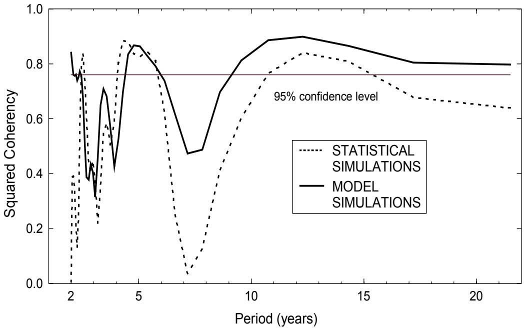

Figure 3. Squared coherence, 1912-1998, between observed and model simulated rainfall (thick line) and observed and statistically simulated rainfall (dashed).

4. CENTURY TIMESCALES

On multi-century timescales there are no rainfall observations, so we must rely on state-of-the-art coupled models. We use a 1400 year control run of the Met Office third generation coupled model, HadCM3, which has an oceanic resolution of 1.25° x1.25° . We have investigated natural variations in the Atlantic component of the global thermohaline circulation (THC) in the model. THC fluctuations are quite prominent in HadCM3, with a typical peak to trough range of about 2Sv. This can be compared to a mean model THC flux of about 16Sv near 30°N, thought to be quite realistic. The period of strongest fluctuations is variable by a factor of near two but is centred near 100 years. Fig. 4 shows worldwide temperature anomalies for the phase when the Northern Hemisphere exhibits maximum warmth during the consecutive 500 years of generally strongest THC fluctuations near the century timescale.

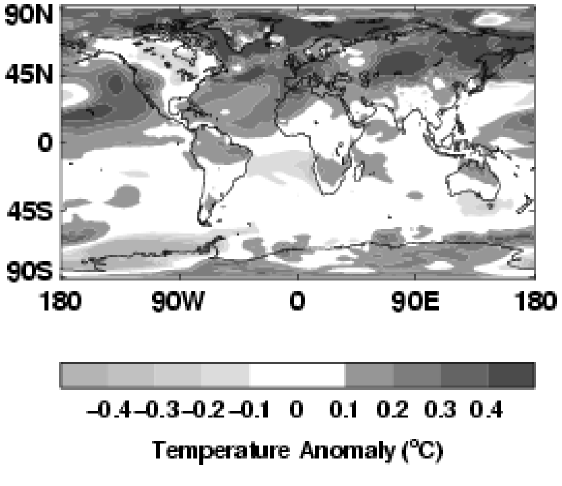

Figure 4. Near surface temperature anomalies at the Northern Hemisphere warm peak of those HadCM3 unforced thermohaline circulation variations having a period near 100 years.

Fig. 4 shows that the north-south SST gradient across the tropical Atlantic is clearly affected by modelled THC variations, the north Atlantic varying more than the south. In the limited observational record, a similar feature (with a nominal period near 70 years) is seen in SST over the last 130 years. This was first demonstrated in the context of Sahel rainfall variations by Folland et al (1986). This feature can probably be identified as the recently named Atlantic Multidecadal Oscillation, noting associated quasi-hemispheric variations in both observed and modelled SST.

Modulation of the SST gradient across the tropical Atlantic in observations and HadCM3 suggests that observed and modelled NEB rainfall should be affected. On these much longer than ENSO timescales, influences of the tropical Atlantic should dominate. Sensitivity has been assessed by comparing the standard deviation (SD) of decadally average observed Mar-May NEB (Hastenrath) rainfall for 1912-2001 with that of HadCM3 for the same region. The observed SD,10.5%, (for little over one 70 year cycle), agrees quite well with the modelled SD, 17.5%, covering about 5 century-long cycles. Furthermore, the regression slope of observed decadal rainfall against the SST anomaly difference between 0-20°N, 20-50°W and 5-20°S, 5-35°W is 1.4±0.9mm/°C while that for HadCM3 is 1.9±0.2mm/°C. These measures of rainfall sensitivity to SST gradient are insignificantly different. So NEB rainfall is likely to be at least moderately sensitive to THC variations, and to vary on near century time scales.

4.1 References

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