STABILITY OF THE RELATIONSHIP BETWEEN REGIONAL RAINFALL IN AFRICA AND ENSO

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1. INTRODUCTION

ENSO impacts on climate in Africa have been documented over different regions but the signal is not always strong and well defined. This could be due to the remote location of this continent from the core of ENSO anomalies and the influence of the Indian and Atlantic oceans, which have their own variability with strong impacts on regional rainfall and which may also modulate the ENSO signal.

Previous studies (Janowiak 1988, Nicholson 1993) have shown the regional-scale nature of rainfall variability in Africa. Bigot *et al.* (1997) have also studied the stability in time of such patterns. This work extends their studies using original rainfall data (CRC, updated from Bigot *et al.* 1997), global SST and ARPEGE-Climat AGCM (Météo-France, Déqué *et al*. 1994).

2. REGIONALISATION AND RELATIONSHIPS WITH ENSO

Rotated Principal Component Analysis of the annual (July to June) rainfall data for 1951-2000 (fig.1) reveals three main regions of covariability:

- Western Africa (20.4% of variance), dominated by a downward decadal trend, with some recovery by the end of 1990's;
- Southern Africa (12.5%), with higher interannual variability;

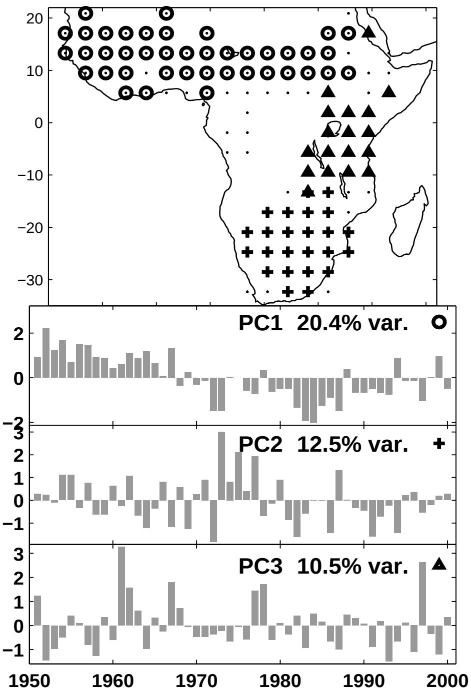

FIGURE 1: *RPCA on annual rainfall in Africa : upper panel - loading maps of the first three PC (values greater than 0.5 are labeled : o for Western Africa; + Southern Africa; ▲ Eastern Africa); lower panel - respective PCs.*

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- Eastern Africa (10.5%) with interannual variability dominated by the wet years of 1961 and 1997.

These regions exhibit correlations with ENSO-related indexes in the cores of their respective rainy seasons : JAS for West Africa, JFM for Southern Africa and OND for Eastern Africa (Camberlin *et al.* 2001). However these relationships are not stable in time. Figure 2 shows running correlations computed on 21-yr windows between regional indexes inferred from

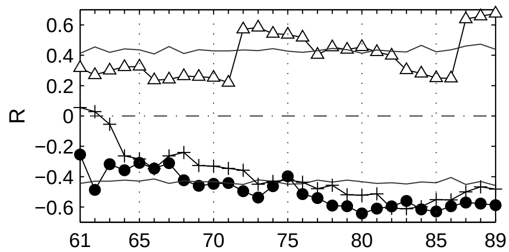

FIGURE 2: *21-yr running-window synchronous correlations between Niño3-4 and: JAS West African Rainfall (•); JFM Southern Africa Rainfall (+);OND Eastern Africa Rainfall (∆); solid line – Monte Carlo 95% significance level; year labels for the middle of the period e.g. 70 for 1960-80.*

RPCA Analysis and Nino3-4 Index. The relationship for Eastern Africa shows abrupt shifts wich are related to the inclusion/exclusion of the highly anomalous rainfall events of 1961 and 1997. As pointed out by Janicot *et al.* (2001) and Richard *et al*. (2000), teleconnections between ENSO and monomodal, tropical West Africa and Southern Africa enhanced between the end of 1960's and the mid-1990's.

The hypothesis for this latter instability involves the modification of the global and regional SST slowly varying contexts in the tropical and extratropical Atlantic and Indian oceans. The latter has particularly experienced significant warming trend during last decades (Casey and Cornillon, 2001).

3. NUMERICAL EXPERIMENTS RESULTS: EXEMPLE OF SOUTHERN AFRICA

Two sets of experiments centered on the cores of the Western and Southern Africa rainy seasons have been performed using different combinations of the recurrent eigen-modes of global SST variability as lower boundary forcings in order to document Pacific, Atlantic and Indian Ocean variability. The design of the experiments has been extensively documented in Trzaska *et al*. (1996) and Richard *et al.* (2000). Preliminary results have shown significant modifications of rainfall and regional atmospheric dynamics during ENSO conditions depending on SST in the Southern and Indian Oceans.

Figure 3 shows the modeled 200hPa divergent circulation and the anomalies simulated in March for

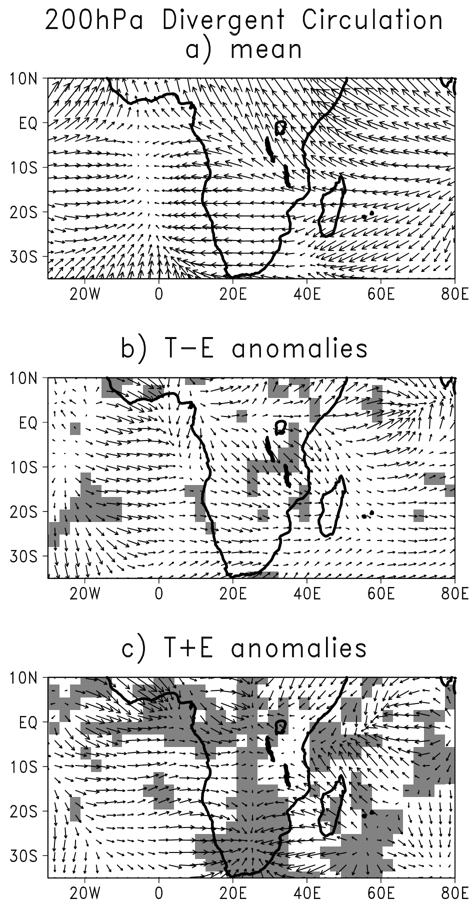

***FIGURE 3**: 200hPa divergent wind simulated with ARPEGE-Climat AGCM in March. a) mean values; b) T-E anomalies; c) T+E anomalies; vectors – horizontal divergent components (in $m.s^{-1}$, identical vector scaling for all plots), grey shadings – vertical velocity anomalies significant at 95% level.*

cases of ENSO occurring in a relatively cooler/warmer southern and Indian oceans context (resp. T-E and T+E experiments). In the cooler southern context the upper level circulation anomalies over Atlantic and Africa are mainly westerly (easterly in the mid and lower levels, not shown) in accordance with an anomalous direct zonal circulation triggered by the eastern Pacific warming and extending to the Indian Ocean. Few vertical motion anomalies are simulated over Africa. In the warmer context two anomalous zonal cells are triggered by the eastern Pacific and tropical Indian Oceans (resp. westerly and easterly upper level anomalies) and converge over the continent where significant downward anomalies are simulated. Note the large extent of the anomalies from the Gulf of Guinea to South Africa and western Indian Ocean. These anomalies extend towards surface where divergent motion is observed (not shown). Such a circulation inhibits moisture convergence and convection over the continent.

4. CONCLUSION

The basic hypothesis explaining these changes in the rainfall/ENSO relationship involves mainly the tropical Indian Ocean, an area of warm surface waters reaching temperatures close to the deep convection limit: any increase of SST leads to a strong increase of convective activity and rising motions hence to an anomalous direct zonal circulation extending westward over Africa. The importance of the Tropical Indian SST for the correct simulation of the ENSO impacts over Southern Africa has been pointed out by Rocha and Simmonds (1997) and Goddard and Graham (1999). The long term warming of the Indian Ocean may then lead to an enhanced direct zonal cell which may restrict the zonal extension of the anomalous zonal circulation over Atlantic and Africa related to the eastern Pacific warming (cf. fig.3b:T-E experiment) and cause extensive subsidence over Africa. However, the reduced impacts observed over some regions during the 1997/98 ENSO events with a warm Indian Ocean, modulate this assertion: the roles of the Indian Ocean "dipole" and the interhemispheric thermal gradient have to be further investigated.

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