4.2 MECHANISMS GENERATING THE DOMINANT MODES OF VARIABILITY IN THE SOUTH ATLANTIC OCEAN: A STUDY WITH A HIERARCHY OF OCEAN-ATMOSPHERE MODELS

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1 Introduction

There are strong indications for the existence of decadal modes of variability in the climate system over the South and Tropical Atlantic (Venegas et al. 1998). However firmly based explanations of the dominant mechanisms and are still lacking.

In this study we have investigated the mechanisms for generating the dominant patterns of coupled decadal variability within the framework of an intermediate complexity atmosphere model and a hierarchy of ocean models.

Analyzing 52 years of NCEP/NCAR analysis data Sterl and Hazeleger (2002; hereafter SH) conclude that anomalous latent heat flux and wind-induced mixed layer deepening are the main causes for generating the dominant patterns of coupled varaibility, with a minor role for anomalous Ekman transport.

Our results confirm basically those of SH, thereby firmly establishing their results. The main difference is the role of Ekman transport, which according to our results is also an important mechanism for generating coupled variability in the South Atlantic.

2 Model structure

The atmosphere model used in this study is SPEEDY (Molteni, 2002). It is an intermediate complexity model based on a spectral primitive-equation core and a set of simplified parameterization schemes. The horizontal resolution is T30 and it has 7 vertical levels.

The state-of-the-art ocean model is the Miami Isopycnal Coordinate Ocean Model (MICOM) confined to the Atlantic from 40S to 20N. The horizontal resolution is 1 degree and it has 16 levels. Outside this basin the ocean model is a passive mixed layer which will be described below.

The different components of the hierarchy of ocean models used in this study are:

- Passive mixed layer
- Horizontal and vertical Ekman transport
- Wind mixing

Details of how these processes are modelled will be discussed below, together with the results of the simulations.

3 Results

The last 40 years of a 60 year integration of SPEEDY-MICOM were analyzed. The first SVD mode of MSLP and SST (fig.1 upper panel) displays a strong resemblance with the first SVD mode of SH. The agreement of the second SVD mode (not shown) with the one of SH is less. The MSLP pattern of this mode shows good agreement, but the SST patterns lacks the tripole structure of the mode computed by SH. The ability of SPEEDY-MICOM to simulate the observed dominant patterns of variability demonstrates that this model configuration contains the essential physics for generating these patterns. Using a hierarchy of ocean models we will in the rest of this paper try to understand what are

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the mechansims for generating the dominant patterns of coupled variability.

3.1 Passive mixed layer

The equation for the mixed layer temperature T is:

$$\frac{\partial T}{\partial t} = -\frac{Q}{h\rho_w c_p} + F \tag{1}$$

where Q is the net surface heat flux, h (80m) the mixed layer depth, ρ_w the density and c_p the specific heat capacity of sea water. F represents the induced heat transport by the ocean which is computed from a 50 year run with prescribed SST's.

The last 100 years of a 120 year integration were analyzed. Similar as SPEEDY-MICOM the first SVD (fig.1 middle panel) shows a dipole pattern for the SST and a monopole for the MSLP. The main heat source for generating the SST anomalies is the latent heat flux.

Notwithstanding the similarity, a closer inspection of the SVD patterns of MSLP and SST reveals significant differences with those of SPEEDY-MICOM. The MSLP pattern is shifted 10 degrees equatorward and shows no clear resemblance with the first EOF mode of MSLP as was the case in SPEEDY-MICOM and was also noticed by SH. Accordingly the SST dipole is also shifted equatorward. In addition the zonal extend of the poleward maximum of the SST dipole is less.

These results clearly demonstrate the active role of the ocean in generating the SST anomalies.

3.2 Ekman transport

As a first step to evaluate the role of ocean dynamcis anomalous Ekman transport terms where inlcuded in the equation for the mixed layer:

$$\frac{\partial T}{\partial t} = -\frac{1}{h}(U_e \cdot \nabla_h T + w_e \Delta T) \tag{2}$$

where $\boldsymbol{U_e}$ is the vertically integrated horizontal Ekman velocity, w_e the Ekman pumping velocity and ΔT the temperature jump across the base of the mixed layer. For ΔT we choose a value $2K$.

The patterns of MSLP and SST of the first SVD mode (not shown) are now located on approximately the right position. Also the variability and explained variance are better in agreement with the SPEEDY-MICOM run.

3.3 Wind mixing

Next we investigated the rol of wind mixing. In order to facilate the comparison between our results and SH we adopted the same expression for wind mixing as derived by SH:

$$\frac{\partial T}{\partial t} = -\frac{\alpha}{h} u_*^3 \tag{3}$$

where u_* is the friction velocity defined by $u_*^2 = \frac{\tau}{\rho_w}$. For α we choose a value of $10Ks^2m^{-2}$.

Comparison of the first SVD mode (fig.1 lower panel) with the one of the SPEEDY-MICOM run reveals that he is almost perfectly simulated. Compared to the mode obtained without wind mixing most notably for the SST pattern is the shift of the maximum of the equatorward lob to the south-east corner of the basin, and the zonal extension of the poleward lob. The tilt of the MSLP pattern changed from southeast - northwest to southwest - northeast. The second SVD mode (not shown) shows in agreement with the second SVD modes of SPEEDY-MICOM and SH a meridional MSLP dipole in south east - north west direction and a a large SST band along approximately 35S.

4 Conclusion

Using an atmosphere model of intermediate complexity coupled to a hierarchy ocean models we have investigated the physical mechanisms responsible for the dominant patterns of coupled MSLP and SST variability. The results show that the patterns are due to a combined effect of turbulent surface heat fluxes, Ekman transport and wind mixing.

References

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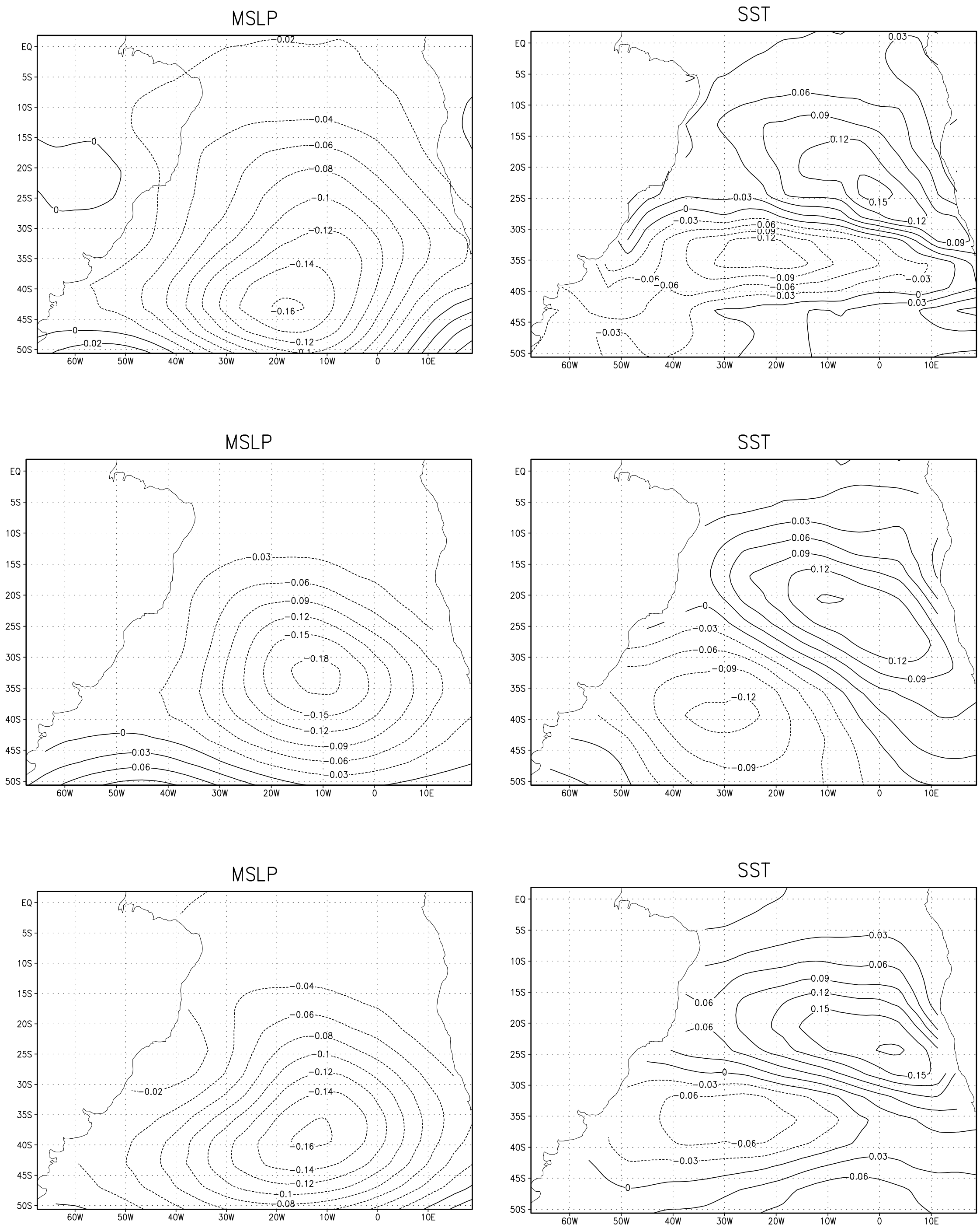

Figure 1: Combined SVD analysis of MSLP and SST anomalies for the SPEEDY-MICOM run (upper panel), passive mixed layer run (middle panel) and passive mixed layer + Ekman + wind mixing run (lower panel), The explained variances are 33 %, 32 % and 30% respectively