THE SOUTHERN ANNULAR MODE: TROPICAL – EXTRATROPICAL INTERACTIONS AND IMPACTS

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1. Introduction

The Southern Annular Mode (SAM, also called Antarctic Oscillation) is the dominant mode of extratropical (south of 20S) low-frequency atmospheric variability in the Southern Hemisphere. It basically consists in a sea-saw of barometric pressure between the Antarctic continent and the mid-latitude, so that in its positive phase, the westerly wind belt is intensified and shifted poleward. The SAM is usually extracted as the first EOF on the pressure field in the Southern hemisphere, explaining around 30% of variance. It has been shown to arise as the result of wave – mean flow interaction. It shows a significant trend towards more positive phases during the last decades, seemingly related to anthropogenic forcing (via combination of ozone depletion and GHG radiative forcing). The SAM has a profound impact on the southern ocean dynamics, primary productivity and biogeochemistry therefore a better understanding of the SAM is important towards an assessment of the future role of the Southern Ocean as a sink of anthropogenic CO_2 as well as on the adjustment in the natural CO_2 fluxes

In this context, the relationships between the SAM and tropical modes of atmospheric variability suffer from incomplete or somehow contradictory description. In this study we investigate in particular its links with the Madden-Julian-Oscillation and ENSO, the dominant modes of tropical atmospheric variability at the intra-seasonal and interannual time-scales, respectively. It is showed here that, contrarily to suggestions made in other papers, the SAM is not significantly and unambiguously related to the MJO. On the other hand, we confirm that the SAM shares up to 25% of variance with the ENSO during summer. The independent and combined effects of those modes on Southern African summer rainfall is next investigated and we discuss the importance of a better understanding of tropical – extratropical interactions in the context of the role of the Southern Ocean in modulating fluxes of anthropogenic and natural CO_2.

1. Data and Methods

We make use of the NCEP-DOE II reanalyses (Kanamitsu et al, 2002) to document the atmospheric dynamics over the Southern Hemisphere related to the SAM, MJO and ENSO. The SAM has been defined as the 1st EOF on the daily (unfiltered) 700 hPa field south of 20S, it has been checked that the results are not dependant on the SAM index. The MJO signal is extracted through the real-time daily indices developed by Wheeler and Hendon (2004). ENSO is defined through the Multivariate ENSO Index (MEI, Wolter and Timlin). Rainfall over South Africa is documented by daily station time-series compiled in the WRC dataset (Lynch, 2003).

3. Results

a. time-scales of variability

The time-scales of SAM variability are first investigated using the EMD (Huang, 1998) method. It is found that a large part of variance is concentrated in the synoptic to intraseasonal time-scales (10 - 60 days).

b. Relationship with the MJO

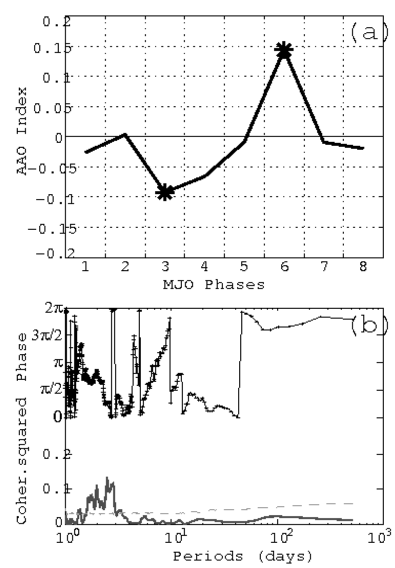

Figure 1: relationships between the SAM and MJO.

The Figure 1 presents respectively the composite anomalies of the SAM index as a function of the MJO phases and the cross-spectrum (coherence and phase) of the two indexes. While the SAM index presents significant negative (positive) anomalies locked onto the phase #3 (#6) of the MJO life-cycle, the cross-spectrum shows that the relationship between the two indexes is not coherent at the ISO scale and lacks a constant phase relationship. Further analyses show that the MJO signal into the SH pressure and wind-field projects imperfectly onto the SAM pattern, allowing to understand these seemingly conflicting results. Altogether these results challenge some conclusions of recent studies (Carvalho et al, 2005, Matthews and Meredith, 2004) on the impact of the MJO on the SAM variability.

c. Relationship with the ENSO

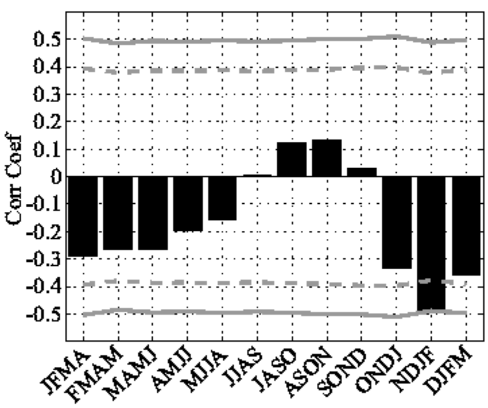

Figure 2: relationship between the SAM and ENSO

The Figure 2 shows the seasonally (4-months averages) stratified correlation coefficients between the SAM and the MEI. Significant negative correlations are found during the austral summer, indicating that El Nino (La Nina) tends to be related to an average negative (positive) SAM index during SH summer. These results confirm those of L'Heureux and Thompson (Further analyses show that the spatial pattern of pressure anomalies related to ENSO in the SH presents a high degree of zonal symmetry, and is highly congruent to the SAM pattern.

Based on these results, we then isolate the specific influence of the AAO on rainfall variability. The example taken here is South Africa, a region under the influence of both the MJO and ENSO, recording its main rainy season in austral summer, and containing a relatively dense network of rain-gauge measurements. *At the interannual timescale*, the significance of the teleconnections between South African rainfall and the AAO reveals to be a statistical artefact, and become very weak once the influence of ENSO is removed. *At the intraseasonal timescale* however, the AAO is seen to significantly affect the rainfall amounts over the major part of the country, independently of other modes of variability. Its influence in modulating the rain appears to be strongest during La Niña years. We then discuss the implications of these tropical – extratropical interactions on the relationships between the SAM and the Southern Ocean physics and biology.

4. References

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