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STUDY OF THE HORIZONTAL AND VERTICAL ENERGY EXCHANGES DURING SACZ EPISODES: INFLUENCE OF THE RESOLUTION OF THE ANALYSES AND THE MODELS AND THE CONVECTION PARAMETERIZATION

Renata Weissmann Borges Mendonça and José Paulo Bonatti
Center for Weather Forecasting and Climate Studies/National Space Research Institute
Cachoeira Paulista, SP, Brazil

1. INTRODUCTION

The South Atlantic Convergence Zone (SACZ) is a characteristic of the atmospheric circulation over South America during the summer. It is responsible for great part of the annual precipitation in the Southern and Southeastern of Brazil. These events exemplify the interactions between the tropical convection and large scale systems.

The adjustment to the convective forcing occurs through the propagation of waves that interact one with others to restore the atmospheric balance. Thus, a convenient evaluation of the forcing and the generated waves scales provides a better comprehention of the atmospheric behaviour.

In this work, the horizontal and vertical energy exchanges for a composite of seven SACZ episodes were studied by expansion into three-dimensional normal mode functions (Kasahara and Puri, 1981). In the first part of this study (observational part) energetics analyses for the SACZ composite were performed with an emphasis on the vertical energy partition between external and internal modes and on the energy interactions within and between various horizontal oscillation modes, such as Rossby, Kelvin, Mixed Rossby-Gravity and West and East Gravity modes. In the second part (modelling experiments), the performance of the CPTEC Global Model in simulating the modal energetics for the SACZ composite was evaluated, empahsizing the influence of the model resolution and the three different deep convection parameterizations: Kuo, Relaxed Arakawa-Schubert (RAS) and Grell.

2. DATA AND METHODOLOGY

The data utilized in the following analysis consist of the National Centers for Environmental Prediction (NCEP) analyses with T062L28, T126L28 and T170L42 resolutions.

The area considered in this study is the South America, emphasizing the SCAZ region, as Fig. 1.

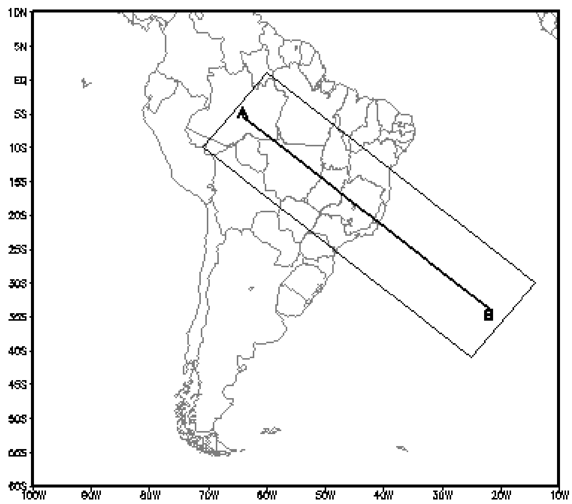


Fig. 1 - Region defined for energy partition over South America.

The procedures to decompose the vertical and horizontal structures in normal modes are shown in Fig. 2.

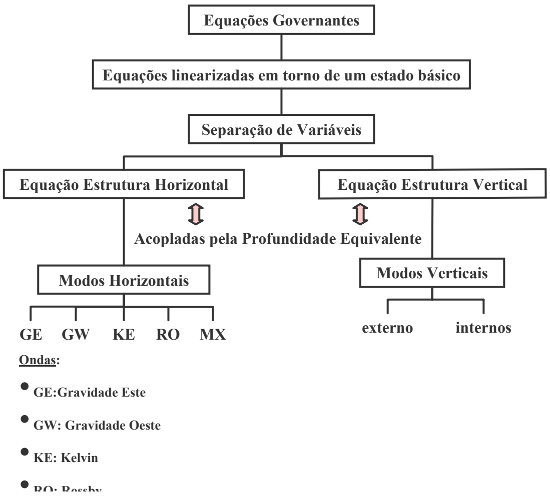


Fig. 2 – Procedure to decompose the vertical and horizontal modes. (Adapted from Ko et al., 1989).

The vertical structure equation and the contour conditions form a Stürm-Liouville problem, whose vertical modes are eigenvectors, and the associated eigenvalues are proportional to the phase velocity of the pure gravity wave (height equivalent) and provide the horizontal structure for each normal vertical mode.

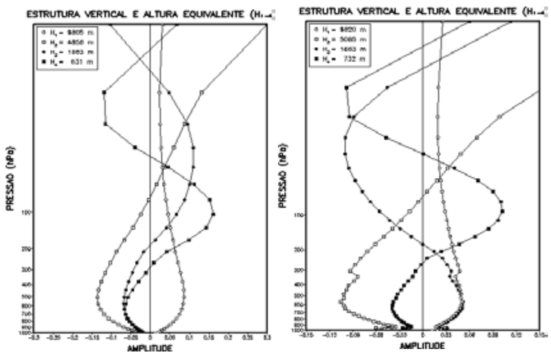
The equations (1) and (2) represent the contributions for the total energy in each vertical and horizontal modes, respectively:

$$P_n = \frac{E_{Cn} + E_{Pn}}{\sum_{n=0}^{N}\left(E_{Cn} + E_{Pn}\right)} \times 100\% \qquad \textbf{(1)}$$

$$PE_w = \frac{\sum_{n=n_1}^{n_2} E_{wn}}{\sum_{n=1}^{M} E_{Tn}} \times 100\,\% \qquad \textbf{(2)}$$

3. RESULTS AND DISCUSSIONS

The vertical atmospheric structure in terms of normal modes is dependent of the model resolution (Silva Dias e Bonatti, 1985). In agreement with Silva Dias and Bonatti (1986) is distinguished the 5th internal mode with equivalent heights of 284m and 342m, respectively for 28 and 42 levels, that attain maximum values around 800 and 200 hPa, and a zero around 400 hPa. This mode retain most of the energy in the tropics, mainly next to the regions with intense convective activity. The external mode, with equivalent height around 9800m is dominant in the region of high pressures (Fig. 3).



(a) (b)

Fig. 3 – Vertical structures, correspondig to equivalent height Hn for the CPTEC Global Model: (a) 28 and (b) 42 levels.

To simplify the analysis of the results, had been considered three categories of vertical modes: (I) n=1 to 3, with Hn above of 600m; (II) n=4 to 7, with Hn between 100 and 600m; and (III) n=8 to 12 (14, for 42 levels), with Hn between 10 and 100m.

A maximum share of the total energy (about 60%) was found in the 4th to 7th internal modes with equivalent depths between 100 and 600 meters, especially over the great part of the central South America and near equator including the SACZ region. As the latitude increases, the energy is distributed towards the lower order modes (1 to 3) with the external modes category becoming dominant at higher latitudes (Fig. 4).

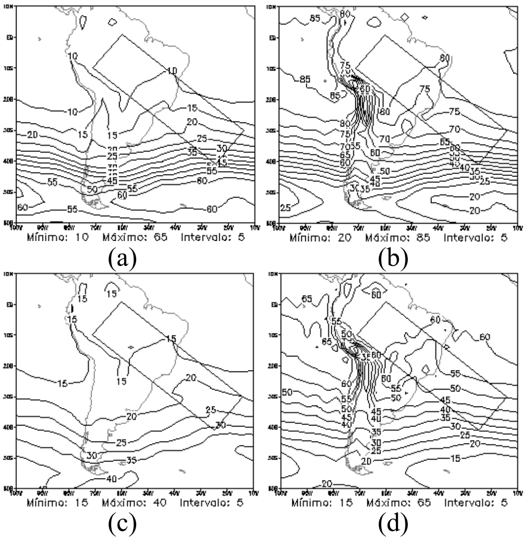


Fig. 4- Total energy (%), NCEP Analyses T126L28 (top) and T170L42 (botton): (a) and (c) 1st to 3rd; (b) and (d) 4th to 7th vertical modes.

For the horizontal energy partition, the most expressive contributions were obtained for the auto-interactions of the Rossby and Kelvin modes and for Rossby-Kelvin cross interactons in all vertical categories, as shown in Fig. 5. The Rossby-Kelvin interactions (Fig. 6) were the main process for constructive energy interferences in the SACZ region.

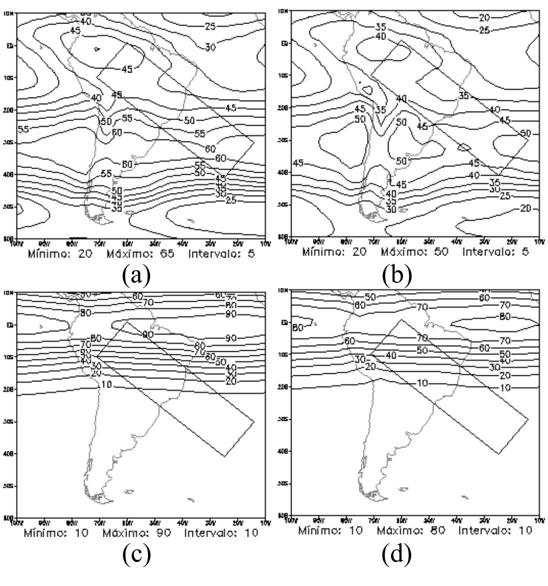


Fig. 5 – Total energy (%) of the horizontal modes corresponding to 4th to 7th vertical modes, NCEP Analyses T126L28 (left) and T170L42 (right): (a) and (b) Rossby; (c) and (d) Kelvin.

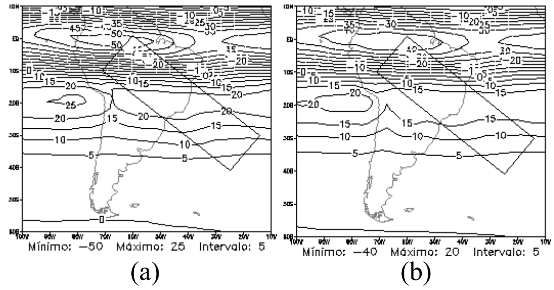


Fig. 6 - Total energy (%) of the Rossby-Kelvin cross interactions corresponding to 4th to 7th vertical modes, NCEP Analyses: (a) T126L28) and (b) T170L42.

The vertical modes interactions indicated that the percentage of total energy increases from low levels to the stratophere with maximum positive (negative) interferences in high levels (stratosphere), for the 4th to 7th internal modes, as observed in the Fig. 7 and Fig. 8.

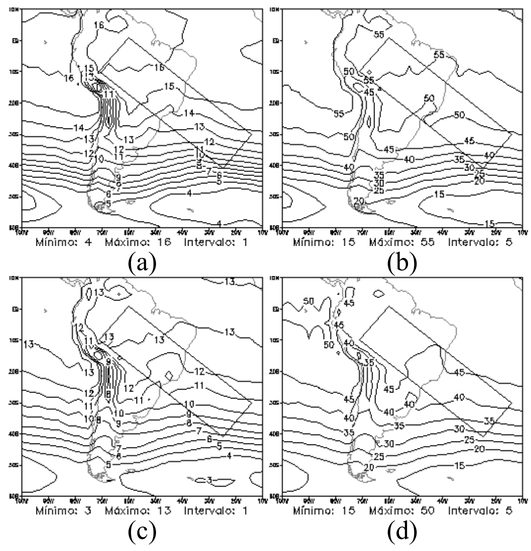


Fig. 7- Total energy (%) corresponding to 4th to 7th vertical modes, NCEP Analyses T126L28 (top) and T170L42 (botton): (a) and (c) high levels; (b) and (d) stratosphere.

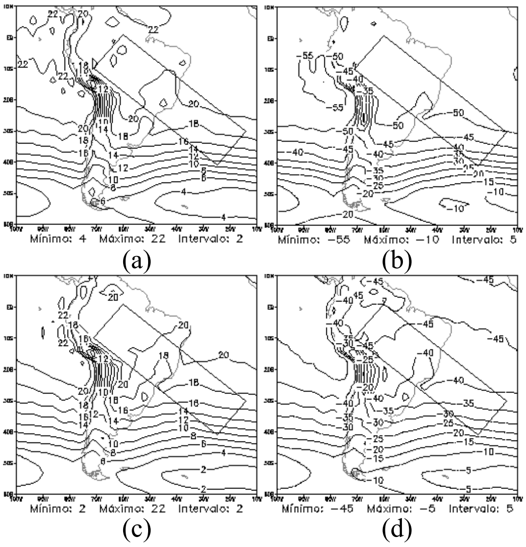
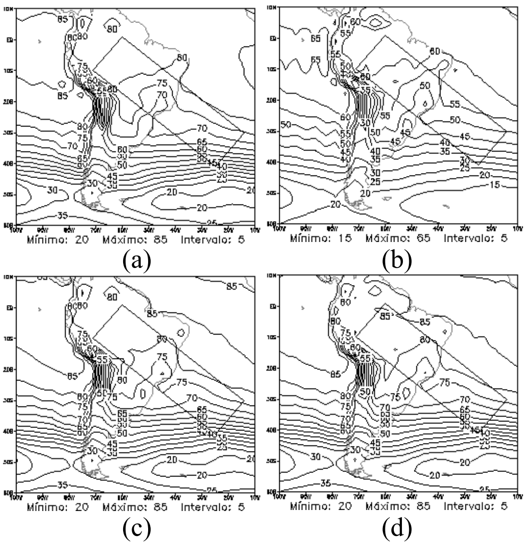


Fig. 8- Total energy (%) corresponding to 4th to 7th vertical modes interactions, NCEP Analyses T126L28 (top) and T170L42 (botton): (a) and (c) high levels; (b) and (d) stratosphere.

The results from the modelling experiments showed that the model predictions using the Kuo, RAS and Grell deep convection schemes were similar with each other and had a good agreement with the patterns obtained in the observational part. The use of different deep convection schemes did not present significant impact in the partition and interaction of energy between vertical and horizontal modes, as observed in Fig. 9.



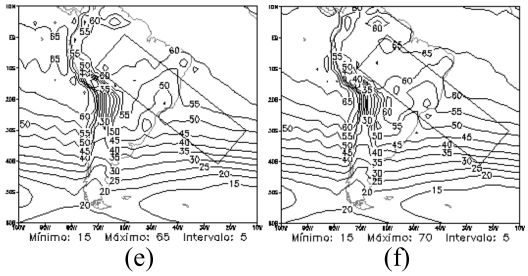


Fig. 9- Total energy (%) of the vertical modes, CPTEC Global Model T126L28 (left) and T170L42 (right): (a) and (b) Kuo; (c) and (d) RAS; (e) and (f) Grell deep convection schemes.

A greater impact was obtained increasing the vertical resolution of the analyses and the model from 28 to 42 levels. A greater number of internal modes shows a relevant whole in the horizontal and vertical energy exchanges, in terms of representing the observed characteristics.

4. REFERENCES

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