WAVELET ANALYSIS TO STUDY THE BEHAVIOR OF SYNOPTIC TO INTRASEASONAL VARIATIONS IN CONVECTIVE PRECIPITATION OVER SOUTH AMERICA

Srinivasa Rao Chapa, Vadlamudi Brahmananda Rao, and Regina Célia dos Santos Alvalá
Instituto Nacional de Pesquisas Espaciais, São José dos Campos-SP, Brasil
Fone: (012)345-6644, Fax: (012)345-6666, e-mail:chapa@met.inpe.br

ABSTRACT

Wavelet transform (WT) and spectral analysis have been analyzed to study the behavior of synoptic to intraseasonal variations in convecive precipitation over South America. Convective precipitation data derived from the reanalysis of National Center for Environmental Prediction (NCEP) have been analyzed over four approximately 9°-square areas between the latitudes 4.5°N and 31.5°S, and longitudes 54°-45°W. Spectral analysis could only supply frequency characteristics, whereas WT applied to the time-series allowed not only to detect the features in frequency space, but also their temporal localization. As many periodic events in the atmosphere are intermittent, WT is used to identify the time-localization of these periodic events.

Keywords: Climatology, Wavelet Transform, Spectral Analysis, Convective Precipitation

1. Introduction

In the tropics convective activity varies in different timescales ranging from a few hours to a few months. Among the various timescales of tropical convection, diurnal and annual cycles are more prominent. The diurnal cycle of tropical cloudiness may be due to the interaction between the local and large scale environmental circulation, and it is found to be more prominent over regions with intense convection (Murakami 1983; Nitta and Sekine 1994). The other prominent variations observed in the tropics are intraseasonal oscillations.

Many investigators, such as Nakazawa (1988), and others have reported that the intraseasonal oscillations are accompanied by large scale convective activity that propagates eastward from the Indian Ocean into the western Pacific. Knutson and Weickmann (1987) and Hsu et al. (1990) have reported eastwardly propagating signals in the western Pacific, the central Africa, and South America, where active convection persists. They also observed srong standing oscillations in these areas, which play na important role in the evolution of intraseasonal oscillations there. Kousky (1988) used pentad outgoing longwave radiation (OLR) data and found intraseasonal variations over South America. Hsu et al. (1990), and others reported the existence of intraseasonal oscillations in the extratropics.

Nakazawa (1988) suggested the presence of organized high frequency structures embedded in tropical intraseasonal oscillations over the tropical western Pacific. The high frequency oscillations are governed by interactions among intraseasonal oscillations, synoptic scale disturbances, the organized deep convection. Lau et al. (1991) and Weng and Lau (1994) have suggested that the interaction of diurnal and annual variations with self-excited oscillations like synoptic and intraseasonal oscillations. The high frequency oscillating systems exist for a season or two in a year, but they may be related to the occurrence of low frequency oscillations. Using wavelet analysis, which can demonstrate time-frequency localization of events, the existence of all such oscillations in terms of convective precipitation can be verified.

2. Study area and data

The data used in the present study are daily averaged time series of convective precipitation of NCEP reanalysis for two years from 1 January 1994 to 31 December 1995. The study areas are four approximately 9°-square areas between the latitudes 4.5°N and 31.5°S, and longitudes 54°-45°W. Spatial mean precipitation over these areas are used. The areas are not exact squares as the precipitation data are on Gaussian grid.

3. Results

Figures 1a-d present the 2-year daily averaged convective precipitation at four different areas in South America. Abscissa of these figures is time shift in days, in which day 1 denotes 1 January 1994, while the day 730 denotes 31 December 1995. All the figures (a-d) show two annual cycles with minima in austral winter (June through August), and maxima in austral summer (December through February), and higher frequency oscillations embedded in them. To extract more information of periodicities, the time series data are subjected to the technique of wavelet transform (WT) and spectral analysis.

WT is applied to the real-valued convective precipitation data over the four areas in South America by using complex Morlet analyzing wavelet. WT was first developed by Morlet (1983) to seismic data analysis, and recently it was applied to time series data in many diversified fields including meteorology (Kumar and Foufoula-Georgiou 1993, Weng and Lau 1994, Chapa et al. 1998, and many others). Figures 2a-d present the time-scale display of the real component of wavelet coefficients (ω=10) for convective precipitation over the four areas. Abscissa of these figures is time shift in days, and the time domain considered is from 1 July 1994 to 31 June 1995. The ordinate is a scale. Apendix A shows a table of relationship between scale and periodicities for ω=10

In the Figures 2a-d there are oscillations in the range of 10-80 day period in the scale interval (4,7). The most pronounced intraseasonal timescale is 30-50 days in the austral summer. Other prominent oscillation seen in all these figures is approximately 20-day period. Both the intraseasonal and approximately 20-day period oscillations are seems to be less prominent in austral summer than in the other seasons over the area 2, 4.5°-13.5°S, 54°-45°. Over the areas 3 and 4, between the latitudes 13.5°S and 31.5°S, both the above mentioned oscillations are quite prominent in the summer, and virtually absent in the winter. However, over the area 1, near the equator, both the oscillations are prominent throughout a year.

As a comparison, Figures 3a-d present the spectral density of the 2-year data over the four areas. The spectral peaks are seen at 40-50 days, and at approximately 20 days, which correspond to the periodicities seen in the Figures 2a-d. The power spectrum provided the information of the distribution of multiple frequencies, clearly unable to provide information on time-frequency localization provided by the wavelet analysis.

4. References

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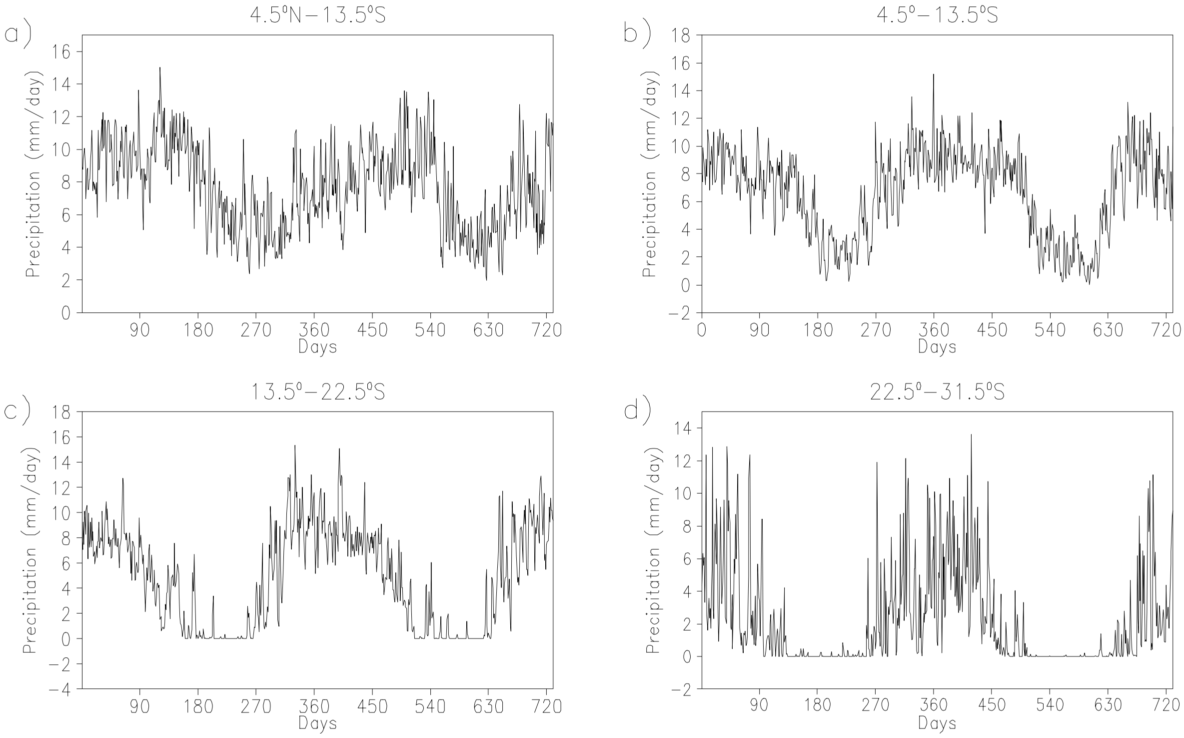
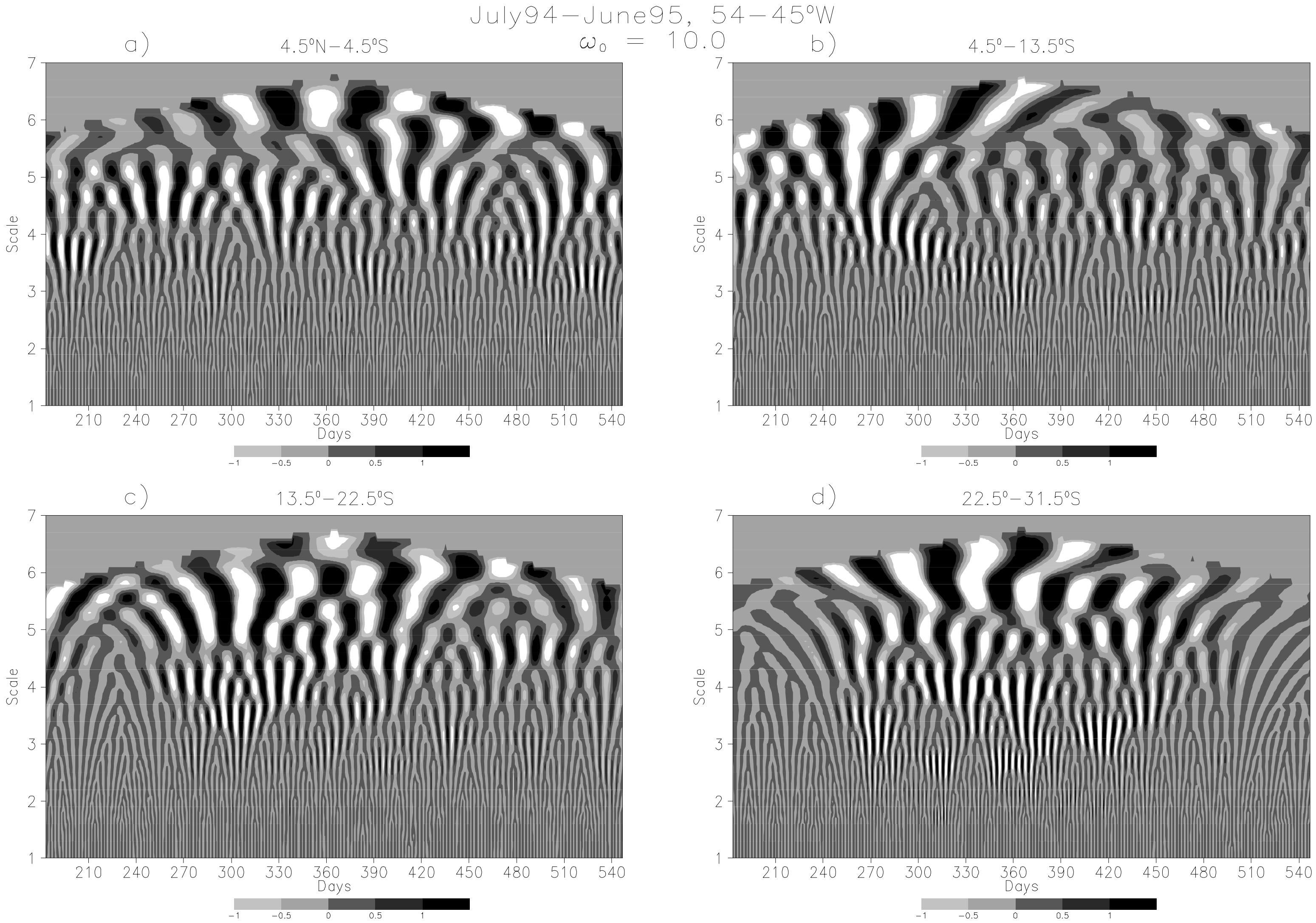
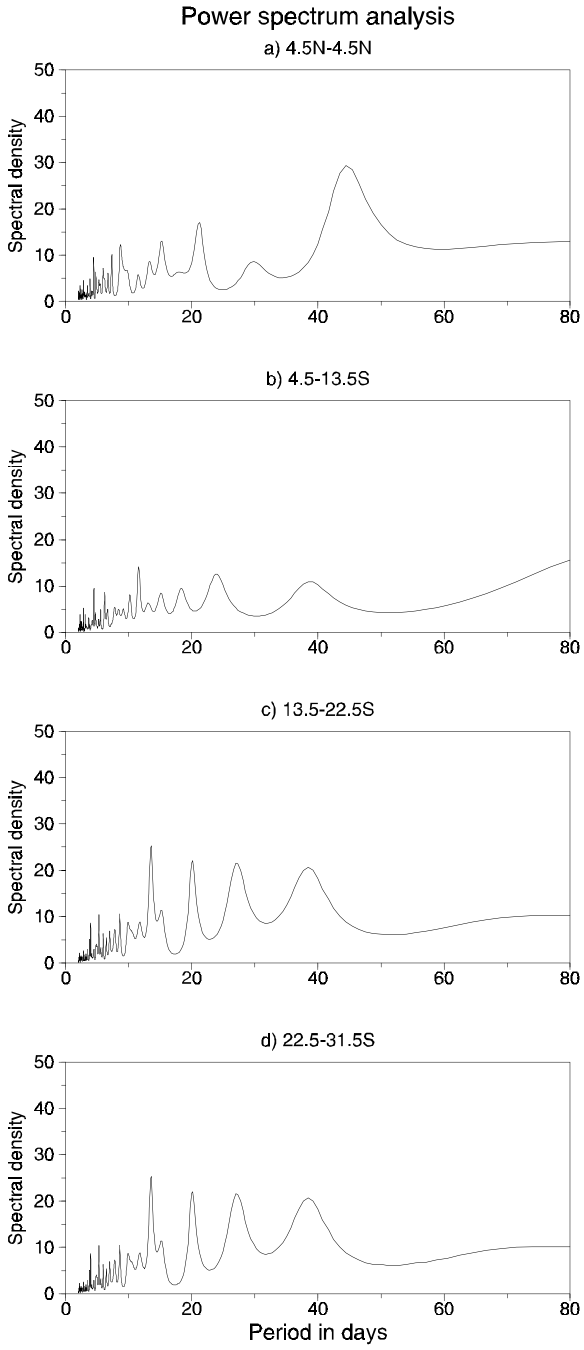


Figures 1a-d Daily averaged convective precipitation at four different areas in South America.



Figures 2a-d Time-scale displays of the real component of wavelet coefficients (ω=10) for convective precipitation over the four areas.



Figures 3a-d present the spectral density of the 2-year data over the four areas.

Appendix A

Scale	Period in day
1.0	1.25
1.1	1.34
1.2	1.44
1.3	1.54
1.4	1.65
1.5	1.77
1.6	1.90
1.7	2.03
1.8	2.18
1.9	2.33
2.0	2.50
2.1	2.68
2.2	2.87
2.3	3.08
2.4	3.30
2.5	3.54
2.6	3.79
2.7	4.06
2.8	4.36
2.9	4.67
3.0	5.00
3.1	5.36
3.2	5.75
3.3	6.16
3.4	6.60
3.5	7.08
3.6	7.58
3.7	8.13
3.8	8.71
3.9	9.34
4.0	10.01
4.1	10.73
4.2	11.50
4.3	12.32
4.4	13.20
4.5	14.15
4.6	15.17
4.7	16.26
4.8	17.42
4.9	18.67
5.0	20.01
5.1	21.45
5.2	22.99
5.3	24.64
5.4	26.41
5.5	28.30
5.6	30.34
5.7	32.51
5.8	34.85
5.9	37.35
6.0	40.03
6.1	42.90
6.2	45.98
6.3	49.28
6.4	52.82
6.5	56.61
6.6	60.67
6.7	65.03
6.8	69.70
6.9	74.70
7.0	80.06