The Implications of ENSO Signal for South China Monsoon Climate

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Abstract

The objective of this research is to explore the impacts of ENSO on possible connection between winter monsoon and summer monsoon over South China. In boreal winter, the strong or weak northernly anomalies due to the East Asian winter monsoon sweep across the continent to the costal regions and might push the water over western Pacific to the eastern Pacific or Kuroshino current to North Pacific, which might be favorable for the occurrence of ENSO event. In boreal summer, South China tends to experience less (more) rainfall and more (less) temperature extremes might be in the mature phase of warm (cold) ENSO event. It is also found that more frequent cold surges might be followed by less temperature extremes in the coming year, and vice versa. The possible connection might be the western Pacific subtropical High after a strong (weak) EAWM year would move northward (southward) through the modification of ENSO event, this northward (southward) western Pacific subtropical high might result in earlier (later) south China summer monsoon onset and lead to a strong (weak) summer monsoon in the coming year.

Keywords: ENSO, cold surge, summer monsoon

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1. Introduction

Monsoon Asia is an area where more than one-half of the world's population carries out their socio-economic activities. As an area most affected by monsoons, it also has one of the most vigorous circulation systems in existence over the globe. The South China Sea summer monsoon (SCSSM) is sometimes regarded as an eastern extension of the Indian summer monsoon and the root of the East Asian summer monsoon (EASM) (e.g., Xie et al. 1998; Ding and Liu 2001). Geographically, the South China Sea (SCS, 110-120o E, 5-20 o N) is a marginal sea located in Southeast Asia and is a junction between South and East Asia along the rim of the Asian continent. Meteorologically, the Indian and EASM systems interact over the SCS region. In addition to its dominance in the local climate over the Asian continent and its surrounding oceans,there is increasing evidence that shows the important role of the Asian monsoon in the global climate systems such as El Niño (e.g., Huang et al., 2004).

The Northern Hemisphere has been experiencing warming well above the global average for the past few decades, particularly during the boreal winter season. Hurrel (2003) observed that winter temperatures have been 1-2^{o}C warmer than the average over much of North America and from Europe to Asia since the early 1980s. Wallace et al. (1995, 1996) suggested that the interdecadal variations of ENSO might be one of the main reasons for the warm winter during recent decades. Some other climate signals that interact with ENSO, are superimposed on ENSO or otherwise modify ENSO (e.g. Trenberth and Hurrell 1994; Deser and Blackmon 1995; Latif and Barnett 1996; Gu and Philander 1997; Chen et al., 2005; Chan and Zhou 2005; Zhou and Chan 2007; Wang et al., 2007; Zhou 2006, 2007, 2009). Since there is more to the climate system than just ENSO, and if we are to extract every ounce of predictability from the system, we have to understand how the other components work and how they interact with ENSO in modifying our climate. Hurrel (1996) identified that ENSO signal accounted for 16% of the wintertime interannual variance of Northern Hemisphere extratropical temperatures over the latter half of the 20th century. Chang et al. (2001) suggested that the strengthening and poleward shift of the jet stream over the North Atlantic could be the reason for the weakening relationship between the Indian monsoon rainfall and ENSO. If this were indeed correct, it would mean that the midlatitude atmospheric response has to be given serious consideration in tropical climate variability, in particular, summer rainfall or winter temperature.

However, ENSO is a very strong naturally-occurring climate signal on earth, recognition of a strong linkage among winter and summer monsoon climate, and the role of ENSO in such winter-monsoon transition is essential from a societal impact perspective.

2. DATA

The data used in this study are mainly from the National Centers for Environmental Prediction (NCEP) reanalysis. These include the daily (monthly) mean values of geopotential height, wind speed, air temperature, sea surface temperature (SST) (only monthly), sea-level pressure (SLP), specific humidity from 1979-2001 (1955-2001). Daily and monthly outgoing longwave radiation (OLR) data from the National Oceanic and Atmospheric Administration for 25 years from 1979-2001 are also used. The horizontal resolution of these data is 2.5º latitude/longitude square. The monthly mixed-layer ocean temperature (0/400m) data on a 2o latitude x 5o longitude grid from 1955-2001 are obtained from the Scripps Institute of Oceanography. Monthly rainfall of 160 stations are provided by the Chinese Meteorological Bureau for 50 years from 1951-2000.

3. Summer and winter monsoon activities in South China

It is generally agreed that the distribution of summer rainfall is affected by anomalous monsoon activities. Wang and Lin (2002) suggested that a typical monsoon rainy season should possess some features such as significant annual variation, an intense rainfall rate and a concentration of annual rainfall in the local summer. Before May, the increased precipitation mainly results from the intrusions of cold fronts into the South China region, and stationary fronts that linger around the Nanling mountain range or over the northern part of the SCS. Around mid-May, the rainy season starts in the SCS, which indicates the onset of the SCS summer monsoon (SCSSM). The onset and evolution of the SCSSM signal the seasonal change of the atmosphere and the coming of the rainy season in East Asia. It is generally agreed that the distribution of summer rainfall is at least partly affected by anomalous monsoon activities. The SCSSM brings abundant moisture to South China, so that strong or weak SCSSM may have devastating effects on the climate of South China. Furthermore, a strong EASM generally brings too much rainfall to the northeastern part of China and too little rainfall to the Yangtze River region, and vice versa (e.g. Li 1990). But the rainbelt starts to migrate from South China to the Yangtze River region in June. In August, the increased rainfall is due to tropical cyclones. The rain-bearing synoptic systems responsible for South China region are therefore many. That is why a consensus has yet to be reached on the monsoon rainy season over South China (e.g., Guo and Wang 1981). In South China the fraction of May-June rainfall to the annual mean is about 35% to 40%, which is equal to or even larger than that in summertime (July-August-September) (Fig. 1). This corresponds to the pre-summer rainy season in South China resulting from the first step of East Asian summer monsoon (EASM) progress (Ding, 2004; Chen et al., 2009). Hence, the spring precipitation variations play an important role for the total precipitation received over South China. In other words the main characteristic of precipitation in South China can not be comprehended if we only consider the situation in summer.

In South China, the active (inactive/ break) of summer monsoon corresponds to the heavy rainfall / lower temperature (less rainfall /high temperature). Chen et al. (2000) found that these summer monsoon rainfall or high temperature variations are largly related to the previous winter monsoon activies. As we know, the features of a strong winter monsoon are assoicated with anormalously strong northerly winds along coastal East Asia, cold East Asian continent and surrounding sea and warm ocean from the subtropical central Pacific to the tropical western Pacific, high pressure in East Asian continent and low pressure in the adjacent ocean and deep East Asian trough at 500 hPa, and vise versa (Chen et al. 2000). Their results further prove that these winter monson variations are closely connected to the SST anomaly in the tropical Pacific, both in the western and eastern Pacific, and the SST anomaly in the South China Sea is found to be closely related to the EAWM and may persist to the following summer. The wave power spectrums of summer high temperature days(daily mean temperature larger than 35C) over South China and winter cold surge days (temperature drop 6 C within 24hours) over South China suggest that both have a dominant period of 2 –year cycle with significant high power (Fig. 2). Moreover, the crosswavelet analysis (Grinsted et al. 2004) between summer high temperature and winter cold surge shows a high common power around 2 years and antiphase relationship (Fig. 3), which is consistent with the results of chen et al. (2000). A strong winter monsoon with more frequent cold surges or more winter temperature extremes might be followed by more summer monsoon rainfall or less summer temperature extremes. Therefore, we speculate that there is a stronger link between summer monsoon activies and winter monsoon activies than that implied by the cross wavelet power (Grinsted, et al.).

4. The impacts and the reponse of ENSO to the monsoon climate in South China

The numbers in Table 1 are very consistent with the results of Chen et al. (2000) and Chen (2002). On interanuual timescale, more (less) cold surges occurred prior to (after) warm ENSO events, and less high temperatures found in the year of cold ENSO envents. To understand better the roles of sub-surface ocean temperature (SOT) versus propagation of remotely forced waves in thermocline adjustment, we use the reconstructed SOT along equator from 1969 to 1973 based on the first mode of ceof1. The purpose of Fig. 4, therefore, is to address the gaps in our observational description of the annual thermocline variations, and it is obvious that warm water and cold water exchange periodically between eastern Pacific and western Pacific along the thermocline. In 1969, the SOT over the central and eastern Pacific is warmer, and the maximum center is along the sub-layers (100m-200m) from Jan to Mar, which is the mature phase of the El Niño. However, from May to Nov, the negative SOT over the equatorial western Pacific extends to the EEP along the 100m, even though the SST over the EEP is positive, but the SOT over the equatorial eastern Pacific changed the sign within 100-200 m. In 1970, the depth of the maximum SOT over the equatorial eastern Pacific sharply decreased in Jan. But the situation is completely changed after Mar. 1970. The negative SOT is over the central and eastern Pacific, while positive SOT is over the central and western Pacific. This La Niña pattern lasts for 22 months until Jan 1972. The positive SOT over Central Western Pacific then extends to the central and eastern Pacific along the sub-layers (100-200m) in Mar 1972. The El Niño pattern then occurs again from May 1972 to Mar 1973. In the summer of 1973, another La Niña pattern has begun. Therefore, the reconstructed SOT from the winter of 1969 to the winter of 1971, is a transition from El Niño event to La Niña event occurred, and another transition follows again with a sign of warm water over eastern Pacific at the autumn of 1972. The results might indicate that the strength of the EAWM might be associated with the SST anomaly over the tropical Pacific. A weak EAWM generally links to a positive SST anomaly in the tropical eastern Pacific (El Niño), while a strong one correponds to a negative SST anomaly (La Niña) in the tropical eastern Pacific.

As for the impacts of ENSO on summer monsoon activities (Zhou and Chan 2005), an apparent interannual variation in the SCSSM onset is found due to the ENSO adjustment, i.e., from an La Niña event to an El Niño event, the onset sequence tends to be a normal to early or early onset and then a normal to late or late onset. From an El Niño event to an La Niña event, the onset time sequence reverses. During a two-year period (year –2) prior to the late onset, warm water in the equatorial western Pacific (EWP) from winter to spring might result from the weak East Asian winter monsoon (EAWM). If the Ocean heat content (OHC) anomalies over the EWP increase, while the OHC anomalies over the equatorial eastern Pacific (EEP) decrease, which is a typical mature phase of La Niña event. The SCSSM onset then occurs earlier due to the weakened WPSH (Philippine cyclone). Furthermore, warm SST over the EWP eastwards because westerlies (Kelvin wave), and causes upwelling of seawater over the EWP because of the earth rotation. The thermocline depth there therefore becomes shallow. Meanwhile, the cold seawater over the EEP migrates westward (Rossby wave). Finally, a switch of OHC over the EWP and EEP lasting for 2 yrs would lead to El Niño and the SCSSM would have a late onset because of the development of the Philippine anticyclone. Therefore, such a transition should have a strong control on the monsoon early-late onset cycles, and further affect more or less summer monsoon rainfall over South China.

5 Discussion

Whether the monsoon climate over south China is predictable or not makes climate research both interesting and challenging. It is obvious that ENSO signal is very important in the winter and summer monsoon connections in which EAWM might trigger the occurrence of ENSO event, and ENSO signal might modulate the Philippine anticyclone or the western Pacific subtropical High and further affect the South China Sea summer monsoon onset. But the question is what else can change the frequency of cold surges in South China or what factors could result in the intensity change of EAWM? Our recent studies have shown that changes in PDO might be related to the localized atmospheric forcings such as EAWM, and hence the response of the PDO to the "upstream" winter monsoon could lead to the interdecadal variability of the ENSO activity (Zhou et al. 2006). The winter-summer monsoon connection is thus potentially predictable in terms of the different signals, and vice versa. Our present work highlights the " Oceanic bridge" role of ENSO for the possible winter-summer monsoon connection. Though the causes for this relationship on interdecadal timescales are not currently known, at least the mechanisms giving rise to PDO or ENSO-decadal pattern could likely determine whether skillful decade-long PDO climate predictions are possible. Suppose PDO arises from air-sea interactions that require 10-year ocean adjustment times, then aspects of the phenomenon might be potentially predictable at lead times of up to 10 years. Thus even without a theoretical understanding, PDO or NAO climate information may improve season-to-season and year-to-year climate predictabilities because of its strong tendency for multi-season and multi-year persistence. Moreover, recognition of a strong linkage among monsoon climate and other signals such as ENSO, NAO and PDO is very important because it shows that how climate conditions vary greatly over different periods and its impacts on social economy.

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Table 1 liststhe high temperature days and cold surges days in associarion with the EL Nino and La Nina transitions (1969-1972)

	1968	1969	1970	1971	1972	1973
Cold Surge (days)	68	40	8	13	65	
ENSO	E-1/L+1	E0	E+1/L-1	L0	L+1/E-1	E0
High Temp (days)		40	42	38	74	25

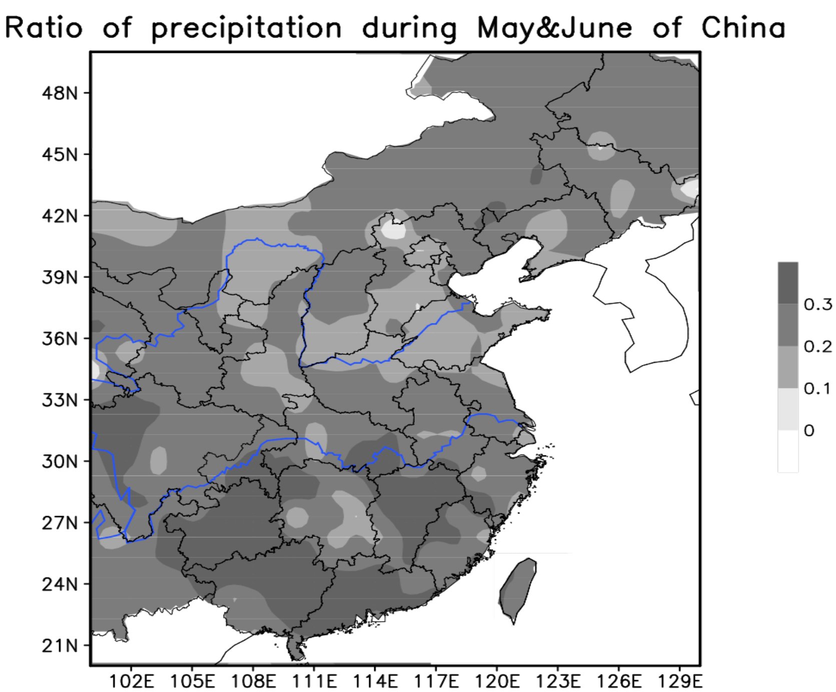

Fig. 1 The fractional percentage of Rainfall in May-June to the annual mean.

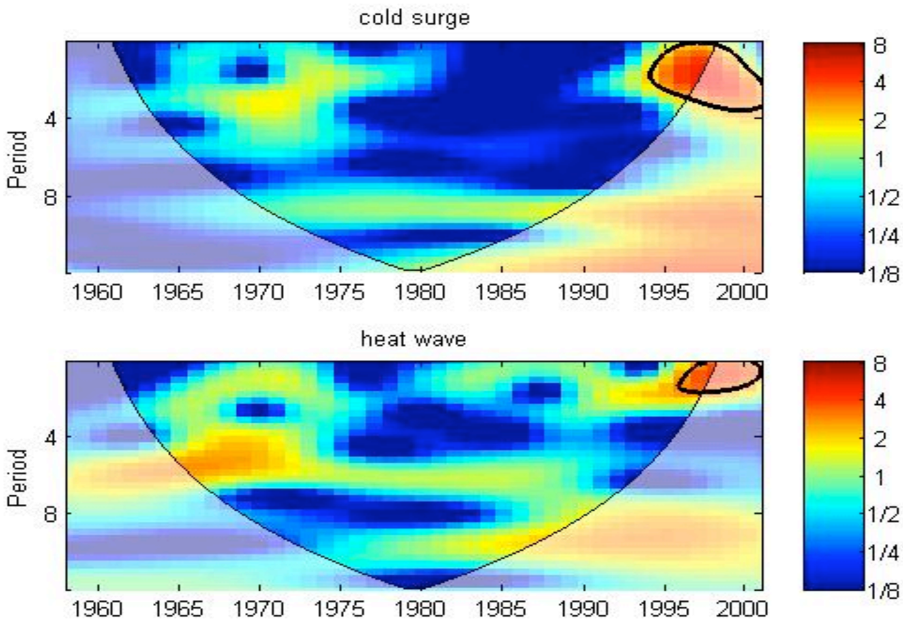

Fig. 2 The continuous wavelet power spectrum of cold surges days(top) and high temperature days (bottom). The thick black contour designates the 5% significance level against red noise and the cone of influence (COI) where edge effects might distort the picture is shown as a lighter shade.

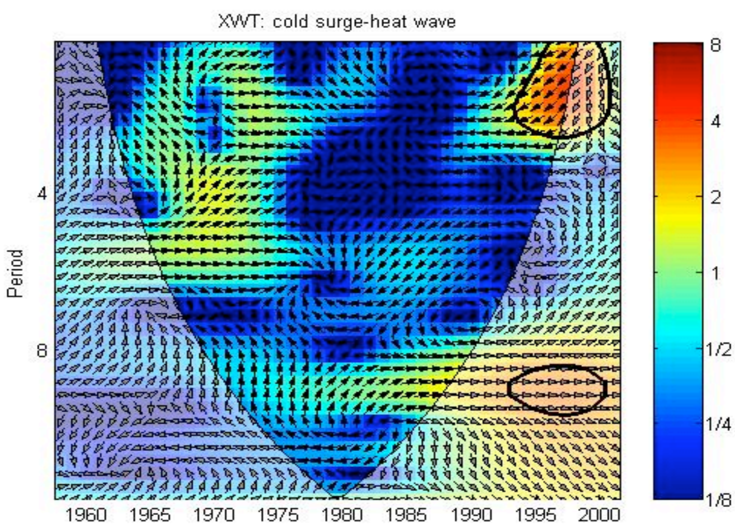

Fig. 3 Cross wavelet transform of the standardized cold surges days and high temperature days time series. The 5% significance level against red noise is shown as a thick contour. The relative phase relationship is shown as arrows (with in-phase pointing right, anti-phase pointing left, and cold surges leading high temperature by 90○ pointing straight up)

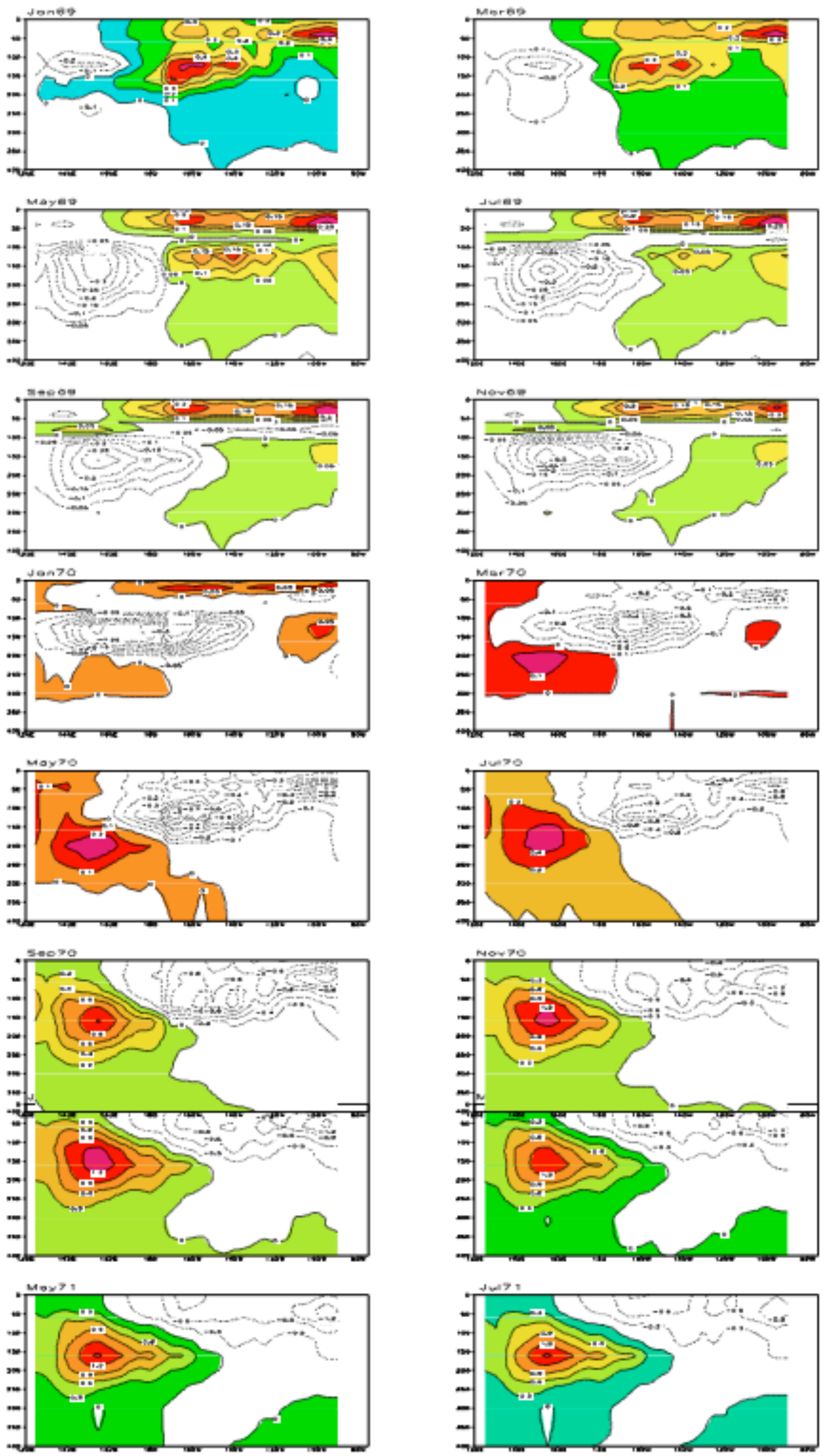

Fig. 4 Reconstructed sub-surface ocean temperature (SOT) along equator from 1969 to 1973 based on the first mode of complex empirical orthogonal function (CEOF1).

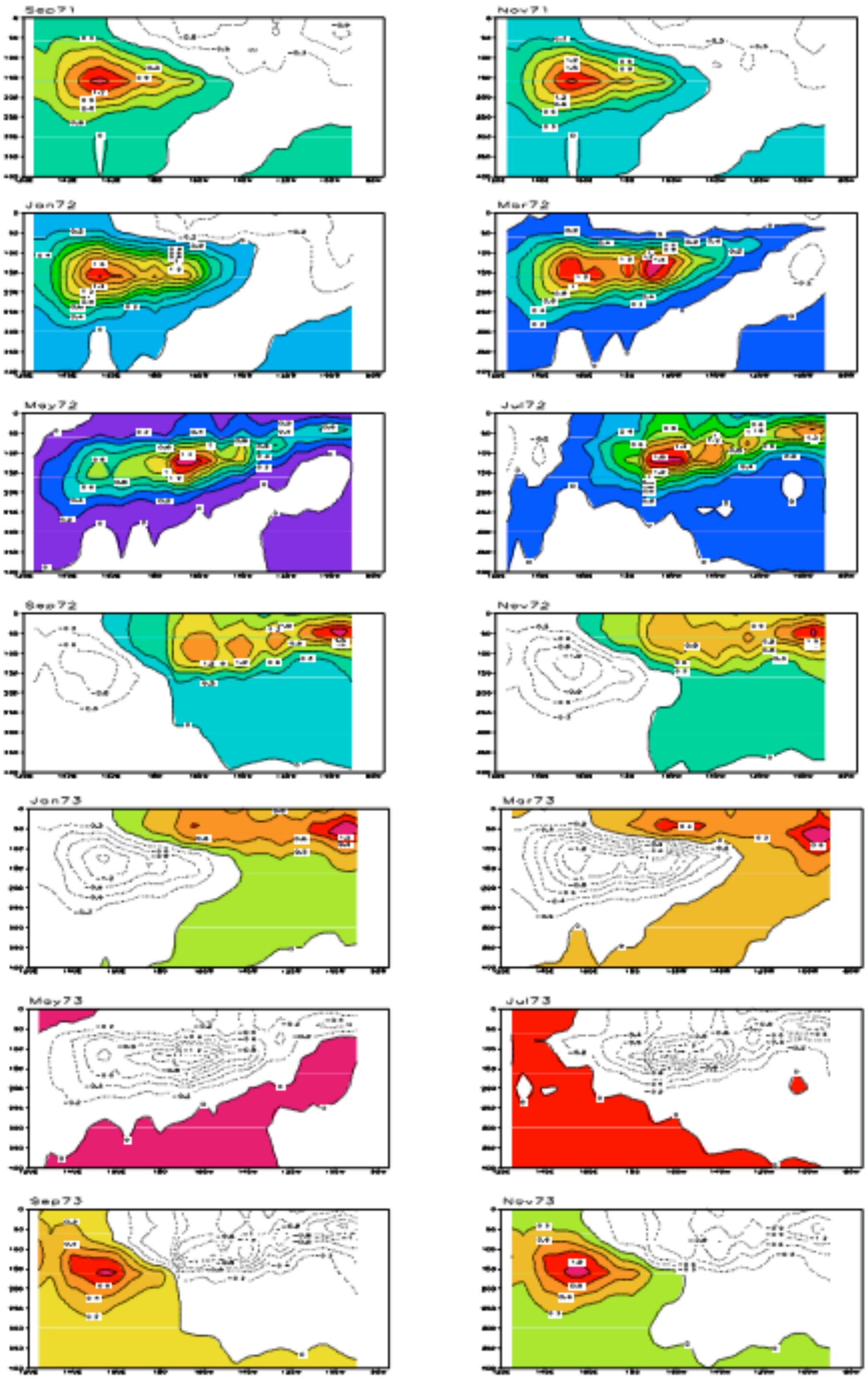

Fig. 4 Continued.