SPATIAL PATTERNS OF ENSO IMPACT ON INDONESIAN RAINFALL

Edvin Aldrian[1]

Abstract

A monthly temporal and spatial assesment on ENSO impact on Indonesian rainfall has been done. The study uses monthly ensemble averages of El Nino and La Nina years from 1961 to 1993. There are 6 El Niño years and 5 La Niña years during that period. Indonesia experiences negative ENSO influences from April on both El Niño (warm phase) and La Niña (cold phase). The influences of ENSO reach their peaks in August and September by both types of events and decay afterward. The influences diminish totally by December. Since the influences occur in the dry season, El Niño contributes a negative impact, while La Niña a positive impact to the Indonesian climate. The maximum spatial extension of ENSO reaches almost all parts of Indonesia except north Sumatera and some parts of Kalimantan. There is an indication of a negative influence of ENSO to the onset of Asian monsoon in the Southeast Asian.

Intisari

Kajian bulanan secara temporal dan geografis tentang pengaruh ENSO terhadap curah hujan Indonesia telah dilakukan. Penelitian ini memakai nilai rata-rata gabungan bulanan dari tahun El Niño dan La Niña dari 1961 hingga 1993. Ada 6 tahun El Niño dan 5 tahun La Niña pada perioda tersebut. Indonesia menerima pengaruh negatif dari ENSO mulai April pada tahun ENSO. Pengaruh ENSO mencapai puncaknya pada bulan Agustus dan September pada keduanya dan menurun setelahnya. Pengaruhnya benar-benar hilang pada bulan Desember. Karena pengaruh ENSO terjadi pada musim kering, El Niño memberikan kontribusi negative terhadap iklim Indonesia, sementara La Niña memberikan kontribusi positive. Luasan daerah pengaruh ENSO yang maksimal terjadi di hampir seluruh wilayah Indonesia kecuali bagian utara Sumatera dan sebagian Kalimantan. Ada indikasi pengaruh negative dari ENSO terhadap kedatangan muson Asia ke wilayah Asia tenggara.

1. INTRODUCTION

There have been many researches on El Niño Southern Oscillation (ENSO; Philander, 1983) impact on global rainfall. ENSO is the most coherence global climate phenomenon, whose impact can be detected around the globe. On the Indonesian region, the study on ENSO impact has also been studied so far (Aldrian, 1999; Kirono *et al.*, 1999; Gutman *et al.*, 2000 and Curtis *et al.*, 2001).

During ENSO events, the sensitivity against SST over the Pacific is in negative side, which means that the increase in SST will reduce the amount of rainfall Hence, during the warm phase (El Niño), which is indicated by a high SST anomaly over the equatorial Pacific, this region typically experiences lower rainfall amount (negative anomaly). On the other hand, during the cold phase (La Niña), this region experiences higher rainfall amount. For a more in-depth background of ENSO, the reader is referred to the monograph by Philander (1989).

The purposes of this study are to give spatial and temporal descriptions on what is going on with

1. Max Planck Institut für Meteorologie, Hamburg, Jerman

the Indonesian rainfall during ENSO events, illustrate the influence of ENSO on rainfall anomaly and describe monthly pictures from as early as boreal spring, when people believe that ENSO must start from. The study is important for our understanding on how is ENSO mechanism in this region, how far is the affected region, how long is the effect of ENSO, how can we describe stages of ENSO impact in this region. The paper will be divided as follow. Section 2 discusses data sources and methods, section 3 the result, follows by section 4 the discussion and concluding remarks.

2.   DATA AND METHOD

This study uses all land station data over an area 20E - 180E and 25S - 25N. Over this area there are 5419 rain gauge stations. In Indonesian region (19S - 8N and 90E - 140E) there are 884 rain gauges from the Southeast Asian countries and Australia. Among those there are 526 stations collected by the Badan Meteorologi dan Geofisika (BMG). The rest of data comes from the World Meteorological Organization-National Ocean and Atmospheric Administration (WMO-NOAA) project on the Global Historical Climatology Network (GHCN) (Vose *et. al*, 1992) version 2. The rainfall data used here is the mean monthly data of those stations from 1961 until 1993. For the purpose of analysis below, those stations are gridded into the T106 resolution, which corresponds to a spatial resolution about 1.125^0 or 110 km.

SST data from the GISST2 or Global Ice and Sea Surface Temperature dataset (Rayner *et al*. 1996) version 2.3 is used in this study. This dataset is compiled from SST observation from 1871 – present with a spatial resolution of 1^0, which is comparable to that of rainfall data set. The data used in this paper is data from 1961 to 1993. The SST data in NINO3 area ($150^0W – 90^0W, 5^0S – 5^0N$) is used to determine the ENSO years. With the definition of an ENSO year by Roeckner *et al*. (1996), SST anomalies are classified as an ENSO event if they are greater than 1^0K in amplitude and persist for more than one year. Gershunov (1998) used a similar definition without considering the length of the anomaly. As a result, below is the list of ENSO years from 1961 - 1993 as follows:

El Niño year: 1965, 1969, 1972, 1982, 1987, and 1991

La Niña year: 1964, 1970, 1973, 1975, and 1988

After we determine the ENSO years, we will divide the rainfall data into rainfall of normal, El Niño and La Niña years. The study of each ENSO event will focus on 18 months from the boreal spring or March of the ENSO year until August in the following year. Although, in the definition of ENSO years, the following ENSO years are not considered as an ENSO year. Thus from 33 years of

observations, there are 6 El Niño years, 5 La Niña years and 22 normal years. From analysis of 18 months, we will understand the impact of ENSO on Indonesian rainfall during starting, mature, decay stages and the ongoing impact after that until 18 month after the event start.

We are interested in the average impact of all ENSO events in 33 years of observations (1961 – 1993). In order to do that, we make ensemble average of each clasification above, the normal, El Niño and La Niña averages. The aim of this ensemble average is to give superimpose views of anomalies in each month. The anomaly of each month is defined as

$$rain_{anom} = \frac{rain_{ENSO} - rain_{normal}}{rain_{normal}} \times 100\%$$

The spatial patterns of each month from ensemble averages of El Niño and La Niña event will be produced using that formula.

3.   RESULTS

The spatial patterns of rainfall anomalies during ENSO events are given from Fig. 1 until Fig. 6. Figure 1 until 3 describes the anomalies during ensemble El Niño events from the first 6 months or related to Northern Hemisphere summer, the next 6 months in winter and the next 6 months of summer in the following year. Figure 4 until 6 describe similar conditions during ensemble La Niña events.

3.1. Ensemble El Niño years

From Fig. 1, El Niño is detected first in April with a sharp decrease of rainfall amount in northern Australia. In March there is no indication of El Niño, since there is no significant signal (> |20%|) over Indonesia. There are some areas even with rainfall reductions more than 100% or totally dry. Then from May onward, the anomaly increases and diverges toward the Indonesian archipelago. The distribution of negative anomaly extends from southeast Indonesia westward and northward. By August the anomaly coverage reaches almost the whole country except Jambi province up to Aceh and north of Kalimantan. The distribution of highly dry areas varies among regions. However most of the regions experience negative anomalies more than 60%.

Figure 2 shows the time evolution of rainfall anomaly in the next half year. The maximum anomaly distribution seems to be in September when the distribution of negative area reaches its maximum. The distribution of anomaly, which has values less than 60%, covers the same areas as in August. What interesting here is that: in Southeast

Asia, Indonesia and north Australia are the only affected areas. The rainfall data is limited into land area data. If the data covers the ocean rainfall data, there will be clearer pictures on how the propagation of the real El Niño influence through ocean surfaces or currents.

Then from October, the influence of El Niño decays as the time evolves. From Fig. 2 the influence diminishes in December. In November, there is an indication of a higher rainfall amount coming from the north. November is the onset month of the Asian monsoon, as the Inter Tropical Convergence Zone (ITCZ) move southward through this region. The significant positive anomaly of rainfall amount north of Indonesia suggests an El Niño – Asian monsoon interaction. The positive anomaly appears until February in the following. There is a need of further investigations on this issue, which is beyond the scope of this paper.

In the next figure, Fig. 3, there are no significant negative signals until August of the following El Niño year, when there are some positive anomaly areas. Those areas indicate the presence of La Niña effect in the similar region as in August of El Niño year, although the distribution and strength of signals are weaker than those in El Niño year (with opposite signs). This fact suggests that the El Niño year may be followed by the La Niña year immediately after. In our definition of ENSO years there are only two El Niño years, which is followed by La Niña immediately. Those are 1969 and 1972. Even with only two years out of five La Niña years from our inspection, the signal is significant because of their deviations from normal. The spatial pattern of July in the following year shows unique signals with a strong negative pattern over Australia. The cause of the abnormality so far is not known.

3.2. Ensemble La Nina years

Figure 4 shows that the situation in the ensemble La Niña year is only in the opposite of the ensemble El Niño year with the same spatial and temporal distribution. The La Niña signal or positive anomaly has been detected as soon as March of the La Niña year, although those signals are not significant (mostly below 40% anomaly) and they are sparsely distributed. Like in the El Niño year significant signals in April exists in north Australia. From that month onward, the positive anomaly increases spatially and in values, although some unsignificant signals remain. The distribution of positive anomaly extends northward and westward from southeast Indonesia. There is abnormality in July, where the rainfall in north Australia is negative, which reminds us to the similar case of July in the following El Niño year. That abnormality comes from

the La Niña years, which follow the El Niño years (1970 and 1973). The different between the pattern in July in this ensemble La Niña year and that of July of the following El Niño year is more positive anomalies in some other parts, which is attributed to signals of the other three La Niña years.

From Fig. 5, the peak of the La Niña influence has been in August and September, when the extension of the spatial distribution is largest. In September, most of the affected areas experience more than 100% positive anomaly. Like El Niño years, the spatial distributions of ENSO anomaly in the ensemble La Niña years do not include north Sumatera and some parts of Kalimantan. After September, the influence decay with time and the influence of La Niña is undetected in January.

Interestingly, from October to December, there is an influence of incoming Asian monsoon as in case of El Niño years with opposite signs. Hence, areas, which receive positive anomaly in winter of El Niño years, will receive negative anomaly during October to December. This consistent feature indicates a possible negative influence of ENSO on the onset of Asian monson to the Southeast Asian region.

The spatial patterns of Fig. 6 do not show strong coherence signals except in Australia in March and July of the following year, because the La Nina influence has diminished in December. It is possible that the abnormality in July is due to the El Niño year, which follow La Niña year (1965). The case of abnormality in March in Australia is so far unknown.

4. DISCUSSION AND CONCLUSIONS

We have analyzed the spatial patterns of rainfall anomaly during ENSO years. We made analysis based on the ensemble averages of El Niño and La Niña years starting from March of the boreal string to the end of summer in the following year. The analysis focused on monthly spatial distributions.

Indonesia experiences ENSO influences from April on both El Niño (warm phase) and La Niña (cold phase). Although some indications of La Niña impacts exist as soon as March, the signal in March is too weak. The influences of ENSO reach their peaks in August and September by both types of events and decay afterward. By the end of the year, as the Asian monsoon comes, there is no clear signal that ENSO influences still exist. This is in aggrement to what is found by Kirono *et al*. (1999)

The rainfall anomalies on those phases appear in Northern Hemisphere summer or dry season in Indonesia. In the case of El Niño the reduction of rainfall amount in the dry season means a severe negative impact. On the other hand, the increase of

rainfall amount in the dry season during La Niña events means a positive impact.

The peaks of ENSO rainfall anomaly in Indonesia occur in August and September or 4 to 5 months after they start, which is different from other parts of the globe. Philander (1983) reported that the peak of the ENSO's SST anomaly in the Pacific occurs in December – February. Meanwhile, Webster and Palmer (1997) reported the highest SST anomaly and subsurface temperature anomaly of El Nino 1997 in October. In the world of climatology, especially in ENSO prediction, there exists the spring predictability barrier, which means that any ENSO prediction will faill or less accurate before the boreal spring, for example: Balsameda *et al.* (1995), Davey *et al.* (1996), Weiss and Weiss (1999) and Thompson and Battisti (2001). Hence, there is a possibility to construct an effective warning system 4 months ahead before the most severe impact happen. Please bear in mind that this study uses ensemble averages, so that the time evolution of each ENSO event will varies. Therefore, there is limited time to manage and react to the incoming ENSO.

The spatial extensions of ENSO influences on Indonesian rainfall are similar for both El Niño and La Niña. Almost all areas except some in northwest Indonesia experience ENSO influences with different time spans and strengths. The maximum extent of spatial patterns of ENSO influences resembles the spatial pattern introduced by Ropelowski and Halpert, 1987. This study goes event further by introducing the temporal evolution of that spatial extension.

The consistent feature at the end of the year (October to December) from both ENSO cases suggest possible negative ENSO influences to the onset of Asian monsoon. Those influences are detected in some part of the Southeast Asian region.

This study is limited in many cases. The original data are land surface data. If there is also ocean data, it is possible to track monthly propagation of the ENSO effect. Thus allowing other seasonal and sea-air interaction analysis. The data is also limited only to 6 El Niño and 5 La Niña events. In order to gain a better statistic, more cases are needed. Since the ENSO spectrum is easily known, it is possible to confirm the spatial extension of ENSO effect by filtering rainfall spectra in a similar bandwith as the ENSO signals. This is a possible future extension of this paper.

5. ACKNOWLEDGEMENT

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BIOGRAPHY

EDVIN ALDRIAN. Born in Jakarta, 2 August 1969, received Bachelor degree in Engineering Physics in McMaster University Canada, 1993, received Master of Science in Earth Science in Radar Meteorology from Nagoya University Japan, 1998. Now doing a Doctoral degree in Max Planck Institut für Meteorologie, Germany. Work as a scientist in UPT Hujan Buatan, BPPT since November 1993. Participating several short courses: STMDP preparation program, 1988-1989; short course on Meteorology in UI, March 1995; training on data analysis of wind profiler radar in Radio Atmospheric Science Center, Kyoto University, Japan, November 1995; basic training Geographic Information System, Geography Dept. UI, June 1996; International Hydrology Programme Training Course with topic Ice and Snow Hydrology, IHAS, Nagoya University and UNESCO, March 1998; Visiting scientist in Max Planck Institut für Meteorologie, Hamburg, learn the Indonesian climate variability and ECHAM GCM, Jan – March and July – September 1999; Advanced Course: Climate change in the mediterranean region part I: physical Aspects, The Abdus Salam International Center for Theoretical Physics, Trieste, Italy, March 2001; short course on Meteorology: Predictability, Diagnostics and Seasonal Forecasting, European Center for Medium Range Weather Forecast (ECMWF), Reading, UK, April 2001; PRISM/COACh Summer School on Climate Modelling, Max Planck Institut für Meteorologie-KNMI Nederland, Les Diablerets, Switzerland; School on the physics of the Equatorial Atmosphere, The Abdus Salam International Center for Theoretical Physics, Trieste, Italy, September 2001.
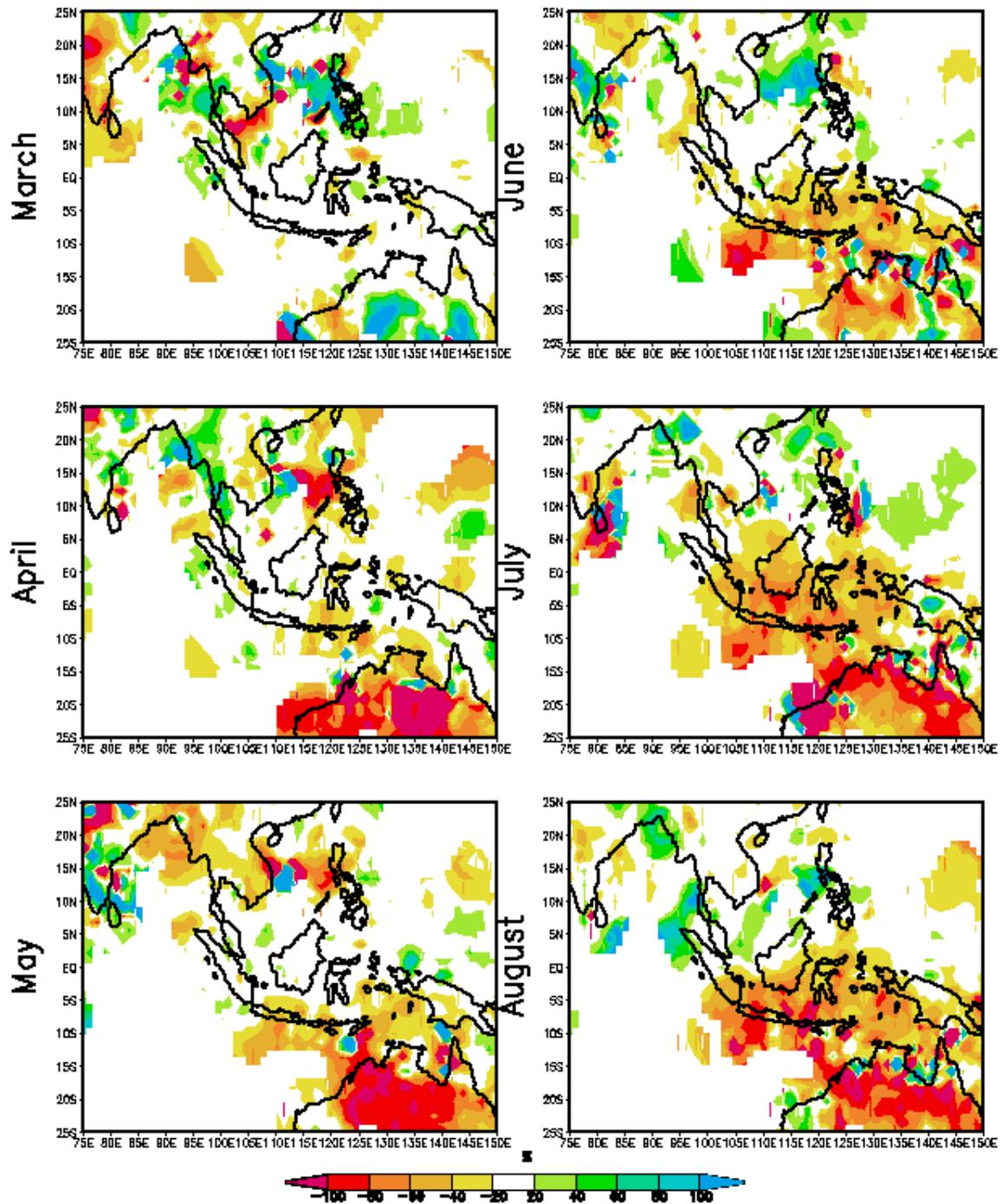
Figure 1. The spatial patterns of rainfall anomaly during specific months of ensemble El Nino year in summer of El Nino year. The ensemble ENSO years are combination of 1965,1969,1972,1982,1987 and 1991. The contour scales are given in percentage of rainfall anomaly.
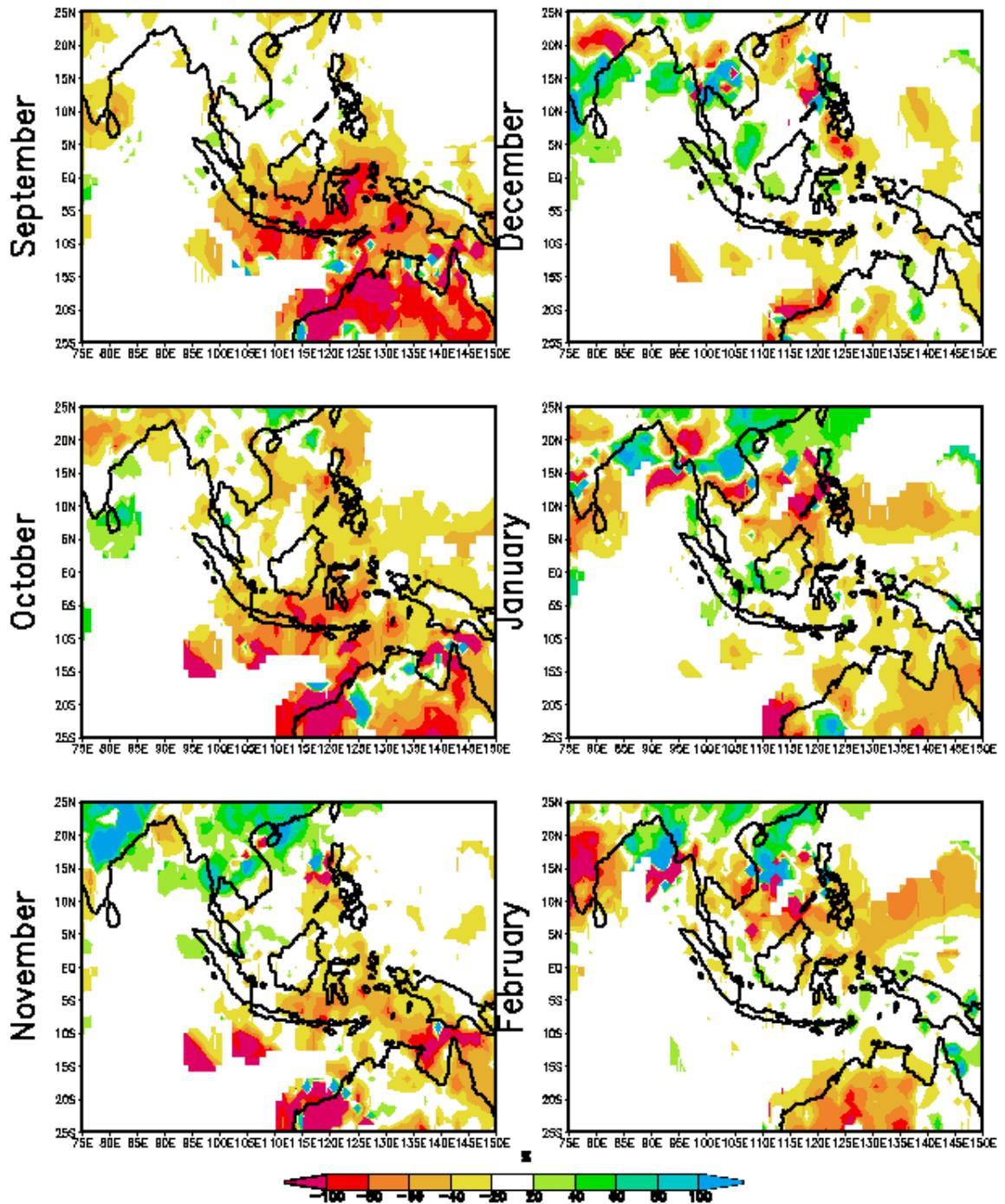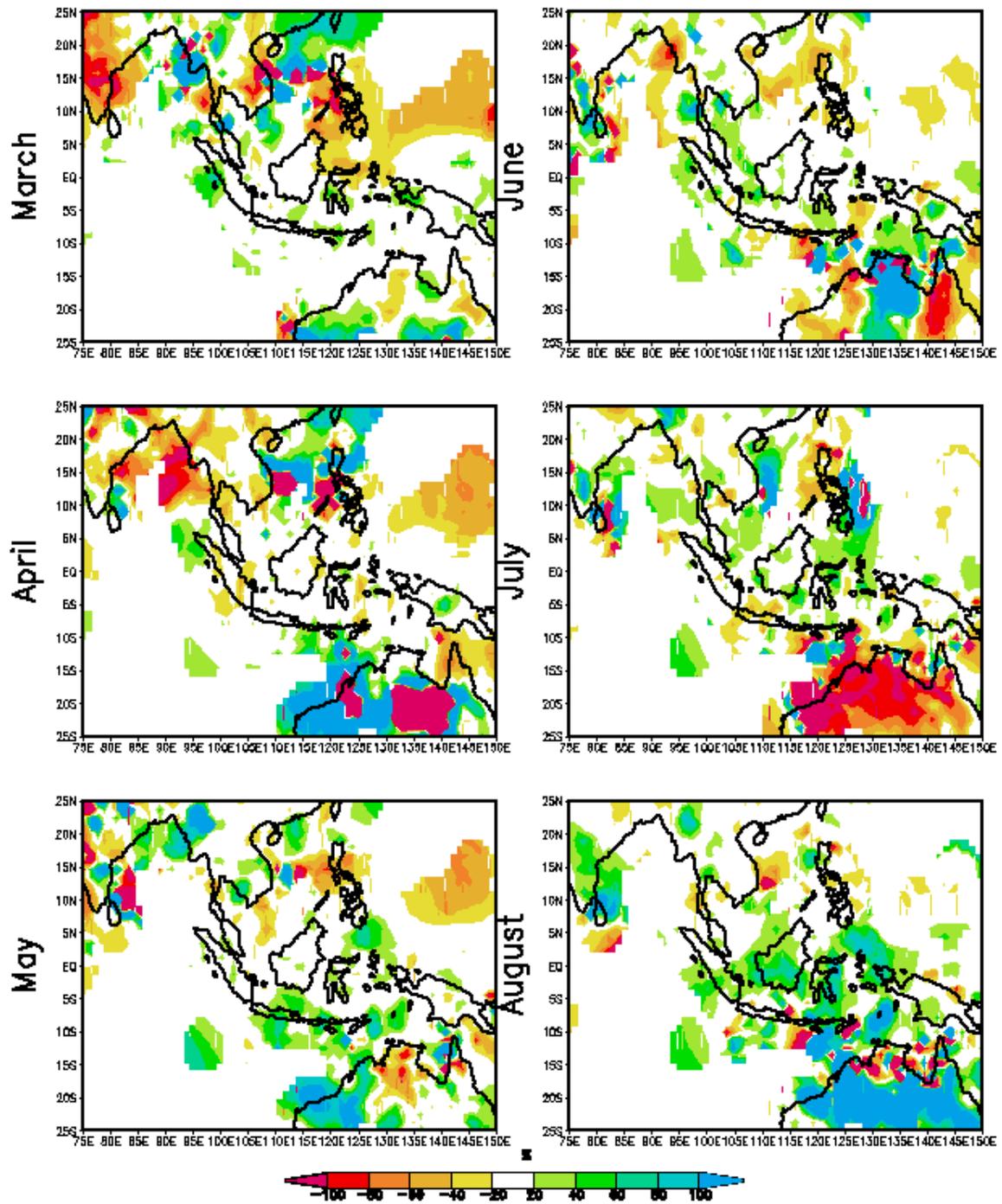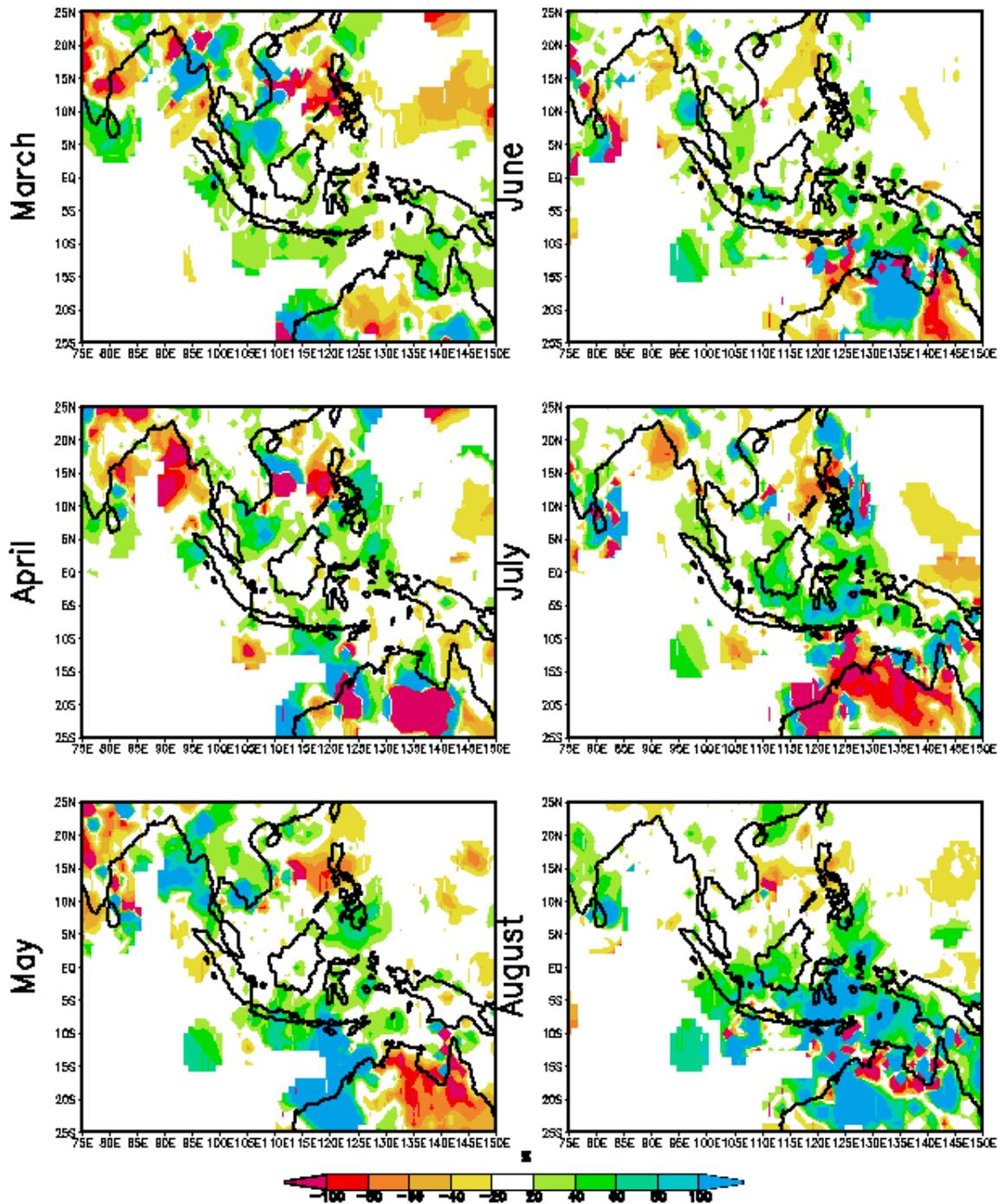
Figure 2. as Fig. 1, but for winter of the El Nino year

Figure 3. as Fig. 1, but for summer of the following year

Figure 4. The spatial patterns of rainfall anomaly during specific months of ensemble La Nina year in summer of La Nina year. The ensemble ENSO years are combination of 1964,1970,1973,1975 and 1988. The contour scales are given in percentage of rainfall anomaly.
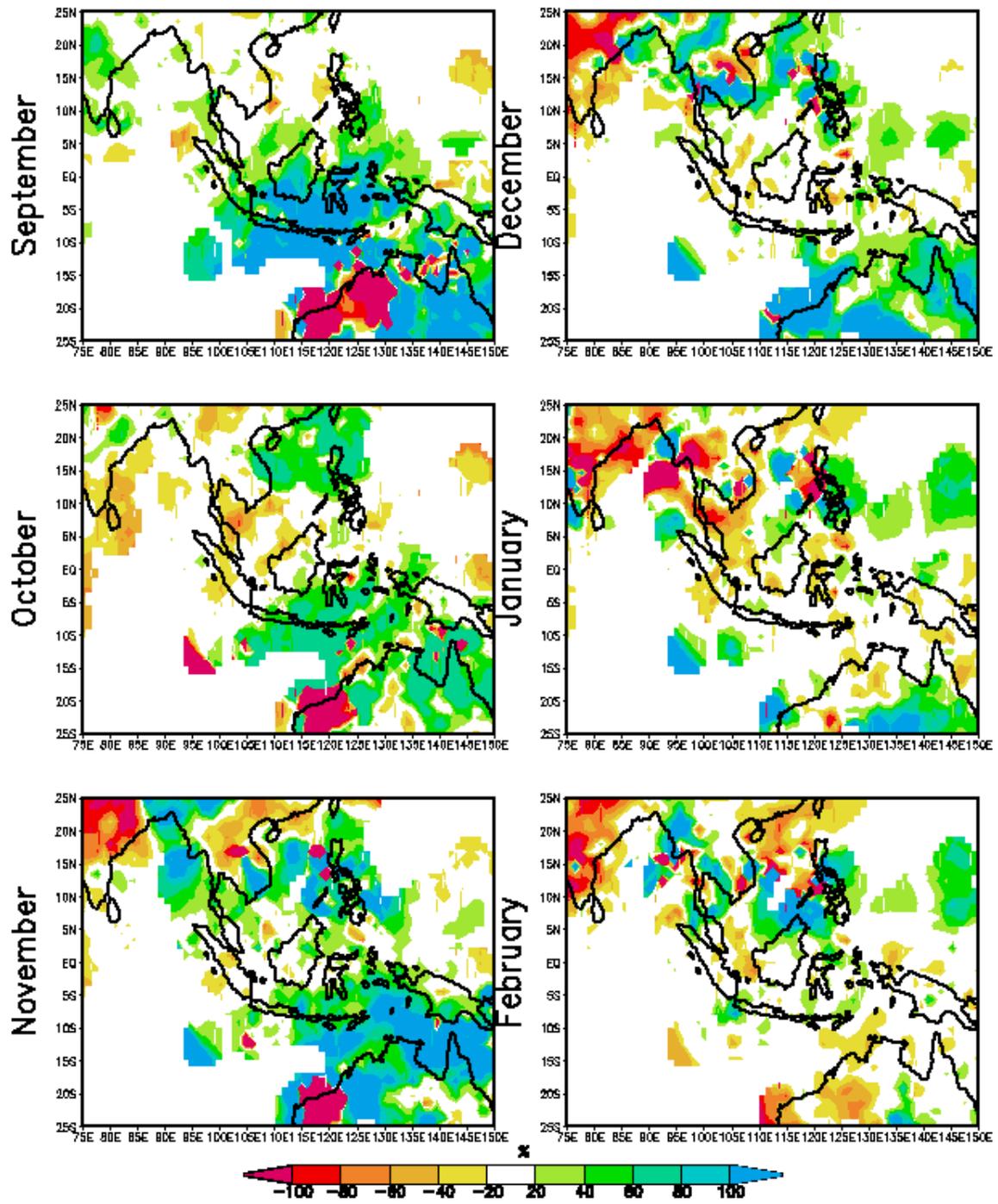
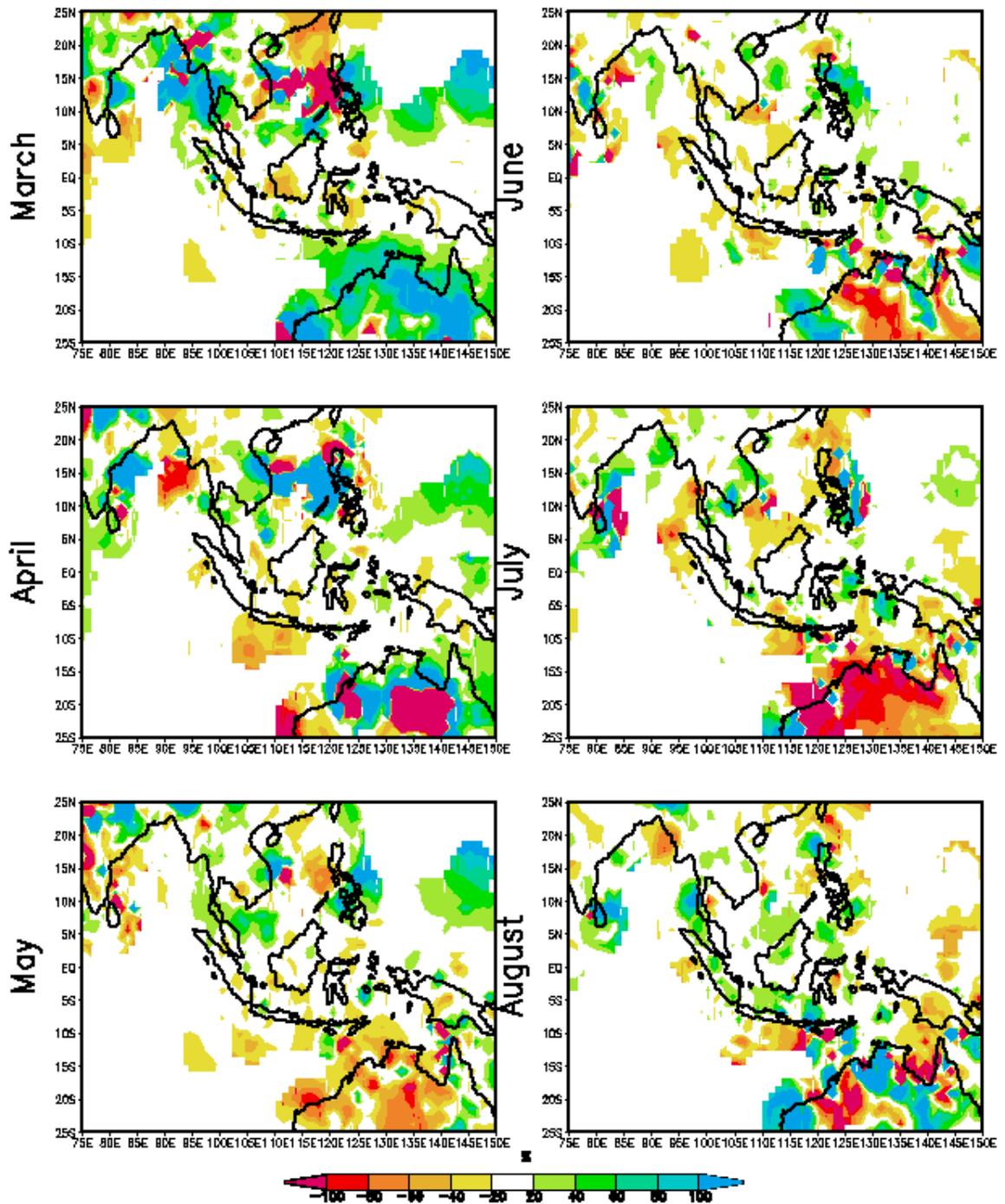**Figure 5.** as Fig. 4, but for winter of the La Nina year

Figure 6. as Fig. 4, but for summer of the following year