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The La Nina episode and the heavy winter rainfall of 1999 over Peninsular Malaysia

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Abstract

Prolonged events of heavy rainfall which commenced in September 1999 and continued until January 2000 during the northeast monsoon over the Malaysian Peninsula showed that the enhanced rainfall conditions were related to the larger scale La Nina phenomenon. This was substantiated by large-scale observational features, such as the monthly precipitation, anomaly of outward long wave radiation, zonal and meridional wind fields at the lower and upper levels, vorticity and vertical motion, that exhibited a disparity from the El Nino conditions of 1997. Low-level convergence concentrating over the maritime continent coincided with the region of enhanced rainfall. The more frequent occurrences of heavy rainfall and flooding during this period fell within the La Nina episode, occurring approximately two years after the major dry episode of the El Nino phenomenon. The enhanced rainfall encountered by Peninsular Malaysia was considered to be related to the transitional phase of the Tropical Biennial Oscillation. The causes of these heavy rainfall episodes were variable and included the localized and organized enhanced afternoon convection resulting from the radiative diurnal cooling and heating effects. The heavy rainfall in early October 1999 was associated with the presence of the confluence of airstreams along the Malaysian Peninsula at cyclonic vortices of 850, 250 and 100 hPa over the northern Malaysian Peninsula. Two westward propagating tropical cyclones which existed over the Bay of Bengal and the Gulf of Siam were among the main contributors to the heavy rainfall over the region during October.

Keywords: El Nino phenomenon, La Nina phenomenon, meridional wind fields, Tropical Biennial Oscillation, tropical cyclones, vorticity and vertical motion

Introduction

The monsoon system is still a mystifying phenomenon that is emerging as a macroscale feature than a regional entity entangled with the global scale circulation (Webster *et al.,* 1998). The Tropical Ocean-Global System programme which concentrates on the Pacific basin, did not fully capture the importance of the role of monsoons to the general circulation of the atmosphere, where the understanding of seasonal to interannual climate variability is an important feature. The interannual variability within the monsoon system is also associated with the global and interactive El Nino -La Nina phenomenon. As many aspects of the El Nino Southern Oscillation (ENSO) are still not well understood, particularly its inter-decadal modulation, the ENSO and monsoon systems cannot be treated as a separate entity but a global and interactive system (U.S. CLIVAR, 2000). The mechanisms and process studies that include the interactions within the ocean-atmosphere-land systems deserve further investigation under the Global Ocean Atmosphere Land System (GOALS) programme because of the lack of success in simulating the mean state of the monsoon with the general circulation model, imposed with the sea surface temperatures (Spencer and Palmer, 1996).

Meehl *et al.* (1996) postulated a biennial mechanism involving the coupled atmosphere-land-ocean interactions that considers the monsoon as an active component in the tropical biennial oscillation. Anomalous heat sources with heat sinks and sources associated with sea surface temperatures and convective anomalies produced by the air-sea interaction and the east-west circulation over the Indian and Pacific Ocean maybe the forcing circulation anomalies in the mid-latitudes *via* remote Rossby wave responses.

Embedded within the regional and a specific time scale of the monsoon system, is the winter monsoon over the Indonesia -maritime continent of South East Asia. Peninsular Malaysia is located over the latitudes of 0ºN to 7ºN and 100ºE to 105ºE within the equatorial region of Southeast Asia dominated by an equatorial climate. As a country located within the maritime continent, its total annual rainfall of 3**,**000mm is high. Approximately**,** a third of the total amount of rainfall is received during the northeast monsoon, which falls from late October to March. Records of reports from the Global Extreme Flood Events by the Dartmouth Flood Observatory affirm that extreme heavy rainfalls over Malaysia, Indonesia and southern Thailand are not unusual during the winter monsoon (Dartmouth Flood Observatory, 2002).

The many incidences of heavy rainfall and floods that began early in the late September through December of 1999 during the northeast monsoon over Peninsular Malaysia were considered abnormal. The reason for this is that the onset of the heavy rainfall in late September falls within the transitional season from the southwest monsoon to the northeast monsoon, not usually associated with very heavy rainfall. The affected flooded areas were widespread along the west coast of the Peninsula, extending from the northwest towards the south of the Malaysian Peninsula. Table 1 shows some of the headlines from the local media regarding the extent of the floods describing the severity of the flood incidences during the winter monsoon of this year. The widespread floods that took place along the western coast of the Malay Peninsula, extending from the states of Perlis, Penang, Perak, Selangor, Melaka, Negeri Sembilan and Johor fall within a La Nina episode (Figure 1). The latter phase of the flooding occurred during the northeast monsoon from the months of November and December 1999, affecting the north eastern coast states of Kelantan and Terengganu, whilst also involving the Peninsula’s central and southwestern states of Selangor, Perak and Pahang.

Table 1. Reports of the flooded areas in Peninsular Malaysia from September to December 1999

Dates	Areas	Newspaper Titles
6 Sep	Penang and Baling, Kedah	Flash flood in Penang and Baling.
3 Oct	Kerian, Perak	Flood: 42 people moved to schools.
7 Oct	Kerian and Teluk Intan, Perak	Flooding in Kerian worsens.
9 Oct	Kerian, Perak	Flooding in Perak worsens.
25 Oct	Penang, Baling, Kuala Muda, Kulim, Kedah	Many roads in low lying areas flooded.
26 Oct	Kuala Muda and Baling, Kedah	Kuala Muda worst hit. Flooding in the north: 14935 moved, 10 schools closed.
27 Oct	Northern Seberang Prai, Central Seberang Prai, Krian	Flood in Krian, 8 schools closed. Flood in Krian worsens, more than 300 moved.
29 Oct	Krian, Kedah	Two states recovered, flood in Perak worsens.
16 Nov	Seremban	Flash flood in Seremban.
22 Nov	Tumpat, Kelantan	Boy, 9, first flood victim in Kelantan.
23 Nov	Klang valley	111 moved due to flooding.
3 Dec	Klang valley	Mud floods, highway closed.
6 Dec	Puchong	10,000 threatened by mud flood.
7 Dec	Klang valley, Tapah, Perak	Flood: Traffic in KL-Klang haywire. Landslide in Tapah, driver injured.
9 Dec	Kuantan and Tapah	More than 300 moved due to flood.
10 Dec	Mentakab, Pahang	Flood in Mentakab worsens.
27 Dec	Kuala Rompin	Ipoh, Perak hit by big floods.

Source: New Straits Times, Berita harian and Utusan Malaysia

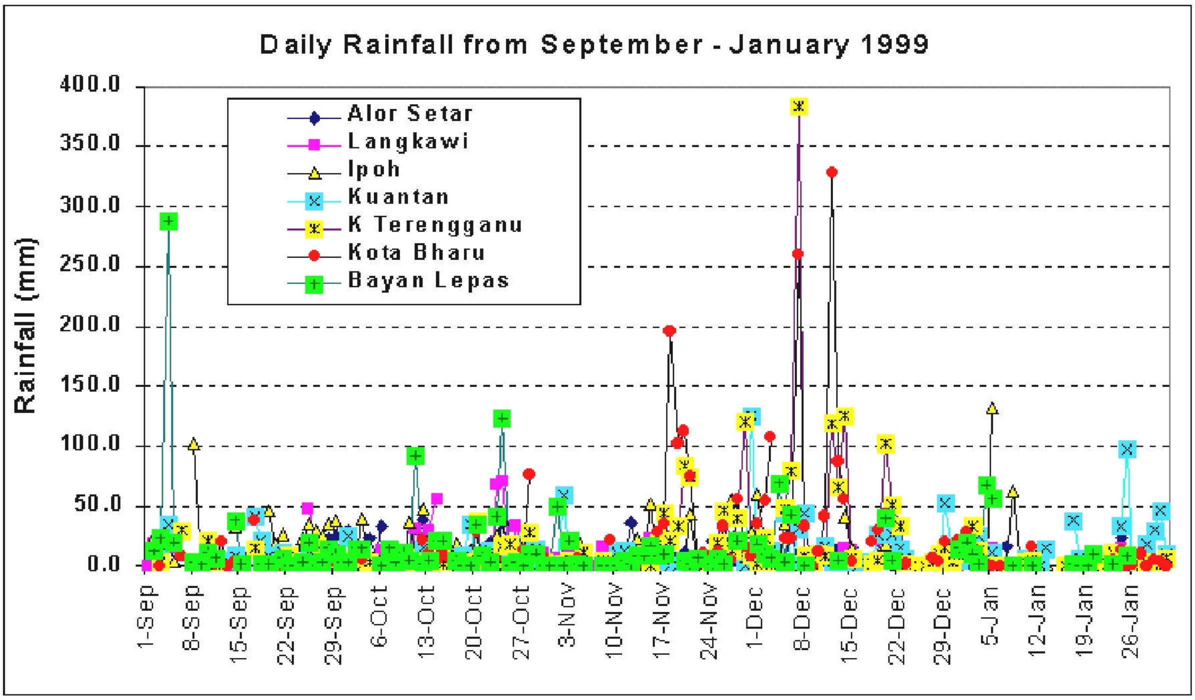

Figure 1. *The daily rainfall over some selected stations over the Malaysian Peninsula from September 1999 to January 2000. The heavy rainfall from September to October over the Bayan Lepas, Ipoh, Langkawi and Alor Setar stations represent the northwestern region of the Peninsula. Stations such as Kuala Terengganu, Kota Bharu and Kuantan correspond to the northeast to the central east coast of the peninsula that received heavy rainfall in November and December*

The La Nina phenomenon is a cold episode, where abnormal cold waters exist over the equatorial central Pacific Ocean. It is characterized by lower than normal pressure over the Indonesian region and higher than normal pressures over the eastern tropical Pacific. During the La Nina episode, enhanced precipitation is observed over northern Australia, Indonesia and Malaysia during winter and spring due to the stronger than normal Walker circulation. The Walker circulation is also characterized by increased lower level easterly winds and increased upper level westerlies across the eastern Pacific. The seasonal month from January to March of 1999 is considered a strong La Nina episode. April, May and June are regarded as a weak phase of the La Nina, followed by a moderate La Nina from July to September. The episode ended with a weak La Nina in October, November and December. This cold episode classification is utilised using the reanalyzed dataset of the NCEP (National Centers for Environmental Prediction) and that of the UKMO or the United Kingdom Meteorological Office (Climate Prediction Center, 2002).

The theory postulated by Meehl *et al.* (1996) on the existence of a Tropical Biennial Oscillation (TBO) arises from the interaction between the annual monsoon cycle and the El Nino Southern Oscillation (ENSO) cycle. TBO is defined as the tendency for a relatively weak monsoon to occur and followed by a relatively strong one, and *vice versa* (Meehl and Arblaster, 2002a). It is suggested to be the determining factor in setting up the ENSO cycle (Shen and Lau, 1995). The sea surface temperature anomalies across the Pacific region (through the role of the atmosphere-ocean interactions) play an important part in the maritime continent-Australian monsoons (Chen and Yen, 1994; Palmer *et al.*, 1992). Sea surface temperature anomalies in the tropical Indian and Pacific Oceans are found to be in phase with the biennial oscillation and the Southern Oscillation (Meehl, 1997). The mechanism of the TBO depends on the coupled land-atmosphere-ocean interactions in the Indian-maritime continent sector, large-scale atmospheric east-west circulations in the tropics, the equatorial Asian convective heating, and the tropical and mid-latitude interactions in the northern hemisphere.

The postulated biennial mechanism entails coupled atmosphere-land-ocean interactions that involve the monsoon as an active component in the TBO (Meehl *et al.*, 1996). Anomalous heat sources with heat sinks and sources associated with sea surface temperatures and convective anomalies produced by the air-sea interaction and the east -west circulation over the Indian and Pacific Ocean maybe the forcing circulation anomalies in the mid-latitudes *via* remote Rossby wave responses. Transitions from March to May and from June to September were found to have established the system for the following year, with an opposite transition in the subsequent year (Meehl and Arblaster, 2002b). The TBO, having a cycle of approximately two to three years, includes most ENSO years and additional years that contribute to biennial transitions.

The above hypothesis proposed by Meehl *et al.*, (1996) is highly idealised with several assumptions. This scenario is not perceived to have occurred at regular cycles, since the ENSO events occur at intervals of 2 to 7 years, although their occurrences have been more frequent lately in the 1990's (Trenberth, 1997).

The TBO is a plausible cause of the enhanced occurrence of precipitation occurring in the fall of September, October and November (SON) and the winter of December-January- February, after the major ENSO of 1997/1998. The ENSO episode caused drought conditions over the Malaysian region including the Borneo states of Sabah and Sarawak. The water supply for the northern and central states of the Malaysian Peninsula was depleted and this had affected the agriculture industry and reduced the water consumption of the public. In Sabah, several villages had to be supplied with food since the rice crops had failed due to the drought. The occurrence of the transboundary haze, caused by the Indonesian forest fires through deliberately uncontrolled burning by local farmers and by estate plantations during the dry season, is also highlighted as a consequence of the dry ENSO episode. The lack of intermittent rainfall could not have cleansed the air, which had been polluted by the smoke particles of the biomass burning.

The enhanced rainfall that the Malaysian Peninsula received approximately two years after the major ENSO event, therefore, may be a consequence of the El Nino-La Nina phenomena explicable by the TBO theory. Meehl *et al.*, (1996), on examining the northern winter of the East Asian region, showed the existence of sub-seasonal eastward propagation of convection from the Indian Ocean to the western Pacific, which was mainly contributed by the strong air-sea interactions. The first of the two timescales associated with the convection are the sub-monthly timescales (6-30 days). These would initiate eastward, moving equatorial Kelvin wave (Wieckmann and Khalsa, 1990) where the east Asian baroclinic trough is noted as part of the northern hemisphere upper level wave train. The latter is associated with low pressure surges contributing to near-equatorial surface pressure gradient from the northern hemisphere and the subsequent convection over Southeast Asia. The sub-monthly timescale could be evident from the existence of features such as the anticyclonic circulation over southern Asia, a trough over Korea, a ridge over western North Pacific, and a cyclonic circulation near 170^0W 20^0N (Meehl *et al.*, 1996). The second timescale is the slow Madden-Julian Oscillation (MJO) eastward propagation of 30-70 days. The features associated with the MJO are a trough existing off eastern Japan, a midlatitude upper troposphere wave train that arches to the northern hemisphere tropics, and the symmetric features of wave trains south of the equator in the central Pacific. This timescale is associated with the convection in the western equatorial Pacific (Meehl *et al.*, 1996). A possible third mechanism is the westward propagating cyclone pairs with a structure of equatorial Rossby waves (Meehl *et al.*, 1996; 1993). Both Kiladis and Wheeler (1995) and Namaguti (1995) noted that vorticity intrusions into the tropics of the eastern Pacific could be associated with 850 hPa cyclonic circulations exhibiting the characteristics of an equatorial Rossby wave. These disturbances propagate westward and are associated with an anomalous convection in the western Pacific (Kiladis *et al.*, 1994). Meehl *et al.*, (1996) also noted that pressure surges from either hemisphere are important in the development of near -equatorial surface pressure gradients, leading to subsequent surface convergence and blow up of convection, and followed by the strengthening of upper level westerlies.

The above explanations provide the background theories and postulations on a planetary scale as to the occurrences of the heavy rainfall over the maritime continent that led to the serious and prolonged flooding of various parts of the country which occur approximately two years after the major El Nino events of 1997/98 across the Pacific Ocean. Clearly, the atmosphere-land-ocean interactions did play a major part in the convective activity across the equator, the Indian Ocean, the equatorial South China Sea, or the Pacific. In this study, the observational large scale and the regional synoptic scale studies were investigated to unearth the causes of the heavy rainfall and flooding that occurred in the Malaysian region. The comparison between the El Nino and La Nina episodes were examined generally to investigate the large-scale conditions that were in contrast during the major dry period and the considerably wet period of the La Nina in 1999.

Observational aspects over the equatorial maritime continent

a. The outward long wave radiation and precipitation

The outward long wave radiation (OLR) for the period from September 1999 to January 2000 along the equatorial longitudes showed the existence of the negative anomalies of OLR, evident from the longitudes of 90°E to 120°E. The Hovmuller time series plot illustrating the presence of clouds over the equatorial latitude is shown in Figure 2. Negative OLR anomaly could be observed over Peninsular Malaysia, which lies at 100°E, from mid -September until late October. This indicates the existence of above normal convection during the period. Another period of above normal convection occurred from early December until mid-January of 2000. Throughout this period, the area near the international dateline was an area of positive OLR anomaly, indicating the forming of less convection over this region.

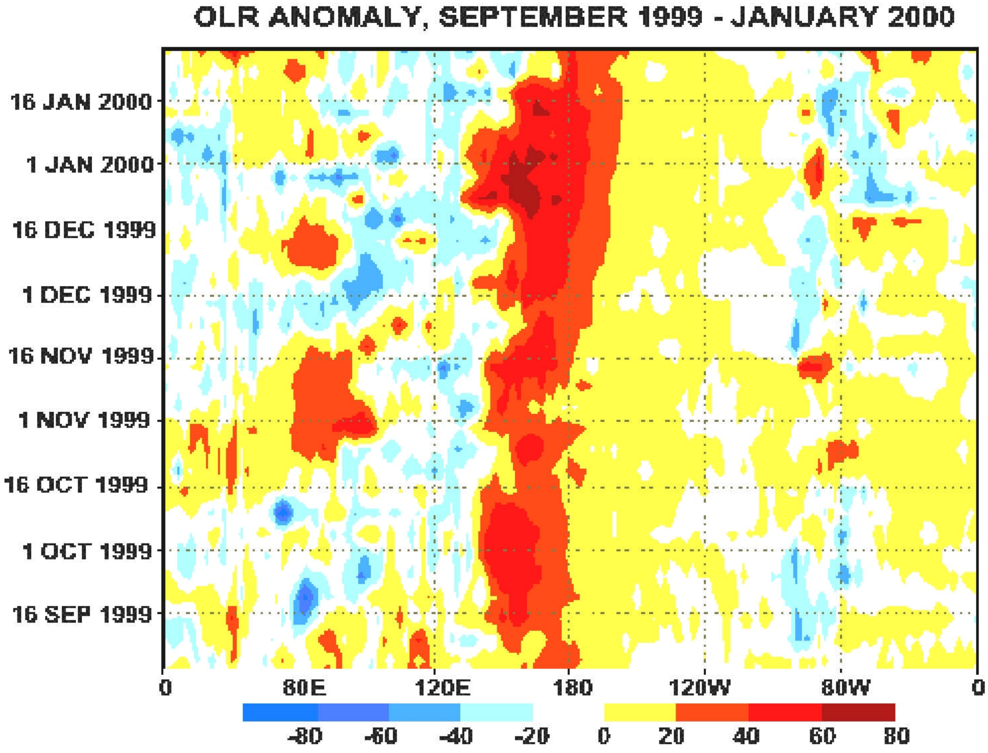

Figure 2. *The longitude-time sections of the anomalies of OLR along the equatorial latitudes from September 1999 to January 2000. Units are in Wm^{-2}*

The observed monthly precipitation taken from the Xie and Arkin dataset, which consists of satellite and rain gauge data during the period of September to December of the 1997 El Nino and the 1999 La Nina, is shown in Figure 3. This Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP) is considered the best available dataset, even better than individual data sources (Xie and Arkin, 1997) . The contrasting two years are shown to highlight the different precipitation features during the two periods. The sequence of precipitation maps from September to December 1997 shows that the maximum area of precipitation is concentrated to the east of 160°E and over the tropical Pacific Ocean, a state associated with the enhanced precipitation over the eastern Pacific due to the El Nino episode. The maritime continent, particularly Indonesia and to a lesser extent, Malaysia, is dry from September to October compared to the rest of the region. The total monthly rainfall over the maritime continent is less than 5 mm/month, except for the drier Indonesia. Wetter conditions are found in November and December over the maritime continent that is now influenced by the northeast monsoon. This can be substantiated from the local rainfall gauges in Malaysia, where the delayed northeast monsoon of November brings wetter conditions in the equatorial Southeast Asian region.

The above feature is in contrast to that of the La Nina year of 1999. The major convective region is now concentrated over the maritime continent, which is considered one of the major energy sources for the global circulation. Most of the region of the maritime continent, particularly Malaysia and Indonesia exhibit enhanced rainfall totals of more than 15mm/month in October and December compared to those of approximately 5 mm/month during the El Nino months. The precipitation map is in conformity with the OLR Hovmuller plot shown earlier. The very low rainfall over the region validates the positive OLR feature; a fact, which serves to indicate the presence of little convection over the equatorial latitudes from 140ºE to 180ºE. Negative OLR anomaly, coincides with the enhanced precipitation over the maritime continent. Thus, the enhanced precipitation over Malaysia from October to December is not only a local feature but also a large scale feature associated with the La Nina episode as validated by the satellite and rainfall gauge data.

The relationship between the total annual rainfall (gauged from the Department of Drainage and Irrigation's forty rainfall stations and covering the entire period of 1959 to 1999) and the Southern Oscillation Index (SOI) is weak, at a coefficient of 0.24. The SOI is a measure of an El Nino/La Nina episode that is calculated from the monthly or seasonal fluctuations of the surface pressure difference between Darwin and Tahiti. Below average rainfall linked to the El Nino years for the Malaysian Peninsula occurred for 19 percent of the time compared to the above average rainfall of 24 percent. The La Nina events related to above average rainfall accounted for only 7.3 percent. This is in contrast to the below average rainfall of 9.8 percent associated with La Nina. Below and above average rainfall occurring during the non-El Nino and La Nina years accounted for 39 percent. Records showed that the La Nina period which coincided with the period of the study began in May 1998 and extended to May 2000. Although the rainfall records for Peninsular Malaysia are not conclusive in illustrating the association of enhanced rainfall with the La Nina event for most of the time, the floods in the Malaysian Peninsula did occur over an extended period of the La Nina episode.

b. Intraseasonal oscillation of the zonal winds

The low level easterlies were less prominent over the Pacific Ocean during 1997, while the westerlies were weaker to the west of 120ºE and at the Indian Ocean longitudes (Figure 4a). This burst of westerlies over the Pacific Ocean that occurred in late May- June 1997 signified the onset of the El Nino. The maritime continent was affected by westerlies in May and June, but was under the influence of weak easterlies throughout the rest of the year, when the El Nino was established. This shows that the intraseasonal oscillations of the Madden and Julian feature of timescale of 30 to 60 days was prominent prior to the onset of the El Nino in late May of 1997. Teleconnections exist between the existence of the zonal winds over the southern Indian Ocean and the succeeding onset of the El Nino in the equatorial Pacific Ocean (Krishnamurti *et al.,* 2000).

The low level zonal wind components in 1999 showed a different pattern (Figure 4e). The magnitudes of the easterlies over the Pacific Ocean were stronger, with little intrusion of westerlies. Low level westerlies were confined to the region from 60ºE to 120ºE, which included the Indian Ocean and maritime continent. September was influenced by weak westerlies, but the northeast monsoon of October to December was affected by stronger westerlies at 850 hPa.

The 850 hPa meridional winds showed that southerlies were comparatively stronger over the 40ºE longitudes during the La Nina year compared to the El Nino year of 1997 onwards of June (Figures 4b and 4f). The magnitudes of southerlies were also stronger from 80ºW to the dateline. The upper level zonal winds also exhibited contrasting features between the two years. From June magnitudes of easterlies over the equator have increased from 15 m/s to 20 m/s from July to

August in 1999 (Figures 4d and 4h). Upper level easterlies stretched across the eastern Pacific from June towards the end of the year compared to the appearance of upper level westerlies, which were confined within 60ºE to 80ºW from October to December during 1999. Upper level meridional winds did not exhibit an exceptional difference between the two years.

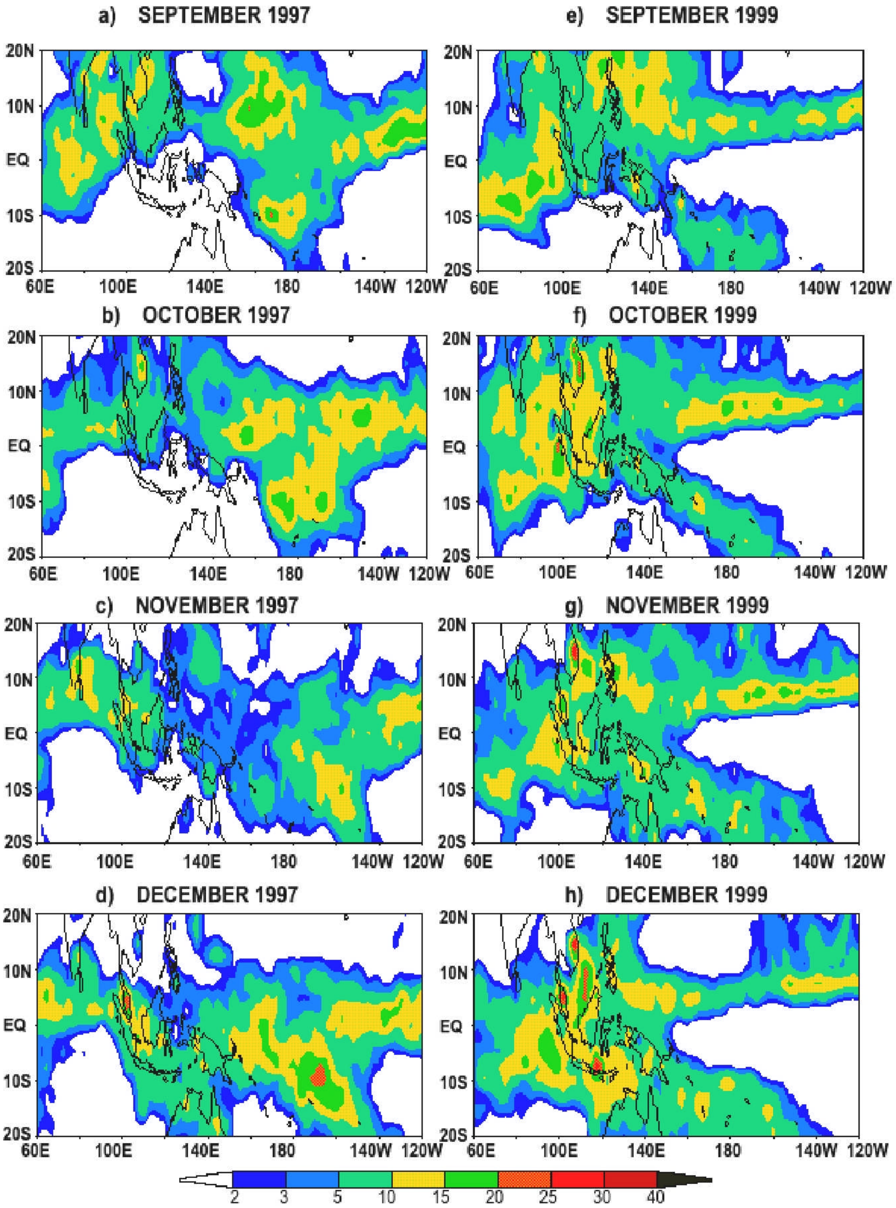

Figure 3. *The CMAP mean precipitation from September to December during 1997 and 1999. The unit of precipitation is mm per month*

The low level meridional component of the winds during the El Nino year of 1997 shows that the northerlies were dominant throughout the year around the equatorial globe. The southerlies were still present during the Indian monsoon from June to September. The strength of the southerlies appears to indicate that the onset of the monsoon was later and shorter than normal. The meridional wind component across the equator from January to December 1999 reflects that the southerlies were strong from 50ºE to 80ºE near the Indian continent from May to the end of October 1999 demonstrating the existence of the strong southwest monsoon compared to the El Nino of 1997.

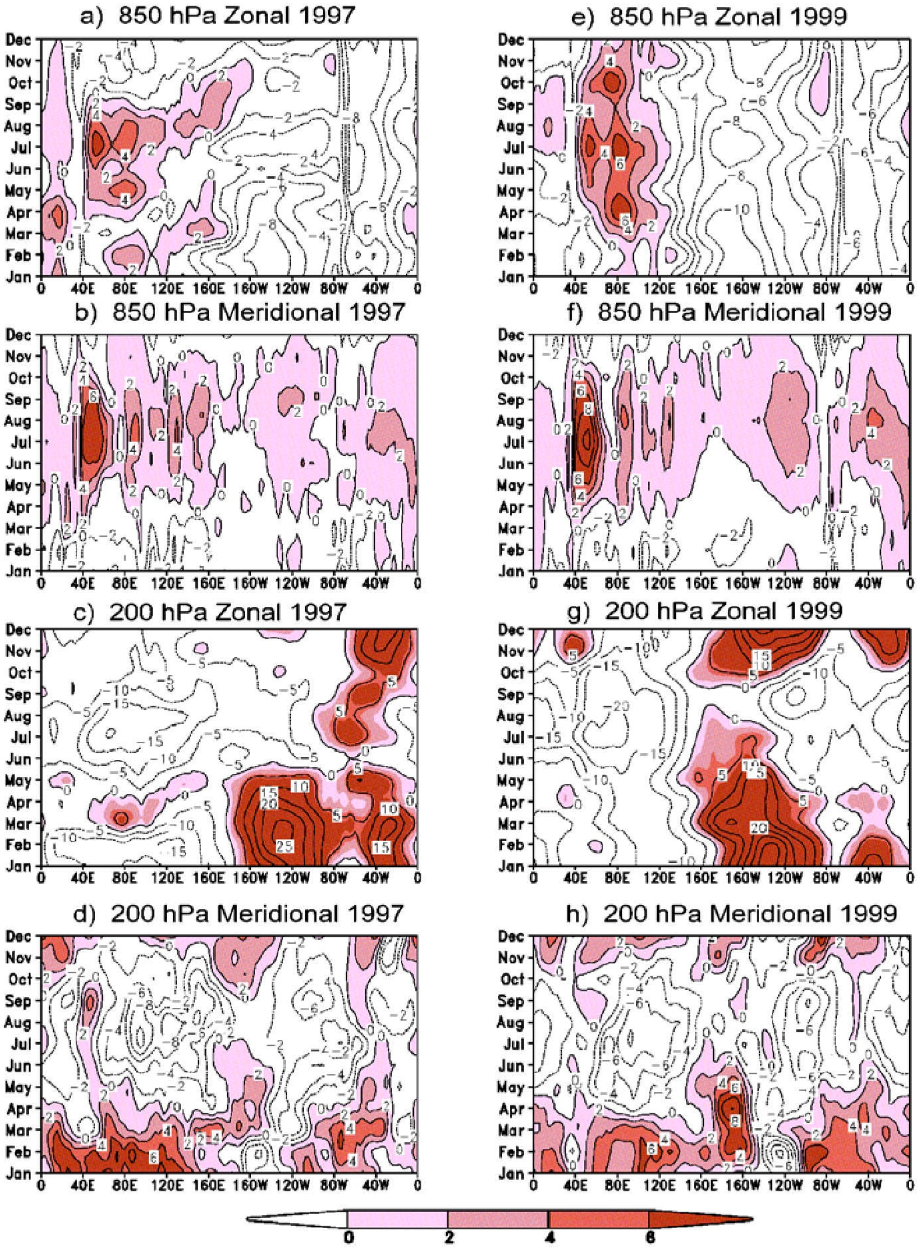

Figure 4. *The contrasting lower and upper zonal and meridional wind fields across the equator during 1997 and 1999.c. The large scale wind field analysis*

The low level 850 hPa wind field between the two contrasting years is shown in Figure 5. During the El Nino year, the general wind field over the equatorial region (5ºN to 5ºS) is shown as weak westerlies eastward of 140ºE. This feature existed from September through December of 1997, and was a typical feature of the wind field during El Nino. Stronger wind speeds of more than 5 m/s were found poleward of 10ºN, thus flanking this region on either sides of the equator.

The La Nina period in 1999 illustrated the opposite conditions. Easterlies were found to be dominant throughout September to December, the period investigated. The strength of the wind speeds was also stronger now compared to the El Nino period, with more than 5 m/s over the equatorial Pacific Ocean westward of 160ºE. Stronger wind speeds of more than 10 m/s were found in November and December. Another feature of interest is the reversal of the wind directions over the equatorial South Indian Ocean. During the El Nino period, easterlies were dominant from September to December. This was in contrast to the flow of westerlies during the

La Nina year throughout the four month period. The areas of convergence at low levels appear to concentrate on the maritime continent, which coincides with the region of heavy precipitation during the La Nina period.

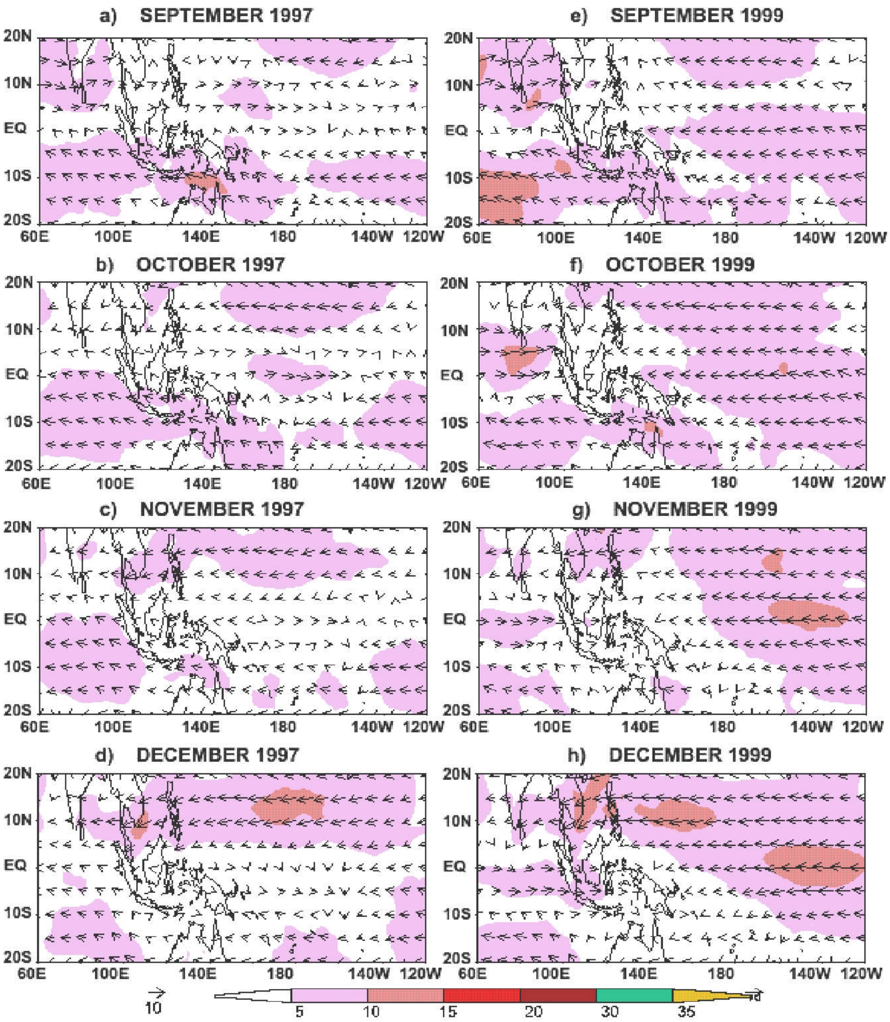

Figure 5. *The 850 hPa wind field from September to December during the El Nino years in 1997 and during 1999. The shaded region shows the magnitude of the wind speeds in m/s. The strengthening of the lower level easterlies over the equatorial Pacific is found in November and December of 1999*

The 200 hPa wind field also exhibited some distinct features. During the El Nino year of 1997, easterlies are dominant over the equatorial Pacific (Figure 6). Moderate strength wind speeds of 10m/s were dominant over the maritime continent. This was in contrast to the La Nina period, when westerlies were the main feature over the equatorial Pacific. Stronger wind speeds of more than 20m/s were found to the east of 180°W in November and December in contrast to the weaker strength during the same months in 1997.

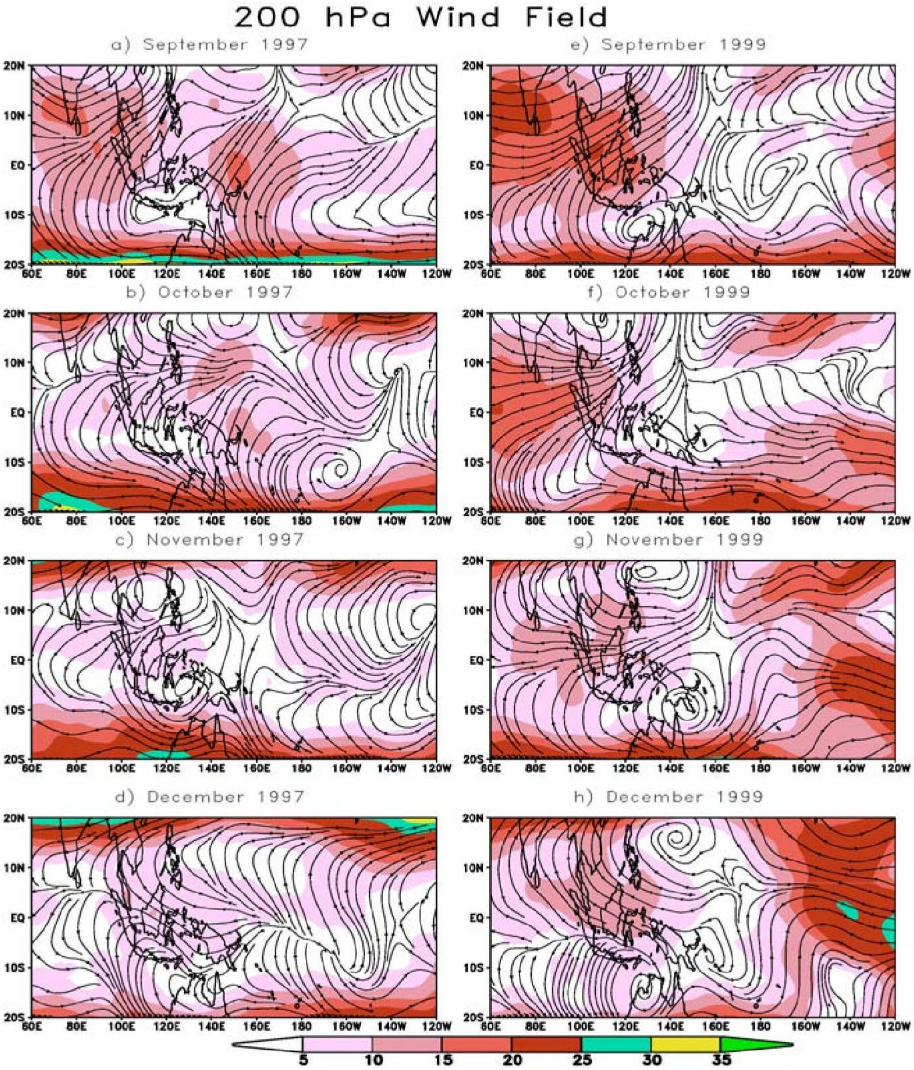

Figure 6. *The 200 hPa wind field streamlines from September to December of 1997 and 1999. The shaded region shows the magnitude of wind speeds in m/s. Strengthening of the upper level westerlies over the equatorial Pacific was found from October through December of 1999*

Low-level vorticity at 850 hPa during the two periods is shown in Figure 7. September 1997 was dominated by the presence of negative vorticity along the equatorial belt from 10ºN to 10ºS, with positive vorticity flanking this region. A marked contrast was observed during October and November. The magnitudes of the negative and positive vorticities had declined during these two months, from $–0.6x10^{-6}$ s^{-2} to more than $–0.2x10^{-6}$ s^{-2} along the equator, and the area had contracted and exhibited a southward shift by a few degrees compared to the previous month. Further southward shift towards the South Pacific Convergence Zone was found in November. The magnitude of the positive and negative vorticity was more pronounced in December.

A dissimilar situation was found during the La Nina year. The stronger negative vorticity over the maritime continent and southern Indian Ocean also displayed a southward shift towards the southern hemisphere from September to December towards the Australian monsoon. Positive vorticity was located throughout the studied area across the equatorial Pacific to the southern hemisphere. This appeared as a dipole feature, where negative vorticity was found westwards of 140ºE, from the maritime continent to the southern Indian Ocean throughout the four months. Positive vorticity was instead found over equatorial Pacific and in the southern hemisphere.

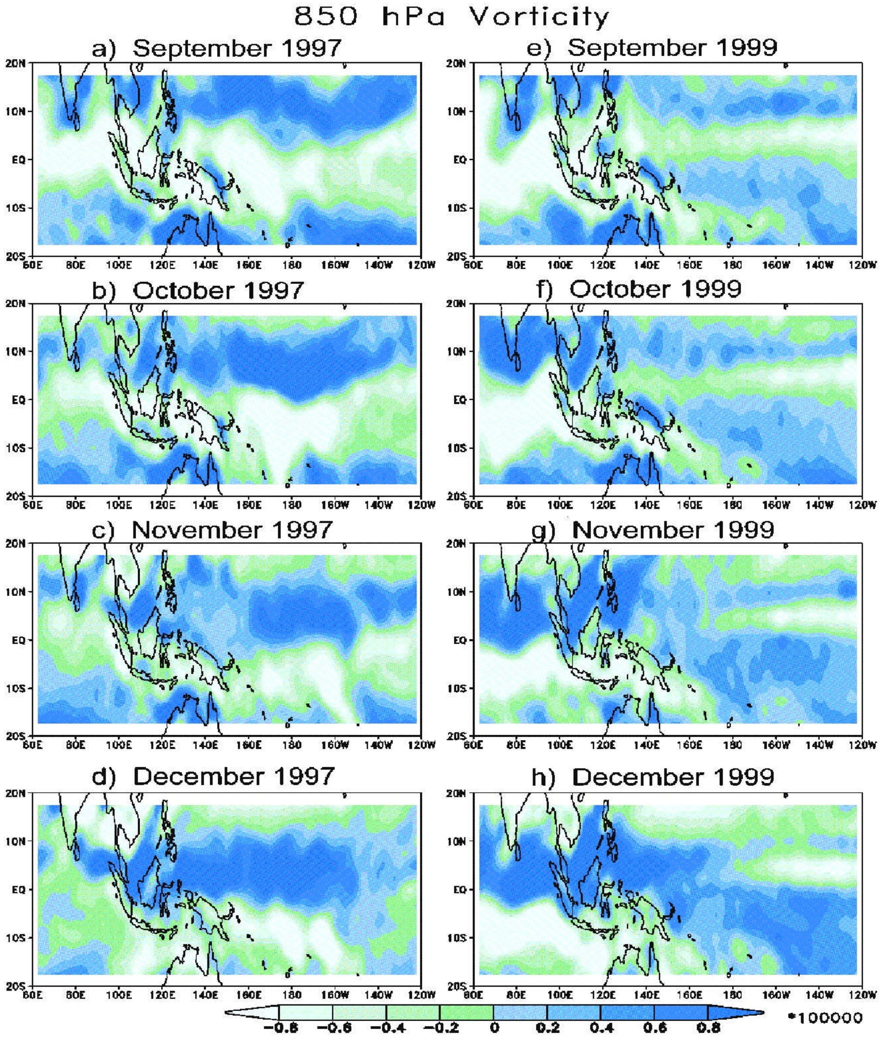

Figure 7. *The 850 hPa vorticity field from September to December during the El Nino year in 1997 and during the La Nina year of 1999. Units are in* s^{-2}

Low level convergence was generally found over the maritime continent throughout both periods investigated (Figure 8). It appears that enhanced convergence was found over the central Pacific region in September and December 1997. A slight low level divergence was observed in September 1997 over the Indonesian region, which conformed to the dry conditions reported in that country. During the La Nina year of 1999, much of the low level convergence was concentrated over the maritime continent, where enhanced convergence occurred in October, November and December.

Omega distribution at lower levels were plotted to investigate the large-scale vertical motion in p coordinates. The quasi- geostrophic vertical motion is a response to the disrupting influence of the geostrophic advection on the weather systems present. The mean monthly vertical motion map from September to December is shown in Figure 9. It shows that the Malaysian Peninsula-Andaman Sea region was under the influence of slight negative vertical motions, implying convergence, whilst the western Pacific was under the influence of low level downward motion. Most of the western Pacific region was dominated by positive omega, which implied low level divergence.

The above large scale features illustrate the different types of circulations over the maritime continent and its neighboring equatorial Pacific region. It is evident that the local scale weather conditions over the maritime continent were influenced by the larger scale phenomenon, whether it was the monsoon, the El Nino-La Nina phenomena or the associated transition of the TBO features.

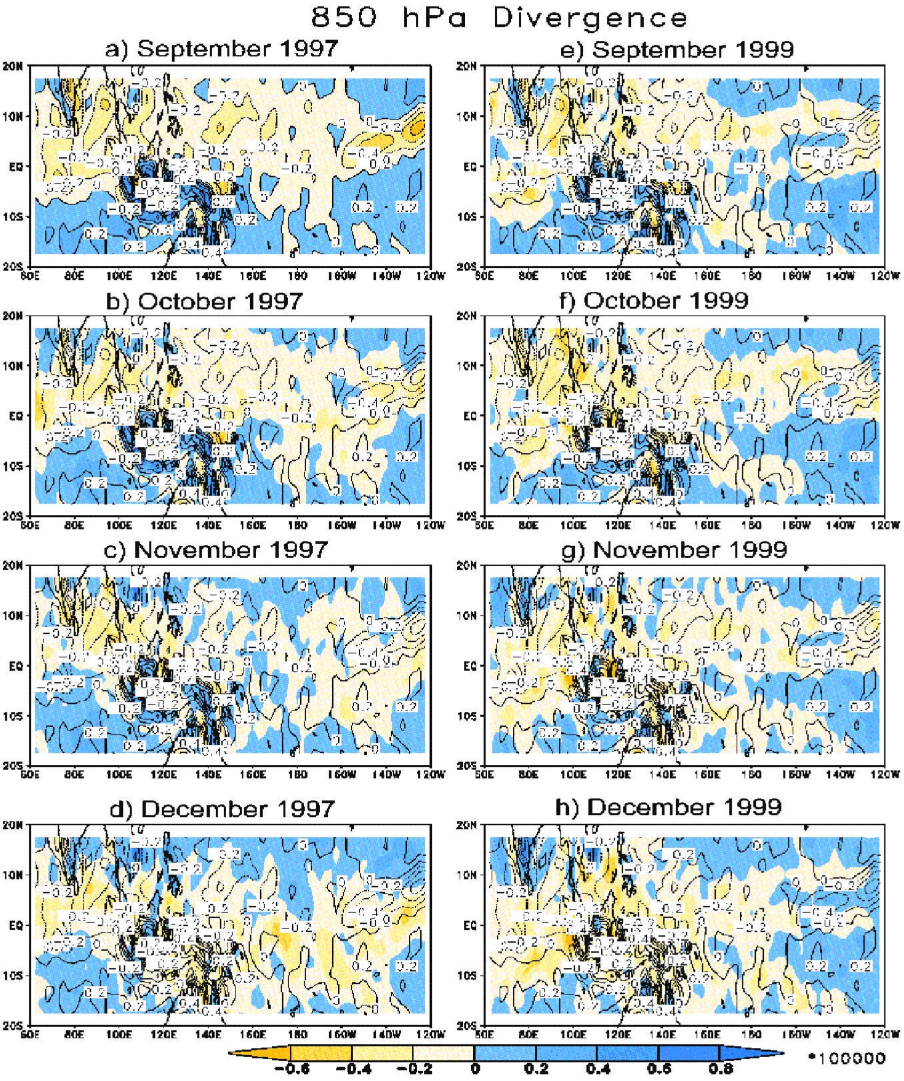

Figure 8. *The 850 hPa divergence field from September to December during the El Nino year in 1997 and during the La Nina year of 1999. The shaded region shows the magnitude of the divergence in* s^{-1}

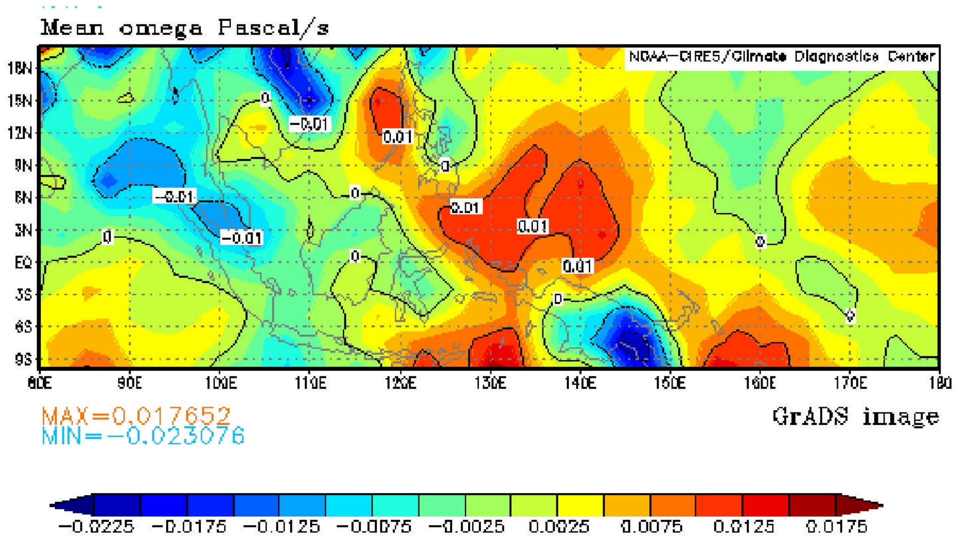

Figure 9. *The omega distribution across the maritime continent from September to December 1999. Units are in Pa* s^{-1}*. Source: NOAA-CIRES/Climate Diagnostics Center*

Synoptic analyses

The case study approach is taken to include some of the major flooding events over the Peninsula. Each event is investigated to find out if the events are caused by similar synoptic phenomena.

Case 1: 4th - 5th September 1999

One of the first flooding events in the Malaysian Peninsula occurred in the north west coast region. The flash flood that took place in Georgetown in Penang and Baling in Kedah caused the water level to rise to 1.3m from the 4 th to 5th September and resulted in the evacuation of 600 from their homes. The rainfall recorded at the Bayan Lepas station was 280mm on 4th September. The Geostationary Meteorological Satellite (GMS) satellite images obtained from the Malaysian Meteorological Services illustrate the presence of a persistent afternoon cloud cluster that lasted for a few hours over the north west coast of the Peninsula over the Straits of Malacca near the island of Penang (not shown).

Synoptic charts show the presence of a low level monsoon trough at 1000 hPa on the 3rd and 4th September for up to two days prior to the heavy rainfall near the Malaysian peninsula-South China Sea region. The mid-troposphere and upper levels were dominated a by trough and a vortex, respectively. The positions of the middle to high vortex coincided with the circulatory cloud cluster over the South China Sea region.

The wind field pattern also shows the presence of an envelope of strong westerlies with the strength of more than 20m/s at 1000 hPa on 4th September. This transitional period when the southwest monsoon was still evident showed that stronger westerlies could also be found at 850 hPa, from the Bay of Bengal traversing the Malaysian Peninsula and along the South China Sea. The trough in the westerlies over the Malay Peninsula acts as a region of instability to the lower levels of the atmosphere.

The wind field pattern at higher levels, such as 500 and 300 hPa showed the presence of a middle to high level cyclonic vortex over the southern South China Sea region on the 4th and 5th September. This region of instability coincided with the convective clouds over the same region.

The vertical p-velocity on 4th September showed that at 850 hPa, much of the region across the SCS was affected by upward motion with a value of about –15 mb/hr. The Malaysian Peninsula was dominated by generally downward motion bearing the magnitude of 15 mb/hr.

It can be concluded, therefore, that stronger low level westerlies and the presence of a middle level cyclonic vortex are amongst the reasons why this region was unstable, and thus conducive to the formation of convection that brought heavy rainfall to the north western region of the Malaysian Peninsula.

Case 2: 5th October 1999

The heavy rainfall event that hit the western region of the Malaysian Peninsula from 4th October 1999 occurred as a result of the presence of a high level vortex over it. By 5th. October, the states of Penang and Kedah, in particular, were badly affected by the floods which then spreaded further southwards to Perak and Selangor by the 7th until the 9th of October.

Although some reference is made to the satellite images, no actual GMS images are shown in this paper. In any case, the presented sequence of hourly satellite GMS images showed the presence of isolated cumulonimbus cloud clusters forming over the western coast of the Malaysian Peninsula. These cloud systems developed along the Peninsula's western coast states of Perlis, Selangor, Melaka, Negeri Sembilan from 0832 GMT (4 32pm LST), indicating the formation of the evening convection. The cloud systems dissipated approximately three hours later, and the coastal area was cleared of clouds by early night, local time. This showed that afternoon rainfall associated with cloud clusters lasting for a few hours and forming along the western coast of the Peninsula was the cause of the widespread heavy rainfall.

The same situation was also found for the convective activity the next day of 5th October. By 0832 GMT (1632 LST) afternoon convection dominated the Peninsula's western coast states of Selangor, Melaka and Penang (not shown). The cloud at Penang became active and developed to a moderately sized cluster before it too dissipated by 1233 GMT (0833 LST).

Tropospheric easterlies were found across the Southern South China Sea, with a high level vortex from 250 hPa to 150hPa over the Gulf of Siam on 5th October. At these high levels, the wind speeds were found to be weak, below 5 knots within the vortex region. At lower levels, moderate winds of less than 10 knots were dominant, with a slight trough axis along 105^0E from the equator to 5^0N within the southern South China Sea, to the east of the Malaysian Peninsula. Near-persistent high-level cyclonic vortex and low level vortices were found across South China Sea and the Andaman Sea until 9th October 1999, causing the area to be unstable and conducive to the formation of convection hence heavy rainfall associated with it.

Case 3: 15th -17th October 1999

The flooding that occurred in the northern and western states of the Malaysian Peninsula during the October of 1999 8000 people not due to the early onset of the northeast monsoon. Rather, it was the southwesterlies that were dominant at that time in addition to the presence of two strong westward propagating tropical cyclones existing respectively across the Bay of Bengal from 17th October 1999 and the Andaman Sea from 25th October 1999.

The sequence of GMS infrared images highlighted the existence of a dynamic convective activity over the Gulf of Thailand and much of the Malaysian Peninsula from 14th October onwards. A large, active, and cold cloud top convective cluster dominated the Gulf of Siam on 14th October at 0132 GMT. Over the next 24 hours, this active convective system slowly propagated westwards, with its centre of coldest cloud top covering the Isthmus of Kra. Over the Malaysian Peninsula, a few embedded cold cloud cells that developed by late afternoon (0932 GMT) over the states of Selangor and Melaka dissipated six hours later. This was followed by another convective system developing in the north east coast of the Peninsula by 2030GMT.

The surface and 850 hPa synoptic analysis on 14th October showed the existence of a low level trough along the Malaysian Peninsula, with an area of confluence to the east of the Peninsula. The wind speed over the region was of moderate strength, with the existence of a low level vortex over the Isthmus of Kra and Andaman Sea region. This vortex was associated with the tropical cyclone named 04B found over the Bay of Bengal.

A region of confluence over the South China Sea on the surface pressure, and the presence of a cyclonic vortex over the Isthmus of Kra region, in particular, the Andaman Sea at 850 hPa, were found on 15th October. Although this event did not record much rainfall at the climatological stations, the local media, nevertheless, reported heavy rainfall and flooding occurring in the northwestern coast of the Malaysian Peninsula. The flood water level, rising to 0.3 m on 16th October 1999 in Krian, Perak, a location to the northwest of the Peninsula, resulted from several days of light rainfall. Synoptic analysis showed the presence of a deep trough over Peninsular Malaysia at 700 hPa. The confluence of winds was observed over Peninsular Malaysia on 18th and 19th October.

The vortex associated with this tropical cyclone was deep and exhibited a westward tilting with height. Its presence can be detected over the Bay of Bengal-Andaman Seas from the surface to the mid troposphere, at 500 hPa. The vortex later developed into tropical cyclone O5B and caused destruction over India on 27th October 1999.

Case 4: 23rd October 1999

The second tropical cyclone to affect India had also an effect on the rainfall of western Malaysian Peninsula. It caused extensive flooding over the northwestern region of the Peninsula thus aggravating the area already stricken by the flood of 16th October. The peninsular states particularly affected were Penang, Perak and Kedah where 8000 people had to be evacuated. The presence of a strong, deep cyclonic vortex centered over the Isthmus of Kra could be observed up to 500 hPa on 25th October. Strong winds of up to 40 knots accompanying the vortex were located over the southwest sector of the vortex. Synoptic analyses have shown that this vortex was observed over the Gulf of Siam as early as 16th October 1999. The sequence of GMS images showed the dramatic activity of clouds associated with the tropical storm. It originated from the Gulf of Thailand and propagated westward, traversing the Isthmus of Kra by 25th October before regenerating and moving to the Andaman Sea and the Bay of Bengal.

The cloud system dissipated ten hours following the 8 a.m local time image, but regenerated again after crossing the Isthmus of Kra. On 26th October 1999, the tropical cyclone could be detected over the Andaman Sea while its cyclonic circulation could be observed over Perlis, a northern state of the Malaysian Peninsula. The tropical cyclone was strong and deep, and its vortex could be observed from 1000 hPa until 500 hPa. The widespread heavy rainfall events, particularly over the western region of the Peninsula, thus showed the influence of the tropical cyclone.

There was a break in the heavy rainfall period in early November before it then resumed in late November 1999. This was due to the onset of the strong northeast monsoon and a cyclonic vortex across and throughout the troposphere of the southern South China Sea, where heavy rainfall mainly affected the northeastern states of the Malaysian Peninsula.

Case 5: December Floods

The heavy rainfall period in early December 1999 affected a large portion of the Peninsula, where widespread flooding was observed across the northeastern states of Kelantan and Terengganu, the central and southern states of Pahang and Johor and the western states of Perak and Selangor. Synoptic chart analyses showed the presence of a deep cyclonic vortex that could be detected to 500 hPa across the Malaysian Peninsula from 3rd to 5th December. A near-equatorial trough stretched across Peninsular Malaysia and South China Sea at 5^0N from the surface to 850 hPa.

The subsequent prolonged rainfall that extended towards the end of December was also due to the presence of low level and mid-tropospheric cyclonic vortices across the southern South China Sea region. The east-west near equatorial troughs existing across Peninsular Malaysia-South China Sea-Borneo also acted as a breeding place for convective activity across the region.

By the tenth of December, more than 1,215 people were evacuated near Mentakab, Pahang. In Kelantan, nearly 100 fishermen families at Kampung Pantai Santai, near Kota Bharu, were in danger of coastal erosion due to the onslaught of huge waves reaching a height of 3 m since the previous two days. Meanwhile, the residents in the Hilir Perak district who had been in sheltered centres since 7 th December were allowed home as the water receded. They were evacuated when the water level rose to 0.6m due to the heavy rainfall that inundated the Batang Padang, the Bidor and the Perak rivers.

Strong winds of 40-50 km/hr were found over the South China Sea and associated with this was the presence of a mid -tropospheric cyclonic vortex and trough over the Malaysian Peninsula at 500 hPa on 10th, 11th and 12th December 1999. In Mentakab, Pahang, about 2000 people from 12 villages were evacuated to flood shelters due to the rising water level. The event caused most of the water levels of rivers in Kelantan and Terengganu, the two eastern states of the Peninsula, to reach dangerous levels.

Discussion

The near-continuous heavy rainfall events occurring during the northeast, winter monsoon of 1999 and coincided with the La Nina episode, had caused widespread flooding and hardship to the people affected. The large-scale observational aspects of parameters such as monthly precipitation, anomaly of outward long wave radiation, zonal and meridional wind fields at the lower and upper levels, vorticity and vertical motion all indicate a contrasting scenario from the El Nino conditions of 1997. During the La Nina period of September to December 1999, a stronger negative vorticity was found over the maritime continent and south Indian Ocean, with a disparity positive vorticity region over equatorial Pacific and the southern hemisphere. A Low-level convergence was also found to have concentrated over the maritime continent, which coincided with the region of enhanced rainfall. The above parameters illustrate that the enhanced rainfall conditions that were experienced by Peninsular Malaysia particularly was not an isolated regional feature, but related to the larger scale La Nina phenomenon. The stronger-than- normal northeast monsoon - here taken as the enhanced rainfall encountered by Peninsular Malaysia - was related to the TBO that appeared to have played an important role in contributing to the rise of this phenomenon. The TBO, defined as the tendency for a relatively strong monsoon to be followed by a weak one (Meehl and Arblaster, 2002a), and its opposite conditions was the effect of the coupled land-ocean-atmosphere processes occurring over the Indo-Pacific region (Meehl, 1997).

This paper does not attempt to evaluate the TBO phenomena specifically, but by comparing the contrasting observational features of circulations over the Indo- Pacific region, the variability between the El Nino and La Nina conditions over the maritime continent and its teleconnections to the conditions over the central Pacific region is highlighted. No continuity of conditions from the El Nino through to the La Nina events, or the sea surface temperatures teleconnections between the episodes, was evaluated. Quantification of the processes and conditions associated with the biennial tendency of the south Asian-Australian monsoon and the ENSO interaction have been found to be difficult (Webster *et al.,* 1998). Similarly, no evaluation is performed to link any previous Indian monsoon rainfall with the December- to-January Australian monsoon rainfall; on the contrary, the investigation is purely focused on the Malaysian Peninsula for being located within the maritime continent during a specific transitional period of the TBO which, in this case, was from September to December, 1999. In concentrating on the Malaysian Peninsula-maritime continent, the research merely represents a regional portion that associates the large-scale parameters investigated during the September-October-November (SON) season hypothesis proposed by Meehl and Arblaster (2002a) with the observations found during the La Nina event in the Pacific. The SON season premised by Meehl and Arblaster (2002b) was characterized by a strong convective maximum that, as shown by the low level convergence over the maritime continent from the October-to- December of 1999, shifted from the south India monsoon towards the maritime continent. As such it was a feature to be associated with the La Nina event in the Pacific. It is the outcome of a strong convective maximum with the western Walker cell and the monsoon as shown by the strong upper level divergence at approximately 10ºN and along 140ºE from October to December of the year concerned.

On a local scale, numerous occurrences of the cyclonic vortices were found over the South China Sea region during this period, including the two occasions of major westward propagating tropical cyclones that developed over the southern South China Sea – Gulf of Siam region. This is in agreement with the large-scale enhanced low level cyclonic vorticities being centered over the maritime continent-south Indian Ocean in October and November. The tropical cyclones that regenerated over the Bay of Bengal had resulted in thousands of casualties in the western part of India. The earlier-than-normal flooding that took place over the Malaysian Peninsula from September to late October had occurred during the transitional monsoon period, wherein the prevailing winds on some occasions were still westerlies. Indeed, middle to high-level vortices were some of the contributors of the flooding events, and they were not accompanied by strong southwesterlies. The latter widespread flooding that occurred in late November to late December was associated with the strong surges of the northeast monsoon. Most of the occasions during this period were associated with low to mid-level cyclonic vortices that could be found occurring over the South China Sea-Peninsular Malaysia-Borneo region.

Conclusion

Clearly, neither the extremes of the El Nino nor those of the La Nina events are desirable, particularly to the locals affected by these events. On the one hand, the major El Nino event of 1997 had produced drier and warmer conditions in several states of the Malaysian Peninsula to the extent that water rationing had to be conducted by the authorities to reduce water consumption. The effects of the dry conditions aggravated the advection of the transboundary smoke pollution across the region due to the large-scale burning caused by the slash-and-burn agricultural practices in neighbouring Indonesia. On the other hand, the extensive prolonged flooding that occurred over the four months from late September to December 1999 also disrupted the lives of the locals and brought about much destruction. The El Nino and the La Nina events are extreme deviations of the TBO and is part of the natural underlying trait of the coupled land-ocean-atmosphere climate system within which the monsoon is embedded. The transition to a relatively strong or weak monsoon is caused by a variety of large and regional-scale conditions in the seasons preceding the monsoon established by the coupled air-sea interactions of the year before (Meehl & Arblaster, 2002a).

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