Effects of Biomass Burning in Southeast Asia on Meteorological Conditions in Malaysia

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1.0 INTRODUCTION

There has been increasing occurrence of dense haze episodes in Malaysia in recent years. Most of these haze episodes were transboundary in nature (September 1982, October 1991, August - October 1994 and July - October 1997) and they were associated with outbreaks of forest fires in Indonesia caused by El Nino induced droughts (Chow and Lim, 1994). The most recent episode is the most severe of all. The burning of huge tracts of forest in southern Sumatra and Kalimantan went on uncontrollably for several months leading to the most prolonged and pervasive haze phenomenon ever encountered in South East Asia. In fact, the massive biomass burning has been described to have not only regional climate implications but certain global impacts as well.

Because of strong international interest in the 1997 Southeast Asia smoke haze, initiatives were taken by both local and foreign academic institutions to conduct observational studies on the phenomenon. The majority of the investigations were focussed on the impacts of the smoke haze on the environmental and human health. This paper represents one of the few preliminary reports on the effects of the biomass burning on meteorological conditions in the region.

2.0 TRANSBOUNDARY HAZE EPISODE OF JULY - OCTOBER 1997

Slight haze was first observed especially in Kedah, Penang and the Klang Valley in Peninsular Malaysia (Figure 1) around 11 July 1997. The haze spread to Kelantan, Terengganu and northern Pahang around 18 July, and affecting Sarawak, Sabah and southern part of Peninsular Malaysia around 24 July, 31 July and 2 August respectively. Thenceforth, the haze condition in the country deteriorated further with widespread dense haze peaking from mid-September to end of September. The haze began its retreat with decreasing intensity and extent in Sabah, Sarawak and Peninsular Malaysia around 2, 29 and 30 October 1997 respectively.

(a) *Total Suspended Particulates Variation*

A glimpse of the daily variation of total suspended particulates (TSP) for Bayan Lepas, Petaling Jaya, Senai, Kuantan, Kuching and Kota Kinabalu from July to October 1997 as shown in Figure 2 shows clearly the intensity and extent of the haze. The long term mean of TSP for all these places are in the neighbourhood of 50 - 100 microgram per cubic meter. During the period 1 August - 30 September, most places registered TSP above 100 $\mu g/m^3$ most of the time. One can also notice that the worst hit area is in Kuching, particulary during 16 - 28 August and 11 - 26 September. However, for the country as a whole the worst occurred during 11 - 26 September during which TSP values surged simultaneously to their maximum values. In fact, on 23 and 24 September, the TSP for Kuching reached a value of 1032.0 and 1033.0 $\mu g/m^3$ respectively. The correspondingly high Air Pollution Index (API) led to the declaration of National Disaster on Kuching. Beginning from 6 October, TSP values for most places tapered off to below 100 $\mu g/m^3$.

(b) *Evidence of Transboundary Haze*

The extent and intensity of the daily TSP variation as discussed in Section 2.0(a) show that the haze that engulfed Malaysia during the period could not be caused by local sources. It must be transported from persistent sources in the neighbouring countries. By enhancing the infra-red satellite imageries taken by the NOAA-12 and NOAA-14 polar orbiting satellites during the period, many "hot spots" were detected over the southern part of Sumatra and Kalimantan, inferring large-scale biomass burning there. This is further evidenced by SPOT satellite images of forest/plantation fires near Banjarmasin(Kalimantan), Jambi(Sumatra), Palembang(Sumatra), in southwest and over inland area in Kalimantan since June 1997.

The presence of the extensive haze covering Malaysia, Singapore, Brunei Darussalam, parts of Indonesia, the South China Sea and parts of the Indian Ocean was closely monitored using enhanced imageries on the visible NOAA-12 and 14 satellite data during August - October 1997. The variation of the weekly coverage of the transboundary haze is shown in Figure 3.

(c) *Haze Top Observation during Cloud-Seeding Operations*

During this episode of smoke haze, the Malaysian Meteorological Service together with the cooperation of the Royal Malaysian Air Force conducted a series of cloud-seeding operations over the whole of Malaysia as well as Indonesia. One of the observations made during the cloud-seeding operations is the height of the haze (Table 1) which was found to be well mixed from the ground level up to the haze top. It could be seen that the TSP values correspond very well with the variation of haze thickness during the period from 15 September 1997 until 2 October 1997. The maximum thickness was observed on 23 September which corresponds to the highest API recorded.

Table 1. Maximum observed haze heights (feet)

Period	*Peninsular Malaysia*	*Sarawak*	*Southern Sumatra*	*Kalimantan*
15/9 - 21/9	7,000	11,000	-	-
22/9 - 28/9	12,000	14,000	-	-
29/9 - 5/10	8,000	7,000	11,000	-
6/10 - 12/10	12,000	8,000	12,000	10,000
13/10 - 19/10	9,000	9,000	11,000	-
20/10 - 26/10	9,000	8,000	11,000	-
27/10 - 2/11	7,000	7,500	12,000	-

3.0 METEOROLOGICAL FACTORS IN RELATION TO HAZE EPISODE

(a) *Sea Level Pressure and 850 hPa Winds*

Based on the CDAS (1996, 1997) Reanalysis, in 1996 (a non-El Nino year), the sea level pressure for the period July to November (except October) indicates mainly negative anomalies in the Southeast Asia - Australia region (Figure 4). On the other hand, in 1997 (an El Nino year), positive anomalies dominate the region (Figure 5). As such, the equatorial Southeast Asia was dominated by higher sea level pressure and also the whole region further to the north was influenced by a pronounced monsoon trough particularly in August 1997. In association with the strong southwest monsoon in China, there were reports of above normal rainfall over southern China in connection with the Mei-Yi. By October 1997, less intense northern winter monsoon set in and penetrated further southwards as compared to those in 1996. In consonance with the strong positive anomaly of sea level pressure particularly over the eastern Indonesia - northern Australia region, equatorial Southeast Asia was dominantly influenced by southwesterlies and southerlies in the lower troposphere (Figure 7).

In September 1997, southeasterly in the southern hemisphere was particularly strong as compared with that of the same month in 1996 (Figure 6). This has led to the penetration of southeasterlies far northwards into the northern hemisphere, replacing the normally observed southwesterlies from the Indian Ocean and the Bay of Bengal. Both the Peninsular Malaysia and East Malaysia lie in the downstream end of the southeasterlies which advected smoke particulates from the forest fire in southern Sumatra and Kalimantan. For this reason, the steady and strong southeasterlies during the month of September 1997 culminated into the most severe haze event encountered. By November 1997, the appearance of easterlies had virtually cleared the haze in Malaysia.

(b) *El Nino and its Impacts*

A major El Nino event began in March 1997. This event which is regarded to be equal or worst than the one that occurred in 1982-83 is expected to maintain (at the time of writing) its intensity until March of the following year. Being close to the core of the El Nino activity, Indonesia normally receives deficit precipitations from June to November associated with such extreme El Nino situation (WMO, 1990). Climatogically, the southern parts of Sumatra and Kalimantan have rainfall peak in the months of March/April to be followed by a relatively dry period from June to September. Therefore, land clearing and open burnings are usually carried out over there after the peak rainfall period. Regretably, the major El Nino event in 1997 has not only dwindled the rainfall but also brought along the severe and extended drought, causing the biomass burning especially that of peat fire to become uncontrollable and extensive. Million hectares of forest and plantation land had been destroyed. This major El Nino had also led to significant low-level wind anomalies favourable for the mass transport of the smoke particulates out of the southern parts of Sumatra and Kalimantan towards the Malaysian and the South China Sea region.

(c) *Temperature, Dew Point and Equivalent Potential Temperature*(θ_{vc})

Figure 8 depicts the 0000 and 1200 UTC temperature and dew point profiles for selected days over Petaling Jaya. High TSP was recorded on 23 September 1997 (328.6 $\mu g/m^3$) and near normal value on 31 August (75 $\mu g/m^3$) and 29 October (80.8 $\mu g/m^3$). Based on these profiles, one could notice that the haze day troposphere was made of a relatively moist lower troposphere up to a height between 700 and 600 hPa (approximately the height of the haze) and a relatively dry upper troposphere. In contrast, the normal day structure does not show a significant dry upper troposphere. In fact, a closer examination of the temperatures during normal and hazy days reveals that the temperature in the layer between 700 and 600 hPa underwent stronger diurnal variation during the haze day, which thus reflects the result of radiational heating during the day and radiational cooling during the night in the vicinity of the haze top.

The equivalent potential temperature structures (Figure 9) shows clearly that the haze day is relatively more potentially unstable as compared to normal day (Harris and Ho, 1969) or in other words, convection was considerably reduced during the haze day.

(d) *Rainfall*

In general, the southern Peninsular Malaysia and western Sarawak were the worst hit areas in terms of rainfall deficit during the period July - October 1997 (Figure 10). This could be attributed to the fact that these two areas were closest to the burning forests in Indonesia and were thus most affected by the impacts of the smoke haze. The effect of the transboundary haze was very much evident in September 1997 when the whole country except the Klang Valley region received significantly below normal rainfall. In addition, the influence of El Nino on rainfall was expected to be strongest in Sabah (Figure 11), but this time around, it was Sarawak which most felt its impact. Peninsular Malaysia which was least expected to be affected by the global phenomenon, was in fact, to a large extent, suffered a severe rainfall deficit.

The rainfall pattern recovered somewhat to the characteristic El Nino pattern during the months of November and December 1997 when the largest rainfall anomaly returned to Sabah.

(e) *Mean Global Solar Radiation*

In Peninsular Malaysia, the significant global solar radiation anomaly (greater or equal -1.0) was first evident in the northern and central west coast states in July 1997(Figure 12). The anomaly was confined to the central state in August but became widespread throughout the Peninsular in September 1997. By October, all the northern Peninsular registered positive anomaly while the significant negative anomaly still persisted in the central and southern west coast states. The severe haze episode has significant impact on the global radiation received which in turn, through its feedback mechanism, further stabilizes the atmosphere. This could consequently reduce local/mesoscale phenomena such as convection and land/sea breezes, thereby inhibiting convective activities as a whole over the peninsula.

Inadequate solar radiation observation network does not permit similar analysis for the states of Sabah and Sarawak. However, the solar radiation measurement at Kuching reflects much larger negative anomaly, as large as - 4.5 in September 1997.

4.0 MEASUREMENT OF OPTICAL AEROSOL PROPERTIES

In order to advance the study of the effects of Southeast Asian forest fire on the atmospheric environment and regional climate, the Institute of Meteorology, University of Leipzig and the Malaysian Meteorological Service collaborated in a scientific initiative to carry out measurement of the climate relevant aerosol parameters. This measurement campaign was mounted from 11 to 24 October 1997 at the Subang Meteorological Station in Malaysia (latitude 3.1°N longitude 101.6° E) which was located in the downstream spread of forest fire plumes emanating from Indonesia. Using radiometers combined with a Coupled Inversion Radiation Transfer Program (CIRATRA, Wendisch/von Hoyningen-Huene, 1994), the main climate relevant radiative aerosol parameters (aerosol size distribution, real part of the refractive index, phase function, asymmetry parameter) have been determined. The results of the measurement campaign was reported in the IGAC special session (Wolfgang von Hoyningen-Huene, 1997) in Nagoya recently.

Figure 13 shows the daily variations of the Angstrom turbidity parameters, viz. α, the spectral slope and β, the turbidity coefficient. During the experiment in October 1997, α is found to be relatively constant throughout while β varies, decreasing during less hazy period and increasing during more intense period. Correspondingly, aerosol optical thickness (Figure 14) shows higher values during the more intense days.

5.0 *Concluding Remarks*

The major 1997 El Nino which induced severe drought in equatorial Southeast Asia is the main contributing factor in causing the large-scale biomass burning in Indonesia. The role of this global phenomenon can also be connected to the persistent southeasterlies and southerlies over the Malaysian and the South China Sea region, which effected the mass tranport of smoke particulates from Indonesia towards other parts of Southeast Asia.

Preliminary analysis indicates that the smoke haze had drastically altered the thermodynamic structure of the troposphere because of its interference with radiation processes and, in turn enhanced the atmospheric stability in the region. The rainfall pattern in Malaysia had, as a consequence, differed from the normal El Nino associated pattern with drier than normal rainfall being felt in almost throughout the country particularly in areas most affected by the haze.

Arisng from the above findings, one may be encouraged to speculate that the regional smoke haze could have intensified the drought conditions in Southeast Asia through the above mentioned radiation process and thereby aggravating the forest burning situation in Indonesia. Feedback processes may also affect the regional circulation but such relationship can only be elicited through numerical experiments. In this connection, the results of observational studies conducted by von Hoyningen-Huene(1997) would provide valuable input with respect to relevant radiative aerosol parameters for such studies.

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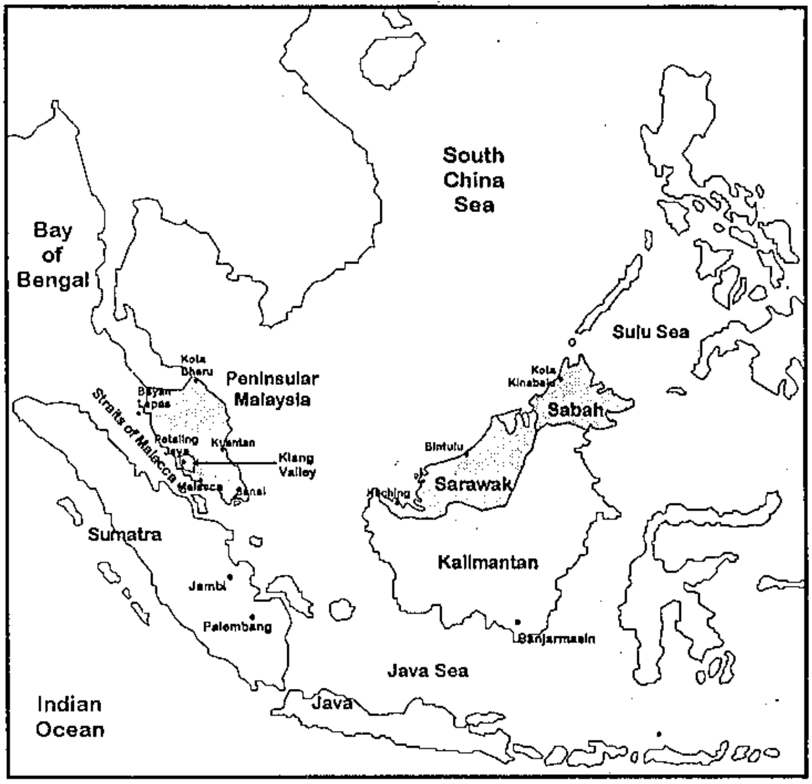


Figure 1: Location of the places and stations referred to in the paper.

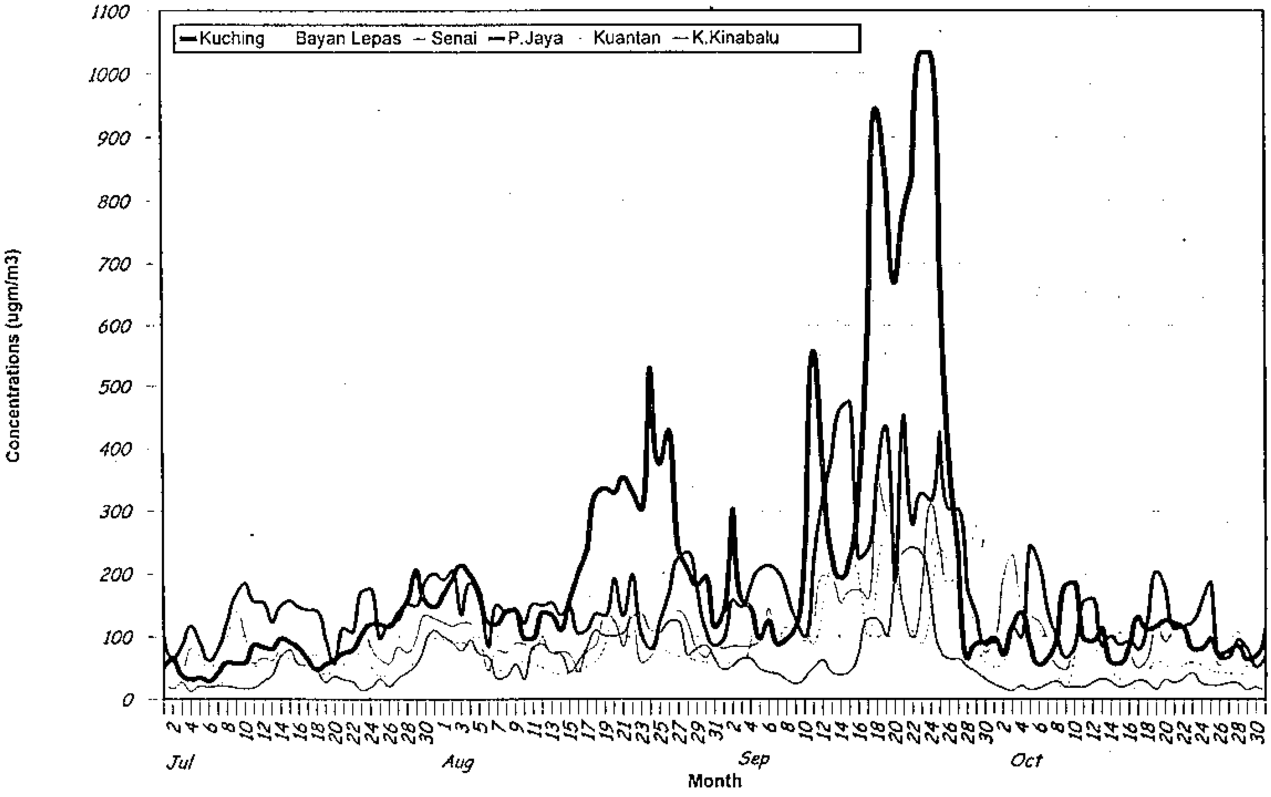
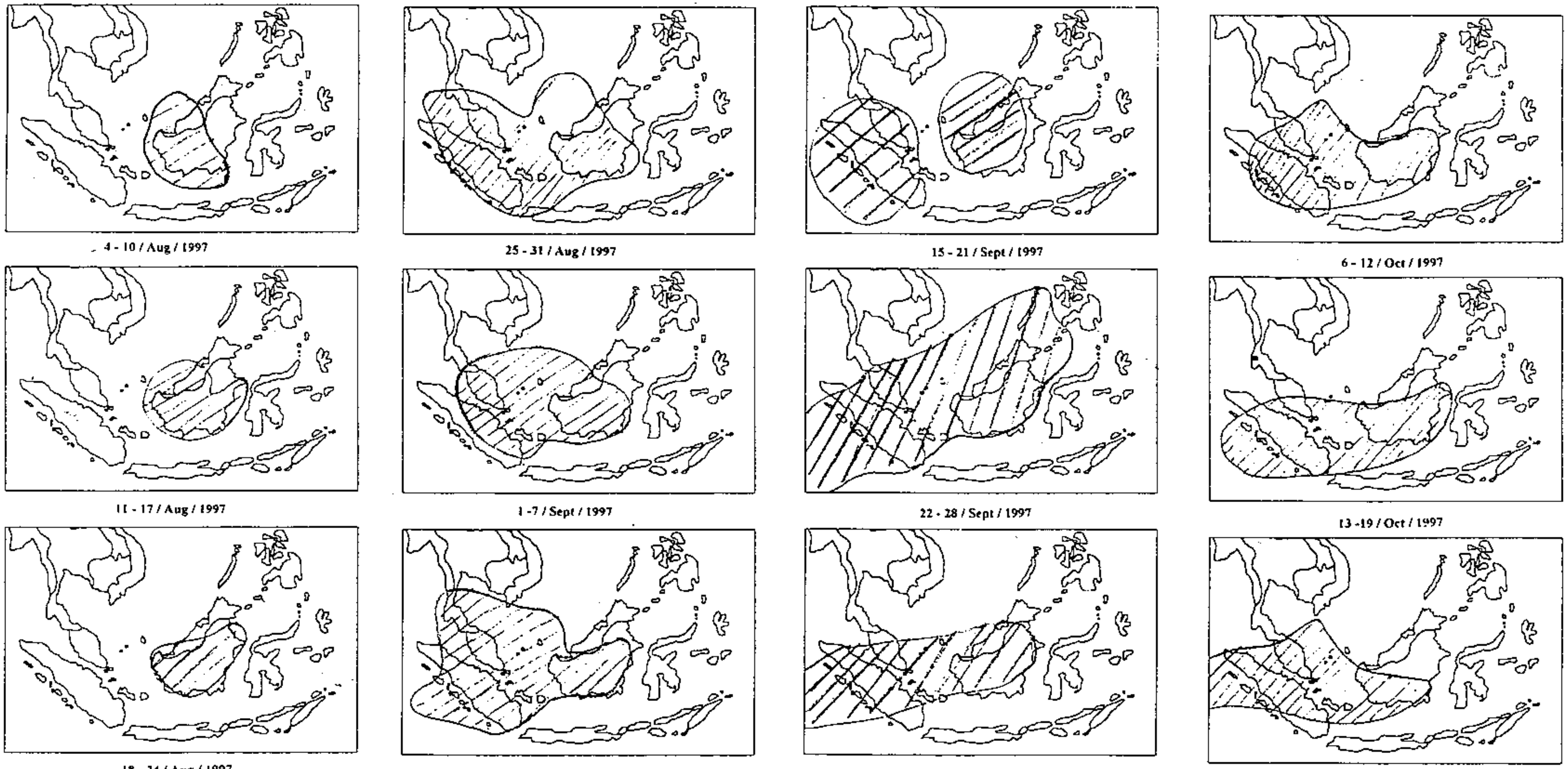


Figure 2 : Total suspended particulate concentrations during July - October 1997



4 - 10 / Aug / 1997

11 - 17 / Aug / 1997

18 - 24 / Aug / 1997

25 - 31 / Aug / 1997

1 -7 / Sept / 1997

8 - 14 / Sept / 1997

15 - 21 / Sept / 1997

22 - 28 / Sept / 1997

29 Sept - 5 Oct 1997

6 - 12 / Oct / 1997

13 -19 / Oct / 1997

20 - 26 / Oct / 1997

Figure 3 : Weekly coverage of transboundary haze over equatorial Southeast Asia based on satellite analysis.

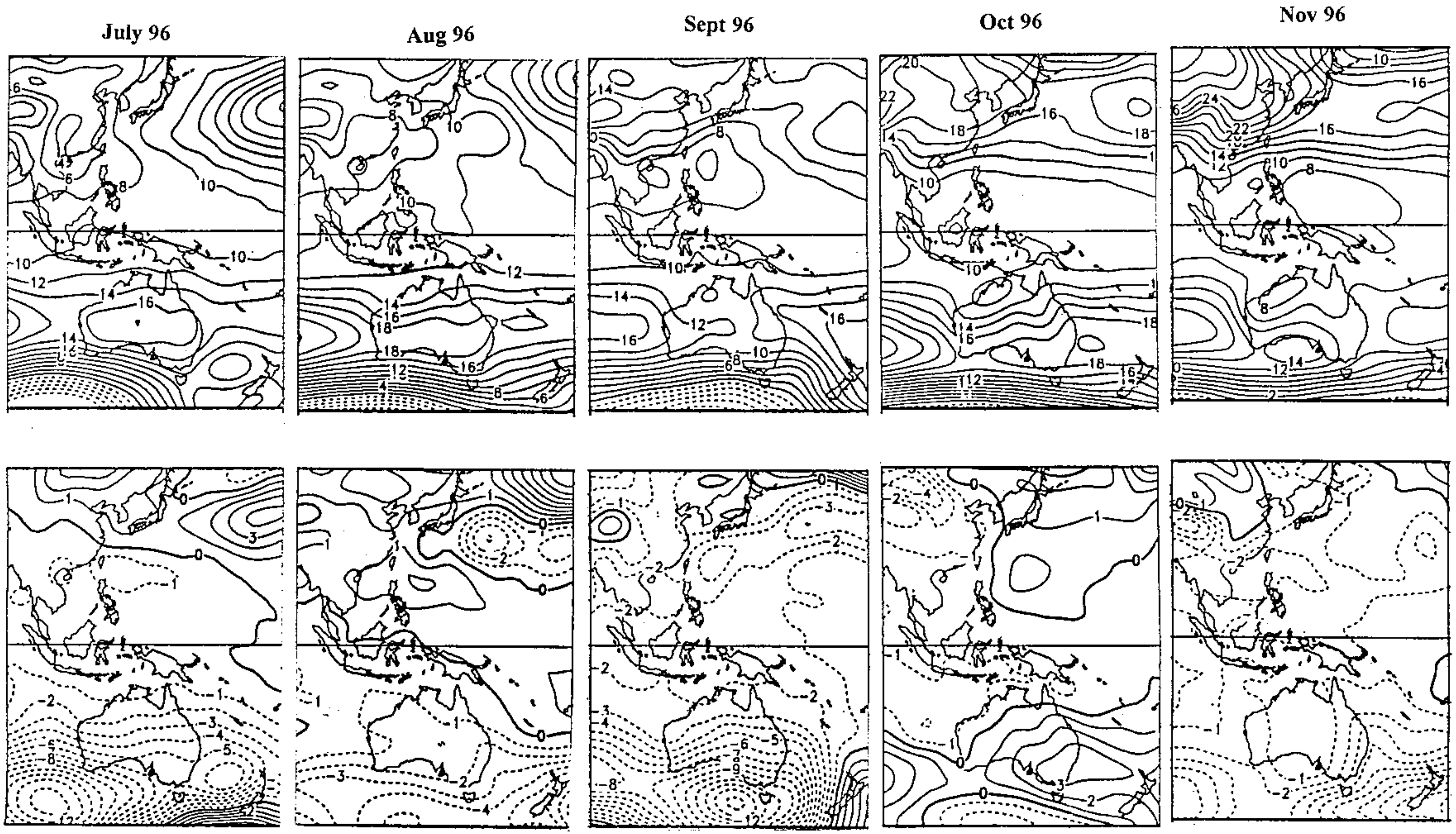


Figure 4: Mean (top) and anomalous (bottom) sea level pressure (SLP). SLP contour interval is 2hPa, and 1000hPa has been subtracted from contour labels. SLP values below 1000hPa are indicated by dashed contours. Anomaly contour interval is 1hPa and negative anomalies are indicated by dashed contours.

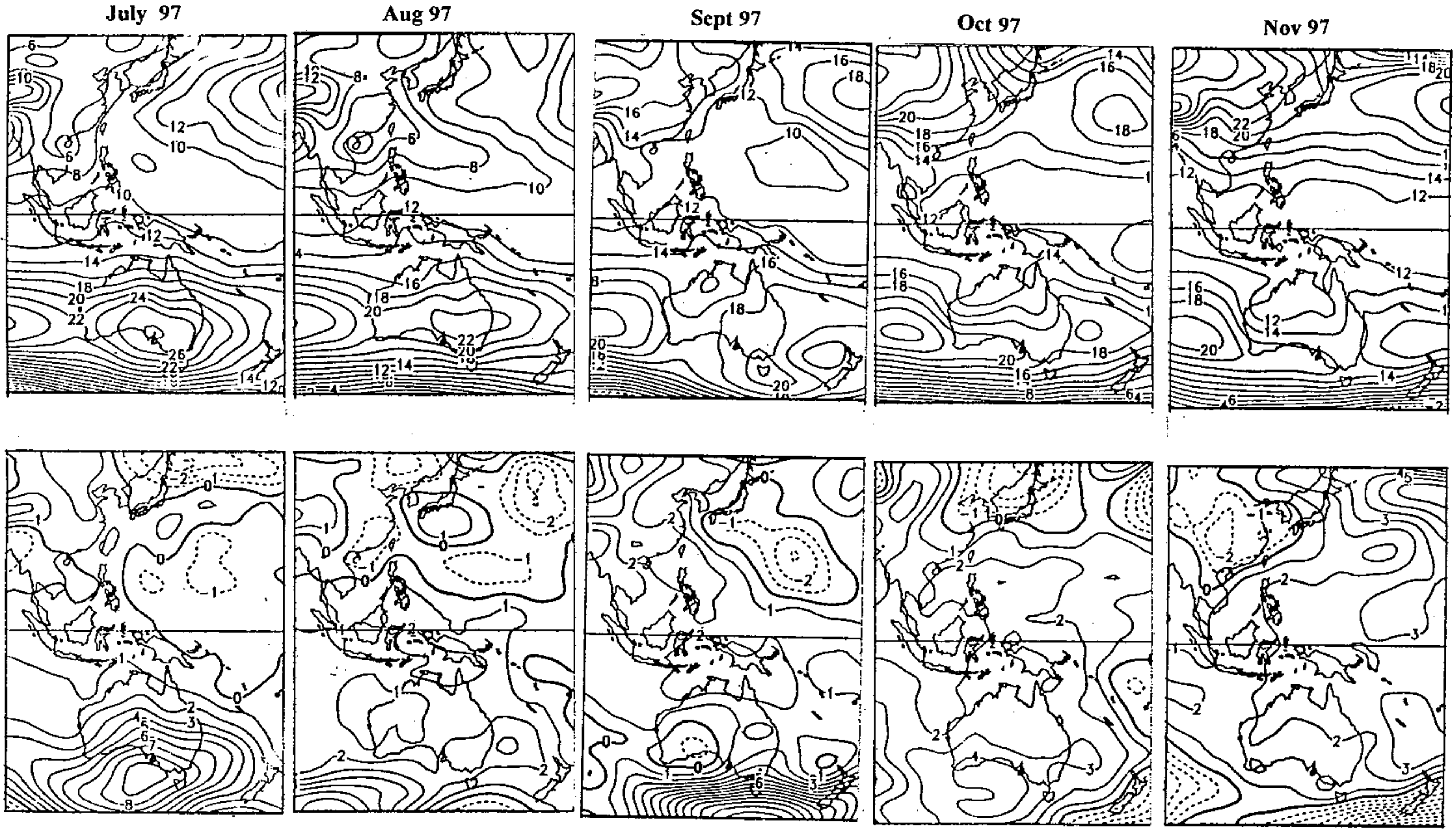


Figure 5: Mean (top) and anomalous (bottom) sea level pressure

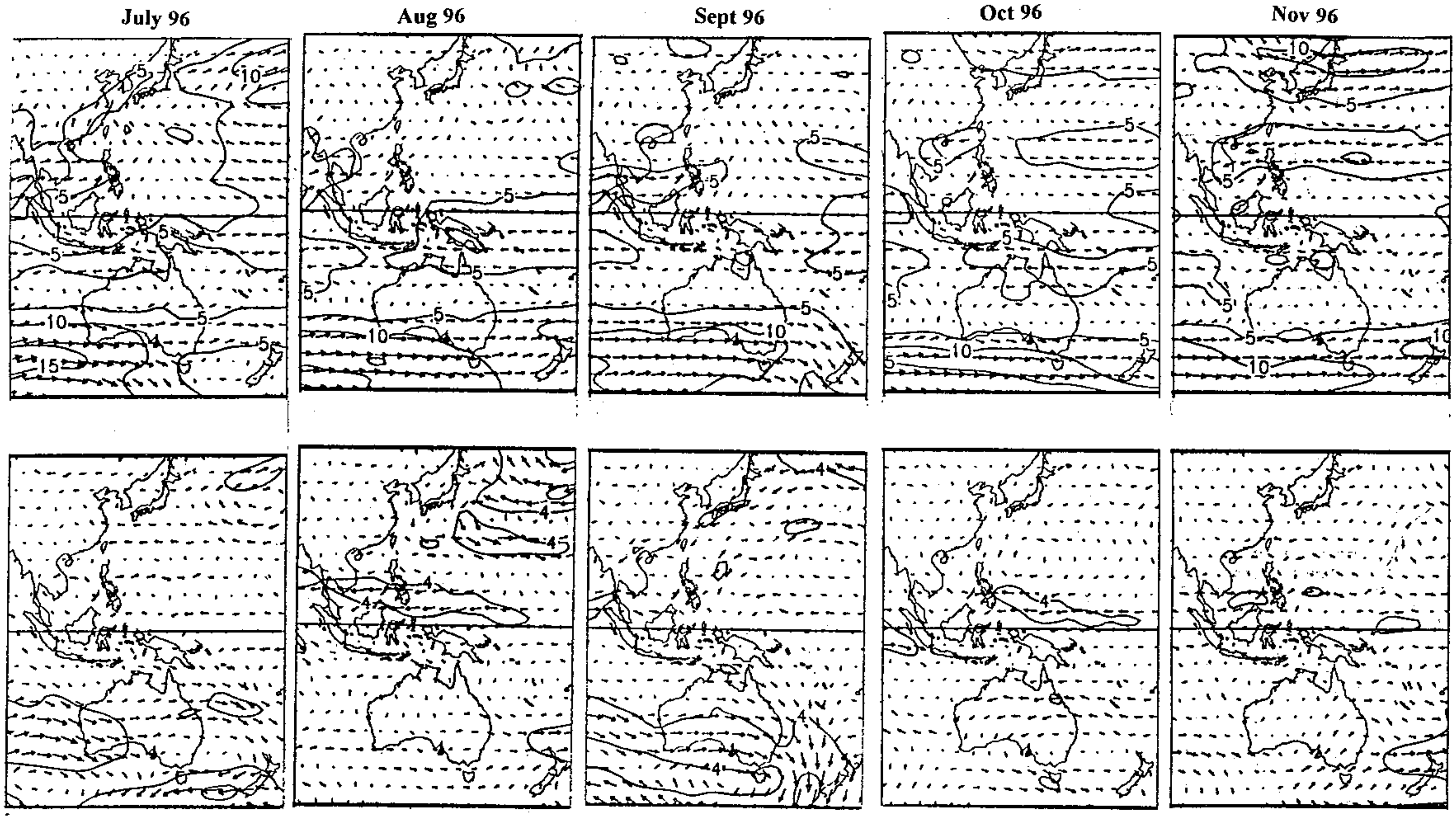


Figure 6: Mean (top) and anomalous (bottom) 850hPa vector wind

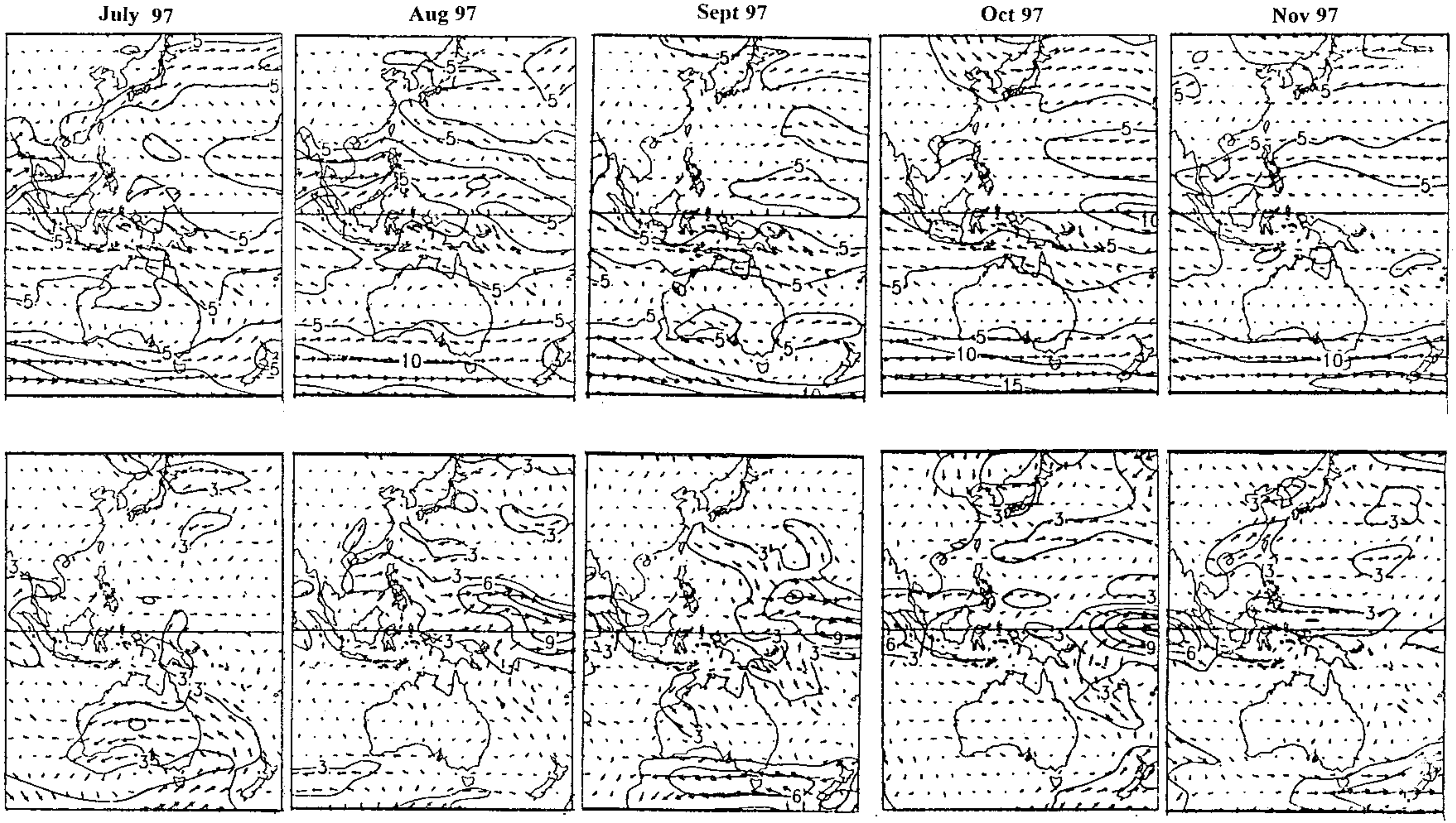
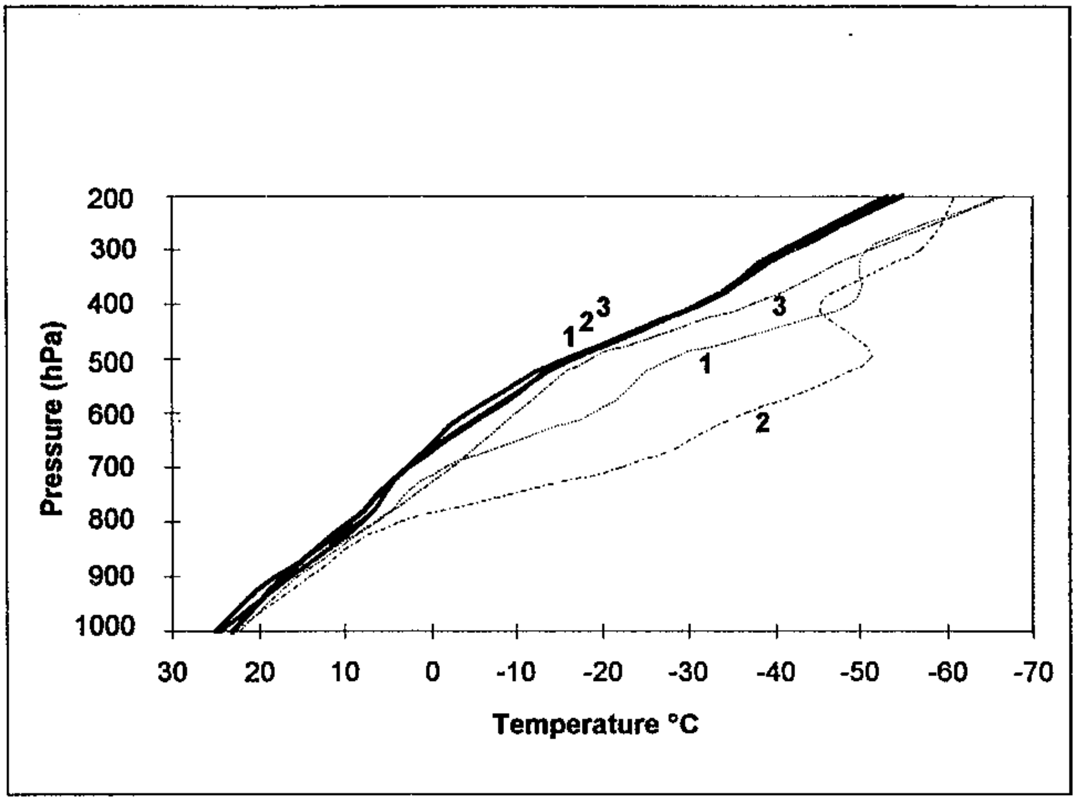
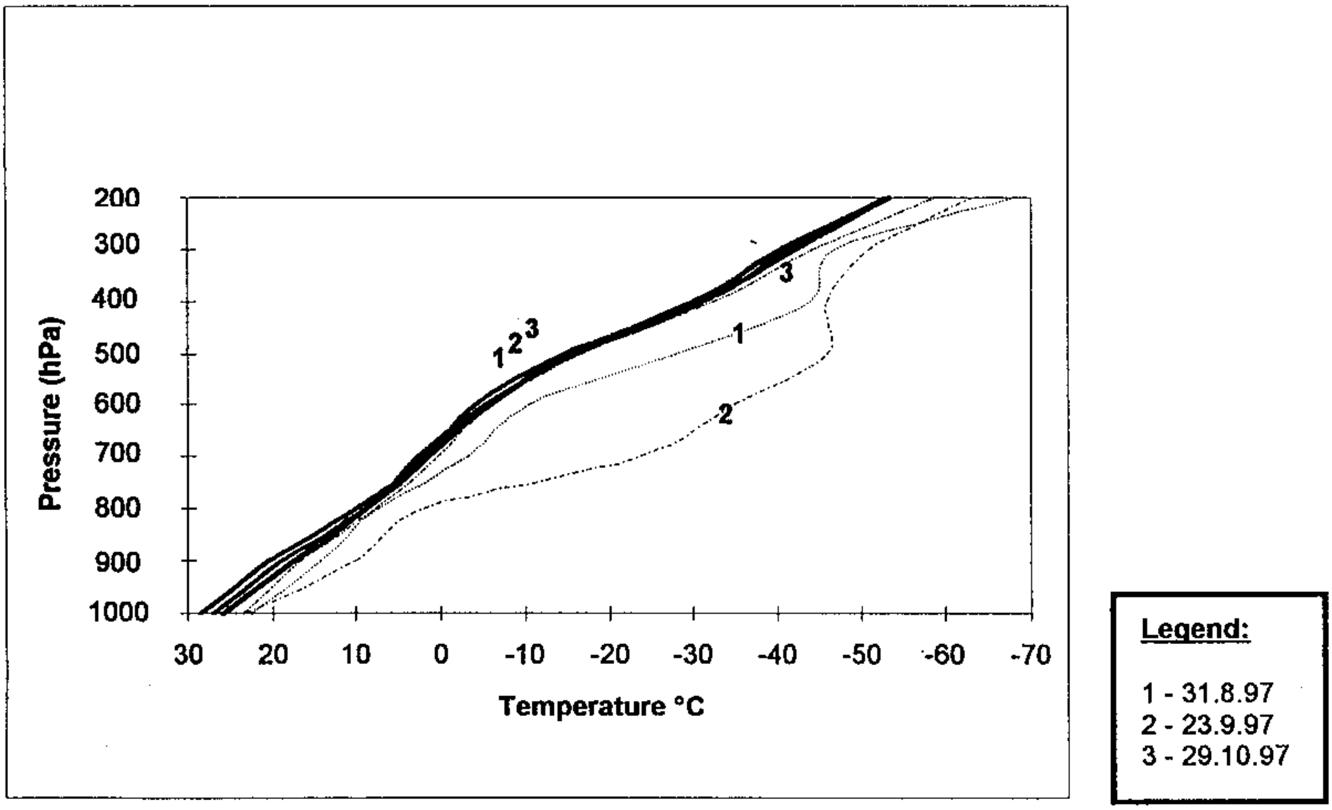


Figure 7: Mean (top) and anomalous (bottom) 850hPa vector wind

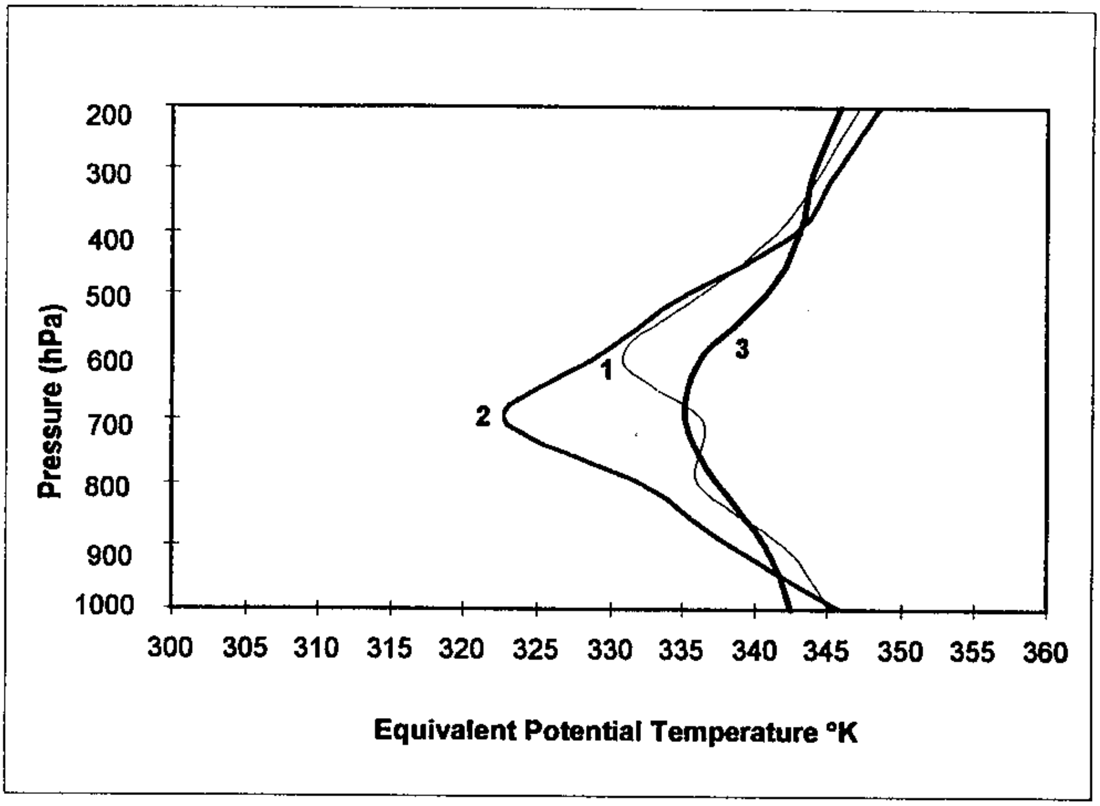


0000 UTC

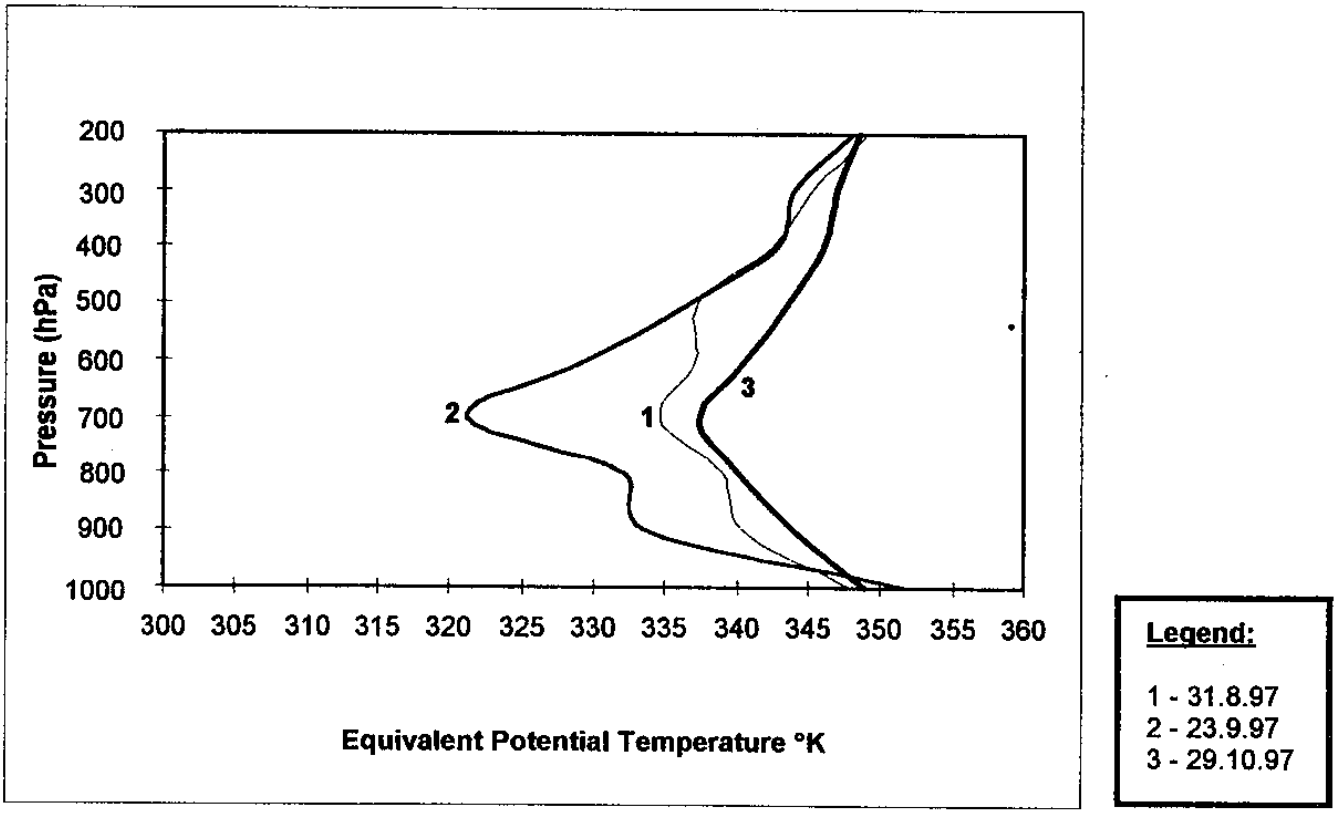


1200 UTC

Figure 8 : Variation of temperature (——) and dew point (------) over Petaling Jaya at 0000 UTC (top) and 1200 UTC (bottom) on selected days.



0000 UTC



1200 UTC

Figure 9 Equivalent Potential Temperature in Petaling Jaya on selected days.

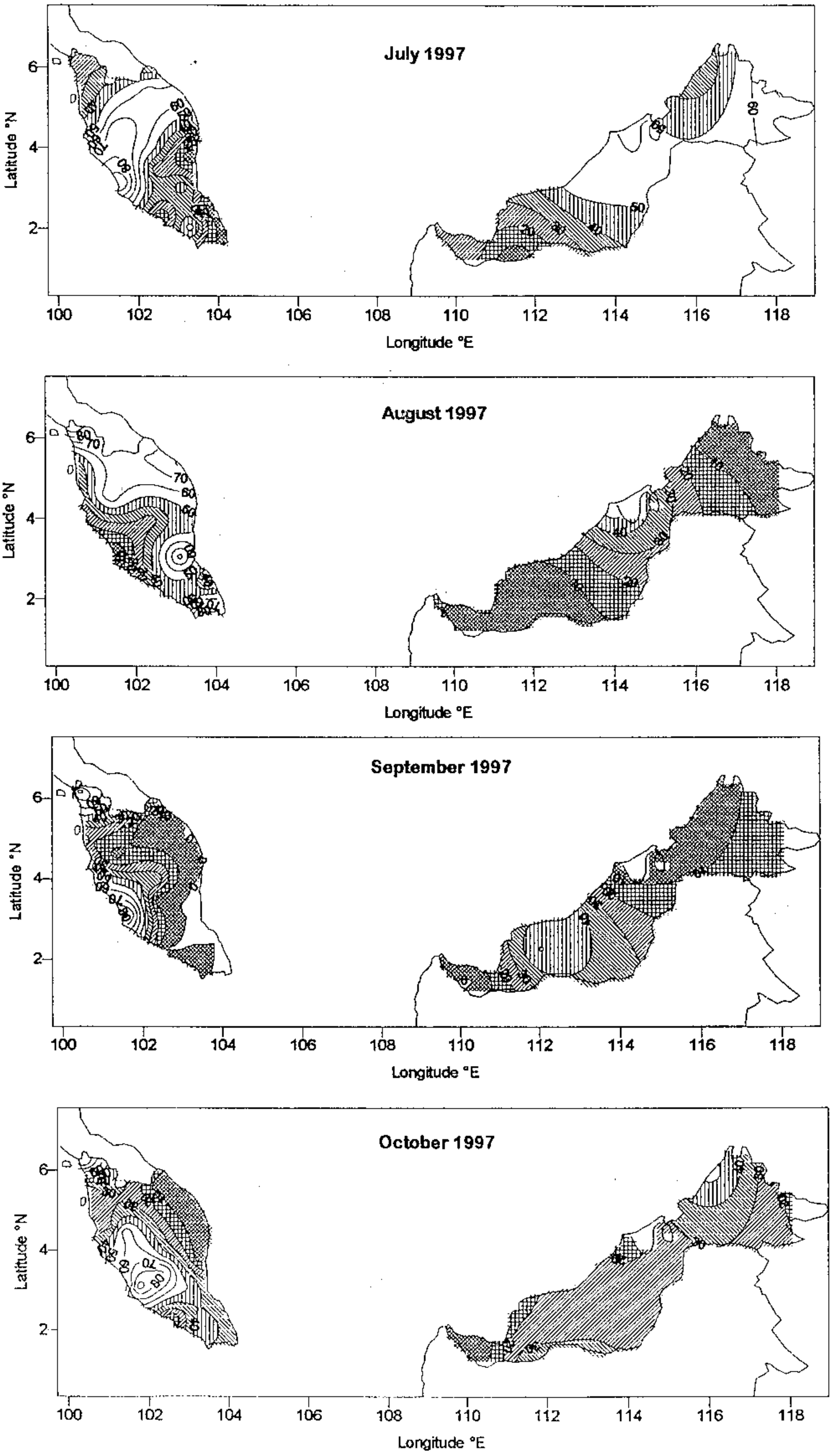
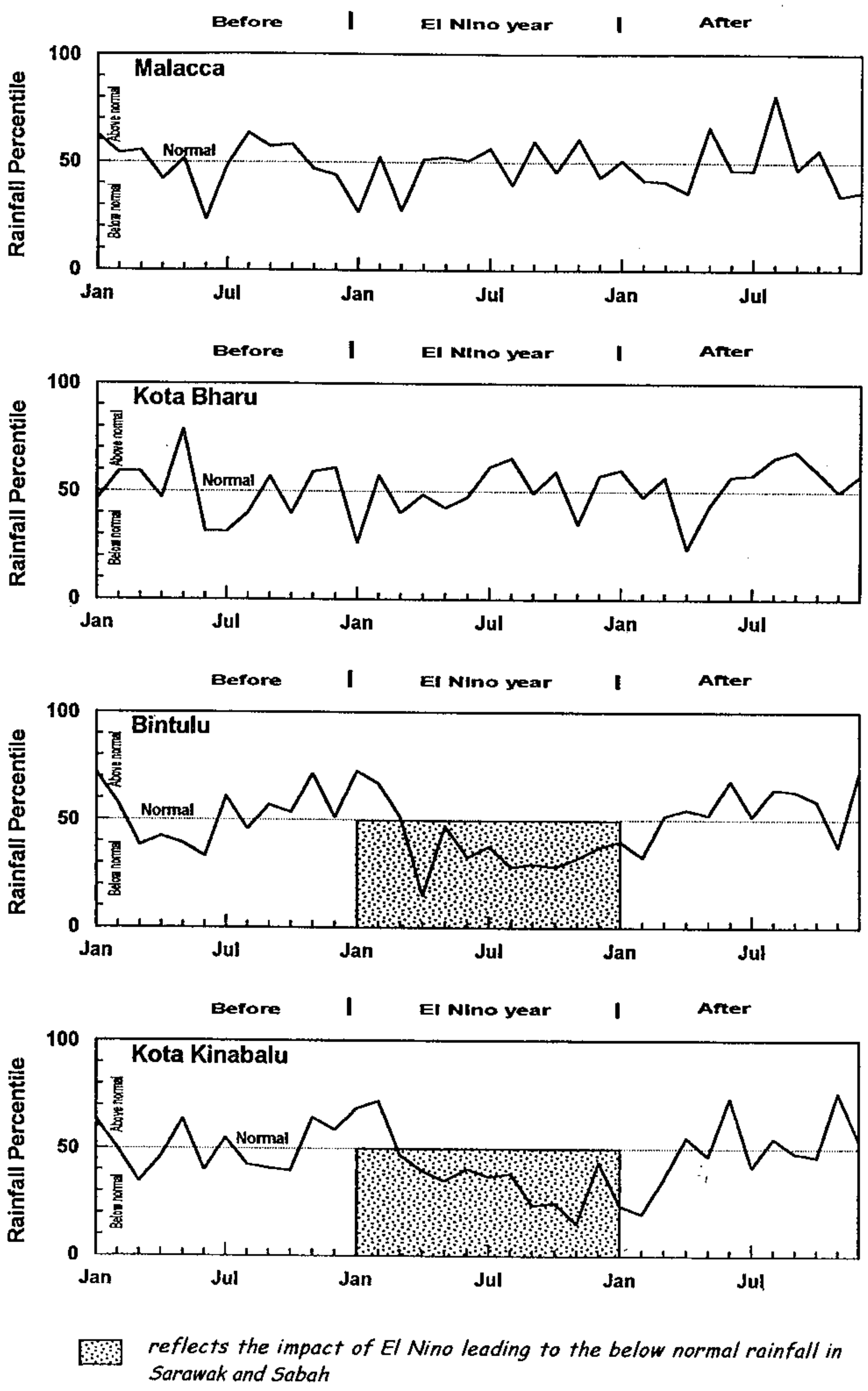
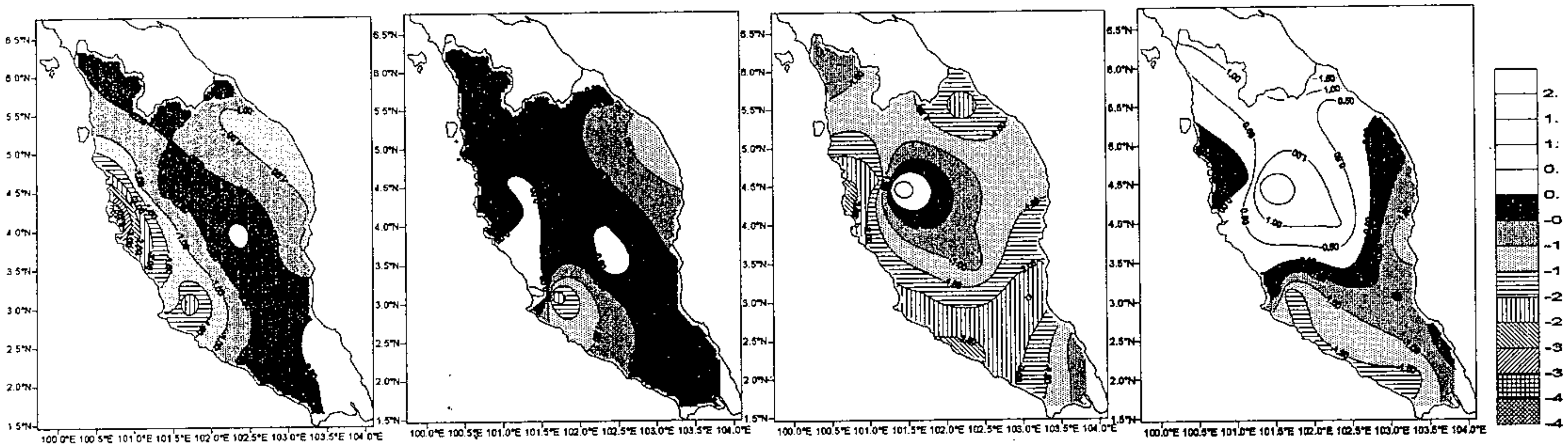


Figure 10. . Rainfall Percentile Distributrion Map



▨ *reflects the impact of El Nino leading to the below normal rainfall in Sarawak and Sabah*

Figure 11 : **Significant El Nino composite in terms of rainfall percentile index**



JULY 1997

AUGUST 1997

SEPTEMBER 1997

OCTOBER 1997

Figure 12 ***Mean global solar radiation anomaly.***

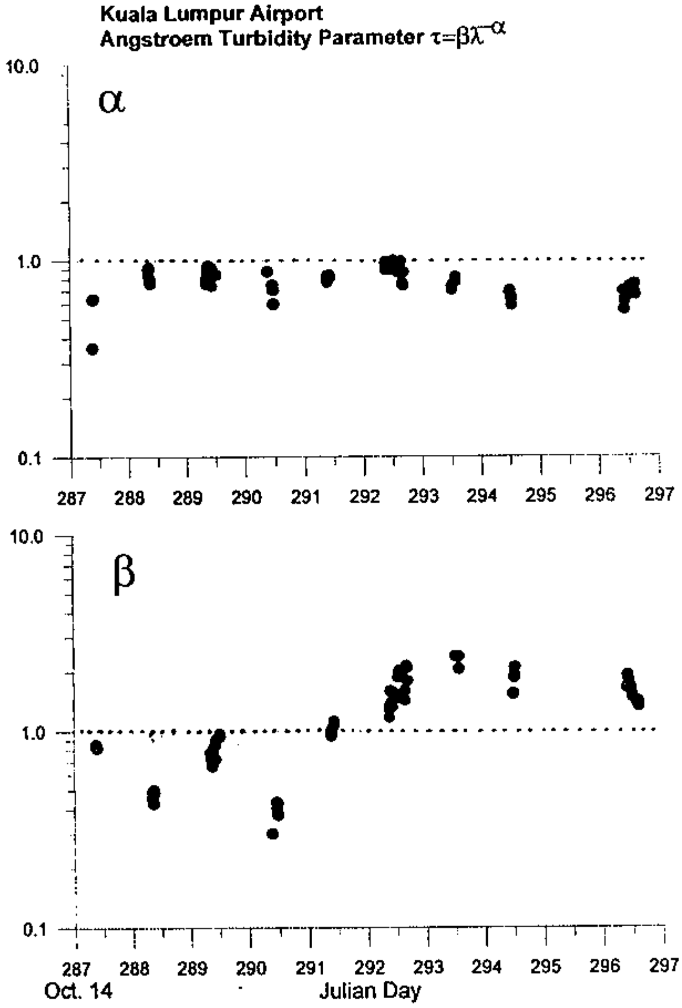


Figure 13: Variation of Angstroem Turbidity Parameters, α and β

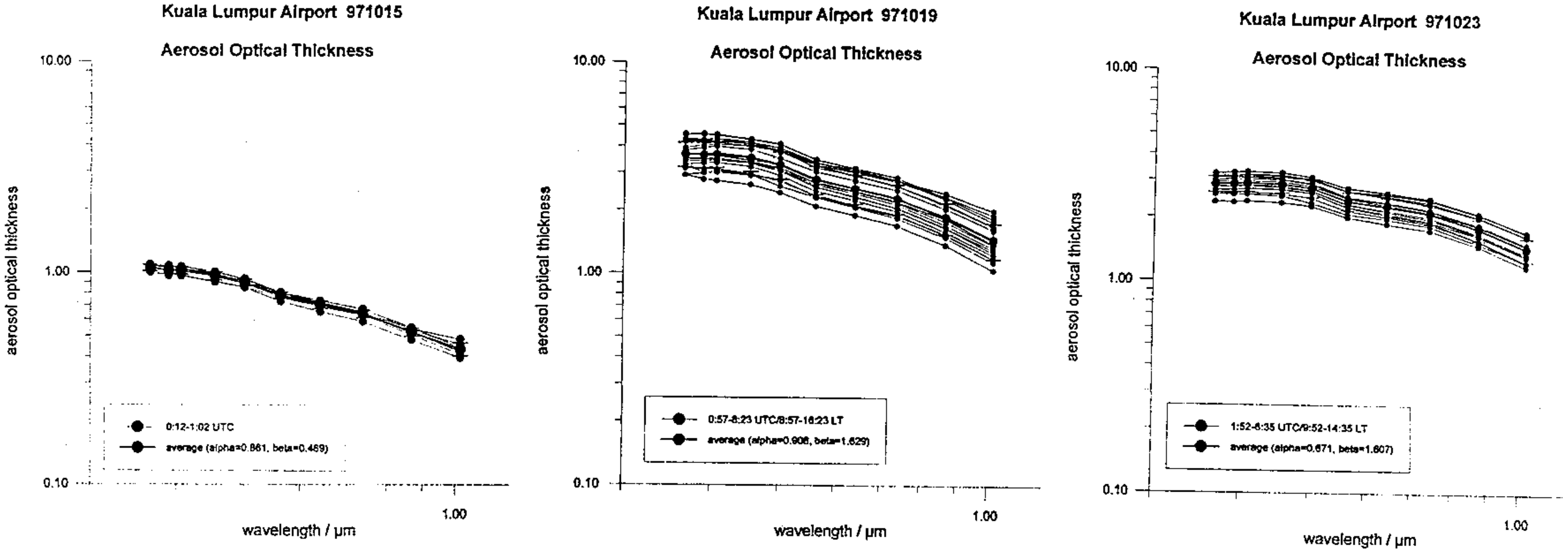


Figure 14: Aerosol Optical Thickness over Kuala Lumpur Airport on selected days