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Correlation between Hotspots and Air Quality in Pekanbaru, Riau, Indonesia in 2006-2007

(Korelasi antara Titik Panas dengan Kualiti Udara di Pekanbaru, Riau, Indonesia pada 2006-2007)

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ABSTRACT

Biomass burning is one of the main sources of air pollution in South East Asia, predominantly during the dry period between June and October each year. Sumatra and Kalimantan, Indonesia, have been identified as the regions connected to biomass burning due to their involvement in agricultural activities. In Sumatra, the Province of Riau has always been found to have had the highest number of hotspots during haze episodes. This study aims to determine the concentration of five major pollutants (PM_{10}, SO_2, NO_2, CO and O_3) in Riau, Indonesia, for 2006 and 2007. It will also correlate the level of air pollutants to the number of hotspots recorded, using the hotspot information system introduced by the Malaysian Centre for Remote Sensing (MACRES). Overall, the concentration of air pollutants recorded was found to increase with the number of hotspots. Nevertheless, only the concentration of PM_{10} during a haze episode is significantly different when compared to its concentration in non-haze conditions. In fact, in August 2006, when the highest number of hotspots was recorded the concentration of PM_{10} was found to increase by more than 20% from its normal concentration. The dispersion pattern, as simulated by the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT), showed that the distribution of PM_{10} was greatly influenced by the wind direction. Furthermore, the particles had the capacity to reach the Peninsular Malaysia within 42 hours of emission from the point sources as a consequence of the South West monsoon.

Keywords: Air quality; biomass burning; HYSPLIT model; hotspots

ABSTRAK

Pembakaran biojisim merupakan antara punca utama pencemaran udara di Asia Tenggara, terutamanya pada musim kering antara Jun hingga Oktober setiap tahun. Sumatera dan Kalimantan, Indonesia, telah dikenal pasti sebagai rantau yang dikaitkan dengan pembakaran biojisim yang disebabkan oleh aktiviti pertanian. Di Sumatera, Propinsi Riau, merupakan daerah yang telah dikenal pasti sebagai daerah yang merekodkan jumlah titik panas yang paling tinggi semasa episode jerebu. Kajian ini bertujuan untuk menentukan kepekatan lima parameter utama bahan pencemar udara (PM_{10}, SO_2, NO_2, CO dan O_3) di Daerah Riau, pada tahun 2006 dan 2007. Aras bahan tersebut telah dikorelasi dengan jumlah titik panas yang direkodkan melalui sistem informasi titik panas yang telah diperkenalkan oleh Pusat Remote Sensing Negara, Malaysia (MACRES). Keseluruhannya, kepekatan bahan pencemar udara yang direkodkan didapati meningkat dengan peningkatan jumlah titik panas yang direkodkan. Walau bagaimanapun, hanya kepekatan PM_{10} yang menunjukkan perbezaan yang signifikan semasa episod jerebu berbanding dengan masa di mana tiada jerebu berlaku. Malahan pada bulan Ogos 2006, semasa jumlah titik panas direkodkan pada jumlah yang tertinggi, didapati kepekatan PM_{10} meningkat sebanyak 20% berbanding kepekatan yang biasa direkodkan. Corak sebaran yang disimulasi menggunakan Model Trajektori Integrasi Lagrangian Hibrid Partikel Tunggal (HYSPLIT) menunjukkan taburan PM_{10} amat dipengaruhi oleh arah pergerakan angin. Tambahan lagi, pergerakan partikel berkeupayaan untuk sampai ke Semenanjung Malaysia dalam tempoh 42 jam dari titik sumber disebabkan oleh monsun Barat Daya.

Kata kunci: Kualiti udara; model HYSPLIT; pembakaran biojisim; titik panas

INTRODUCTION

Biomass burning is defined as the burning of living and dead vegetation, predominantly burning of grasslands, forests and agricultural lands after harvest, land clearing and also when land use changes (Saharjo & Munoz 2005). Two places which contribute significantly to air pollution from biomass burning are the islands of Sumatra and Kalimantan in Indonesia, and the burning is most notable during June and October, the dry period in South East Asia (Mahmud 2008). Biomass burning not only produces smoke but also contains a large and diverse number of chemicals, many of which are associated with adverse health risks (Ostermann & Brauer 2001). On a regional scale, biomass burning can result in transboundary haze, poor visibility, degradation of local air quality between neighboring countries and economic loss (Mahmud 2005; Miettinen & Liew 2005). It is also noteworthy that haze events in South East Asia in 1982, 1983, 1987, 1991, 1994, 1997, 1998, 2002, 2004 and 2005 were tightly coupled with the presence of El Niño conditions (Byron 2004; Groot et al. 2007; Heil & Goldammer 2001; Kita 2000; Mahmud 2008).

In South East Asia biomass burning has become a traditional method of clearing land in the practice of shifting cultivation (Chin 2001; Jones 2006), which involves field rotation and the slashing and burning of a new plot of land once the existing plot has lost its fertility (Ketterings et al. 1999). The setting fire to forest by subsistence farmers as they clear land leads to low intensity haze. Moreover, fire risk is dramatically increased as forests are converted to rubber and oil palm plantations. Furthermore, the logging of natural forests opens up the canopy and dries out the ground cover (Saharjo & Munoz 2005). The combination of low intensity haze and drying out of the forest and its floor, which worsened during El Niño, leads to a long dry season like the one in 1997.

During 1997's extended dry season, the fires burned out of control, creating a human health hazard and making navigation treacherous throughout most of Indonesia, Malaysia and Singapore. It is estimated that between 0.81 and 2.57 Gt of carbon were released to the atmosphere in 1997 as a result of burning peat and vegetation in Indonesia (Page et al. 2002). This is equivalent to 13–40% of the mean annual global carbon emissions from fossil fuels and has been a major contributor to the annual increase in atmospheric CO_2 concentration detected since 1957. In a global sense, the carbon dioxide produced by these fires represented some 22% of the world carbon dioxide released in that year, or more than 700 million tonnes, which made Indonesia one of the largest contributors of carbon emissions worldwide (Saharjo 2007). Following a large bushfire which occurred in 1994, destroying 5.11 million ha of forest, the Indonesian government declared a "no burn" policy in June 1995. However, in 1997/98 about 10 million ha of forest in Indonesia was destroyed, mostly due to the burning of forests to prepare land for plantation development on peat soil or simply to arson (Jepson et al. 2001; Murdiyarso & Adiningsih 2007; Saharjo & Munoz 2005; Suyanto et al. 2004).

During the 1997 fires in Indonesia, the Riau province was found to have the highest number of forest fire hotspots in Sumatra. The total number of hotspots for Riau Province was 5,870 or 23% of the total number of hotspots recorded in Sumatra, with 34% of the total hotspots located in palm oil plantations and 20% in the mosaic of grassland and cultivation (Suyanto et al. 2004). In this study we, compiled the concentration of atmospheric pollutants, namely $PM_{10,}$ $SO_{2,}$ CO, NO_2 and $O_{3,}$ at the three sampling stations in Riau Indonesia in 2006 and 2007. The concentration of air pollutants measured was then correlated to the number of hotspots and the distribution of atmospheric pollutants, particularly $PM_{10,}$ as determined through the use of the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT).

Materials and Methods

Air quality data (CO, NO_2, O_3, PM_{10}, and SO_2) in 2006 and 2007 were obtained from the Regional Government Office of the Riau Province (*Badan Pengendalian Dampak Lingkungan, Propinsi Riau*). The three stations involved in the monitoring of air quality in this province were Kulim, Sukajadi and Tampan. The hotspots data were recorded by the Malaysian Remote Sensing Agency's (MACRES) Naddi Hotspot System through the website: http://naddi.macres.gov.my/hotspot.html. The distribution of atmospheric pollutants, particularly suspended particulate matter (PM_{10}), from the three locations in Sumatra were simulated using the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT) introduced by the United States National Oceanic and Atmospheric Administration (NOAA). Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS).

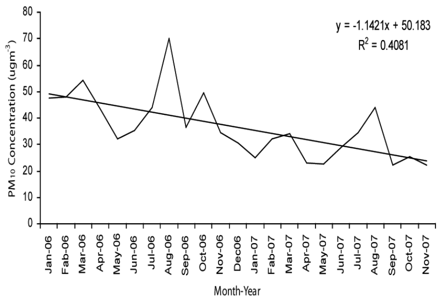
Results and Discussion

The results obtained at the three stations in Riau showed that, on average, the concentrations of all parameters recorded in 2006 and 2007 were far below the air quality standard concentrations suggested by the Indonesian government (Table 1). The highest concentration of each air pollutant was recorded mostly at the Sukajadi sampling station, especially in 2006. The location of this sampling station close to an urban area was considered a contributing factor to the amount of atmospheric pollutants in the ambient air. A higher concentration of PM_{10} and O_3 was recorded at all stations in 2006 than in 2007. The concentration of the other three 3 gases (NO_2, CO and SO_2), however, was higher in 2007 than in 2006. Further investigation, supported by monthly data, clearly demonstrated a reduction in PM_{10} and O_3 concentrations between 2006 and 2007, while the concentration of NO_2 showed a tendency to increase (Figure 1). Factors other than biomass burning, such as urbanization and the use of motor vehicles, were also expected to contribute to the amount of NO_2 entering the atmosphere. This upward trend was also found for the concentration of CO recorded in the atmosphere in Riau in 2007.

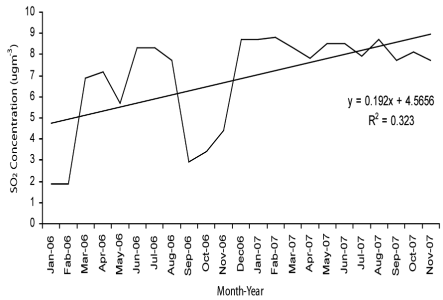
The number of hotspots recorded by the Naddi Hotspot System is summarised in Table 2. The highest number of hotspots, which is an indicator of biomass burning in Riau, was recorded in August 2006 and in July 2007. The number of hotspots was expected to be influenced by the dry season during the South West Monsoon between June and October as well as by agricultural activities. The correlation

TABLE 1. The average concentration of the main air pollutants (μgm^{-3}) recorded in Riau in 2006 and 2007

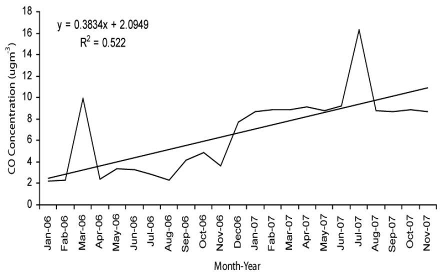
Parameter	Station	Year		Indonesian Standard
		2006	2007	
PM_{10}	Kulim	40.9 ± 12.8	27.8 ± 6.9	150 (24 hour)
	Sukajadi	47.3 ± 16.2	28.2 ± 6.2	
	Tampan	42.6 ± 11	34.5 ± 8.9	
SO_2	Kulim	5.1 ± 2.9	8.6 ± 0.7	60 (1 hour)
	Sukajadi	5.9 ± 2.2	8.2 ± 0.7	
	Tampan	5.8 ± 3.4	8.0 ± 0.6	
CO	Kulim	3.8 ± 2.2	9.3 ± 1.1	100 (1 hour)
	Sukajadi	4.2 ± 2.5	7.9 ± 0.8	
	Tampan	4.2 ± 2.6	8.9 ± 0.9	
O_3	Kulim	38.8 ± 10.5	17.2 ± 2.9	50 (1 hour)
	Sukajadi	42.0 ± 10.9	18.2 ± 3.3	
	Tampan	38.2 ± 10.9	21.0 ± 2.8	
NO_2	Kulim	4.6 ± 5.5	18.3 ± 2.9	30000 (1 hour)
	Sukajadi	5.6 ± 62.0	21.1 ± 3.9	
	Tampan	4.4 ± 4.9	22.6 ± 4.6	



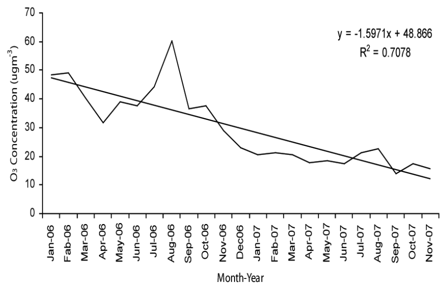
(a) PM_{10} concentration



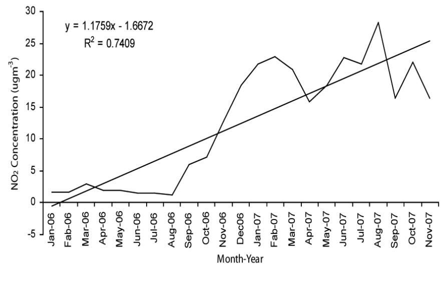
(b) SO_2 concentration



(c) CO concentration



(d) O_3 concentration



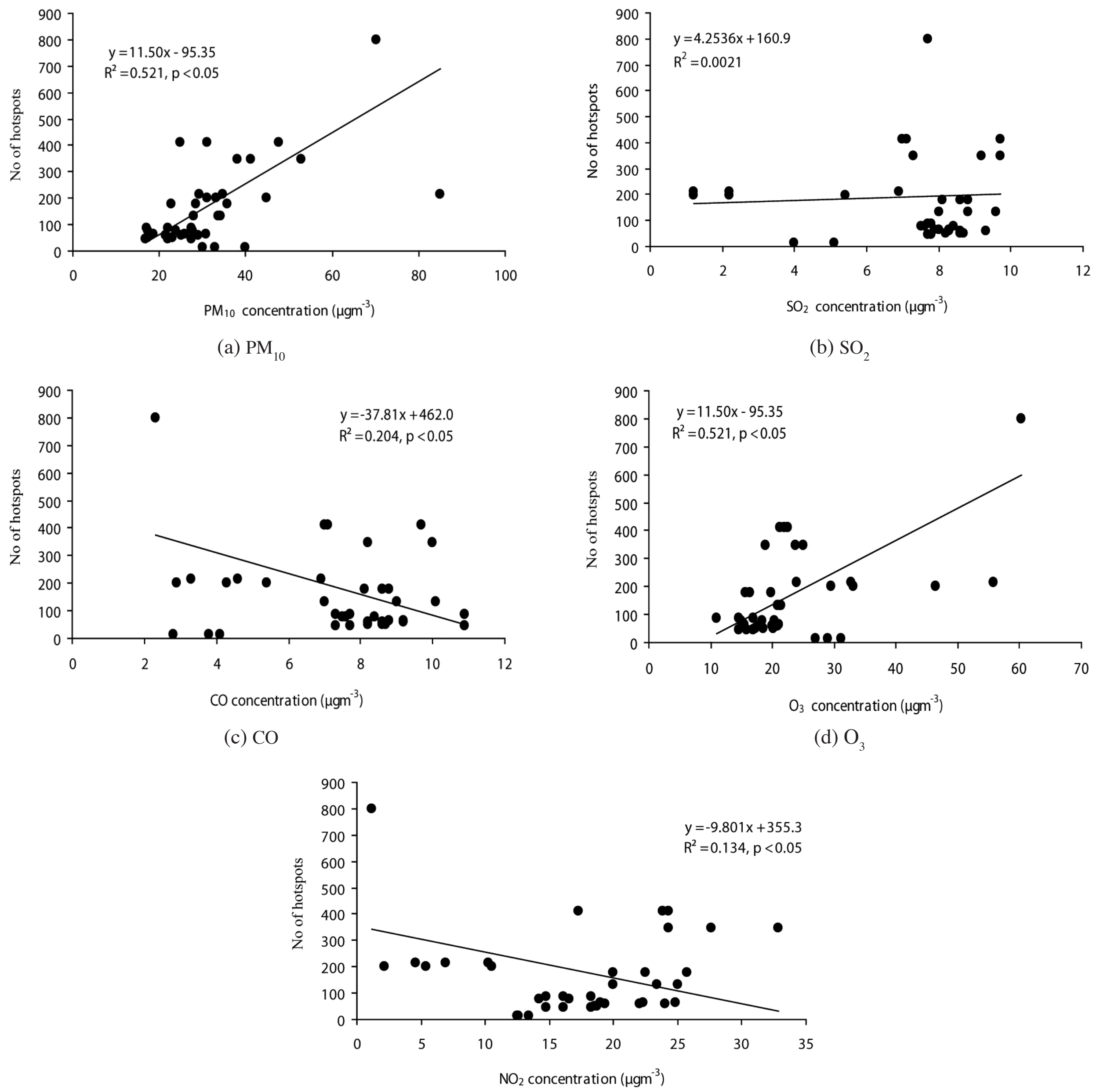
(e) NO_2 concentration

FIGURE 1. Monthly concentrations of selected atmospheric pollutants in 2006-2007 in Riau (a) PM_{10} concentration, (b) SO_2 concentration, (c) CO concentration, (d) O_3 concentration and (e) NO_2 concentration

TABLE 2. The number of hotspots recorded in Riau, Indonesia, in 2006 and 2007

Month/Year	2006	2007
January	0	59
February	0	133
March	0	0
April	0	78
May	0	50
June	0	178
July	0	413
August	801	349
September	199	86
October	213	64
November	14	46
December	0	0

between the number of hotspots and the concentration of air pollutants showed that the level of PM_{10} and O_3 increased significantly as the number of hotspots rose (Figure 2). The significant correlation ($p < 0.05$, $r^2 = 0.545$) between the number of hotspots and PM_{10} concentration indicates that particulate matter was the major atmospheric pollutant trigger from the biomass burning. The high amount of hydrocarbon in the atmosphere was a result of the biomass burning proceses and was also influenced to the amount of ozone in the atmosphere. Ozone can be generated by the interaction of hydrocarbon and nitrogen oxide with sunlight (Kansal 2009). Whilst other gases, such as carbon monoxide and nitrogen dioxide, did not indicate a strong correlation with the number of hotspots (Figure 2), they did increase markedly during haze episodes over the normal



(a) PM_{10} (b) SO_2 (c) CO (d) O_3 (e) NO_2

FIGURE 2 . Correlation between the number of hotspots at different months in 2006-2007 and the concentration of selected atmospheric pollutants (a) PM_{10} (b) SO_2 (c) CO (d) O_3 and (e) NO_2

concentrations recorded in Riau as shown by peaks of these two gases recorded between July and August 2007 (Figure 1c and Figure 1e). The short life of gases and their rapid transformation to another form as a result of photo-oxidation processes is also believed to affect the amount of gases in the atmosphere.

The predicted distribution of PM_{10} from the three hotspots indicated that the amount of particulate matter in the surrounding areas was dependent on wind direction and the dispersion of air pollutants from various sources, ultimately depending on the air mass which carried these pollutants. During haze episodes the dominant wind was the South West Monsoon. This wind direction and velocity was capable of bringing the suspended particulate matter to the Peninsular Malaysia within 42 hours (Figure 3). The concentration of the pollutant was found to reduce as it dispersed.

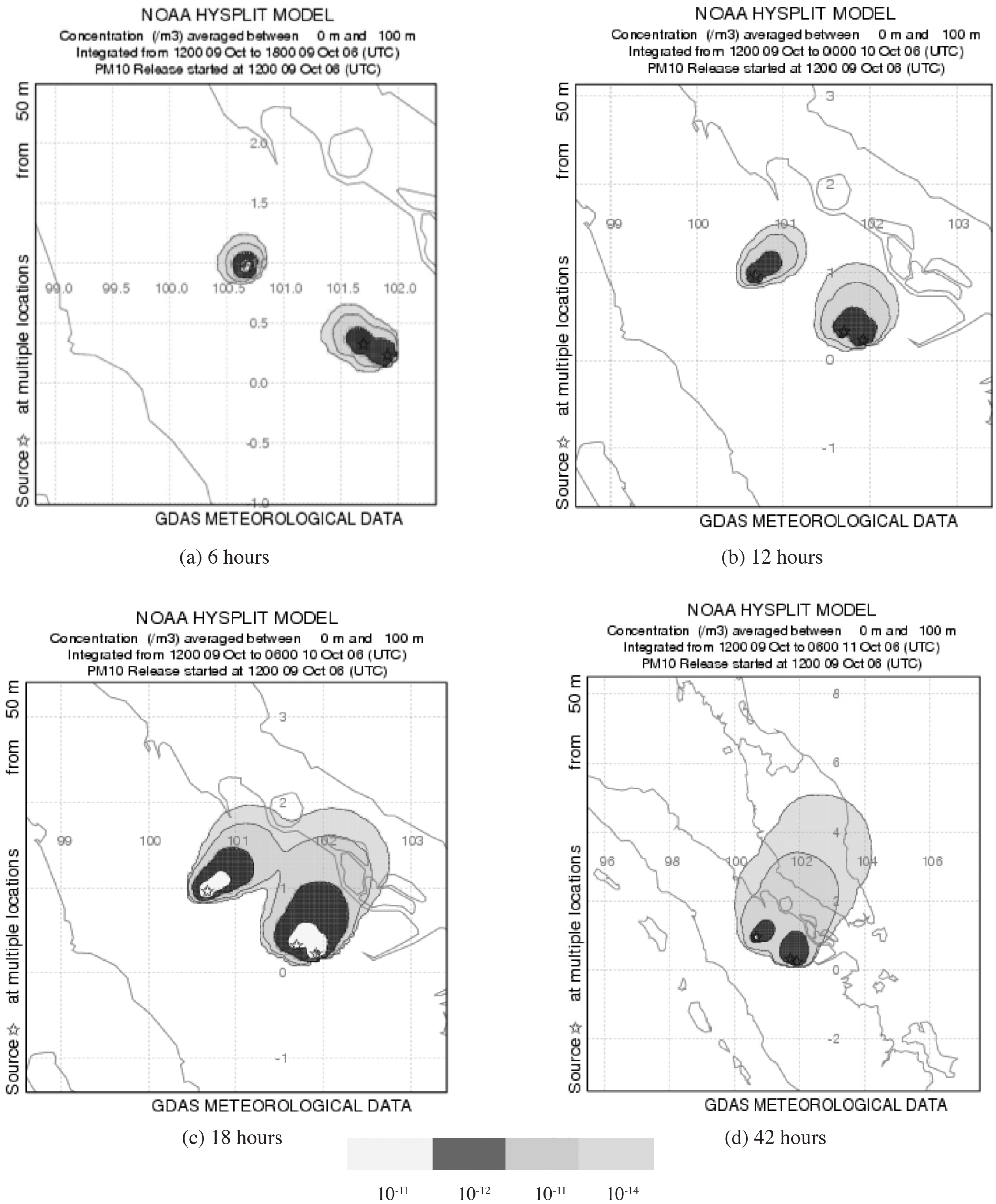


FIGURE 3. Distribution of atmospheric aerosols at different times from the three hotspots in Riau from 9 October 2007. Contours are given in mass/m^3

CONCLUSION

The study indicated that the concentrations of atmospheric pollutants (PM_{10}, SO_2, NO_2, CO and $O_{3)}$ recorded at three sampling stations in Riau, Sumatra, Indonesia in 2006 and 2007 was still under the permissible levels recommended by the Indonesian government. The highest number of hotspots in 2006 and 2007 was recorded between June and October. Agricultural activity, in particular that related to biomass burning, was believed to contribute to the number of hotspots as well as the traditional slash and burn agricultural activities.

The concentrations of PM_{10} and ozone were found to be significantly correlated to the number of hotspots in Riau, and biomass burning contributed to the high amount of fine aerosols and suspended particulate matter in the atmosphere. The concentration of PM_{10} increased by more than 20% from its normal level during August 2006, when the highest number of hotspots was recorded. Hydrocarbon in the atmosphere as a result of biomass burning is considered to have contributed to the amount of ozone as a secondary atmospheric pollutant. The dispersion model, simulated through the use of the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT), demonstrated that the distribution of PM_{10} was related to wind direction and velocity and is capable of reaching the Malaysian Peninsular within 42 hours of emission from the hotspot point sources carried by the South West Monsoon.

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