

ASSESSMENT ON THE AEROSOLS VARIATION DURING THE INTENSE HAZE EVENT OF JUNE 2013 OVER MALAYSIA BY UTILIZING THE SATELLITE REMOTE SENSING AND GROUND-BASED MEASUREMENT

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ABSTRACT: The rapid occurrence of forest fires in Southeast Asia and associated biomass burning, has contributed obviously to the problem of trans-boundary haze and the dispersion of pollutants in the region. Atmospheric pollutants, such as particulate matter in the atmosphere, have received extensive attention, mainly because of their adverse effect on people's health. In 2013, Malaysia experienced an intense haze episodes with a high concentration of aerosols were recorded and degrading the local air quality and reduce the visibility. This paper aim is to analyze the spatio-temporal variation of aerosols concentration during intense haze event in 2013 over Malaysia by using remote sensing data and ground-based measurement. The air quality data across Malaysia was assessed based on PM₁₀ concentration which provided by Malaysia Department of Environment (MDOE) and the spatial view of aerosols optical depth (AOD) data from satellites (Terra Moderate-resolution Imaging Spectroradiometer (MODIS)). The environmental parameters including temperature, rainfall, and wind speed were obtained from NOAA's National Climatic Data Center (NCDC) while an additional information about the occurrence of active fires in surrounding region was retrieved from MODIS Active Fire Data was retrieved from NASA/LANCE – FIRMS. In June 2013, the PM₁₀ value was recorded high in few stations over the Peninsular Malaysia with the highest PM₁₀ was recorded in the Bukit Rambai Station from 21st until 23rd of June with more than 400 µg/m³. Low wind speed and low mixing depth, together with the absence of rainfall persisted during this hazy condition. The PM₁₀ was began cleared with the increase of wind speed starting 26th of June with the rainfall also contributed to disperse the haze from the atmosphere. The sources and destination of aerosols are identified via the HYSPLIT trajectory model, revealing that aerosols during June 2013 are mainly originated from the west and southwest area (Sumatera, Indonesia).

Keywords: Haze, Air quality, Remote sensing, Aerosols, Malaysia

1. INTRODUCTION

Haze situation is generally defined as the existence of fine particles with 0.1–1.0 µm in diameter range dispersed in a highly concentrated portion at the atmosphere which reducing the horizontal visibility, giving the atmosphere a characteristic opalescent appearance [1][2]. This particle which are of respirable sizes is of concern because of their negative effect on health, as well as their other environmental impacts [3][4][5][6].

In Malaysia, haze phenomenon has been plaguing almost every year since 1980's. The recent haze event was in 2013 which severely weakened regional horizontal visibility as thick smoke blanketed Peninsular Malaysia and Singapore. Extensive biomass burning from the land and forest clearing process in some places in the neighboring country had to result in trans-boundary haze which degrading the air quality in Peninsular Malaysia [3][7][8][9][10]. Therefore,

this study aimed to provide a spatio-temporal assessment of aerosols concentration during intense haze event in 2013 over Malaysia by using remote sensing data and ground-based measurement. Particularly emphasize on PM₁₀ as the aerosols and pollutant indicator. Other metrological parameters such as surface wind speed and direction, rainfall amount, hotspot, temperature, and visibility were also analyzed. Meanwhile, HYSPLIT backward trajectories were assessed to tack the pollutant transport during a haze episode in 2013.

2. DATA AND MATERIALS

2.1 Air Quality and Metrological Data

Daily PM₁₀ concentration for 2013 was acquired from Malaysian Department of Environment (MDOE). Meanwhile, the metrological parameters such as rainfall amount,

temperature, wind speed, and visibility were gathered from NOAA's National Climatic Data Center (NCDC). Thirteen monitoring stations were considered in this analysis of the aerosol properties located all over Peninsular Malaysia and East Malaysia (Fig. 1). The station locations represent highly urbanised or industrialised areas (Kuching and Sultan Abdul Aziz International Airport (SAAIA)), moderately urbanised/industrialised areas (Kota Kinabalu, Setiawan, Bukit Rambai), high traffic areas (Johor Bahru), coastal areas (Sultan Ismail Petra Airport (SIP), Kuantan, Tawau, Sandakan, Labuan) and a rural/unurbanised site (Sibu, Limbang). Daily mean composites of wind vector were computed over the Southeast Asia region. In this region, it strategically depicts the tropospheric flow patterns where; it covers Malaysia and other neighboring countries. The maps were constructed from NCEP/NCAR Reanalysis Product developed by NOAA-ESRL9

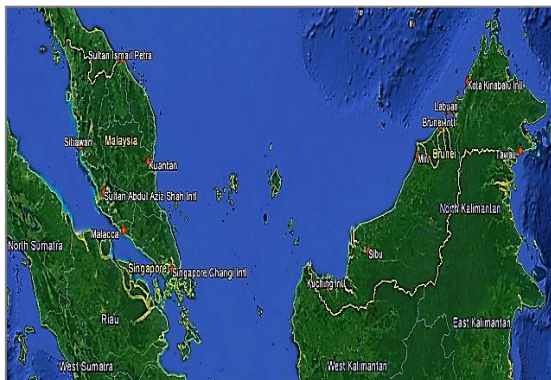


Fig. 1 Map of the 13 monitoring stations over Malaysia which the air quality and meteorological data were obtained.

2.2 Active Fire and Hotspot Data

In order to do the analysis on the occurrence of active fires in Sumatra, the active fire and hotspot data were used and obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) from the Terra and Aqua satellite. MODIS Active Fire Data acquired from the NASA/LANCE – FIRMS website to monitor the distribution of hotspots within the Sumatra area. A polygon area was outlined which includes Riau (0° 32' N, 101° 27' E) and Jambi (1° 35' S, 103° 36' E) province in Sumatra. Only hotspot counts with confidence level higher than 30% were included in this study.

2.3 Aerosol Optical depth (AOD)

Aerosol Optical Depth (AOD) from Terra satellite on Moderate-resolution Imaging

Spectroradiometer (MODIS AOD) was used in this study to analyze the spatial distribution of aerosols during the haze episode in 2013 over Malaysia. In general, the MODIS aerosol data are retrieved twice daily; in the morning from MODIS on Terra platform and in the afternoon (on Aqua platform) at 10 x 10 km spatial resolution [13]. Seven channels between 0.47 and 2.13 μm (calibrated and geo-located reflectance level 1B data) are used to retrieve aerosol properties [13][14]. AOD data that were used in this study was the level 2 data and it represents the first level of MODIS aerosol retrieval. These data had been revised frequently and widely being used to retrieve AOD with high accuracy of 0.05 ± 0.2 [14][15].

3. RESULTS AND DISCUSSION

3.1 PM₁₀ Variation in Malaysia during the 2013 Intense Haze

The daily PM₁₀ concentration at 13 selected air quality monitoring stations and the daily average of wind speed are presented in Fig. 2, from which can be seen that the PM₁₀ peak occurred in June 2013, which started on 20th of June and keep increased until 25th of June 2013. The highest PM₁₀ was recorded in the Bukit Rambai Station from 21st until 23rd of June (PM₁₀ concentration more than 400 $\mu\text{g}/\text{m}^3$). PM₁₀ concentration was also recorded high in few other stations mainly over Peninsular Malaysia which are; Bukit Rambai, Singapore, SAAIA, and Setiawan. In addition, a high concentration of PM₁₀ during this period indicating a high level of haze and air pollution over Malaysia during the dry season in 2013.

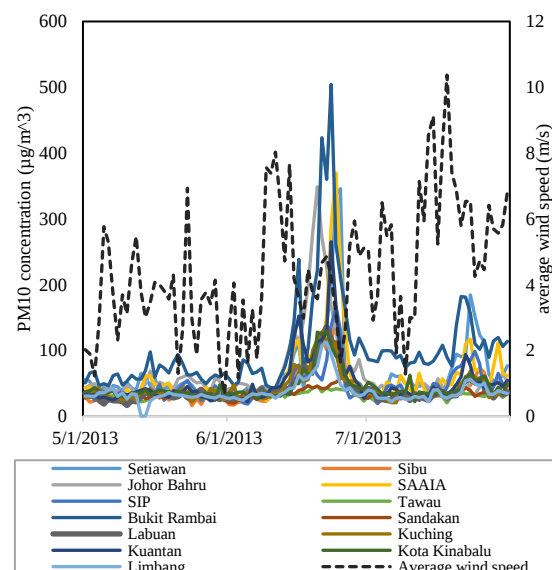


Fig. 2 Variation of PM₁₀ concentration at 13 monitoring stations over Malaysia and the daily average wind speed within three consecutive months (May until July) in 2013.

As been shown in Fig.2, the haze episode was started from the southern region and move to the north of Peninsular Malaysia. Besides that, the daily average wind speed was recorded low and initially shown a low mixing depth in the atmosphere during the hazy period in June 2013.

In the Fig. 3a) and 3b) illustrates the variation of daily surface wind speed and rainfall amount together with the PM₁₀ concentration for the period of May until July 2013.

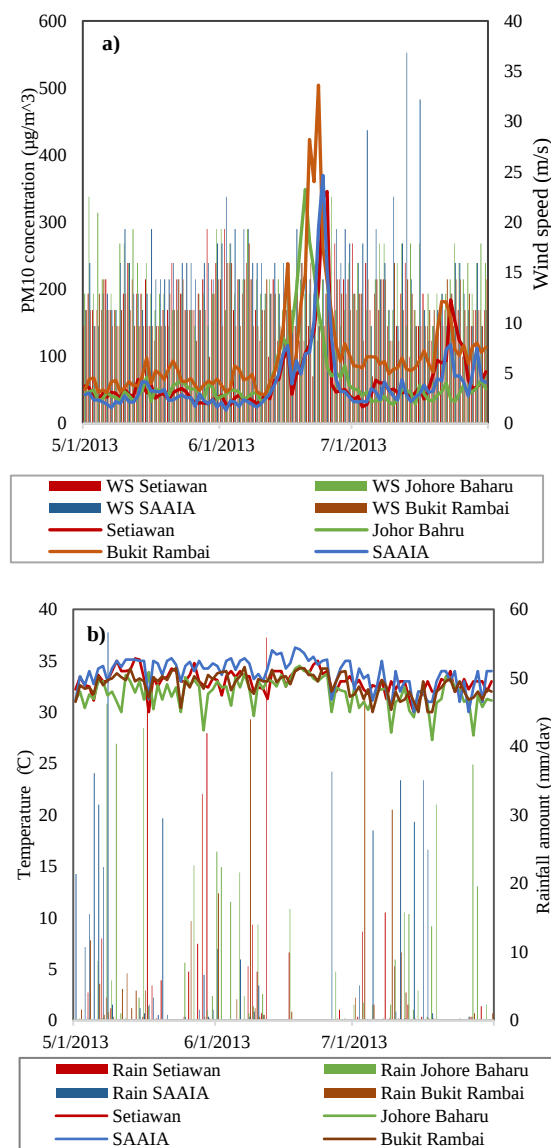


Fig. 3 The daily variations at four selected stations for a) PM₁₀ concentration and surface wind speed, and b) temperature and rainfall amount within May until July

The wind speed was relatively low for every four stations within 20th of June until 25th of June 2013, while the daily temperature was increased up to 36.11°C with the absences of rainfall. Hence, low wind speed with lack of rainfall which introduced to low mixing depth that worsened the condition during these intense haze episodes. The persistent supply of haze particles from it sources coupled with the surface inversion associated with the dry situation, light surface winds, and the nature of the topography resulted in the haze particles being trapped in Peninsular Malaysia.

The mixing depths and the wind speeds are relatively low, which also indicate inefficient ventilation in the atmosphere. Thus, this condition was intensified with high temperature and less rainfall that may relate to the southwest monsoon season. As shown in the Fig. 4, the wind direction maps show a weakening of the regional wind over Southeast Asia mainly at Malaysia and Indonesia area from 20th until 24th of June 2013.

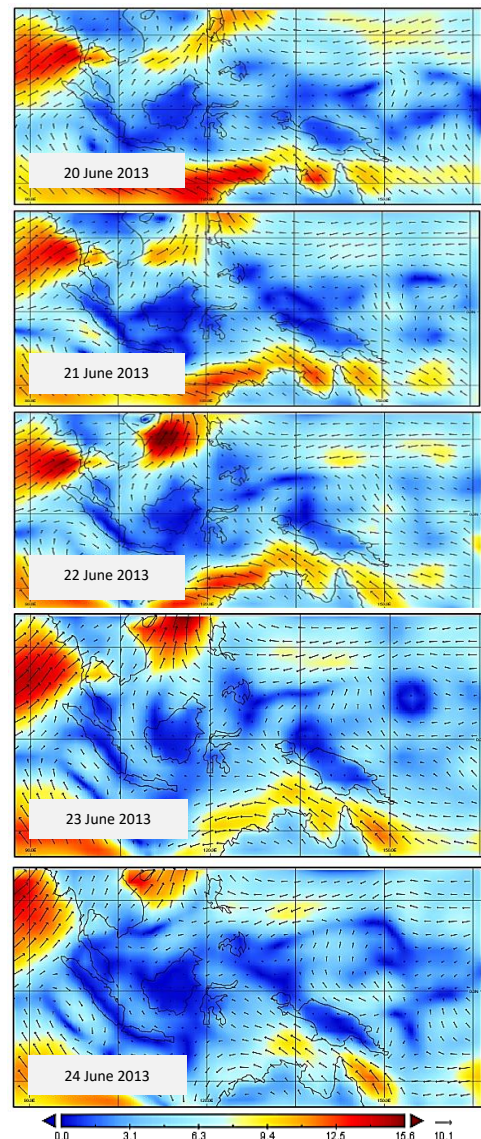


Fig. 4 Daily wind direction map at 10m over Southeast Asia region for the period of 20th until 24th of June 2013.

Generally, the southwest monsoon season flow was strengthened by a south to the north pressure gradient, with northern hemisphere having a lower surface pressure than the southern hemisphere. The pressure gradient is a consequence of the temperature contrast between the northern and southern hemisphere due to seasonal variations. Moreover, during the haze period (June 2013) equatorial trade winds above the western Pacific weakened to a lesser extent. Since the effects of northeasterly trade winds were offset by the stronger southwesterly monsoonal flow, the northeasterly flow was essentially suppressed. The resulting southwesterly flow brought relatively less rainfall from the Straits of Melaka to the west coast of Peninsular Malaysia. Less rainfall in the west coast and southern part of Malaysia resulted in surging PM₁₀ concentrations in this area.

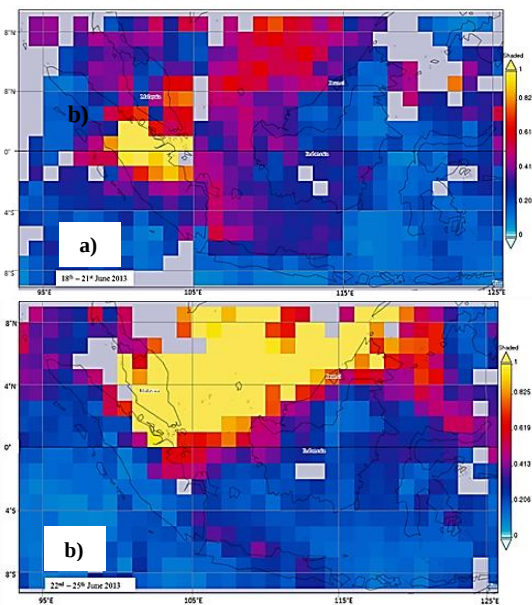
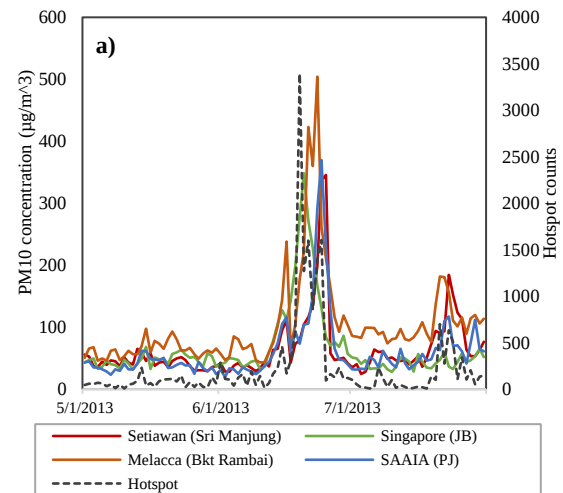


Fig. 5 The four-day time average map of Terra Modis AOD during the intense haze a) 18th – 21st June 2013 and b) 22nd – 25th June 2013.

Spatial distribution of AOD during the intense haze in 2013 over Southeast Asia region were displayed in the Fig.5. The AOD distribution map was plotted based on high PM₁₀ concentration day as shown in Fig. 2. Based on Fig. 5(a), the AOD reaches the maximum value, particularly along the Sumatra Island. According to the previous study, southwest monsoon will induce wind circulation that blows the wind from south to north which may relate to trans-boundary pollution happen during this period [2][3]. As shown in Fig. 5(b) the AOD distribution were moved towards Peninsular

Malaysia and South China Sea region. This finding is justified by the result of that been presented in Fig. 6(b) the HYSPLIT trajectory model that ran during the hazy period in June 2013.

According to MODIS satellite observation, the hotspot counts in Fig. 6 show a prominent peak on 19 June 2013 with more than 3000 hotspots were found over Sumatra, Indonesia on that particular date. This situation can be attributed to the existence of biomass burning activity that occurred in the Riau Province which had been reported by [1]. Therefore, biomass burning in surrounding area had indicated on the increasing of PM₁₀ concentration in Peninsular Malaysia during June 2013 [9][10][11]. As the biomass burning activities in Sumatra were detected on 19th of June 2013, the meteorological effects were not immediately shown on Peninsular Malaysia. Long-range trans-boundary haze across the Straits of Melaka was further delayed by lower southwesterly wind speeds during the monsoon season. The HYSPLIT backward trajectories in Fig. 6, shown that the polluted substance were brought up to Peninsular Malaysia from 21st until 24th June 2013 were mainly from Sumatra within 24 hours.



NOAA HYSPLIT MODEL
Backward trajectories ending at 1200 UTC 23 Jun 13
GDAS Meteorological Data

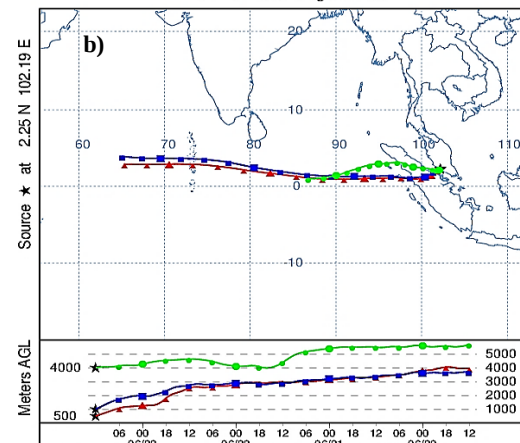


Fig. 6 a) The hotspot counts in Sumatera and PM₁₀ concentration from May until July 2013 and b) 5 days backward trajectories ending on 23rd of June 2013 which ends at the Bukit Rambai station.

3.2 Impact of June 2013 Haze Episode in Malaysia

Visibility deprivation is a proxy measurement of the polluted atmosphere. Poor visibility may cause by scattering and absorption of solar radiation of particles and gaseous pollutants [4][5][6]. The visibility in Malaysia was recorded poor during the 20th until 25th of June 2013 as it dropped until less than 2 km compared to during non-polluted day with visibility more 10km. Thus, these hazy condition has given a huge impact towards the economy and health crisis to the surrounding community not only in Malaysia but also in Singapore and Indonesia.

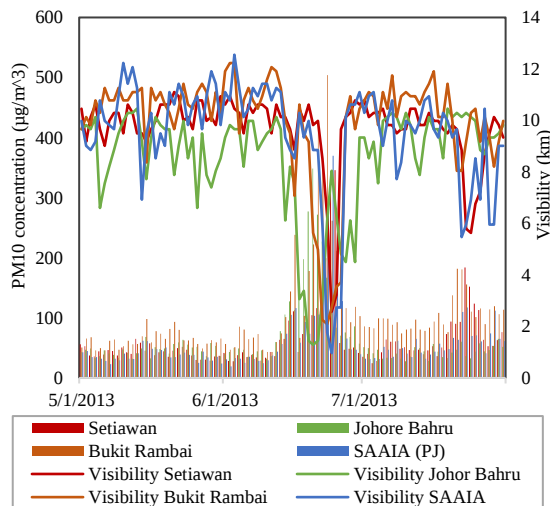


Fig. 7 Relationship of PM₁₀ concentration and visibility over four stations in Peninsular Malaysia.

4. CONCLUSIONS

This study had analyzed the spatio-temporal variation on PM₁₀ concentration during intense haze condition in 2013 by utilizing all source of data including remote sensing data and ground-based data. In this study comprised of numerous parameters such as hotspots, rainfall amount, temperature, visibility, HYSPLIT trajectories, surface wind speed and direction via PM₁₀ as the aerosols indicator. This assessment found that during 2013 the highest peak of PM₁₀ concentration started on 20th until 24th of June 2013 and was detected high at four stations over Peninsular Malaysia; Bukit Rambai, Singapore, SAAIA and Setiawan station. This condition coupled with low wind speed and less rainfall amount which relatively causing to low mixing

depth and inefficient ventilation to the atmosphere. Haze episode in 2013 also occurs during the southwest monsoon season where; the wind flow south-westerlies and the pollutant substance were transported from Sumatera, Indonesia to Peninsular Malaysia. Thus, these trans-boundary haze were proved by the hotspot count in Sumatera, which were recorded high on 19th of June 2013 (more than 3000 counts). Trajectory modeling with HYSPLIT showed that smoke fire moves from Sumatera area towards Peninsular Malaysia. A decline in air quality also affecting towards the decreasing in visibility. Hence, this situation may slow down the economy and disturb community health in the surrounding area.

5. ACKNOWLEDGEMENTS

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