IOP Conference Series: Materials Science and Engineering

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To cite this article: N Dahari *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **636** 012005

IOP Conf. Series: Materials Science and Engineering **636** (2019) 012005 doi:10.1088/1757-899X/636/1/012005

Long-Range Transport and Local Emission of Atmospheric $PM_{2.5}$ in Southern Region of Peninsular Malaysia

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Abstract. The excessive inhalation of pollutant particles with aerodynamic diameters less than 2.5 µm ($PM_{2.5}$) results in risking the human respiratory health. The aim of this study is to investigate the possible pathways of long range and local tranportation for $PM_{2.5}$ sources. The route patterns are analyzed by using the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT 4.9) software during August 2017 to January 2018, covering three main monsoon seasons of Malaysia; southwest (SW), intermonsoon (IM) and northeast (NE) monsoon. This study represents the 72 h air mass backward trajectories in a mixed commercial-residential-industrial site of Skudai, Johor Bahru. The identified source origins are largely varied with different monsoon seasons and meteorological factors. The air-flow at different altitudes results in different effects, as the trajectory at height 500 m contributes to the greatest impact on the pollution level. The potential sources were generally from the Sumatera, Indonesia, during SW monsoon and China, during NE monsoon. The $PM_{2.5}$ exceedance pattern in the Skudai area is also strongly influenced by the localized circulation, anthropogenic emission and dispersion characteristics. The increased levels of $PM_{2.5}$ are predominantly contributed by the primary sources of vehicular emissions and industrial activities.

1. Introduction

One of the main pollutants that contributes to the negative impact of the global climate is airborne particulate matter (PM) [1]. $PM_{2.5}$ pollutant can reside for a longer period of time in the atmosphere. The excessive exposure to $PM_{2.5}$ can pose severe health problems due to its capability of penetrating deep into the alveolar region of human respiratory system and causing various diseases including heart attack, acute bronchitis, asthma and lung cancer [2]. Location, background area, gaseous pollutants and seasonal meteorological factors influence the composition and chemical variability of the fine particles [3]. Source apportionment is a method that can quantify the sources of chemically speciated particles including $PM_{2.5}$ pollutant in order to ascertain the sources responsible for each particle emission [4]. The approach of determining the emission sources involves working backwards after collecting $PM_{2.5}$ samples at the required receptor [5].

2. Methodology

2.1. Study Area

The location is selected at southern part of Malaysian Peninsula with coordinates, 1°33'54"N 103°38'24"E (1.565, 103.64), located at Universiti Teknologi Malaysia (UTM) Skudai, Johor Bahru, in order to study the pathways of the ambient air. The study was conducted during 6 consecutive months to cover southwest (SW; August 2017-September 2017), inter-monsoon (IM; October 2017-November 2017) and northeast monsoon (NE; December 2017-January 2018) of Malaysia.

2.2. Air-Mass Backward Trajectory Analysis

Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT 4.9) software model of National Oceanic and Atmospheric Administration's (NOAA) Air Resources Laboratory (ARL) was used to generate three dimensional (3-D) plots, also, to calculate findings and air mass trajectories based on metrological parameters [6]. This approach is to investigate the source origin and transport patterns of the pollutant emission at the sampling sites [7]. The approach was done at the initial step of evaluating the ambient particulate concentration prior to determining the emission source. To analyse seasonal variations, HYSPLIT was computed each month from August 2017 to January 2018 using the meteorological data obtained from the Global Data Assimilation System (GDAS) provided by the National Centers for Environmental Prediction (NCEP). Since the $PM_{2.5}$ has the ability to travel long distance, thus, the 72 h air-mass back-trajectories for wind direction were calculated every 6 h a day (00, 06, 12 and 18 h UTC) onto the plot simulation diagram. Trajectory data of multiple altitudes of 500 m, 1000 m and 1500 m above ground level (AGL) represented the air masses arriving at UTM Skudai.

3. Results and Discussions

Figure 1 shows the pathways of the air mass patterns during the seasonal periods of southwest (SW), intermonsoon (IM) and northeast (NE) monsoon, while Figure 2 displays the zoomed-in route patterns of backward air trajectories covering the three monsoon seasons. The airstreams during SW are mainly maritime as they are usually drawn from the western Pacific and from the Indian Ocean, while the air during NE is normally supplied by the regions of Northeast Asian and Australian continents. Based on Figure 1(a) and Figure 1(b), the long range air mass is found to be originated from the regional source of Sumatra, Indonesia, particularly during the southwesterly monsoon. Based on Figure 1(a) and Figure 1(b), the long range air masses are found to be originated from the regional source of Sumatra, Indonesia, particularly during the southwesterly monsoon. The boundary layers of altitudes 500 m, 1000 m and 1500 m seem to also originate from the same region. During August, the airmass trajectories of different altitudes started to traverse northwest of Java, directed towards Singapore, before shifting to Skudai. Although, when the long range tranported pollutants are taken into account, the source was far from Malaysia, but the prevailing airstream only took 3 days to arrive to Skudai. Hence, the particular $PM_{2.5}$ mass concentration was the highest during the sampling duration period of three monsoon seasons. The source of airmass during this monsoon is from southern Sumatra and stretches to the end of Jakarta. Its diurnal upslope position flows towards the neighbouring landmasses.

Locally, during the SW monsoon of August 2017−September 2017 (Figure 2(a) and Figure 2(b)), the $PM_{2.5}$ pollutant is observed to be emitted from the industrial area of Gelang Patah and Johor Bahru

City Centre, and a few trajectories directed from the Strait of Johor. All the trajectories were pointed from the same direction. Since the SW monsoon is still well developed during this period, the airstream is southeasterly, it results in the rising of $PM_{2.5}$ mass concentration in Skudai. By the end of SW monsoon time, the SW winds started to weaken and move the southern boundary further south to Peninsular Malaysia, affecting the $PM_{2.5}$ mass concentration in the study area. The $PM_{2.5}$ peaks were due to the other meteorological conditions, and collided with the shift in the wind patterns. It can be seen that the source of emission is directed north towards Skudai, through Singapore and Johor Bahru centre. Moreover, the proximity of Johor Bahru and Singapore to these sources enhances the region to be more susceptible to the pollutants, hence, the rising of its concentration during this period. In addition, the increase of pollution level in the SW monsoon can also be attributed by nearby anthropogenic and local sources, as stated above. At this time, the high $PM_{2.5}$ concentration in Skudai was favoured by the surges of prevailing wind system and the local pollution, suggesting that the worse air pollution was due to transboundary airmass transportation and nearby emissions [8].

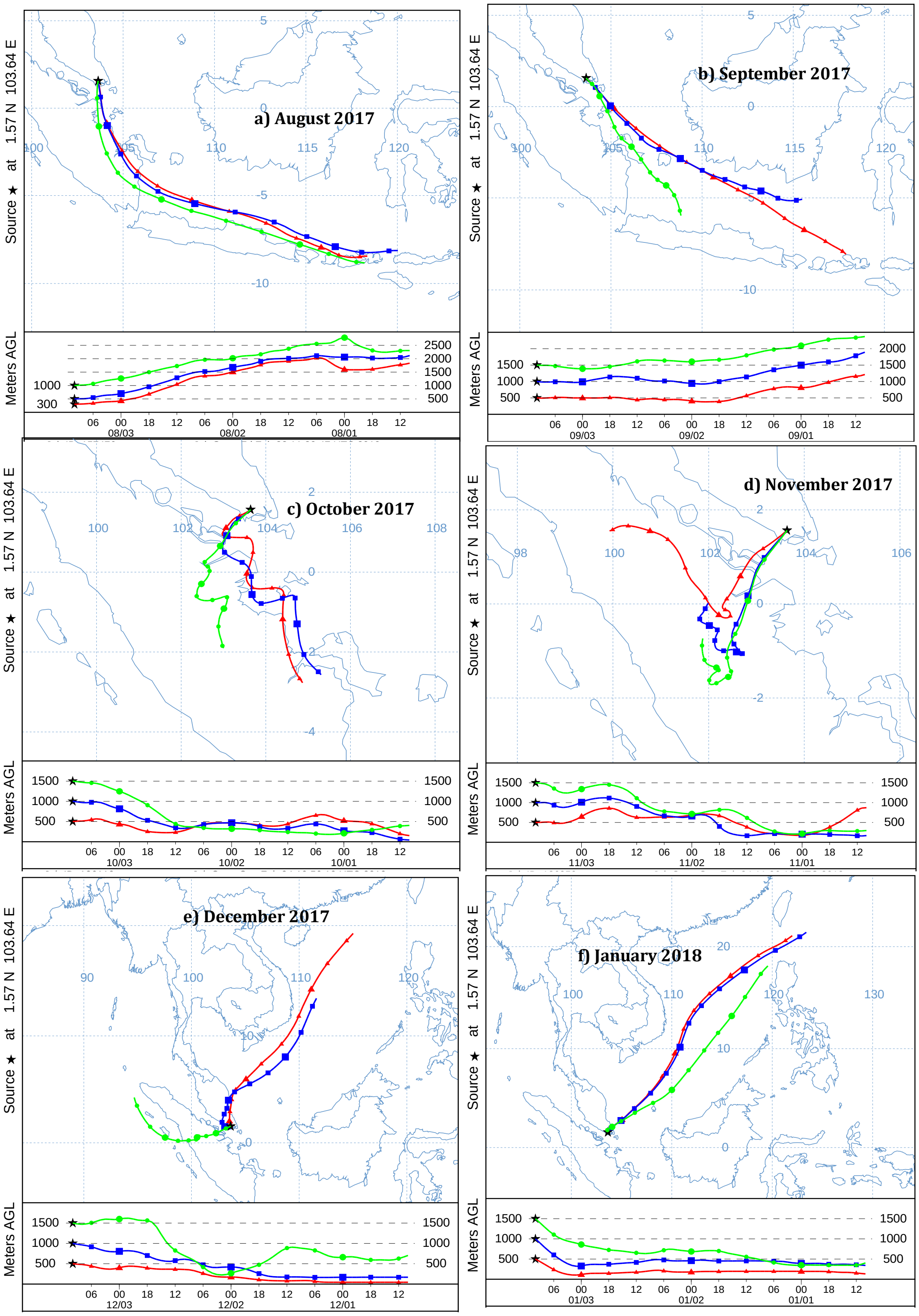

Figure 1. 72 h Backward Trajectory Pathways of SW, IM and NE Monsoons

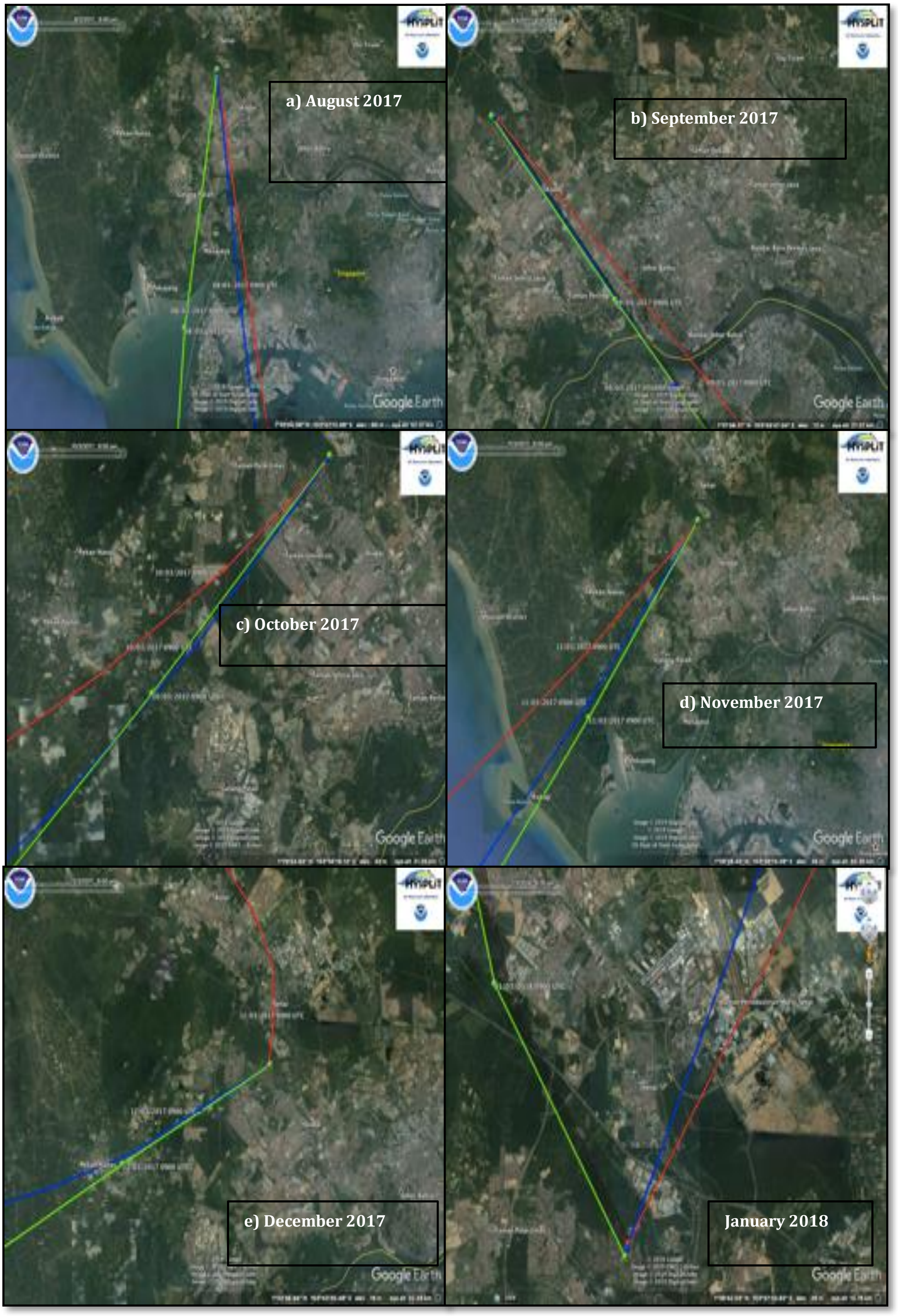

Figure 2. 72 h Backward Trajectory Pathways of SW, IM and NE Monsoons (Zoomed-In)

By the early October, the SW monsoon was starting to fade as the winds were varying and lowering during this duration. Later, the inter-monsoon started to signal as the Northern Equatorial Boundary was observed to move towards the south. The wind field during the intermonsoon season (IM) shows that the wind blows from west Sumatra (Figure 1(c)). However, during November 2017 (Figure 1(d)), the lowest altitude of airmass had a different pathway pattern compared to the other two altitudes, as the lowest mixing layer is observed to be transported in a long range originated from North Sumatra, while others are from Central Sumatra. The winds and the height of the mixing layer that were representated by the lowest layer (active boundary layer) had great influence on the concentration of $PM_{2.5}$ [9]. Since the single height analysis had large uncertainties [10], the analysis consisted of the well-mixed convective boundary layer of low, middle and high atmosphere layers which had different characteristics on the $PM_{2.5}$ concentrations [11].

During the IM monsoon period, the winds are normally lighter. Figure 2(c) and Figure 2(d) display that the pollutant is transported from Pekan Nenas and Pontian during the IM period. In the last days of the transition monsoon, the $PM_{2.5}$ mass concentration in the study area was already decreasing, suggesting significant findings contributed by the PM mass and seasonal variations. The weak winds enhanced the aerosol transboundary transportation from neighbouring region towards the southern region of Peninsular Malaysia. By the end of IM monsoon, the trajectories started to shift northeast as in Figure 2(e) and Figure 2(f), which show that the NE monsoon winds start to develop in the far north of Pacific, slowly advancing to move southwards through the eastern China Sea arriving at the study area (SEA). The trajectories in the starting of NE monsoon of December were dispersed, directing southwards. As the boundaries are well developed, the monsoons dominate the circulation over a region. The concentration of $PM_{2.5}$ is largely dependent on the direction of the prevailing winds and the intensity of anthropogenic emissions localized in Senai and Pekan Nenas.

4. Conclusions

In this study, the $PM_{2.5}$ backward trajectories suggested the high possibilities of pollutants being transported in a long range from the highly polluted regions that could significantly influence the air quality in the less polluted areas. However, it is undoubtable that the local emissions also affect the $PM_{2.5}$ concentration due to the results of the study area which was located in a mixed residential-industrial-commercial environment. It is clear that despite the anthropogenic activities as the sources of particulates, a minor fraction of pollutants is also due to the regional transboundary transport. This valuable information is essential to prevent the likely health threats to the community of Skudai-Iskandar developed region since the $PM_{2.5}$ pollutant was locally generated, predominantly from vehicular emissions. In addition, the findings also suggest that the emission of primary pollutants was favoured by the proximity of the site to the Skudai Highways, Johor Bahru city centre and Senai industrial areas, suggesting probable source origins of mobile and industrial emissions that contribute to the variations of $PM_{2.5}$ mass concentrations. In conclusion, the local authorities should encourage the use of public transportation to improve the state of air quality at local and regional levels.

Acknowledgements

This research is assisted by the financial support from the research university FRGS grant (R.J130000.7822.4F984) from Universiti Teknologi Malaysia, Skudai and GUP TIER II grant (Q.J130000.2622.14J61, Q.J130000.2722.02K82 and Q.J130000.2622.02J54)

References

[1] Mallet M, Dulac F, Formenti P, Nabat P, Sciare J, Roberts G, Pelon J, Ancellet G, Tanré D, Parol F, Denjean C, Brogniez G, di Sarra A, Alados-Arboledas L, Arndt J, Auriol F, Blarel

L, Bourrianne T, Chazette P, Chevaillier S, Claeys M, D'Anna B, Derimian Y, Desboeufs K, Di Iorio T, Doussin J-F, Durand P, Féron A, Freney E, Gaimoz C, Goloub P, Gómez-Amo JL, Granados-Muñoz MJ, Grand N, Hamonou E, Jankowiak I, Jeannot M, Léon J-F, Maillé M, Mailler S, Meloni D, Menut L, Momboisse G, Nico- las J, Podvin T, Pont V, Rea G, Renard J-B, Roblou L, Schepanski K, Schwarzenboeck A, Sellegri K, Sicard M, Solmon F, Somot S, Torres B, Totems J, Triquet S, Verdier N, Verwaerde C, Waquet F, Wenger J and Zapf P 2016 Overview of the Chemistry-Aerosol Mediterranean Experiment/Aerosol Direct Radiative Forcing on the Mediterranean Climate (ChArMEx/ADRIMED) Summer 2013 Campaign *Atmos. Chem. Phys.* **16** 455–504

[2] Gao JJ, Tian HZ, Cheng K, Lu L, Zheng M, Wang SX, Hao JM, Wang K, Hua SB, Zhu CY and Wang Y 2015 The variation of chemical characteristics of PM2.5 and PM10 and formation causes during two haze pollution events in urban Beijing, China *Atmos. Environ.* **107** 1–8

[3] Tai APK, Mickley LJ and Jacob DJ 2010 Correlations between fine particulate matter (PM2.5) and meteorological variables in the United States: Implications for the sensitivity of PM2.5 to climate change *Atmos. Environ.* **44** 3976–84

[4] Yang F, Tan J, Zhao Q, Du Z, He K, Ma Y, Duan F and Chen G 2011 Characteristics of PM2.5 speciation in representative megacities and across China *Atmos. Chem. Phys.* **11** 5207-19

[5] Amil N, Latif MT, Khan MF and Mohamad M 2016 Seasonal variability of PM2.5 composition and sources in the Klang Valley urban-industrial environment *Atmos. Chem. Phys.* **16** 5357–81

[6] Draxler RR and Rolph GD 2003 HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) Model access via NOAA ARL READY Website. http://www.arl.noaa.gov/ready/hysplit4.html NOAA Air Resources Laboratory Silver Spring MD

[7] Stein AF, Draxler RR, Rolph GD, Stunder BJB, Cohen MD and Ngan F 2015 NOAA's HYSPLIT atmospheric transport and dispersion modeling system *Bull. Am. Meteorol. Soc.* **96** 2059–77

[8] Koe LCC, Arellano AF, McGregor JL 2001 Investigating the haze transport from 1997 biomass burning in Southeast Asia: its impact upon Singapore *Atmos. Environ.* **35**: 2723–34

[9] Su L, Yuan Z, Fung JC and Lau AK 2015 A Comparison of HYSPLIT backward trajectories generated from Two GDAS datasets *Sci. Total Environ*. **506–507** 527–537.

[10] Stohl A 1998 Computation, accuracy and application of trajectories - A review and bibliography *Atmos. Environ*. **32** 947–966

[11] McGowan H and Clark A 2008 Identification of dust transport pathways from lake eyre, australia using hysplit *Atmos. Environ.* **42** 6915–25