Source Apportionment of $PM_{2.5}$ During Haze and Non-haze in Kuala Lumpur Urban Environment

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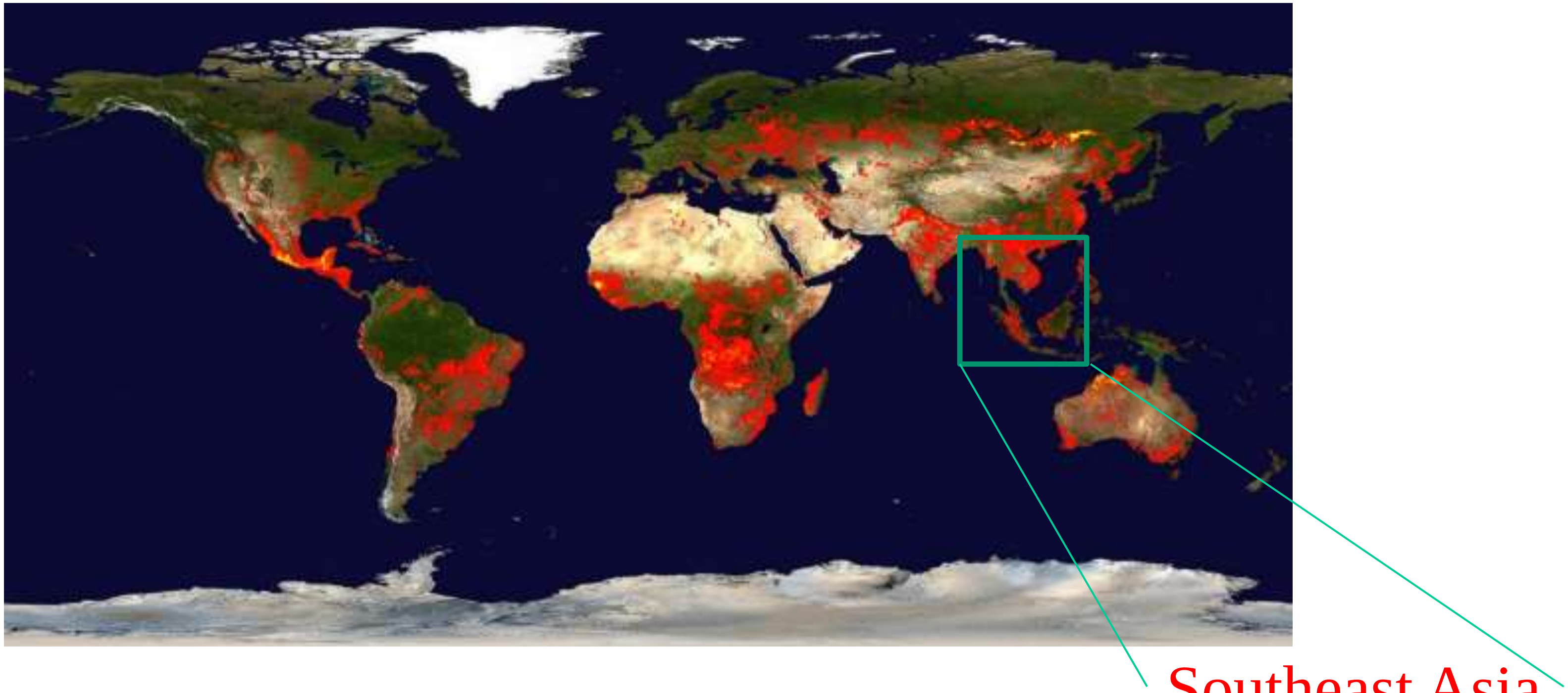
Introduction

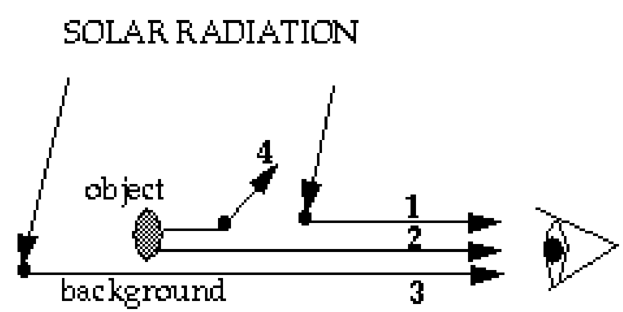
Biomass burning in Southeast Asia



Ichoku and Kahn (2012)

Kuala Lumpur Hazy Condition

- $PM_{2.5} \geq 35\ \mu g\ m^{-3}$
- Visibility < 10 km
- Dry/Low humidity



Trigger to Biomass Burning

- In South East Asia biomass burning has become a traditional method of clearing land in the practice of shifting cultivation, which involves field rotation and the slashing and burning of a new plot of land once the existing plot has lost its fertility

Biomass Burning from Peat Soil Combustion

Haze: Bad new folks! Sumatra hotspots double to 118 on Saturday

JUNE 23, 2013 BY ADMIN LEAVE A COMMENT

Smouldering

High amount of soot and smoke !!

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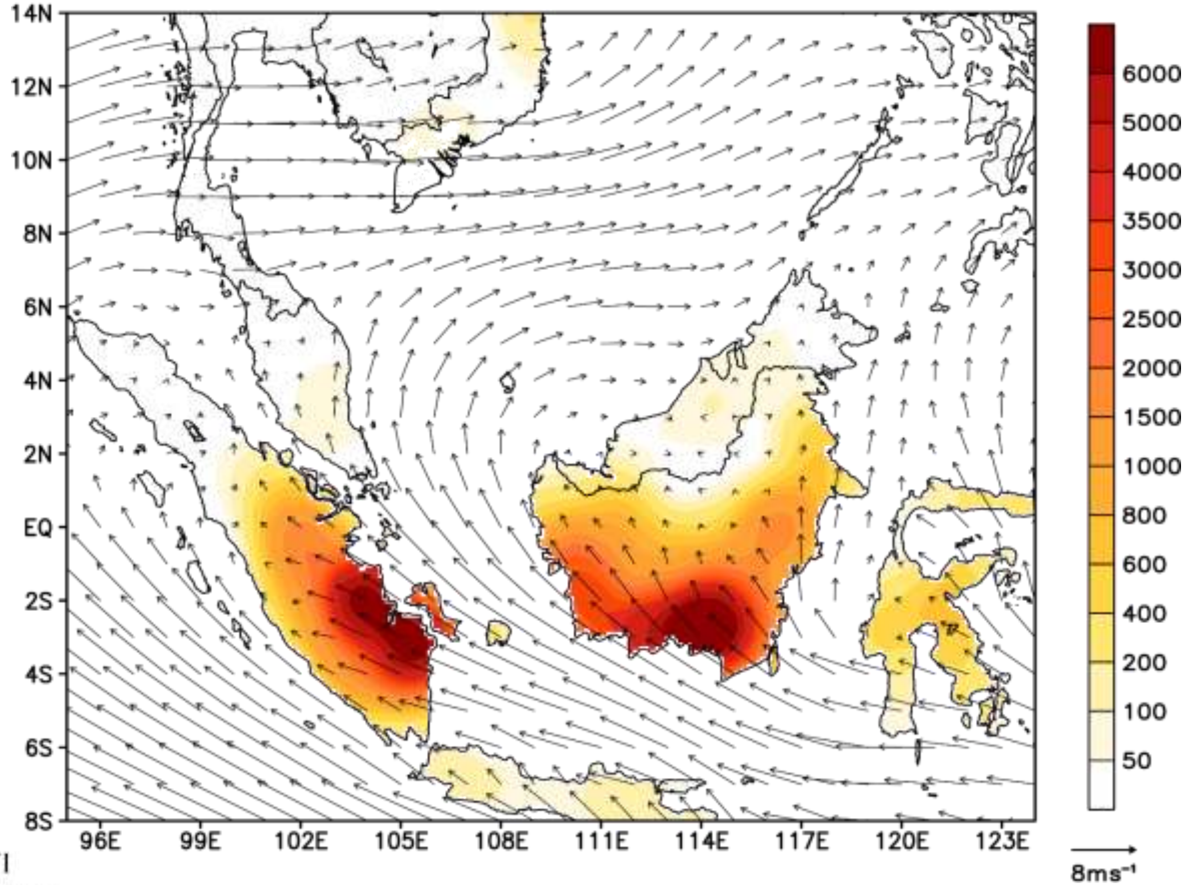
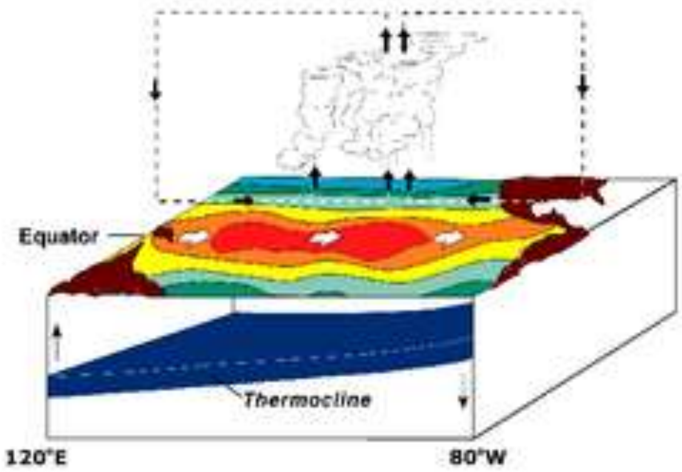
Atmospheric Chemistry and Air Pollution Research Group

Wind Direction – Southwest Monsoon

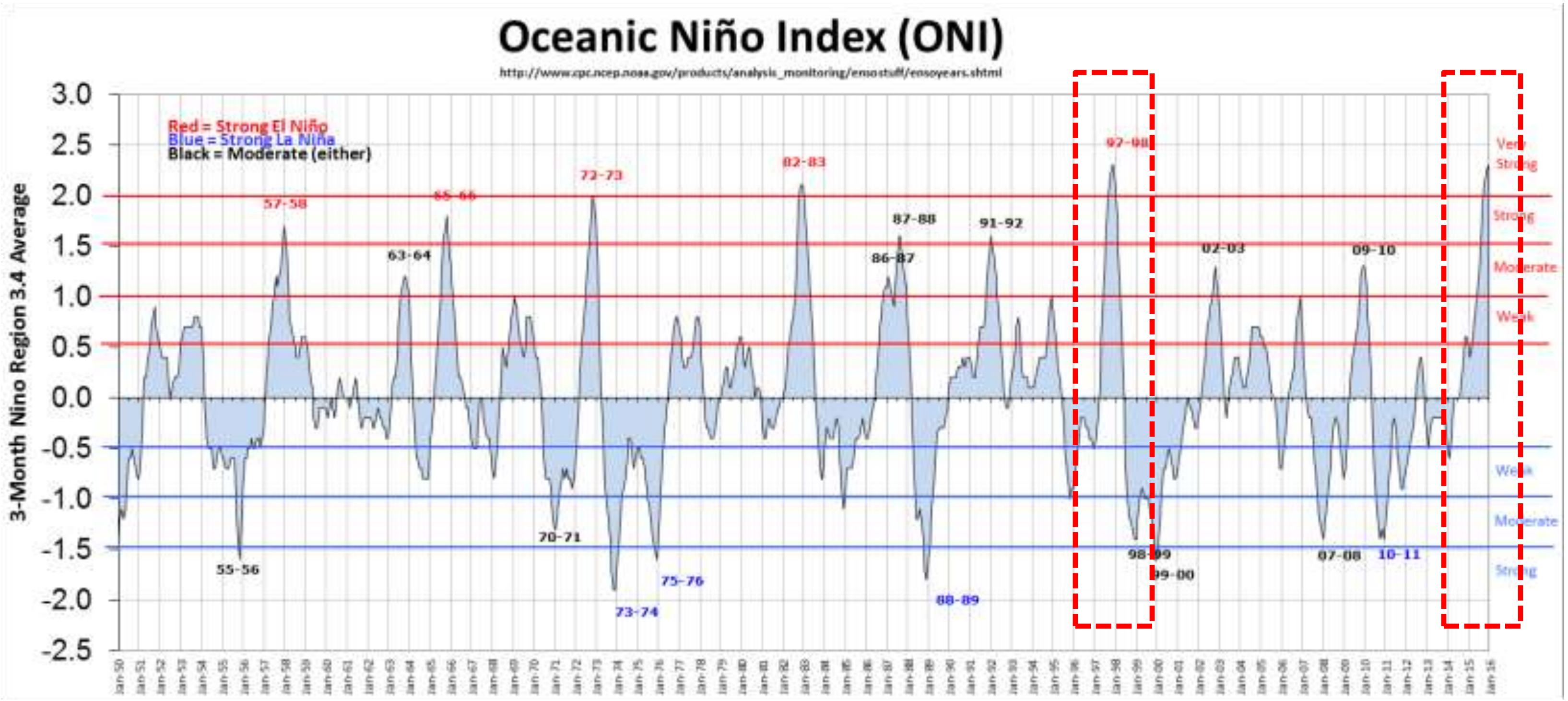


Trigger to Biomass Burning

- El Ni˜no–Southern Oscillation (ENSO) event have repeatedly created conditions that make even rainforest susceptible to wildfires.



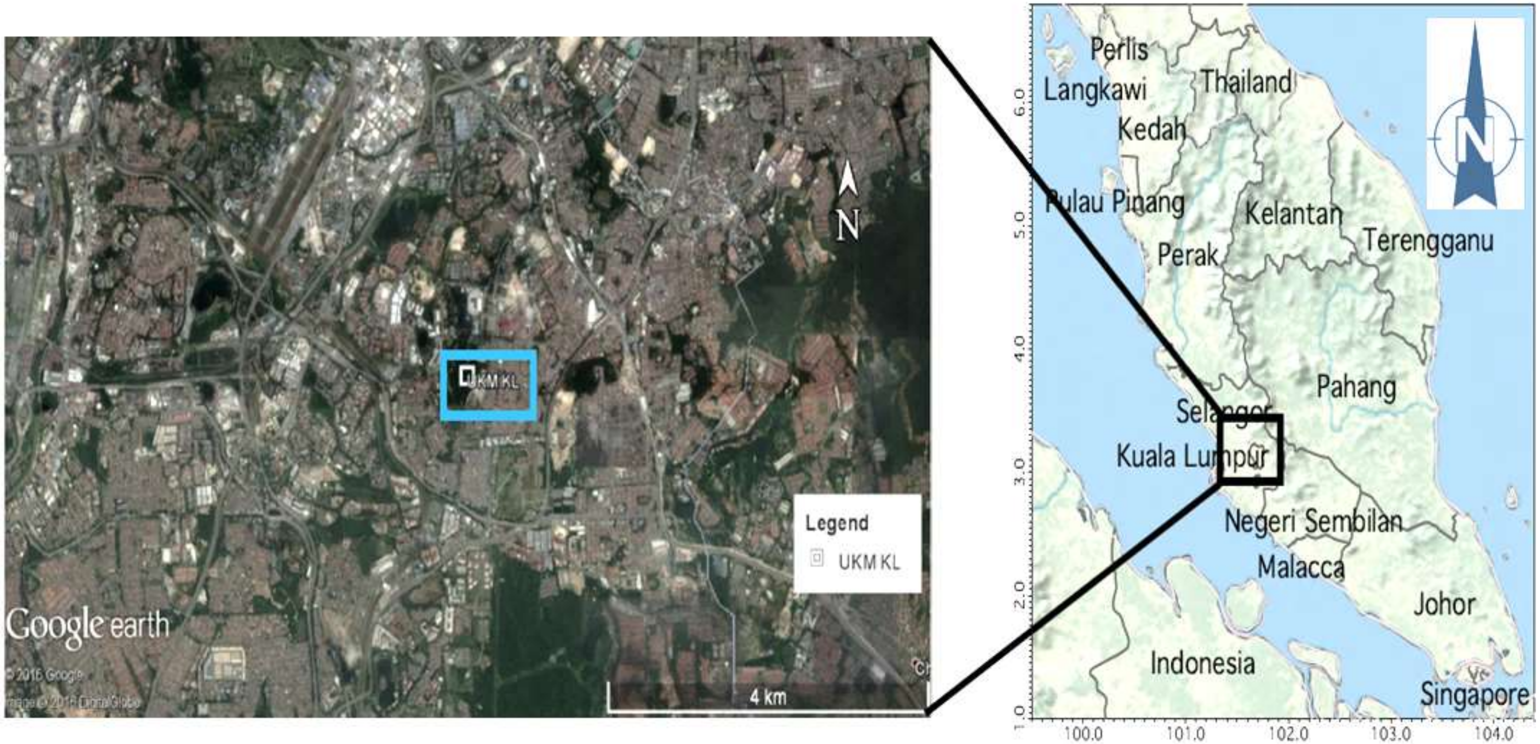
El-Niño and La-Niña



Research Objectives

- To determine the concentrations of $PM_{2.5}$ in Kuala Lumpur and its inorganic compositions during pre-haze, haze and post-haze periods.
- To predict the $PM_{2.5}$ concentration transported towards Kuala Lumpur using Numerical Atmospheric-dispersion Modelling Environment (NAME) together with the Global Fire Assimilation System (GFAS).
- To apportion possible sources of $PM_{2.5}$ using Positive Matrix Factorisation (PMF).
- To estimate the carcinogenic and non-carcinogenic health risks among specific age groups during pre-haze, haze and post-haze episodes.

Study Location



Sampling Site

- Kuala Lumpur located within the Klang Valley and situated in the middle of the west coast of the Malaysian Peninsular.
- In 2015, Kuala Lumpur had an estimated population of 1.78 million people in an area of just 243 km^2 with an average annual population growth rate of 2.4% (DOSM, 2016).
- The $PM_{2.5}$ aerosol sampling was conducted on the rooftop (30 m above ground level) of a building within the compound of Universiti Kebangsaan Malaysia Kuala Lumpur's campus.

$PM_{2.5}$ Sampling

- Tisch HVS $PM_{2.5}$
- Flowrate of 1.13 m^3 min^{-1}
- 24 h sampling/filter
- Quartz filter [Whatman QM-A; 8’ X 10’]
- June 2015– January 2016
- Nine samples per month

$PM_{2.5}$ Samples

$PM_{2.5}$ Mass

Microbalance

Major Ions

IC

Trace Metals

ICP-MS

Results Interpretation

Descriptive statistics
Source Apportionment (PMF-MLR)
Health Risk Assessment

Backward Trajectories

- Numerical Atmospheric-dispersion Modelling Environment (NAME), a Lagrangian particle dispersion model, produced by the United Kingdom's Met Office's.

- The backward trajectories started at the latitude-longitude coordinates of the measurement site in Kuala Lumpur within an altitude range of 0 – 100 m and ran for 5 days.

Modelled $PM_{2.5}$ concentration

- Global Fire Assimilation System (GFAS) $PM_{2.5}$ emissions data.
- This dataset relies on fire radiative power (FRP) observations obtained from the Terra and Aqua satellites - Moderate Resolution Imaging Spectroradiometer (MODIS) instruments.
- Combination of emission sensitivities derived from NAME with the GFAS emissions - modelled $PM_{2.5}$ concentration

Modelled $PM_{2.5}$ concentration

- Combination of emission sensitivities derived from NAME with the GFAS emissions - modelled $PM_{2.5}$ concentration

Mass/cubic meter ($\mu g\ m^{-3}$)

= Emission sensitivities ($s\ m^{-1}$) x GFAS emissions ($g\ m^{-2}\ s^{-1}$) x 10^6 ($\mu g\ g^{-1}$)

Source Apportionment of $PM_{2.5}$

- Positive Matrix Factorization (PMF) 5.0 model from the United States Environmental Protection Agency (US EPA).

$$X_{ij} = \sum_{i=1}^{p} g_{ik} f_{kj} + e_{ij}$$

Normalized data

Source profile

Source contribution

Measurement error

Other Air Pollutants and Meteorological Data

- Temperature, rainfall, relative humidity, visibility, wind speed and wind direction (MetMalaysia Petaling Jaya station, 9 km from the sampling station)
- Air Pollution Index (API) data was collected from Malaysian DOE (Batu Muda Station, 6 km from the sampling site)

Carcinogenic Metal Health Risk

Lifetime average daily dose (LADD) ($\mu g kg^{-1} day^{-1}$) = $\frac{C \times IR \times ED \times EF}{BW \times AT}$

C = Concentration of the contaminant in the atmosphere ($ng\ m^{-3}$),

IR = inhalation rate ($m^3\ day^{-1}$)

ED = exposure duration (years)

EF = exposure frequency ($day\ year^{-1}$)

BW = body weight (kg)

AT = averaging time (70 years x 365 days).

Excess lifetime cancer risk (ELCR Inhalation)

= LADD × inhalation unit risk $(\mu g\ m^{-3})^{-1}$

Non-Carcinogenic Metal Health Risk

Average daily dose ($mgkg^{-1}day^{-1}$) = $\frac{C \times IR \times ED \times EF}{BW \times AT}$

Hazard quotients (HQ) =ADD/RfC

ADD = average daily dose

RfC = reference concentration

HI = $\sum$ HQ

If the HQ ≤ 1, it is believed that there is no risk of developing non-cancer health effects.
Non-cancer effects may occur if the HQ > 1.

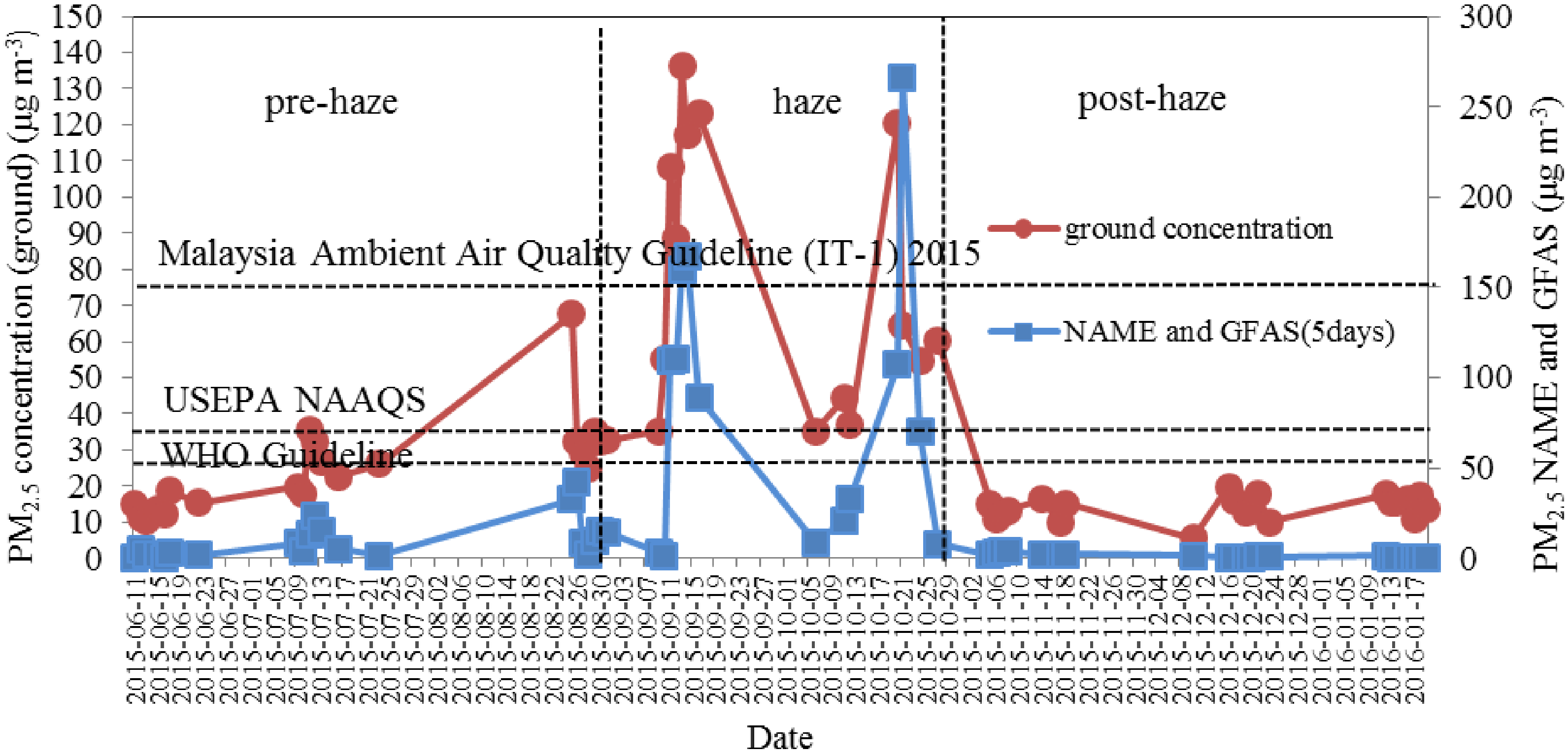
An adverse effect is deemed more likely to occur if the HQ value is larger.

Exposure factors for calculating the exposure dose in health risk assessment

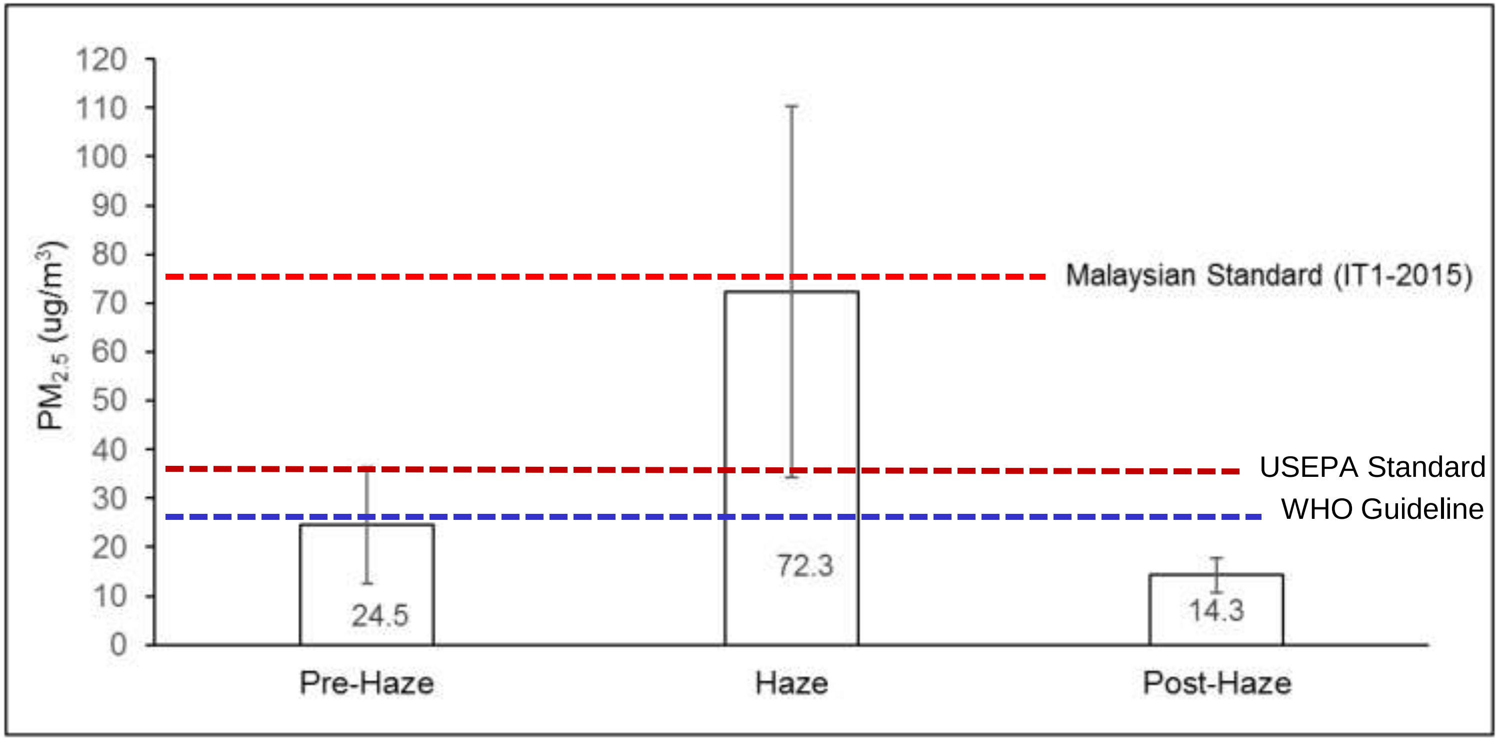
EP	Unit	Infant	Toddler	Children	Adolescent	Adult
		0-<1year	1-<6years	6-<12years	12-<18years	18-<70years
IR	m^3 day^{-1}	5.4	9	12	15.7	15.7
ED	years	1	5	6	6	52
EF	days $year^{-1}$	60[a], 305[b]	60, 305	60, 305	60, 305	60, 305
BW*	kg	7	15	31.2	38	66
AT	years	70**, 1***	70, 5	70, 6	70, 6	70, 52

* Adapted from National Health and Morbidity Survey III 2006 (NHMS III, 2008)
a exposure factors of haze episode
b exposure factors of non-haze episode
** AT for carcinogens (fixed at 70 years of exposure)
*** AT for non-carcinogens (average years of exposure)

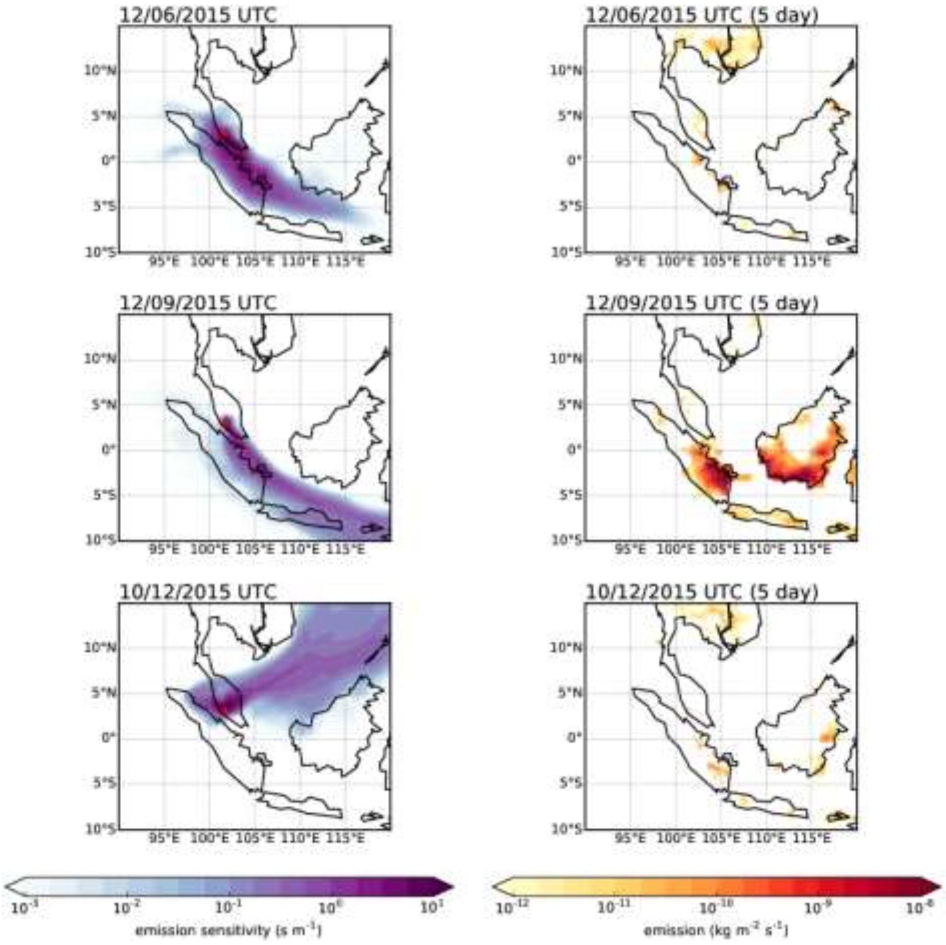
Measured HVS $PM_{2.5}$ vs Predicted NAME-GFAS $PM_{2.5}$



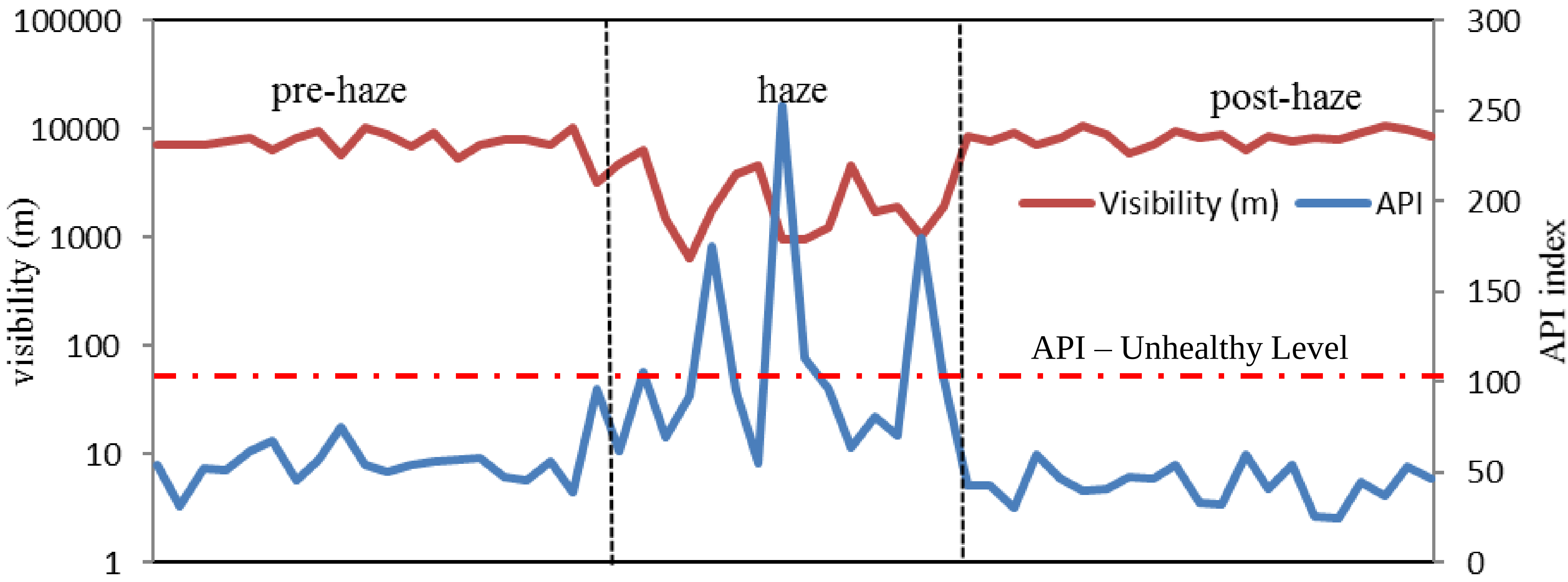
Average $PM_{2.5}$ Concentration



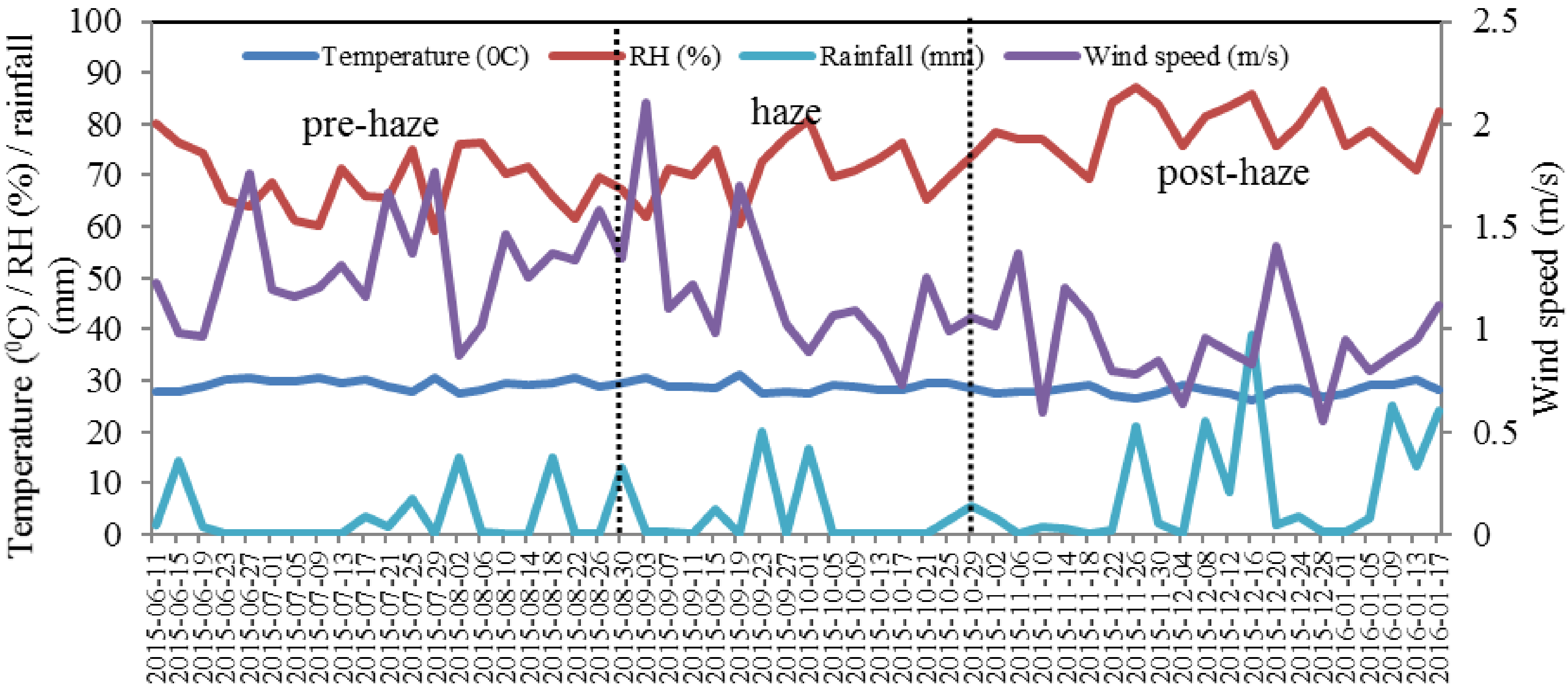
Emission Sensitivity and Emission



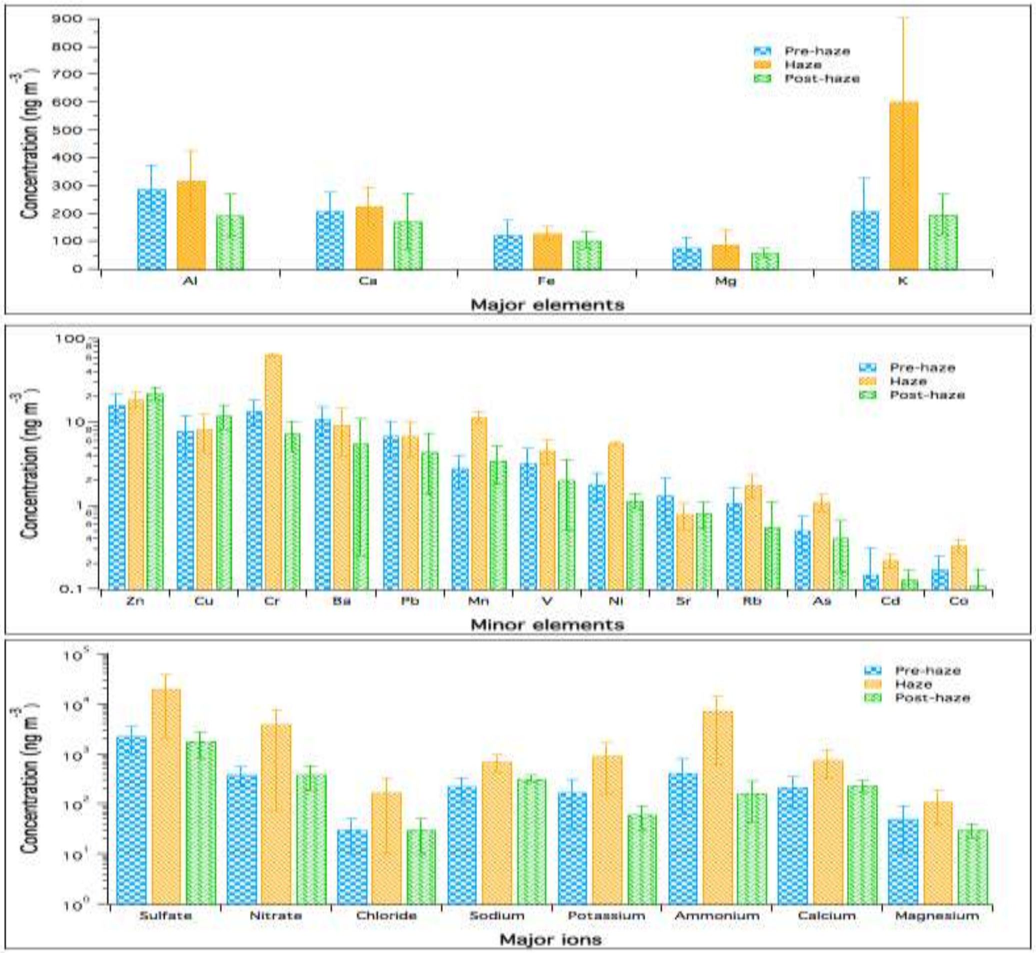
Visibility and API Index



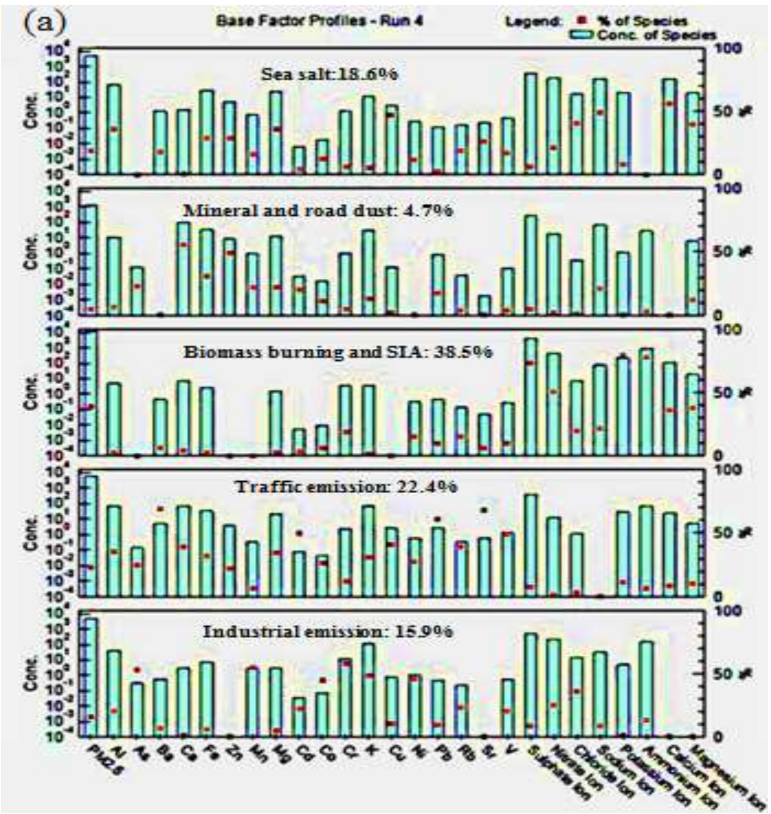
Other Meteorological Data

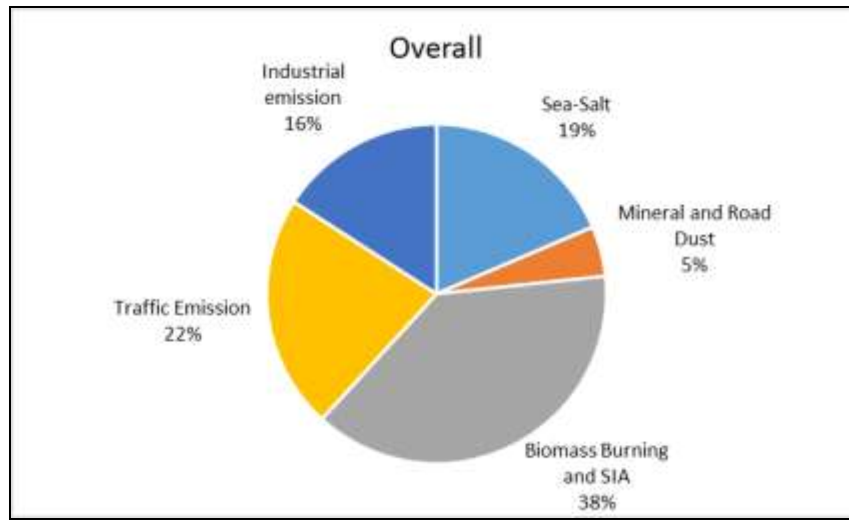


$PM_{2.5}$ Inorganic Composition



Source Apportionment -Overall





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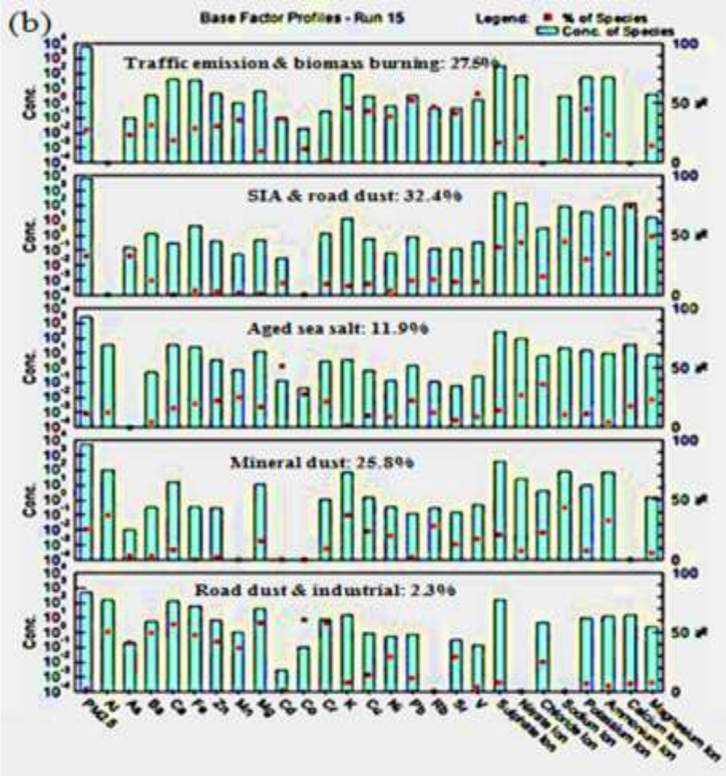
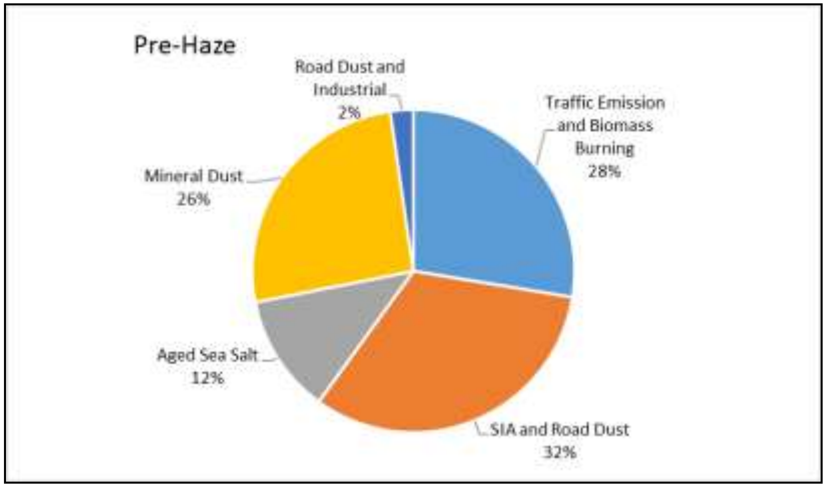
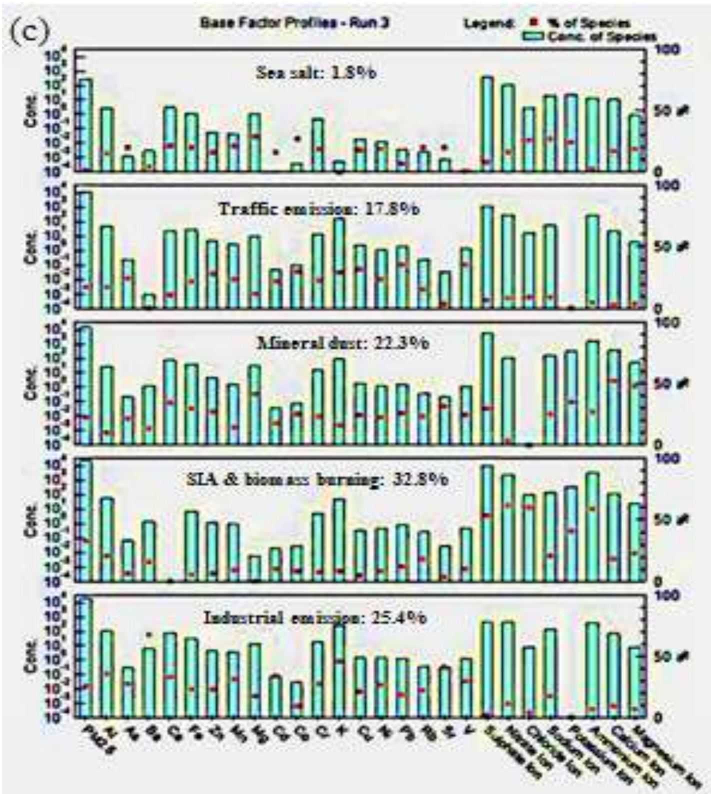
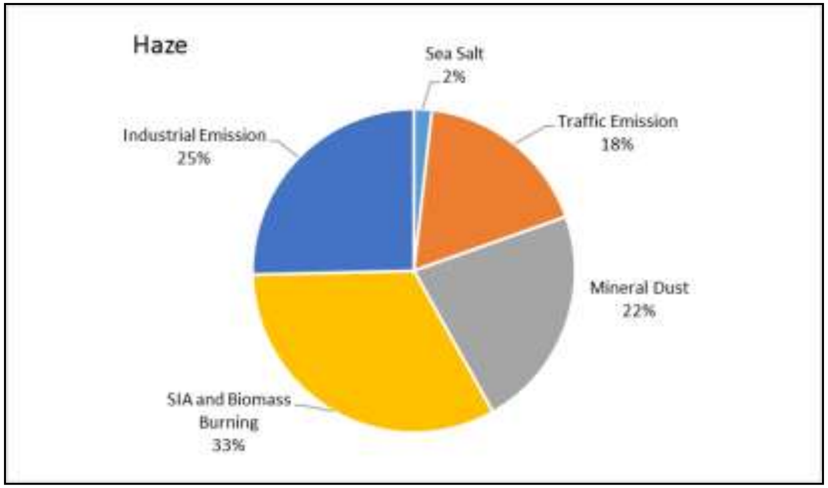
Source Apportionment –Pre-haze





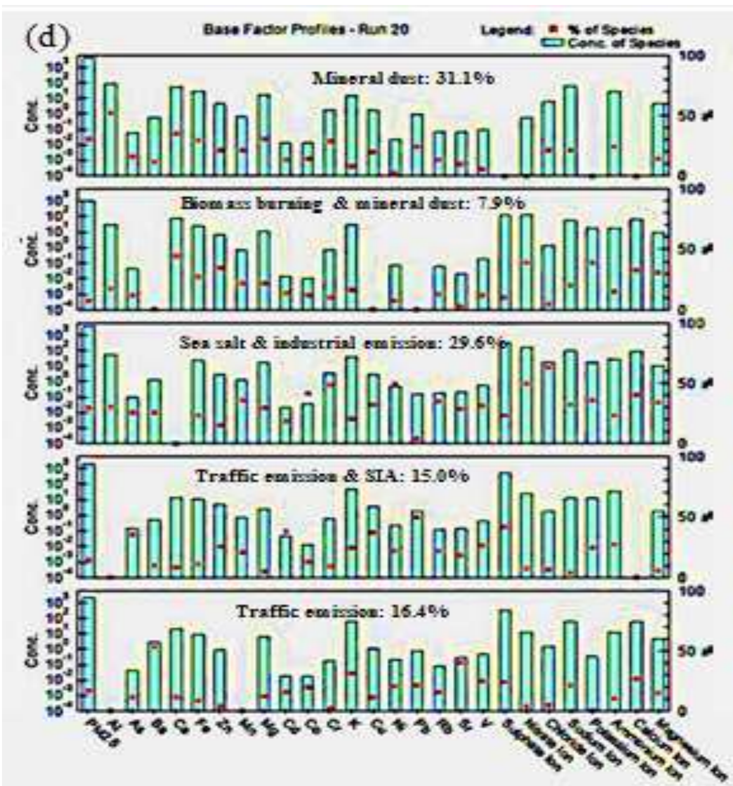
Source Apportionment –Haze

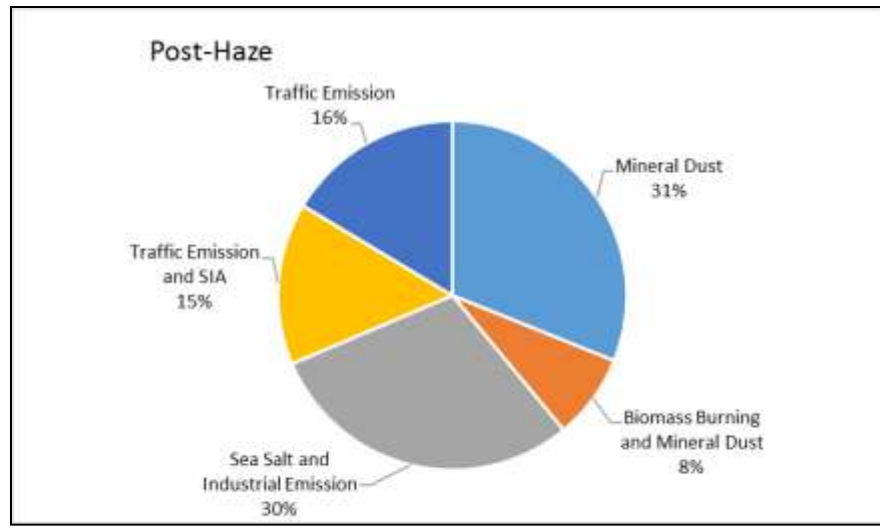




Atmosphere Investigation

Source Apportionment –Post-Haze





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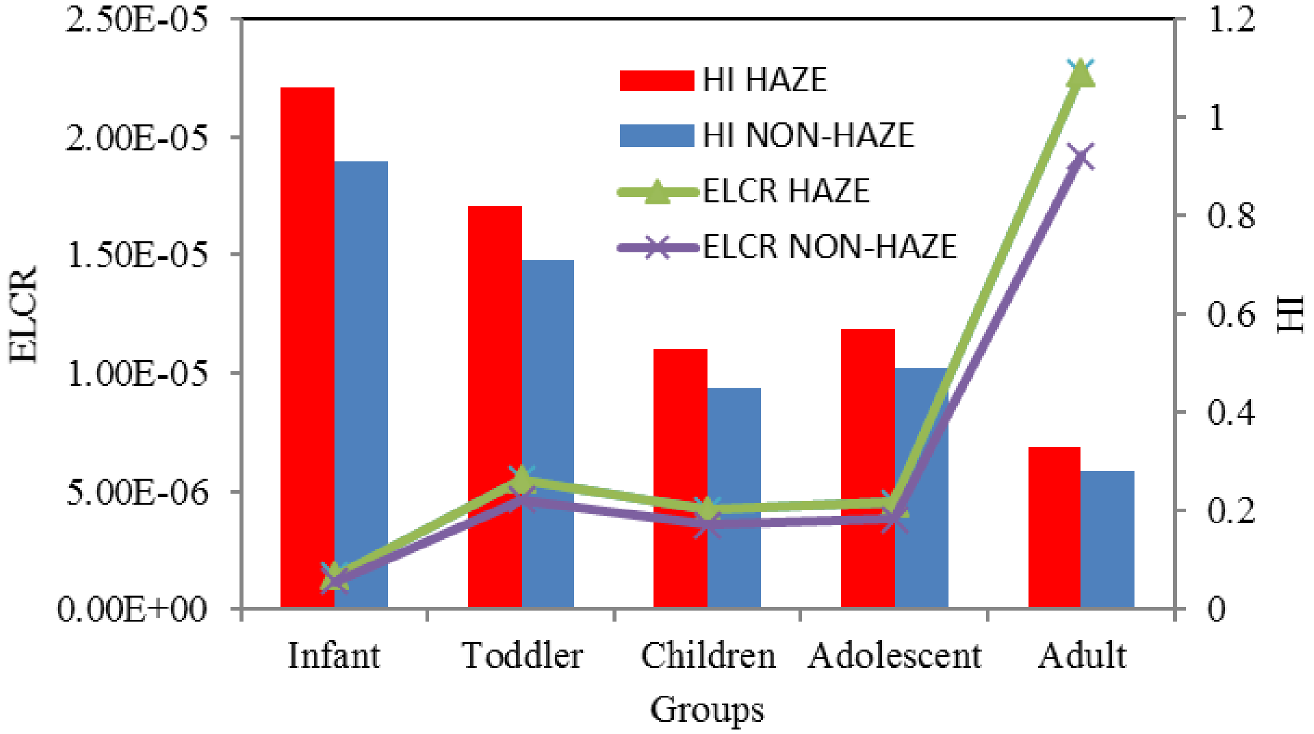
Hazard index (HI) and hazard quotient (HQ)

Elements	RfC (mg m^{-3})	HQ Infant 0-<1year	HQ Toddler 1-<6years	HQ Children 6-<12years	HQ Adolescent 12-<18years	HQ Adult 18-<70years
Pre-haze						
Cr	8.00×10^{-6}	1.10×10^{0}	8.59×10^{-1}	5.50×10^{-1}	5.91×10^{-1}	3.40×10^{-1}
Mn	5.00×10^{-5}	3.60×10^{-2}	2.80×10^{-2}	1.80×10^{-2}	1.93×10^{-2}	1.11×10^{-2}
Ni	2.00×10^{-4}	5.70×10^{-3}	4.46×10^{-3}	2.86×10^{-3}	3.07×10^{-3}	1.77×10^{-3}
Cd	1.00×10^{-5}	9.67×10^{-3}	7.52×10^{-3}	4.82×10^{-3}	5.18×10^{-3}	2.98×10^{-3}
As	5.00×10^{-5}	6.57×10^{-3}	5.11×10^{-3}	3.28×10^{-3}	3.52×10^{-3}	2.03×10^{-3}
∑HI		1.16	0.90	0.58	0.62	0.36
Haze						
Cr	8.00×10^{-6}	1.02×10^{0}	7.93×10^{-1}	5.08×10^{-1}	5.46×10^{-1}	3.14×10^{-1}
Mn	5.00×10^{-5}	2.94×10^{-2}	2.29×10^{-2}	1.47×10^{-2}	1.58×10^{-2}	9.07×10^{-3}
Ni	2.00×10^{-4}	3.51×10^{-3}	2.73×10^{-3}	1.75×10^{-3}	1.88×10^{-3}	1.08×10^{-3}
Cd	1.00×10^{-5}	2.79×10^{-3}	2.17×10^{-3}	1.39×10^{-3}	1.49×10^{-3}	8.60×10^{-4}
As	5.00×10^{-5}	2.81×10^{-3}	2.19×10^{-3}	1.40×10^{-3}	1.51×10^{-3}	8.68×10^{-4}
∑HI		1.06	0.82	0.53	0.57	0.33
Post-haze						
Cr	8.00×10^{-6}	5.87×10^{-1}	4.57×10^{-1}	2.93×10^{-1}	3.15×10^{-1}	1.81×10^{-1}
Mn	5.00×10^{-5}	4.53×10^{-2}	3.52×10^{-2}	2.26×10^{-2}	2.42×10^{-2}	1.40×10^{-2}
Ni	2.00×10^{-4}	3.67×10^{-3}	2.86×10^{-3}	1.83×10^{-3}	1.97×10^{-3}	1.13×10^{-3}
Cd	1.00×10^{-5}	8.38×10^{-3}	6.52×10^{-3}	4.18×10^{-3}	4.49×10^{-3}	2.58×10^{-3}
As	5.00×10^{-5}	5.29×10^{-3}	4.11×10^{-3}	2.63×10^{-3}	2.83×10^{-3}	1.63×10^{-3}
∑HI		0.65	0.51	0.32	0.35	0.20

∑HI	Haze	1.06	0.82	0.53	0.57	0.33
∑HI	Non-haze*	0.91	0.71	0.45	0.49	0.28

Excess lifetime cancer risks (ELCR) of carcinogenic

Elements	IUR $(\mu g\ m^{-3})^{-1}$	Excess lifetime cancer risk $(\mu g\ m^{-3})^{-1}$ Infant 0-<1year	Toddler 1-<6years	Children 6-<12years	Adolescent 12-<18years	Adult 18-<70years
Pre-haze						
Pb	1.20×10^{-5}	7.53×10^{-10}	2.93×10^{-9}	2.25×10^{-9}	2.42×10^{-9}	1.21×10^{-8}
Cd	1.80×10^{-3}	2.49×10^{-9}	9.67×10^{-9}	7.44×10^{-9}	8.00×10^{-9}	4.00×10^{-8}
Cr	1.20×10^{-2}	1.51×10^{-6}	5.89×10^{-6}	4.53×10^{-6}	4.86×10^{-6}	2.43×10^{-5}
Ni	2.40×10^{-4}	3.93×10^{-9}	1.53×10^{-8}	1.18×10^{-8}	1.26×10^{-8}	6.31×10^{-8}
As	4.30×10^{-3}	2.02×10^{-8}	7.85×10^{-8}	6.04×10^{-8}	6.49×10^{-8}	3.24×10^{-7}
Co	9.00×10^{-3}	1.41×10^{-8}	5.48×10^{-8}	4.22×10^{-8}	4.53×10^{-8}	2.26×10^{-7}
∑		1.56×10^{-6}	6.05×10^{-6}	4.65×10^{-6}	5.00×10^{-6}	2.49×10^{-5}
Haze						
Pb	1.20×10^{-5}	1.50×10^{-10}	5.83×10^{-10}	4.49×10^{-10}	4.82×10^{-10}	2.41×10^{-9}
Cd	1.80×10^{-3}	7.17×10^{-10}	2.79×10^{-9}	2.15×10^{-9}	2.31×10^{-9}	1.15×10^{-8}
Cr	1.20×10^{-2}	1.40×10^{-6}	5.44×10^{-6}	4.18×10^{-6}	4.49×10^{-6}	2.24×10^{-5}
Ni	2.40×10^{-4}	2.41×10^{-9}	9.37×10^{-9}	7.21×10^{-9}	7.74×10^{-9}	3.86×10^{-8}
As	4.30×10^{-3}	8.65×10^{-9}	3.36×10^{-8}	2.59×10^{-8}	2.78×10^{-8}	1.39×10^{-7}
Co	9.00×10^{-3}	5.38×10^{-9}	2.09×10^{-8}	1.61×10^{-8}	1.73×10^{-8}	8.63×10^{-8}
∑		1.42×10^{-6}	5.50×10^{6}	4.23×10^{-6}	4.55×10^{-6}	2.27×10^{-5}
Post-haze						
Pb	1.20×10^{-5}	4.91×10^{-10}	1.91×10^{-9}	1.47×10^{-9}	1.58×10^{-9}	7.87×10^{-9}
Cd	1.80×10^{-3}	2.15×10^{-9}	8.38×10^{-9}	6.45×10^{-9}	6.92×10^{-9}	3.46×10^{-8}
Cr	1.20×10^{-2}	8.06×10^{-7}	3.13×10^{-6}	2.41×10^{-6}	2.59×10^{-6}	1.29×10^{-5}
Ni	2.40×10^{-4}	2.52×10^{-9}	9.80×10^{-9}	7.54×10^{-9}	8.10×10^{-9}	4.04×10^{-8}
As	4.30×10^{-3}	1.62×10^{-8}	6.31×10^{-8}	4.86×10^{-8}	5.22×10^{-8}	2.60×10^{-7}
Co	9.00×10^{-3}	8.29×10^{-9}	3.22×10^{-8}	2.48×10^{-8}	2.66×10^{-8}	1.33×10^{-7}
∑		8.35×10^{-7}	3.25×10^{-6}	2.50×10^{-6}	2.68×10^{-6}	1.34×10^{-5}
∑ ELCR	Haze	1.42×10^{-6}	5.50×10^{-6}	4.23×10^{-6}	4.55×10^{-6}	2.27×10^{-5}
∑ ELCR	Non-haze*	1.20×10^{-6}	4.65×10^{-6}	3.58×10^{-6}	3.84×10^{-6}	1.92×10^{-5}


2.50E-05
2.00E-05
1.50E-05
1.00E-05
5.00E-06
0.00E+00
ELCR
HI HAZE
HI NON-HAZE
ELCR HAZE
ELCR NON-HAZE
1.2
1
0.8
0.6
0.4
0.2
0
HI
Infant
Toddler
Children
Adolescent
Adult
Groups

Conclusion

- $PM_{2.5}$ mass collected during pre-haze (24.5±12.0 µg m^{-3}), haze (72.3±38.0 µg m^{-3}), and post-haze (14.3±3.58 µg m^{-3} events in Kuala Lumpur were significantly different ($p < 0.005$)

- The highest concentration of $PM_{2.5}$ during haze episode - 5 times higher than WHO guidelines, 3.9 times higher than the US EPA standards and 1.8 times higher than the Malaysian Ambient Air Quality Standards 2015 (IT-1)

- The concentration of $PM_{2.5}$ recorded during the haze episode had a good correlation with the Malaysian Air Pollutants Index (API) ($r = 0.466$; $p < 0.05$) and significantly reduce the visibility ($r = -0.631$; $p = 0.005$).

Conclusion

- The SIA (SO_4^{2-}, NO_3^- and NH_4^+) dominated the composition of $PM_{2.5}$ - contribute to 43% inorganic composition of $PM_{2.5}$ mass during haze compared to pre-haze and post-haze, where they only contributed 12% and 16%, respectively.
- The overall dominant sources of $PM_{2.5}$ in Kuala Lumpur urban environment were SIA and biomass burning (38.5%); and traffic emission (22.4%).

Conclusion

- The non-carcinogenic health risk assessment - infant group faced more significant health risk than the other age groups during haze (HI = 1.06).
- The carcinogenic health risk assessment - adult group is the most affected group for haze exposure (ECLR= 2.27×10^{-5})
- The lowest ELCR estimation was posed by the infant group during non-haze (1.20×10^{-6}) indicating that 1 – 2 individuals in 1,000,000 are likely to develop cancer in their lifetime due to exposure of urban $PM_{2.5}$ aerosols.

Atmosphere Investigation

Further reading….

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Source apportionment and health risk assessment among specific age groups during haze and non-haze episodes in Kuala Lumpur, Malaysia

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ABSTRACT

This study aims to determine $PM_{2.5}$ concentrations and their composition during haze and non-haze episodes in Kuala Lumpur. In order to investigate the origin of the measured air masses, the Numerical Atmospheric-dispersion Modelling Environment (NAME) and Global Fire Assimilation System (GFAS) were applied. Source apportionment of $PM_{2.5}$ was determined using Positive Matrix Factorization (PMF). The carcinogenic and non-carcinogenic health risks were estimated using the United State Environmental Protection Agency (USEPA) method. $PM_{2.5}$ samples were collected from the centre of the city using a high-volume air

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- United Kingdom’s Met Office for NAME Model

THANK YOU