The Impact of Forest Fires on Air Quality in South-East Asia

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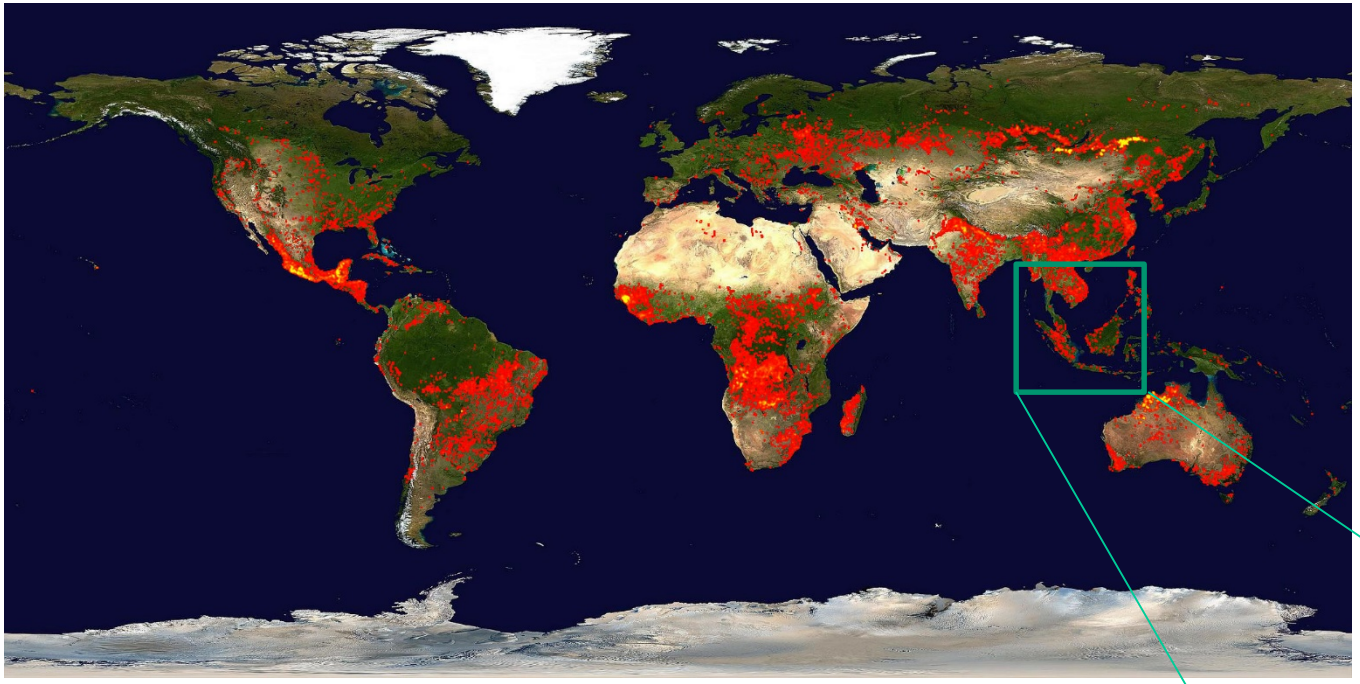
Introduction



Southeast Asia

Ichoku and Kahn (2012)

Land-use changes

Slash and burn

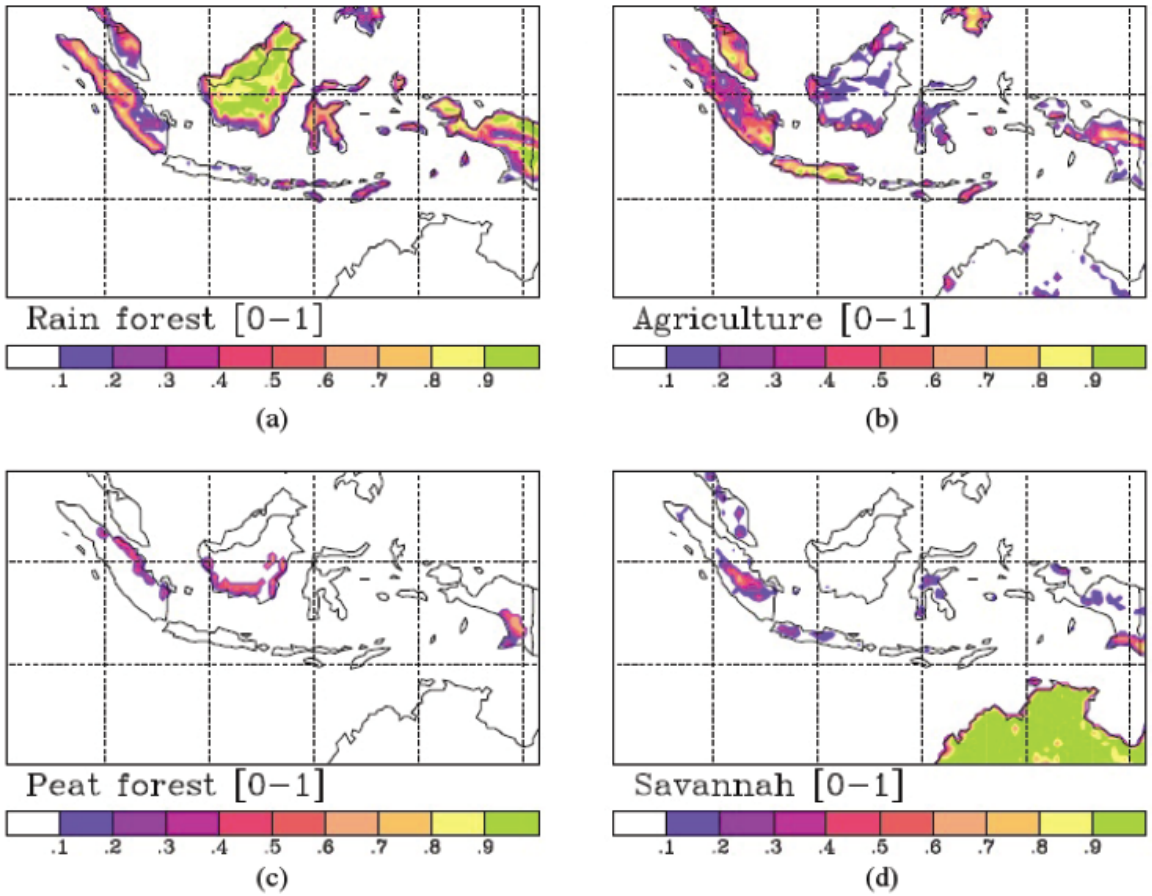
Peat combustion

Burning within oil palm plantation

Local anthropogenic activities

Biomass burning in Southeast Asia

Distribution of the major vegetation classes



REMO model domain in fraction (0–1) per model grid cell (0.5° · 0.5°)

Langmann and Heil (2004)

Forest Fire (Bangkok Post, 3rd March 2018)

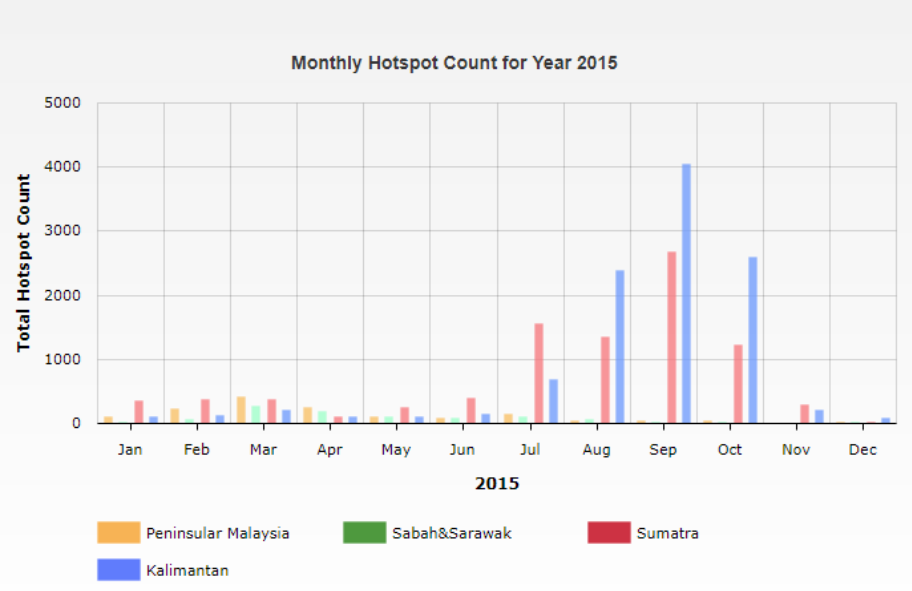
Bush Fire

Agricultural Burning (Kanokkanjana et al 2011)

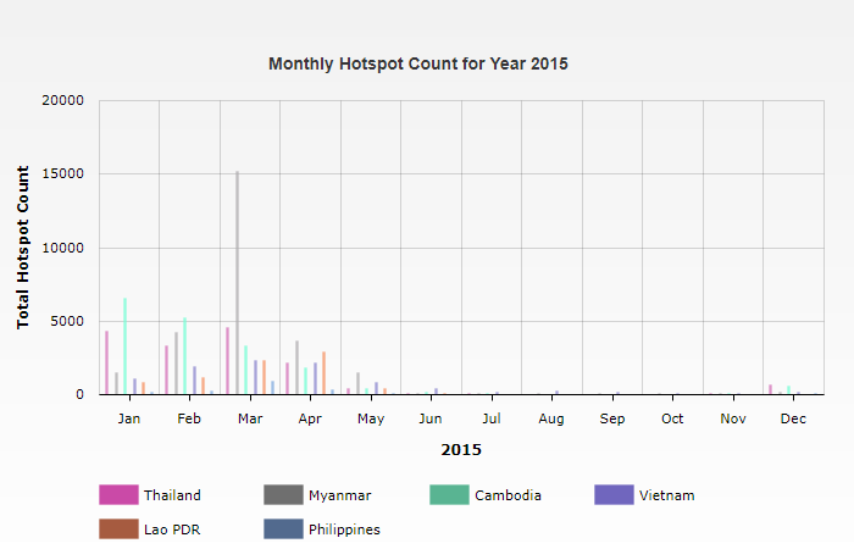
Peat Combustion during Dry Weather Condition

Monthly hotspot counts in 2015

South ASEAN

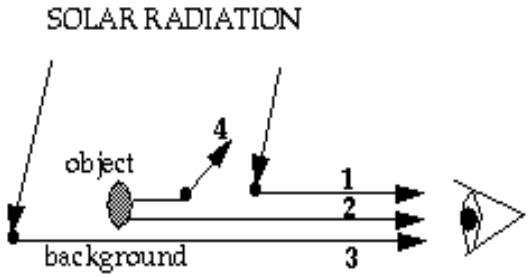


North ASEAN



Haze Phenomenon

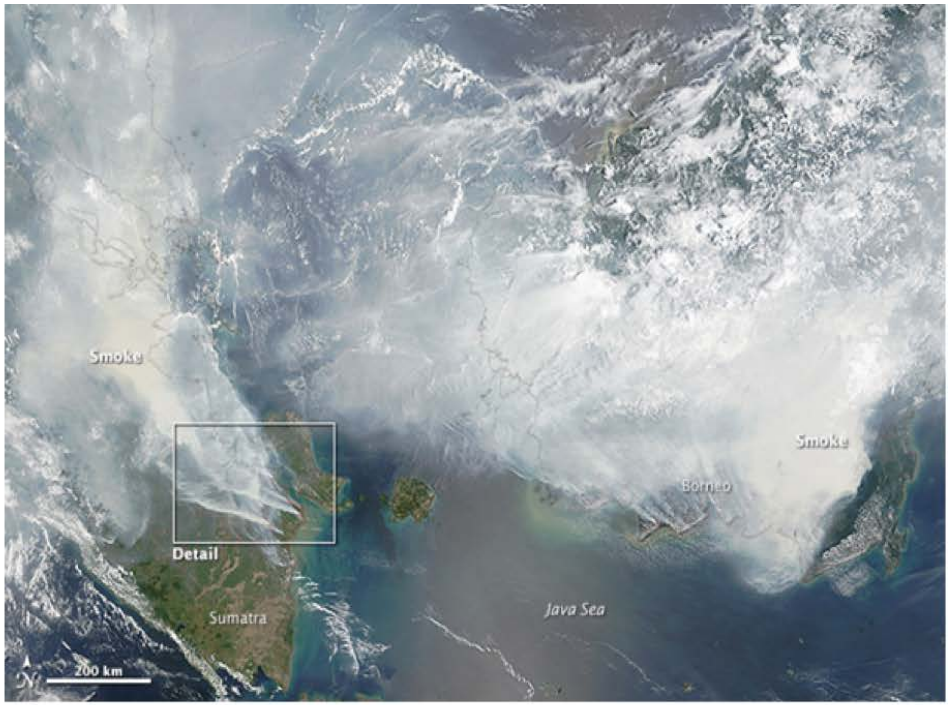
Haze is a phenomenon that occurs when a sufficient concentration of aerosols in the atmosphere scatter visible light and this results in a measurable reduction in visual range (Seinfeld and Pandis, 2006)



- Visibility < 10 km
- Dry/Low humidity (< 80%)

Source of Haze Based on Satellite Image

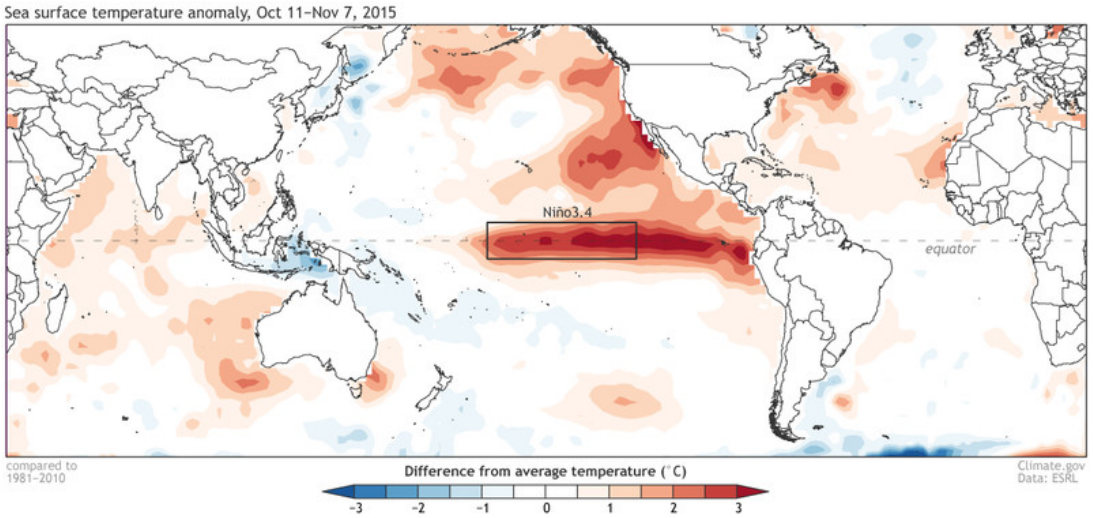
a) Satellite image during haze episode in 2001 (NASA 2016)

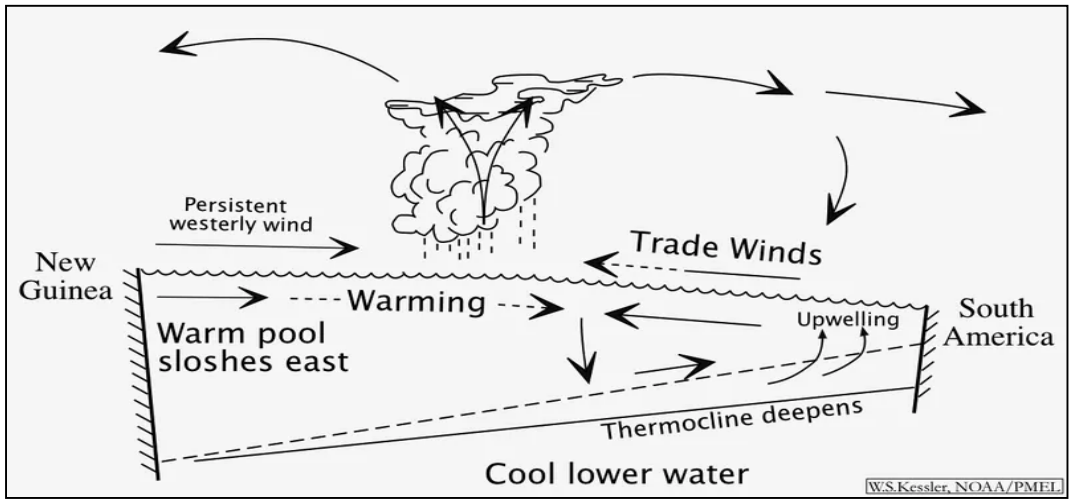


b) Haze episode in September 2015 (NASA 2015)

EL NI˜NO–SOUTHERN OSCILLATION (ENSO)

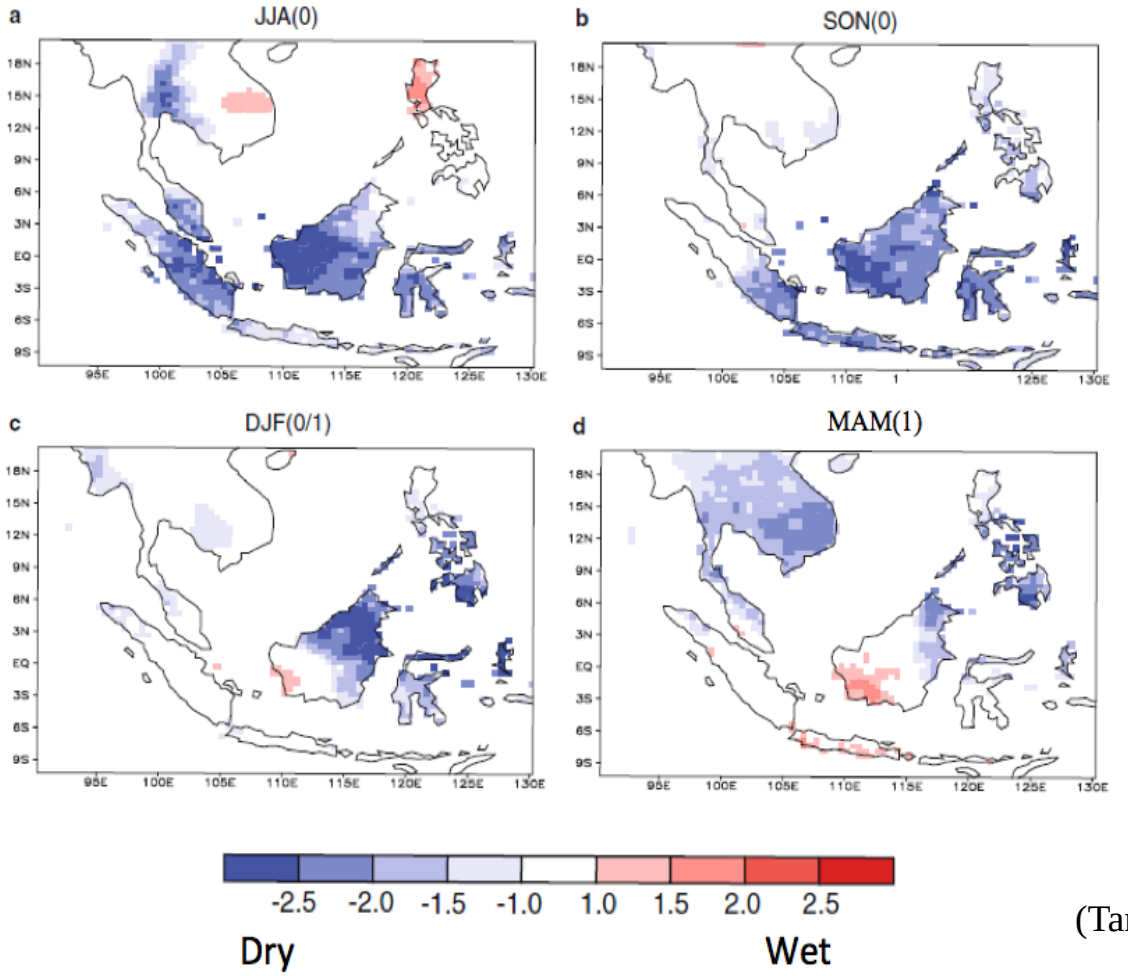
El Ni˜no


Sea surface temperature anomaly, Oct 11–Nov 7, 2015
Niño3.4
equator
compared to 1981–2010
Difference from average temperature (°C)
−3 −2 −1 0 1 2 3
Climate.gov
Data: ESRL


Persistent westerly wind
Trade Winds
New Guinea
Warming
Warm pool sloshes east
Upwelling
South America
Thermocline deepens
Cool lower water
W.S.Kessler, NOAA/PMEL

Rainfall Anomaly Patterns

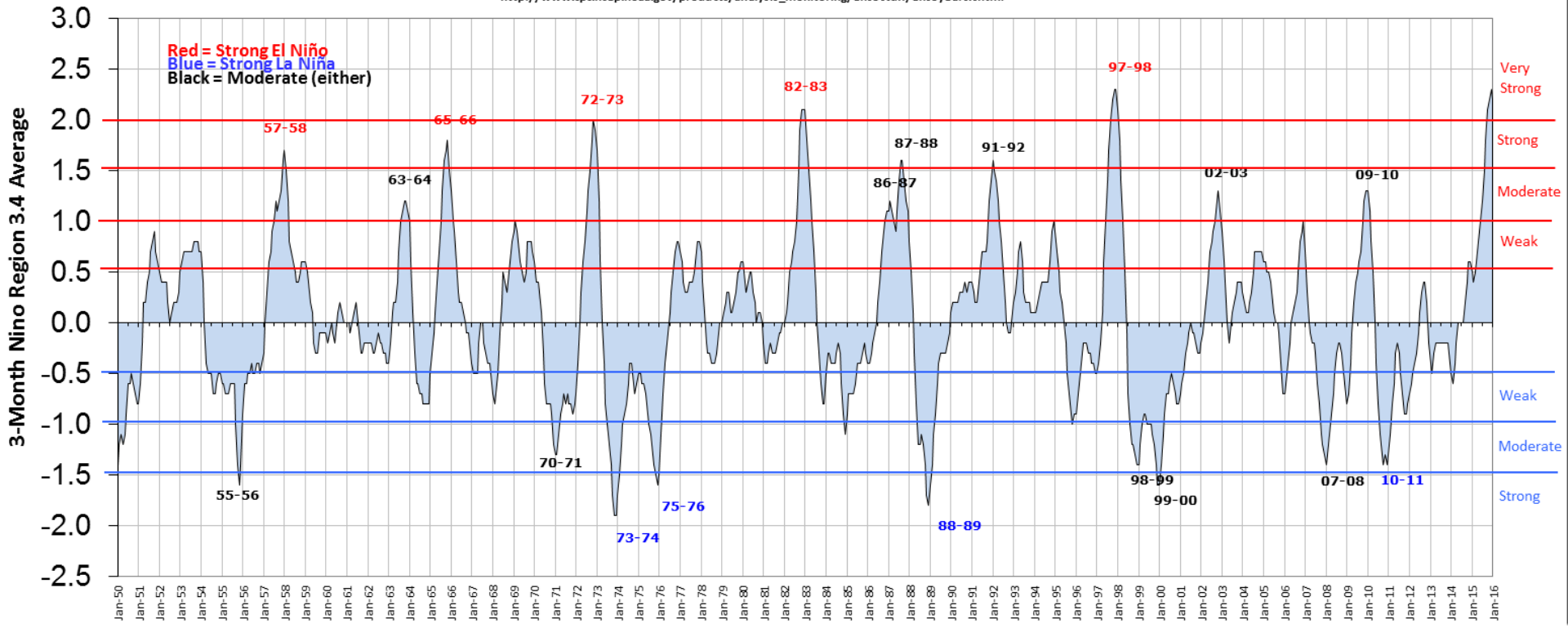
El-Niño – Southern Oscillation (ENSO)



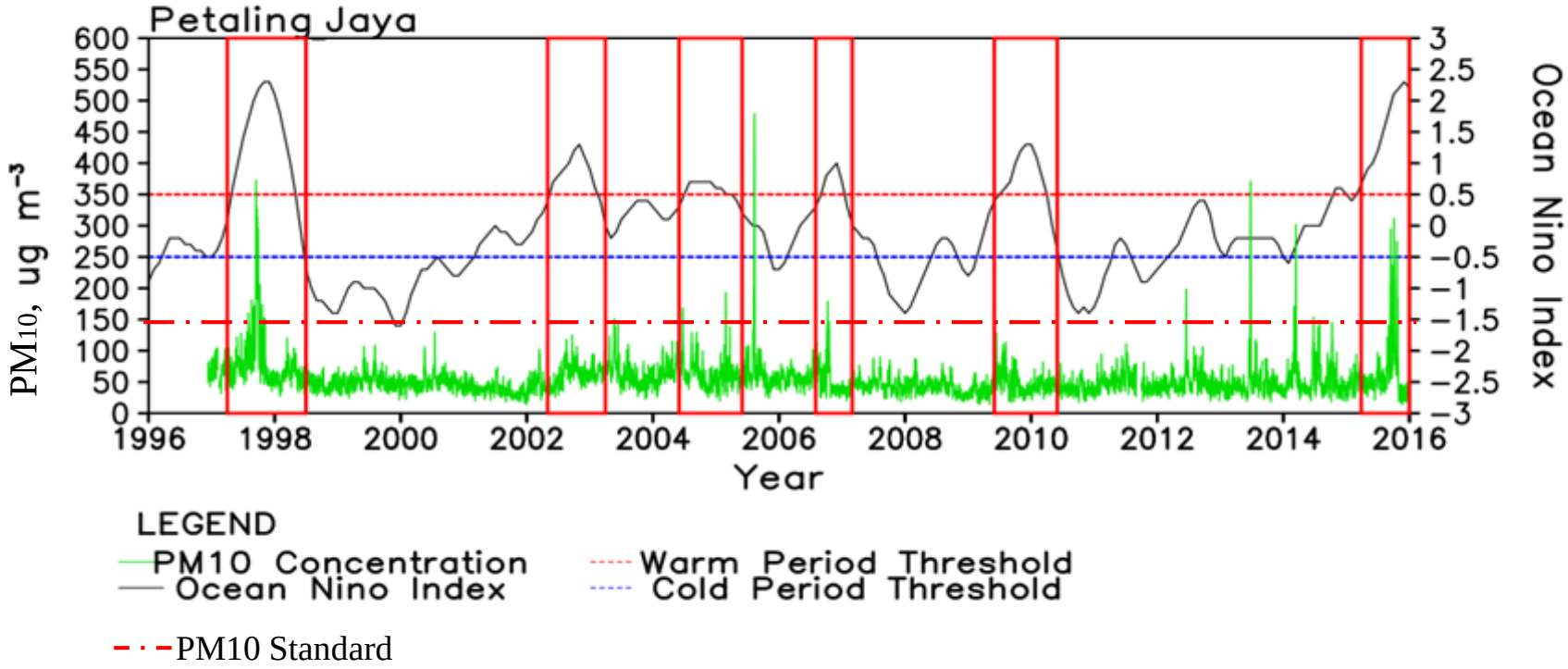
(Tangang et al. 2010)

Oceanic Niño Index (ONI)

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

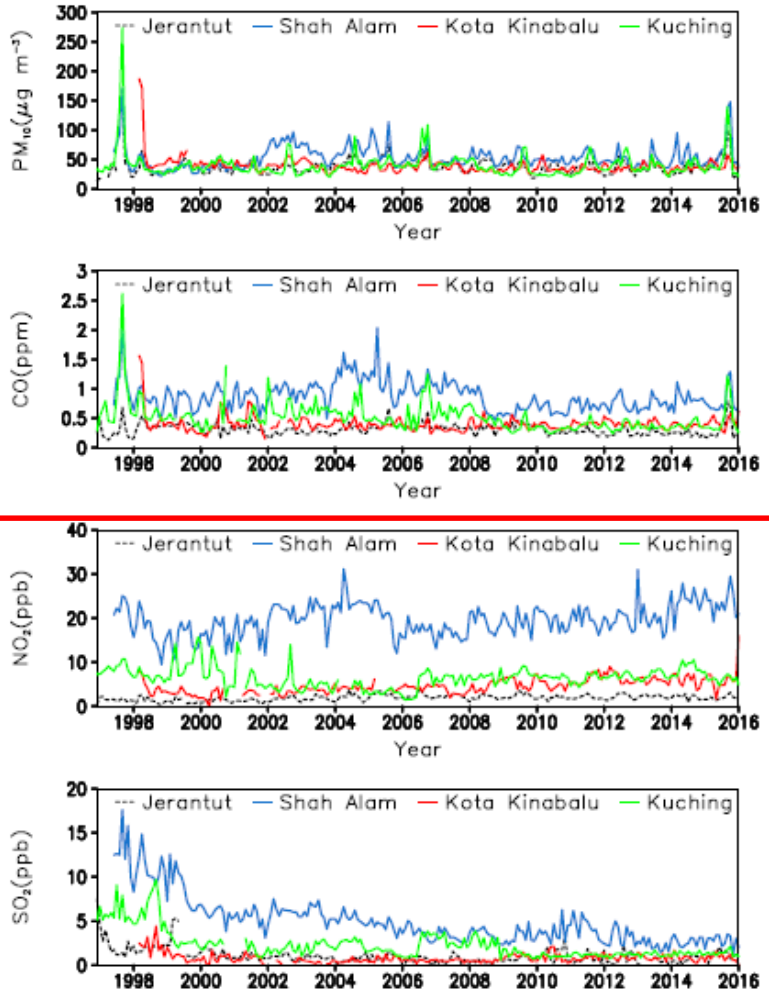


PM_{10} Concentration in Petaling Jaya during El-Niño and La-Niña

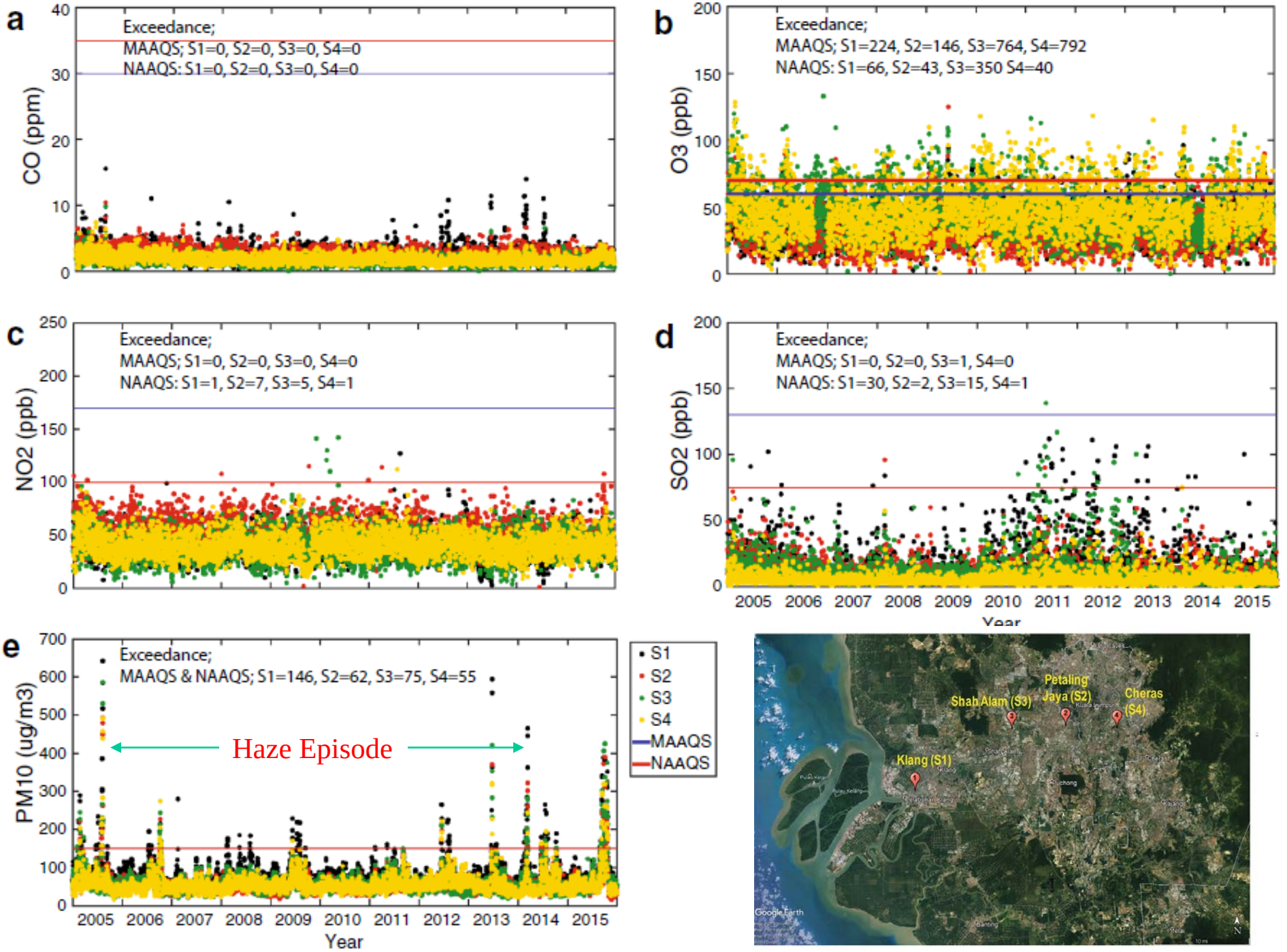


CONCENTRATION OF MAJOR AIR POLLUTANTS

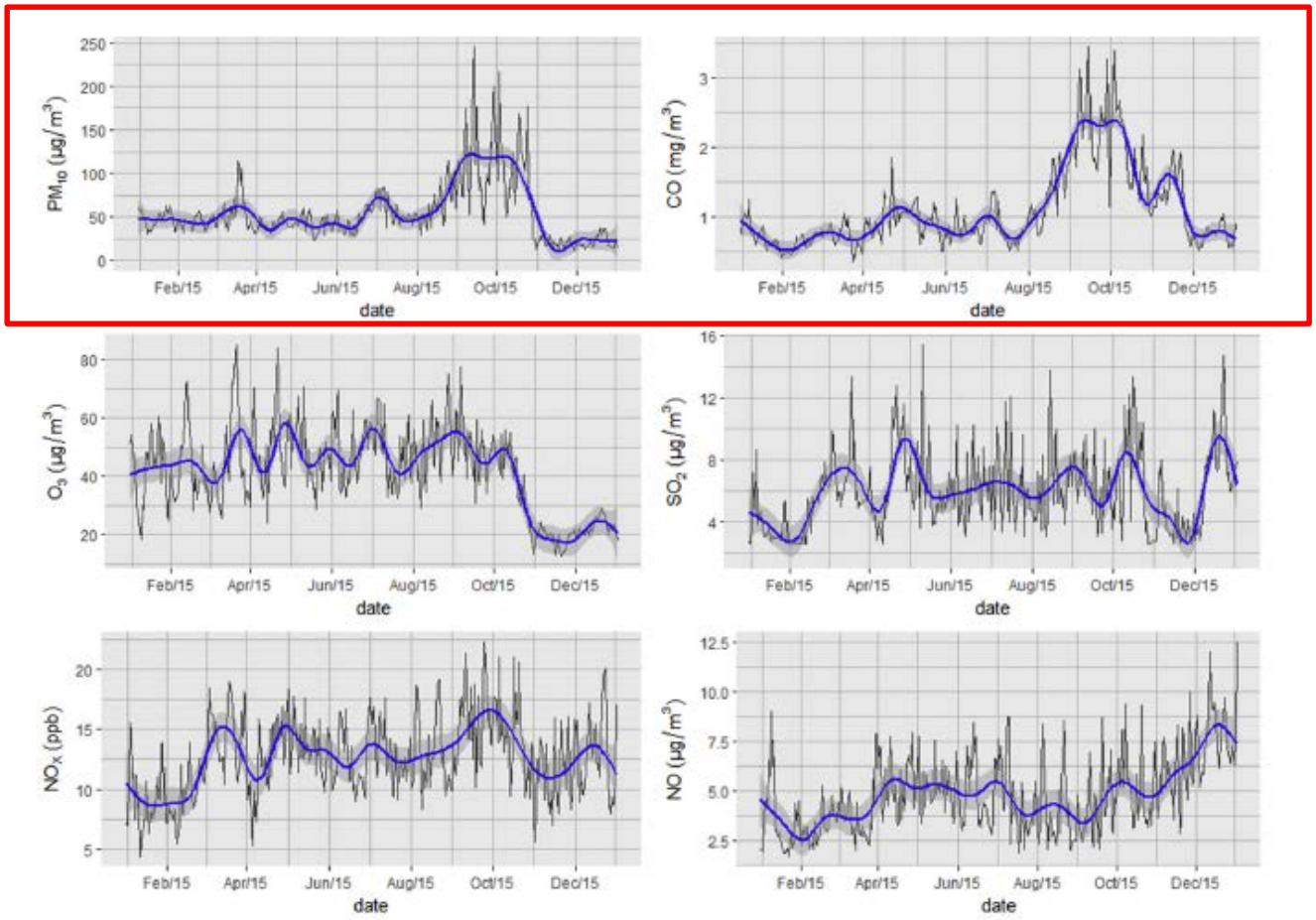
Atmosphere Investigation



(Latif et al. 2018, Atmos Env))

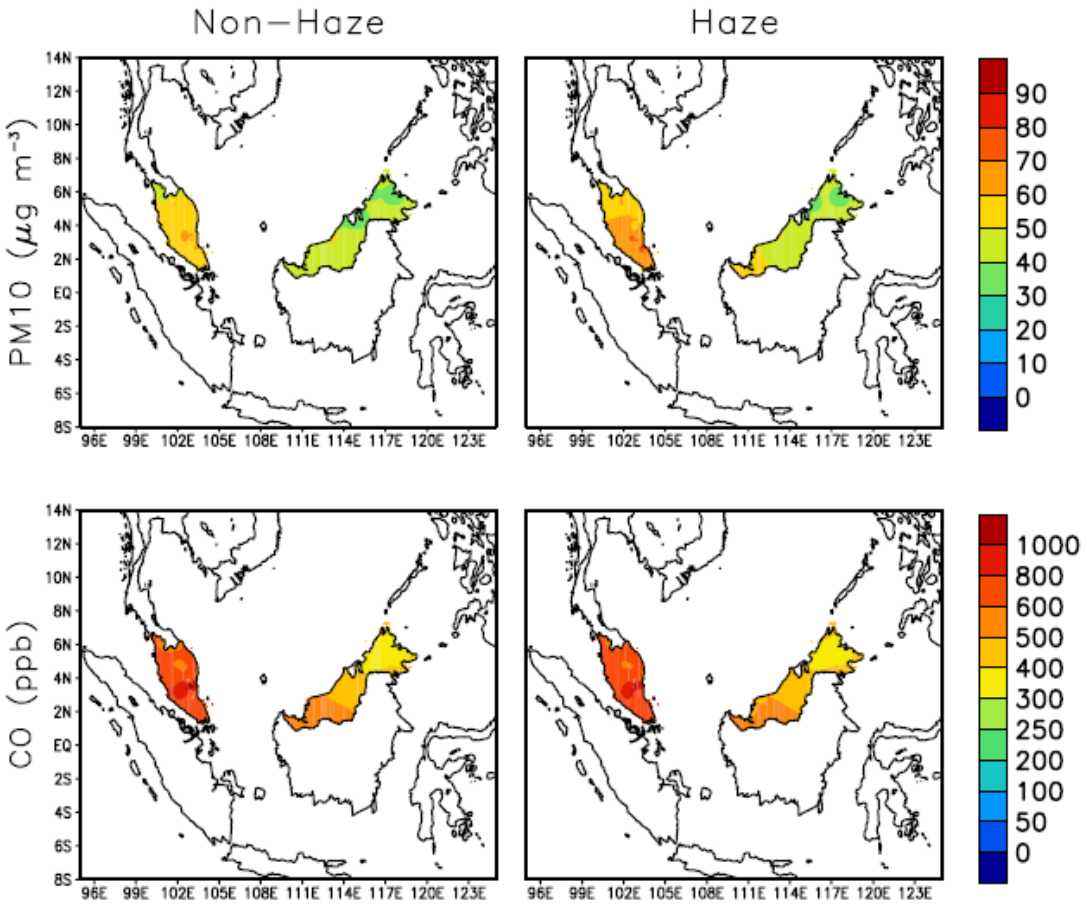

a
Exceedance;
MAAQS; S1=0, S2=0, S3=0, S4=0
NAAQS: S1=0, S2=0, S3=0, S4=0
CO (ppm)
b
Exceedance;
MAAQS; S1=224, S2=146, S3=764, S4=792
NAAQS: S1=66, S2=43, S3=350 S4=40
O3 (ppb)
c
Exceedance;
MAAQS; S1=0, S2=0, S3=0, S4=0
NAAQS: S1=1, S2=7, S3=5, S4=1
NO2 (ppb)
d
Exceedance;
MAAQS; S1=0, S2=0, S3=1, S4=0
NAAQS: S1=30, S2=2, S3=15, S4=1
SO2 (ppb)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Year
e
Exceedance;
MAAQS & NAAQS; S1=146, S2=62, S3=75, S4=55
Haze Episode
S1
S2
S3
S4
MAAQS
NAAQS
PM10 (ug/m3)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Year
Shah Alam (S3)
Petaling Jaya (S2)
Cheras (S4)
Klang (S1)
Google Earth

Haze 2015 (Muar station, Southern region of Peninsular Malaysia)



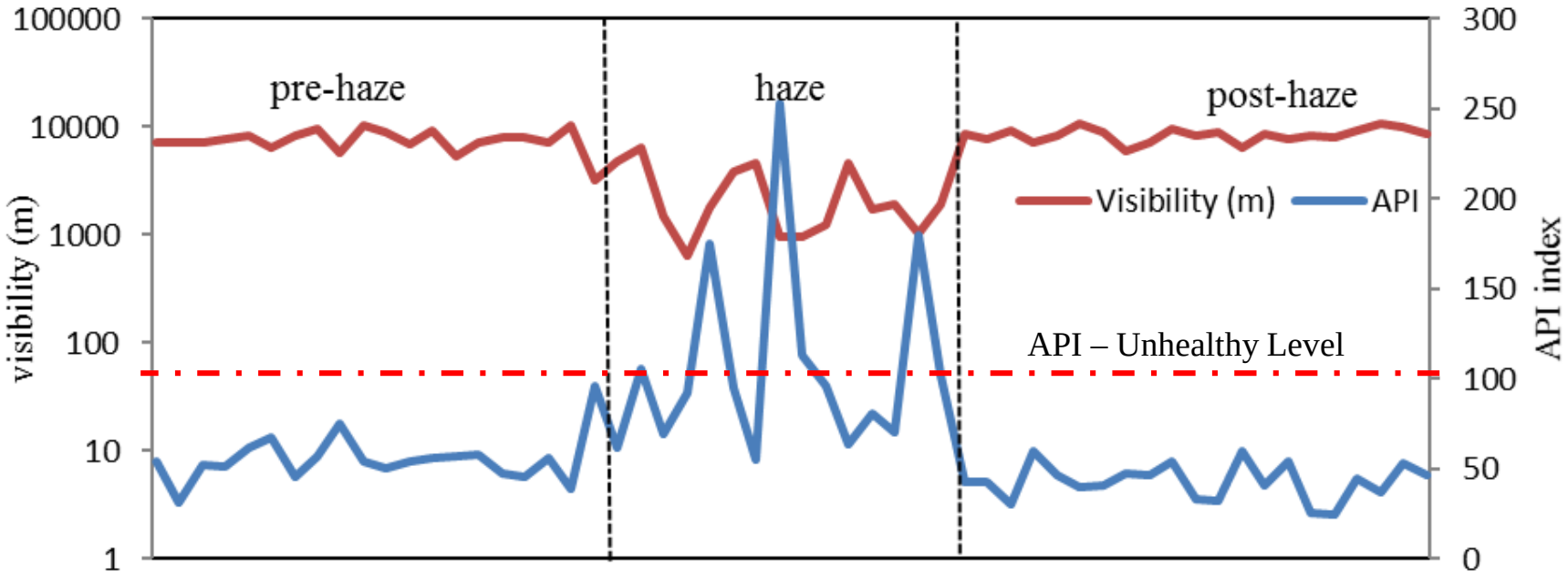
(Samsuddin et al. 2018, STOTEN)

Overall Concentration: Non-Haze and Haze



(Latif et al. 2018, Atmos Env)

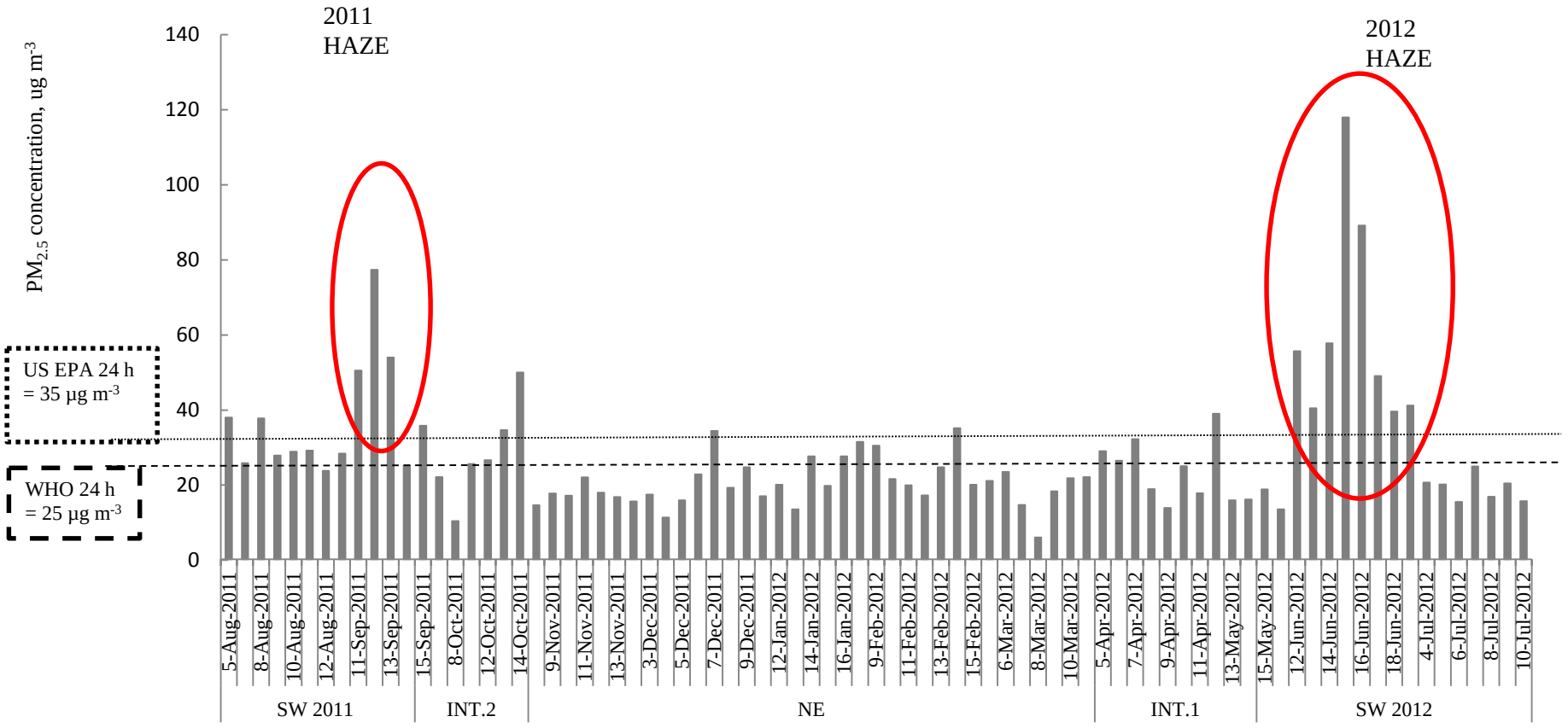
Visibility and API Index (2015)



Sulong et al. (2017, STOTEN)

PM2.5 DURING NON HAZE AND HAZE EPISODE

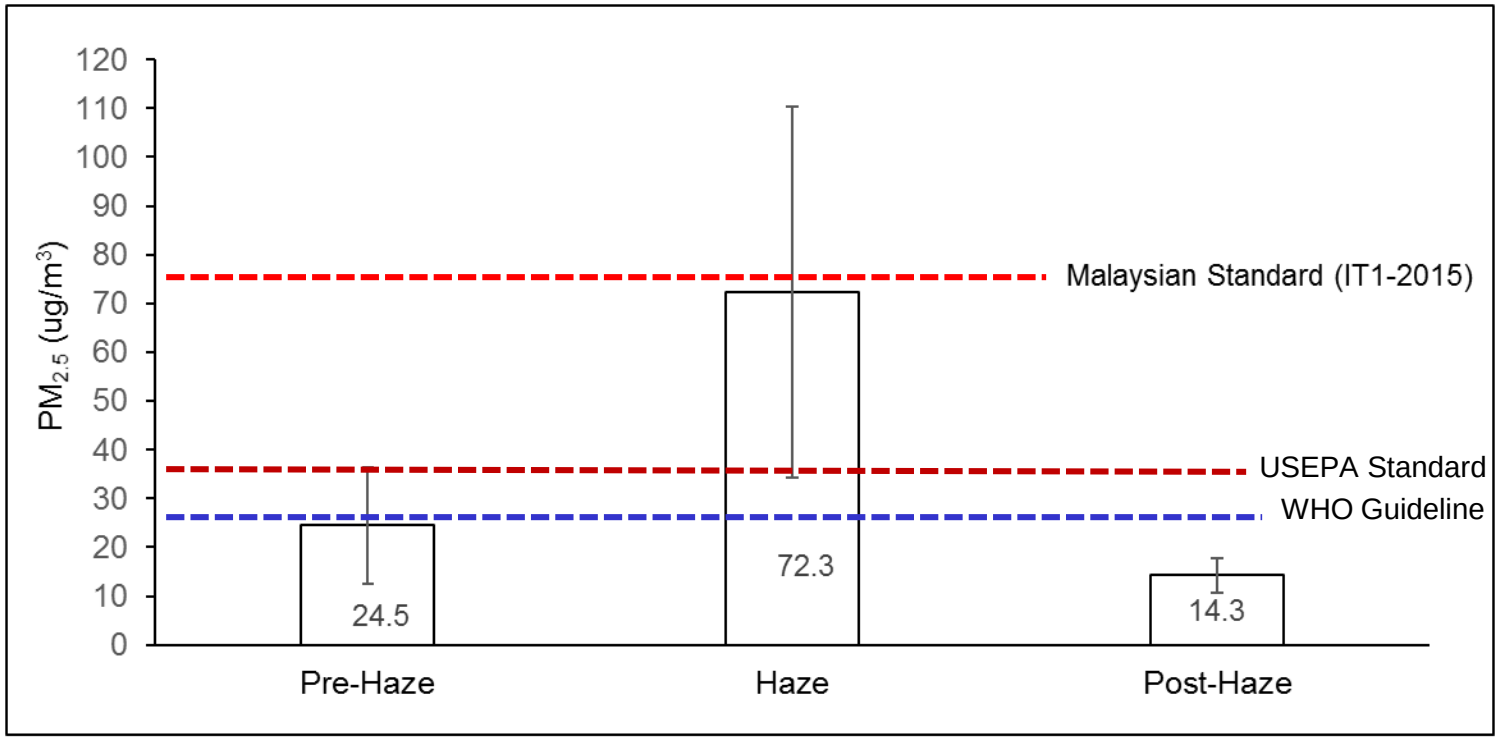
$PM_{2.5}$ mass concentration



Amil et al. (2016, ACP)

Elements	Unit	ANNUAL 5 Aug 2011 until 18 July 2012 n = 81	HAZE n = 11
API	-	49.98 ± 15.75 (28.58 - 126.75)	77.51 ± 21.9 (49.46 - 126.75)
T	^{o}C	28.49 ± 1.19 (26.05 - 31.55)	29.5 ± 1.33 (26.66 - 31.55)
RH	%	71.23 ± 7.91 (50.42 - 86.67)	63 ± 9.91 (50.42 - 81.63)
WS	ms^{-1}	1.29 ± 0.19 (0.87 - 1.77)	1.49 ± 0.14 (1.27 - 1.7)
WD	Degree	128.83 ± 31.64 (23.13 - 208.21)	102.84 ± 33.19 (23.13 - 136.88)
Rainfall	mm	10.37 ± 17.51 (0 - 85.4)	2.28 ± 5.18 (0 - 15.8)
CO	ppm	1.29 ± 0.31 (0.61 - 2.16)	1.45 ± 0.31 (0.89 - 1.99)
O_3	ppm	0.01 ± 0.01 (0 - 0.03)	0.02 ± 0 (0.01 - 0.02)
SO_2	ppm	0 ± 0 (0 - 0.01)	0 ± 0 (0 - 0.01)
NO_X	ppm	0.06 ± 0.01 (0.03 - 0.11)	0.06 ± 0.01 (0.03 - 0.07)
NO	ppm	0.03 ± 0.01 (0.01 - 0.07)	0.02 ± 0.01 (0.01 - 0.04)
NO_2	ppm	0.03 ± 0.01 (0.02 - 0.05)	0.03 ± 0.01 (0.02 - 0.05)
$PM_{2.5}$	$\mu g\ m^{-3}$	28 ± 17 (6. - 118)	61 ± 24 (40 - 118)
$PM_{2.5}/PM_{10}$	-	0.72 ± 0.18	0.74 ± 0.07
$PM_{2.5}$/TSP	-	0.46 ± 0.13	0.54 ± 0.07
PM_{10}/TSP	-	0.63 ± 0.12	0.73 ± 0.12

Average $PM_{2.5}$ Concentration (Haze 2015)



(Sulong et al. 2017, Atmos Environ)

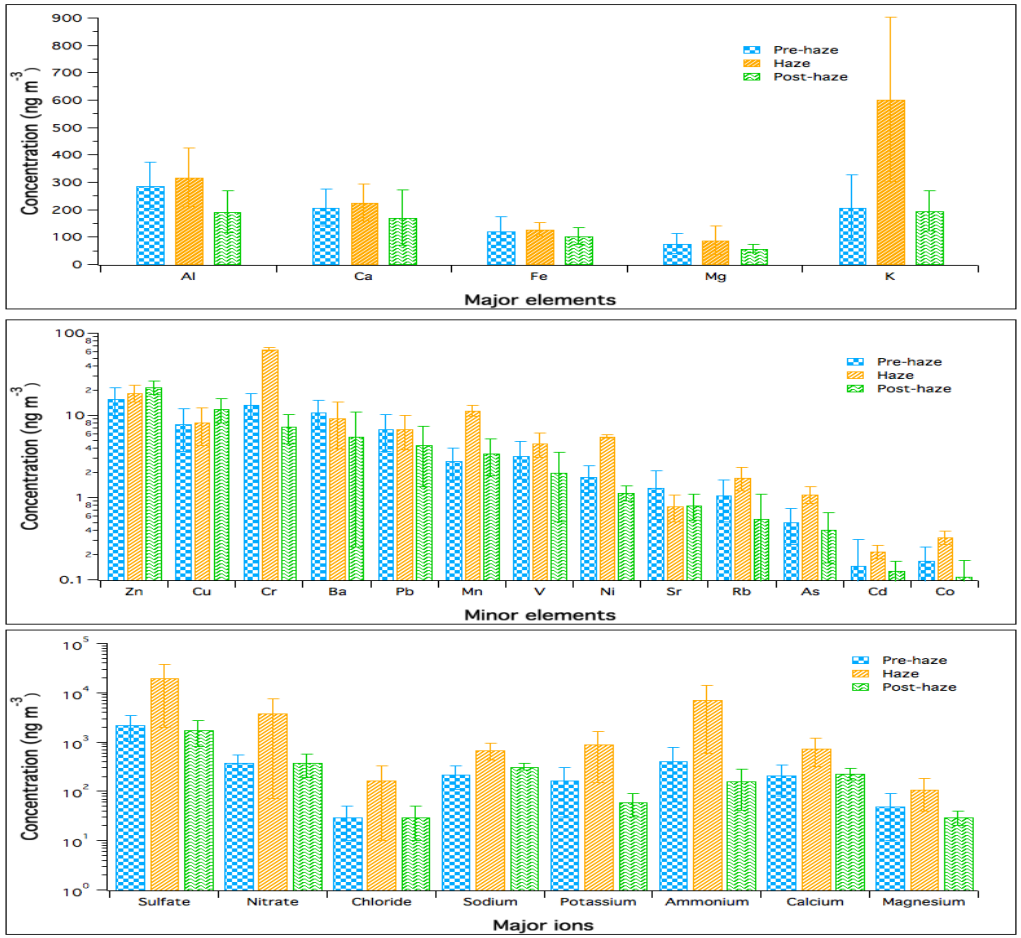
CHEMICAL COMPOSITION DURING HAZE EPISODE

Concentration of inorganic composition of $PM_{2.5}$ during haze in Malaysia

Reference	SO_4^{2-}	NO_3^-	Cl^-	NH_4^+	Na^+	K^+	Ca^{2+}	Al	V	Cr	Mn	Fe	Ni	Cu	Zn	As	Se	Pb	Cd
Unit	μg m^{-3}	μg m^{-3}	μg m^{-3}	μg m^{-3}	μg m^{-3}	μg m^{-3}	μg m^{-3}	μg m^{-3}	ng m^{-3}	ng m^{-3}	ng m^{-3}	ng m^{-3}	ng m^{-3}	ng m^{-3}	ng m^{-3}	ng m^{-3}	ng m^{-3}	ng m^{-3}	ng m^{-3}
Haze																			
Pinto et al. (1998) (*Petaling Jaya)*	10.0		0.07[a]			0.20[a]	0.098[a]		9.30	0.2	4.5	120	2.2	9.3	34.3	2.3	0.7	39	
Fujii et al. (2015) (*Petaling Jaya*)																			
Amil et al. (2016) *(Petaling Jaya)*	2.40	0.21	0.030	2.21	0.23	0.51	0.28	2.78	1.02	2.87	1.39	1.90	0.59	3.49	175	0.337	0.207	94.0	0.13
Khan et al. (2016b) *(UKM Bangi)*	1.98	0.28	0.023	0.54	0.14	0.21	0.20	0.011	1.31		1.19	5.67	0.73	2.46	15.8	3.29	0.37	4.54	0.21
Sulong et al. (2017) *(Kuala Lumpur)*	20.4	3.85	0.17	7.16	0.68	0.60	0.23	0.32	4.57		11.6	129	5.54	8.34	19.0	1.11		6.90	0.22
Jaafar et al. (2017) *(UKM Bangi)*	3.10	0.98	0.13		0.27[a]	0.61[a]	0.12[a]												

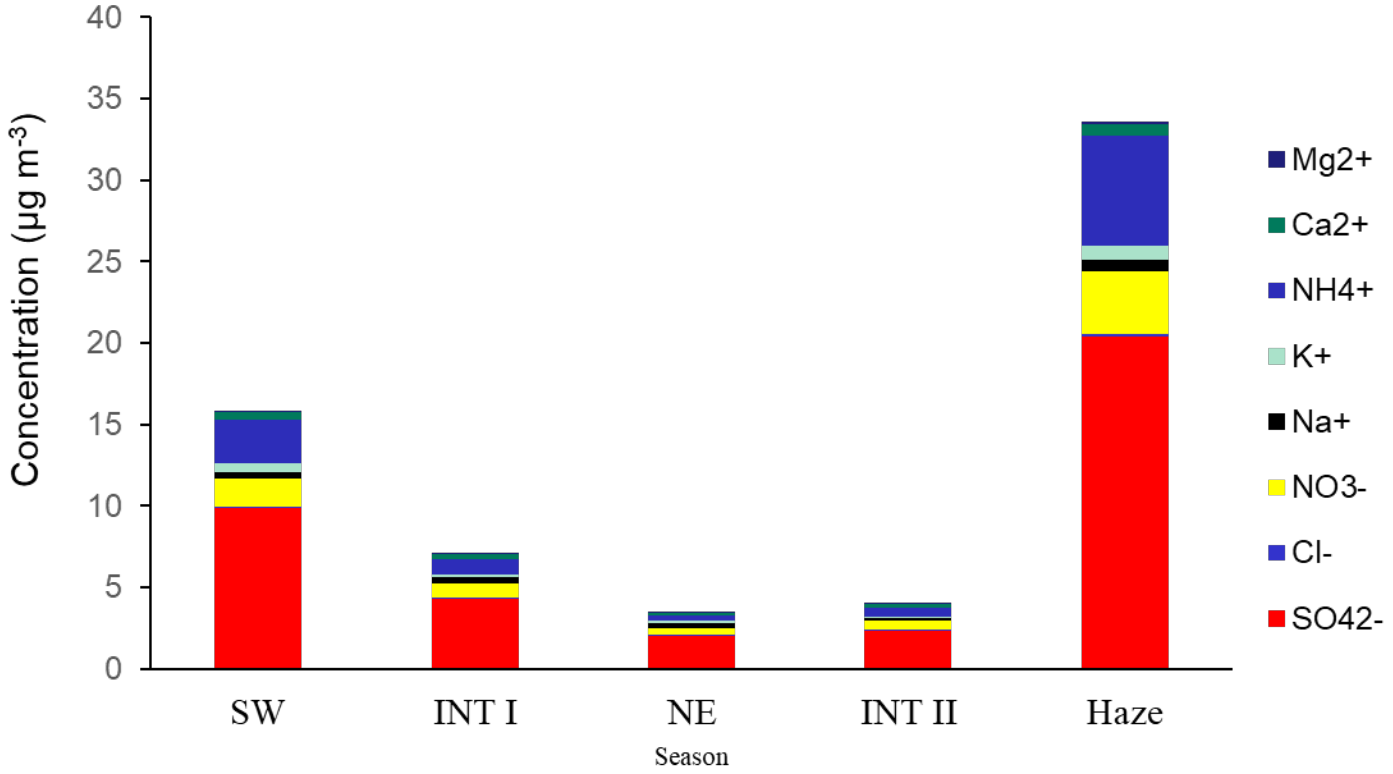
(Latif et al. 2018, Atmos Environ)

$PM_{2.5}$ Inorganic Composition(2015-2016)



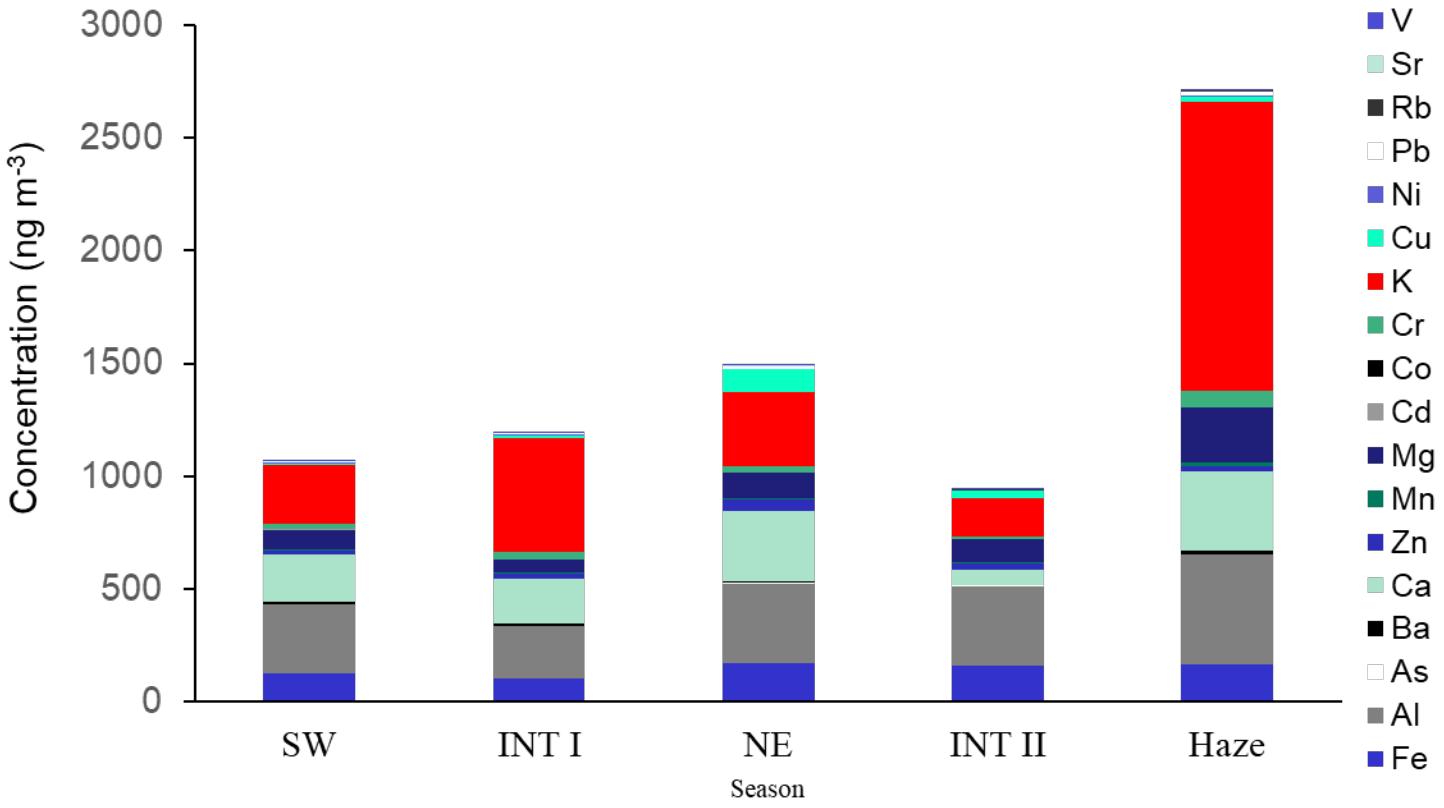
(Sulong et al. 2017, STOTEN)

Concentration of Major Ions based on Seasons (2015-2016)

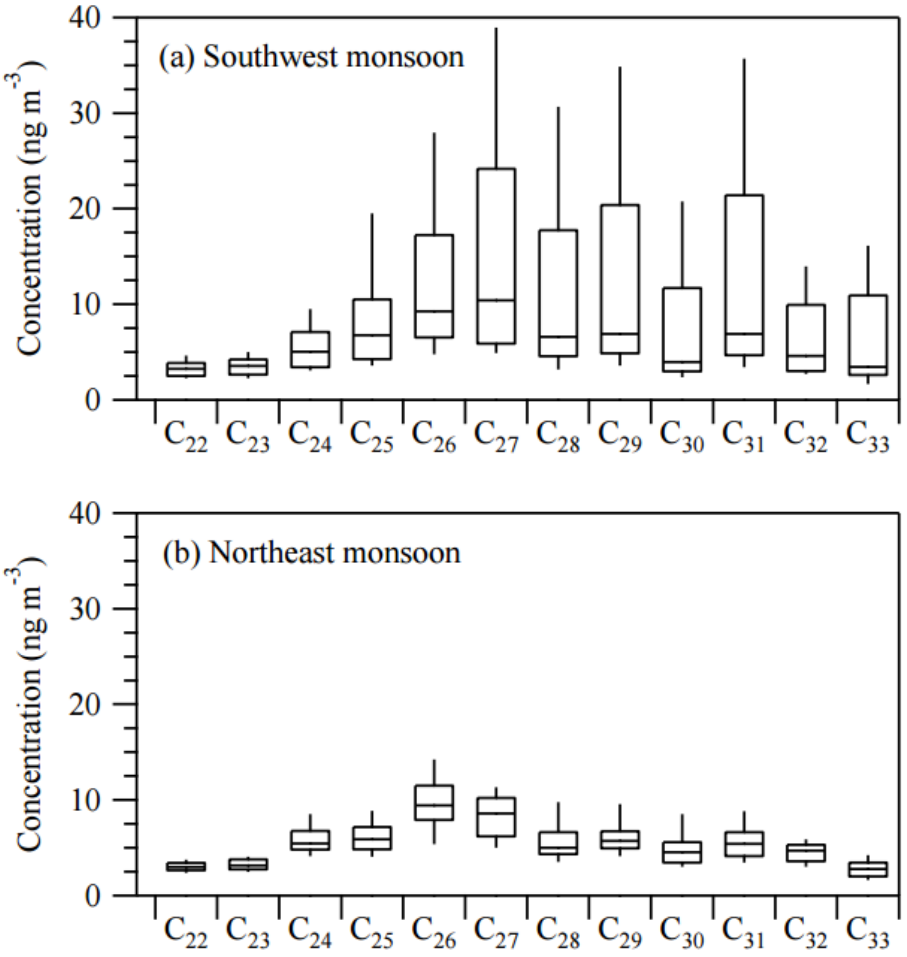


(Sulong et al. 2017, STOTEN)

Concentration of Metals based on Seasons (2015-2016)



(Sulong et al. 2017, STOTEN)

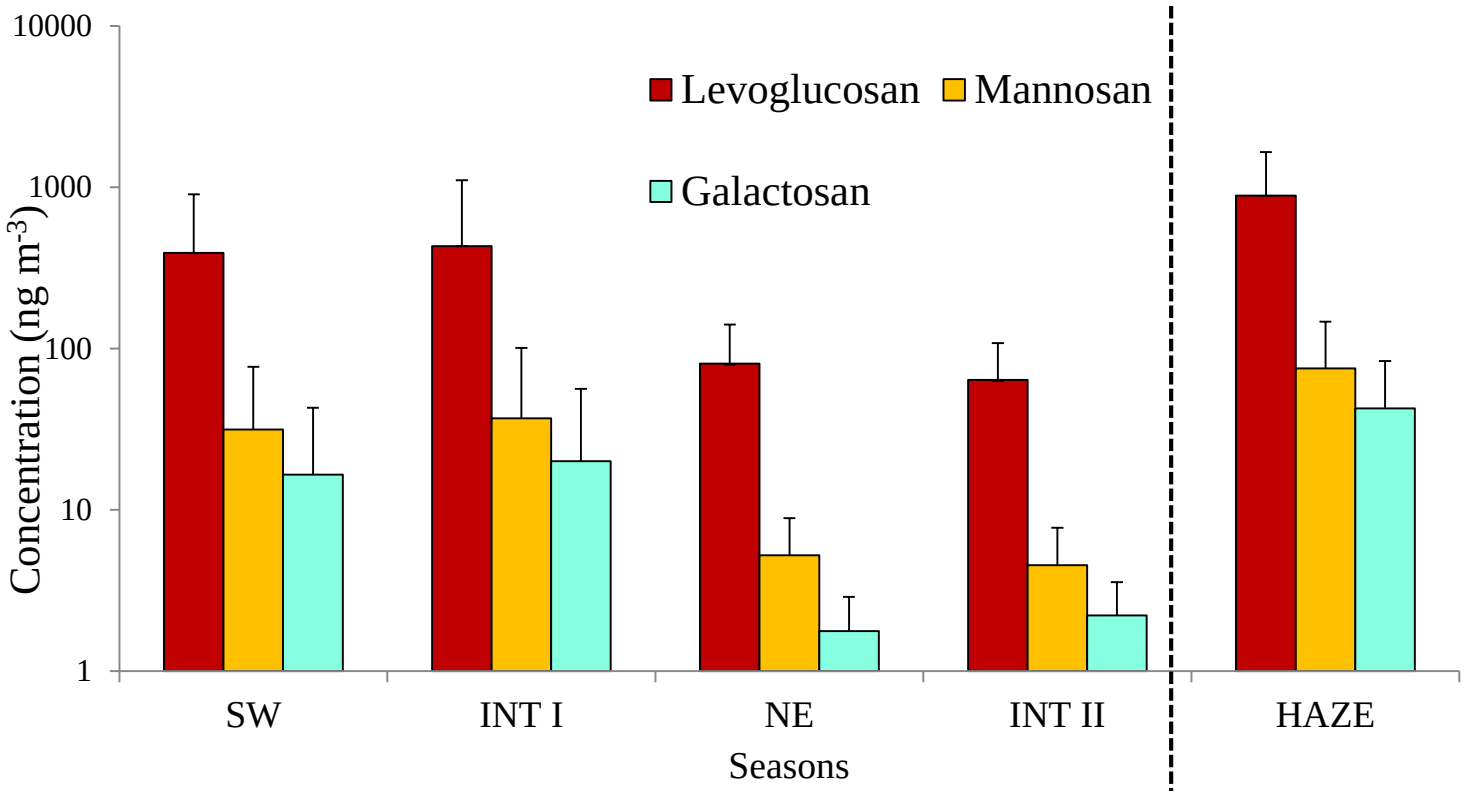


Haze

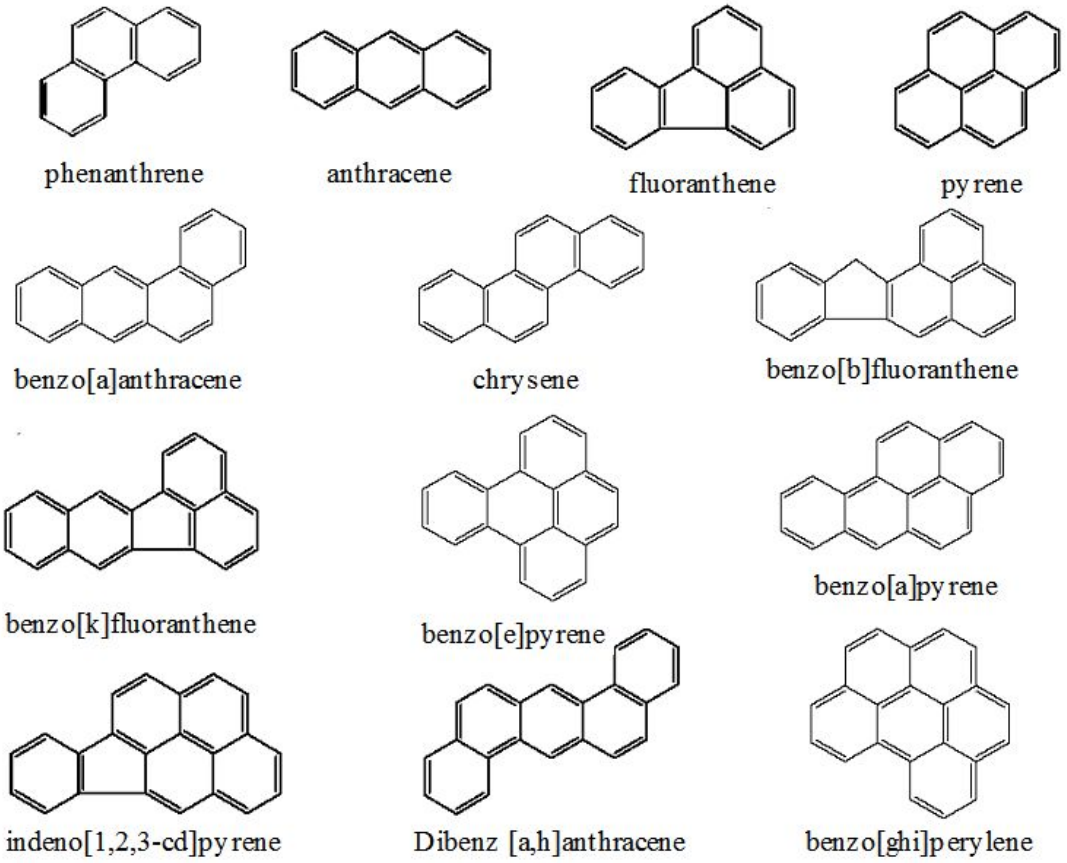
Non-Haze

(Fujii et al., 2016)

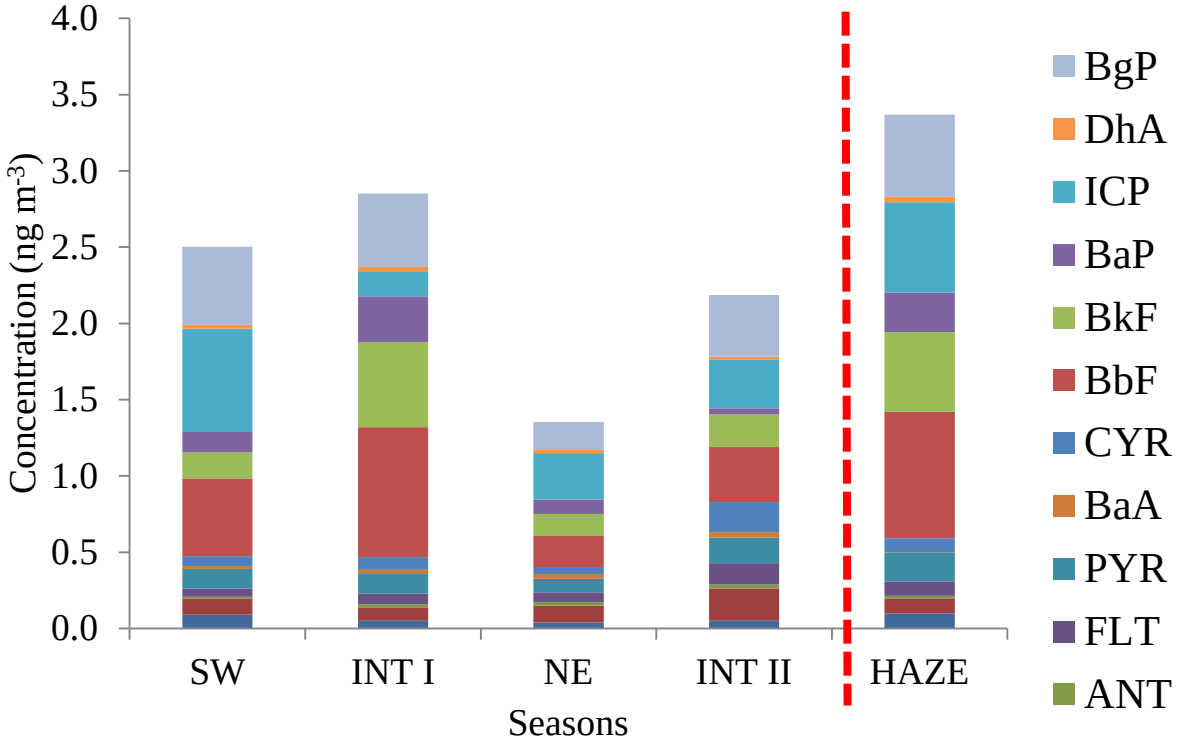
Concentration of Biomass Tracer (2015-2016)



USEPA Priority Pollutants
16 PAHs



PAHs Concentration (2015-2016)

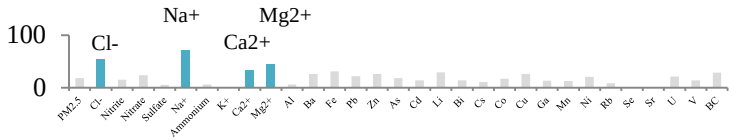


NAP = Napthalene; ACY = Acenapthelyne; ACP = Acenapthene; FLR = flourene; PHE = Phenanthrene; ANT = Anthracene; FLT = Fluoranthene; PYR = Pyrene; BaA = Benzo[a]anthracene; CYR = Chrysene; BbF = Benzo[b]fluoranthene; BkF = Benzo[k]fluoranthene; BaP = Benzo[a]pyrene; IcP = Indeno[1,2,3cd]pyrene; DhA = Dibenzo[a,h]anthracene; BgP = Benzo[g,h,i]perylene

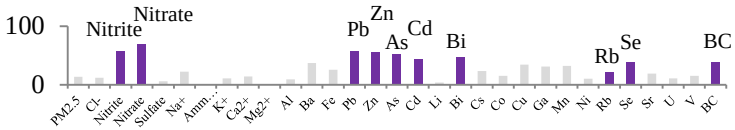
SOURCE APPORTIONMENT STUDY

PMF-MLR SOURCE APPORTIONMENT: PM2.5 CHEMICAL COMPOSITION (INORGANIC & BC)

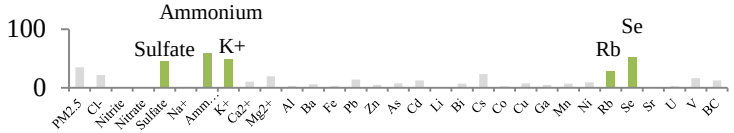
F5: Sea salt



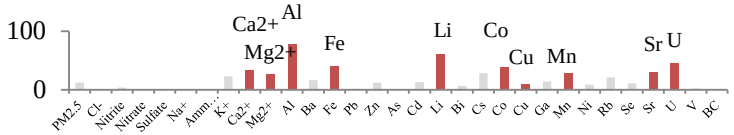
F4: Mixed traffic & industrial



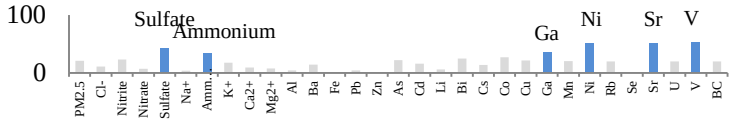
F3: Mixed SIA & biomass burning

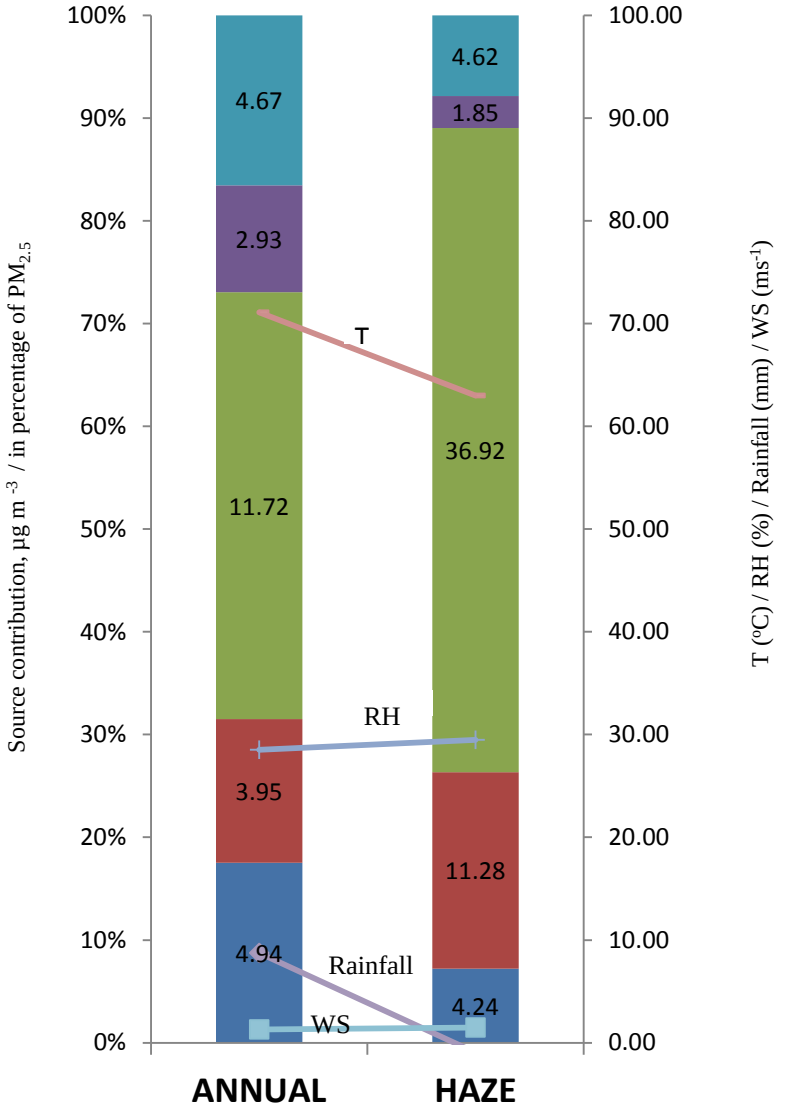


F2: Mineral dust

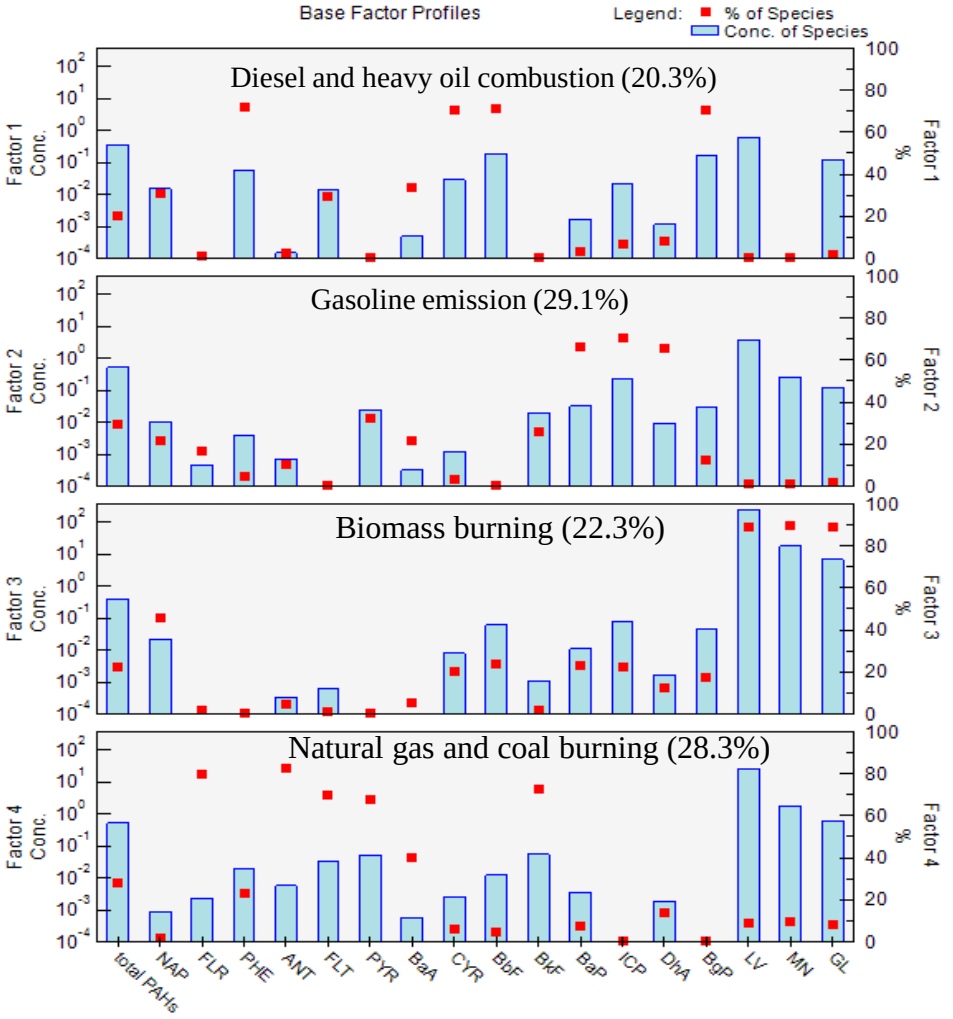


F1: Combustion of engine oil





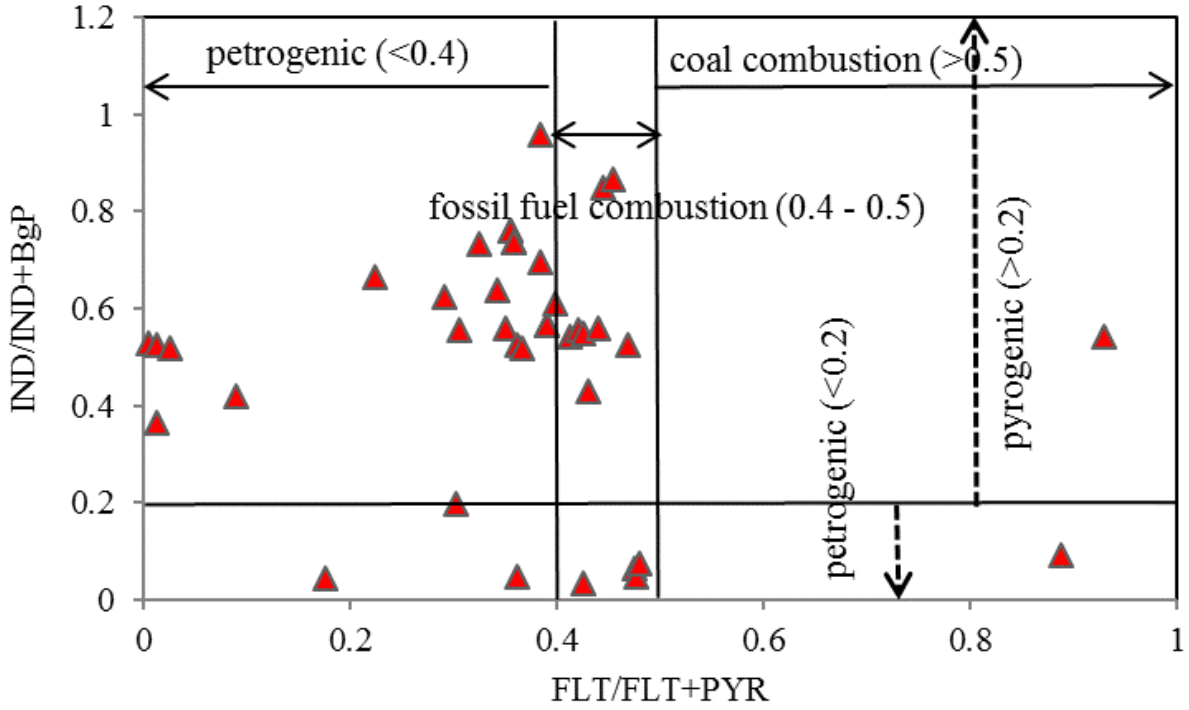
Source factor profile of PAHs and biomass tracers identified from PMF



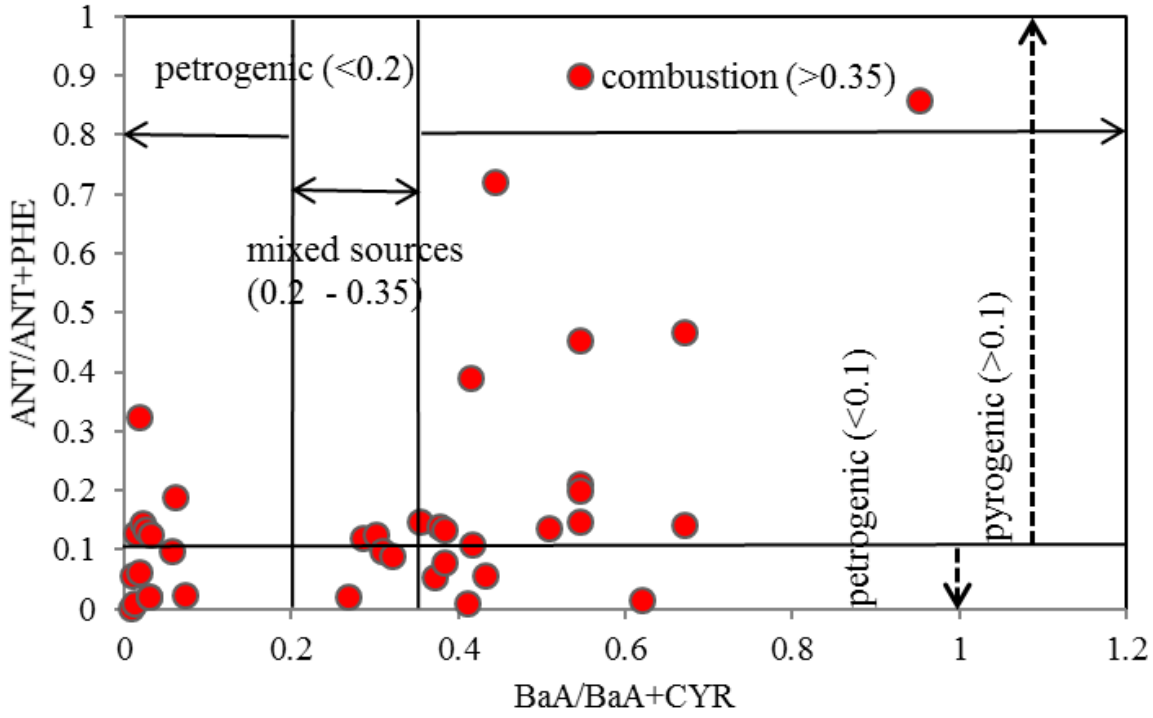
Source Indicator of PAHs based on Diagnostic Ratio

PAH ratio	Value	Source	Reference
∑LMW/∑HMW	<1	Pyrogenic	(Zhang et al., 2008)
	>1	Petrogenic	
∑COMB/PAHs	0.3	Petrogenic	(Pandey et al., 1999)
	0.7	Pyrogenic	
BaP/BgP	<0.6	Non-traffic	(Katsoyiannis et al., 2007)
	>0.6	traffic	
BaA/CHR	0.2 – 0.35	Coal combustion	(Akyuz and Cabuk, 2009)
	>0.35	vehicular emission	
ANT/(ANT/PHE)	<0.1	Petrogenic	(Pies et al., 2008)
	>0.1	Pyrogenic	
FLT/(FLT + PYR)	<0.4	Petrogenic	(Yunker et al., 2002)
	0.4 – 0.5	Fossil fuel combustion	
	>0.5	Grass, wood, coal combustion	
BaA/(BaA + CHR)	<0.2	Petrogenic	(Yunker et al., 2002)
	>0.35	Combustion	
IcP/(IcP + BgP)	<0.2	Petrogenic	(Yunker et al., 2002)
	>0.2	Pyrogenic	

Diagnostic Ratio



Diagnostic Ratio



HEALTH IMPACT OF HAZE EPISODE

Health Impact

- The number of respiratory disease outpatient visits at Kuala Lumpur General Hospital also increased from 250 to 800 people per day in the 1997 haze episode (Afroz et al., 2003; WHO, 1998).
- Haze episode contributed to a 19% increase in respiratory mortality. 41.4% increase in the delayed effects of haze on the natural mortality of children and a 66% increase in the respiratory mortality of adult females (Sahani et al. 2014)
- For the 2015: Estimated that excess deaths with 95% confidence intervals was 6,500 (1,700–11,300) in Malaysia. A (Koplitz et al. 2016)

HEALTH RISK ASSESSMENT BASED ON PM2.5 COMPOSITION

Hazard index (HI) and hazard quotient (HQ) – Inorganic composition

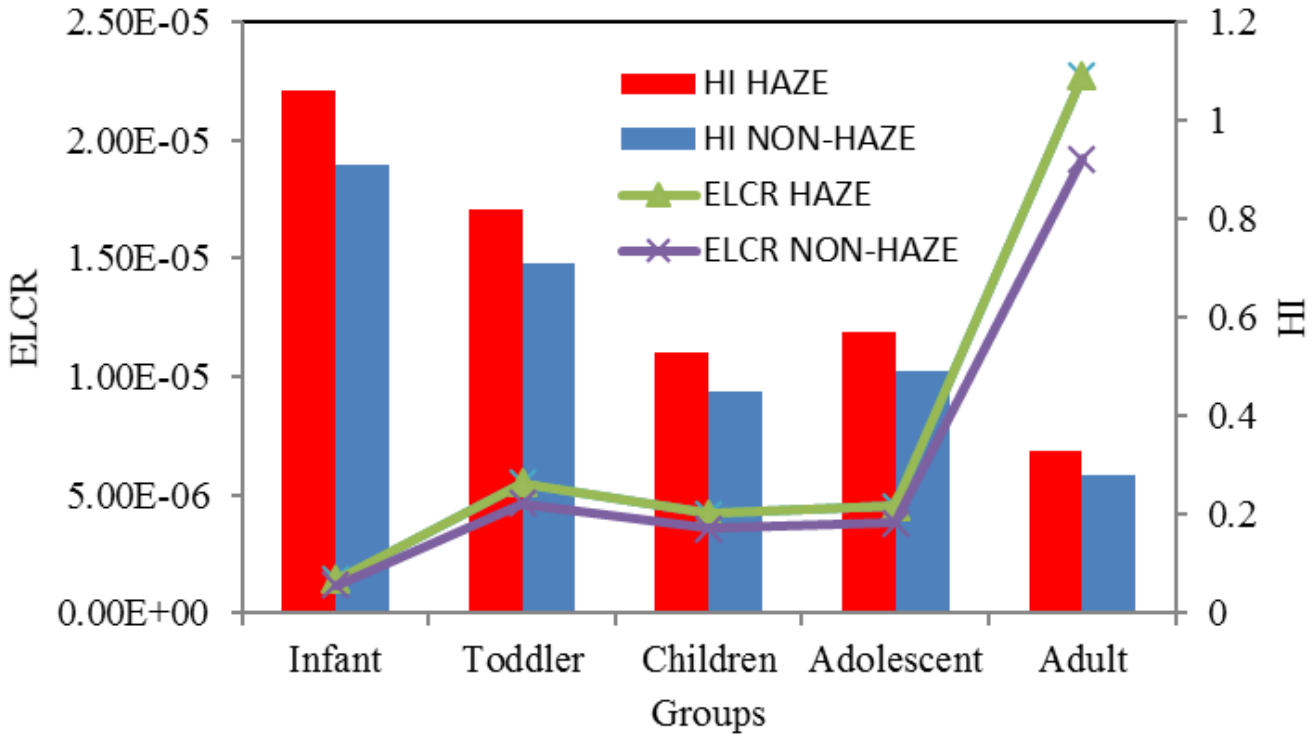
Elements	RfC (mg m^{-3})	HQ				
		Infant 0-<1year	Toddler 1-<6years	Children 6-<12years	Adolescent 12-<18years	Adult 18-<70years
Pre-haze						
Cr	8.00×10^{-6}	1.10×10^{0}	8.59×10^{-1}	5.50×10^{-1}	5.91×10^{-1}	3.40×10^{-1}
Mn	5.00×10^{-5}	3.60×10^{-2}	2.80×10^{-2}	1.80×10^{-2}	1.93×10^{-2}	1.11×10^{-2}
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	Excess lifetime cancer risk (μg m^{-3})$^{-1}$				
	(μg 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}

Health effect based on inorganic composition



(Sulong et al. 2017, STOTEN)

The toxicity of individual PAH (ng m^{-3}) based on B[a]Peq concentration (pg m^{-3})

PAHs	Concentration (ng m^{-3})	TEF*	B[a]Peq (pg m^{-3})
NAP	0.06	0.001	0.06
ACY	UD	0.001	0.00
ACP	UD	0.001	0.00
FLR	UD	0.001	0.00
PHE	0.12	0.001	0.12
ANT	0.02	0.01	0.20
FLT	0.07	0.001	0.07
PYR	0.12	0.001	0.12
B[a]A	0.03	0.1	3.00
CYR	0.08	0.01	0.80
B[b]F	0.43	0.1	43.0
B[k]F	0.22	0.1	22.0
B[a]P	0.13	1	130
I[c]P	0.43	0.1	43.0
D[h]A	0.02	1	20.0
B[g]P	0.39	0.01	3.90
		Total	266.27

(Sulong et al. 2018, Chemosphere)

The LADD and the ILCR from PAHs inhalation exposure

Infant	Toddler	Children	Adolescent	Adult	
	0-<1year	1-<6years	6-<12year	12-<18years	18-<70years
LADD (mg/kg/day)	2.81E-09	1.09E-08	8.42E-09	9.04E-09	4.51E-08
ILCR	8.84E-09	3.44E-08	2.64E-08	2.84E-08	1.42E-07

ILCR (70 years exposure) = 2.40E-07

(Sulong et al. 2018, Chemosphere)

Conclusion and the Way Forward

- Anthropogenic causes, primarily related to forest fire, agricultural practices, and meteorological factors, particularly during El Niño events, have been attributed to uncontrollable fires from peatland areas.

- The compositions of inorganic and organic substances in PM have been identified as markers for emissions from BB that contribute to the haze episodes in SEA.

- Haze was found to severely affect human health and it has been associated with an increased number of respiratory illnesses, and with increased cancer risk and mortality.

Conclusion and the Way Forward

- Collaboration through ASEAN Agreement on Transboundary Haze Pollution that has been ratified by all ASEAN member countries.
- Improve forecasting system and database through ASEAN Specialised Meteorological Centre (ASMC) Fire Danger Rating System.
- Regional scientific community can be encouraged to come to an agreement on the specific major air pollutants breakpoints for the ASEAN Air Quality Index base on the impact of air pollutants to human health in SEA region
- Detail study on the impact of haze to human health is important to be conducted in SEA region especially during haze episode.

THANK YOU

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