South-westerly monsoon impact on fine particulate matter in Malaysia: trend, source apportionment and health implication

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June 7, 2017
Third Atmospheric Composition and Asian Monsoon (ACAM), Guangzhou, China

Today’s topics

1. Background info

2. Aerosol and Urban Pollution: Emissions and Source Areas

3. Measurements and an Integrated Data Analysis System

4. Discussion

5. Findings

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Background

HAZE / SMOG

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- Air pollution is a major environmental issue

- Causes **stroke, heart disease, lung cancer**, and both chronic and acute **respiratory diseases**, including asthma (WHO, 2016)

- In 2013, globally **88%** of the world's population lived in areas **exceeding** the WHO annual Air Quality Guideline

- Between 1990- 2013, **20.4%** increased in global population-weighted $PM_{2.5}$ driven by trends in South Asia, Southeast Asia, and China

- A recent research showed that **air pollution can cause brain damage** to people living near roadways and power plants

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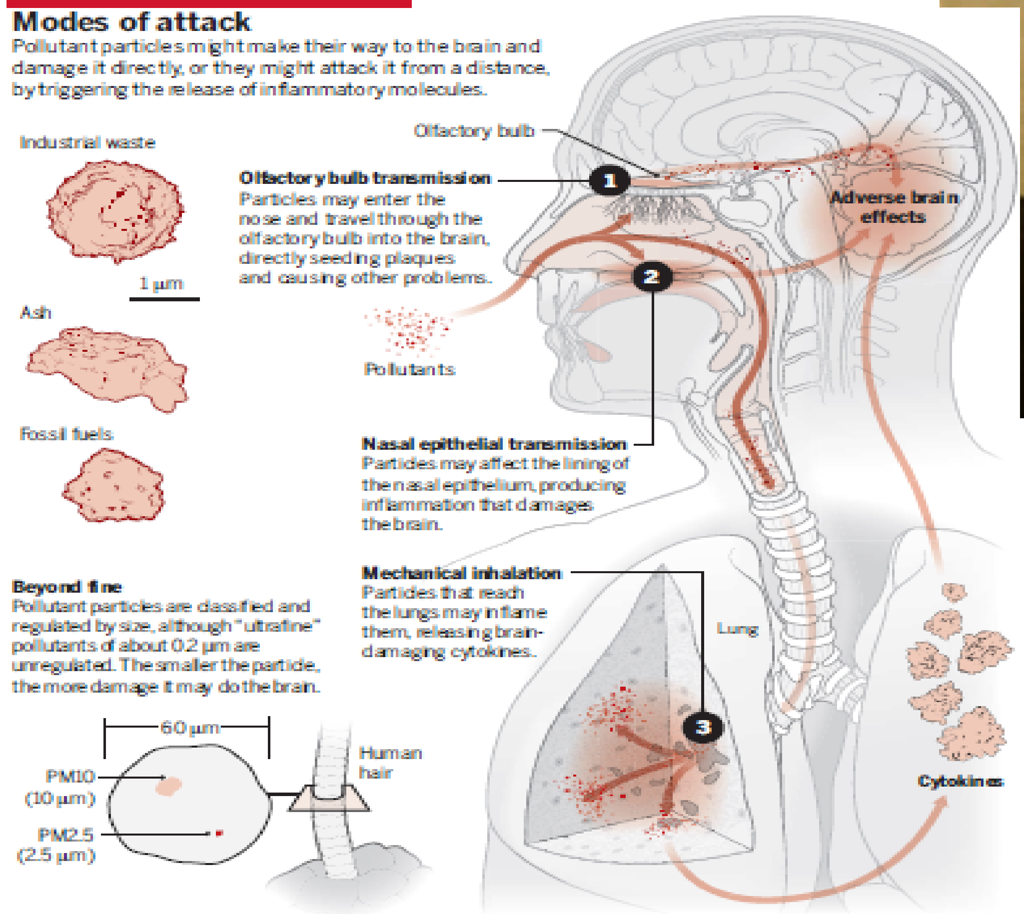
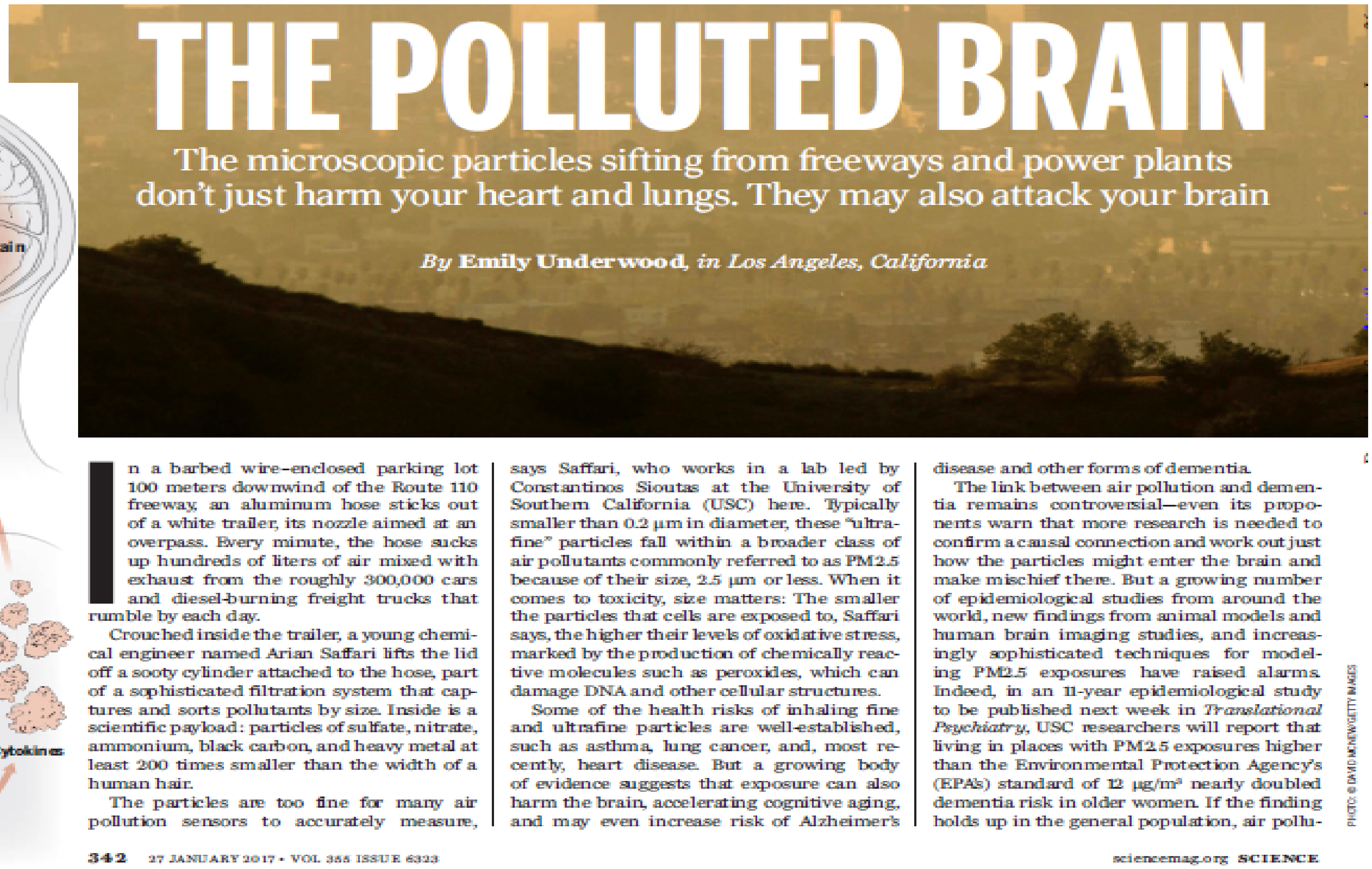
Airborne Particulate Matter: Source and Effect

Adapted from Underwood et al. 2017, Science

Science AAAS





THE POLLUTED BRAIN

The microscopic particles sifting from freeways and power plants don't just harm your heart and lungs. They may also attack your brain

By **Emily Underwood**, *in Los Angeles, California*

In a barbed wire–enclosed parking lot 100 meters downwind of the Route 110 freeway, an aluminum hose sticks out of a white trailer, its nozzle aimed at an overpass. Every minute, the hose sucks up hundreds of liters of air mixed with exhaust from the roughly 300,000 cars and diesel-burning freight trucks that rumble by each day.

Crouched inside the trailer, a young chemical engineer named Arian Saffari lifts the lid off a sooty cylinder attached to the hose, part of a sophisticated filtration system that captures and sorts pollutants by size. Inside is a scientific payload: particles of sulfate, nitrate, ammonium, black carbon, and heavy metal at least 200 times smaller than the width of a human hair.

The particles are too fine for many air pollution sensors to accurately measure, says Saffari, who works in a lab led by Constantinos Sioutas at the University of Southern California (USC) here. Typically smaller than 0.2 µm in diameter, these "ultrafine" particles fall within a broader class of air pollutants commonly referred to as PM2.5 because of their size, 2.5 µm or less. When it comes to toxicity, size matters: The smaller the particles that cells are exposed to, Saffari says, the higher their levels of oxidative stress, marked by the production of chemically reactive molecules such as peroxides, which can damage DNA and other cellular structures.

Some of the health risks of inhaling fine and ultrafine particles are well-established, such as asthma, lung cancer, and, most recently, heart disease. But a growing body of evidence suggests that exposure can also harm the brain, accelerating cognitive aging, and may even increase risk of Alzheimer's disease and other forms of dementia.

The link between air pollution and dementia remains controversial—even its proponents warn that more research is needed to confirm a causal connection and work out just how the particles might enter the brain and make mischief there. But a growing number of epidemiological studies from around the world, new findings from animal models and human brain imaging studies, and increasingly sophisticated techniques for modeling PM2.5 exposures have raised alarms. Indeed, in an 11-year epidemiological study to be published next week in *Translational Psychiatry*, USC researchers will report that living in places with PM2.5 exposures higher than the Environmental Protection Agency's (EPA's) standard of 12 µg/m³ nearly doubled dementia risk in older women. If the finding holds up in the general population, air pollu-

PHOTO: © DAVID MCNEW/GETTY IMAGES

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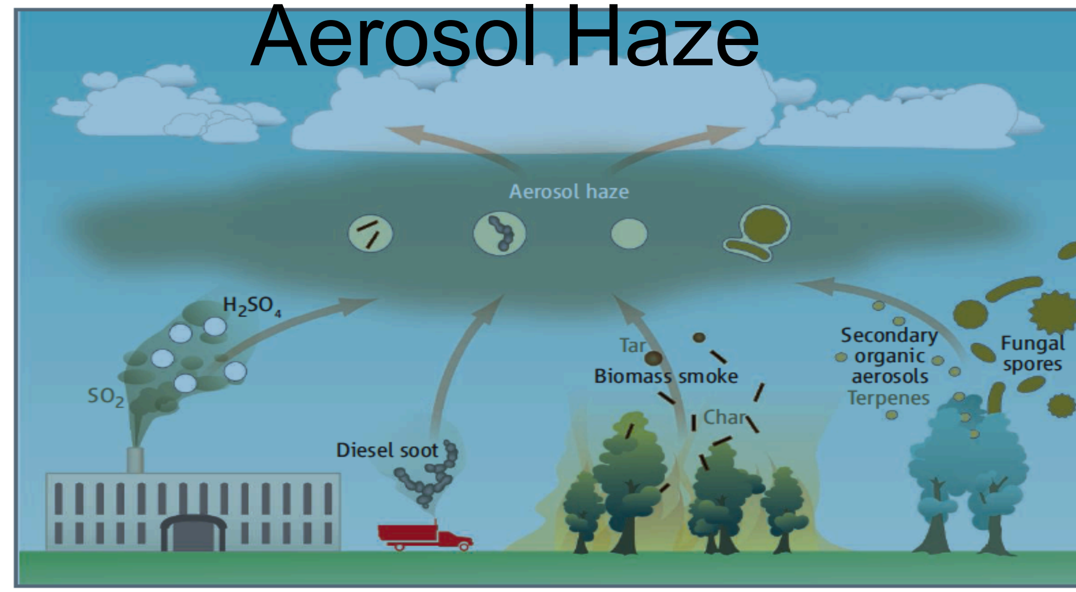
Causes and Trigger to Haze



Andreae 2009

In the **Southeast Asia** the common practice of burning agricultural residues enhances the haze pollution. The **slash and burn** is a common practice as it is the most cost efficient method in the management of agricultural waste in the shifting of cultivation.

Here you can find more info:

Reporting on Haze (Earth to Space, Half yearly Issue): http://www.ukm.my/ipi/?page_id=1559

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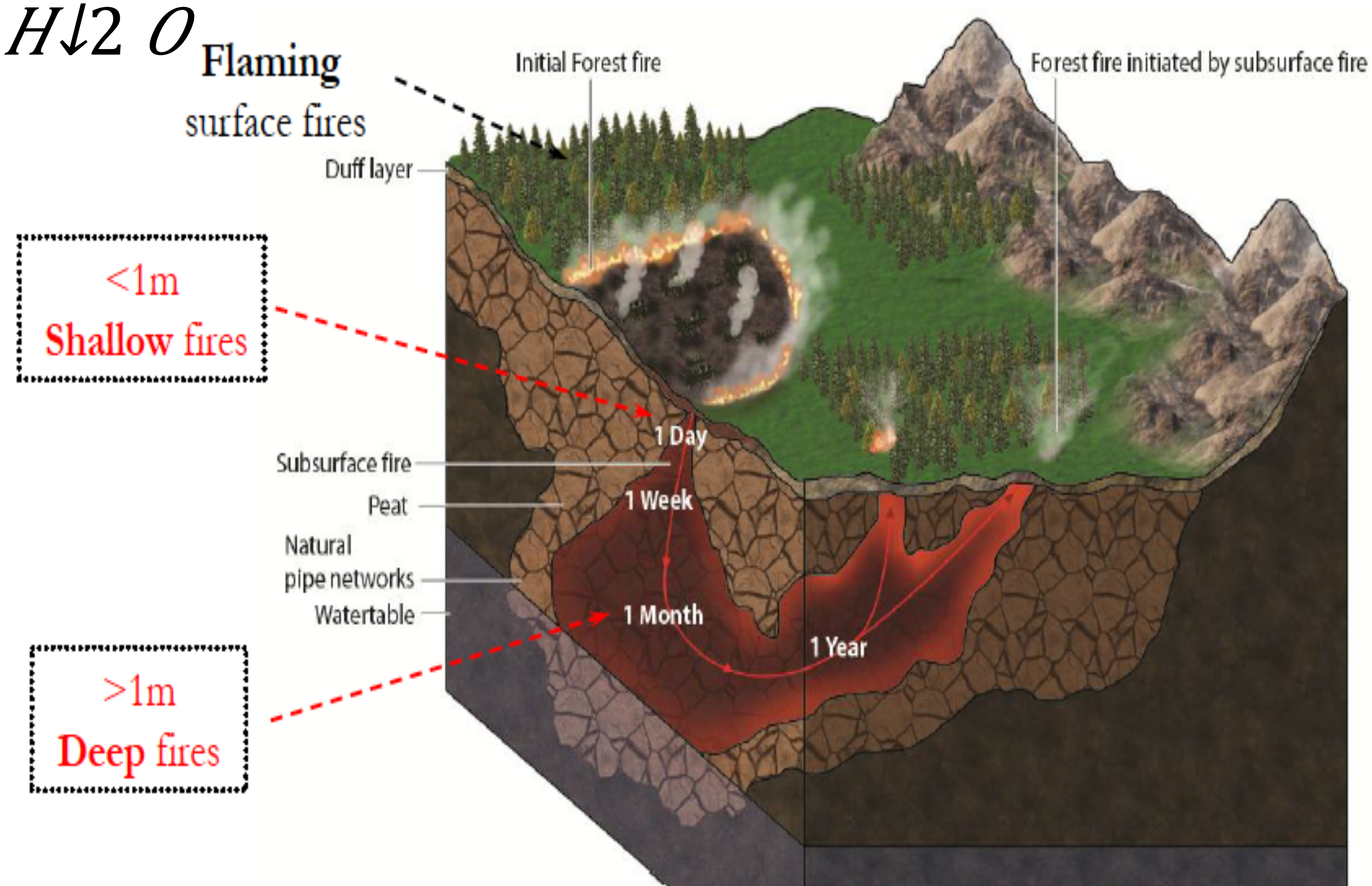
2-step Peat Soil combustion reactions:

$$Peat \xrightarrow{heat} Char + \sum (\boldsymbol{volatiles}, \boldsymbol{CH_4}, \boldsymbol{PAHs})$$

$$Char + O_2 \xrightarrow{} heat + \boldsymbol{ash} + CO_2 + CO + H_2O$$



Rein et al. (2008)

Atmos. Chem. Phys., 16, 597–617, 2016
www.atmos-chem-phys.net/16/597/2016/
doi:10.5194/acp-16-597-2016

Atmospheric Chemistry and Physics
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Adapted from Khan et al. 2016, ACP

Fine particulate matter in the tropical environment: monsoonal effects, source apportionment, and health risk assessment

M. F. Khan[1,2], M. T. Latif[1,3], W. H. Saw[1], N. Amil[1,4], M. S. M. Nadzir[1,2], M. Sahani[5], N. M. Tahir[6,7], and J. X. Chung[1]

The mass closure model identified four sources of $PM_{2.5}$: a) mineral matter (MIN) (35%), b) secondary inorganic aerosol (SIA) (11%), c) sea salt (SS) (7%), d) trace elements (TE) (2%) and e) undefined (UD) (45%). PMF 5.0 identified five potential sources and **motor vehicle emissions and biomass burning** were dominant followed by marine and sulfate aerosol, coal burning,nitrate aerosol, and mineral and road dust.

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The systemic risk (HI) posed by the exposure of $PM_{2.5}$ was at a considerably safer level compared to the SEA region. The lifetime CR indicated follows the order of As > Ni > Pb > Cd for mineral/road dust, coal burning and overall $PM_{2.5}$ concentration and; As > Pb > Ni > Cd for motor vehicle/biomass burning. Among the trace metals studied, **As predominantly showed the largest lifetime cancer risk in $PM_{2.5}$**

collected at a semi-urban area using a high-volume air sampler at different seasons on 24 h basis. Analysis of trace elements and water-soluble ions was performed using inductively coupled plasma mass spectroscopy (ICP-MS) and ion chromatography (IC), respectively. Apportionment analysis of $PM_{2.5}$ was carried out using the United States Environmental Protection Agency (US EPA) positive matrix factor-

coupled with biomass burning (31 %) were the most dominant, followed by marine/sulfate aerosol (20 %), coal burning (19 %), nitrate aerosol (17 %), and mineral/road dust (13 %). The hazard quotient (HQ) for four selected metals (Pb, As, Cd, and Ni) in $PM_{2.5}$ mass was highest in $PM_{2.5}$ mass from the coal burning source and least in $PM_{2.5}$ mass originating from the mineral/road dust source. The main carcinogenic

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ELSEVIER

Seasonal effect and source apportionment of polycyclic aromatic hydrocarbons in $PM_{2.5}$

CrossMark

Md Firoz Khan [a,*], Mohd Talib Latif [a,b], Chee Hou Lim [b], Norhaniza Amil [b,c], Shoffian Amin Jaafar [b], Doreena Dominick [a,b], Mohd Shahrul Mohd Nadzir [a,b], Mazrura Sahani [d], Norhayati Mohd Tahir [e]

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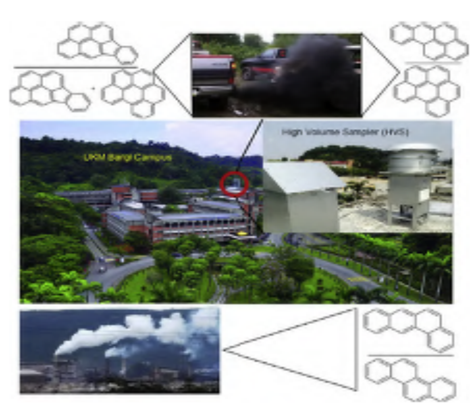
The health risk evaluation, by means of the lifetime lung cancer risk (LLCR), showed no potential carcinogenic risk from the airborne BaPeq (which represents total PAHs at the present study area in Malaysia). The seasonal LLCR showed that the carcinogenic risk of total PAHs were two fold higher during south-westerly monsoon compared to northeasterly monsoon.

HIGHLIGHTS

- Sixteen USEPA priority PAHs determined in $PM_{2.5}$ at a tropical semi-urban site.
- High molecular weight PAHs are significantly higher in $PM_{2.5}$.
- The combustion of gasoline, diesel and heavy oil are dominant sources of PAHs.
- No potential carcinogenic risk of the airborne BaP_{eq} was found at current site.
- Monsoon effect influences the PAHs distributions as well as health risk.

GRAPHICAL ABSTRACT



Adapted from Khan et al. 2015, Atmos Env

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Knowledge Gap in Forest Fires and Urban Air Pollution / Scopes in Future Research

- **VOCs, PAHs, Soot particle, pyrolysis product** of lignin and cellulose in the forest/peat soil burning

- **Aerosol lifecycle** was not studied so far!

- Air pollution data at the **street level or hotspot areas** was not reported so far!

- Health impact **PM-mortality** was not reported!

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Methods

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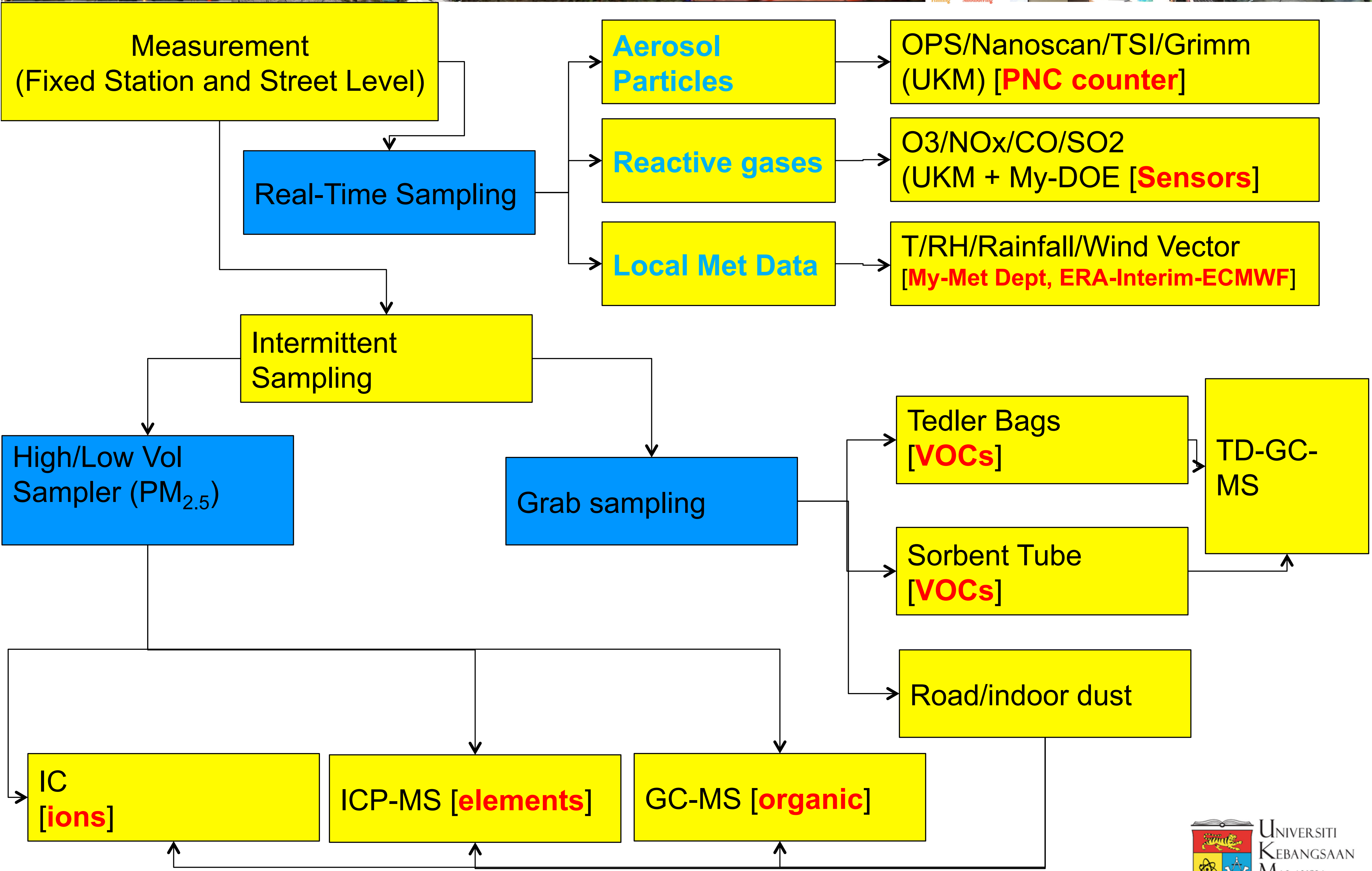

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An Integrated Data Analysis Systems

Air Pollution Modeling [receptor modeling]

Size Distribution and New Particle Formation

Health Risk Assessment (HRA) by US EPA Model

PCA/Absolute principal component score (**APCS**)

Positive Matrix Factorization (**PMF**)

EPA'S Chemical Mass Balance(CMB)

Deals "zero score" but lack of non-negativity requirement

Low uncertainty and identify sources without prior info of sources

Require prior info of sources

Validation of the Emission Sources by **Bivariate Rose Plot**/ Potential Source Contribution Function (**PSCF**)/Concentration Weighted Trajectory (**CWT**)/**HYSPLIT density model**/wind vector by GrADS

Establishment of Appropriate Emission Sources (Hotspots)

Strategic Mitigation Plan

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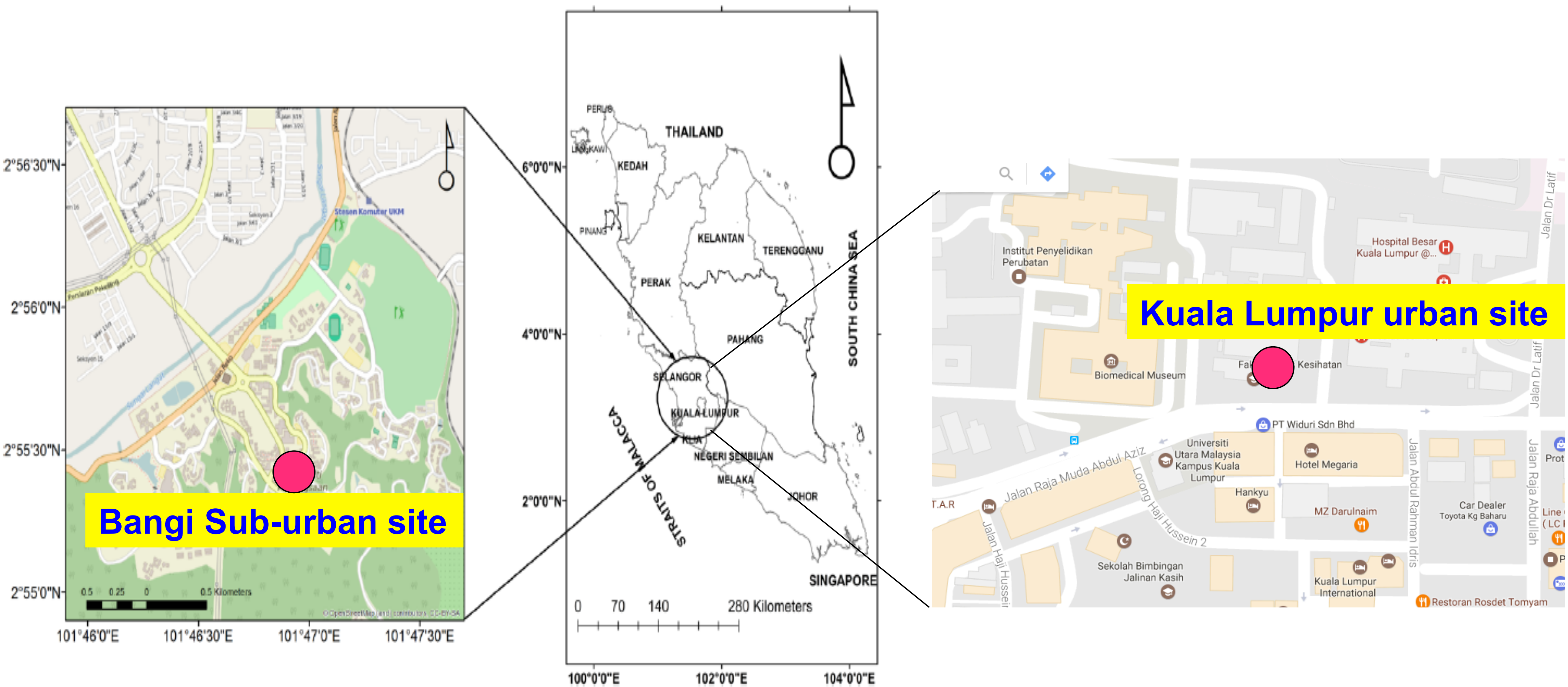
Measurement sites in Urban and Sub-urban area



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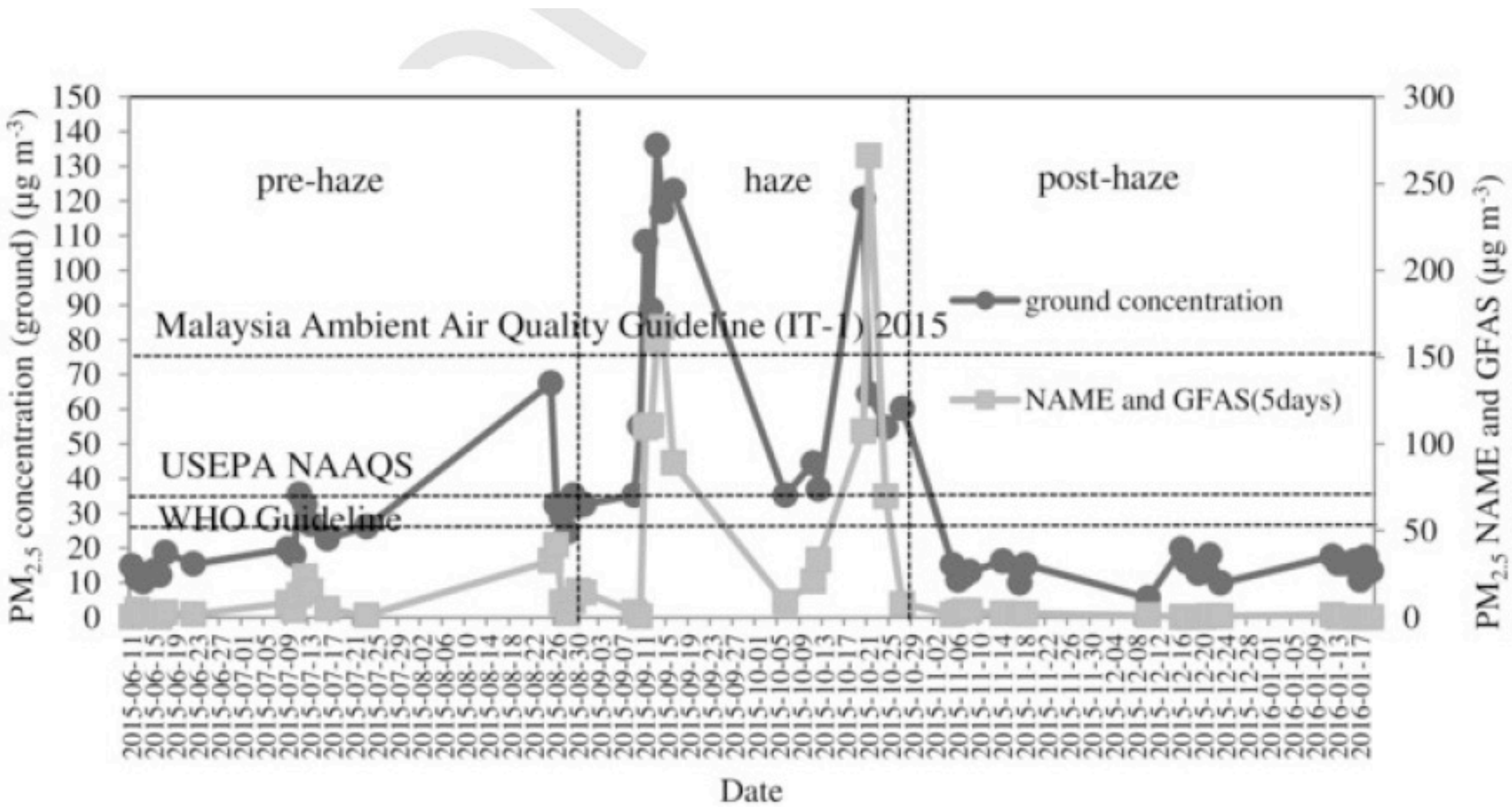
$PM_{2.5}$: Kuala Lumpur-2015 [Urban site]



Sulong NA et al. (2017) Source apportionment and health risk assessment among specific age groups during haze and non-haze episodes in Kuala Lumpur, Malaysia. Sci Total Environ 601–602:556-570 doi:https://doi.org/10.1016/j.scitotenv.2017.05.153

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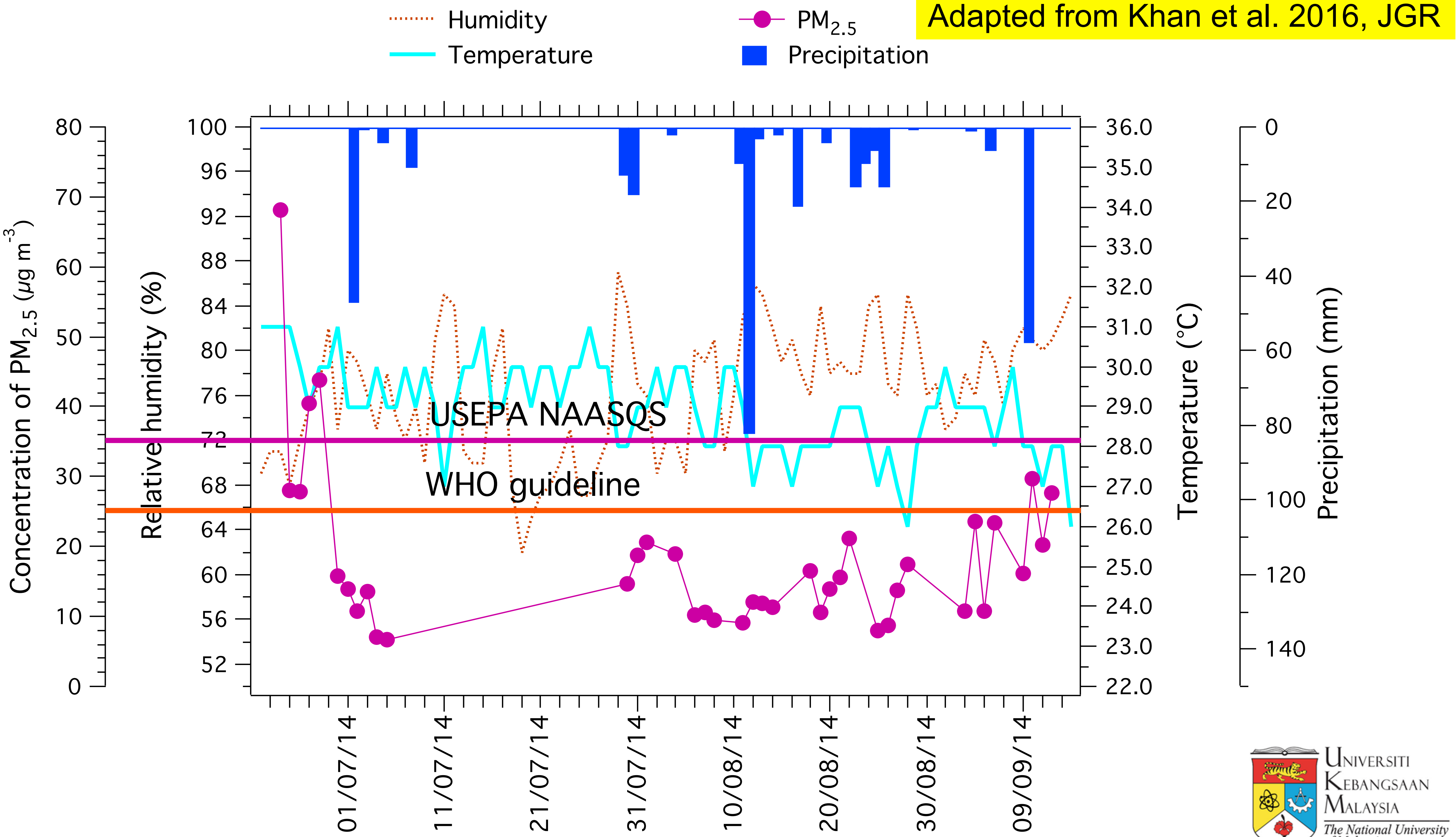
$PM_{2.5}$: Bangi area-2014 [Sub-urban site]



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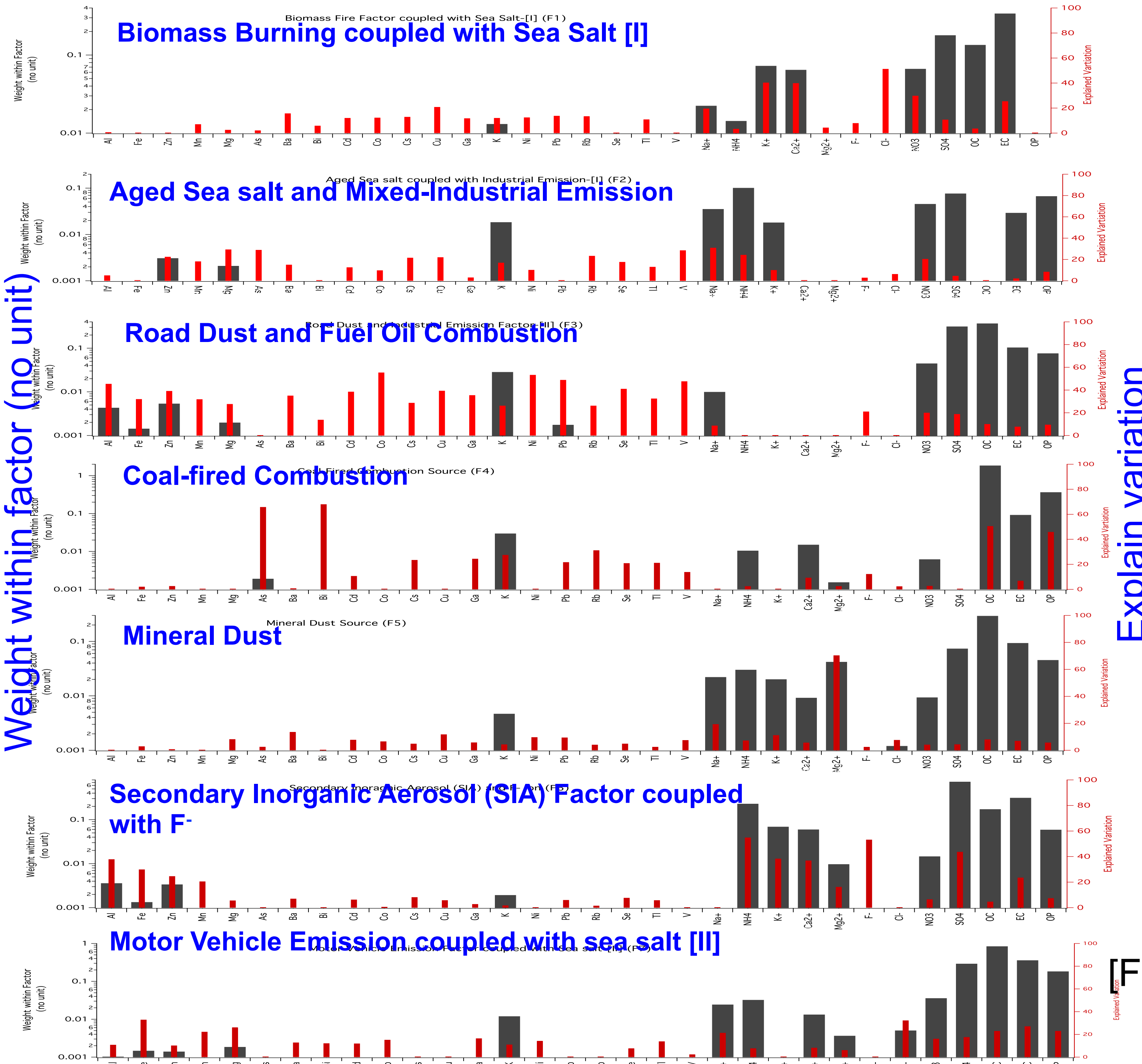
Identified sources of $PM_{2.5}$ by PMF in suburban site



Refereed Tracers

[**K^+**, Ca^{2+}, **Na^+, Cl^-**, NO_3^-, **EC**]

[**Na^+**, NH4, **Mn**, Mg, **V, As, Cs, Cu**]

[**Pb, Cu**, Se, **V, Ni,** Cd, Al, Zn, Co]

[**As**, Bi, **OC**, OP]

[**Mg^{2+}**, Na^+, Ba, Cu, K^+]

[**NH_4^+, F^-, SO_4^{2-}**]

[Fe, Mn, Mg, **EC, OC**, OP, **Na^+, Cl^-**]

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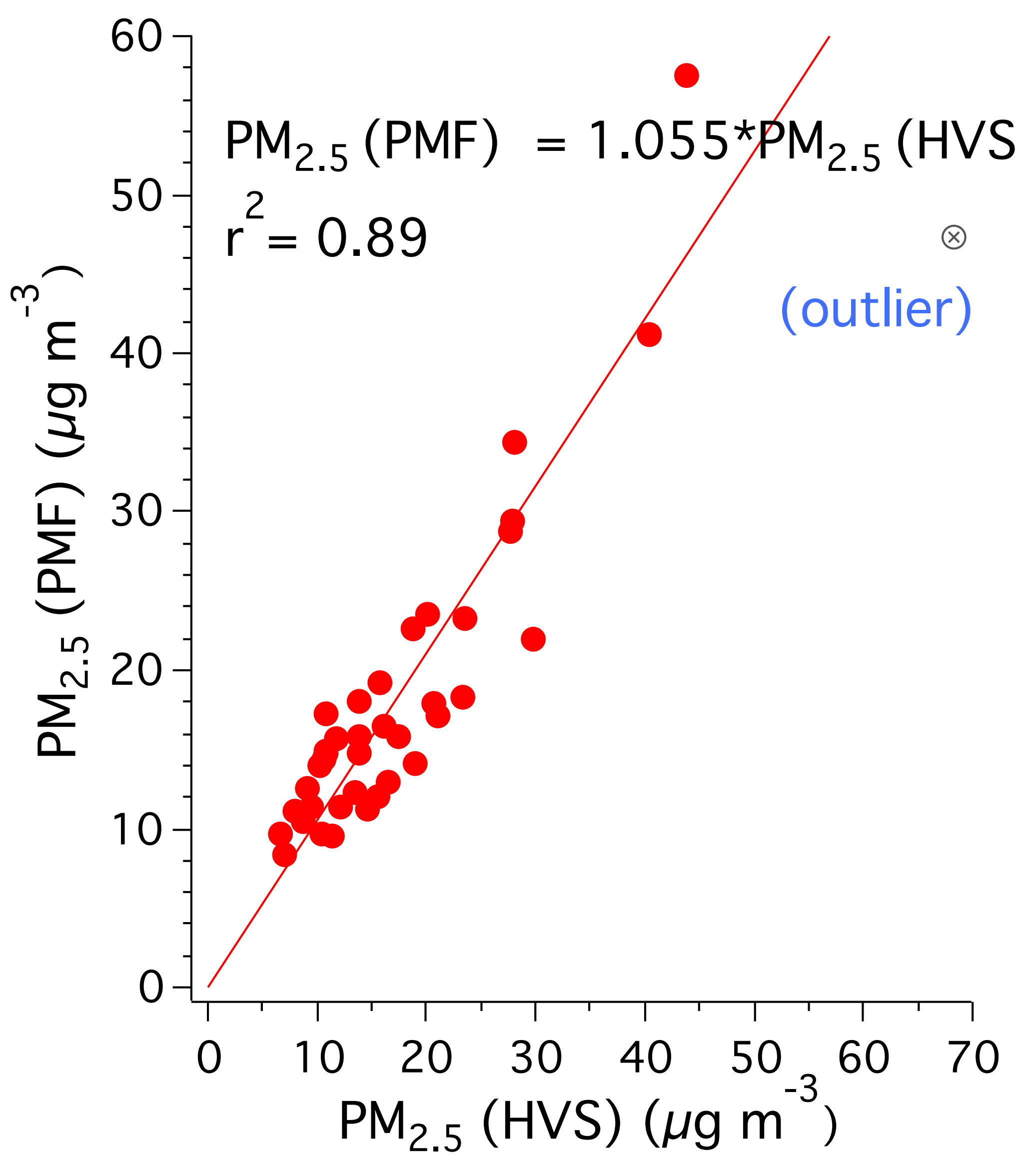
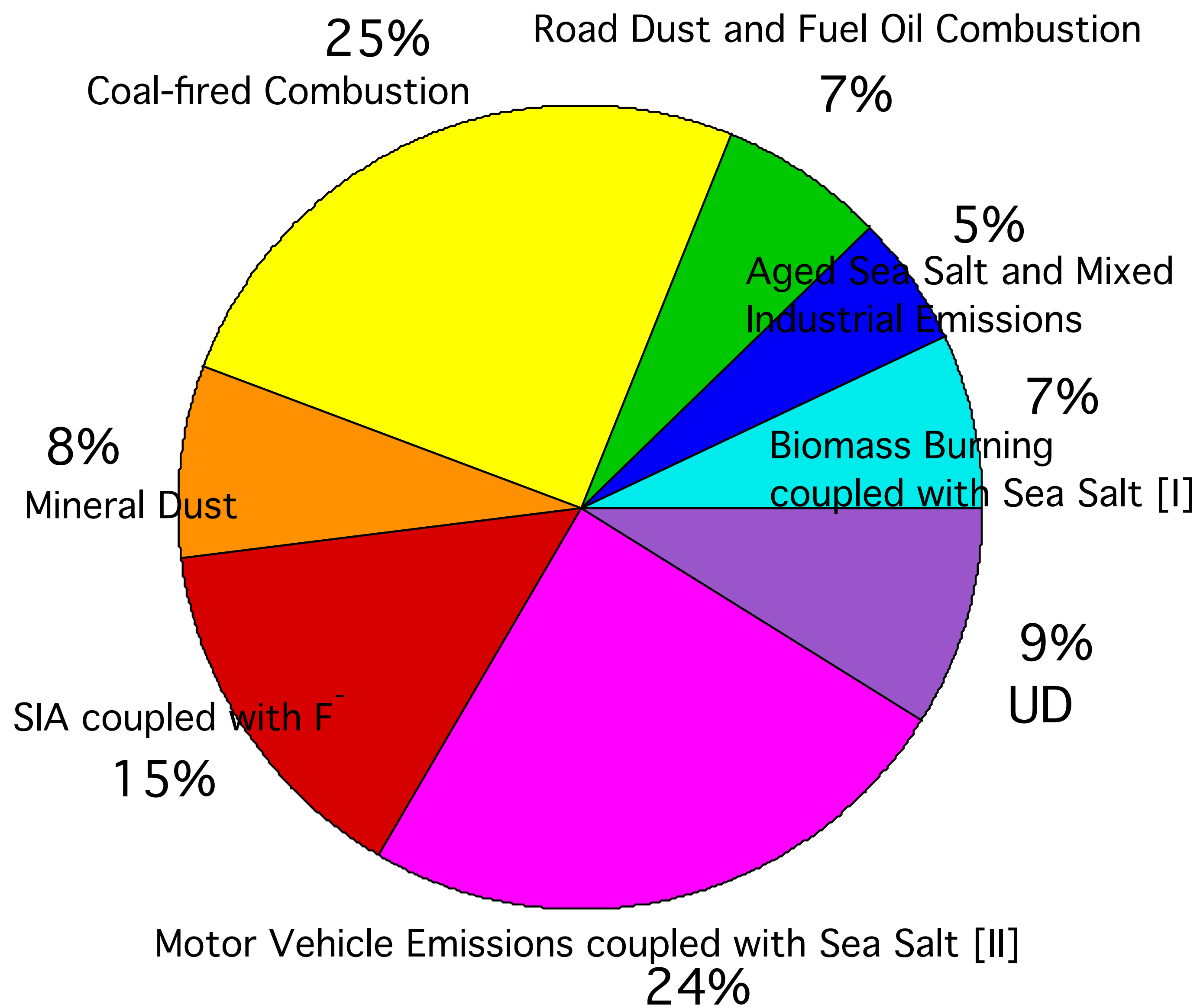
Contribution of each source by the percentage





- ❑ The measured $PM_{2.5}$ concentrations and the predicted $PM_{2.5}$ were in **good concordance**
- ❑ Motor vehicle emissions, SIA and coal-fired power plant are the **predominant sources**

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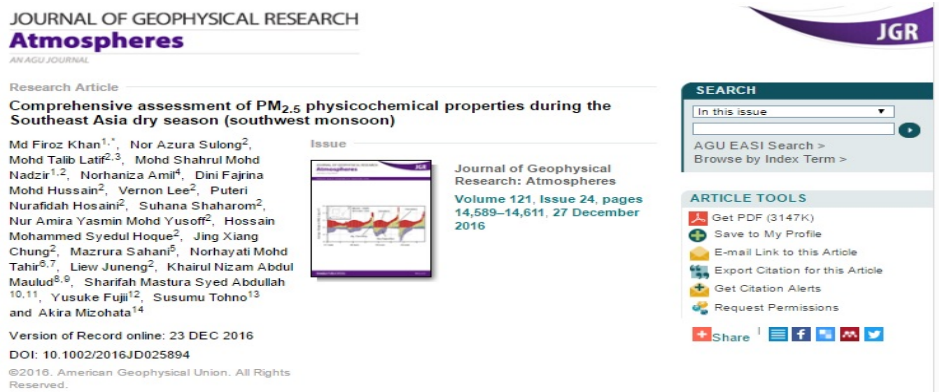
Validation of the source region by PSCF

- Clackson University, USA
- Chines Academy of Sciences
- UKM Group, **Khan et al. 2016 (Hysplit-Matlab-GrADS)**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JGR

Research Article

Comprehensive assessment of $PM_{2.5}$ physicochemical properties during the Southeast Asia dry season (southwest monsoon)

Md Firoz Khan[1,*], Nor Azura Sulong[2], Mohd Talib Latif[2,3], Mohd Shahrul Mohd Nadzir[1,2], Norhaniza Amil[4], Dini Fajrina Mohd Hussain[2], Vernon Lee[2], Puteri Nurafidah Hosaini[2], Suhana Shaharom[2], Nur Amira Yasmin Mohd Yusoff[2], Hossain Mohammed Syedul Hoque[2], Jing Xiang Chung[2], Mazrura Sahani[5], Norhayati Mohd Tahir[6,7], Liew Juneng[2], Khairul Nizam Abdul Maulud[8,9], Sharifah Mastura Syed Abdullah[10,11], Yusuke Fujii[12], Susumu Tohno[13] and Akira Mizohata[14]

Issue

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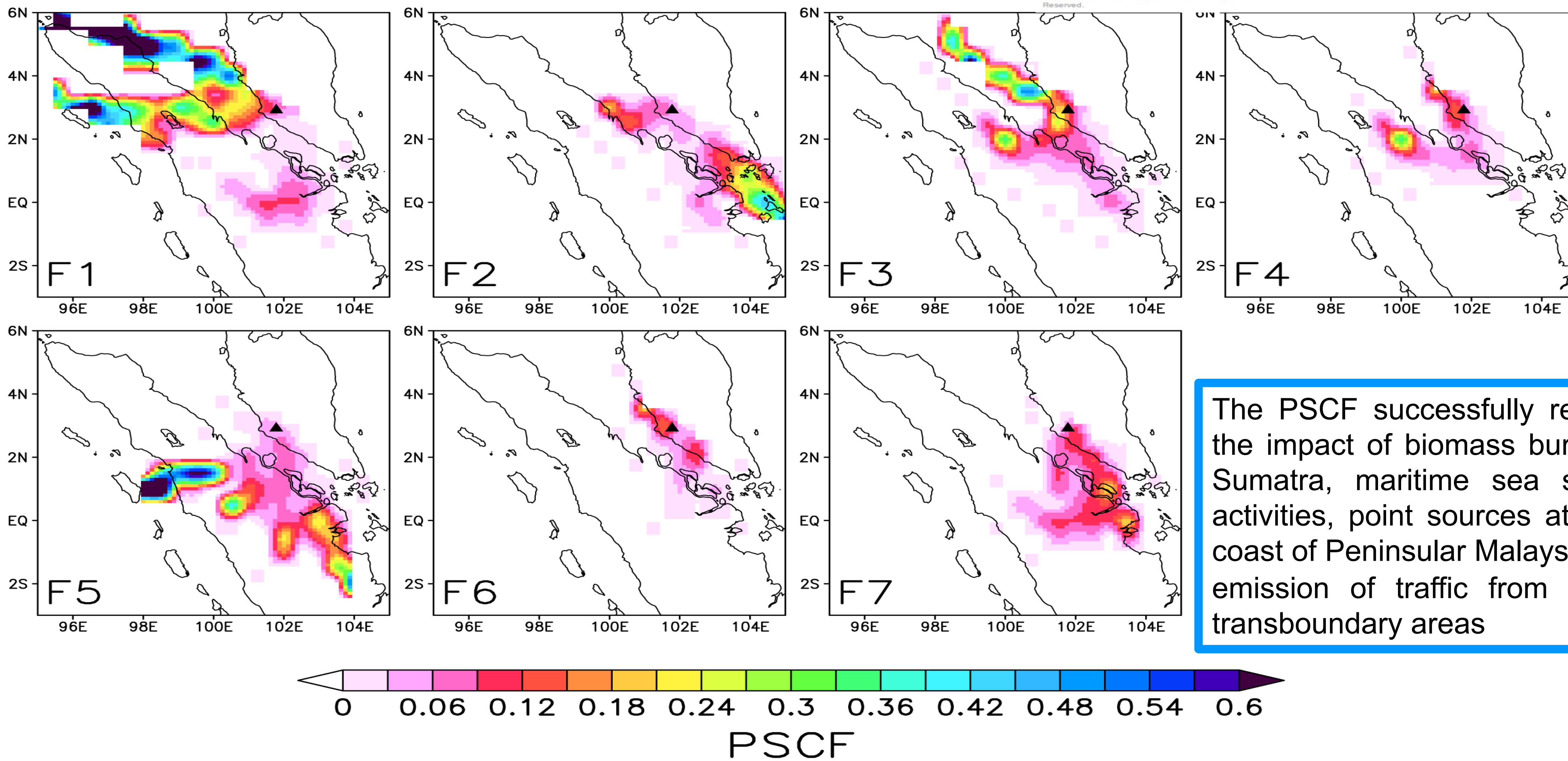

The PSCF successfully reproduced the impact of biomass burning from Sumatra, maritime sea salt, local activities, point sources at the west coast of Peninsular Malaysia and the emission of traffic from local and transboundary areas

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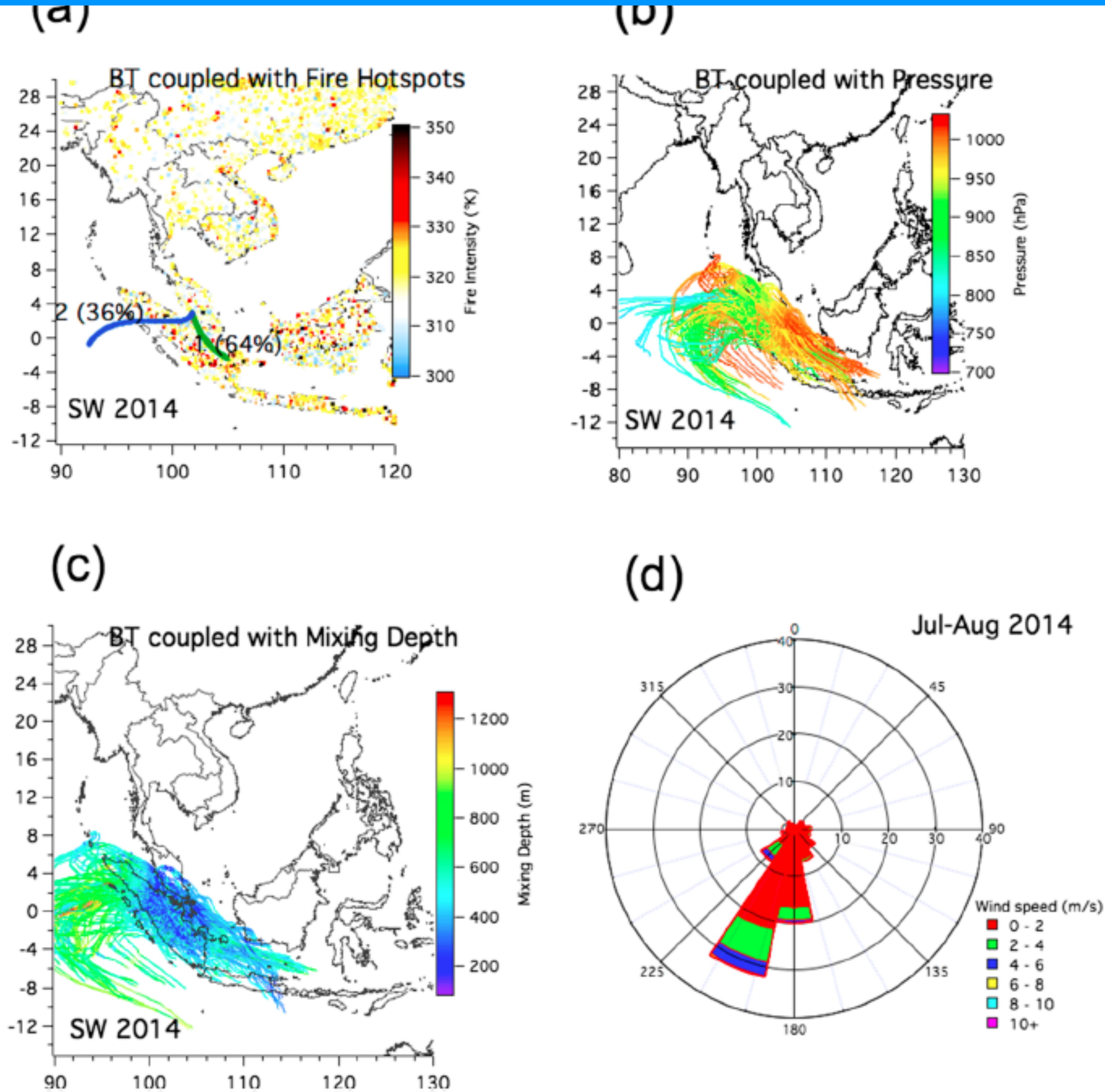
Impact of biomass fire hotspots, PBL and wind component



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Results from a recent campaign in Kuala Lumpur City

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A Mobile Car used in the campaign

Team Members

Instruments in Operation

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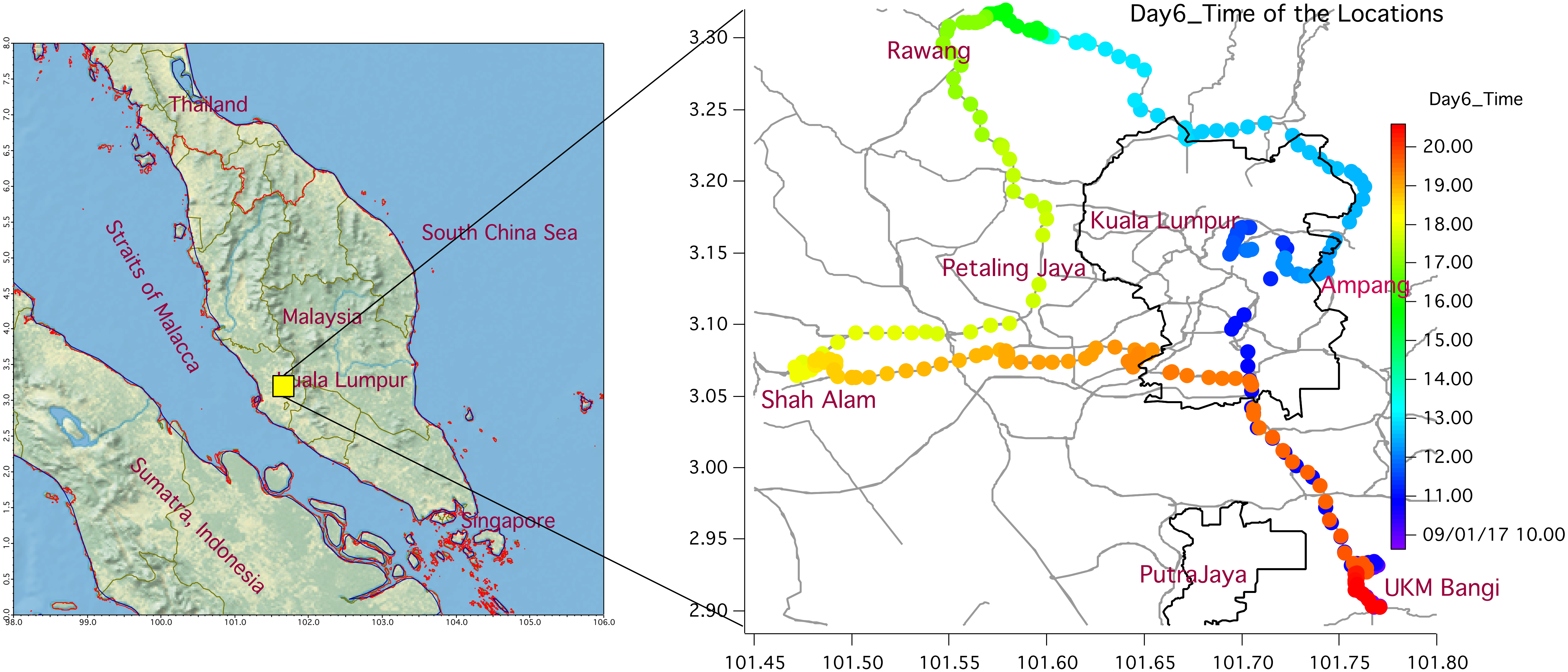
The Pathways of the Trajectories in the Campaign



UKM Bangi – KL – Rawang – Shah Alam – UKM Bangi

[Sub-urban – Urban – Residential – Industrial/Res. – Sub-urban]

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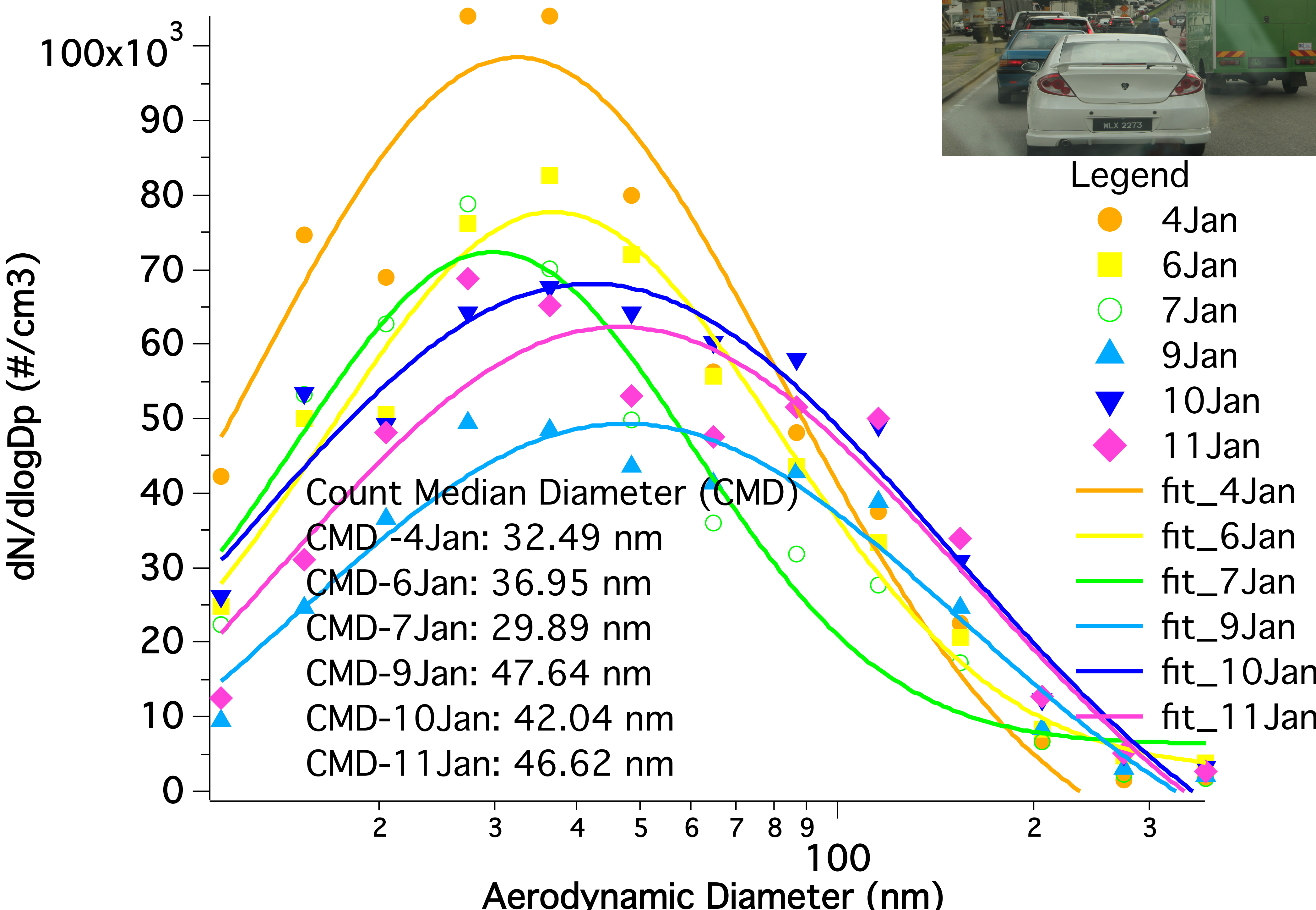
Particle Number Distribution



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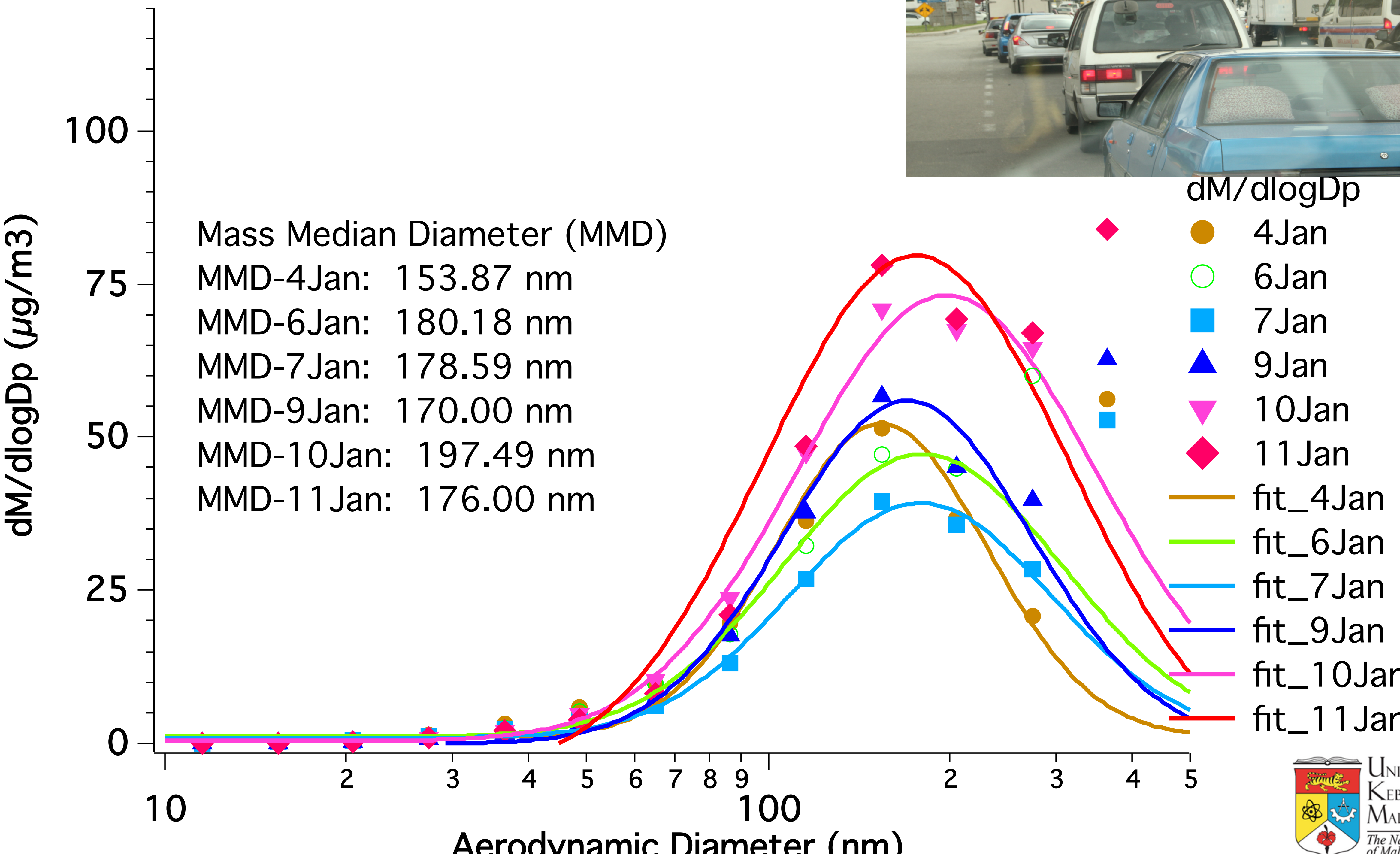
Particle Mass Distribution



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Key Points from the campaign in Kuala Lumpur

- A lognormal fitting model was applied to the normalized PNC and mass concentration (Khan et al. 2015)
- Particle count measured at a wide range of <0.4 micro meter spectrum which is new in this location
- CMD value < 100 nm → nucleation mode → freshly generated combustion sources

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Key Findings of the Studies

- Receptor modelling interprets data in terms of source contributions and / or their locations.
- Large scale field studies are expensive and causes a lot of time. Receptor modelling uses data obtained from souces and receptor sites. Thus, this method require less logistics and time.
- Motor vehicle emissions, SIA and coal-fired power plant are the **predominant sources** contributing to $PM_{2.5}$
- The **PSCF successfully reproduced the impact of biomass burning, maritime sea salt, local activities, point sources at the west coast of Peninsular Malaysia and the emission of traffic from local and transboundary areas**
- The source information can be used to meet the PM2.5 standards and to justify the implimentation plan of the local regulatory body through **a cost-effective emissions reductions strategies**

- CMD value < 100 nm → nucleation mode → freshly generated combustion sources

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References

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Md Firoz Khan, M. T. Latif, W. H. Saw, N. Amil, M. S. M. Nadzir, M. Sahani, N. M. Tahir, and J. X. Chung (2016), Fine particulate matter in the tropical environment: monsoonal effects, source apportionment, and health risk assessment, *Atmos. Chem. Phys.*, *16*(2), 597-617, doi:10.5194/acp-16-597-2016.

Md Firoz Khan, M. T. Latif, N. Amil, L. Juneng, N. Mohamad, M. S. M. Nadzir, and H. M. S. Hoque (2015), Characterization and source apportionment of particle number concentration at a semi-urban tropical environment, *Environmental Science and Pollution Research*, 1-16.

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Thank you for your kind attention!!!

Any possible collaboration, please contact: mdfiroz.khan@ukm.edu.my; mdfiroz.khan@gmail.com

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Question and Answer

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