

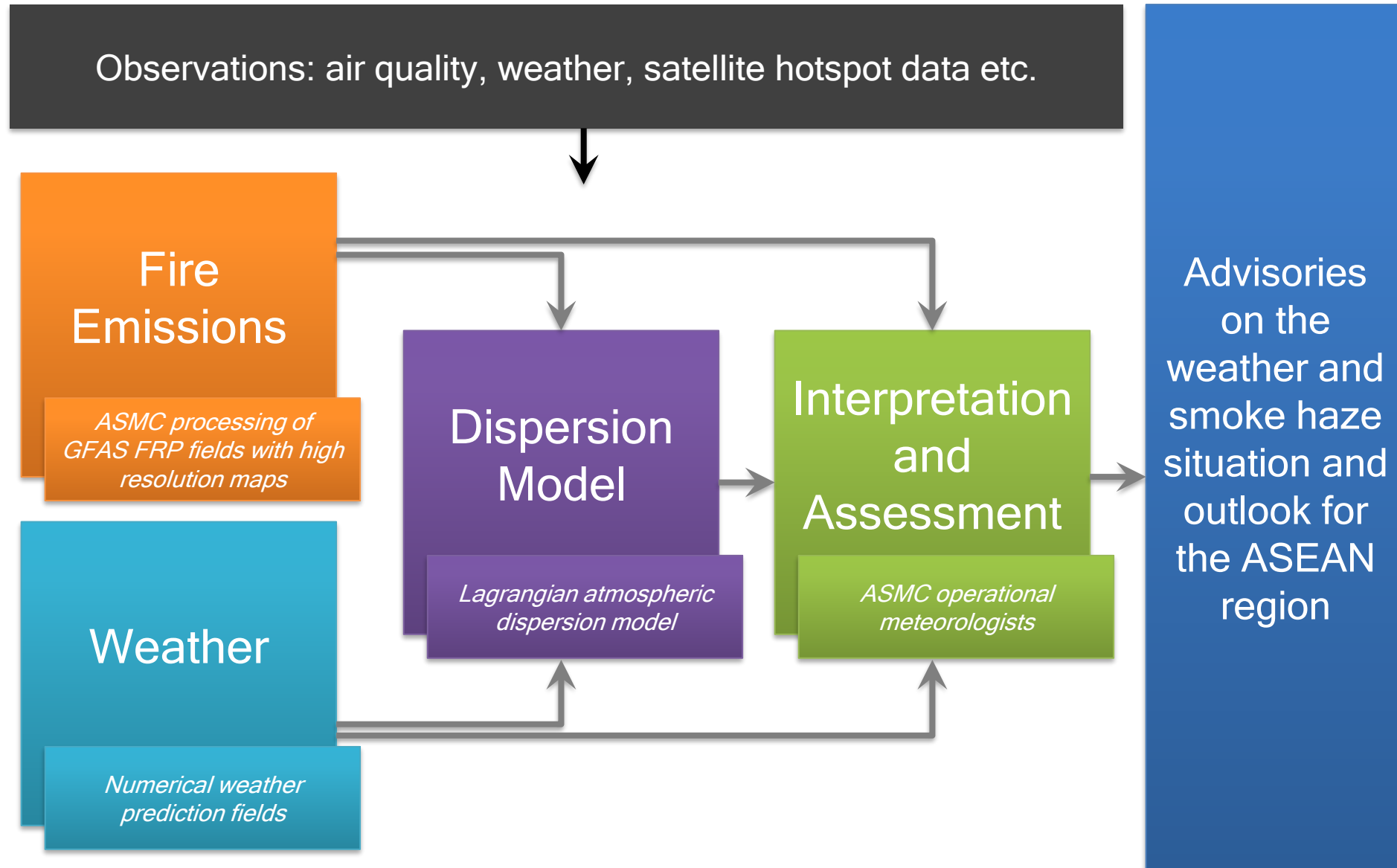
# Smoke Haze Dispersion Modelling at the ASMC

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**Executive Meteorologist**  
**ASEAN Specialized Meteorological Centre**

# Acknowledgement

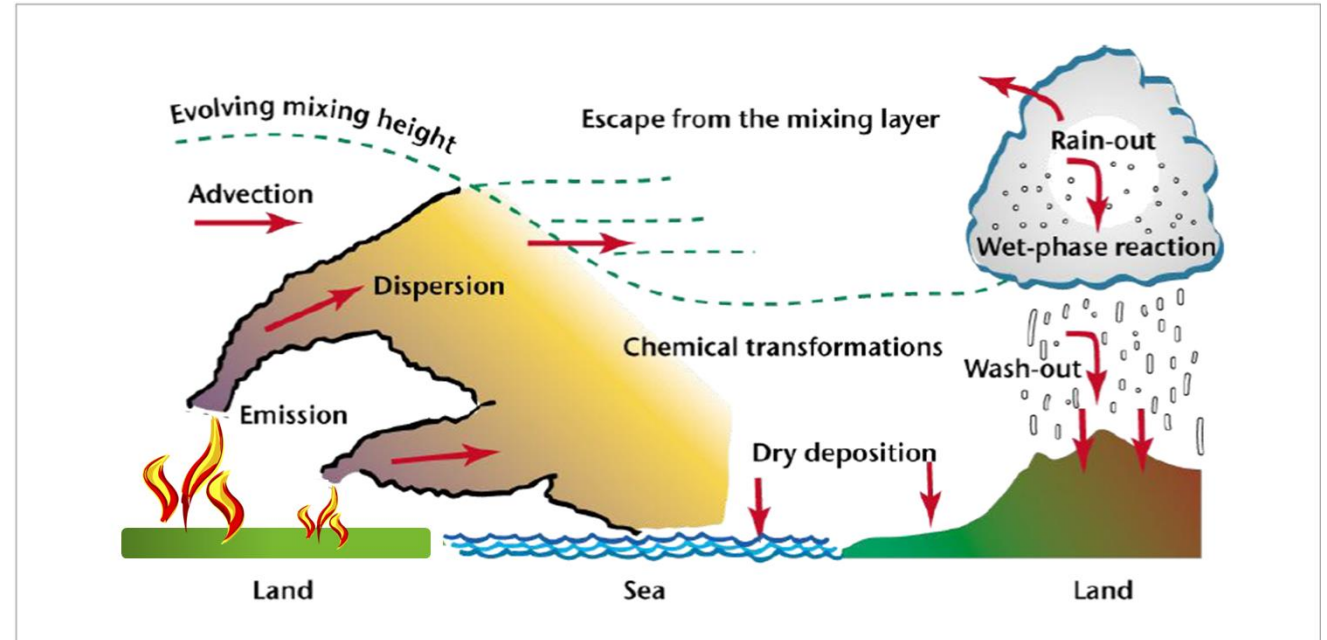
- Past and present contributors to the system development
  - Christopher Gan
  - Boon Ning Chew
  - Chee Kiat Teo
  - Shaoyi Lee
  - Wei Ming Chong
  - Kaiyuan Zheng
  - Zhong-Yi Chia
  - Sahu Shovan Kumar
  - Rachel Soh

# Overview of Dispersion Modelling System

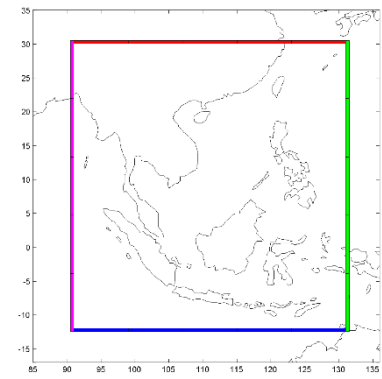


# Basics of modelling smoke dispersion

- Description of emission sources, which include pollutants and heat released
- Determination of plume rise through examination of atmospheric stability and wind profiles, and fire-source rate of heat release to determine the vertical extent of the plume
- Transport and dispersion of smoke by ambient wind
- Chemical transformations of smoke pollutants as they react with each other and with the ambient atmosphere



# MSS-UKMO NAME model

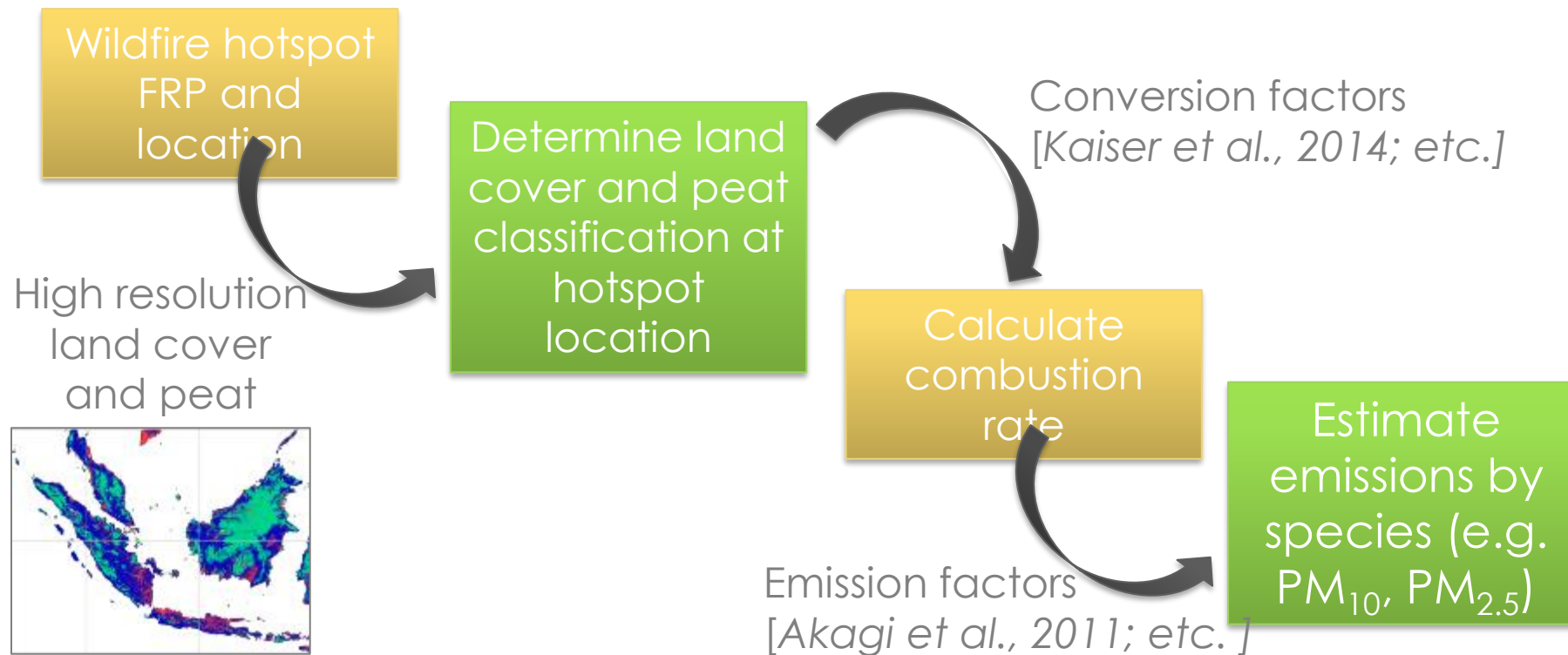


- We are using NAME (Numerical Atmospheric-dispersion Modelling Environment) model for smoke haze dispersion modelling [*Hansen et al., 2019; Hertwig et al., 2015; Lee, Gan and Chew, 2016*]
- NAME atmospheric pollution dispersion model was first developed by the UK Met Office (UKMO) in 1986 after the nuclear accident at Chernobyl.
- Partnership with UKMO since 2013 to develop NAME for use in Southeast Asia.
- NAME is a Lagrangian model with chemistry scheme.

	Existing Haze System
<b>Forecast species</b>	PM <sub>10</sub> , PM <sub>2.5</sub> , and 550nm-AOD
<b>Wildfire emissions</b> (modified CAMS-GFAS)	CAMS-GFAS (Global Fire Assimilation System) applied on high resolution landcover map
<b>Other emissions</b>	Regional emission inventories
<b>LBCs</b>	Monthly averaged oxidant fields from AQUM climatology
<b>NWP</b>	ECMWF HRES (deterministic)
<b>Initialisation</b>	Cold start (7 days spin up)
<b>Configuration</b>	0.25° chemistry grid 15 min sync time
<b>Domain</b>	91°E – 131°E; 12°S – 24°N; 0-8 km above ground level

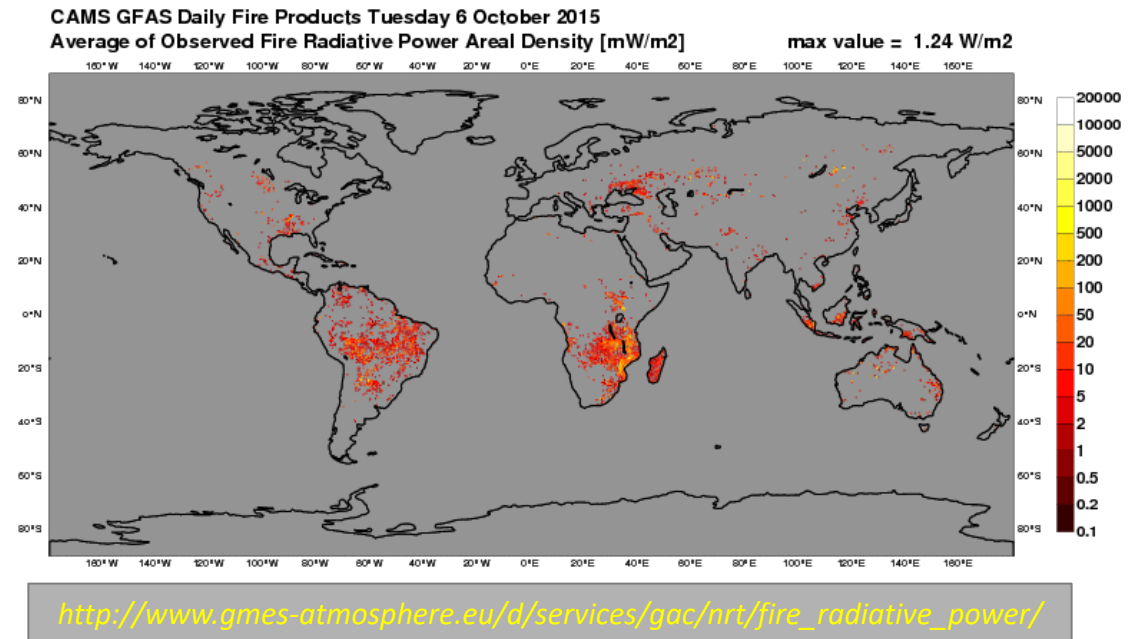
# Wildfire emissions - Overview

- Fire Radiative Power (FRP) provides information on the measured radiant heat output of detected fires
- It has been demonstrated that FRP is related to the rate of fuel combustion and can be combined with land use information to estimate emissions from biomass burning [Wooster *et al.*, 2005]



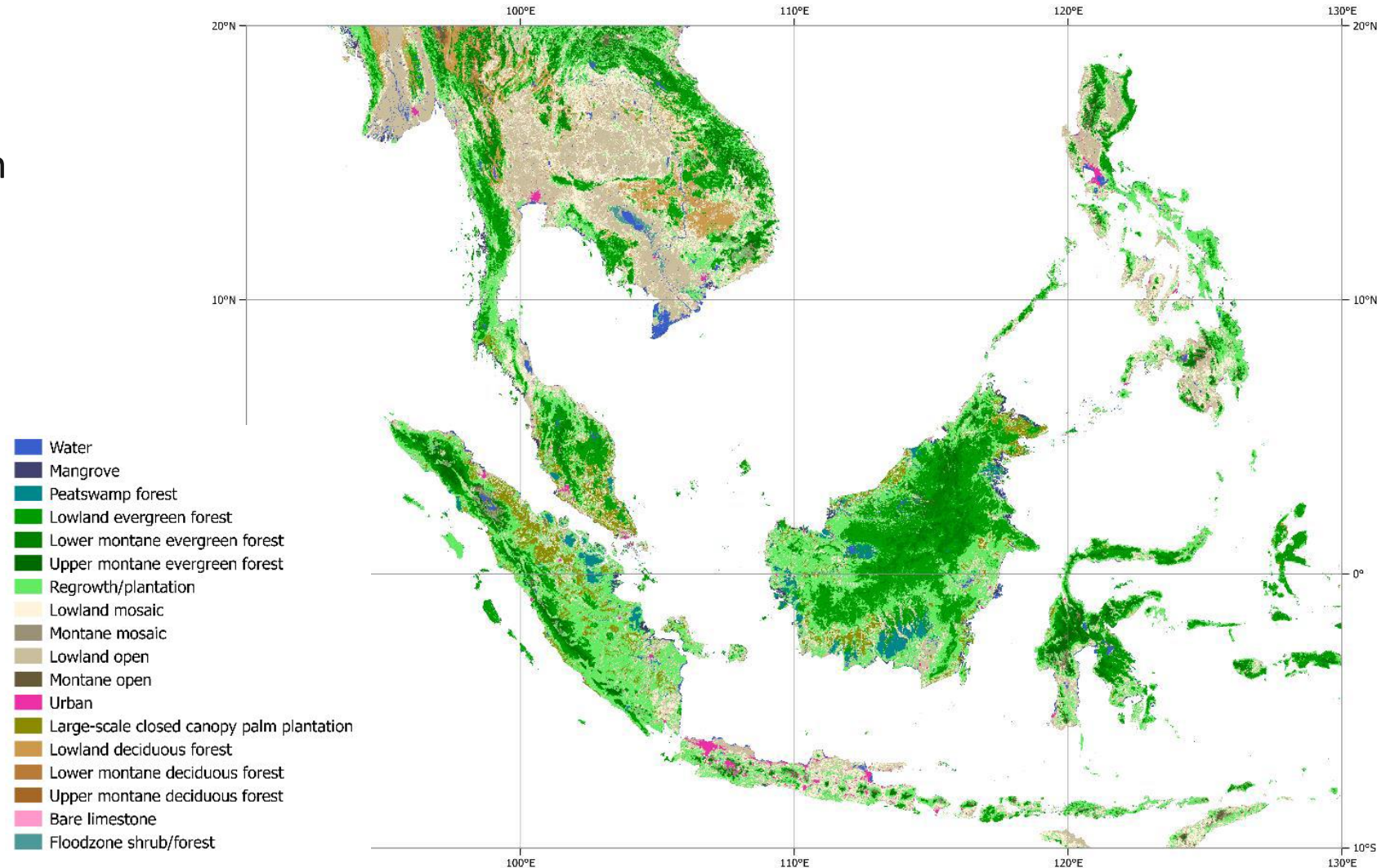
# Wildfire emissions – Fire radiative power

- Variables retrieved from the Global Fire Assimilation System (GFAS) of the Copernicus Atmospheric Monitoring Service (CAMS)
  - Fire radiative power (FRP)
  - Plume height information
    - Mean altitude of maximum injection (until 2023)
    - Altitude of plume top (2023 onwards)
- GFAS fields are available at  $0.1^\circ$  spatial resolution and values are assumed to be constant within each 24-hour window
- In the set-up of MSS-UKMO NAME forecast, the latest available fire information is assumed to persist into the prediction period.



# Wildfire emissions – Land cover map

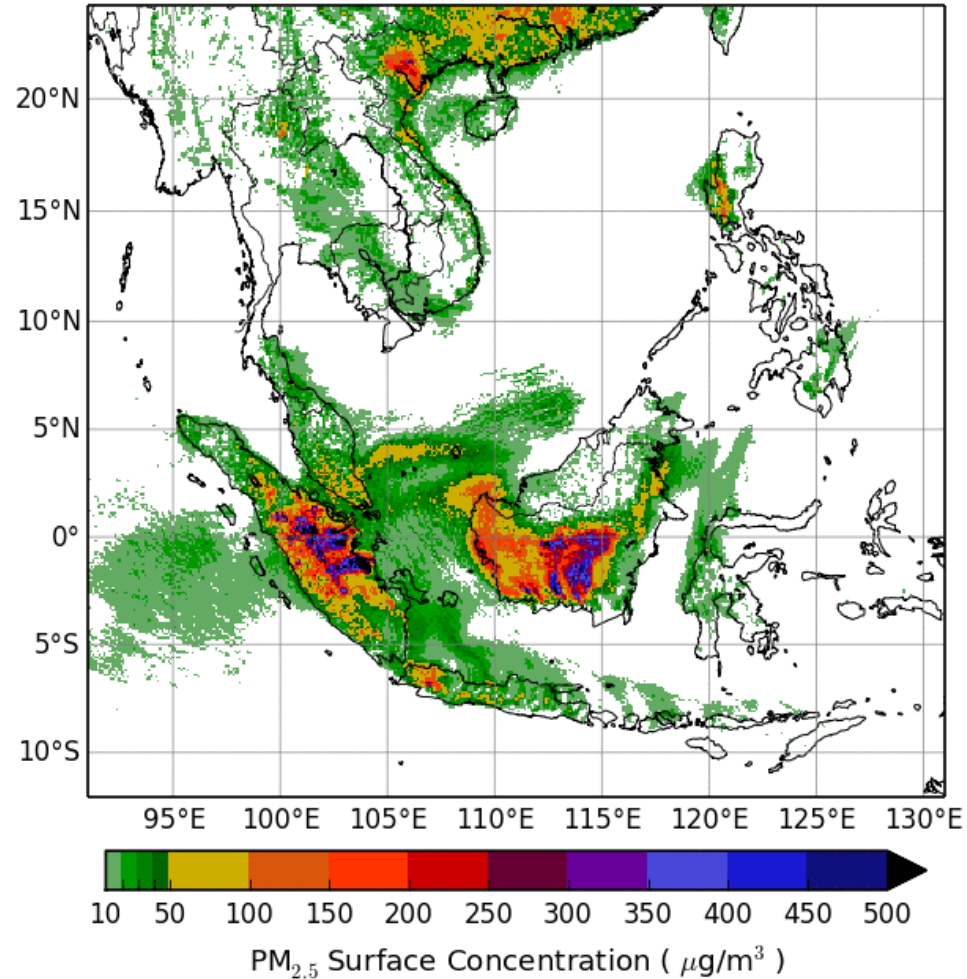
- Emissions of  $PM_{2.5}$  and  $PM_{10}$  are estimated from FRP using land cover specific conversion and emission factors
- Land cover information from public domain sources and satellite analysis, developed by the Centre for Remote Imaging, Sensing and Processing (CRISP) [Miettinen *et al.*, 2016]



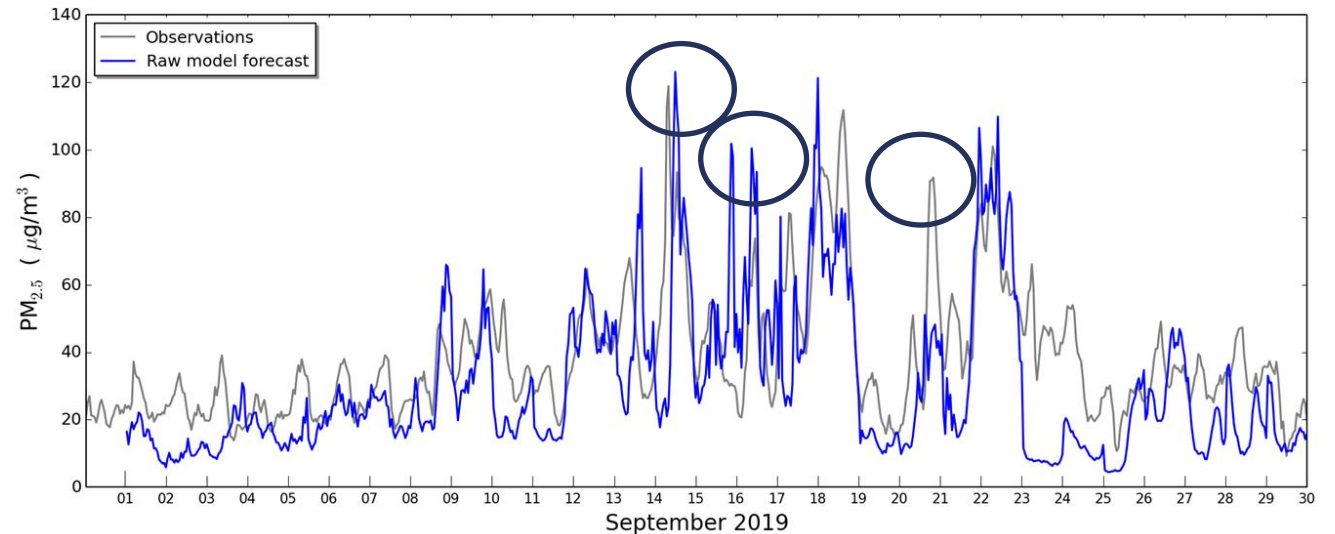
# An example of model performance during the last prolonged haze episode in Singapore in 2019

Forecast cycle on 14 Sep 2019 00 UTC

Valid: 13/09/2019 00:00 UTC

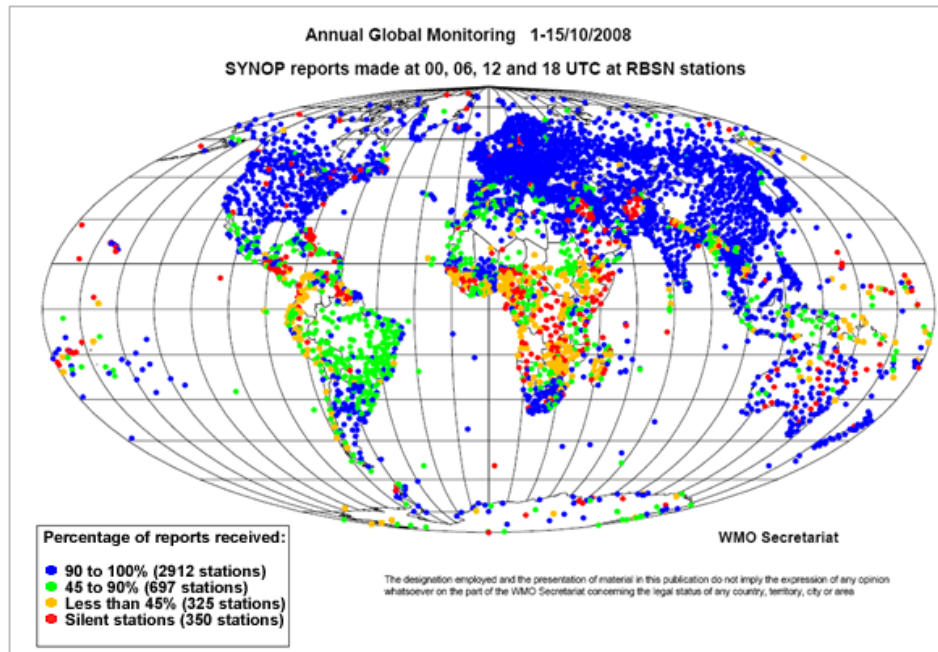


Surface PM<sub>2.5</sub> forecast (Day 2 forecast concatenated from all 00 UTC cycles) versus ground observation over Singapore

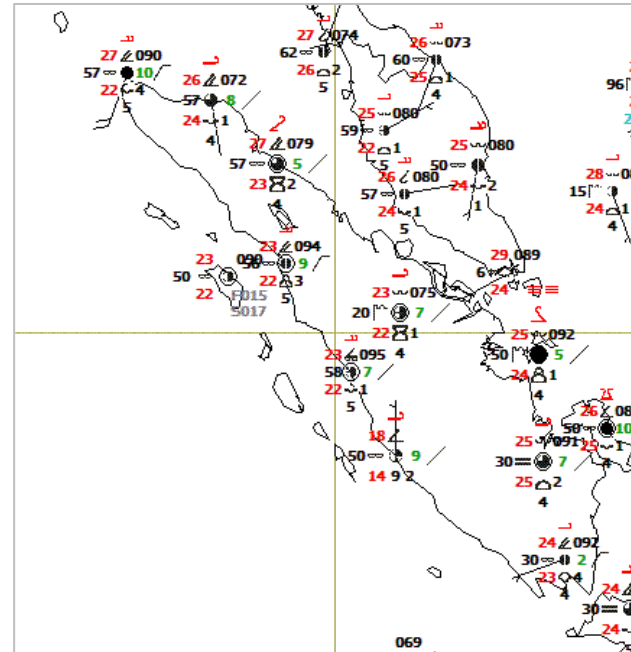


# Difficulties in modelling smoke haze dispersion

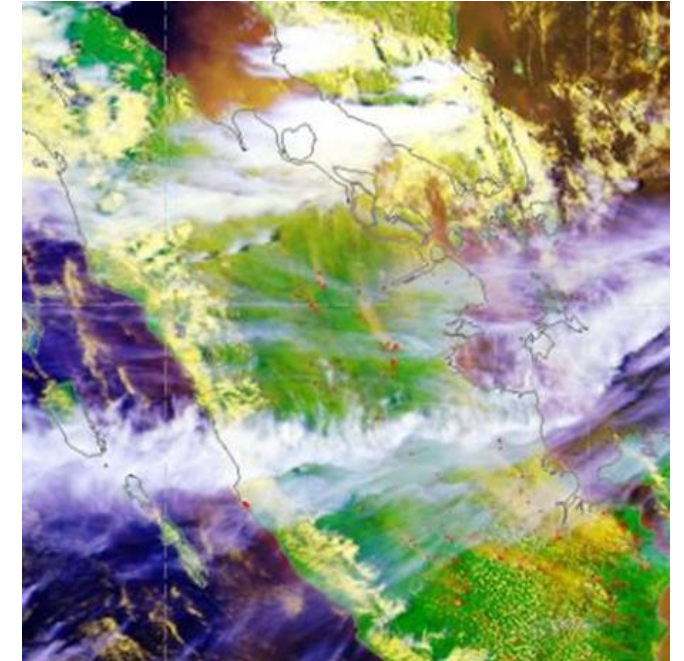
- Tropical weather in our region poses challenges for predicting local wind flows (e.g., land-sea interactions) and transient, small-scale weather systems such as localised thunderstorms
- Large expanse of sea areas and low density of weather station coverage in the region over land
- Limited availability of air quality observations
- Obscuration of fires and haze from thick cloud cover in the equatorial region



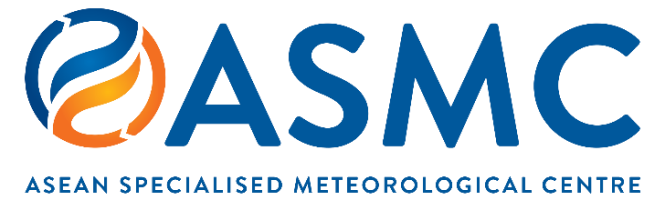
WMO's Network of Weather Monitoring Stations



Weather SYNOP stations



Cloud cover can obscured fires and haze observation



# Website for RSMC-VFSP Singapore

- Website for the RSMC-VFSP: [www.mss-int.sg/vfsp-was](http://www.mss-int.sg/vfsp-was)
- Products are updated in real-time and assessable via the public website, grouped into three main areas:

## Forecasts

- Atmospheric dispersion modelling products for smoke haze (AOD, PM2.5, PM10)
- Evaluation metrics
- NWP wind forecast
- Subseasonal outlook

## Observations

- Fire hotspots
- Satellite images (Polar-orbiting and Geostationary)

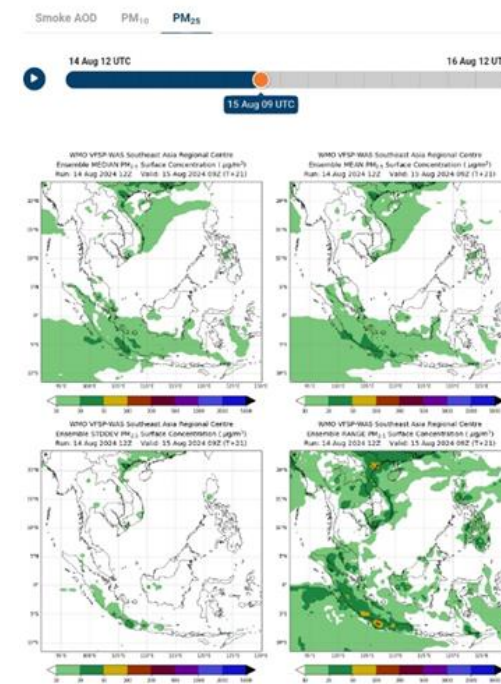
## Fire Risk

- ASEAN Fire Danger Rating System (FDRS) - produced by Met Malaysia

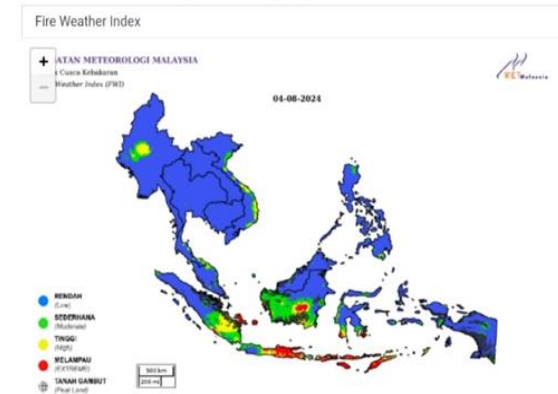
Landing page of RSMC-VFSP website



Multi-model Ensemble

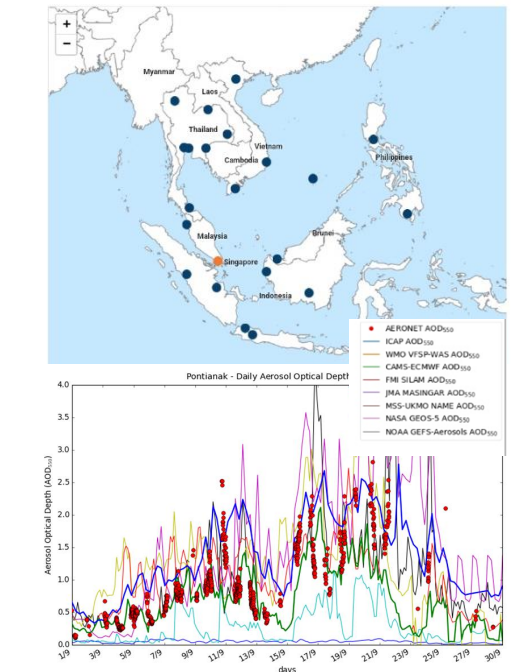


ASEAN FDRS –produced by Met Malaysia



Model Forecast Evaluation

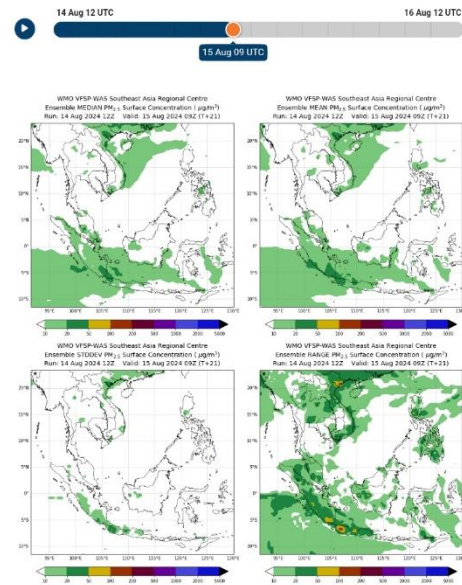
Near real-time comparison between model forecasts and observations of smoke aerosol optical depth (AOD).



# Dispersion Model Products

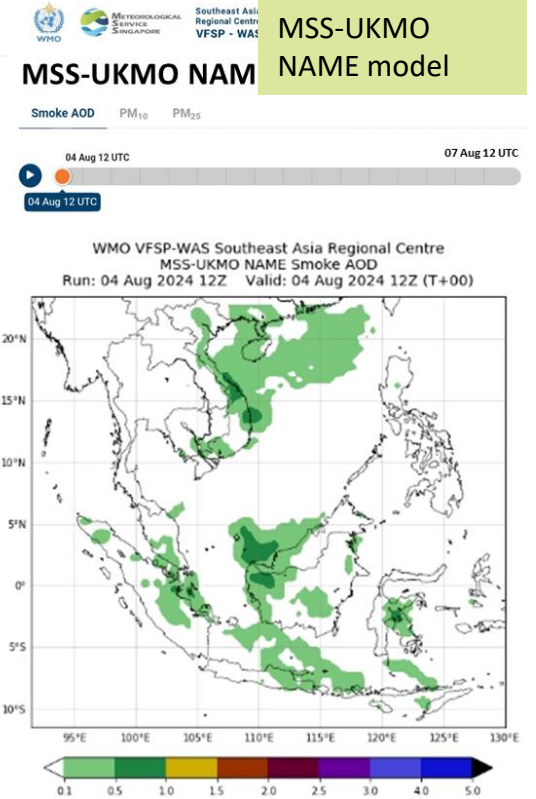
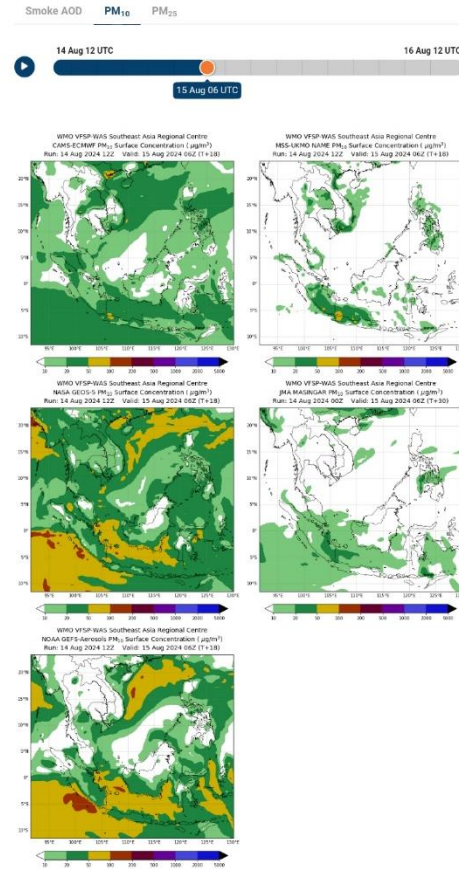
- 6 members currently, 5 global models: ECMWF-CAMS (Europe), JMA MASINGAR (Japan), NASA GEOS-5 (USA), NOAA GEFS-Aerosols (USA), FMI SILAM (Finland) and 1 regional model: MSS-UKMO NAME (Singapore)
- 00 and 12 UTC Aerosol Optical Depth (AOD),  $PM_{2.5}$  and  $PM_{10}$  forecast products
- Ensemble grid resolution at  $0.5^\circ \times 0.5^\circ$
- Ensemble has two products describing centrality (multi-model median and mean) and another two describing the spread (standard deviation and range of variation)

## Multi-model Ensemble model forecasts of $PM_{2.5}$ , $PM_{10}$ and AOD



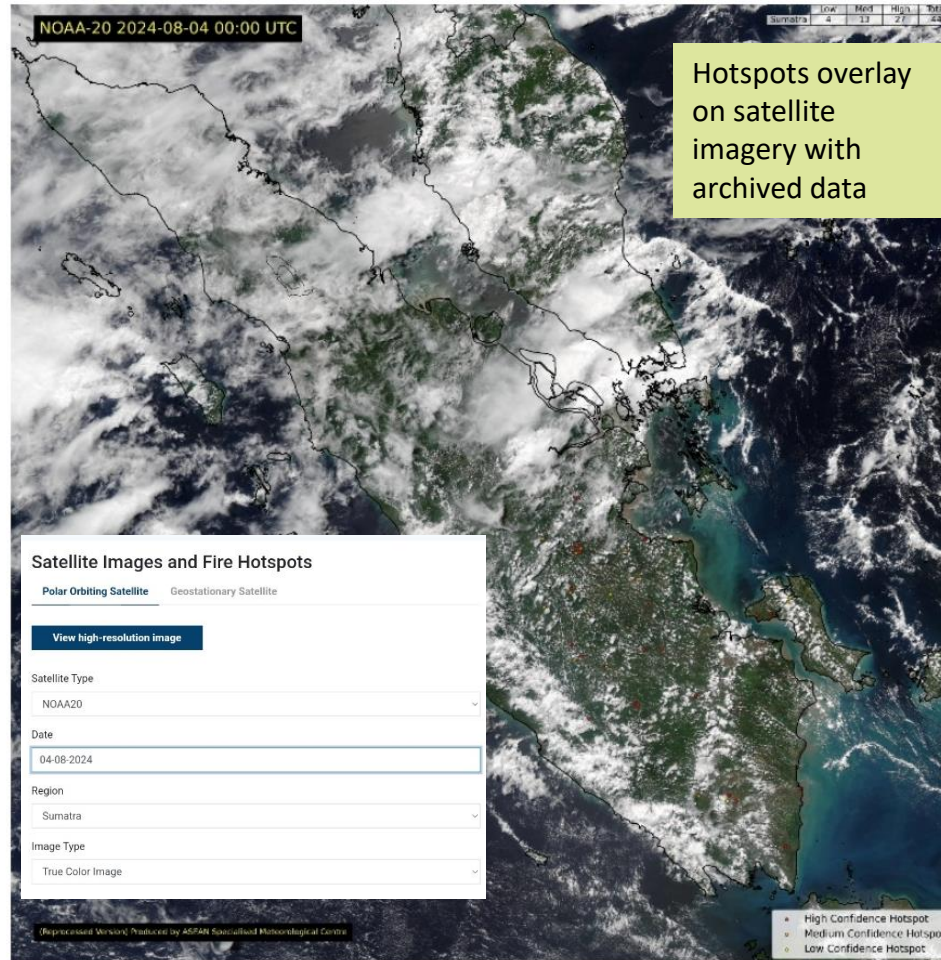
## Models intercomparison

Forecasts of smoke aerosol optical depth (AOD) and surface particulate matter concentrations from individual models.



The MSS-UKMO NAME model forecasts are up to 72 hours ahead and at 3-hourly intervals. The outputs from the model are represented using a common grid at a resolution of  $0.5^\circ \times 0.5^\circ$ , and a geographical domain covering the major burning areas and smoke transport pathways in Southeast Asia. More information on the model can be found [here \[link to FAQ page\]](#).

# Fire and Haze Activity/ Satellite Products



## Weather & Haze Situation

Wet weather and cloudy conditions were observed over most of the ASEAN region, except over Kalimantan, Java, the Lesser Sunda Islands and the southern parts of Sumatra where conditions were drier. In the northern ASEAN region, a few hotspots were detected in Thailand and Viet Nam, while in the southern ASEAN region, isolated to scattered hotspots were mostly detected in the western parts of Kalimantan and the southern parts of Sumatra. No significant smoke plumes were observed. The full extent of the hotspot and smoke haze situation over the region could not be determined due to cloud cover. Over the coming days, wet weather is forecast over most of the ASEAN region, except for Java, the Lesser Sunda Islands, the southern and western parts of Kalimantan and the southern parts of Sumatra where drier conditions are expected. Isolated hotspots with localised smoke plumes may develop in parts of the region which remain dry. The prevailing winds are forecast to blow from the southwest to west over areas north of the Equator, while the prevailing winds over areas south of the Equator are forecast to blow from the southeast to south.

Updated 6:31 PM 04 Aug

Daily weather and haze analysis and outlook

## Weather & Haze Outlook

Over the coming days, wet weather is forecast over most of the ASEAN region, except for Java, the Lesser Sunda Islands, the southern and western parts of Kalimantan and the southern parts of Sumatra where drier conditions are expected. Isolated hotspots with localised smoke plumes may develop in parts of the region which remain dry. The prevailing winds are forecast to blow from the southwest to west over areas north of the Equator, while the prevailing winds over areas south of the Equator are forecast to blow from the southeast to south.

Updated 6:31 PM 04 Aug



# Fire and Haze Activity/ Satellite Products

## Satellite Images and Fire Hotspots

Polar Orbiting Satellite

Geostationary Satellite

Satellite Products  
(Geostationary and  
Polar-Orbiting)

Region

Southern ASEAN

Image Type

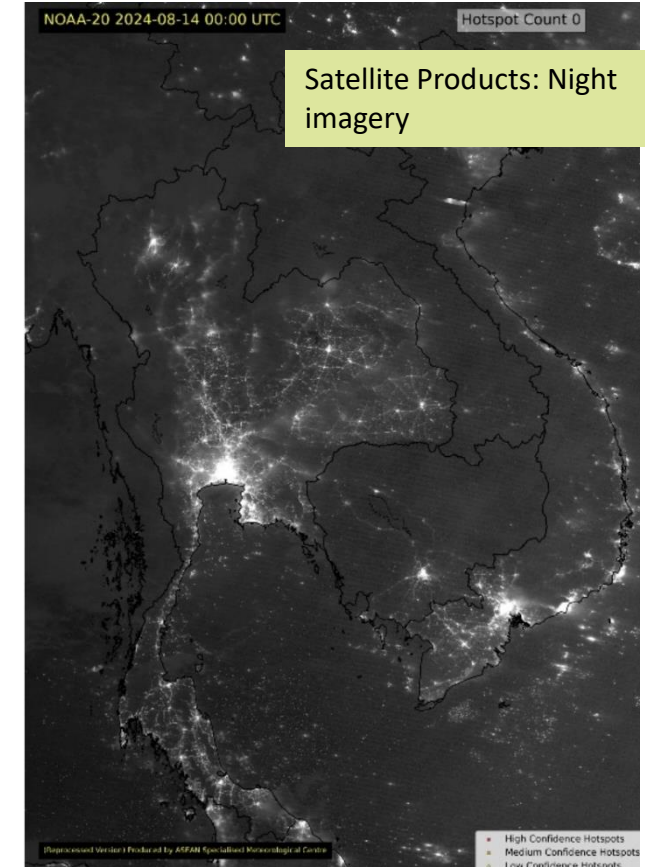
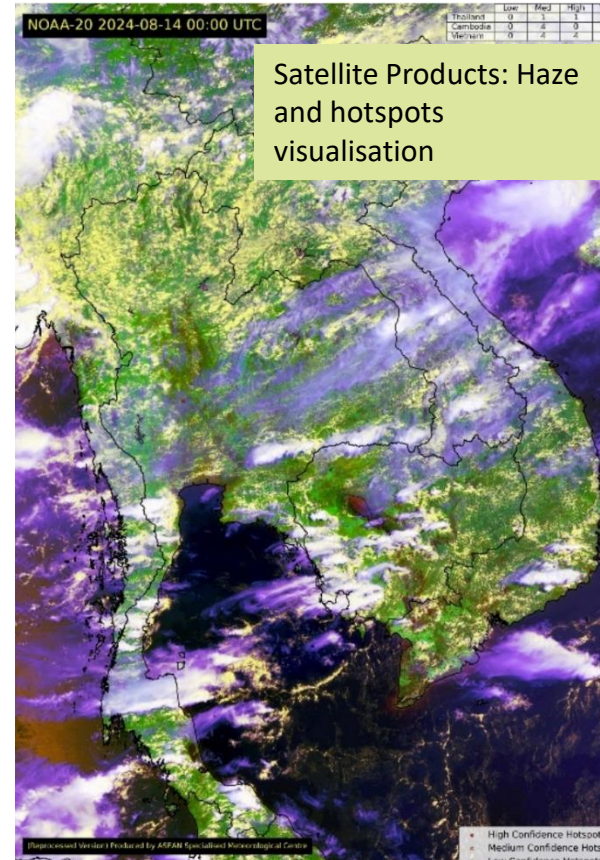
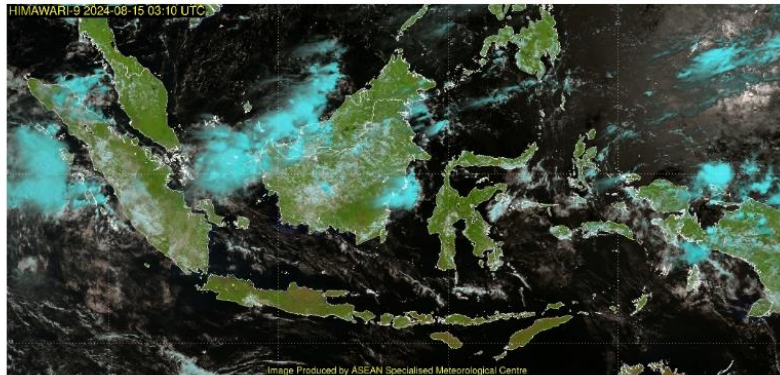
Natural Color Image

15 Aug 0310 UTC

15 Aug 0540 UTC

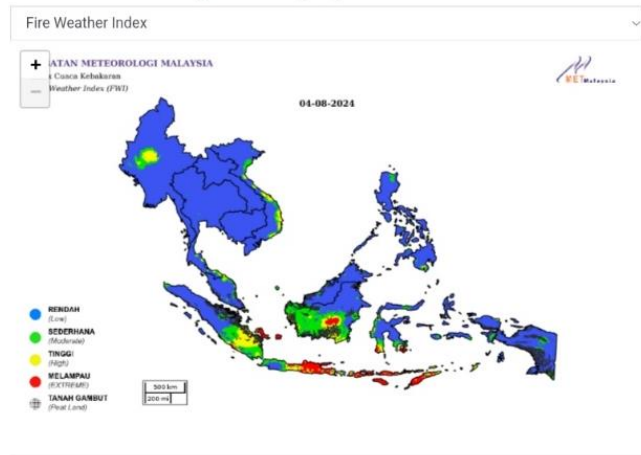


15 Aug 0310 UTC



# Fire Risk and Model Verification

## Fire Risk/Fire Danger Rating System – from Met Malaysia ASEAN Fire Danger Rating System

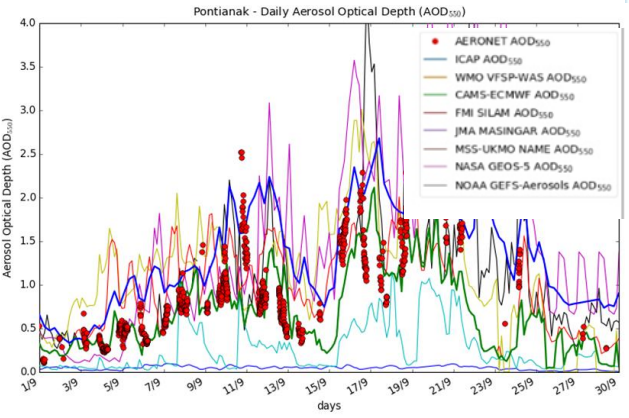


Class Ignition Potential	Interpretation
<b>Low</b>	Low fire intensity. Fire will spread slowly or be self-extinguishing. Grassland fires can be successfully controlled using hand tools.
<b>Medium</b>	Moderate fire intensity in grass. Hand tools will be effective along the fire's flanks, but water under pressure (pumps, hose) may be required to suppress the head fire in grasslands.
<b>High</b>	High fire intensity in grass. Direct attack at the fire's head will require water under pressure, and mechanized equipment may be required to build control lines. (e.g. bulldozer)
<b>Extreme</b>	Very high fire intensity in grass. Fire control will require construction of control lines by mechanized equipment and water under pressure. Indirect attack by back-burning between control lines and the fire may be required.

## Forecast Evaluation Model Forecast Evaluation

### Forecast Evaluation

Near real-time comparison between model forecasts and observations of smoke aerosol optical depth (AOD).



### July 2024

	BIAS						
	CAMS-ECMWF	FMI-SILAM	JMA-MASINGAR	MSS-UKMO-NAME	NASA-GEOS-5	NOAA-GEFS-AEROSOLS	VFSP-WAS-MEDIAN
Northern ASEAN show stations	-0.06	0.06	0.04	0.02	0.03	0.06	0.04
Southern ASEAN show stations	-0.11	0.12	-0.11	-0.01	0.08	-0.13	-0.09
Total	-0.10	0.11	-0.09	-0.01	0.07	-0.11	-0.08

	ROOT MEAN SQUARE ERROR						
	CAMS-ECMWF	FMI-SILAM	JMA-MASINGAR	MSS-UKMO-NAME	NASA-GEOS-5	NOAA-GEFS-AEROSOLS	VFSP-WAS-MEDIAN
Northern ASEAN show stations	0.07	0.13	0.06	0.11	0.05	0.08	0.06
Southern ASEAN show stations	0.16	0.34	0.16	0.29	0.17	0.17	0.15
Total	0.15	0.30	0.15	0.27	0.16	0.16	0.14

	CORRELATION COEFFICIENT						
	CAMS-ECMWF	FMI-SILAM	JMA-MASINGAR	MSS-UKMO-NAME	NASA-GEOS-5	NOAA-GEFS-AEROSOLS	VFSP-WAS-MEDIAN
Northern ASEAN show stations	0.61	0.59	0.25	0.51	0.69	0.37	0.70
Southern ASEAN show stations	0.52	0.77	0.56	-0.12	0.70	0.71	0.33
Total	0.56	0.77	0.57	-0.05	0.72	0.73	0.39

	FRACTIONAL GROSS ERROR						
	CAMS-ECMWF	FMI-SILAM	JMA-MASINGAR	MSS-UKMO-NAME	NASA-GEOS-5	NOAA-GEFS-AEROSOLS	VFSP-WAS-MEDIAN
Northern ASEAN show stations	1.11	0.52	0.62	1.72	0.43	1.19	0.90
Southern ASEAN show stations	0.93	0.66	0.84	1.59	0.45	1.14	0.76
Total	0.96	0.62	0.80	1.62	0.45	1.15	0.79

	NUMBER OF CASES						
	CAMS-ECMWF	FMI-SILAM	JMA-MASINGAR	MSS-UKMO-NAME	NASA-GEOS-5	NOAA-GEFS-AEROSOLS	VFSP-WAS-MEDIAN
Northern ASEAN show stations	81	42	65	81	80	81	81
Southern ASEAN show stations	372	129	350	372	353	372	372
Total	453	171	419	453	433	453	453

# Additional Features

## Subseasonal Weather Outlook (10 – 23 June 2024)

Subseasonal Outlooks

Issued: 6 June 2024  
 First forecast week: 10 – 16 June 2024  
 Second forecast week: 17 – 23 June 2024

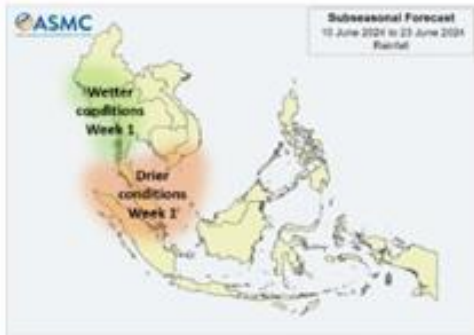


Figure 1: Rainfall Outlook

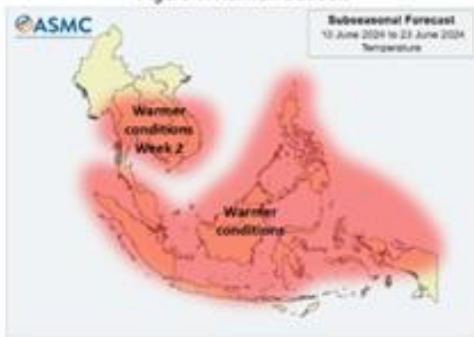


Figure 2: Temperature Outlook

NWP Forecasts

Numerical Weather Prediction wind forecasts

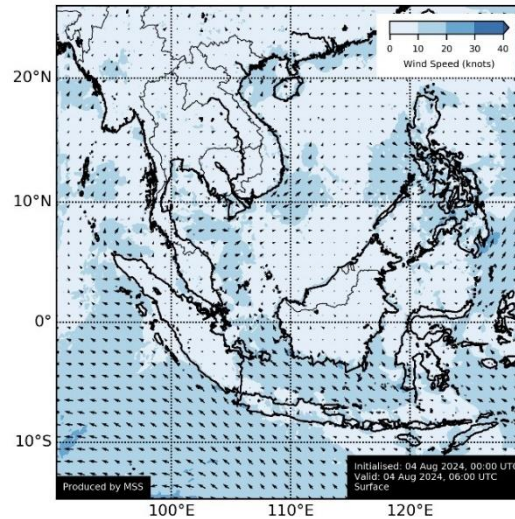
### Wind Forecast

NWP (Numerical Weather Prediction) model forecast of winds at various height levels.

Surface 2500FT 5000FT 10000FT

4 Aug 2024 6 UTC 6 Aug 2024 0 UTC

4 Aug 2024 6 UTC



The wind forecasts shown are up to 48 hours ahead and at 6-hourly intervals. The wind forecast is based on the model wind data from the Meteorological Service Singapore's SINGV model.

## FAQ

FAQ page

### What is the air quality dispersion model operated by MSS?

The MSS-UKMO Numerical Atmospheric-dispersion Modelling Environment (NAME) air quality and dispersion model runs for the Southeast Asia region are developed and operated by MSS in collaboration with the UK Met Office. It simulates the transport, dispersion, chemical transformation and eventual deposition of pollutants in the atmosphere. It provides 00 UTC smoke forecasts with a spatial resolution of 0.1° x 0.1° and a forecast range of 48 hours extendable to 72 hours.

Fire radiative power (FRP) products are obtained from CAMS-GFAS and applied over a high-resolution landcover and peatland map (Miettinen et al., 2016) to derive smoke emissions calibrated for the SEA region. Regional anthropogenic (REAS Version 3.2.1; Kurokawa and Ohara, 2020), biogenic (CAMS-GLOB-BIO; Granier et al., 2019; Sindelarova et al., 2014) and shipping (EDGAR Version 4.3; Janssens-Maenhout et al., 2012) emissions are also used.

The NAME model chemistry scheme includes the formation of secondary particulate matter and is used to generate realistic background pollutant levels compared to earlier system versions described in Hertwig et al. (2015). Aerosol optical depth (AOD) forecasts are computed based on PM2.5 aerosol optical properties derived from an empirical study of biomass burning smoke over Singapore by Lee et al. (2016).

### What is the VFSP-WAS ensemble model?

### What are the products for assessment of the fire situation?

# Designation and Launch of RSMC-VFSP Singapore

- Singapore was designated as the Regional Specialised Meteorological Centre (RSMC) for Vegetation Fires and Smoke Pollution Forecasts (VFSP) at the 78<sup>th</sup> Session of the WMO Executive Council in June 2024.
- The centre conducts atmospheric smoke haze dispersion modelling and provides forecast products to advise on fire activity and surface concentration of pollutants originating from fires.
- The centre was launched on the sidelines of the ASMC-WMO regional climate forum in Singapore on 4<sup>th</sup> September 2024



*(From left) Prof. Celeste Saulo, WMO Secretary-General; Ms Grace Fu, Singapore's Minister for Sustainability and the Environment and Minister-in-charge of Trade Relations; Ms Koh Li-Na, Assistant Chief Executive/Director General Meteorological Service at the launch of the centre*



**METEOROLOGICAL  
SERVICE  
SINGAPORE**