7-SEAS INTERNATIONAL WORKSHOP OF TECHNOLOGIES AND SCIENCES ON TRANSBOUNDARY HAZE
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National Space Centre, Banting, Selangor, Malaysia

TRANSBOUNDARY HAZE: MONITORING AND MITIGATION

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SCOPE

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Introduction

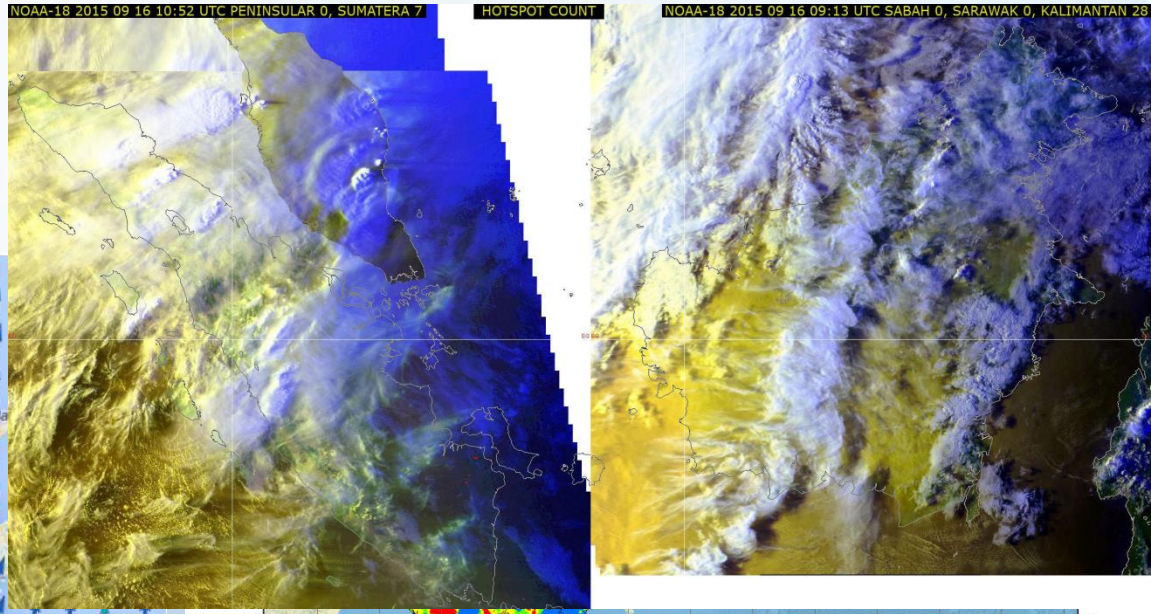
General Weather Patterns of Malaysia

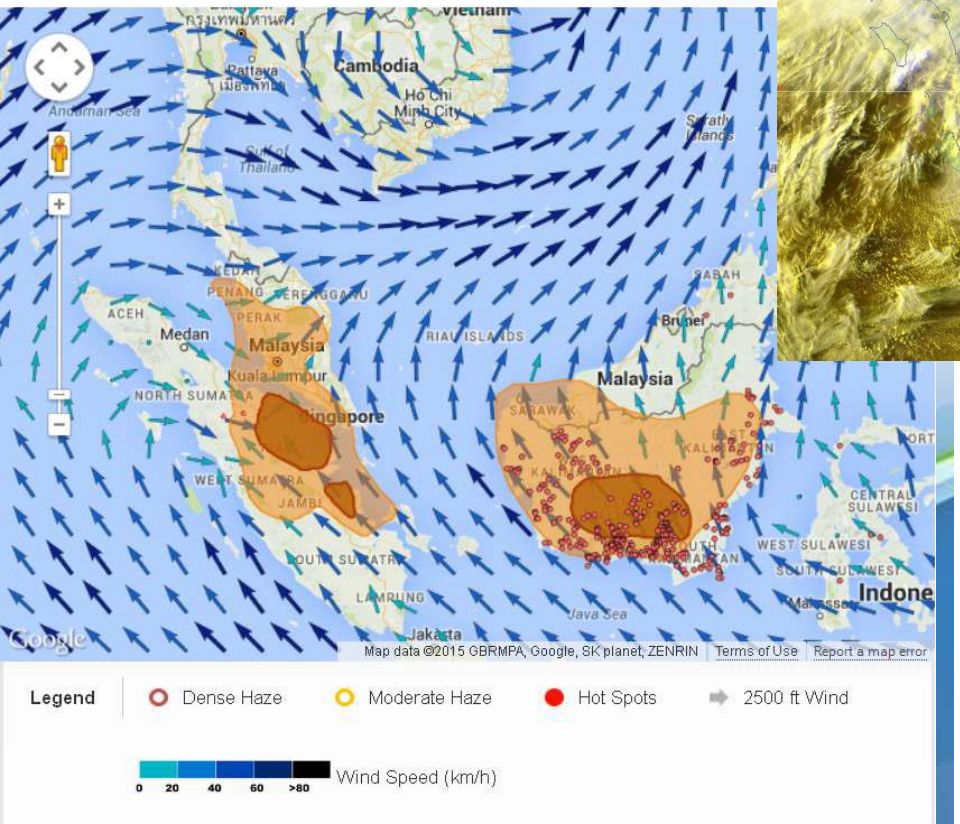
Two main seasons, separated by two shorter inter-monsoon periods:

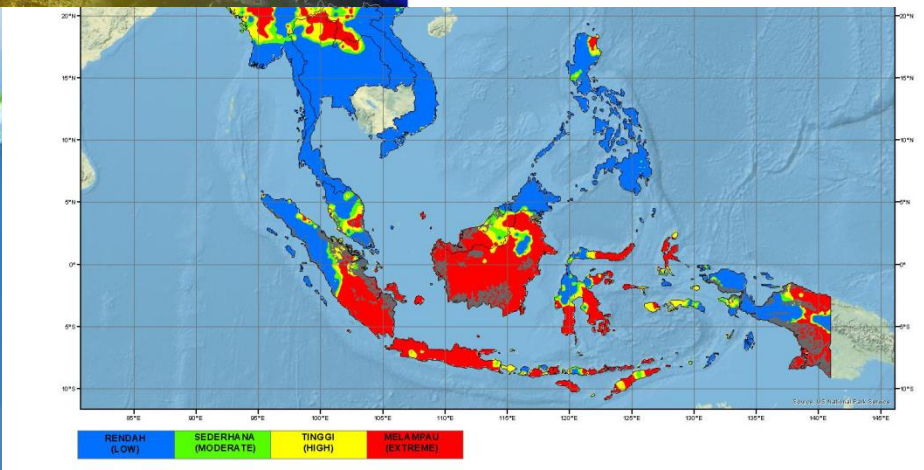
- **Southwest Monsoon season (June-September):** Dry season characterized by prevailing light wind generally below 15 knots from the southwest. Favourable for open burnings and forest fires which often contribute to localized and transboundary haze.
- **Northeast Monsoon season (November-March):** Wet season with cold surges from Siberia High that produce heavy rains which often cause severe floods along the east coast states of Peninsular Malaysia, as well as Sarawak in East Malaysia.
- **Inter-monsoon periods (April-May & October):** Clear morning sky with light and variable wind conditions favourable for development of afternoon thunderstorms with occasional heavy rains which often cause flash floods, especially over the west coast states of Peninsular Malaysia. Abnormal dry condition may extend into the 2nd inter-monsoon period during El Niño years.

Latest Severe Haze Episode

- **August-September 2015 (Southwest Monsoon season)**
- **October 2015 (Inter-monsoon period):** Reduced amount of rainfall due to El Niño phenomenon







Monthly Total Rainfall Deviation (August 2015)

State	Station Name	WMO Code	Accumulated (mm)	Mean (mm)	Hi (mm)	Lo (mm)	Deviation (%)
Johore	BATU PAHAT	48670	159.2	168.5	320.8	59.9	-6
Johore	KLUANG	48672	137	142.6	338.1	36.3	-4
Johore	MERSING	48674	203.6	169.5	323.2	79.5	20
Johore	SENAI	48679	148.2	201.1	359.2	26	-26
Kedah	ALOR SETAR	48603	309.8	211	468.4	42.8	47
Kedah	LANGKAWI	48600	412.2	352.3	871	130.9	17
Kelantan	KOTA BHARU	48615	225.2	163.1	346.9	46.9	38
Kelantan	KUALA KRAI	48616	269.2	188.1	346.5	70.3	43
Malacca	MELAKA	48665	409.6	190.3	490.6	63.7	115
Pahang	BATU EMBUN	48642	68.8	159.6	317.2	42.4	-57
Pahang	CAMERON HIGHLANDS	48632	270.8	238.3	479.3	56.1	14
Pahang	KUANTAN	48657	272.8	188.5	367	59	45
Pahang	MUADZAM SHAH	48649	204.6	144.4	328.8	44.8	42
Pahang	TEMERLOH	48653	100.8	154.4	450.5	6.2	-35
Penang	BAYAN LEPAS	48601	366.2	243.3	591	92.2	51
Penang	BUTTERWORTH	48602	281.8	238.8	568.4	37.1	18
Perak	IPOH	48625	249.2	169.1	356.2	48.8	47
Perak	LUBOK MERBAU	48623	110.6	139	282.8	23	-20
Perak	SITIAWAN	48620	45.4	122.8	392.6	9.3	-63
Perlis	CHUPING	48604	331	193.3	341.2	27.8	71
Sabah	KOTA KINABALU	96471	369.2	267.6	622.5	66.9	38
Sabah	KUDAT	96477	160.2	124.6	268.1	26.2	29
Sabah	LABUAN	96465	289.2	299.3	682.7	22.1	-3
Sabah	SANDAKAN	96491	175.6	225.1	487.4	80	-22
Sabah	TAWAU	96481	141.6	205.1	429.3	52.6	-31
Sarawak	BINTULU	96441	291	288.7	679	54.9	1
Sarawak	KUCHING	96413	153.4	231.5	546.5	22.2	-34
Sarawak	MIRI	96449	170.4	217	600.5	20.7	-21
Sarawak	SIBU	96421	281.2	218.5	621.9	43.6	29
Sarawak	SRI AMAN	96418	111.8	239.6	734	42.9	-53
Selangor	PETALING JAYA	48648	283	168.1	454.2	17.3	68
Selangor	SEPANG (KLIA)	48650	47.8	144.5	250.4	30.6	-67
Selangor	SUBANG	48647	325.8	158.9	348.9	36.6	105
Terengganu	KUALA TERENGGANU	48618	179.2	128.4	384.9	11.9	40

Monthly Total Rainfall Deviation (Sept 2015)

State	Station Name	WMO Code	Accumulated (mm)	Mean (mm)	Hi (mm)	Lo (mm)	Deviation (%)
Johore	BATU PAHAT	48670	162.4	153.3	333.9	17.9	6
Johore	KLUANG	48672	134	156.7	351.3	42.5	-14
Johore	MERSING	48674	165.2	169.8	340.1	2.5	-3
Johore	SENAI	48679	185.8	208.2	407.3	40.9	-11
Kedah	ALOR SETAR	48603	346.8	276.3	634.2	103.9	26
Kedah	LANGKAWI	48600	545.6	351.1	729.2	146.6	55
Kelantan	KOTA BHARU	48615	143.6	181	404.9	58	-21
Kelantan	KUALA KRAI	48616	149.4	232.8	397.7	90.6	-36
Malacca	MELAKA	48665	113.2	193.1	407	69.3	-41
Pahang	BATU EMBUN	48642	168	189	347.6	73.8	-11
Pahang	CAMERON HIGHLANDS	48632	226.4	277.9	444.9	140.6	-19
Pahang	KUANTAN	48657	120.4	216.3	413	13.1	-44
Pahang	MUADZAM SHAH	48649	62.2	152.7	314.5	16.1	-59
Pahang	TEMERLOH	48653	51.8	171.3	302.6	10.2	-70
Penang	BAYAN LEPAS	48601	485.6	331	629.1	127.8	47
Penang	BUTTERWORTH	48602	364	288.2	611.4	98.8	26
Perak	IPOH	48625	156.2	205.4	481.7	53.8	-24
Perak	LUBOK MERBAU	48623	333.8	172.1	305	53.3	94
Perak	SITIAWAN	48620	204.2	165.8	310.9	31.2	23
Perlis	CHUPING	48604	376.6	226.3	389.3	95.2	66
Sabah	KOTA KINABALU	96471	149.6	304.1	658.6	95.2	-51
Sabah	KUDAT	96477	138.8	131.3	291.2	14.8	6
Sabah	LABUAN	96465	120.6	354.2	968.4	23.3	-66
Sabah	SANDAKAN	96491	246.6	246.3	1057.4	32.3	0
Sabah	TAWAU	96481	106.8	155.3	475.2	7.4	-31
Sarawak	BINTULU	96441	125.8	306.3	800.3	101.3	-59
Sarawak	KUCHING	96413	133.4	266.2	451.4	94.8	-50
Sarawak	MIRI	96449	164.8	252.8	514.6	58.6	-35
Sarawak	SIBU	96421	85	258.2	510.2	84.7	-67
Sarawak	SRI AMAN	96418	120.8	280.7	494.9	52.4	-57
Selangor	PETALING JAYA	48648	131.6	216.6	409.8	53.4	-39
Selangor	SEPANG (KLIA)	48650	174	184.6	276.2	66.6	-6
Selangor	SUBANG	48647	196.2	201	496.8	58.9	-2
Terengganu	KUALA TERENGGANU	48618	99.8	171	297.1	54.8	-42

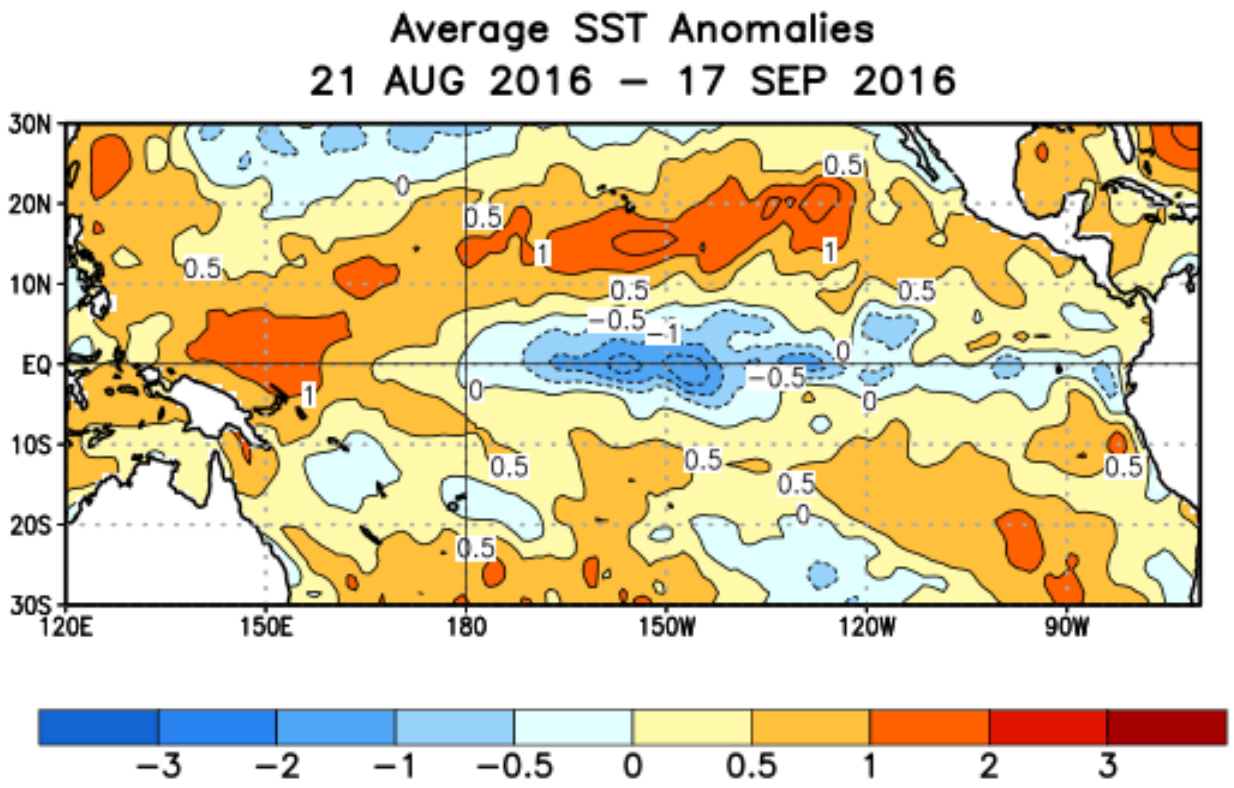
Monthly Total Rainfall Deviation (Oct 2015)

State	Station Name	WMO Code	Accumulated (mm)	Mean (mm)	Hi (mm)	Lo (mm)	Deviation (%)
Johore	BATU PAHAT	48670	142.4	183	309.8	45.6	-22
Johore	KLUANG	48672	138.4	197	492.1	53.1	-30
Johore	MERSING	48674	124.6	202	430.2	51.8	-38
Johore	SENAI	48679	219	219.7	506.5	65.4	0
Kedah	ALOR SETAR	48603	218	294.1	453.6	134.9	-26
Kedah	LANGKAWI	48600	122.6	354.5	682.3	158.5	-65
Kelantan	KOTA BHARU	48615	229.2	282.1	595.9	83.4	-19
Kelantan	KUALA KRAI	48616	125.8	245.5	518.5	114.4	-49
Malacca	MELAKA	48665	244.2	205.3	394.7	58.4	19
Pahang	BATU EMBUN	48642	199	235	436.8	83.6	-15
Pahang	CAMERON HIGHLANDS	48632	431	366.1	522.6	100.8	18
Pahang	KUANTAN	48657	237.4	274.4	591.2	71.4	-13
Pahang	MUADZAM SHAH	48649	120	229.8	480.5	47.2	-48
Pahang	TEMERLOH	48653	134.8	202.6	349.9	72.6	-33
Penang	BAYAN LEPAS	48601	245.2	363.9	869.1	98.5	-33
Penang	BUTTERWORTH	48602	284	354.9	675.4	103	-20
Perak	IPOH	48625	427.2	300.9	581.2	92.2	42
Perak	LUBOK MERBAU	48623	206.2	238.3	375	146.7	-13
Perak	SITIAWAN	48620	214.4	220.2	564.2	41.4	-3
Perlis	CHUPING	48604	189.4	249.1	412.5	109	-24
Sabah	KOTA KINABALU	96471	210.4	358.1	677.9	30.7	-41
Sabah	KUDAT	96477	248.8	190.2	378.7	42.1	31
Sabah	LABUAN	96465	201.6	398.5	748.5	79.4	-49
Sabah	SANDAKAN	96491	284	279.9	650.4	59.7	1
Sabah	TAWAU	96481	53.8	172.4	535.2	9.1	-69
Sarawak	BINTULU	96441	284.4	357.8	766.1	137.9	-21
Sarawak	KUCHING	96413	217.2	340.2	625.2	142.7	-36
Sarawak	MIRI	96449	150.4	314	547.6	118.2	-52
Sarawak	SIBU	96421	249.6	277.6	547.2	107.8	-10
Sarawak	SRI AMAN	96418	202.3	308.3	500.8	102.4	-34
Selangor	PETALING JAYA	48648	289	295.1	624	71.4	-2
Selangor	SEPANG (KLIA)	48650	115	204.1	342.8	104.4	-44
Selangor	SUBANG	48647	416.8	267.9	502.9	58.7	56
Terengganu	KUALA TERENGGANU	48618	201.2	259.3	525	75	-22

Haze Monitoring: Current Status and Outlook of ENSO

SST Departures (ºC) in the Tropical Pacific Ocean

During the last four weeks, equatorial SSTs were near-to-below average east of the International Date Line.



Recent Niño Evolution

ENSO-neutral conditions are present. Equatorial Sea Surface Temperature (SST) are near or below average in the east-central and eastern Pacific Ocean. The latest weekly SST for Niño 3.4 is -0.6°C, while the most recent Oceanic Niño Index (ONI) value (June-July-August 2016) is -0.3°C.

The latest weekly SST departures are:

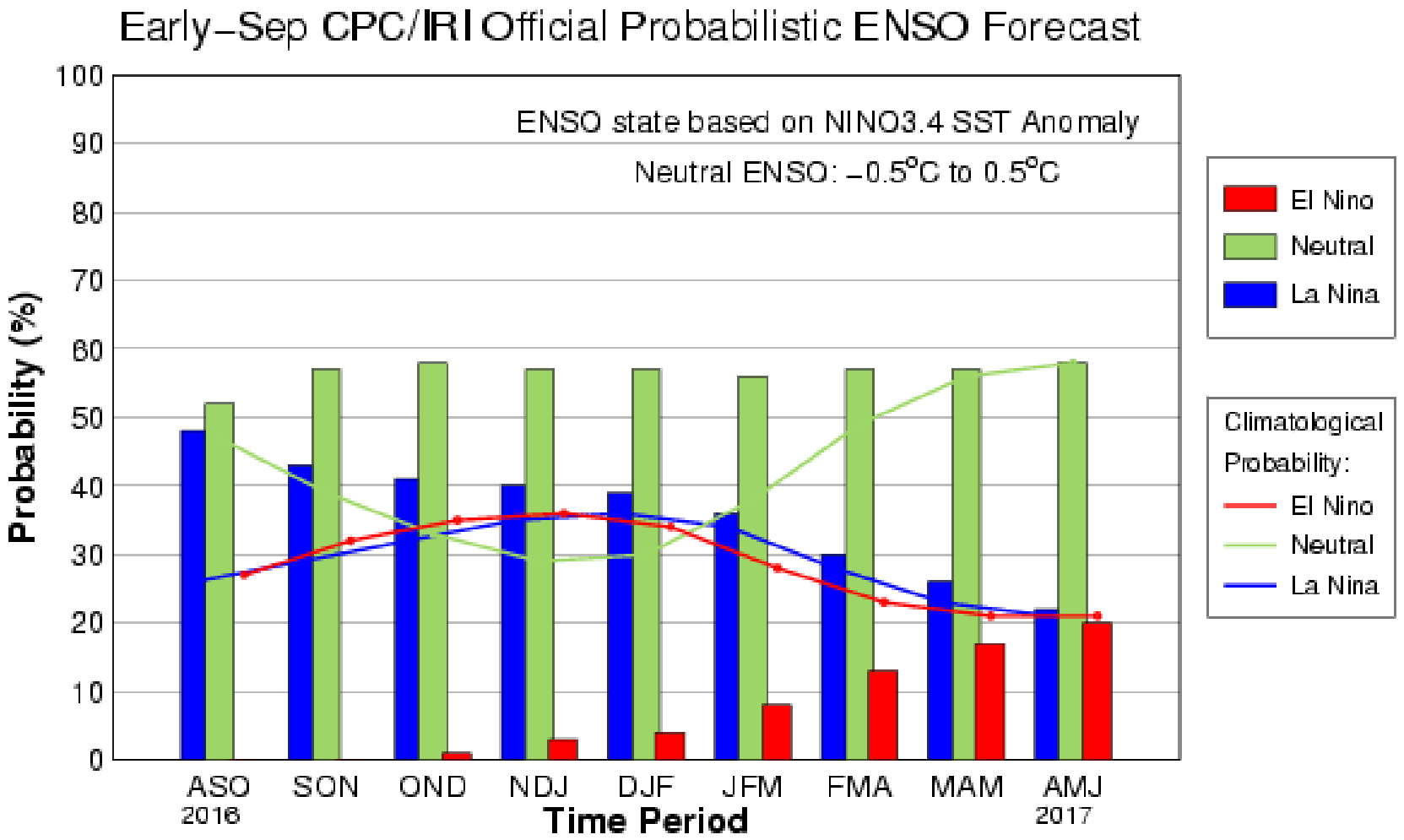
Niño 4	-0.2°C
Niño 3.4	-0.6°C
Niño 3	-0.2°C
Niño 1+2	0.2°C

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2004	0.3	0.2	0.1	0.1	0.2	0.3	0.5	0.7	0.7	0.7	0.7	0.7
2005	0.6	0.6	0.5	0.5	0.4	0.2	0.1	0.0	0.0	-0.1	-0.4	-0.7
2006	-0.7	-0.6	-0.4	-0.2	0.0	0.1	0.2	0.3	0.5	0.8	0.9	1.0
2007	0.7	0.3	0.0	-0.1	-0.2	-0.2	-0.3	-0.6	-0.8	-1.1	-1.2	-1.3
2008	-1.4	-1.3	-1.1	-0.9	-0.7	-0.5	-0.3	-0.2	-0.2	-0.3	-0.5	-0.7
2009	-0.8	-0.7	-0.4	-0.1	0.2	0.4	0.5	0.6	0.7	1.0	1.2	1.3
2010	1.3	1.1	0.8	0.5	0.0	-0.4	-0.8	-1.1	-1.3	-1.4	-1.3	-1.4
2011	-1.3	-1.1	-0.8	-0.6	-0.3	-0.2	-0.3	-0.5	-0.7	-0.9	-0.9	-0.8
2012	-0.7	-0.6	-0.5	-0.4	-0.3	-0.1	0.1	0.3	0.4	0.4	0.2	-0.2
2013	-0.4	-0.5	-0.3	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.3
2014	-0.5	-0.6	-0.4	-0.2	0.0	0.0	0.0	0.0	0.2	0.4	0.6	0.6
2015	0.5	0.4	0.5	0.7	0.9	1.0	1.2	1.5	1.8	2.1	2.2	2.3
2016	2.2	1.9	1.6	1.1	0.6	0.1	-0.3					

CPC/IRI Probabilistic ENSO Outlook

Updated: 8 September 2016

ENSO-neutral is slightly favoured (55-60% chance) through the Northern Hemisphere fall and winter 2016-17.



IRI/CPC Pacific Niño 3.4 SST Model Outlook

Most multi-model averages indicate borderline ENSO-neutral/La Niña conditions during the Northern Hemisphere fall and winter 2016-17.

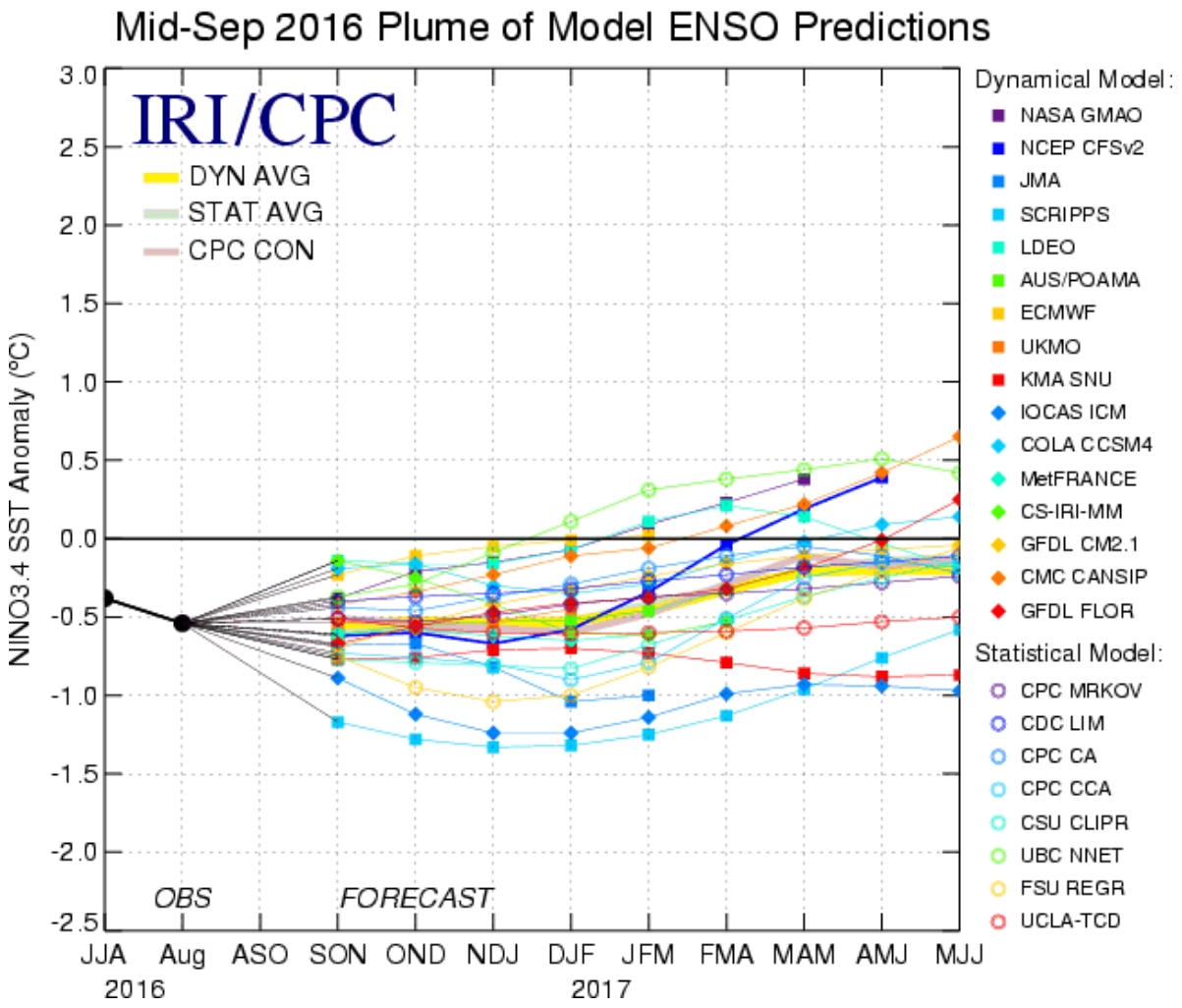


Figure provided by the International Research Institute (IRI) for Climate and Society (updated 13 September 2016)

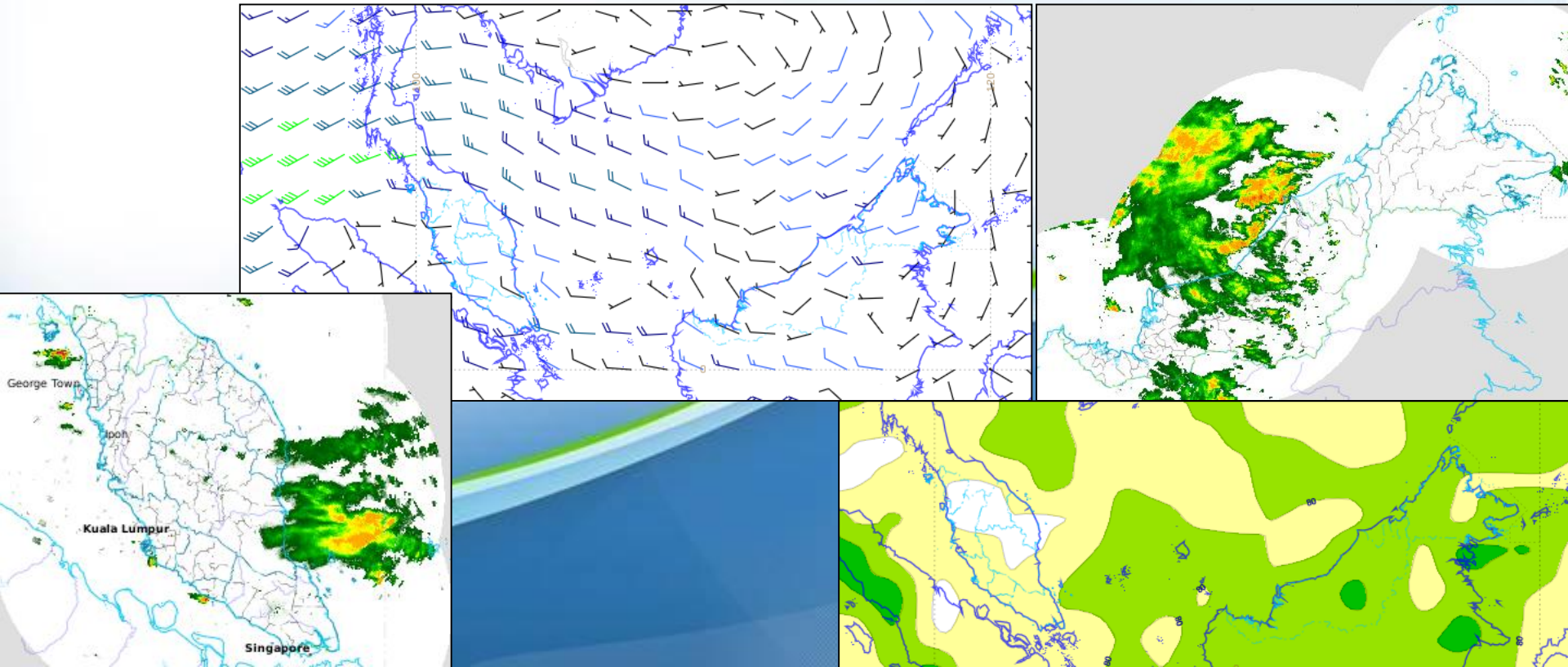
Haze Monitoring: Current Weather Condition and Long Range Weather Outlook

Current Rainfall Distribution (till 19.9.2016)

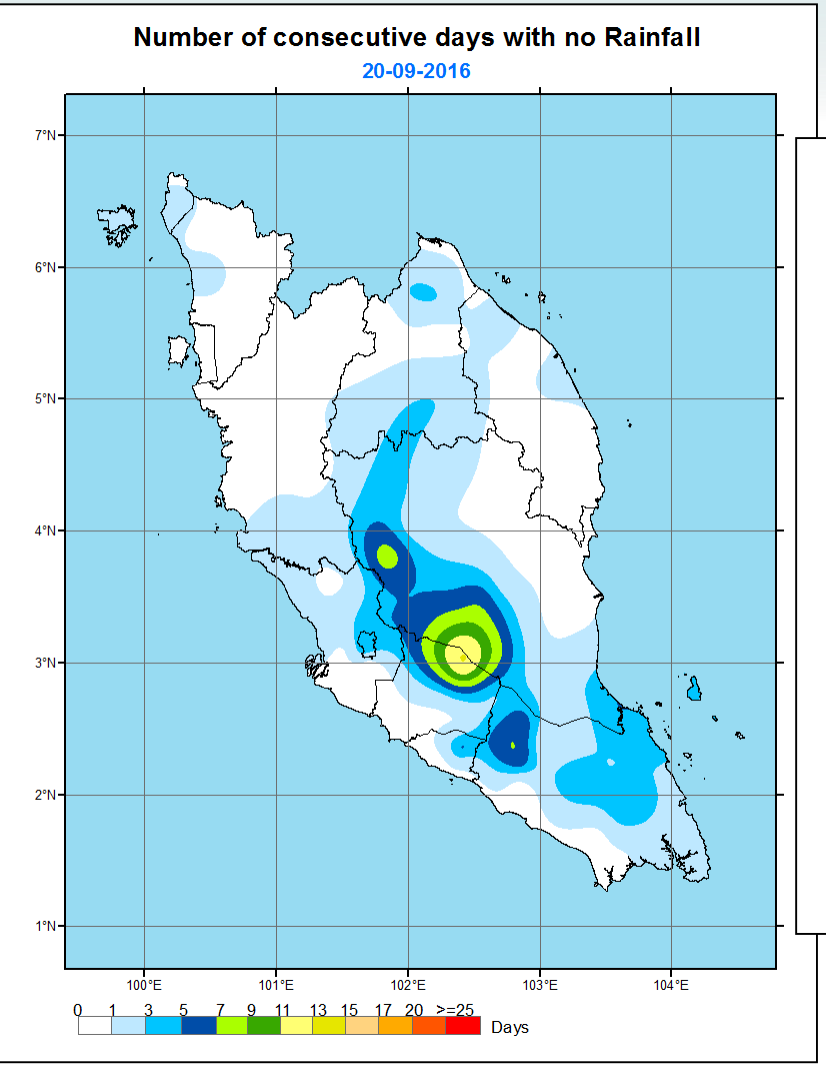
State	Station Name	Accumulated (mm)	Mean (mm)	Hi (mm)	Lo (mm)	Deviation (%)
Johore	BATU PAHAT	168.4	153.7	333.9	17.9	73
Johore	KLUANG	73.4	156.2	351.3	42.5	-26
Johore	MERSING	122.4	169.8	340.1	2.5	14
Johore	SENAI	156.4	207.7	407.3	40.9	19
Kedah	ALOR SETAR	181.2	277.4	634.2	103.9	3
Kedah	LANGKAWI	156.2	357.8	729.2	146.6	-31
Kelantan	KOTA BHARU	182.6	180.4	404.9	58	60
Kelantan	KUALA KRAI	173.2	230.2	397.7	90.6	19
Malacca	MELAKA	100.2	191.8	407	69.3	-18
Pahang	BATU EMBUN	136.6	189.8	347.6	73.8	14
Pahang	CAMERON HIGHLANDS	107	276.3	444.9	140.6	-39
Pahang	KUANTAN	101	214.8	413	13.1	-26
Pahang	MUADZAM SHAH	55.2	149.9	314.5	16.1	-42
Pahang	TEMERLOH	34.4	168.2	302.6	10.2	-68
Penang	BAYAN LEPAS	306	333.4	629.1	127.8	45
Penang	BUTTERWORTH	364	290.7	611.4	98.8	98
Perak	IPOH	108.2	204.7	481.7	53.8	-17
Perak	LUBOK MERBAU	122.6	179.1	333.2	53.3	8
Perak	SITIAWAN	139.2	166.4	310.9	31.2	32
Perlis	CHUPING	287.2	230.3	389.3	95.2	97
Sabah	KOTA KINABALU	279.8	302.2	658.6	95.2	46
Sabah	KUDAT	286.4	131.6	291.2	14.8	244
Sabah	LABUAN	316.2	350.6	968.4	23.3	42
Sabah	SANDAKAN	83.2	246.2	1057.4	32.3	-47
Sabah	TAWAU	95	154.4	475.2	7.4	-3
Sarawak	BINTULU	86.8	303.5	800.3	101.3	-55
Sarawak	KUCHING	219.2	264.2	451.4	94.8	31
Sarawak	MIRI	90	251.5	514.6	58.6	-43
Sarawak	SIBU	149.8	255.1	510.2	84.7	-7
Sarawak	SRI AMAN	181	277	494.9	52.4	3
Selangor	PETALING JAYA	251	214.7	409.8	53.4	85
Selangor	SEPANG (KLIA)	207.2	183.4	276.2	66.6	78
Selangor	SUBANG	220.2	200.9	496.8	58.9	73
Terengganu	KUALA TERENGGANU	102.4	168.7	297.1	54.8	-4

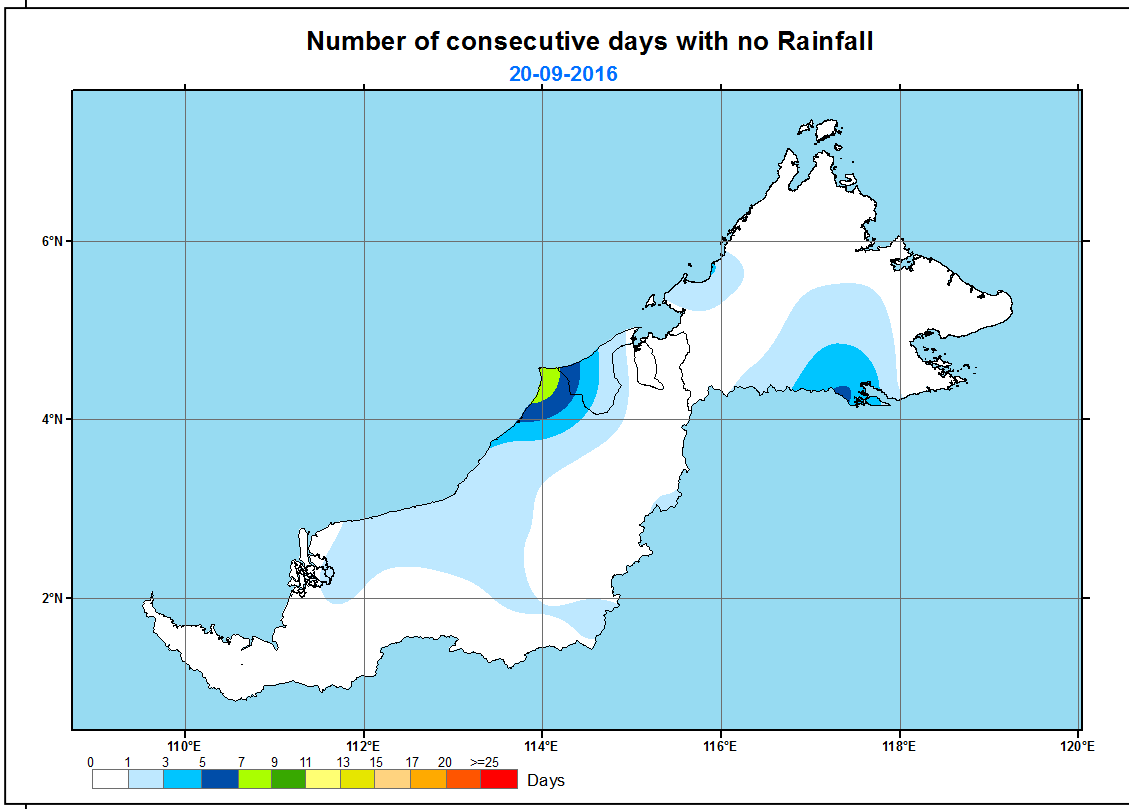
Current Weather Condition

- The current Southwest Monsoon season experienced in Malaysia, characterized by prevailing light wind generally below 15 knots from the southwest, is expected to end in early October 2016.
- From October till mid-November, the light and variable wind conditions during the inter-monsoon period would bring more rain as thunderstorms with occasional heavy rains are expected in the late afternoons and evenings, especially over the inland areas.

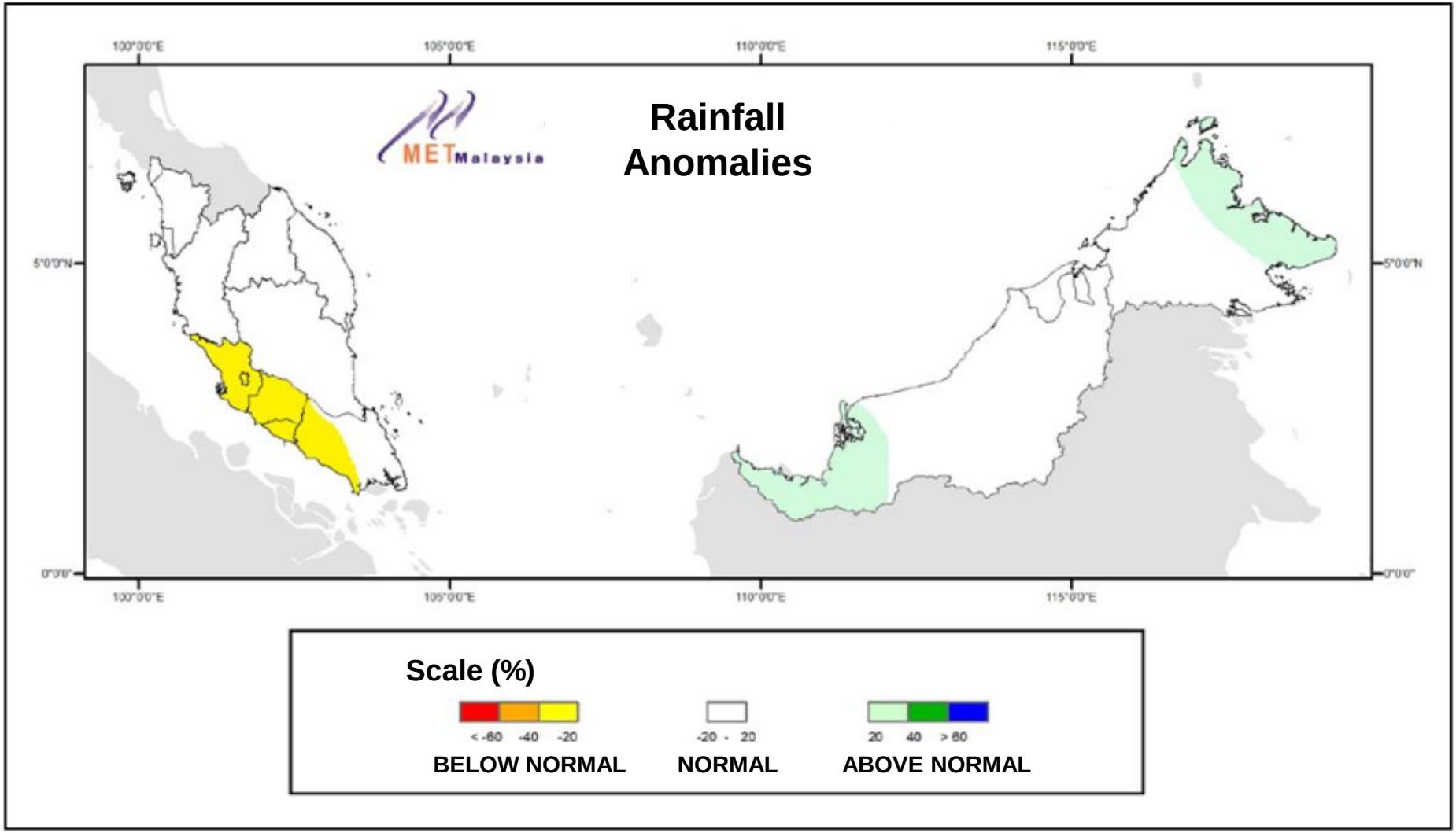


Number of Consecutive Days without Rainfall

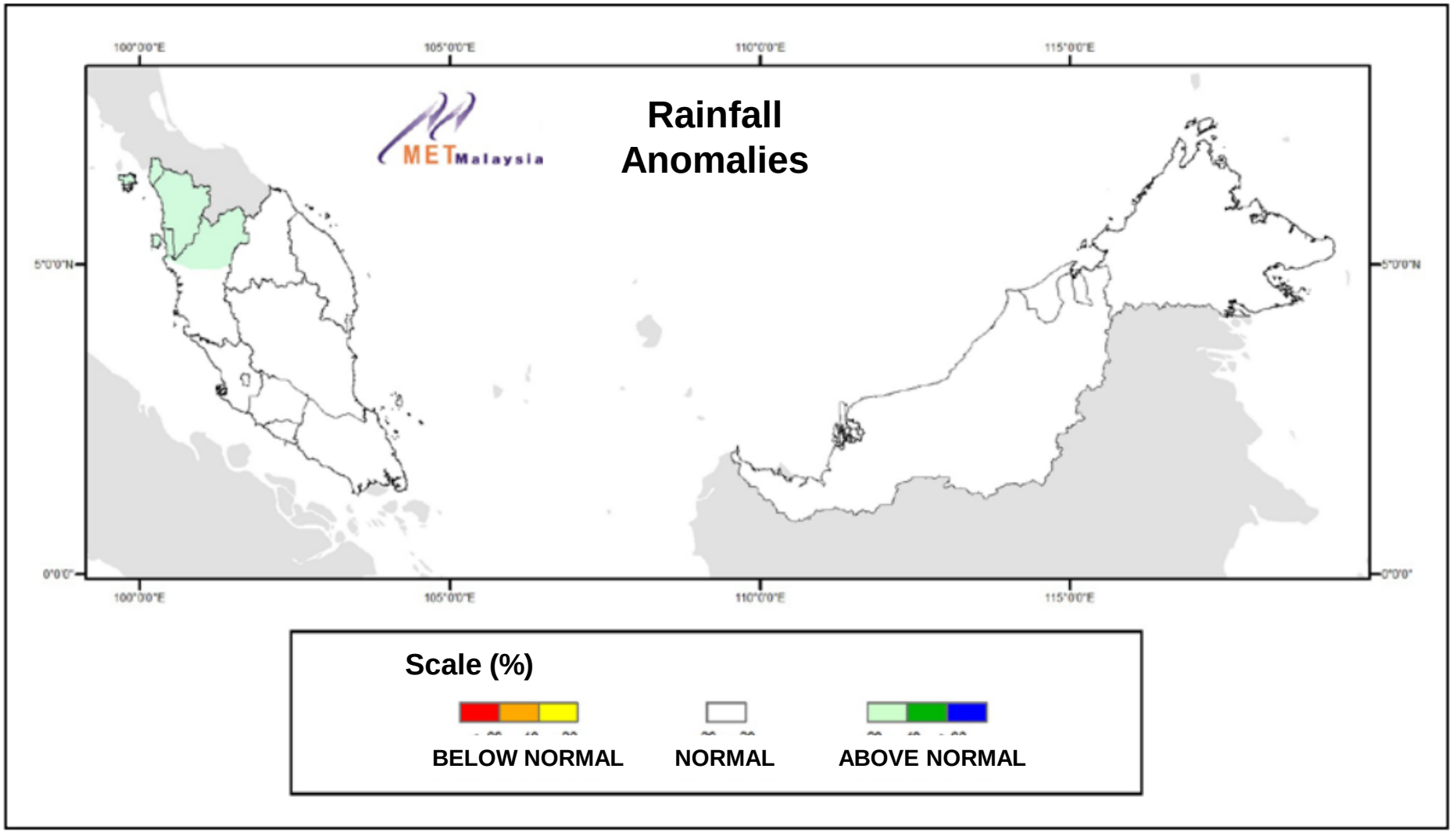




Weather Outlook (October 2016)



Weather Outlook (November 2016)

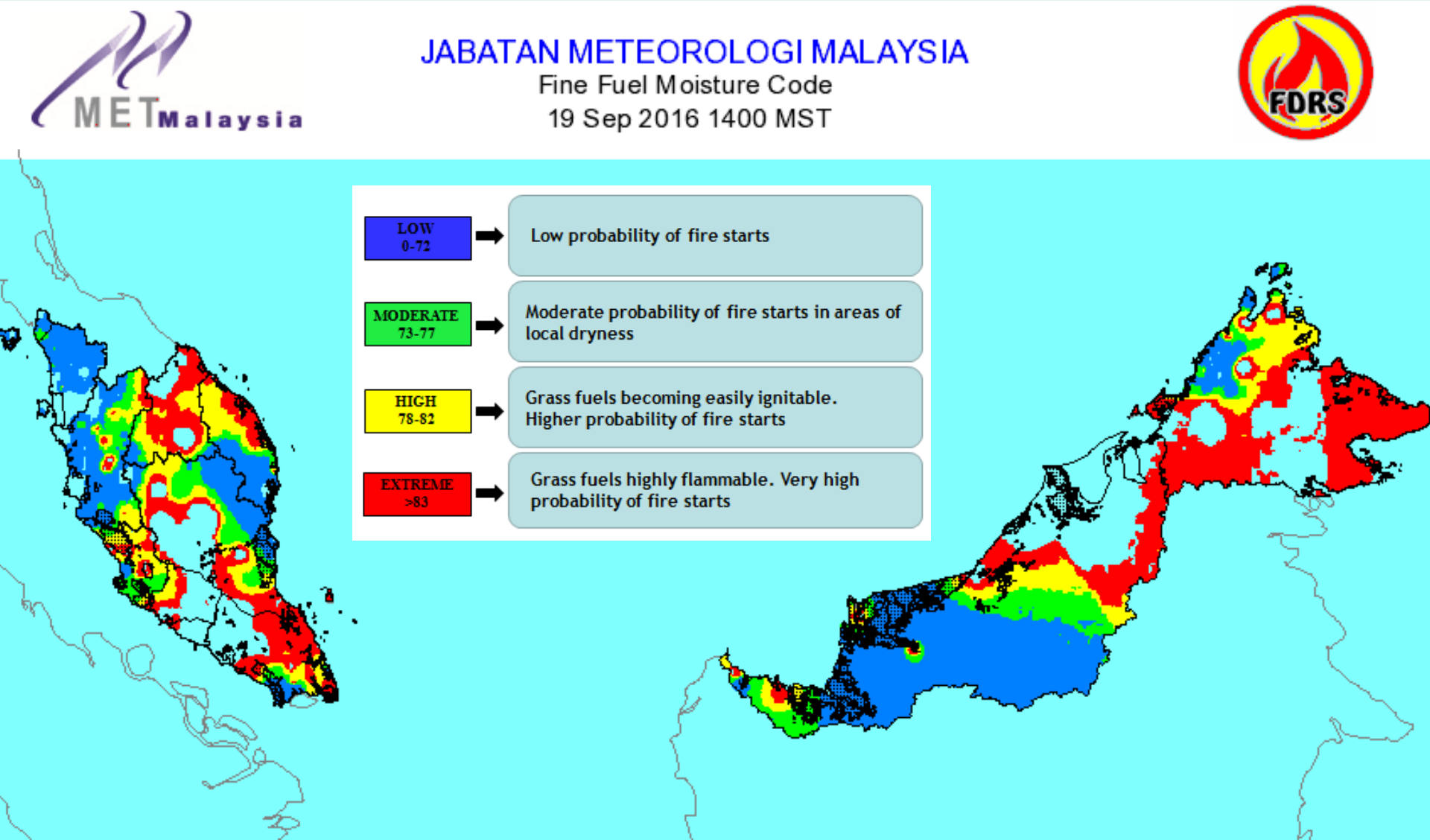


Haze Monitoring: Fire Danger Rating System (FDRS)

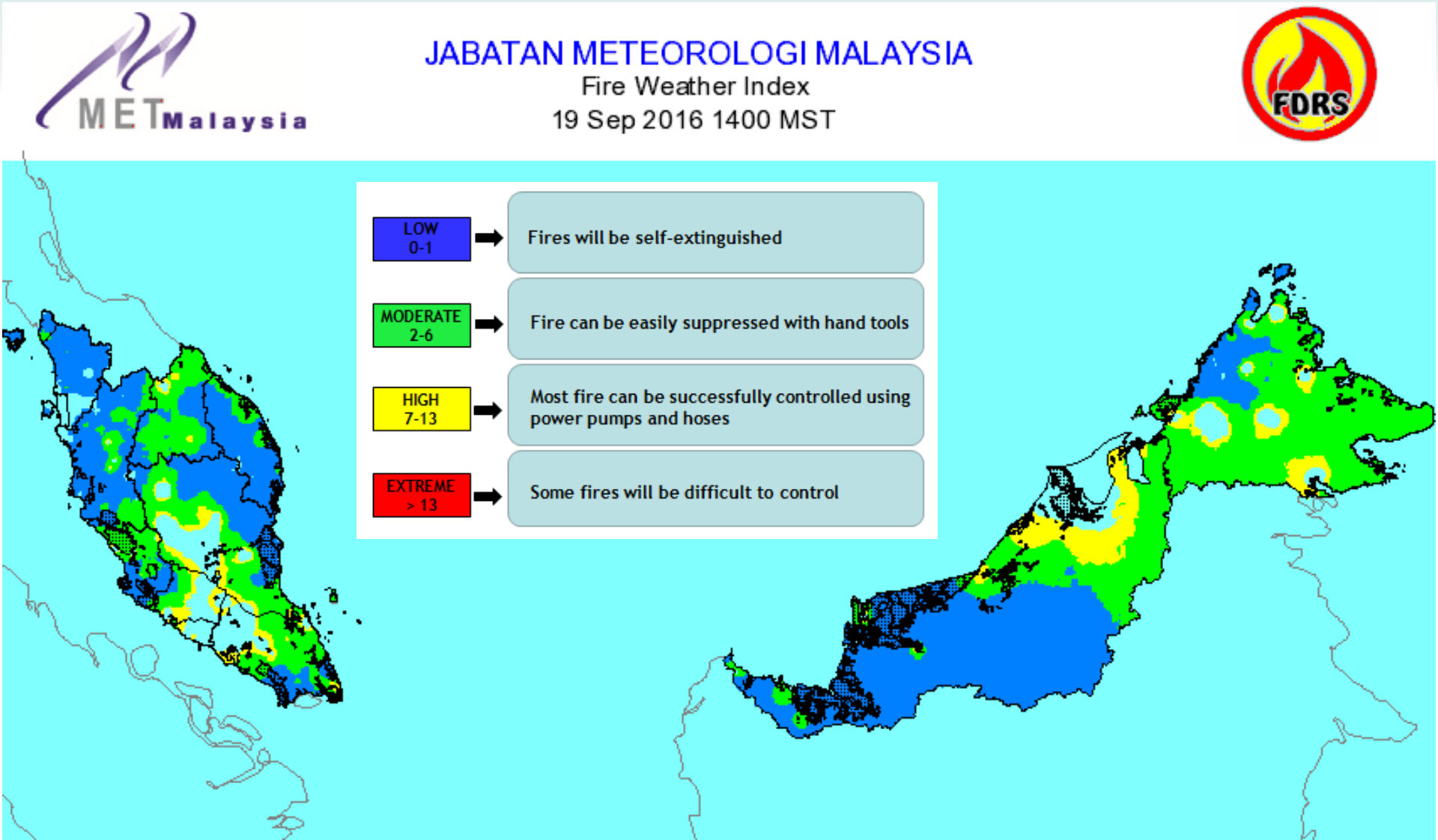
Fire Danger Rating System (FDRS)

- Fire danger rating is the evaluation of meteorological factors that influence fire danger (Fire danger is the ability of a fire to start, spread and do damage)
- A system that monitors forest/vegetation fires risk and supplies information that assists in fire prevention and management
- To predict possible fire occurrence and behaviour
- A guide to policy-makers in developing mitigation actions to protect life, property and the environment

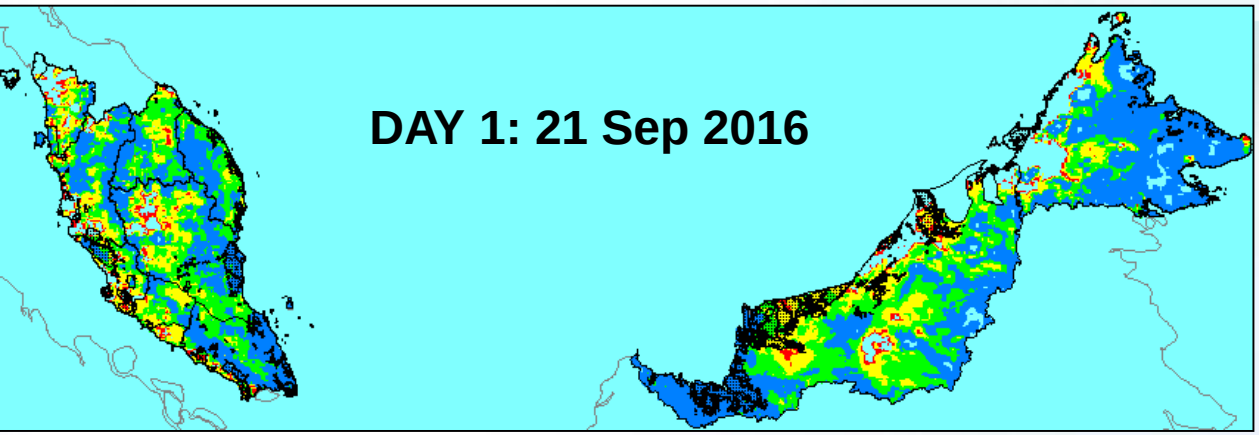
Current Fine Fuel Moisture Code (FFMC)

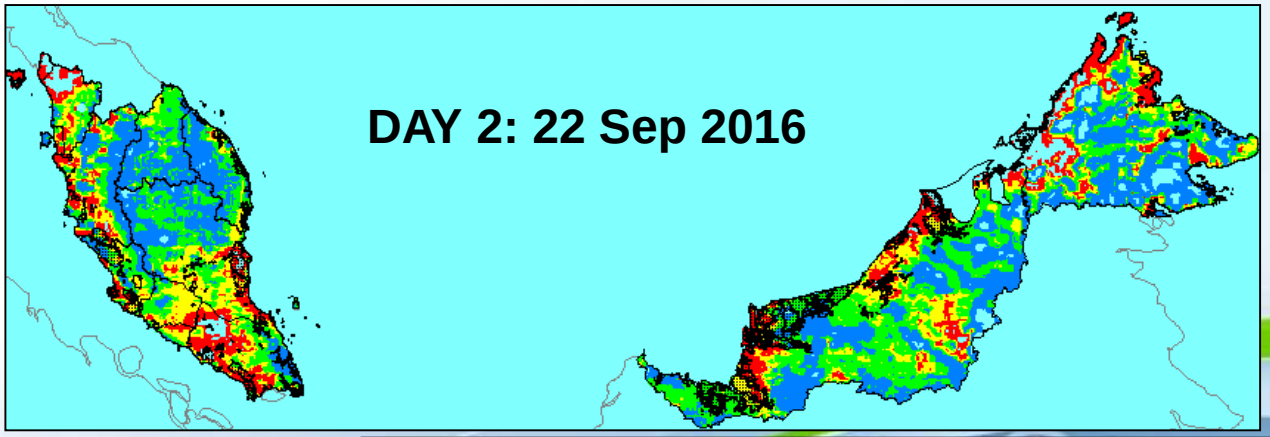


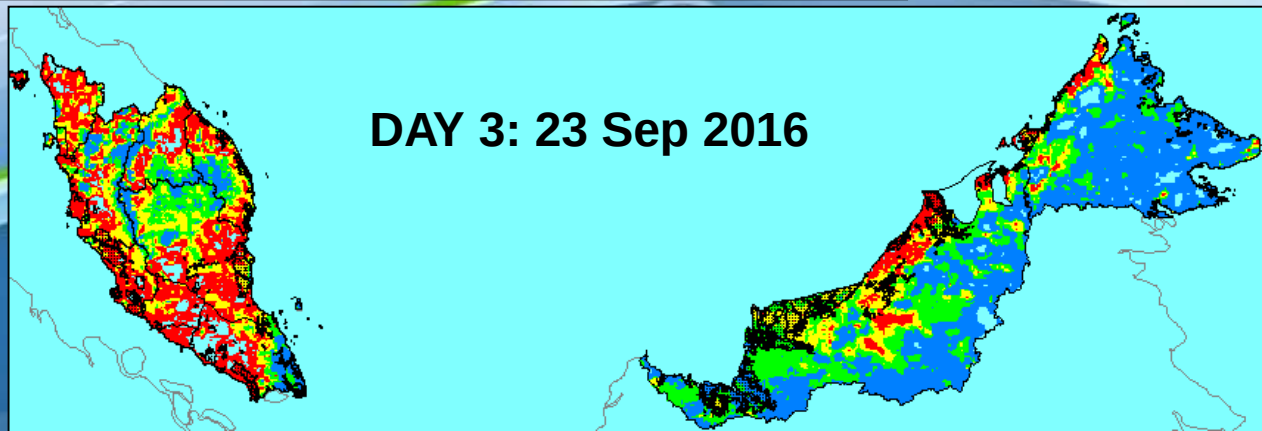
Current Fire Weather Index (FWI)



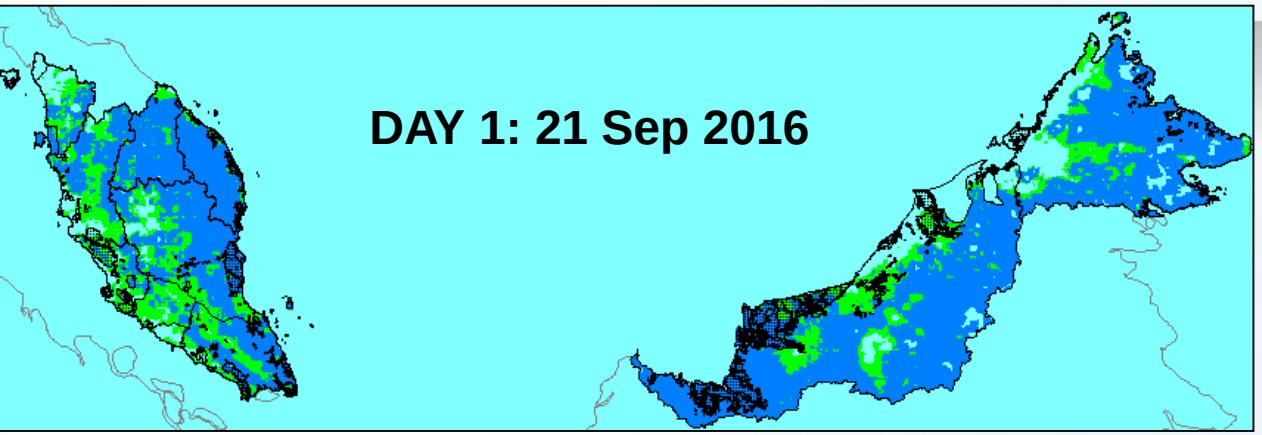
FDRS Forecasts (FFMC)

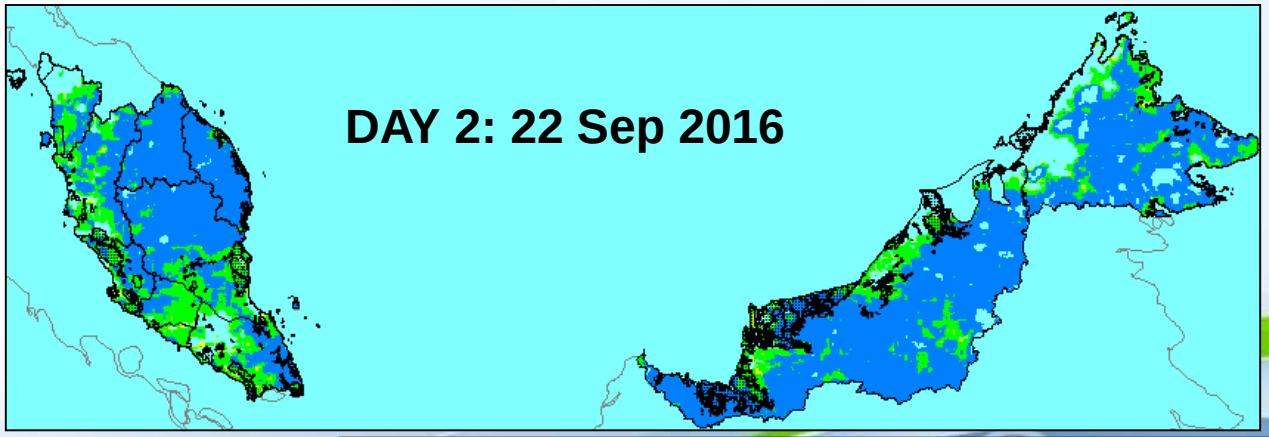


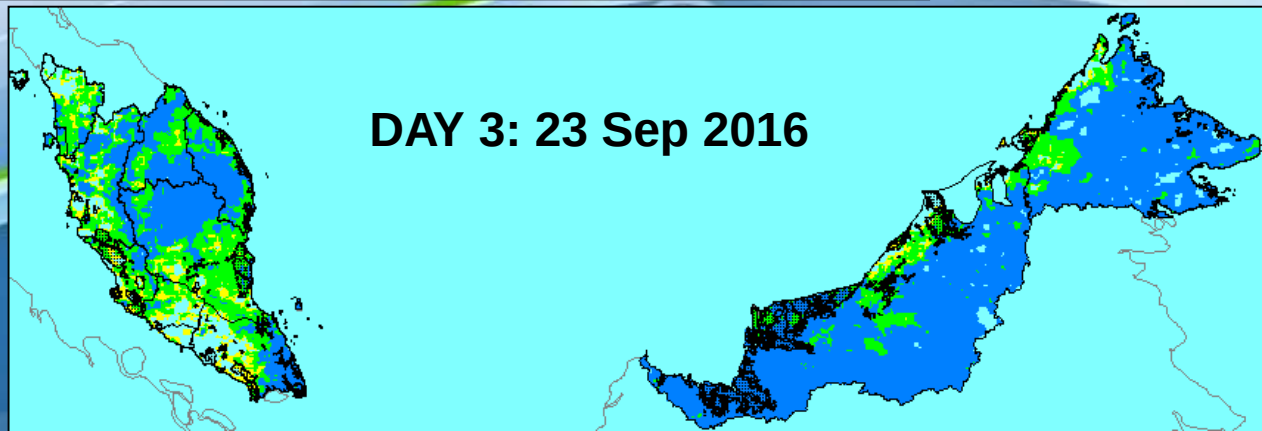




FDRS Forecasts (FWI)



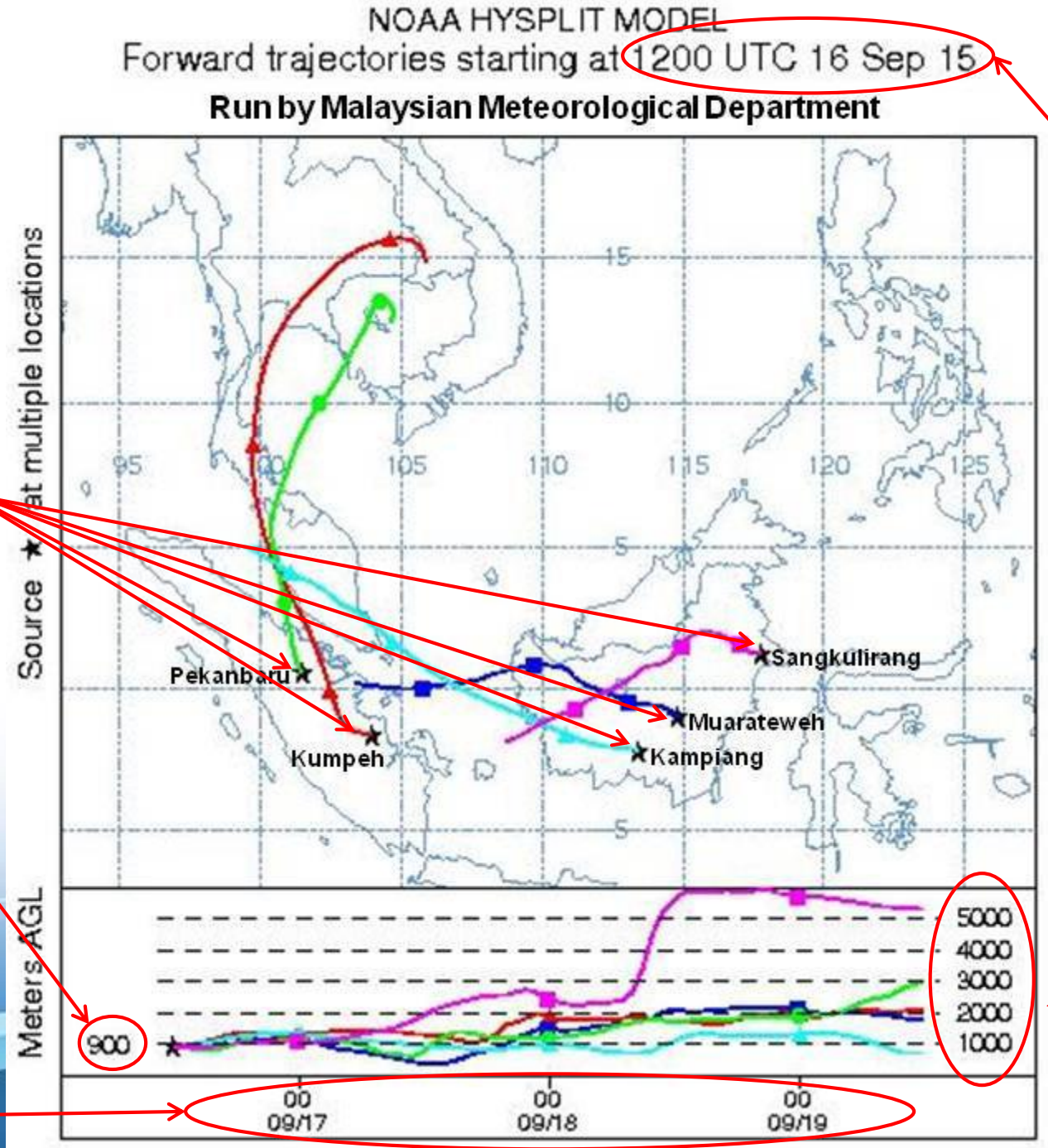




Haze Monitoring: HYSPLIT Model and others

HYSPLIT – Hybrid Single Particle Lagrangian Integrated Trajectory Model

- A complete system for computing simple air parcel trajectories, as well as complex transport, dispersion, chemical transformation and deposition simulations.
- Uses meteorological data file as input data.
- Could be run for forecasting (Forward Trajectories) or to determine the origin of source pollutants (Backward Trajectories).
- Used around the world for:
  - Emergency Response
  - Aviation Safety (volcanoes)
  - Interpretation of Pollutant Measurements
  - Fate and Transport Modeling of Pollutants
  - Balloon Flights



Input data started from 16 Sep 2015, 8pm.

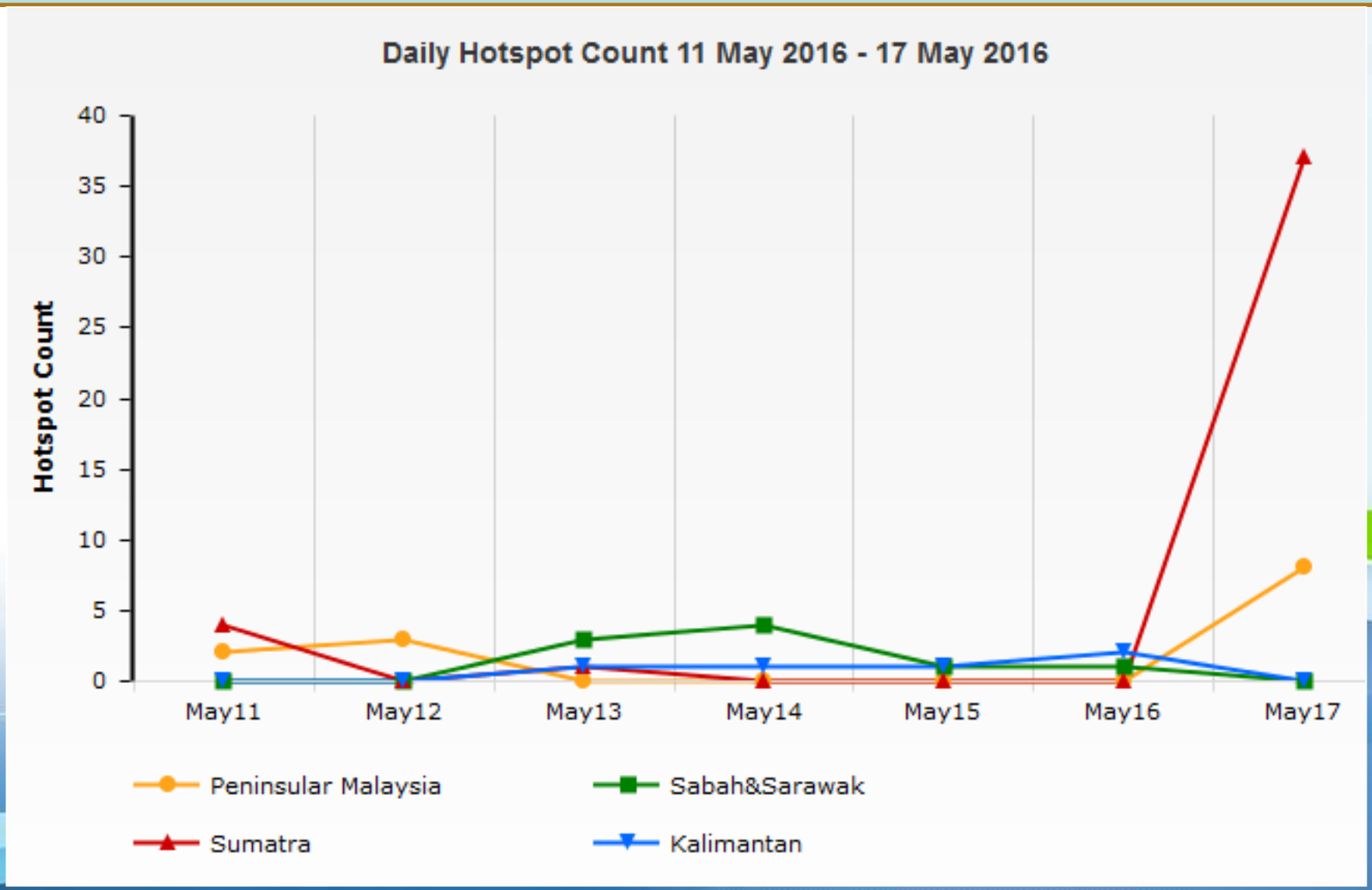
Starting locations of pollutant obtained from the ASEAN Specialised Meteorological Centre (ASMC) website.

The height of source is set as 900m AGL.

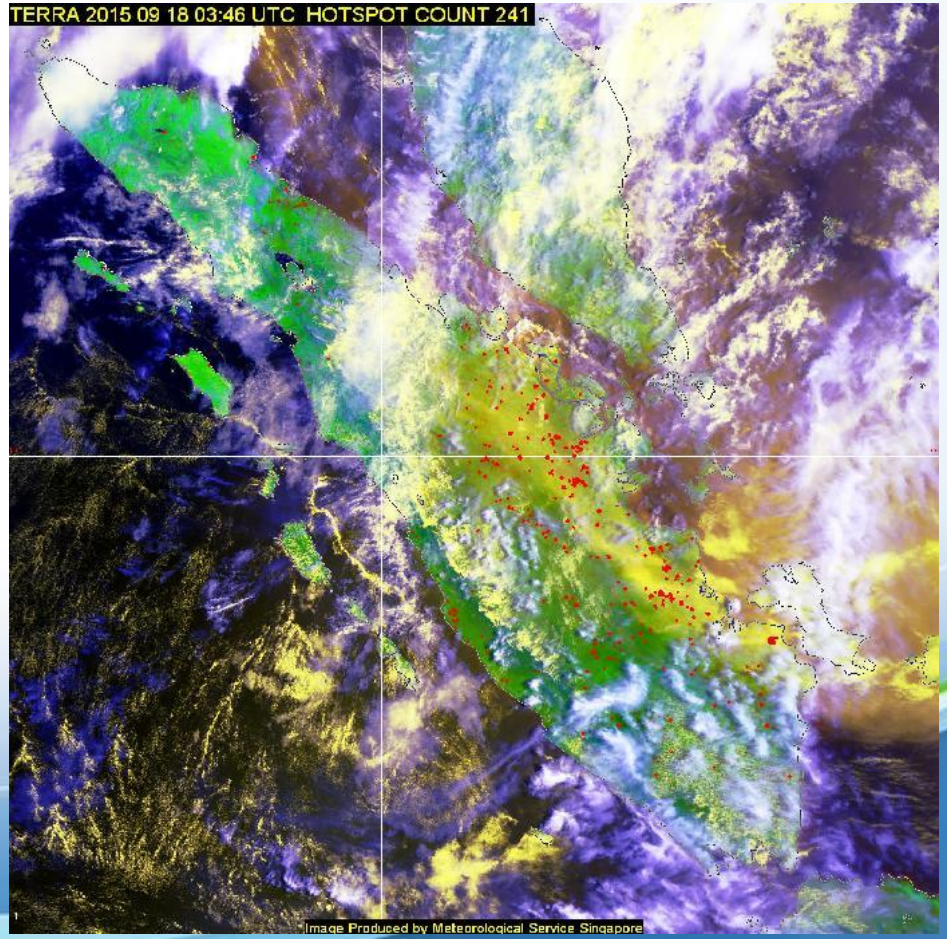
3-Days forecast from the Input data (24 hours cycle).

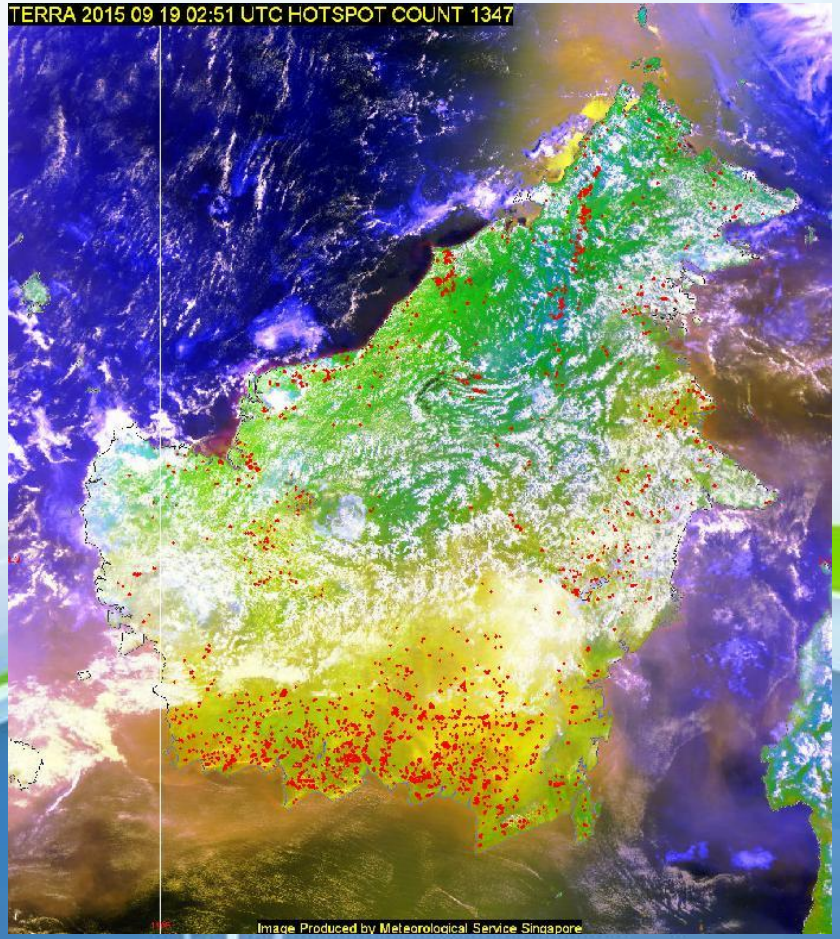
The maximum height the pollutants able to be transported (m AGL).

Daily Hotspot Count

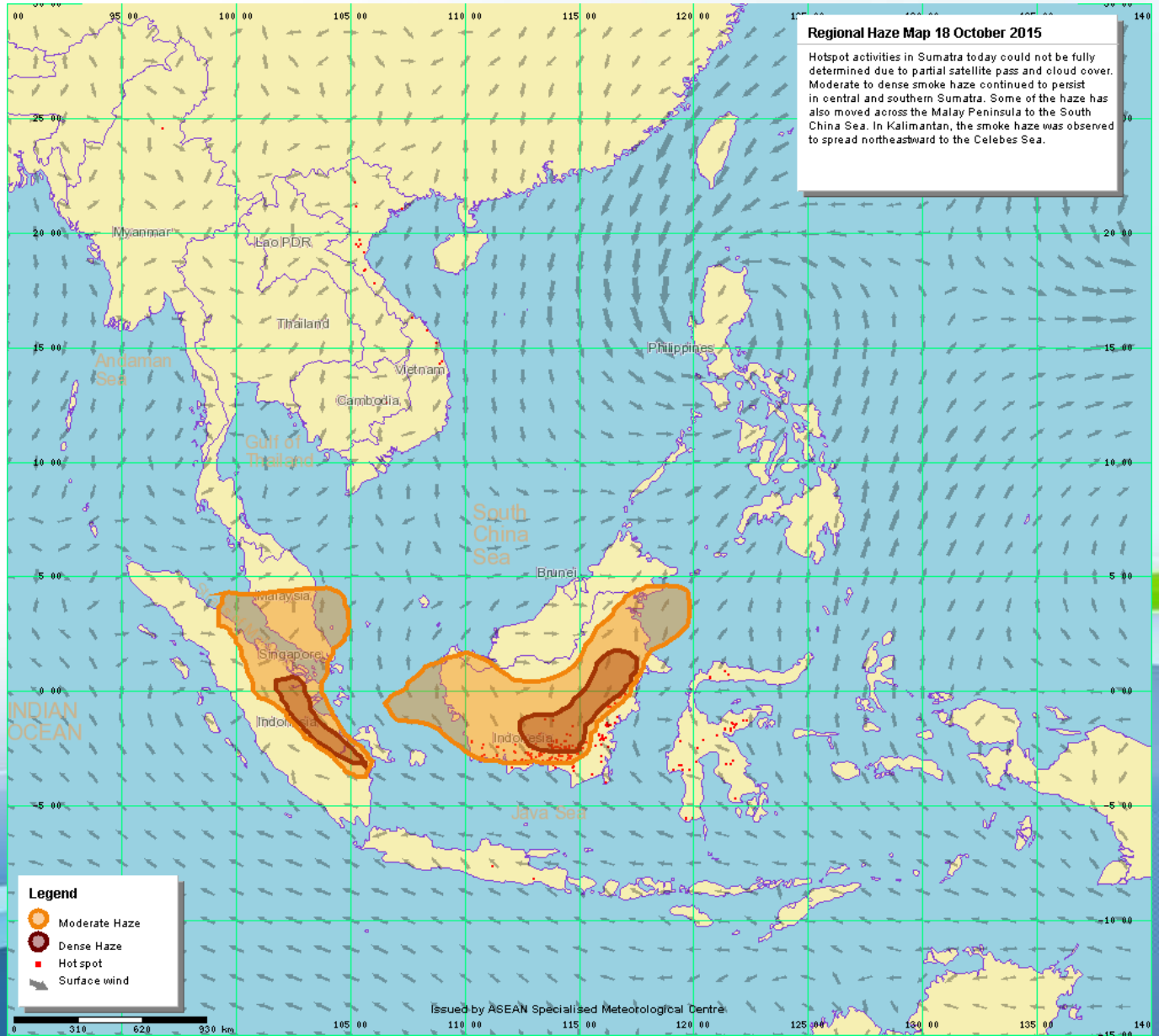


Hotspot Monitoring Using Satellite Imagery

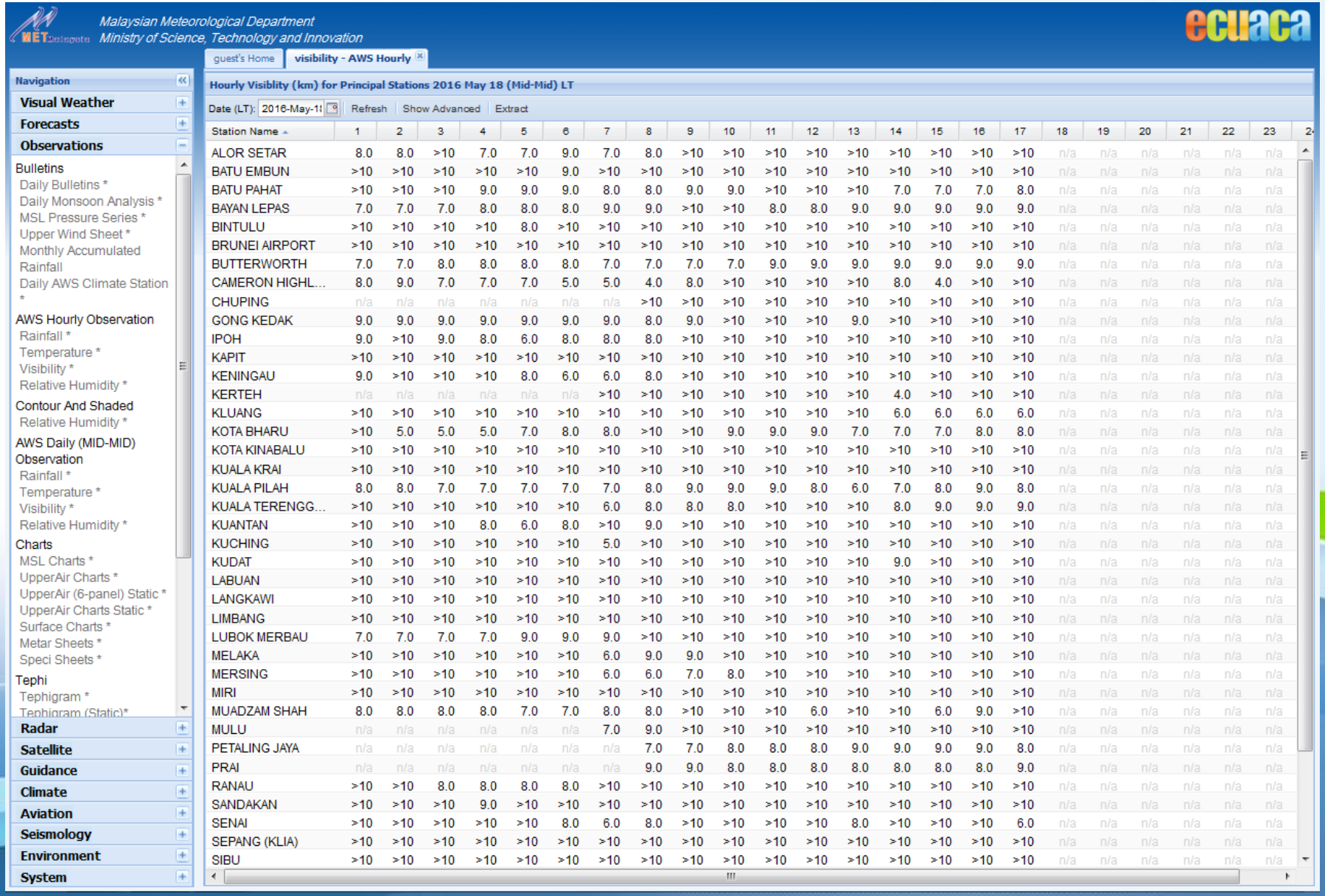




Regional Haze Map



Monitoring Horizontal Visibility



Malaysian Meteorological Department
Ministry of Science, Technology and Innovation

ecuaca

guest's Home | visibility - AWS Hourly

Navigation

- Visual Weather
- Forecasts
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    - Daily Bulletins *
    - Daily Monsoon Analysis *
    - MSL Pressure Series *
    - Upper Wind Sheet *
    - Monthly Accumulated Rainfall
    - Daily AWS Climate Station *
  - AWS Hourly Observation
    - Rainfall *
    - Temperature *
    - Visibility *
    - Relative Humidity *
  - Contour And Shaded
    - Relative Humidity *
  - AWS Daily (MID-MID) Observation
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    - Tephigram *
    - Tephigram (Static)*
- Radar
- Satellite
- Guidance
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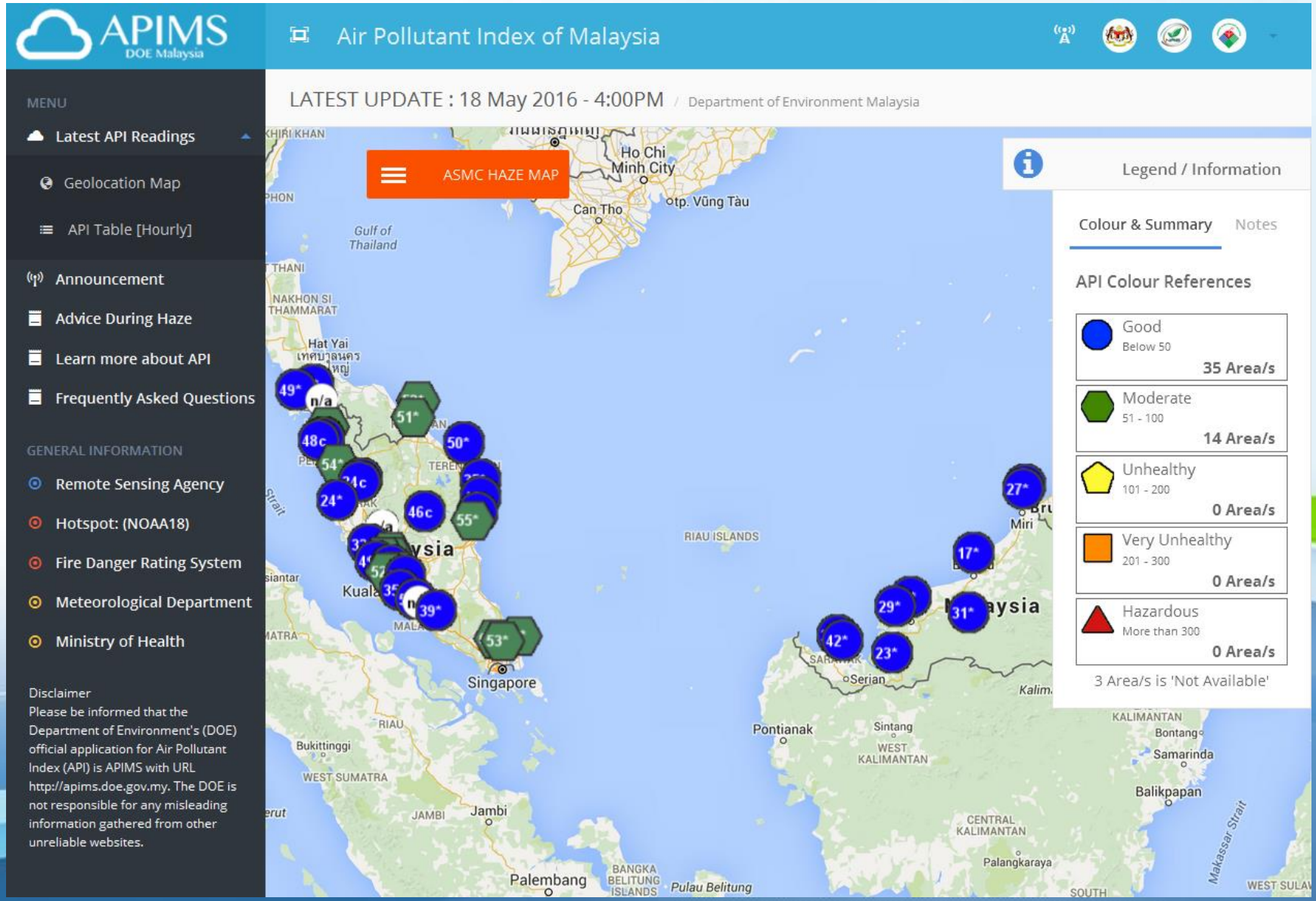
- Aviation
- Seismology
- Environment
- System

Hourly Visiblity (km) for Principal Stations 2016 May 18 (Mid-Mid) LT

Date (LT): 2016-May-18 | Refresh | Show Advanced | Extract

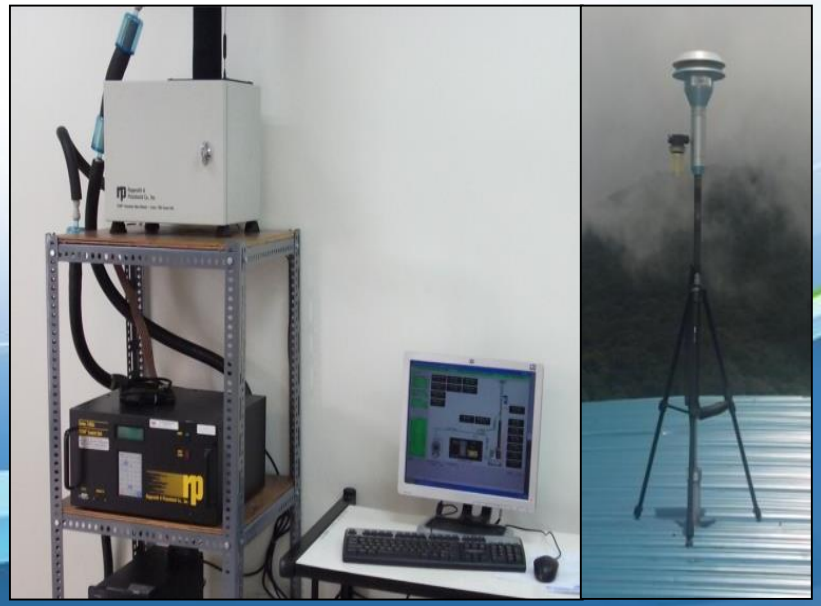
Station Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ALOR SETAR	8.0	8.0	>10	7.0	7.0	9.0	7.0	8.0	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
BATU EMBUN	>10	>10	>10	>10	>10	9.0	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
BATU PAHAT	>10	>10	>10	9.0	9.0	9.0	8.0	8.0	9.0	9.0	>10	>10	>10	7.0	7.0	7.0	8.0	n/a	n/a	n/a	n/a	n/a	n/a	
BAYAN LEPAS	7.0	7.0	7.0	8.0	8.0	8.0	9.0	9.0	>10	>10	8.0	8.0	9.0	9.0	9.0	9.0	9.0	n/a	n/a	n/a	n/a	n/a	n/a	
BINTULU	>10	>10	>10	>10	8.0	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
BRUNEI AIRPORT	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
BUTTERWORTH	7.0	7.0	8.0	8.0	8.0	8.0	7.0	7.0	7.0	7.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	n/a	n/a	n/a	n/a	n/a	n/a	
CAMERON HIGHL...	8.0	9.0	7.0	7.0	7.0	5.0	5.0	4.0	8.0	>10	>10	>10	>10	8.0	4.0	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
CHUPING	n/a	n/a	n/a	n/a	n/a	n/a	n/a	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
GONG KEDAK	9.0	9.0	9.0	9.0	9.0	9.0	9.0	8.0	9.0	>10	>10	>10	9.0	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
IPOH	9.0	>10	9.0	8.0	6.0	8.0	8.0	8.0	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
KAPIT	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
KENINGAU	9.0	>10	>10	>10	8.0	6.0	6.0	8.0	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
KERTEH	n/a	n/a	n/a	n/a	n/a	n/a	>10	>10	>10	>10	>10	>10	>10	4.0	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
KLUANG	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	6.0	6.0	6.0	6.0	n/a	n/a	n/a	n/a	n/a	n/a	
KOTA BHARU	>10	5.0	5.0	5.0	7.0	8.0	8.0	>10	>10	9.0	9.0	9.0	7.0	7.0	7.0	8.0	8.0	n/a	n/a	n/a	n/a	n/a	n/a	
KOTA KINABALU	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
KUALA KRAI	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
KUALA PILAH	8.0	8.0	7.0	7.0	7.0	7.0	7.0	8.0	9.0	9.0	9.0	8.0	6.0	7.0	8.0	9.0	8.0	n/a	n/a	n/a	n/a	n/a	n/a	
KUALA TERENGG...	>10	>10	>10	>10	>10	>10	6.0	8.0	8.0	8.0	>10	>10	>10	8.0	9.0	9.0	9.0	n/a	n/a	n/a	n/a	n/a	n/a	
KUANTAN	>10	>10	>10	8.0	6.0	8.0	>10	9.0	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
KUCHING	>10	>10	>10	>10	>10	>10	5.0	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
KUDAT	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	9.0	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
LABUAN	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
LANGKAWI	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
LIMBANG	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
LUBOK MERBAU	7.0	7.0	7.0	7.0	9.0	9.0	9.0	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
MELAKA	>10	>10	>10	>10	>10	>10	6.0	9.0	9.0	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
MERSING	>10	>10	>10	>10	>10	>10	6.0	6.0	7.0	8.0	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
MIRI	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
MUADZAM SHAH	8.0	8.0	8.0	8.0	7.0	7.0	8.0	8.0	>10	>10	>10	6.0	>10	>10	6.0	9.0	>10	n/a	n/a	n/a	n/a	n/a	n/a	
MULU	n/a	n/a	n/a	n/a	n/a	n/a	7.0	9.0	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
PETALING JAYA	n/a	n/a	n/a	n/a	n/a	n/a	n/a	7.0	7.0	8.0	8.0	8.0	9.0	9.0	9.0	9.0	8.0	n/a	n/a	n/a	n/a	n/a	n/a	
PRAI	n/a	n/a	n/a	n/a	n/a	n/a	n/a	9.0	9.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	9.0	n/a	n/a	n/a	n/a	n/a	n/a	
RANAU	>10	>10	8.0	8.0	8.0	8.0	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
SANDAKAN	>10	>10	>10	9.0	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
SENAI	>10	>10	>10	>10	>10	8.0	6.0	8.0	>10	>10	>10	>10	8.0	>10	>10	>10	6.0	n/a	n/a	n/a	n/a	n/a	n/a	
SEPANG (KLIA)	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	
SIBU	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10	n/a	n/a	n/a	n/a	n/a	n/a	

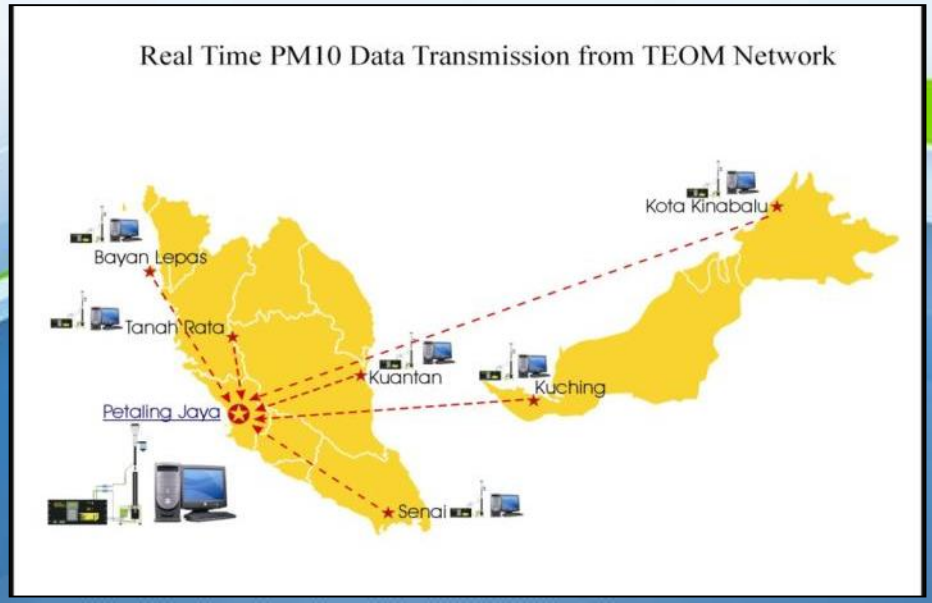
Monitoring Air Pollution Index (API)



Continuous Monitoring of PM10

- To measure the suspended particulate matter of diameter less than 10 micrometer in ambient air automatically and continuously.
- There are 8 stations operating this instrument, namely Petaling Jaya, Senai, Bayan Lepas, Kuantan, Cameron Highlands, Kuching, Kota Kinabalu and Danum Valley.
- The data of TEOM instrument for all stations can be viewed real-time except for data from Danum Valley GAW Station.





Haze Mitigation: Cloud Seeding Operation

Cloud Seeding?

Cloud seeding is a form of WEATHER MODIFICATION. It can be used to disperse fog, suppress hail, or control winds, but is most often used to increase precipitation. In order to understand the process, however, a basic understanding of clouds and how PRECIPITATION is formed is needed.

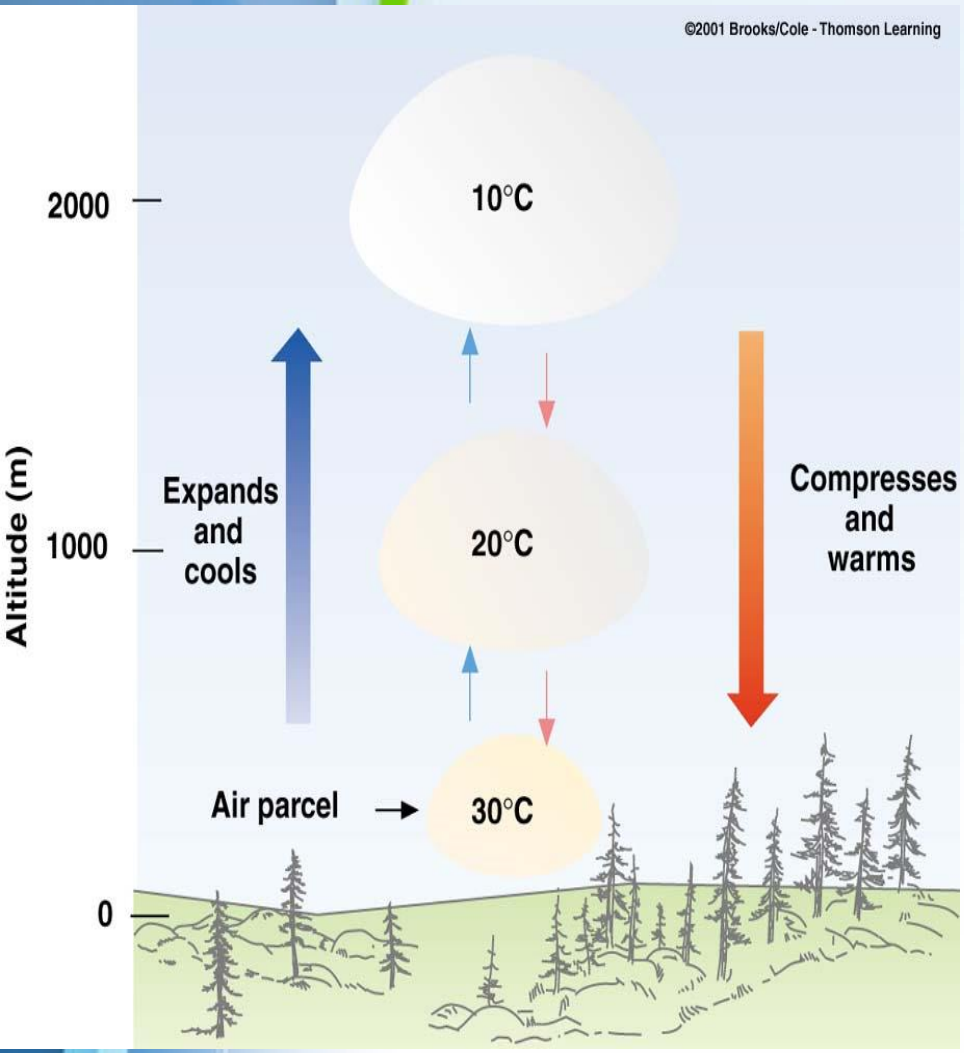
Cloud Formation - Source

- Clouds have their origins in the water that covers 70 per cent of the earth's surface
- Millions of tons of water vapour are evaporated into the air daily from oceans, lakes and rivers, and by transpiration from trees, crops and other plant life
- As warm air rises from the earth surface, it begins to cool and condense to form tiny cloud droplets of water

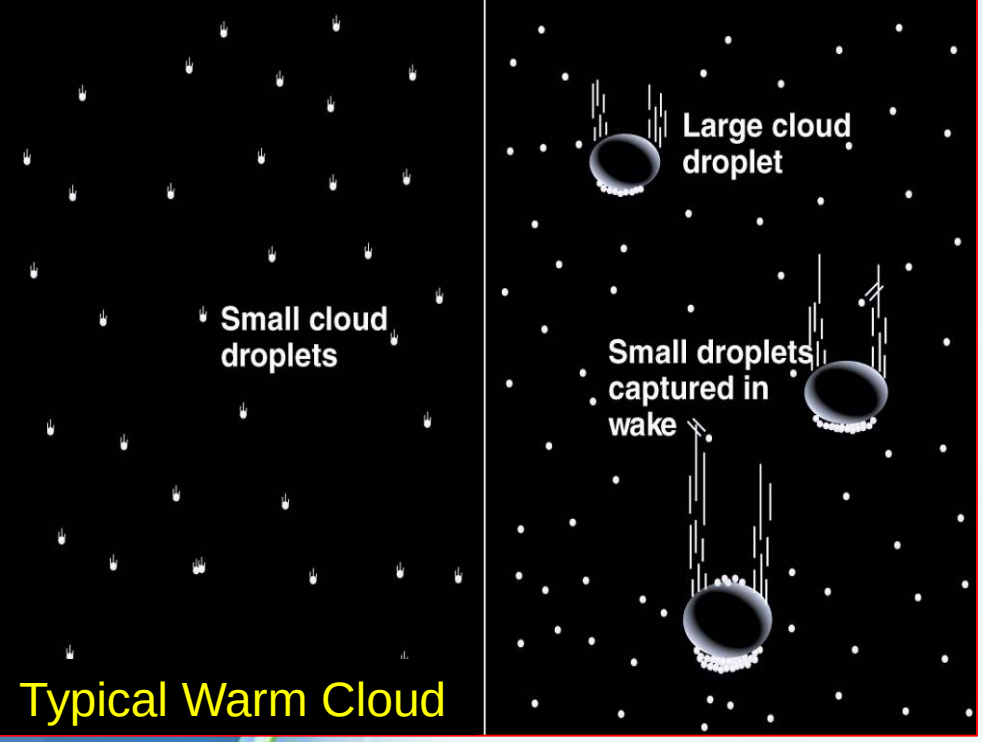
The Cloud Formation Process

- Cloud droplets are formed around particles of dust, salt, or soil (called *cloud condensation nuclei*) that are always present in the atmosphere
- In warm temperatures, the droplets in the cloud merge with many other droplets and become heavy enough to fall to the ground as rain
- In colder temperatures, the droplets of water form ice crystals. Other droplets freeze onto these ice crystals, which grow larger and heavier until they fall to the ground as rain, snow, or hail

The Cloud Formation Process



- **Homogeneous nucleation of Water droplets require high degree of super saturation (~350-400%)**
- **Heterogeneous nucleation in the presence of Cloud Condensation Nuclei (CCN)**
- **Two important processes of how rain is produced**
  - **Collision-Coalescence Process**
  - **Ice-crystal (or Bergeron) Process**



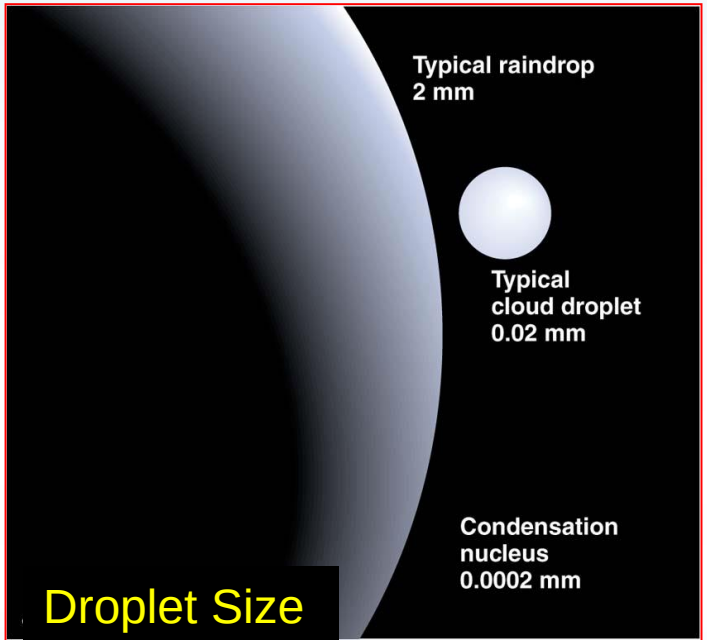
Warm Clouds

- Collision and Coalescence

Cold Clouds

- Ice Crystal Process

Droplet Growth



Ice Crystal Process

- Bergeron process of rain formation: A process that produces precipitation; involves tiny ice crystals in a supercooled cloud growing larger at the expense of the surrounding liquid droplets
- Ice crystals and liquid cloud droplets must coexist in clouds at below freezing temperature
- Accretion or riming of ice crystals: Ice crystals grow larger by colliding with the supercooled liquid droplets; the droplets freeze into ice and stick to the ice crystal

Cloud Seeding – Definition

- The deliberate treatment of certain clouds or cloud systems with the intention of affecting the precipitation processes within those clouds
- Cloud seeding is actually a very complex process. In the simplest terms, it introduces other particles into a cloud to serve as cloud condensation nuclei (CCN) which aid in the formation of precipitation

Cloud Seeding – Mode

- **Static mode** cloud seeding seeks to increase rainfall by adding ice crystals (usually in the form of silver iodide or dry ice) to cold clouds.
- **Dynamic mode** cloud seeding increases rainfall by enhancing "vertical air currents in clouds and thereby vertically process more water through the clouds." Basically, in this method of seeding, a much larger number of ice crystals are added to the cloud than in the static mode.
- In **hygroscopic seeding**, salt crystals are released into a cloud. These particles grow until they are large enough to cause precipitation to form. Clouds can be seeded from above with the help of airplanes that drop pyrotechnics, or from the ground by using artillery or ground-to-air rockets

Cloud Seeding – Concept

Static Seeding

Alter the microphysical properties of clouds

Dynamic Seeding

Attempt to modify the air motion within the clouds

Hygroscopic Seeding

Use of hygroscopic material to obtain the intended result (eg. salt)
Static or Dynamic

Cloud Seeding – Type

Warm Cloud Seeding

↓

Cumulus Clouds

↓

To increase population of water drops

↓

Sodium Chloride or Urea

Cold Cloud Seeding

Glaciogenic Seeding

↓

Cumulus Clouds having cloud top temp < 0°C

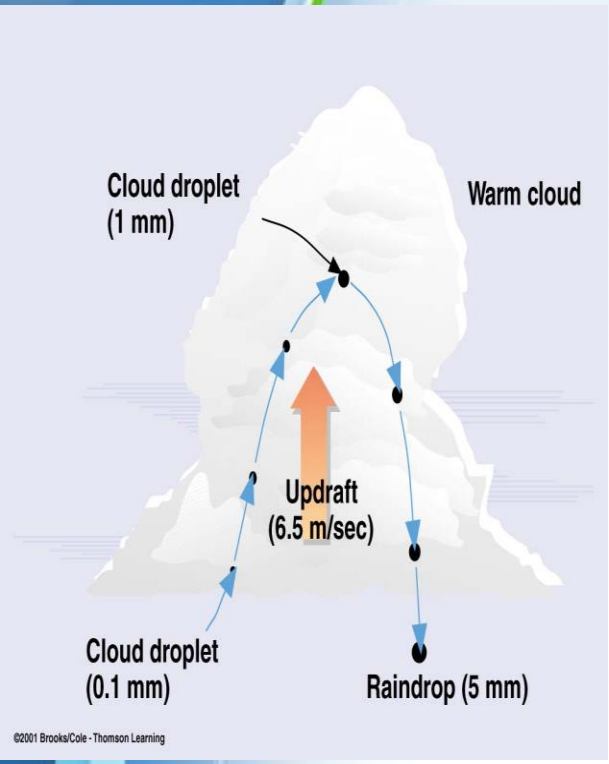
↓

To increase population of ice crystals

↓

Silver Iodide

Cloud Seeding – Warm



Formation of Rain through Hygroscopic Seeding

Hygroscopic Particles:

- Extremely moisture absorbent
- Grow in low humidity air below cloud base

Examples of Hygroscopic Material

- Common Table Salt
- Ammonium Nitrate – Urea Fertilizer

Objective of Hygroscopic Seeding

Introduce large drops into cloud

Large drops collide with small cloud droplets and grow into rain drops (Coalescence)

Rain drops heavy and large enough to fall out of cloud and reach ground

Cloud Seeding Operation for Warm Cloud

Cloud seeding aircraft loaded with hygroscopic (salt) solution/particles heading towards favourable developing cumulus cloud

Minute hygroscopic droplets /particles are sprayed/injected towards the base of cumulus clouds so as to enhance collision and coalescence processes among water droplets within the warm clouds to accelerate and enhance rainfall

Cloud seeding operations always involve risk as the aircraft has to fly into turbulent clouds.

If the atmospheric conditions are favourable, more rain will fall

Pre-requisite Condition for Successful Cloud Seeding Operation

1) Unstable atmospheric condition

2) High moisture content in atmosphere

3) Existence of towering cumulus cloud

Cumulus Cloud Favourable for Cloud Seeding Operation

CLOUD SEEDING OPERATION IN MALAYSIA

Basic Statistics of Cloud Seeding Operation

- Since1973 ~ more than 40 years experience
- Total number of operations > 1200 (since 1998)
- Total number of flights > 1300 (since 1998)
- Types of seeding ~ wet & dry
  - Wet seeding agent
    ~ Urea $CO(NH_2)_2$ ~ from 1973 until 1980
    ~ Salt (NaCl) ~ from 1973 until now
  - Dry seeding agent ~ *Hygroscopic flare (NaCl and KCl)* ~ from 2005 until now

Aircrafts Used for Cloud Seeding Operations

Past	Present	
		Wet
		Dry

Main Purpose of Cloud Seeding Operations

Rainfall Enhancement

1) To mitigate water shortage at dams
2) To mitigate the effects of haze

Wet Seeding - Preparation

Emptying salt into the water tank

Preparing Salt Solution

Spray with water jet to dissolve salt

Wet Seeding - Loading

Loading Water Tanks Onboard the Hercules C130

Wet Seeding - Briefings

Weather Briefing

Flight Plan Briefing

Wet Seeding – In Action

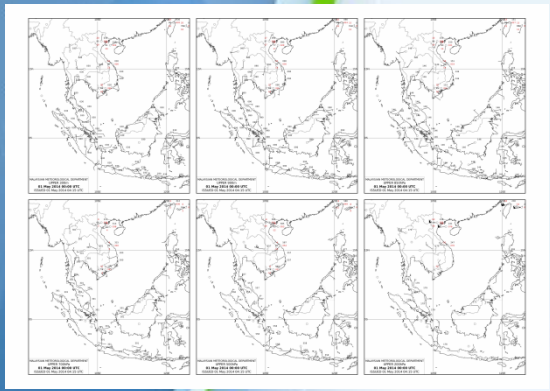
Spraying the salt solution from Hercules C130

Dry Seeding - Preparation

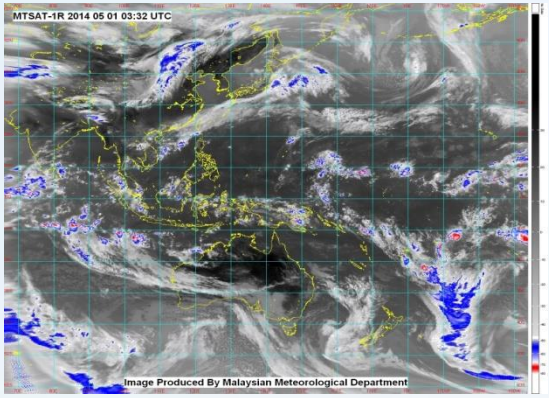
Dry Seeding – In Action

Briefing Material

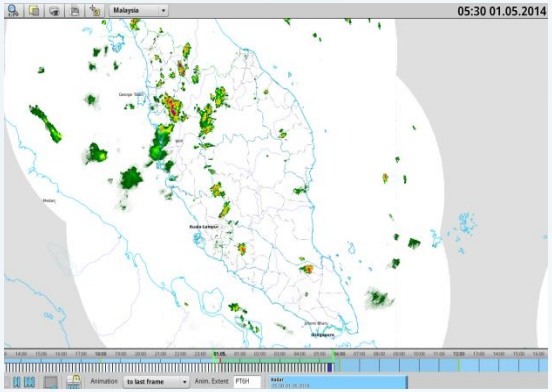
Current Wind Pattern

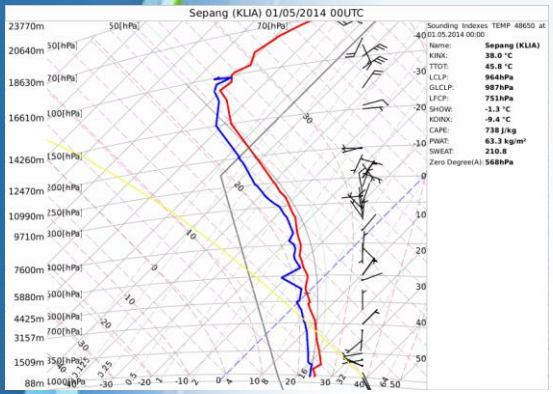


Current Satelite Image

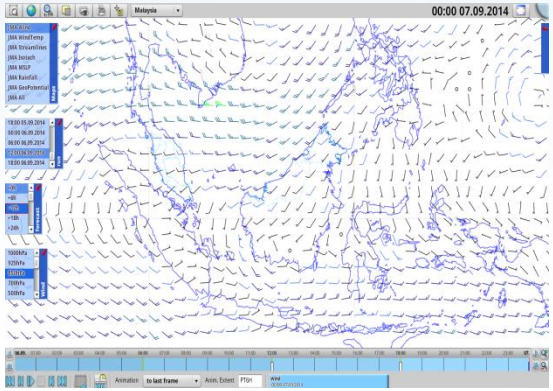


Current Radar Image

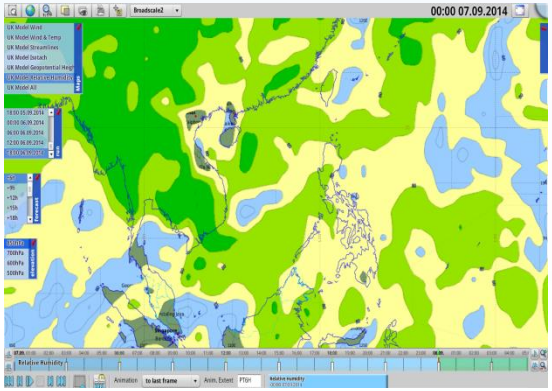




Current Tephigram Chart



Wind Forecast at Various Levels



Relative Humidity Forecast at Various Levels

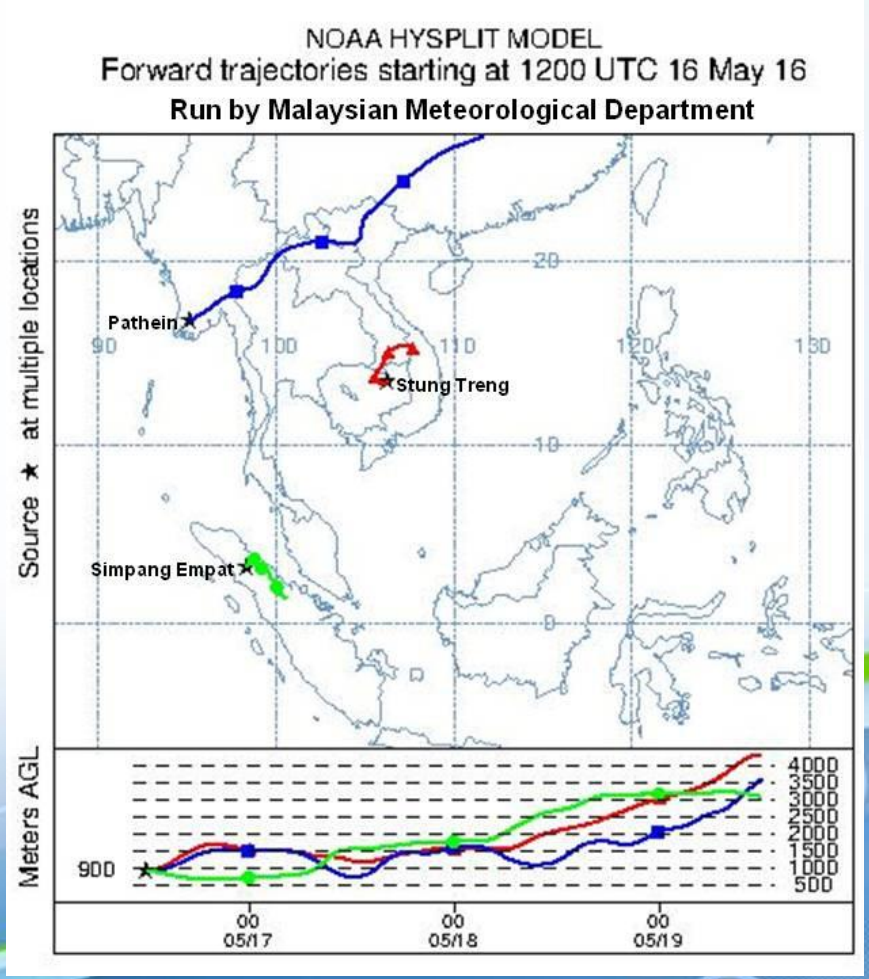
Conclusion

Continuous Monitoring during Haze Episode

1. Regular reporting of current weather and forecast (haze report) to related agencies.
   - Weather outlook
   - HYSPLIT model output
   - Hotspots (Hotspots Map & Satellite Map)
   - Regional Haze Map
   - Visibility
   - Wind
   - Fire Danger Rating System (FDRS) output
   - Air Pollution Index (API)
   - Areas with no rainfall for 5 consecutive days - Criteria for open burning prohibition

Action and Mitigation

2. Simulation of HYSPLIT Model on daily basis.



3. Conducts cloud seeding operations based on National Haze Action Plan.


Thank You