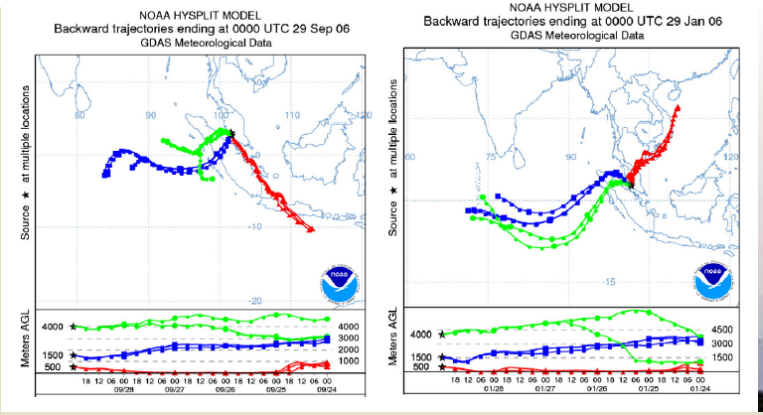
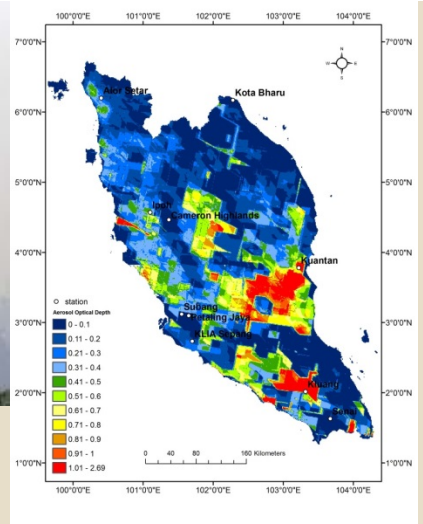
REMOTE SENSING FOR AEROSOL STUDIES IN MALAYSIA





International Workshop on Land Use/Cover Changes and Air Pollution in Asia
4-7 Aug 2015, Bogor, Indonesia

UTM
UNIVERSITI TEKNOLOGI MALAYSIA
UNIVERSITI PENYELIDIKAN

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PRESENTATION OUTLINE

1. Significance of aerosols studies in Malaysia
2. Sources of aerosol data
3. Aerosol studies using remote sensing
4. Research gaps & Challenges in studying atmospheric aerosol in Malaysia

SIGNIFICANCE

- Air pollution -serious environmental problem in the developing Southeast Asian countries
- Major sources of air pollution – urbanisation & associated industrial and transportation activities, land clearing, open burning & forest fire.
- Trans-boundary aerosols transport –southwest monsoon
- Malaysia is ranked as the 55th worst country among 178 nations worldwide in terms of air quality- EPI
- Effects:
  - Health
  - Poor visibility
  - Radiative forcing

- Aerosols large uncertainties in earth's climate system due to their high spatio-temporal variability and various optical properties

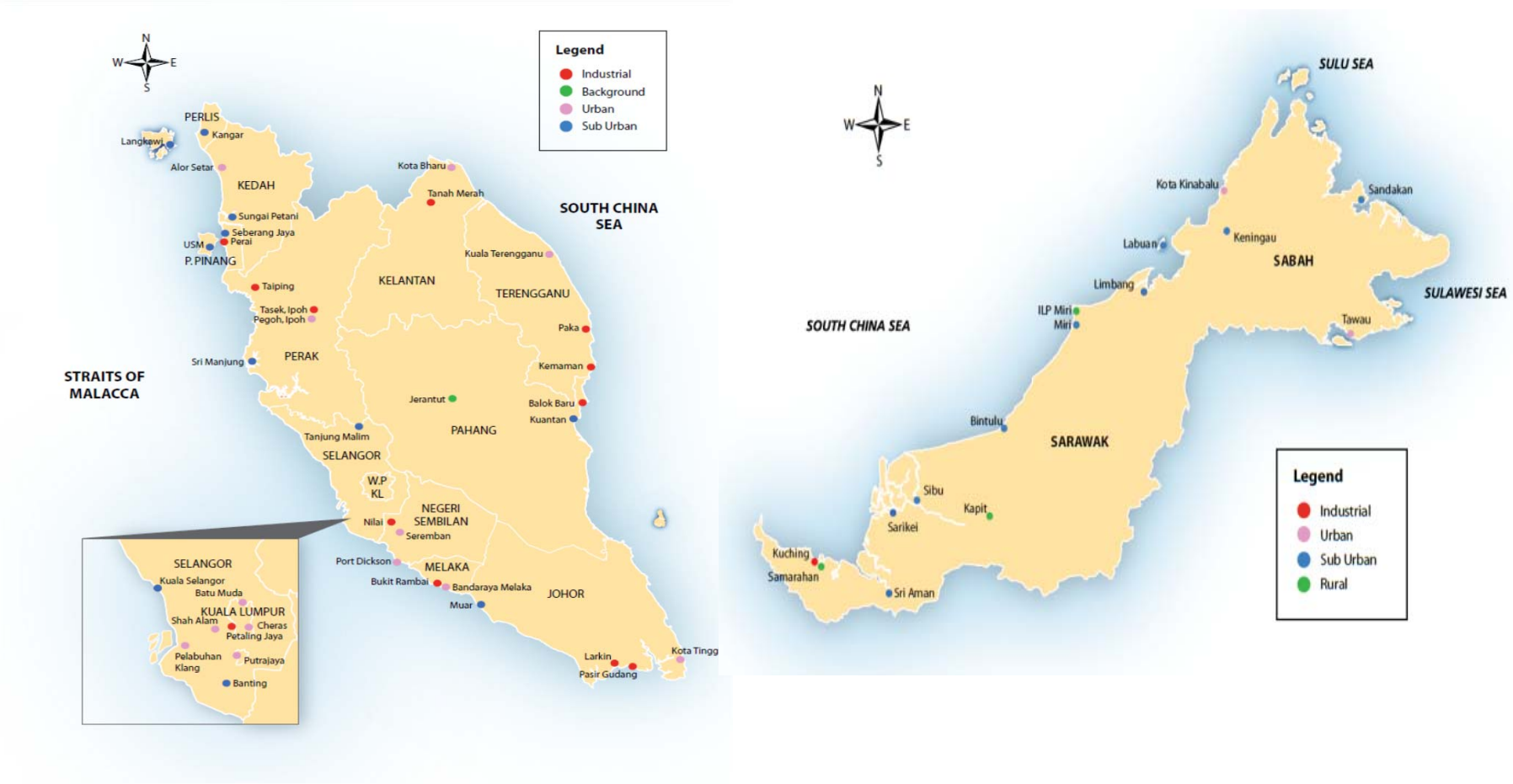
AEROSOL MONITORING IN MALAYSIA

- Ground based monitoring
- WMO Global Atmospheric Watch (GAW) Network
- AERONET
- Space borne remote sensing

GROUND BASED AIR QUALITY MONITORING

Dept. Environment	Malaysian Meteo. Services
➢ 52 Continuous Automatic Air Quality Monitoring (CAQM) stations and 19 Manual Air Quality Monitoring (MAQM) stations	➢ 14 stations measure TSP (PM <100 μm) & 9 stations measure PM10
➢Measurements from industrial, residential, traffic and rural areas	➢ Only ambient conditions are monitored
➢ CAQM measures PM_{10} and other gases such as SO2 NOx , CO, O3 , CH4, Non-Methane Hydrocarbon ➢ Meteorological parameters i.e. Wind Speed, Wind Direction, Temperature and Ultra Violet radiation	➢ TSP, atmospheric O3 and reactive gases (i.e. surface O3, CO, volatile organic compounds (VOCs), oxidised nitrogen compounds (NOx, NOy), and SO2 ➢ Co-located with climatological stations
➢ MAQM measures heavy metals such as lead, mercury, iron, sodium, copper and etc. every six days ➢ Manually collected and delivered for analysis & delivered on a monthly basis	

AIR QUALITY MONITORING STATIONS BY DOE



AIR QUALITY MONITORING STATIONS BY MMS

WMO GLOBAL ATMOSPHERIC WATCH (GAW) NETWORK OF STATIONS

- One global (Danum Valley, Sabah) and two regional (Tanah Rata in Cameron Highlands and Petaling Jaya) stations
- Regional stations:
  - PJ stations measures TSP & PM_{10}
  - The samples are then sent for analysis to determine its chemical compositions.
  - To study urban air quality and meteorology and providing urban air pollution forecasts
  - Tanah Rata station includes Rainwater chemical composition, reactive gases, aerosol load and chemical composition, surface ozone and meteorology.
- Global station monitors background concentrations of atmospheric parameters to study long-range transport of pollutants and ability of forests to act as sinks for atmospheric pollutants

WMO GLOBAL ATMOSPHERIC WATCH (GAW) NETWORK OF STATIONS

AERENET STATIONS

- Information of columnar aerosol properties
- Available in Malaysia since 2011
- Three AERONET stations

AERONET Stations	Kuching	USM, Penang	Tahir
Started operation	2nd Aug 2011	8th Nov 2011	21st Jun 2012
Location	Kuching International Airport	Universiti Sains Malaysia	Universiti Sains Malaysia
Others		Ground-based backscatter Lidar data (operated at 355 nm)	

REMOTE SENSING FOR AEROSOLS

Satellite sensor	Operational period	Aerosol products	Resolutions	Wavelengths used	Accuracy	Reference
AVHRR	Since 1979	Aerosol Optical Depth (AOD), Angstrom exponent	Daily, weekly, monthly, 1 degree	Visible Shortwave infrared	AOD (10%) for single channel AOD (3.6%) for two channel	Stowe et al. (1997); Mishchenko et al. (1999)
TOMS	1979-1993 and 1996-2005	Ultra Violet (UV)-absorbing aerosol index, UV Aerosol Optical Thickness (AOT)	Monthly, 1 degree	Ultra violet channels (331 and 360 nm)	AOT (20 ~ 30%)	Torres et al. (2002)
OMI	Since 2004	UV Aerosol Index, Aerosol Absorption Optical Depth, Aerosol Extinction Optical Depth (AOD) and Single Scattering Albedo	Daily, monthly, 13 × 12 km², 13 × 24 km², 13 × 48 km²	Includes 330 to 380 nm channels	AOD (30%)	Torres et al. (2007)
SeaWIFS	1997 - 2010	AOD and Angstrom exponent	1.1km (Local Area Coverage), 4.5km(Global Area Coverage)		AOD (5 ~10%)	Gordon and Wang (1994)
MODIS	Since 1999 (Terra) Since 2002 (Aqua)	AOD, Angstrom exponent, Fine mode fraction,	Daily, 8days, monthly, 10km, 1 degree		AOD (5 ~15%)	Remer et al. (2005)
MISR	Since 1999	AOD, Angstrom exponent, single scattering albedo, non-spherical fraction	1.1km (non-red band) 275m (red band)		AOD (10 ~20%)	Kahn et al. (2005)

REMOTE SENSING FOR AEROSOLS

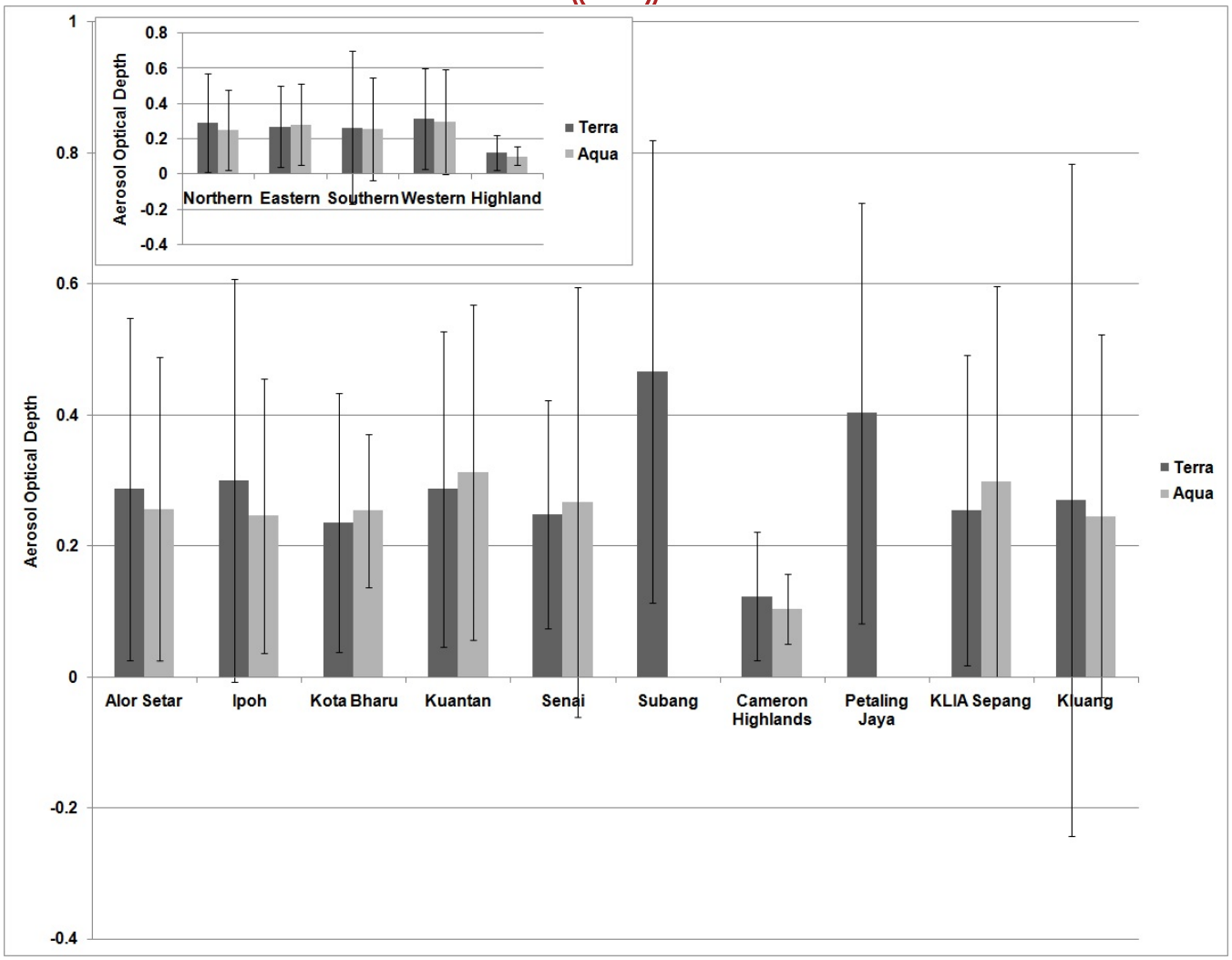
POLDER	1996 -1997 2002 – 2003 2004 - present	AOD, Angstrom exponent, non-spherical fraction, scattering phase function	Daily, 18.5 km	0.443, 0.490, 0.565, 0.665, 0.765, 0.865 and 0.910µm	AOD (20 ~30%) Angstrom exponent correlated well with AERONET, but with underestimation of 30%	Herman et al. (1997)
SCIAMACHY	Since 2002	UV-absorbing Aerosol Index (AI)	Daily, monthly, 60 × 30 km², 120 × 30 km², 240 × 30 km²		AI (~40%)	Graaf and Stammes (2005)
MERIS	Since 2002	AOD, Angström Coefficient	Daily, 1.2km (reduced resolution)	15 channels between 0.39-1.04 µm	AOD (~20%) AOD retrieved at both blue and red bands show an overestimation of AOD compared to AERONET AOD	Vidot et a. (2008)

Validation of MODIS AOD in Malaysia using AOD from AERONET

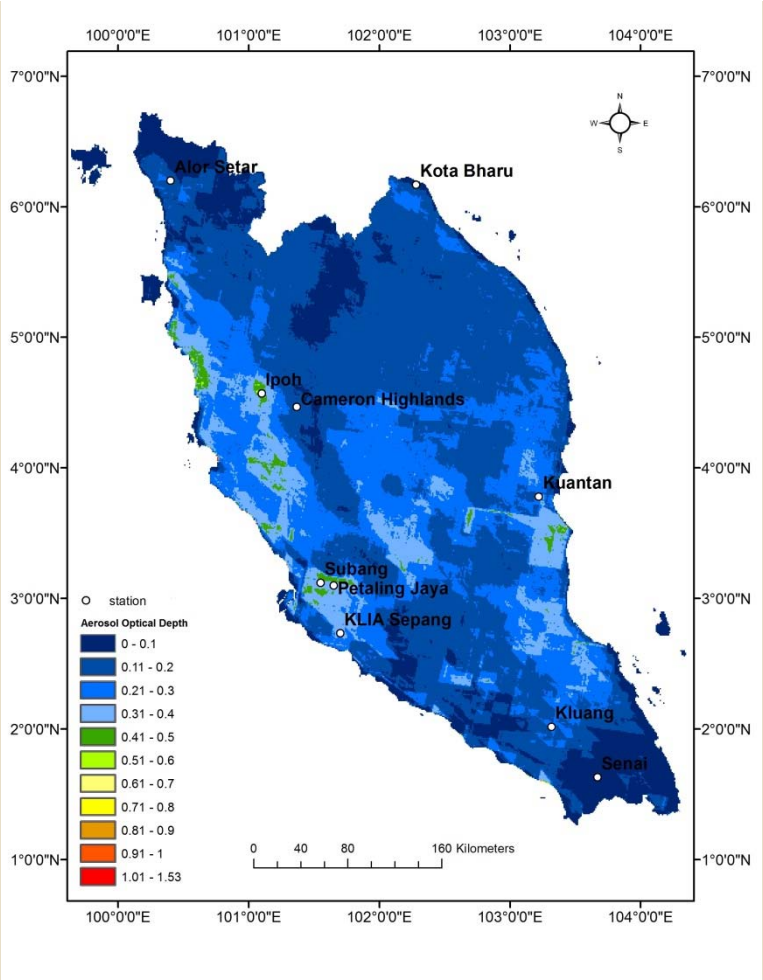
REMOTE SENSING FOR AEROSOLS

- Spatial and temporal patterns of AOD
- Aerosol size and types
- Identifying source regions of aerosols
- Impact of Aerosols on Solar radiation
- Particulate Matters Modeling

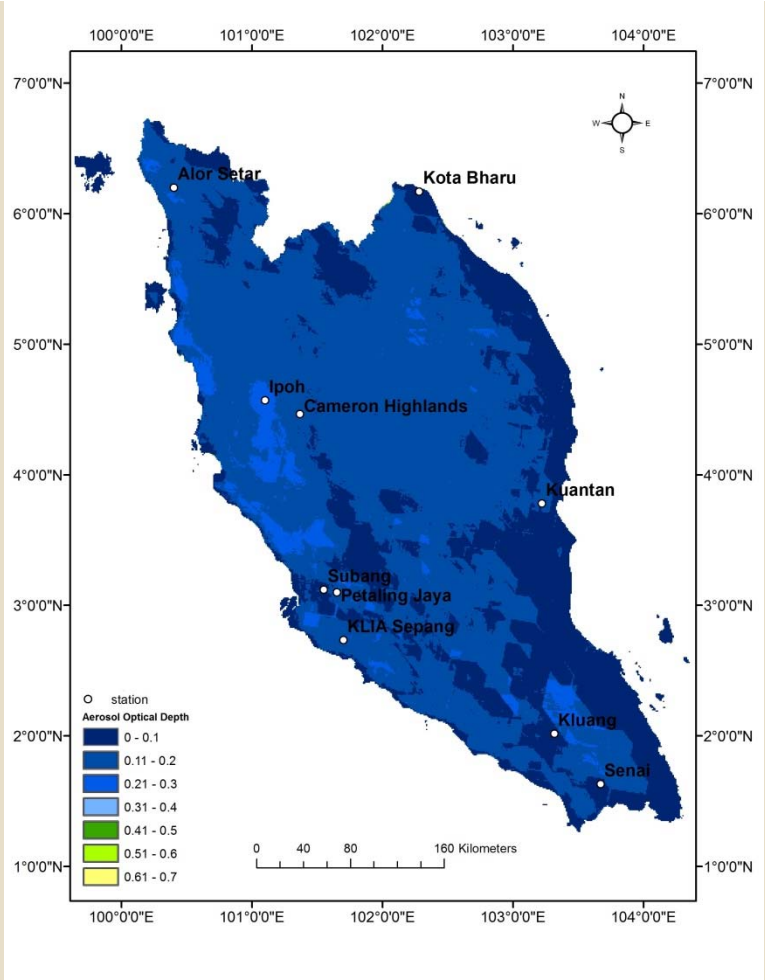
SPATIAL PATTERN AOD



SPATIAL PATTERN AOD (MODIS)

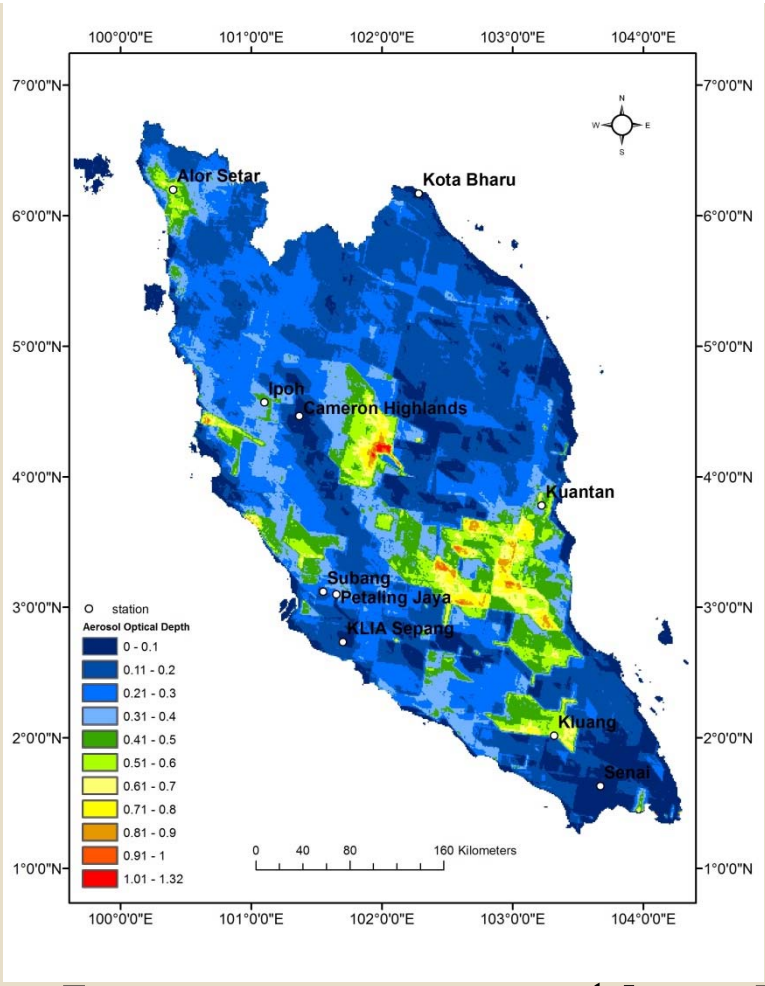


Dry Season (June-Sept)

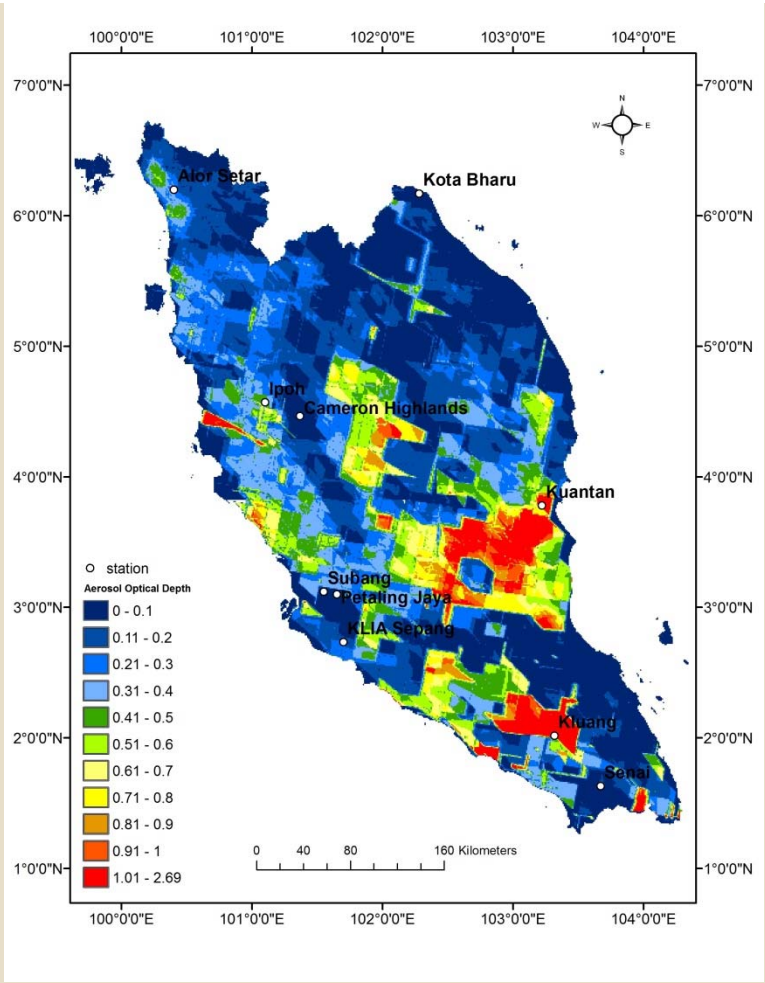


Wet Season (Dec-Mar)

SPATIAL PATTERN AOD

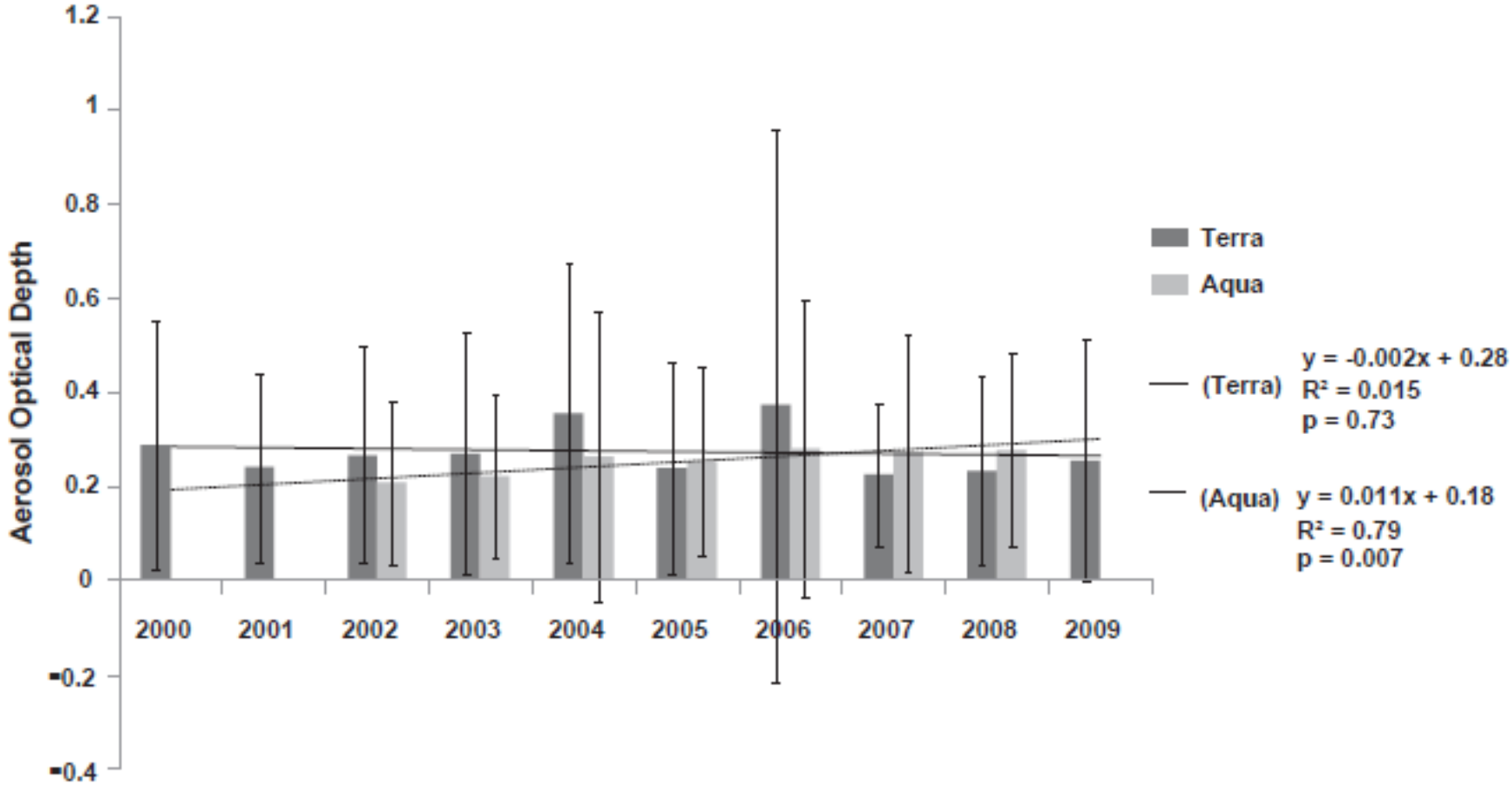


Inter-monsoon (Apr-May)

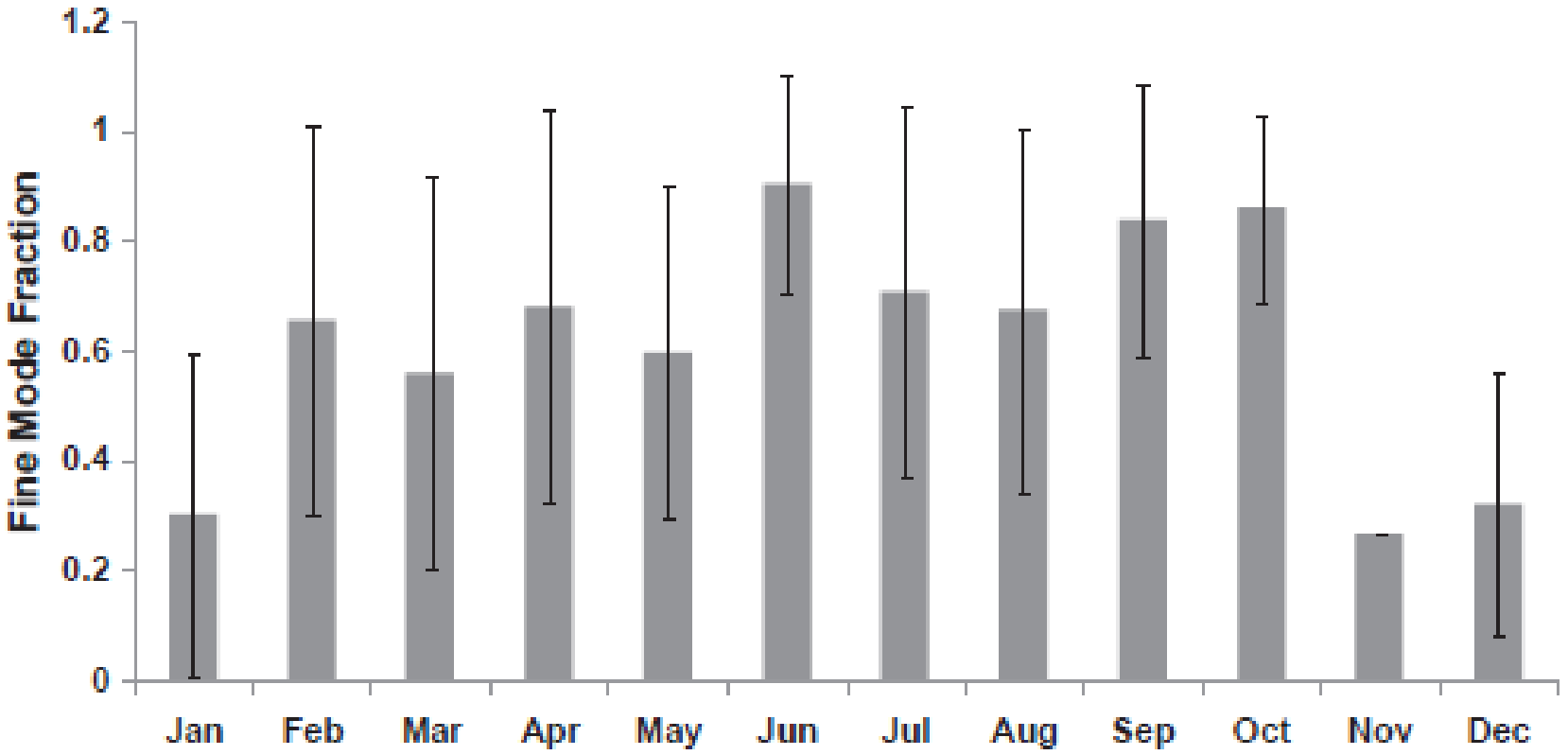


Inter-monsoon (Oct)

TEMPORAL PATTERN AOD

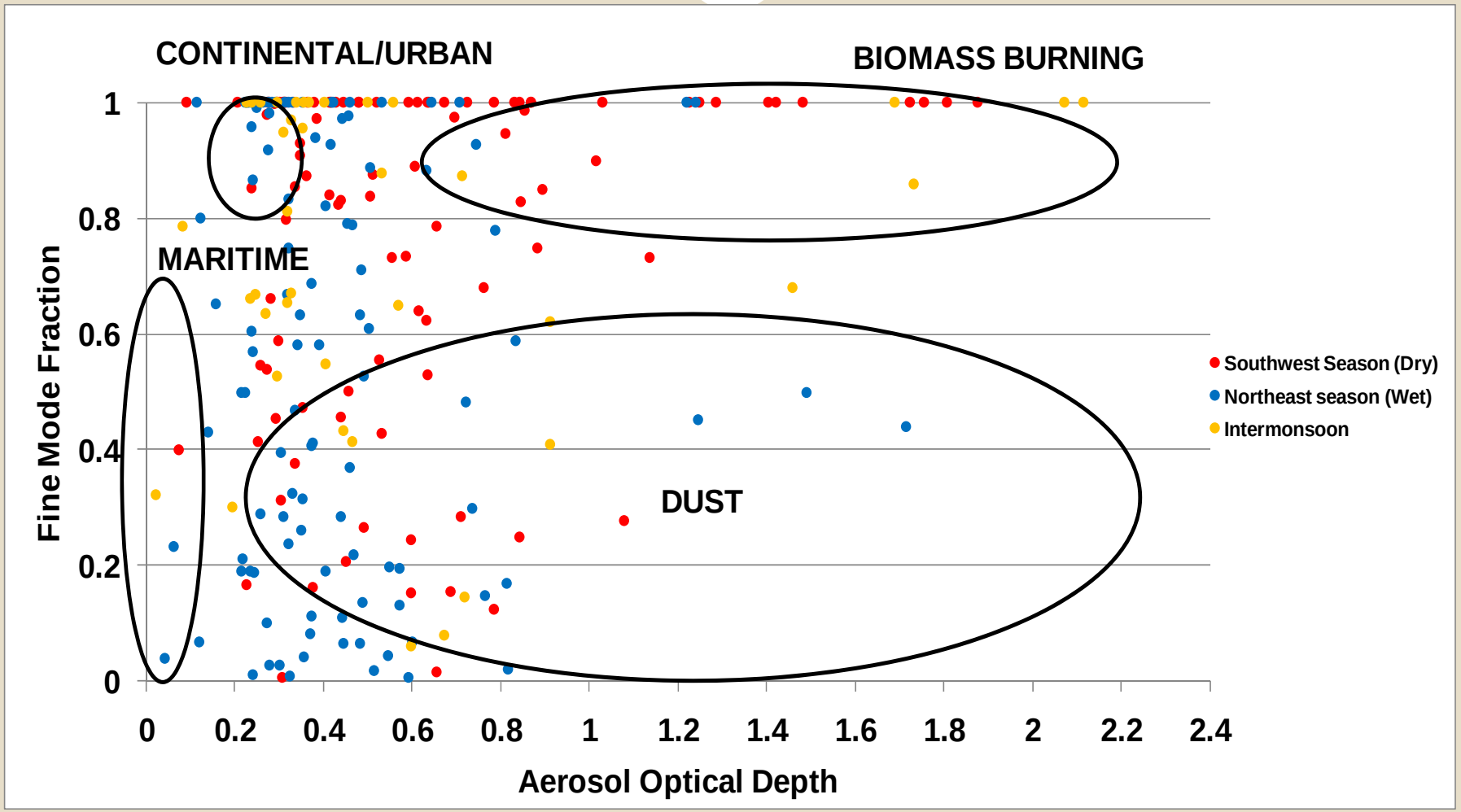


AEROSOL SIZE

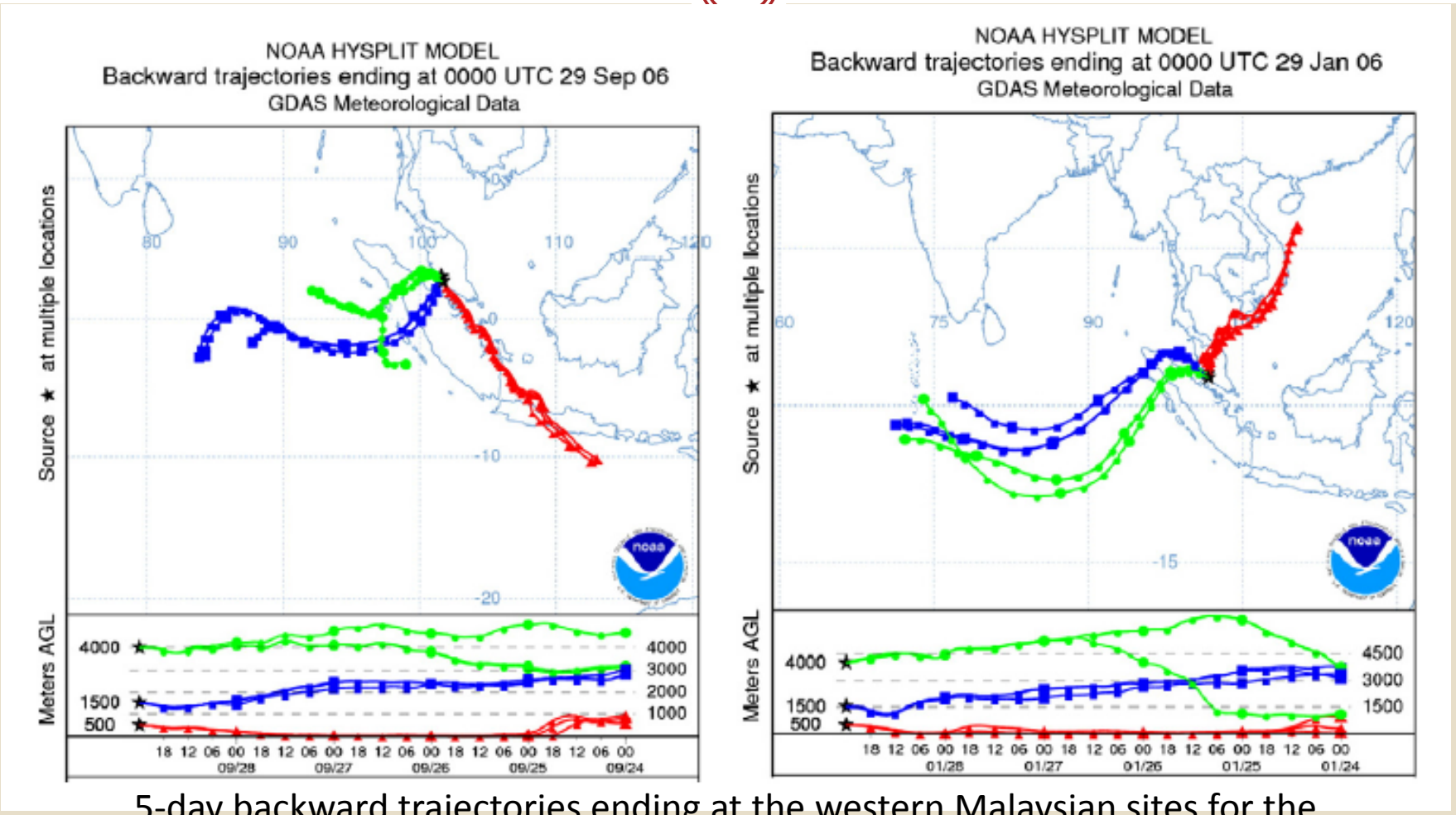


Monthly-mean (±1 standard deviation) variation of the Terra MODIS FMF values averaged over 10 selected sites in Peninsular Malaysia

AEROSOL TYPES

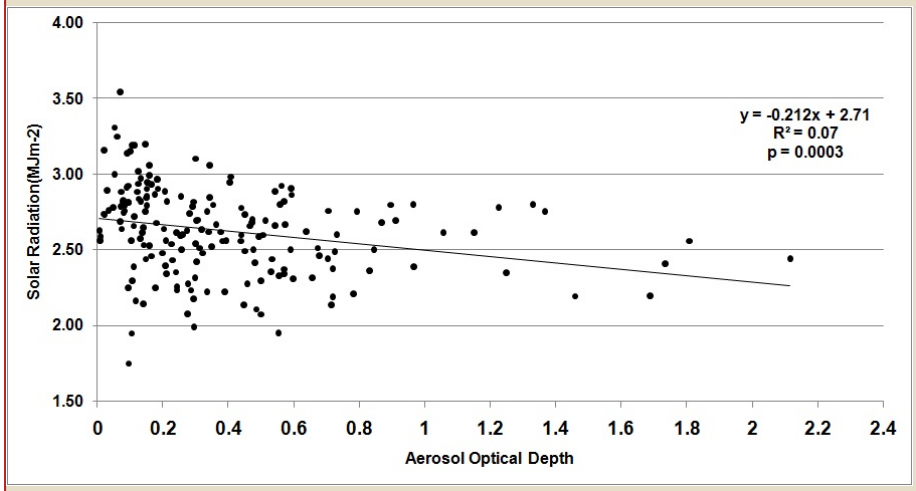


SOURCE REGIONS OF AEROSOLS



5-day backward trajectories ending at the western Malaysian sites for the dry (left) and wet (right) seasons

AOD VERSUS SOLAR RADIATION



- Enhanced aerosol loading attenuates (scatters and absorbs) solar radiation decreasing the amount reaching the Earth surface
- The decrease in global solar radiation (~0.21 or 0.8% for a 0.1 increase in AOD
- Biomass burning and local emissions of fossil-fuel black carbon

PM10 MODELING

Multiple Linear Model

PARAMETER	R^2
MODIS AOD	0.59
Relative Humidity	0.13
Surface Temperature	0.21
Atmospheric Stability	0.21
All	0.73

PM10=245.07 + (19.69*AOD) + (-0.05*RH) + (-1.66*surface temperature) + (-0.55*atmospheric stability)

PM10 MODELING

Artificial Neural Network

Training PM10	Training Data	Validation Data
R^2	0.73	0.83
Sample Size	128	65

PM10= 45.47+3.42*H1 + -14.76 *H2 +-6.34*H3

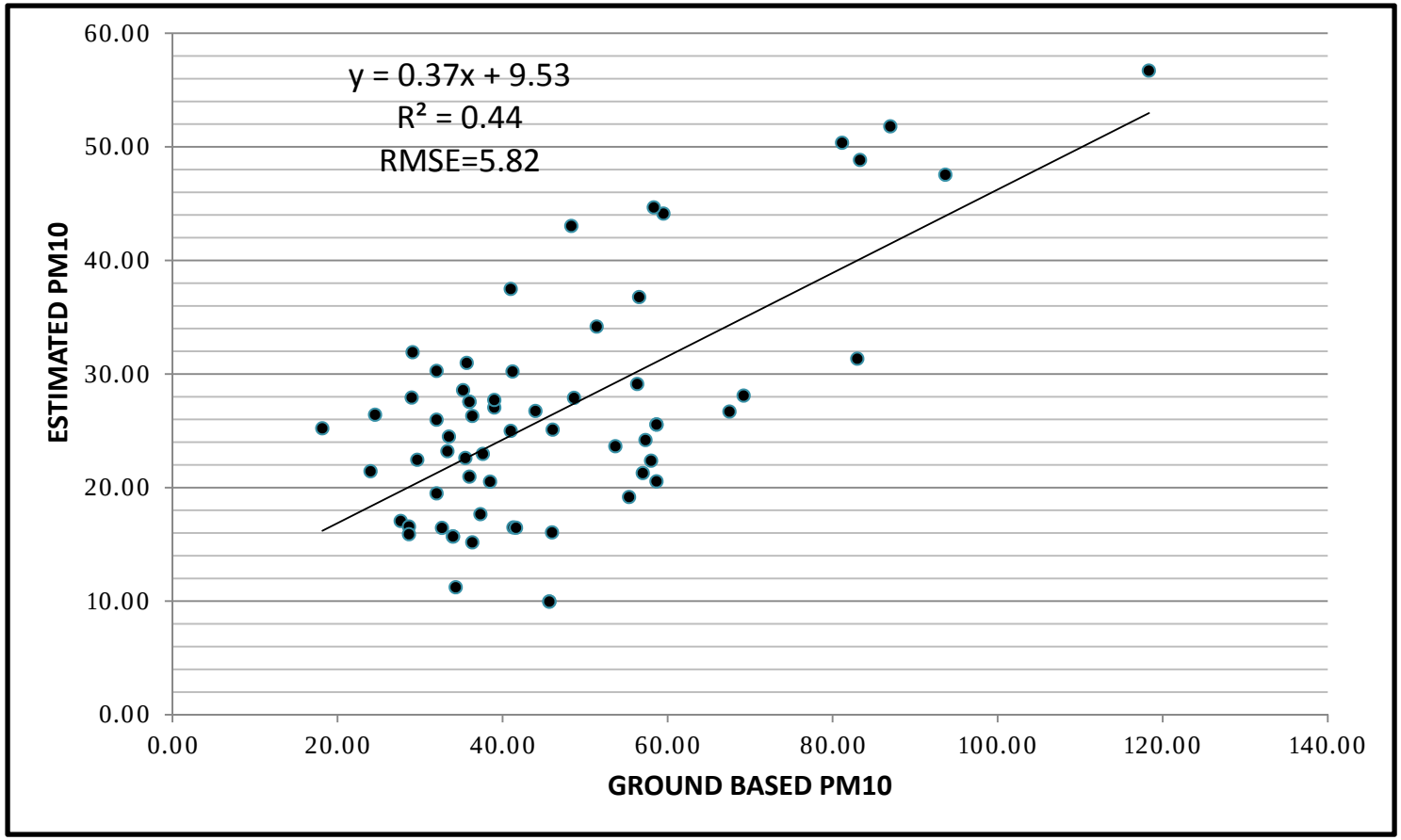
Where:

H1= TANH(0.5*((71.02)+(2.45*AOD)+(0.11*RH)+(1.24*surfacetemperature)+(0.06*Atmospheric stability)))

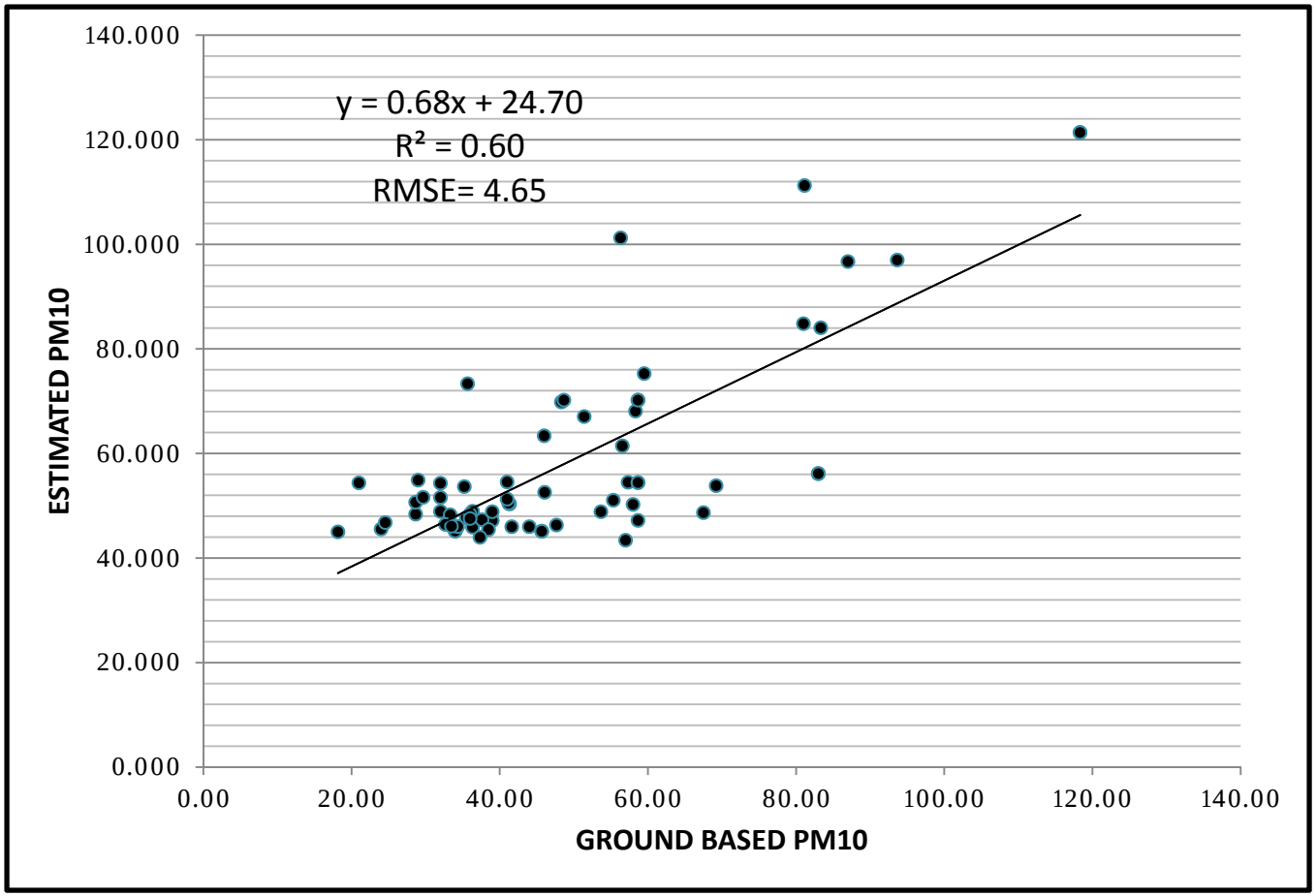
H2=TANH(0.5*((-82.69)+(-0.24*AOD)+(0.07*RH)+(0.36*surface temperature)+(0.22*Atmospheric Stability)))

H3=TANH(0.5*((59.74)+(-6.02*AOD)+(0.05*RH)+(-1.26*surface temperature)+(0.06*Atmospheric Stability)))

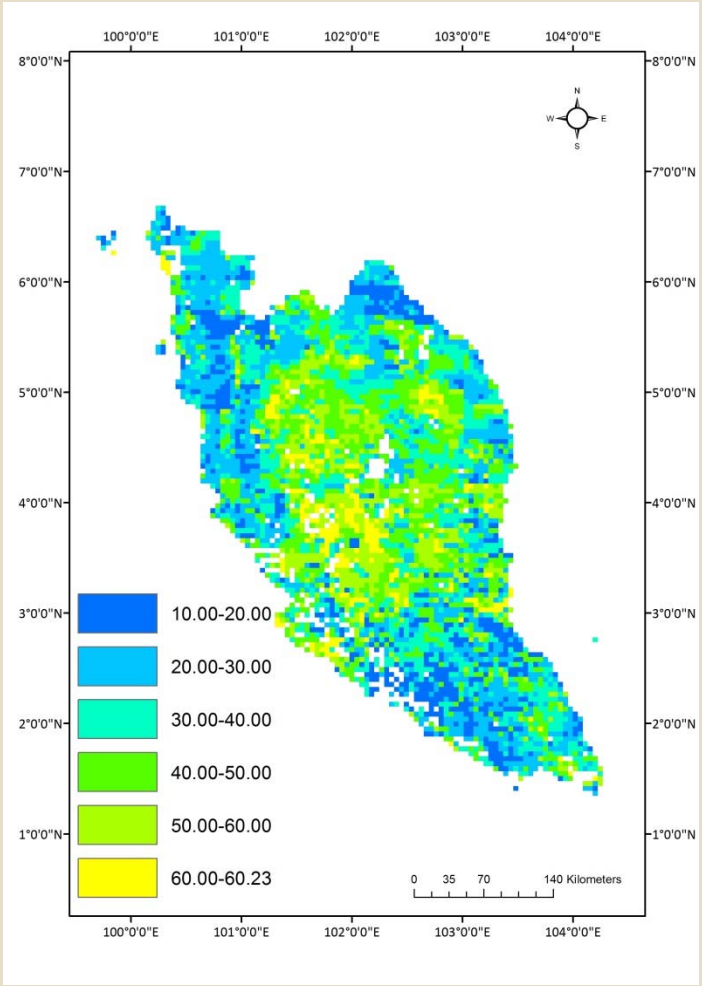
MODEL VALIDATION (MLR)

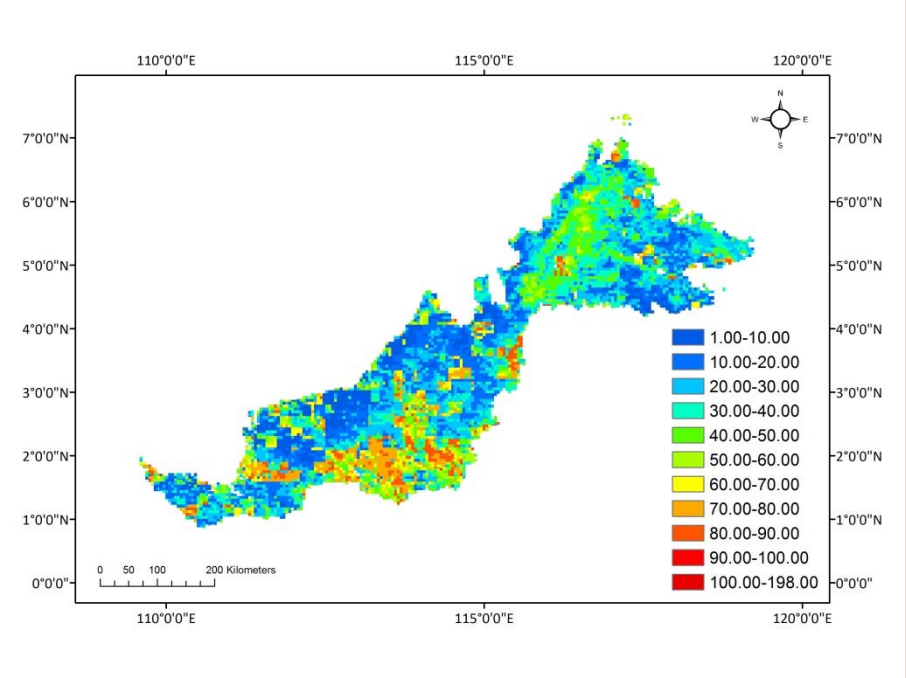


MODEL VALIDATION (ANN)

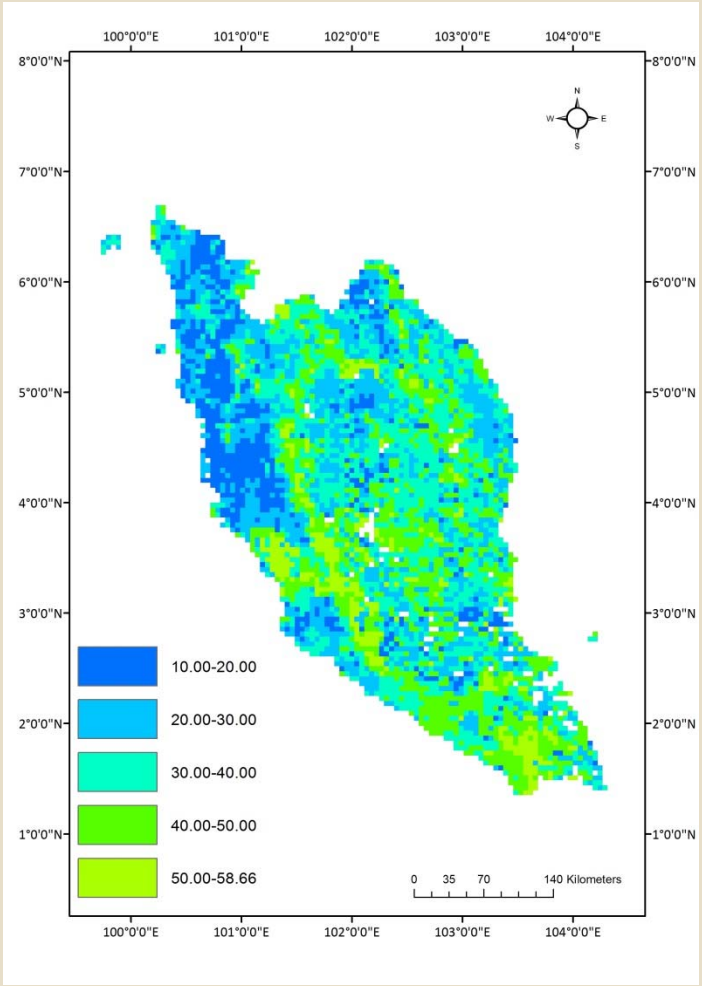


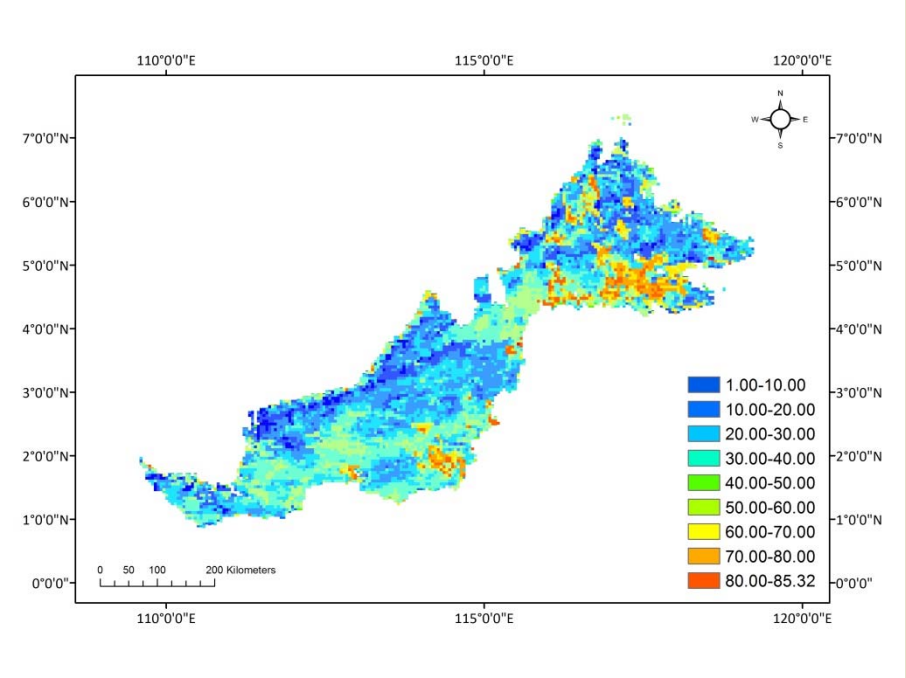
PM 10 (μm m^{-3})DRY SEASON (JUNE-SEP)



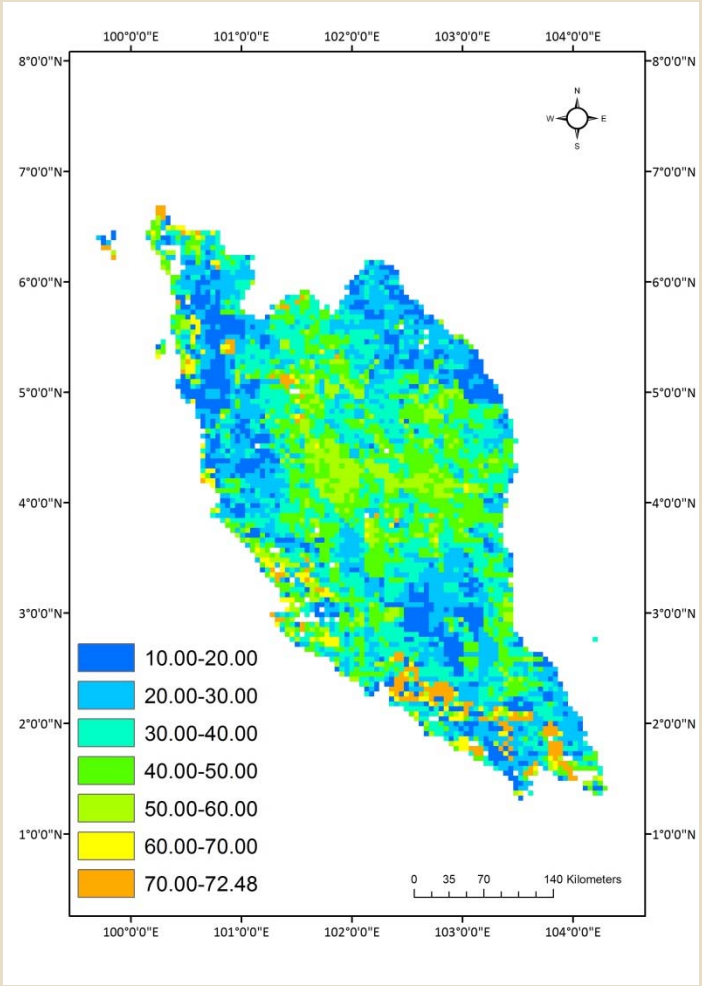


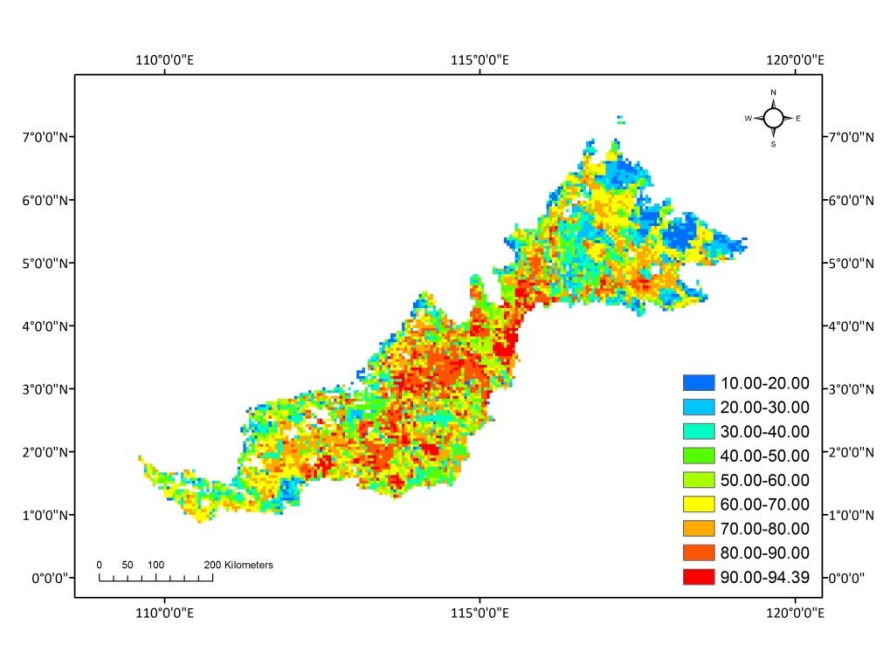
PM 10 (μm m^{-3})WET SEASON (DEC-MAC)



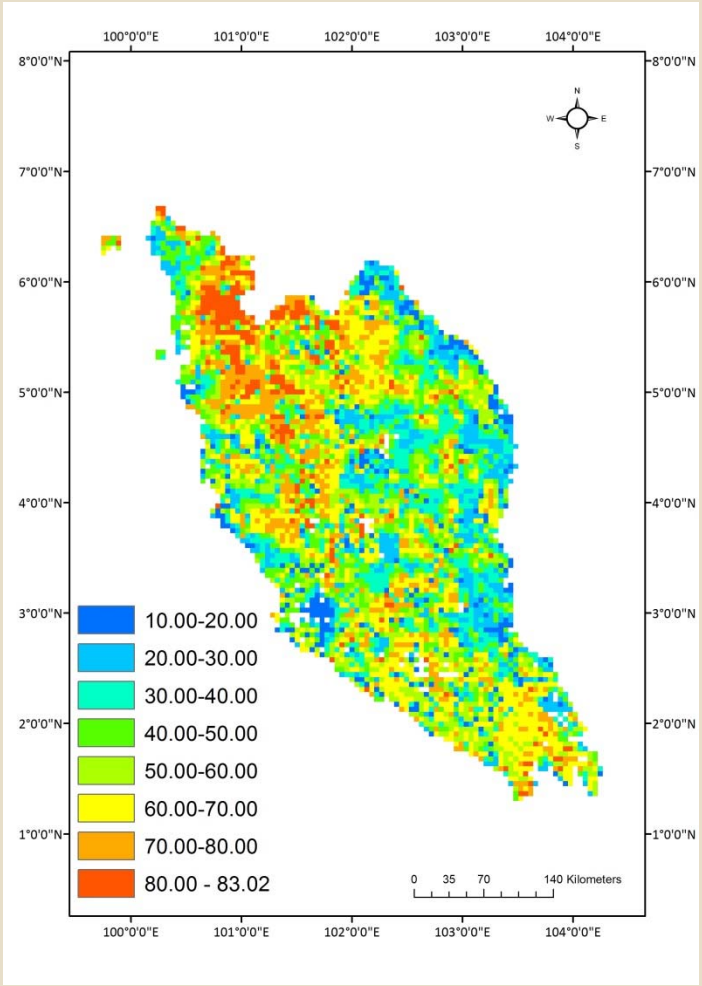


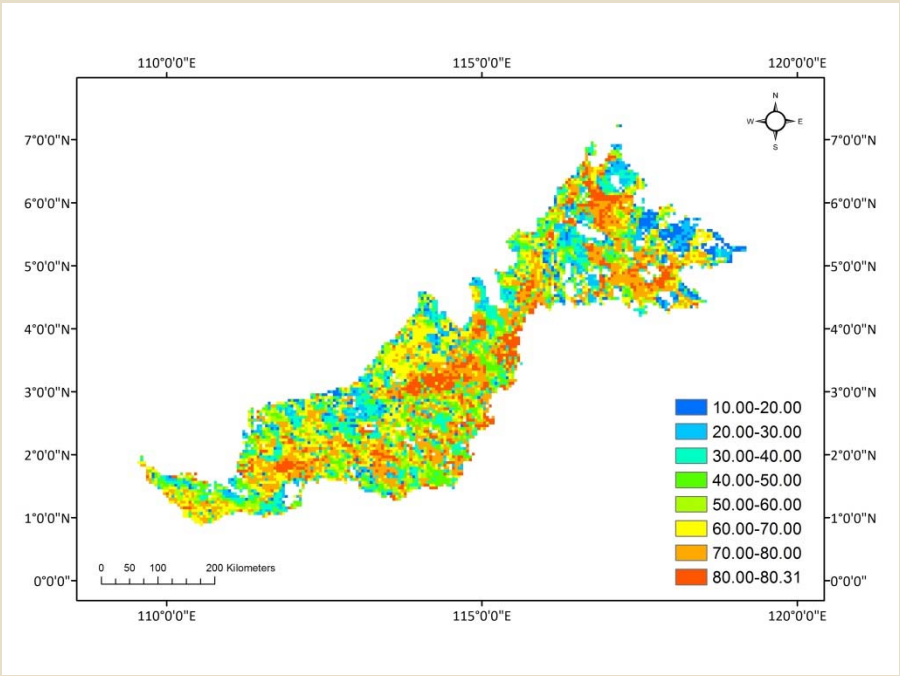
PM 10 (μm m^{-3}) INTER-MONSOON (APR-MAY)





PM 10 (μm m^{-3}) INTER-MONSOON (OCT)





GAPS & CHALLENGES

GAPS

- Aerosol quantification in urban areas at high spatial resolution
- Quantification of aerosol amount from source regions yet to be investigated
- Less understanding on how the atmospheric aerosols interact with the regional climate system at various temporal and spatial scale.

CHALLENGES

- PM10 monitoring stations – DOE (52 stations) and MMD (22 stations)
- AERONET- 3 stations (Kuching, Penang, Tahir)
- Satellite observation having limitations as cloud cover and orbital gaps of satellite track
- Limited data on fine particle concentrations such as $PM_{2.5}$ limits studies on the impact of fine particles to human health and physical environment particularly during haze episodes.