Interactions of Monsoon, Precipitation, Aerosol Composition and Transport - Philippines (IMPACT-PH)

Kevin C. Henson

4th Atmospheric Composition and Asian Monsoon Workshop

Universiti Kebangsaan Malaysia (UKM)

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Jeffrey S. Reid, NRL
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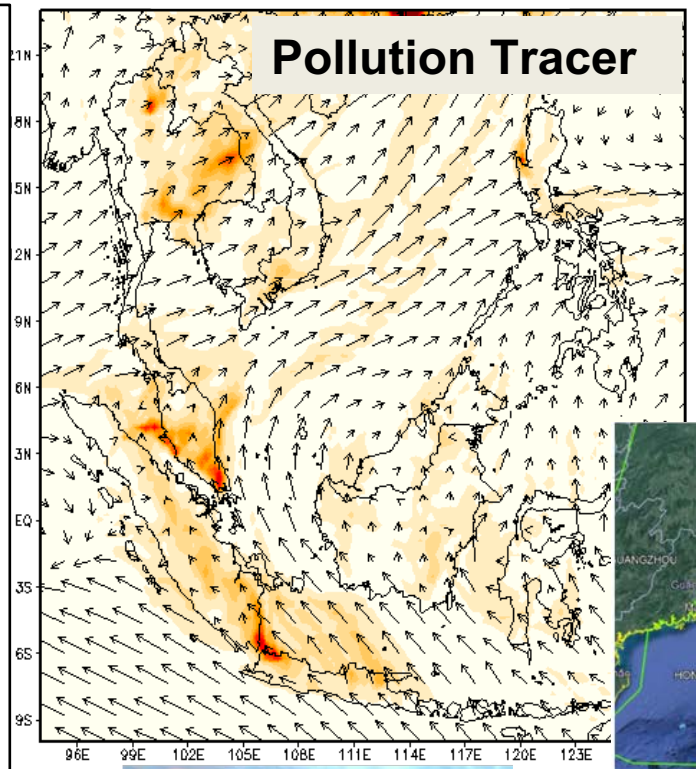
What is CAMP²Ex?

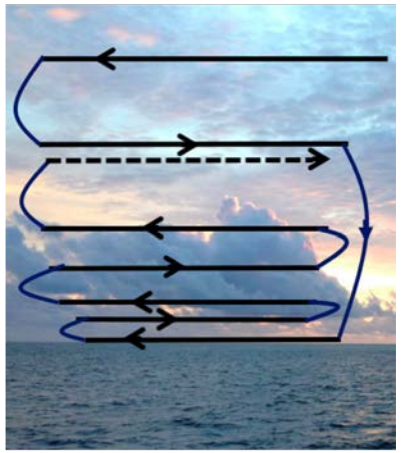
Cloud, Aerosol and Monsoon Processes Philippines Experiment

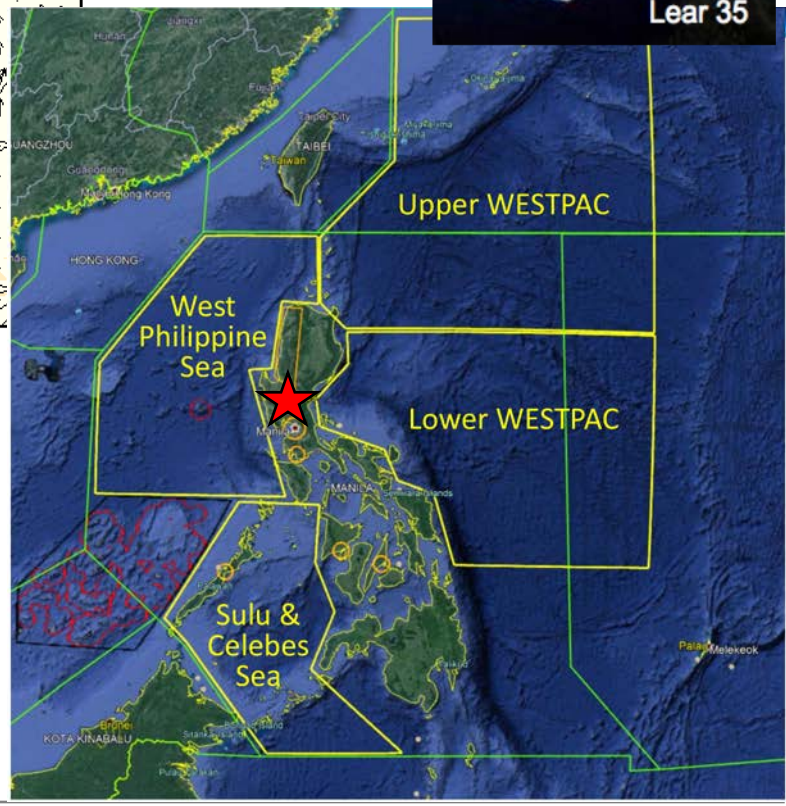
- NASA, Manila Observatory, and NRL
- Airborne campaign out of Clark, Philippines in September 2019
- To measure cloud and pollution environment in the Philippines.

Key Research Areas:

1) Aerosol Particles and Cloud Microphysics
2) Cloud and Aerosol Particle Influence on Radiation
3) Aerosol Particle and Cloud Meteorology



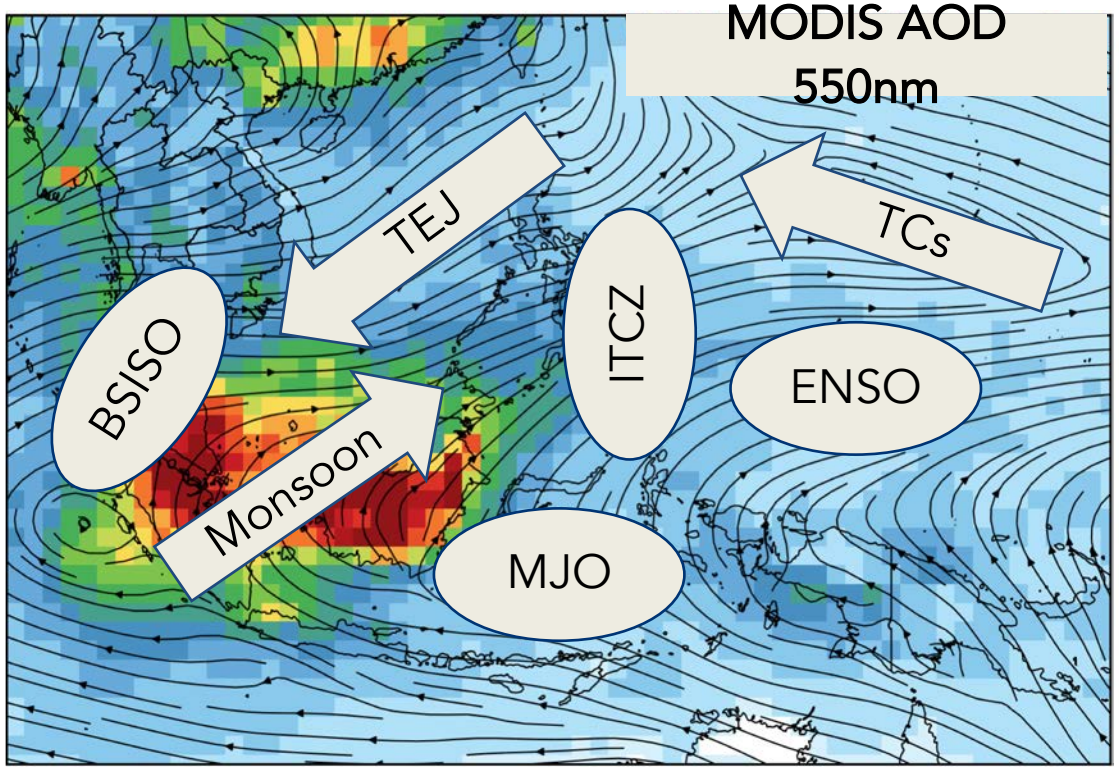


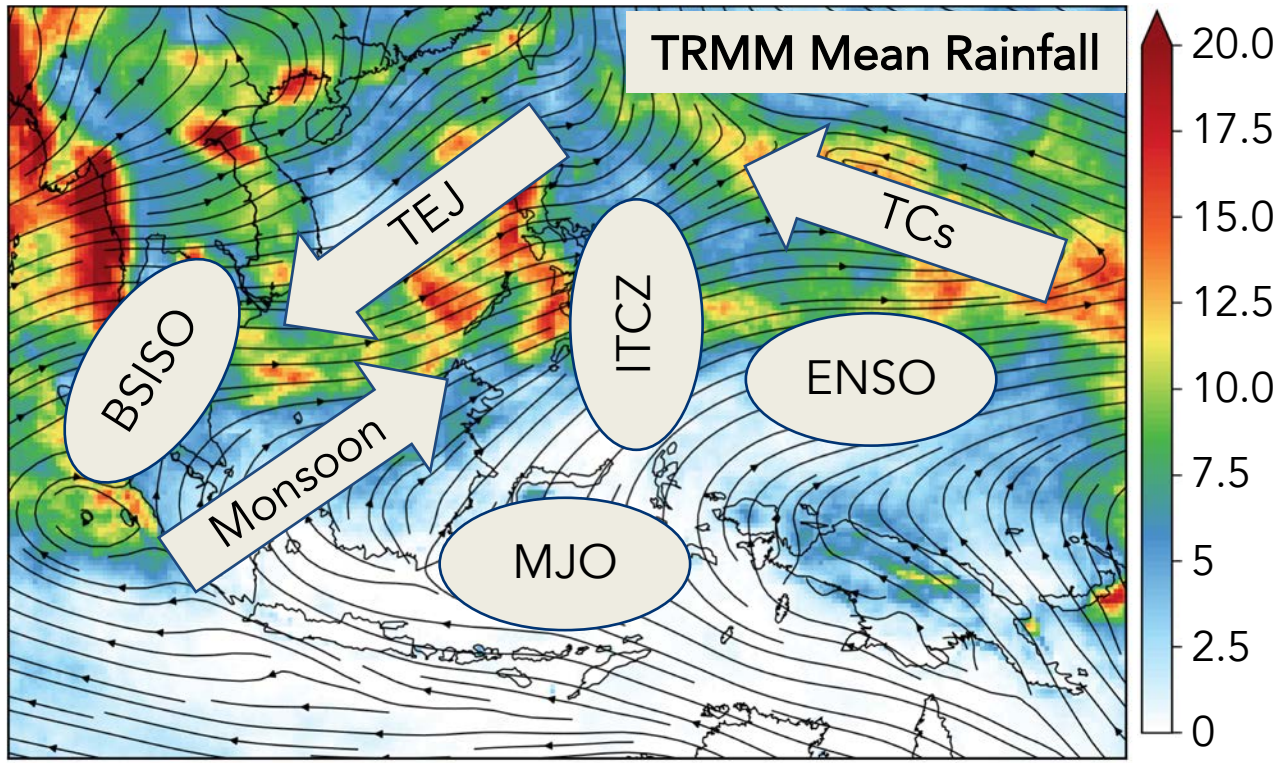


Why CAMP²Ex?

Complexity of Philippine Aerosol-Meteorology Environment

Case Study: July-September 2015





Streamlines: FNL 850mb

- High AOD values observed over Sumatra-Borneo region
- High amounts of rainfall over western PH
- Several phenomena: Monsoons, BSISO, MJO, ENSO, ITCZ, TCs, upper level 'counter-flow'

Extensive Measuring and Modeling

- Philippine counterpart project to CAMP2Ex
- First-time extensive ground-based and airborne atmospheric measurements in the country
- Multiple ground-based aerosol instruments from US Naval Research Laboratory, University of Wisconsin, and University of Arizona
- Several model experiments and model-measurement inter-comparisons
- Significant leap in understanding how aerosols are affecting air quality and meteorology in the Philippines


Disdrometer


SSFR

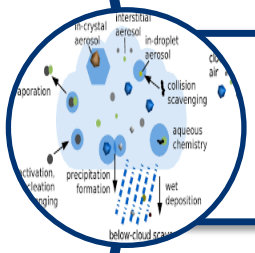

MOUDI


AERONET

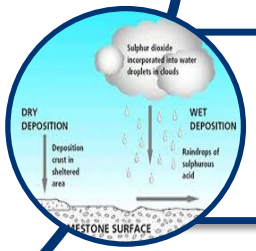
Main Objective: to characterize and study the Philippine atmospheric and aerosol environments and their interactions

Specific Objectives:

To characterize and study aerosol transport patterns in the country, both from transboundary and local pollution



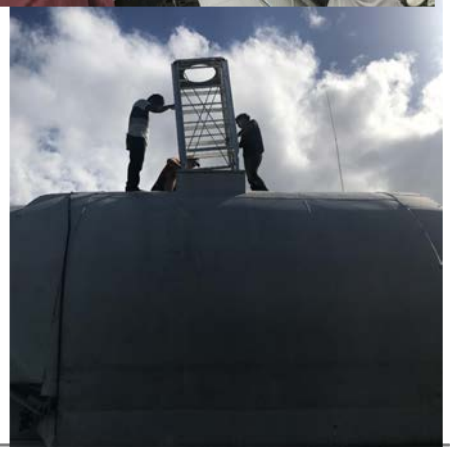
To investigate the potential influence of urban pollution on clouds, temperature, and precipitation



To investigate the potential influence of meteorology on the spatial distribution of aerosols

Methodology

Pre-CAMP2Ex
Installation, Initial Testing, Configuration, and Calibration of Ground-Based Instruments and Dynamic Atmospheric Model



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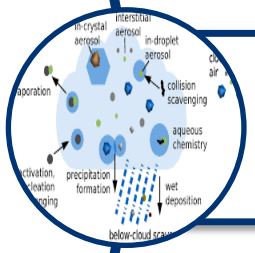

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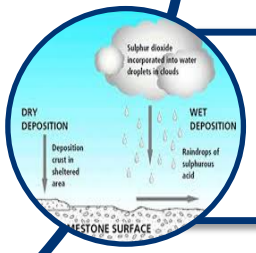
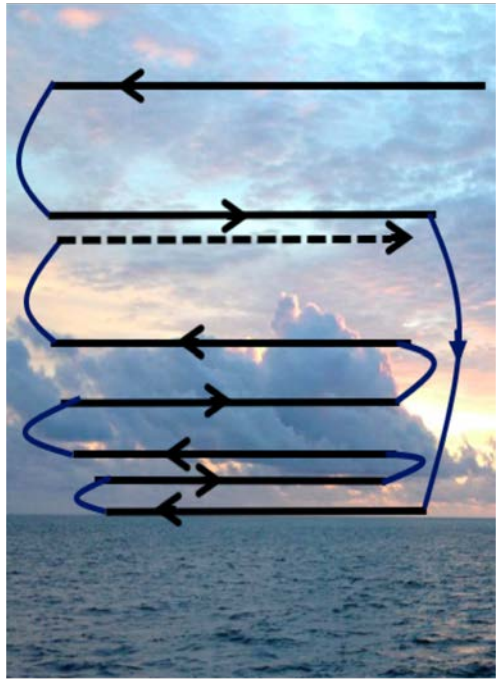


To investigate the potential influence of meteorology on the spatial distribution of aerosols

Methodology

During CAMP2Ex

Data Gathering through Airborne Sampling, Satellite Observations, and Model Runs for Weather and Aerosol Transport Forecasting



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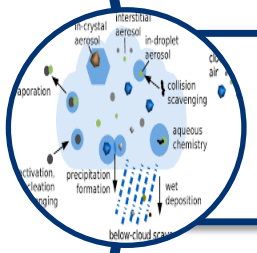

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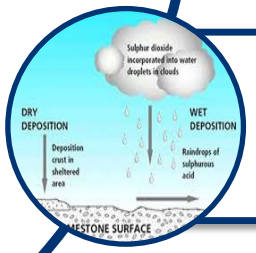

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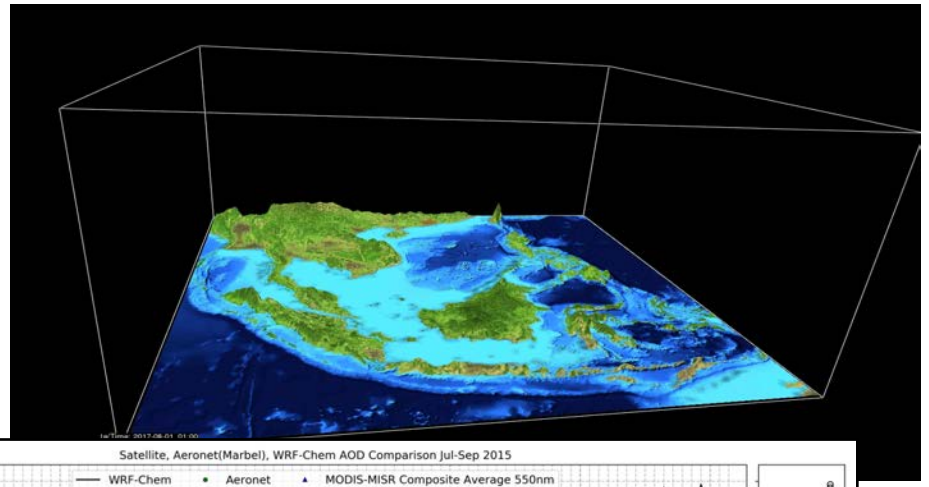
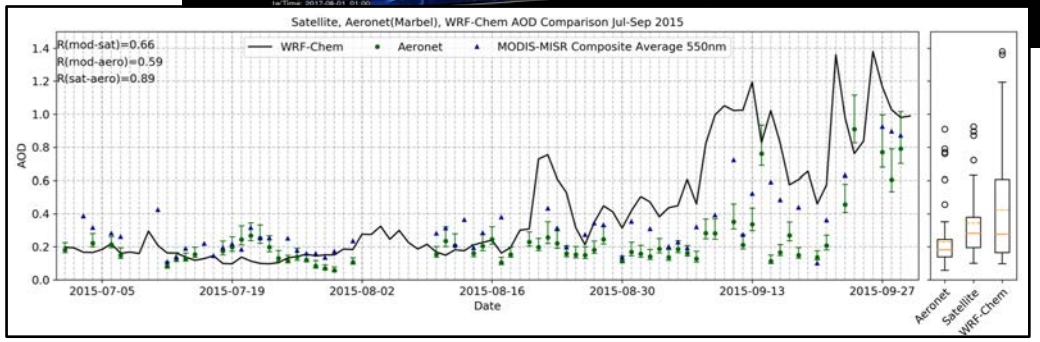
Methodology

Post-CAMP2Ex

Analysis of Data, Continuation of Ground - Based Measurement, and Further Model Simulations for CAMP2Ex Campaign Period

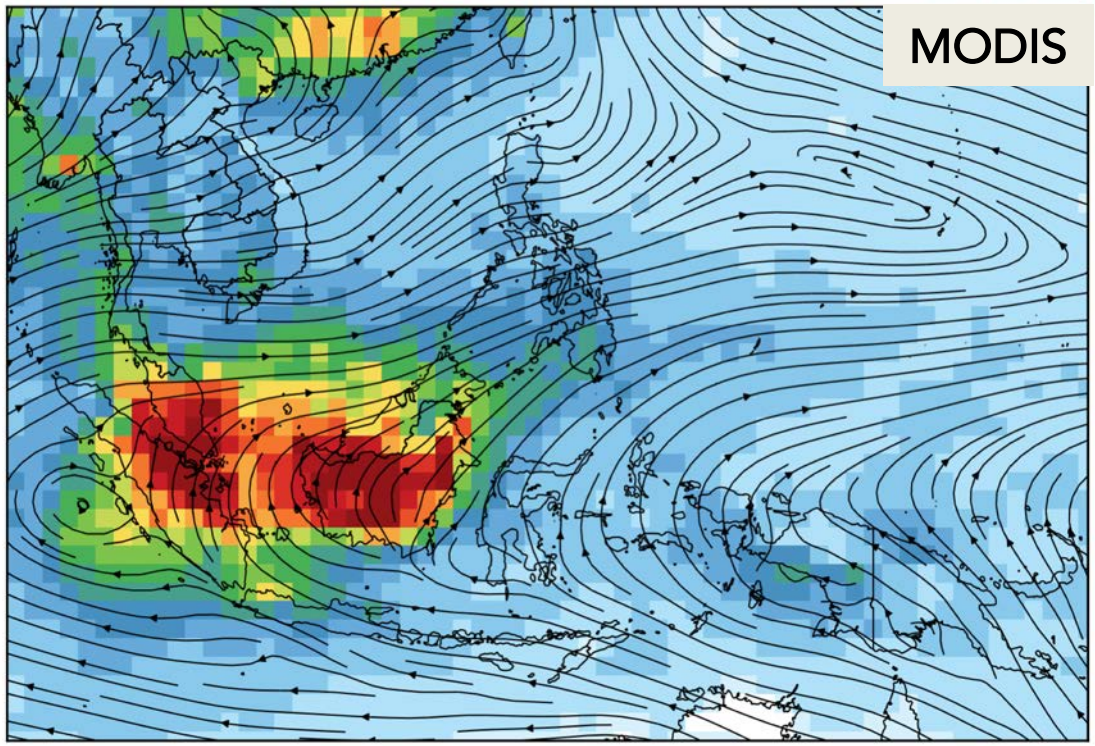




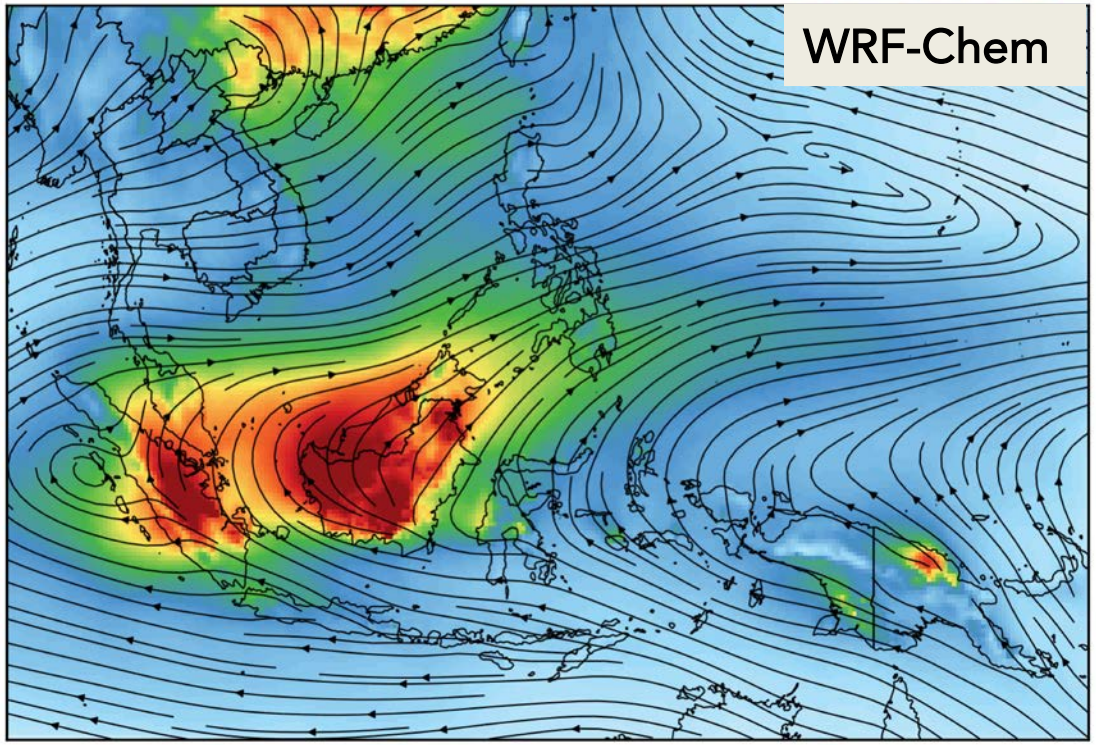
Aerosol Transport

Model vs Satellite Observation

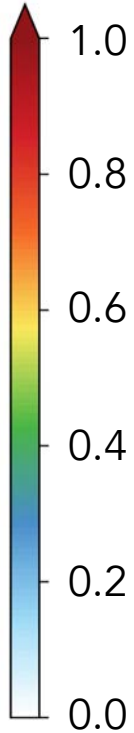
AOD 550nm July-September 2015



Streamlines: FNL 850mb



Streamlines: Model 850mb

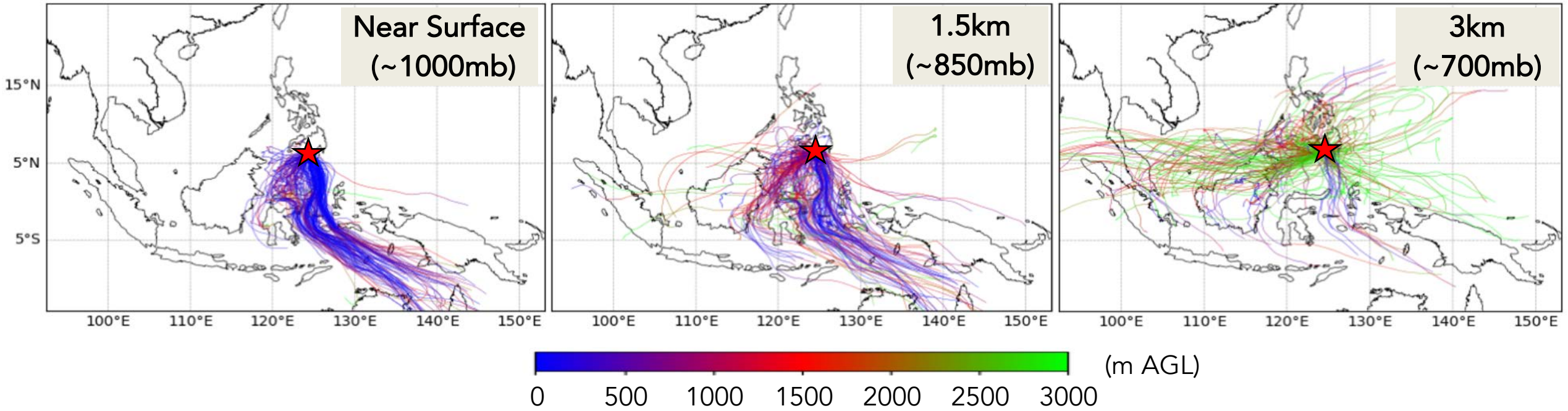


- Generally consistent spatial pattern of AOD values, with local maxima in Sumatra and Borneo
- Biases may be due to inaccurate wet deposition and domain boundary pollution inflow

Emissions from EDGAR-HTAP and FINN

Pollution Transport Pathways

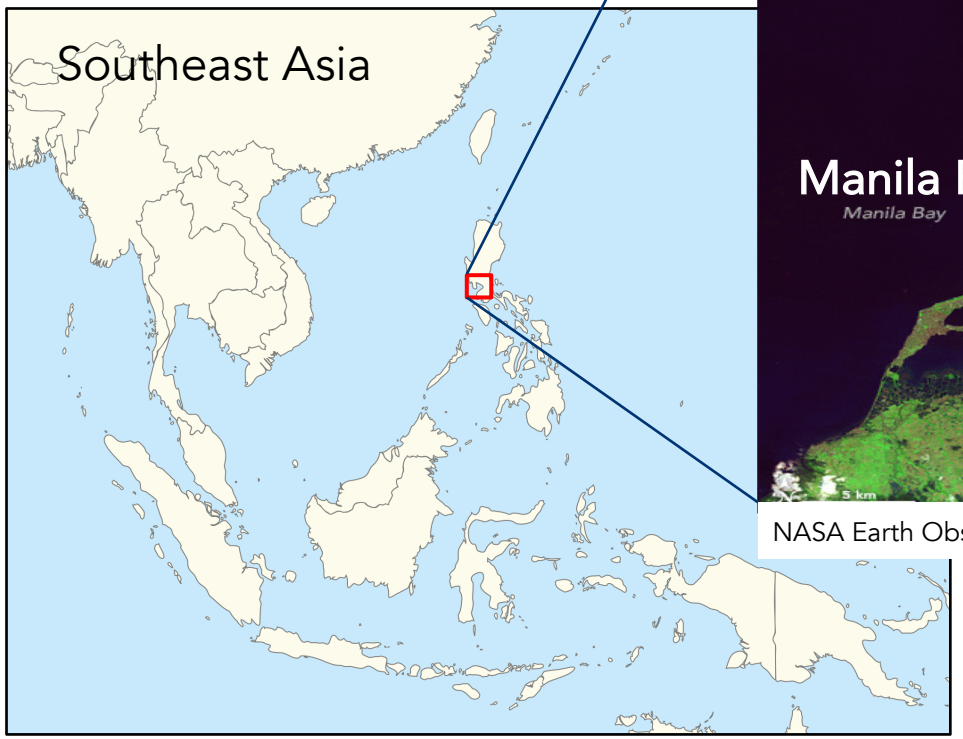
HYSPLIT Jul-Sep 2015 5-day Back Trajectories
at Marbel University, Mindanao

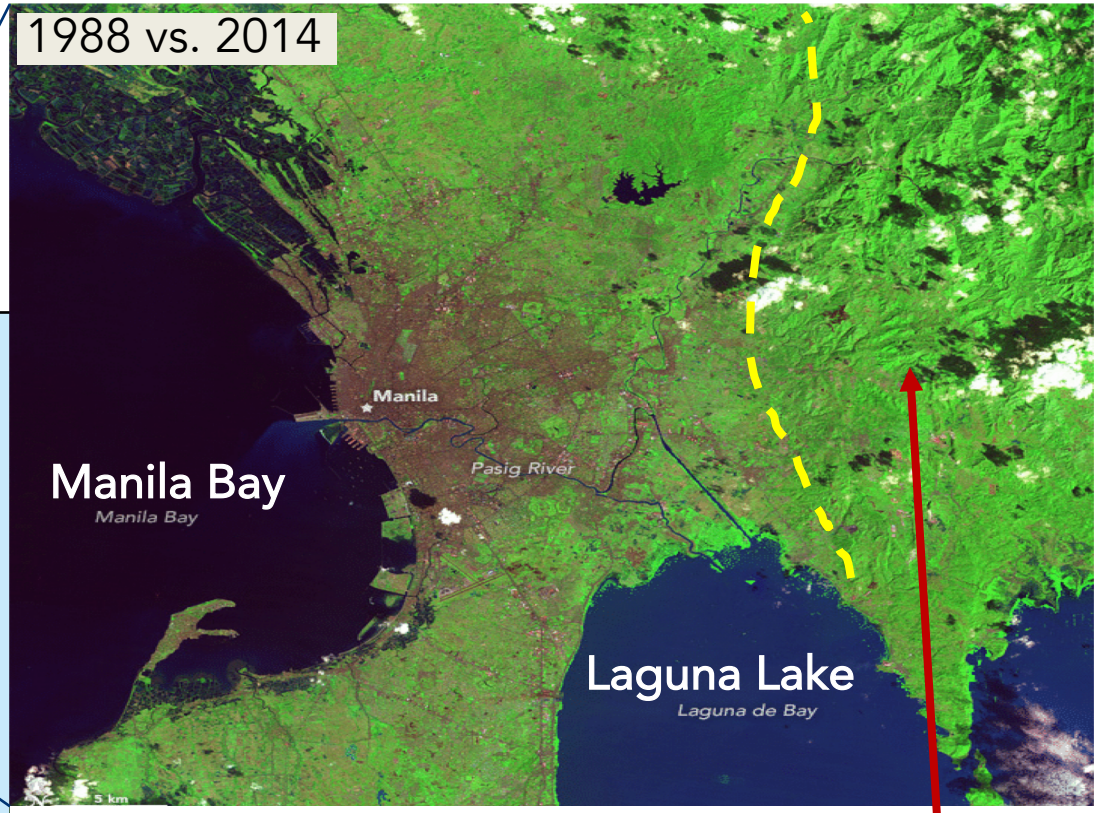


- 3 levels approximate Surface, Boundary Layer Top, and Free Troposphere
- Frequent southerly flow towards the surface, becoming westerly towards upper levels
- More scattered trajectories in the upper levels, with 3km level also showing frequent flow from east.

Urban Area Case Study: Metro Manila

- For local emissions, lots of interest in the Manila Plume.
- Where does the Manila Plume go?

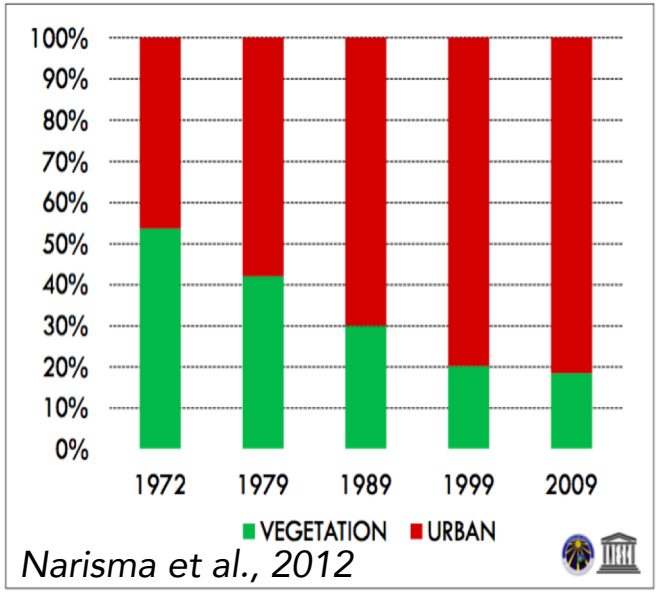




NASA Earth Observatory, Landsat 5, Landsat 8 data

Mountain Range Boundary

Sierra Madre Mountain Range

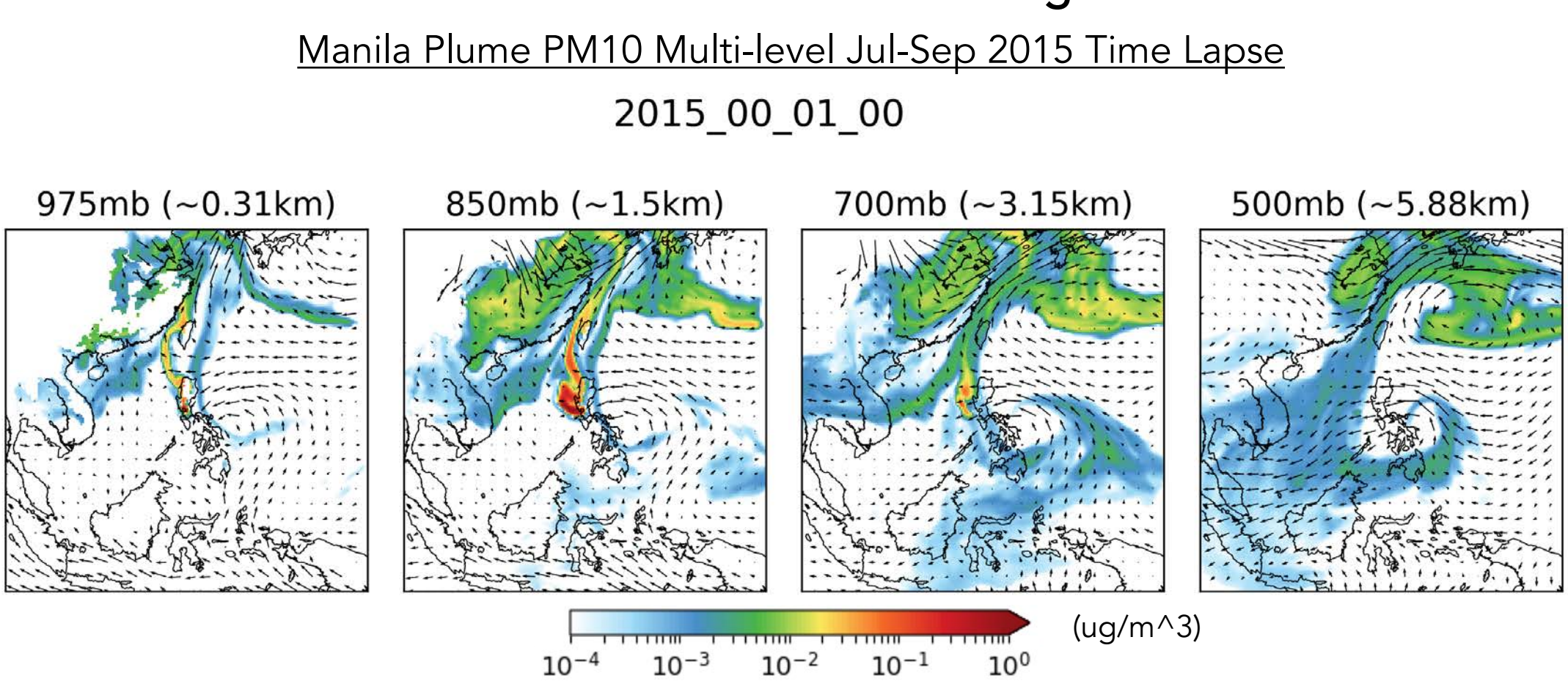


Narisma et al., 2012

- Extensive urban expansion over the years
- Possibly altering surface parameters and land-atmosphere interactions

Where does the Manila Plume go?

Manila Plume PM10 Multi-level Jul-Sep 2015 Time Lapse

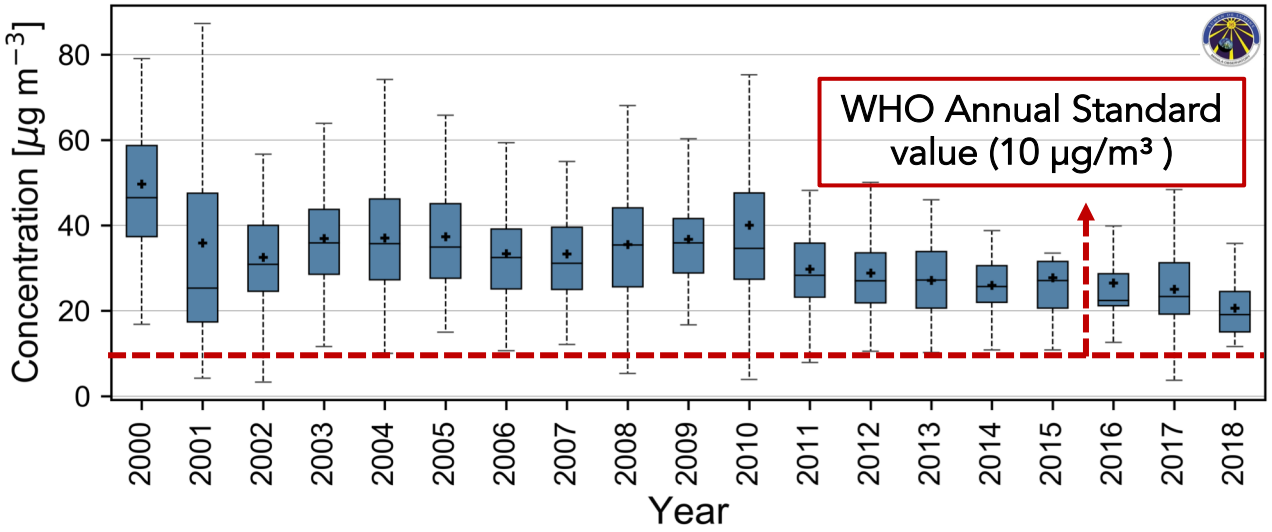


- Emissions outside Metro Manila set to zero (Streets, et al. 2007)
- Frequent north-northeast orientation of pollution
- Importance of TCs and Anticyclones in pollution transport

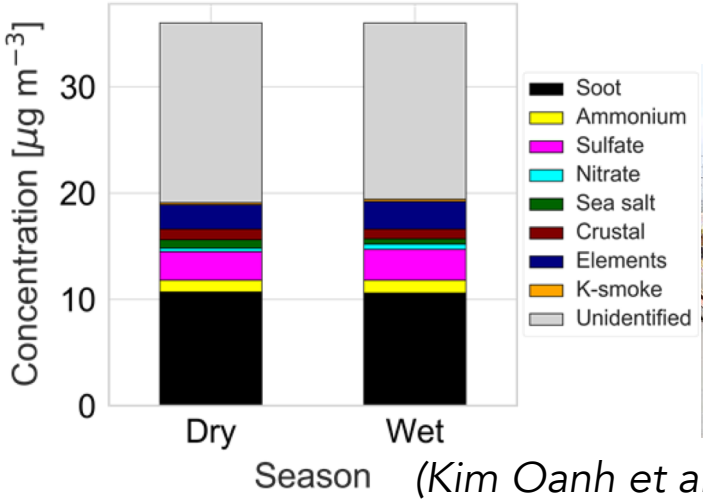
Urban Aerosol-Meteorology Interactions

Metro Manila Aerosol Environment

2000 – 2018 $PM_{2.5}$ Levels at the Manila Observatory mixed urban background site



Reconstructed $PM_{2.5}$ Mass - Manila Observatory



(Kim Oanh et al., 2014)

- Levels of fine particulate matter consistently exceeding WHO's annual standard value of 10 μg/m3.
- Large fraction of aerosol content in Metro Manila from Black Carbon

Science Questions:

What is the influence of urban air pollution on clouds and precipitation?

What is the aerosol life cycle for the Metro Manila plume?

Hypothesis:

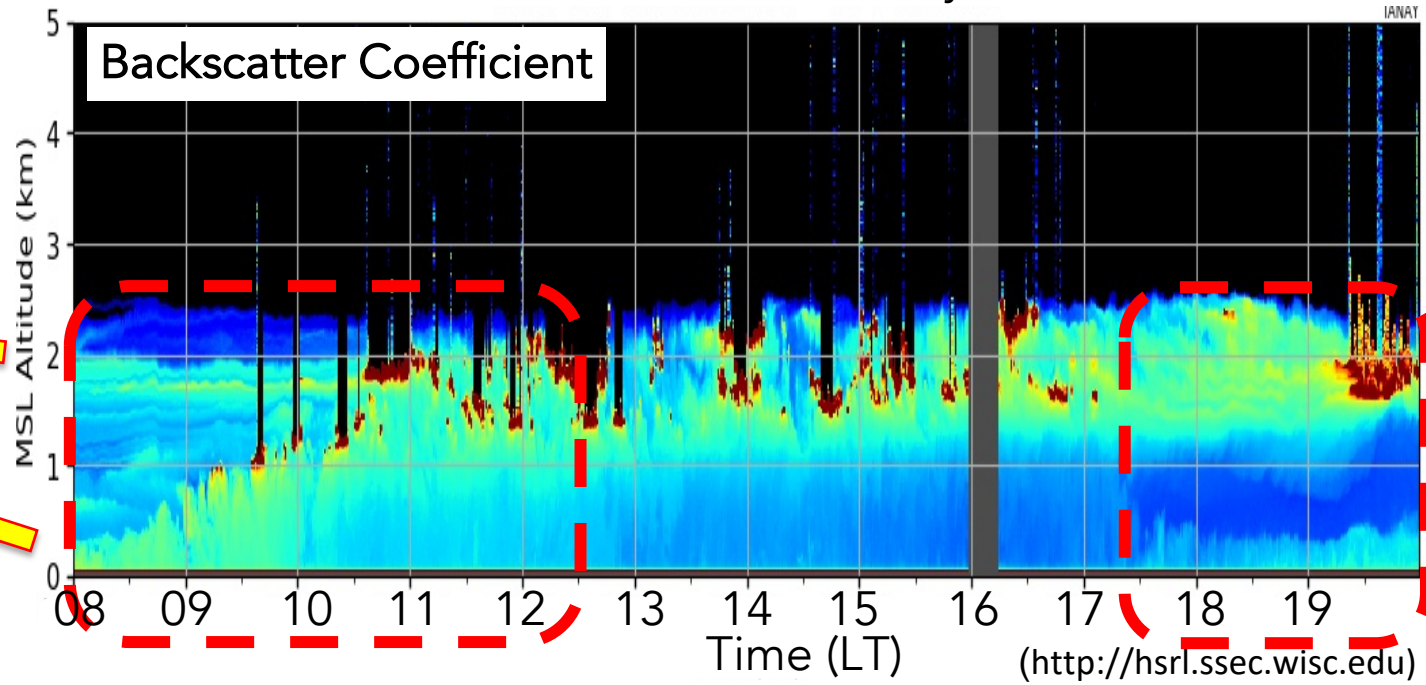
Enhanced rainfall over Metro Manila during the Summer Monsoon is due to the combined effects of urban land use and fine particulate pollution on local convection.

Urban Aerosol-Meteorology Interactions

Metro Manila Aerosol Environment

Morning in Manila: February 25th, 2019

High Spectral Resolution Lidar (HSRL)
at Manila Observatory



- Observed double aerosol layer
- Observed evolution of PBL:

  Development of Mixed Layer --> Residual Layer

Slide courtesy of Jeffrey Reid

Maraming Salamat!

For any inquiries, please contact Kevin Henson at
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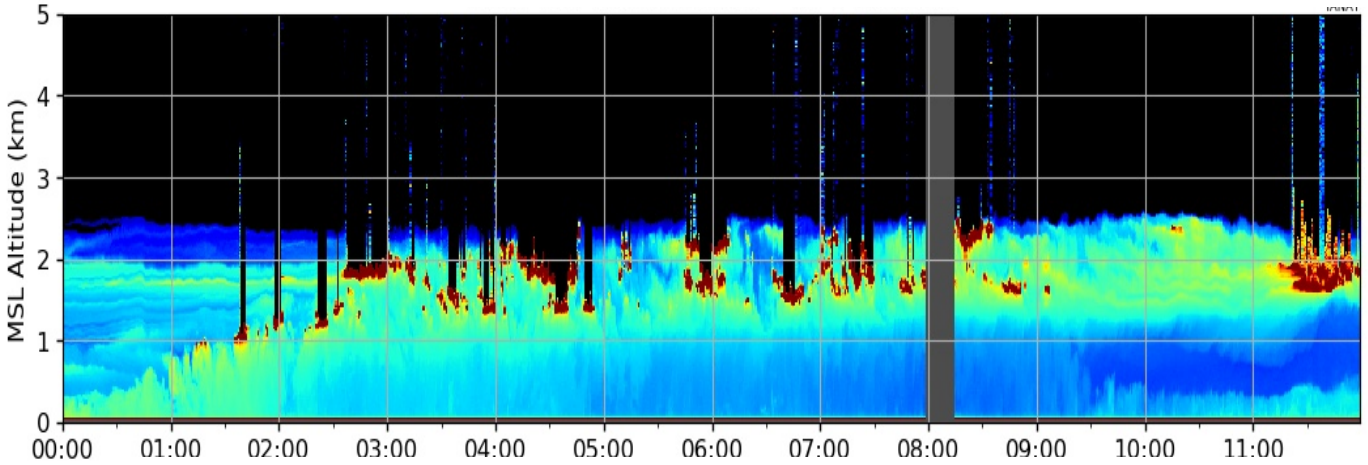
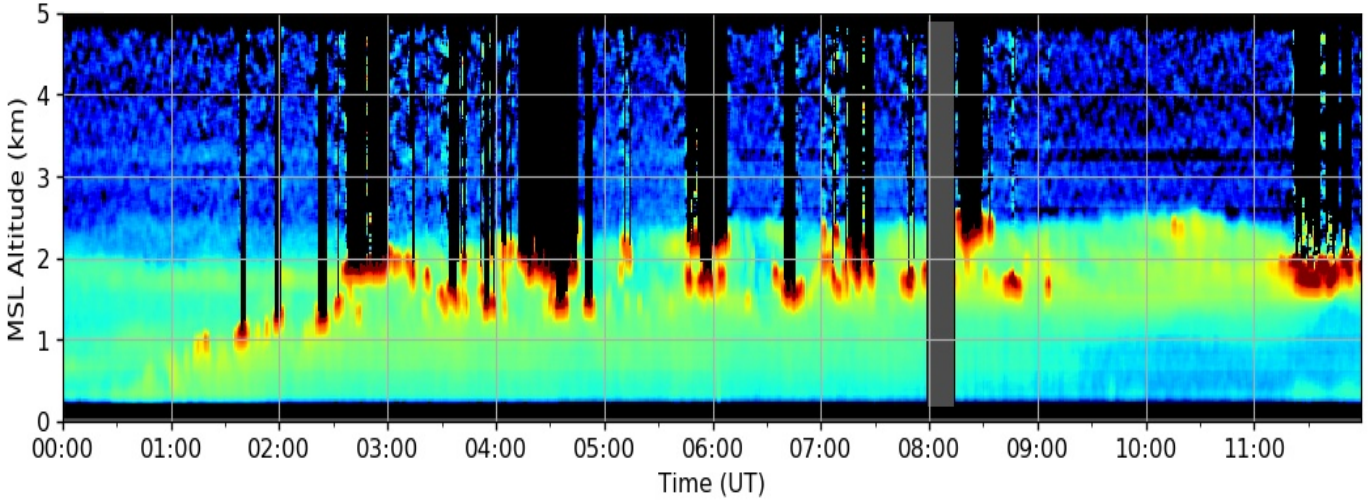
Urban Aerosol-Meteorology Interactions

High Spectral Resolution Lidar (HSRL) at Manila Observatory
Morning in Manila: February 25th, 2019

Backscatter Coefficient



Extinction

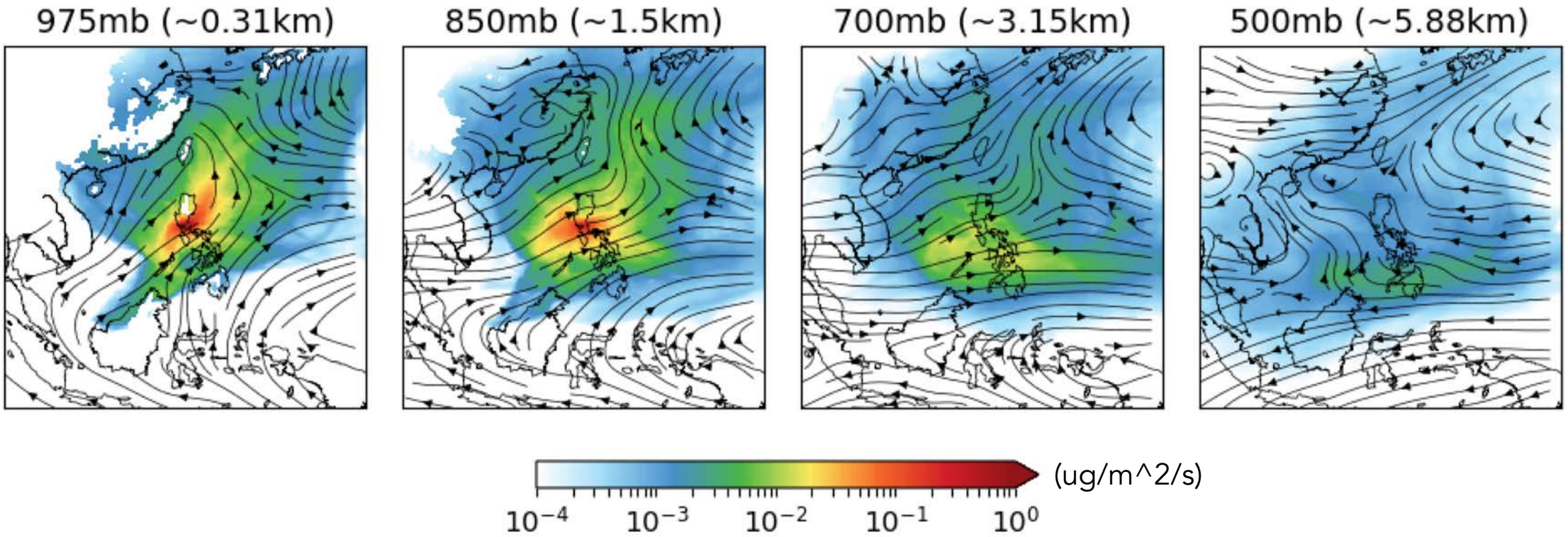


- Observed evolution of PBL: Development of Mixed Layer --> Residual Layer
- In some cases, observed double aerosol layer

Slide courtesy of Jeffrey Reid

Aerosol Transport

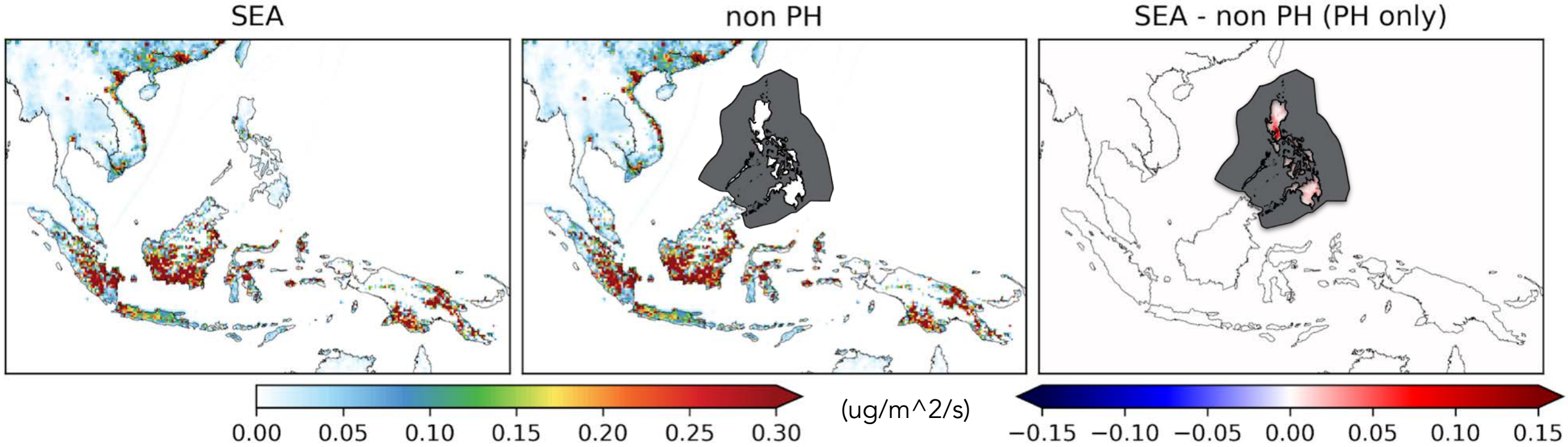
Manila Plume Multi-level Mean PM10 Jul-Sep 2015



- Surface to upper levels, decreasing concentration gradient
- SW to NE orientation of concentrations from Surface to ~ 500m
- Pollutants more dispersed from ~1km upwards
- In upper levels (>~2.7km), higher concentrations in southern regions
- Average concentrations do not strictly follow average wind flow patterns

Aerosol Transport

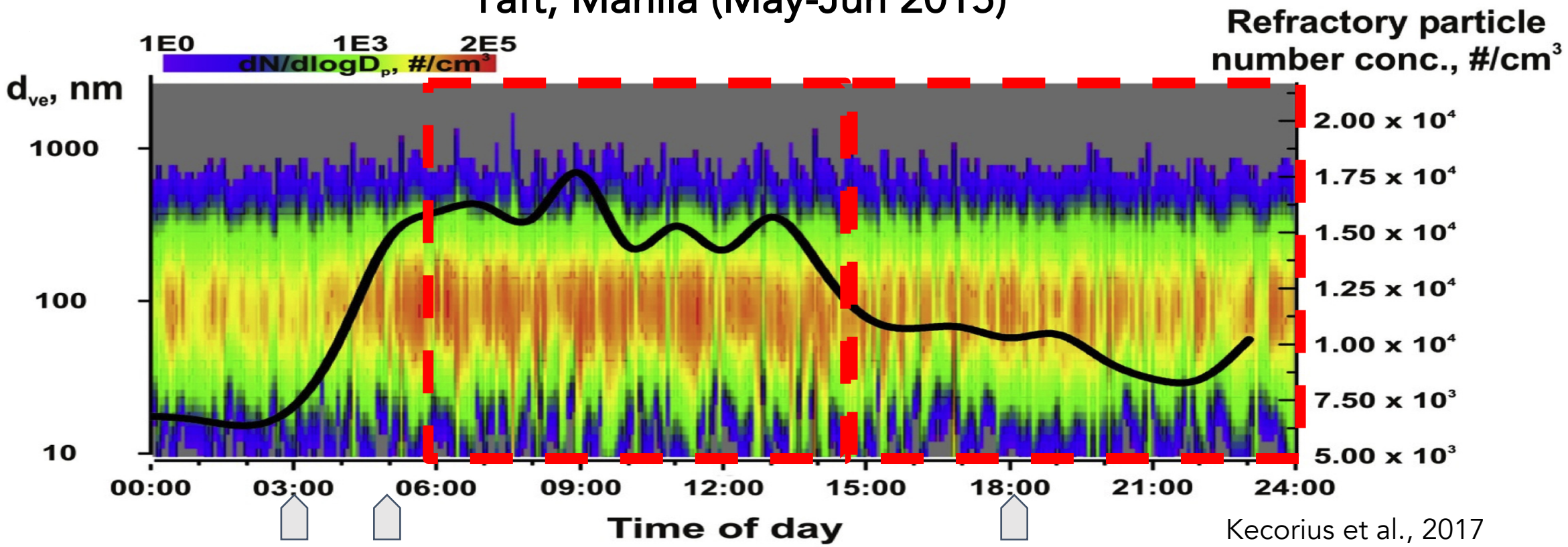
PM10 Mean Emissions for July-September 2015 from Anthropogenic (EDGAR-HTAP) and Biomass Burning Sources (FINN)



- Transport pathways, horizontal & vertical distribution of aerosols in PH, and relative contribution of long-range transboundary vs local Pollution
- 3 Simulations, following Zero-out method (Streets et al. 2007) :
  - Whole SEA
  - Non-PH
  - PH only
- Exclusive Economic Zone as boundary for local vs external emissions

Urban Aerosol-Meteorology Interactions

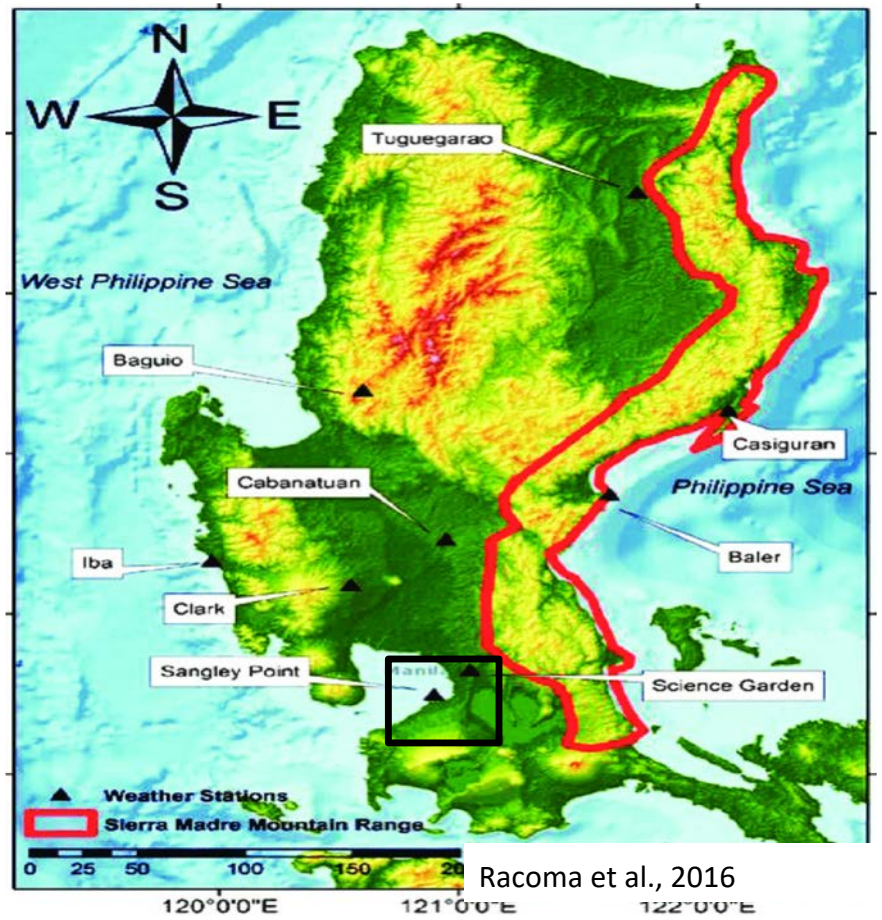
Roadside Diurnal Number Size Distribution of Refractory Particle
Taft, Manila (May-Jun 2015)



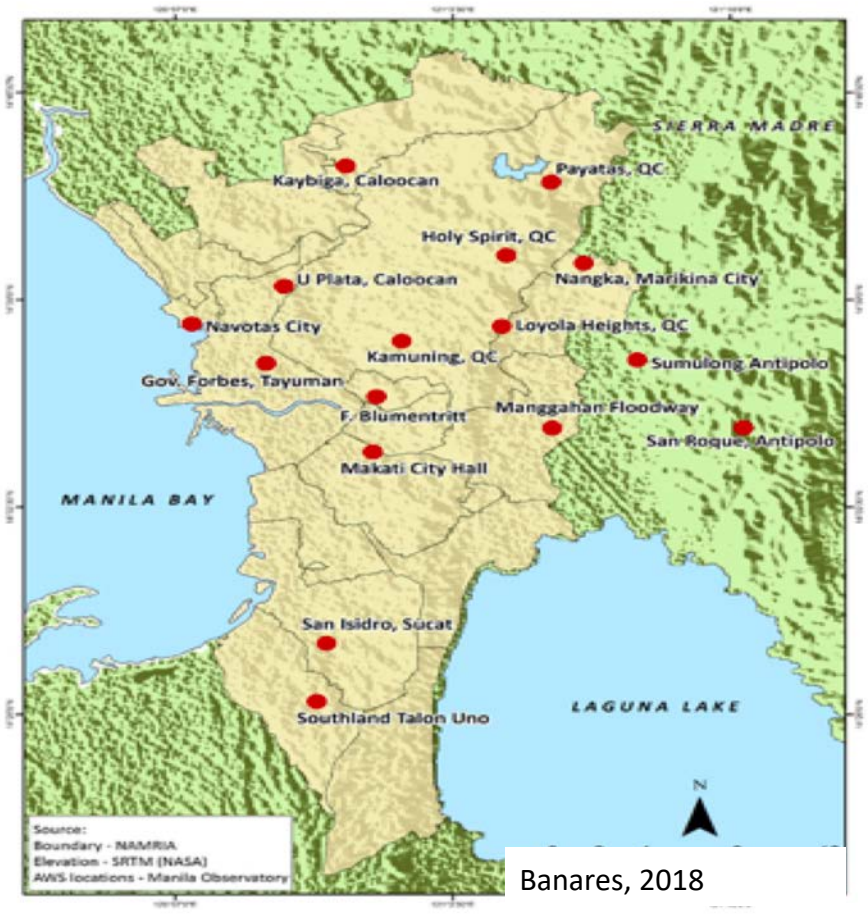
Kecorius et al., 2017

intense traffic from 6 AM - 6 PM but when prevailing winds were from SW, W and NW sectors, (opposite to the roadside), there is lower number concentration

Metro Manila Characteristics



Racoma et al., 2016



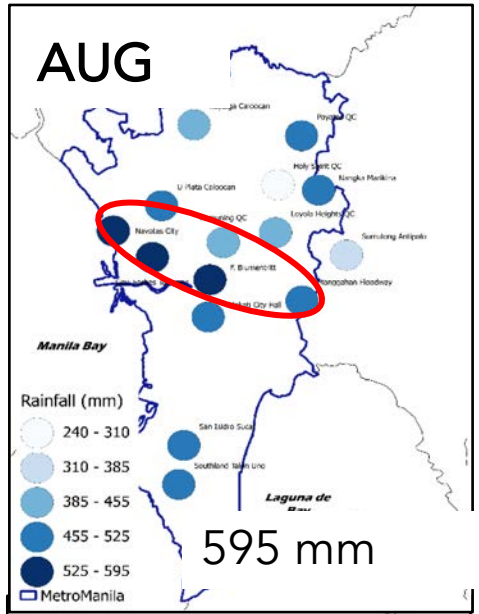
Banares, 2018

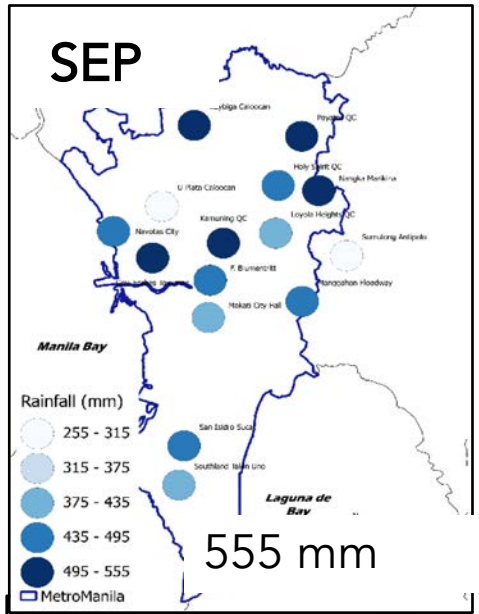
located in western part of Luzon, surrounded by Manila Bay (W), Sierra Madre mountains (NE), Laguna Lake (SE)

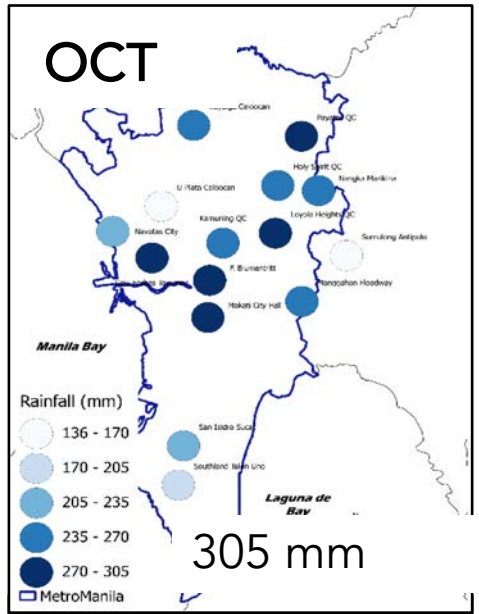
Rainfall over Metro Manila from Aug - Oct, 2013-2014

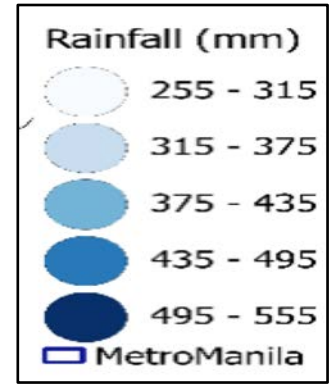
Annual Rainfall

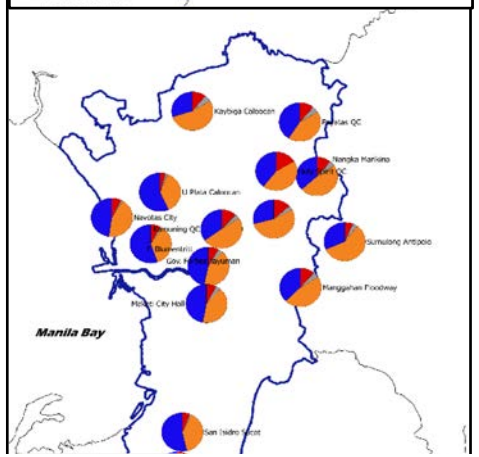
Proportion of Rainfall

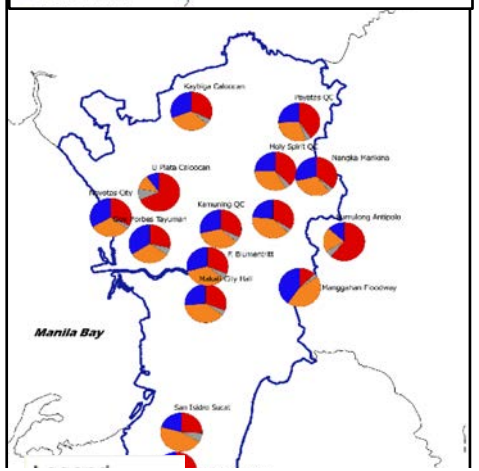


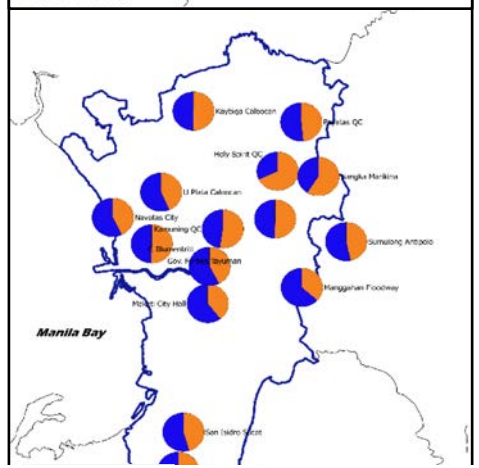


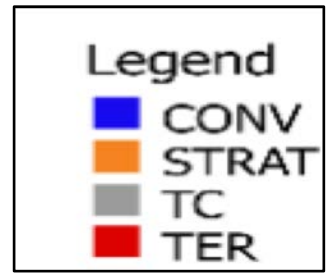










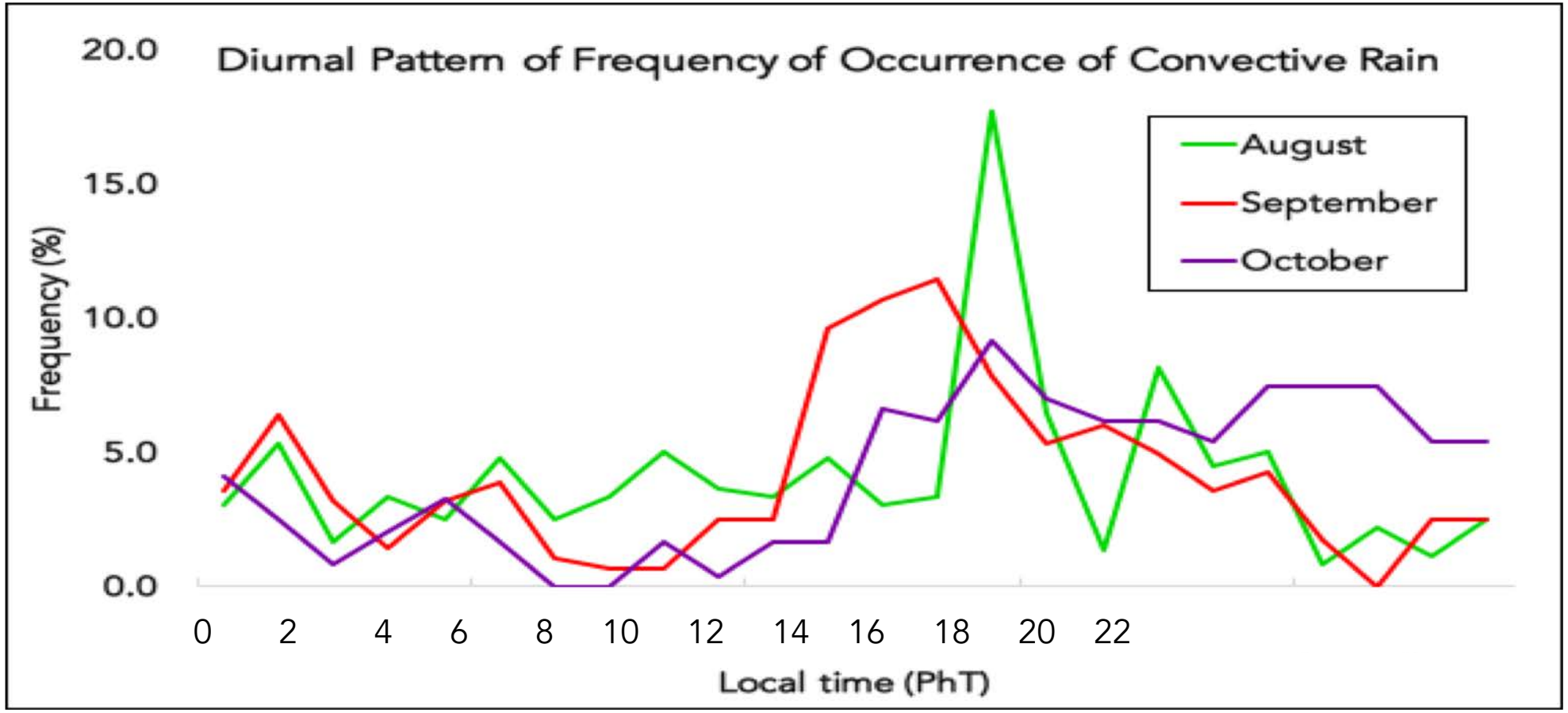


Stratiform rain dominates for most stations

Most of rainfall are attributed to TC

equal proportion convective and stratiform (~50% of total rain)

Rainfall over Metro Manila from Aug - Oct, 2013-2014



Convective rain persisted throughout the day

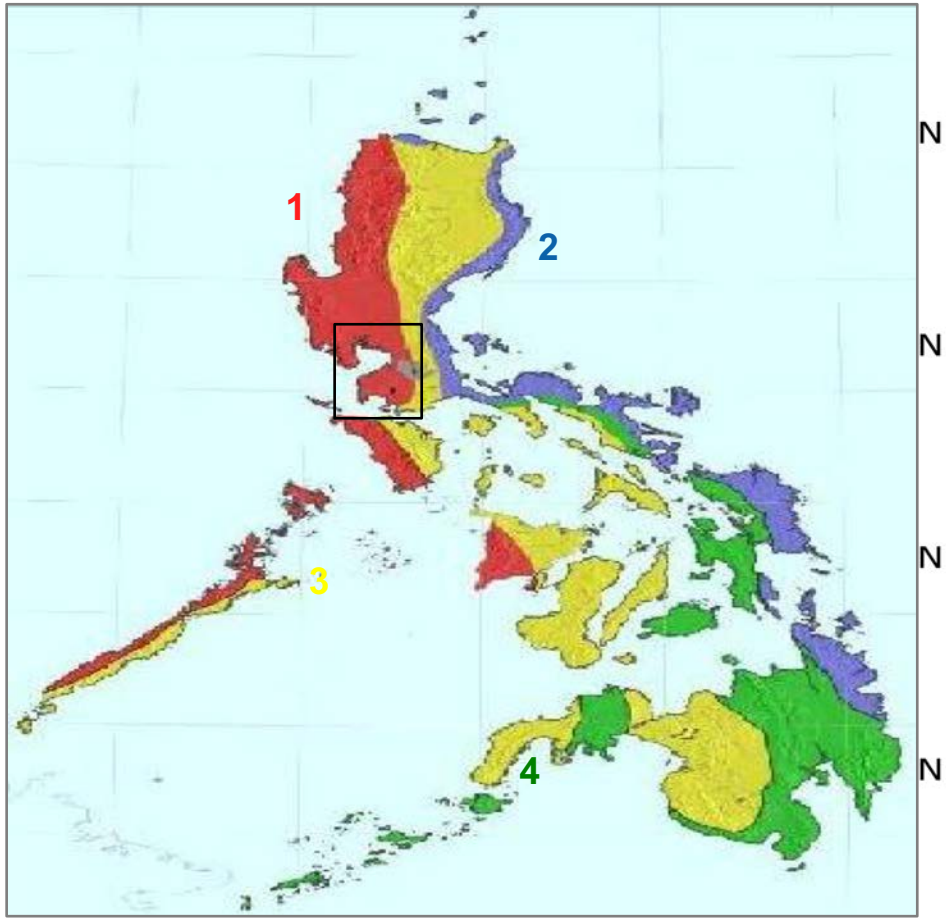
Afternoon peaks of convective rain during August, September, and October

Most frequent convective rain during August

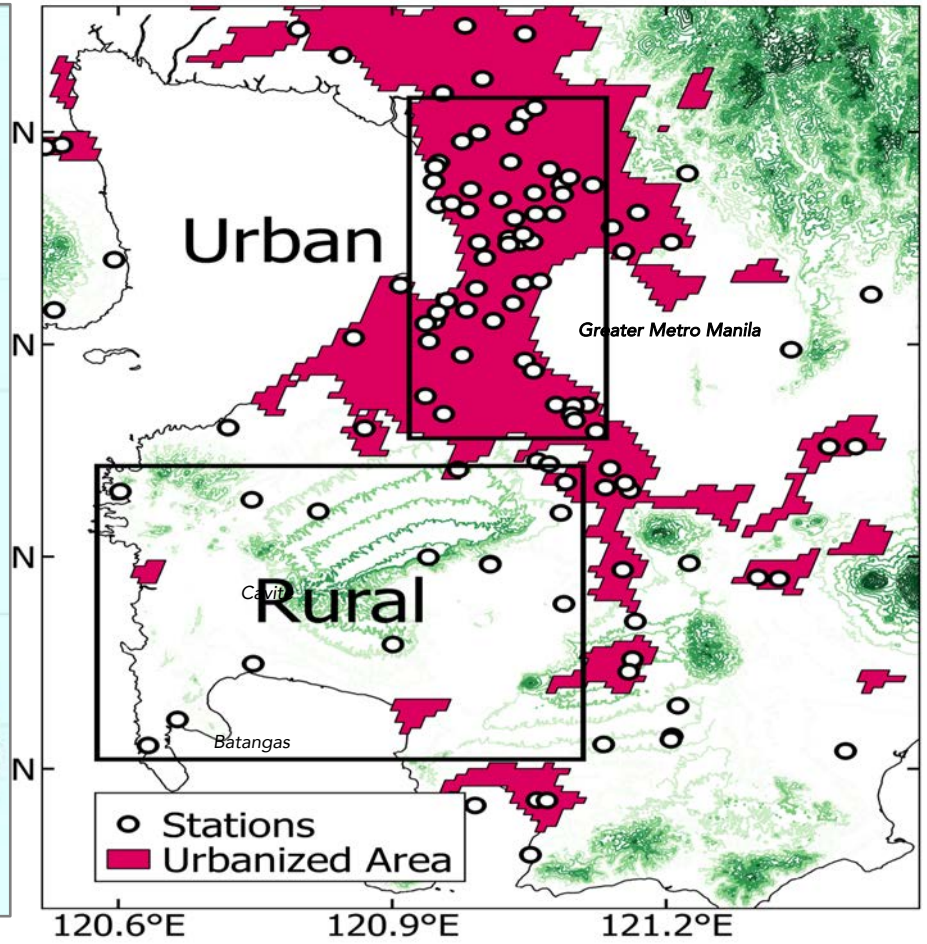
Diurnal Pattern of Rainfall over Urban and Rural Areas

To isolate the effects of land use on precipitation, rain profile over urban and rural areas were compared.

Criterion:
Both urban and rural areas affected by southwest monsoon (climate type I).



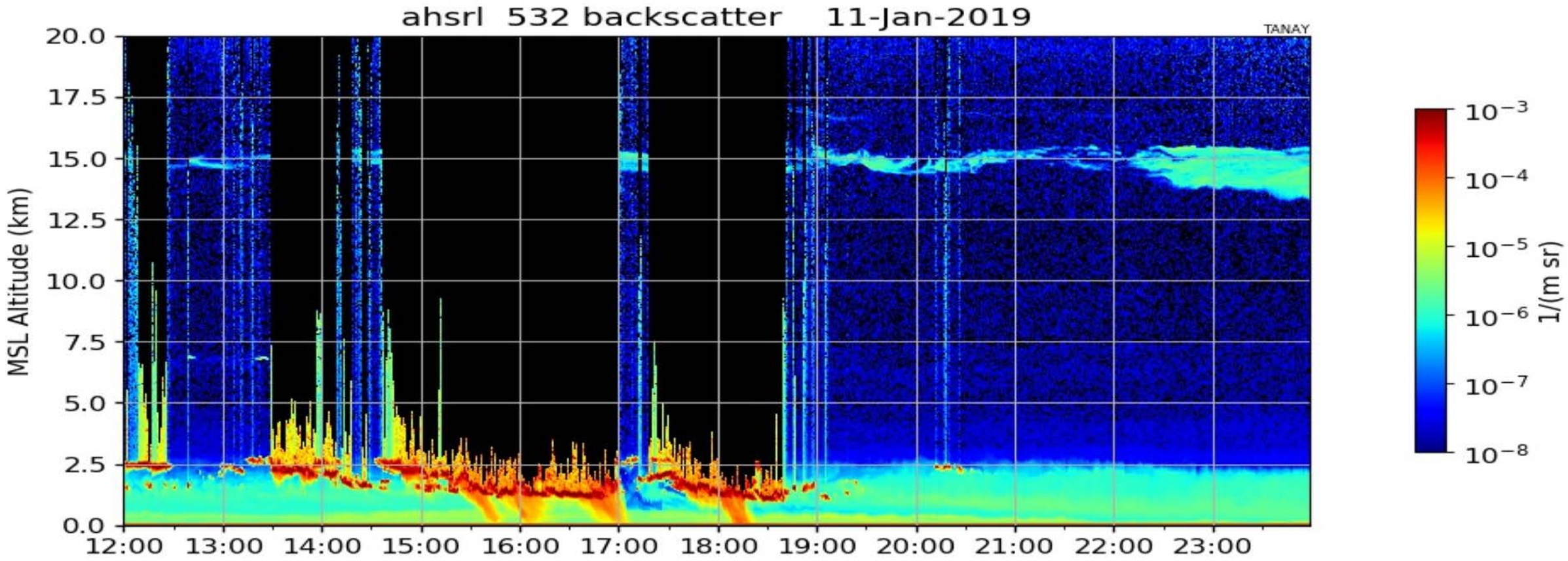
Climate Types (Kintanar, 1984)
Type I climate
Nov to Apr - dry period
May to Oct - wet period



Pesaresi et al, 2019. Global Human Settlement Urban Centre Database

58 stations (urban) Greater Metro Manila
16 stations (rural) Cavite & Batangas
Jan 2011 - July 2018, Weather Philippines Foundation

High Spectral Resolution Lidar (HSRL) at Manila Observatory



Other events:

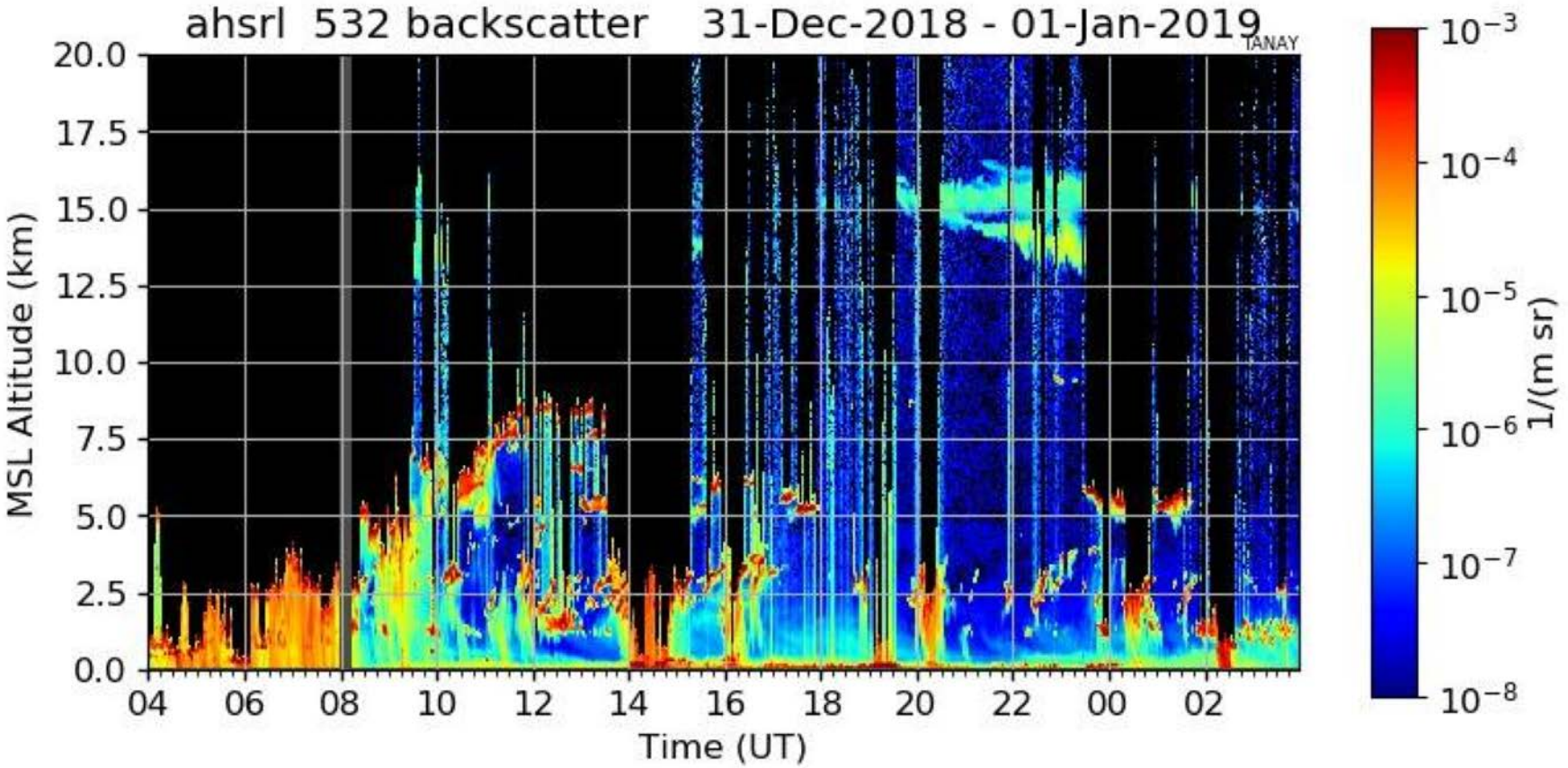
Aerosol Backscatter from the High Spectral Resolution Layer (HSRL)

precipitation between 13:30 - 17 UT (9:30 - 11 PM) seen with the attenuation of the lidar at 2.5 km

Very high cirrus clouds are detected starting around 10 UT (3 AM) centered at 15 km.

http://hsrl.ssec.wisc.edu/by_site/30/all/2019/03/04/

High Spectral Resolution Lidar (HSRL) at Manila Observatory



during New Year 2019

precipitation 04 -08 UT seen with attenuation of liidar at about 2 km

precipitation lightens afterwards and mid-level water cloud is present 5 - 14 UT

very high cirrus clouds are detected starting around 20 UT centered at 15 km

Case Study: July - Sept 2015

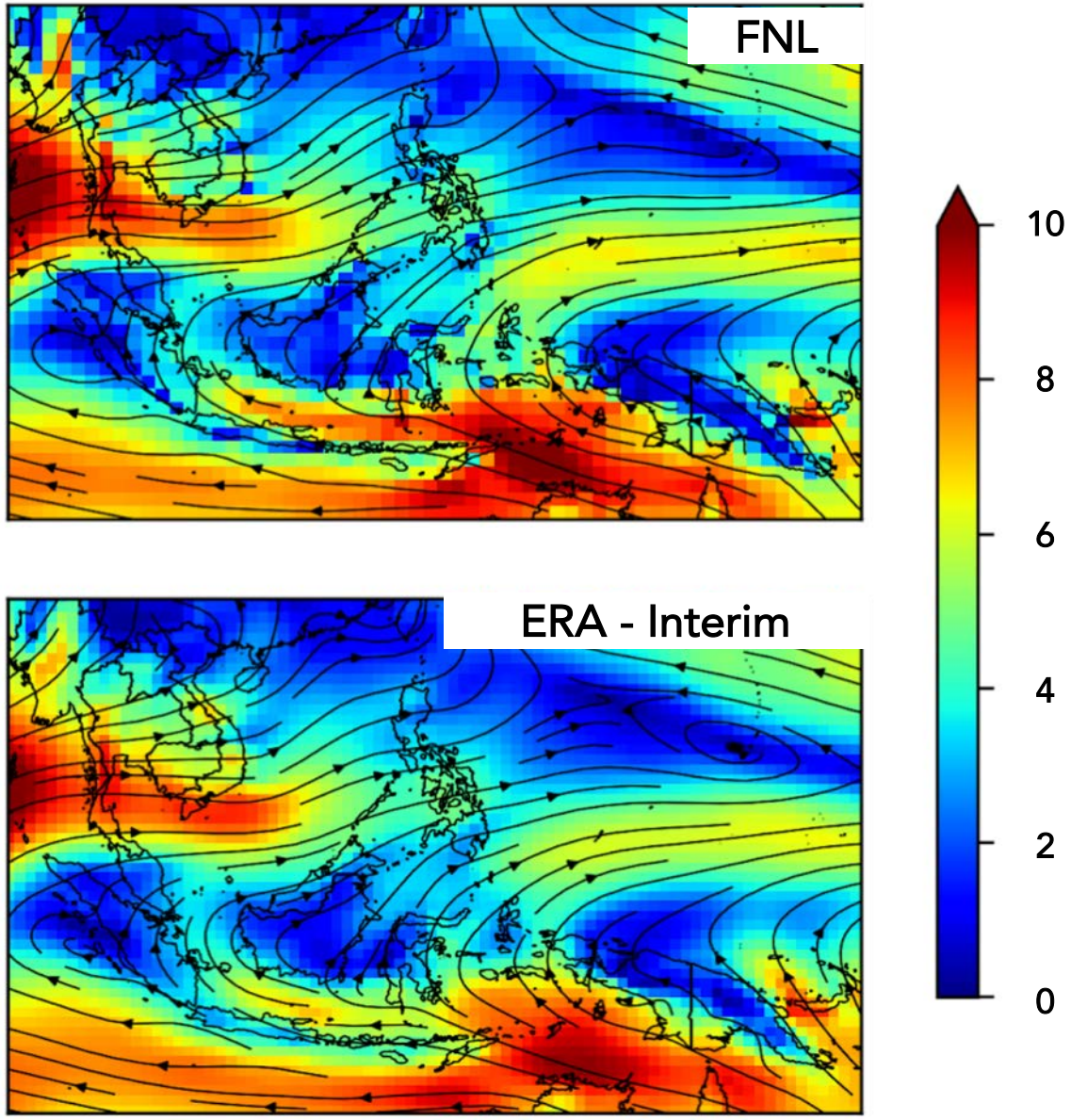
Why July-September 2015?

- Prevalence of SWM during JAS
- Data availability (AERONET, Satellite, and model input data)
- Intense biomass burning event

Characteristics

- Strong El Nino Year - ONI: 1.5 (JJA), 1.8(JAS), 2.1(ASO), max during NDJ (2.6)
- Less Rainfall over PH
- More active Biomass Burning season due to El Nino (Xian et al, 2014; Reid 2013; Lawrence & Lelieveld 2010)
- Stronger eastward countercurrent east of Mindanao, inducing stronger flow towards Mindanao

850mb Wind Speed (m/s) and Streamlines



Data Products

WRF-Chem

Simulation Period: June 20 – Oct 1, 2015

Analyzed Period: Jul 1 - Oct 1, 2015

IC/BC: GFS FNL 1x1 degree, 6 hourly

Resolution: 25x25km , 31 vertical layers(top=50mb), Hourly

Chemistry Scheme: Mozart-Mosaic

Anthropogenic Emissions: EDGAR-HTAP (0.1 x 0.1 deg., monthly, base year - 2010)

Fire Emissions: Fire Inventory from NCAR (FINNv1.5, 1x1km, hourly)

Chem IC/BC: Model for Ozone and Related chemical Tracers (MOZART)

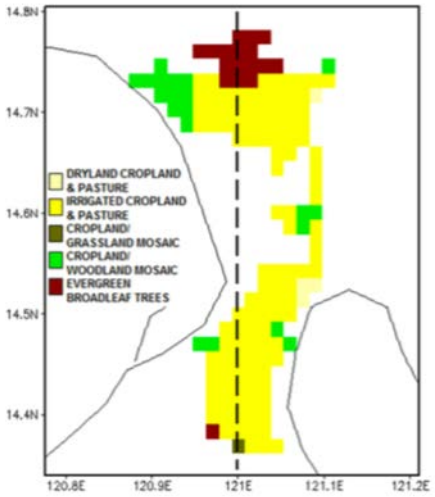
MODIS AOD 550nm Dark Target Product

Satellite: Terra and Aqua, averaged

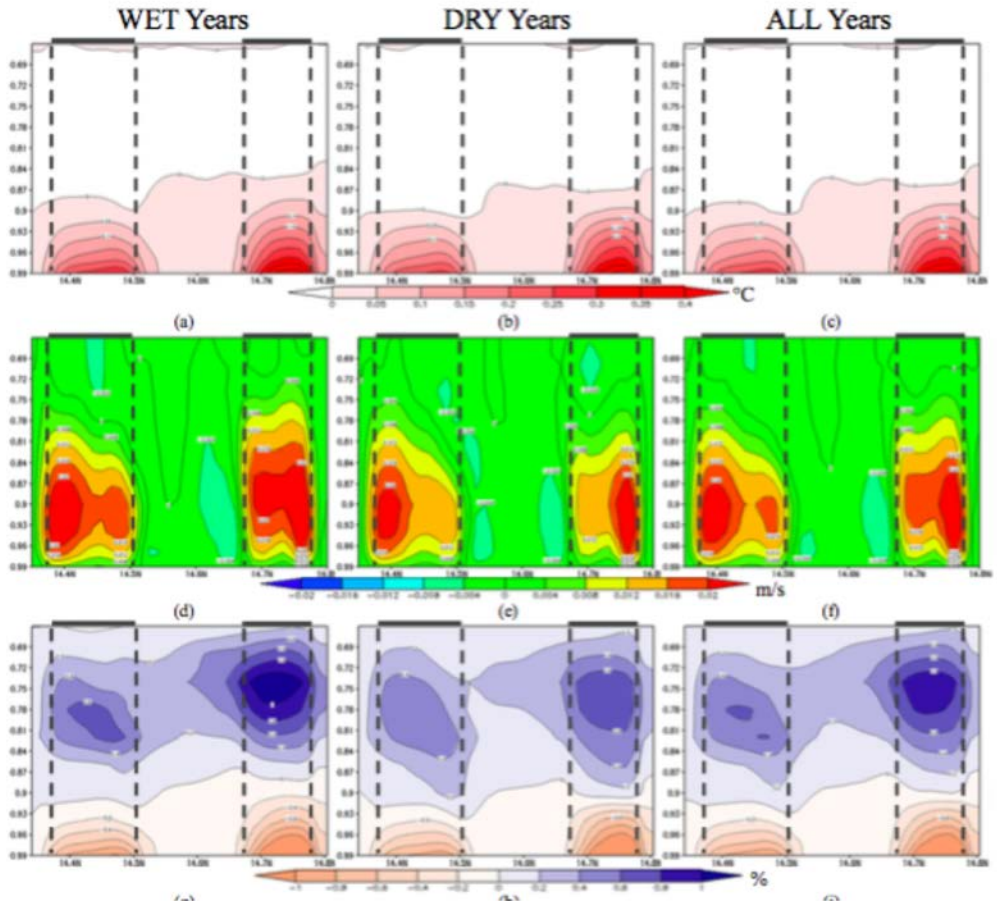
Resolution: 1x1 deg, Daily

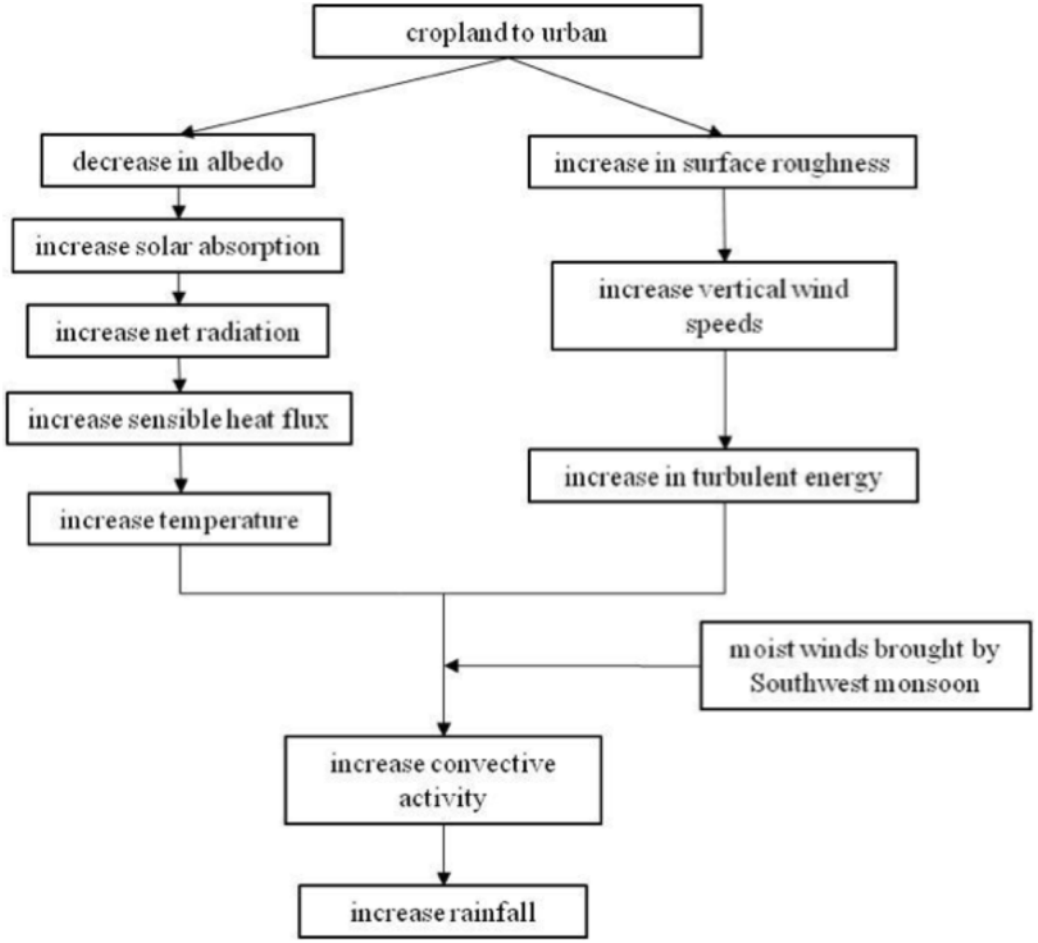
AERONET Sun and Sky-scanning Radiometers

What is the impact of urbanization on rainfall?



LC types (1972) converted to urban (2000).
black dashed line (121° E),
region of vertical profiles analysis

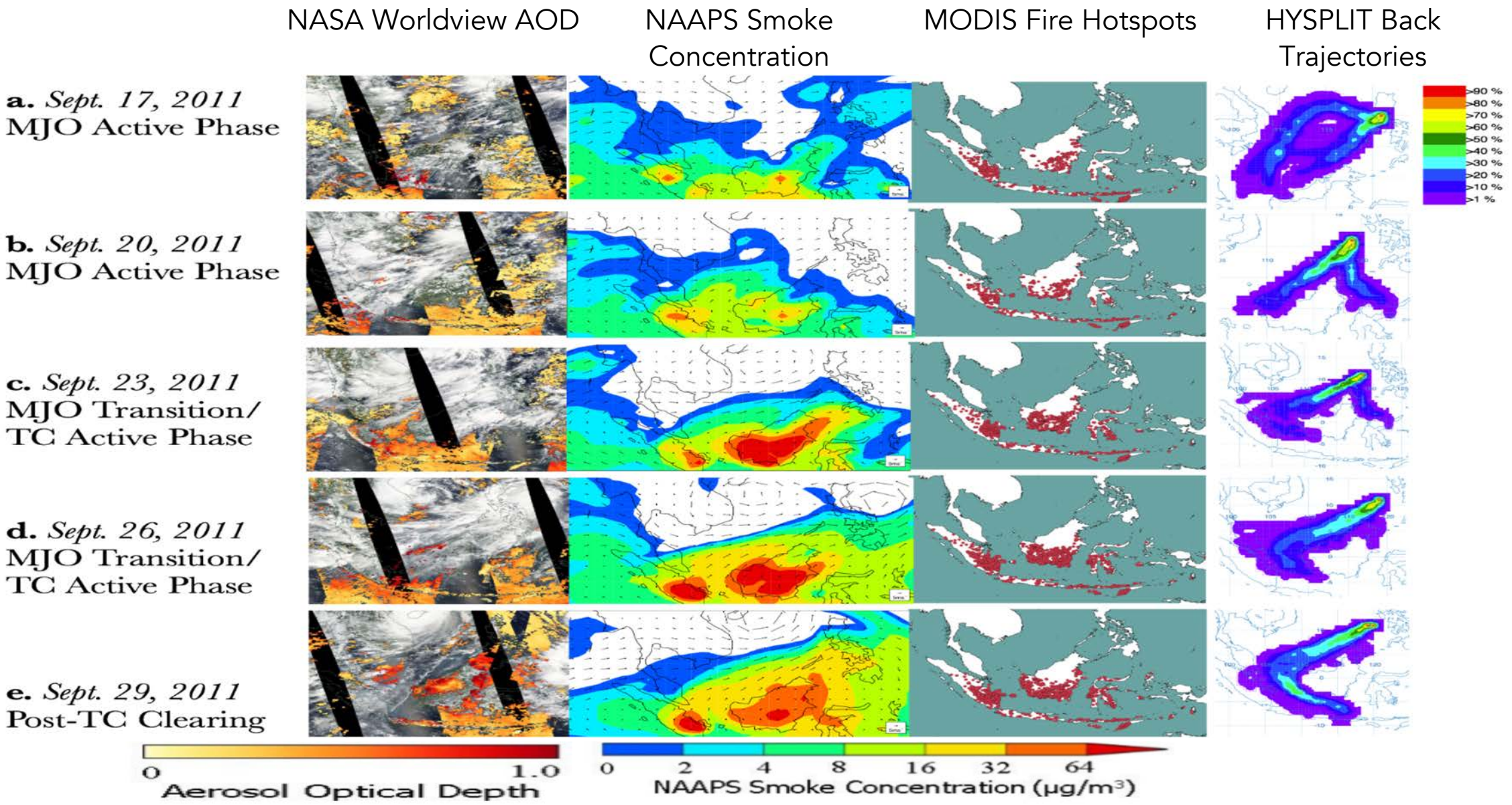




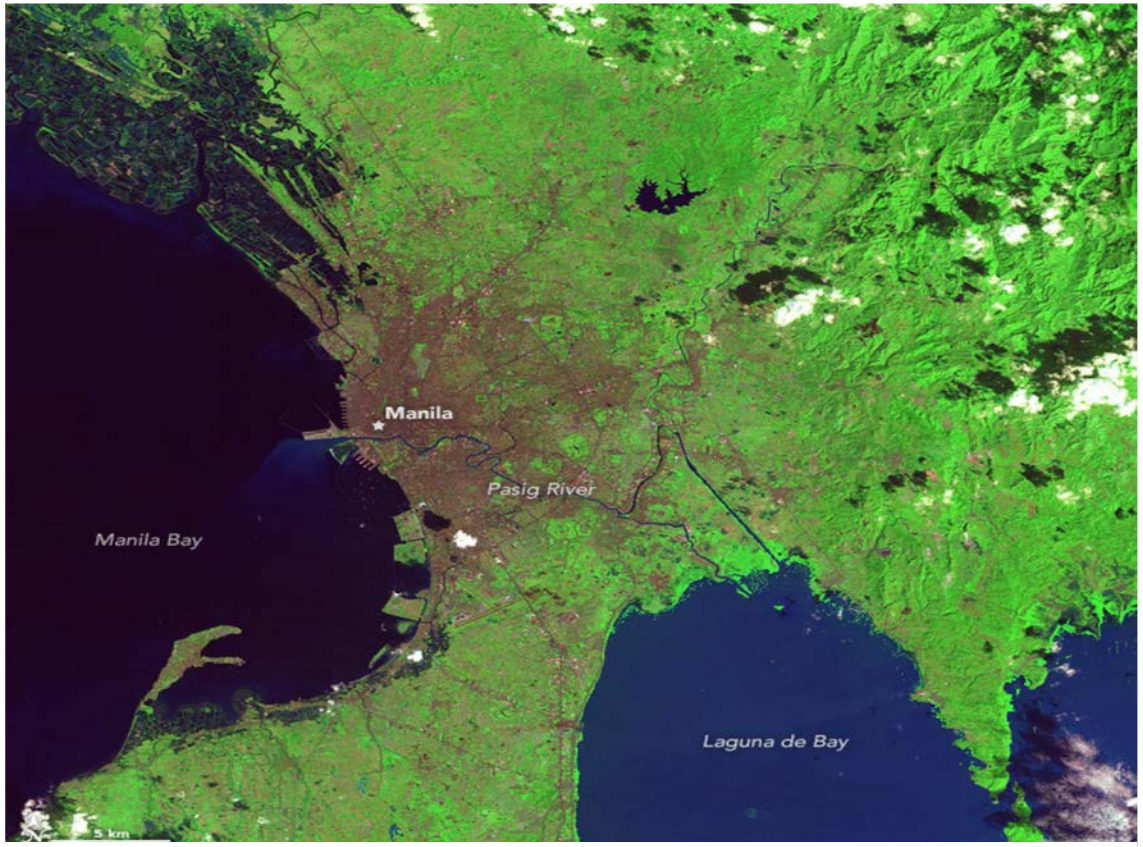
inc. convective activity & rainfall potentially due to combined effects of inc. temperature (top), inc. vertical winds (mid) ,
and Southwest monsoon bringing in moisture (bot).

(Dado et al 2019. submitted)

Large-scale Meteorology for 2011 Vasco Cruise in Coron, Palawan



What is the influence of urban land use and fine particulate pollution on rainfall?



NASA Earth Observatory, Landsat 5, Landsat 8 data

1988 vs. 2014

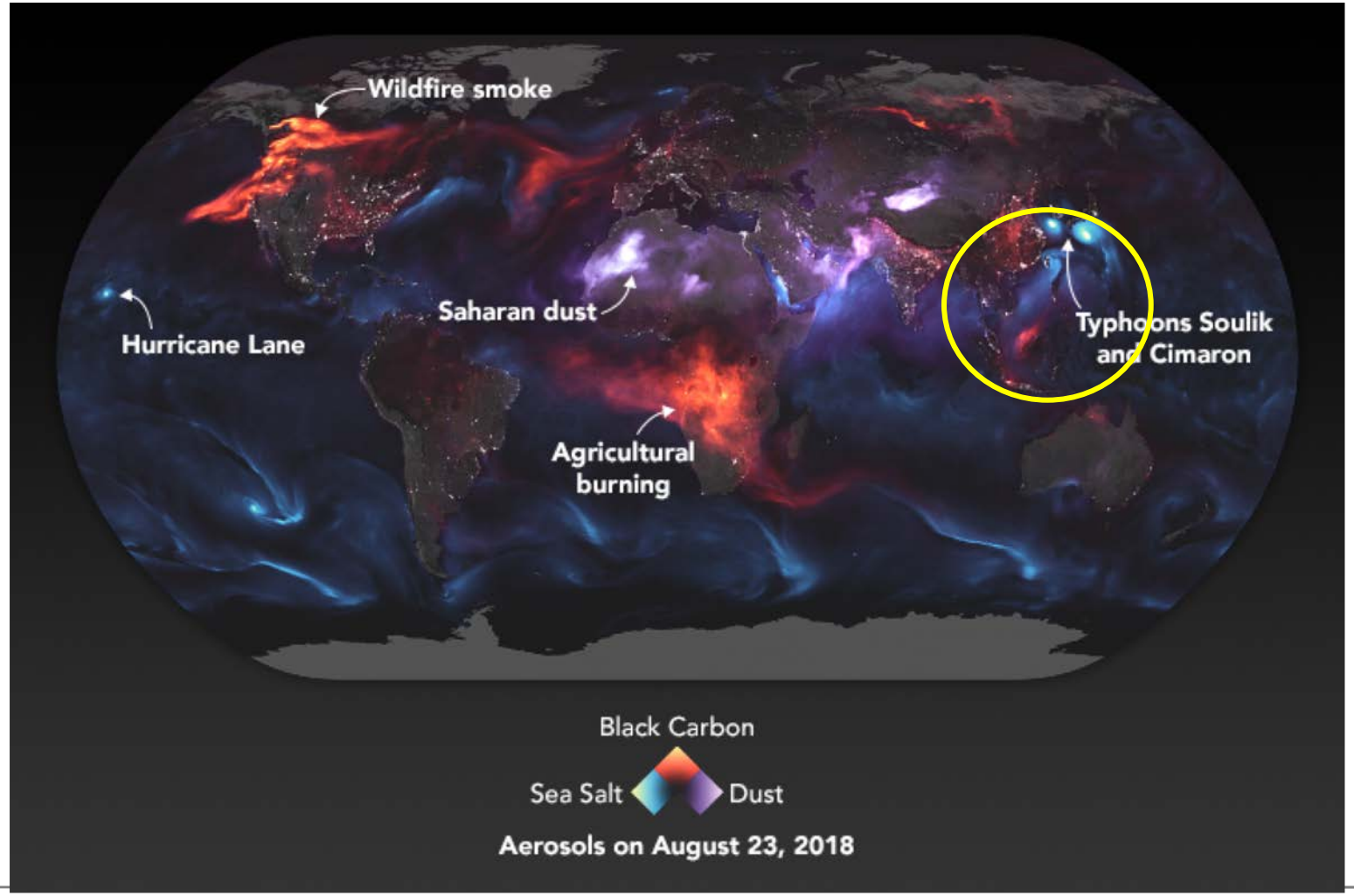
Alas et al., 2018

MACE 2015 Aerosol Characterization

Hypothesis:
Enhanced rainfall over Metro Manila during the Southwest Monsoon is due to the combined effects of urban land use and fine particulate pollution on local convection.

Why Study Aerosols?

Global Aerosol Distribution

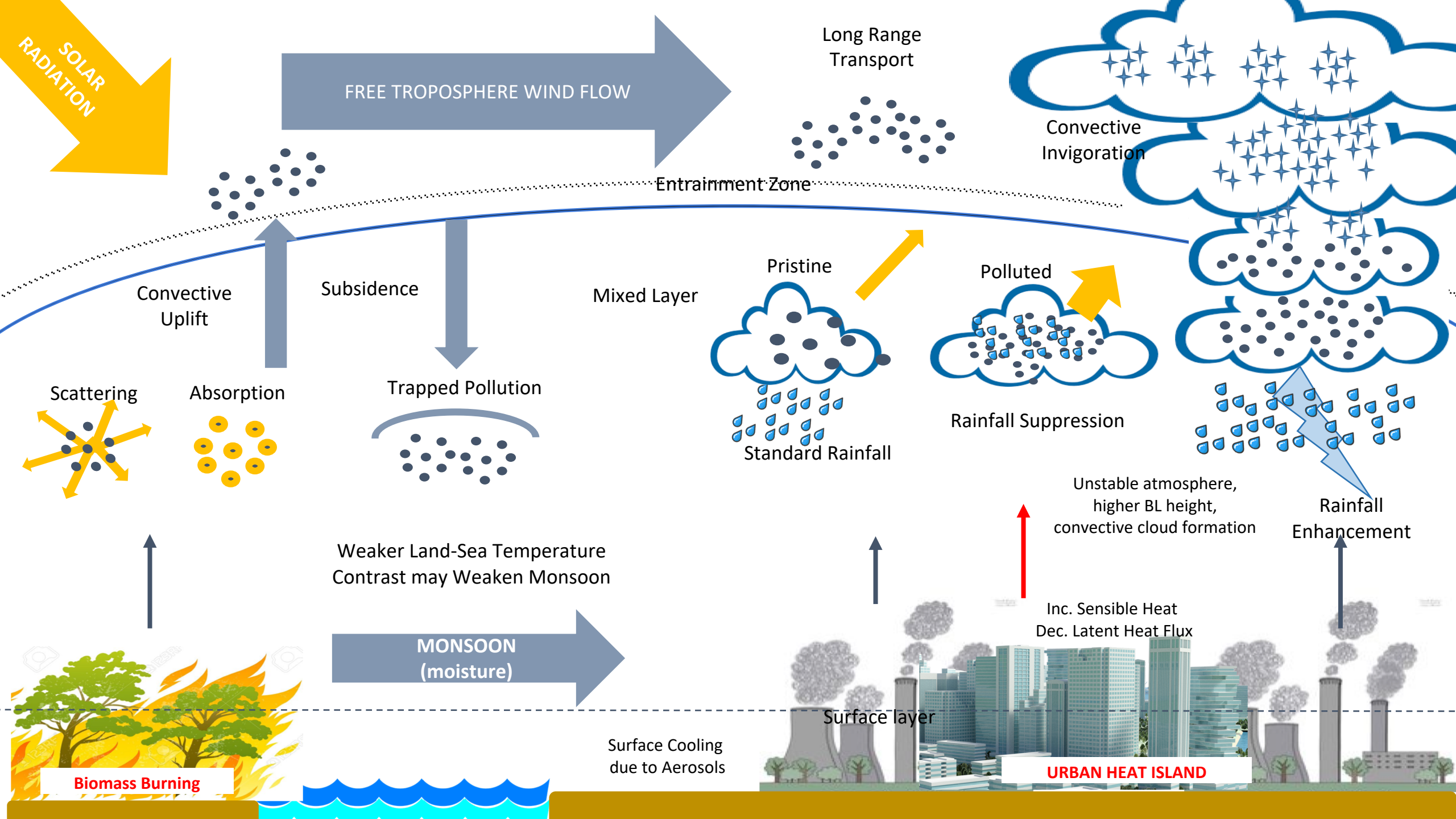


Source: NASA

Carbonaceous Aerosols from biomass burning in Indonesia

and sea salt from West Philippine Sea

are possible dominant sources of aerosols transported into the Philippines during southwest monsoon season.


SOLAR RADIATION
FREE TROPOSPHERE WIND FLOW
Long Range Transport
Convective Invigoration
Entrainment Zone
Convective Uplift
Subsidence
Mixed Layer
Pristine
Polluted
Scattering
Absorption
Trapped Pollution
Standard Rainfall
Rainfall Suppression
Unstable atmosphere, higher BL height, convective cloud formation
Rainfall Enhancement
Weaker Land-Sea Temperature Contrast may Weaken Monsoon
MONSOON (moisture)
Inc. Sensible Heat
Dec. Latent Heat Flux
Surface layer
Surface Cooling due to Aerosols
Biomass Burning
URBAN HEAT ISLAND

CAMP2Ex, CHECSM, and CAMP2Ex IMPACT-PH

2018	2019	2020 - 2022

May — March — July — September

CHECSM
CAMP2Ex Weather and CompoSition Monitoring

CAMP2Ex
Airborne Mission

IMPACT - PH

Intensive field campaign in Manila Observatory: instruments from US Naval Research Laboratory, University of Wisconsin, University of Arizona

IMPACT - PH
(Philippine activity)

continuous Air Quality Monitoring, Aerosol and Climate Modeling

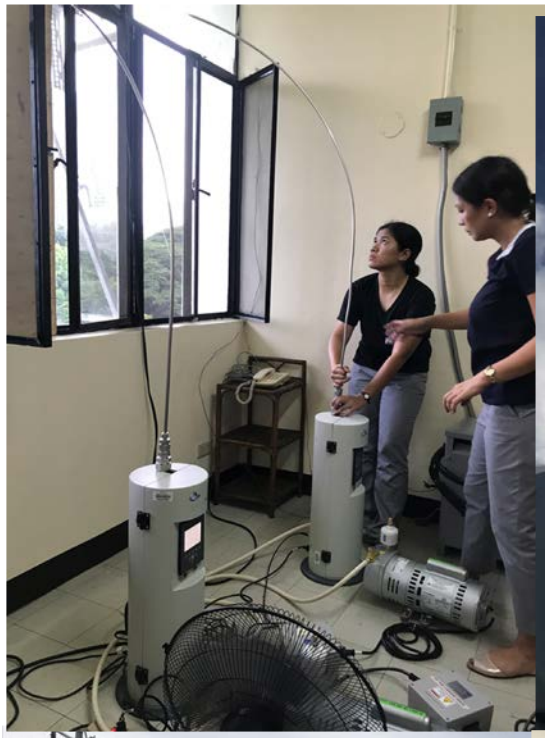
Manila Observatory
Palawan

CAMP2Ex, NASA & Manila Observatory

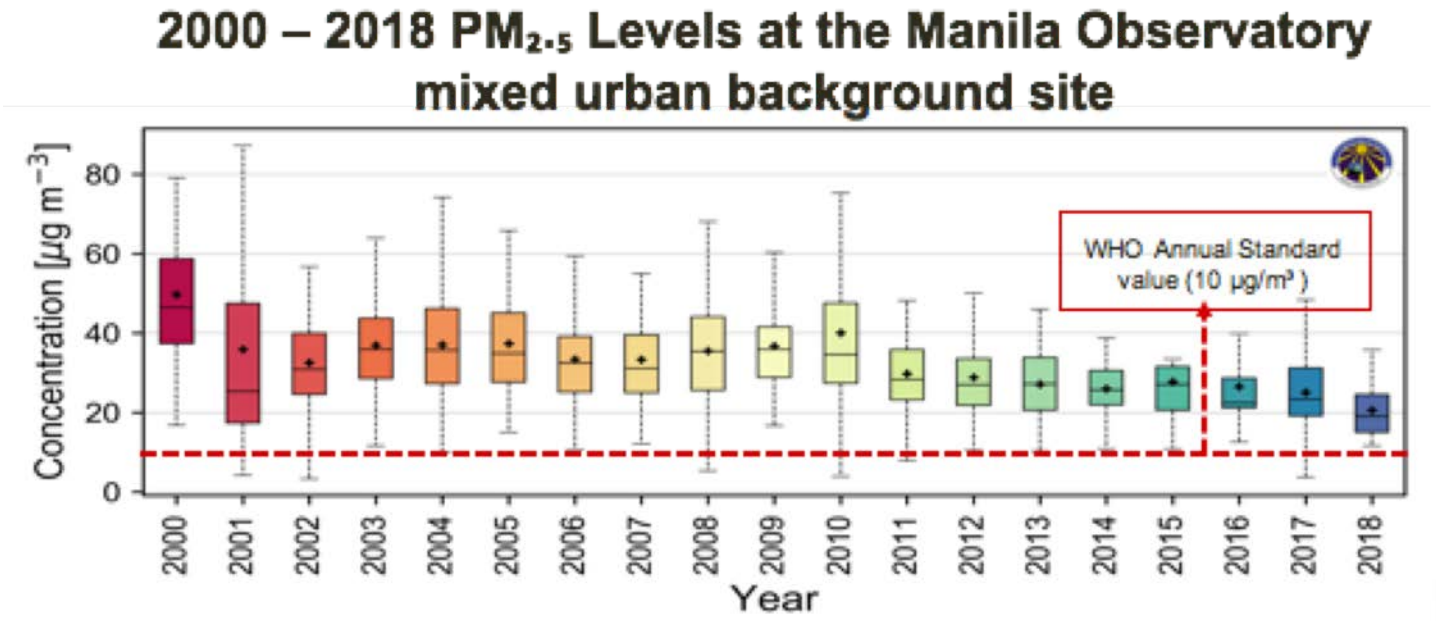
Mission Management

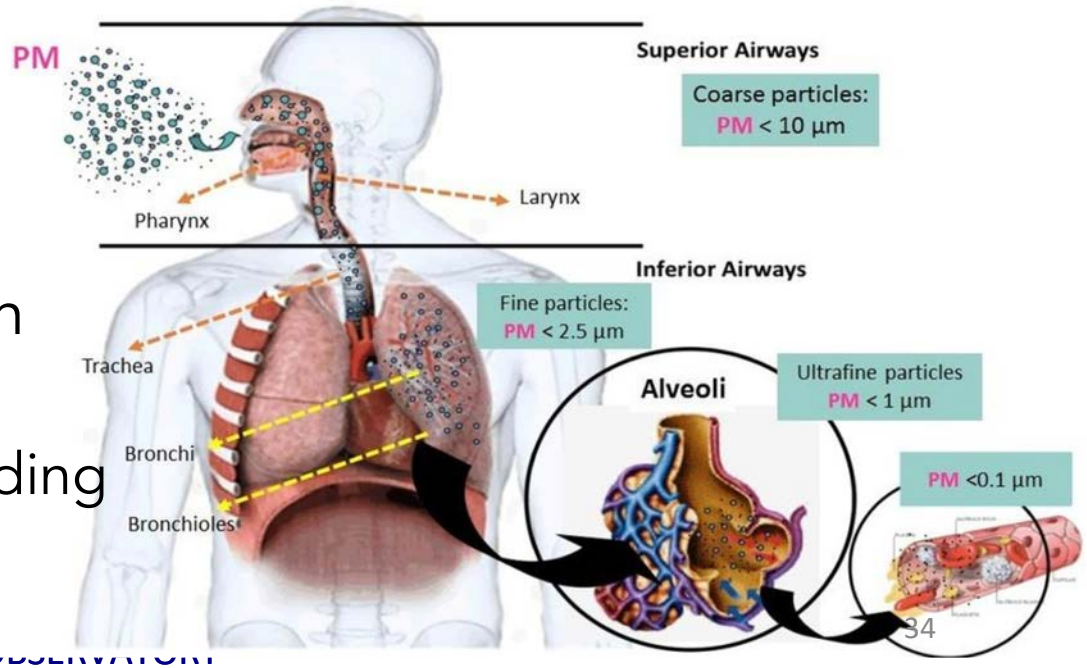
Name	Organization	Title
Hal Maring	NASA HQ	Program Science
Jeffrey Reid	NRL	Mission Science
James Simpas	Manila Observatory AdMU / AMU	MO Project Manager
Gemma Teresa Narisma	Manila Observatory AdMU	MO Science

- Manila Observatory as Philippine counterpart of CAMP2Ex.
- Continuous ground-based measurement in Manila Observatory grounds since late 2018 and continue until 2022
- MO also has its own scientific agenda in the CAMP2Ex campaign , which is recognized by the US science partners.
- Specific flight plans will be designed for these scientific agenda.



Philippine Aerosol Environment





- Air pollution expected to increase with population and economic development over urban areas
- Aerosols have significant impacts on human health (respiratory illnesses)
- Levels of fine particulate matter consistently exceeding WHO's annual standard value of 10 µg/m3.

IMPACT-PH

Main Objective: to characterize and study the Philippine atmospheric and aerosol environments and their interactions

Specific Objectives:

- To characterize and study aerosol transport patterns in the country, both from transboundary and local pollution
- To investigate the potential influence of urban pollution on clouds, temperature, and precipitation
- To investigate the potential influence of meteorology on the spatial distribution of aerosols

Methodology

Pre-CAMP2Ex
Installation, Initial Testing, Configuration, and Calibration of Ground-Based Instruments and Dynamic Atmospheric Model

During CAMP2Ex
Data Gathering through Airborne Sampling, Satellite Observations, and Model Runs for Weather and Aerosol Transport Forecasting

Post-CAMP2Ex
Analysis of Data, Continuation of Ground - Based Measurement, and Further Model Simulations for CAMP2Ex Campaign Period

Philippines: a hotspot for climate risk

High climate risk: high vulnerability, high exposure to hazards of air quality, and weather and climate extremes. (World Risk Report, 2016)