



CENTRAL AMERICA HEALTH & AIR QUALITY

Identifying Particulate
Matter and Aerosols in
Central America Using
NASA Remote Sensing Data

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Study Area



Central American Integration System (SICA) countries:

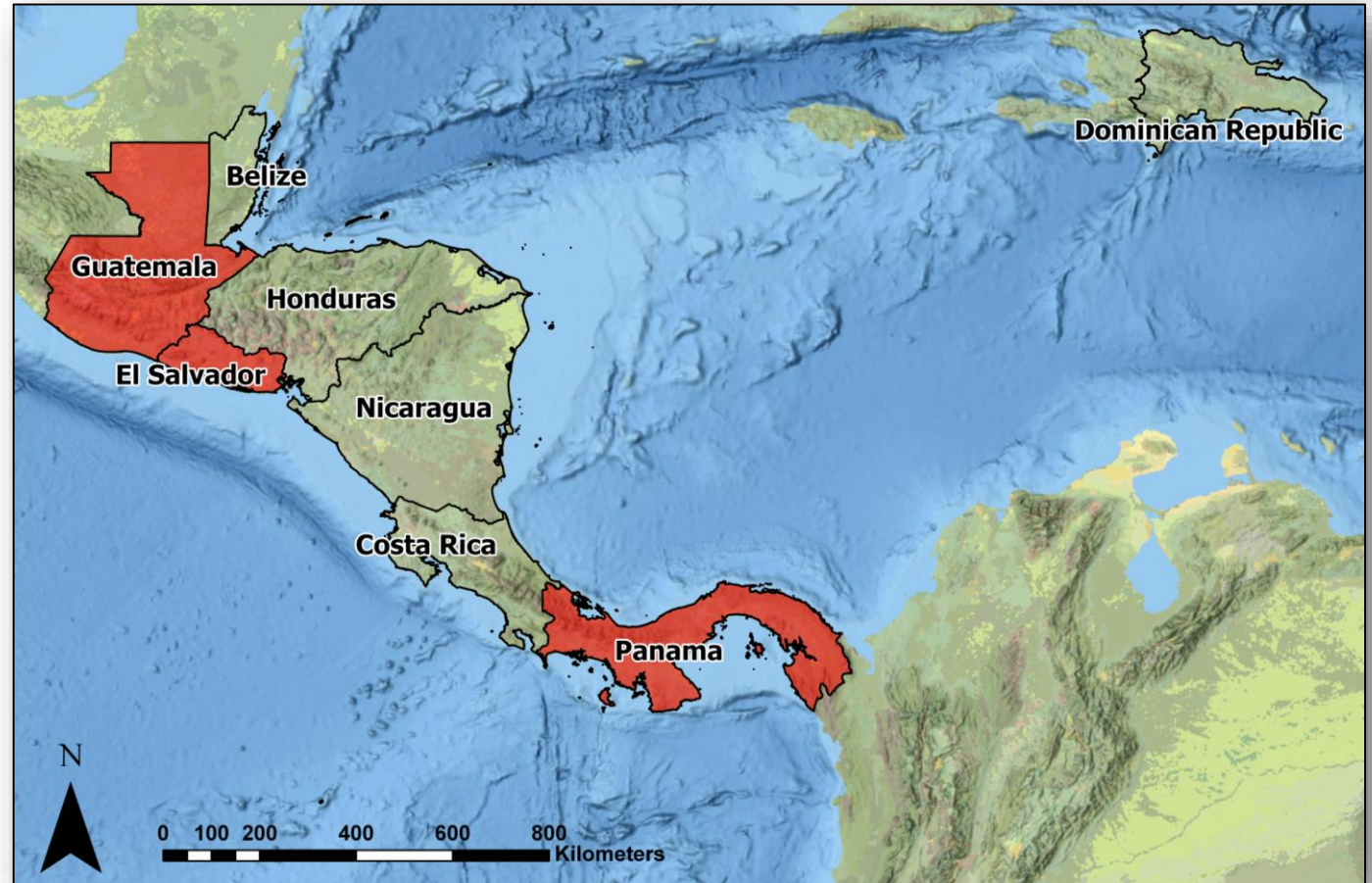
Belize
Costa Rica
Dominican Republic
El Salvador
Guatemala
Honduras
Nicaragua
Panama

Study Period:

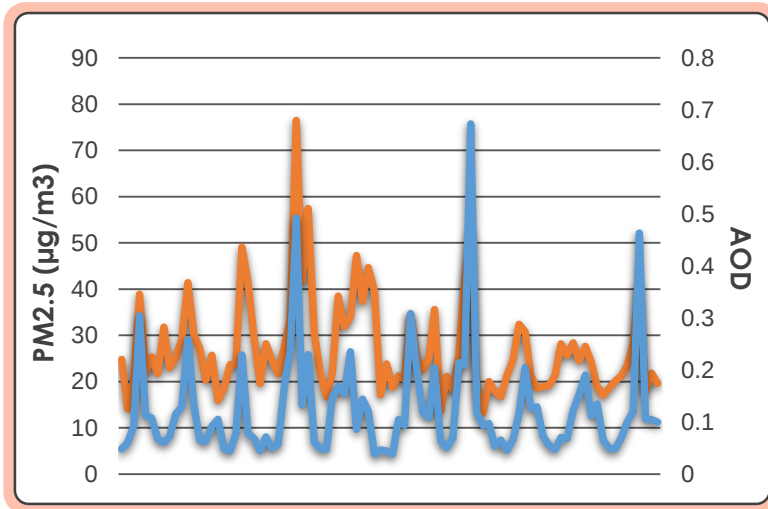
January 2008 –
September 2019

Project Partners

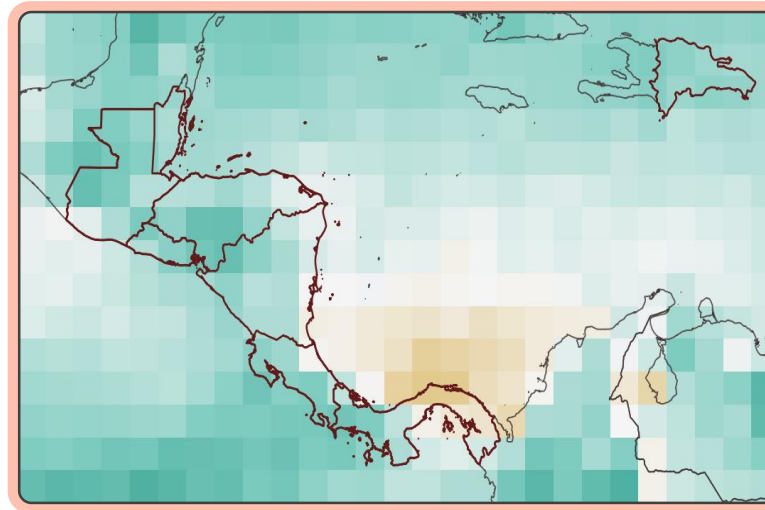
- ▶ **Ministry of Environment and Natural Resources (MARN) El Salvador**
(Ministerio de Medio Ambiente y Recursos Naturales)
- ▶ **Ministry of Environment and Natural Resources (MARN) Guatemala**
- ▶ **Technological University of Panama**
(Universidad Tecnológica de Panamá)
- ▶ **The Autonomous University of Ciriqui**
(La Universidad Autónoma de Ciriqi)
- ▶ **Specialized Institute of Analysis of the University of Panama**
(Instituto Especializado de Análisis de la Universidad de Panamá)



Objectives



**PM_{2.5} & AOD
Relationship**



**Aerosol Distribution
Baseline Map**



**How Data Can be
Applied to SICA
Countries**

Community Concerns

Identified Sources of Aerosols:

- ▶ Mining Activities
(Cobre Panamá Copper Mine)
- ▶ Biomass Burnings
- ▶ Pyrotechnics

Measureable Impacts:

- ▶ Health Issues
- ▶ Water Acidification
- ▶ Soil Nutrient Depletion
- ▶ Damaged Crops
- ▶ Damaged Monuments



Image credit: Project_Im9



Image credit: Anthony Roberts

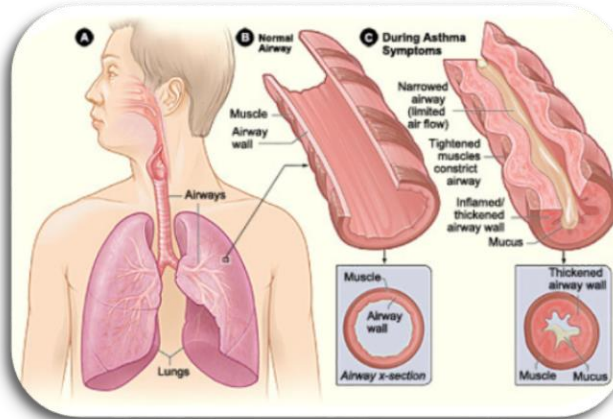


Image credit: National Institute of Health (NIH)



Image credit: Sebastian Pichler

Measurements

Particulate Matter (PM_{2.5})

In situ measurements

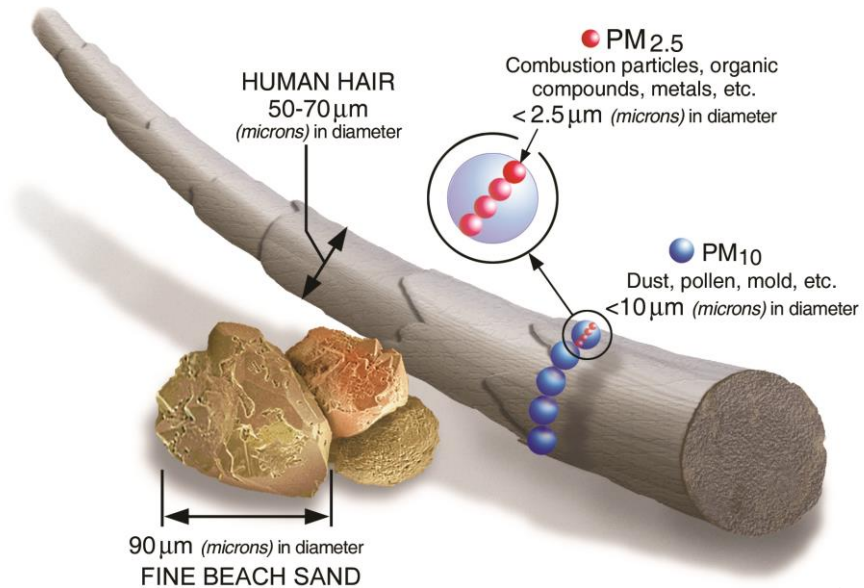


Image credit: EPA

Aerosol Optical Depth (AOD)

Remotely sensed measurements

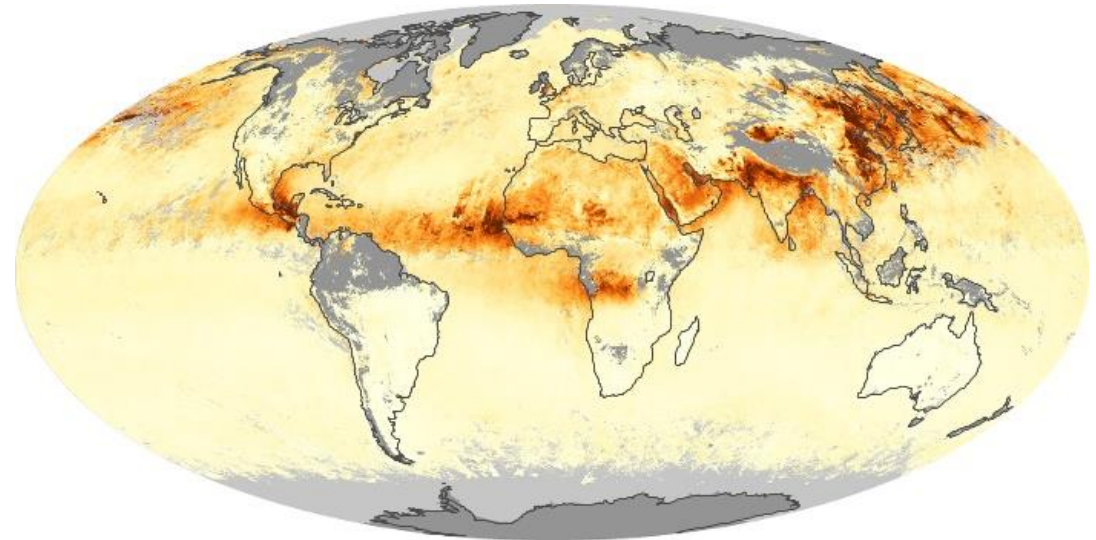


Image credit: NASA

Satellites Used

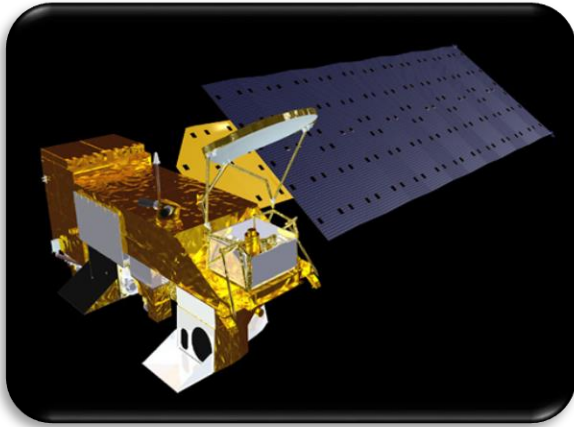


Image credit: NASA

Aqua
MODIS



Image credit: NASA

CALIPSO
CALIOP



Image credit: NASA

Terra
MODIS



Image credit: NASA

Suomi-NPP
VIIRS

Dataset Information

Data Type	Satellite(s)	Sensor	Product	Data Portal	Temporal Res	Spatial Res
AOD	Aqua & Terra	MODIS	MOD04 & MYD04	LAADS DAAC	Daily	10km x 10km
AOD	Aqua & Terra	MODIS	MOD08 & MYD08	LAADS DAAC & Giovanni	Daily	1deg x 1deg
Fire	Aqua & Terra	MODIS	MOD14 & MYD14	FIRMS	Daily	1km x 1km
AOD	Suomi NPP	VIIRS	AERDB	LAADS DAAC	Daily	6km x 6km
Fire	Suomi NPP	VIIRS	VNP14IMGTDL_NRT	FIRMS	Daily	375m x 375m
AOD	CALIPSO	CALIOP	CAL_LID	ASDC	Hourly/Daily	5km (along track)

Ancillary Datasets

NASA FIRMS: MODIS & VIIRS

Point data

Quantifies brightness levels

Spatial Res:

MODIS: 1km x 1km

VIIRS: 375m x 375m

END USERS: Health Data

El Salvador:

Department-level

Annual sums by sex & age

Recorded by appointment

Respiratory Diseases

Panama:

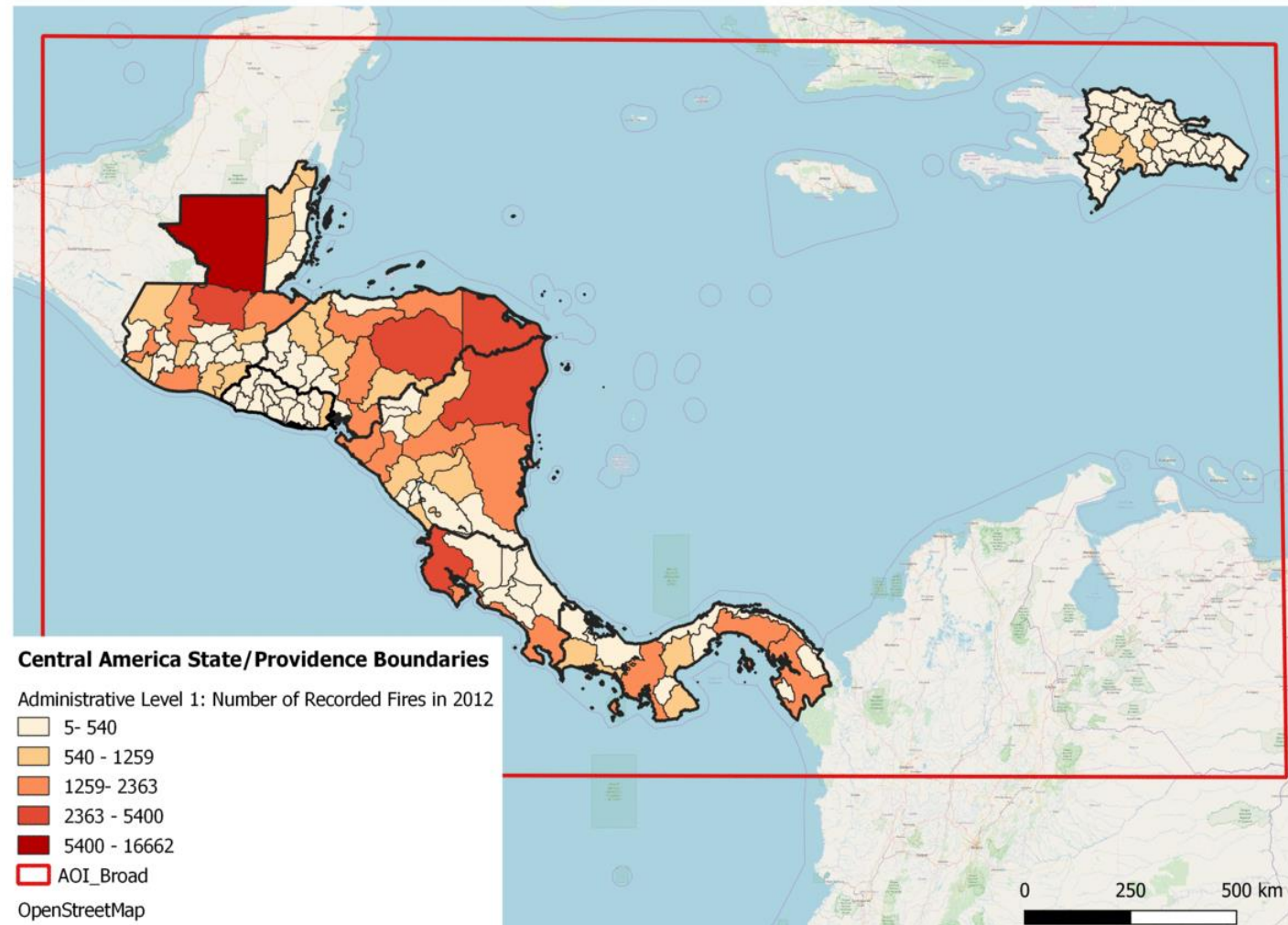
Province-Level

Annual sums by sex & age

Recorded by reported death

All causes

Fire Data for Central America



Data

LAADS DAAC, ASDC
Giovanni, FIRMS,
In situ PM_{2.5} & Health data



Processing

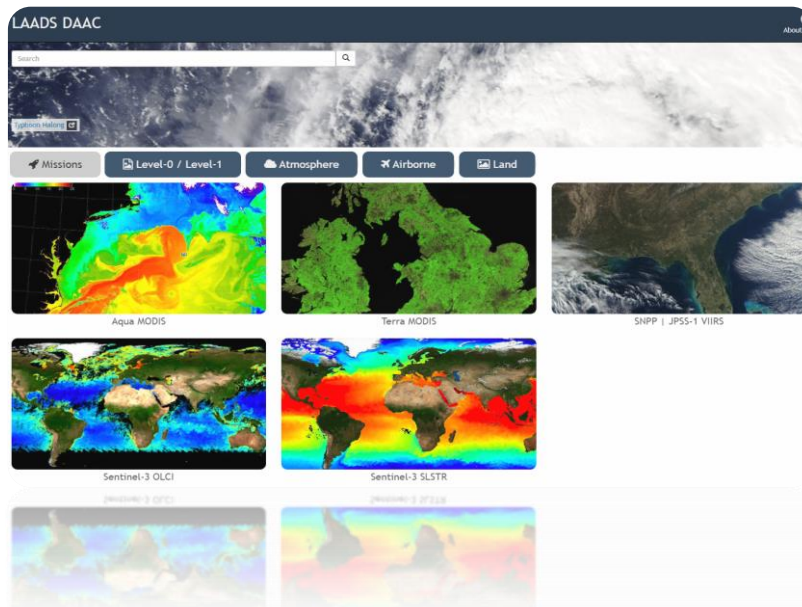
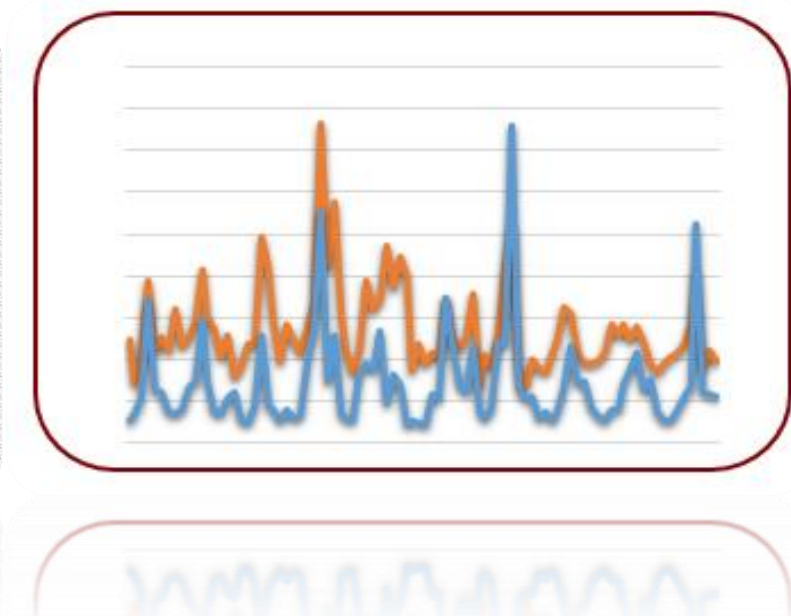
Converting files
Extracting AOD data
Aligning with *in situ* PM_{2.5}



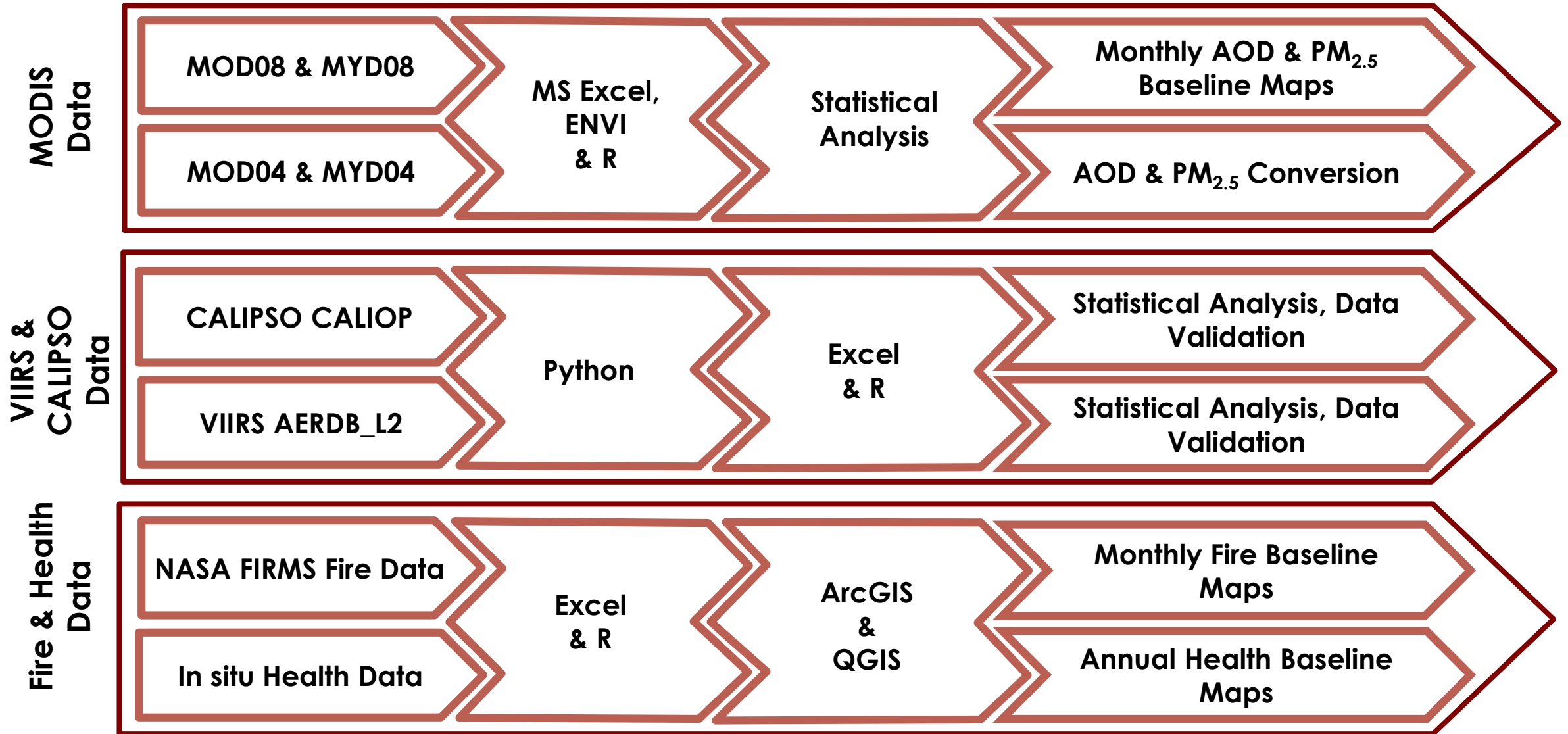
Analysis and Mapping

Statistical & Spatial Analysis

AOD, Fire, and Health Maps

[illegible]

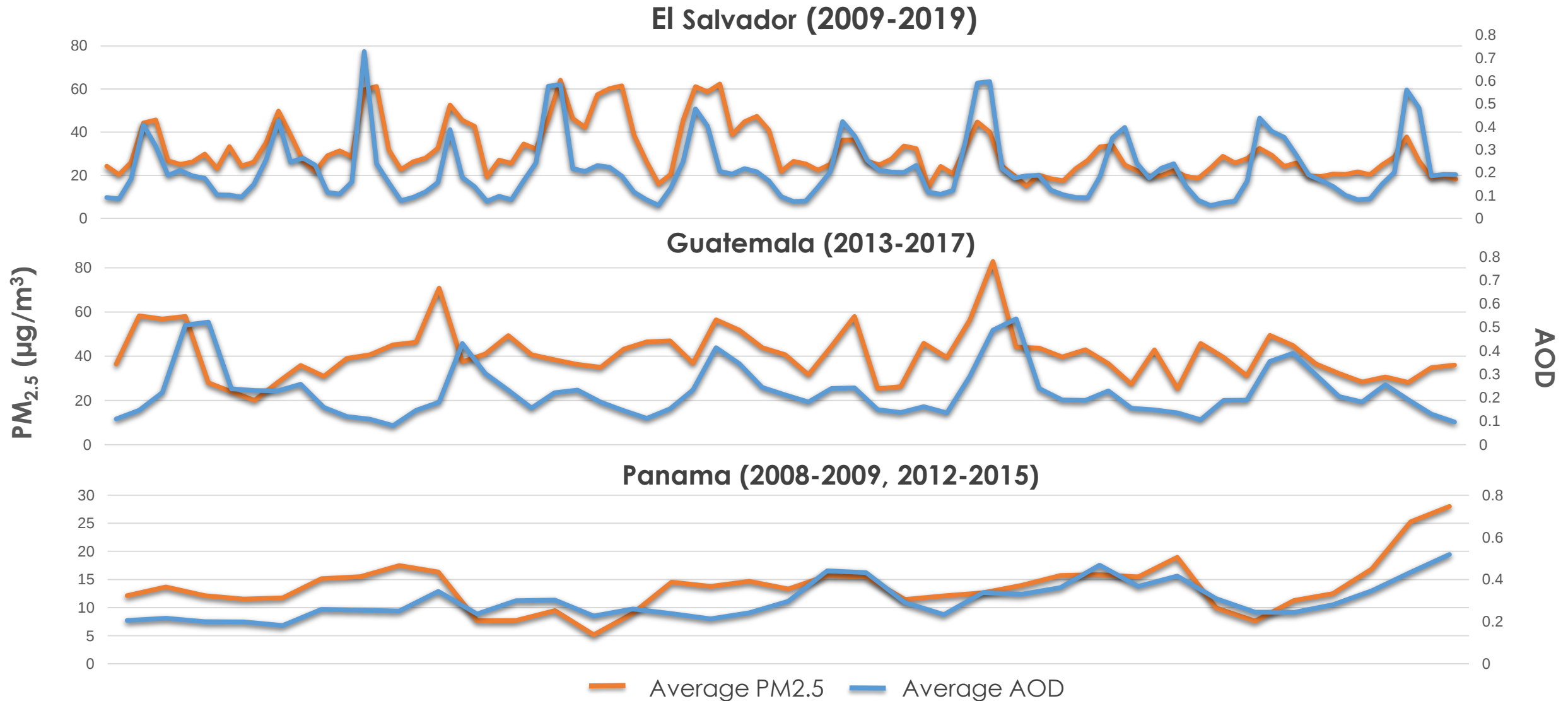
Step-by-step Methodology



Results - MODIS Data Product Selection – MODIS04 and MODIS08

	MODIS04	MODIS08	VIIRS	CALIPSO
User Friendly (Pre-gridded)	—	✓	—	—
Data storage and file size	—	✓	—	—
Strong statistics	✓	—	✓	—
Consistent measurements	✓	✓	✓	—

Results – Average Monthly AOD & PM_{2.5}

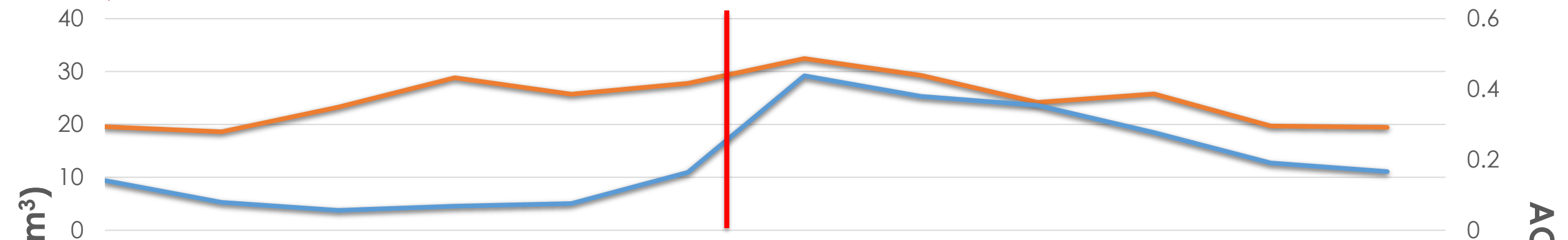


Results – Statistical Analysis: MODIS08 Regression

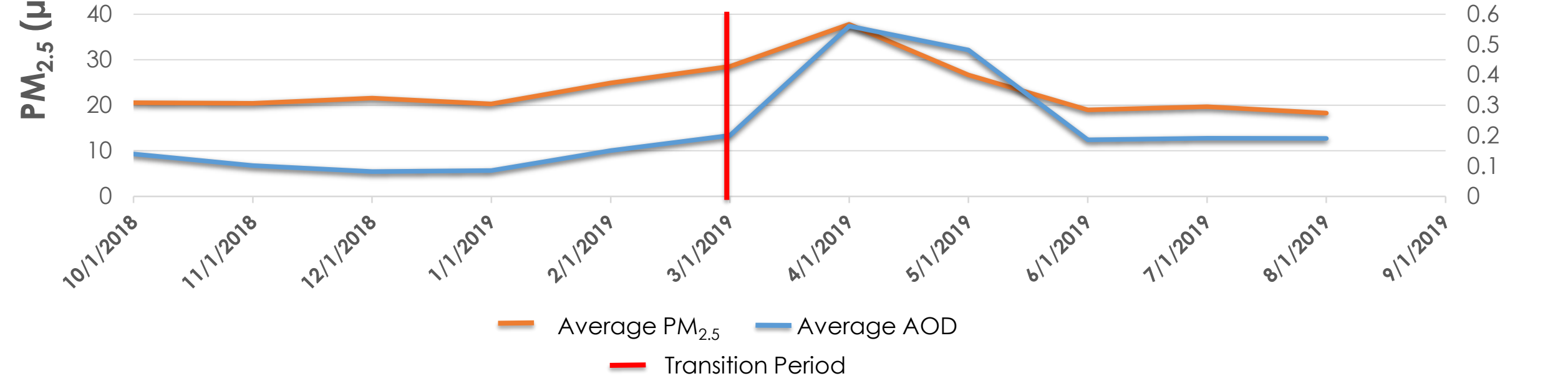
COUNTRIES	B (SE)	BETA	R ²	OBSERVATIONS
EL SALVADOR				
OVERALL MODEL	49.24(7.13)***	0.55	0.30	111
DRY SEASON	72.40 (16.30)***	0.51	0.26	57
WET SEASON	46.21 (12.64)***	0.45	0.20	54
GUATEMALA				
OVERALL MODEL	32.18(13.33)*	0.30	0.09	59
DRY SEASON	71.96(43.73)	0.30	0.09	29
WET SEASON	52.39(17.72)**	0.49	0.24	30
PANAMA				
OVERALL MODEL	34.53 (6.81)***	0.66	0.44	35
DRY SEASON	20.04(10.10)	0.44	0.20	18
WET SEASON	47.86(9.85)***	0.78	0.61	17

Results – Seasonal Analysis

El Salvador Dry and Wet Season 2017- 2018



El Salvador Dry and Wet Season 2018 - Present

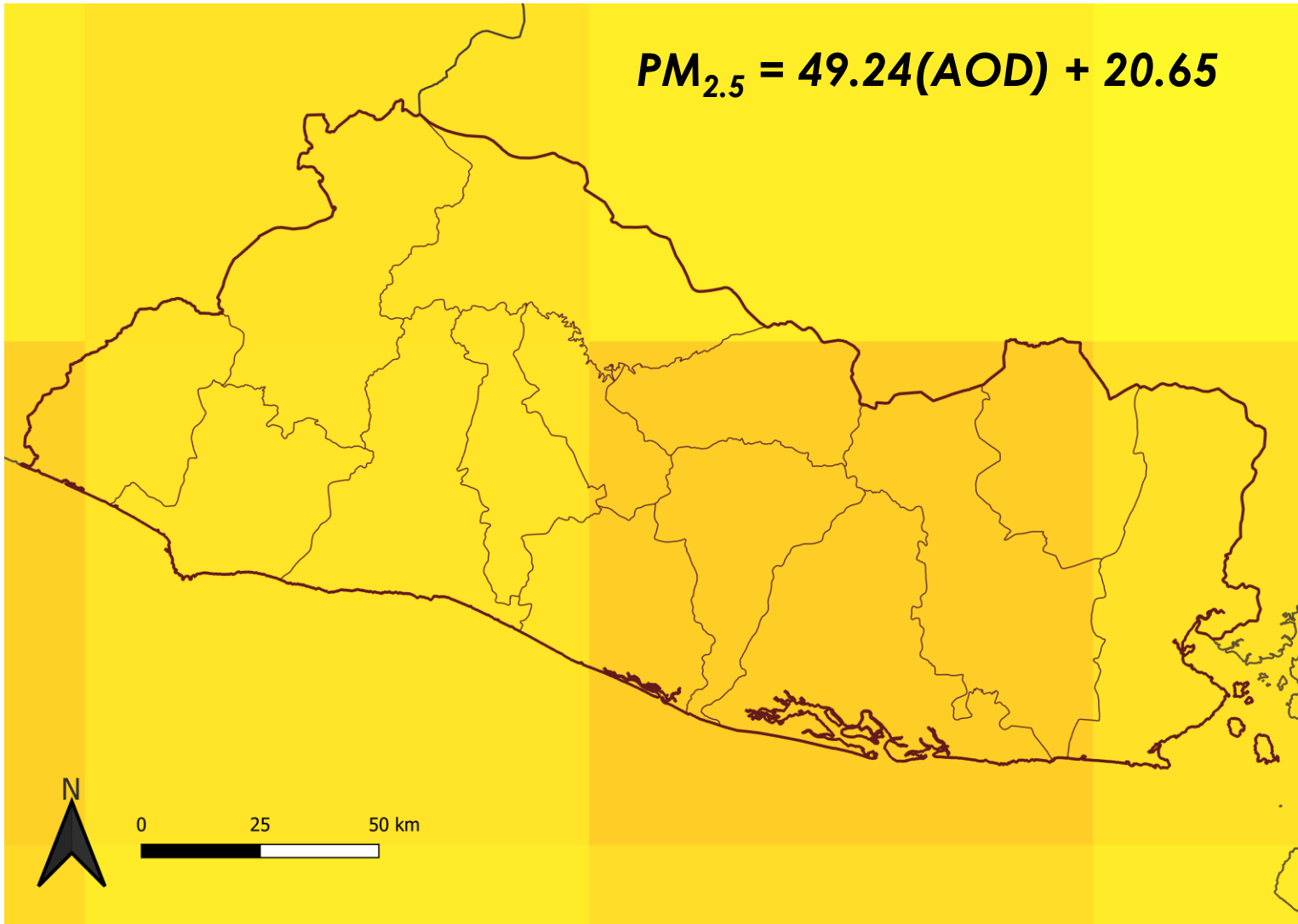
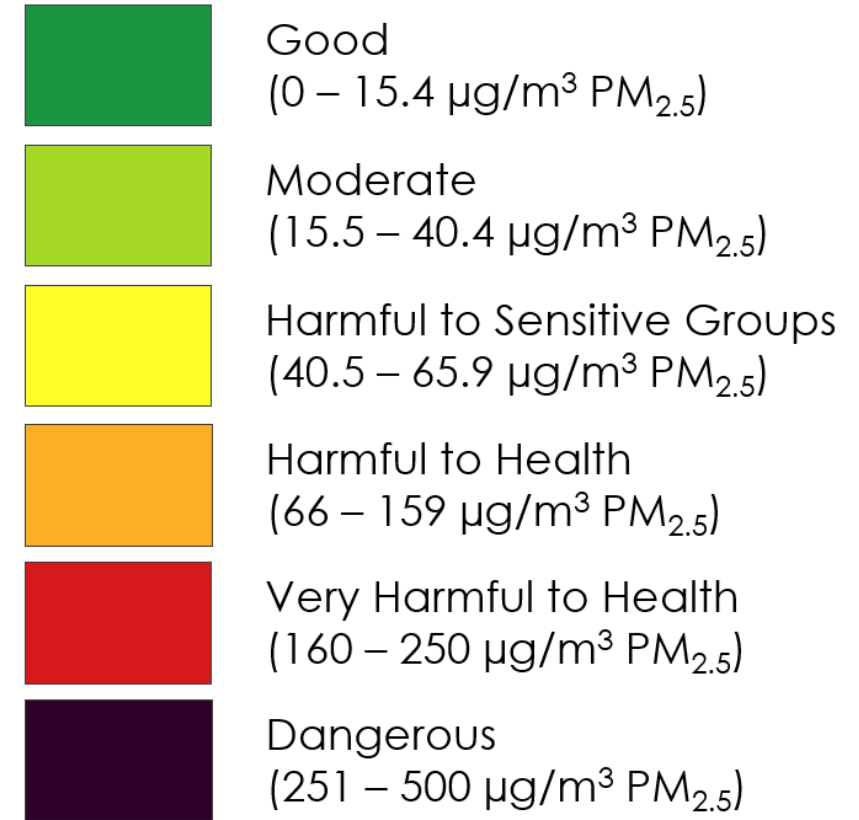


Results – Air Quality Index

El Salvador Air Quality Index May 2013

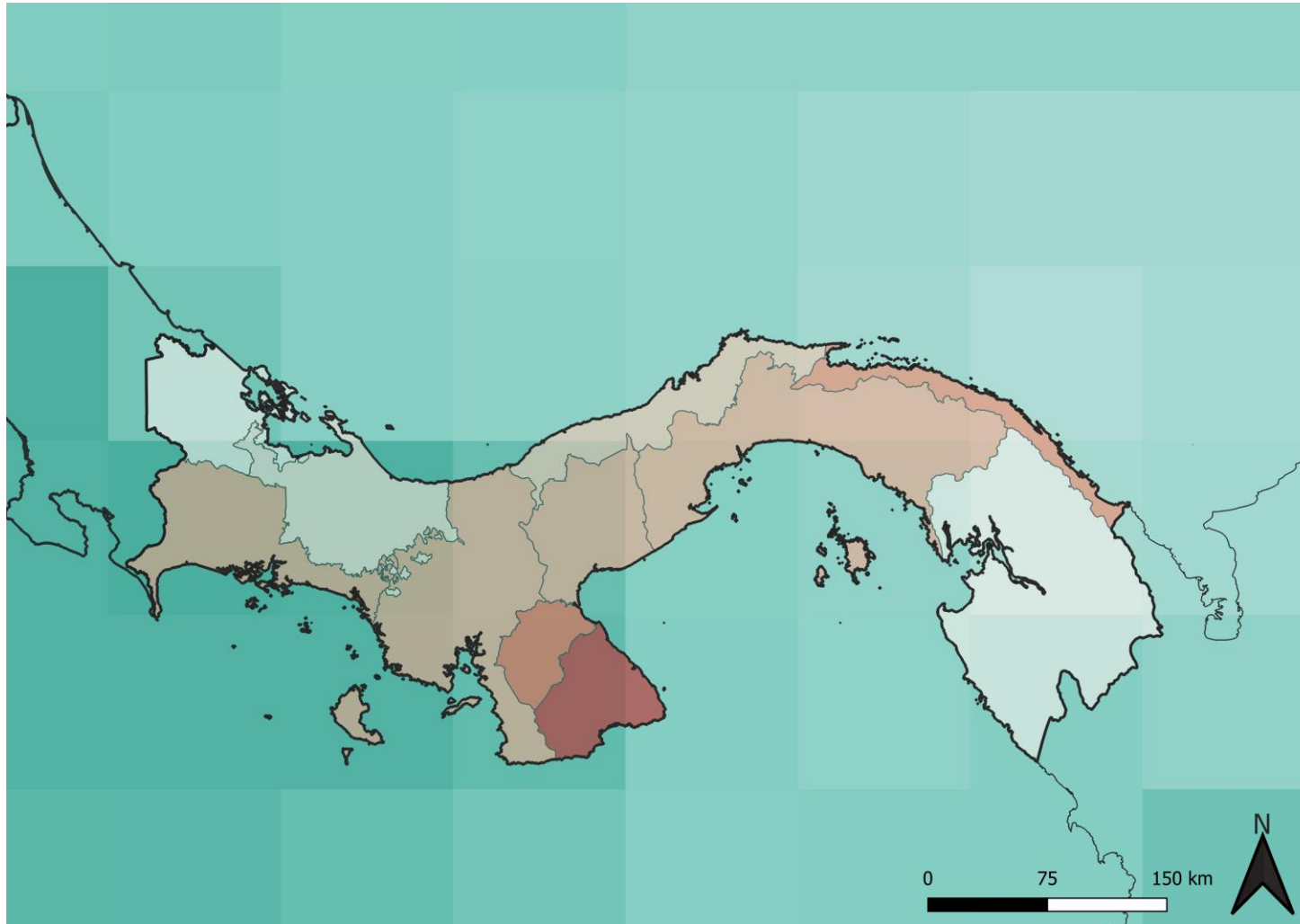
$$PM_{2.5} = 49.24(AOD) + 20.65$$

Average $PM_{2.5}$ Values – May 2013

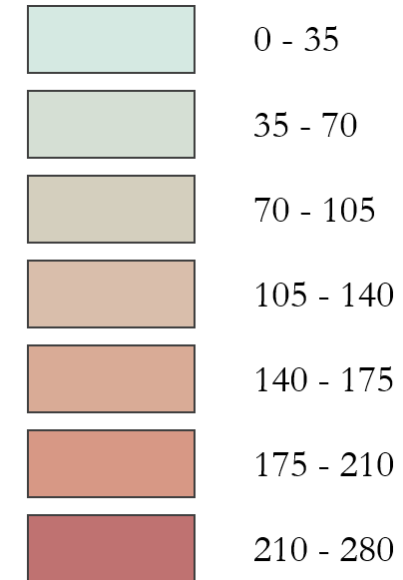


Discussion – Health Concerns

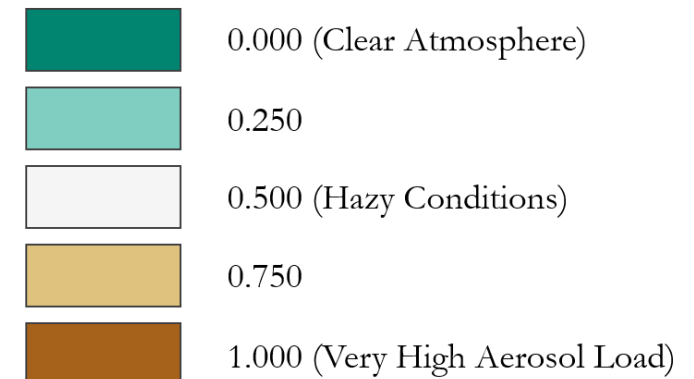
Panama Health Map 2009



No. Deaths per 100,000 People

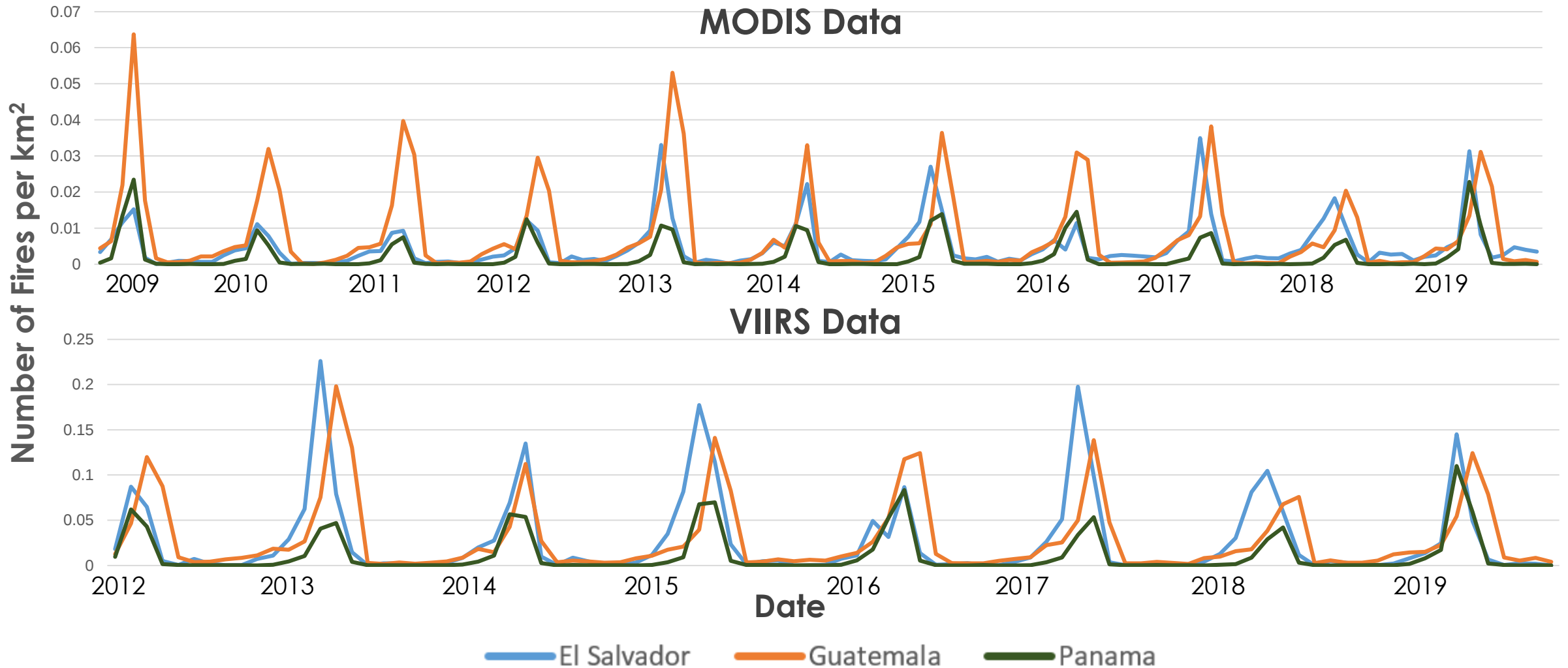


Average AOD Values – 2009



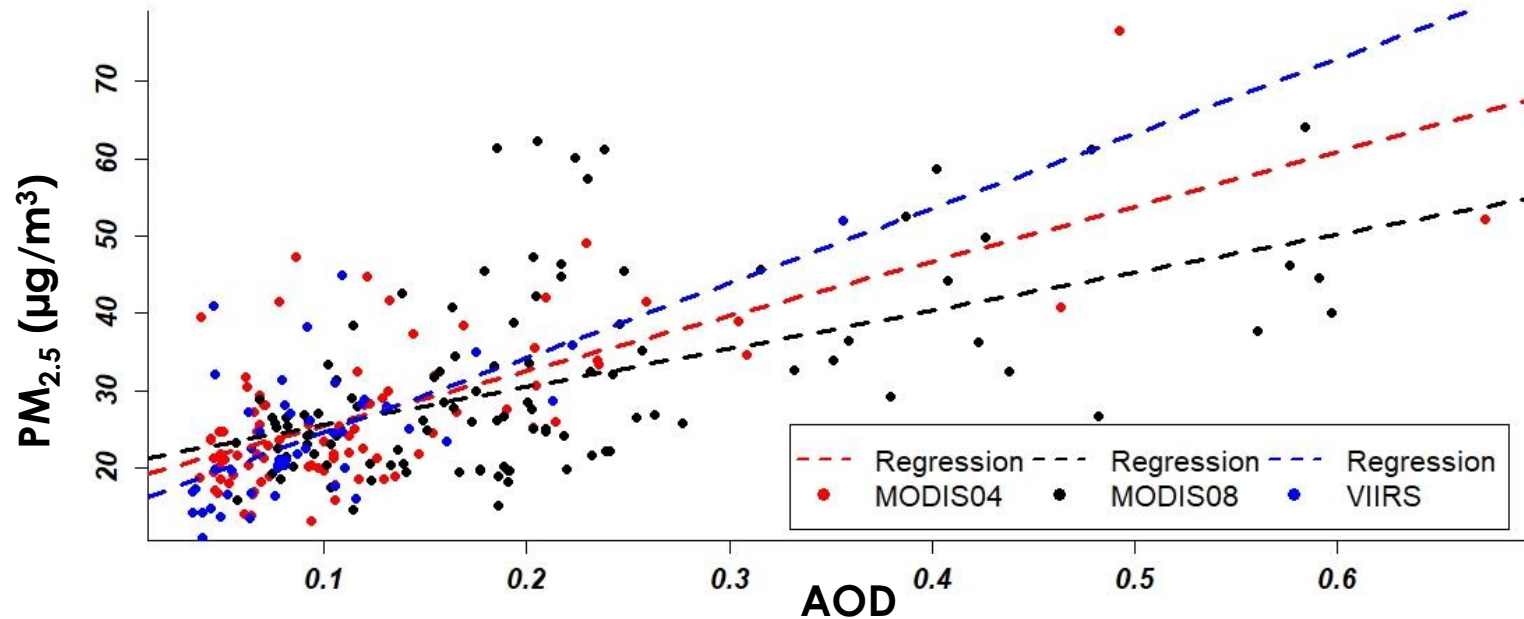
Results – Biomass Burning

No. of Fires per km² in El Salvador, Guatemala, and Panama
(Jan 2009 - Sept 2019)



Results – Comparison VIIRS and MODIS

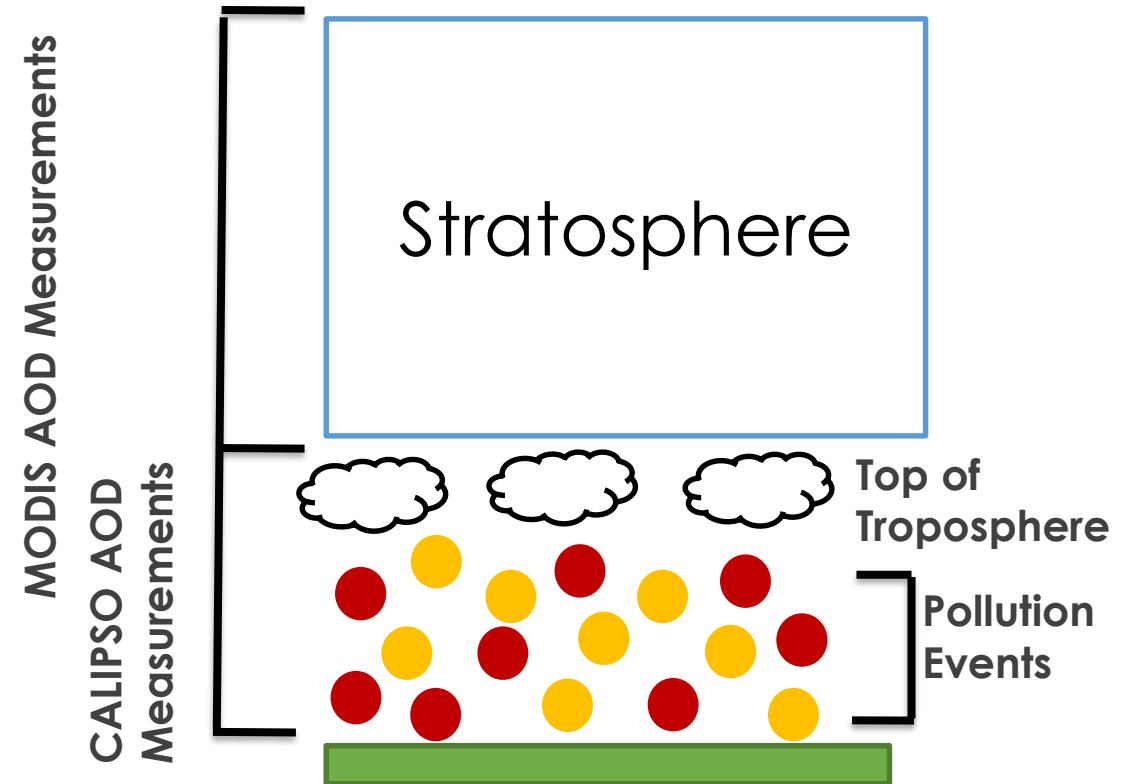
VIIRS and MODIS data for El Salvador (2009-2019)



SATELLITES	B (SE)	BETA	R ²	OBSERVATIONS
MODIS 04				
MODEL	70.89(8.07)***	0.68	0.47	90
VIIRS COMPARISON	57.30(11.46)***	0.60	0.36	47
MODIS 08				
MODEL	49.24(7.13)***	0.55	0.30	111
VIIRS COMPARISON	47.77(8.77)***	0.63	0.40	47
VIIRS				
MODEL	96.53(17.85)***	0.63	0.39	47

Results – CALIPSO and MODIS

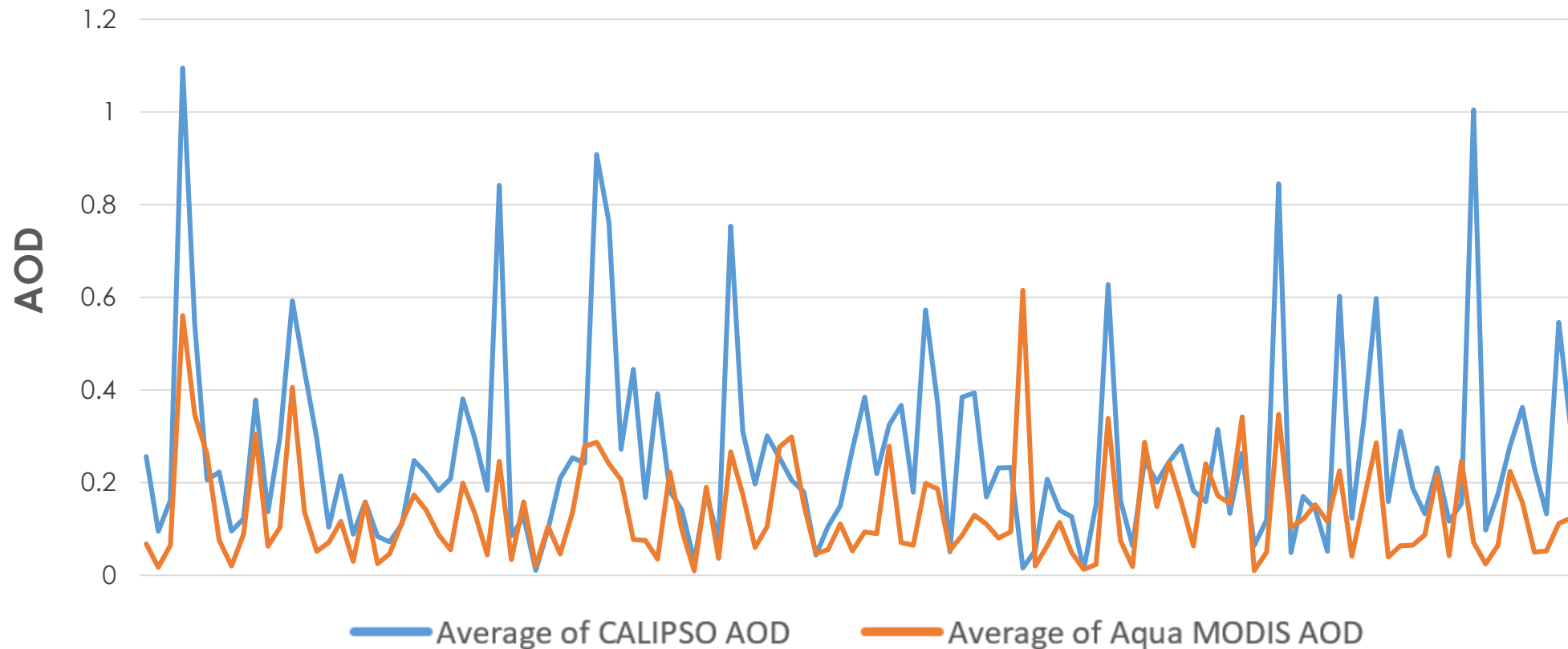
- ▶ CALIPSO measures tropospheric AOD
- ▶ MODIS measures total column



Results – CALIPSO and MODIS

CALIPSO AOD data were used to validate MODIS04 AOD Data

CALIPSO Aqua MODIS Time Plot (2009 - 2019)





Conclusions - Correlations

AOD and PM_{2.5}:

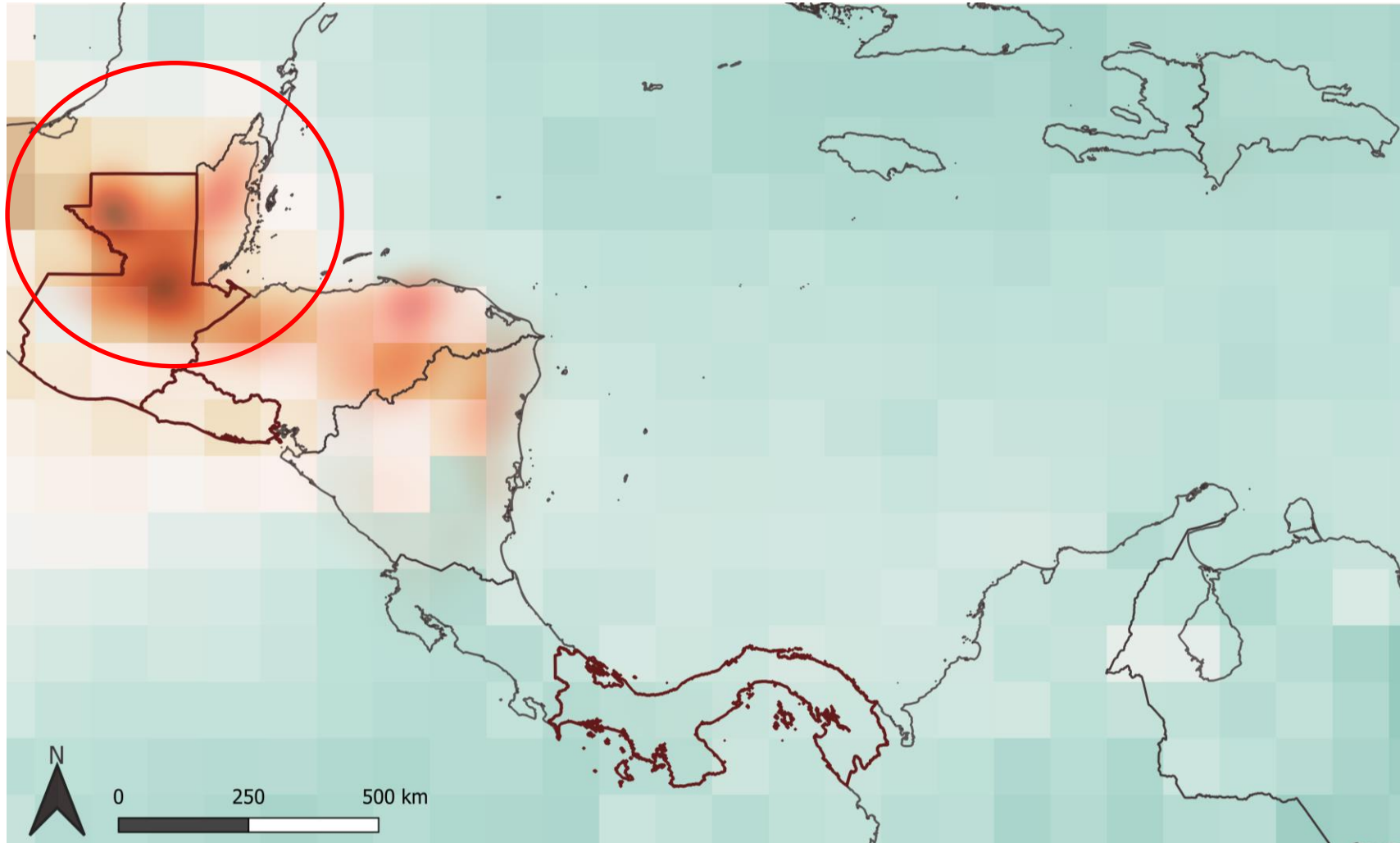
- ▶ There exists a moderate relationship between AOD and PM_{2.5}
- ▶ Simple Linear Regression fails to account for other factors that influence AOD levels
 - ▶ Composition of aerosols
 - ▶ Humidity, wind and temperature

Seasonal discrepancies:

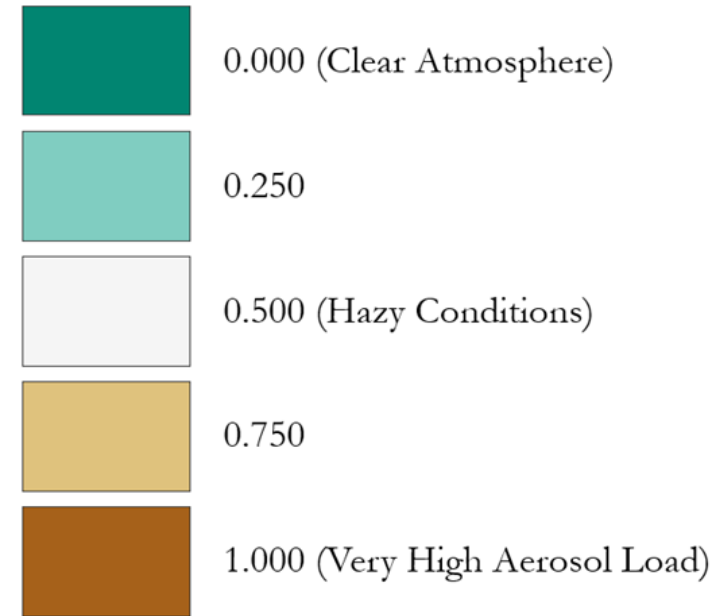
- ▶ Transitions between seasons
- ▶ Instances of fire
- ▶ Greater transportation use and traffic congestion during the rainy season

Conclusions

Fires contribute to high concentrations of aerosols



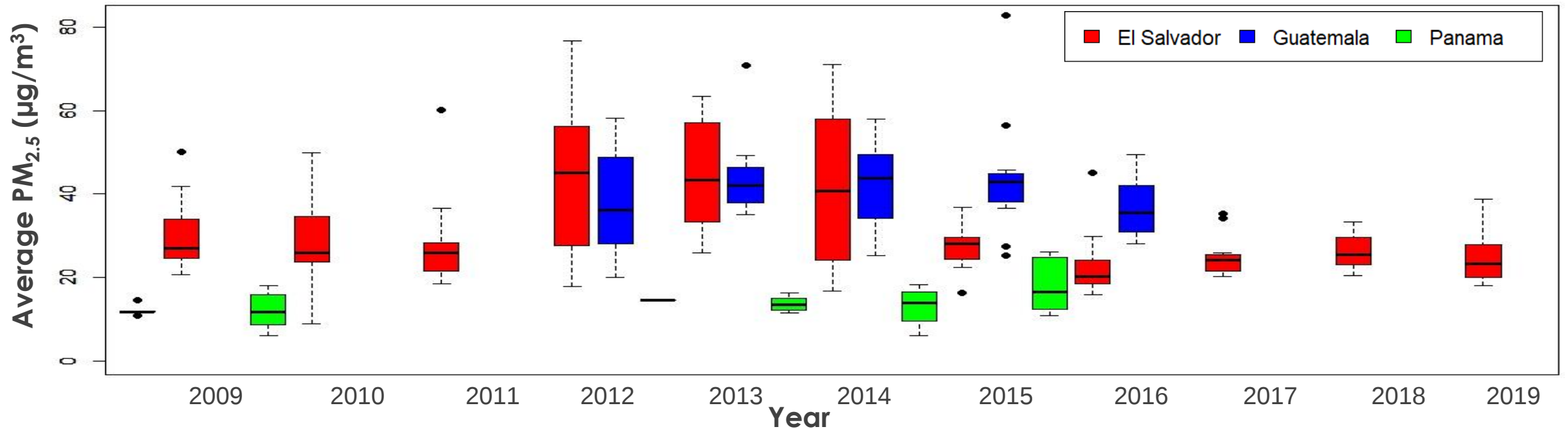
Average AOD Values – May 2013



Errors & Uncertainties

- ▶ Cloud coverage during some days limited observations
- ▶ Inaccurate data or gaps in $PM_{2.5}$ data
- ▶ AOD accounts for Humidity, $PM_{2.5}$ does not
- ▶ AOD takes into account aerosols larger than $PM_{2.5}$

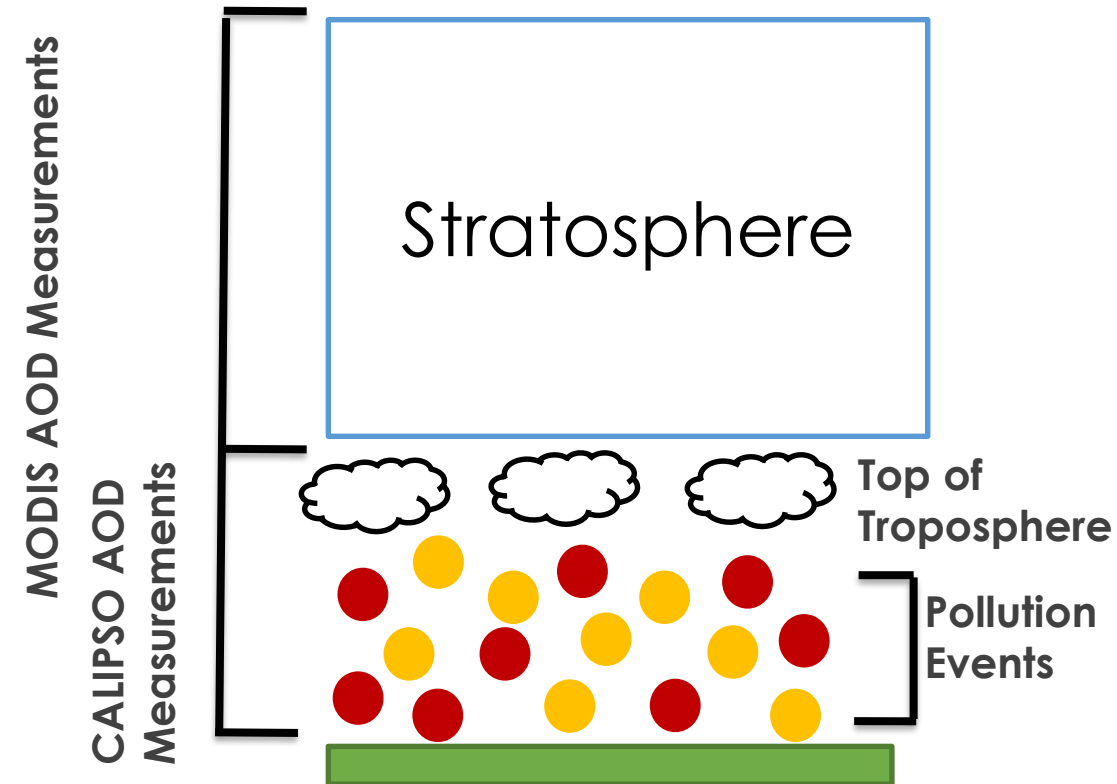
Average yearly measurements for El Salvador, Guatemala and Panama



Future Work

- ▶ Determine the impact from other factors (i.e. humidity, wind, and temperature, etc.)
- ▶ Use VIIRS for all statistical analysis
- ▶ Further Analyses Regarding Community Concerns:
 - ▶ Investigate potential correlation with health impacts
 - ▶ Measure the impact particulate matter has on the environment
 - ▶ Air quality baseline maps can be done using MODIS04
 - ▶ Quantify aerosols sourced from the newly-commissioned Cobre Mine in Panama

- ▶ Understanding the aerosol vertical distribution/boundary layer height issue



ACKNOWLEDGEMENTS

DEVELOP

► Advisors

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► Partners

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Marco Tuilo Guillen, Autonomous University of Chiriqui

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Wilfredo Urriola, Specialized Institute of Analysis of the University of Panama

► Contributors

Carlos Gonzalez, CCAD

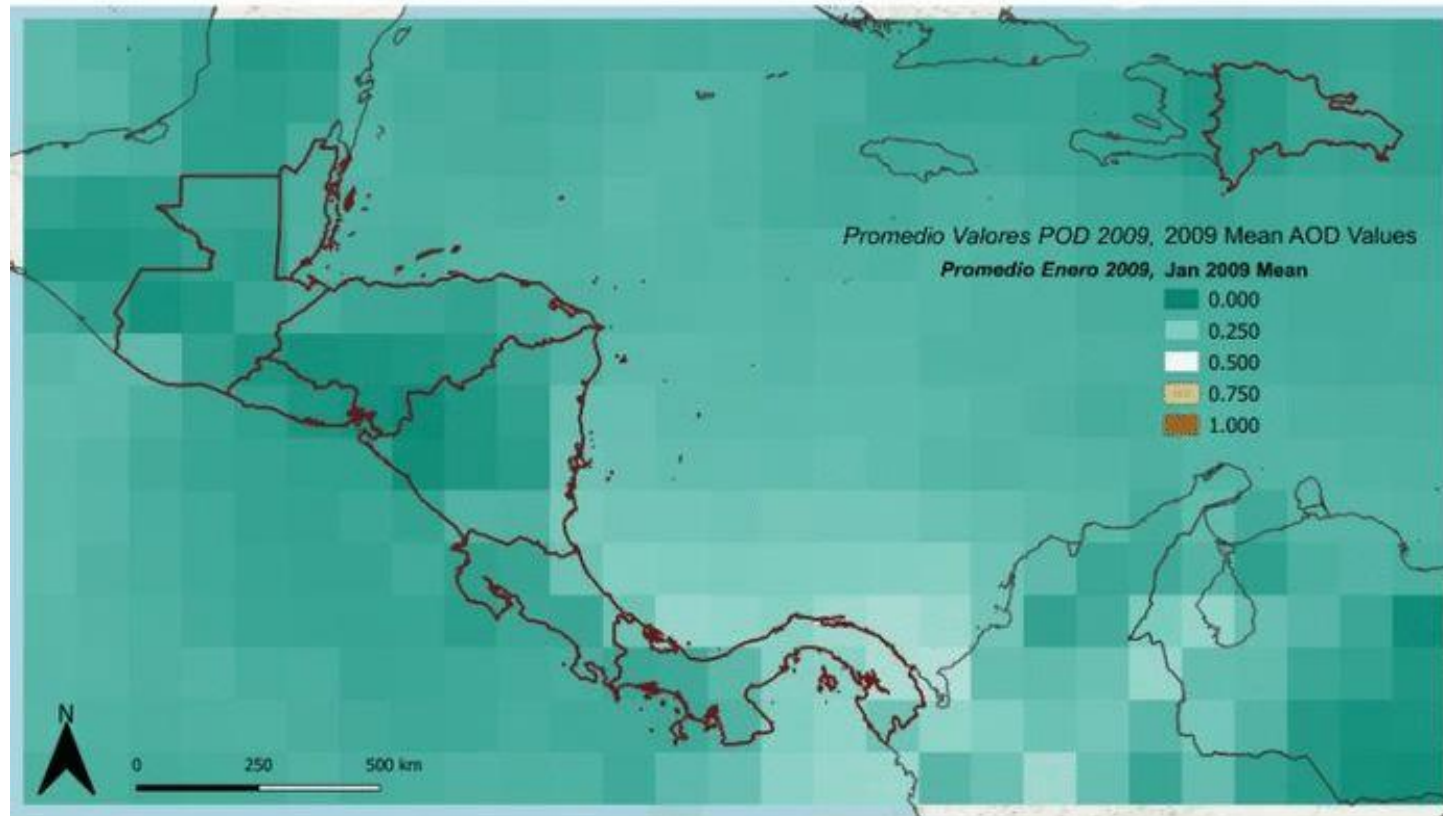
Steve Padgett, SSAI Translator

Emil Cherrington, SERVIR

Sean McCartney, NASA Goddard Space Flight Center

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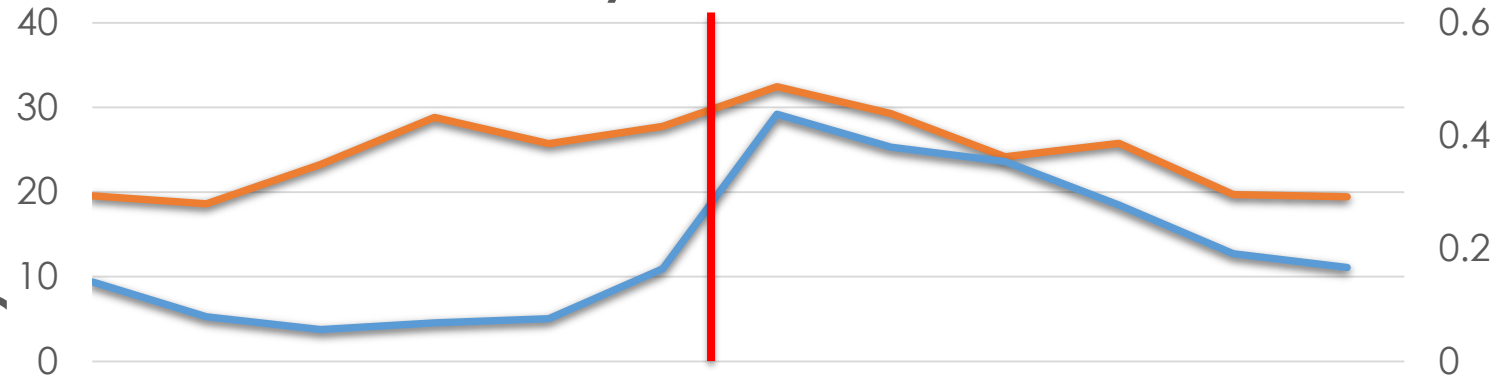
Questions?



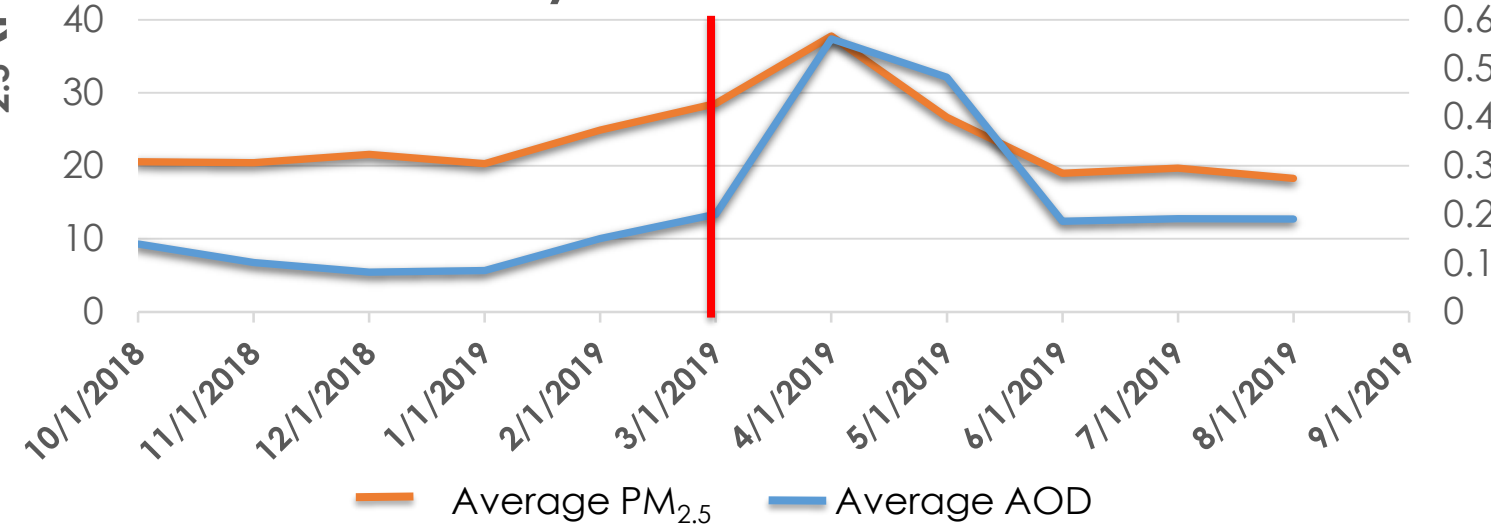
Thank you!

Results - Seasonal Analysis

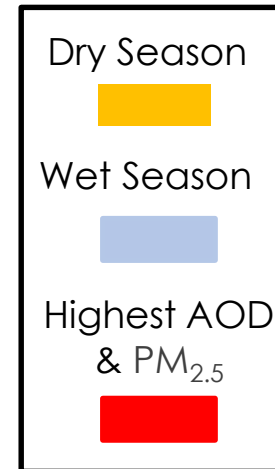
El Salvador Dry and Wet Season 2017- 2018



El Salvador Dry and Wet Season 2018 - Present



AOD



El Salvador MODIS08 Monthly Average AOD PM_{2.5}

Date	AVG AOD	AVG PM _{2.5}
10/1/2016	0.12	18.44
11/1/2016	0.10	17.53
12/1/2016	0.09	23.12
1/1/2017	0.09	26.97
3/1/2017	0.18	33.18
4/1/2017	0.35	33.90
5/1/2017	0.40	24.83
6/1/2017	0.24	22.16
7/1/2017	0.18	19.61
8/1/2017	0.22	19.83
9/1/2017	0.24	22.13
10/1/2017	0.14	19.54
11/1/2017	0.08	18.59
12/1/2017	0.06	23.27
1/1/2018	0.07	28.81
2/1/2018	0.08	25.72
3/1/2018	0.16	27.78
4/1/2018	0.44	32.44
5/1/2018	0.38	29.25
6/1/2018	0.35	24.15
7/1/2018	0.28	25.75
8/1/2018	0.19	19.72
9/1/2018	0.17	19.43
10/1/2018	0.14	20.56
11/1/2018	0.10	20.42
12/1/2018	0.08	21.57
1/1/2019	0.09	20.30
2/1/2019	0.15	24.87
3/1/2019	0.20	28.54
4/1/2019	0.56	37.77
5/1/2019	0.48	26.64
6/1/2019	0.19	18.98
7/1/2019	0.19	19.69
8/1/2019	0.19	18.28