

# Aerosol Observations from Geostationary Sensors

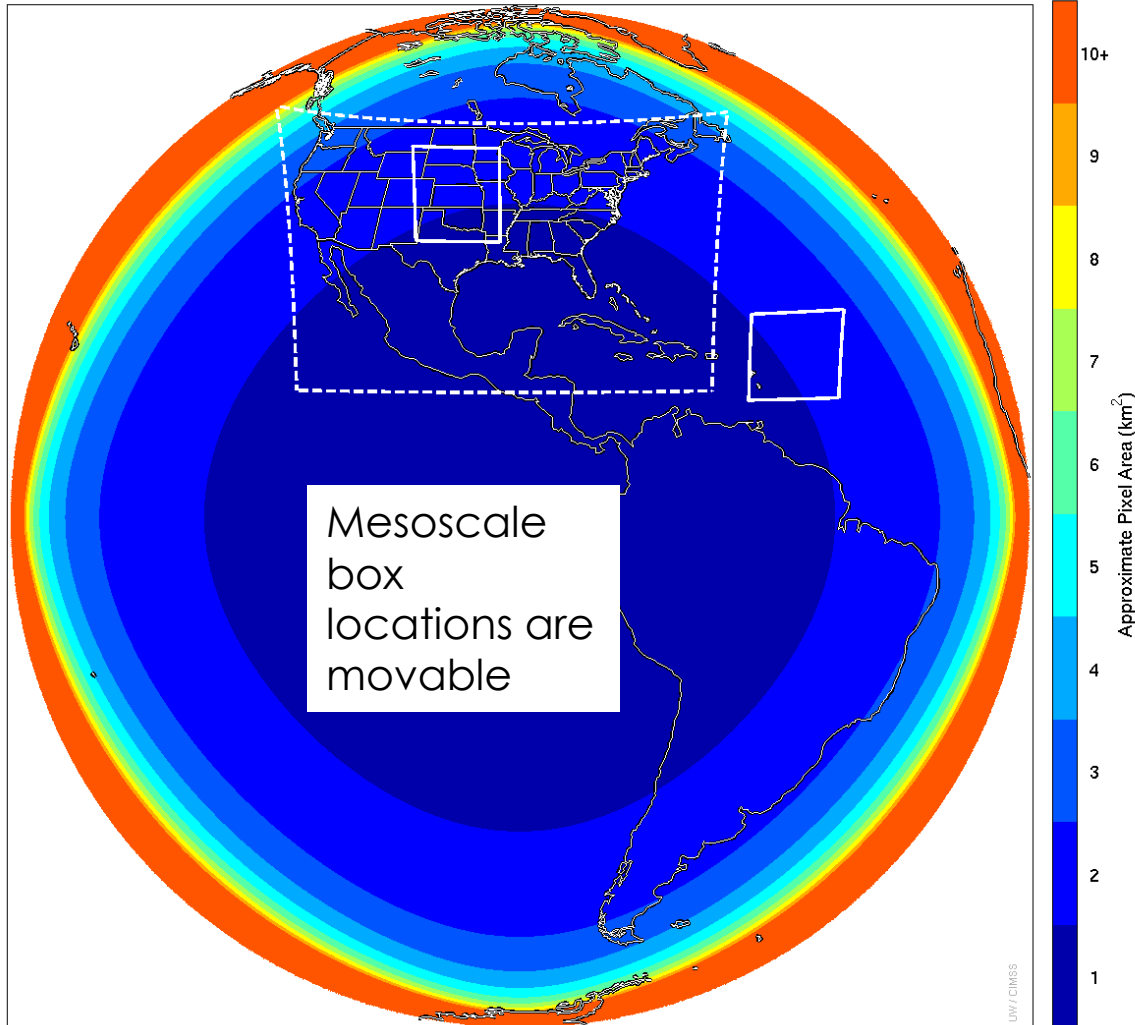
Pawan Gupta, Melanie Follette-Cook, Sarah Strode, Carl Malings

NASA Air Quality Remote Sensing Training, US EPA, Raleigh, NC, March 21-23, 2023

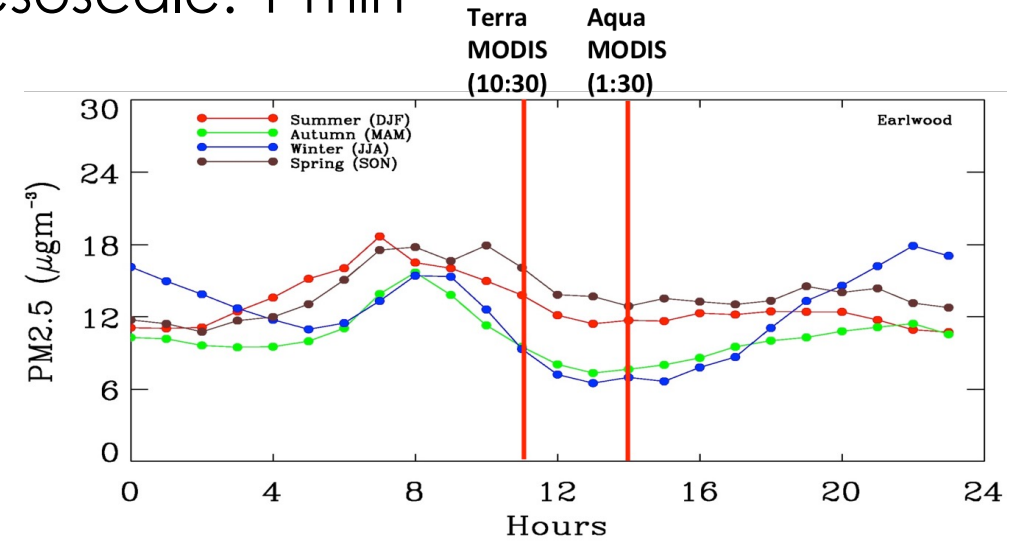
# GOES-R ABI



Approximate Pixel Area (Nominally 1km at Nadir) from -89.5 West



- Default Operational Mode:
  - Full Disk: 15 min
  - CONUS: 5 min
  - Mesoscale: 1 min

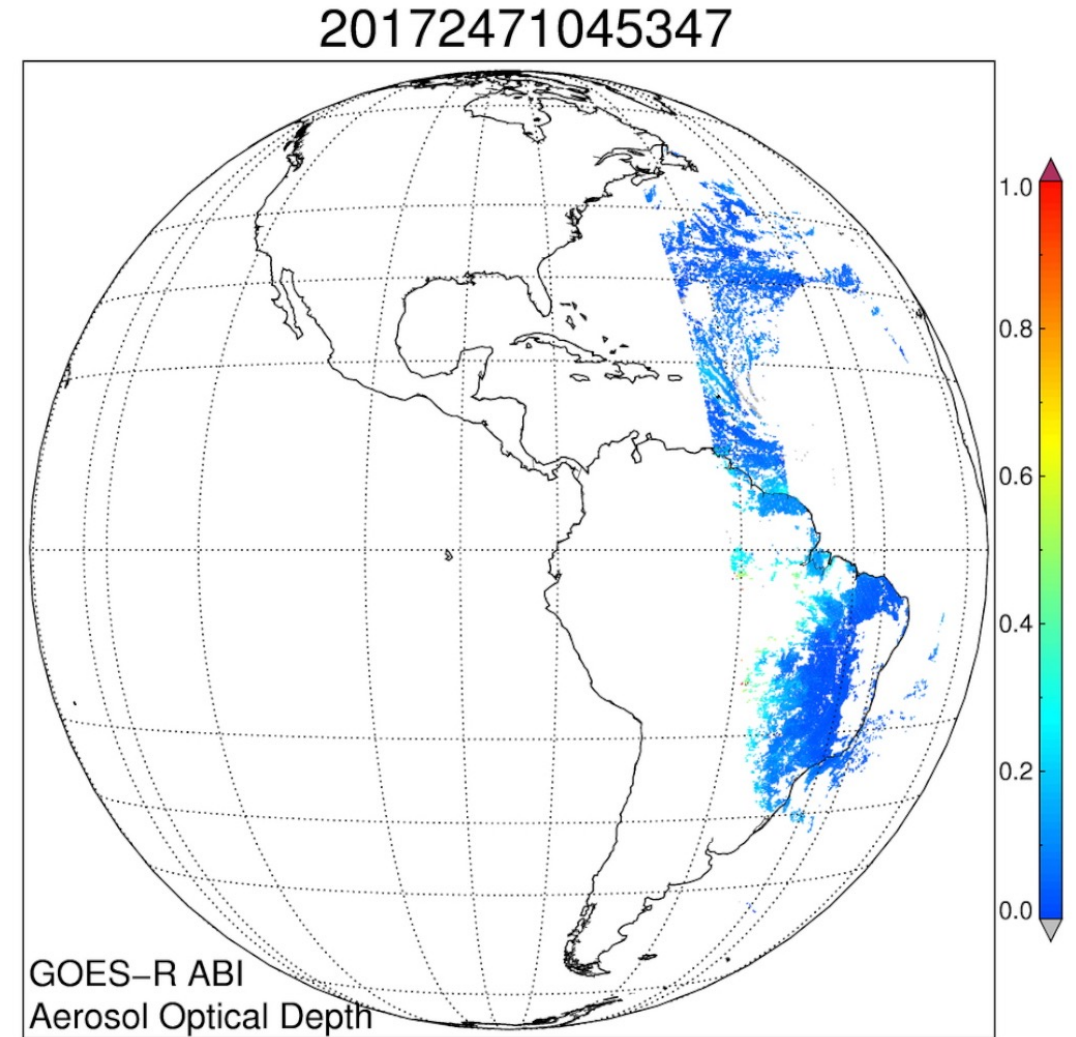


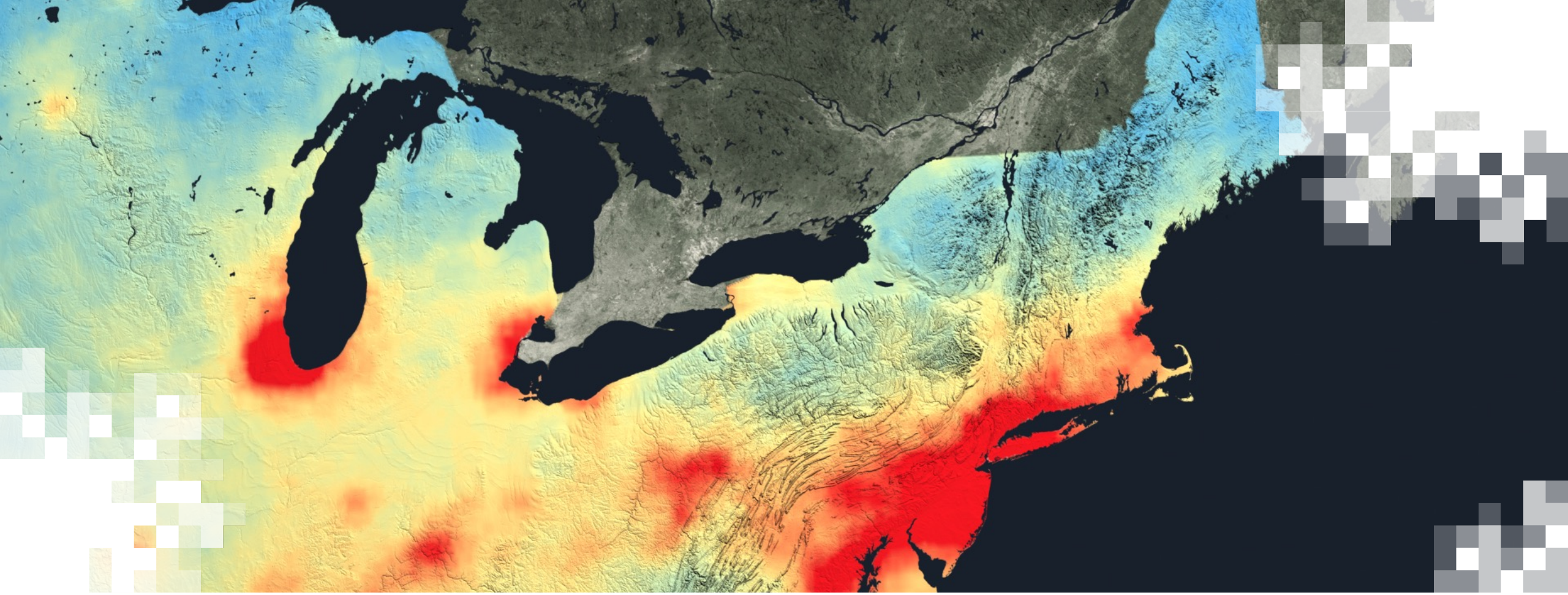
**Polar orbiting satellites only provide 1-2 observations per day, which limits their application for continuous air quality monitoring.**



# Aerosols Datasets

- **NASA**
  - Dark Target (10 km) – Available on request
  - Deep Blue (10 km) – Future
  - MAIAC (2km?) – Future
- **NOAA**
  - 2 km – Available





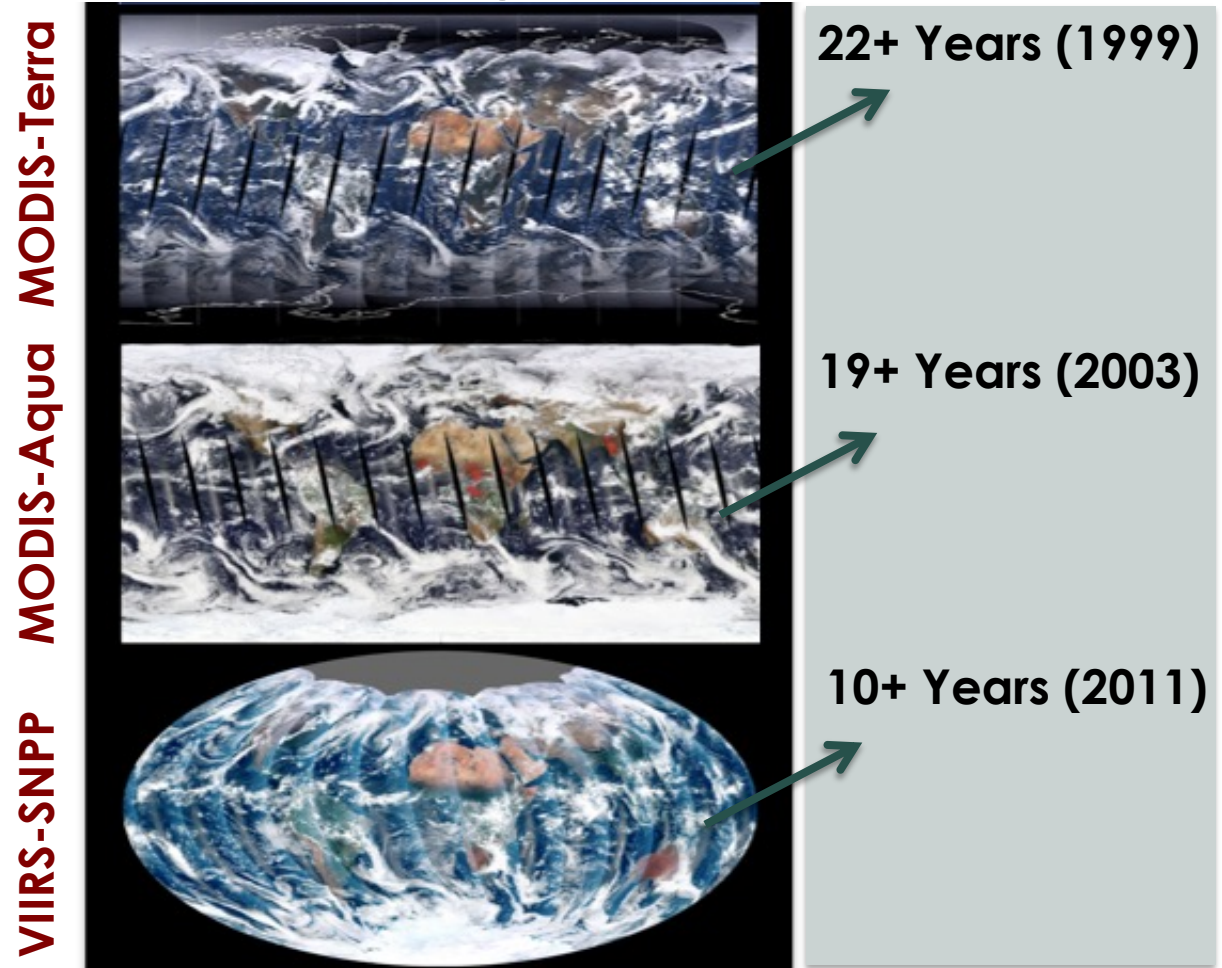
NASA Aerosol Datasets  
Dark Target (<https://darktarget.gsfc.nasa.gov/>)



# Global Aerosol Retrieval from MODIS

- Dark Target (“DT” Ocean and Land) Operational at 3 and 10 km from both Terra & Aqua MODIS since their launch.
- Initially developed by Kaufman & Tanre, 1997
- Revised - Levy & Remer, 2007, 2013
- 3 km Product - Remer et al., 2013
- Urban Surfaces - Gupta et al., 2016
- Applied to AH1 – Gupta et al., 2019
- Today, multiple aerosol retrieval algorithms coexist.

## Polar Orbiting Sensors



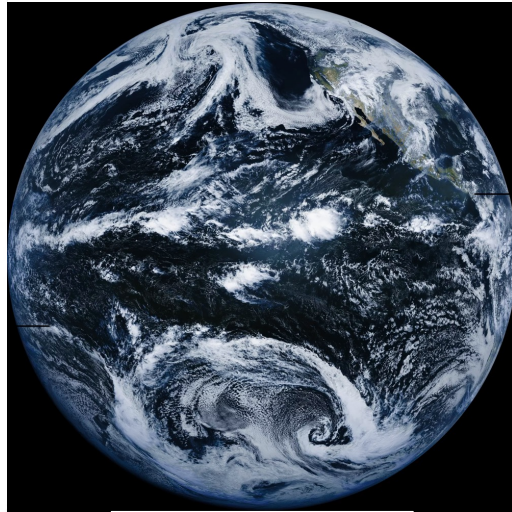




# GEO Constellation



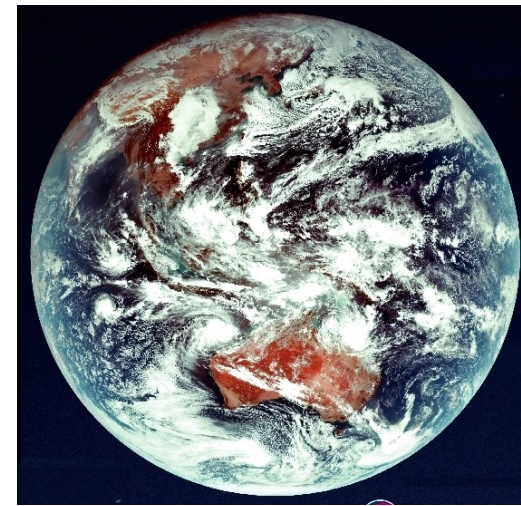
**GOES-R**



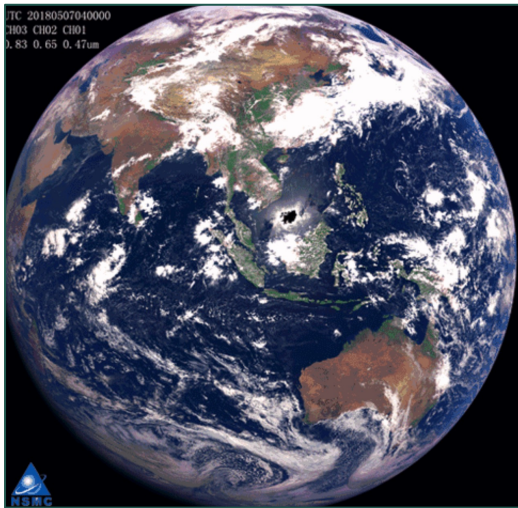
**GOES-S/T**



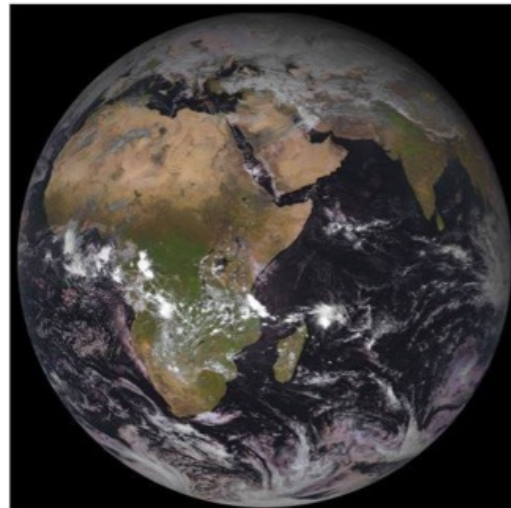
**Himawari -8/9**



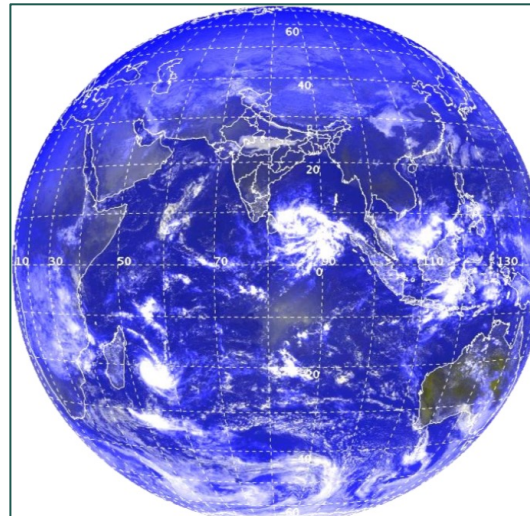
**AMI-GK-2A**



**Fengyun-4**



**MST - (FCI)**



**INSAT - (?)**

- New regional opportunities
- New retrieval challenges
  - Surface characterization
  - Viewing geometry
  - Cloud masking
  - Spectral differences
  - Regional accuracies vs. global consistency

# Importing the MDT Algorithm to AHI & ABI

- ABI does not have a green channel – ocean retrieval.
- Surface characterization needs revision to account for the change in wavelength. SWIR NDVI are revised and estimated using a pair of 0.86 & 2.3  $\mu\text{m}$  channels as compared to 1.24 and 2.1 in MODIS.
- Pixel selection, cloud masking (no cirrus band (1.37  $\mu\text{m}$ ) in AHI), and aerosol model selection remain the same as the MODIS DT algorithm.
- Gas corrections and look-up tables are revised for GEO channels.
- The revised algorithm is applied on AHI and ABIs.





# Himawari – April-May 2016

## KORUS-AQ

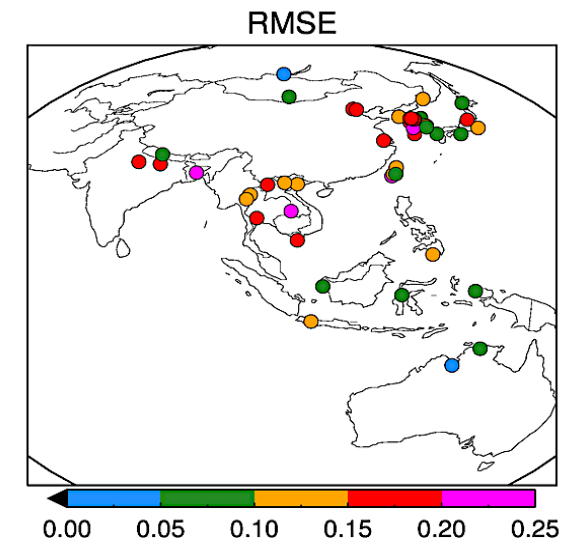
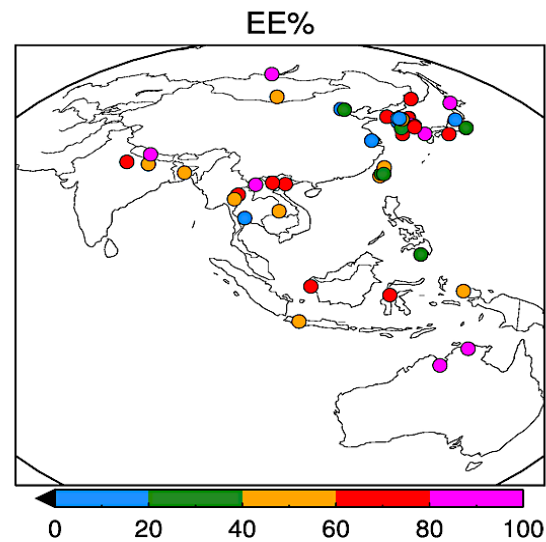
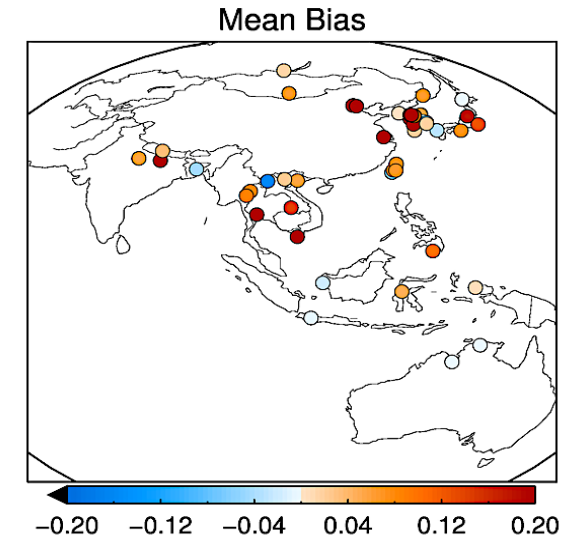
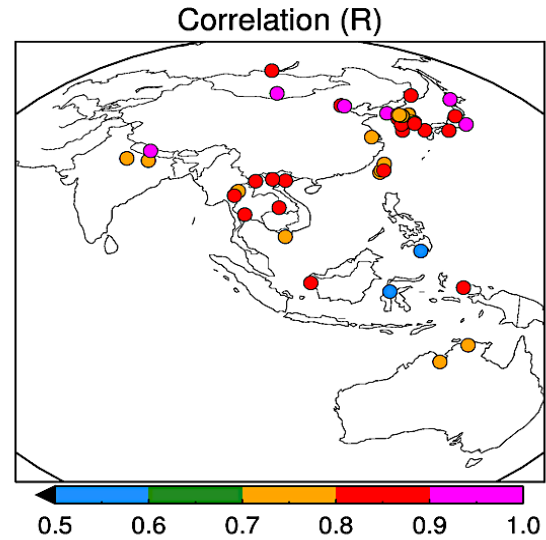
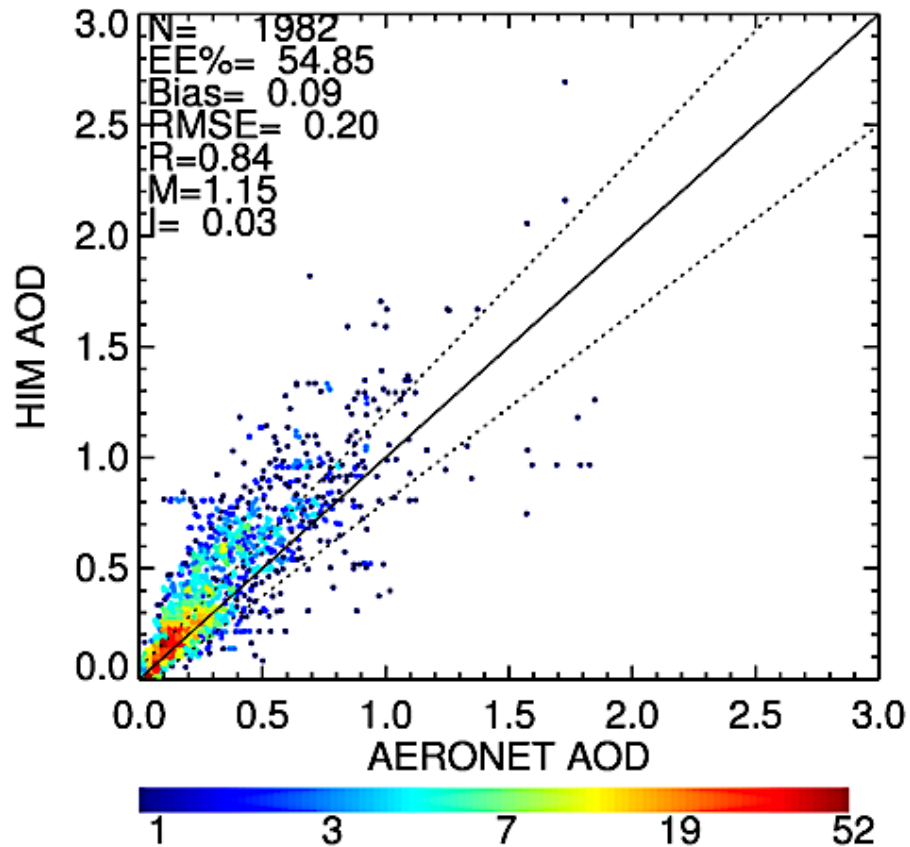


Gupta et al., 2019  
<https://www.atmos-meas-tech-discuss.net/amt-2019-65/>

NASA's Applied Remote Sensing Training Program



# AHI vs. AERONET



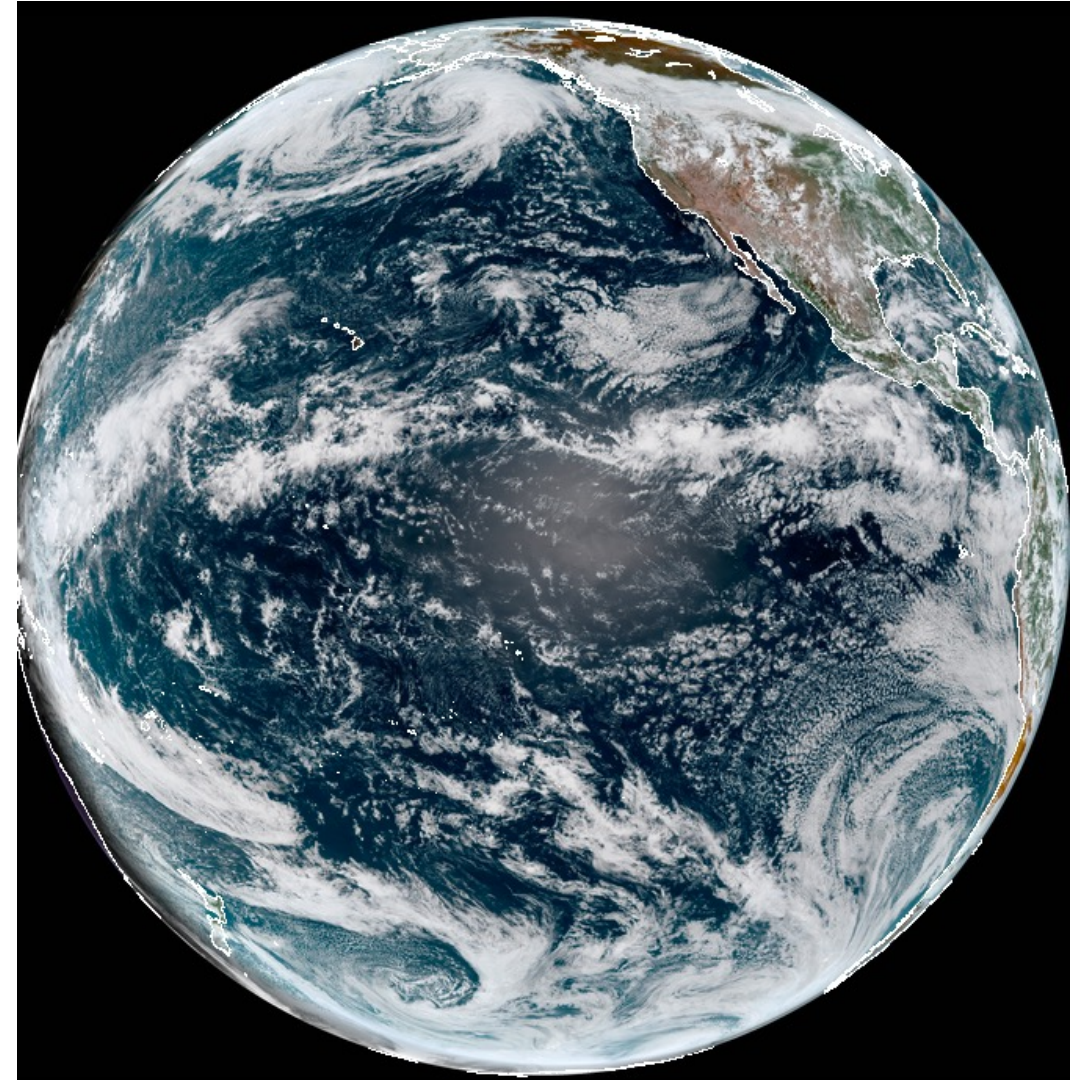
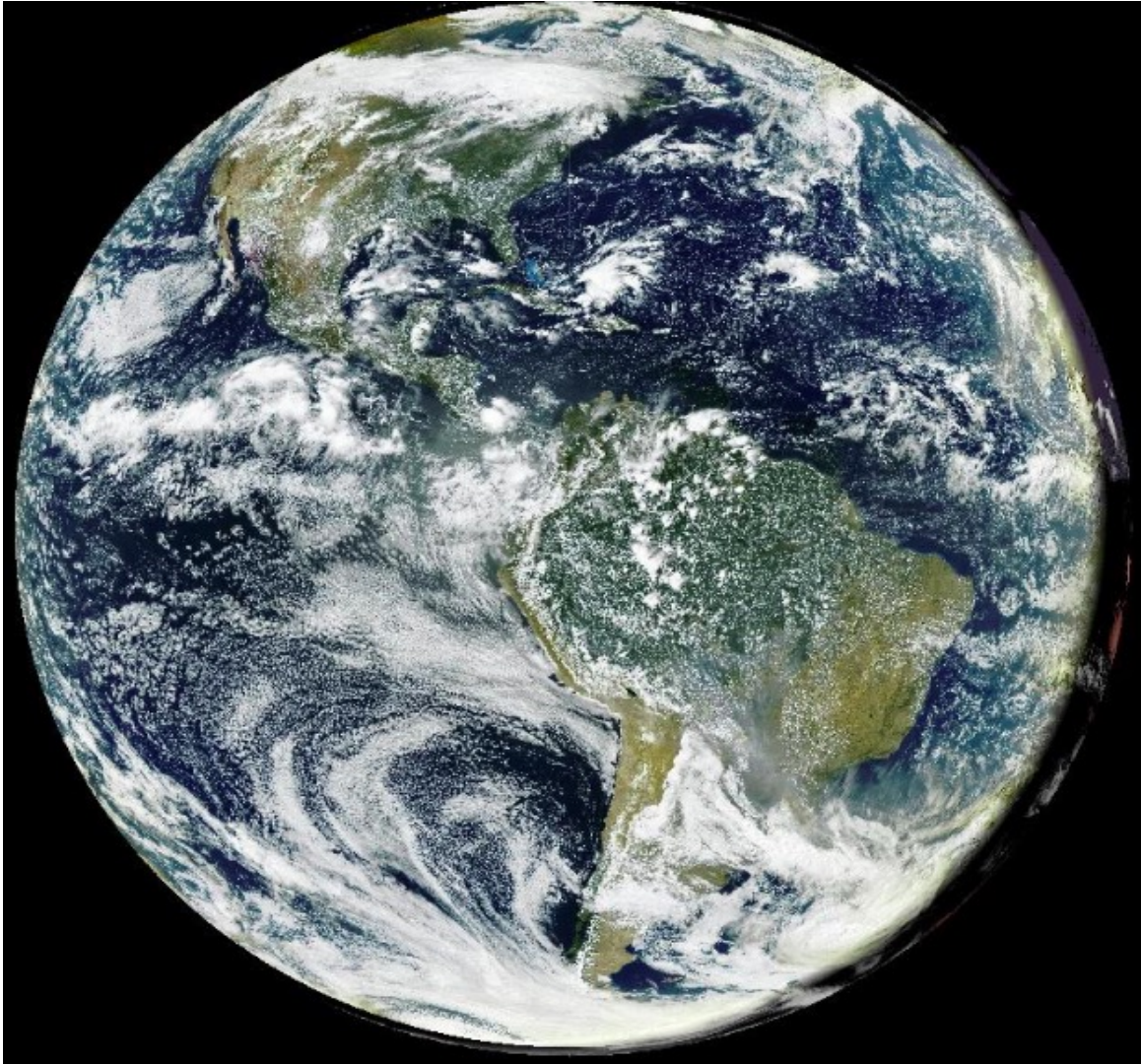
Gupta et al., 2019  
<https://www.atmos-meas-tech-discuss.net/amt-2019-65/>

NASA's Applied Remote Sensing Training Program



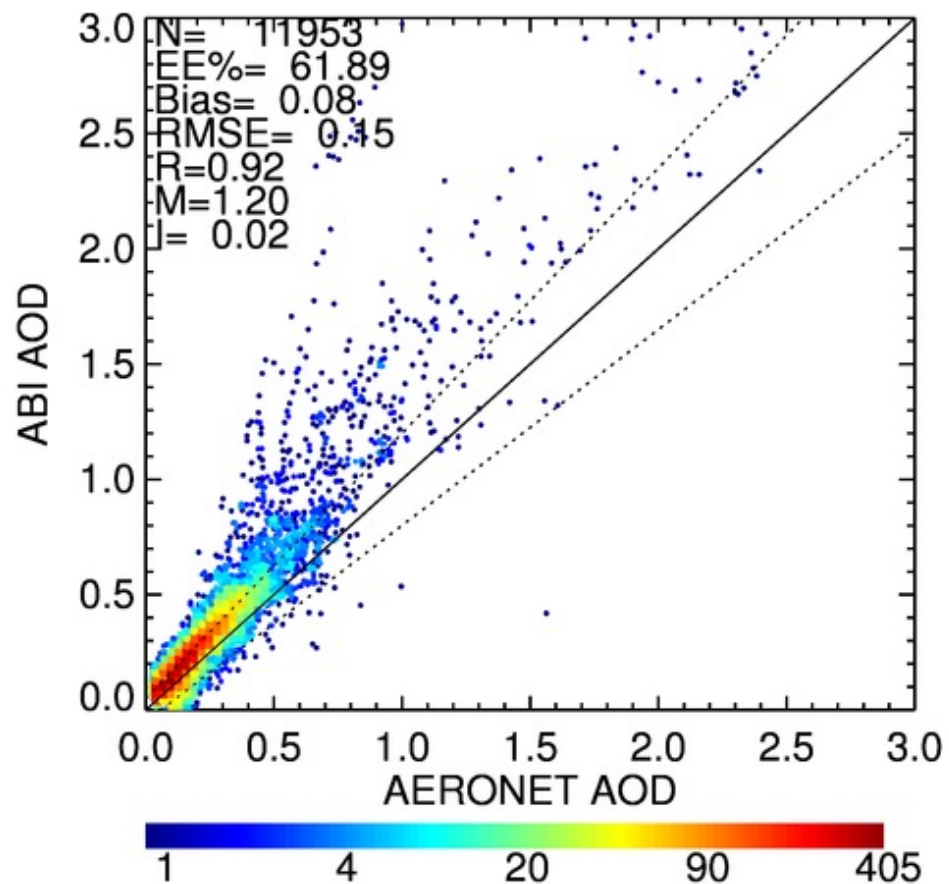


# GOES-East & GOES-West

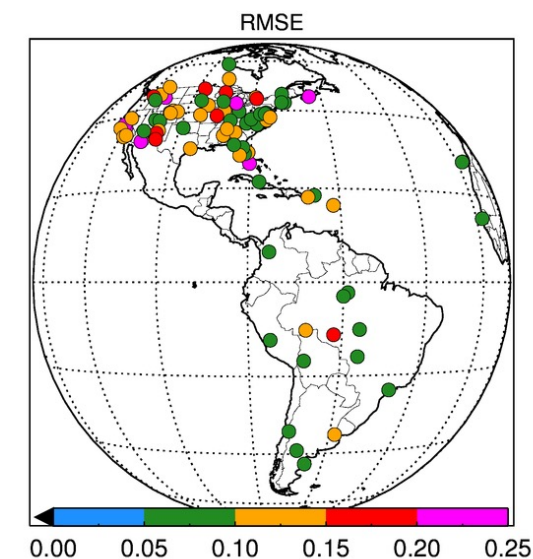
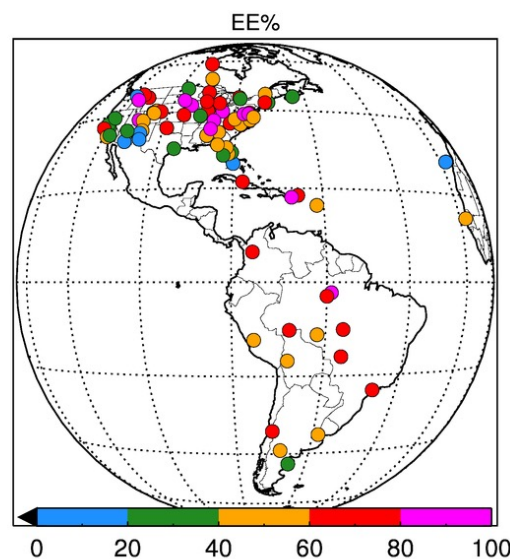
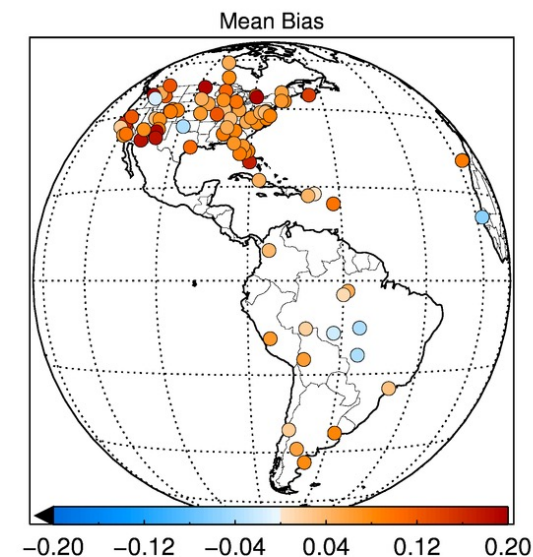
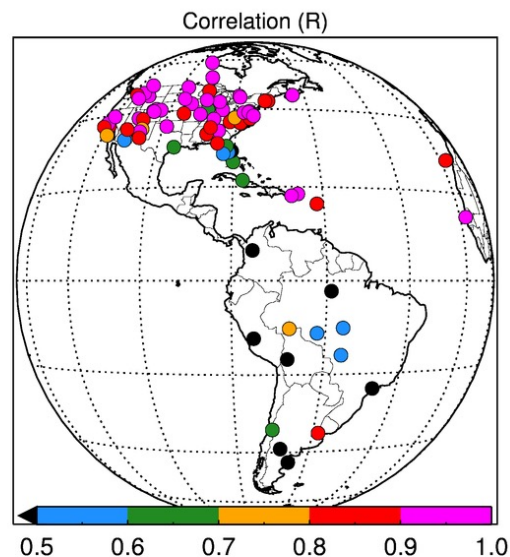




# Preliminary ABI Validation – August 2018



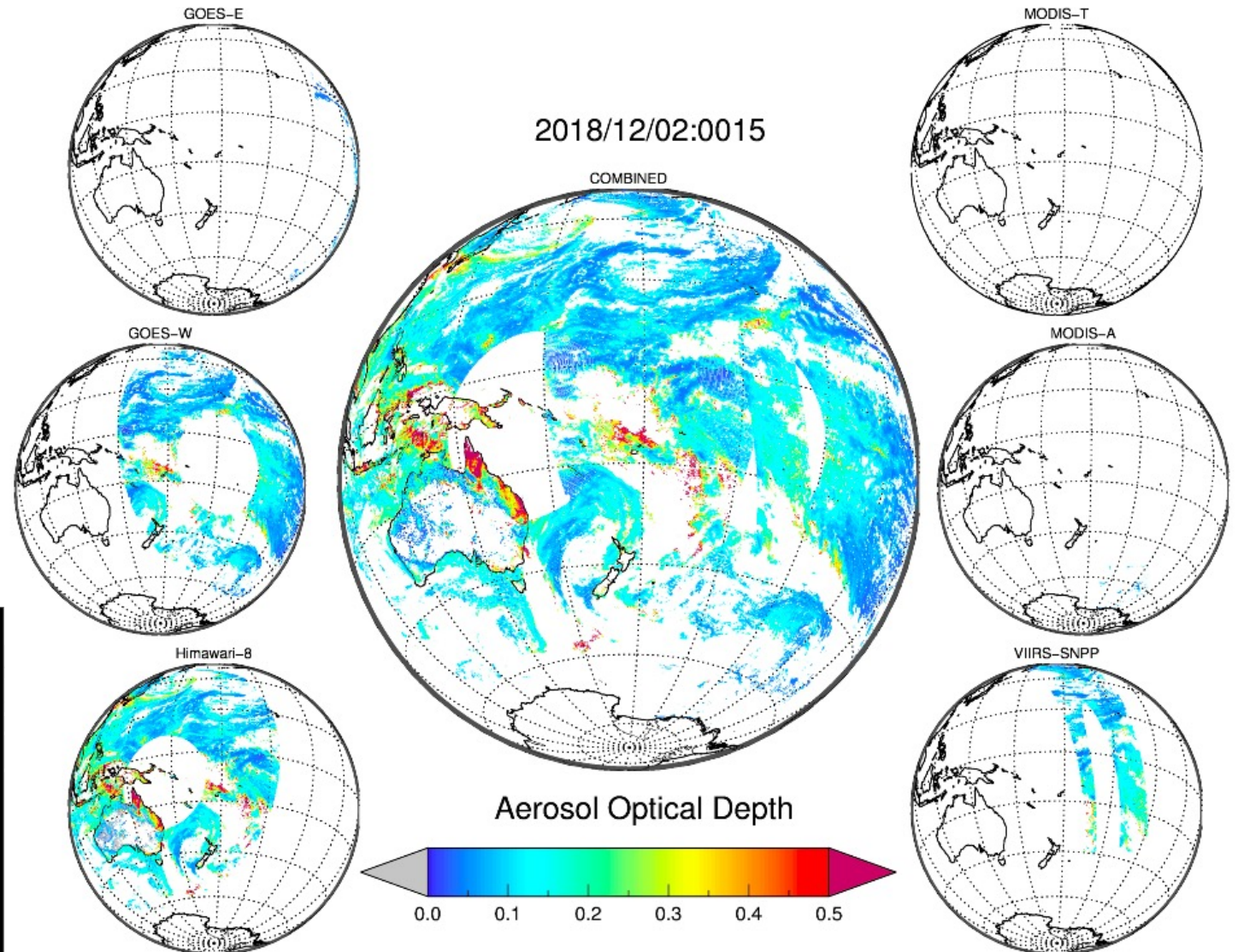
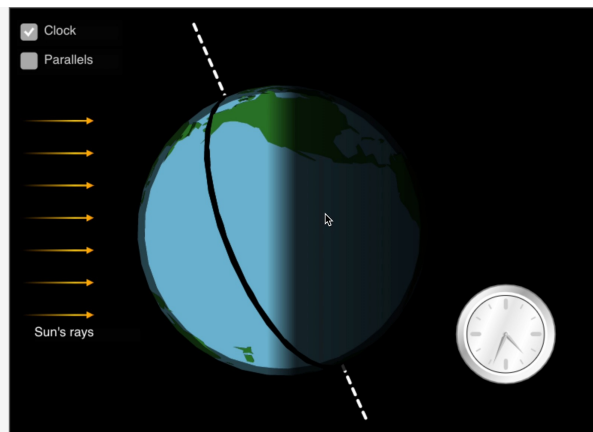
**15-minute full disk data from ABI are used for this analysis.**

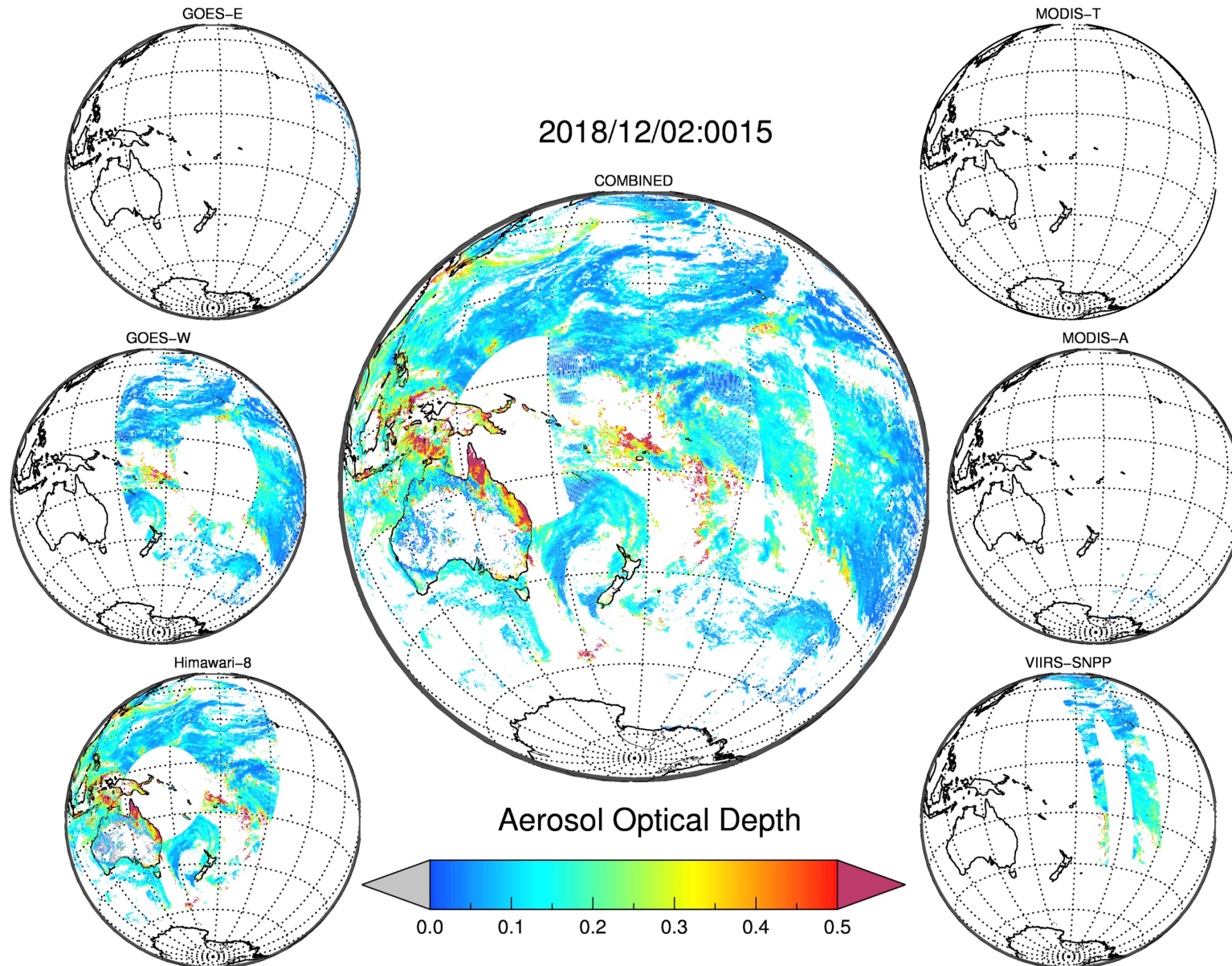




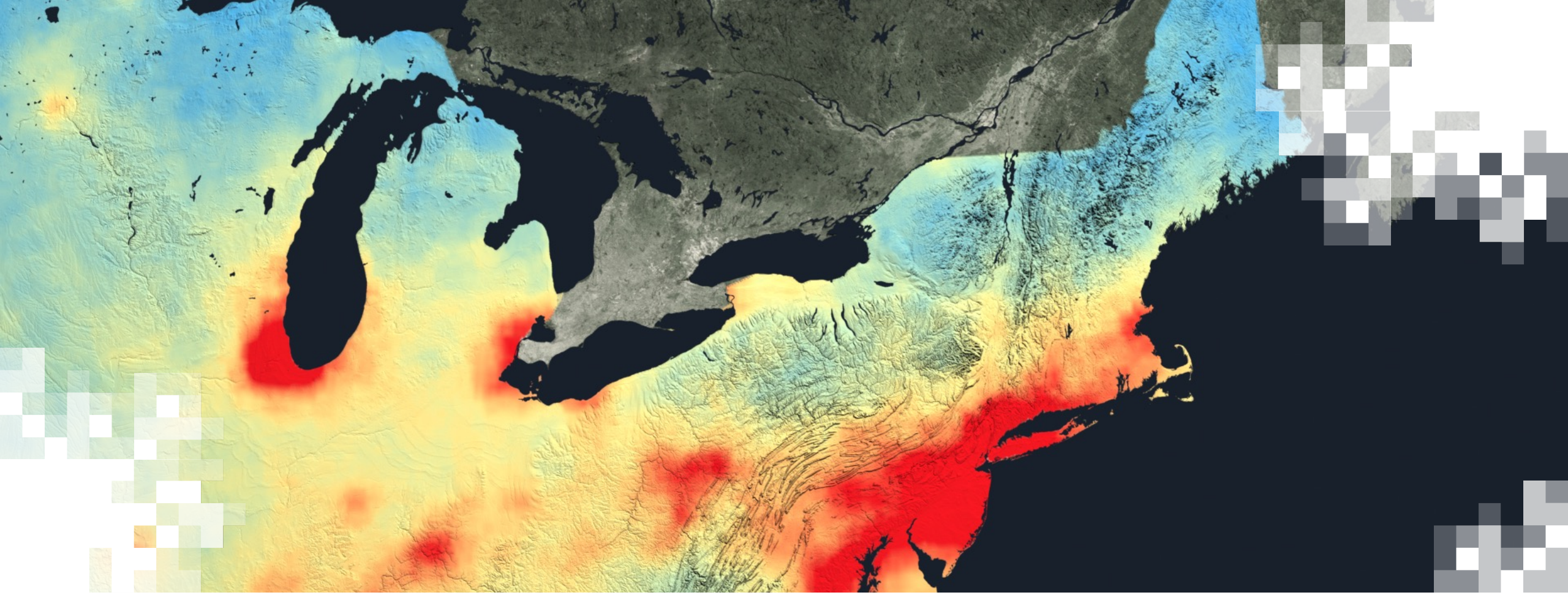
# Integrated Data – Preliminary Work

- Same DT algorithm applied to 3 LEO and 3 GEO sensors
- Initial data are integrated using simple box averaging method
- December 1, Every 30 Minutes









NOAA Aerosol Products  
(Slides Taken from Amy K. Huff, Presented at  
ARSET Training on [GEO](#))



# ABI AOD Specifications and Availability

- AOD is available from ABI on GOES-16 (GOES-East) and GOES-17 (GOES-West).
  - GOES-18 replaced GOES-17 as GOES-West in January 2023.
- ABI AOD Data Range: [-0.05, 5]
- Separate AOD algorithms for over land and water
- MODIS and Early VIIRS Heritage (*Tanre et al., 1997; Remer et al., 2005; Levy et al., 2007, Vermote et al., 2007*)

ABI Band	Wavelength (μm)	AOD Retrieval		Internal Test	
		Land	Water	Land	Water
1	0.47	X			X
2	0.64	X	X		
3	0.865		X	X	
4	1.378			X	X
5	1.61		X	X	
6	2.25	X	X		
14	11.2			X	X

Sensor	Satellite	Spatial Resolution (km) at Nadir	Coverage**	Maturity Level†	Availability Starting
ABI	GOES-16	2.0	Full Disk CONUS	Provisional*	7/25/2018
	GOES-17			Provisional*	1/1/2019

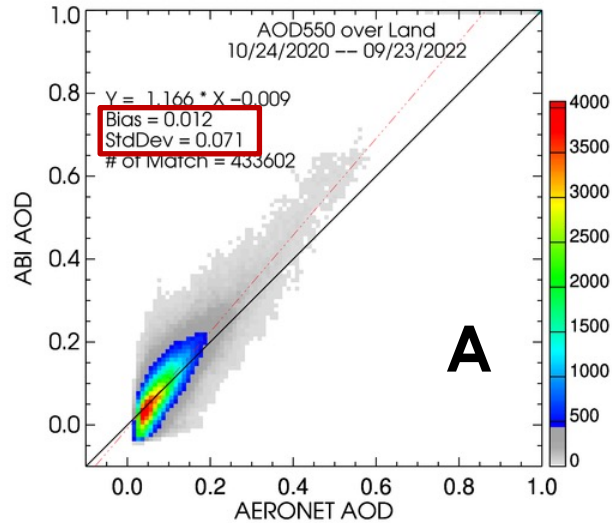
\*\*AOD is **not** available from the ABI Mesoscale sectors!

†Definitions of aerosol product maturity levels (e.g., validated, provisional, beta) are listed [here](#).

\*Provisional status means product quality may not be optimal; incremental product improvements are still occurring; product is ready for operational evaluation; and the research community is encouraged to participate in the quality assurance/validation of the product.

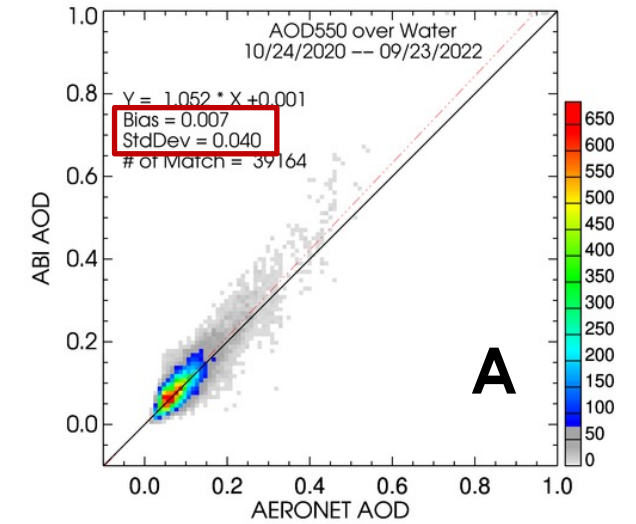
# GOES-16 ABI AOD Validation

## Over Land

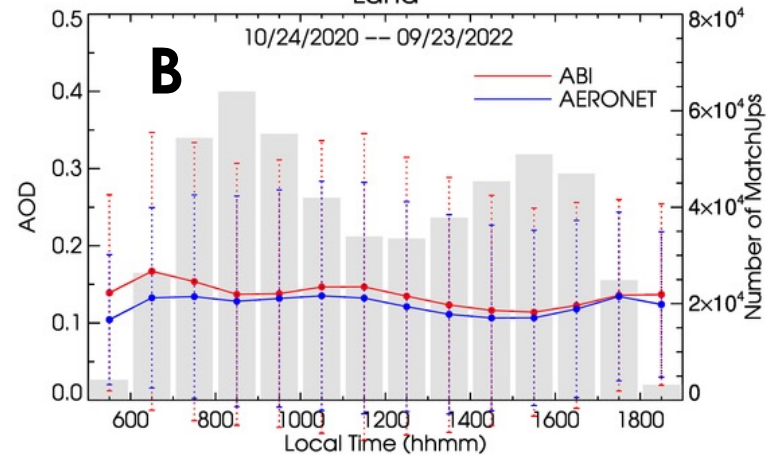


- High quality GOES-16 ABI AOD (most recent version)
- Validated with Version 3 Level 1.5 Near Real-Time AERONET AOD
- Validation Period: 24 Oct 2020 to 23 Sep 2022

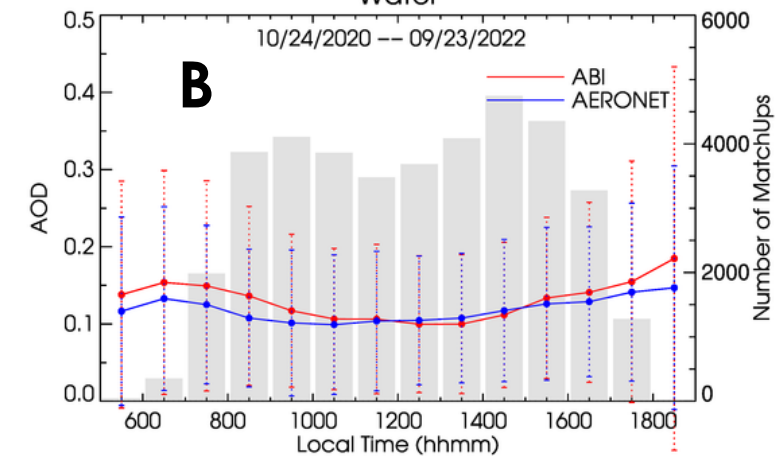
## Over Water



## Land



## Water





# ABI AOD Data Quality Flags

- ABI AOD data files include **data quality flags**.
  - Express confidence in AOD data
  - Figure: Example of ABI AOD Quality Flags
- **High-Quality:** Most accurate, use for all quantitative applications (e.g., modeling)
- **Medium-Quality:** Some uncertainty, use for qualitative applications (e.g., forecasting)
- **Low-Quality:** High uncertainty, avoid for most applications
- ABI AOD **not retrieved** in areas with:
  - Clouds
  - Snow or Ice
  - Bright Land Surface
  - Sun Glint (measurement artifact; occurs when sunlight reflects off surface of ocean/lake at same angle that sensor is viewing surface)
  - Nighttime (need visible light)

H	High Quality
M	Medium Quality
Low Quality	
L1	Contradicting Cloud Masks
L2	Low Satellite Angle
L3	Low Sun Angle
L4	Out of Spec Range
L5	Coastal Area
L6	Shallow Inland Water
L7	High Residual
L8	High Inhomogeneity
No Retrieval	
N1	Invalid Input
N2	Cloud
N3	Snow
N4	Bright Land Surface
N5	Sun Glint

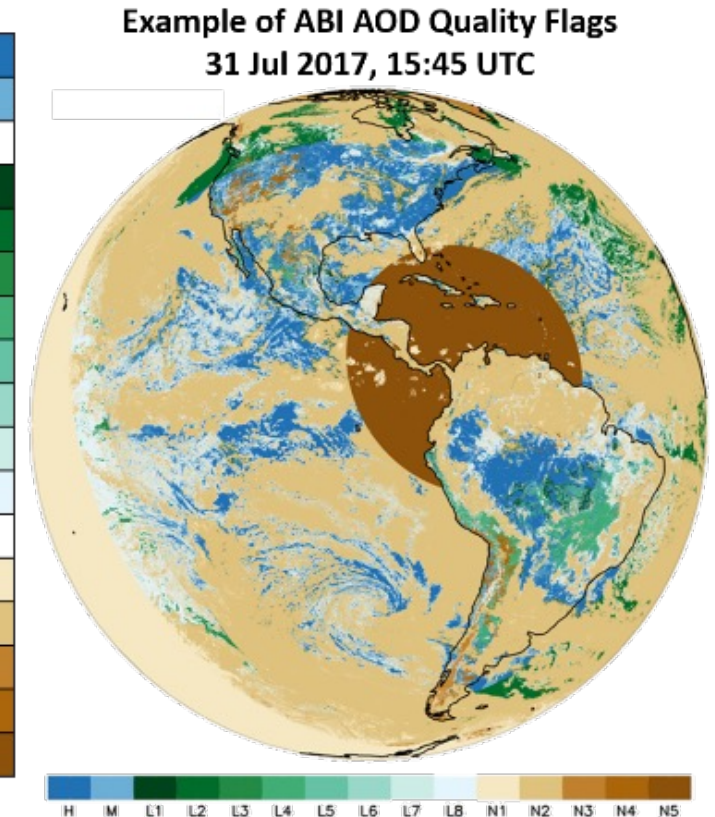
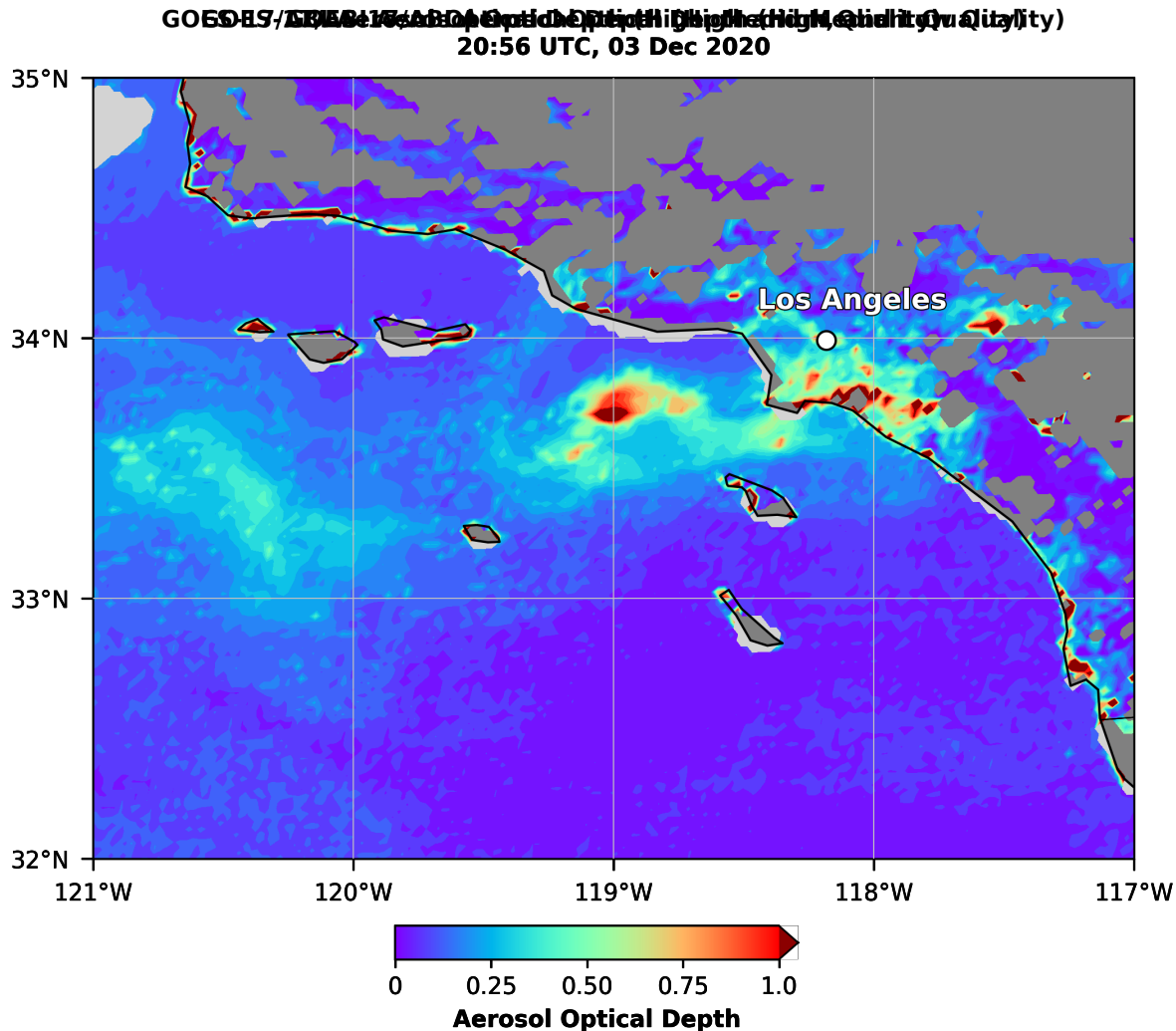


Figure courtesy of Mi Zhou (IMSG) and Istvan Laszlo (NOAA)

# Examples of High-, Medium-, and Low-Quality ABI AOD



ABI AOD Images Generated from netCDF4 Files using Python

- Example: GOES-17 ABI AOD, highlighting smoke from Airport and Bond fires near Los Angeles, CA on Dec 3, 2020
- **High-Quality AOD** is the most accurate, but is missing part of the smoke plume. Also, there are big gaps along coastlines (very stringent screening).
- **High- + Medium-Quality AOD (“top 2 qualities”)** fills in most of the smoke plume and some of the gaps along the coastlines.
- **High- + Medium- + Low-Quality AOD (“all qualities”)** fully resolves the smoke plume, but at the expense of erroneous high AOD values along coastlines and over inland shallow lakes.
- Bottom Line: **Make sure you process AOD using the appropriate data quality flags!**
  - Avoid low-quality AOD for most situations.
  - **Use high- + medium- (“top 2”) qualities AOD for routine operational applications!**



# Strengths and Limitations of GOES-R ABI AOD

## • **Strengths:**

- Quantitative Measure of Aerosols
  - Can be used to estimate surface concentrations of  $PM_{2.5}$
- Easy to interpret and identify areas of high aerosol concentration from smoke, blowing dust, haze
- Supplements visible imagery
  - L1b Radiances (e.g., ABI band 1 & 2)
  - True Color or GeoColor Imagery

## • **Limitations:**

- Column Measurement
  - Geographic 2D location of aerosols only
  - No information about vertical distribution of aerosols in atmosphere
  - Smoke/dust/haze may not be reaching surface
- No ABI AOD in areas with clouds, snow, ice, sun glint, bright surfaces
- Available during daytime only

# Decoding ABI L2 Data File Names

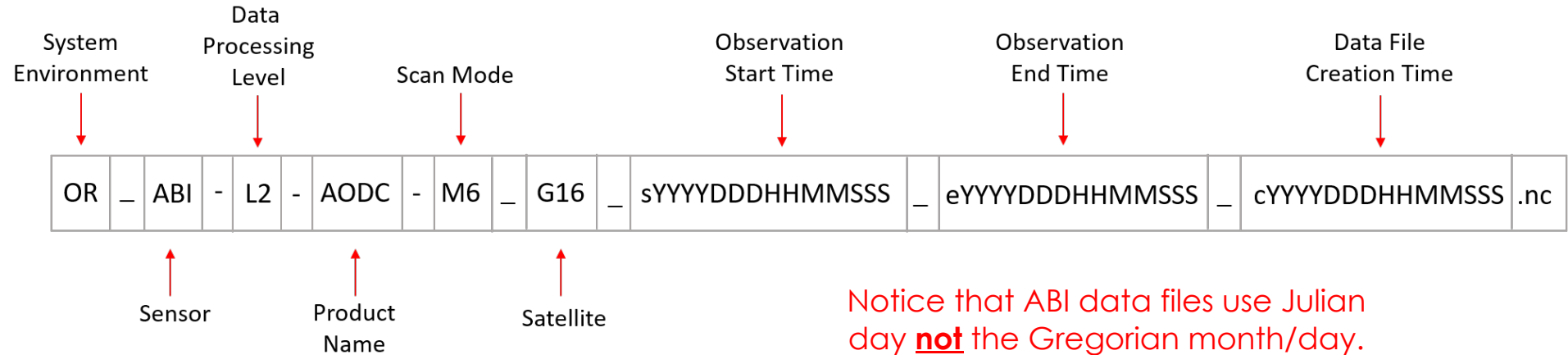
Aerosol Detection:

ADPF  
ADPC  
ADPM

OR\_ABI-L2-AODC-M6\_G16\_s20202601501123\_e20202601503496\_c20202601506349.nc

Aerosol Optical Depth:

AODF  
AODC



- System Environment: **O**perational system using **R**real-time data
- Sensor: **A**dvanced **B**aseline **I**mager
- Data Processing Level: **L**evel **2**
- Product Name: abbreviation for product ("**AOD**") + scan sector ("**C**" = CONUS, "**F**" = Full Disk)
- Scan Mode: **M**ode **6** (current "flex mode"); also, **M3**, **M3G**, **M4**
- Satellite: **G**OES-**16**; also, **G17** and **G18**
- Observation **s**tart/**e**nd, file **c**reation time:
  - YYYY (4-digit year. e.g., **2020**)
  - DDD (3-digit Julian day, e.g., **260**)
  - HHMM (4-digit hour/minutes in UTC, e.g., **1501**)
  - SSS (3-digit seconds to tenth of second)

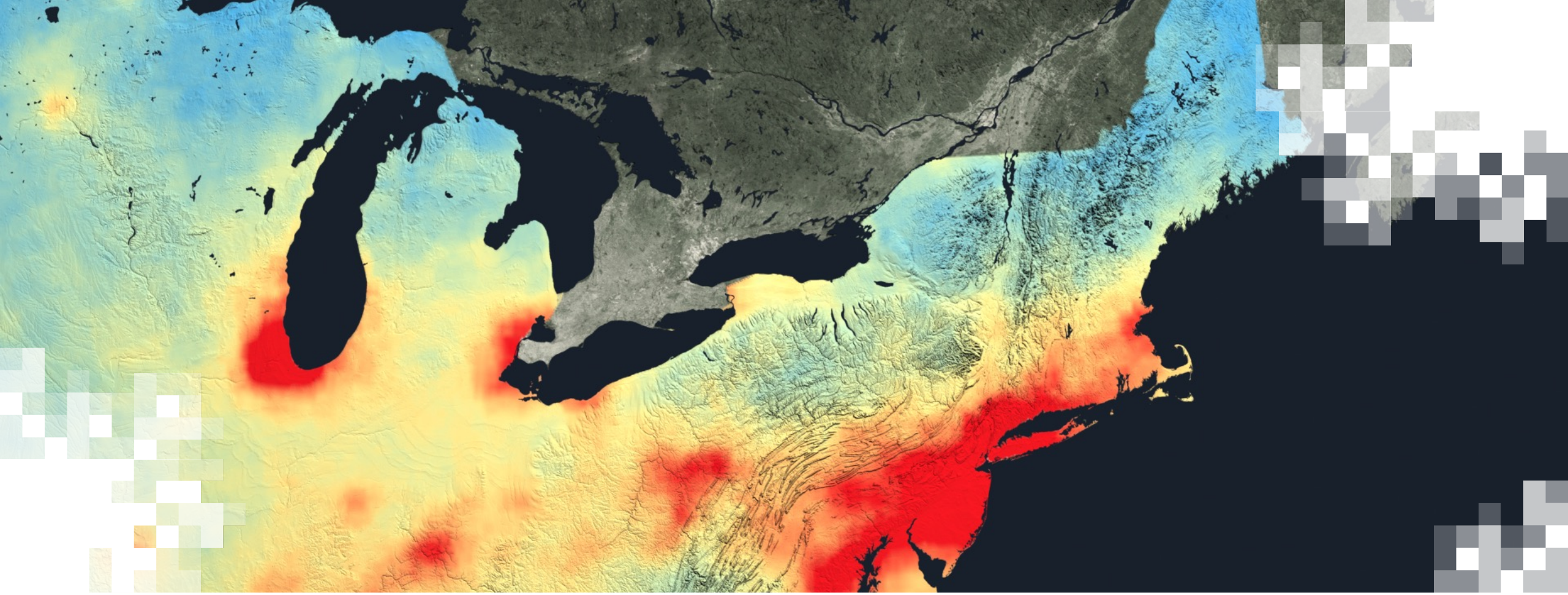


# Where to Find ABI AOD Data Files

- **ABI L1b (radiances) and L2 data files** (including AOD) are available via the [NOAA GOES-R data archive on Amazon Web Services \(AWS\)](#).
  - Separate links (“buckets”) for [GOES-16](#) and [GOES-17](#) and [GOES-18](#) data
  - Available files updated in near real-time
  - You can download files manually or programmatically.
  - Free and easy! No registration is required!
  - You do NOT need to have an AWS account!!
- Part of NOAA’s [Open Data Dissemination \(NODD\) Program](#)

## NOAA Geostationary Operational Environmental Satellites (GOES) 16, 17 & 18

agriculture disaster response earth observation geospatial meteorological satellite imagery sustainability weather



Questions & Discussion