

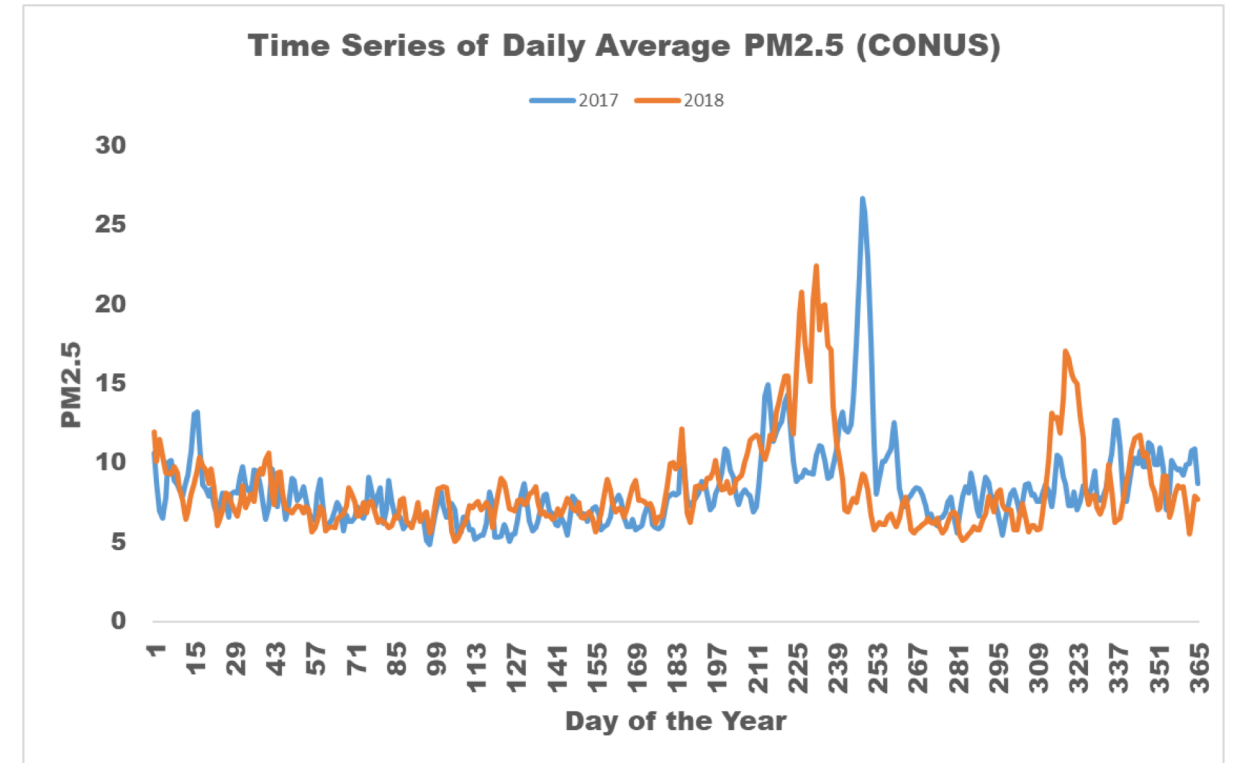
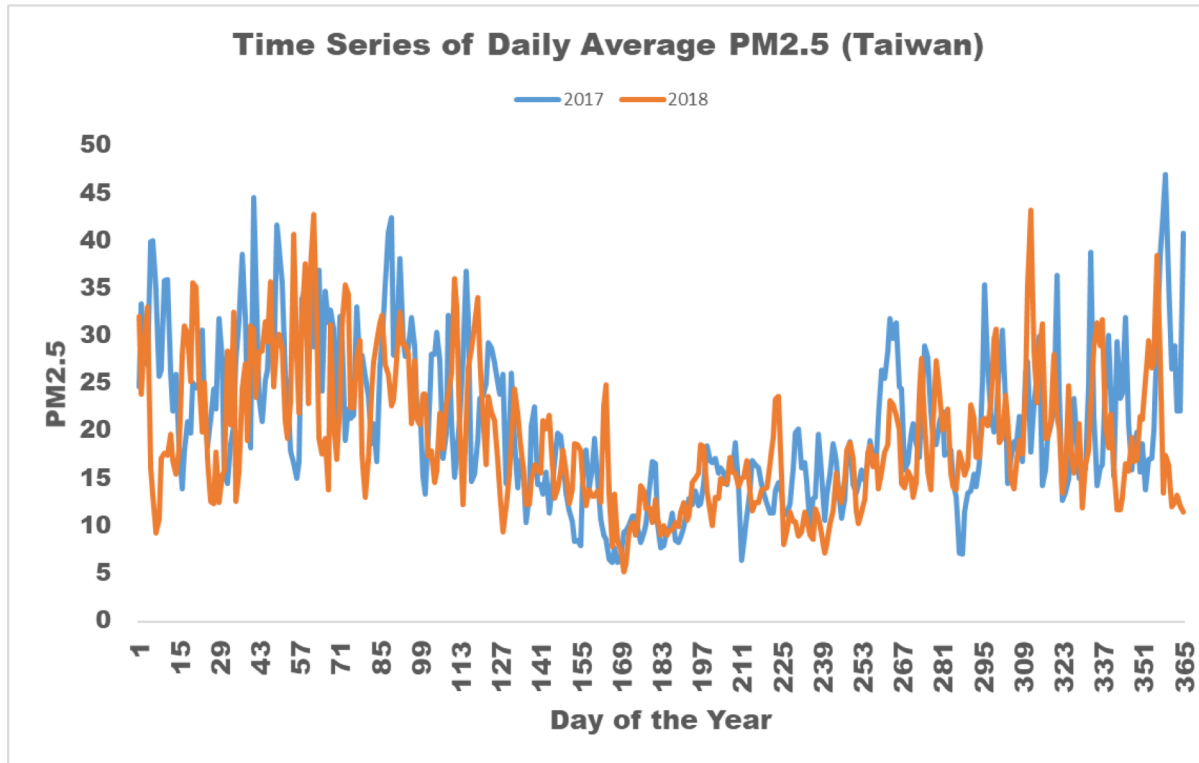
Scaling AOD to Surface PM_{2.5}: USA vs. Taiwan

Hai Zhang and Shobha Kondragunta

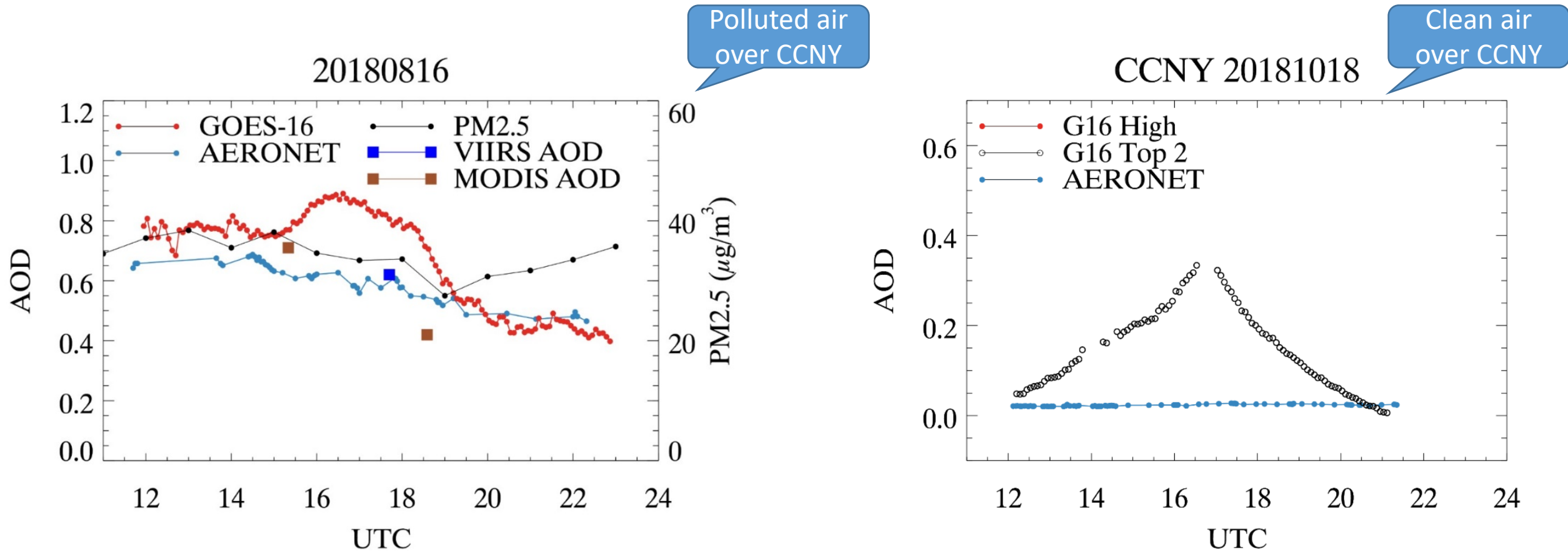
NOAA/NESDIS/STAR

Amy K. Huff

Pennsylvania State University



- When using satellite AOD to estimate surface PM_{2.5}, need to understand regional differences in PM_{2.5} morphology, AOD accuracies, and the relationship between AOD and PM_{2.5}
- In this study, we explored the AOD-PM_{2.5} relationships over Continental United States (CONUS) and Taiwan using GOES-16 ABI AOD and Himawari-8 AHI AOD



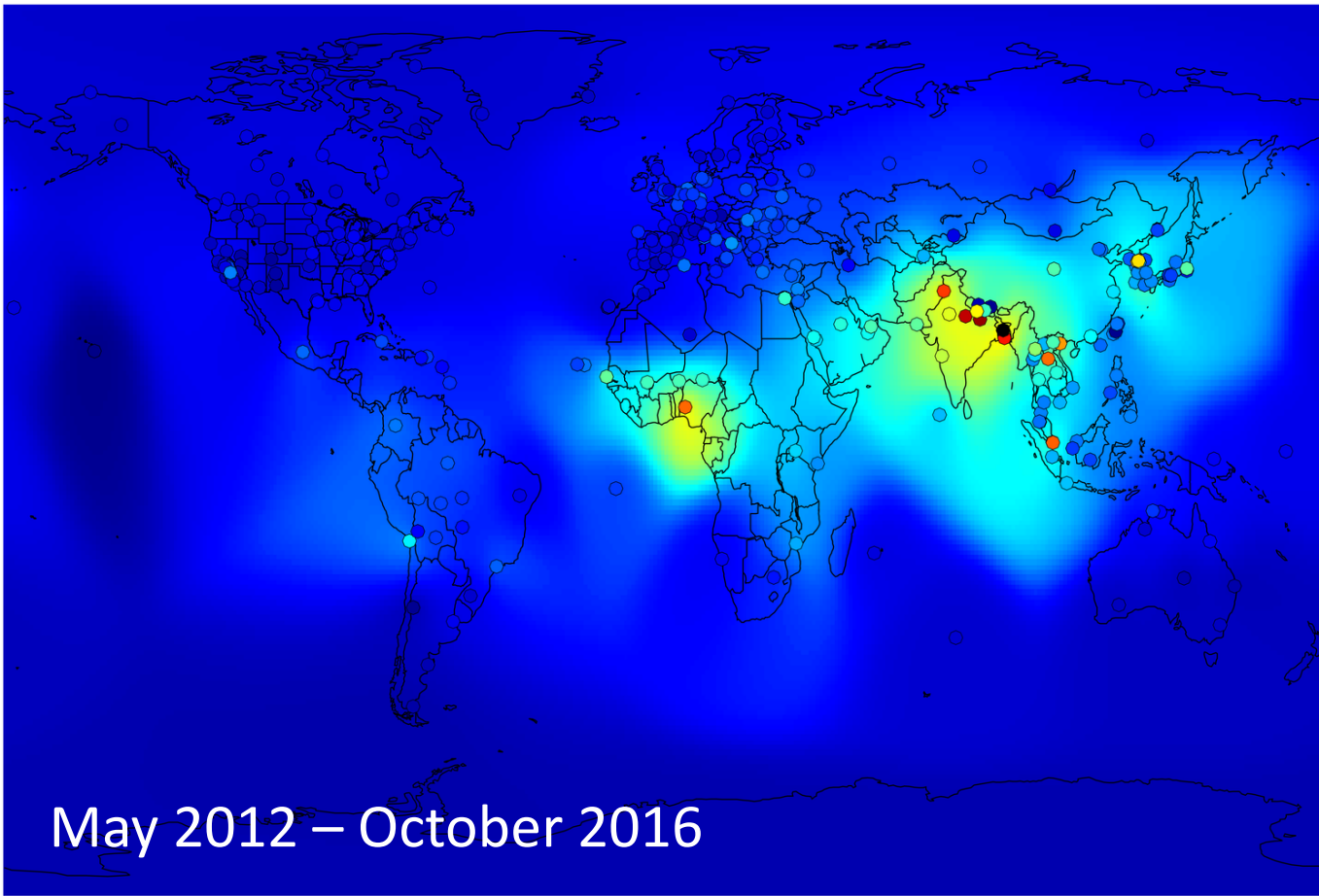
- Diurnal bias evident in GOES-16 ABI AOD, especially over **urban areas**
 - Maximum around noon local time
 - Attributed to surface spectral reflectance ratios
- A bias correction has been developed and is recommended until surface spectral reflectance ratios (*valid for the time of the day*) are included in the ABI AOD algorithm

GOES-16 ABI AOD Bias Correction Technique over CONUS

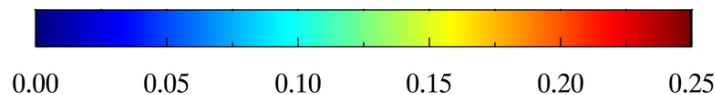
- Analysis used ~5 months of ABI AOD data
 - August 6 – December 31, 2018
 - 15-min composite interval
- For each composite of time steps, found lowest ABI AOD in 30-day period
- Assumed the **lowest AOD minus background AOD is the bias** for each time step
 - Background AOD is obtained from multi-year **AERONET AOD** analysis (next slide)
- Bias fit to a 2nd degree polynomial as a function of UTC time
 - Separate equations for before noon and after noon
- Example (New York City, NY metro area):
 - Before 17 UTC: $-0.28 + 0.007862t + 0.001288t^2$
 - After 17 UTC: $5.24 - 0.4815t + 0.01101t^2$
- Calculate the bias and subtract it from the original ABI AOD at each time step

Where t is time in UTC,
e.g. $t = 13.5$ for 1330 UTC

Background AOD (Derived from AERONET)



Background AOD

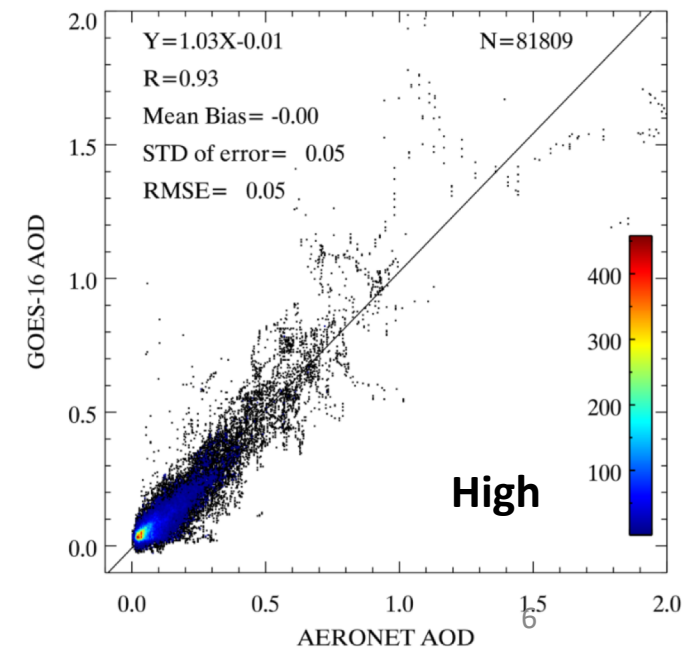
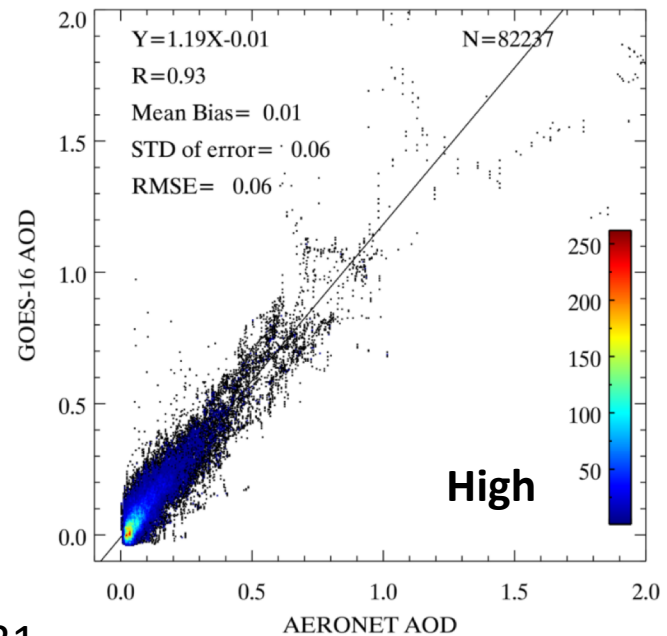
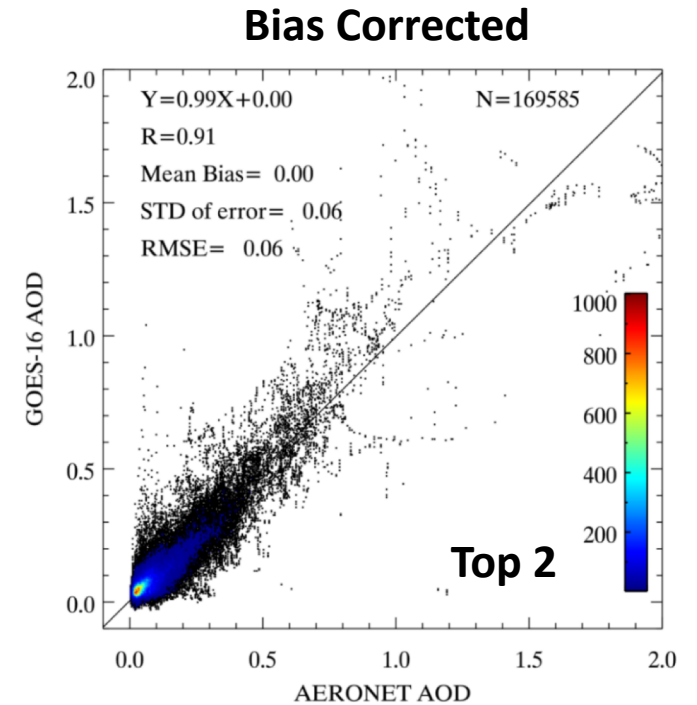
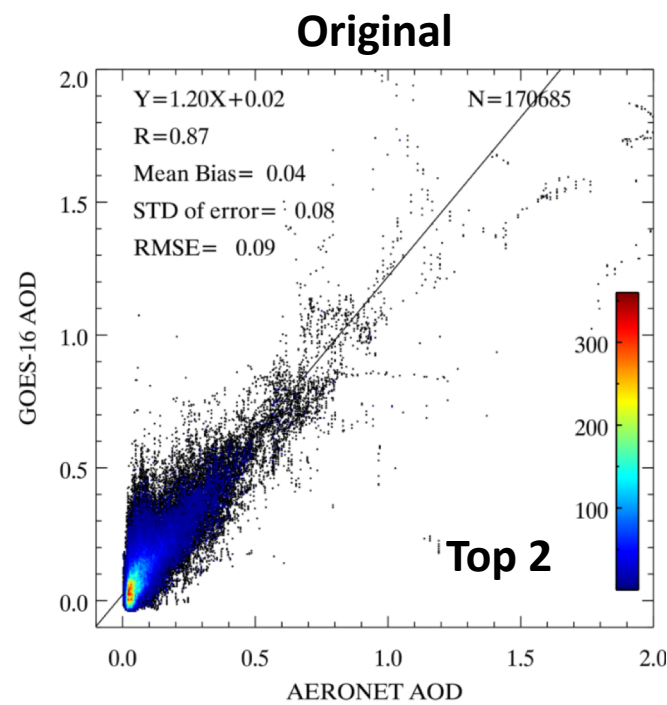


- From multi-year AERONET AOD, obtain the lowest 5th percentile AOD as the estimate of the background AOD at each site i (τ_i)
- Then interpolate the background AOD to all the places over the globe, i.e. the background AOD at a location is estimated as $\tau_b = \frac{\sum_i w_i \tau_i}{\sum_i w_i}$, where τ_b is the interpolated background AOD, w_i is the weight defined as a function of the distance (d) between the site i and the interpolation point:

$$w_i = e^{-d/d_0} \quad (d_0 = 500 \text{ km})$$

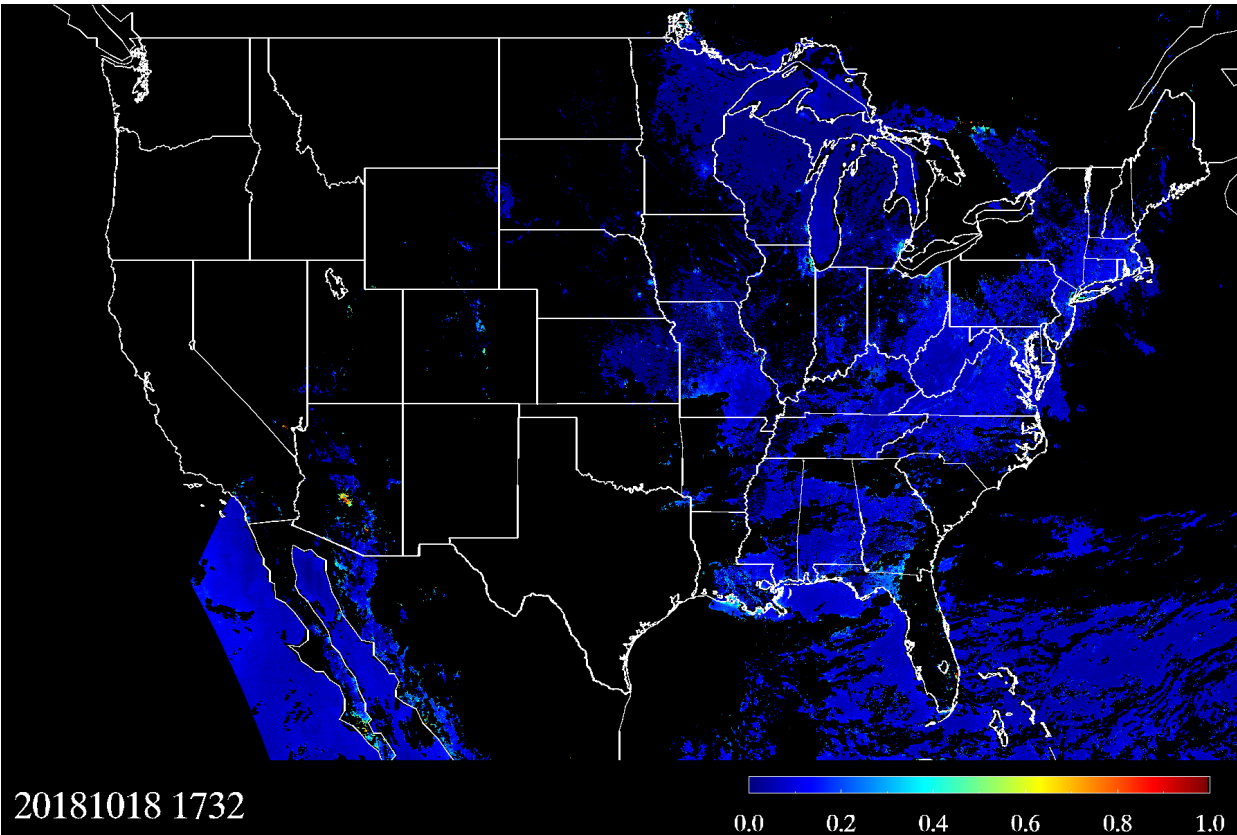
Example: average background AOD over CONUS = 0.025

- GOES-16 ABI AOD was post-processed to correct diurnal bias
- GOES-16 ABI AOD come in three quality flags: High, Medium, Low
 - Top 2 = High + Medium quality
- Correlation, bias, and root mean square error improved for both Top 2 and high quality AOD datasets
 - Greater improvement for Top 2 qualities
 - High quality AOD already filters out some of the biased pixels

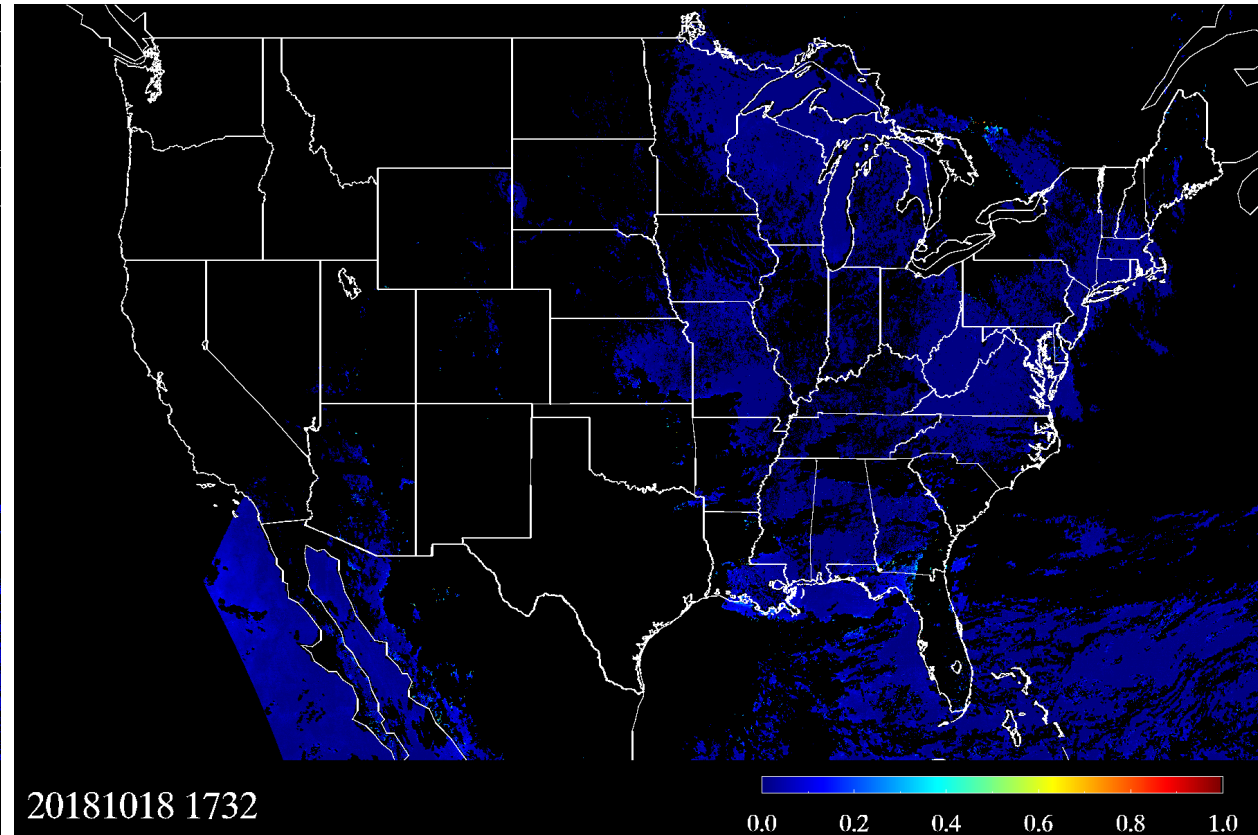


Bias Corrected GOES-16 ABI AOD, October 10, 2018 (CONUS, 17:32 UTC)

Original Top 2 Qualities

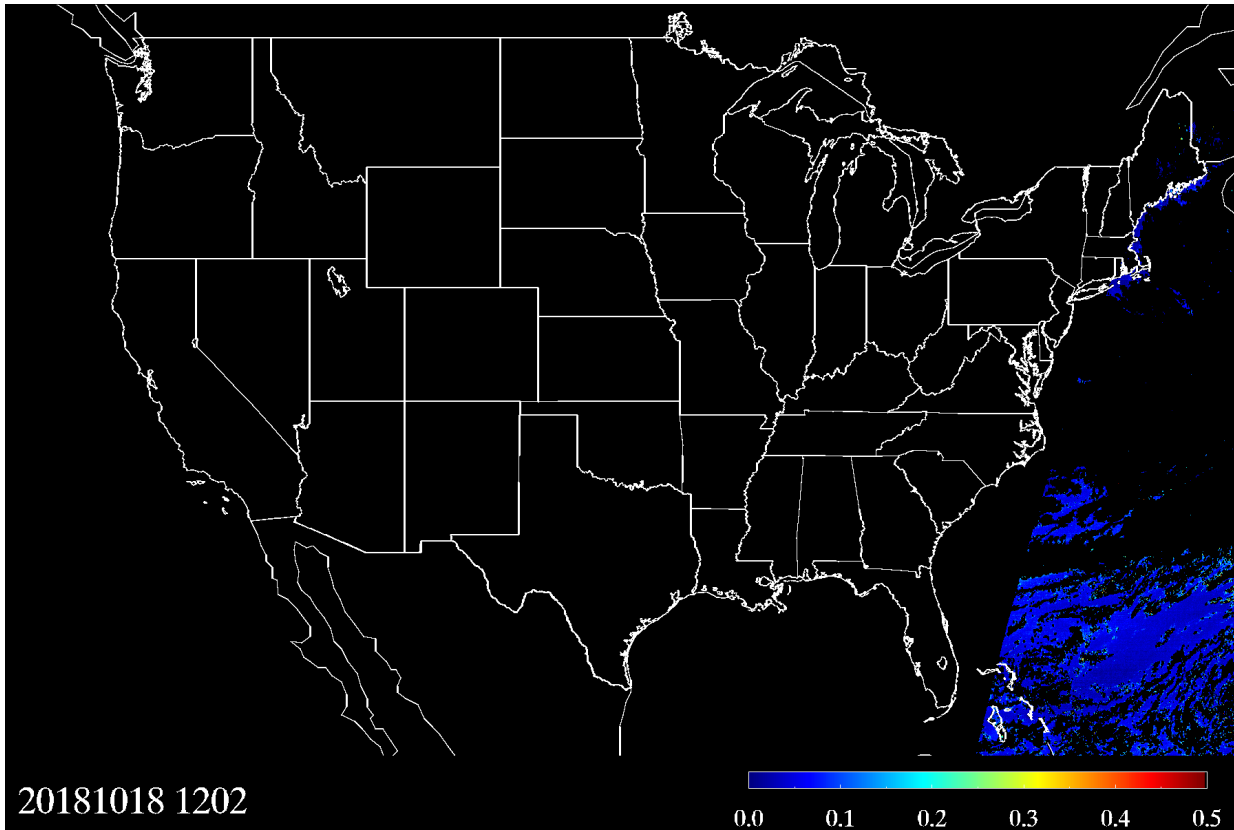


Bias Corrected Top 2 Qualities

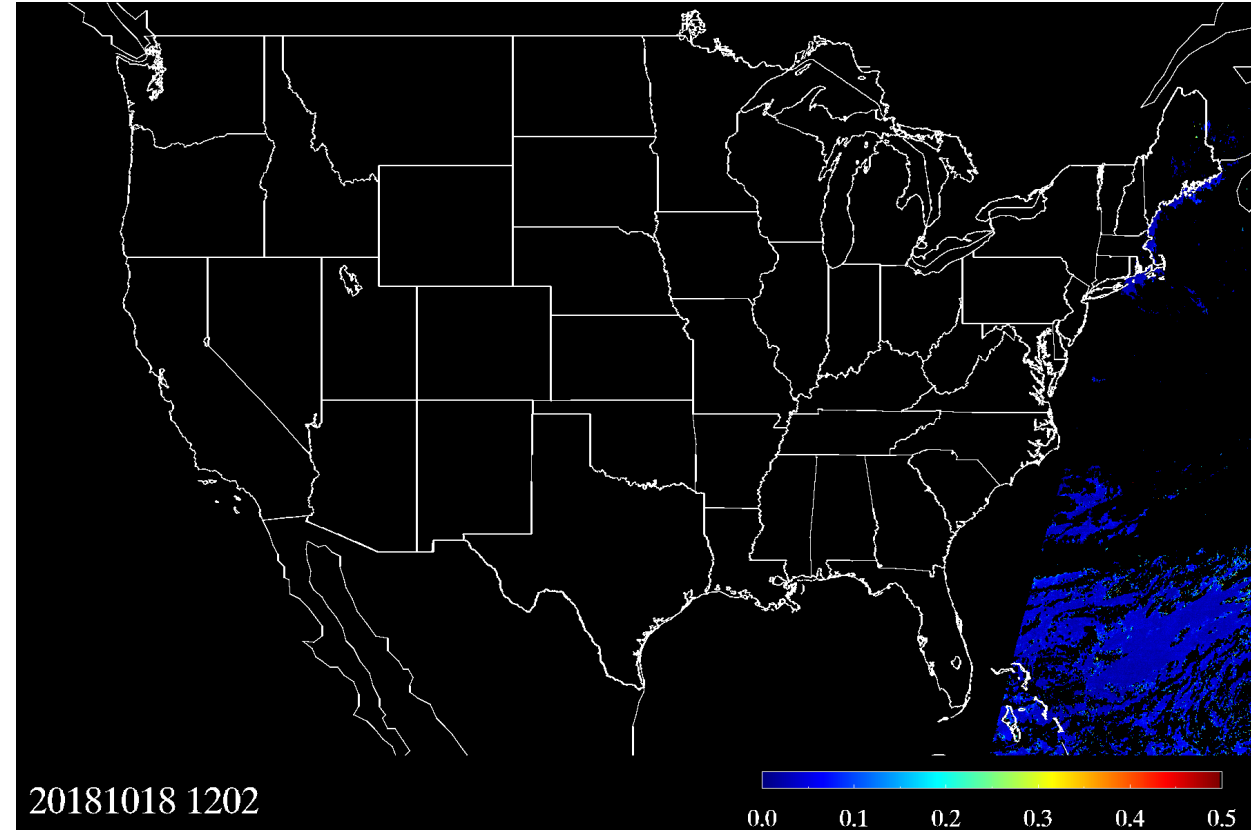


Bias Corrected GOES-16 ABI AOD, October 10, 2018 (CONUS, daytime animation)

Original Top 2 Qualities

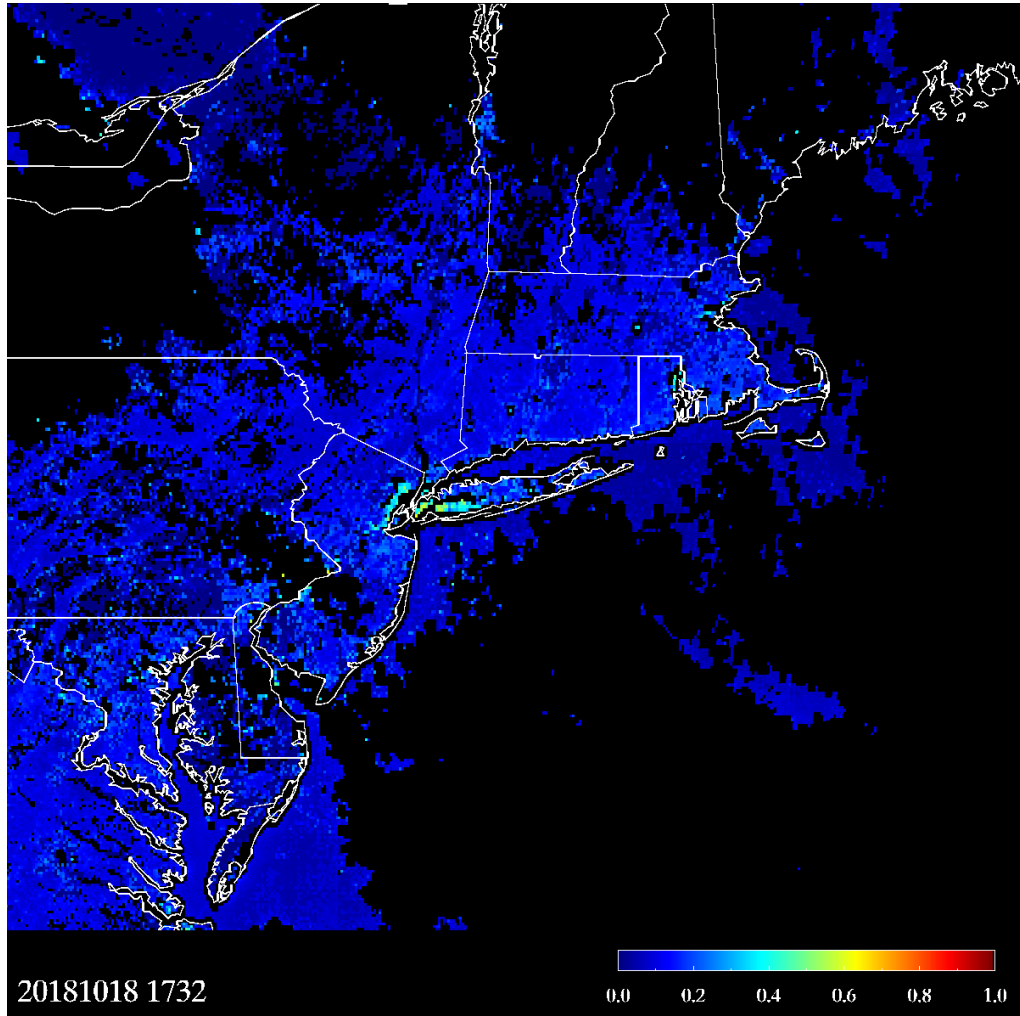


Bias Corrected Top 2 Qualities

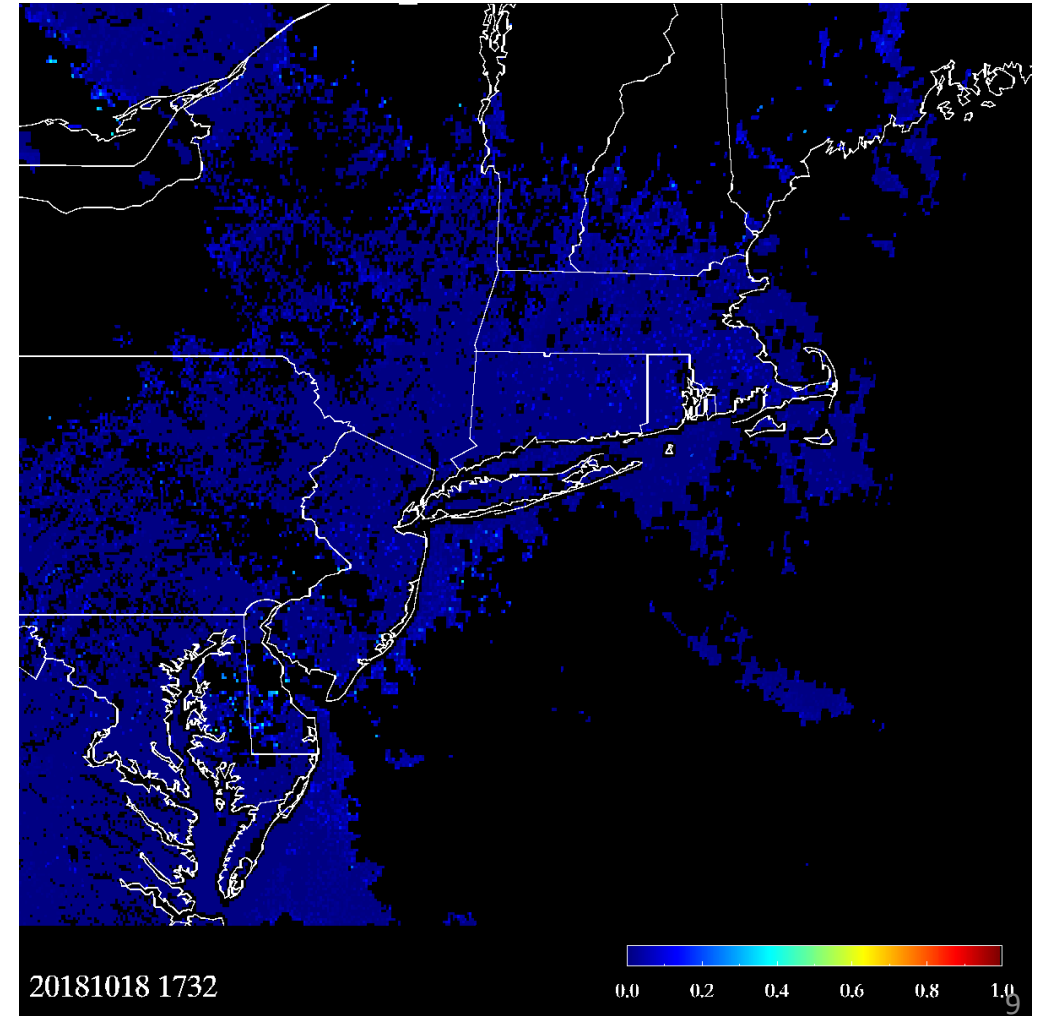


Bias Corrected GOES-16 ABI AOD, October 10, 2018 (Northeast US, 17:32 UTC)

Original Top 2 Qualities



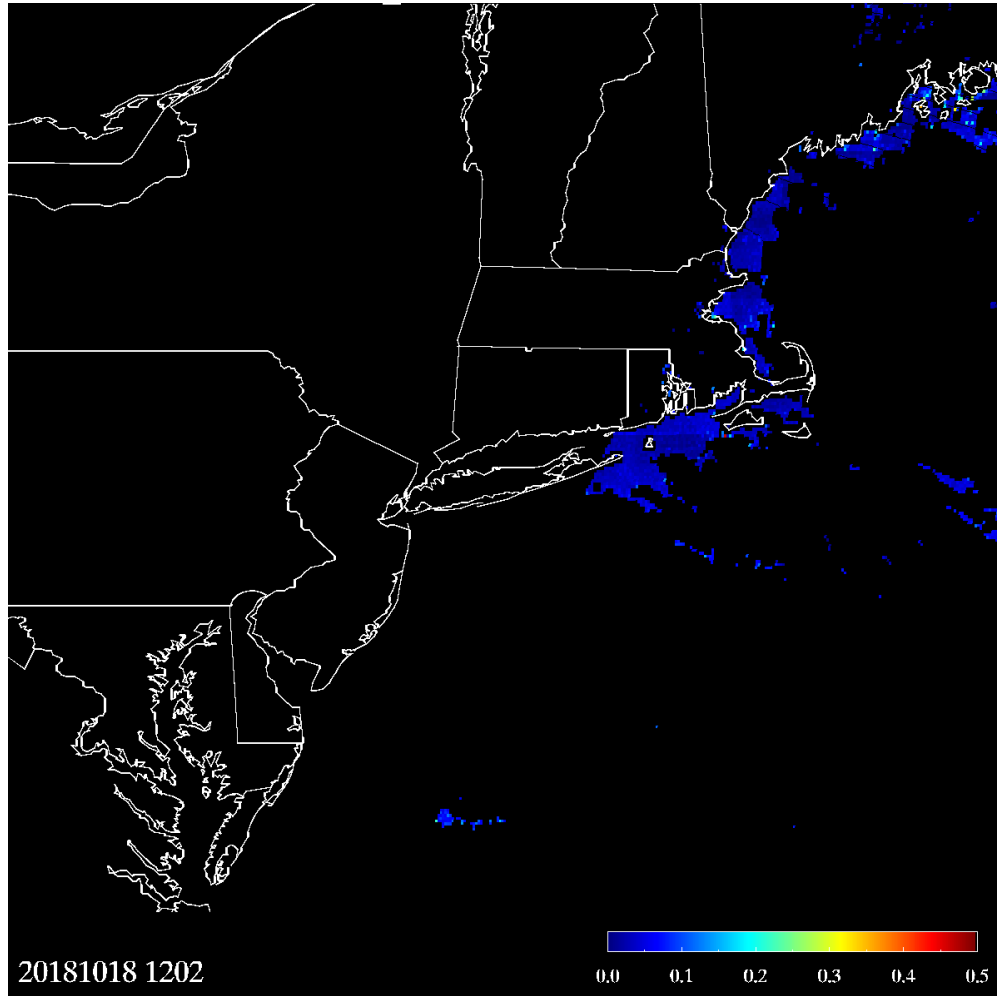
Bias Corrected Top 2 Qualities



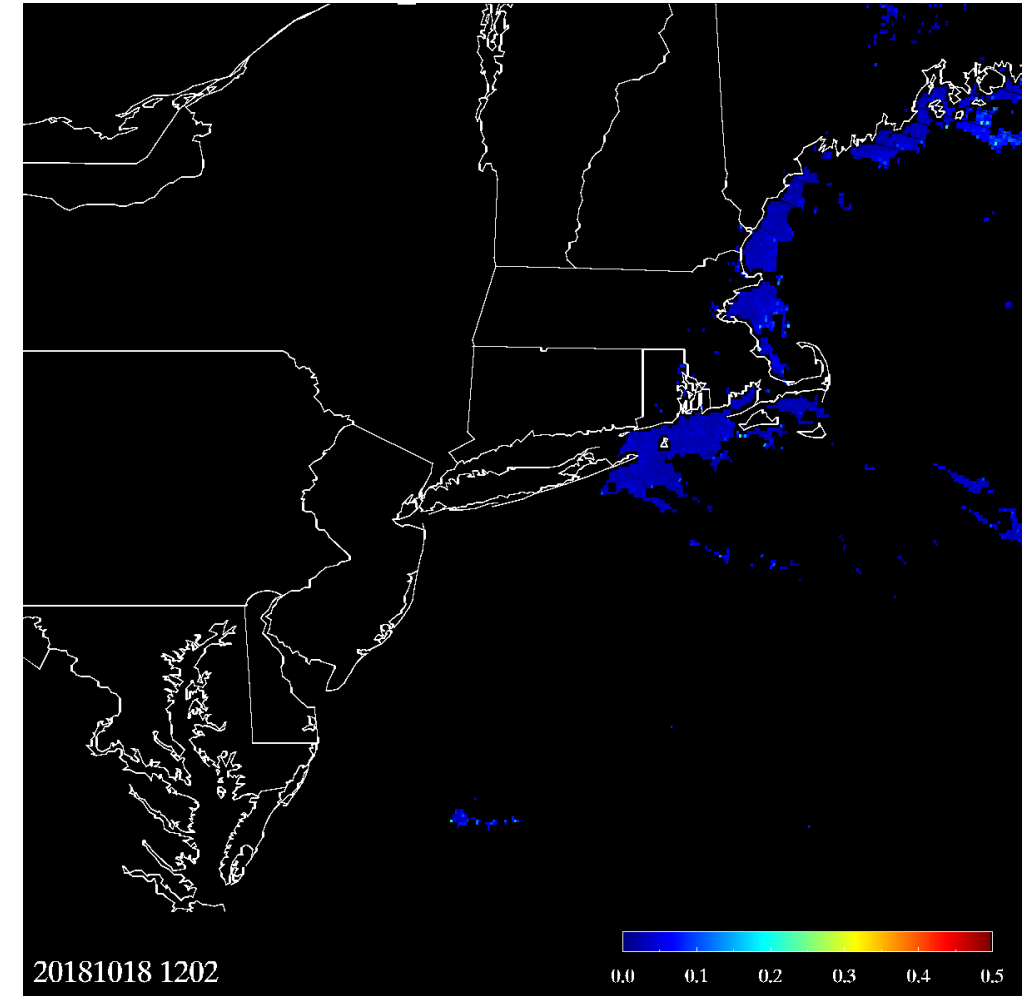
Bias Corrected GOES-16 ABI AOD, October 10, 2018

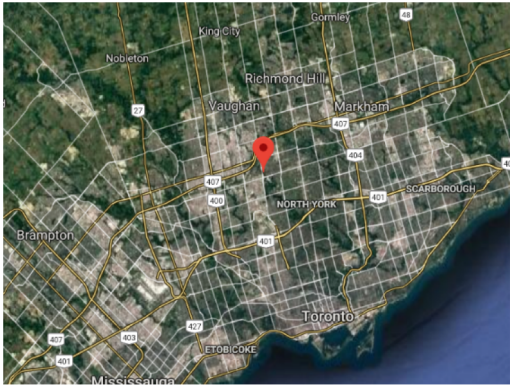
(Northeast US, daytime animation)

Original Top 2 Qualities



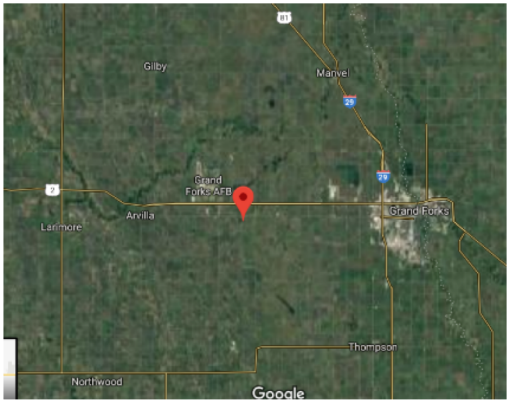
Bias Corrected Top 2 Qualities





ABI AOD Bias Correction Comparison

AOD histogram for pixels within 27.5 km circle

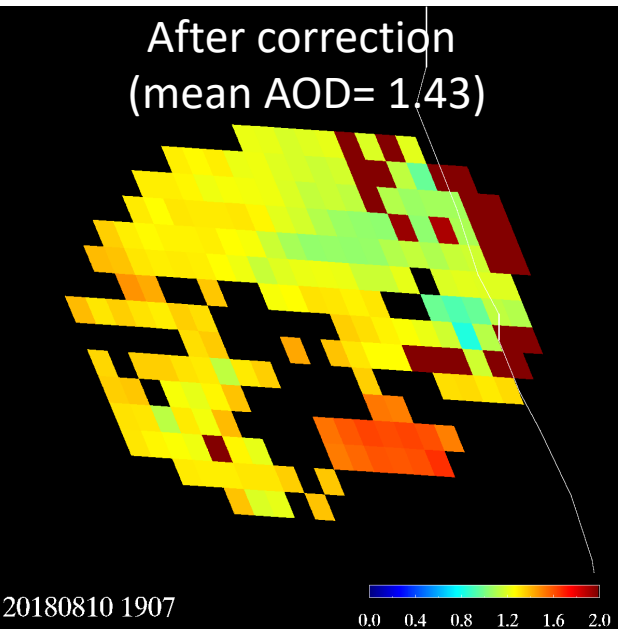
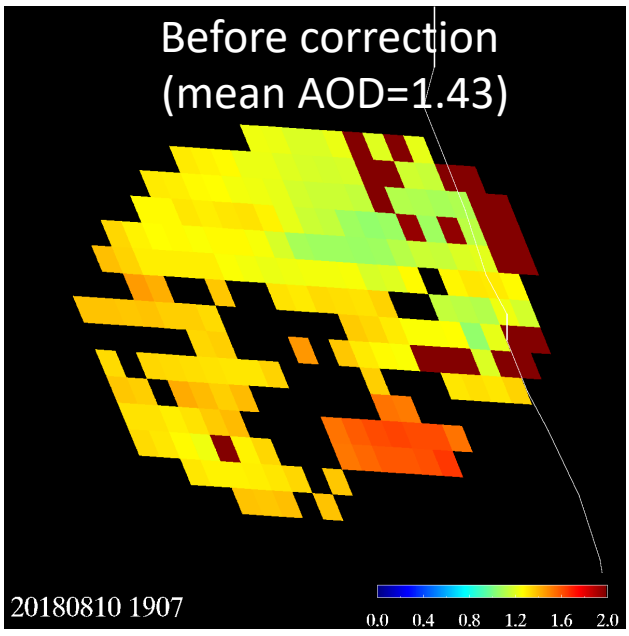
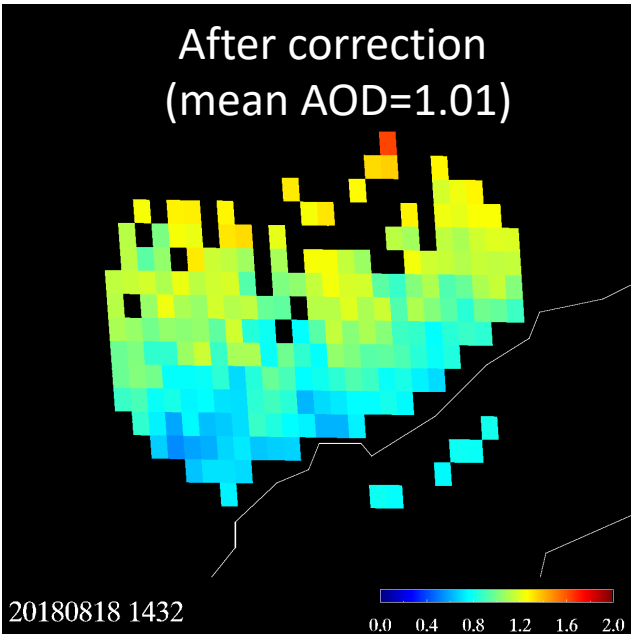
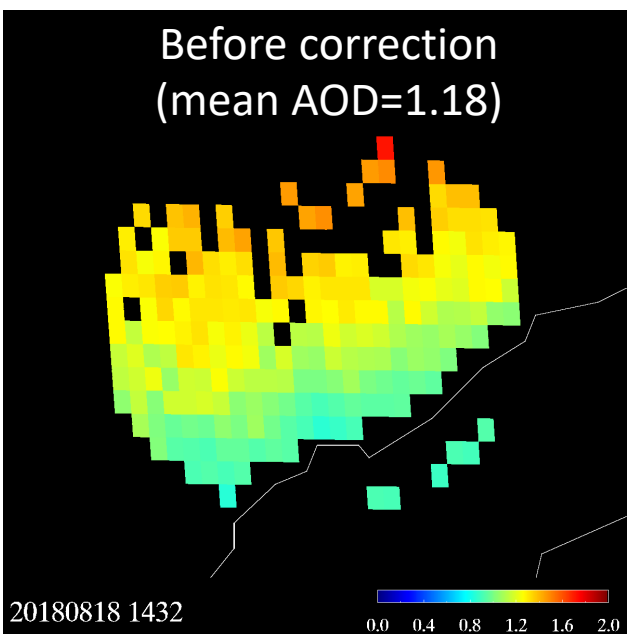


Toronto, ON, Canada (urban site)

AERONET AOD = 1.12

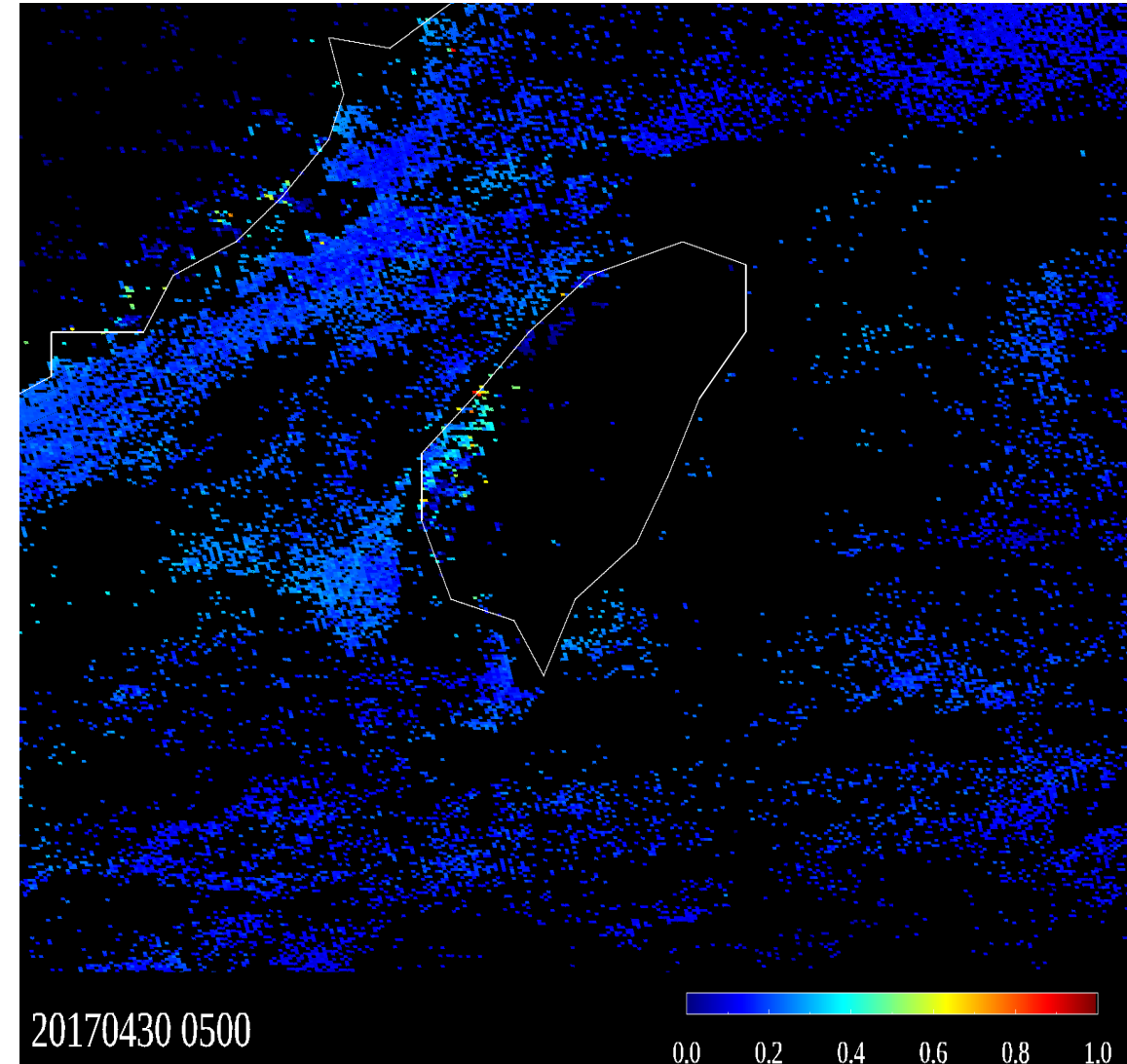
Grand Forks, ND, USA (rural site)

AERONET AOD= 1.23



Bias Correction for Himawari-8 AHI AOD over Taiwan

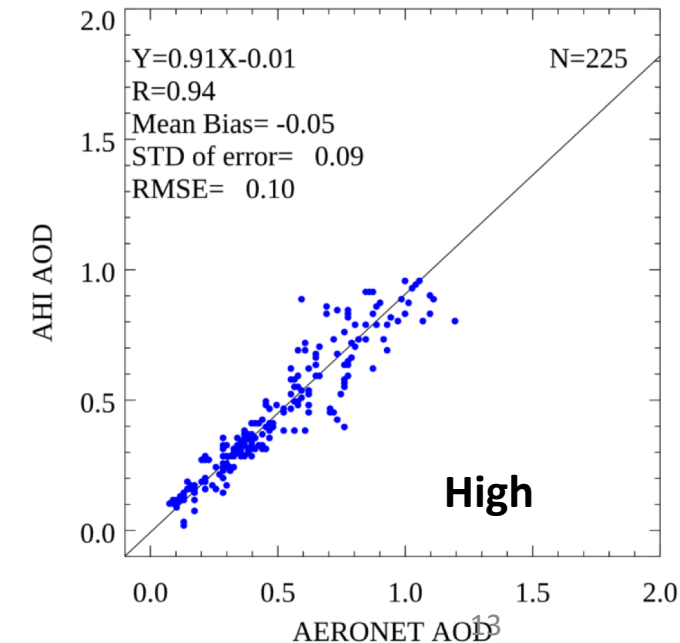
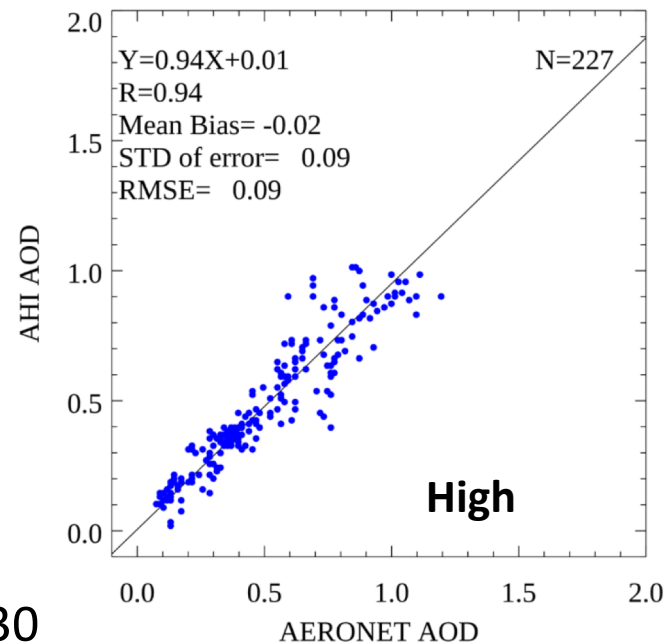
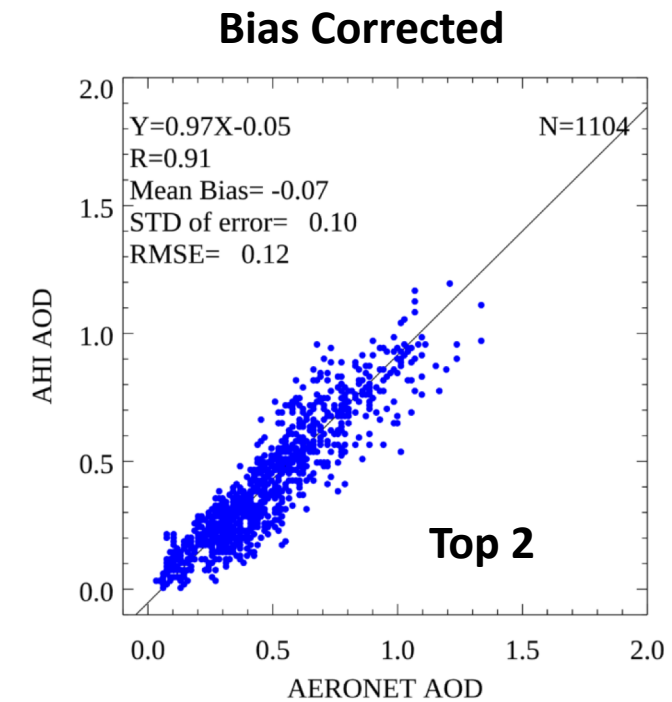
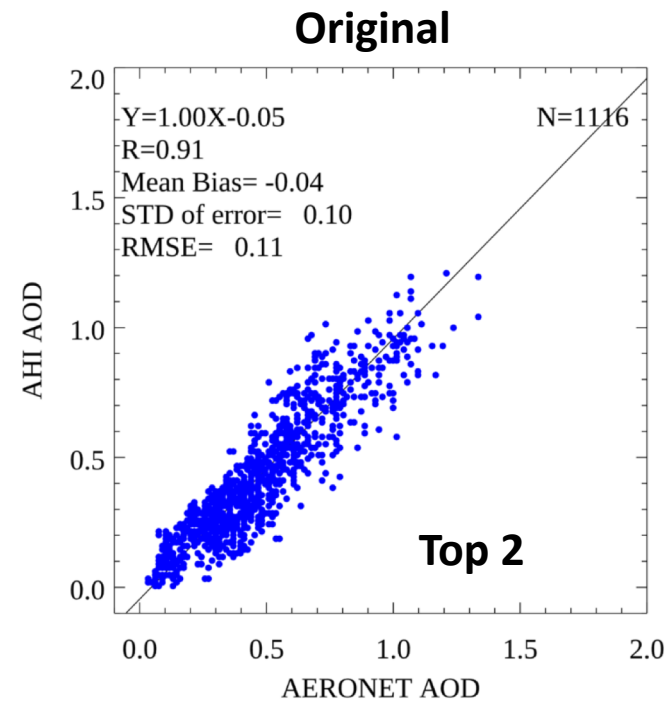
- Analysis used 2 months of AHI AOD data
 - March 1 – April 30, 2017
 - 30-min composite interval
- Background AOD = 0.069
- Problem arose when developing the bias correction algorithm:
 - Taiwan region is often cloudy, so limited AOD retrievals
 - Measured AOD is relatively high
 - Thus, difficult to quantify **lowest AOD**
 - lowest AOD – background AOD = bias



60-day composite lowest AOD with requirement that at least 5 days have retrieval

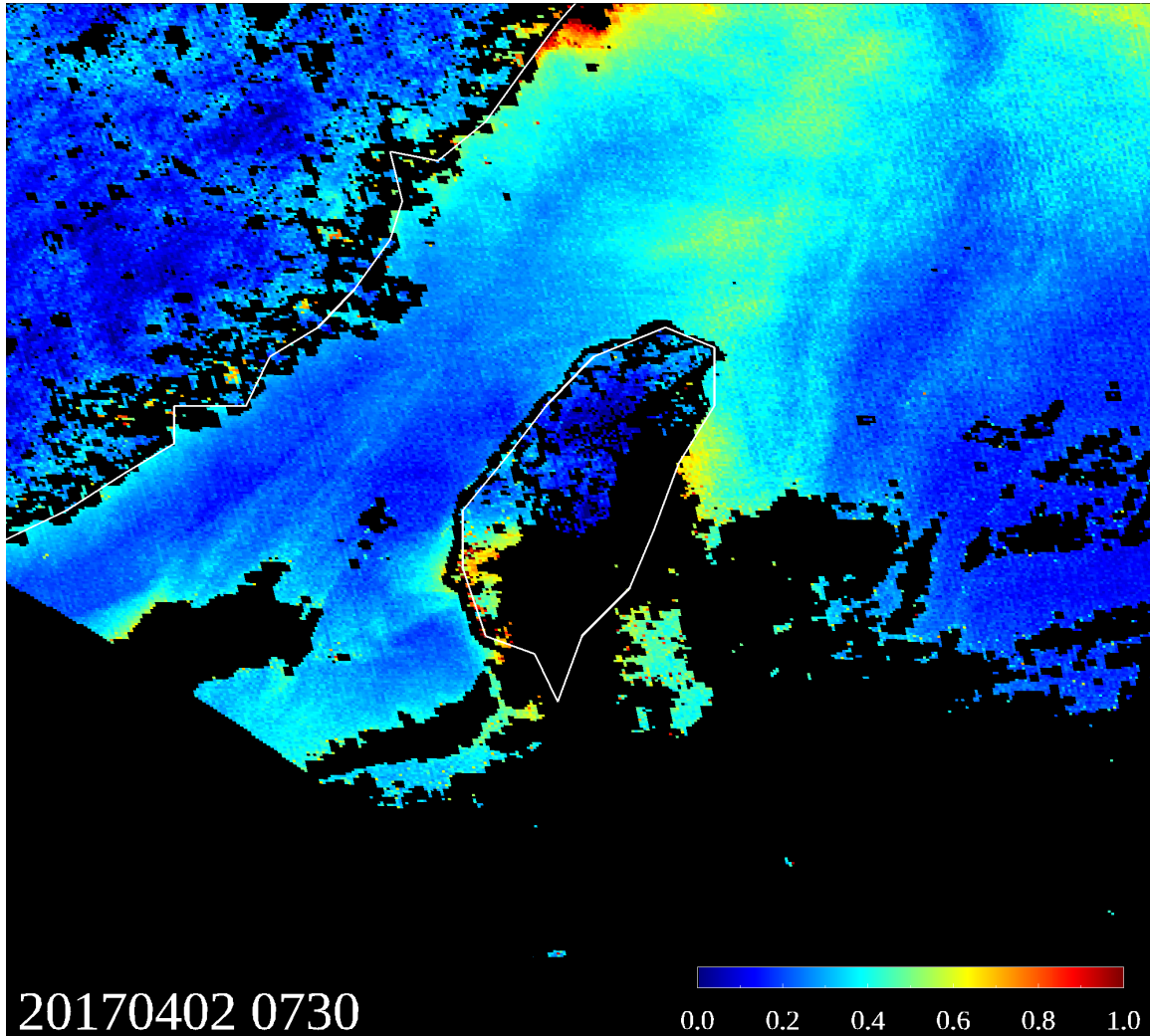
- Himawari-8 AHI AOD post-processed using same technique as for ABI AOD
- Himawari-8 AHI AOD come in three quality flags: High, Medium, Low
 - Top 2 = High + Medium
- Little change in correlation, bias, or root mean square error for Top 2 and high quality AOD datasets
 - The large difference in surface reflectance between urban and rural areas seen in CONUS is not present in Taiwan

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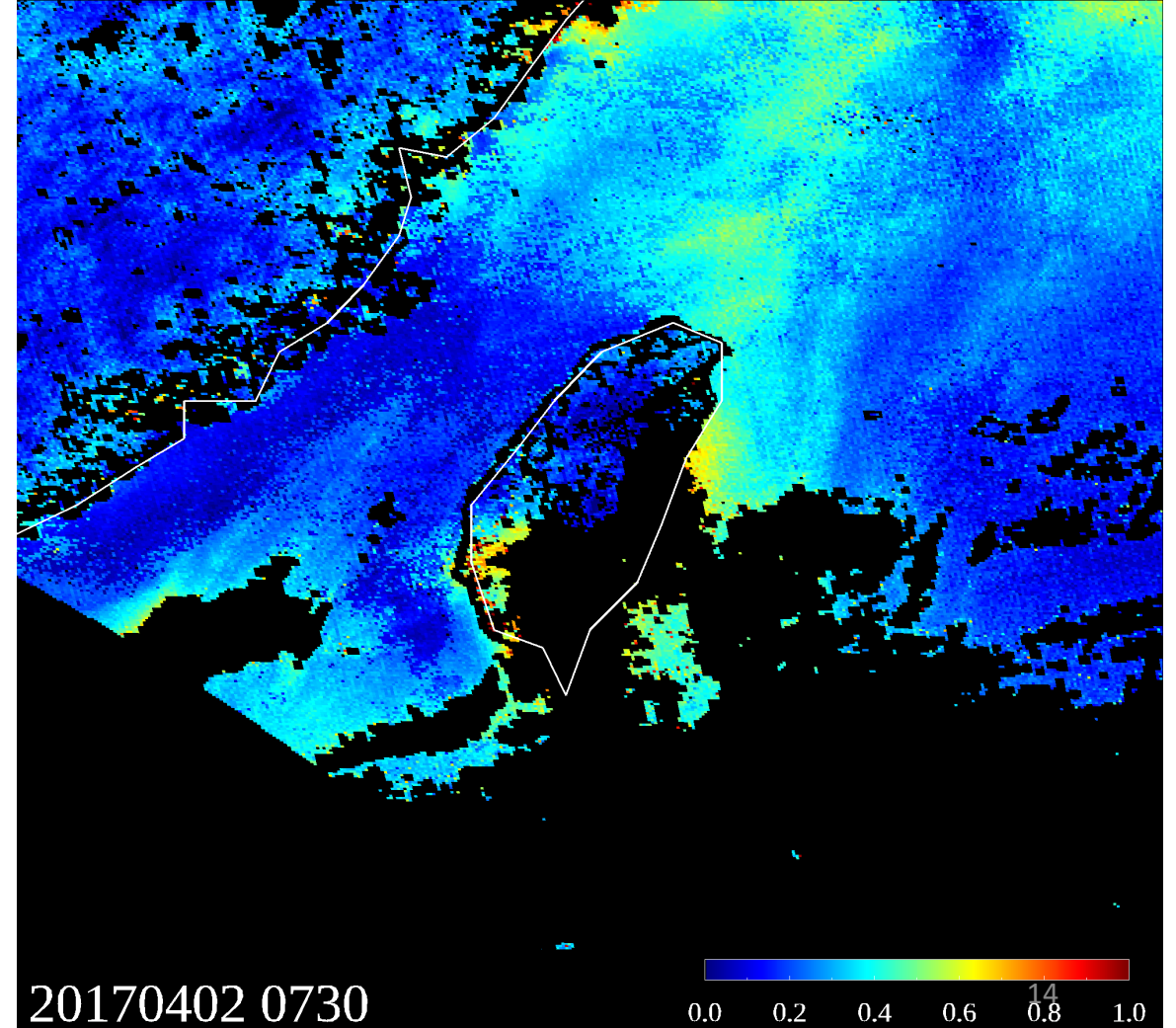


Bias Corrected Himawari-8 AHI AOD, April 2, 2017 (Taiwan, 7:30 UTC)

Original Top 2 Qualities



Bias Corrected Top 2 Qualities



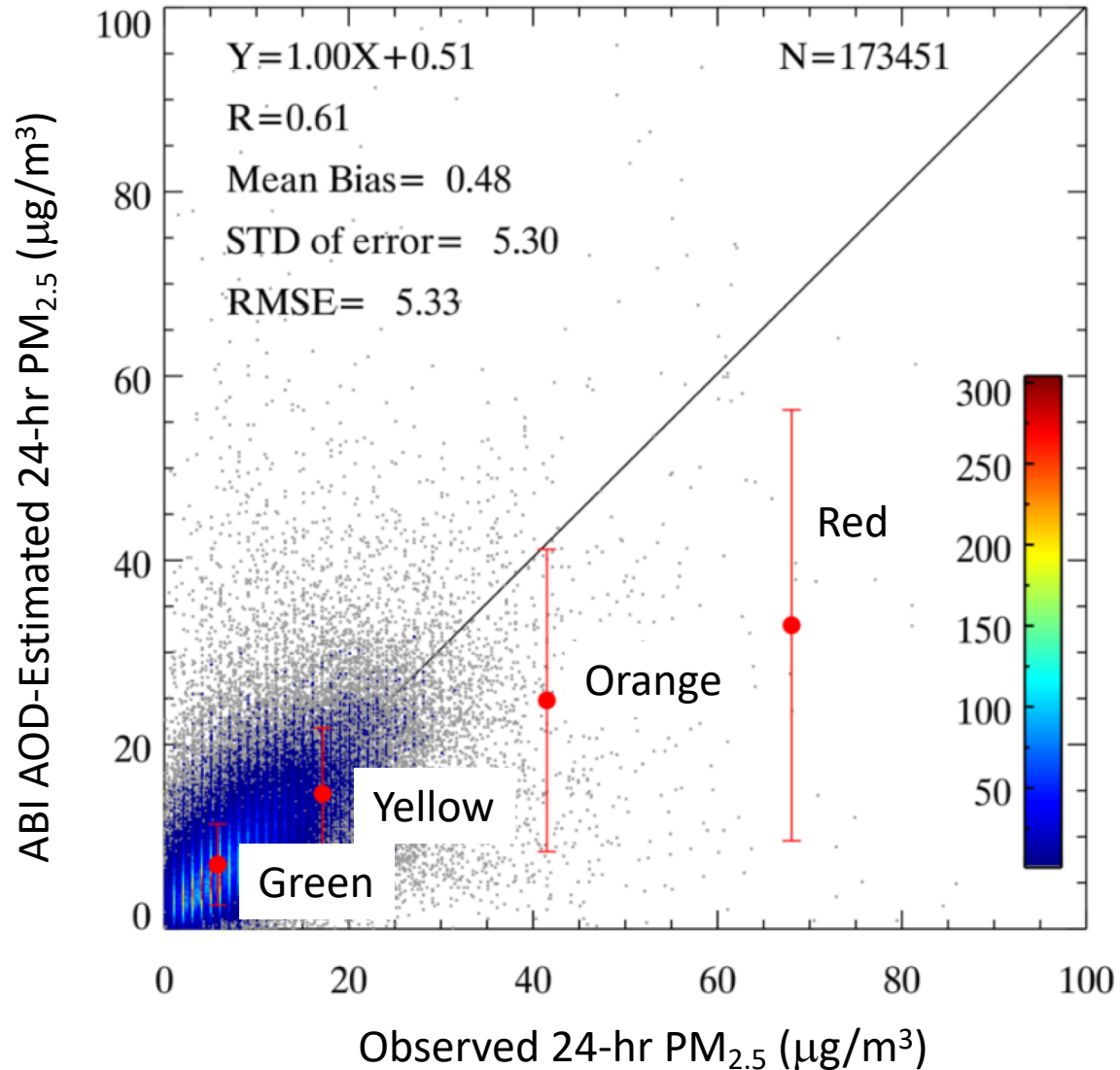
PM_{2.5}-AOD Correlation Statistics for CONUS and Taiwan

CONUS PM _{2.5} – AOD Matchups	Code Green (Good) 0-12.0 µg/m ³			Code Yellow (Moderate) 12.1-35.4 µg/m ³			Code Orange (USG) 35.5-55.4 µg/m ³			Code Red (Unhealthy) 55.5-150.4 µg/m ³		
	Bias	RMSE	N	Bias	RMSE	N	Bias	RMSE	N	Bias	RMSE	N
High Quality	1.1	4.2	87314	-2.5	7.2	19589	-15.3	23.6	322	-35.7	49.5	45
Top 2 Qualities	1.2	4.3	142322	-2.5	7.4	30529	-16.7	23.5	520	-35.0	48.7	76

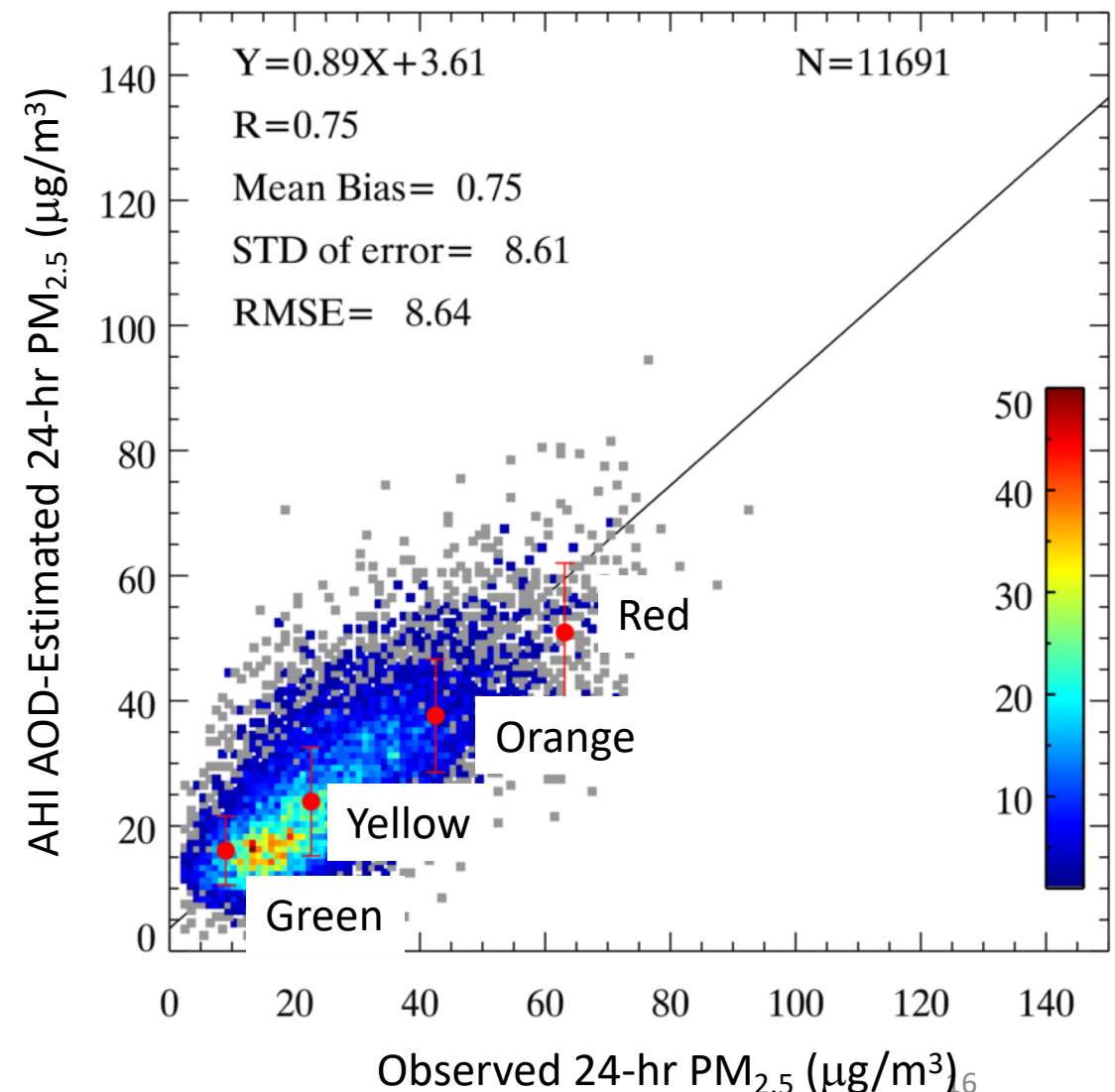
Taiwan PM _{2.5} – AOD Matchups	Code Green (Good) 0-12.0 µg/m ³			Code Yellow (Moderate) 12.1-35.4 µg/m ³			Code Orange (USG) 35.5-55.4 µg/m ³			Code Red (Unhealthy) 55.5-150.4 µg/m ³		
	Bias	RMSE	N	Bias	RMSE	N	Bias	RMSE	N	Bias	RMSE	N
High Quality	5.9	8.3	456	1.4	7.9	1513	-4.0	10.1	464	-11.0	14.7	112
Top 2 Qualities	7.0	9.1	1697	1.3	7.8	7767	-4.9	9.6	1927	-12.2	16.3	300

PM_{2.5}-AOD Correlations for CONUS and Taiwan

CONUS, August 6 – December 31, 2018



Taiwan, March 1 – April 30, 2017



Summary

- ABI and AHI provide multi-channel AOD at high temporal resolution
 - Potentially revolutionary for use in deriving surface $\text{PM}_{2.5}$ in areas without ground-based pollutant monitors
- Diurnal bias discovered in ABI AOD
 - Due to fixed surface reflectance ratios in current AOD algorithm
 - Worse in urban vs. rural areas (in CONUS)
- Simple bias correction technique developed
 - Reduces observed diurnal bias, with largest improvement in urban areas in CONUS
 - Not needed over Taiwan due to more clouds, higher AOD on average
 - Recommended for use with ABI AOD data until algorithm is updated with surface reflectance ratios that vary by time of day
- Resulting AOD- $\text{PM}_{2.5}$ correlation relationships can be used to estimate surface $\text{PM}_{2.5}$ in CONUS and Taiwan
 - US relationship most accurate at lower $\text{PM}_{2.5}$ (Code Green and Yellow)
 - Taiwan relationship accurate from low to high $\text{PM}_{2.5}$ (up to Code Red)