Issues impacting the study of long-term aerosol forcing trends

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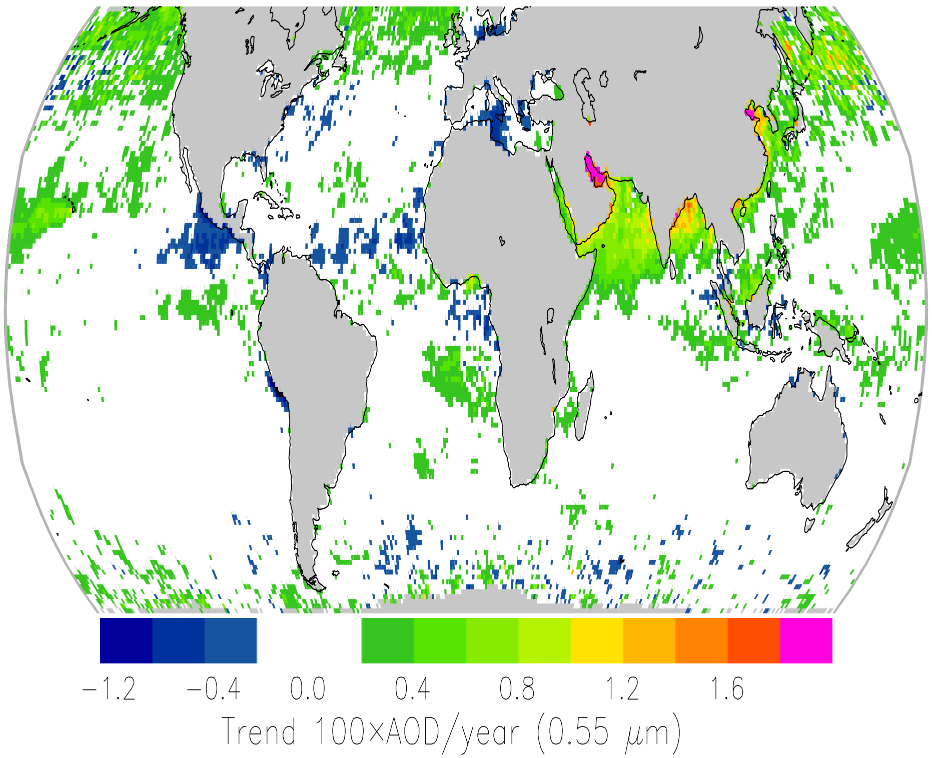
Goals and Objectives in the First Research Year



Goal: Examine decadal trends in Terra and Aqua's AOT and radiative forcing products from MODIS and CERES by accounting for uncertainties and biases in the next generation of aerosol products.

Objectives of Year 1:

(1) Expand the investigation of aerosol trends to the vertical coordinate.

(2) Study temporal variation of above-cloud aerosol events

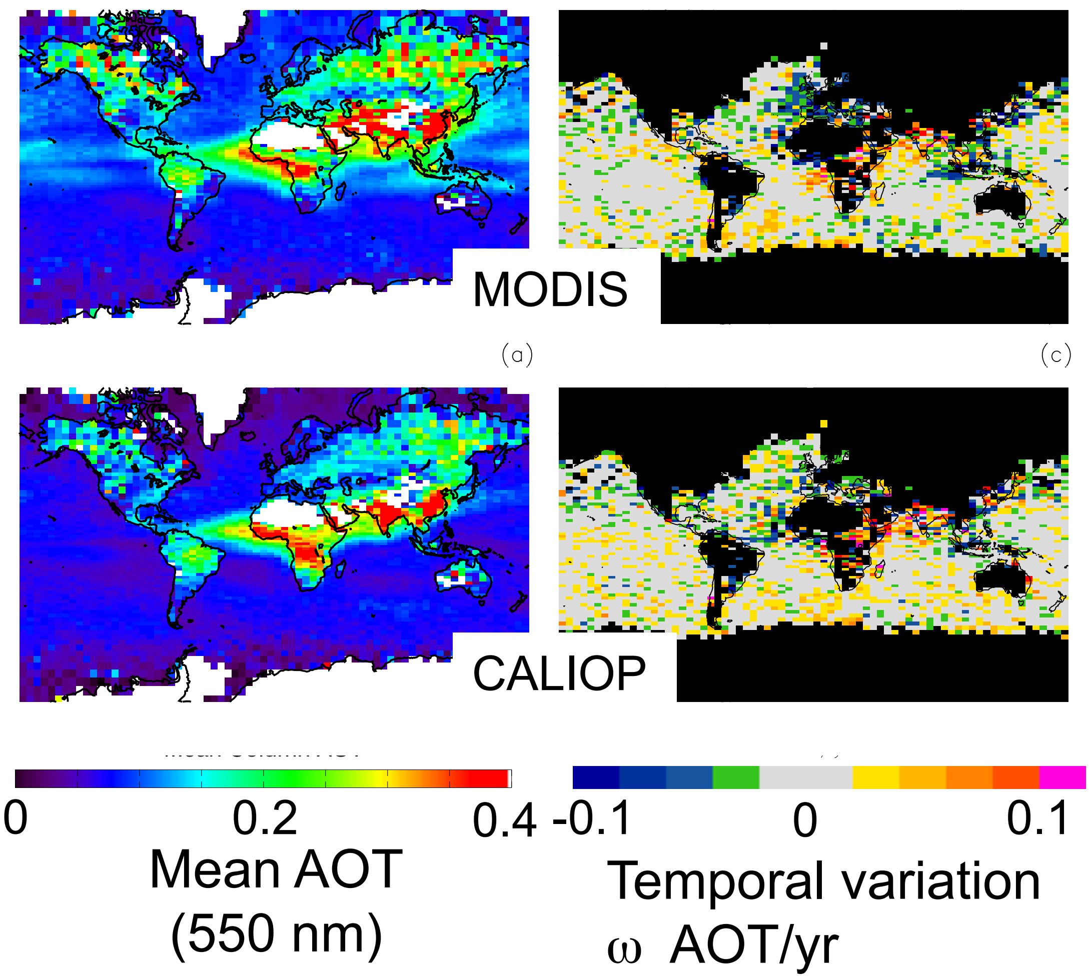
(3) Further explore the Southern Oceans aerosol anomaly, through studying of subsurface oceanic bubbles

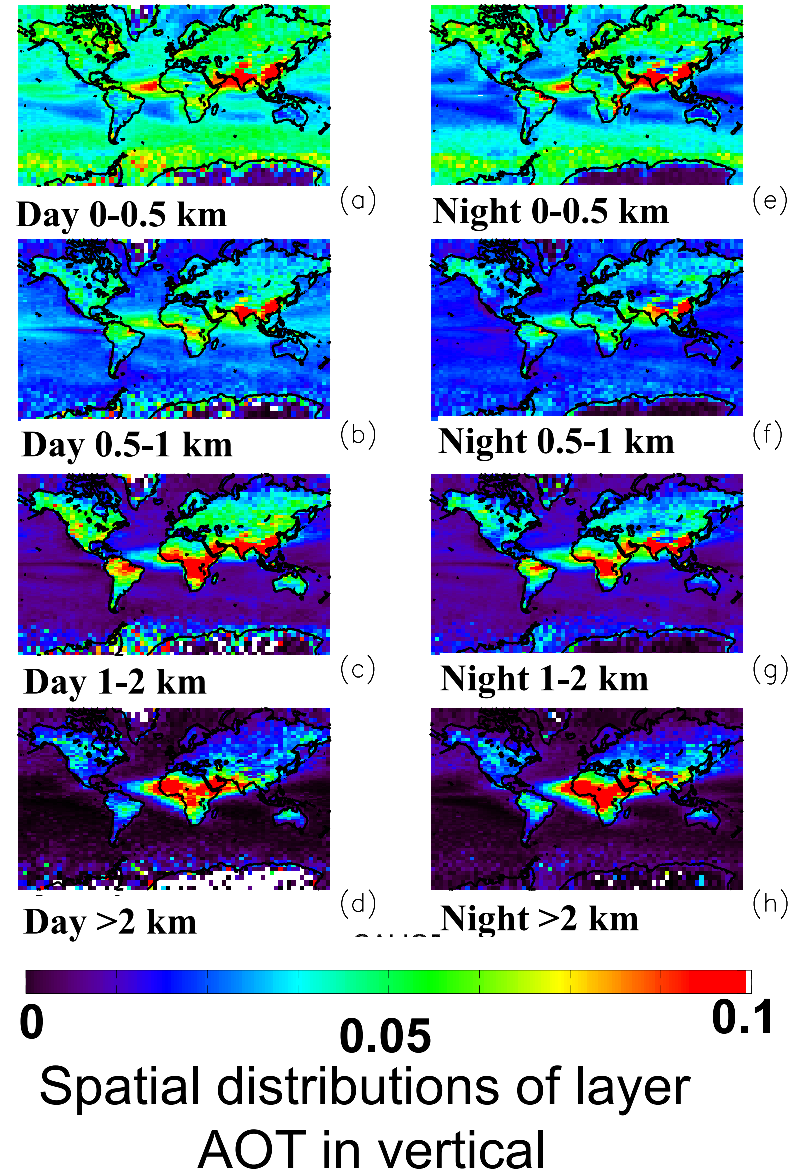
(4) Develop trend-quality aerosol products

(5) Explore use of nighttime aerosol retrievals jointly with VIIRS

Area 1: For regions with significant AOT trends, identify the sources of the trends in the vertical - Is there a consistent story?

Collocated MODIS and CALIOP (2006-2013)





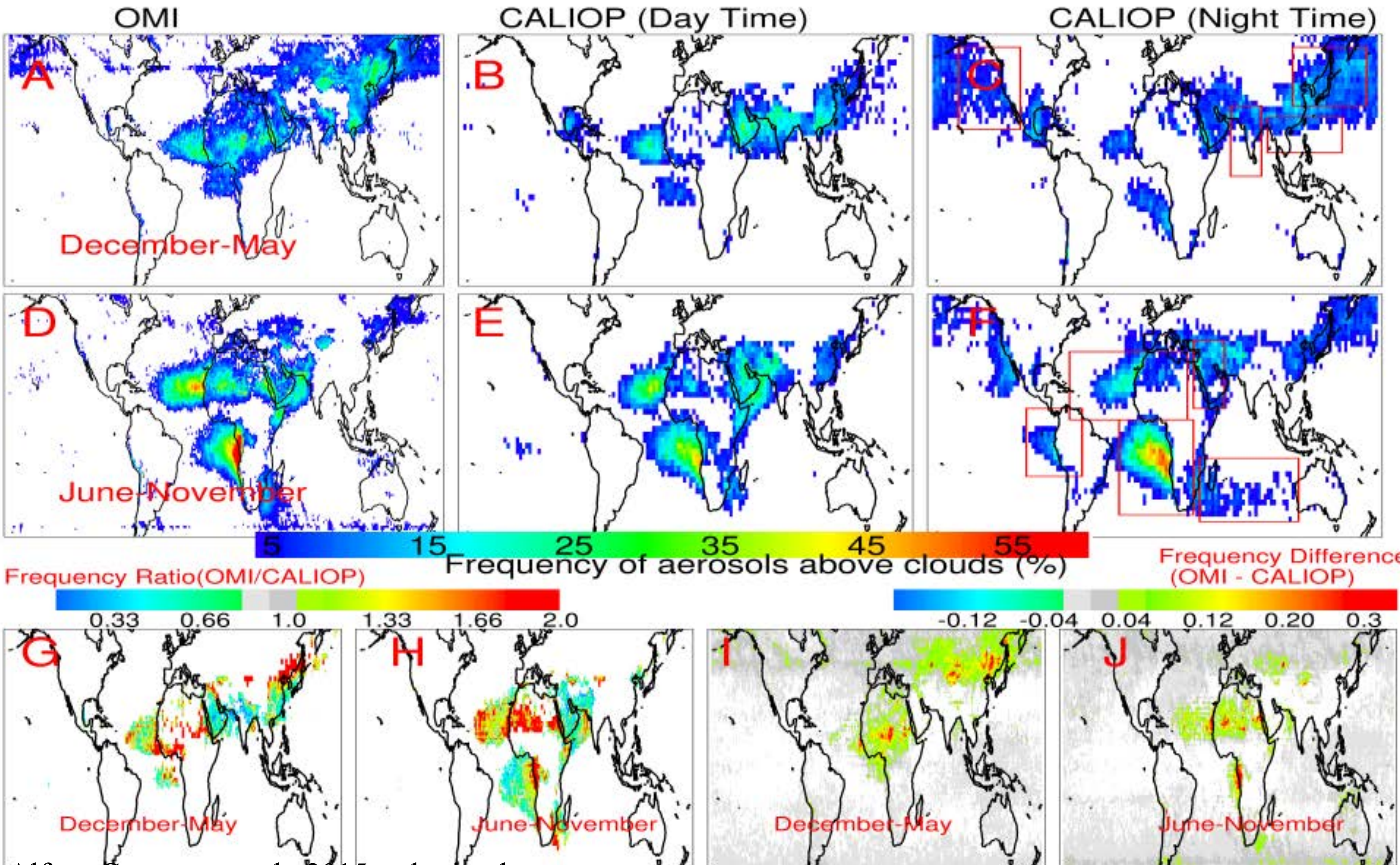
Toth et al., 2015 (submitted)

Aerosol Profile Variability (CALIOP only)

Region	Daytime			Nighttime		
	Column Trend	Peak AOT	Primary Contributor to Column Trend	Column Trend	Peak AOT	Primary Contributor to Column Trend
Northern Africa		> 2 km	1-2 km		> 2 km	1-2 km
Southern Africa		1-2 km	> 2 km		> 2 km	> 2 km
Eastern China		0-0.5 km	1-2 km		0-0.5 km	1-2 km
India		0-0.5 km	0-0.5 km		0-0.5 km	0-0.5 km
Middle East		> 2 km	1-2 km		> 2 km	0-0.5 km
Indonesia		0.5-1 km	1-2 km		0-0.5 km	1-2 km
Europe		0-0.5 km	0-0.5 km		0-0.5 km	1-2 km
Eastern U.S.		0-0.5 km	1-2 km		0-0.5 km	1-2 km
Western U.S.		1-2 km	0-0.5 km		0-0.5 km	0-0.5 km
South America		1-2 km	> 2 km		1-2 km	1-2 km

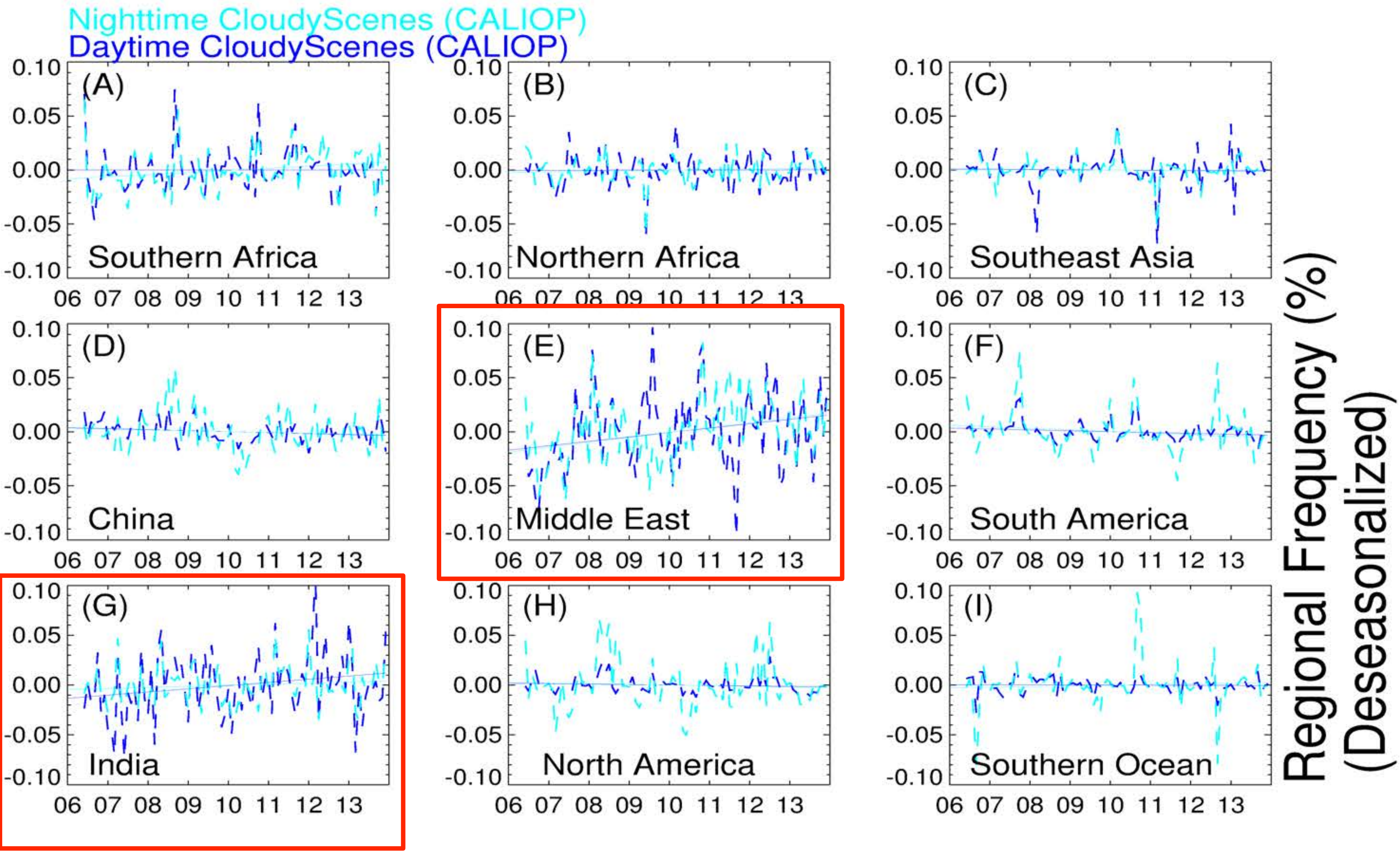
Toth et al., 2015 (submitted)

Area 2: Investigate the climatology of aerosol above cloud aerosol events



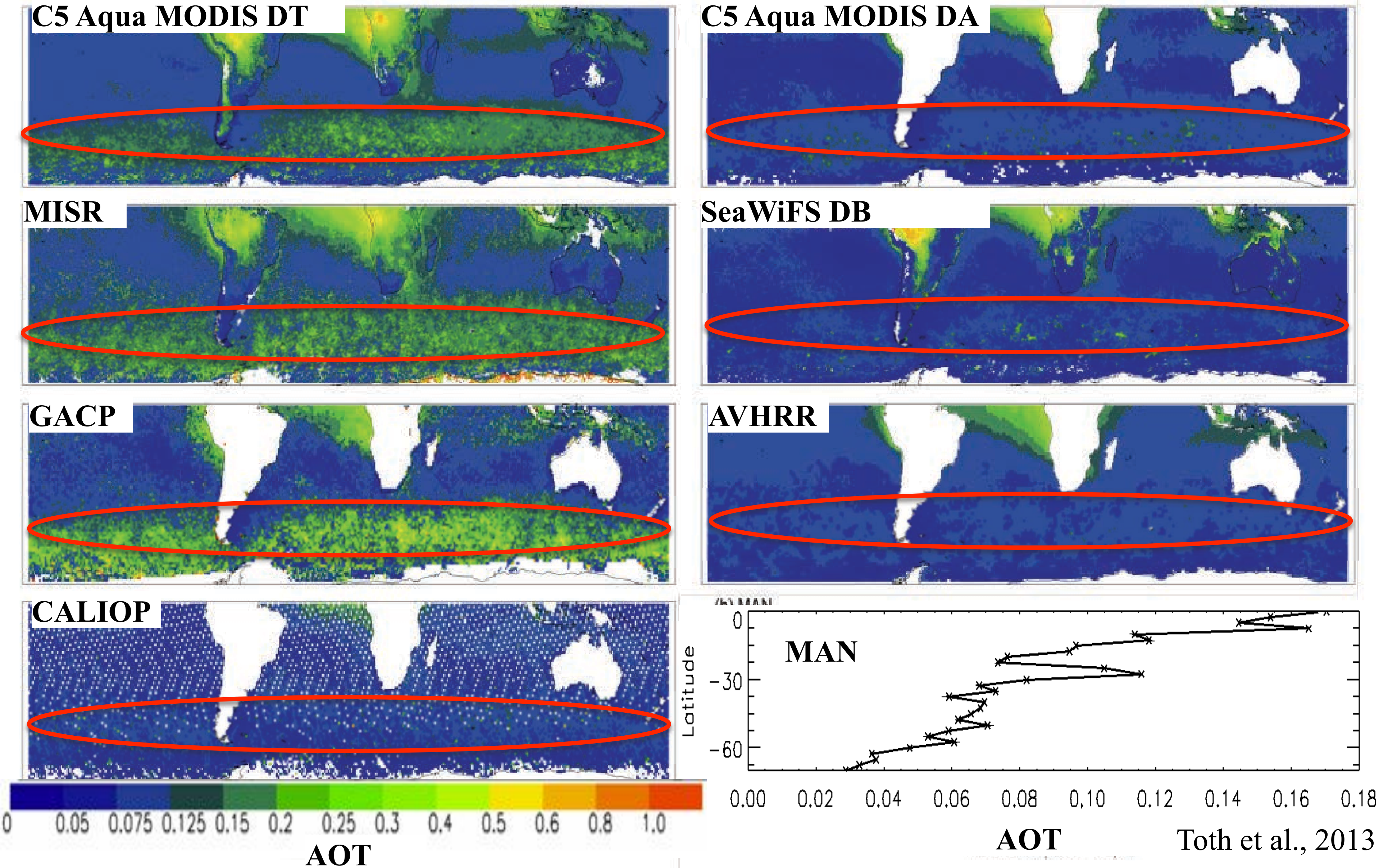
Alfaro-Contreras et al., 2015, submitted

Area 2: Investigate Aerosol Climatology for Above-Cloud Aerosol Events



Alfaro-Contreras et al., 2015, submitted

Area 3: Bubble Investigation of the Enhanced Southern Ocean Aerosol Anomaly (ESOA)



Toth et al., 2013

ESOA can't be fully explained by cloud contamination… Sub-surface bubble contribution?

• **Whitecaps are simply air bubbles on the surface. However, they have significantly different lifetime: minutes to hours for subsurface bubbles vs seconds for whitecaps (e.g. Johnson and Cooke, 1981).**

Radiative Transfer Models (RTMs):

- 6S atmospheric RTM.
- HydroLight oceanic RTM.

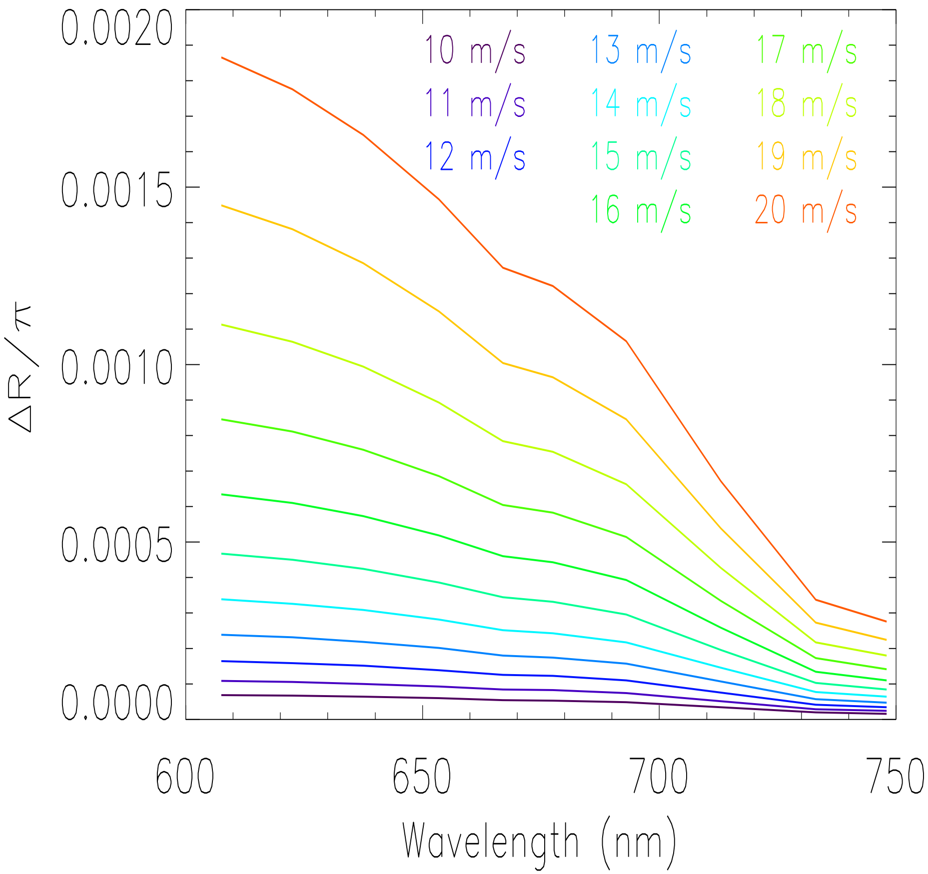
Ocean bubble data:

- *Ocean bubble phase function* is adopted from Zhang et al. (2002).
- *Ocean bubble concentrations* are obtained from Zhang (2001) and Zhang and Lewis (2002), denoted default bubble concentration.

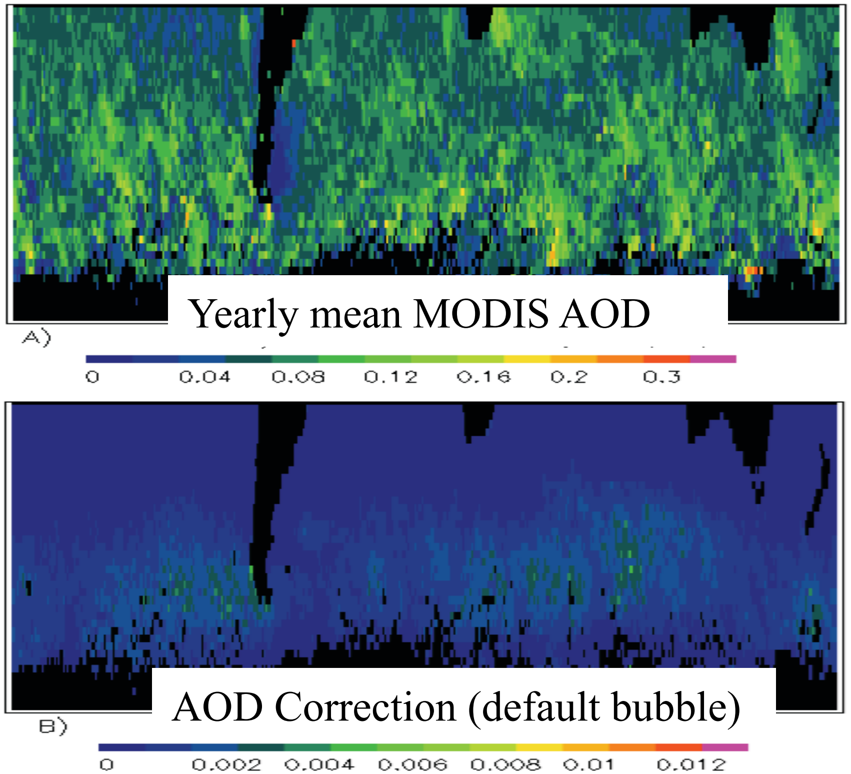
Christensen et al., 2015, accepted

http://upload.wikimedia.org/wikipedia/commons/a/ab/Wake_%28Kilwater %29_behind_a_ferry.jpg

Can't be fully explained by cloud contamination… Sub-surface bubbles?



The difference in surface reflectance (ΔR/π) with and without consideration of oceanic bubbles are plotted as functions of wavelength and near-surface wind speed



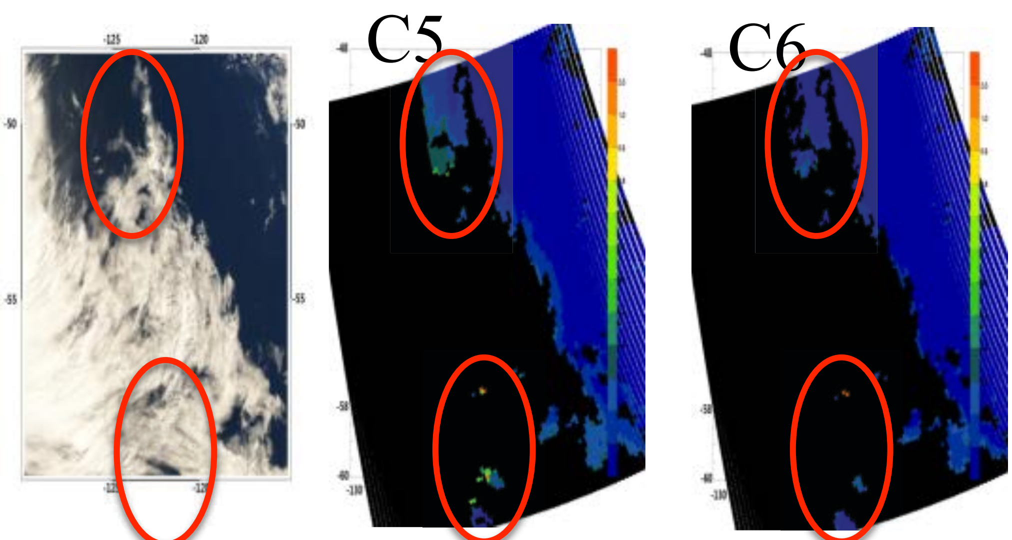
- Subsurface bubbles are not the cause of ESOA
- Subsurface bubbles may not be important for AOT, but it has been show its importance for TOA energy and ocean color retrievals

Christensen et al., 2015, accepted

Area 4: Working Toward Trend-Quality MODIS Aerosol Data though Rigorous QA

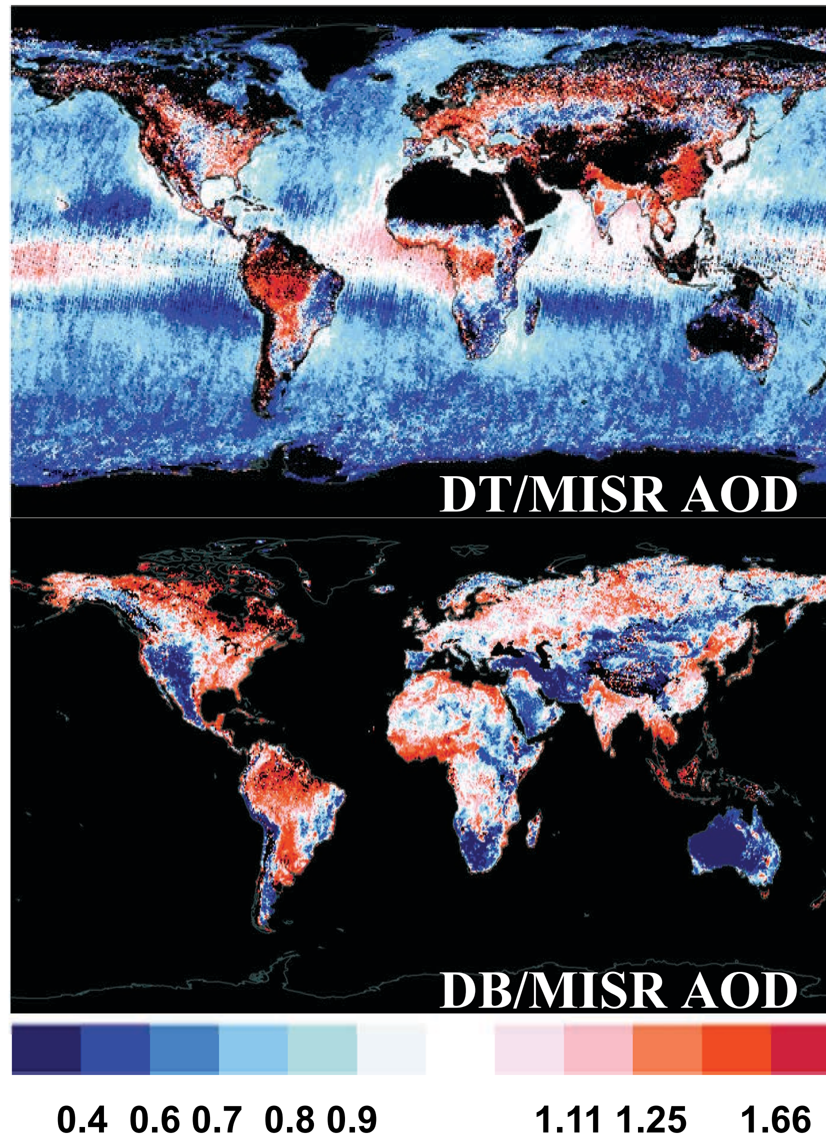
Our Quality-Assured C5 MODIS aerosol products are accessible through the GODAE server

Terra C6 just completed! Working towards constructing trend-quality C6 MODIS aerosol products (DT+DB) following Shi et al., 2011; 2014



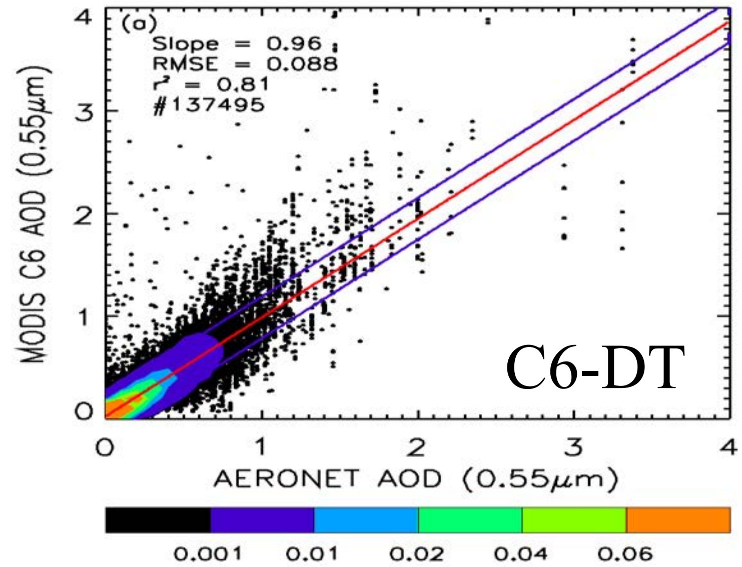
2007-01-03 48-60° S, 115-130° W (DT)

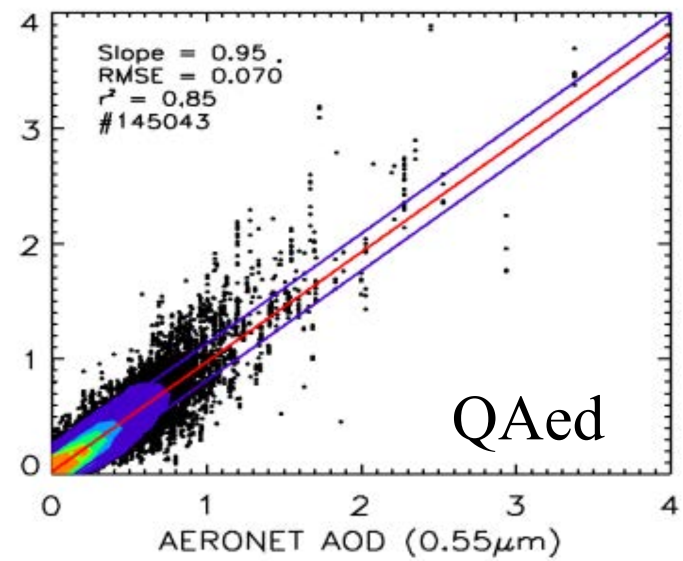
2005-2007



Area 4: Working Toward Trend-Quality QA MODIS aerosol data (cont…)

- Validated using AERONET data, <u>cloud contamination</u>, as well as biases related to aerosol microphysical properties and near-ocean surface wind speeds are reduced when comparing with C5 MODIS DT over-ocean aerosol products.
- The ESOA feature is also greatly reduced in the c6 MODIS aerosol products.
- Our study suggests that cloud contamination still exists and is observable in the C6 dataset.
- By applying data screening and empirical correction steps similar as used in constructing the C5 version of the DA-quality product, our preliminary results show a further reduction of uncertainties in AOD by 17%, and the outliers by 20%.



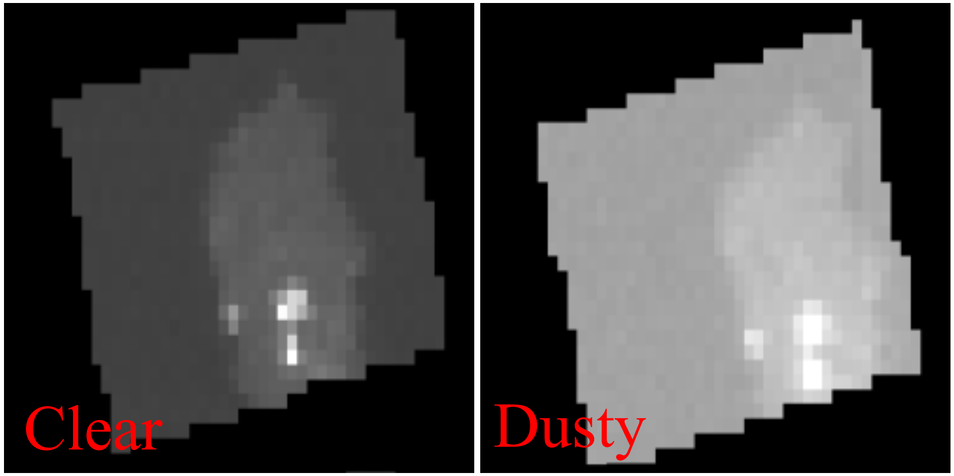


Area 5: Nighttime Aerosol Retrievals are Limited. Can VIIRS Fill the Observational Gap?

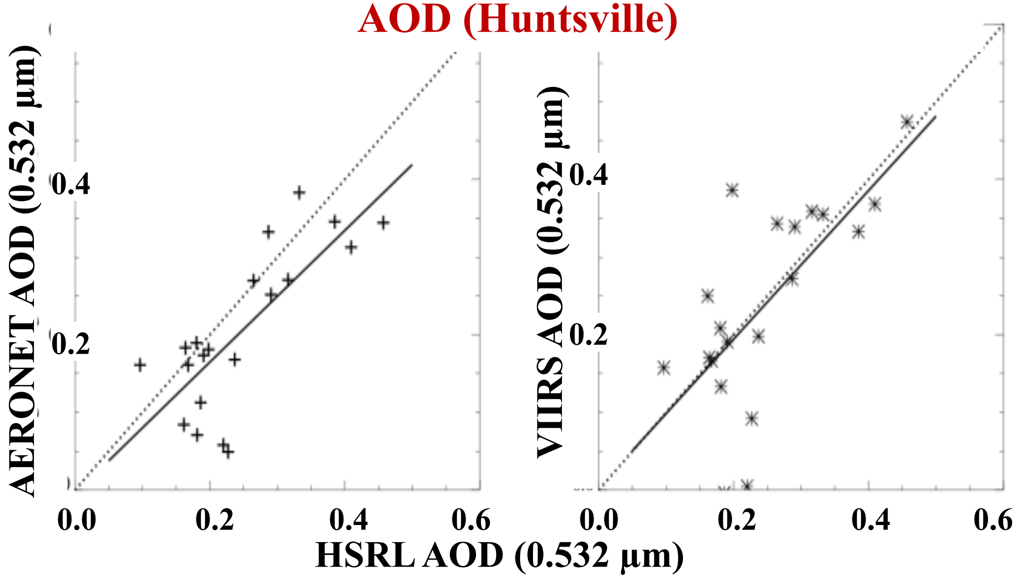
- Reliable nighttime measurements of aerosol optical properties, such as optical depth (τ,) are needed for both climate studies and aerosol modeling efforts (e.g., Zhang et al. 2003, 2008).
- Recently-launched Visible/Infrared Imager/Radiometer Suite (VIIRS) includes a calibrated Day/Night Band (DNB) that can be used to observe nocturnal anthropogenic sources of radiation (e.g., city lights).
- This study presents a new method that uses the statistical variance of pixels within a given artificial light source.
- See the poster section for details

Theodore et al., 2015, submitted

Cape Verde, clear versus dusty skies



VIIRS DNB and AERONET AOD vs. HSRL AOD (Huntsville)



Conclusions and Plans for Year 2

- The significant positive daytime regional AOT trends over India and the Middle East are contributed to the most from the near-surface (0-0.5km) and an elevated layer (1-2km), respectively. Positive temporal variation is also observed from the two regions for above-cloud AOT.

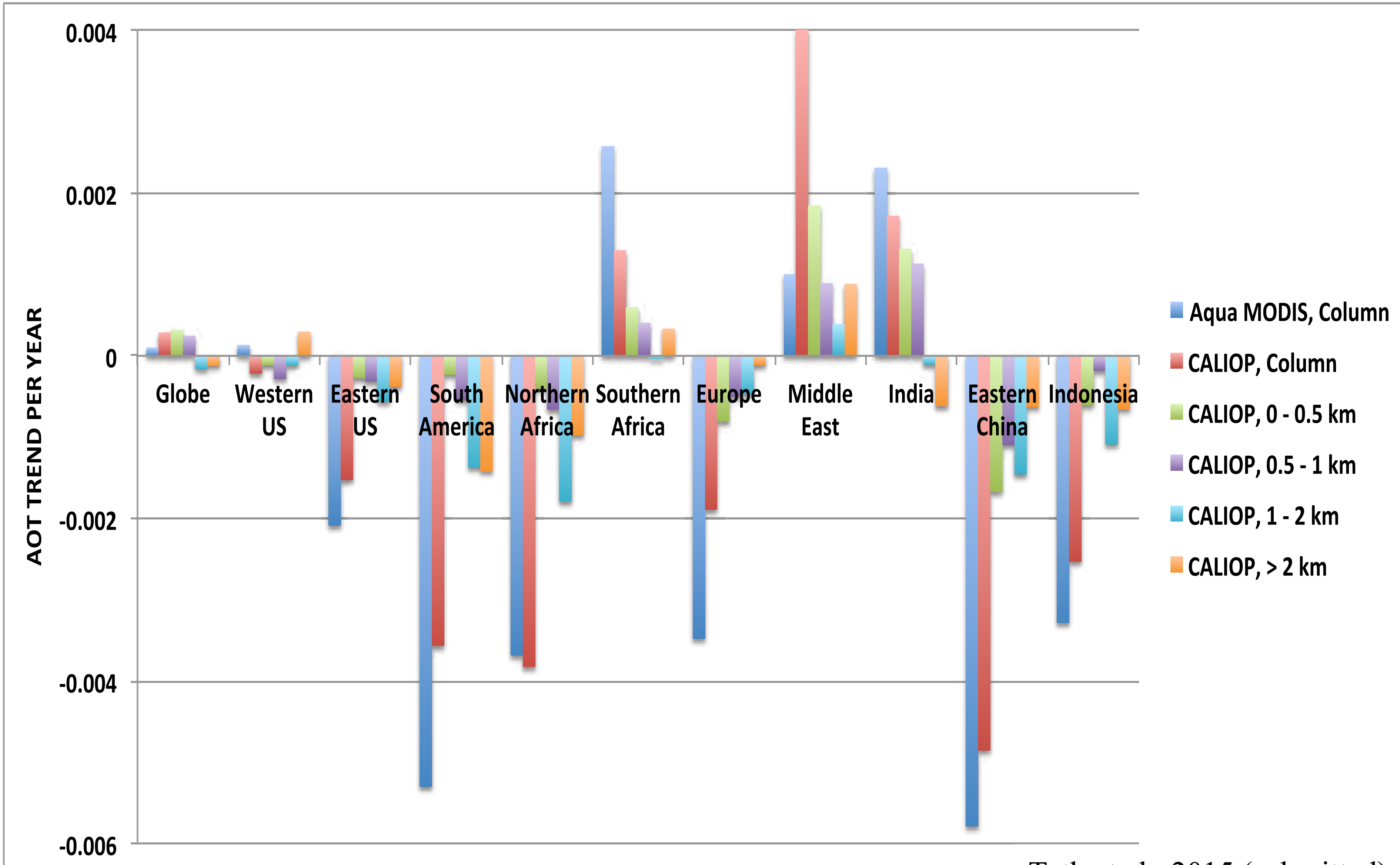
- While working on understanding uncertainties in C5 and C6 MODIS aerosol products, we have evaluated the impacts of subsurface bubbles on the ESOA phenomenon. This study suggests that submerged bubbles are not the primary cause for ESOA. That being said, submerged bubbles have been shown their importance for TOA energy and ocean color retrievals.

- For the coming year, emphasis will be given to:

(1) Development of trend-grade aerosol datasets (DT+DB).
(2) Start looking at MAIAC data
(3) Although not shown, we have been working towards aerosol forcing trend analysis through a multi-sensor based approach (including MODIS and CERES).

Region	Zhang and Reid (2010)		Hsu et al. (2012)		Li et al. (2014)		This Study	
	Terra MODIS/MISR		SeaWiFS		AERONET		CALIOP	
	March 2000 – December 2009		January 1998 – December 2010		2000 – 2013 (station-dependent)		June 2006 – December 2013	
	Latitude Longitude	Trend (AOT/year)	Latitude Longitude	Trend (AOT/year)	Latitude Longitude	Trend (AOT/year)	Latitude Longitude	Trend (AOT/year)
Northern Africa	8°N-24°N 60°W-18°W	-0.0013/-0.0035 (-0.0009)	10°N-15°N 5°W-15°E	0.0049 (-0.0020)	13.3°N 5.9°W	-0.007	0°N-30°N 20°W-20°E	-0.0022
Southern Africa	23°S-7°S 20°W-15°E	0.0009/-0.0001 (0.0013)					30°S-0°N 10°E-30°E	0.0023
Eastern China	20°N-40°N 110°E-125°E	0.0062/0.0038 (-0.0032)	35°N-40°N 110°E-120°E	0.0032 (-0.0042)	40°N 116.4°E	-0.01	20°N-40°N 100°E-120°E	-0.0037
India	10°N-25°N 78°E-103°E	0.0069/0.0035 (0.0005)	20°N-30°N 75°E-85°E	0.0063 (0.0036)	26.5°N 80.2°E	0.008	5°N-30°N 70°E-90°E	0.0020
Middle East	5°N-23°N 50°E-78°E	0.0058/0.0047 (0.0039)	10°N-35°N 35°E-60°E	0.0092 (0.0035)			15°N-40°N 40°E-60°E	0.0029
Indonesia	15°S-10°N 80°E-120°E	0.0007/0.0002 (-0.0010)	15°S-10°N 80°E-120°E	0.00011 (-0.0010)			10°S-5°N 95°E-130°E	-0.0012
Europe	30°N-45°N 0°E-40°E	-0.0016/-0.0022 (-0.0014)	43°N-55°N 0°E-30°E	-0.0027 (-0.0025)			40°N-60°N 10°W-30°E	-0.0020
Eastern U.S.	30°N-45°N 80°W-60°W	-0.0015/-0.0019 (-0.0011)	30°N-45°N 70°W-90°W	-0.0028 (-0.0026)			25°N-50°N 95°W-65°W	-0.0015
Western U.S.							25°N-50°N, 125°W-95°W	-0.0010
South America			10°S-20°S 40°W-65°W	-0.0009 (-0.0013)			30°S-0°N 80°W-50°W	-0.0020
Global Land				0.00058				0.0004
Global Oceans		0.0003/-0.0003		0.0008				0.0004
Globe				0.00078				0.0003

Collocated Collection 6 Aqua MODIS/CALIOP Analysis



Toth et al., 2015 (submitted)