Spanning temporal scales: An Evaluation of the Impacts of Aerosol Particles from Long-Term Climate Forcing Variation to Short-Term Weather Forecasts

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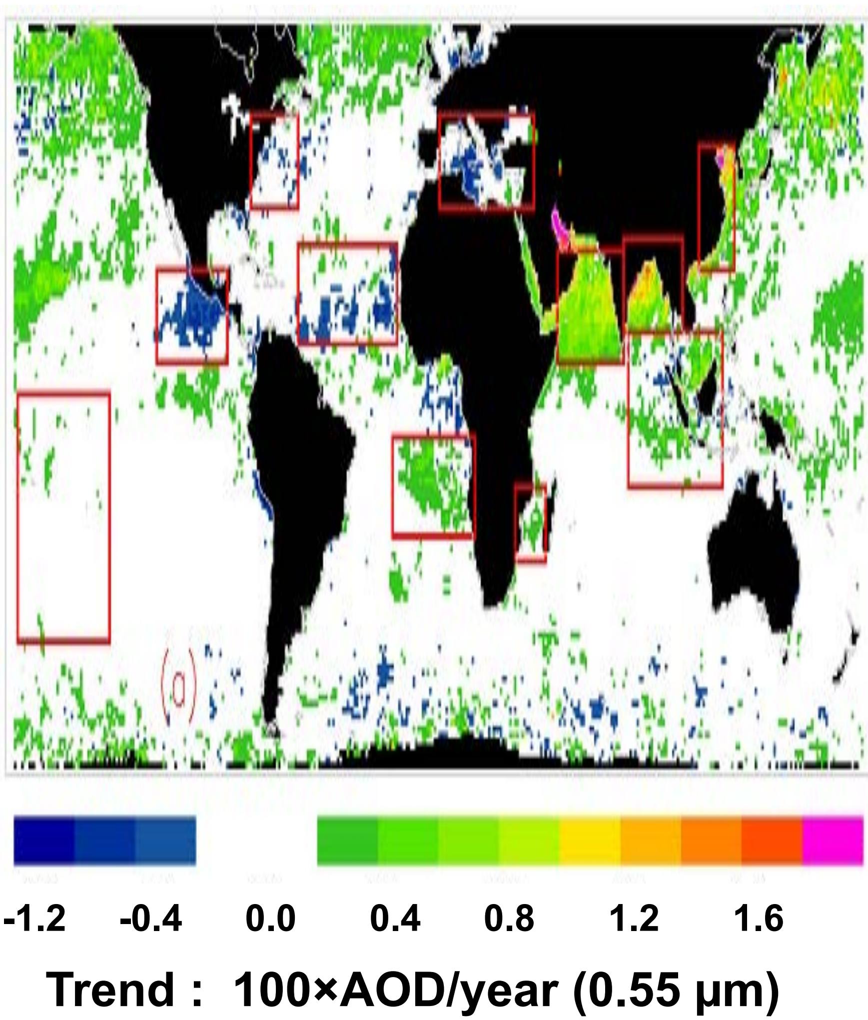
Goals and Objectives / Opportunities

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

Opportunities: With nearly 16 years of CERES and MODIS data and 10 years of CALIPSO data, it is possible to study the relatively long-term variation and radiative impact of aerosol vertical distribution. Now we can evaluate column-integrated AOT (e.g. MODIS and MISR), the aerosol vertical profile (e.g. CALIOP and OMI) and TOA SW aerosol-induced energy perturbations (TOA SW aerosol direct forcing, SWARF) simultaneously.

New opportunities: While the study of aerosol and aerosol forcing trends improves our understanding of climate variation, aerosol particles also likely affect daily surface temperature forecasts. This is particularly interesting as advances in aerosol satellite remote sensing and aerosol data assimilation have pushed this topic to the research forefront.

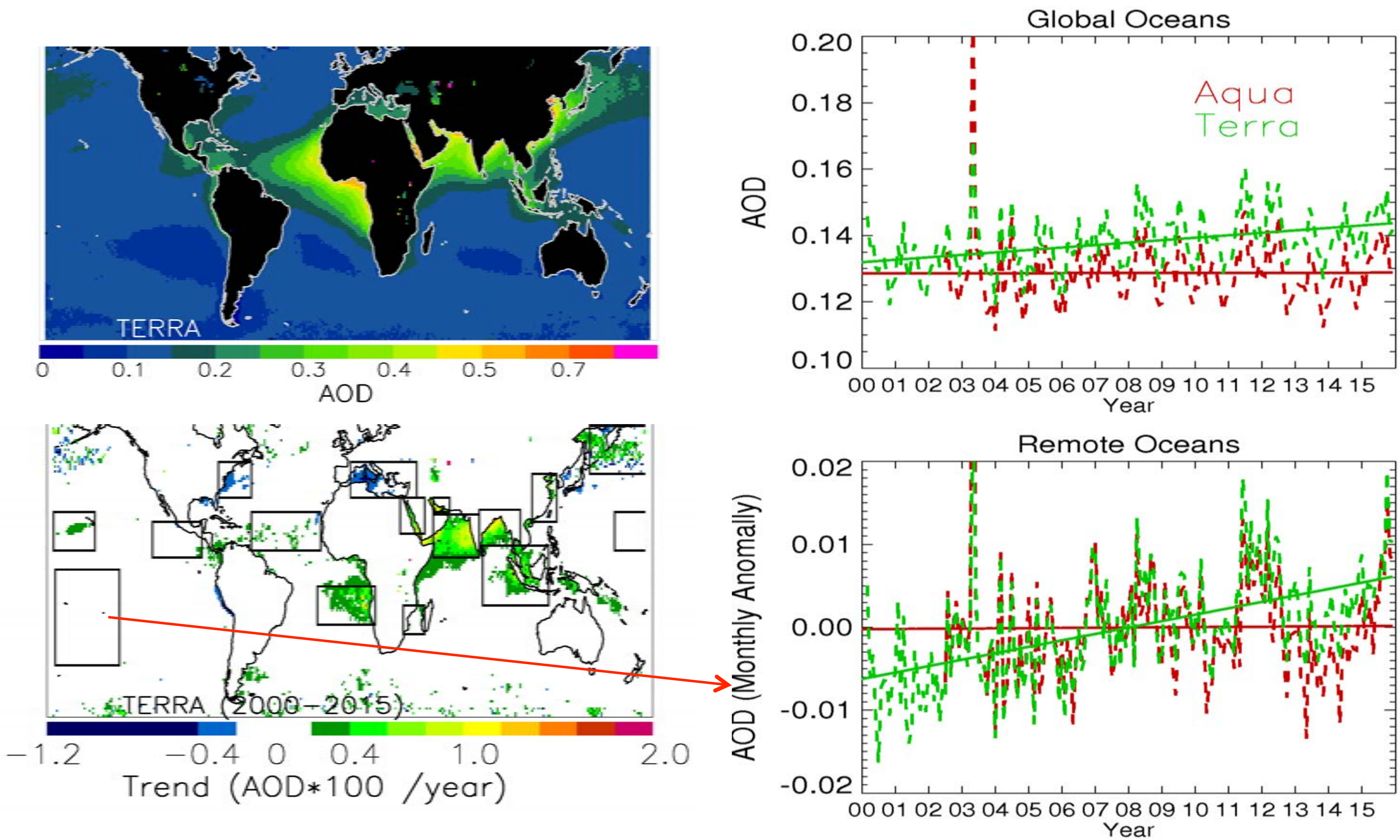
Inter-Comparison of Trend Analysis from C5 and C6 of Terra MODIS AOT datasets (2000-2009)



Regions	Corrected Slope AOD /decade (Terra)	
	C5	C6
Global	0.003	0.005
Africa (NW Coast)	-0.013	-0.011
Bay of Bengal	0.069	0.071
Coastal China	0.062	0.068
Central America	-0.023	-0.015
Arabian Sea	0.058	0.069
Mediterranean Sea	-0.016	-0.015
Africa (SW Coast)	0.009	0.016
N. Amer. (E Coast)	-0.015	-0.013
Africa (SE Coast)	0.010	0.012
Southeast Asia	0.007	0.014

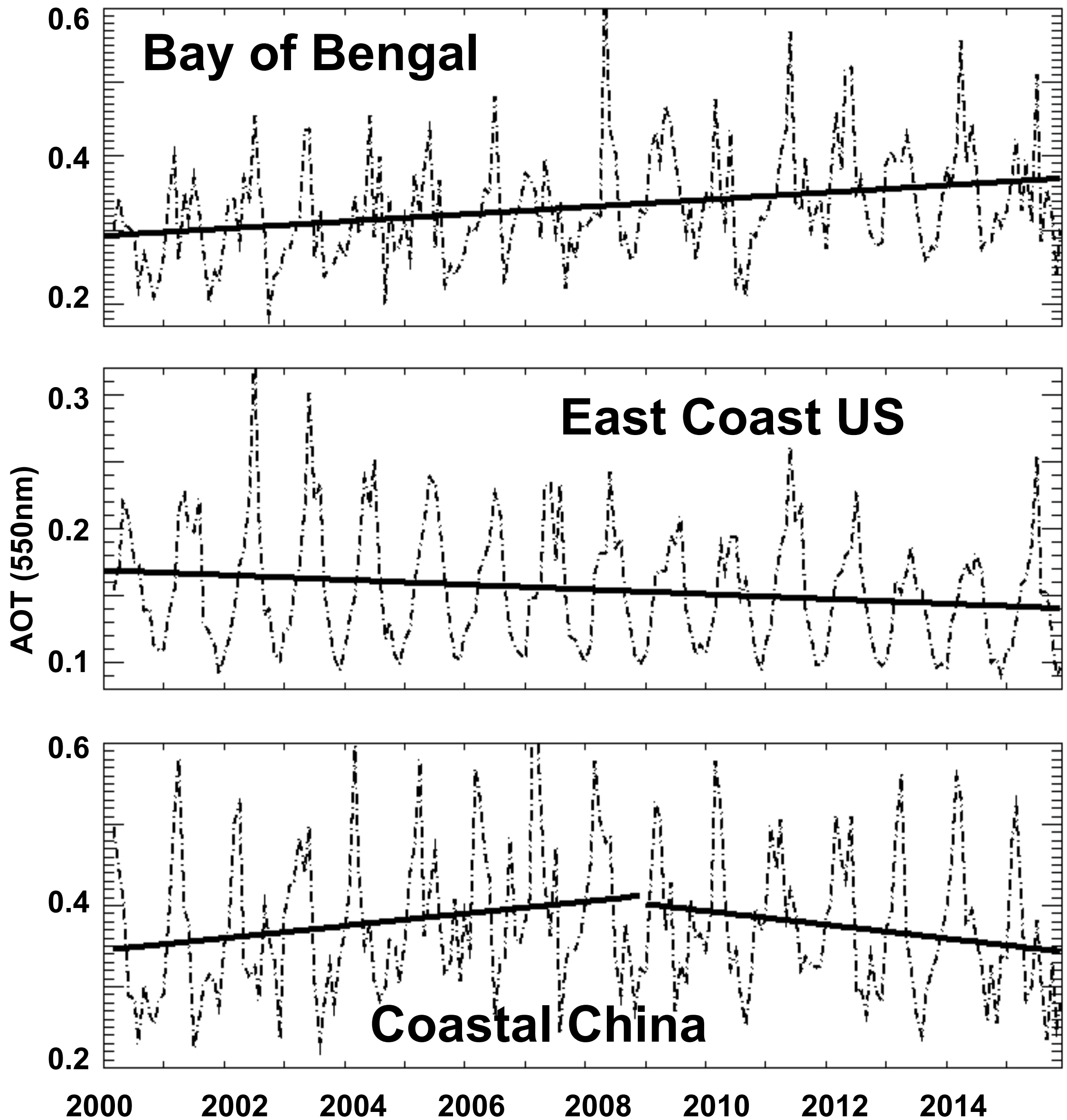
Zhang and Reid, 2010

Extend the AOT Trend Analysis to 16 years (2000-2015)



Alfaro-Contreras et al., et al., 2016 (in preparation)

Regional-based Trend Analysis (Terra, 2000-2015)

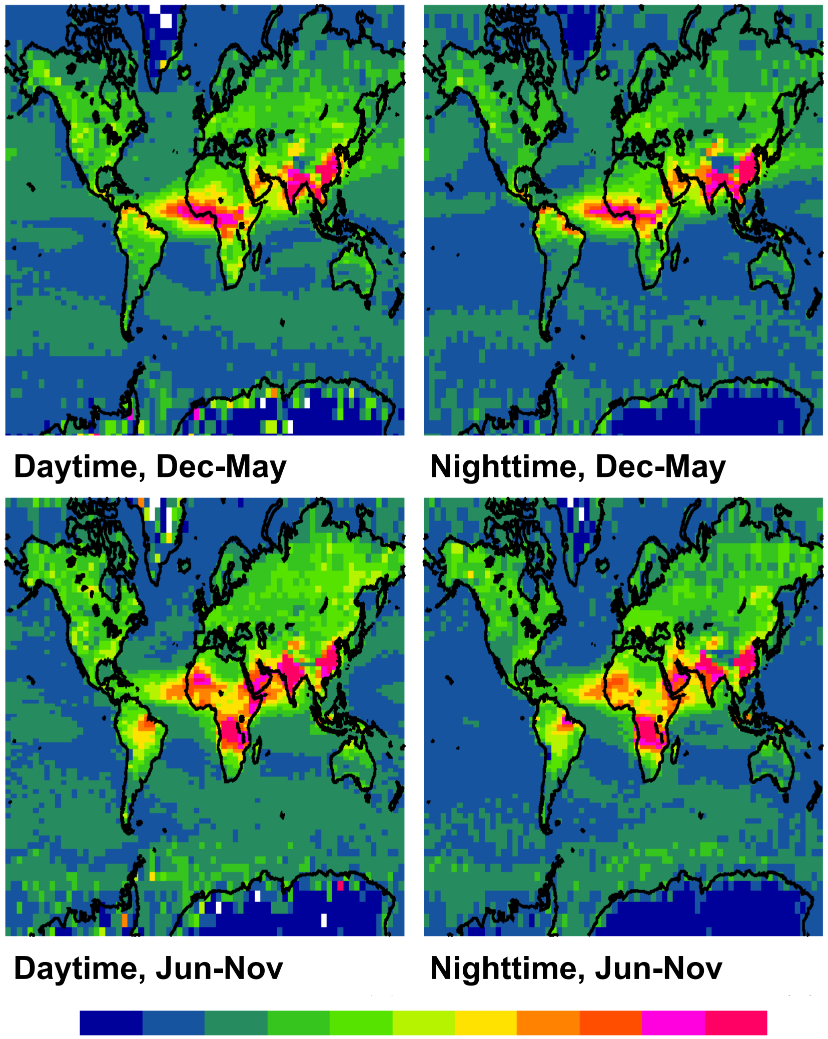


Operational DT MODIS

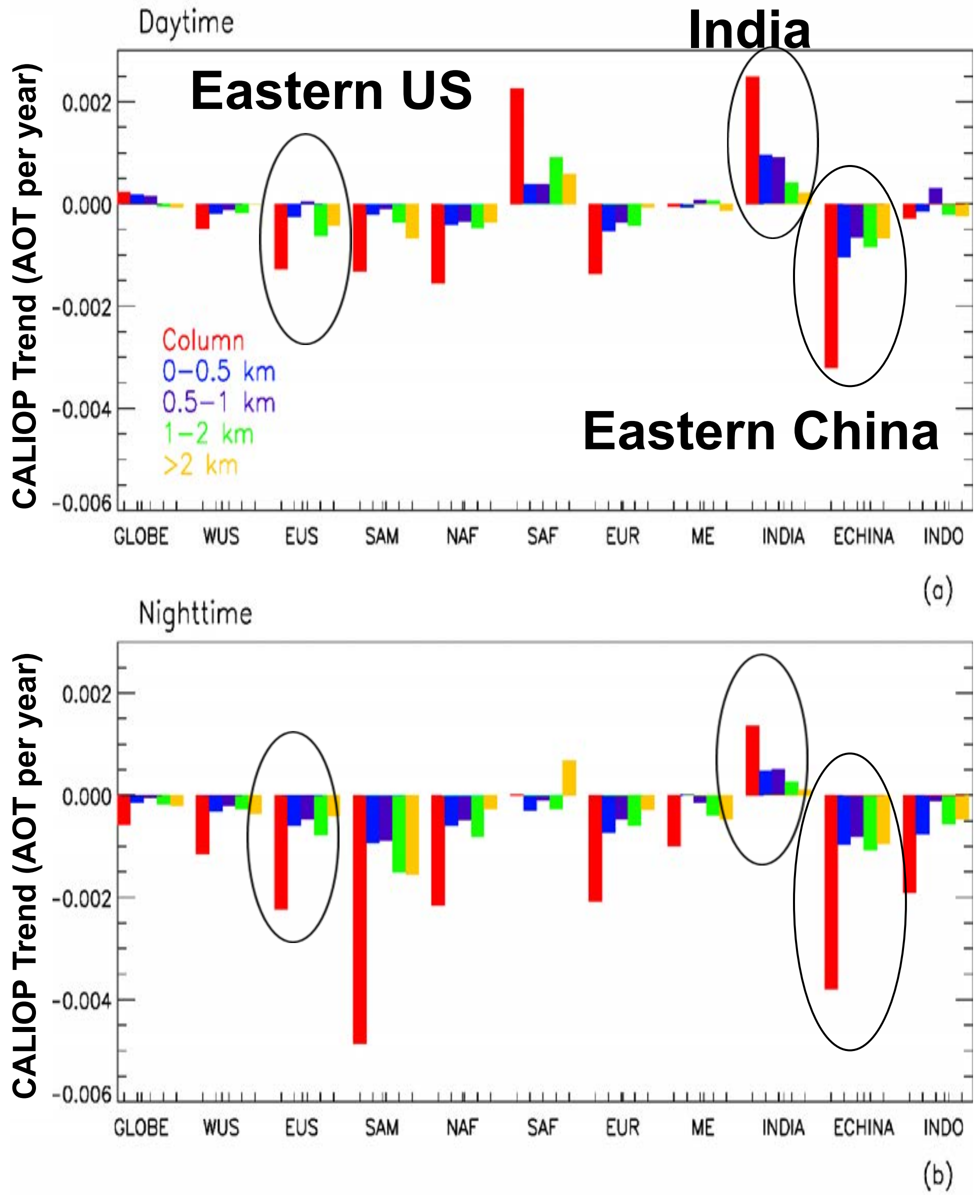
Regions	ΔAOD/ decade (Terra)
Global	0.002
Coastal China	0
Mediterranean Sea	-0.023
N. Amer. (E Coast)	-0.021
Bay of Bengal	0.047
Arabian Sea	0.048
Red Sea	0.064
Persian Gulf	0.072

Alfaro-Contreras et al., et al., 2016 (in preparation)

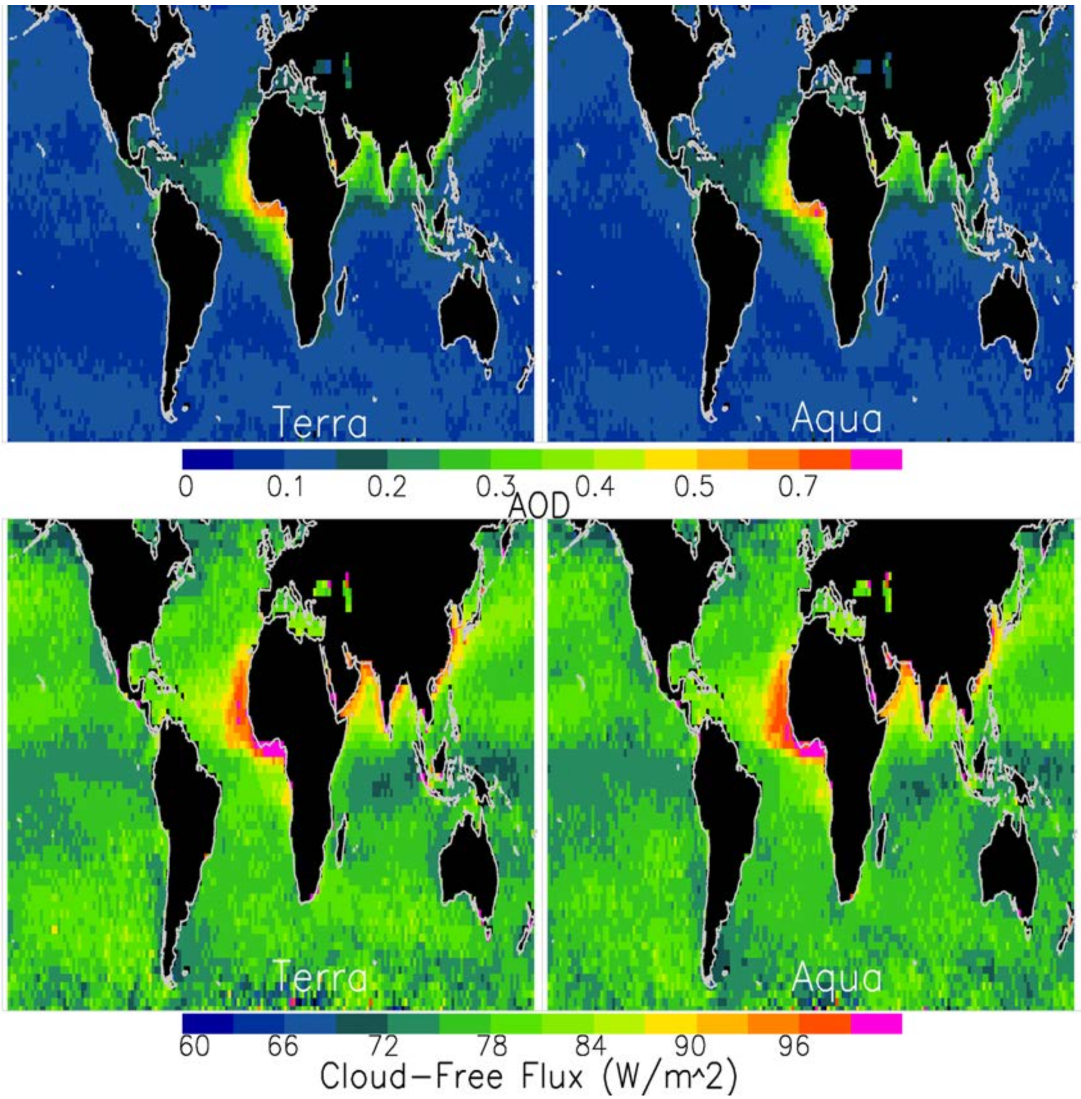
What do CALIOP Observations Tell Us About Vertical Trends? (2006-2014)



Toth et al., 2016 (submitted)



What do CERES Observations Tell Us About Trends in Aerosol Radiative Flux? (2000-2015)



Goal: Use collocated MODIS and CERES observations for estimating the trend in SW aerosol direct forcing

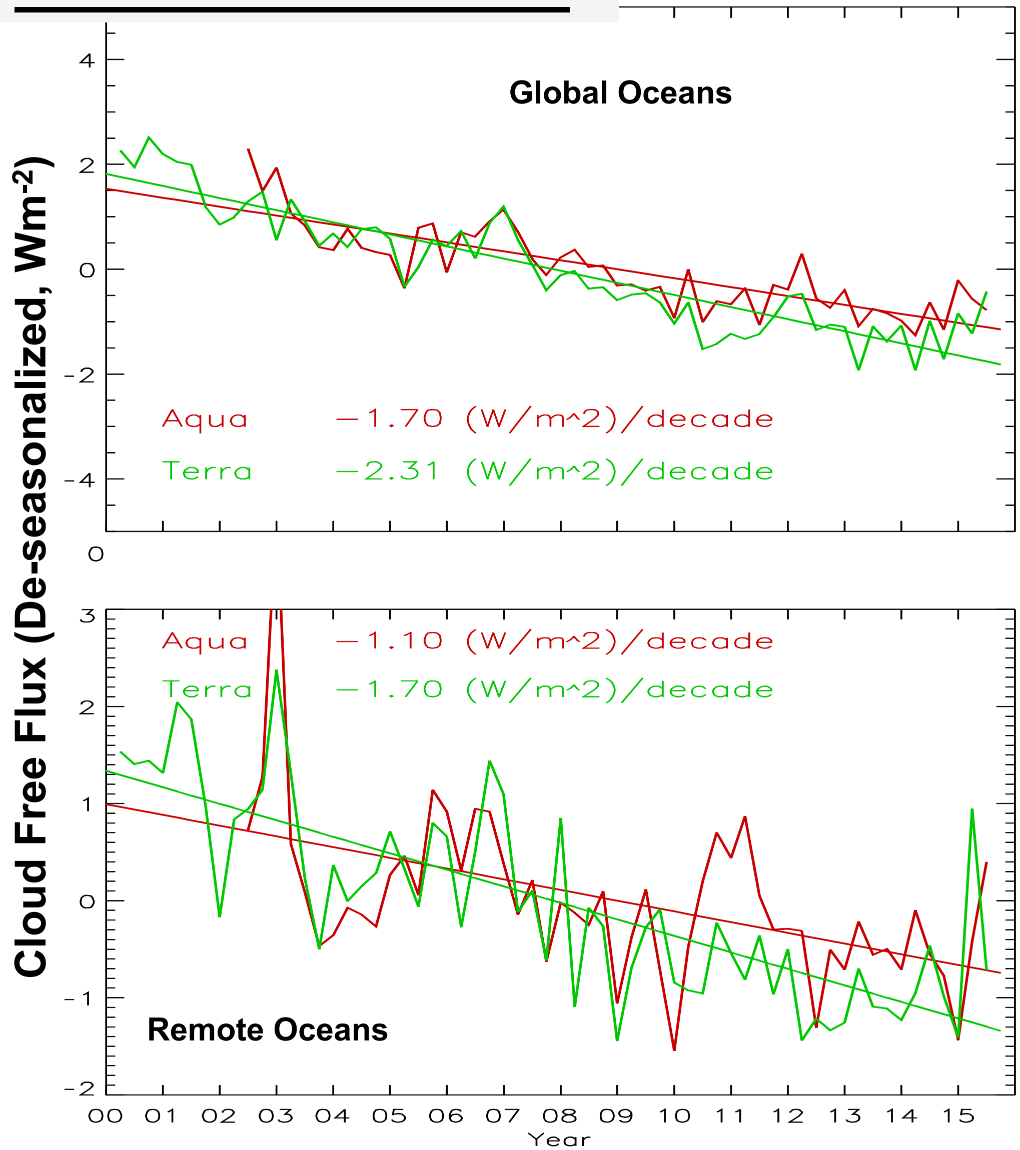
Collocated MODIS data are used for estimating cloud and aerosol status for CERES observations.

Here we assume that longer term variation in CERES cloud-free scenes (defined by MODIS) represent longer term variations in SWARF

Alfaro-Contreras et al., et al., 2016 (in prepare)

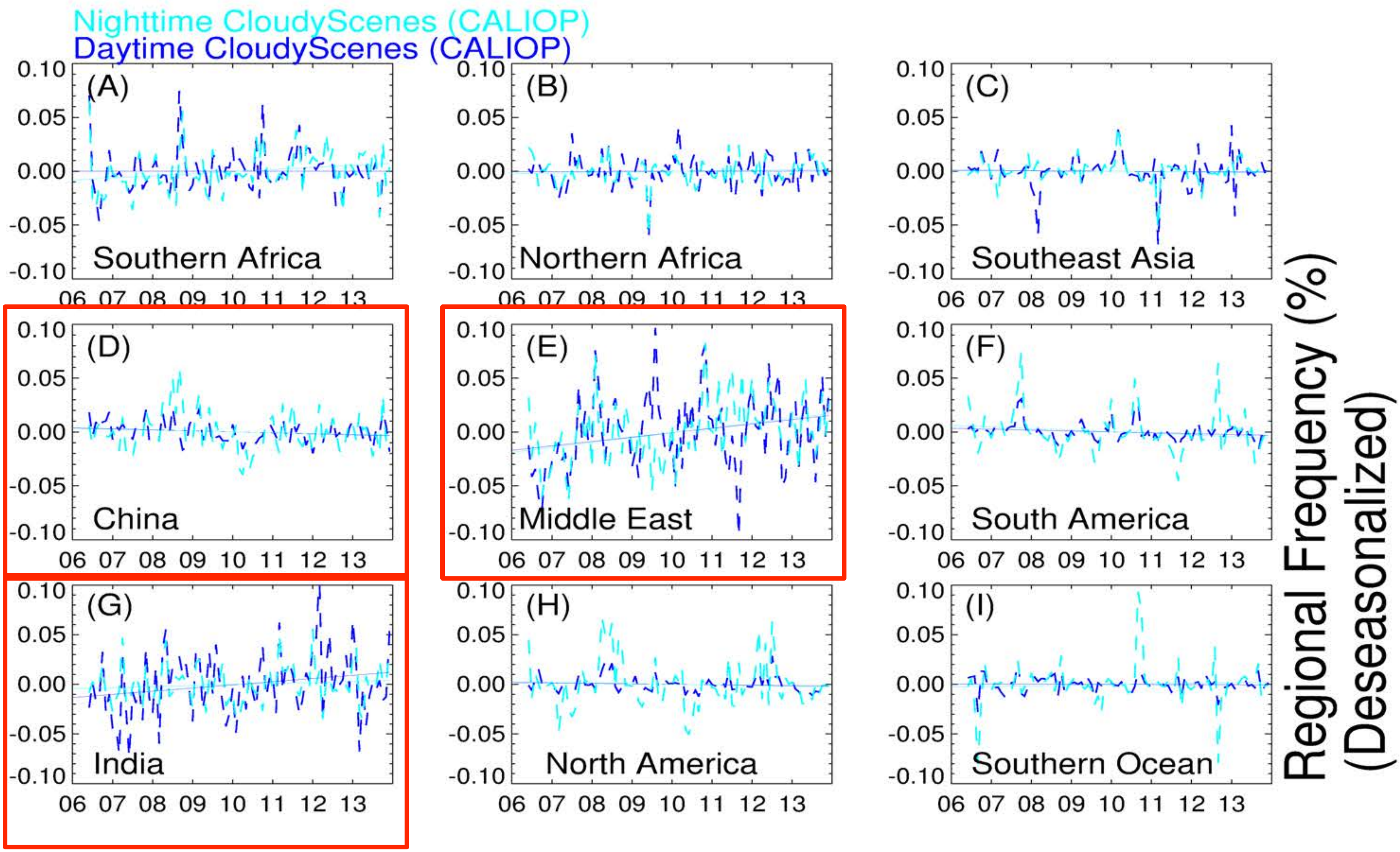
Aerosol-Induced TOA SW Perturbations from Collocated Terra MODIS and CERES data (2000-2015)

Calibration issue?



Regions	Corrected AOD / Decade (Terra)	Corrected Cloud-Free Flux W/m^{-2}/decade (Terra)
Global	-0.0028	-0.61
Bay of Bengal	0.0560	3.17
Arabian Sea	0.0510	3.60
Red Sea	0.0530	3.40
Persian Gulf	0.0682	3.48
Coastal China	-0.009	-2.86
Cent. America	-0.010	-0.91
Med. Sea	-0.011	-1.48
N. America (East Coast)	-0.011	-2.24

Can Similar Trends be Detected for Aerosol-Above-Cloud Events (CALIOP, 2006-2013)?



Alfaro-Contreras et al., 2015

What About the Direct Impact of Aerosol Particles on Weather?

Climate is a scale composed by the long-term integration of weather phenomena. The impact of aerosol particles on climate is being extensively studied. However, the impact of aerosol particles on short-term weather scales is not well known.

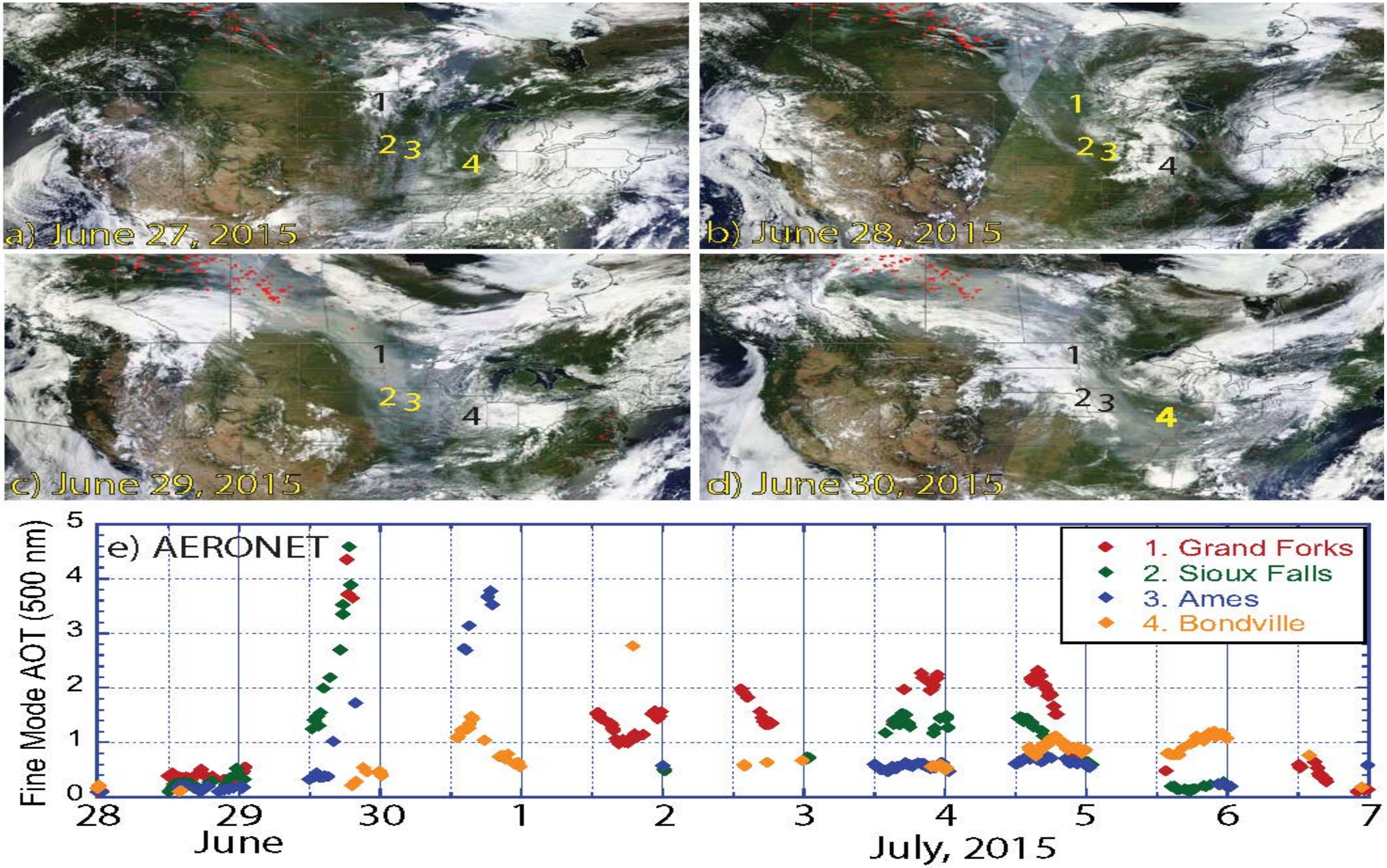
In the past decade, breakthroughs have been made in both satellite remote sensing of aerosol properties and aerosol modeling through satellite data product assimilation.

Improvements in our ability to observe and model aerosol events have led to the coupling of prognostic aerosol fields into numerical weather models for advanced weather forecasts.

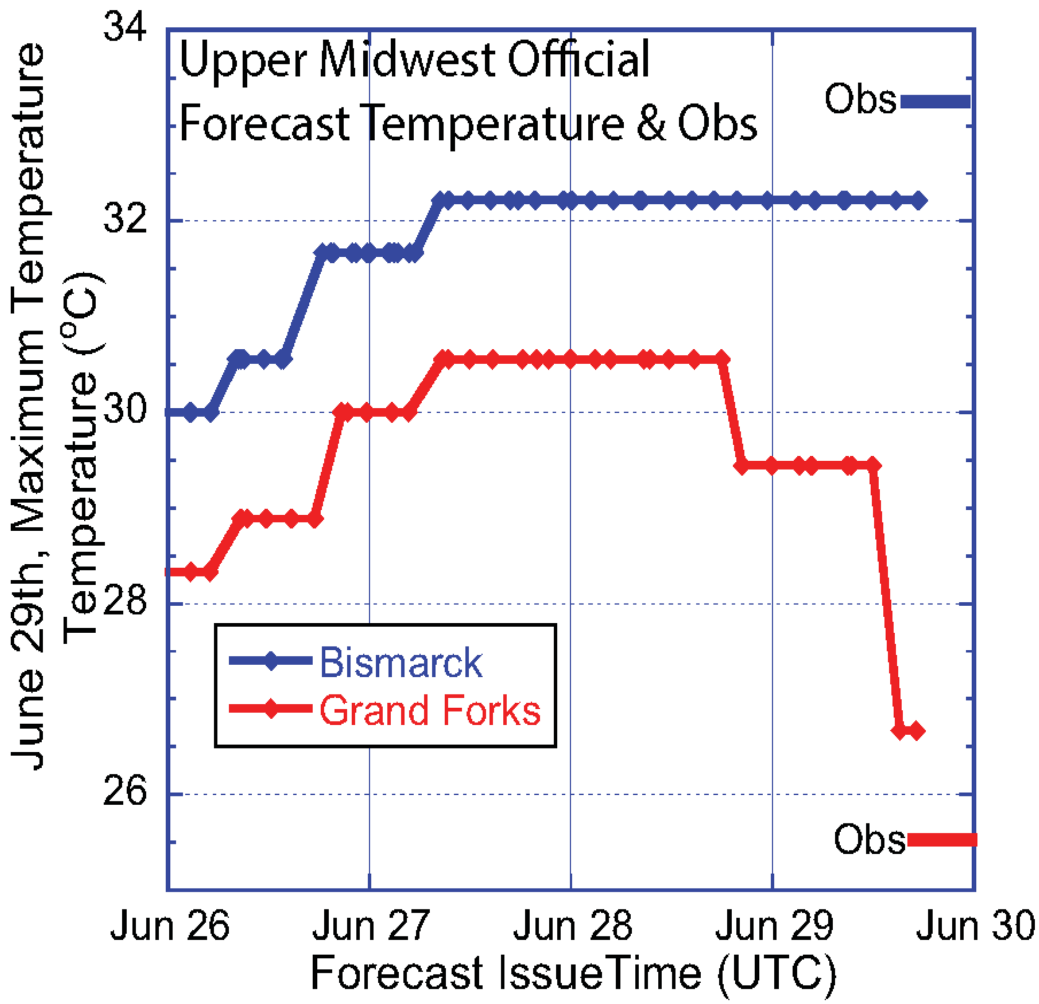
Is this initiative worth the time/computational effort?

Zhang et al., 2016

The 27-30 June 2015 Smoke Event of the Northern Great Plains



Weather Forecasts are Noticeably Affected by the Smoke Event

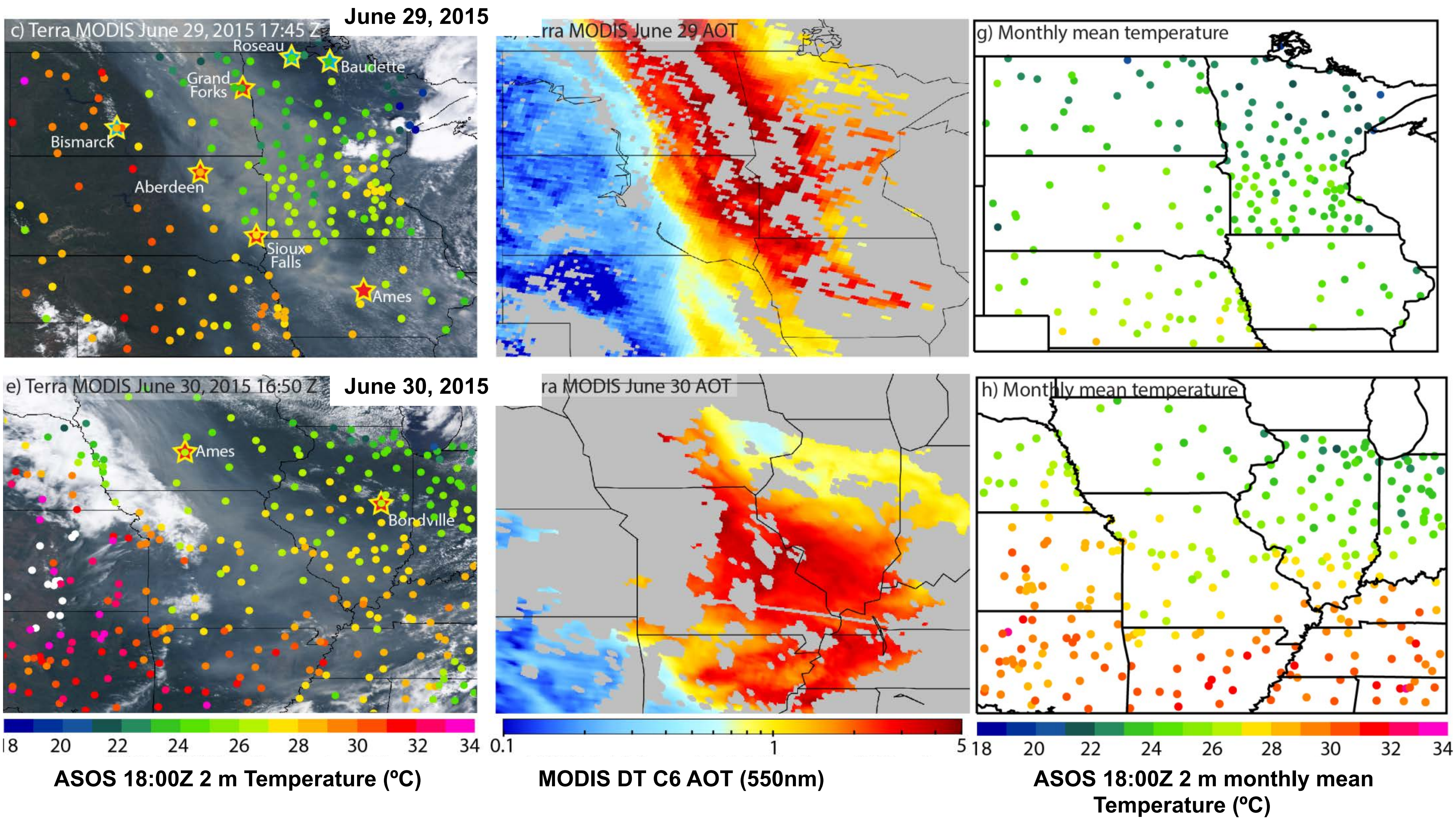


The forecast discussion issued by the Grand Forks NWS station at 10:00am CDT on June 29, stated:

"VERY THICK SMOKE TODAY WILL LIMIT TEMPERATURE RISE AT LEAST 2 TO 5 DEGREES...SO HAVE LOWERED TEMPS SOME AT LEAST. THIS IS VERY THICK SMOKE SO TEMPS COULD BE HELD DOWN INTO THE 70S..."

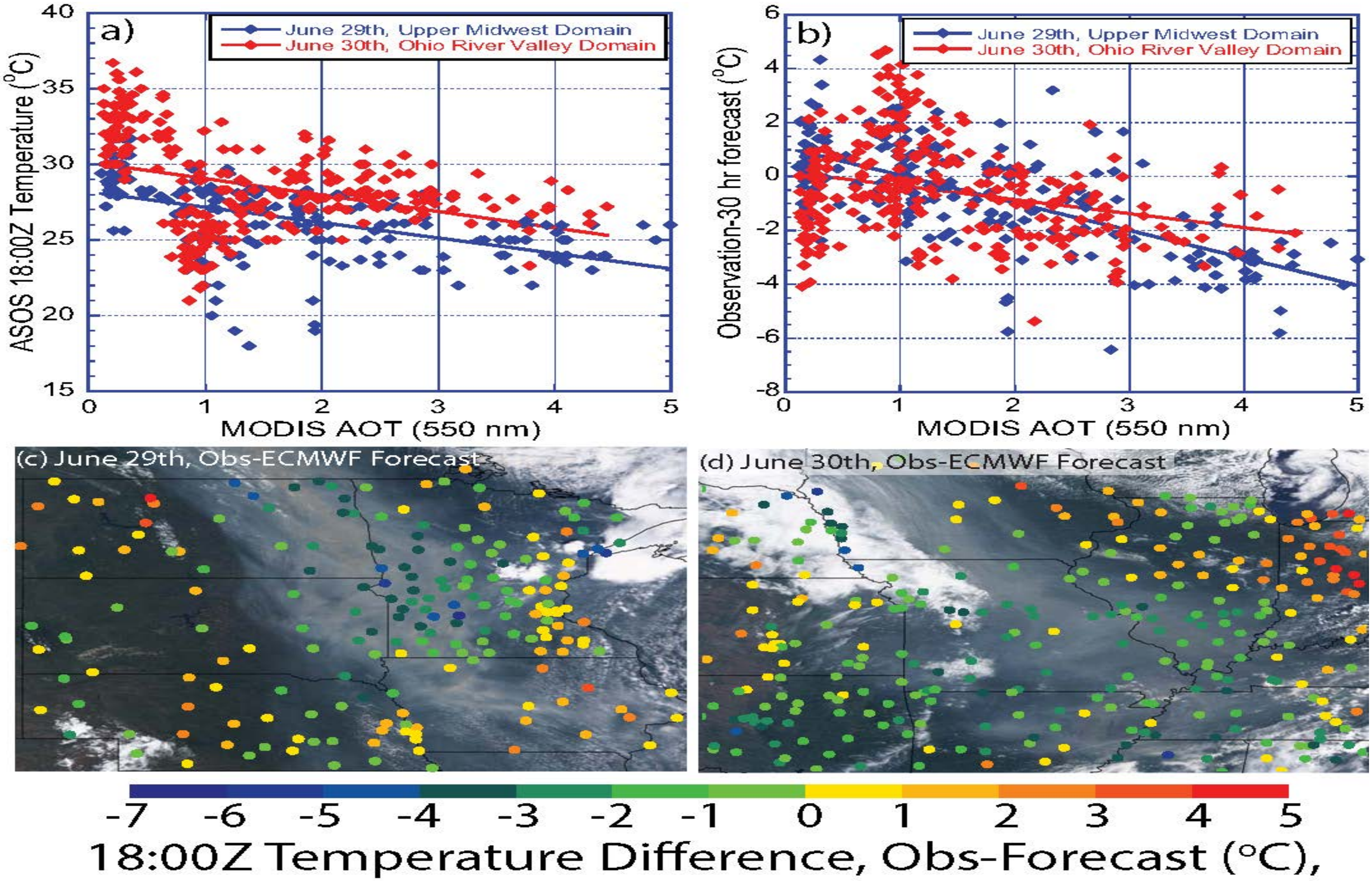
Zhang et al., 2016

Aerosol Direct Cooling Effects can be Observed from Surface Observations

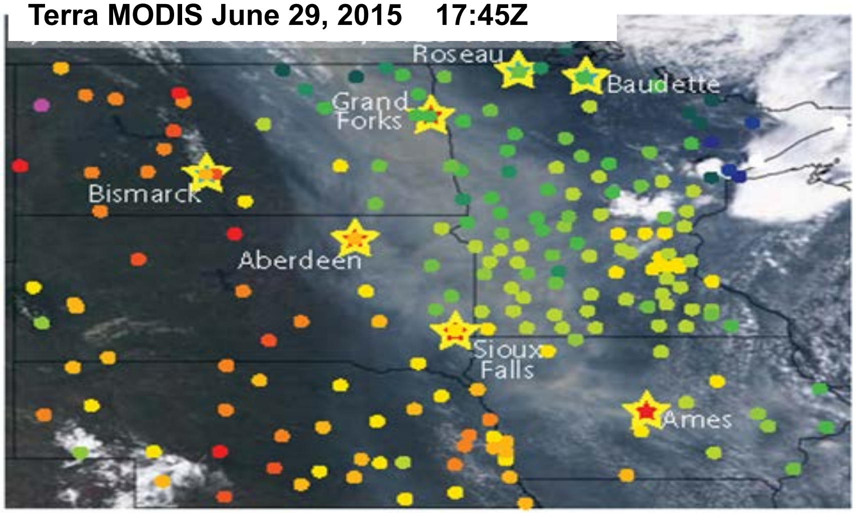


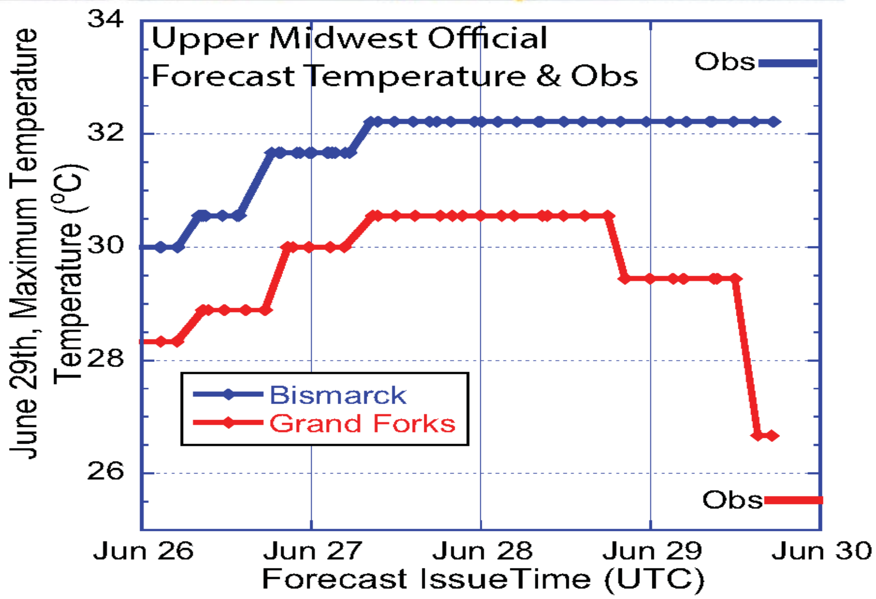
Zhang et al., 2016

The Impact of Aerosol Particles on Near-Surface Temperature Forecasts is Distinguishable



Estimate the Aerosol Direct Cooling Efficiency from Grand Forks and Bismarck Surface Observations





Zhang et al., 2016

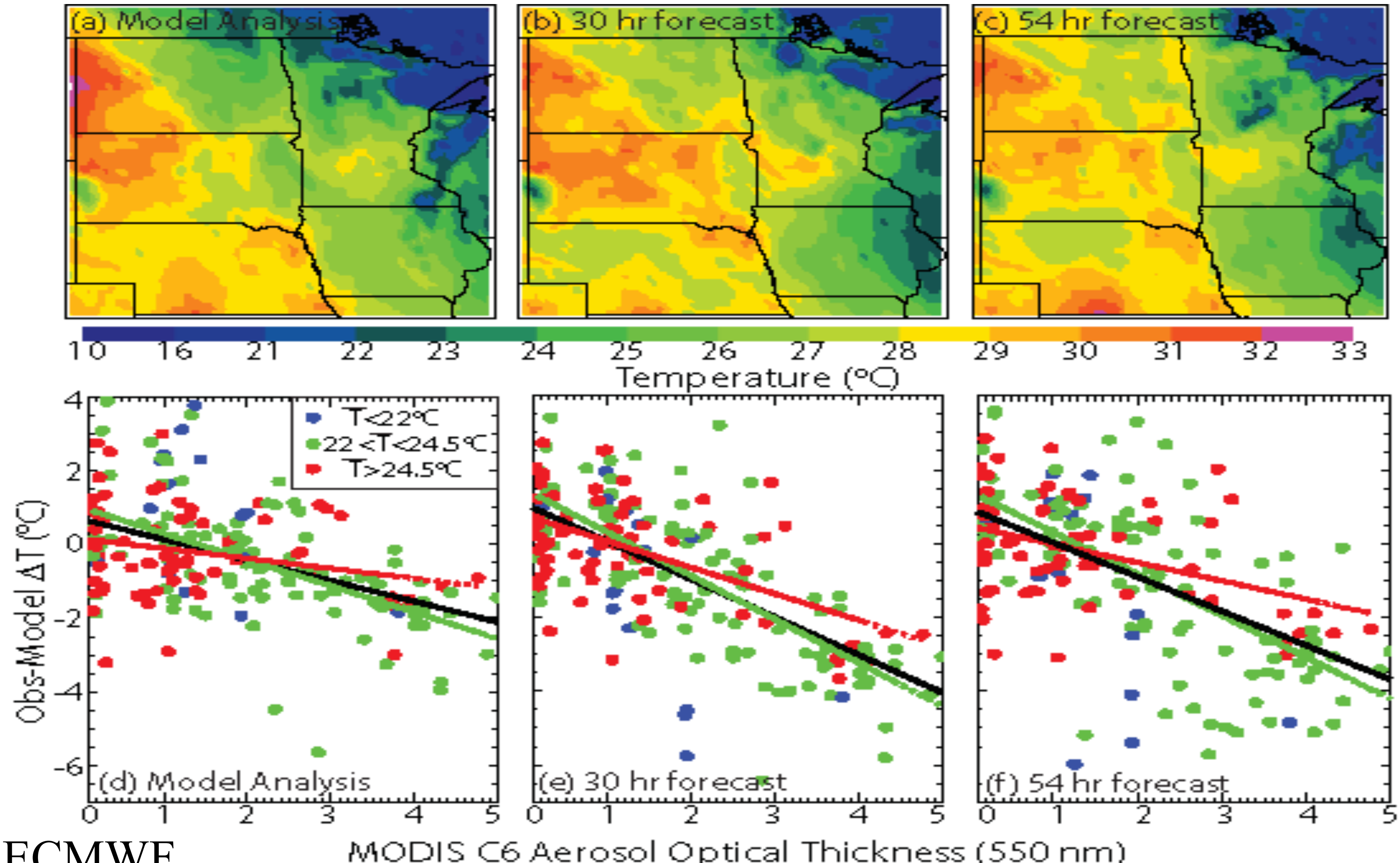
The near-surface temperatures between Bismarck and Grand Forks share a high degree of correlation (0.9) with Bismarck is 1.0+-2.0 degree warmer for 15 June – 14 July 2015, excluding 29 June data.

An 8 degree temperature difference is found between Bismarck and Grand Forks on 29 June 2015.

AOT difference is ~3 - 4 for the two sites.

Aerosol direct cooling efficiency of ~ -1.5° C per 1.0 AOT (550nm, τ_{550})

Aerosol Direct Cooling Efficiency Estimated from Model (ECMWF. UKMO and NCEP) Analysis and Forecasts (~ -0.25 - 1 °C per 1.0 τ_{550})



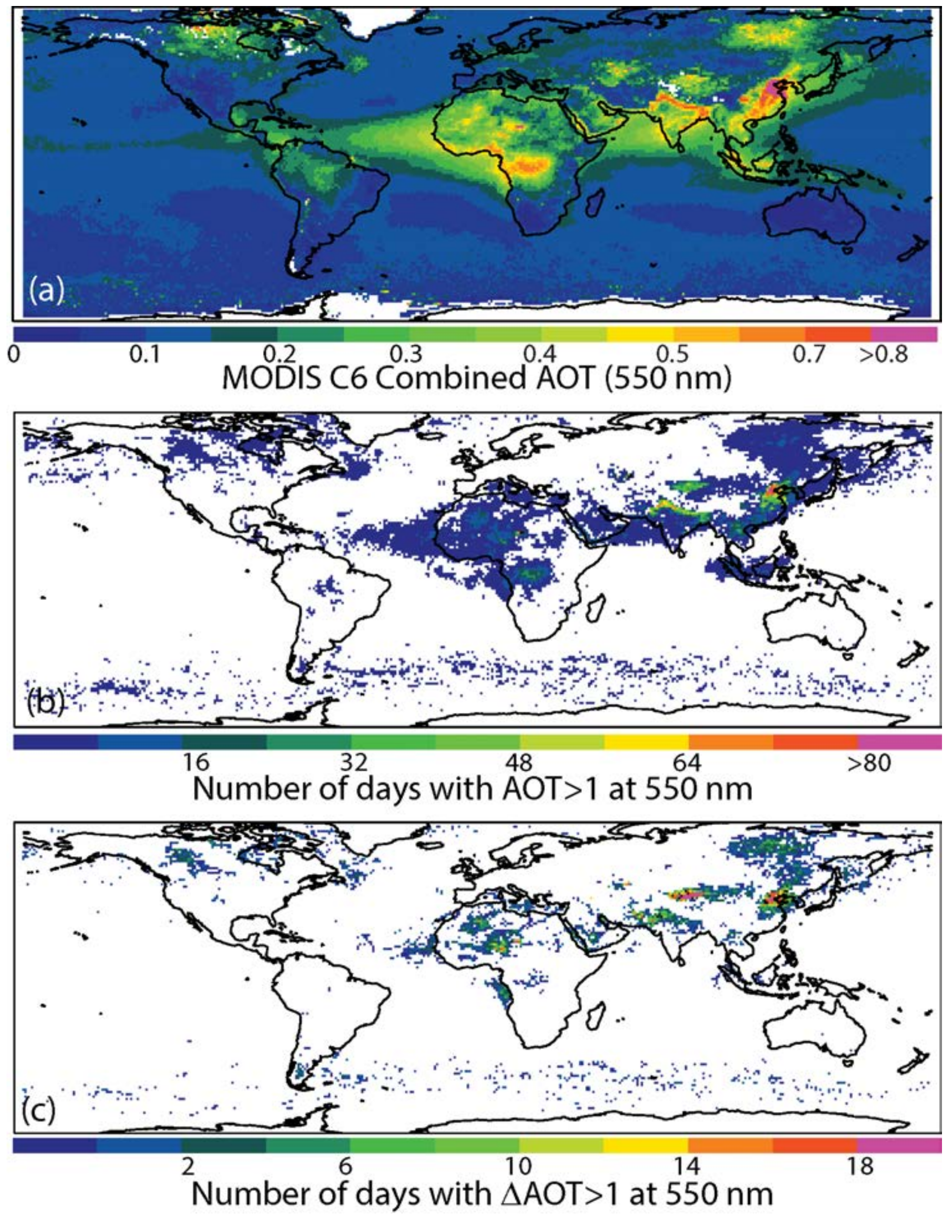
ECMWF

Issues?

Using one month of observed surface temperatures from the study region, baseline uncertainties for near-surface air temperatures from the 0-, 24(30)-, and 48(54)-hr forecasts (ECMWF, NCEP, UKMO models) are 1.3-2.3, 2.0-2.5 and 2.0-2.7°C, respectively.

Thus, for the aerosol-induced direct cooling effect to be observable from the 0-hr model forecasted near-surface air temperature fields, a daily change in τ_{550} of ~1.0-1.5 (550nm) is needed, assuming the estimated daytime C_τ of ~ -1.5°C per unit τ_{550} is applicable.

Not worth the clock time for now for surface temperature forecasts?



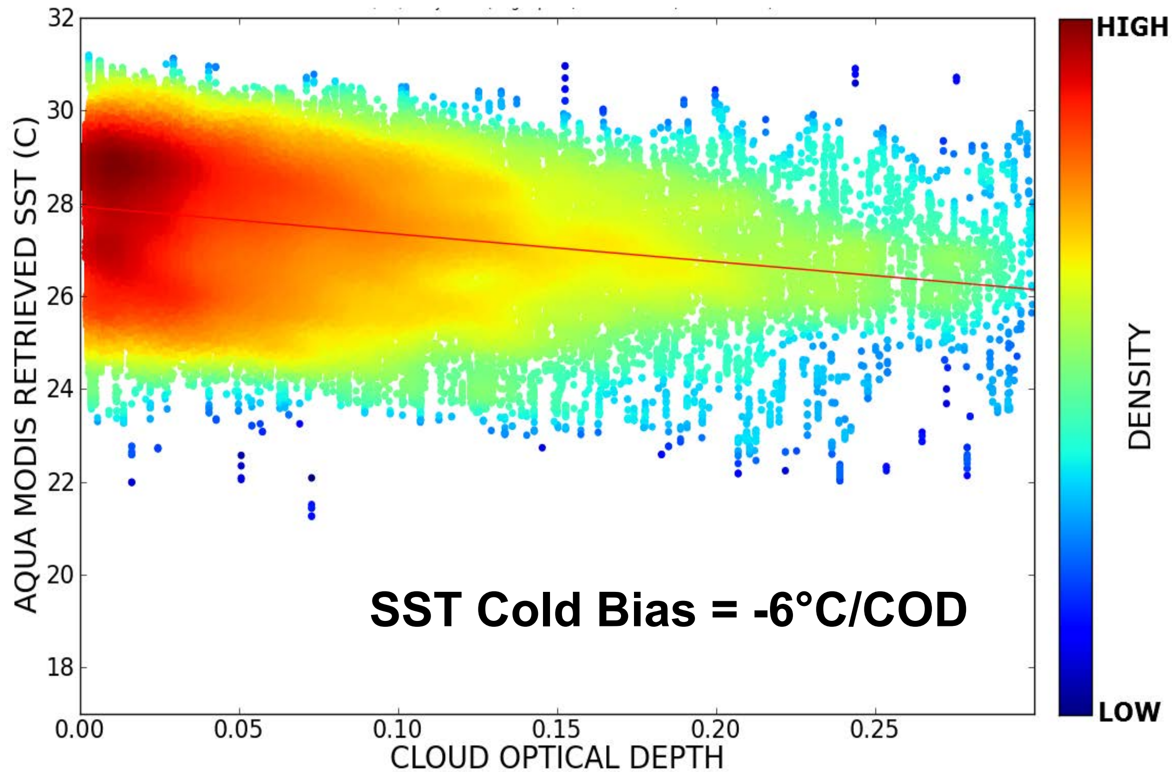
More Eye Candy – The Impact of Optically-Thin Cirrus Clouds On Operational SST Retrievals

We have estimated the impact of unscreened optically-thin cirrus clouds (OTC) on operational MODIS- AVHRR- and VIIRS-SST retrievals.

Passive radiometric sensors fail to screen OTC at cloud optical depths less than ~ 0.3.

Split-window relative OTC cold biases (single observation) range from 0.40°-0.49° C, with an absolute (bulk mean) bias between 0.10°-0.13° C.

Triple-window retrievals are more resilient, ranging from 0.03°-0.04° C relative and 0.11°-0.16° C absolute.



CALIOP cloud optical depth versus Aqua-MODIS SST from OTC-contaminated retrievals for August-October 2012 over the Maritime Continent (75°W/ 15°S – 135°W/30°N).

Marquis et al., 2016 (submitted)

Conclusions

The study of longer-term changes of aerosol properties is necessary for our understanding of climate, but at the same there are NWP applications.

MODIS, OMI, CALIOP, CERES we now have column and vertical data

While consistent trends are found in India & Middle East (positive), Mediterranean Sea & Eastern US (negative), inconsistencies are found for regions such as Eastern China. Sampling?

Findings suggest an increase in coastal China from 2000-2008, followed by a negative trend after 2008. The reason for the change is not known, though we are beginning work on a new study pairing CALIOP with MODIS to understand trends in surface-based $PM_{2.5}$.

Moving to acute effects and NWP applications, a serendipitous boreal smoke event became an excellent natural laboratory.

Our study suggests that the smoke aerosol participles have an observable impact on near-surface temperature, with an estimated aerosol direct cooling efficiency ranging from – 0.25 to -1.5 °C per 1.0 AOT (550nm, τ_{550}) for AOT>1.