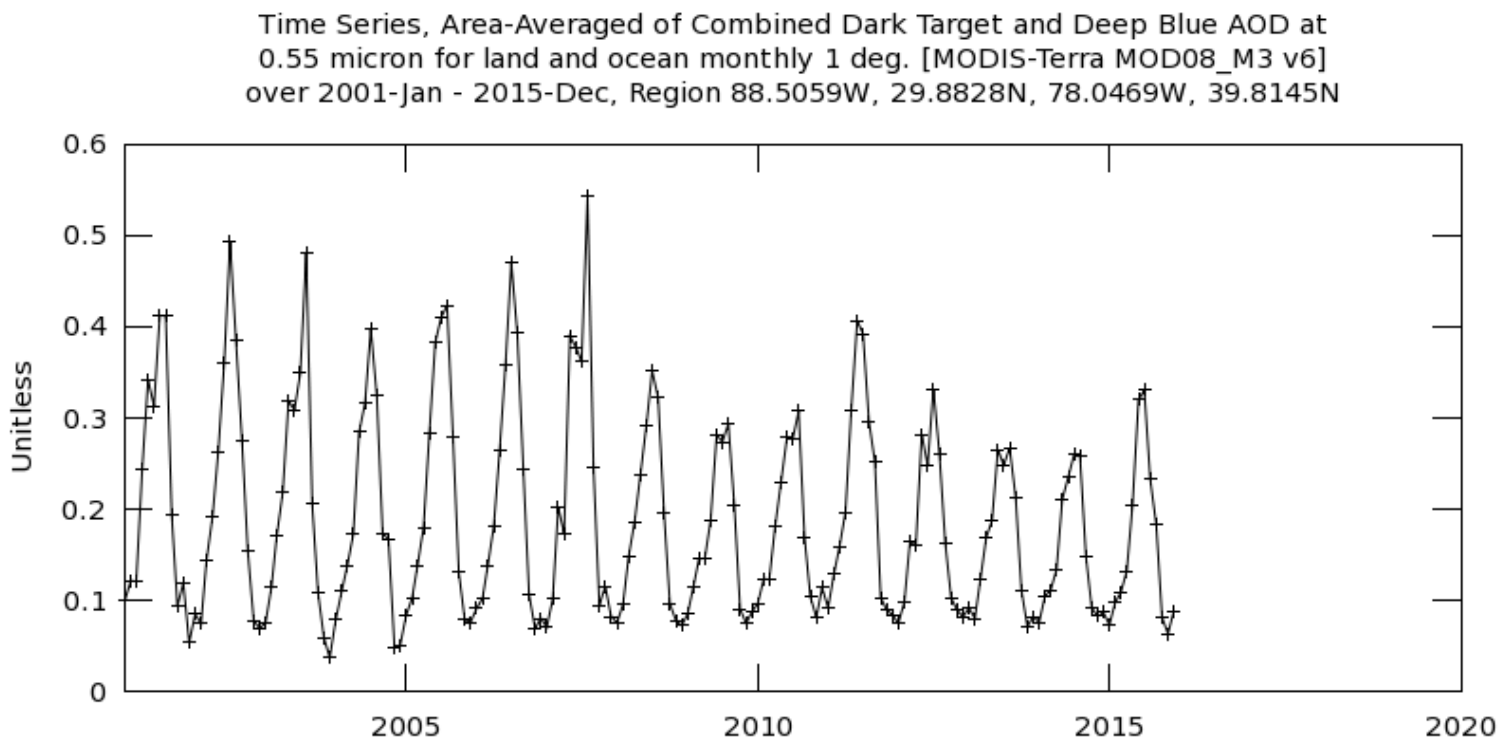
AOD long-term trends and dust

- How has AOD in the US changed over time?
- What about dust?
- We'll use Giovanni to explore these trends

Time series of AOD in the eastern U.S.

- Time Series, Area-Averaged
- Map area in eastern U.S.
- Parameter: Aerosol Optical Depth – MOD08_M3_v6
- Time range: 2001-01-01 to 2015-12-31



A word on AOD algorithms

- Dark Target
  - Relies on assumptions that are not satisfied over bright surfaces (i.e., deserts)
  - Provides more derived parameters (e.g., effective radius)
- Deep Blue
  - Focused on shorter wavelengths to retrieve AOD over bright surfaces
  - Collection 6 now expanded to include dark surfaces as well
- Combined algorithm
  - Selects one our the other based on location and time of year

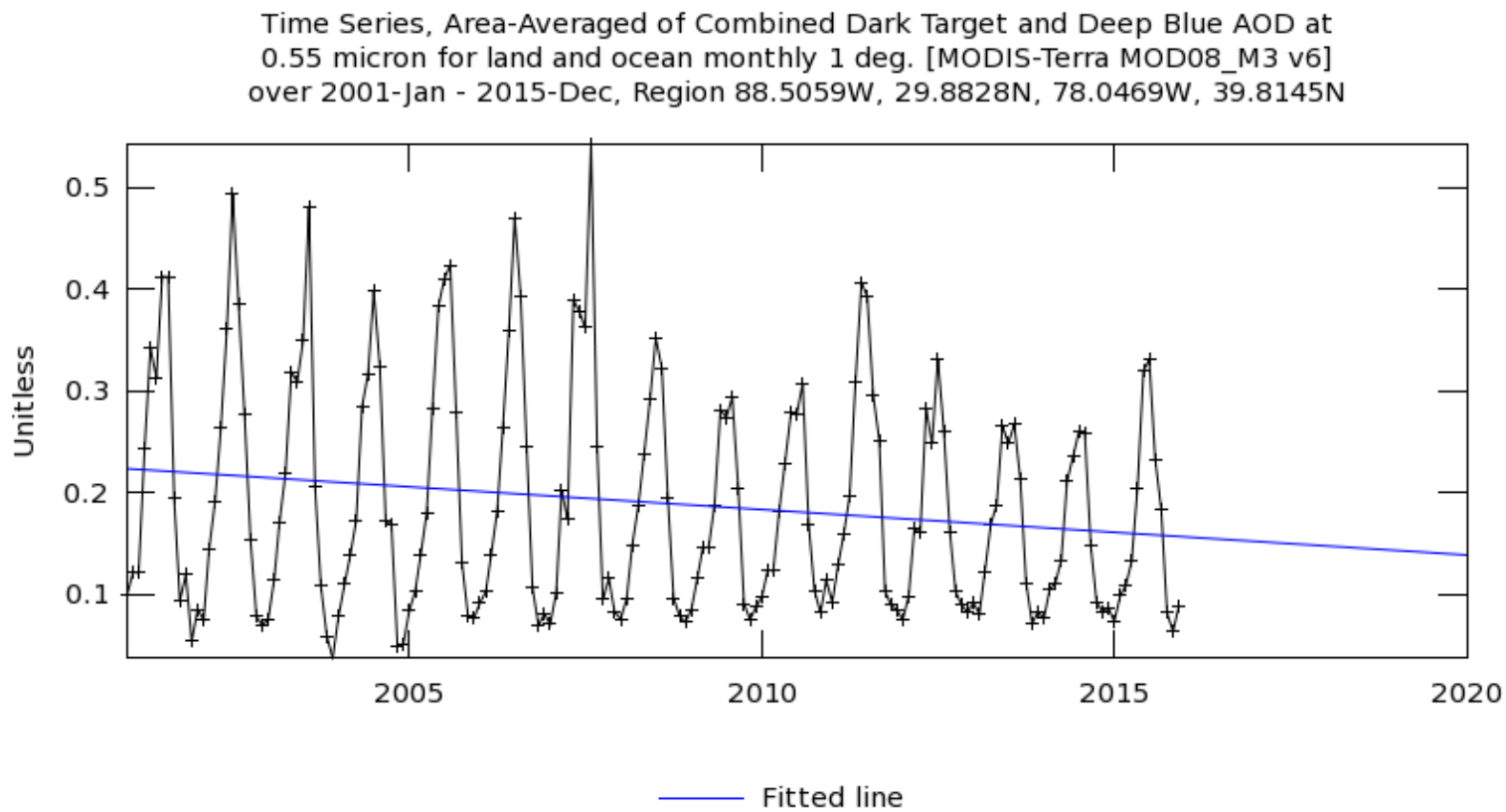
Algorithm summaries

Characteristic	e-Deep Blue (DB)	Dark Target (DT)	Ocean
Domain	Land	'Dark' (i.e. partly/fully vegetated) land	Dark (i.e. non-turbid/shallow) water
Averaging method	Retrieve then average	Average then retrieve	Average then retrieve
Aerosol optical model	Prescribed regionally/seasonally Sometimes retrieved	Fine model prescribed regionally/seasonally Coarse (dust analogue) model mixed in	Combination of 4 fine and 5 coarse modes 'Best' and 'average' solutions reported
Surface properties prescribed	Database or type-dependent dynamic, pseudo-Lambertian	Global dynamic relationship, pseudo-Lambertian	BRDF model incorporating glint, whitecaps, and fixed underlight
550 nm AOD uncertainty confidence envelope	~+/-(0.03+0.2*AOD_{MODIS}) (depends on geometric air mass)	+/-(0.05+0.15*$AOD_{AERONET}$)	+(0.04+0.1*$AOD_{AERONET}$) to -(0.02+0.1*$AOD_{AERONET}$)

Table taken from MODIS Atmospheres webinar series

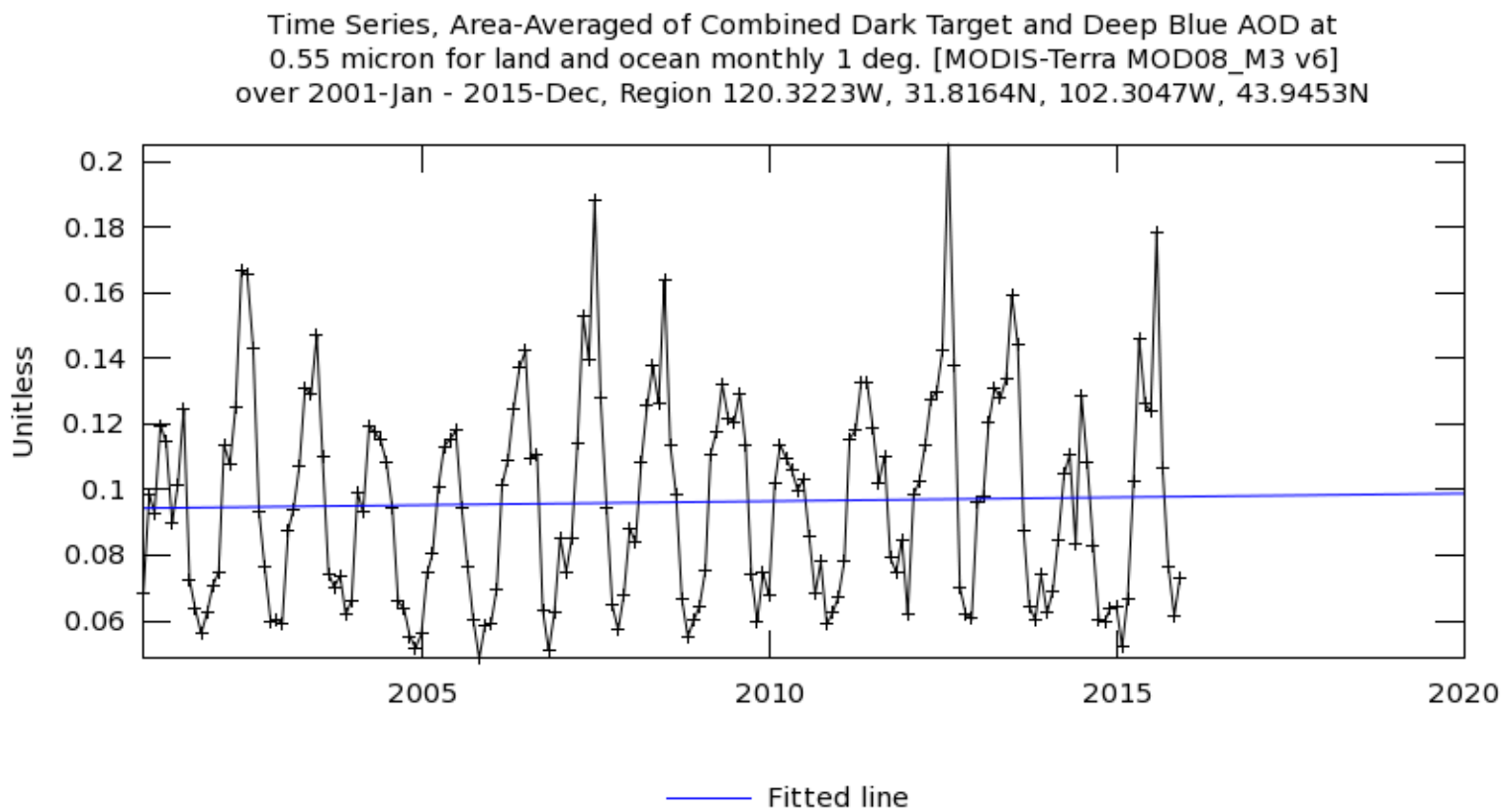
Time series of AOD in the eastern U.S.

- Plot Options
  - Show fitted line
  - Re-Plot



Time series of AOD in the southwestern U.S.

- Time Series, Area-Averaged
- Map area in soutwestern U.S.
- Parameter: Aerosol Optical Depth – MOD08_M3_v6
- Time range: 2001-01-01 to 2015-12-31



AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER

10.1002/2016GL068519

Key Points:

- Fine dust concentrations have increased across the southwestern United States in spring
- The onset of the spring dust season has shifted earlier by 1 to 2 weeks

Earlier onset of the spring fine dust season in the southwestern United States

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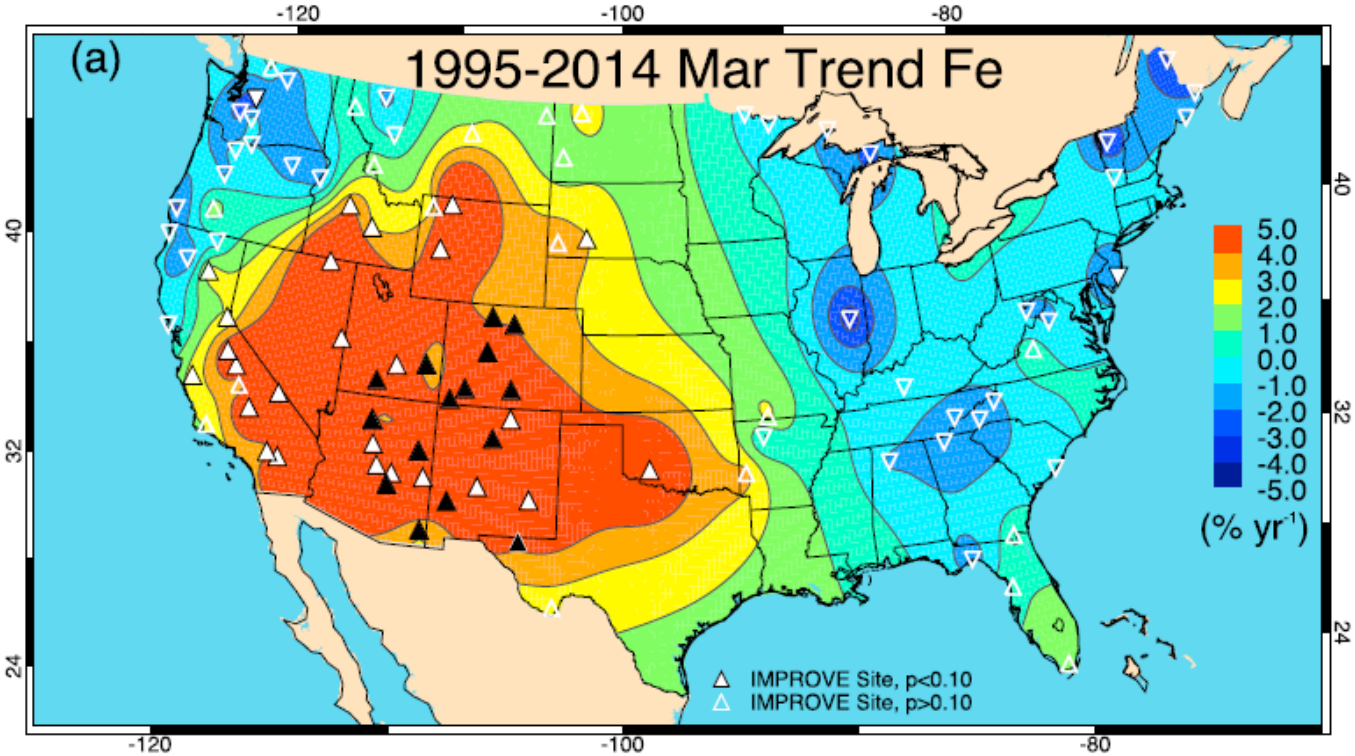


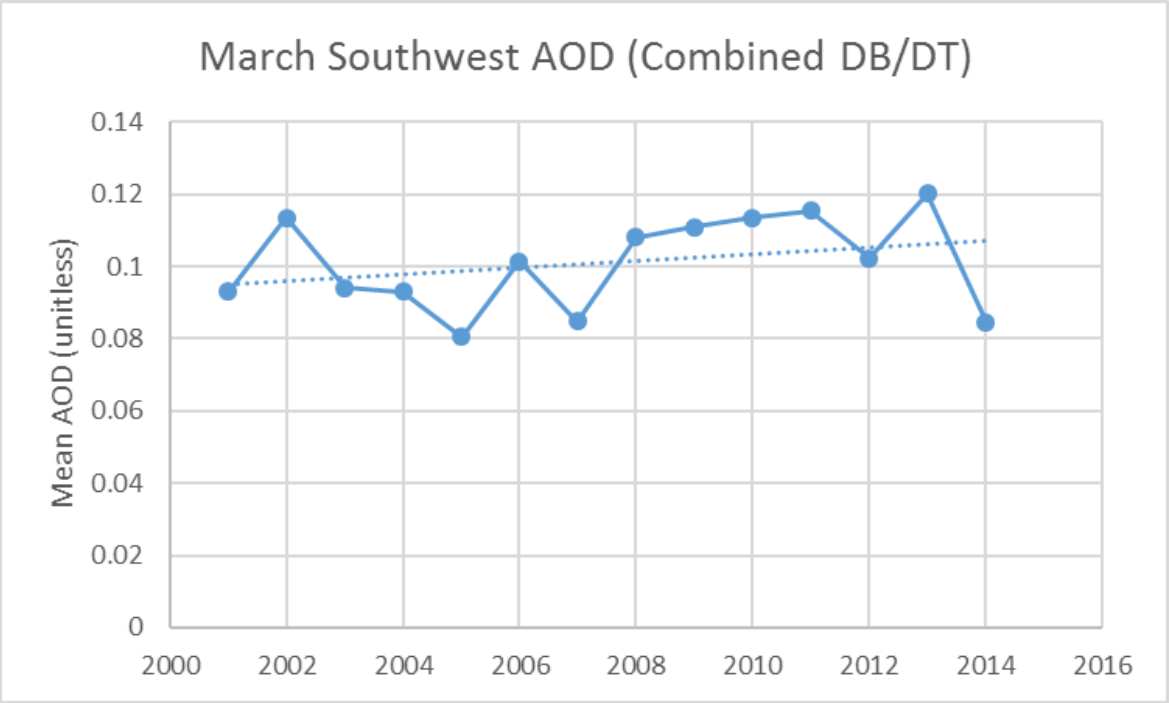
Can we see dust increase in March southwestern AOD?

- Downloads
  - ASCII CSV
- Manipulate in your favorite analysis tool

	A	B	C	D	E	F	G	H	I	J	K	L
1	Title:	Time Serie	Area-Averaged of Combined Dark Target and Deep Blue AOD at 0.55 micron for land and ocean monthly ()									
2	User Start Date:	2001-01-01T00:00:00Z										
3	User End Date:	2015-12-31T23:59:59Z										
4	Bounding Box:	-120.3223,31.8164,-102.3047,43.9453										
5	URL to Reproduce Results:	http://giovanni.gsfc.nasa.gov/giovanni/#service=ArAvTs&starttime=2001-01-01T00:00:00Z&endtime=2015-12-31T23:5										
6	Fill Value (mean_MOD08_M3_6_AOD_550_Dark_Target_Deep_Blue_Combined_Mean_Mean): -9999											
7												
8	time	mean_MOD08_M3_6_AOD_550_Dark_Target_Deep_Blue_Combined_Mean_Mean										
9	1/1/2001 0:00	0.068378										
10	2/1/2001 0:00	0.098418										
11	3/1/2001 0:00	0.093004										
12	4/1/2001 0:00	0.119617										
13	5/1/2001 0:00	0.114416										
14	6/1/2001 0:00	0.089831										
15	7/1/2001 0:00	0.101309										
16	8/1/2001 0:00	0.124578										
17	9/1/2001 0:00	0.072532										
18	10/1/2001 0:00	0.063663										
19	11/1/2001 0:00	0.056075										
20	12/1/2001 0:00	0.062432										
21	1/1/2002 0:00	0.070723										
22	2/1/2002 0:00	0.074922										
23	3/1/2002 0:00	0.113569										
24	4/1/2002 0:00	0.107749										

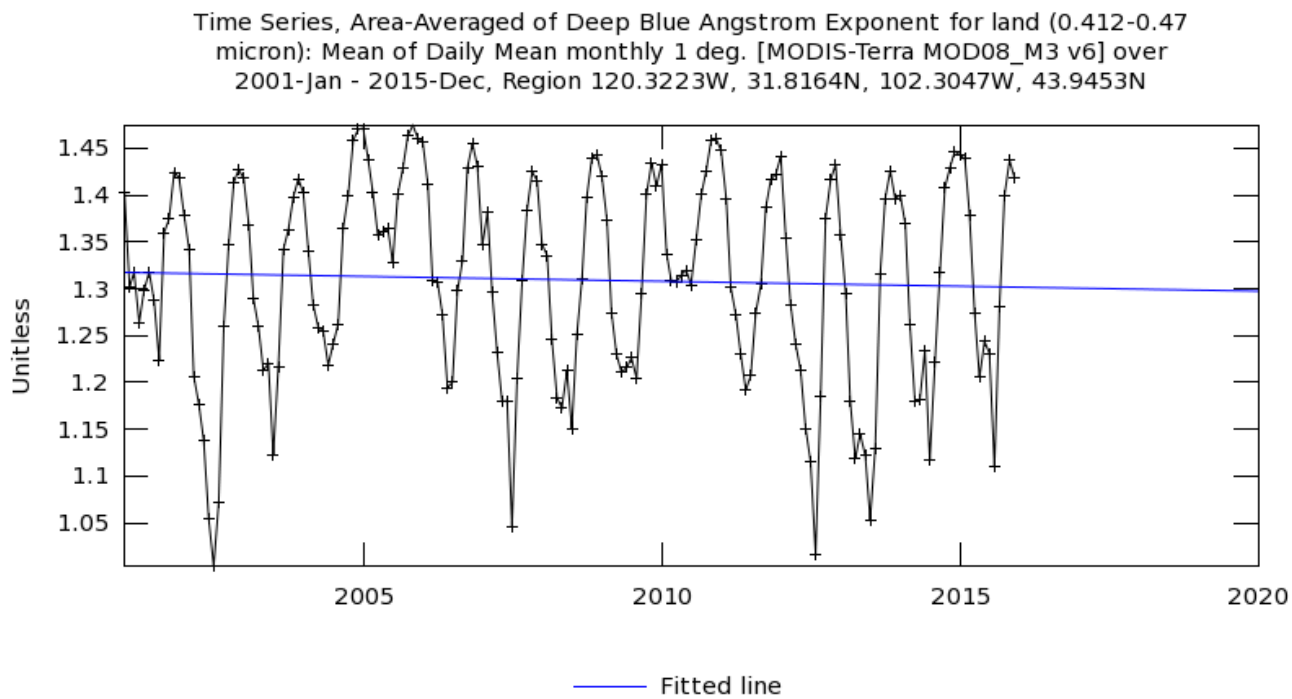
Can we see dust increase in March southwestern AOD?

- Modest increase?
- Dust is only part of AOD
- Can we explore this further?



Angstrom exponent over time

- User inputs
- Angstrom Exponent
  - Deep Blue Terra Daily (MOD08_M3_v6)
- All other inputs the same



Ångström Exponent α

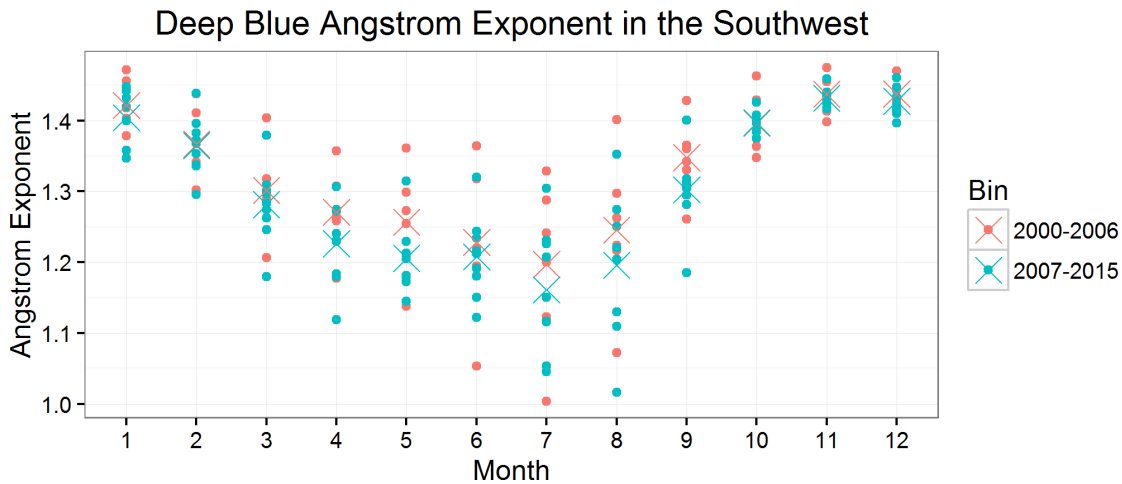
- Dependence of aerosol optical depth on wavelength
- $\frac{\tau_\lambda}{\tau_{\lambda_0}} = \left(\frac{\lambda}{\lambda_0}\right)^{-\alpha}$

$$\tau_\lambda = optical\ depth\ at\ wavelength\ \lambda$$
$$\tau_{\lambda_0} = optical\ depth\ at\ reference\ wavelength\ \lambda_0$$

- Given measurements of optical depth at two wavelengths:
  - $\alpha = -\frac{\log\frac{\tau_{\lambda_1}}{\tau_{\lambda_2}}}{\log\frac{\lambda_1}{\lambda_2}}$
- α is inversely related to average particle size (i.e., smaller particles → larger α)
- Very roughly
  - α > 2: fine mode dominant
  - α < 1: course mode (dust) dominant

Looking at the data

- Decreasing Angstrom in latter period suggests increase on ratio of course to fine particles (more dust?)
- Largest difference in April – August for satellite data
- Dust measurement shows largest difference in March



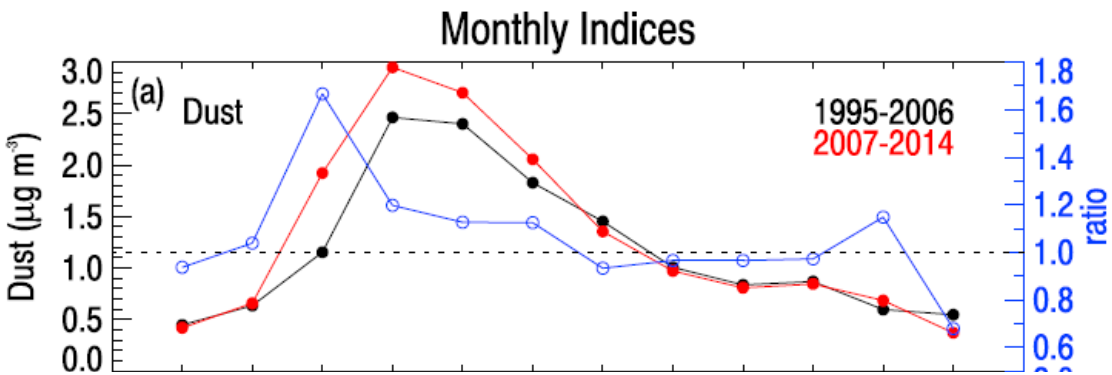
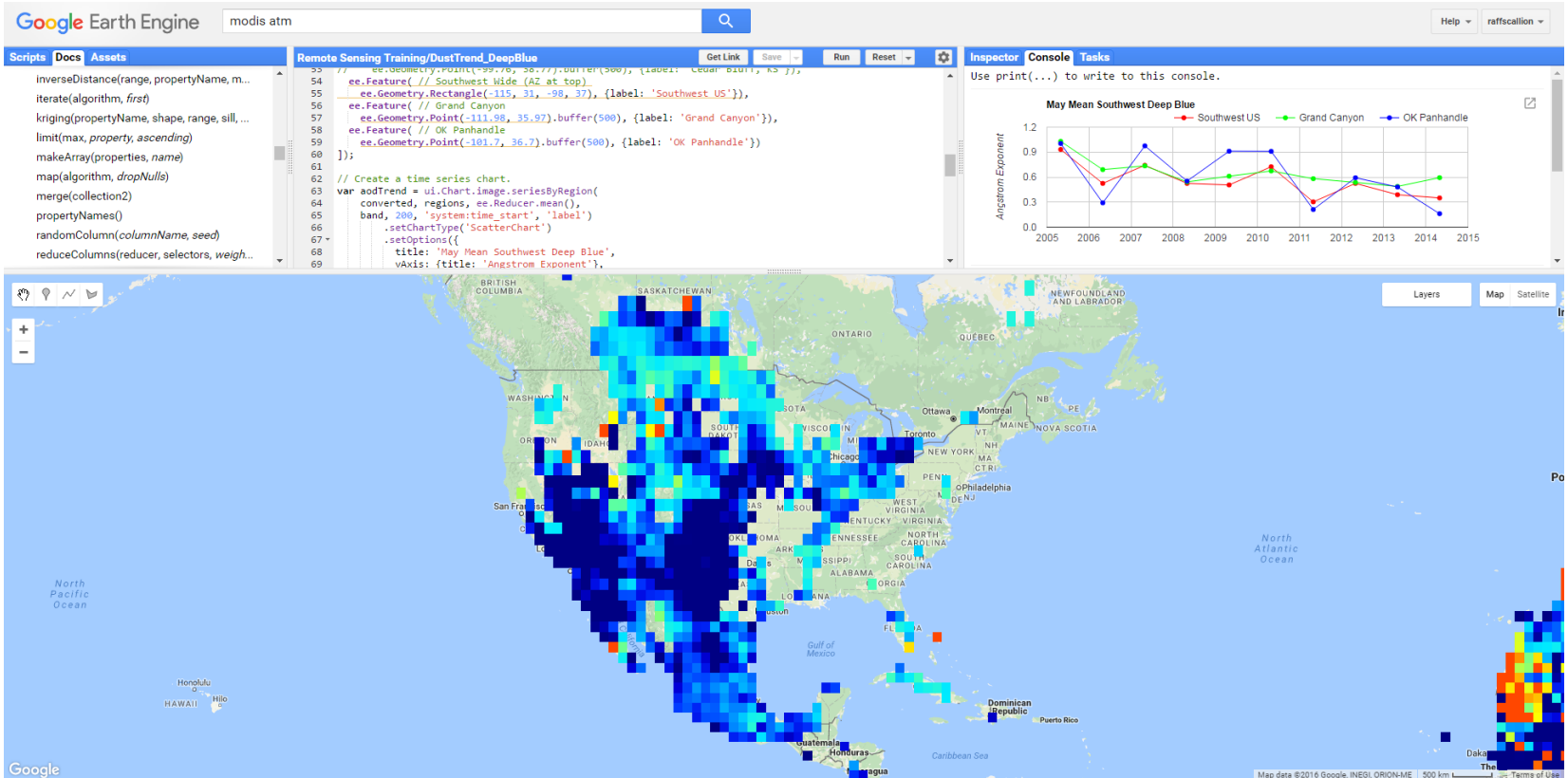


Figure 1. Southwest regional monthly mean (a) fine dust ($\mu g\ m^{-3}$) for 1995–2006 (black) and 2007–2014 (red) and the ratio of the later to the earlier period on the right axis (blue),

Quick Aside: Google Earth Engine

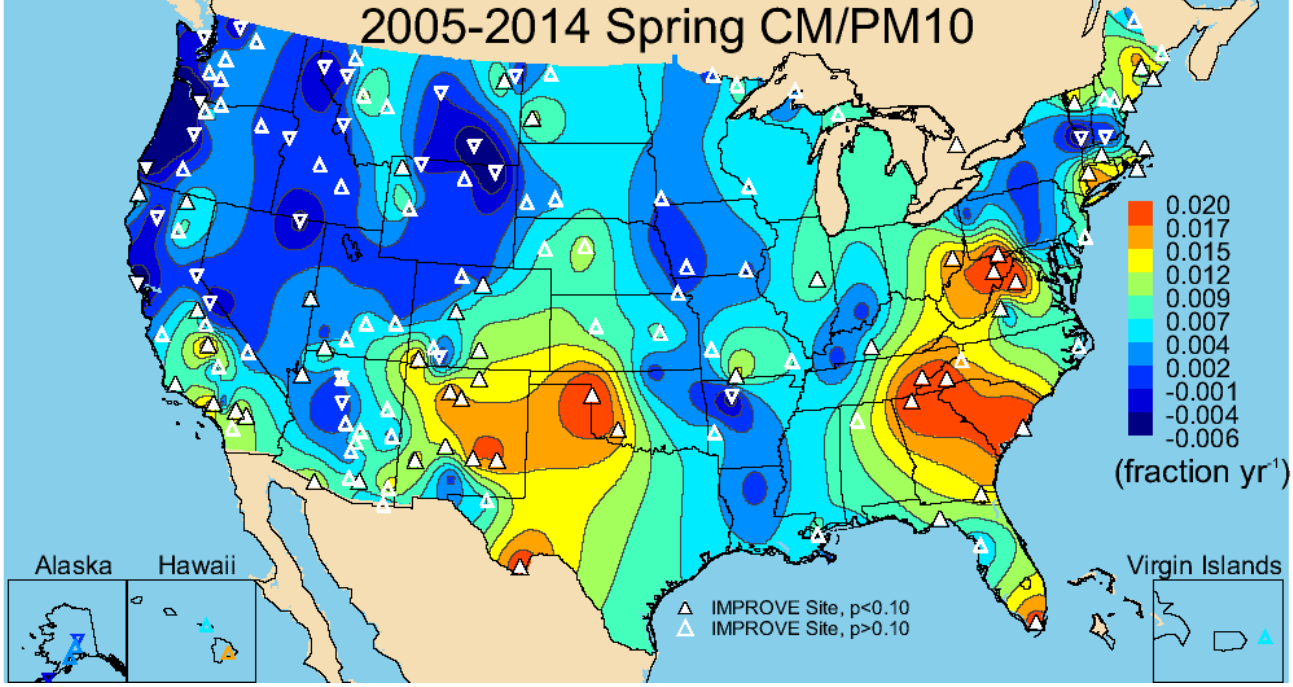
- Fast, global processing
- Powerful API
- Many gridded data sets available
  - All of Landsat
  - Most MODIS land products
  - Climate models
  - Weather data

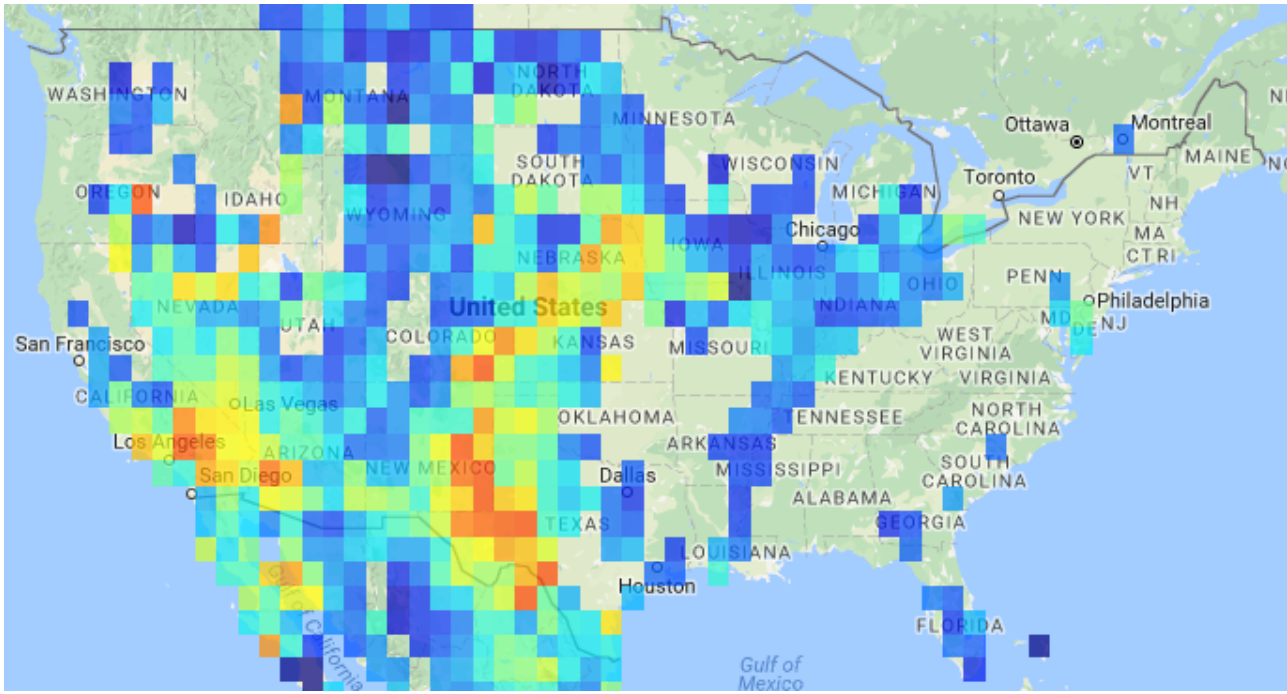
- Requires sign up
- Requires JavaScript (or Python) knowledge
- Only monthly 1° atmosphere data available



From IMPROVE data

- Change in springtime course mass (PM_{10} - $PM_{2.5}$) to PM_{10} from 2005-2014
- Warmer colors indicate increase in PM_{10} relative to $PM_{2.5}$ (i.e., more dust)



From MODIS via EE

- Change in springtime angstrom exponent from 2005-2014
- Warmer colors indicate decrease angstrom exponent (i.e., more dust, probably)