Surface-measured trends of aerosol optical depth as an indicator of stratospheric aerosol trends

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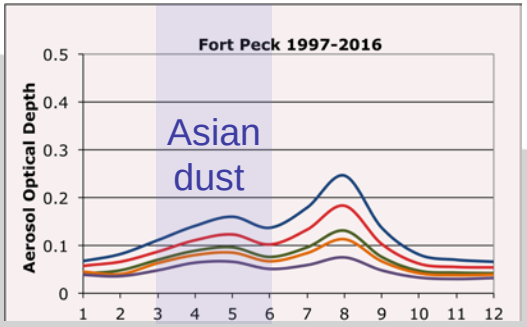
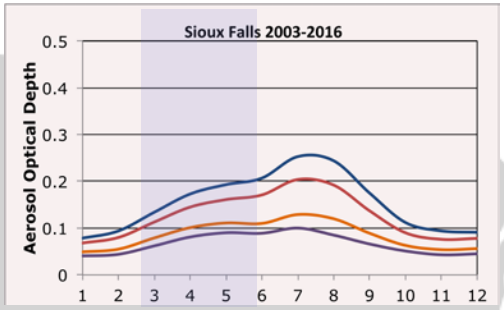
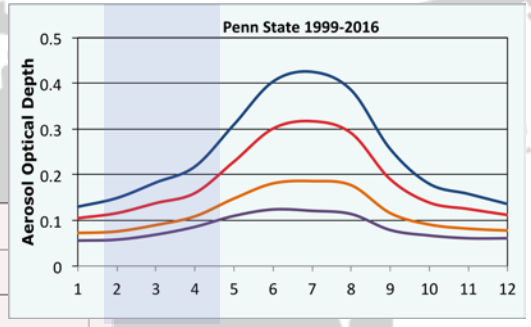
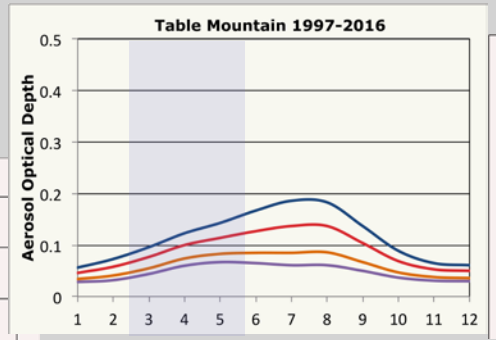
Multi-Filter Rotating Shadowband Radiometer

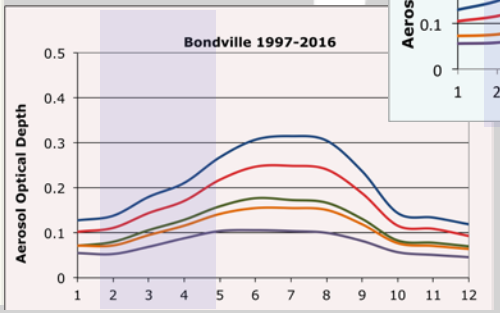
U.S. AOD Climatology 1997 to 2016

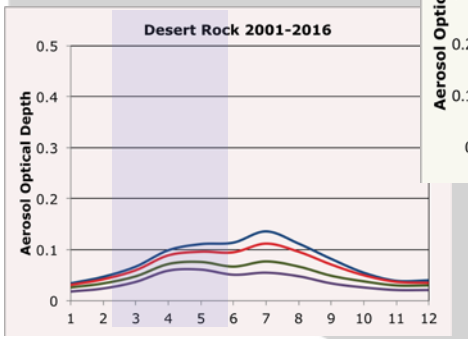


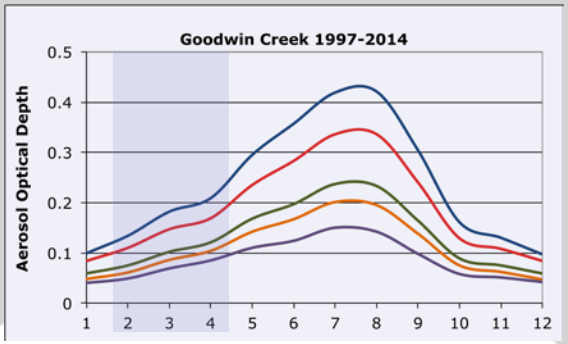






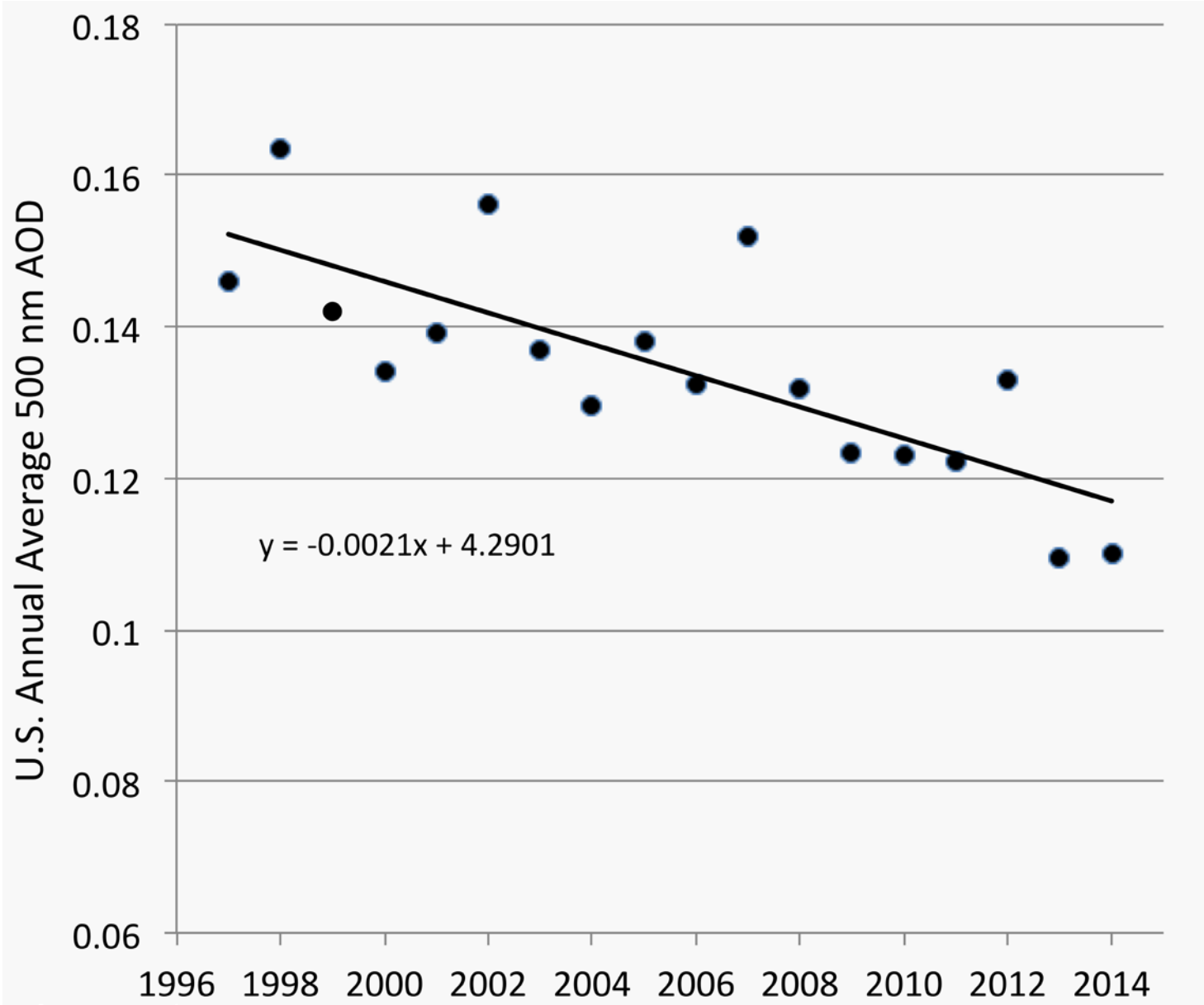






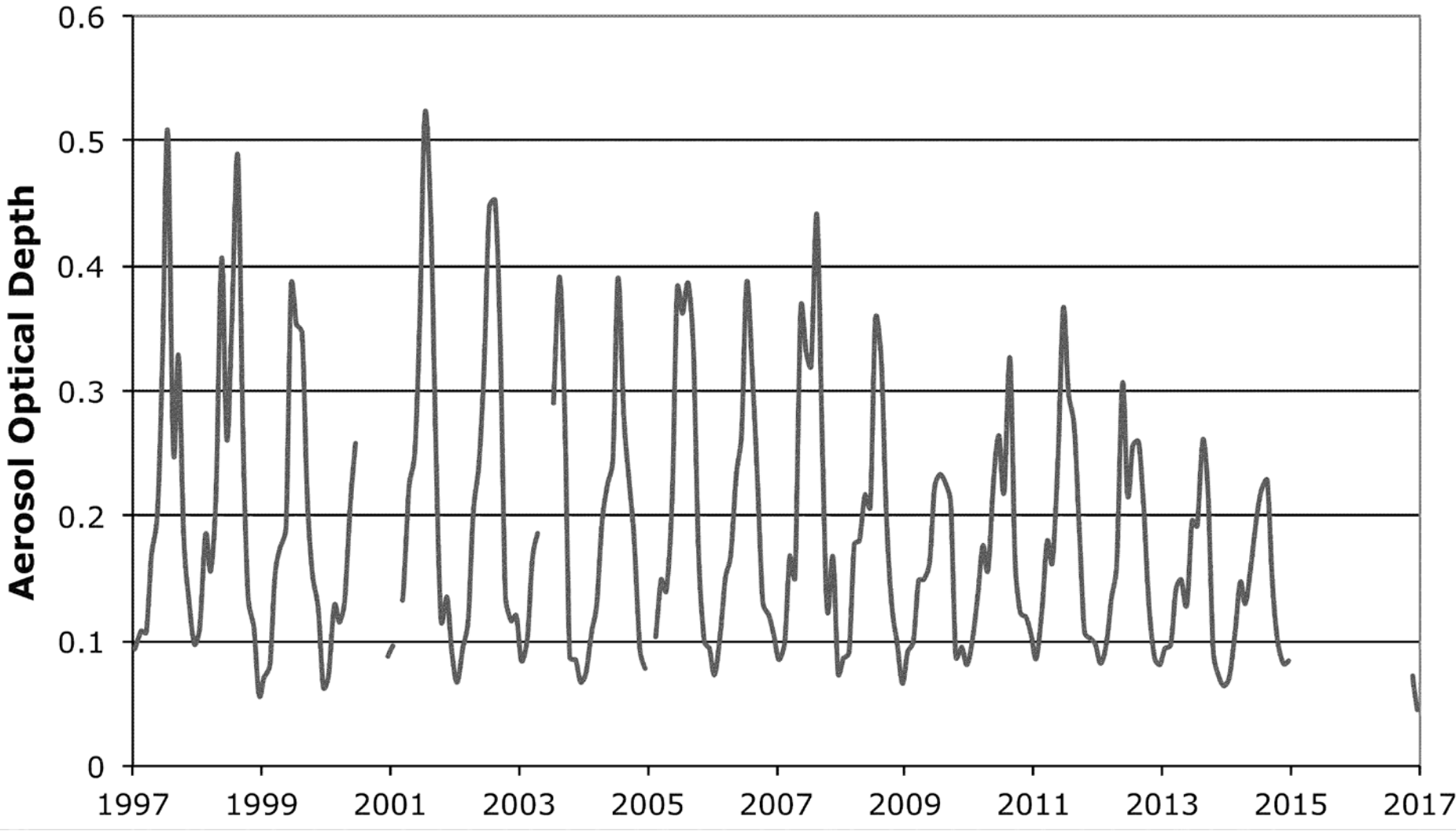
415 nm
500 nm
614 nm
670 nm
870 nm

U.S. annual average AOD (500 nm)



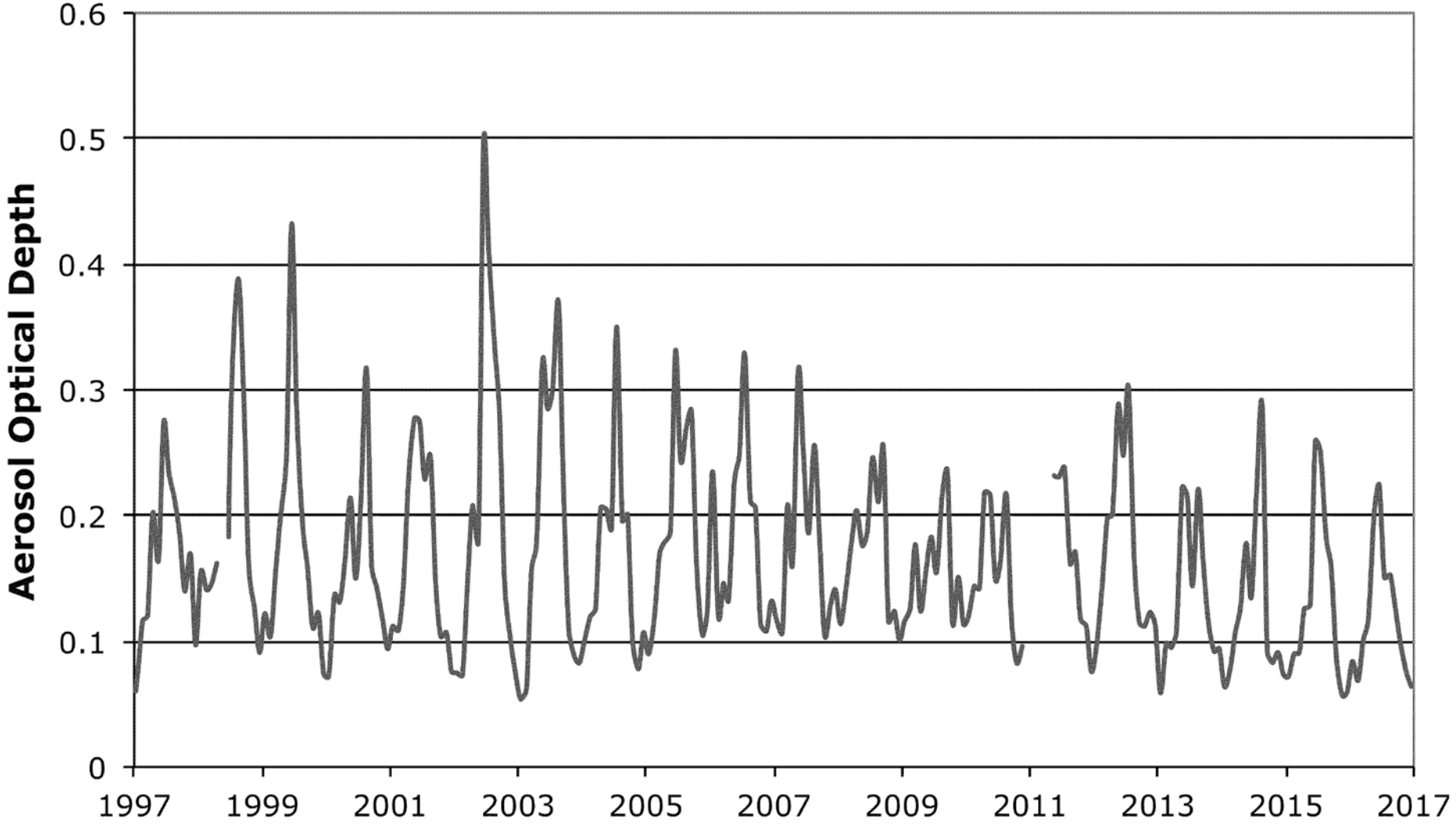
Monthly average AOD

Goodwin Creek, Mississippi



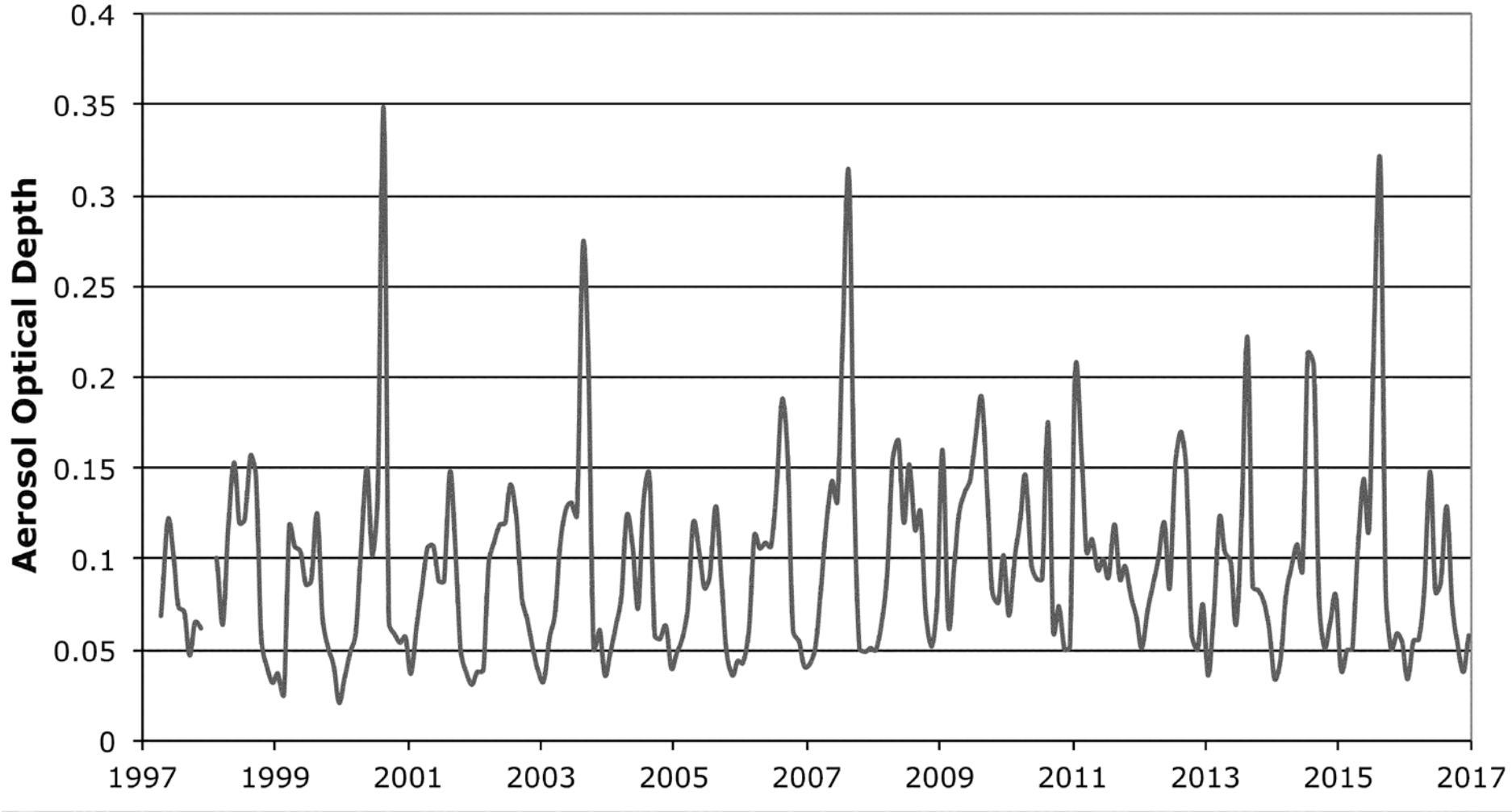
Monthly average AOD

Bondville, Illinois



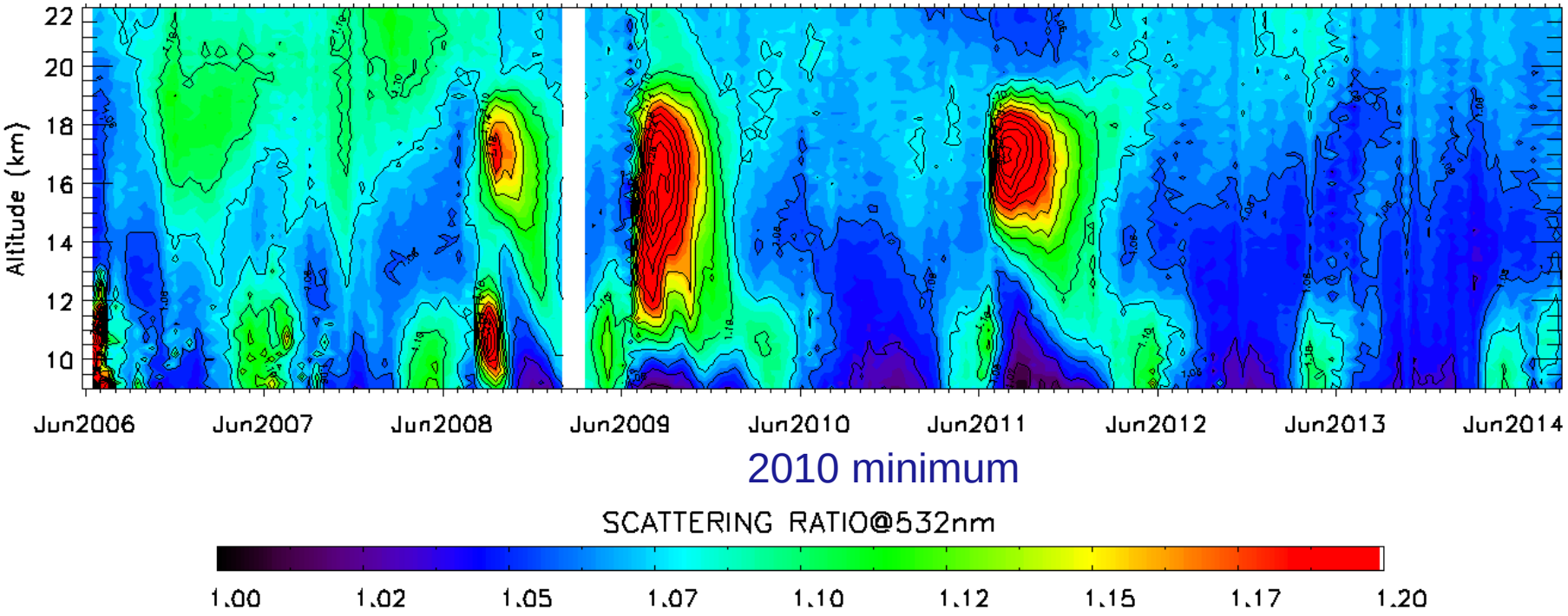
Monthly average AOD

Fort Peck, Montana



Time series of backscatter from the Cloud-Aerosol LIDAR Orthogonal Polarization (CALIOP) aboard NASA's CALIPSO satellite

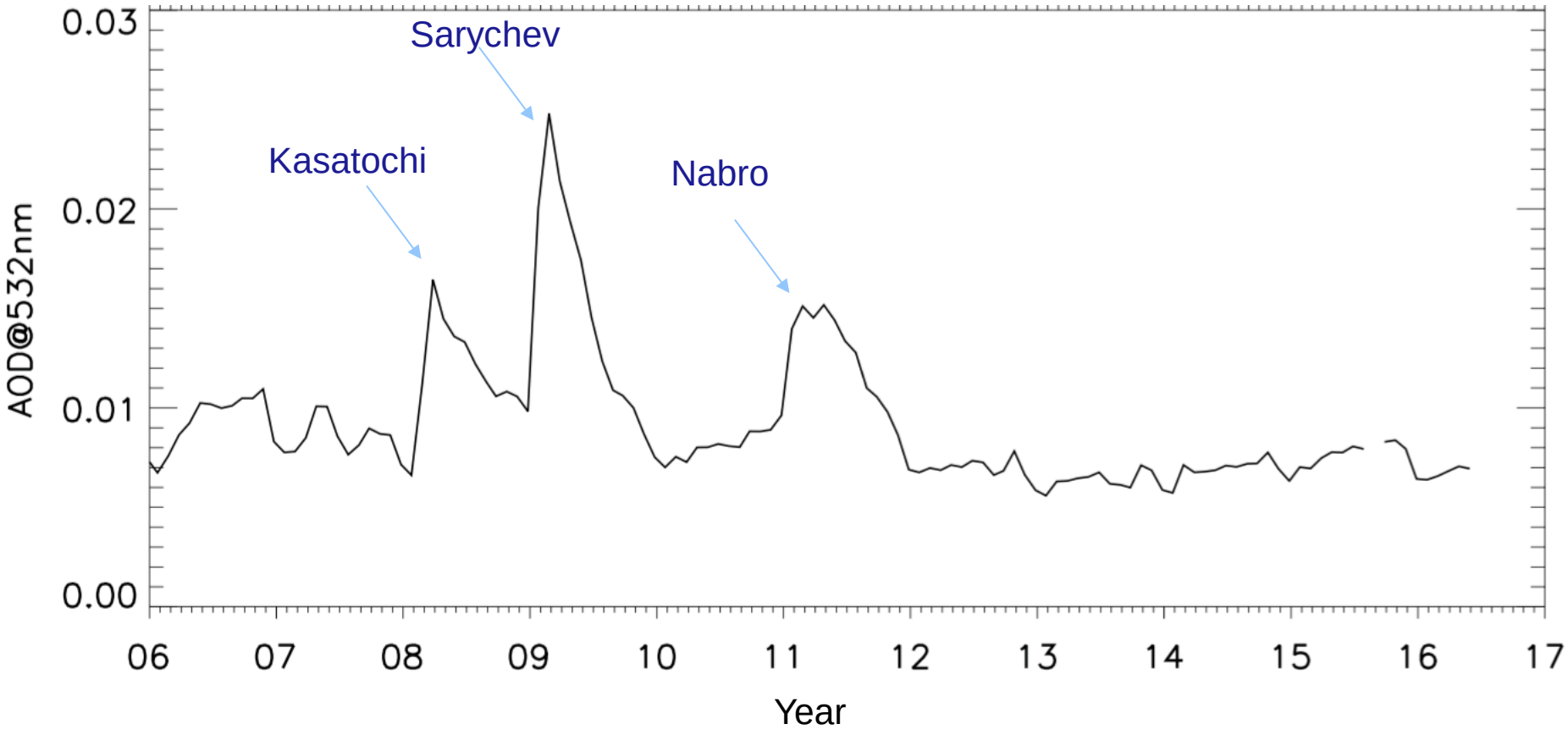
Upper troposphere – lower stratosphere
Averaged over 30° – 60° N



Source: Jean-Paul Vernier, NASA Langley

CALIOP Monthly Mean Stratospheric AOD (532 nm)

for the Northern Hemisphere 30° – 60° N Tropopause to 35 km



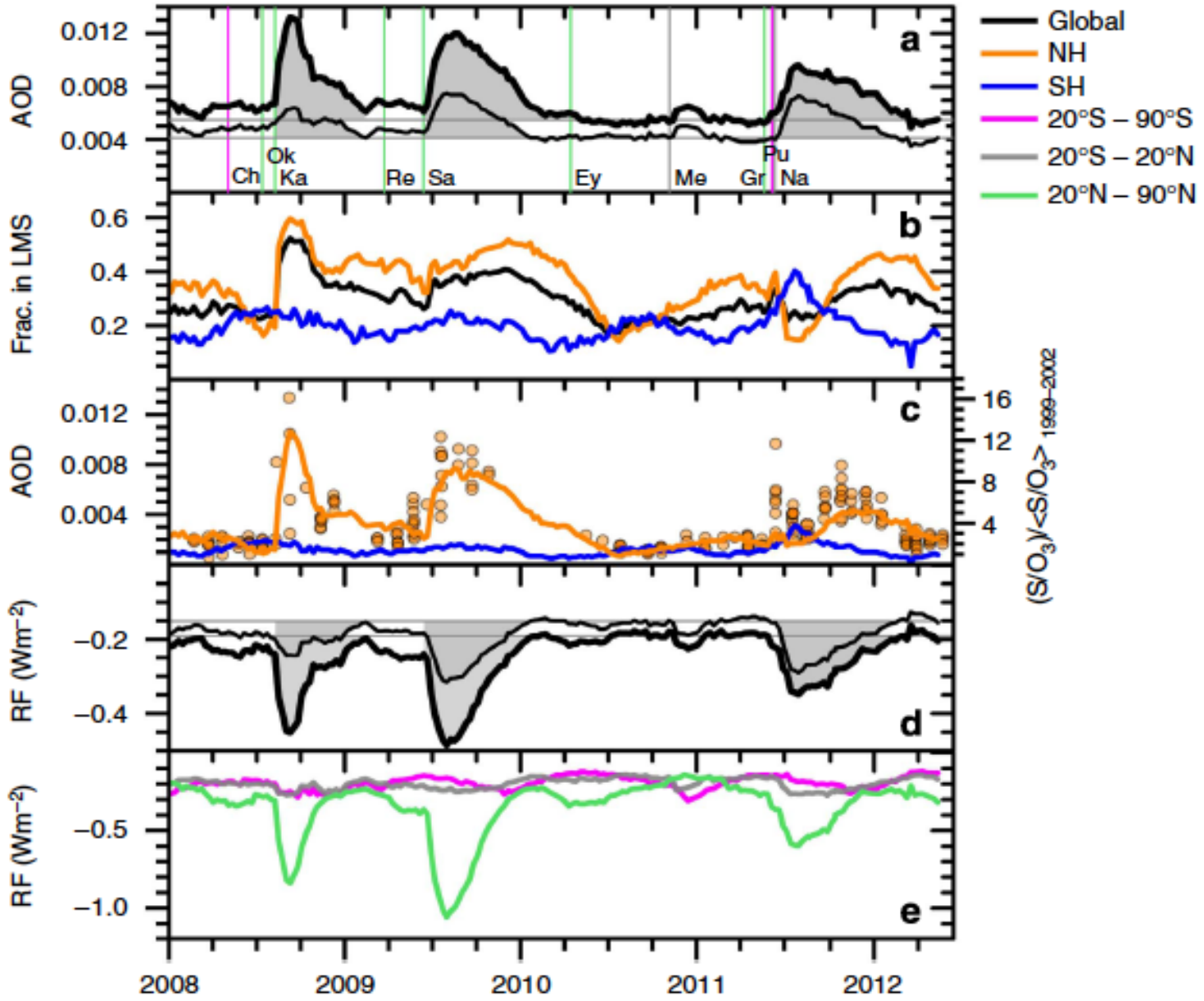
Volcanic Eruptions 2000 to 2011

From Andersson et al. (2015) *Nature Communications*

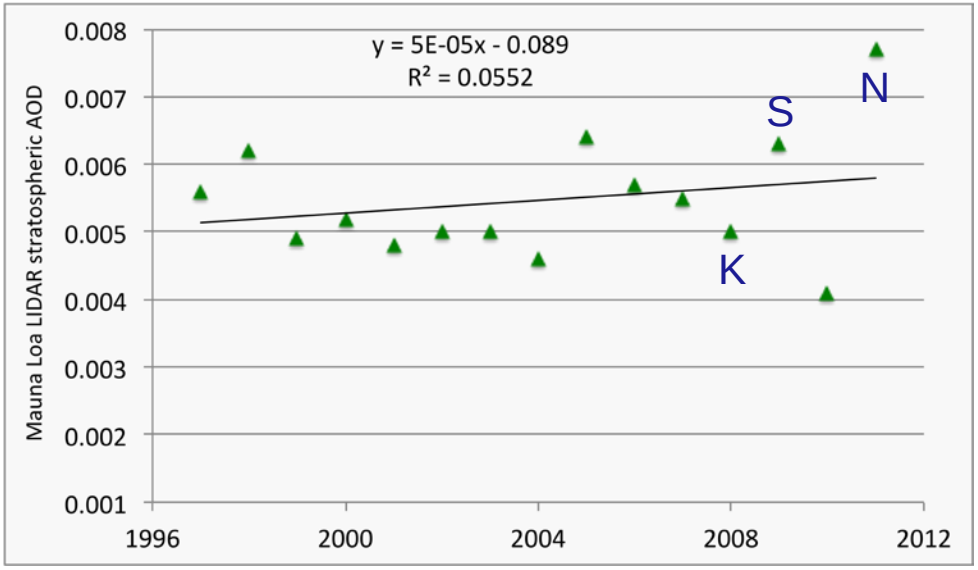
Table 1 | Volcanic eruptions in the 21th century that affect (or have the potential to affect) the aerosol loading of the stratosphere.

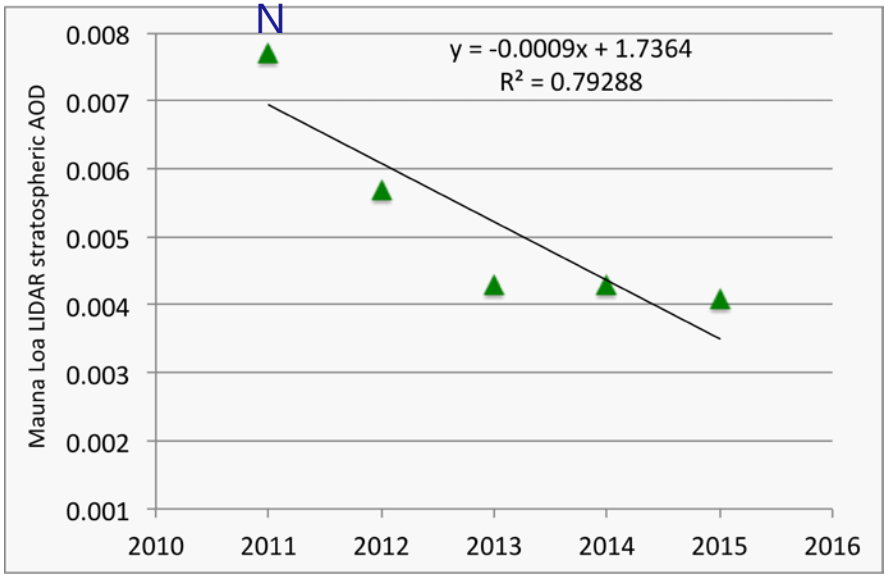
Volcano		Date	Lat.	Long.	VEI*	SO_2 (Tg)
Ulawun	Ul	29 Sep 2000	5° S	151° E	4	†
Sheveluch	Sh	22 May 2001	57° N	161° E	4	†
Ruang	Ru	25 Sep 2002	2° N	125° E	4	0.03 (ref. 50)
Reventador	Ra	3 Nov 2002	0° S	78° W	4	0.07 (ref. 50
Anatahan	At	10 May 2003	16° N	146° E	3	0.03 (ref. 50)
Manam	Ma	27 Jan 2005	4° S	145° E	4	0.09 (ref. 50)
Sierra Negra	Si	22 Oct 2005	1° S	91° W	3	†
Soufrière Hills	So	20 May 2006	17° N	62° W	3	0.2 (ref. 51)
Rabaul	Rb	7 Oct 2006	4° S	152° E	4	0.2 (ref. 50)
Jebel at Tair	Je	30 Sep 2007	16° N	42° E	3	0.08 (ref. 52)
Chaitén	Ch	2 May 2008	43° S	73° W	4	0.01 (ref. 53)
Okmok	Ok	12 Jul 2008	53° N	168° W	4	0.1 (ref. 52)
Kasatochi	Ka	7 Aug 2008	52° N	176° W	4	1.7 (ref. 52)
Redoubt	Re	23 Mar 2009	60° N	153° W	3	0.01 (ref. 54)
Sarychev	Sa	12 Jun 2009	48° N	153° E	4	1.2 (ref. 55)
Eyjafjallajökull	Ey	14 Apr 2010	64° N	20° W	4	†
Merapi	Me	5 Nov 2010	8° S	110° E	4	0.4 (ref. 56)
Grimsvötn	Gr	21 May 2011	64° N	17° W	4	0.4 (ref. 57)
Puyehue-Cordón Caulle	Pu	6 Jun 2011	41° S	72° W	5	0.3 (ref. 57)
Nabro	Na	12 Jun 2011	13° N	42° E	4	1.5 (ref. 57)

Andersson et al. (2015) *Nature Communications*
CALIOP AOD Tropopause to 35 km (thick line top panel)

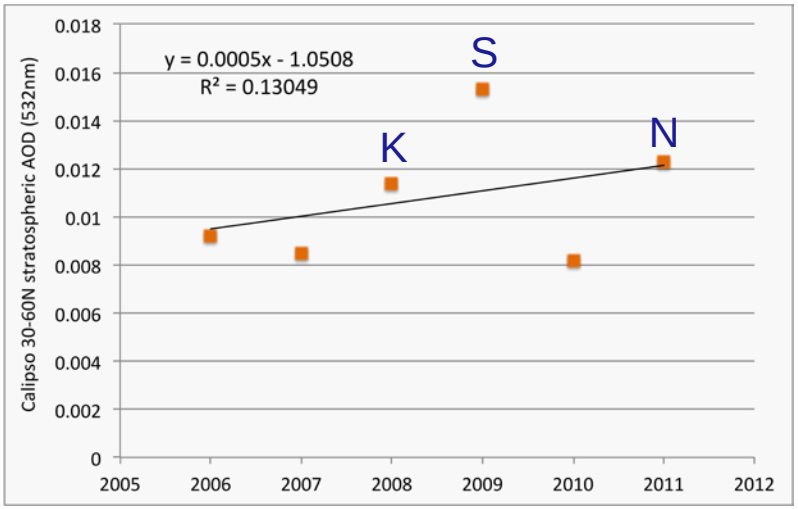


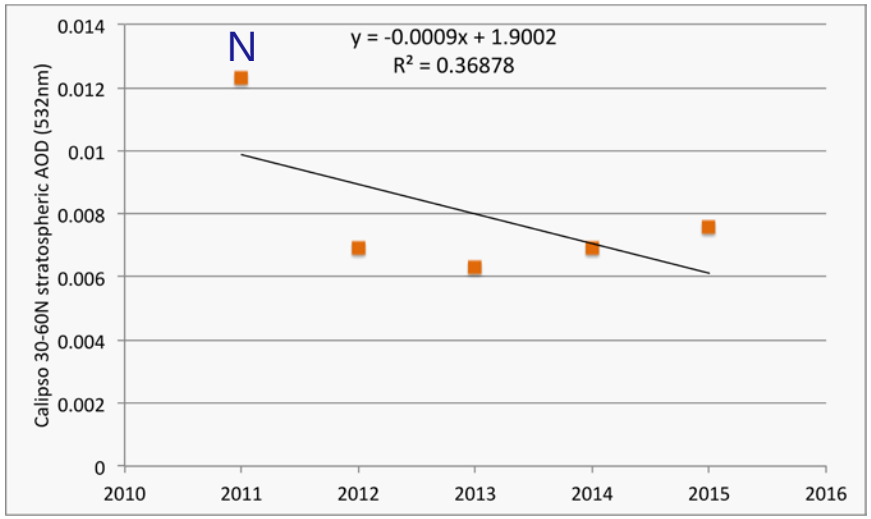
Mauna Loa ground-based LIDAR stratospheric AOD 532 nm
15.8 to 33 km

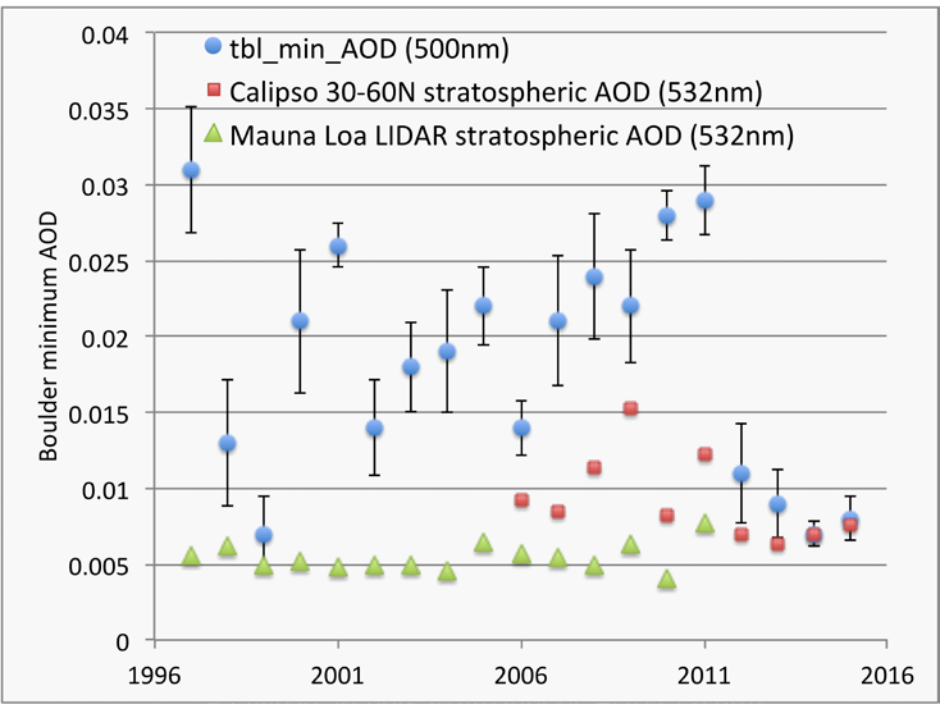


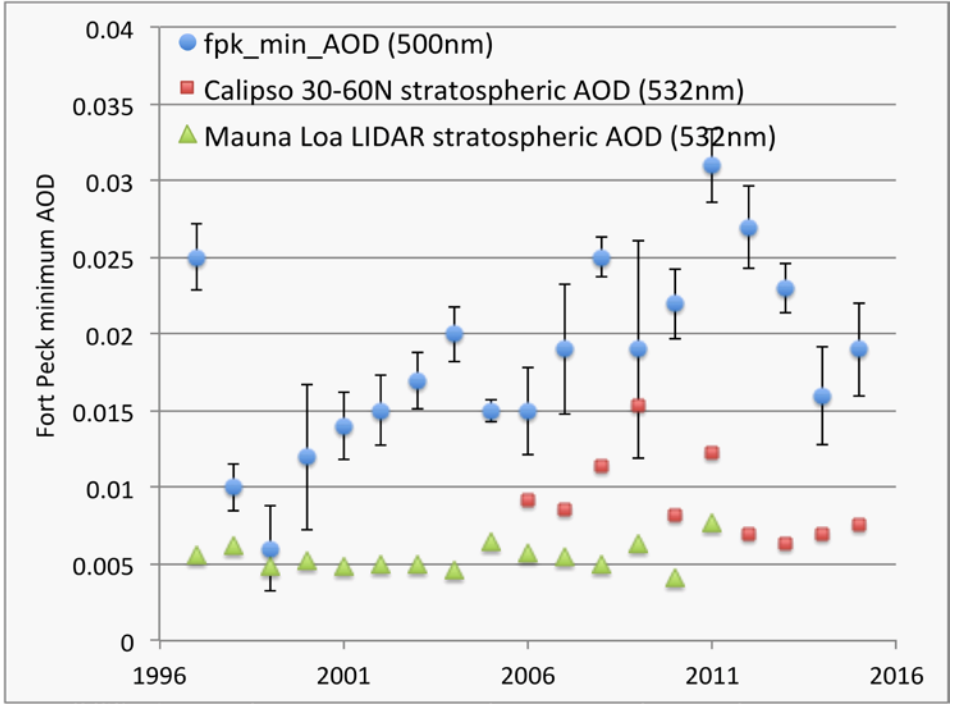


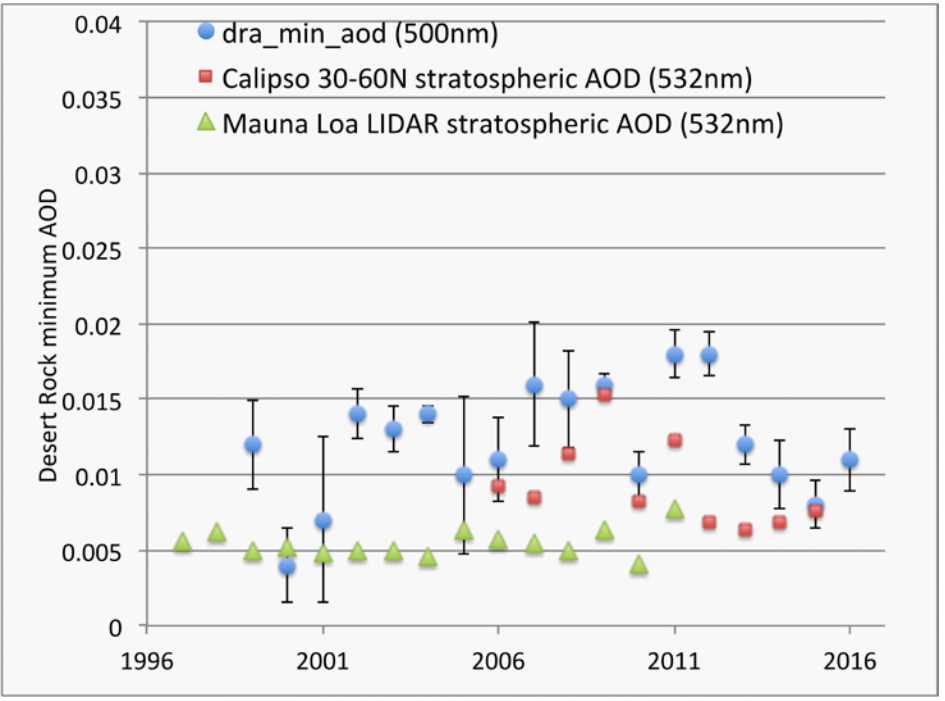
CALIOP space-based LIDAR (30°-60°N) stratospheric AOD 532 nm
Tropopause to 35 km

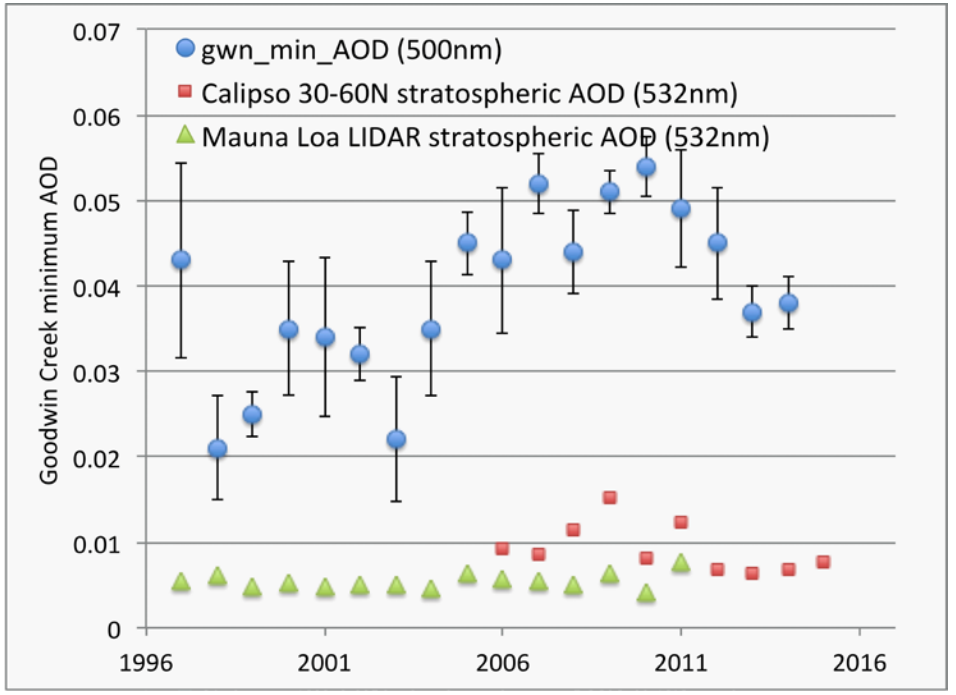


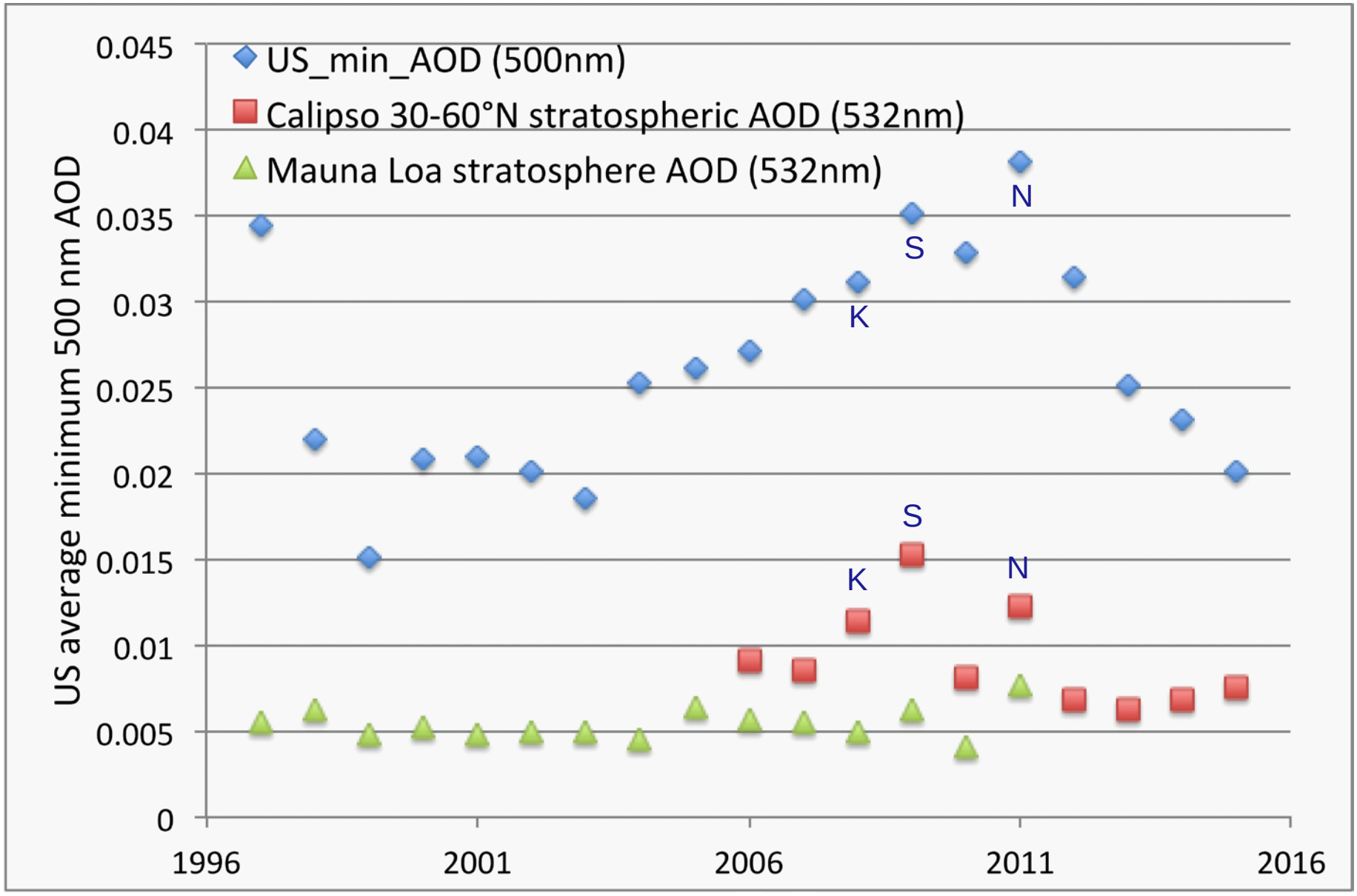



tbl_min_AOD (500nm)
Calipso 30-60N stratospheric AOD (532nm)
Mauna Loa LIDAR stratospheric AOD (532nm)
Boulder minimum AOD
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1996
2001
2006
2011
2016


fpk_min_AOD (500nm)
Calipso 30-60N stratospheric AOD (532nm)
Mauna Loa LIDAR stratospheric AOD (532nm)
Fort Peck minimum AOD
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1996
2001
2006
2011
2016


dra_min_aod (500nm)
Calipso 30-60N stratospheric AOD (532nm)
Mauna Loa LIDAR stratospheric AOD (532nm)
Desert Rock minimum AOD
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1996
2001
2006
2011
2016


gwn_min_AOD (500nm)
Calipso 30-60N stratospheric AOD (532nm)
Mauna Loa LIDAR stratospheric AOD (532nm)
Goodwin Creek minimum AOD
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1996
2001
2006
2011
2016


US_min_AOD (500nm)
Calipso 30-60°N stratospheric AOD (532nm)
Mauna Loa stratosphere AOD (532nm)
US average minimum 500 nm AOD
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1996
2001
2006
2011
2016
S
N
K
S
K
N

AOD trends (per decade)

	2006 – 2011	*2011 – 2015*
Stratosphere		
Calipso (30-60°N)	+.005	-.009
Surface-based total column AOD minima		
U.S. Average	+.019	-.044
Desert Rock NV	+.005	-.019
Boulder CO	+.027	-.046
Fort Peck MT	+.024	-.035
Goodwin Creek MS	+.012	-.041
Bondville IL	-.014	-.040
Sioux Falls SD	+.061	-.051

Summary

- Trends in annual minima of surface-based total column AOD do indicate the direction of stratospheric AOD trends
- Surface-based AOD minima trends are typically greater than stratospheric trends – dry sites best indicate actual behavior of stratospheric AOD
- Minor volcanic eruptions can have a non-negligible influence on stratospheric aerosol forcing
- Radiative effects of some minor volcanoes can last on the order of a year with maximum forcing approaching -1 Wm^{-2}