The SURFRAD aerosol optical depth product and 11-year climatology

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Previous U.S. Aerosol Optical Depth (AOD) Climatologies

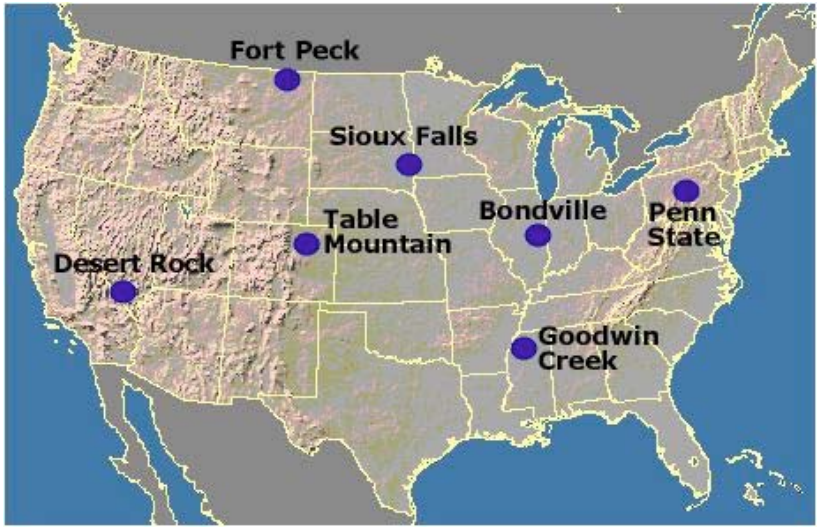
- Flowers et al. (JAM, 1969), 29 stations across the U.S., 1961 - 1966
- Michalsky et al. (JGR, 2001), 9 stations, Northeast quadrant of U.S., 1992 - 1999
- Holben et al. (JGR, 2001), 3 U.S. stations (Maryland, Oregon, New Mexico), 1993 - 1999

These all include effects of large volcanic eruptions

The SURFRAD AOD climatology contains no effects from volcanic activity

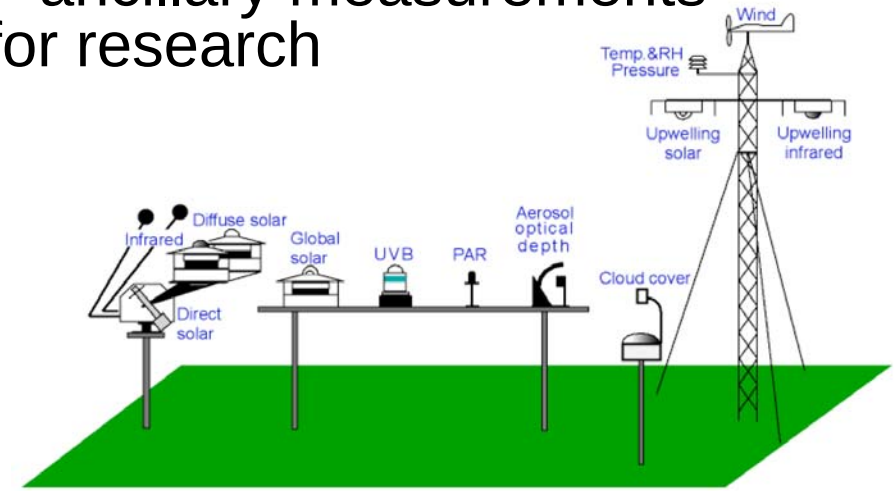
SURFRAD Network

Operational since 1995



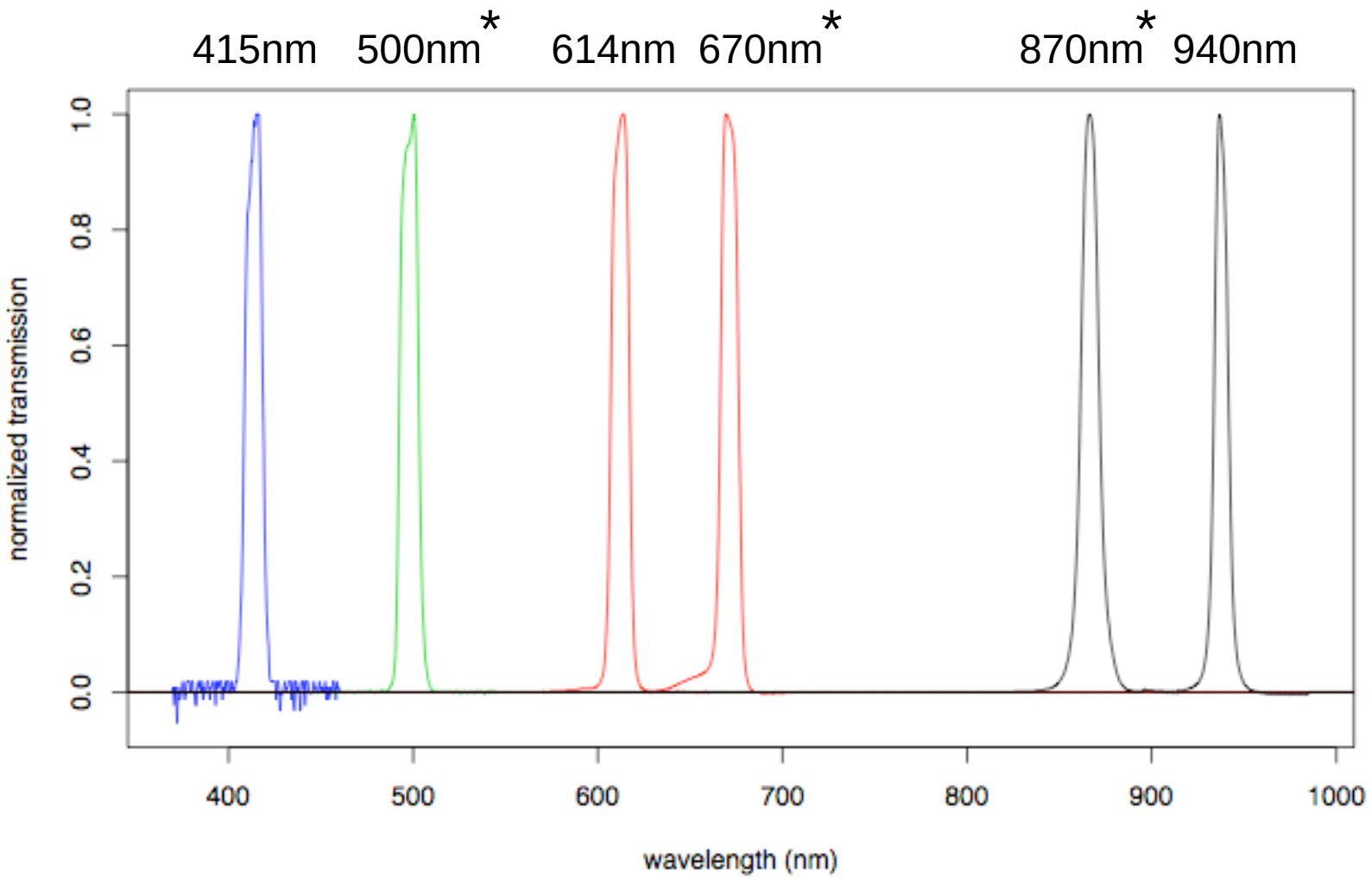
Fort Peck, Montana

Surface Radiation Budget
+ ancillary measurements
for research



Multi-Filter Rotating
Shadowband Radiometer

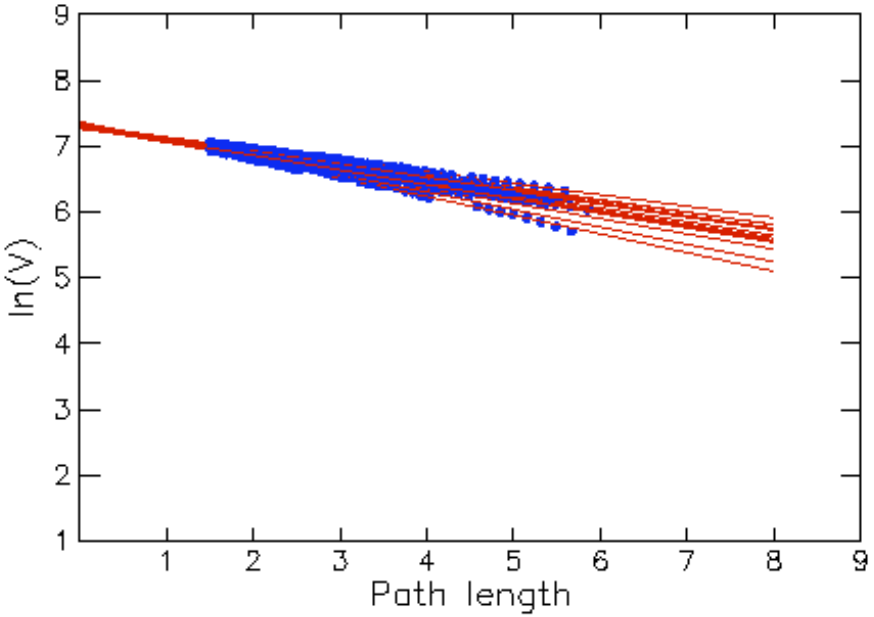
Nominal MFRSR filter profile

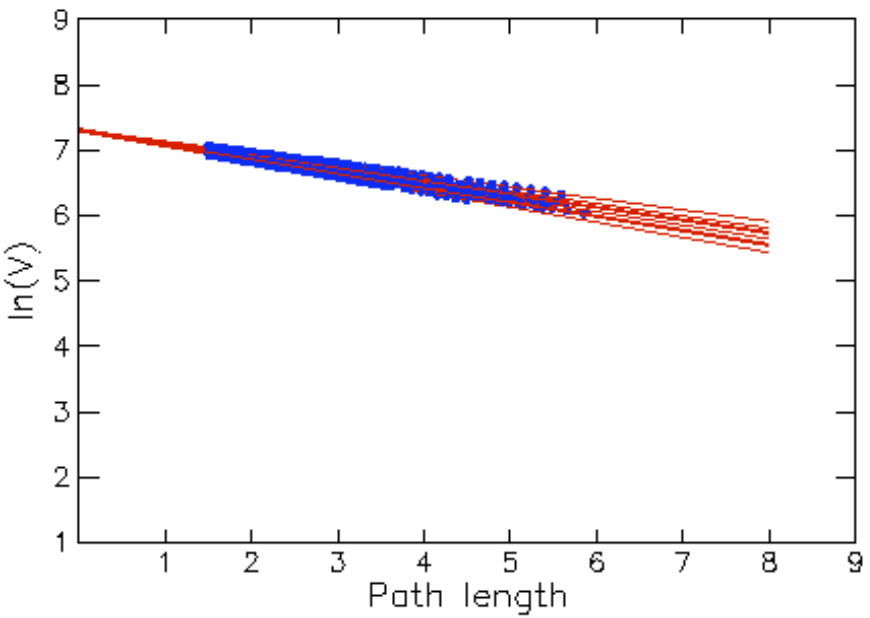


* AERONET channels

Langley Calibration

Long and Ackerman clear-sky identification method used to objectively define Langley-plot points





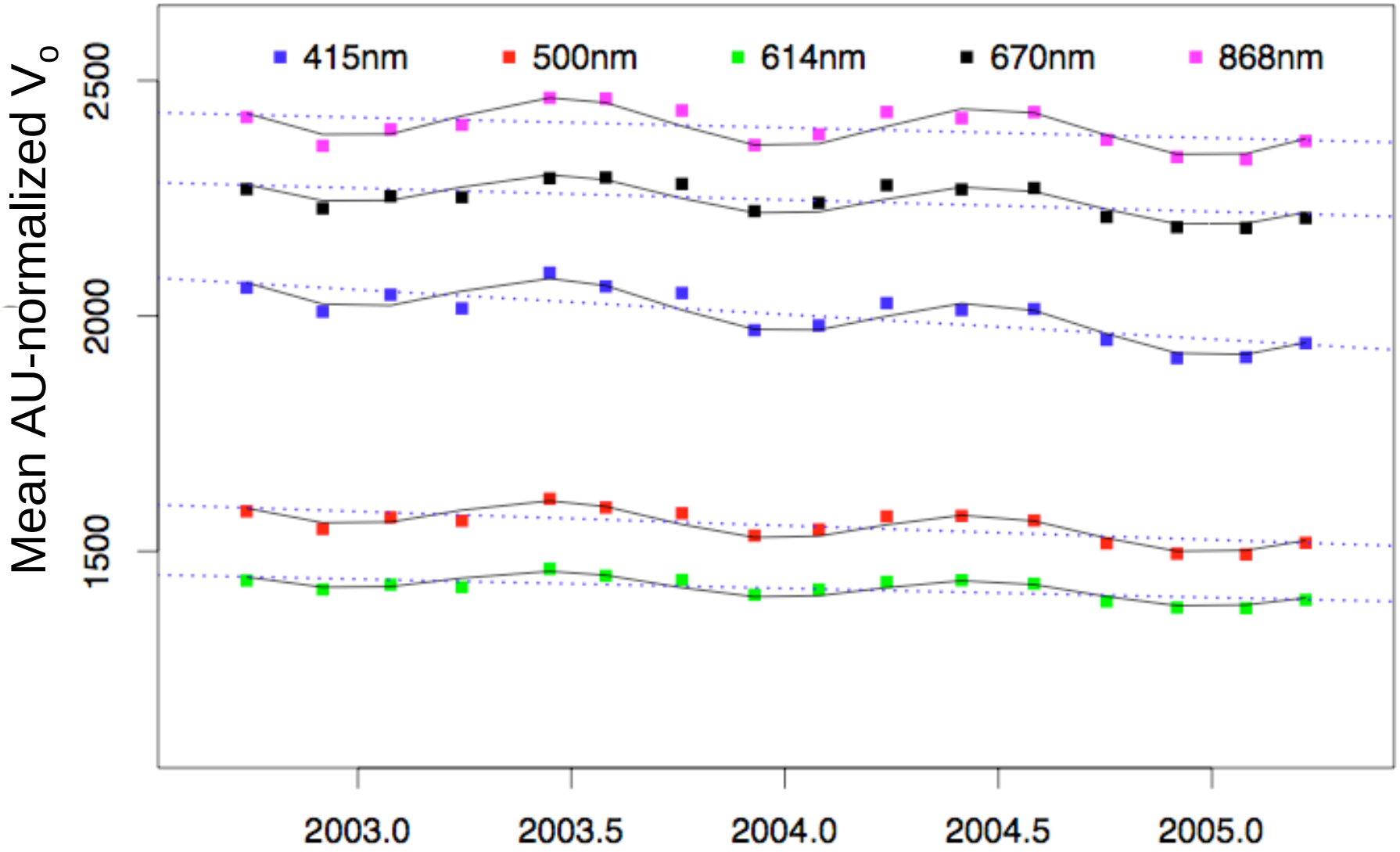
Langley plots compiled over 1 to 2 month periods

Extrapolated V_o's normalized to one AU

V_o sample statistically reduced and averaged.

Variability of the reduced V_o sample defines the uncertainty

Time series of mean 1-2 month mean Langley calibrations



Computing Aerosol Optical Depth:

- Interpolate V_o to a particular day using a periodic function, and correct it to the appropriate earth-sun distance

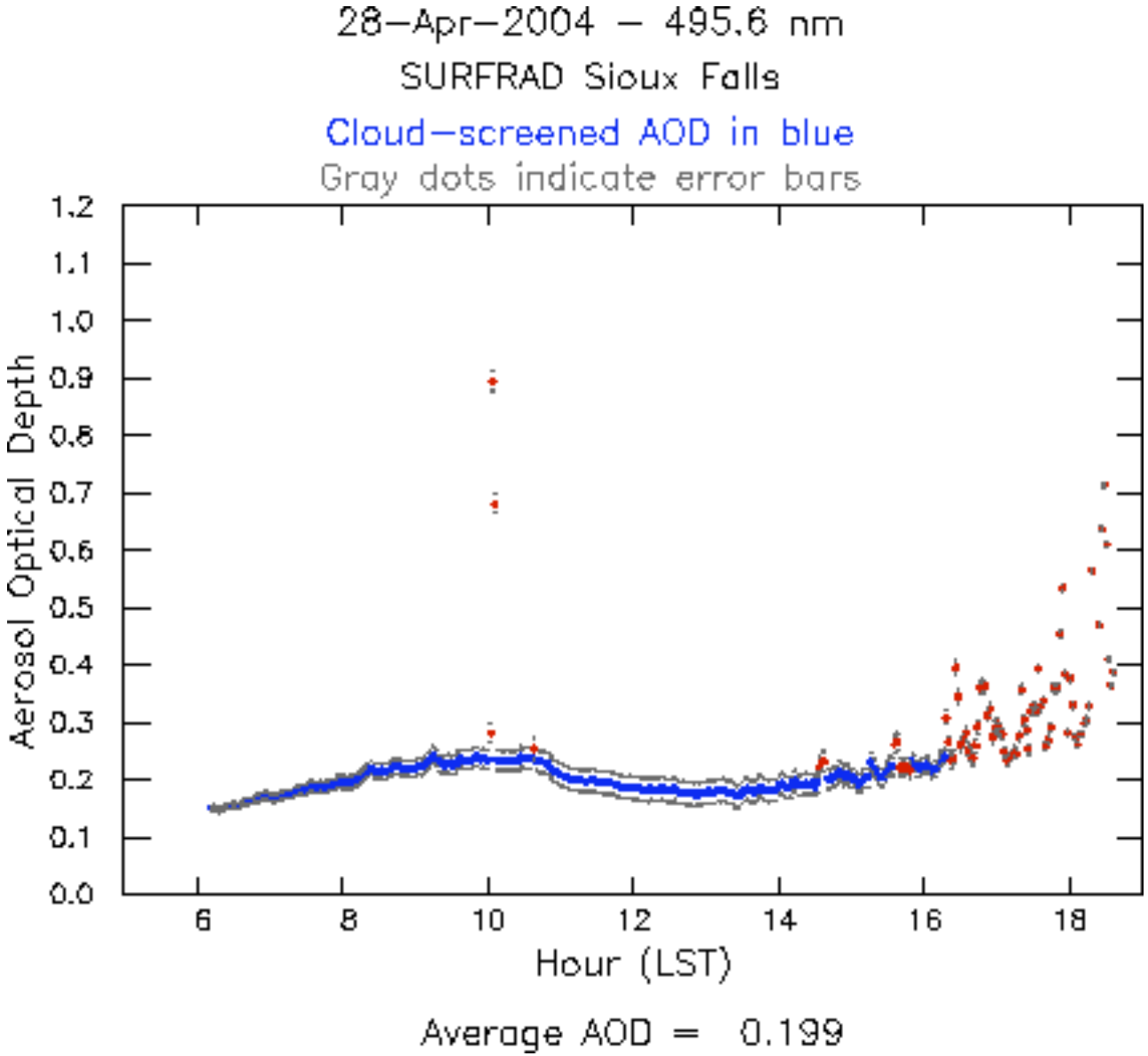
- Compute "total optical depth" ($\Sigma\tau$) for each MFRSR 2-min. measurement (V)

$$V = V_o e^{-m\Sigma\tau}$$

- Subtract the effects of molecular scattering and ozone absorption

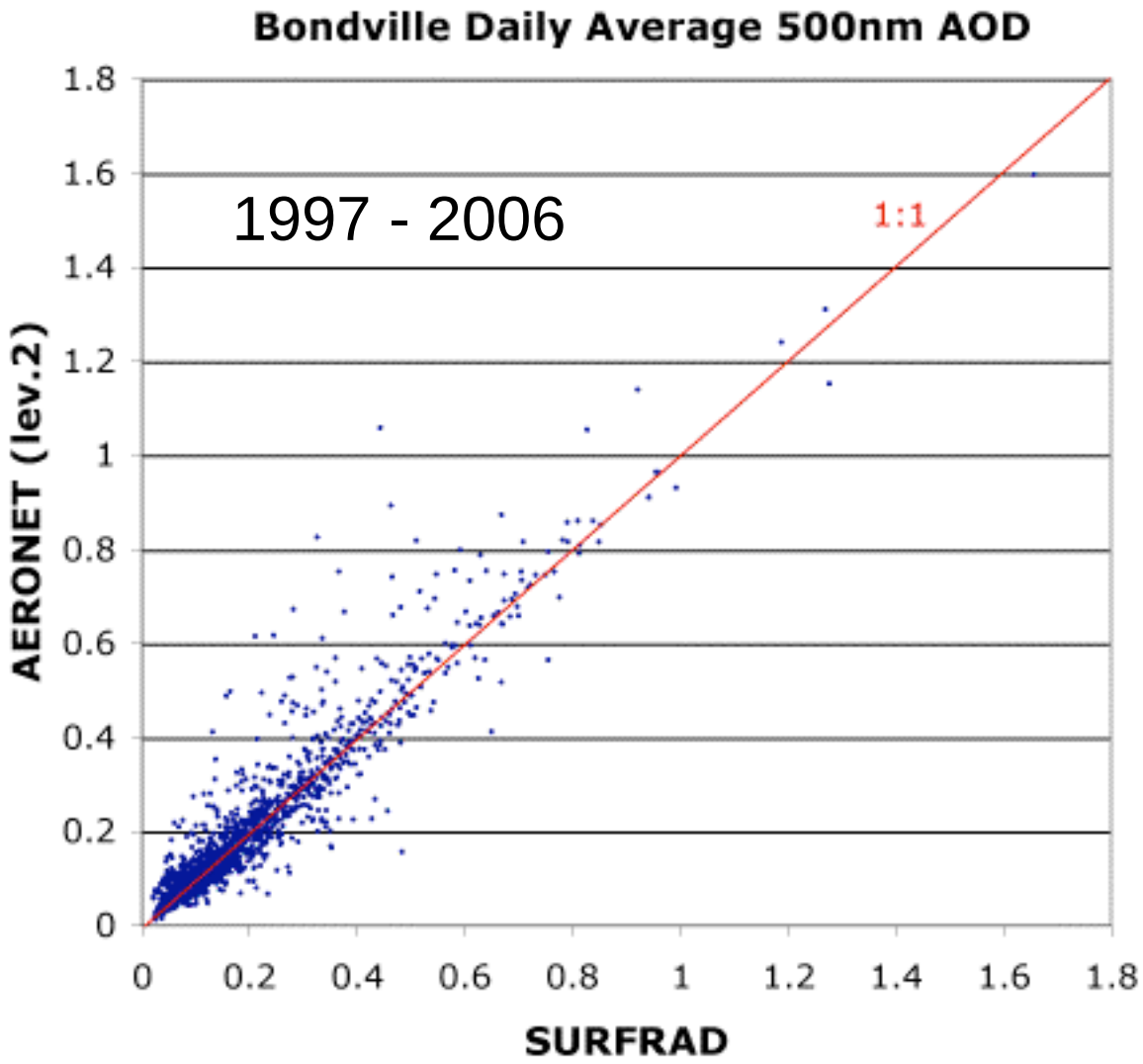
$$\tau_a = \Sigma\tau - \tau_m - \tau_o$$

Aerosol optical depth product

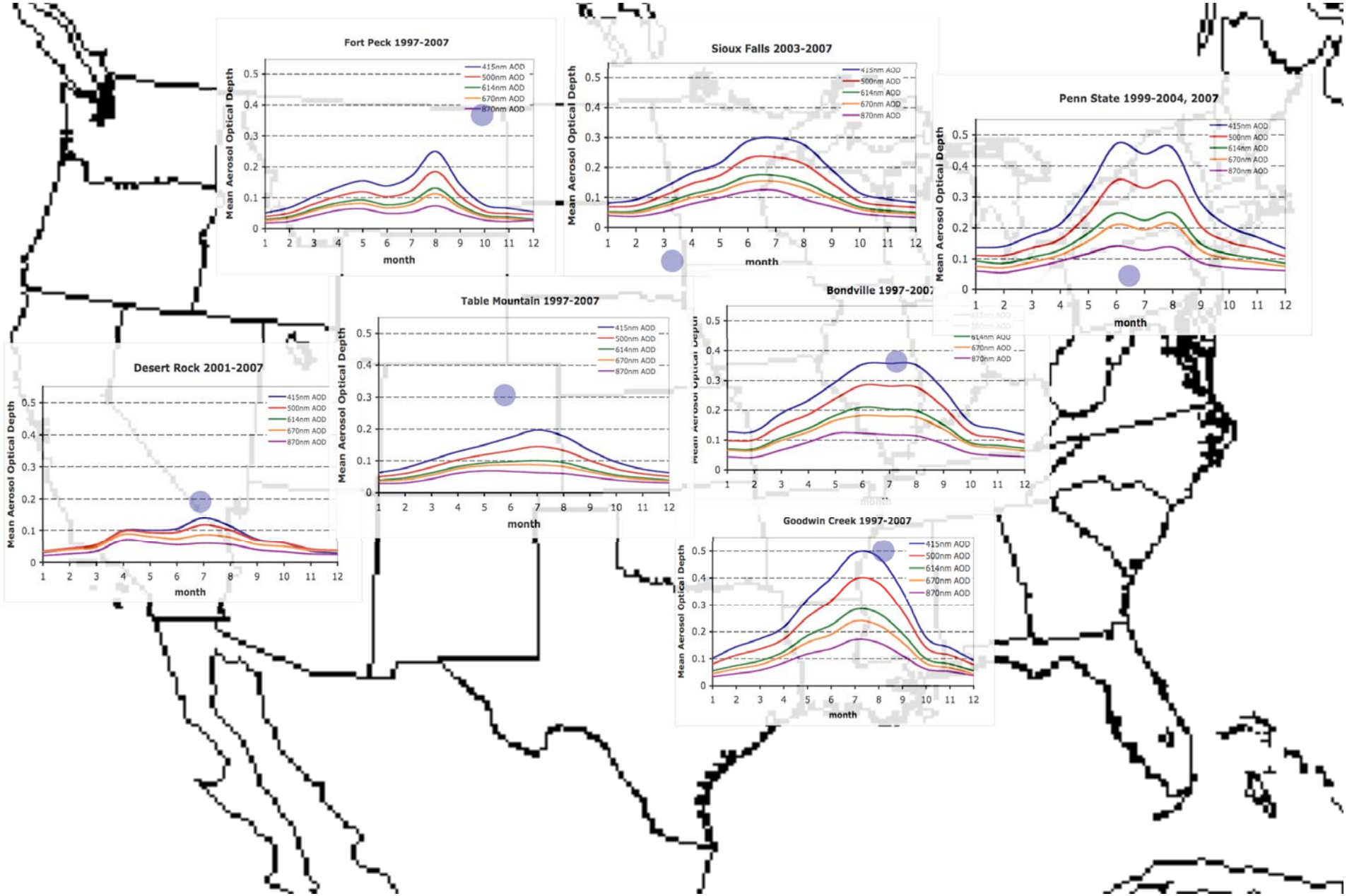


Comparison to NASA's AERONET

Collocated at Bondville, IL and Sioux Falls, SD



Composite annual multi-spectral AOD time series



Mean Angstrom Exponent

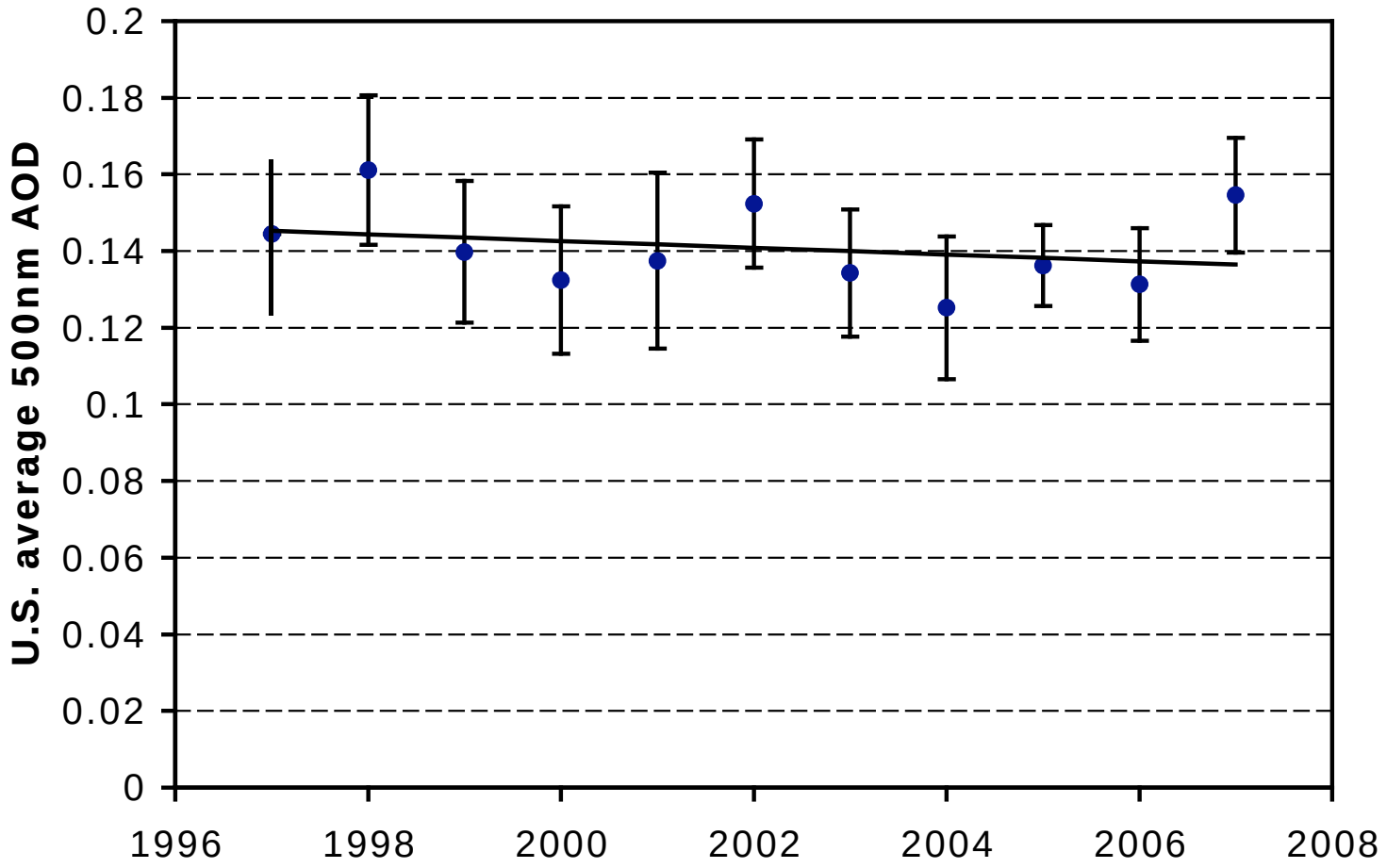
inversely proportional to particle size

log-normal particle size distribution -- may not be always appropriate

	BON	FPK	GWN	TBL	DRA	PSU	SXF
Jan.	1.54	1.26	1.57	0.95	0.98	1.06	0.87
Feb.	1.66	1.33	1.70	1.17	1.06	1.21	1.23
Mar.	1.50	1.19	1.55	1.15	0.90	1.11	1.29
Apr.	1.27	1.00	1.28	0.96	0.65	0.99	1.09
May	1.19	1.12	1.38	1.02	0.76	1.32	1.00
June	1.53	1.28	1.51	1.24	1.02	1.68	1.18
July	1.57	1.44	1.51	1.48	1.30	1.70	1.11
Aug.	1.61	1.65	1.58	1.42	1.13	1.66	1.40
Sep.	1.63	1.40	1.67	1.27	1.03	1.46	1.36
Oct.	1.50	1.26	1.54	1.14	1.06	1.29	1.12
Nov.	1.60	1.22	1.40	1.02	0.83	1.26	1.18
Dec.	1.50	1.15	1.33	0.96	0.78	0.94	1.23
Annual	1.50	1.27	1.50	1.15	0.96	1.31	1.17

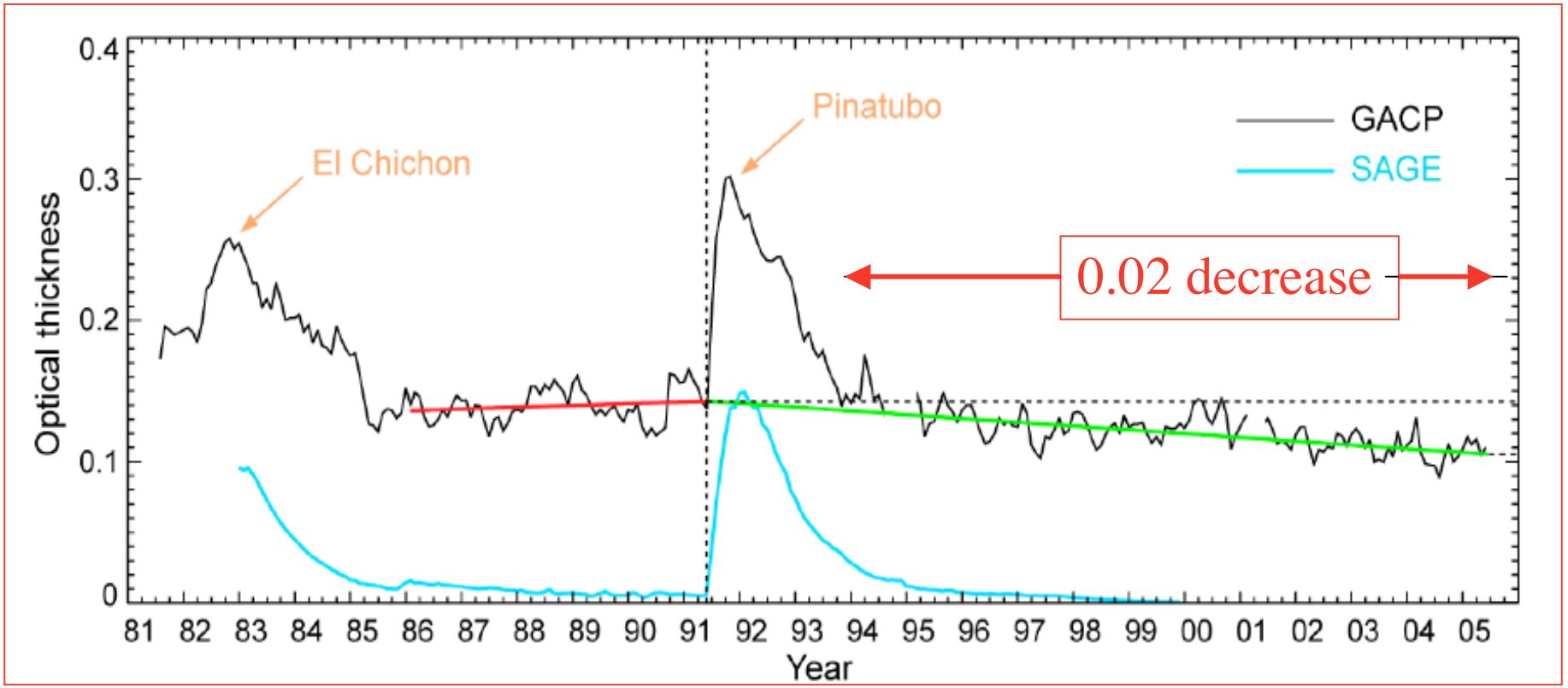
Decadal tendency of Network-wide 500nm AOD

0.01 decrease/decade (-6%)

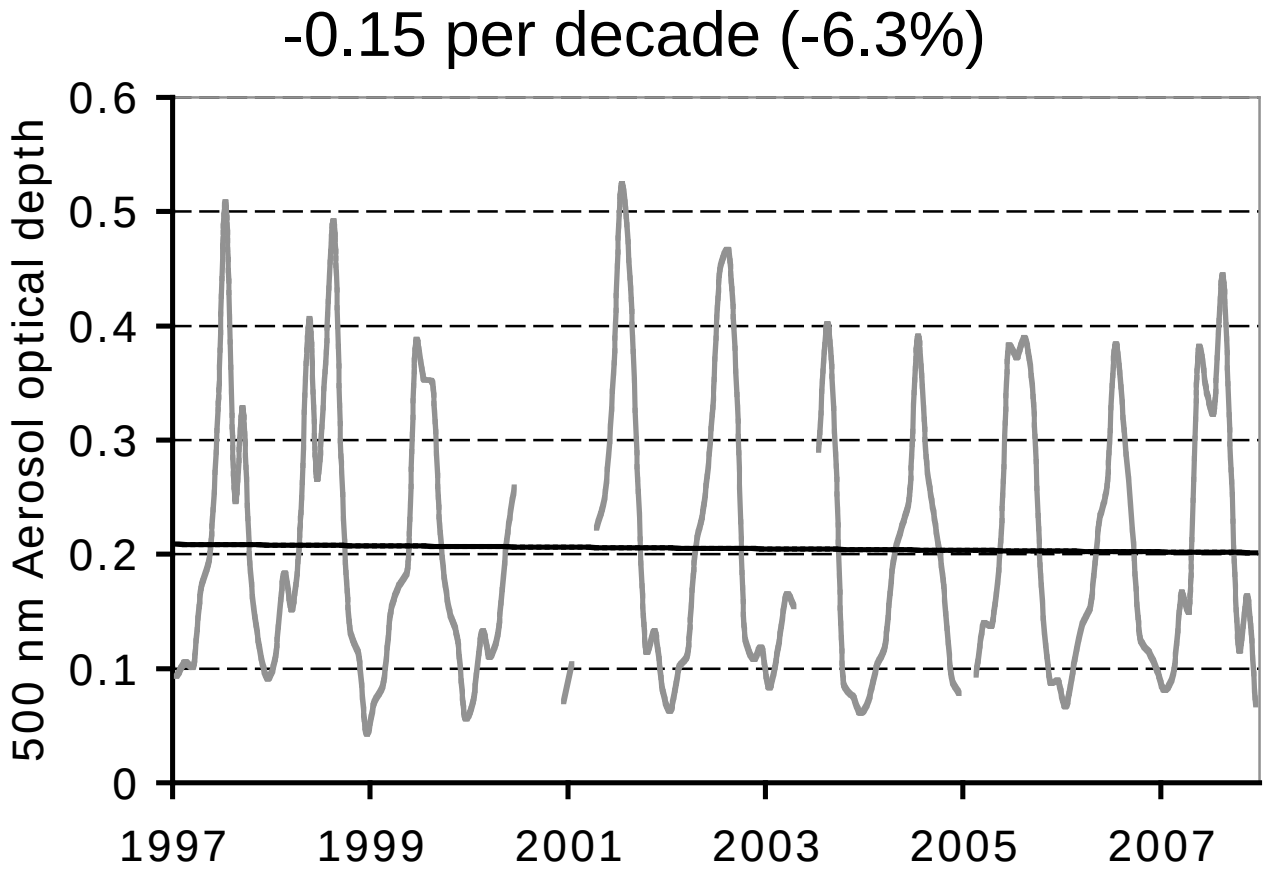


Aerosol optical thickness over the oceans as measured by satellite (ISCCP DX radiance) and SAGE

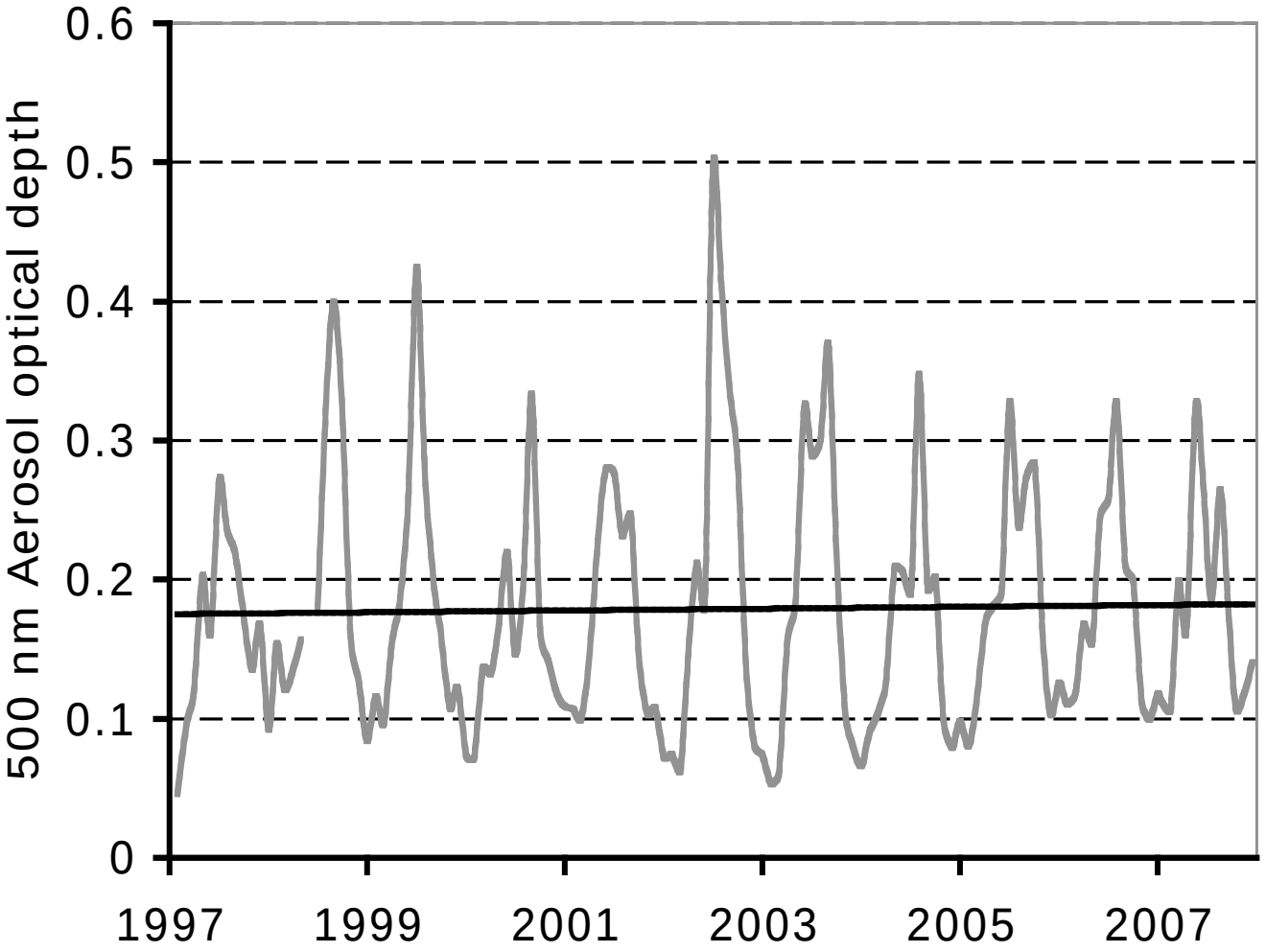
Mischenko and Geogdzhayev (GEWEX NEWS, May 2007)



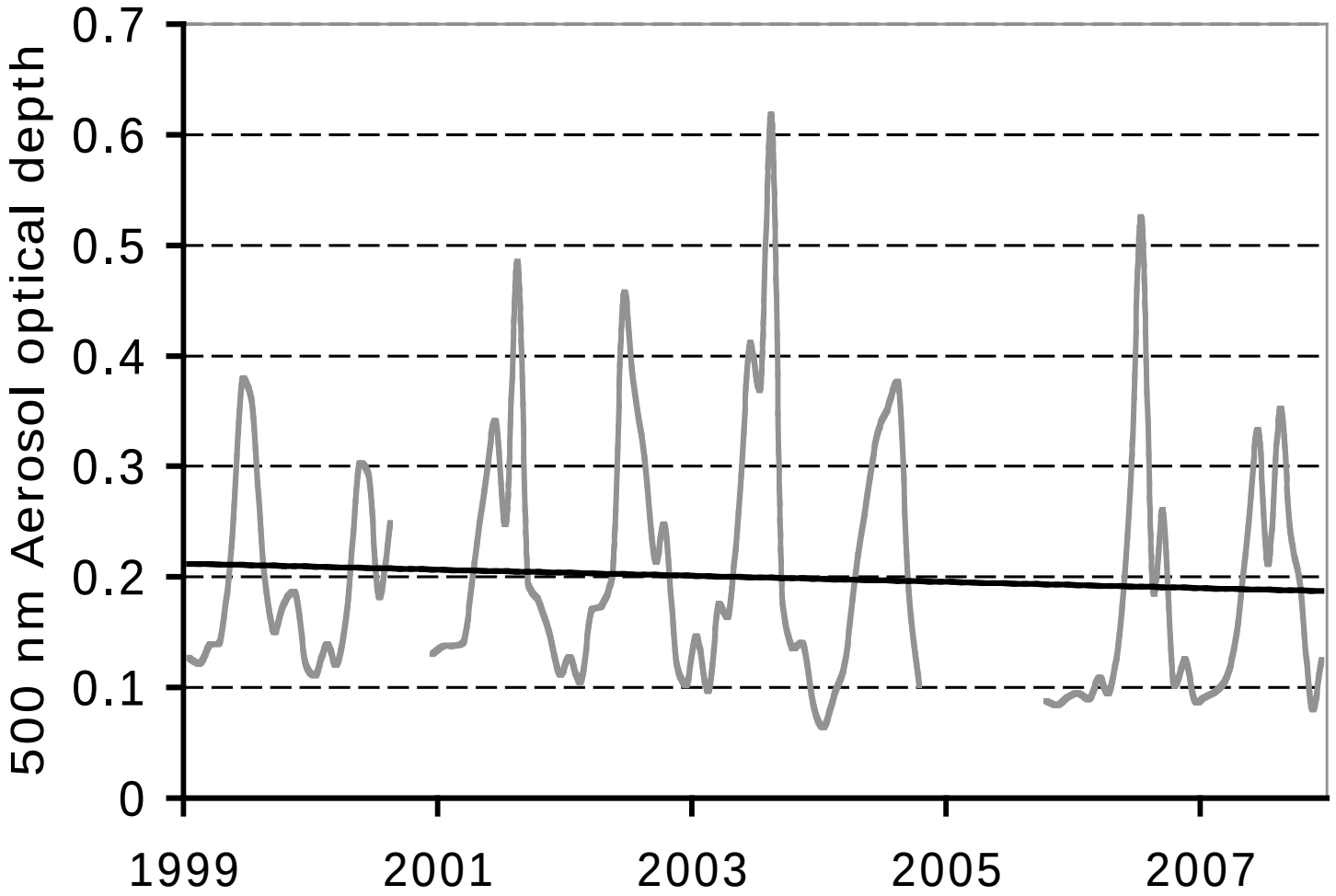
Goodwin Creek, Mississippi



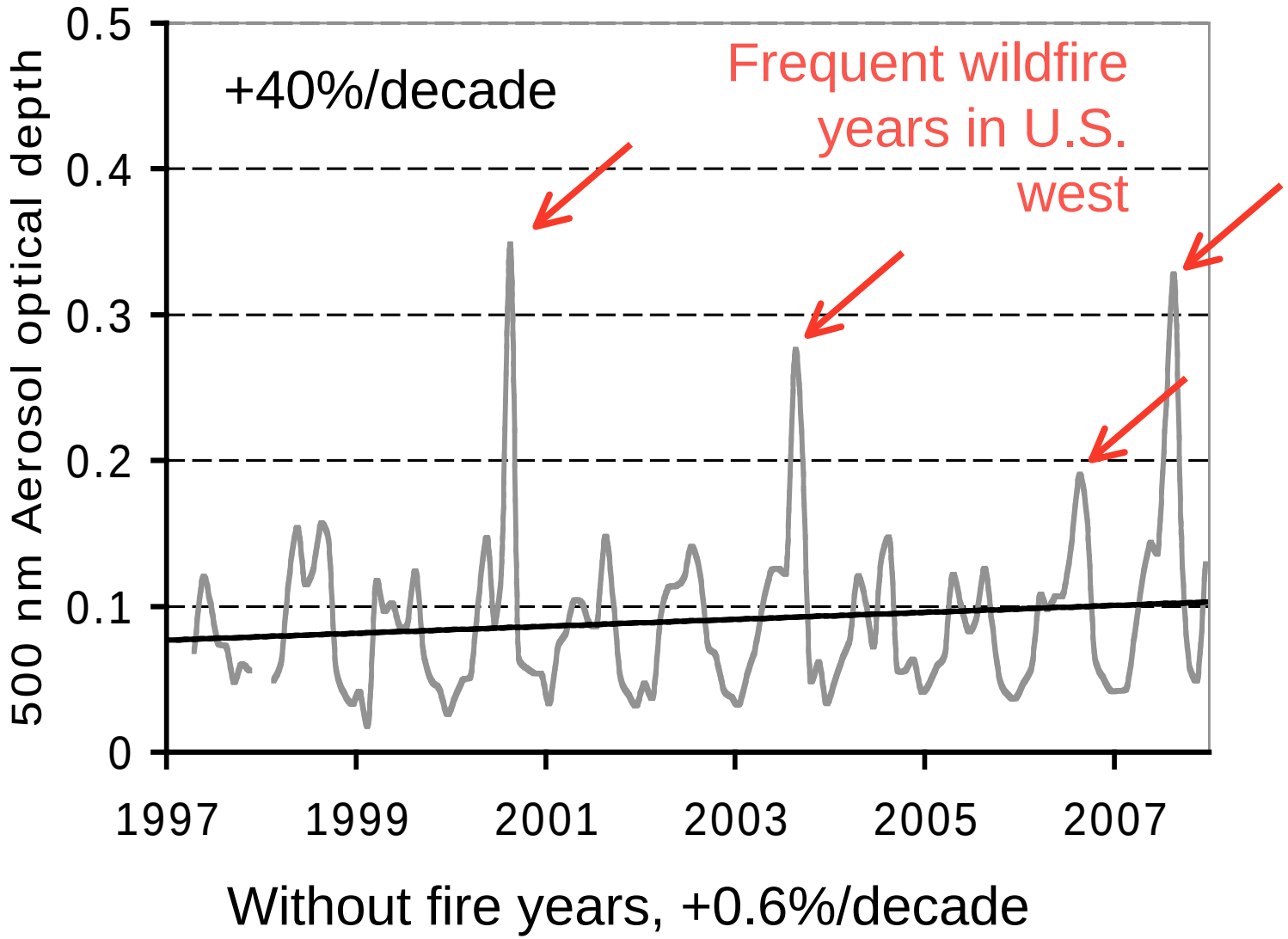
Bondville, Illinois



PENN STATE

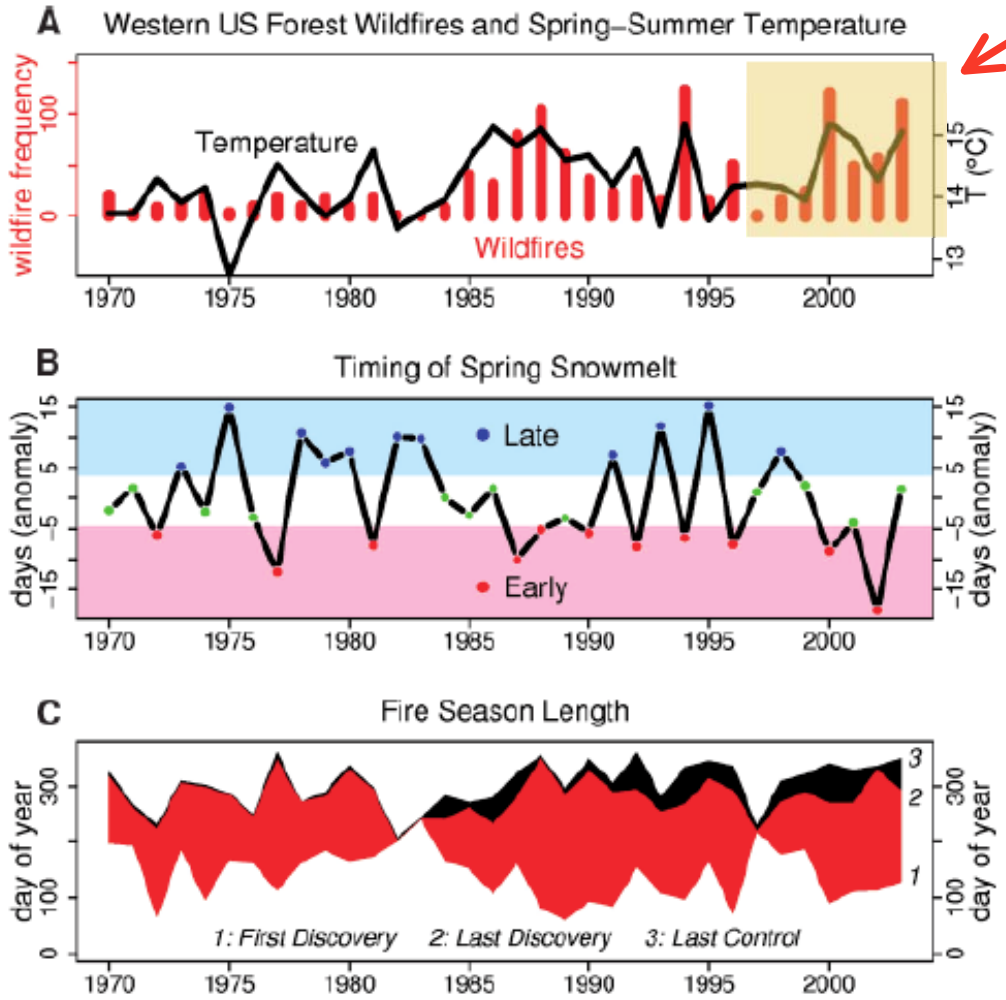

500 nm Aerosol optical depth
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1999
2001
2003
2005
2007

Fort Peck, Montana



Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity

A. L. Westerling,[1,2*] H. G. Hidalgo,[1] D. R. Cayan,[1,3] T. W. Swetnam[4]



Period of SURFRAD AOD record

High wildfire years: 2000, 2003, 2006, 2007

✓Average fire duration has increased from 1 to 5 weeks

✓Linked increased wildfire activity to global warming

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Updated wildfire statistics

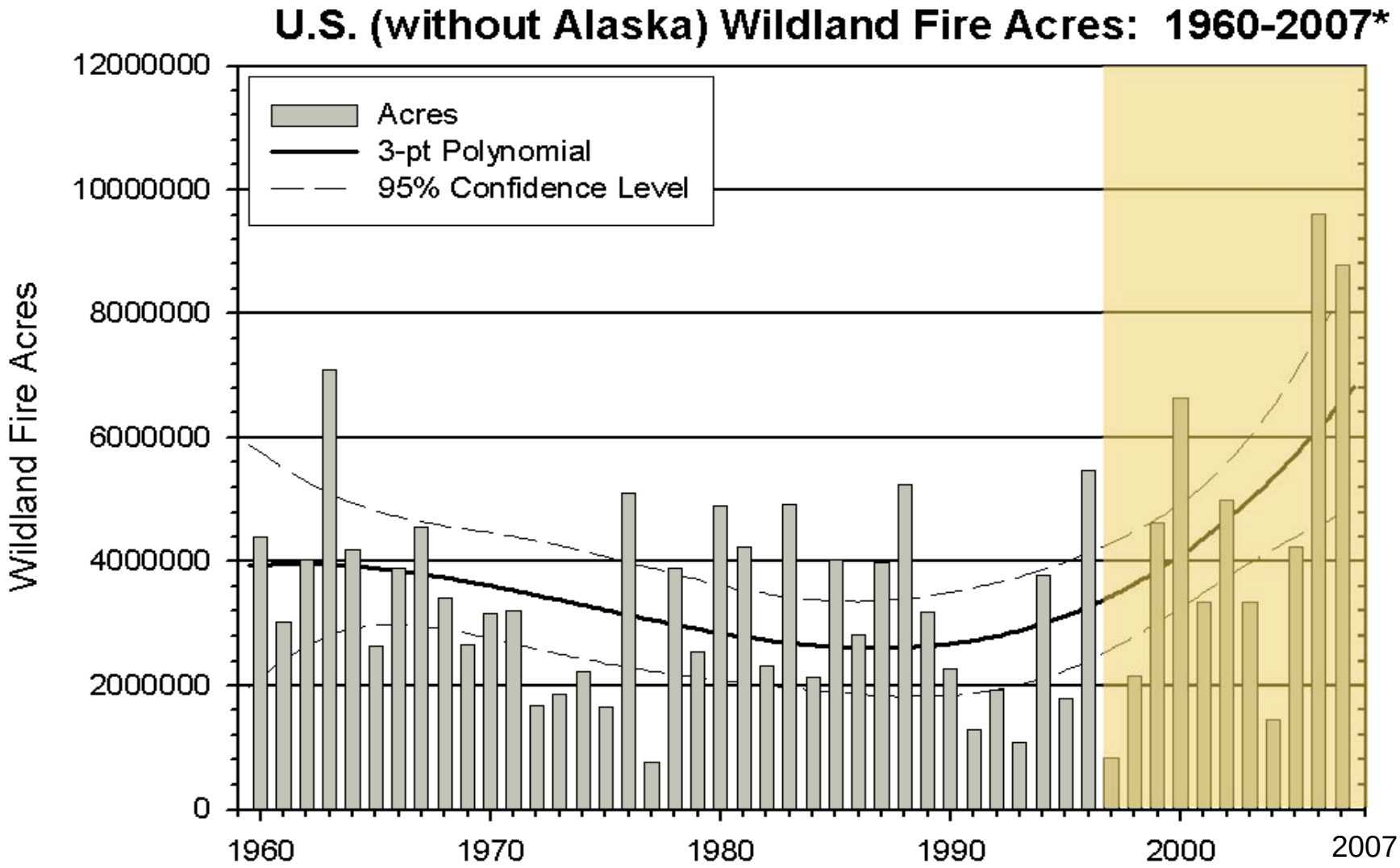
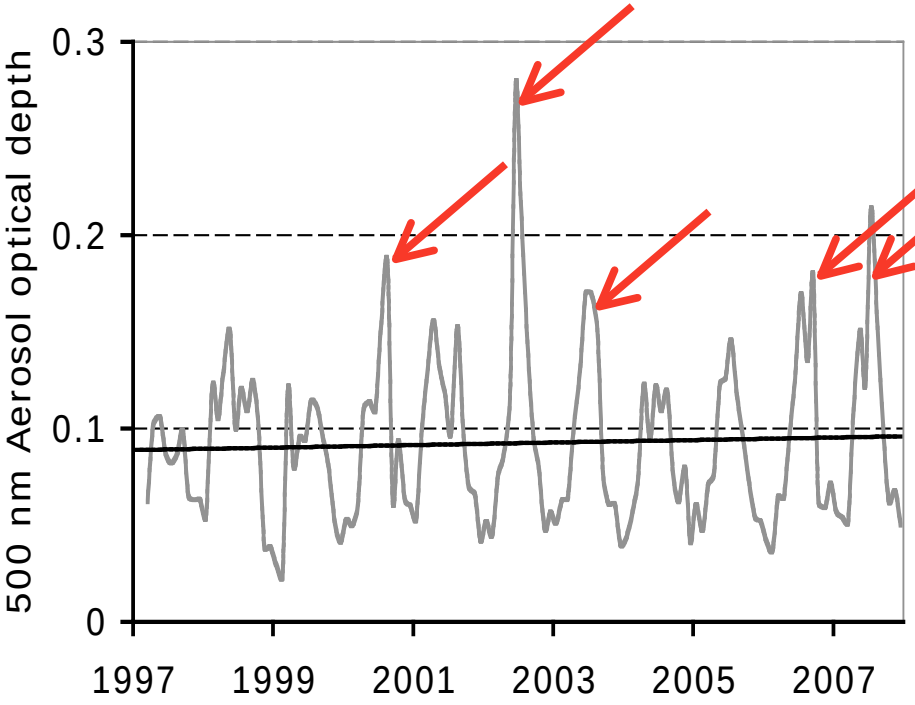
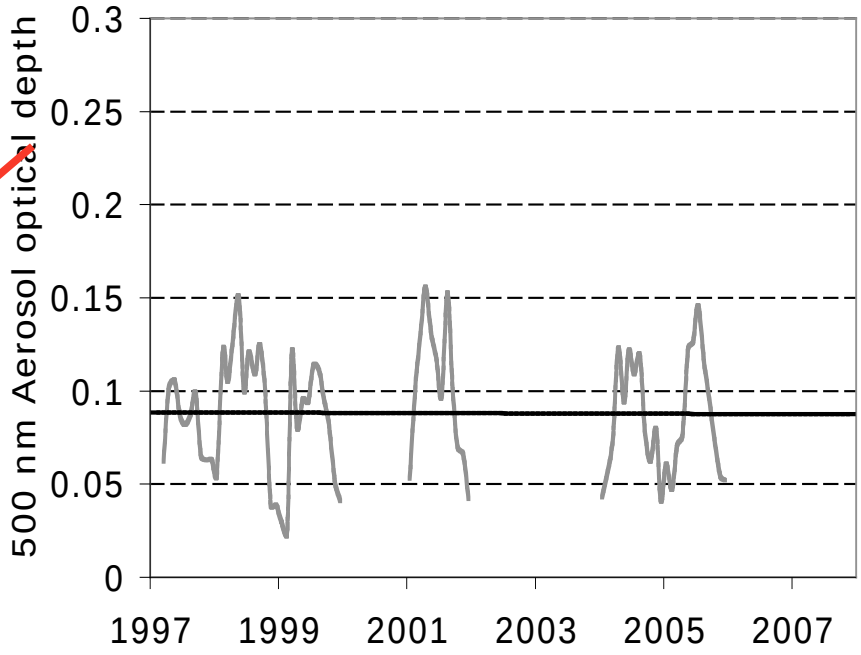


Table Mountain, Colorado



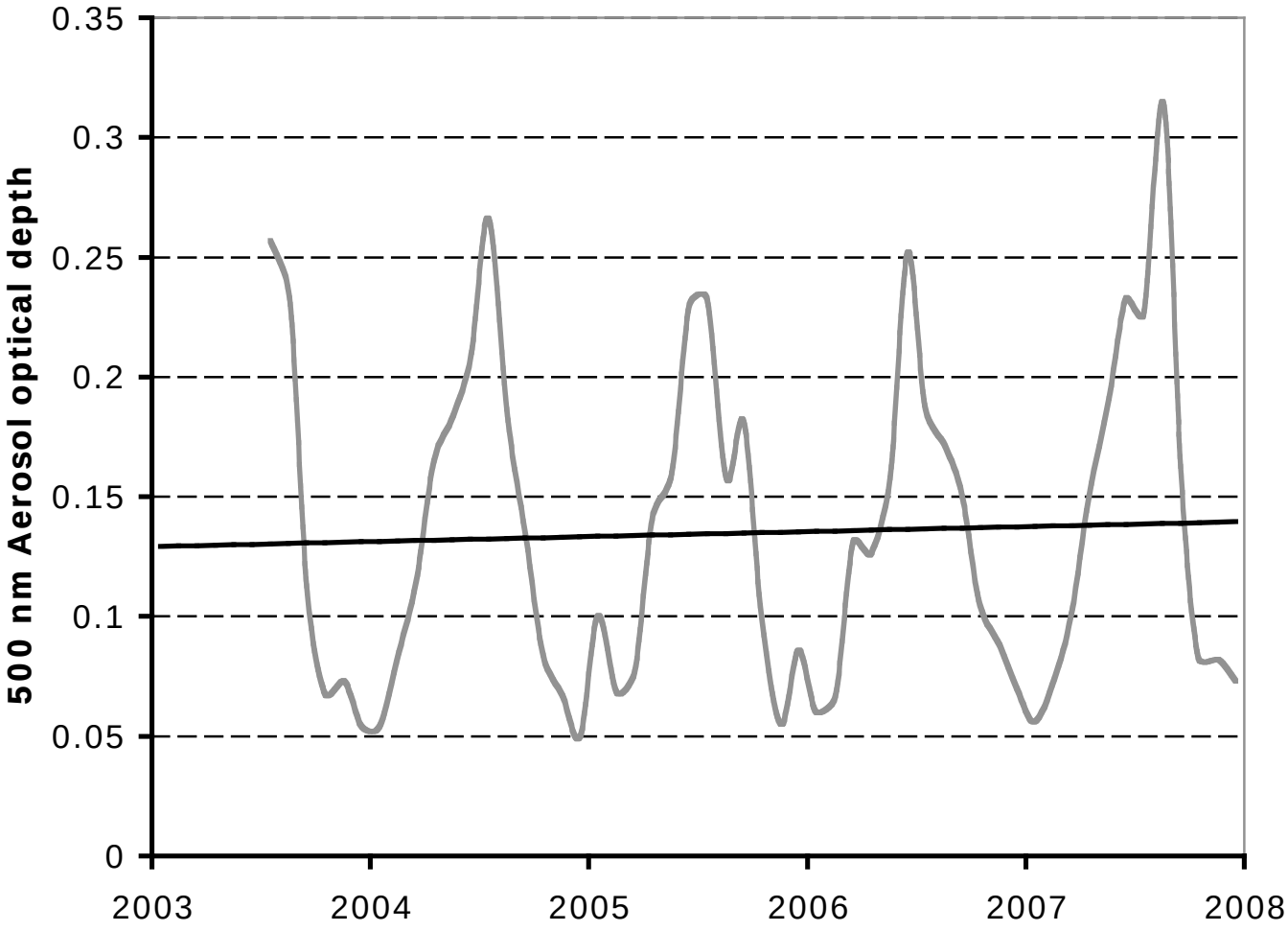
+11%/decade

Without major fire years

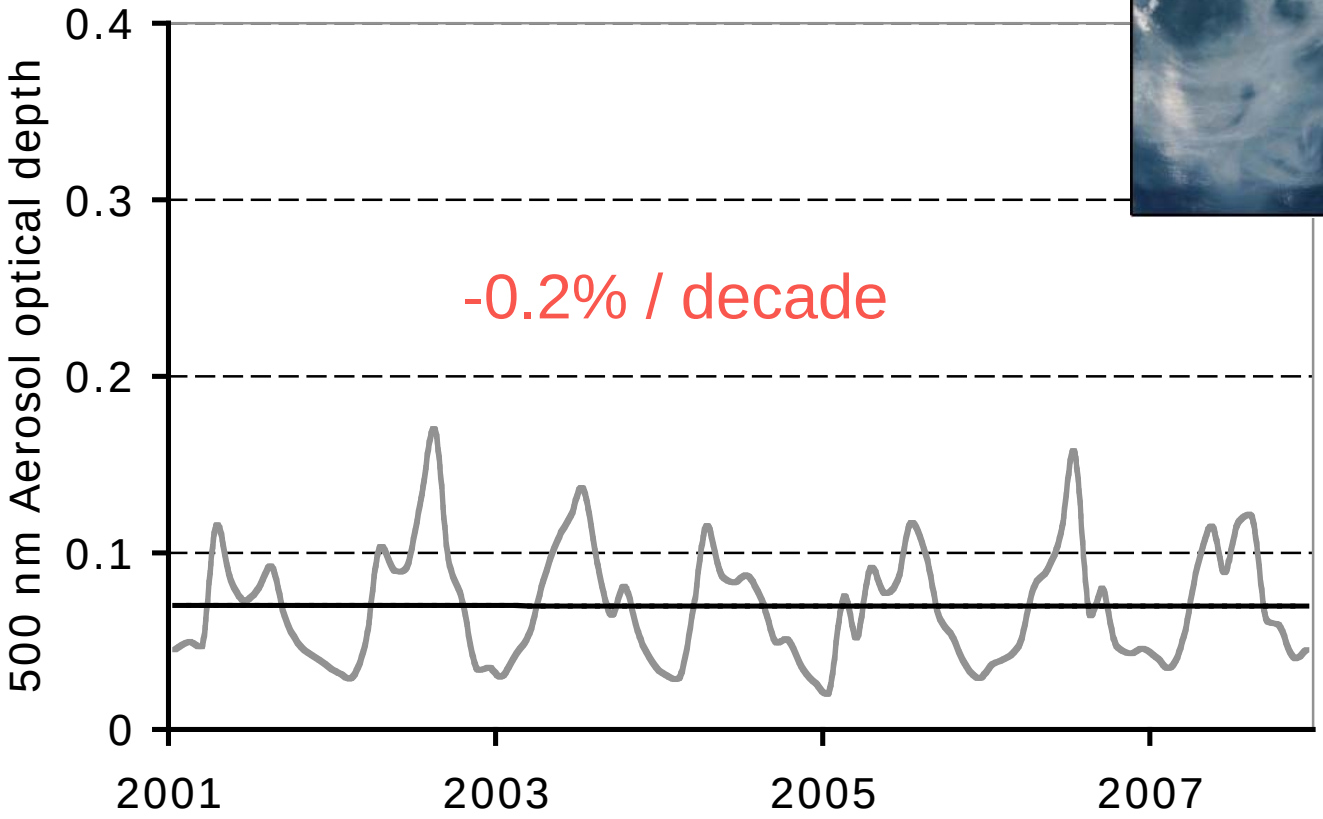


< 1% / decade

Sioux Falls, South Dakota



Desert Rock,Nevac



Summary

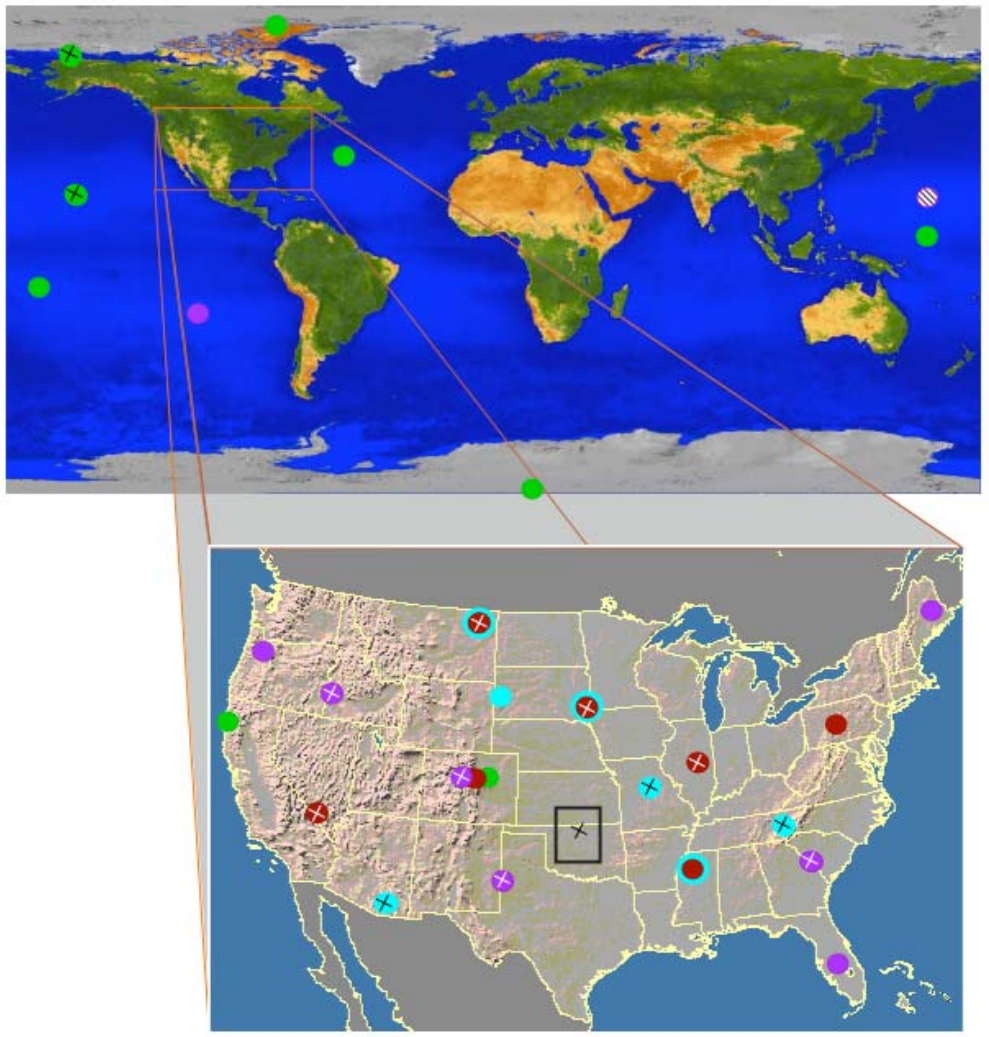
- 11-year AOD record (1997-2007) completed for SURFRAD
- Highest AOD in eastern U.S., lowest in west
- Springtime Asian dust signature prominent in western U.S.
- AOD decreased slightly over the U.S.from 1997 to 2007 -- similar over the oceans
- AOD decreases only in the eastern U.S.
- Decadal AOD *increase* at two western stations is consistent with increased frequency *and duration* of Rocky Mt. wildfires

- Climate-change induced drought may be increasing wildfire frequency and duration in U.S.west -- increasing AOD there would be a negative feedback to greenhouse-gas warming
- AOD record is not long enough to give confidence to the observed tendencies
- Longer time series are needed

The SURFRAD aerosol optical depth product and 11-year climatology

Questions?

Possible future Surface Energy Budget Network -- SEBN



500nm channel calibration results for May and June 2005

```
500-nm channel results:
 1 2005 05 19  82 500nm AM  7.313 0.9763  1535.44 -0.175  0
 2 2005 05 19  71 500nm PM  7.332 0.9763  1565.50 -0.223  0
 3 2005 05 22  58 500nm AM  7.302 0.9751  1521.45 -0.194  0
 4 2005 05 23  71 500nm AM  7.309 0.9747  1532.29 -0.196  0
 5 2005 05 27  57 500nm PM  7.371 0.9733  1633.59 -0.284  1
 6 2005 06 06  77 500nm AM  7.303 0.9703  1529.48 -0.207  0
 7 2005 06 07  79 500nm AM  7.312 0.9701  1544.90 -0.218  0
 8 2005 06 08  68 500nm AM  7.291 0.9698  1513.34 -0.196  0
 9 2005 06 11  81 500nm AM  7.266 0.9691  1475.71 -0.182  0
10 2005 06 14  78 500nm AM  7.302 0.9685  1531.21 -0.187  0
11 2005 06 14  70 500nm PM  7.285 0.9685  1505.65 -0.231  0
12 2005 06 18  67 500nm AM  7.326 0.9679  1569.71 -0.190  0
13 2005 06 19  79 500nm AM  7.325 0.9677  1568.76 -0.199  0
14 2005 06 23  70 500nm AM  7.275 0.9672  1493.27 -0.209  0
15 2005 06 27  60 500nm AM  7.362 0.9669  1628.63 -0.265  0
16 2005 06 30  73 500nm AM  7.298 0.9667  1528.80 -0.220  0

 average y_intercept =         1542.36
 weighted average y_intercept =  1540.09
 y_int std. dev. =                 43.09
 y_int minimum  =                1475.71
 y_int maximum  =                1633.59
 AOD error      =               0.028

1633.59 rejected because gt 1 sigma from mean
1475.71 rejected because gt 1 sigma from mean
1493.27 rejected because gt 1 sigma from mean
1628.63 rejected because gt 1 sigma from mean
1569.71 > 1.5 sigma from refined mean, rejected by 2nd pass

New sample (reduced to 11 values):
      1535.44
      1565.50
      1521.45
      1532.29
      1529.48
      1544.90
      1513.34
      1531.21
      1505.65
      1568.76
      1528.80

 refined average y_intercept =         1534.26
 refined weighted average y_intercept =  1534.97
 refined y_int std. dev. =                 19.40
 refined y_int minimum  =                1505.65
 refined y_int maximum  =                1568.76
 refined AOD error      =               0.013
```

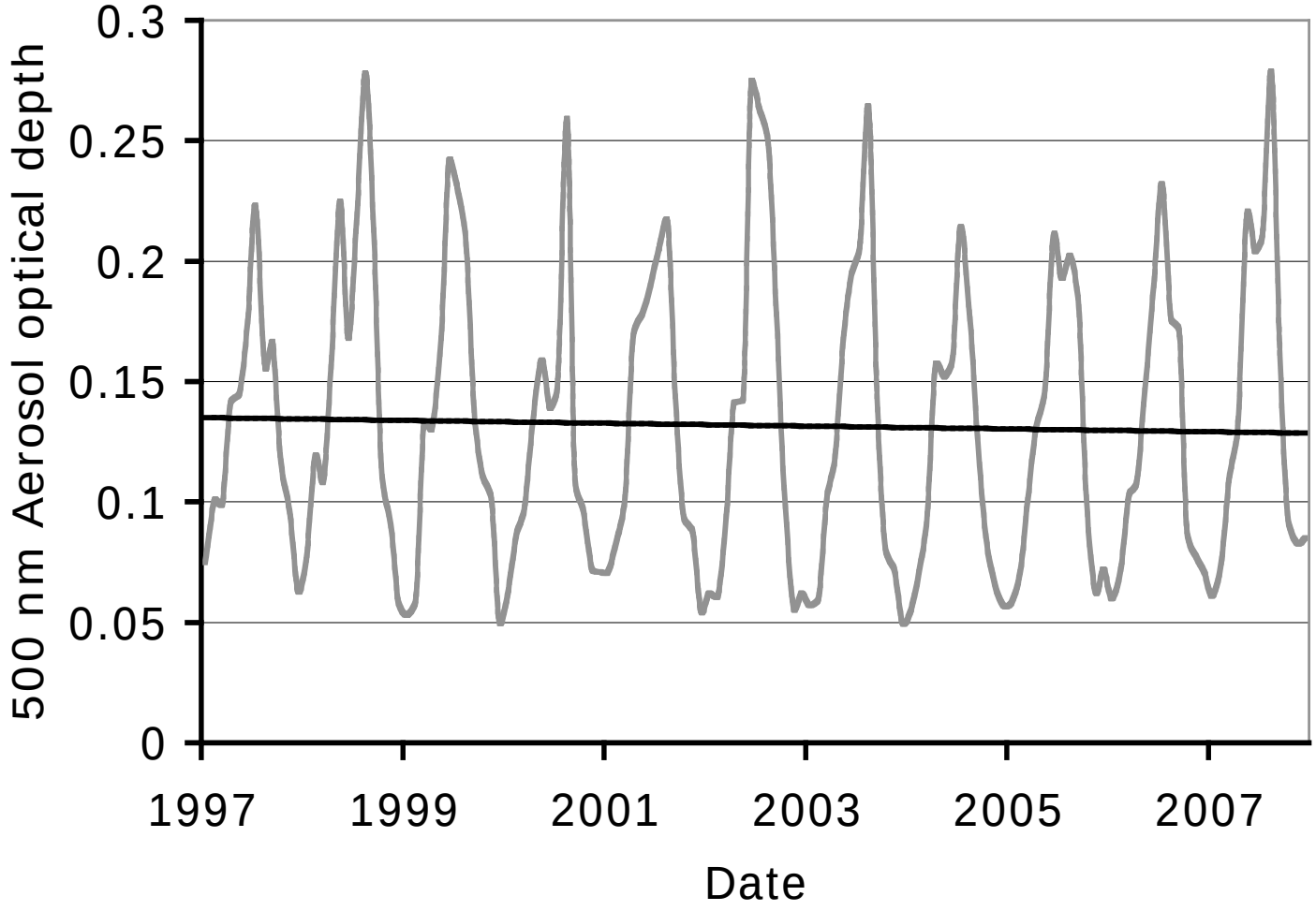
Error analysis:

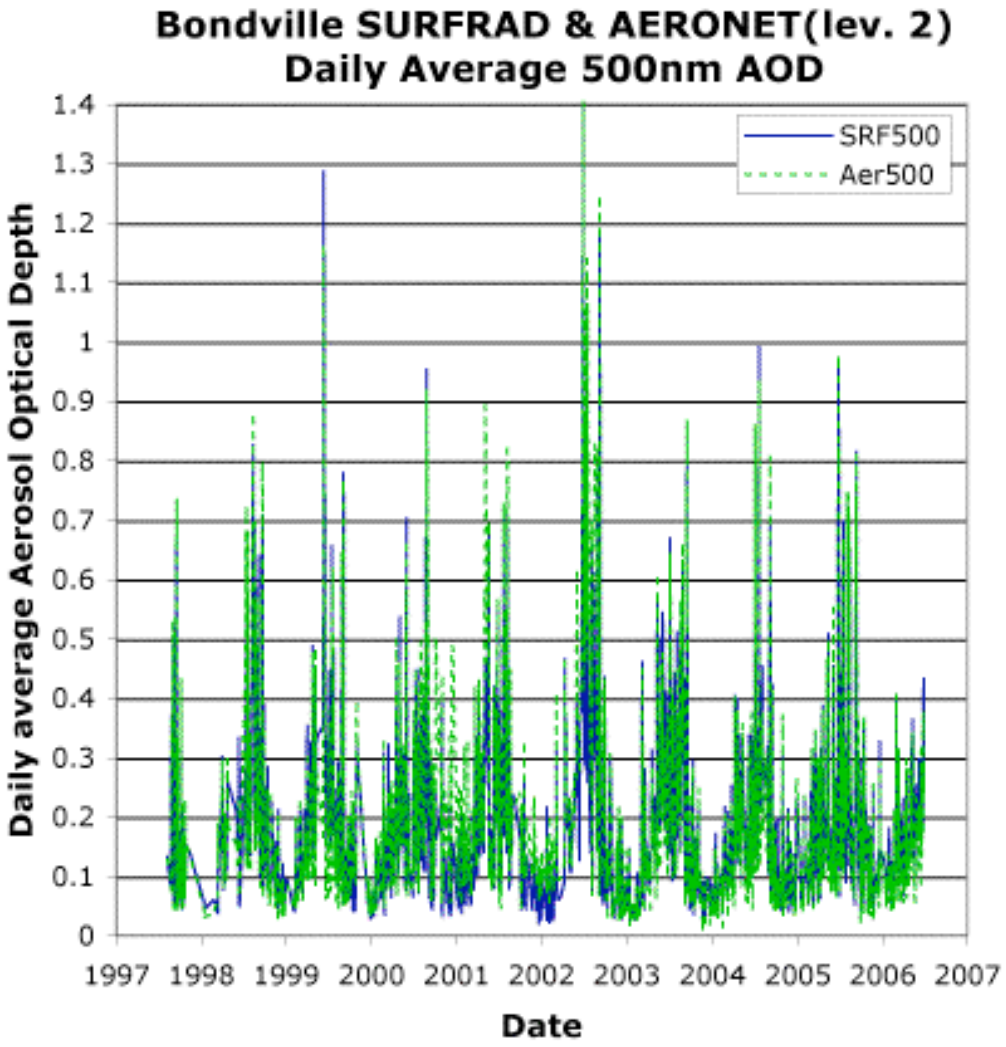
$$(\sigma\tau)^2 = (\sigma V_o / m V_o)^2 + (\sigma V / m V)^2$$

0

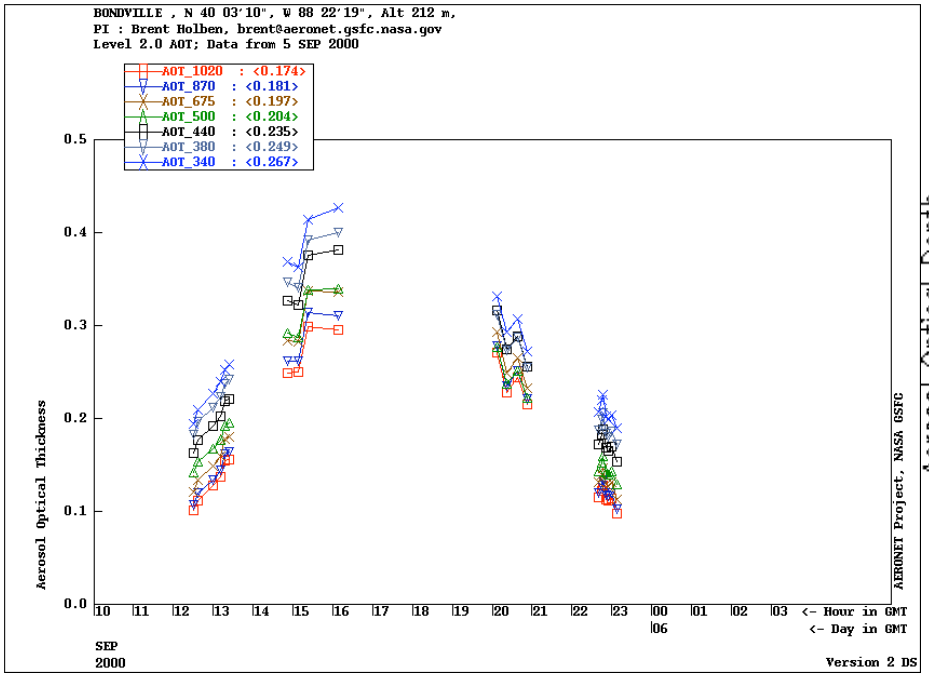
$$\sigma\tau = \sigma V_o / m V_o$$

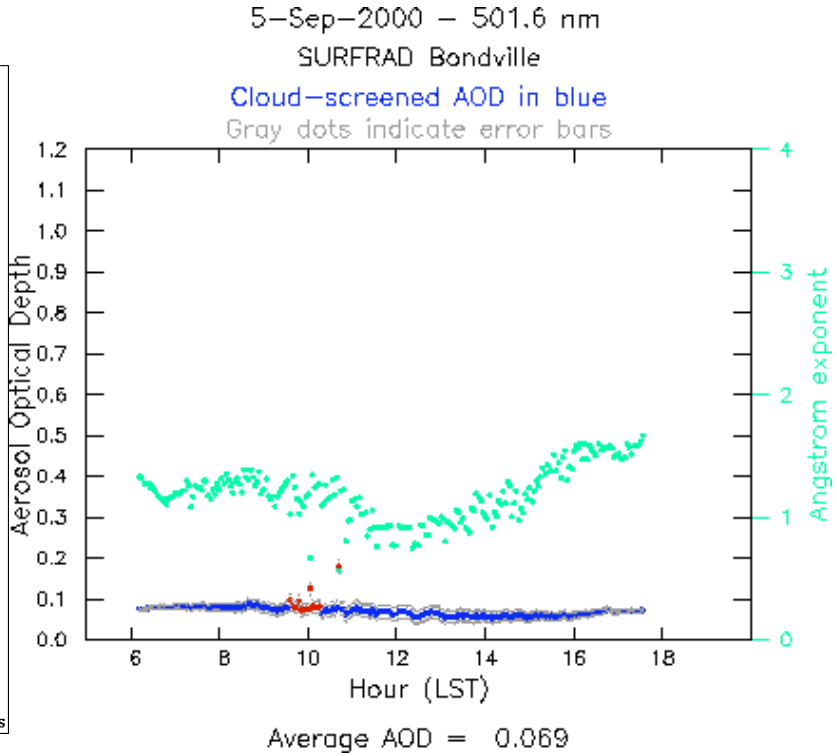
Whole-network time series of monthly mean 500nm AOD



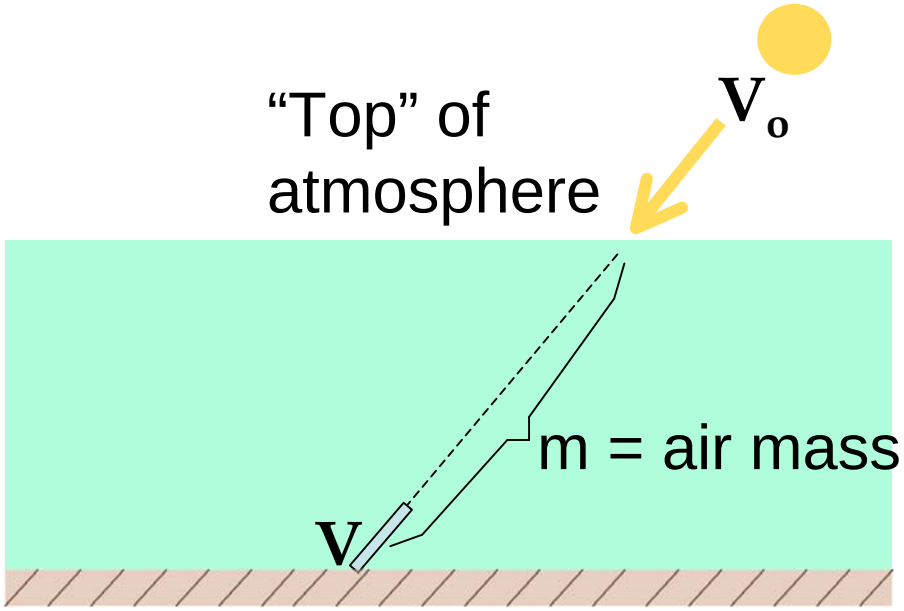

Bondville SURFRAD & AERONET(lev. 2)
Daily Average 500nm AOD
SRF500
Aer500
Daily average Aerosol Optical Depth
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007
Date

Calibration problem



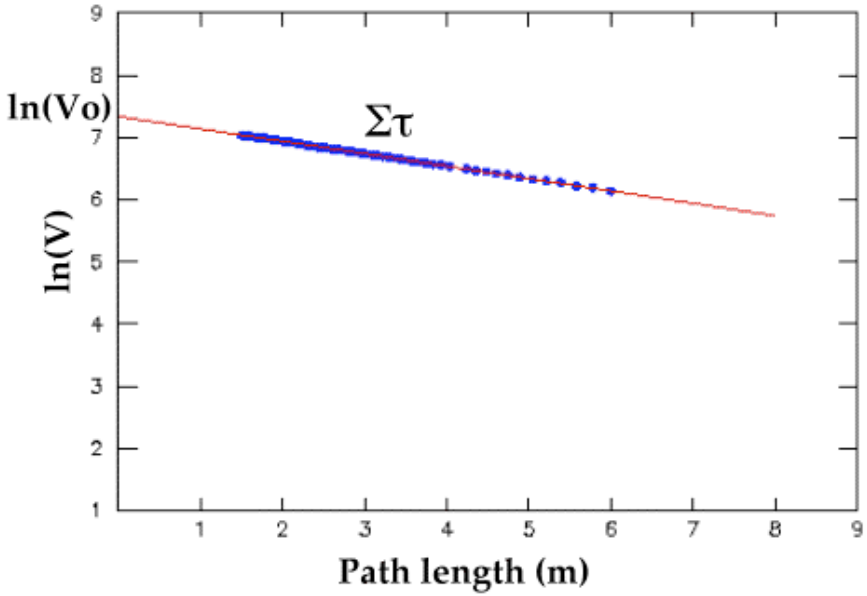


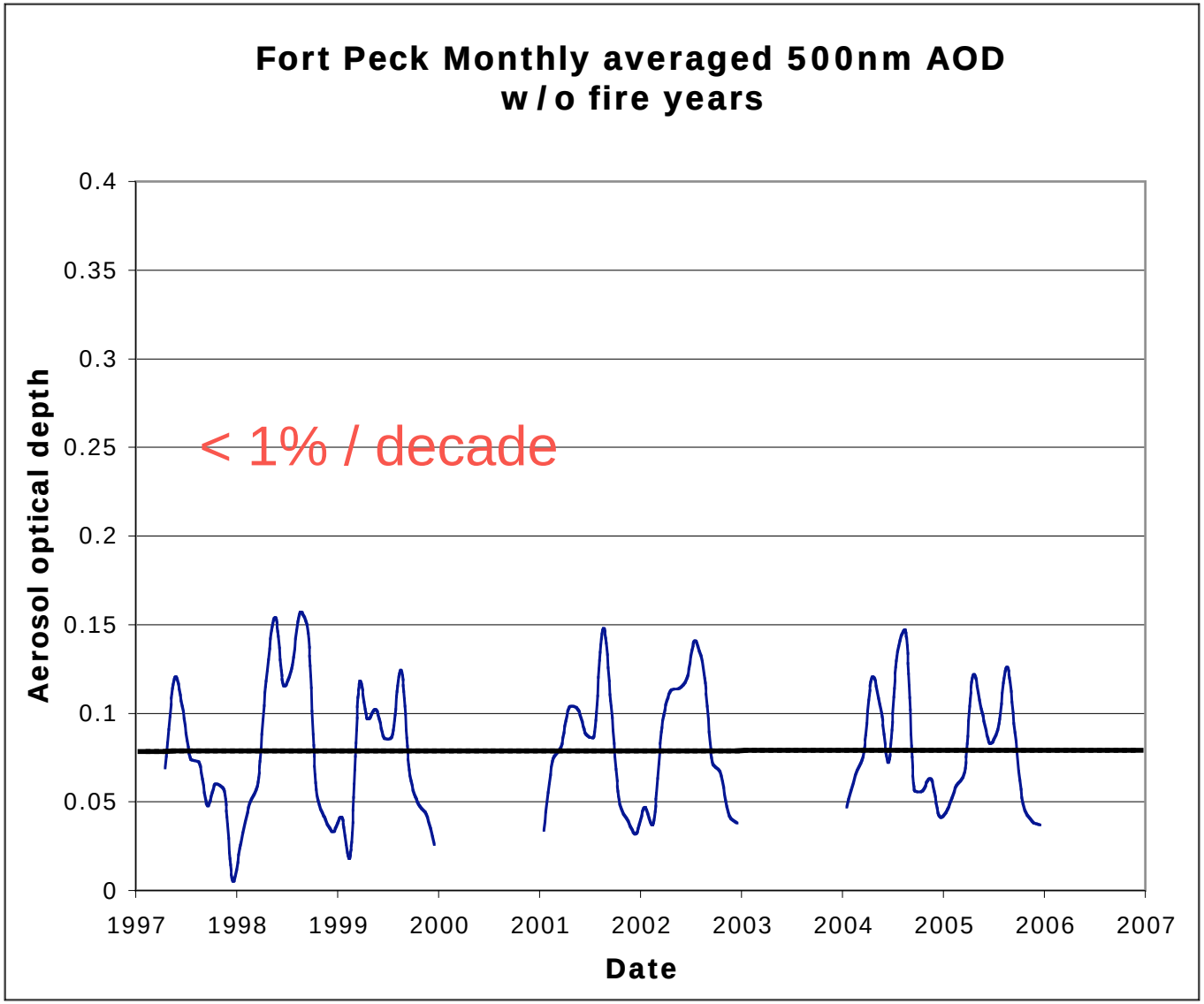
MFRSR calibration



$$V = V_0 e^{-m\sum\tau}$$

$$\ln V = -m\sum\tau + \ln V_0$$




Fort Peck Monthly averaged 500nm AOD
w/o fire years
Aerosol optical depth
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
< 1% / decade
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
Date

ScienceDaily (Sep. 1, 2004) — The area burned by wildfires in 11 Western states could double by the end of the century if summer climate warms by slightly more than a degree and a half, say researchers with the U.S. Department of Agriculture Forest Service and Pacific Northwest Climate Impacts Group at the University of Washington.