Recent Observed Variations in Background Aerosol Optical Depth and Associated Direct Radiative Forcing Estimates

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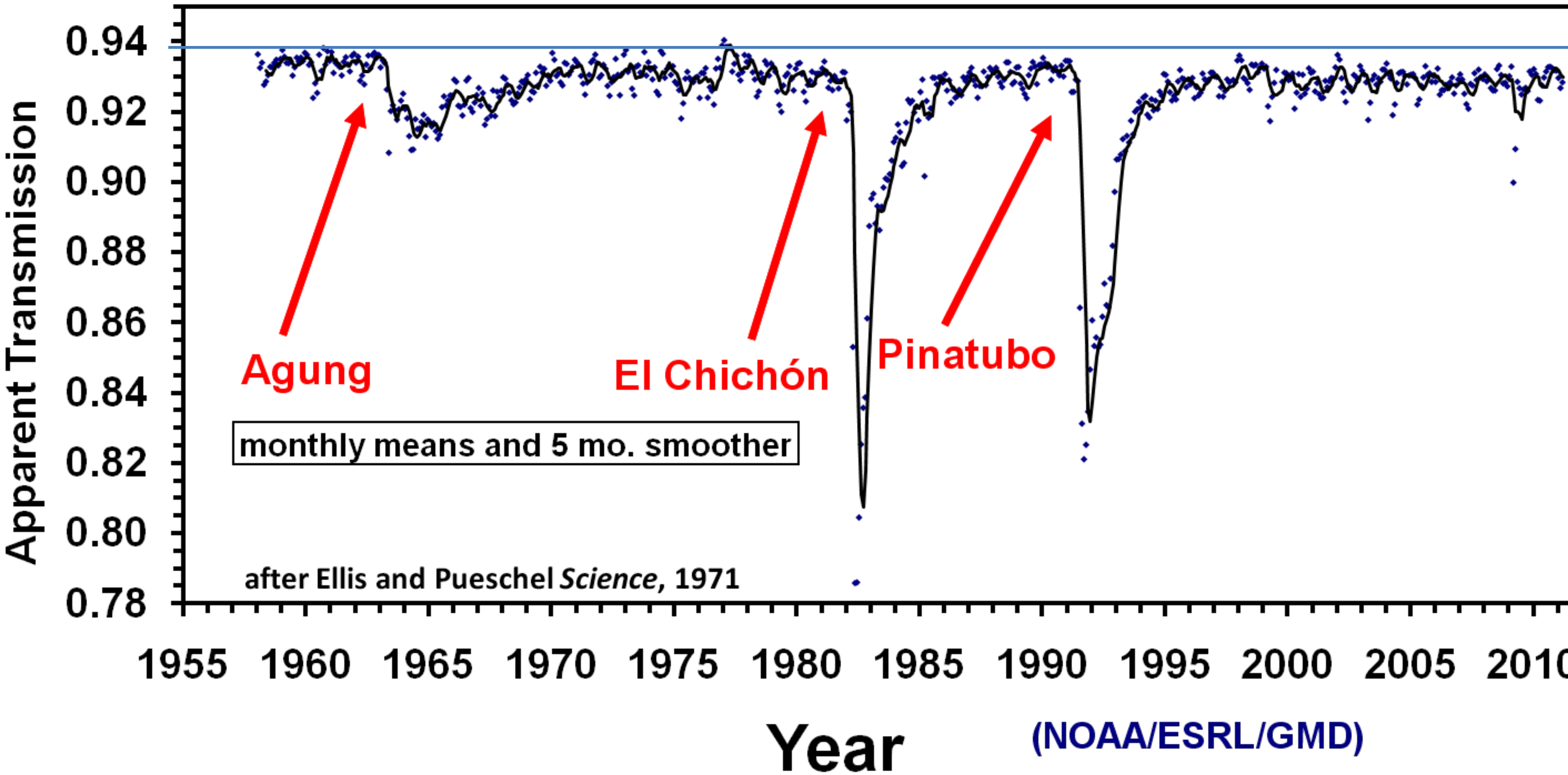
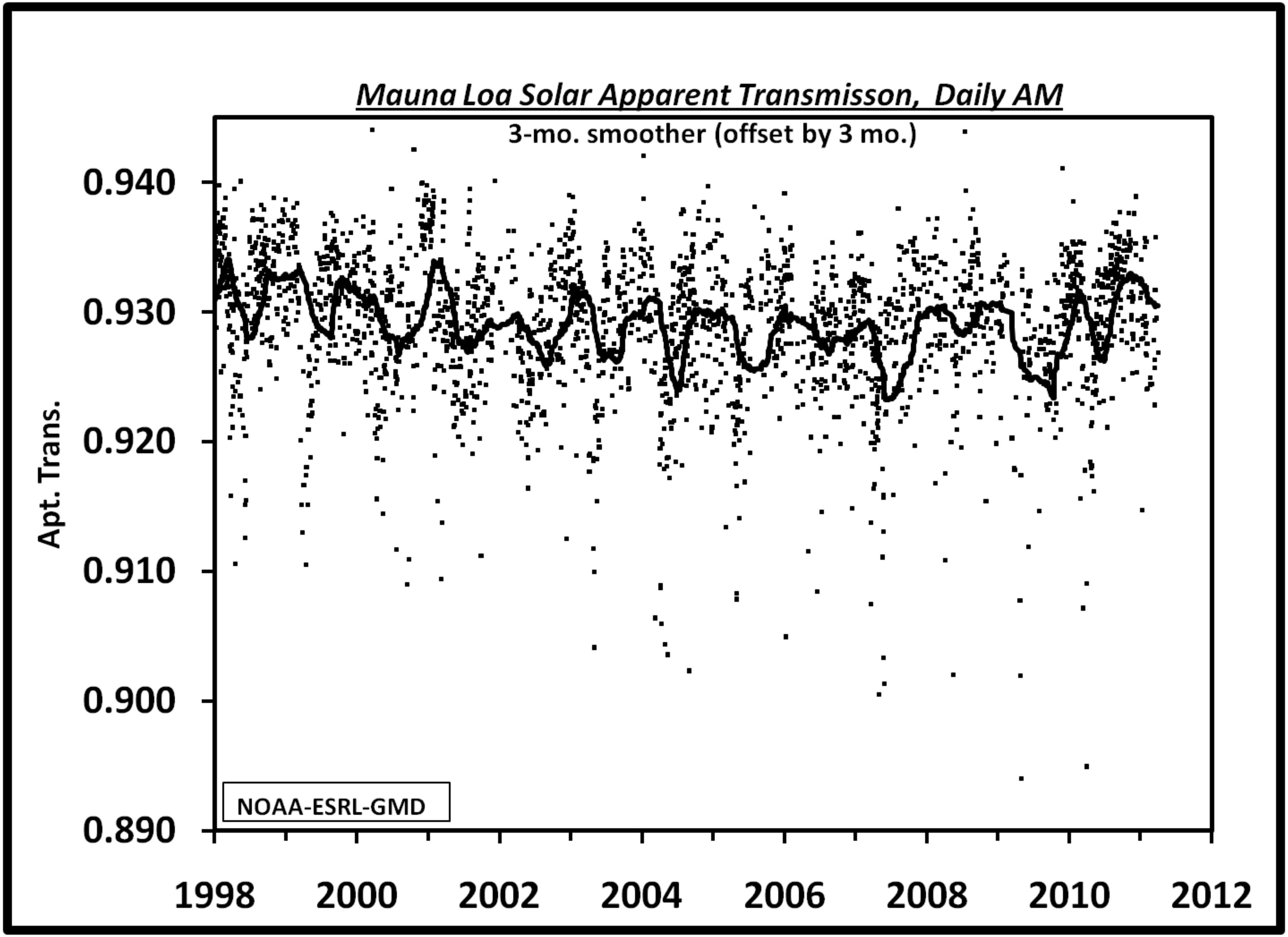
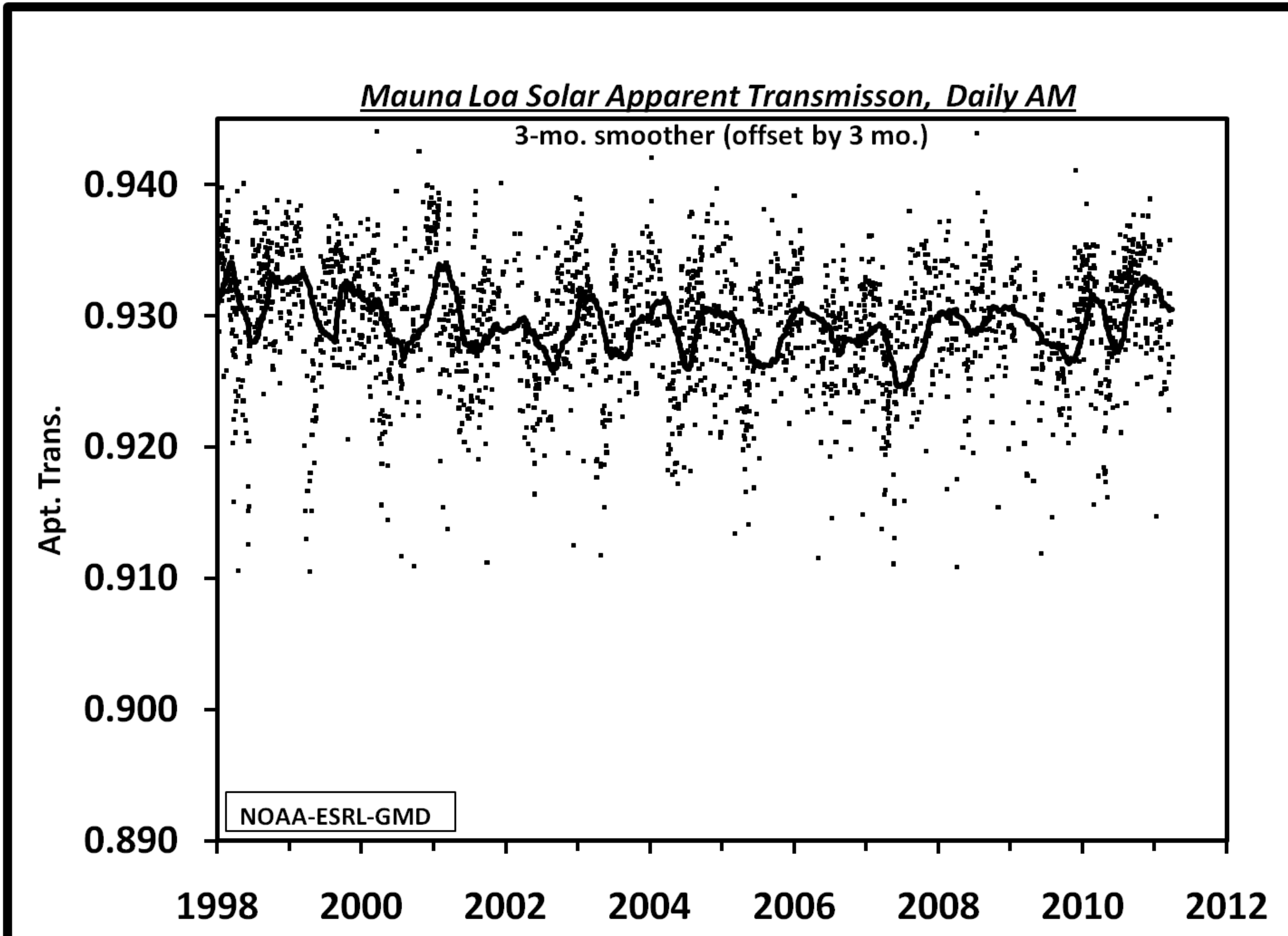
Mauna Loa Clear Sky Solar Transmission and Major Volcanic Eruptions



E.G. Dutton, GMAC 2011
May 17 Boulder, CO



Mauna Loa Solar Apparent Transmisson, Daily AM
3-mo. smoother (offset by 3 mo.)
Apt. Trans.
0.940
0.930
0.920
0.910
0.900
0.890
NOAA-ESRL-GMD
1998
2000
2002
2004
2006
2008
2010
2012



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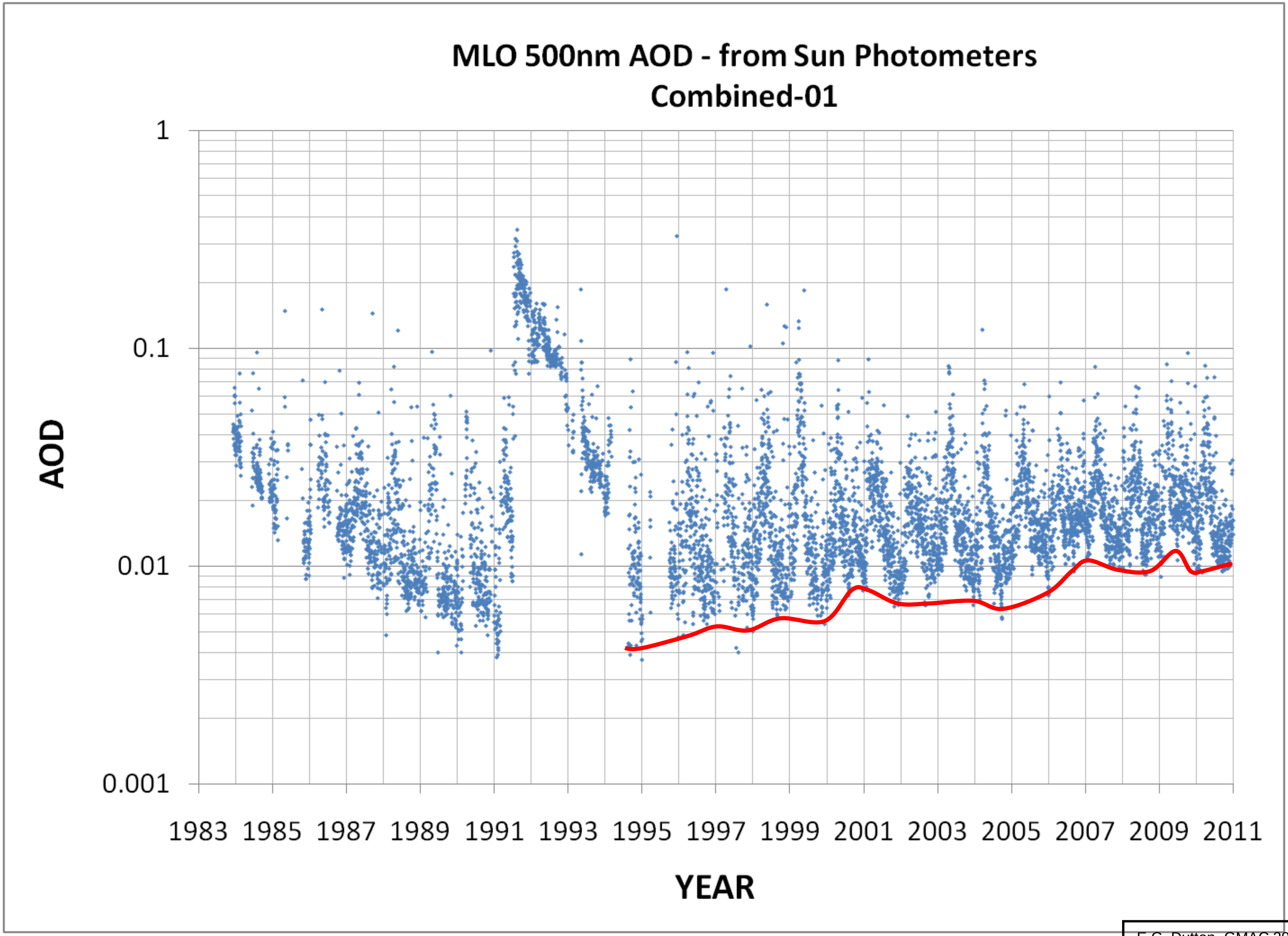

E.G. Dutton, GMAC 2011
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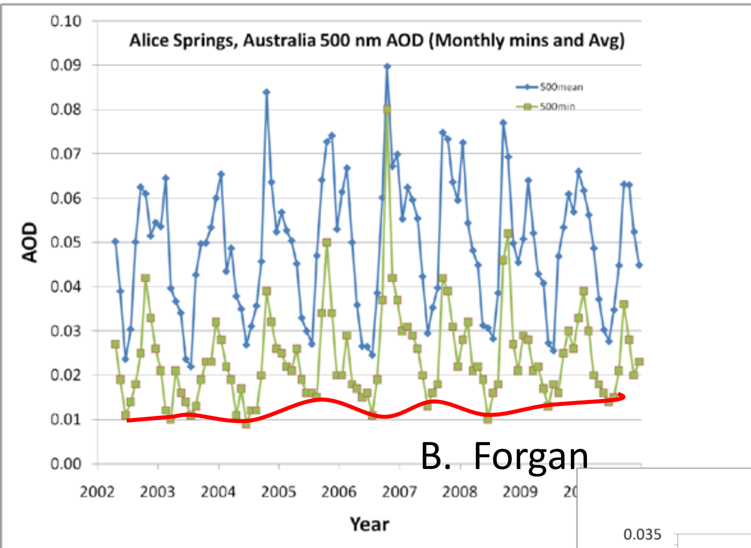
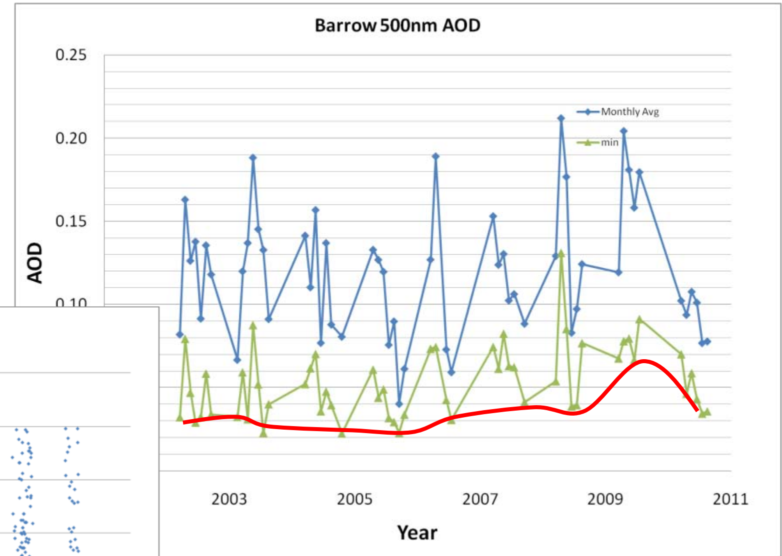
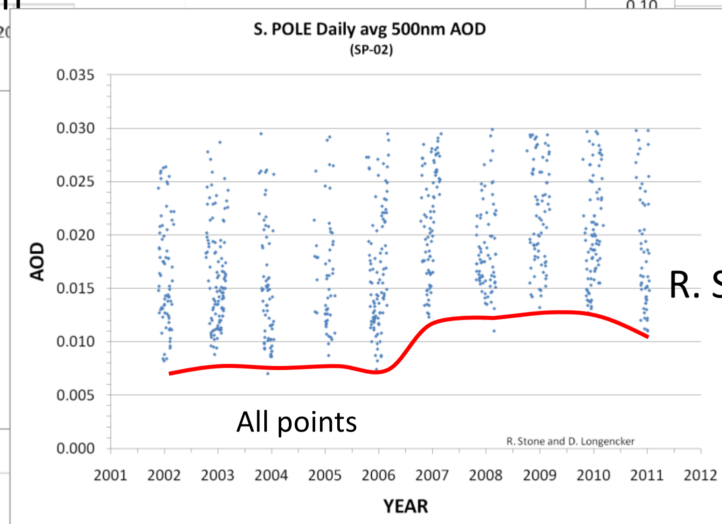
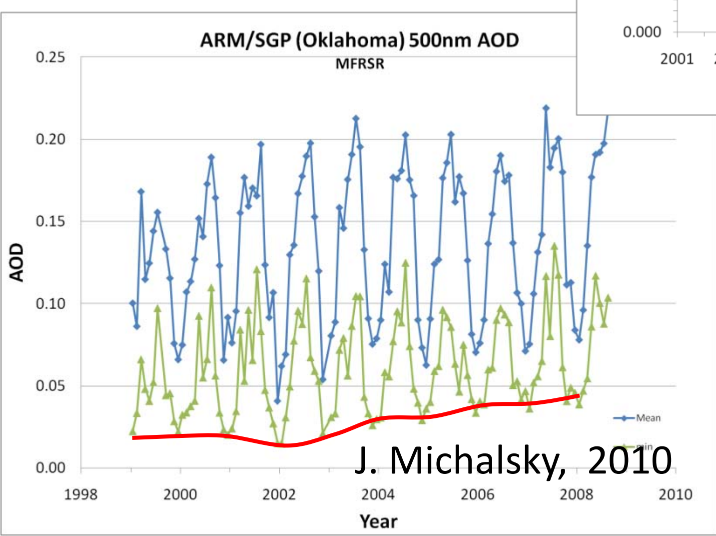
Other independent AOD obs. monthly minimums and averages

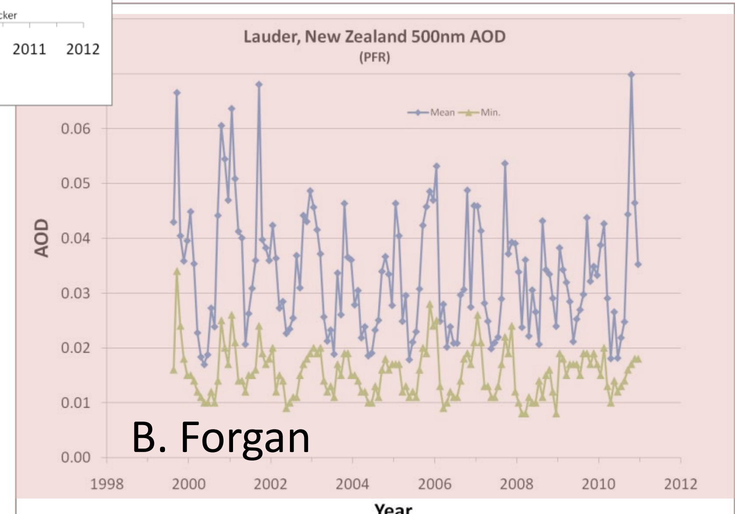






R. Stone & D. Longenecker





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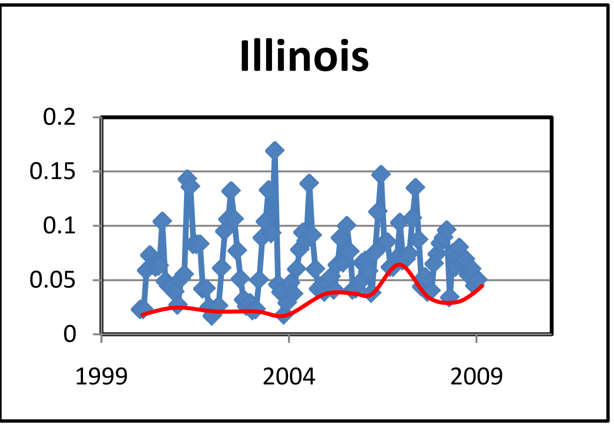
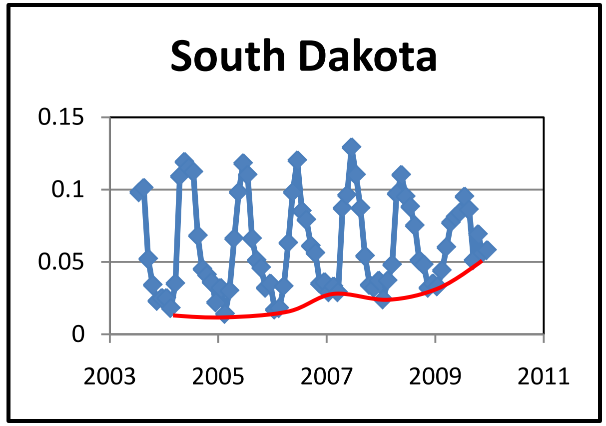
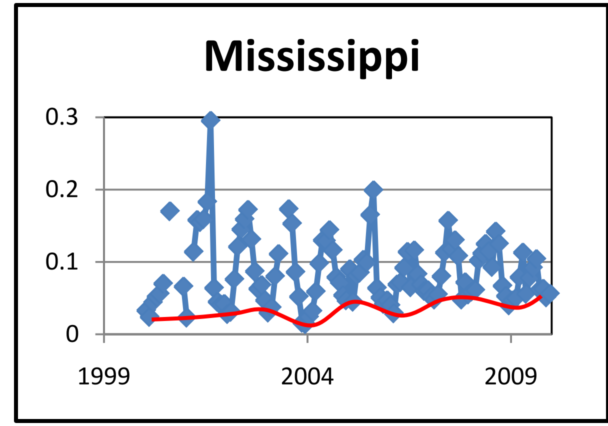
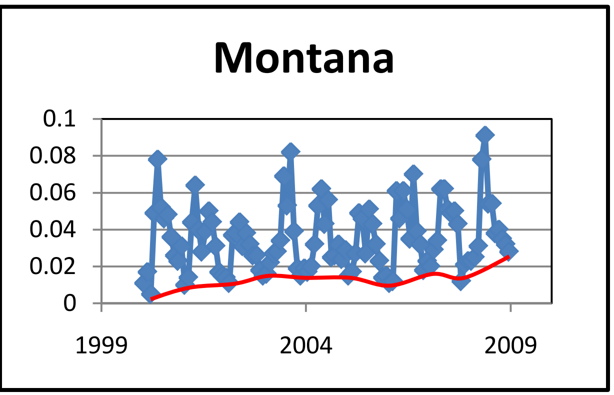
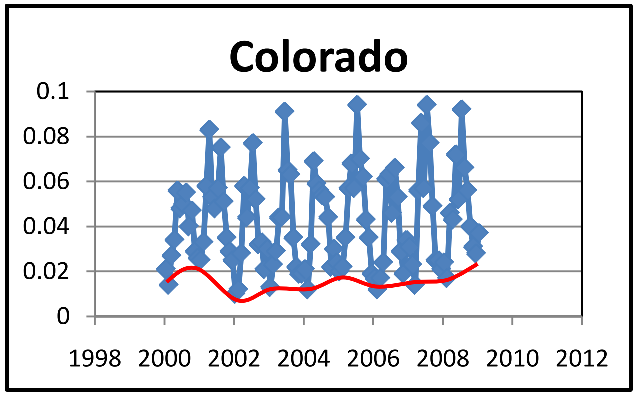
U.S. SURFRAD Network Monthly Minimum 500 nm AOD

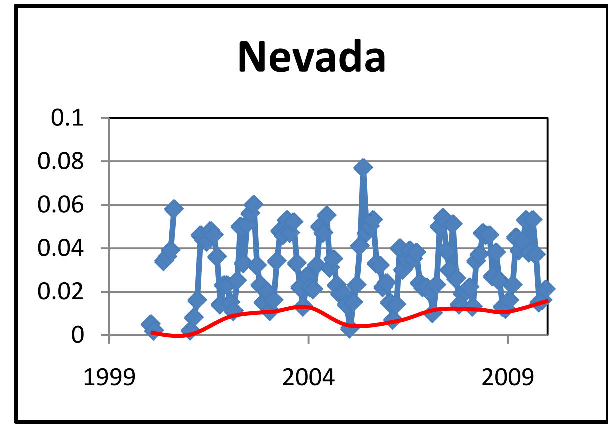


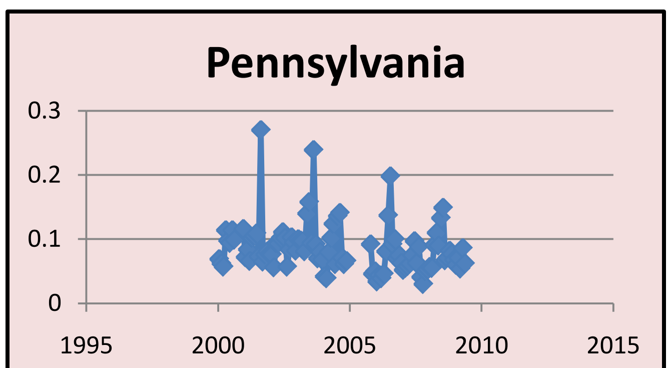








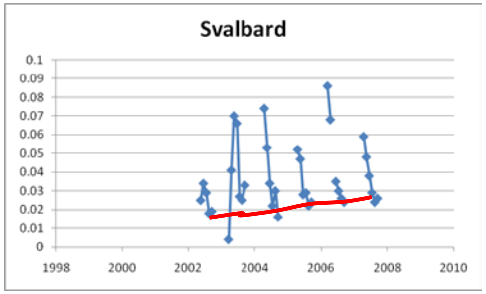


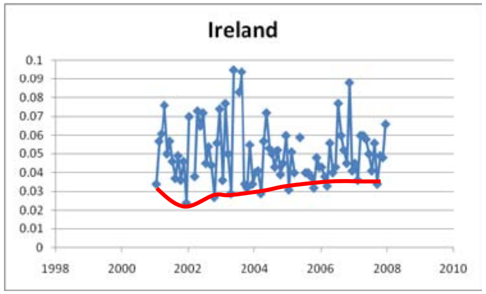


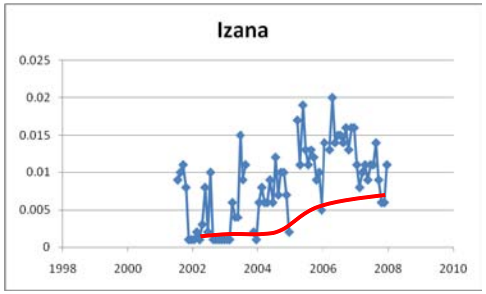
J. Augustine et al., 2008

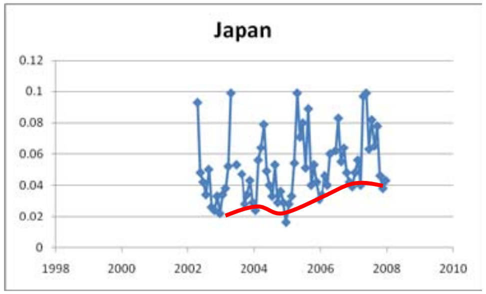
International GAW AOD network - 500nm AOD Monthly Minimums

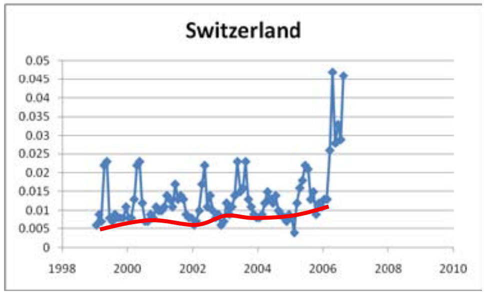
(PFR Sun Photometer)



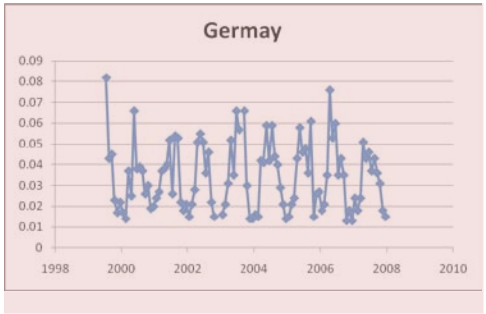


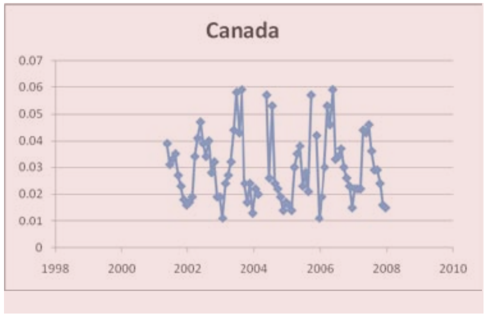


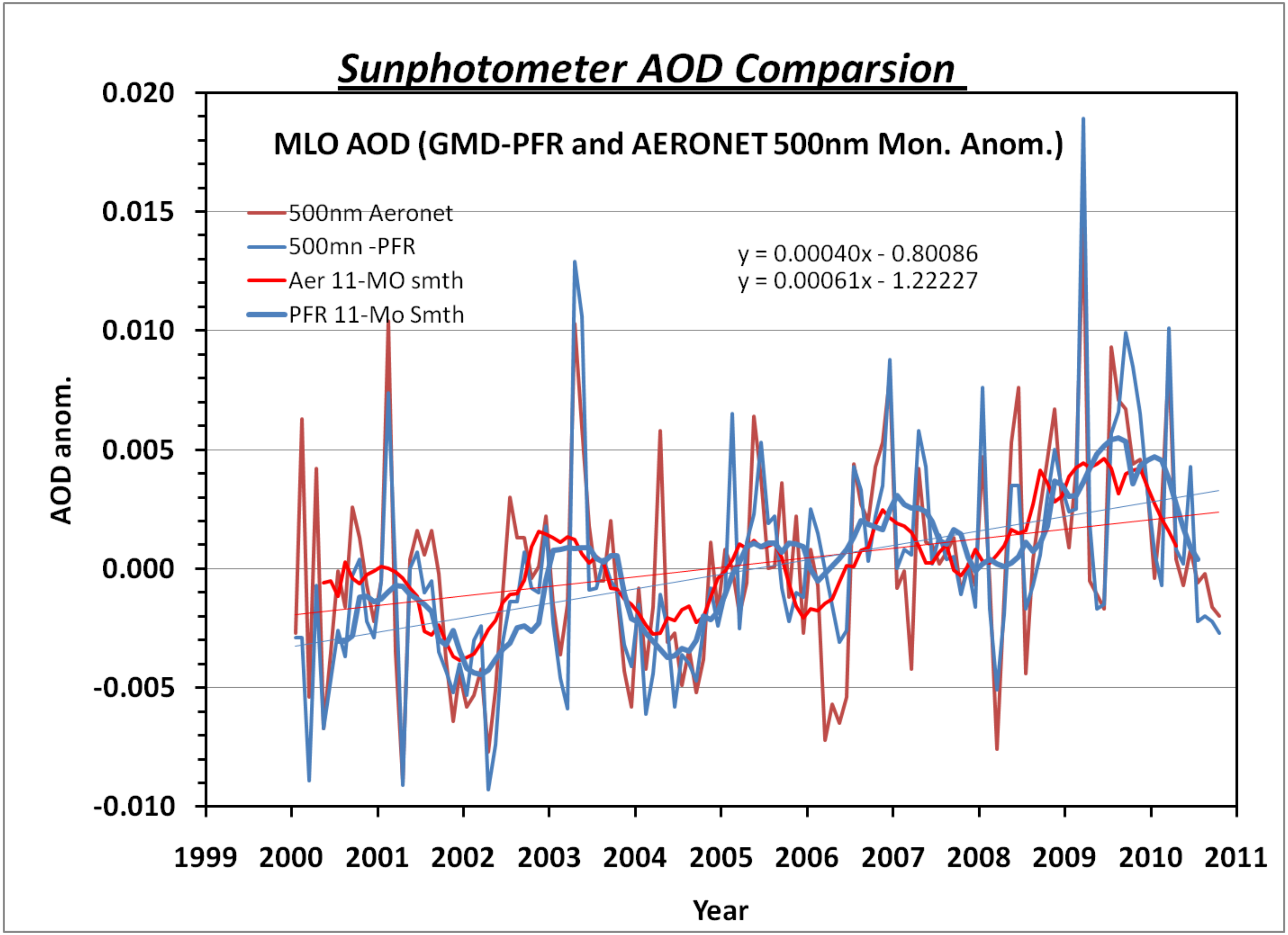




C. Wehrli
GAW/PFR Archive







Sunphotometer AOD Comparsion
MLO AOD (GMD-PFR and AERONET 500nm Mon. Anom.)
500nm Aeronet
500mn -PFR
Aer 11-MO smth
PFR 11-Mo Smth
y = 0.00040x - 0.80086
y = 0.00061x - 1.22227
AOD anom.
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year

Hofmann et al., *GRL* 2009

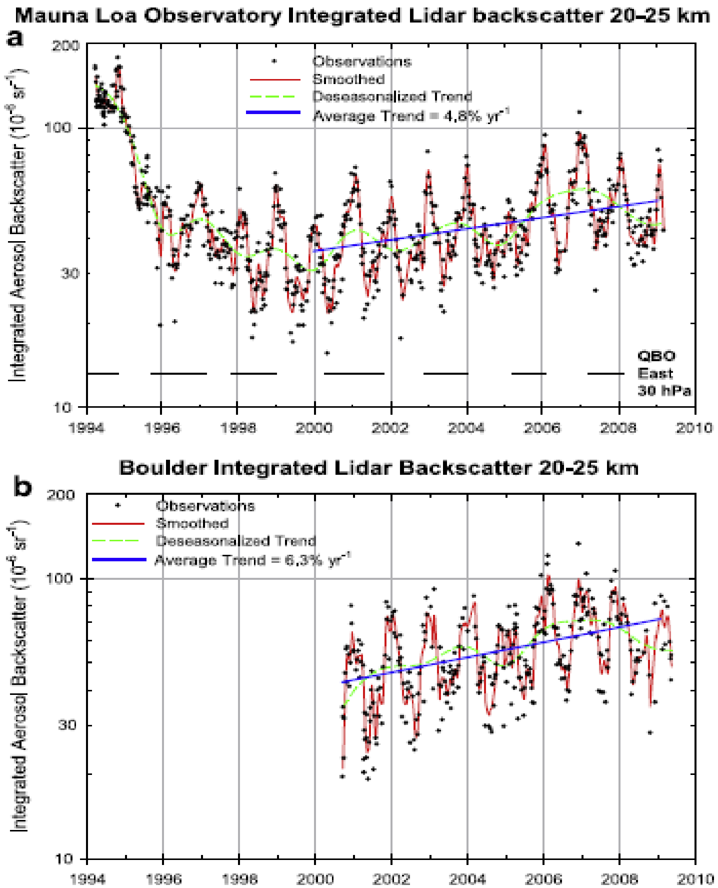
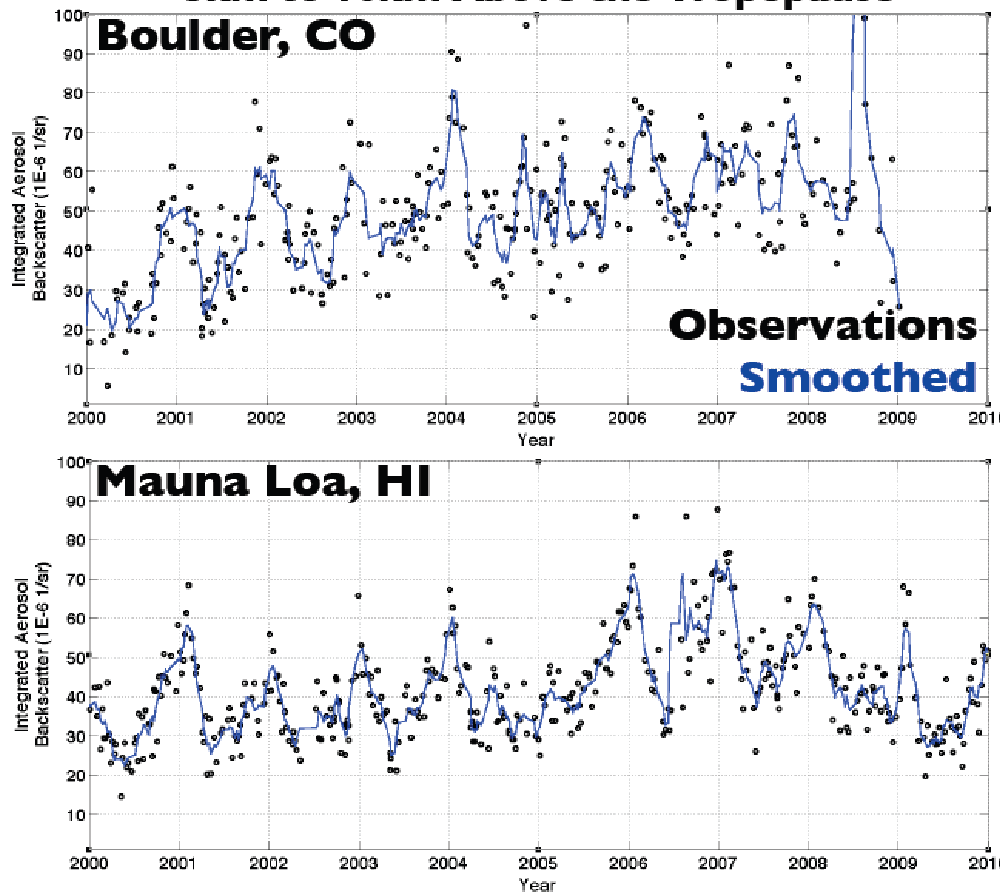


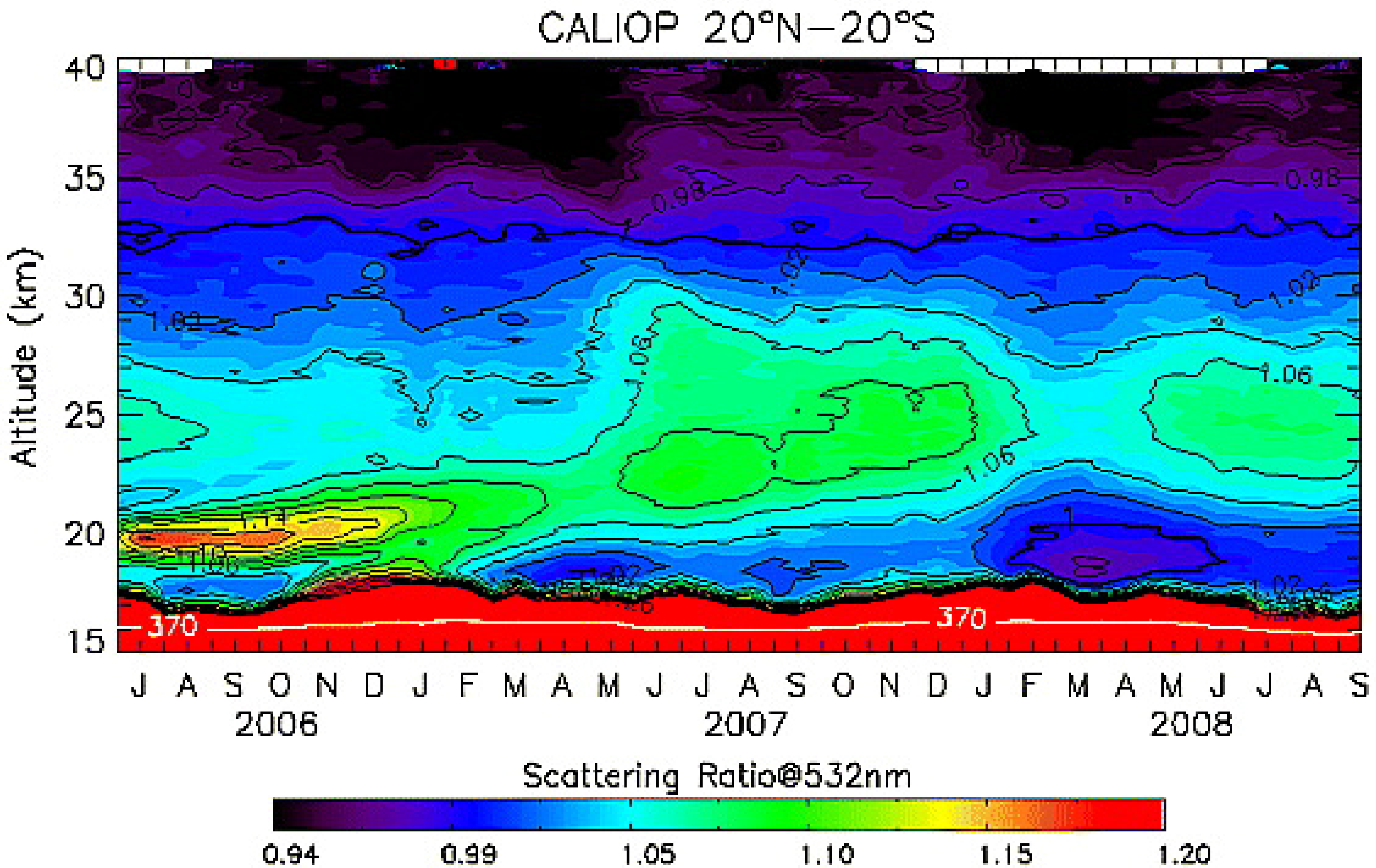
Figure 2. Integrated backscatter for the 20–25 km altitude range at (a) Mauna Loa Observatory and (b) Boulder, Colorado.

Lidar Derived Integrated Aerosol Backscatter from 5km to 10km Above the Tropopause



R. Neely updates

CALIPSO Satellite Lidar Backscatter (NASA)



Vernier et al., JGR 2009

What is the global direct radiative forcing for a change in stratospheric aerosol? An example estimate for the 2000s

Solar forcing (greatly simplified)

- $RF \approx -S_o \cdot (1-\alpha) \cdot (1-\exp(-\Delta\tau)) \cdot (1-g) \cdot (\omega_o)$

  where:

  RF - direct aerosol radiative forcing

  S_o - avg. incident solar irradiance at TOA (340 Wm^{-2})

  α - underlying albedo, mean planetary (0.30)

  $\Delta\tau$ - change in aerosol optical depth (+0.003 to +0.005 at 500nm)

  g - aerosol asymmetry factor (0.7 to 0.85)

  ω_o - single scat. albedo (1- absorption) >~ 0.97 (strat. warm)

- RF = -0.10 to -0.34 Wm^{-2}
- RF efficiency (RFE) = RF / $\Delta\tau$ = -34 to -69 Wm^{-2}/unit τ

Infrared forcing?

E.G. Dutton, GMAC 2011
May 17 Boulder, CO

2000s Aerosol Radiative Forcing Example Calcs. (Con't)

Infrared RF contribution

- Very few observations of optical properties
- Several published calcs. for volcanic: -⅓ to -¼ of solar RF

Net Direct Aerosol Forcing Efficiency (Solar + IR Forcing)

- From example: $-34 \cdot 0.66$ to $-69 \cdot 0.75$ (-23 to -52) W m^{-2}/unit τ
- From detailed Pinatubo calcs. – 25 (*J. Hansen, 2005), 30 (A. Lacis, 2000), 31 (E.G. Dutton, 1995)* W m^{-2}/unit τ
- NetRF estimate for the 2000s BG
  - Use detailed calcs for netRFE = -25 to -31 W m^{-2}/unit τ
  - $RF_{net} = \Delta\tau \cdot netRFE = (0.003 \text{ to } 0.005) \cdot (-25 \text{ to } -31)$
  - RF_{net} range = -0.08 to -0.16 W/m^{-2}
  - How does this compare to CO_2 forcing over same time period ?

Compared to CO_2 radiative forcing over same time period (2000-2009)

- RF_{2xCO_2} = 3.7 W m^{-2}, 270 to 540 ppm (IPCC)
- RFE_{CO2} = 3.7/ln(2) = 5.34 W m^{-2} per $\ln(ppm_2/ppm_1)$
- Delta CO_2 , 369 to 390 ppm (2000 to 2010 MLO)
- $RF_{\Delta CO_2}$ = 5.34 · ln(390/369) = +0.29 Wm^{-2}
- $netRF_{aerosol}$ = -0.08 to -0.16 Wm^{-2}
- Potential global surface air temperature impact
  - Volcanic Aerosol Efficacy = ~0.91 (Hansen 2005)
  - RF'_{aero} = 0.91 • (-0.08 to -0.16) Wm^{-2} dec^{-1}

2000s "observed BG" direct aerosol global temperature forcing could be equal, but opposite in sign, to 1/4 to 1/2 that of CO_2 for the same time period.

Summary/Conclusions

- Widely observed baseline total column AOD (strat. supported by lidar and satellite) is seen to increase during the 2000s, not necessarily monotonically.
- Observed aerosol change, if global, appears sufficient to potentially negate 1/4 to 1/2 of the CO_2 warming over the same time period, which may have happened (also, strat. not cooling as much)
- To refine, better information is needed on the spatial/temporal distribution of the aerosol optical properties, specifically τ, g, and ω_o in that order, and then the use of a climate model to incorporate the combined forcing.