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

(monthly means and 5 mo. smoother)

after Ellis and Pueschel Science, 1971

(NOAA/ESRL/GMD)
Other independent AOD obs. monthly minimums and averages

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May 17 Boulder, CO
U.S. SURFRAD Network Monthly Minimum 500 nm AOD

Illinois

South Dakota

Mississippi

Montana

Colorado

Nevada

Pennsylvania

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

\[ y = 0.00040x - 0.80086 \]
\[ y = 0.00061x - 1.22227 \]
Figure 2. Integrated backscatter for the 20–25 km altitude range at (a) Mauna Loa Observatory and (b) Boulder, Colorado.
CALIPSO Satellite Lidar Backscatter (NASA)

Scattering Ratio@532nm

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)

- \( \text{RF} \approx -S_o \cdot (1-\alpha) \cdot (1 - \exp(-\Delta \tau)) \cdot (1 - g) \cdot (\omega_o) \)

where:
- \( \text{RF} \) - direct aerosol radiative forcing
- \( S_o \) - avg. incident solar irradiance at TOA (340 Wm\(^{-2}\))
- \( \alpha \) - 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)
- \( \omega_o \) - single scat. albedo (1- absorption) >~ 0.97 (strat. warm)

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

Infrared forcing?

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

Infrared RF contribution

• Very few observations of optical properties
• Several published calcs. for volcanic: -1/3 to -1/4 of solar RF

Net Direct Aerosol Forcing Efficiency (Solar + IR Forcing)

• From example: -34 · 0.66 to -69 · 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
  – \( RF_{\text{net}} = \Delta \tau \cdot \text{netRFE} = (0.003 \text{ to } 0.005) \cdot (-25 \text{ to } -31) \)
  – \( RF_{\text{net}} \) range = -0.08 to -0.16 W/m⁻²
  – How does this compare to CO₂ forcing over same time period?
Compared to $\text{CO}_2$ radiative forcing over same time period (2000-2009)

- $\text{RF}_{2\text{xCO}_2} = 3.7 \text{ W m}^{-2}$, 270 to 540 ppm (IPCC)
- $\text{RF}_{\text{ECO}_2} = \frac{3.7}{\ln(2)} = \frac{5.34}{\text{W m}^{-2}}$ per $\ln(\text{ppm}_2/\text{ppm}_1)$
- Delta CO$_2$, 369 to 390 ppm (2000 to 2010 MLO)
- $\text{RF}_{\Delta \text{CO}_2} = 5.34 \cdot \ln(390/369) = +0.29 \text{ Wm}^{-2}$
- $\text{netRF}_{\text{aerosol}} = -0.08 \text{ to } -0.16 \text{ Wm}^{-2}$
- Potential global surface air temperature impact
  - Volcanic Aerosol Efficacy = $\sim0.91$ (Hansen 2005)
  - $\text{RF}'_{\text{aero}} = 0.91 \cdot (-0.08 \text{ to } -0.16 \text{ ) Wm}^{-2} \text{ dec}^{-1}$

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.

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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 $\tau$, $g$, and $\omega_0$ in that order, and then the use of a climate model to incorporate the combined forcing.