Volcanic Aerosol Climate Forcing, 1979-2015
Global values derived from Lunar Eclipse observations

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Summary Abstract
In 2004, Hofmann et al. summarized five decades of stratospheric aerosol observations, "Surface-Based Observations of Volcanic Emissions to the Stratosphere," in Volcanism and the Earth's Atmosphere, AGU Monograph 139. Among the records were lunar eclipse aerosol optical depth (AOD) determinations, updated here to April, 2015.

About once per year, on average, the moon is totally eclipsed; the moon is then illuminated by sunlight refracted into the umbra, primarily by the stratosphere. Stratospheric aerosols can affect the brightness of the eclipsed moon, and AOD can be determined from the difference between observed and predicted brightness.

AOD data from 1979 to 2015 show that the eruptions of el Chichon (1982) and Pinatubo (1991) reduced the solar heating by 2 W/m² and 3 W/m², respectively. Since 1996, stratospheric AOD have been near zero; this is the longest period with a clear stratosphere since before 1960.

Between 1979-1995 and 1996-2014, mean AOD decreased from 0.035 to 0.002, corresponding to a net increase in climate forcing of +0.7 W/m² (e.g. Hansen et al., 2002). This is slightly greater than the +0.6 W/m² increase due to total long-lived greenhouse gases over the same period (ESRL, 2014). Computed radiative equilibrium temperature changes between the same intervals are +0.13°C due to decreasing AOD and +0.11°C due to increasing GHG, accounting for most of the observed +0.27°C warming of MSU global temperatures. After subtracting AOD and GHG effects from annual MSU temperatures, over half of the residual variance can be attributed to el Niño/la Niña (Multivariate ENSO Index).

Implications for Climate
Comparison of Volcano, Solar TSI, and Greenhouse gas forcing, converted to ∆T[Radiative Equilibrium] ...

Comparison of 3 forcings, and their sum. Total greenhouse gas forcing scale range: 0.5 Watts/m² to 1.6°C

All 3: Volcanoes + GHG + Solar

... with global satellite MSU temperatures

Subtract the radiatively forced ∆T (above) from the observed temperatures...

Leaving essentially el Niño. 57 percent of the residual variance (left) can be attributed to the Multivariate ENSO Index (MEI)

A reconstruction of annual temperatures, using only Volcanic and GHG forcing plus el Niño effect = 0.135*MEI, correlates with MSU global temperatures, r = 0.93

Implications for future global climate change


Volcanic Aerosol Optical Thickness Global Values derived from Lunar Eclipse Observations, 1979-2014

Plate 8. Summary of long-term stratospheric aerosol records...

Observations minus Calculated
After calculating the brightness of an eclipse for a clear, volcanic aerosol free atmosphere, go out and observe the eclipse. The brightness of the eclipse, in stellar magnitudes, can be observed with eye or photometer. Or, find observations in the literature.

The difference, Observed minus Calculated, is caused mostly to volcanic aerosols, and can be converted into an aerosol optical thickness.

Due to the grazing path length along the limb of the Earth, the dimming of the moon is roughly 40x the aerosol optical depth.