

# Volcanic Aerosol Forcing of the Global Climate Derived from Lunar Eclipse Observations, 1979-2014

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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*, Geophysical Monograph 139, American Geophysical Union. Among the records were lunar eclipse aerosol optical depth (AOD) determinations, which were updated at the 2013 GMAC [http://www.esrl.noaa.gov/gmd/publications/annual\\_meetings/2013/slides/69-130415-A.pdf](http://www.esrl.noaa.gov/gmd/publications/annual_meetings/2013/slides/69-130415-A.pdf) and are updated again here.

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 2014 show that the eruptions of el Chichón in 1982 and Pinatubo in 1991 reduced the solar heating by  $2 \text{ W/m}^2$  and  $3 \text{ W/m}^2$ , 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  $+0.7 \text{ W/m}^2$  (e.g. Hansen et al., 2002). This is slightly greater than the  $+0.6 \text{ W/m}^2$  increase due to total long-lived greenhouse gases (GHG) over the same period (ESRL, 2014). Computed radiative equilibrium temperature changes between the same intervals are  $+0.13\text{C}$  due to decreasing AOD and  $+0.11\text{C}$  due to increasing GHG, accounting for most of the observed  $+0.27\text{C}$  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).

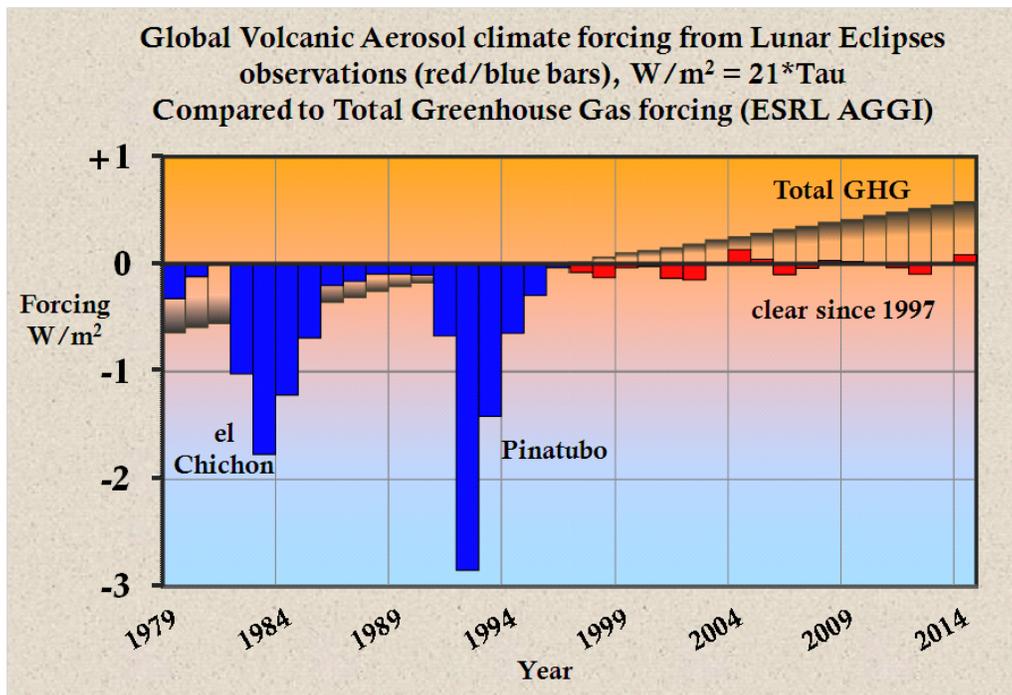


Figure 1. Global Volcanic Aerosol climate forcing from Lunar Eclipse observations, 1979-2014