The Calbuco Chronicle: Volcanic aerosols in the post-Pinatubo stratosphere

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Summary Abstract

The brightness of the moon during a total lunar eclipse depends on, among other things, the presence of volcanic aerosols in the stratosphere. Following the eruptions of Agung, Chichon, and Pinatubo in 1963, 1982, and 1991, the effect was striking, and allowed accurate determination of globally averaged aerosol optical depths (AOD) from each volcano. The most recent lunar eclipse, on 28 September 2015, was seen by many observers to be about 33 percent dimmer than predicted (for an aerosol free stratosphere). While initially this slight dimming was thought to be within the range of observational error, sightings of "volcanic twilights" around the time of the eclipse suggested that the dimming was volcanic in origin.

The source of the aerosols was traced to the eruption of Calbuco in Chile five months earlier. The global AOD derived from the eclipse observations, 0.010, is close to the value by Steve Albers (NOAA) derived from twilight observations. The detection of Calbuco in the eclipse record suggests that other events with small AOD in the 0.010 range could be found (keeping in mind the likely uncertainties could be half this value). Six such events are tentatively identified in the post-Pinatubo era. It should be noted that because of the timing of lunar eclipses - with occasional gaps of two years - other similar AOD events may have "slipped through the cracks" and were not detected.

Background: What is a Lunar eclipse

About once per year, a Lunar Eclipse occurs when Earth passes through the Earth's shadow. At that time, the Earth partially or completely blocks the Sun's direct light, causing a shadow to fall on the Moon. Although the Earth is much closer than the Moon to the Sun, its shadow is much larger than the Moon is, so it mostly covers the Moon, blocking its light. This is why the Moon turns red or orange during a Lunar Eclipse.

How volcanoes affect eclipses

Volcanic eruptions can produce large amounts of volcanic ash and gases that can be injected into the stratosphere. These particles can reflect sunlight, causing the Moon to appear dimmer during a Lunar Eclipse.

Calculating the amount of volcanic aerosol

Observed minus Calculated

First, calculate the heading and attenuation of sunlight passing through the stratosphere to predict the amount of light reaching various parts of the world. Then, calculate the total amount of volcanic aerosol in the stratosphere by subtracting the observed value from the calculated value. This gives the amount of volcanic aerosol in the stratosphere.

Aerosols from other volcanoes since Pinatubo

The 33 percent dimming of the September 2015 eclipse computes to a globally averaged AOD of 0.010, +/- 0.005. Identification of the enhanced AOD with Calbuco suggests that other AOD events since 1995 may be identified with similarly sized eruptions (Volcanic Explosivity Index VEI = 4 or 5).

The culprit: Volcano Calbuco In Chile

Thanks to tips from Steve Albers (NOAA) and Helio Vital (Brazil), who noted the VEI=4 eruption in April 2015 and observed volcanic twilights afterwards, suggesting the presence of a stratospheric aerosol layer.

Implications for climate: the “Pause” since 1998

Since 1998 there has been little or no warming of the surface and lower troposphere of the Earth’s atmosphere. It has been suggested that this lack of warming could be due to increasing background stratospheric aerosols, or several “small” volcanic aerosol events. However, over the past 20 years, stratospheric AOD has declined by an insignificant trend of 0.002, removing stratospheric aerosols as a contender for the cause of the pause.