Continuing results of the Lunar Aerosol Climate Experiment LUNACE
1. Eclipses
2. Volcanoes
3. Climate
About once per year on average, a Lunar Eclipse occurs when the Moon passes through the Earth’s shadow. At these times we can measure the effect of volcanoes on Earth’s climate.
During a lunar eclipse, Sun light (coming from the right) is refracted by the atmosphere (like a lens) into the Earth’s umbra and onto the Moon.

From J. Kepler, “Astronomiae pars Optica” (1604)

According to Kepler, sunlight is reddened & dimmed as it passes through “mists and smoke” in the Earth’s atmosphere (stratosphere, mostly), causing the eclipsed moon to appear orange, red, or darker.
Dirt on the lens…
Volcanic aerosol layer in the stratosphere following the eruption of Pinatubo in 1991
Comparison of two eclipses
1884 (after Krakatau, left), 1888 (right)
Chromolithographs from Sirius

Vergleichende Darstellung der Mondfinsternisse vom

1. Eclipses
2. Volcanoes
3. Climate
The Keens in front of the steaming summit of Anak Krakatau,
1883 + 133 years
“Goal worth pursuing” (Dave Hofmann): fill in the blanks

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

From: Hofmann et al., 2004: “Surface-Based Observations of Volcanic Emissions to the Stratosphere”, in Volcanism and the Earth’s Atmosphere, Geophysical Monograph 139, American Geophysical Union
The Results ....

Volcanic Aerosol Optical Thicknesses 1800-2015
Global Values, derived from Lunar Eclipse Observations
Dr. Richard A. Keen

Photo: Kliuchevskoy volcano from STS-68, Oct. 1, 1994
1. Eclipses
2. Volcanoes
3. Climate
John Augustine, 30 minutes ago

Post-Pinatubo VOLCANIC AEROSOL OPTICAL DEPTHS
Global Values, derived from Lunar Eclipse Observations
Likely VEI = 4 or 5 eruptions noted

AOD

y = -0.000011x + 0.22451
R² = 0.01405

Dr. Richard Keen, 2016
Some climatic conclusions:

- There was more volcanic effect on the climate during 1913-1962, and less from 1816-1882, than previously estimated. Cosegüina in 1835 was a dud.

- Since 1979, Volcanic forcing is responsible for half of the observed warming (global MSU Satellite temperatures).

- There has been no increase of volcanic forcing since 1996, ruling out volcanoes out as a Cause of the Pause.
Thanks to ...
Thanks from the entire LUNACE team (that’s me) to eclipse observers in all 7 continents ...

Antarctica  Jordan  South Africa
Australia    Mexico   Spain
Brazil      Namibia  Sweden
Canada      Netherlands  Tanzania
Cyprus     New Zealand  United Kingdom
Czech Republic  Norway  United States
Germany    Portugal  United Arab Emirates
India    Russia  Venezuela
Iran    Saudi Arabia
Italy    Slovakia
Japan    Slovenia

... for their excellent eclipse observations over the past 30+ years and for observations of future eclipses.
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RETIRED FACULTY ASSOCIATION

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