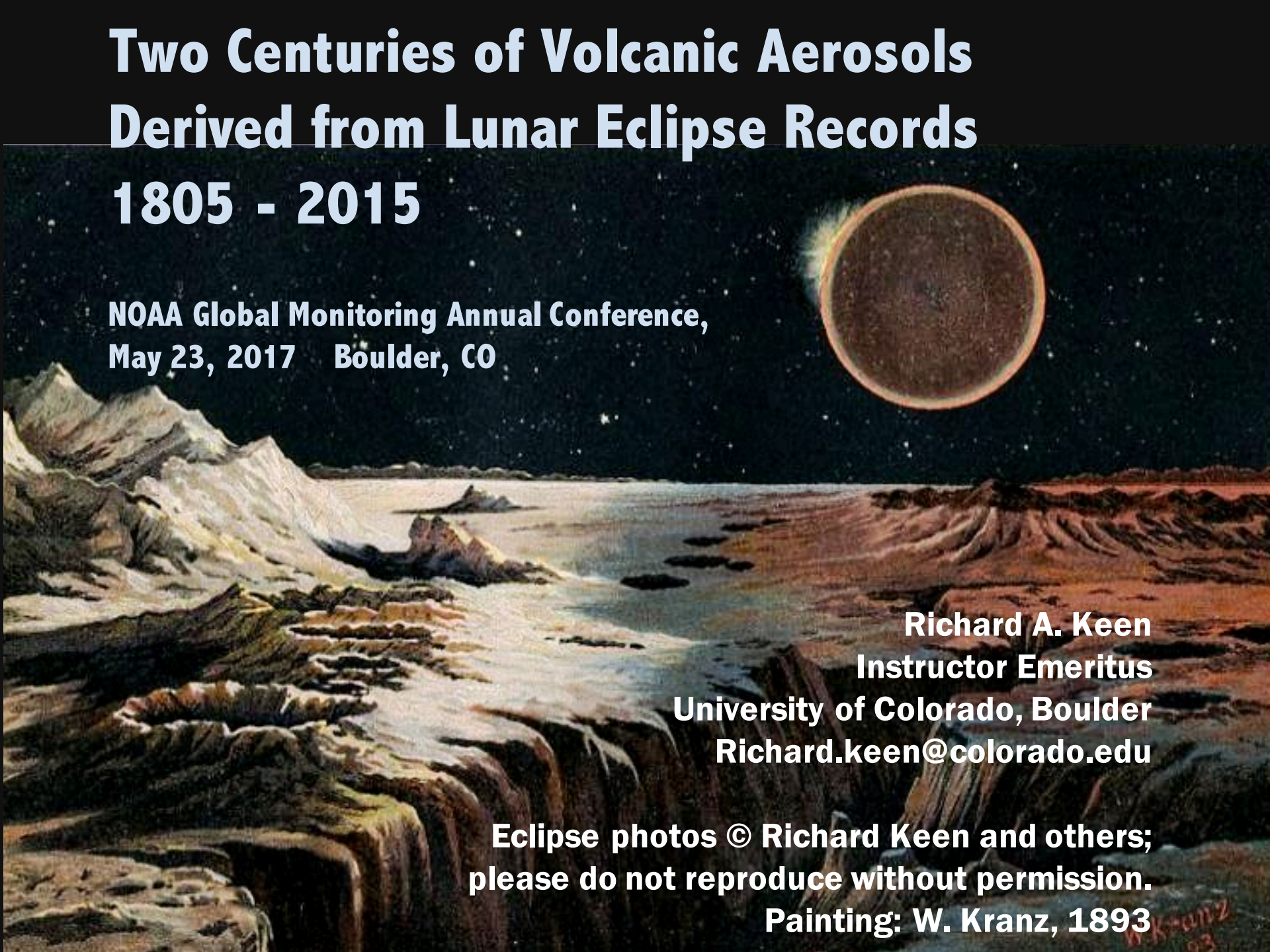


Two Centuries of Volcanic Aerosols Derived from Lunar Eclipse Records 1805 - 2015

**NOAA Global Monitoring Annual Conference,
May 23, 2017 Boulder, CO**

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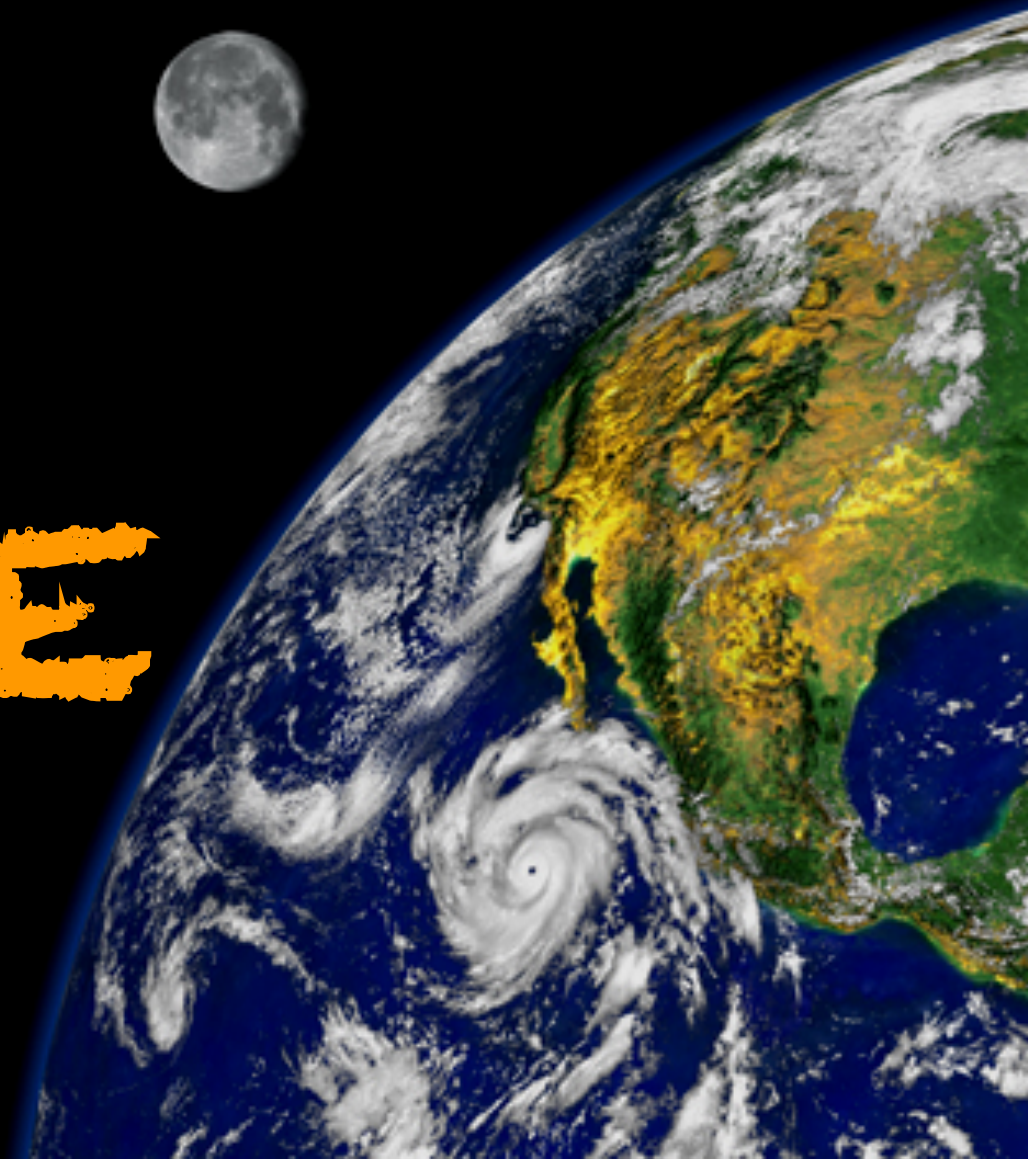
**Eclipse photos © Richard Keen and others;
please do not reproduce without permission.
Painting: W. Kranz, 1893**



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.**

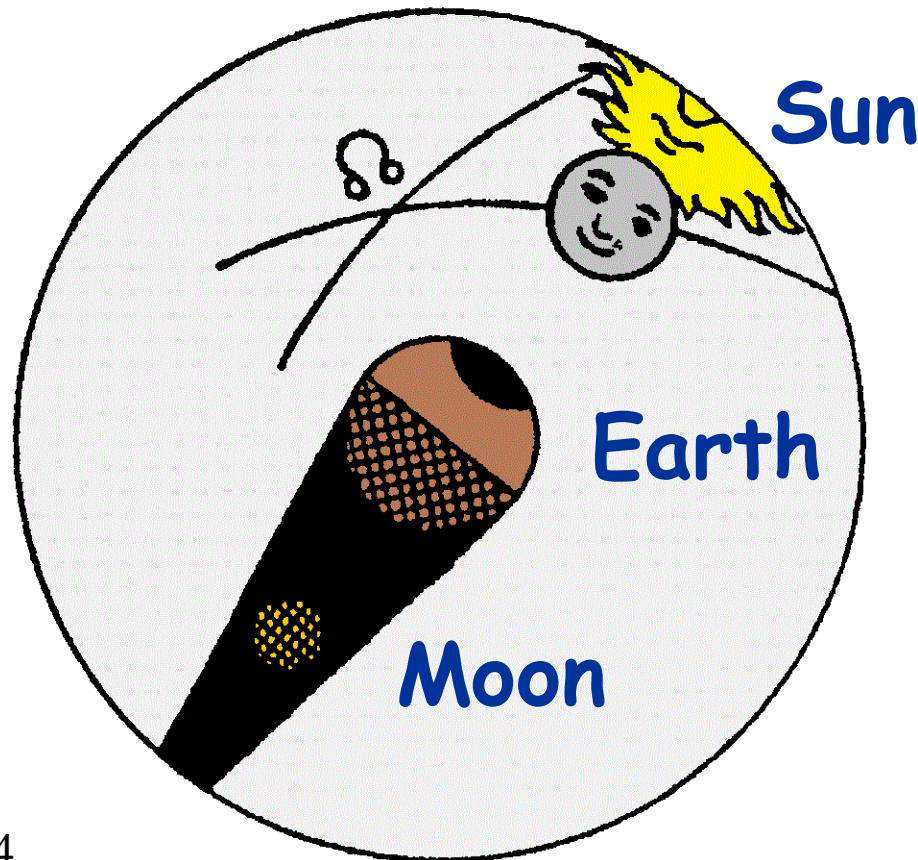
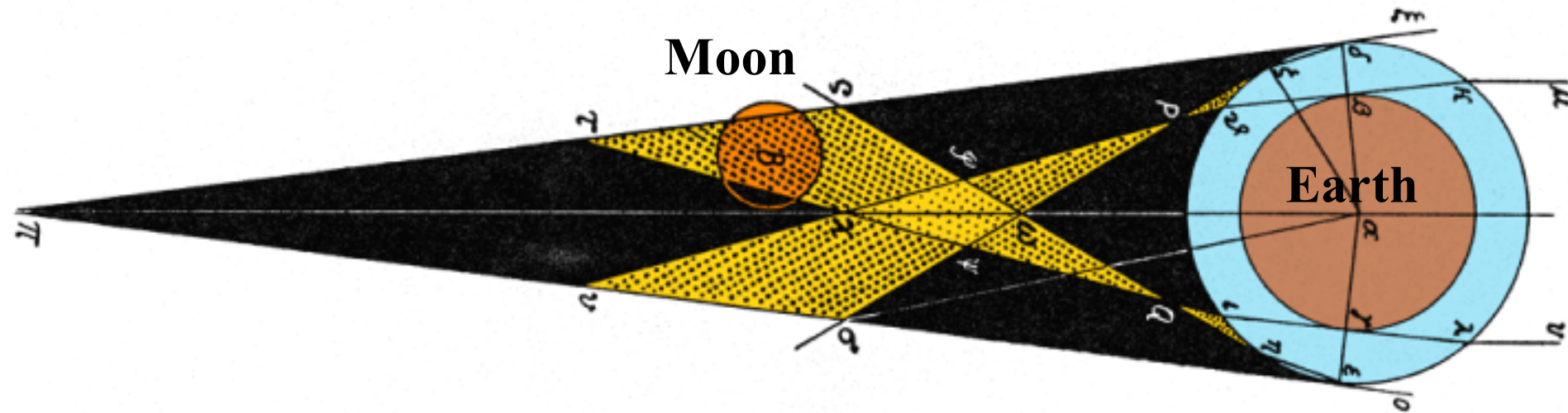


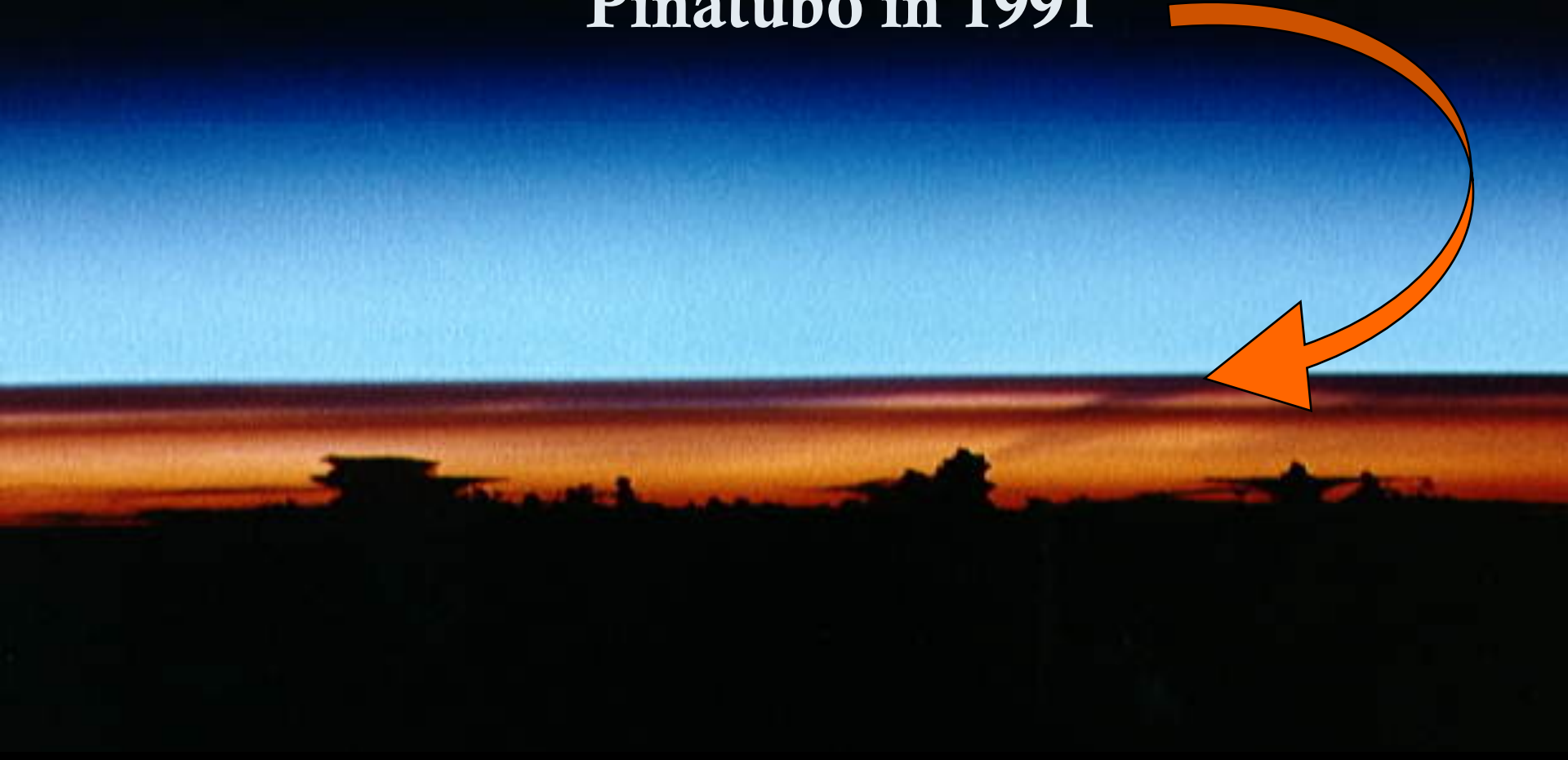
Diagram: Kepler, 1604

**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)**



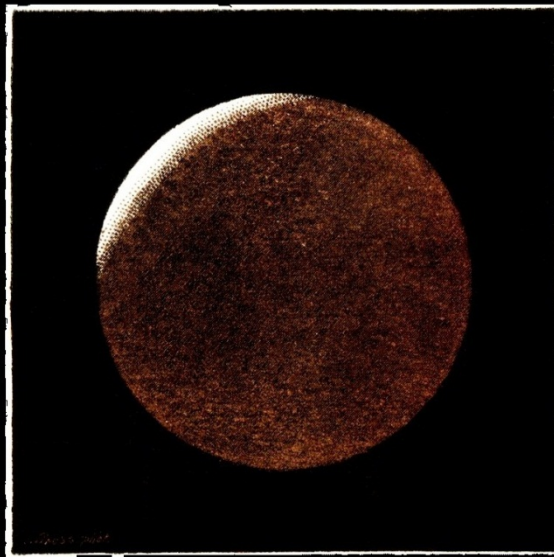
According to Kepler, sunlight is reddened & dimmed as it passes through "mists and smoke" in the Earth's atmosphere (stratosphere, mostly), causing the eclipsed moon to appear orange, red, or darker.

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



4. October 1884

und



28. Januar 1888.

1. Eclipses

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The Keens in front of the steaming
summit of Anak Krakatau,
1883 + 133 years



“Goal worth pursuing” (Dave Hofmann): fill in the blanks

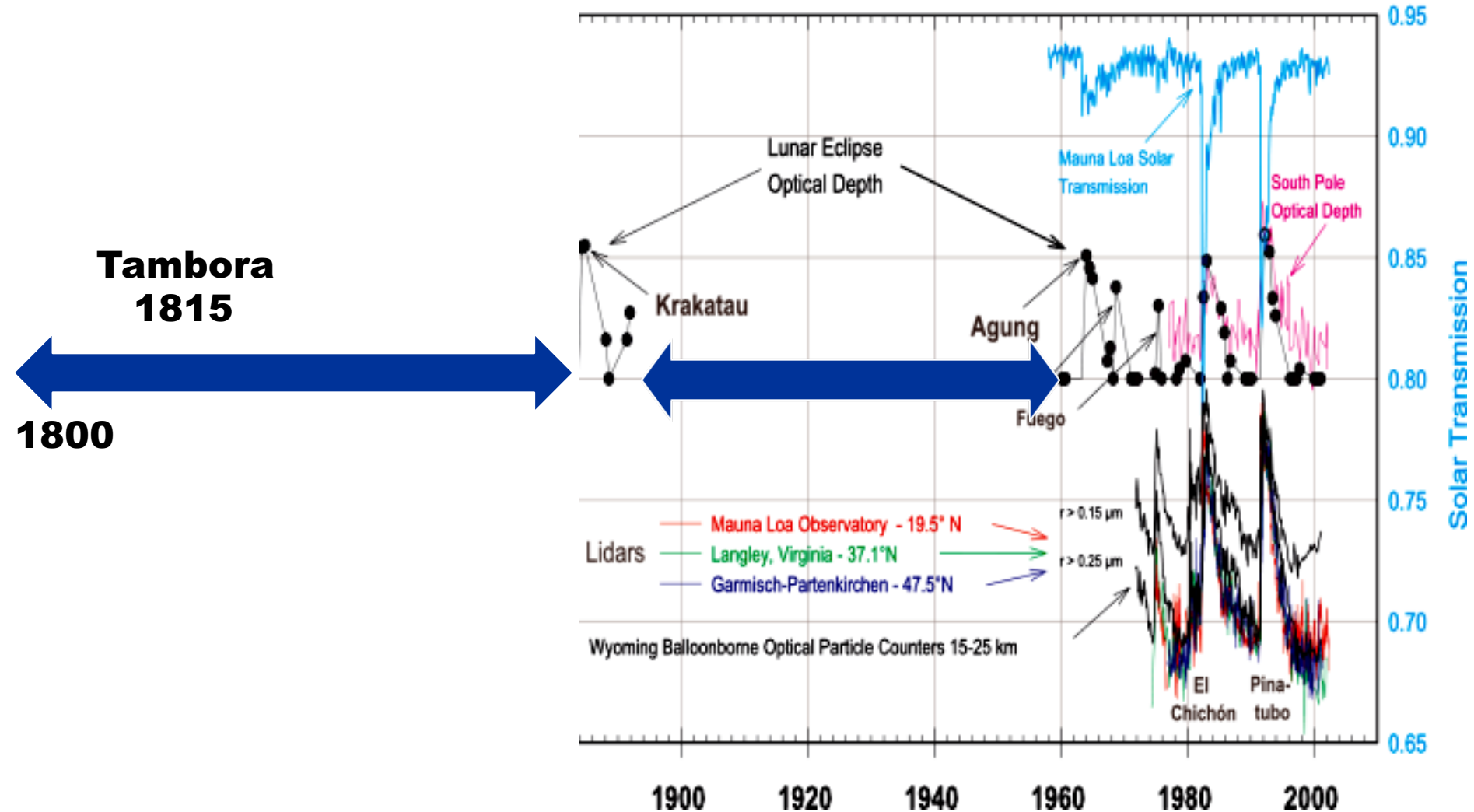


Plate 8. Summary of long-term stratospheric aerosol records....

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

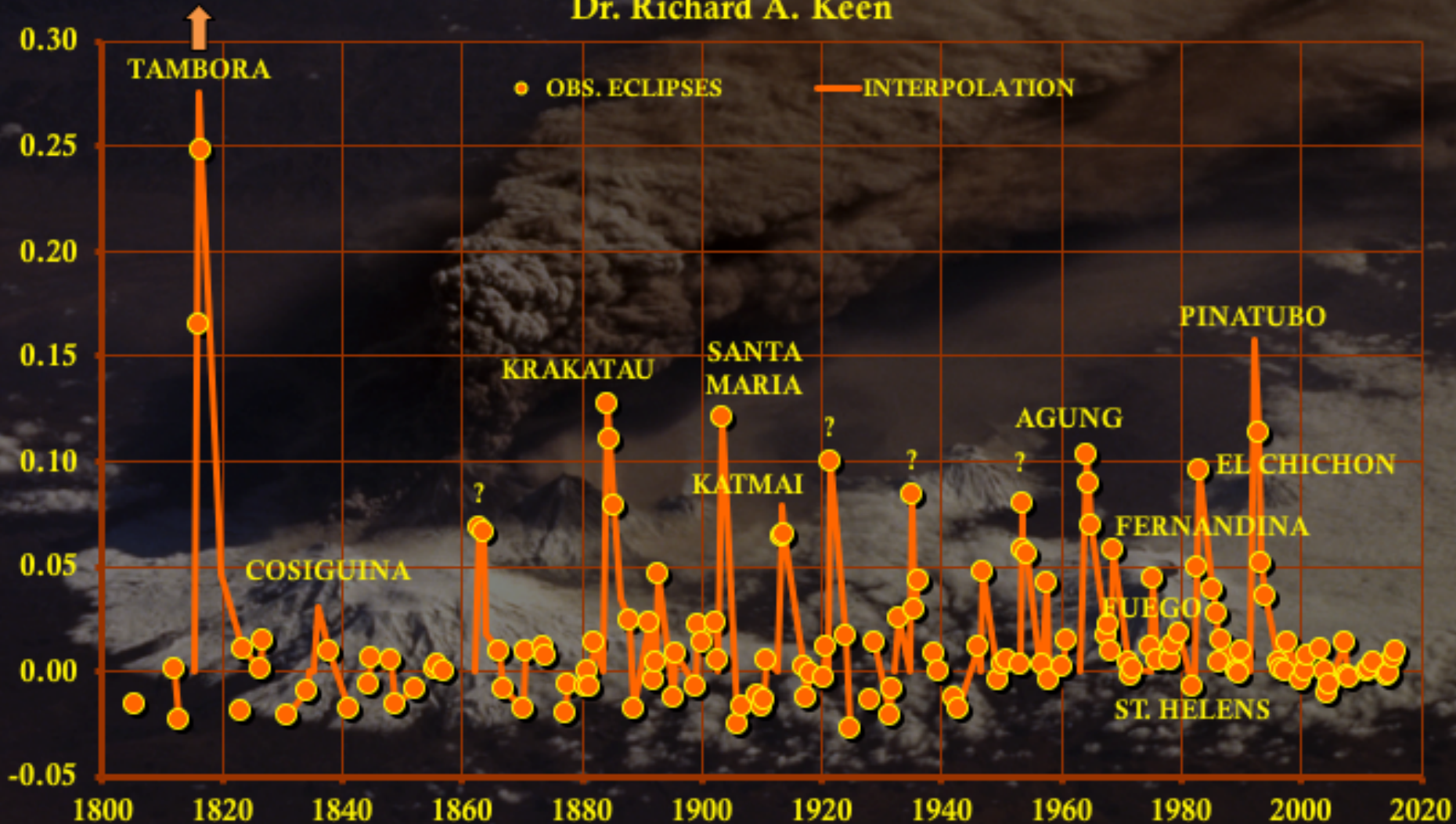
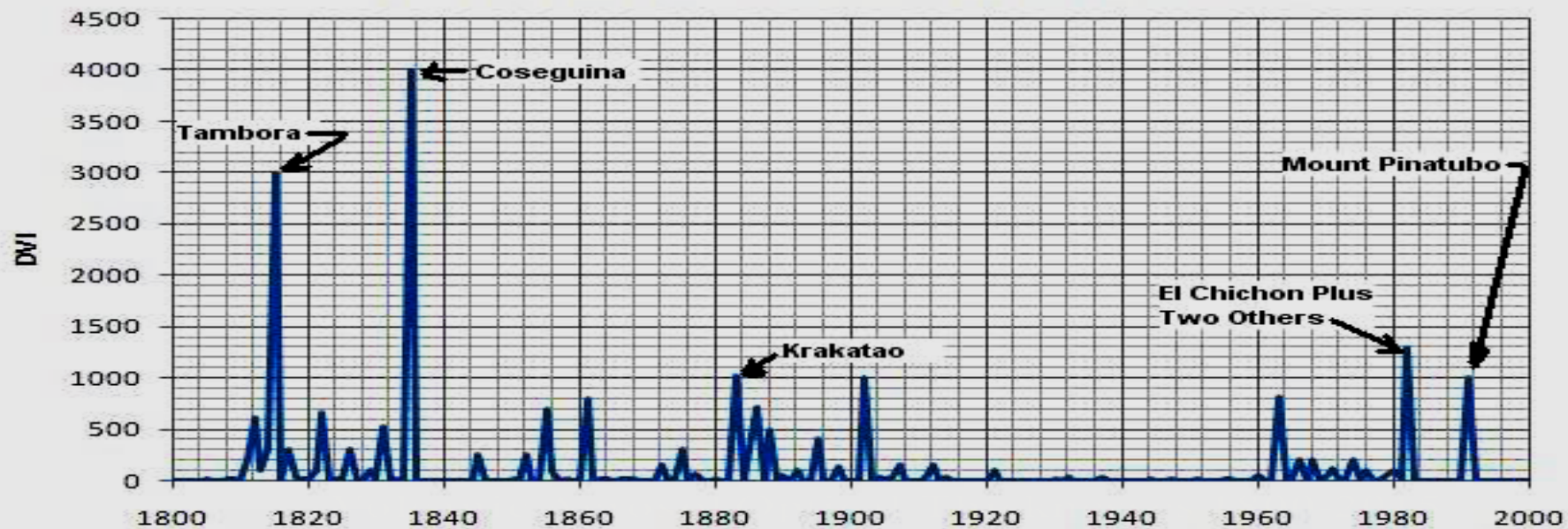
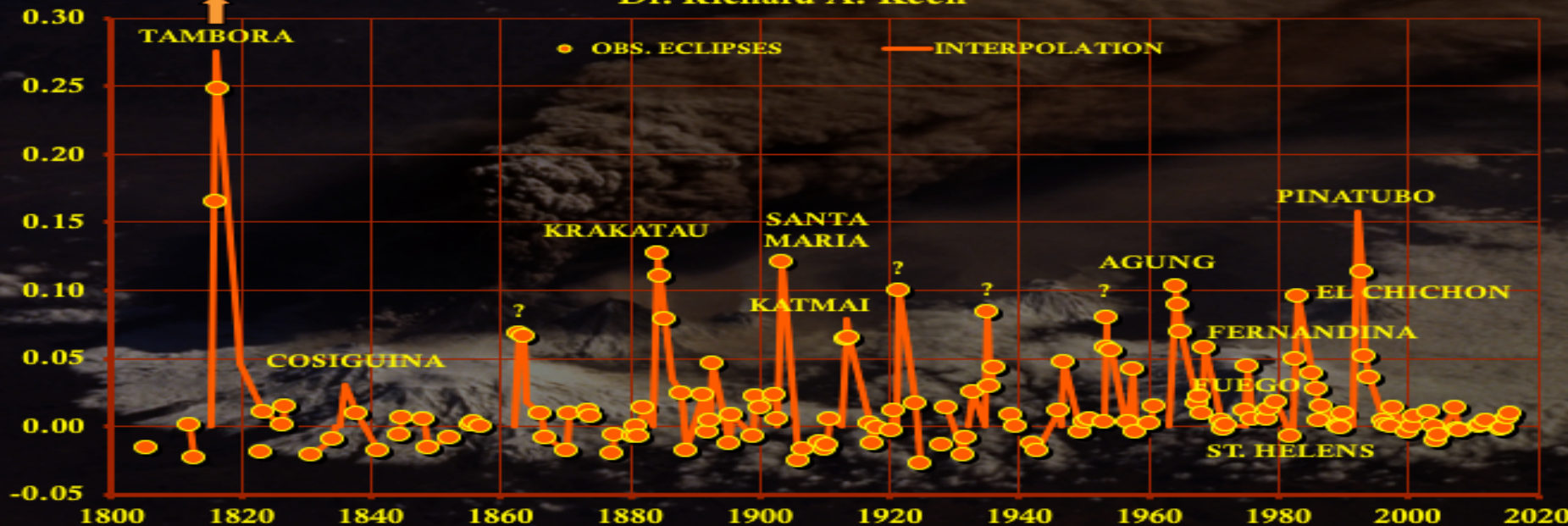


Photo: Kliuchevskoy volcano from STS-68, Oct. 1, 1994

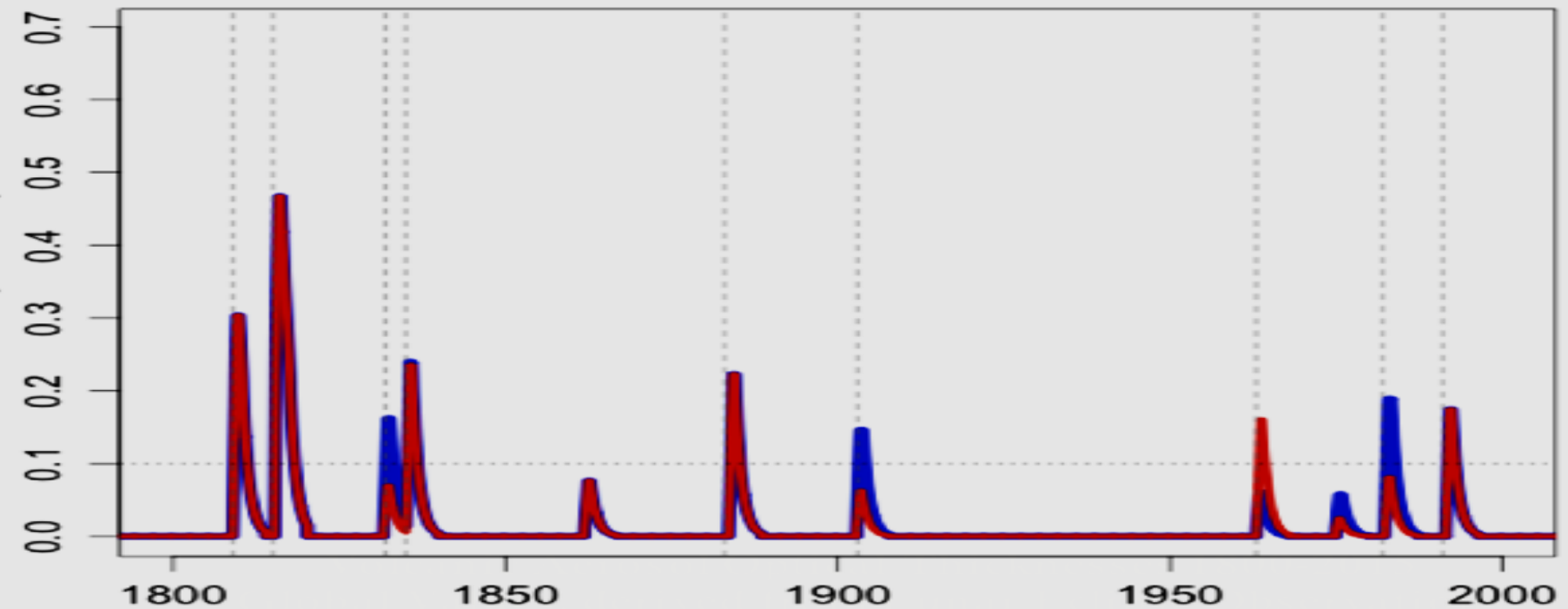
Dust Veil Index (Lamb)
1800 to 2000
(1991 Mt Pinatubo Value of 1000 Assigned by Robock)



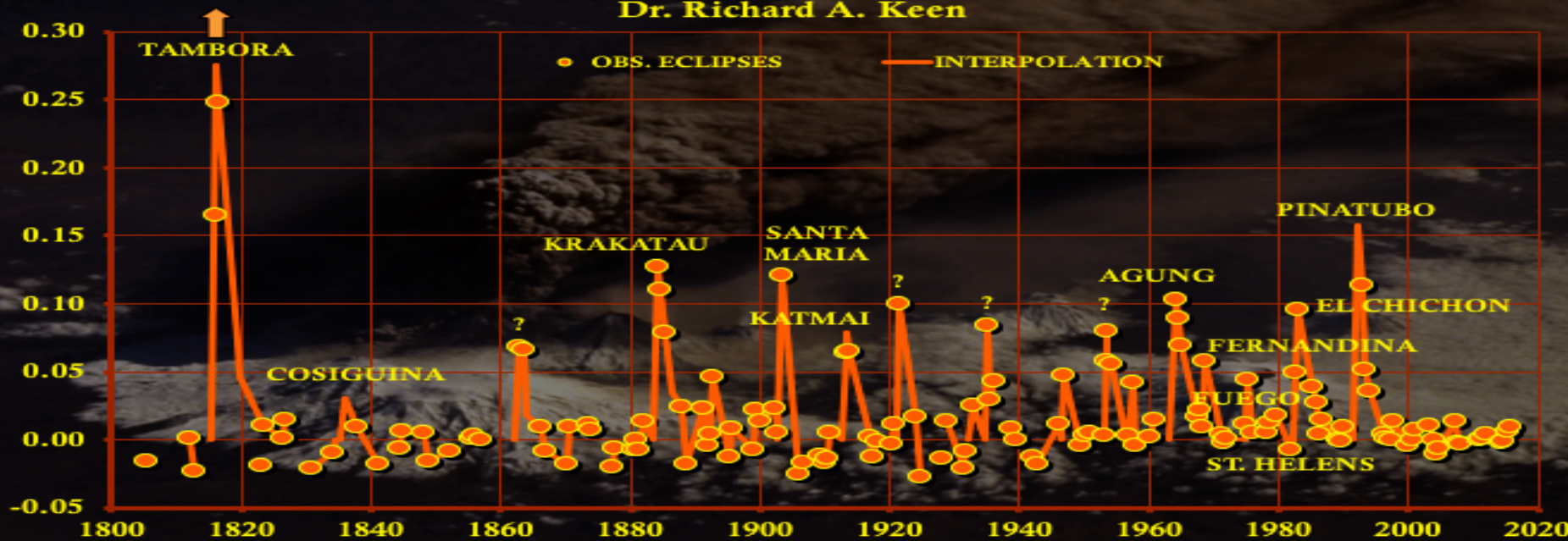
Dr. Richard A. Keen



Aerosol Optical Depth, Crowley & Untermann (2013)
0-30°N (blue) and 0-30°S (red)



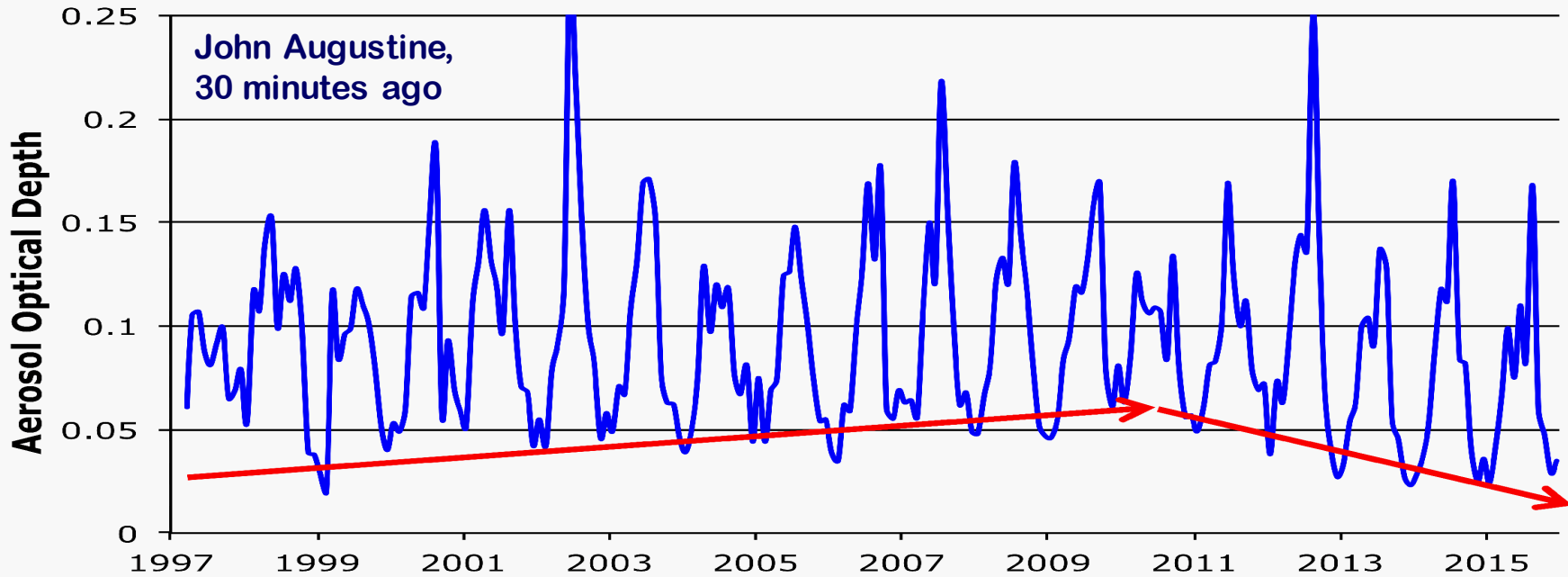
Dr. Richard A. Keen



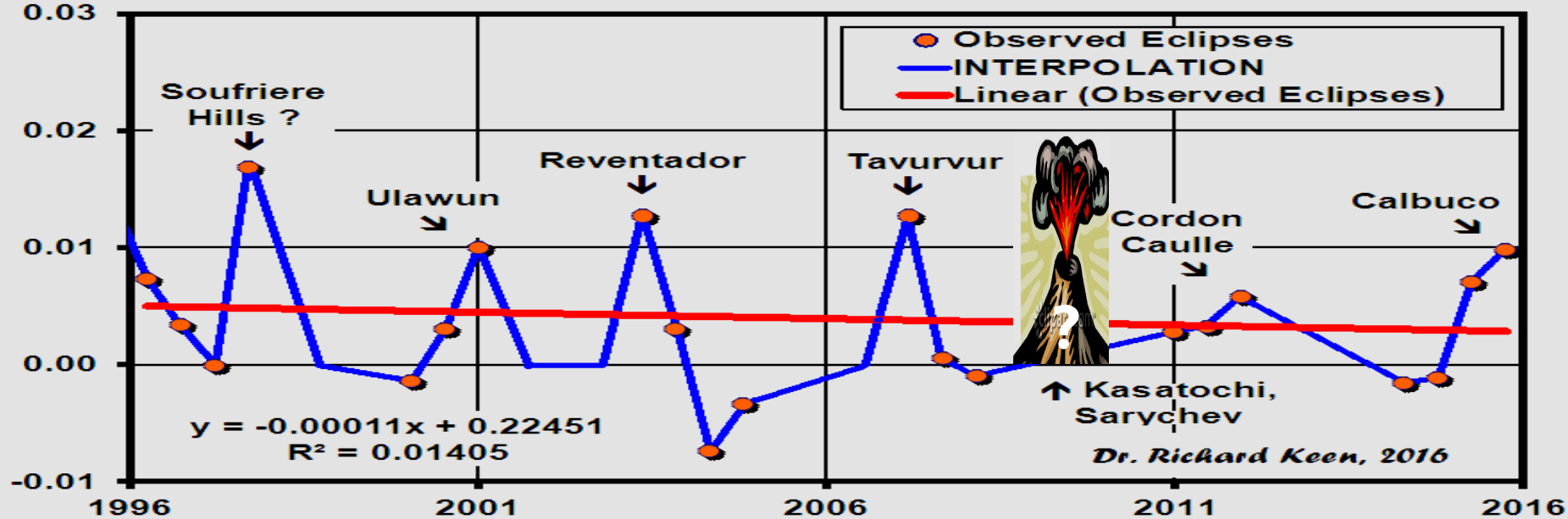
1. Eclipses

2. Volcanoes

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



❖ **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

Australia

Brazil

Canada

Cyprus

Czech Republic

Germany

India

Iran

Italy

Japan

Jordan

Mexico

Namibia

Netherlands

New Zealand

Norway

Portugal

Russia

Saudi Arabia

Slovakia

Slovenia

South Africa

Spain

Sweden

Tanzania

United Kingdom

United States

United Arab Emirates

Venezuela

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

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**No animals, students, or retired faculty were harmed in this
research.**