

Volcanoes, geophysics, climate and art

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> *vGIFT 2022 8 April 2022*

Etna Erupting



The active volcano Laki in Iceland













Volcanic aerosols improve our knowledge of the climate of the past



The volcano Tambora, in 1815, created the «Year Without Summer» (1816)



"Darkness" by Lord Byron (1788-1824)

I had a dream, which was not all a dream. The bright sun was extinguish'd, and the stars Did wander darkling in the eternal space, Rayless, and pathless, and the icy earth Swung blind and blackening in the moonless air; Morn came and went—and came, and brought no day,

And men forgot their passions in the dread Of this their desolation; and all hearts Were chill'd into a selfish prayer for light: And they did live by watchfires—and the thrones, The palaces of crowned kings—the huts, The habitations of all things which dwell, Were burnt for beacons; cities were consumed, And men were gather'd round their blazing homes

To look once more into each other's face; . . .

Nomogramm of R/G and aerosol optical depth as resulted from the model for three solar zenith angles calculated for non-volcanic and volcanic aerosols used to calibrate the measurements on paintings



Estimated aerosol optical depth at 550 nm corresponding to middle latitudes for each major volcanic eruption from this paper in comparison with other studies

| | Volcano Name | Year of the eruption | AOD this study | Nearest estimate from other studies |
|---|------------------------|----------------------|----------------|---|
| 1 | Awu | 1641 | 0.35 | 0.33 (Zielinski, 2000) |
| 2 | Katla | 1660 | 0.29–0.34 | N/A |
| 3 | Tongkoko & Krakatau | 1680 | 0.47 | N/A |
| 4 | Laki | 1783 | 0.30 | 0.21–0.28 (Robertson et al.,2001) 0.19 (Robock and Free, 1996) 0.12 (Zielinski, 2000) |
| 5 | Tambora | 1815 | 0.33–0.60 | 0.5 (Robertson et al., 2001) 0.5 (Robock and Free, 1996) 0.2–0.9 (Stothers, 1996) |
| 6 | Babuyan | 1831 | 0.28-0.29 | 0.24 (Zielinski, 2000) |
| 7 | Coseguina | 1835 | 0.52 | 0.11–0.21 (Robertson et al., 2000) |
| 8 | Krakatau | 1883 | 0.37-0.57 | 0.6 (Deirmendijian, 1973) |

Linear correlation between annual mean aerosol optical depth at 550 nm, estimated from sunset paintings following volcanic eruptions, and mean annual values of DVI. The errors in the AOD are less than 0.05 for values around 0.1 and can be up to 0.18 for AOD values greater than 0.5.



Error in AOD estimates derived from the average R/G variability within a painting (± 0.014) Error in AOD estimates derived from a typical error in estimating the SZA in a painting within $\pm 2^{\circ}$

| Solar Zenith angle | AOD | Error |
|--------------------|------------|------------------------|
| 75 | 0.1 0.5 | < 0.05 0.06 to 0.12 |
| 85 | 0.1 0.5 | < 0.05 0.1 to 0.18 |

| Solar Zenith angle | AOD | Error |
|--------------------|--------------------------|--------|
| 75 | 0.1 | < 0.05 |
| /3 | 0.5 | 0.07 |
| 05 | 0.1 | < 0.05 |
| 65 | 0.1 0.5 0.1 0.5 | < 0.05 |

R/G ratios in the painting "Sunset"



R/G ratio and respective AOD (Unknown volcano ~1809)



Plate 19 John Constable, Dedham Vale, 1810. Private collection



Plate 20 John Constable, The River Stour at Sunset, 1809. Private collection

Thornes, J.E., "John Constable's Skies: A Fusion of Art and Science", University Press, 1999 1810 R/G ratio = 1.021 AOD ≈ 0.22

1809 R/G ratio = 1.137 AOD ≈ 0.30

The famous Minard figurative Map showing winter temperatures and number of troops 1812-1813



ТОРЖЕСТВЕННАЯ УВЕРТЮРА



Frozen Thames 1814



The chromatic understanding of the artist changes after the eruption of Tambora in 1815, and returns to normal levels after a few years

1817: 2 years after Tambora



1817: 3 years after Tambora



Caspar David Friedrich, "Neubrandenburg", 1817 Greifswald, Pommersches Landesmuseum Caspar David Friedrich, "Schiffe im Hafen von Greifswald",1818 Berlin, Alte Nationalgalerie Friedrich Caspar David (1774-1840)



Sunset after Tambora

Sunset without volcano



"Woman in front of the Setting Sun", 1818, Museum Folkwang, Essen, Γερμανία

"Evening", 1824, Kunsthalle, Manheim, Γερμανία

J.M.W. Turner (1775-1851)

Sunset after Babuyan



"Sunset", 1833, Tate Gallery

Sunset without volcano



«Chichester Canal», 1828, Tate Gallery



Aerosol optical depth from paintings and other proxy indices during the past 500 years from different proxies (Zerefos et. al., 2014) *R/G ratios derived from painting digital images from website (low resolution) vs. R/G ratios for the same paintings obtained through colour profile protocol (high resolution) at the Tate Gallery.*

Distribution of the relative differences (in %) between the R/G ratios derived from the high- and the low-resolution images from 124 landscape sunsets at the Tate Gallery. Results from a completely independent sample of paintings. R/G ratios derived from painting digital images from the website (low resolution) vs. the same R/G ratios from high resolution digital images at the National Gallery, London.



Atmospheric aerosols increased after the 19th century (Zerefos et. al., 2014)



Correlation coefficients between volcanic aerosol indices and AOD proxies

| 1500–2000 | DVI | AOD (this study) | AOD (Robertson) | AOD (Crowley and Unterman) | AOD (Sato) | AOD (Stothers) | Sulfate (Gao) |
|----------------------------|--|---------------------|--------------------|----------------------------------|------------------|-------------------|------------------|
| DVI AOD (this study) | 1 • • • • • • • • • • • • • • • • • • • | 1 | | | | | |
| AOD (this study) | 0.85 [102] | | | | | | |
| AOD (Robertson) | 0.65 [227] | 0.58 [118] | 1 | | | | |
| AOD (Crowley and Unterman) | 0.57 [154] | 0.54 [74] | 0.80 [239] | 1 | | | |
| AOD (Sato) | 0.65 [66] | 0.55 [61] | 0.57 [126] | 0.91 [78] | 1 | | |
| AOD (Stothers) | (*) [29] | (*) [21] | 0.83 [37] | (*) [29] | 0.92 [38] | 1 | |
| Sulfate (Gao) | (*) [23] | (*)[14] | 0.88 [33] | (*) [24] | (*)[11] | (*) [6] | 1 |

Bold: all the above correlations are significant at the 99% confidence level (*t* test).

* missing correlations are those possessing less than 30 years of data.

In brackets: number of pairs.

The experiment of Hydra island (19 & 20 June 2010)



Passage of a Saharan dust event



MFR-7 AOD retrievals at 500 nm on 19 and 20 June 2010 at Hydra campaign site. Microtops II AOD retrievals at 1020 nm are superimposed

The profile of Saharan dust



Aerosol measurements during the two days of the experiment



Upper: Digitally compressed paintings by P. Tetsis at the Hydra experiment under higher (left panel) and lower (right panel) AOD conditions. Bottom: Digital camera photos of the landscape.









Percent difference in R/G ratios between the measured at Hydra Sahara dust mineral aerosol profile and a typical modelled volcanic aerosol profile. In both cases AOD (500 nm) was set to 0.25.





Caspar David Friedrich, Griefswald in the Moonlight, 1817. Corresponding R/G ratios were averaged inside each box.



Karl Friedrich Schinkel, The Banks of the Spree near Stralau, 1817. Corresponding R/G ratios were averaged inside each box.



Caspar David Friedrich, Woman in front of the Setting Sun, 1818. Corresponding R/G ratios were averaged inside each box.



Joseph Mallord William Turner, Red sky and crescent moon, c. 1818. Corresponding R/G ratios were averaged inside the box.

Volcanic aerosol indices and AOD proxies

| | | N.H. AOD | | | | | Sulfate |
|------|--------------|----------------|---------------|-----------------|---------------|-------------|---------------|
| Year | N.H. DVI | from paintings | AOD | AOD | AOD | AOD | aerosols (Tg) |
| | (Lamb, 1970, | | (Robertson | Crowley and | (Sato et al., | (Stothers, | (Gao et al., |
| | 1977, 1983) | (this study) | et al., 2001) | Unterman (2013) | 1993) | 1996, 2001) | 2008) |
| 1782 | 45 | 0.115 | 0.0106 | | | | |
| 1783 | 400 | | 0.1643 | 0.009 | | | 92.96 |
| 1784 | 300 | 0.3 | 0.1354 | 0.042 | | | |
| 1785 | 200 | | 0.0005 | 0.01 | | | |
| 1786 | 160 | | 0.0021 | 0.002 | | | |
| 1787 | 45 | | 0.0080 | | | | |
| 1788 | 30 | | 0.0035 | 0.011 | | | |
| 1789 | 15 | | 0.0011 | 0.003 | | | |
| 1790 | | | 0.0022 | 0.001 | | | |
| 1791 | | | | | | | |
| 1792 | | | 0.0013 | | | | |
| 1793 | | | 0.0292 | | | | |
| 1794 | | | 0.0177 | | | | 1.88 |
| 1795 | 120 | 0.098 | 0.0043 | | | | |
| 1796 | 130 | | 0.0017 | 0.018 | | | 6.7 |
| 1797 | 90 | | 0.0041 | 0.006 | | | |
| 1798 | 50 | | 0.0048 | 0.001 | | | |
| 1799 | 130 | | 0.0060 | | | | |
| 1800 | 90 | | 0.0010 | | | | |
| 1801 | 60 | 0.081 | 0.0031 | 0.012 | | | |
| 1802 | 30 | | 0.0036 | 0.004 | | | |
| 1803 | | | 0.0047 | 0.001 | | | |
| 1804 | | | 0.0019 | 0.018 | | | |
| 1805 | | | 0.0043 | 0.006 | | | |
| 1806 | | | 0.0011 | 0.001 | | | |
| 1807 | | | 0.0021 | | | | |
| 1808 | | | | | | | |
| 1809 | | | 0.1391 | 0.198 | | | 53.74 |
| 1810 | | | 0.2308 | 0.18 | | | |
| 1811 | 80 | | 0.0537 | 0.067 | | | |
| 1812 | 180 | 0.199 | 0.0055 | 0.025 | | | |
| 1813 | 170 | 0.181 | 0.0019 | 0.009 | | | |
| 1814 | 170 | 0.142 | 0.0008 | | | | |
| 1815 | 695 | | 0.3351 | 0.199 | | | 109.72 |
| 1816 | 490 | 0.6 | 0.3260 | 0.364 | | | |
| 1817 | 375 | 0.379 | 0.0798 | 0.194 | | | |
| 1818 | 195 | 0.33 | 0.0024 | 0.073 | | | |
| 1819 | 30 | 0.108 | 0.0015 | 0.027 | | | |
| 1820 | 15 | 0.062 | 0.0023 | 0.003 | | | |

SPE Analysis with key year the volcanic eruption with VEI ≥ 5 for AOD and Temperature



Climatic stations: Basel, Berlin, Geneva, Greenwich, Moscow, Paris, Prague, Corfu, St Petersburg, Stokholm

Winter mean temperatures at four sites with long term records



Annual mean temperatures at ten European sites with long term records



(DVI) Independent index of volcanic aerosols. *(AOD)* Absorption of solar radiation in the atmosphere from measurements in paintings.





guardian.co.uk

How old masters are helping study of global warming

Paintings of striking sussets show effect of huge volcanic ecuptions on climate

Prisma

- David Adam, environment correspondent
- The Ouardian
- Monday Celober 1 2007

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Classic paintings had a helping hand from volcano

Thu Oct 4, 2007 12:10pm EDT

By Karolos Grohmann

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RESEARCH HIGHLIGHTS

Volcanic paintings

TRADUCE

Atres. Chem. Phys. 7, 4027-4042 (2007) The ashfrom large volcanic eruptions can cool Earth's climate and cause vivid red sunsets. But the historical effects of volcanic activity on climate are difficult to quantify owing to a lack of direct atmospheric observation.

Christos Zerefos at the Academy of Athens in Greece have come up with a novel way to c particle content in middle latitudes isphere during the period 1500-I sunsets captured in paintings by Mallord William Turner, Edgar Degas Wissenschaft · Technik ictured is one of their subjects. The by Caspar David Friedrich.) foulated red/green colour ratios from dreds of paintings. They found that after major volcanic eruptions such in 1680 and 1883. The team then used to reconstruct how much light was nic ash in the air. The resulting time with and could complement existing tions of atmospheric composition.

Associated Press NATIONAL GEOGRAPHIC The Mashington Times -THE 激励题 HINDU

Art as Window to Climate Change

Kate Schuman, Associated Press, Nov. 29, 2007

The virial susants painted by J.M.W. Tarsor are reversed for their uses of color and light and for their Improviously. Due orded they also help global wavesing opports taxis climate charge? A group of wiserigts has studied the odors in more than 500 paintage of spruch, including more of Tax wateroolens and one, in hopes of gaining insights into the conting efficite caused by encore volcanic employs By better andientaning part charges in classes, they hepe to improve computer models for future classes Christon Zoosfin, who lod the monarch at the Halional Chooreatory of Atlants, said he believed it was the fit

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Tou OLAH KAÎTATZH, 05-10-2007

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Klima auf der Leinwand

Von Axel Bojanowski, 12-10-2007

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Atmospheric effects of volcanic eruptions as seen by famous artists and depicted in their paintings

C.B. Zerrefree et

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Klima-Archiv in der Galerie

sopar David Friedrich, Edger Degas oder William Turner malten Sonnenuntergänge in überwähtgenden Farben. Jetzt bekommen ihre Gemälde

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Contributors:

C. Zerefos, P. Tetsis, A. Kazantzidis, V. Amiridis, S. Zerefos, J. Luterbacher, K. Eleftheratos, E. Gerasopoulos, S. Kazadzis, D. Balis, V. Gerogiannis, I. Kapsomenakis