Response to the Reviewers

We have received comments from two anonymous Reviewers (AR1, AR2) and Alan Robock, which we thank for their extremely constructive comments. The Reviewers comments have been all taken into account and we have made major revisions in the abstract and additions, which we think have indeed improved the manuscript. Three figures have been changed, namely Figure 4, Figure 6 and Figure 10 and one new figure (Figure 11) has been added. Table 1 has been revised. We hereby reply to all reviewers' comments point by point:

Comments from AR1 (1, 2, 3, 4), AR2 (1) and Alan Robock (1) have been all included in the following fully **revised abstract**, which reads as follows:

"We examine sunsets painted by famous artists as proxy information for the aerosol optical depth after major volcanic eruptions. Images derived from precision colour protocols applied to the paintings were compared to online images, and found that the latter, previously analysed, provide accurate information. Aerosol optical depths (AODs) at 550 nm, corresponding to Northern Hemisphere middle latitudes, calculated by introducing red-to-green (R/G) ratios from a large number of paintings to a radiative transfer model, were significantly correlated with independent proxies from stratospheric AOD and optical extinction data, the dust veil index, and ice core volcanic indices. AODs calculated from paintings were grouped into 50-year intervals from 1500 to 2000. The year of each eruption and the 3 following years were defined as "volcanic". The remaining "non-volcanic" years were used to provide additional evidence of a multidecadal increase in the atmospheric optical depths during the industrial "revolution". The increase of AOD at 550 nm calculated from the paintings grows from 0.15 in the middle 19th century to about 0.20 by the end of the 20th century. To corroborate our findings, an experiment was designed in which a master painter/colourist painted successive sunsets during and after the passage of Saharan aerosols over the island of Hydra in Greece. Independent solar radiometric measurements confirmed that the master colourist's R/G ratios which were used to model his AODs, matched the AOD values measured in situ by co-located sun photometers during the declining phase of the Saharan aerosol. An independent experiment was performed to understand the difference between R/G ratios calculated from a typical volcanic aerosol and

those measured from the mineral aerosol during the Hydra experiment. It was found that the differences in terms of R/G ratios were small, ranging between -2.6% and +1.6%. Also, when analysing different parts of cloudless skies of paintings following major volcanic eruptions, any structural differences seen in the paintings had not altered the results discussed above. However, a detailed study on all possible sources of uncertainties involved (such as the impact of clouds on R/G ratios) still needs to be studied. Because of the large number of paintings studied we tentatively propose the conclusion that regardless of the school, red-to-green ratios from great masters can provide independent proxy AODs that correlate with widely accepted proxies and with independent measurements".

The following specific answers refer to **AR1, Comment #4**

"p. 33147 l. 19-26 I would suggest to downscale this in the abstract- and use the work for a somewhat more 'scientific' sensitivity analysis. The authors use 2 (beautiful!) paintings (see Figure 10) to demonstrate the impact of dust as observed by Maestro Panayiotis Tetsis. The paintings show two sunsets. One painting shows rocks- the size of the sun is different, one painting seems to have some cloud cover, the other not. I suspect that such issues are found in most paintings assessed by the authors. Assuming that the authors only analysed the 'sky' in the paintings, can the authors assess the uncertainty associated with such 'structural' differences in the paintings (e.g. analyse parts of paintings)".

Reply:

For the calculation of the R/G ratios we analysed only the parts of the sky over the field of view of the artist near the horizon trying to avoid clouds. Then, we averaged the measured values. The average values and the standard deviation of R/G ratio for each painting were presented in Appendix B of Zerefos et al. (2007). In that study, we reported that the mean error value was 0.014 due to the variability of R/G ratios within the paintings/images. We also examined how that variability could affect the estimated AOD values for different aerosol conditions and solar zenith angles. The reported uncertainty was less than 0.05 for small optical depths and smaller SZA (70°). That number was comparable to the accuracy of other experiment measurements of AOD. The error however increased with increasing AOD and SZA (85°) and can be as large as 0.18 for AOD larger than 0.5. Instead of repeating the methodology in this paper too, we have tried to estimate uncertainties, particularly the structural of the paintings in the revised manuscript. Please also note that during the Hydra experiment, master colourist Panayiotis Tetsis did not have enough time to complete the rocks, since his priority was the sky and he should start working on the next painting. Please see our response to comment #7.

AR1, Comment #5

"p. 33148 Please explain what is meant with 'created with a colour profile protocol'? I expect this related to the camera sensor and the way the digital picture is stored? A few sentences explaining the issue would be essential."

Reply:

A colour profile protocol is the protocol (set of instructions) used to accurately translate colour through different devices. In our work a colour profile was absolutely necessary so that the scanned paintings retained their original colour information when distributed through digital means. Also by having the colour profile along with calibrated scanners it was possible to compare paintings from other colourists with the minimum possible uncertainty caused by differences in colour translation.

The text has been modified as follows:

"Firstly, by correlating the available R/G ratios from the above-mentioned public websites with the same ratios from their respective high quality colour profile protocols. A colour profile protocol is the protocol (set of instructions) used to accurately translate colour through different devices. In our work a colour profile was absolutely necessary so that the scanned paintings retained their original colour information when distributed through digital means. Also by having the colour profile along with calibrated scanners it was possible to compare paintings from other colourists without any uncertainty by differences due to colour translation".

AR1, Comment #6

"p. 33150 l.12 In other words: the errors made previously were larger for the 'red' sunsets used to evaluate the impact of volcanoes?"

Reply:

As expected from statistical theory, the standard deviation and the standard errors for the larger R/G ratios are expected to be larger when compared to the corresponding statistics for smaller R/G ratios. We have randomly generated one hundred numbers with values ranging between 1 and 2 and calculated the standard error of them and we did the same with cases with values ranging between 0 and 1. The statistical difference between the errors still has shown that the 'red' R/G ratios were significantly different from the 'less red' ratios. Therefore the statistical effect of the volcanic eruptions is significant. An example of the results obtained from R/G ratios with a high precision protocol and from random numbers is shown below:

Statistics of R/G from paintings (mean value 1.08) and numbers from a random number generator

	Tate+National High resolution (protocol) R/G >1.08	Tate+National High resolution (protocol) R/G <1.08
Average	1.150	1.020
N	139	155
St. deviation	0.069	0.050
St. error	0.006	0.004

Random numbers (RN) from RN generator

	Random numbers between 1 and 2	Random numbers between 0 and 1
Average	1.494	0.493
N	100	100
St. deviation	0.308	0.251
St. error	0.031	0.025

AR1, Comment #7

"p. 33151 as outlined above: I think the authors dismiss too easily the impact of structural differences, and the cancellation of errors is wishful thinking. It would be great to have some attempts to analyse such differences".

Reply:

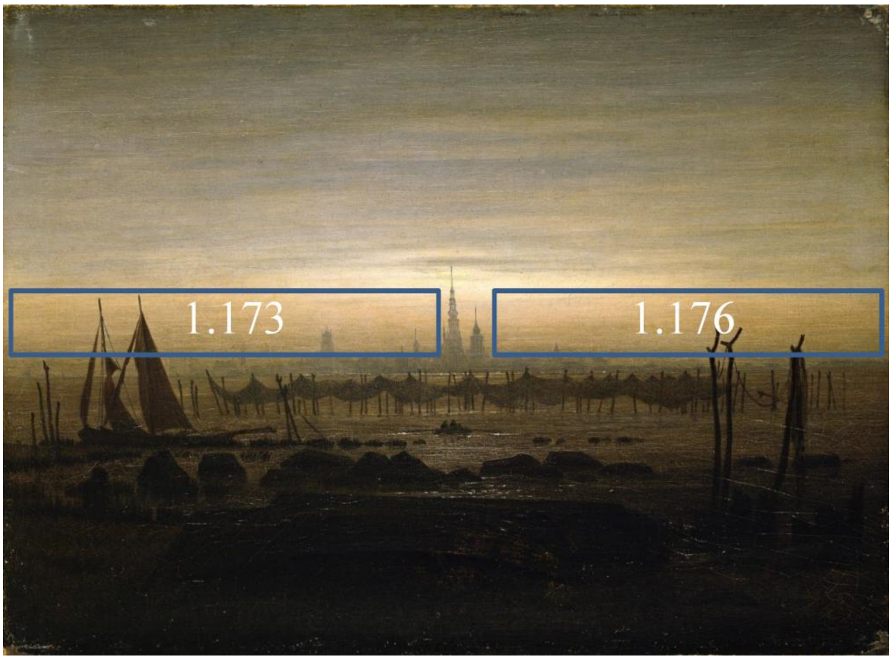
The following text has been added to Section 3:

"This is supported by the signal to noise ratio analysis of the statistical standard errors discussed in the introduction and in Zerefos et al. (2007). In addition, we have searched for a possible impact of structural differences. We provide here examples of paintings with and without structural differences following two major volcanic eruptions namely Tambora (1815) and Krakatau (1883). The calculated R/G ratios in parts of the sky give a similar result in which the differences are small, anyhow smaller than the standard errors we have encountered in this work (see paintings in Appendix C). Therefore, we have to tentatively assume that the impact of structural differences when studying R/G ratios in parts of the sky of the painting are small. We note here that we have made any possible effort to avoid measuring R/G ratios in the presence of clouds. It appears that R/G ratios as measured in this work somehow remind us on the ratios of solar irradiance in different wavelengths which are used in spectrophotometers to measure columnar gases in the atmosphere. In these spectroradiometers the noise introduced by aerosols and other factors related to scattering and related effects are indeed cancelled out and this is how we obtained the long series of

total ozone, total sulphur dioxide, total nitrogen dioxide with remarkably small standard error. We think that the reduction of errors when using R/G ratios provides useful information on the overhead aerosol content which correlates well when averaged with other proxies and/or with real AOD measurements as was the case with the Hydra experiment, discussed in paragraph 5.

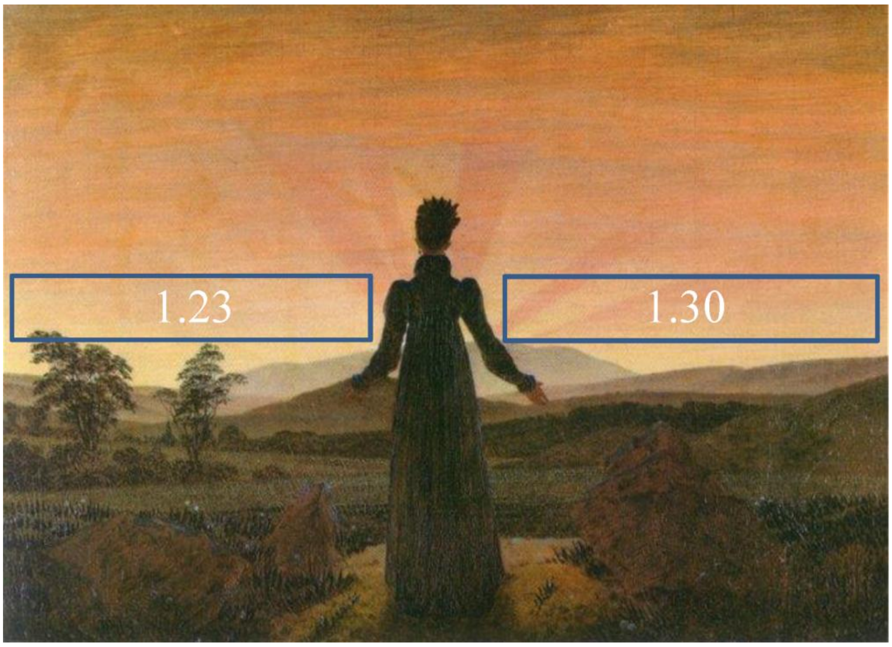
In our study, a detailed quantification of each source of uncertainty was not possible except for the effects of quality in digitization of the paintings, structural differences and the solar zenith angle. Potential sources of uncertainty could be the atmospheric/aerosol related dynamics which affect the magnitude of the impact of each volcano in the area under study (of the painter) as well as the impact of cloudiness on the depicted R/G. Any effects from clouds we think have been avoided by trying to confine our R/G "measurements" to the cloudless parts of the sky in each painting. Following the above discussion and since our goal in this part of the manuscript was focused on the validation of the volcanic eruption effect and not on the actual quantification of the volcanic aerosol in the painting area, we believe that correlation coefficients with the mentioned proxies provide evidence that this goal has been achieved."

Appendix C. R/G ratios with and without structural differences after Tambora (1815) and Krakatau (1883).



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

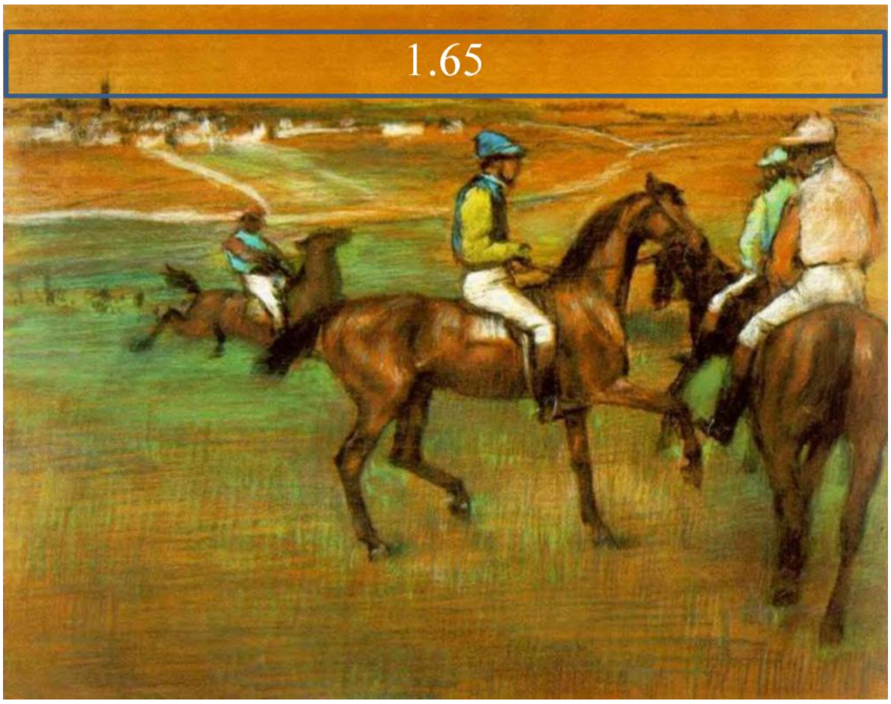
Karl Friedrich Schinkel, The Banks of the Spree near Stralau, 1817. Corresponding R/G ratios were averaged inside each box.



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.

Edgar Degas, Landscape on the Orne, c.1884. Corresponding R/G ratios were averaged inside each box.



Edgar Degas, Race Horses, 1885. Corresponding R/G ratios were averaged inside the box.

AR1, Comment #8:

"p. 33152 It would be logical to first describe the experiment as done here, and then the contrasting datasets. Somewhere the information should be given that the data is really about major volcanic eruptions where emissions reach the stratosphere, and remain for several years. This is also important since it means that datasets are probably more globally representative".

Reply:

Section 4 has been revised as follows:

"The earlier estimates of the aerosol optical depth at 550 nm (based on R/G calibrated ratios from paintings) and the radiative transfer model by Mayer and Kylling (2005) and Mayer and Emde (2007), were used to compile an independent time series with AODs during 1500-2000. Additionally, the time series of AODs calculated from paintings has been divided into 50-yr intervals from 1500 to 2000. The year of each eruption and the 3 following years were defined as "volcanic". The remaining "non-volcanic" years were used to calculate the average AOD value pertaining to these years corresponding to Northern Hemisphere mid latitudes. This paper is based on evidence by Western painters and colourists. The type of art is typical to Western European schools so it was inevitable to have more paintings in European countries. Nevertheless, the paper focuses on big volcanic eruptions that have an effect over the entire planet atmosphere, so the evidence could be noticed in most parts of the world. This long term data set of AODs is compared to other independent proxies as shown in Figure 4. Detailed information on those proxies can be found in the primary literature by Lamb (1970, 1977, 1983), Sato et al. (1993), Stothers (1996, 2001), Robertson et al. (2001), Gao et al. (2008) and Crowley and Unterman (2013). Using the data shown in Figure 4 we found that the correlation coefficients between other proxy indices and the estimated AODs from the R/G ratios from paintings are statistically significant (Table 1). Appendix D presents the data used in the calculations shown in Table 1. The reader is also referred to the precision by which the extreme AODs between paintings and proxies during large volcanic eruptions match in most cases. In particular, in 102 cases for which data of both DVI and this study are simultaneously available, DVI spikes are coinciding to AOD spikes from this study at a percentage of 80% (9 out of 11 cases). As spikes we define the values in both time series that

belong in the upper 10% range of values. In addition, this study revealed two high AOD cases that do not match with DVI spikes and it is worth noting that both failing cases succeeded a period of two consecutive years with spikes in both indices.

Total sulphate is the total measured sulphate concentration in ppb in the core, as resulted from deposition either from the stratosphere (volcanic) or the troposphere (anthropogenic and other biogenic sources), as described by Zielinski et al. (1996) and Robertson et al. (2001). The presented values do not refer directly to the atmospheric concentration, but rather to the deposition on ice which however is related to ambient concentrations. The values of calculated index of total sulphate from Greenland ice cores (Zielinski, 1995; Zielinski et al., 1996) and the longer time series of stratospheric AOD (Robertson et al., 2001) were grouped in 50-year time intervals with the same procedure described above for AODs calculated from paintings. The three datasets are presented in Fig. 5. We note here the point raised by Robertson et al. (2001) that the last 150 years increase in total sulphate from ice core was hypothesized to be the result of tropospheric anthropogenic sulphate deposition. The point raised by Robertson et al. that there have been no major volcanic eruptions between 1900 and 1960, needs some clarification. Indeed in the list of major volcanic eruptions in the past 500 years (Appendix B after Ammann and Naveau, 2003; Robock, 2000), we can see that based on VEI two eruptions, Santa Maria (1903) and Katmai (1912) have been classified with VEI 6. However, VEI is known to be not a good index of stratospheric sulphate loading since it measures the explosivity of a volcano and not its stratospheric injection. A good example is the 1980 St. Helen's eruption, with a VEI of 5 but no stratospheric or climatic impact (A. Robock, private communication). Stratospheric injection is important to ensure its global or hemispheric effects. From the above discussion it can be proposed that compared to the pre-industrial period, the industrial period shows higher painting-derived aerosol content, in agreement to what it is expected from literature (e.g., Neftel et al., 1985; Robock and Free, 1995; Robertson et al., 2001; Forster et al., 2007; Wild, 2012)."

AR1, Comment #9:

"p. 33154 l18 Explain why it is possible to compare the impact of mineral aerosol (in lower atmospheric layers, larger) to volcanic aerosol in terms of RGB".

Reply:

The following text has been added at the end of Section 5.2.

"Finally, a comparison between the impact of mineral aerosol (Saharan dust) and the impact of a typical volcanic aerosol in terms of RGB is also attempted. The mineral aerosol during the Hydra experiment at 500nm was measured to vary close to 0.25. Therefore we have made model runs with the volcanic aerosol setting the volcanic AOD case at 500nm equal to 0.25 also. Note here that the mean volcanic AOD (500nm) in our paintings is very close to that number and equals to 0.22. Figure 11 shows the percent difference in R/G ratios between the ones measured at Hydra Sahara dust aerosol profile and a typical modelled volcanic aerosol profile as was used previously in this work. In both cases AOD (500nm) was set to 0.25. The ratios are shown as isopleths in a graph where the position of the sun is fixed at 80^o solar zenith angle. It was quite surprising to see that although both the nature, size and the vertical profiles of the Saharan and the volcanic aerosols differ, their effect on R/G overhead ratios in the sky induce so small a difference ranging from a minimum of -2.6% to a maximum +1.6%, depending on the solar zenith angle and the angle relative to the position of the sun."

AR1, Comment #10:

"p. 33157 Explain the conclusions (abstract) to what extent 'new' information came out of this study, regarding the historic impact of volcanoes in bringing sulphate into the stratosphere? Or is it mainly 'not-contradicting' other datasets."

Reply:

The following text has been added at the end of the conclusions in the revised manuscript:

"The new information in the paper can be summarized as follows:

1. *The comparison of high precision with low precision colour protocol images at independent samples of paintings from the Tate and the National Galleries in London strengthen the tentative results proposed in an earlier paper by Zerefos et al. (2007).*
2. *AODs from a multi-hundred sample of paintings show statistically significant correlations with independent proxies.*

3. *Structural differences in paintings do not seem to alter the above results. The signal to noise ratios following volcanic eruptions are statistically significant.*
4. *When averaged in 50-year intervals, AODs from paintings in non-volcanic years agree with completely independent data sets with the observed increases of the industrial aerosol in the past 150 years.*
5. *R/G ratios calculated from different natural profiles such as from volcanic aerosols and Saharan mineral aerosols show very small differences. This explains how the experiment performed with an internationally known master colourist arrived at similar results with an increase in R/G ratios during the passage of a Sahara dust event.*
6. *Regardless of the school, red-to-green ratios from great masters can provide independent proxy AODs that correlate with widely accepted proxies and with independent measurements.*

The main conclusion of the paper is that nature speaks to the hearts and souls of the artists. When colouring sunsets the R/G ratios perceived by the brain contain important environmental information. It remains to an interdisciplinary community to study further the evidence presented in this research."

AR2, Comment #1:

"p33147 (Abstract) l16-18: Slight clarification needed for this sentence – the AOD value increases from 0.15 to 0.20 – rather than the increase in AOD being 0.15 to 0.20. (I think the increase in AOD is 0.05)."

Reply:

The clarification was addressed in the revised abstract. The text has been modified as follows:

"The increase of AOD at 550 nm calculated from the paintings grows from 0.15 in the middle 19^{th} century to about 0.20 by the end of the 20^{th} century".

AR2, Comment #2:

"p33149 (Section 2) I am unclear exactly how the paintings are sampled to obtain a red-to-green ratio. I guess only parts of the paintings are sampled? (i.e. just the sky, or just parts of the sky?) Or have I got this wrong and the whole painting is sampled? Please could you elaborate on the exact process, perhaps keeping in mind the principle that based on your description of the technique, anyone should be able to repeat your measurements and (hopefully) obtain the same results? Assuming that just parts of the painting are sampled, presumably this corresponds to many (thousands of?) pixels over the whole digital image. Is the R/G value reported just the mean of all these values? I wonder if the full range, or PDF, of values may also be interesting, even if only to add an error estimate on the R/G value?"

Reply:

The method of painting sampling and an analysis of the corresponding uncertainties is fully described in Zerefos et al. (2007). For the calculation of the R/G ratios we analysed only the parts of the sky over the field of view of the artist near the horizon trying to avoid areas covered by clouds. Then, we averaged the measured values. The average values and the standard deviation of R/G ratio for each painting were presented in Appendix B of Zerefos et al. (2007). In that study, we reported that the mean error value was 0.014 due to the variability of R/G ratios within the paintings/images. We also examined how that variability could affect the estimated AOD values for different aerosol conditions and solar zenith angles. The reported uncertainty was less than 0.05 for small optical depths and smaller SZA (70°). That number was comparable to the accuracy of other experiment measurements of AOD. The error however increased with increasing AOD and SZA (85°) and can be as large as 0.18 for AOD larger than 0.5. Instead of repeating the methodology in this paper too, the following sentence was added in the revised manuscript:

"The method of painting sampling and an analysis of the corresponding uncertainties is described in the study by Zerefos et al. (2007)."

AR2, Comment #3:

"p33150 l13 What is C.L.?"

Reply:

It is confidence level and it has been inserted in the revised manuscript.

AR2, Comment #4:

"p33151 l5 Digitization, rather than digitalization? (Maybe they are equivalent…)"

Reply:

Digitization is the correct word, it has been inserted in the revised manuscript.

AR2, Comment #5:

"p33151 (Section 3) What is the geographic spread of the painting locations, and is this important? I am guessing most if not all are from Europe. I appreciate that volcanic aerosol, at least from very large eruptions, is thought to spread globally or at least hemispherically, so maybe sampling only over Europe is not a significant bias. However you are also interpreting your results in terms of changes of tropospheric aerosol related

to industrialisation. Are you only really surveying AOD changes over Europe (or particular parts of Europe) with the data from the paintings?

Related to this point, the origin of the DVI values should be briefly described. Are they based on ice core data, or by other methods? In other words, it should be clarified if the comparison presented in Figure 4 is really comparing similar quantities, or should we perhaps expect (potentially important) differences due to the different methods employed in calculating each proxy? Are the indices (etc.) presented in Figure 4 considered global, or relating to one or other hemisphere?"

Reply:

This paper is based on evidence by mostly Western painters and colourists. The type of art is typical to Western European schools so it was inevitable to have more paintings in European countries. Nevertheless, the paper focuses on large volcanic eruptions that have an effect over the entire planetary atmosphere, so the evidence could be noticed in most parts of the world. In the revised text it is clearly mentioned that the method was used to calculate the average AOD value pertaining to these years corresponding to Northern Hemisphere mid latitudes. The DVI used in this work refers to the northern hemisphere, other are global.

Regarding the DVI, on Lamb's webpage at http://cdiac.ornl.gov/ndps/ndp013.html it is stated that:

"Lamb's Dust Veil Index (DVI) is a numerical index that quantifies the impact of a particular volcanic eruption's release of dust and aerosols over the years following the event, especially the impact on the Earth's energy balance. DVIs have been calculated for eruptions occurring from 1500 through 1983. The methods used to calculate the DVI have been intercalibrated to give a DVI of 1000 for the eruption of Krakatau in 1883. The DVI for any volcanic eruption is based on a review of the observational, empirical, and theoretical studies of the possible impact on climate of volcanic dust veils. The DVI allows one to compare volcanic eruptions by a single numerical index. The data base includes the name of the erupting volcano, year of eruption, volcano latitude and longitude, maximum extent of the dust veil, veil duration, DVI for the entire globe, DVI for the Northern Hemisphere, and DVI for the Southern Hemisphere."

AR2, Comment #6:

“p33152 l4 at -> from”

Reply:

It was corrected.

AR2, Comment #7:

“p33152 l17 ‘no major volcanic eruptions between 1900 and 1960’ – What about Santa Maria (1903) and Katmai (1912) – both VEI 6 according to your Table A2?”

Reply:

The following revised text has been added in Section 4:

“The point raised by Robertson et al. that there have been no major volcanic eruptions between 1900 and 1960, needs some clarification. Indeed in the list of major volcanic eruptions in the past 500 years (Appendix B after Ammann and Naveau, 2003; Robock, 2000), we can see that based on VEI two eruptions, Santa Maria (1903) and Katmai (1912) have been classified with VEI 6. However, VEI is known to be not a good index of stratospheric sulphate loading since it measures the explosivity of a volcano and not its stratospheric injection. A good example is the 1980 St. Helen’s eruption, with a VEI of 5 but no stratospheric or climatic impact (A. Robock, private communication). Stratospheric injection is important to ensure its global or hemispheric effects. From the above discussion it can be proposed that compared to the pre-industrial period, the industrial period shows higher painting-derived aerosol content, in agreement to what it is expected from literature (e.g., Neftel et al., 1985; Robock and Free, 1995; Robertson et al., 2001; Forster et al., 2007; Wild, 2012).”

AR2, Comment #8:

“p33152 l21 (and at least once elsewhere): IPCC recommends reference is made to individual chapters in its reports rather than the whole report, if possible.”

Reply:

It is Chapter 2, the following citation was corrected: Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D. W., Haywood, J., Lean, J., Lowe, D. C., Myhre, G., Nganga, J., Prinn, R., Raga, G., Schulz M., and Van Dorland, R., 2007: Changes in Atmospheric Constituents and in Radiative Forcing, In: Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment, Report of the Intergovernmental Panel on Climate Change, edited by: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor M., and Miller, H. L., Cambridge University Press, Cambridge, UK, New York, NY, USA, 996 pp., 2007.

AR2, Comment #9

"p33154 l6 Suggest delete 'the needs of'."

Reply:

The proposed change has been addressed in the revised manuscript.

AR2, Comment #10:

"p33155 (Section 5.2) Does dust explain all/most of the AOD? Presumably it is relatively straightforward to convert between dust column amount (in g/m2) and AOD. Couldn't you do this to confirm that dust is the aerosol?

Where was the instrument measuring AOD relative to the painter? (Presumably close by)."

Reply:

According to the AERONET values over Athens (the nearest station) the fraction of coarse aerosol particles is around 0.65 in June 19th and 0.4 in June 20th. However, the local pollution at Hydra is considered negligible. So, we can assume that the AOD values observed at Hydra, to their largest part, can be attributed to the presence of Saharan dust aerosol at least for June 19th, where the phenomenon is significant. We have changed Figure 6 to display AOD. The Figure caption has been revised to read:

“Figure 6. Dust optical (AOD) depth at 550 nm and 3000 m wind fields over Greece for the 19 and 20 June 2010, as simulated by the BSC/DREAM model (18:00 UTC). The greater area of Greece is indicated by a red-lined rectangular. The island of Hydra is on the centre of this shape”.

AR2, Comment #11:

“p33172 (Figure 6) I suggest zooming in a bit on the area of interest (i.e. the Eastern Mediterranean), and increasing the sensitivity of the colour scale for dust load (currently there is just a green blob over Greece at both times). Also indicate the location of Hydra?”

Reply:

In the revised figures, the greater area of Greece is indicated by a red-lined rectangular where the island of Hydra is in the centre. The movement to the east of the high AOD values is clearly seen both in the maps corroborated by the decline of AODs over Hydra.

Reply to Alan Robock further comments

Comment 2

Reply

Reference to the work of Gao et al. (2008) and Crowley and Unterman (2013) have been added in Figure 4 in the text, Table 1 and the references.

Comment 3

Reply

Figure 6 has been replaced to show isopleths of AOD.

Comments 4 and 5

Reply

Corrected

Comment 6

Reply

Has been taken into account as discussed before in the replies to AR1, Comment #8 and to AR2, Comment #7.

All changes made in the manuscript are highlighted with yellow colour

Further evidence of important environmental information content in red-to-green ratios as depicted in paintings by great masters

C. S. Zerefos[1,2], P. Tetsis[1], A. Kazantzidis[3], V. Amiridis[4], S. C. Zerefos[5], J. Luterbacher[6], K. Eleftheratos[7], E. Gerasopoulos[2,8], S. Kazadzis[8], and A. Papayannis[9]

[1] {Academy of Athens, Athens, Greece}

[2] {Navarino Environmental Observatory (N.E.O.), Messinia, Greece}

[3] {Laboratory of Atmospheric Physics, Physics Department, University of Patras, Greece}

[4] {Institute of Astronomy, Astrophysics, Space Application and Remote Sensing, National Observatory of Athens, Greece}

[5] {Hellenic Open University, Patras, Greece}

[6] {University of Giessen, Germany}

[7] {Faculty of Geology and Geoenvironment, University of Athens, Greece}

[8] {Institute of Environmental Research and Sustainable Development, National Observatory of Athens, Greece}

[9] {National Technical University of Athens, Athens, Greece}

Correspondence to: C. S. Zerefos (zerefos@geol.uoa.gr)

Abstract

We examine sunsets painted by famous artists as proxy information for the aerosol optical depth after major volcanic eruptions. Images derived from precision colour protocols applied to the paintings were compared to online images, and found that the latter, previously analysed, provide accurate information. Aerosol optical depths (AODs) at 550 nm, corresponding to Northern Hemisphere middle latitudes, calculated by introducing red-to-green (R/G) ratios from a large number of paintings to a radiative transfer model, were significantly correlated with independent proxies from stratospheric AOD and optical extinction data, the dust veil index, and ice core volcanic indices. AODs calculated from paintings were grouped into 50-year intervals from 1500 to 2000. The year of each eruption and the 3 following years were defined as "volcanic". The remaining "non-volcanic" years were used to provide additional evidence of a multidecadal increase in the atmospheric optical depths during the industrial "revolution". The increase of AOD at 550 nm calculated from the paintings grows from 0.15 in the middle 19th century to about 0.20 by the end of the 20th century. To corroborate our findings, an experiment was designed in which a master painter/colourist painted successive sunsets during and after the passage of Saharan aerosols over the island of Hydra in Greece. Independent solar radiometric measurements confirmed that the master colourist's R/G ratios which were used to model his AODs, matched the AOD values measured in situ by co-located sun photometers during the declining phase of the Saharan aerosol. An independent experiment was performed to understand the difference between R/G ratios calculated from a typical volcanic aerosol and those measured from the mineral aerosol during the Hydra experiment. It was found that the differences in terms of R/G ratios were small, ranging between -2.6% and +1.6%. Also, when analysing different parts of cloudless skies of paintings following major volcanic eruptions, any structural differences seen in the paintings had not altered the results discussed above. However, a detailed study on all possible sources of uncertainties involved (such as the impact of clouds on R/G ratios) still needs to be studied. Because of the large number of paintings studied we tentatively propose the conclusion that regardless of the school, red-to-green ratios from great masters can provide independent proxy AODs that correlate with widely accepted proxies and with independent measurements.

1 Introduction

In the paper by Zerefos et al. (2007), the monochromatic ratios between red, green and blue colours, in paintings before, during and after large volcanic eruptions were examined. In that study, digital images from 554 paintings were downloaded from the websites of several art galleries and museums. These images were processed to derive ratios between the intensities of monochromatic colours. For the calculation of the R/G ratios only the parts of the sky over the field of view of the artist near the horizon avoiding clouds were analysed. The average values and the standard deviation of R/G ratio for each painting were presented in Appendix B of Zerefos et al. (2007). In that study, the mean error value was 0.014 due to the variability of R/G ratios within the paintings/images. That variability and how it could affect the estimated AOD values for different aerosol conditions and solar zenith angles was examined. The uncertainty found was less than 0.05 for small optical depths and smaller SZA (70°). The error increased with increasing AOD and SZA (85°) and could be as large as 0.18 for AOD values exceeding 0.5. The study by Zerefos et al. (2007) concluded that regardless of the school or the style of the painter, the R/G ratios at low solar elevation angles, correlated well to the modelled aerosol optical depth (AOD) values, following large volcanic eruptions. After its publication we were faced with the dilemma that the various digital images available at the above-mentioned websites were not necessarily accurate representations of the true colour profile reproduction, because they were not created following a single colour profile protocol and thus, we decided to revisit the issue.

In this work we provide new evidence that our earlier results, based on R/G ratios to estimate and model AODs in paintings are robust, a hypothesis which is supported using the following three methods: Firstly, by correlating the available R/G ratios from the above-mentioned public websites with the same ratios from their respective high quality colour profile protocols. A colour profile protocol is the protocol (set of instructions) used to accurately translate colour through different devices. In our work a colour profile was absolutely necessary so that the scanned paintings retained their original colour information when distributed through digital means. Also by having the colour profile along with calibrated scanners it was possible to compare paintings from other colourists without any uncertainty by differences due to colour translation. Secondly, by comparing our earlier results of AODs based on art, with results and indices from other proxies (ice cores, pyrheliometric and other data) which cover the past 500 years (Lamb, 1970, 1977, 1983; Sato et al., 1993; Stothers, 1996, 2001; Robertson et al., 2001; Gao et al., 2008 and Crowley and Unterman, 2013). Thirdly, by performing an experiment involving the creation of sunset paintings and then measuring the ratios of the art piece with collocated AOD measurements actually recorded in the atmosphere during and after the passage of a Saharan dust event. More specifically, we have organized an experimental campaign where Panayiotis Tetsis[1] (a well-known Greek landscape painter and colourist) painted the sunsets at the Hydra island in the Aegean Sea, during and after the passage of a Saharan dust event on the 19 and 20 June 2010. During the creation of the paintings, we performed simultaneous measurements of the evolution of the observed AODs and the actual meteorological conditions were carefully monitored. The results from these three methods are described below.

2 Comparison between high and low quality digital images of paintings

As mentioned in the introduction, in an earlier study (Zerefos et al., 2007) the vast majority of images were analysed from museum web sites which were not created following a rigorous colour profile protocol. The method of painting sampling and an analysis of the corresponding uncertainties is described in the study by Zerefos et al. (2007). Since it was not possible to obtain high quality images of paintings from all galleries, we focus here on the subset kept at the Tate Gallery in the United Kingdom (UK). At this gallery we found 124 digital images of paintings (with a 300dpi resolution, RGB, 8-bit compressed jpeg format files) which were also analysed in our earlier work (listed in Appendix A).

Fig. 1 shows the results of the R/G values retrieved from these high quality images in comparison to the ratios (calculated for the same paintings) from the website images, using the same methodology, as described in Zerefos et al. (2007). As can be seen from Fig. 1, the difference of the R/G values between the lower and higher resolution digital images stays within ±4% for almost all paintings. Very few exceptions with overestimations correspond to solar zenith angles exceeding 90 degrees.

This result is clearly seen in Fig. 2 which shows the percent distribution of the relative differences between the R/G ratios derived from the high versus the low resolution 124 images from the Tate Gallery.

Additionally, an independent sample of 186 landscape paintings of high quality/resolution (10000 X 10000 pixel images), covering the 1500-1900 time-period, obtained from the National Gallery, London, calibrated using the Gretag Macbeth 24-patch colour rendition chart (Saunders et al., 2002 and McCamy et al., 1976). None of these paintings has been studied in our earlier study because they did not fulfil the selection criteria set for, i.e.,

[1] http://www.wikipaintings.org/en/panayiotis-tetsis

representing sunsets and the possibility for direct or indirect measurements through clear shades, to facilitate the estimate of solar zenith angle, pertaining to each painting.

The high quality/resolution images obtained directly from the National Gallery, were next compared to their corresponding low quality/resolution images obtained from the website (http://www.nationalgallery.org.uk/cgi-bin/WebObjects.dll/CollectionPublisher), to test further the results obtained from the Tate Gallery comparisons shown in Figs. 1 and 2.

The retrieved R/G values of these images are shown in Fig. 3, from which we see that on the average, the R/G values are overestimated by 0.04±0.08. This result is in agreement with the results from the Tate Gallery sample of paintings and a tentative result is that the overestimation is larger (up to 0.3) deviating from the linear fit for the higher R/G values. At any rate, the correlation coefficients are still highly significant (99% confidence level). It should be noted here that all images in this study were processed with the "nip2" software (e.g., http://www.vips.ecs.soton.ac.uk/index.php?title=Nip2) which comfortably works with multi-gigabyte images. A special work script has been created in order to calculate the average R/G values of the sky from each painting, as derived from the low and high quality/resolution images.

3 Other factors that might affect the R/G ratios from paintings

When trying to estimate a number that would describe the true colour at given solar zenith angle during a sunset, there are several factors that are important sources of uncertainty. Among them included are the coatings, the degradation of colour due to ageing, the unknown systematic practices used by the painters, the mood of the painter and the different styles of schools. However, we have to keep in mind that the earlier and present findings, of a relation between high aerosol content at sunsets, were **not based on true colours** but **confined only to the case of the R/G ratios**. The different factors affecting the true colours mentioned above, being either random or systematic, may also affect the R/G ratios. Although this may be true for an individual painting, the statistics presented here show that when a large number of paintings by different painters are considered, these uncertainties could be much reduced. This is supported by the signal to noise ratio analysis of the statistical standard errors discussed in the introduction and in Zerefos et al. (2007). In addition, we have searched for a possible impact of structural differences. We provide here examples of paintings with and without structural differences following two major volcanic eruptions namely Tambora (1815) and Krakatau (1883). The calculated R/G ratios in parts of the sky give a similar result in which the differences are small, anyhow smaller than the standard errors we have encountered in this work (see paintings in Appendix C). Therefore, we have to tentatively assume that the impact of structural differences when studying R/G ratios in parts of the sky of the painting are small. We note here that we have made any possible effort to avoid measuring R/G ratios in the presence of clouds. It appears that R/G ratios as measured in this work somehow remind us on the ratios of solar irradiance in different wavelengths which are used in spectrophotometers to measure columnar gases in the atmosphere. In these spectroradiometers the noise introduced by aerosols and other factors related to scattering and related effects are indeed cancelled out and this is how we obtained the long series of total ozone, total sulphur dioxide, total nitrogen dioxide with remarkably small standard error. We think that the reduction of errors when using R/G ratios provides useful information on the overhead aerosol content which correlates well when averaged with other proxies and/or with real AOD measurements as was the case with the Hydra experiment, discussed in paragraph 5.

In our study, a detailed quantification of each source of uncertainty was not possible except for the effects of quality in digitization of the paintings, structural differences and the solar zenith angle. Potential sources of uncertainty could be the atmospheric/aerosol related dynamics which affect the magnitude of the impact of each volcano in the area under study (of the painter) as well as the impact of cloudiness on the depicted R/G. Any effects from clouds we think have been avoided by trying to confine our R/G "measurements" to the cloudless parts of the sky in each painting. Following the above discussion and since our goal in this part of the manuscript was focused on the validation of the volcanic eruption effect and not on the actual quantification of the volcanic aerosol in the painting area, we believe that correlation coefficients with the mentioned proxies provide evidence that this goal has been achieved.

4 Atmospheric optical depths based on known proxies and on R/G ratios of paintings in the past 500 years

The earlier estimates of the aerosol optical depth at 550 nm (based on R/G calibrated ratios from paintings) and the radiative transfer model by Mayer and Kylling (2005) and Mayer and Emde (2007), were used to compile an independent time series with AODs during 1500-2000. Additionally, the time series of AODs calculated from paintings has been divided into 50-yr intervals from 1500 to 2000. The year of each eruption and the 3 following years were defined as "volcanic". The remaining "non-volcanic" years were used to calculate the average AOD value pertaining to these years corresponding to Northern Hemisphere mid latitudes. This paper is based on evidence by Western painters and colourists. The type of art is typical to Western European schools so it was inevitable to have more paintings in European countries. Nevertheless, the paper focuses on big volcanic eruptions that have an effect over the entire planet atmosphere, so the evidence could be noticed in most parts of the world. This long term data set of AODs is compared to other independent proxies as shown in Figure 4. Detailed information on those proxies can be found in the primary literature by Lamb (1970, 1977, 1983), Sato et al. (1993), Stothers (1996, 2001), Robertson et al. (2001), Gao et al. (2008) and Crowley and Unterman (2013). Using the data shown in Figure 4 we found that the correlation coefficients between other proxy indices and the estimated AODs from the R/G ratios from paintings are statistically significant (Table 1). Appendix D presents the data used in the calculations shown in Table 1. The reader is also referred to the precision by which the extreme AODs between paintings and proxies during large volcanic eruptions match in most cases. In particular, in 102 cases for which data of both DVI and this study are simultaneously available, DVI spikes are coinciding to AOD spikes from this study at a percentage of 80% (9 out of 11 cases). As spikes we define the values in both time series that belong in the upper 10% range of values. In addition, this study revealed two high AOD cases that do not match with DVI spikes and it is worth noting that both failing cases succeeded a period of two consecutive years with spikes in both indices.

Total sulphate is the total measured sulphate concentration in ppb in the core, as resulted from deposition either from the stratosphere (volcanic) or the troposphere (anthropogenic and other biogenic sources), as described by Zielinski et al. (1996) and Robertson et al. (2001). The presented values do not refer directly to the atmospheric concentration, but rather to the deposition on ice which however is related to ambient concentrations. The values of calculated index of total sulphate from Greenland ice cores (Zielinski, 1995; Zielinski et al., 1996) and the longer time series of stratospheric AOD (Robertson et al., 2001) were grouped in 50-year time intervals with the same procedure described above for AODs calculated from paintings. The three datasets are presented in Fig. 5. We note here the point raised by Robertson et al. (2001) that the last 150 years increase in total sulphate from ice core was hypothesized to be the result of tropospheric anthropogenic sulphate deposition. The point raised by Robertson et al. that there have been no major volcanic eruptions between 1900 and

1960, needs some clarification. Indeed in the list of major volcanic eruptions in the past 500 years (Appendix B after Ammann and Naveau, 2003; Robock, 2000), we can see that based on VEI two eruptions, Santa Maria (1903) and Katmai (1912) have been classified with VEI 6. However, VEI is known to be not a good index of stratospheric sulphate loading since it measures the explosivity of a volcano and not its stratospheric injection. A good example is the 1980 St. Helen's eruption, with a VEI of 5 but no stratospheric or climatic impact (A. Robock, private communication). Stratospheric injection is important to ensure its global or hemispheric effects. From the above discussion it can be proposed that compared to the pre-industrial period, the industrial period shows higher painting-derived aerosol content, in agreement to what it is expected from literature (e.g., Neftel et al., 1985; Robock and Free, 1995; Robertson et al., 2001; Forster et al., 2007; Wild, 2012).

5 A live case: The Hydra experiment

To corroborate our findings, a dedicated experimental campaign has been organized and implemented in Greece, aiming to evaluate the R/G retrieval methodology against ground-truth measurements of the aerosol load in terms of AOD values. The well-known colourist and landscape painter Panayiotis Tetsis (http://www.wikipaintings.org/en/panayiotis-tetsis) kindly offered to paint in real-time a number of sunsets at the island of Hydra. As the great master was painting, a suite of ground-based aerosol measurements has been collected, mainly by means of collocated sun photometry equipment. The master colourist had no idea of the passage of a Saharan dust cloud over Hydra.

5.1 Experiment organization and instrumentation

The experiment was conducted in Hydra, the painter's home base. Hydra is an island located in the Aegean Sea (37.21^{o} N, 23.28^{o} E), 80 km south of Athens, and has a population of about 2000 inhabitants. The size of the island satisfies the main requirement for negligible local aerosol emissions (cars are not allowed in the island). Apart from sea spray particles, that constitute the background aerosol component around the island, the only case of regional pollution influence is under northerly winds when the island is within the outflow of pollution from Athens. In the case of winds from southerly directions, most of the Athenian sources of aerosols do not reach Hydra island.

For the design of the experiment, paintings and measurements during relatively low and high AOD cases was the main goal. According to Gerasopoulos et al. (2011), the typical background AOD for the area is 0.12-0.13 corresponding to long and fast trajectories from westerly to northerly directions, with origin from high altitudes over the Atlantic. Higher aerosol loading over the area is related to the advection of dust particles from desert and arid locations of North Africa and is in the AOD range of 0.3-0.4. The most frequent season for dust outbreaks over the Eastern Mediterranean is well documented to be in late spring (e.g., Kalivitis et al., 2007; Gerasopoulos et al., 2011) and early summer (the latter mostly as elevated dust layers; Papayannis et al., 2008).

For the selection of the experiment days, a regional model designed to simulate and forecast the atmospheric cycle of mineral dust aerosol over the campaign site was deployed. In particular, forecasts from the BSC-DREAM8b dust regional model were used (Nickovic et al., 2001) and the period finally selected to combine an AOD episode followed by clean conditions and the painter's availability was 19-20 June 2010.

The instrumentation used for the campaign, included a Multi-Filter Rotating shadowband radiometer (MFR-7 Yankee Env. System Inc., Turner Falls, MA) and a Microtops II sunphotometer (Solar Light Inc., Philadelphia, USA). The MFR-7 installed at Hydra was used to perform measurements of the total and diffuse solar irradiance to calculate the direct component of the irradiance (Harrison et al., 1994). MFR-7 provided 1-min average measurements and from these the AOD values at 500 nm was extracted. The instrument performs valid measurements during daytime and under clear sky conditions. The methodology followed for the extraction of the AOD values from direct solar irradiance is thoroughly described in Gerasopoulos et al. (2003). The calibrated hand-held sunphotometer (Microtops II) was used to provide the AOD at 1020 nm, at 10-min intervals.

5.2 Experimental Results and discussion

As mentioned, the experiment took place in Hydra on 19 and 20 June 2010. During the campaign, a Saharan dust event passed over Greece (18 – 21 June 2010). On these two dates master Tetsis created two successive paintings; before and during sunset on the 19 and two additional paintings at sunset on the next day, the 20th of June 2010. Although the typical size and vertical profile of the Saharan aerosols differ from the volcanic ones, their effect on solar irradiance and R/G close to sunset was proved to be significant because of their relative high values of AOD (~0.25 at 500nm). The Tetsis experiment has initially started as an experiment dedicated to investigate if AOD's can be calculated from such a live study. During the two day experiment the substantial difference of the aerosol condition between the first and the second day provided a more adequate dataset, supporting the assumption that a painter is able to reproduce such an aerosol change. Quantitatively it has been proven that this assumption was **correct**, as analysed in the following. In the next paragraph it will be shown that the Saharan dust outbreak of the 19 June has been found to affect the R/G ratios of Tetsis' paintings.

The results from the BSC-DREAM8b model simulations of the space and time evolution of the columnar dust loading for the campaign days (19 and 20 June,) are shown in Fig. 6, as isopleths of AODs. Additionally, the wind fields at 3000 m heights are superimposed, showing clearly a southwestern flow affecting the site in both campaign days. No precipitation or cloudiness prevailed over Greece during the campaign period (Fig. 6 – upper panel), also corroborated by MODIS satellite images (not shown here). A massive transport of dust from Saharan desert was observed on the 19 June over Greece and western Turkey, while on June 20 the centre of the dust plume moved to the east and spread and declined (Fig. 6 – lower panel). Following the BSC-DREAM8b simulations, the dust load reached maximum columnar concentration values of the order of 0.75 g/m^2 over the Hydra site on the 19th June.

The model simulations agree with real-time measurements, as shown in Figure 7 by the time evolution of the observed AOD values on site for 19 and 20 June, measured with MFR-7 and Microtops. As stated before, the local pollution at Hydra is considered negligible and under southerly flows urban pollution from Athens does not reach the island. The meteorological conditions prevailing during both days (at sunset hours) were similar, namely temperatures between 28 and 30°C (slightly higher on the second day) relative humidity between about 45 and 60%, and calm wind conditions (1-2 m/s). The AOD values observed at Hydra, to their largest part, can be attributed to the presence of the Saharan dust aerosol and follow the temporal evolution depicted by the dust simulations shown in Fig. 6, from which we see higher AOD values on 19 June and lower on the next day at Hydra. The temporal decay is profound also in the Microtops measurements at 1020 nm, performed at Hydra and shown also in Fig. 7.

Sunphotometric measurements are a trustworthy source for identifying the Saharan dust presence, for which we expect higher AOD values and lower spectral dependences between the multi-wavelength AOD retrievals. This is clearly seen in the data presented in Figure 7, where higher AODs for 19 June are accompanied with lower spectral dependences between the 500 and 1020 nm channels. Moreover, the respective Ångström exponents were on average 0.4 on the first day, indicative of coarse dust aerosols and in the range 0.7-1.0 on the second day, representing a mixture of sea salt particles with low loadings of continental aerosols (see Gerasopoulos et al., 2011, for indicative ranges of Ångström exponents in the area).

Acknowledging the good performance of BSC-DREAM8b model for the days of our campaign, we present in Figure 8 the simulations of the vertical distribution of Saharan dust concentrations over the area for 19 and 20 June 2010. As can be seen from that Figure, large dust concentrations in the lowest one kilometre were observed on the 19 of June, while on the next day the dust concentrations declined significantly, in the boundary layer and in the column as well. We focus mainly on the aerosol load in the planetary boundary layer since this is expected to impact mostly the painter's perception during the late afternoon hours. It is evident that the dust concentrations within the first kilometre are four (4) times higher on 19th of June than those simulated on June the 20th.

Figure 9 shows the temporal evolution of the MFR-7 AOD values at 550 nm during the two days of the campaign together with the R/G ratios from a digital camera on site and from the high precision digital images (produced by National Gallery, London, with the methodology described in paragraph 2) of Tetsis paintings (Fig. 10) for the two sunset cases (high aerosol and low aerosol over Hydra). The paintings were transported to the National Gallery where the digital protocol analysis was done. On 19 June 2010 (Fig. 9, upper panel), the estimated AOD differences between the paintings and the closest time digital photos is ±0.02. However, a bias of about 30% is revealed between these and the MFR measurements on the day of the Saharan dust event. In all three types of measurements/estimations, the variability of AOD with time shows a negative trend as we move from June 19 to the evening of June 20. On 20 June 2010, the agreement between the digitally-derived and the measured AOD values is substantially improved: differences as small as 0.02 can be found. The measured decrease of the AOD values is also successfully represented by the digital estimations. Under each painting a digital photograph at the centre of the time interval it took to paint each painting is displayed for comparison.

Finally, a comparison between the impact of mineral aerosol (Saharan dust) and the impact of a typical volcanic aerosol in terms of RGB is also attempted. The mineral aerosol during the

Hydra experiment at 500nm was measured to vary close to 0.25. Therefore we have made model runs with the volcanic aerosol setting the volcanic AOD case at 500nm equal to 0.25 also. Note here that the mean volcanic AOD (500nm) in our paintings is very close to that number and equals to 0.22. Figure 11 shows the percent difference in R/G ratios between the ones measured at Hydra Saharan dust aerosol profile and a typical modelled volcanic aerosol profile as was used previously in this work. In both cases AOD (500nm) was set to 0.25. The ratios are shown as isopleths in a graph where the position of the sun is fixed at 80^o solar zenith angle. It was quite surprising to see that although both the nature, size and the vertical profiles of the Saharan and the volcanic aerosols differ, their effect on R/G overhead ratios in the sky induce so small a difference ranging from a minimum of -2.6% to a maximum +1.6%, depending on the solar zenith angle and the angle relative to the position of the sun.

6 Conclusions

Understanding the atmospheric composition of the past centuries is a very difficult task due to scarcity of available measurements. Especially for atmospheric components such as aerosols and their variability over the past 500 years, relevant information is rare (Thornes and Constable, 1999; Grattan, 2006; Zerefos et al., 2007). In this work we have expanded the idea of Zerefos et al., 2007, that used an alternative and indirect way of using the Ångström's law of atmospheric physics that describes the different effect of aerosols on the different wavelengths (colours) of solar light, together with the use of an alternative "database of solar light representations", calculated from paintings by great masters in the past centuries.

At first, a series of paintings by master painters (in the period of 1500-2000) have been revisited and comparisons between digital images of paintings from lower resolution versus high resolution, derived from high precision protocols, showed similar results, as far as the R/G ratios measured at sunsets are concerned. Statistically significant correlation coefficients were found between the R/G ratio values retrieved from low quality/resolution and high quality/resolution digital images at a sample of 124 landscape paintings from the Tate Gallery. The earlier estimates of the aerosol optical depth at 550 nm (based on R/G calibrated ratios from paintings) and the radiative transfer model by Mayer and Kylling (2005) and Mayer and Emde (2007), were used to compile an independent time series with AODs during 1500-2000. The correlation coefficients between other proxy indices and the estimated AODs from the

R/G ratios from paintings are statistically significant. Also the precision by which the extreme AODs between paintings and proxies, during large volcanic eruptions, match in most cases.

The comparison between 50-year averages of the AODs (from R/G paintings) with the total sulphate in ice core and the stratospheric AOD, from which the year of known large volcanic eruptions and the three years that followed were excluded, shows that compared to the pre-industrial period, the industrial period had higher aerosol content, as it is well known and expected from independent datasets in the literature (e.g., Neftel et al., 1985; Robock and Free, 1995; Robertson et al., 2001; Forster et al., 2007). Based on the information retrieved from the paintings studied, we estimated this increase to range from 0.15 (middle 19th century) to about 0.20 (by the end of the 20th century).

Finally, to corroborate our findings, an experiment was designed in which a master painter/colourist painted successive sunsets during the passage of Saharan dust outbreak over our experimental site (island of Hydra, Greece) on June 19 and 20, 2010. The master painter did not know anything about the passage of a Saharan dust event. Our independent sunphotometric measurements at Hydra confirmed that the calculated AOD values from R/G ratios measured in the master colourist paintings, matched quite well to the AOD values measured in situ as well as with measurements from a digital camera. It should be noted here that all four watercolours by Panayiotis Tetsis were digitized using the same procedures and standards applied to all works of art photographed by the Photographic Department of the National Gallery, London. These findings point to the conclusion that the experiment provides a new presentation of how a painter, a digital camera and scientific instruments capture changes in R/G ratios at high and low aerosol overhead cases.

The new information in the paper can be summarized as follows:

7. The comparison of high precision with low precision colour protocol images at independent samples of paintings from the Tate and the National Galleries in London strengthen the tentative results proposed in an earlier paper by Zerefos et al. (2007).
8. AODs from a multi-hundred sample of paintings show statistically significant correlations with independent proxies.
9. Structural differences in paintings do not seem to alter the above results. The signal to noise ratios following volcanic eruptions are statistically significant.

10. When averaged in 50-year intervals, AODs from paintings in non-volcanic years agree with completely independent data sets with the observed increases of the industrial aerosol in the past 150 years.
11. R/G ratios calculated from different natural profiles such as from volcanic aerosols and Saharan mineral aerosols show very small differences. This explains how the experiment performed with an internationally known master colourist arrived at similar results with an increase in R/G ratios during the passage of a Saharan dust event.
12. Regardless of the school, red-to-green ratios from great masters can provide independent proxy AODs that correlate with widely accepted proxies and with independent measurements.

The main conclusion of the paper is that nature speaks to the hearts and souls of the artists. When colouring sunsets the R/G ratios perceived by the brain contain important environmental information. It remains to an interdisciplinary community to study further the evidence presented in this research.

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Table 1. Correlation coefficients between volcanic aerosol indices and AOD proxies shown in Fig. 4.

1500-2000	**DVI**	**AOD** (this study)	**AOD** (Robertson)	**AOD** (Crowley and Unterman)	**AOD** (Sato)	**AOD** (Stothers)	**Sulphate** (Gao)
DVI	1						
AOD (this study)	**0.85** [102]	1					
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	
Sulphate (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.

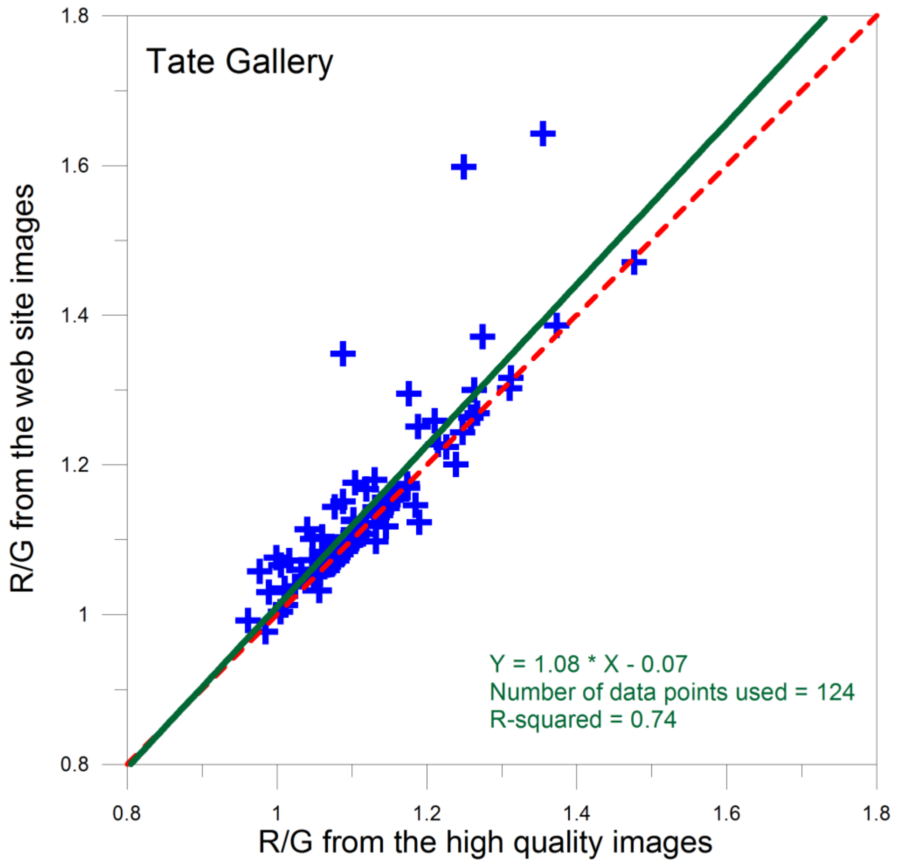


Figure 1. R/G ratios derived from painting digital images from web site (low resolution) versus R/G ratios for the same paintings obtained through colour profile protocol (high resolution) at the Tate Gallery. The corresponding linear best fit (green line) and the perfect correlation line (dashed red line) are also shown. The values correspond to the 124 landscape paintings listed in Appendix A.

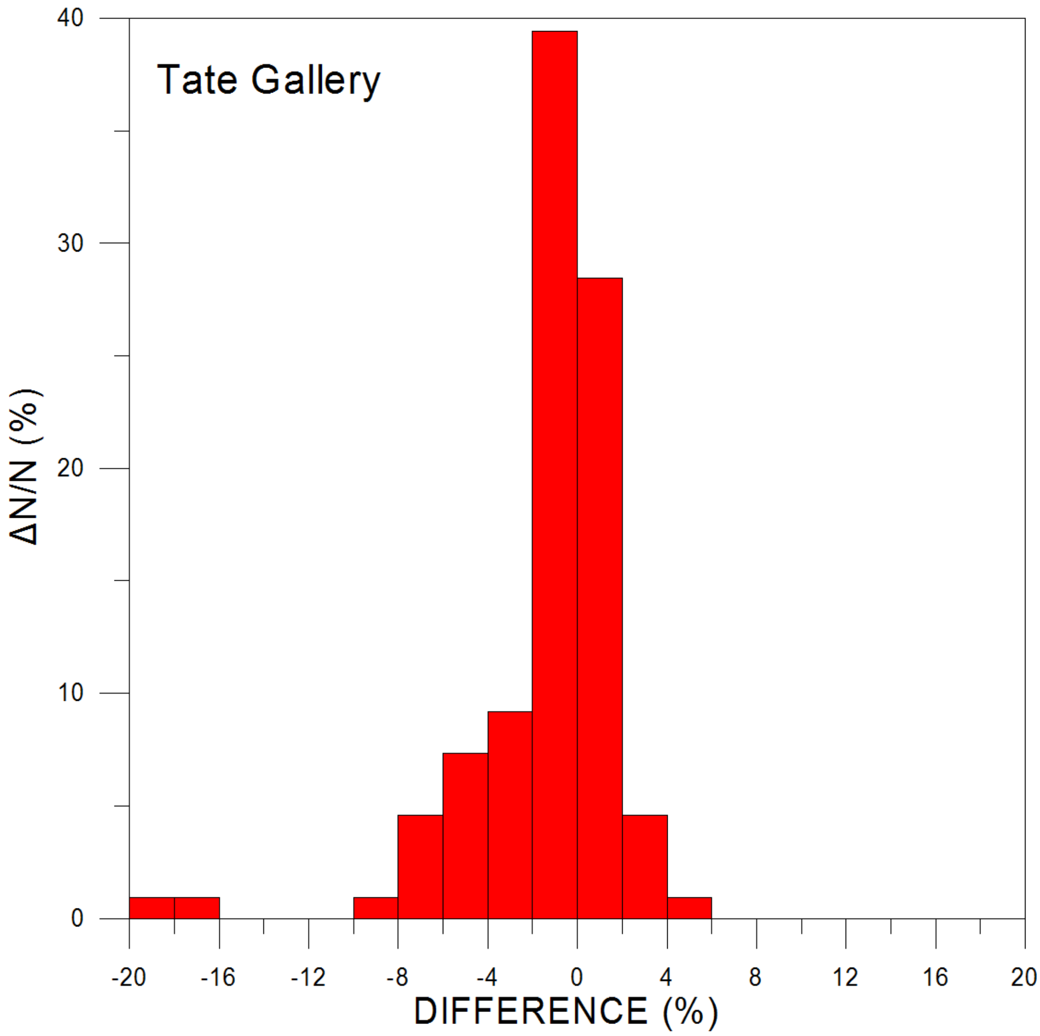


Figure 2. Distribution of the relative differences (in %) between the R/G ratios derived from the high and the low resolution images from 124 landscape sunsets at the Tate Gallery (listed in Appendix A).

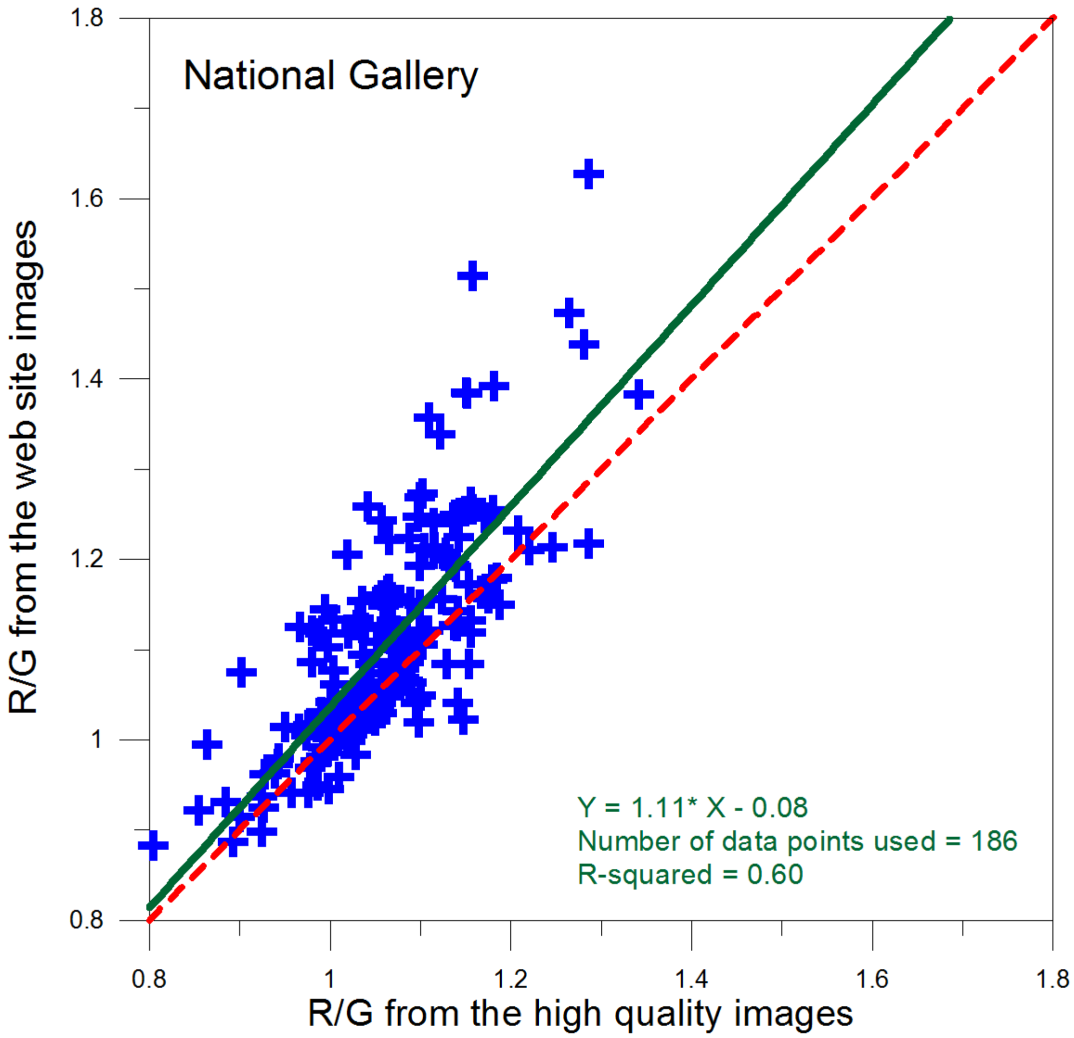


Figure 3. Results from a completely independent sample of paintings. R/G ratios derived from painting digital images from the web site (low resolution) versus the same R/G ratios from high resolution digital images at the National Gallery, London. The corresponding linear fit (green line) and the $y = x$ line (dashed red line) are also shown. The values correspond to 186 landscape paintings, which were not used in the early study by Zerefos et al. (2007), as described in the text.

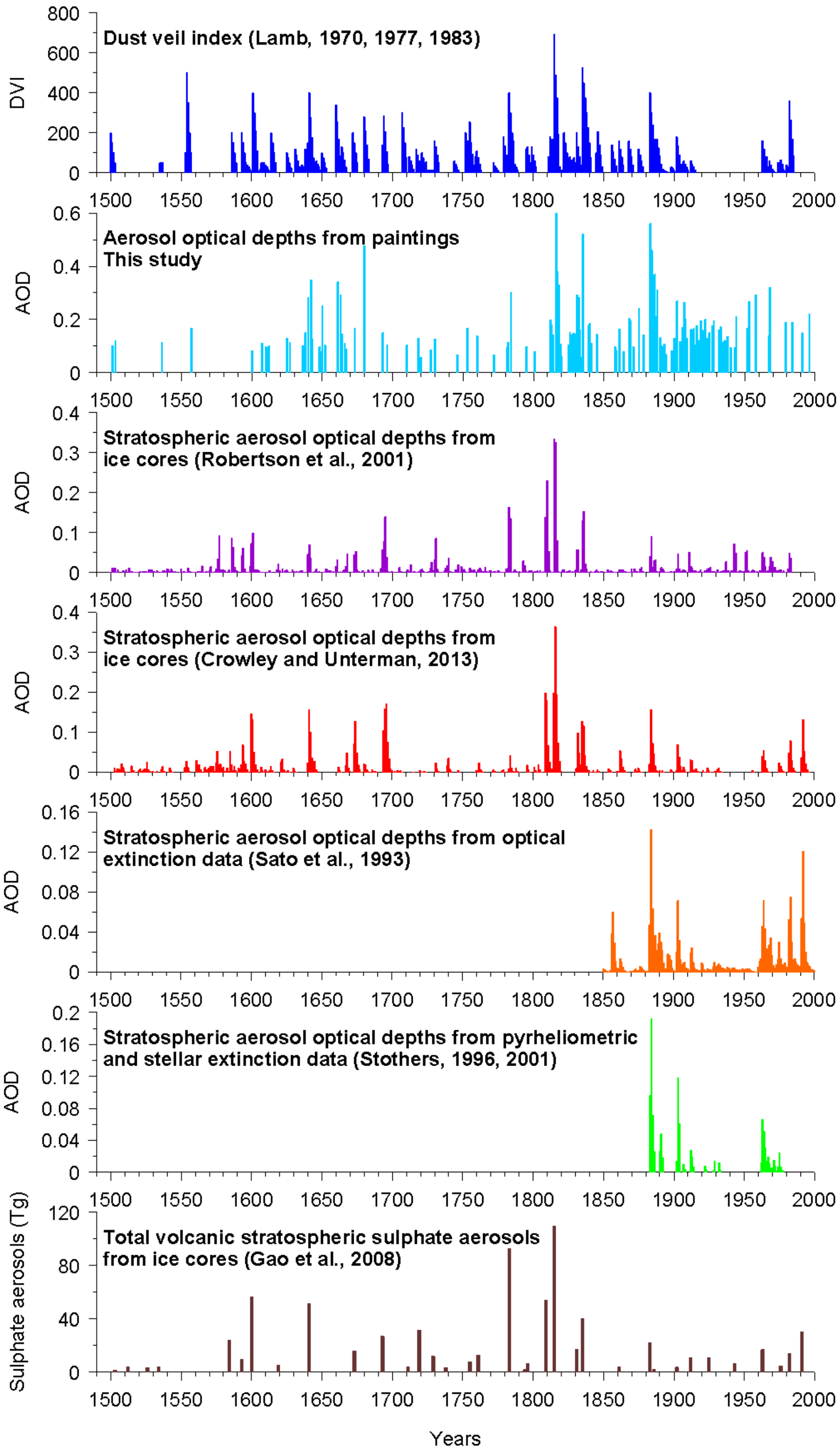


Figure 4. Aerosol optical depth and other proxy indices during the past 500 years from different proxies (see text).

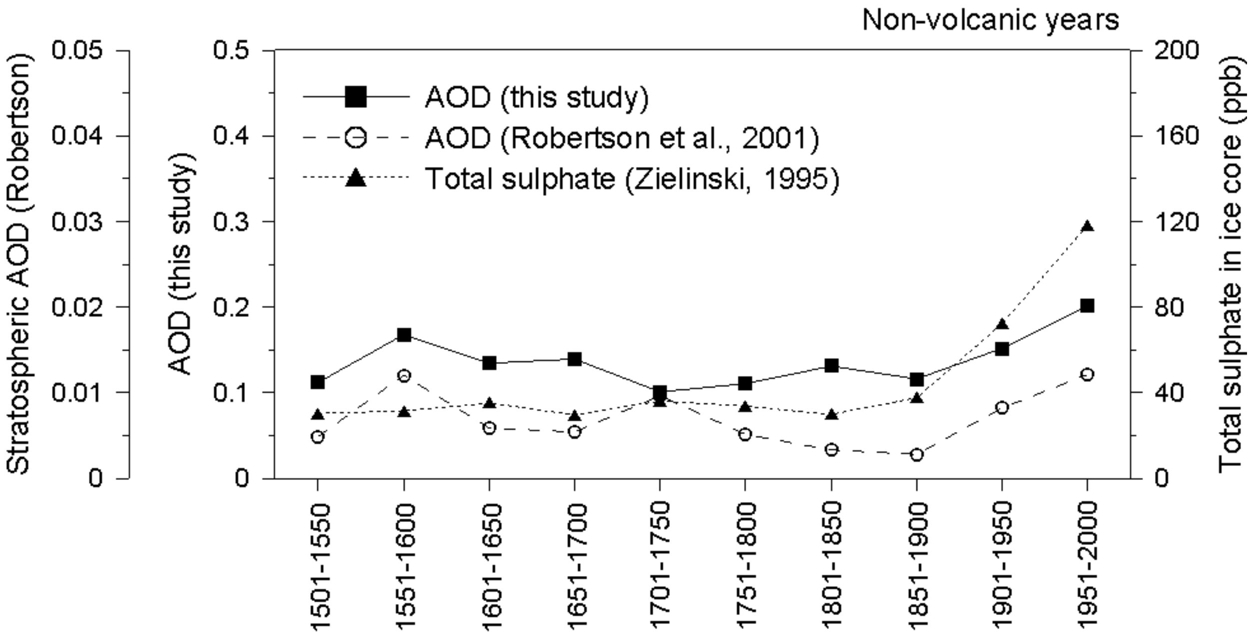


Figure 5. Total AOD from paintings and in the stratosphere and total sulphate in Greenland ice core (in ppb) averaged over 50-year intervals for ‘non-volcanic’ years during the period 1500-2000 A.D.

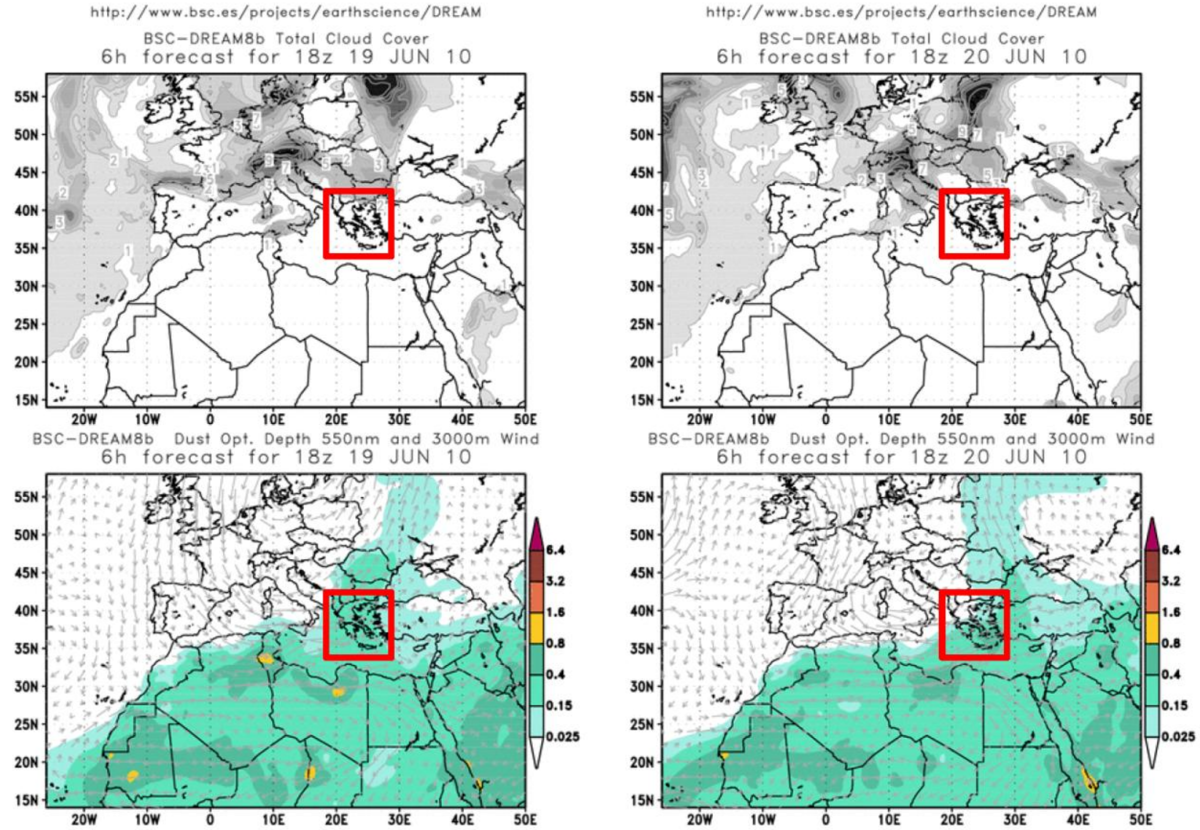


Figure 6. Dust optical (AOD) depth at 550 nm and 3000 m wind fields over Greece for the 19 and 20 June 2010, as simulated by the BSC/DREAM model (18:00 UTC). The greater area of Greece is indicated by a red-lined rectangular. The island of Hydra is on the centre of this shape.

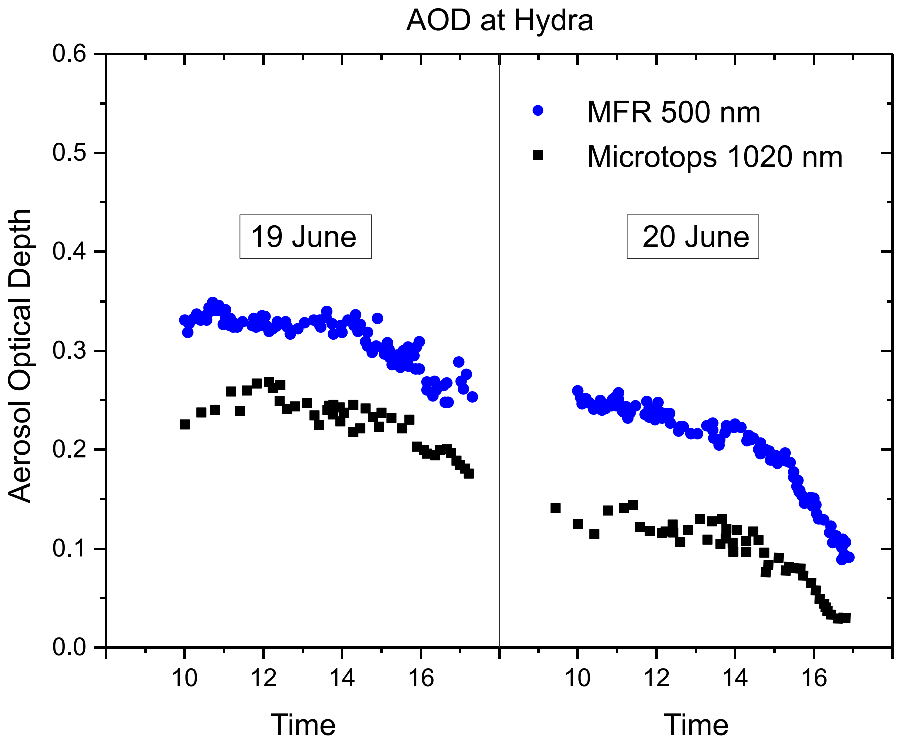


Figure 7. MFR-7 AOD retrievals at 500 nm on 19 and 20 June 2010 at Hydra campaign site. Microtops II AOD retrievals at 1020 nm are superimposed.

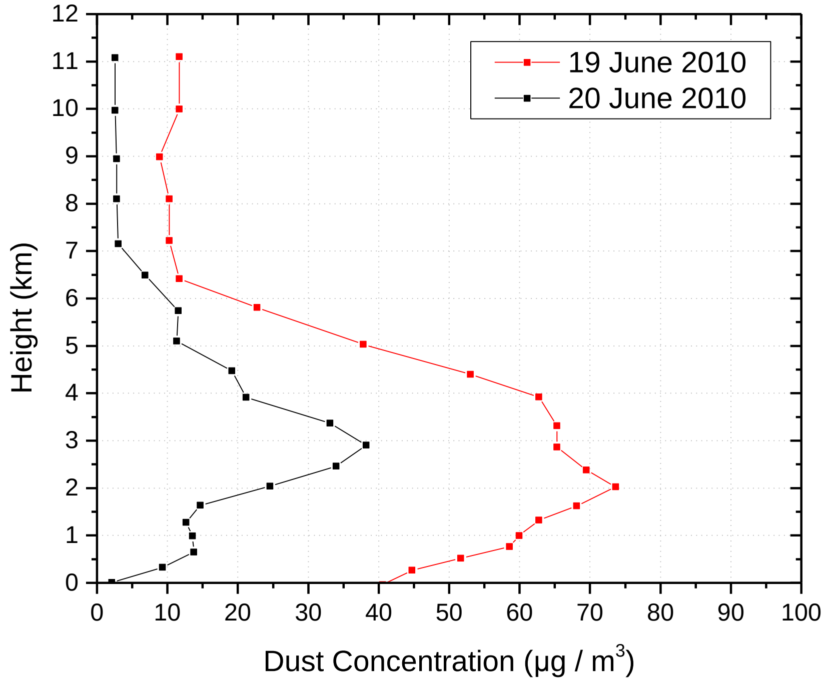
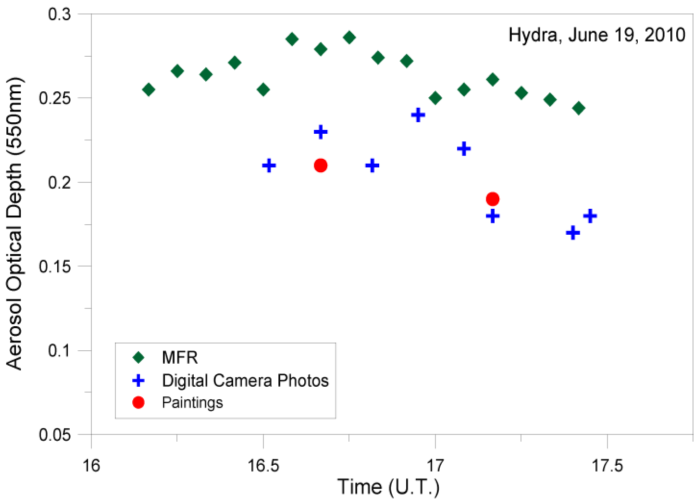


Figure 8. Vertical distribution of Saharan dust concentration loading (μg/m^3) for the 19 and 20 June 2010, as simulated by the BSC/DREAM model (18:00 UTC).



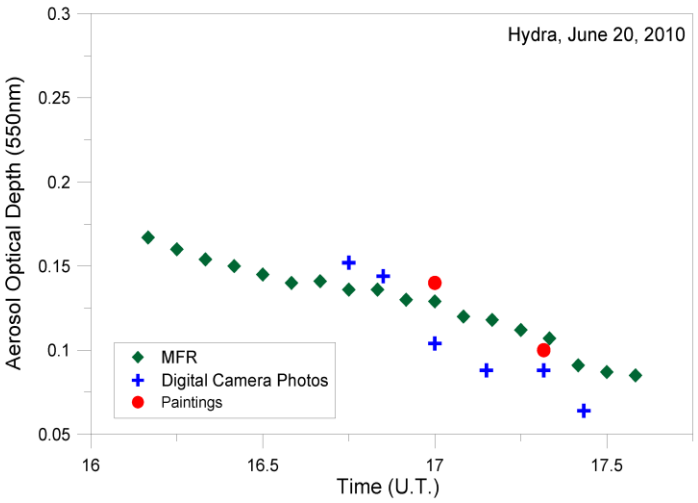


Figure 9. The AOD values from the MFR measurements, the estimations from the digital images and the calculations from R/G ratios of the Hydra sunset paintings for 19 June (left panel, higher aerosol content) and on the 20th of June 2010 (right panel, lower aerosol content).

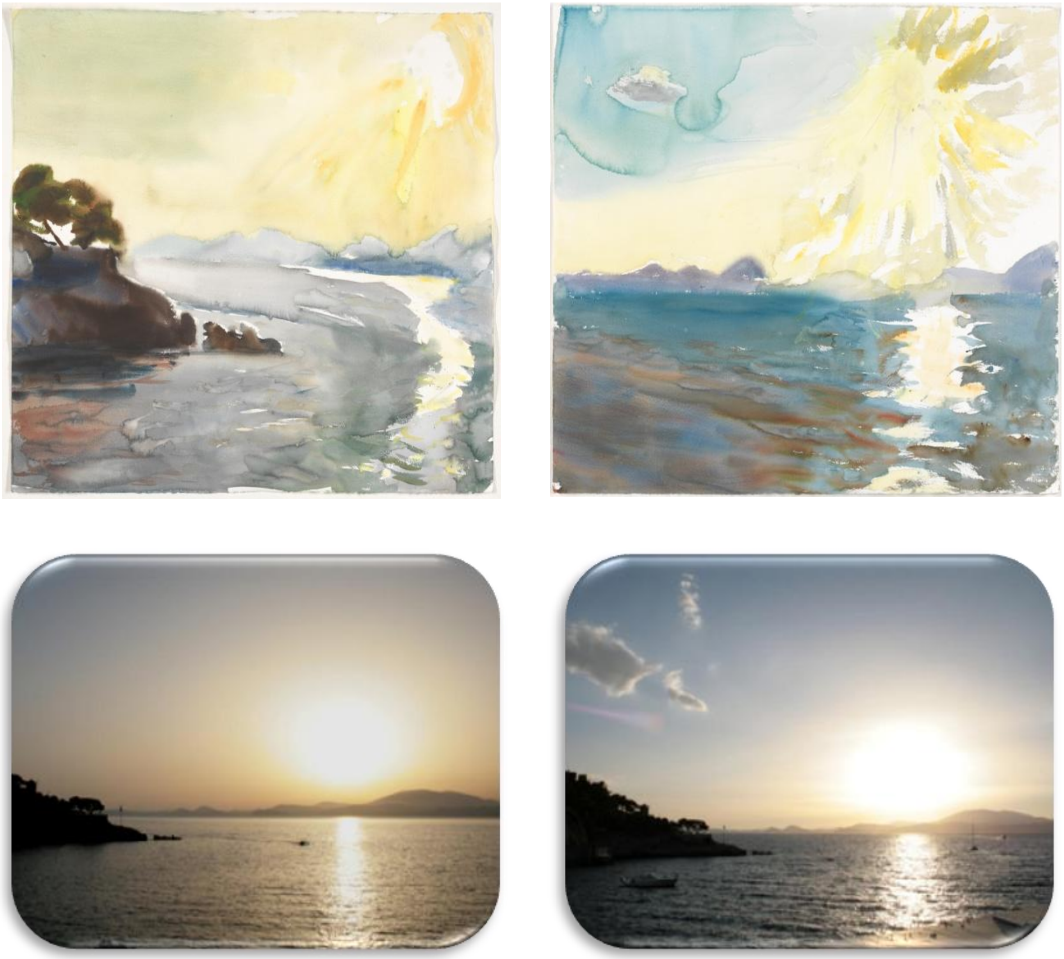


Figure 10. Upper: Digitally compressed paintings by P. Tetsis at the Hydra experiment under higher (left panel) and lower (right panel) AOD conditions. Bottom: Digital camera photos of the landscape. Under each painting a digital photograph at the centre of the time interval it took to paint each painting is displayed for comparison (see text).

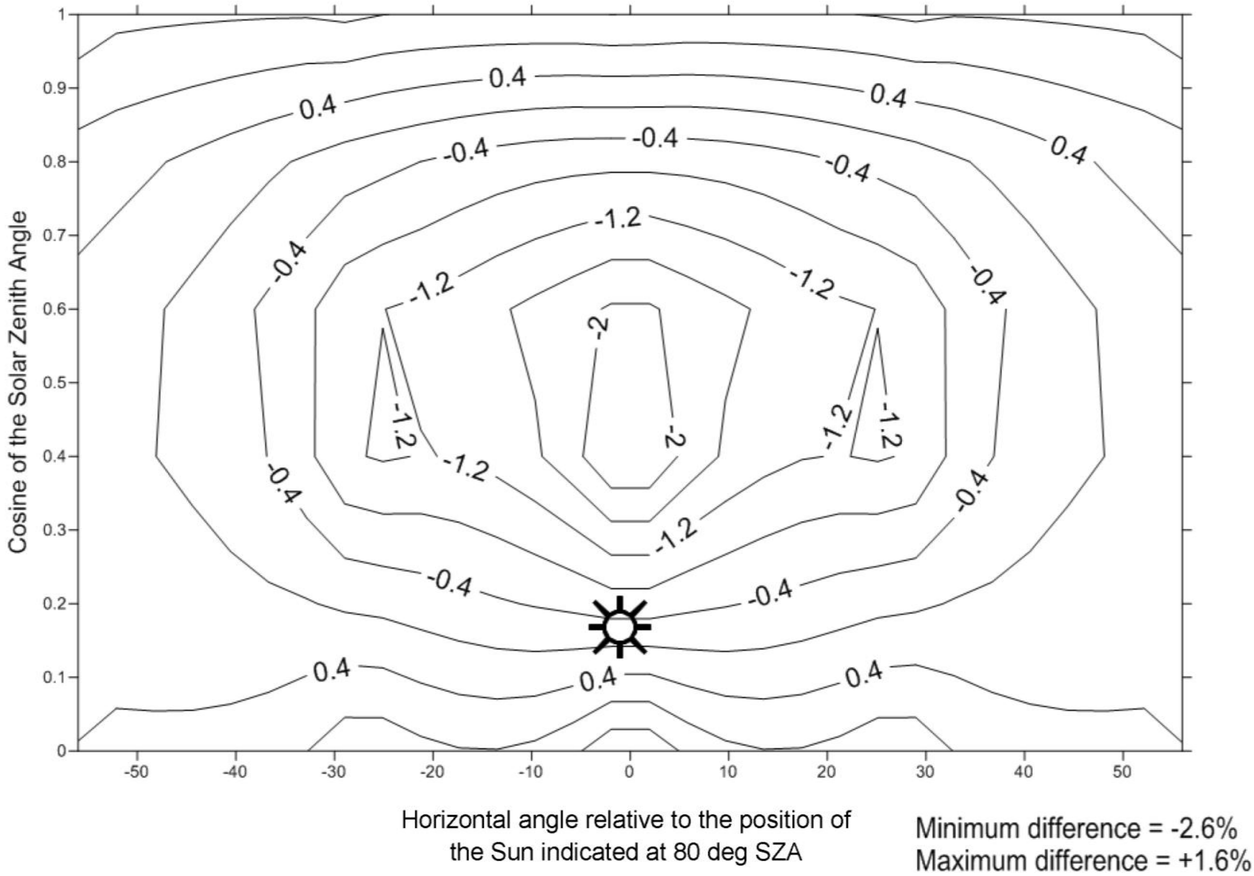


Figure 11. Percent difference in R/G ratios between the measured at Hydra Sahara dust mineral aerosol profile and a typical modelled volcanic aerosol profile. In both cases AOD (500 nm) was set to 0.25.

Appendix A

Table A1. Paintings from the Tate Gallery analysed in this work.

Image ID	Artist Name	Title
1. D00670	Turner, Joseph Mallord William	Windmill on Hill: Valley and Winding River in Middle Distance; Sunset Effect
2. D02474	Turner, Joseph Mallord William	Helmsley Sketchbook [Finberg LIII], Distant View of Whitby from the Moors: A Windmill against a
3. D04118	Turner, Joseph Mallord William	Studies for Pictures Sketchbook [Finberg LXIX], Study for the Composition of `Dolbadern Castle
4. D04119	Turner, Joseph Mallord William	Studies for Pictures Sketchbook [Finberg LXIX], Study for the Composition of `Dolbadern Castle',
5. D04127	Turner, Joseph Mallord William	Studies for Pictures Sketchbook [Finberg LXIX], Snowy Hills beside a Lake: ?Evening Sky
6. D04128	Turner, Joseph Mallord William	Studies for Pictures Sketchbook [Finberg LXIX], Study for the Composition of `Dolbadern Castle',
7. D08176	Turner, Joseph Mallord William	Moonlight at Sea (The Needles)
8. D12502	Turner, Joseph Mallord William	Skies Sketchbook [Finberg CLVIII], Red Sky and Crescent Moon
9. D16131	Turner, Joseph Mallord William	Naples: Rome. C. Studies Sketchbook [Finberg CLXXXVII], The Roman Campagna from Monte Testaccio
10. D16482	Turner, Joseph Mallord William	Small Roman Colour Studies Sketchbook [Finberg CXC], Moonlight over the Campagna

11.	D20254	Turner, Joseph Mallord William	Mayen in the Eifel
12.	D22663	Turner, Joseph Mallord William	Evening: A Windmill at Sunset
13.	D22664	Turner, Joseph Mallord William	Sunset across the Park from the Terrace of Petworth House
14.	D22666	Turner, Joseph Mallord William	Evening: A Boat on a River with a Distant Tower
15.	D22674	Turner, Joseph Mallord William	Sunset over the Ridge Seen from the North Pond in Petworth Park
16.	D22716	Turner, Joseph Mallord William	Setting Sun
17.	D22719	Turner, Joseph Mallord William	The Setting Sun over Petworth Park
18.	D22767	Turner, Joseph Mallord William	Petworth Park; Sunset (`Glade and Greensward')
19.	D22768	Turner, Joseph Mallord William	Sunset: A Boat on a River
20.	D24635	Turner, Joseph Mallord William	A Distant View of the Upperton Monument, from the Lake in Petworth Park
21.	D24640	Turner, Joseph Mallord William	Harbour Scene at Sunrise, possibly Margate
22.	D24666	Turner, Joseph Mallord William	The Scarlet Sunset
23.	D24698	Turner, Joseph Mallord William	Turner's Annual Tour: The Seine 1834 Watercolours, Le Havre: Sunset in the Port
24.	D24757	Turner, Joseph Mallord William	A View of Metz from the North

25.	D25132	Turner, Joseph Mallord William	Sunlight over Water
26.	D25141	Turner, Joseph Mallord William	Cilgerran Castle, Pembrokeshire
27.	D25144	Turner, Joseph Mallord William	The River; Sunset
28.	D25201	Turner, Joseph Mallord William	Looking out to Sea
29.	D25233	Turner, Joseph Mallord William	River with Trees: Sunset
30.	D25246	Turner, Joseph Mallord William	Castle Upnor, Kent: Preparatory Study
31.	D25249	Turner, Joseph Mallord William	River: Sunset
32.	D25253	Turner, Joseph Mallord William	Studies of Skies
33.	D25258	Turner, Joseph Mallord William	Evening
34.	D25263	Turner, Joseph Mallord William	The Line of Cliffs
35.	D25300	Turner, Joseph Mallord William	The Castle by the Sea
36.	D25303	Turner, Joseph Mallord William	River Scene: Sunset
37.	D25315	Turner, Joseph Mallord William	Sunset
38.	D25329	Turner, Joseph Mallord William	Sunset

39.	D25330	Turner, Joseph Mallord William	Fiery Sunset
40.	D25331	Turner, Joseph Mallord William	Crimson Sunset
41.	D25332	Turner, Joseph Mallord William	Sunset over Water
42.	D25336	Turner, Joseph Mallord William	A Ruin: Sunset
43.	D25338	Turner, Joseph Mallord William	Twilight over the Waters
44.	D25361	Turner, Joseph Mallord William	A Stormy Sunset
45.	D25368	Turner, Joseph Mallord William	Sequels to the Liber Studiorum ('Little Liber') Watercolours, The Distant Tower: Evening
46.	D25403	Turner, Joseph Mallord William	The Yellow Sky
47.	D25412	Turner, Joseph Mallord William	A Pink Sky above a Grey Sea
48.	D25430	Turner, Joseph Mallord William	Sequels to the Liber Studiorum ('Little Liber') Watercolours, Gloucester Cathedral
49.	D25433	Turner, Joseph Mallord William	Running Wave in a Cross-Tide: Evening
50.	D25443	Turner, Joseph Mallord William	Barnstaple Bridge at Sunset
51.	D25446	Turner, Joseph Mallord William	Study for `The Golden Bough
52.	D25450	Turner, Joseph Mallord William	Sunset

53.	D25474	Turner, Joseph Mallord William	Rochester Castle and Bridge
54.	D25507	Turner, Joseph Mallord William	Sunset over the Sea
55.	D25514	Turner, Joseph Mallord William	St Michael's Mount from Marazion, Cornwall
56.	D27601	Turner, Joseph Mallord William	Sunset over a City
57.	D27689	Turner, Joseph Mallord William	Rogers's Poems 1835 Watercolours, Tornaro (Rogers's 'Poems')
58.	D27716	Turner, Joseph Mallord William	Rogers's Poems 1835 Watercolours, Datur Hora Quieti
59.	D28994	Turner, Joseph Mallord William	Sunset over Lake or River
60.	D29026	Turner, Joseph Mallord William	Sunset
61.	D32130	Turner, Joseph Mallord William	Roll Sketchbook of Venice [Finberg CCCXV], Venice: Sunset over Santa Maria della Salute and the
62.	D32152	Turner, Joseph Mallord William	Venice: Sunset
63.	D32185	Turner, Joseph Mallord William	View of Town, with Yellow Sky
64.	D32191	Turner, Joseph Mallord William	Sunset on the Sea
65.	D32203	Turner, Joseph Mallord William	Orange Sunset
66.	D33479	Turner, Joseph Mallord William	Fribourg, Lausanne and Geneva Sketchbook [Finberg CCCXXXII], Geneva, the Jura Mountains and

67.	D33484	Turner, Joseph Mallord William	Fribourg, Lausanne and Geneva Sketchbook [Finberg CCCXXXII], Sunset on a Lake
68.	D33501	Turner, Joseph Mallord William	Fribourg, Lausanne and Geneva Sketchbook [Finberg CCCXXXII], Sunset, Lake of Lucerne
69.	D33504	Turner, Joseph Mallord William	Fribourg, Lausanne and Geneva Sketchbook [Finberg CCCXXXII], Mont Pilatus: Sunset
70.	D35260	Turner, Joseph Mallord William	The Whalers Sketchbook [Finberg CCCLIII], Sea Monsters and Vessels at Sunset
71.	D35378	Turner, Joseph Mallord William	Ideas of Folkestone Sketchbook [Finberg CCCLVI], Sunset, over the Water
72.	D35392	Turner, Joseph Mallord William	Ambleteuse and Wimereux Sketchbook [Finberg CCCLVII], Yellow Sun over Water
73.	D35394	Turner, Joseph Mallord William	Ambleteuse and Wimereux Sketchbook [Finberg CCCLVII], Sunset at Ambleteuse
74.	D35927	Turner, Joseph Mallord William	A Lurid Sunset
75.	D35943	Turner, Joseph Mallord William	Sunset over Yellow-Green Waters
76.	D35950	Turner, Joseph Mallord William	Yellow Sunset
77.	D35973	Turner, Joseph Mallord William	The Bass Rock
78.	D35986	Turner, Joseph Mallord William	Sunset: Study for `Flint Castle, on the Welsh Coast'
79.	D36060	Turner, Joseph Mallord William	The Rigi
80.	D36078	Turner, Joseph Mallord William	Sunset. (?Sunrise)

81.	D36123	Turner, Joseph Mallord William	The Red Rigi: Sample Study
82.	D36149	Turner, Joseph Mallord William	Sunset, with Smoke from a Distant Steamer
83.	D36153	Turner, Joseph Mallord William	Distant View of Regensburg from the Dreifaltigkeitsberg
84.	D36159	Turner, Joseph Mallord William	Sunset: A Fish Market on the Beach
85.	D36174	Turner, Joseph Mallord William	The Walhalla, near Regensburg on the Danube
86.	D36211	Turner, Joseph Mallord William	Lausanne: Sunset
87.	D36242	Turner, Joseph Mallord William	Geneva
88.	D36293	Turner, Joseph Mallord William	Yellow and Blue Sunset over Water
89.	D36679	Turner, Joseph Mallord William	Sunset Seen from a Beach with Breakwater
90.	N00304	Wilson, Richard	Lake Avernus and the Island of Capri
91.	N00309	Gainsborough, Thomas	Boy Driving Cows near a Pool
92.	N00342	Callcott, Sir Augustus Wall	Dutch Landscape with Cattle
93.	N00499	Turner, Joseph Mallord William	The Decline of the Carthaginian Empire ...
94.	N00519	Turner, Joseph Mallord William	Regulus
95.	N00559	Turner, Joseph	Petworth Park: Tillington Church in the Distance

	Mallord William	
96. N00560	Turner, Joseph Mallord William	Chichester Canal
97. N00886	Reynolds, Sir Joshua	Admiral Viscount Keppel
98. N00926	Crome, John	A Windmill near Norwich
99. N01290	Wilson, Richard	Landscape with Bathers, Cattle and Ruin
100. N01656	McLachlan, Thomas Hope	Evening Quiet
101. N01876	Turner, Joseph Mallord William	Sunset
102. N01902	Brett, John	The British Channel Seen from the Dorsetshire Cliffs
103. N02064	Turner, Joseph Mallord William	The Chain Pier, Brighton
104. N02065	Turner, Joseph Mallord William	A Ship Aground
105. N02066	Turner, Joseph Mallord William	The Arch of Constantine, Rome
106. N02067	Turner, Joseph Mallord William	Tivoli: Tobias and the Angel
107. N02645	Crome, John	Moonrise on the Yare (?)
108. N02647	Wilson, Richard	River View, on the Arno (?)
109. N02701	Turner, Joseph Mallord William	The Lake, Petworth, Sunset
110. N02990	Turner, Joseph Mallord William	Ariccia (?): Sunset
111. N03026	Turner, Joseph Mallord William	Classical Harbour Scene

112. N03382	Turner, Joseph Mallord William	Claudian Harbour Scene
113. N04665	Turner, Joseph Mallord William	Sun Setting over a Lake
114. N04937	Ward, James	L'Amour de Cheval
115. N05361	Crome, John	Yarmouth Harbour - Evening
116. N05486	Turner, Joseph Mallord William	Sunset From the Top of the Rigi
117. N05530	Turner, Joseph Mallord William	Seacoast with Ruin, probably the Bay of Baiae
118. N05853	Boitard, Louis Philippe	An Exact Representation of the Game of Cricket
119. T00921	De Loutherbourg, Philip James	Travellers Attacked by Banditti
120. T03163	Garstin, Norman	Haycocks and Sun
121. T03543	Anderton, Henry	Mountain Landscape with Dancing Shepherd
122. T03883	Turner, Joseph Mallord William	The Lake, Petworth: Sunset, Fighting Bucks
123. T03884	Turner, Joseph Mallord William	The Lake, Petworth: Sunset, a Stag Drinking
124. T03885	Turner, Joseph Mallord William	Chichester Canal

Appendix B

Table B1. Volcanic eruptions in 1500-2000 with volcanic explosivity index (VEI) of 4 or more.

No	Year	Volcano	VEI*	Reference
1	1522	? Arenal, Costa Rica (C-14: 1525)	4	[1]
2	1568	? Billy Mitchell (C-14: 1580)	6	[1]
3	1586	Kelut, Java	5?	[1]
4	1595	Raung, Java	5?	[1]
5		Ruiz, Colombia	4	[1]
6	1600	Huynaputina, Peru	6?	[1]
7	?*1605	Momotombo, Nicaragua	4	[1]
8	1622	? Colima, Mexico	4	[1]
9	C-14: 1630	Raoul Island, Kermadec	4	[1]
10	1641	Parker, Indonesia	6	[1]
11	1660	? Teon, Banda	4?	[1]
12		? Guagua Pichinchia, Ecuador	4	[1]
13	1665	? Long Island, New Guinea (C-14: 1660)	6?	[1]
14	1674	Gamkonora, Indonesia	5?	[1]
15	1680	Tongkoko, Sulawesi	5?	[1]
16	1693	Serua, Banda	4?	[1]
17	?1721	Raoul Island, Kermadec (C-14: 1720)	4	[1]
18		Cerro Bravo, Colombia (T)	4	[1]

19	?1737	Fuego, Guatemala	4?	[1]
20	1744	Cotopaxi, Equador	4	[1]
21	1760	Michoacan, Mexico	4	[1]
22		Makian, Indonesia	4?	[1]
23	1783	Lakagigar, Iceland	4	[2]
24	1794	? San Martin, Mexico	4?	[1]
25	?1808	Unknown	?	[1]
26	1813	Soufriere St. Vincent, W-Indies	4	[1]
27		Awu, Indonesia	4?	[1]
28		Suwanose-Jima, Japan	4	[1]
29	1815	Tambora, Indonesia	7	[1, 2]
30	1823	Galunggung, Java	5	[1]
31	1831	Babuyan Claro, Philippines	4?	[1]
32	1835	Coseguina, Nicaragua	5	[1, 2]
33	1861	Makian, Indonesia	4?	[1]
34	1875	Askja, Iceland	5	[2]
35	1880	Fuego, Guatemala	4?	[1]
36	1883	Krakatau, Indonesia	6	[1, 2]
37	1886	Tarawera, New Zealand	5	[2]
38	1890	Colima, Mexico	4	[1]
39	1902	Pelee, W-Indies	4	[1]
40		Soufriere St. Vincent, W-Indies	4	[1]
41	1903	Santa Maria, Guatemala	6	[1, 2]
42	1907	Ksudach, Kamchatka, Russia	5	[2]
43	?1911	Lolobau, SW-Pacific	4	[1]

44		Taal, Philippines	4	[1]
45	1912	Katmai, Alaska	6	[2]
46	1953	Ambrym, Vanuatu	4+	[1]
47		Lamington, New Guinea	4	[1]
48		Bagana, SW-Pacific	4	[1]
49	1963	Agung, Indonesia	4	[1, 2]
50	1968	Fernandina, Galapagos	4	[1]
51	1974	Fuego, Guatemala	4	[1]
52	1980	St. Helens, United States	5	[2]
53	1982	El Chichon, Mexico	5	[1, 2]
54	1991	Pinatubo, Philippines	6	[1, 2]

[1]: after Ammann and Naveau (2003) at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/climate_forcing/volcanic_aerosols/ammann2003_eruptions.pdf

[2]: Robock (2000)

* It should be mentioned that VEI is not a good index of stratospheric sulphate loading, since it measures the explosivity of an eruption and not its stratospheric injection.

Appendix C

R/G ratios with and without structural differences after Tambora (1815) and Krakatau (1883)

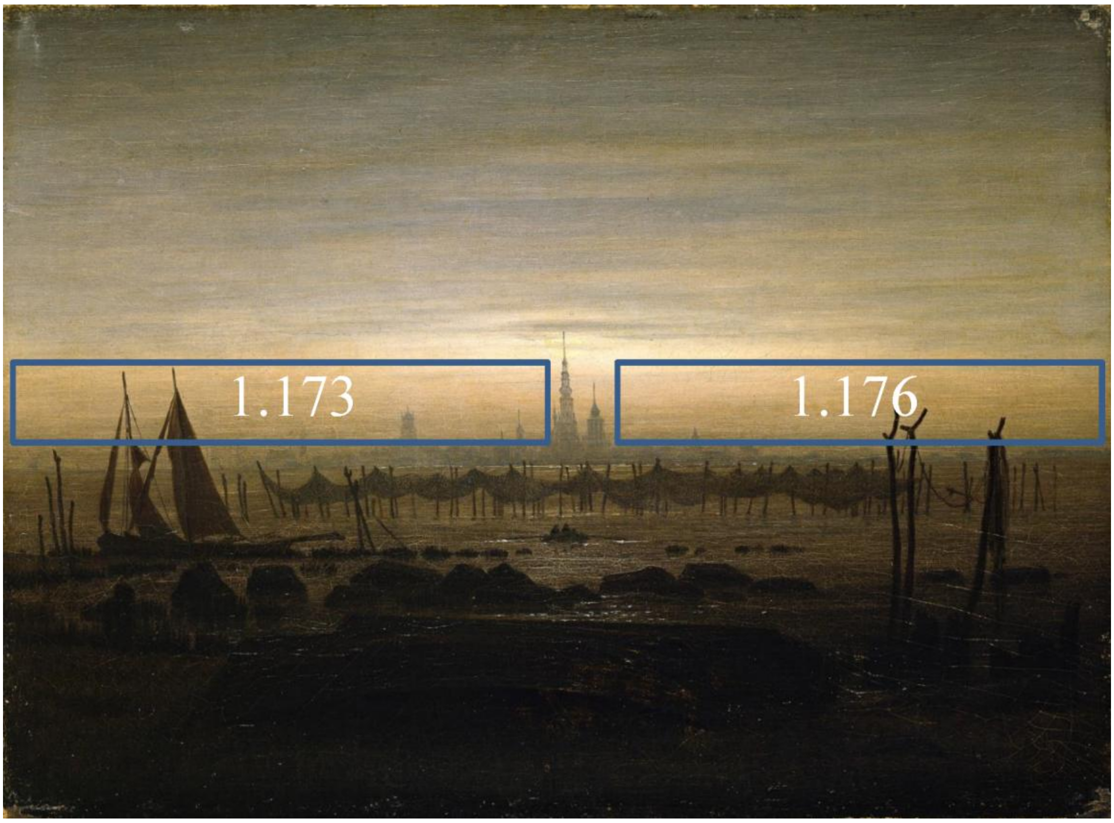


Figure C1. Caspar David Friedrich, Griefswald in the Moonlight, 1817. Corresponding R/G ratios were averaged inside each box.

Figure C2. Karl Friedrich Schinkel, The Banks of the Spree near Stralau, 1817. Corresponding R/G ratios were averaged inside each box.

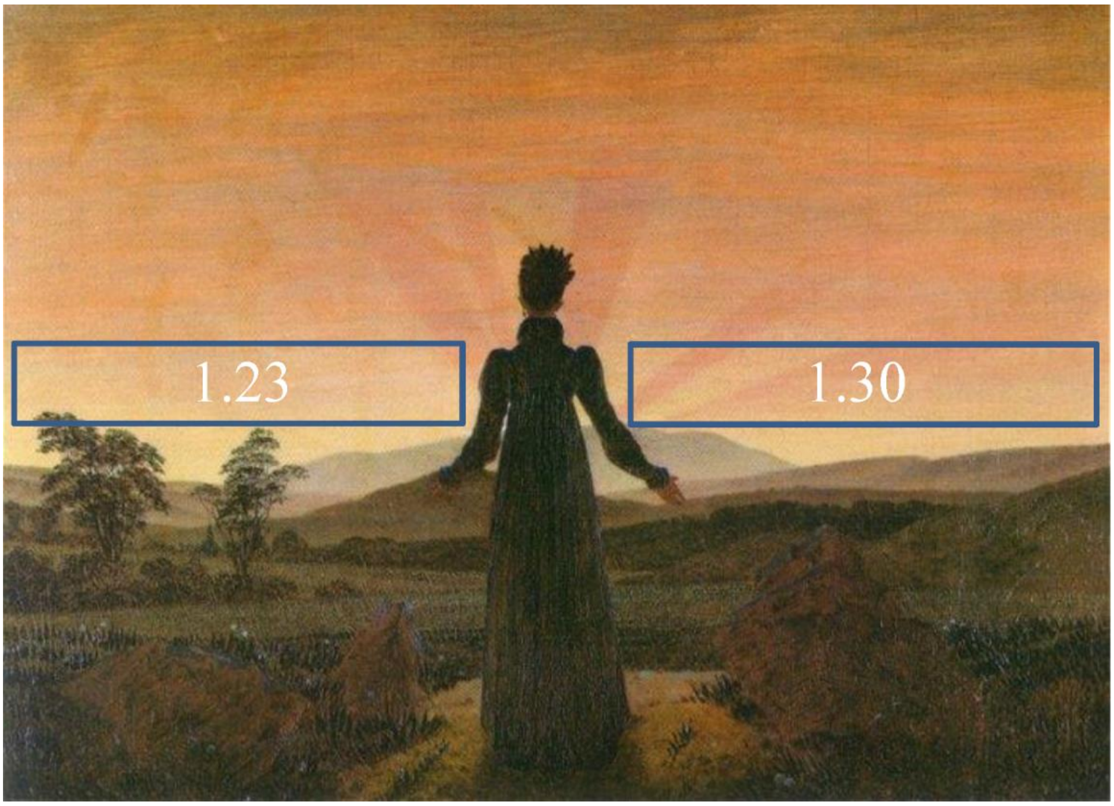


Figure C3. Caspar David Friedrich, Woman in front of the Setting Sun, 1818. Corresponding R/G ratios were averaged inside each box.

Figure C4. Joseph Mallord William Turner, Red sky and crescent moon, c. 1818. Corresponding R/G ratios were averaged inside the box.

Figure C5. Edgar Degas, Landscape on the Orne, c.1884. Corresponding R/G ratios were averaged inside each box.

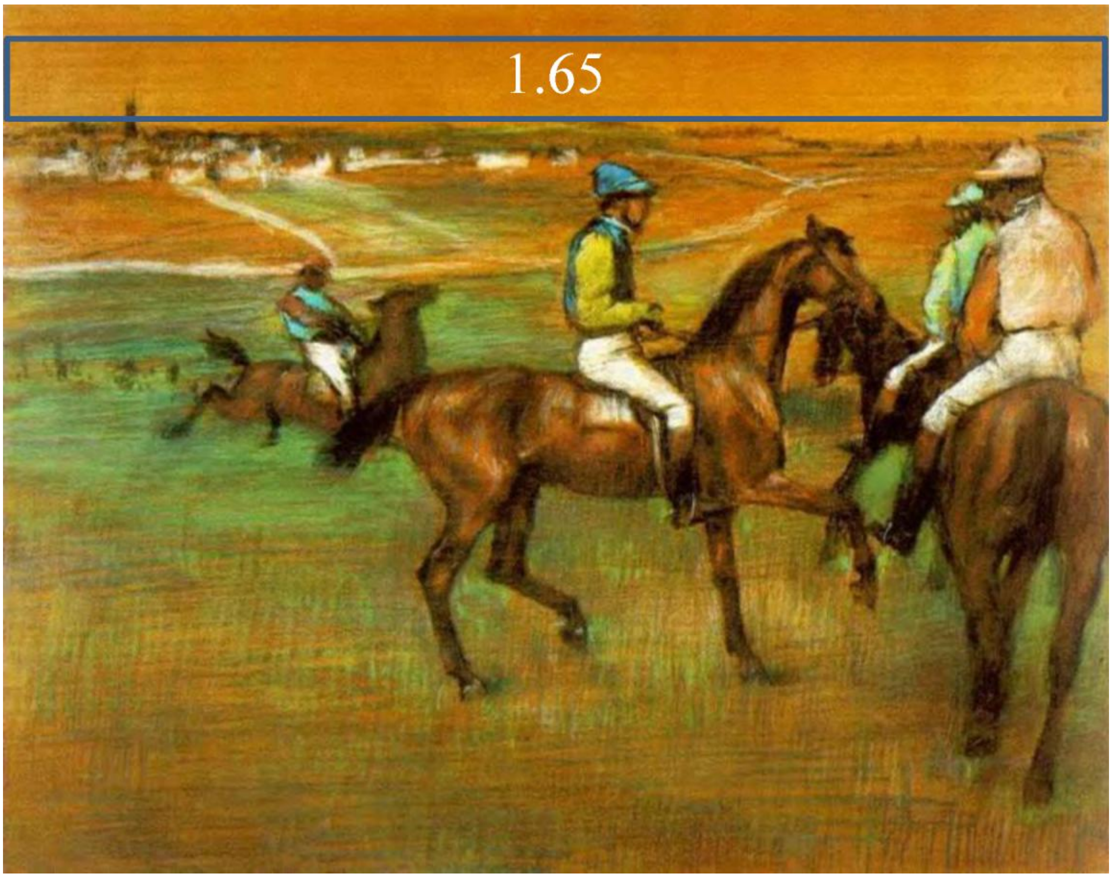


Figure C6. Edgar Degas, Race Horses, 1885. Corresponding R/G ratios were averaged inside the box.

Appendix D

Table D1. Volcanic aerosol indices and AOD proxies shown in Fig. 4.

Year	N.H. DVI (Lamb, 1970, 1977, 1983)	N.H. AOD from paintings (this study)	AOD (Robertson et al., 2001)	AOD Crowley and Unterman (2013)	AOD (Sato et al., 1993)	AOD (Stothers, 1996, 2001)	Sulphate aerosols (Tg) (Gao et al., 2008)
1500	200	----	0.0010	----	----	----	----
1501	150	0.103	0.0117	----	----	----	----
1502	100	----	0.0110	----	----	----	----
1503	50	0.12	0.0110	0.01	----	----	1.72
1504	----	----	0.0002	0.003	----	----	----
1505	----	----	0.0076	0.008	----	----	----
1506	----	----	----	0.008	----	----	----
1507	----	----	----	0.002	----	----	----
1508	----	----	----	0.021	----	----	----
1509	----	----	0.0055	0.012	----	----	----
1510	----	----	0.0022	0.003	----	----	----
1511	----	----	0.0076	0.001	----	----	----
1512	----	----	----	----	----	----	4.24
1513	----	----	0.0112	----	----	----	----
1514	----	----	0.0008	----	----	----	----
1515	----	----	0.0037	0.016	----	----	----
1516	----	----	0.0000	0.005	----	----	----
1517	----	----	0.0010	0.001	----	----	----
1518	----	----	0.0007	----	----	----	----
1519	----	----	0.0007	----	----	----	----
1520	----	----	----	0.004	----	----	----
1521	----	----	0.0039	0.008	----	----	----
1522	----	----	0.0013	0.002	----	----	----

1523	----	----	0.0031	0.004	----	----	----
1524	----	----	0.0035	0.008	----	----	----
1525	----	----	0.0023	0.009	----	----	----
1526	----	----	0.0010	0.025	----	----	3.54
1527	----	----	0.0079	0.006	----	----	----
1528	----	----	----	0.003	----	----	----
1529	----	----	0.0068	----	----	----	----
1530	----	----	0.0026	0.003	----	----	----
1531	----	----	0.0025	0.001	----	----	----
1532	----	----	0.0007	----	----	----	----
1533	----	----	0.0041	0.002	----	----	----
1534	----	----	0.0002	----	----	----	3.86
1535	50	----	----	----	----	----	----
1536	50	----	0.0009	0.007	----	----	----
1537	50	----	0.0052	0.014	----	----	----
1538	----	----	0.0045	0.003	----	----	----
1539	----	----	0.0037	0.001	----	----	----
1540	----	----	0.0095	----	----	----	----
1541	----	----	0.0066	----	----	----	----
1542	----	----	0.0029	0.011	----	----	----
1543	----	----	0.0087	0.004	----	----	----
1544	----	----	0.0021	0.001	----	----	----
1545	----	----	----	----	----	----	----
1546	----	----	0.0023	----	----	----	----
1547	----	----	----	----	----	----	----
1548	----	----	----	----	----	----	----
1549	----	----	0.0020	----	----	----	----
1550	----	----	0.0086	----	----	----	----
1551	----	----	0.0016	----	----	----	----
1552	----	----	0.0030	----	----	----	----
1553	100	----	0.0018	0.012	----	----	----
1554	500	----	0.0020	0.028	----	----	----
1555	350	----	0.0121	0.012	----	----	----
1556	200	----	0.0028	0.003	----	----	----
1557	100	0.168	----	----	----	----	----
1558	----	----	0.0007	----	----	----	----

1559	----	----	0.0018	----	----	----	----
1560	----	----	0.0006	----	----	----	----
1561	----	----	0.0003	0.03	----	----	----
1562	----	----	0.0037	0.01	----	----	----
1563	----	----	0.0028	0.019	----	----	----
1564	----	----	0.0039	0.006	----	----	----
1565	----	----	0.0168	0.001	----	----	----
1566	----	----	0.0011	----	----	----	----
1567	----	----	0.0004	0.012	----	----	----
1568	----	----	0.0033	0.007	----	----	----
1569	----	----	0.0007	0.002	----	----	----
1570	----	----	0.0041	0.011	----	----	----
1571	----	----	0.0151	0.015	----	----	----
1572	----	----	----	0.009	----	----	----
1573	----	----	0.0003	0.015	----	----	----
1574	----	----	0.0024	0.003	----	----	----
1575	----	----	0.0092	0.023	----	----	----
1576	----	----	0.0335	0.053	----	----	----
1577	----	----	0.0917	0.019	----	----	----
1578	----	----	0.0067	0.02	----	----	----
1579	----	----	0.0064	0.007	----	----	----
1580	----	----	0.0071	0.012	----	----	----
1581	----	----	0.0052	0.003	----	----	----
1582	----	----	0.0003	0.001	----	----	----
1583	----	----	----	0.011	----	----	----
1584	----	----	0.0068	0.003	----	----	24.23
1585	----	----	0.0018	0.053	----	----	----
1586	200	----	0.0868	0.018	----	----	----
1587	150	----	0.0639	0.004	----	----	----
1588	100	----	0.0143	0.015	----	----	----
1589	50	----	0.0059	0.005	----	----	----
1590	----	----	0.0029	0.001	----	----	----
1591	----	----	----	0.01	----	----	----
1592	----	----	----	0.003	----	----	----
1593	200	----	0.0421	0.019	----	----	9.54
1594	150	----	0.0620	0.068	----	----	----

1595	100	----	0.0101	0.028	----	----	----
1596	50	----	0.0010	0.021	----	----	----
1597	40	----	0.0008	0.007	----	----	----
1598	30	----	0.0016	0.001	----	----	----
1599	20	----	0.0147	----	----	----	----
1600	10	0.084	0.0729	0.147	----	----	56.59
1601	400	----	0.0994	0.132	----	----	----
1602	300	----	0.0065	0.05	----	----	----
1603	210	----	0.0064	0.019	----	----	----
1604	110	----	0.0062	0.007	----	----	----
1605	10	----	0.0049	----	----	----	----
1606	20	----	0.0007	----	----	----	----
1607	50	0.112	0.0017	0.013	----	----	----
1608	50	----	0.0011	0.004	----	----	----
1609	50	----	0.0014	0.001	----	----	----
1610	40	0.097	0.0005	0.006	----	----	----
1611	30	----	----	0.002	----	----	----
1612	20	0.101	0.0018	----	----	----	----
1613	10	----	0.0059	0.005	----	----	----
1614	200	----	0.0010	0.014	----	----	----
1615	150	----	----	0.004	----	----	----
1616	100	----	----	0.001	----	----	----
1617	50	----	0.0003	----	----	----	----
1618	----	----	0.0072	----	----	----	----
1619	----	----	0.0209	----	----	----	5.23
1620	----	----	0.0042	----	----	----	----
1621	----	----	0.0017	0.025	----	----	----
1622	----	----	0.0102	0.033	----	----	----
1623	----	----	0.0017	0.007	----	----	----
1624	----	----	0.0056	0.002	----	----	----
1625	100	0.13	0.0069	----	----	----	----
1626	75	----	----	0.004	----	----	----
1627	50	0.115	0.0005	0.001	----	----	----
1628	25	----	0.0006	----	----	----	----
1629	----	----	0.0076	----	----	----	----
1630	----	----	0.0022	0.01	----	----	----

1631	120	----	----	0.003	----	----	----
1632	90	----	0.0022	0.001	----	----	----
1633	60	----	0.0010	----	----	----	----
1634	30	----	0.0030	----	----	----	----
1635	----	----	0.0053	----	----	----	----
1636	40	0.102	0.0048	----	----	----	----
1637	30	0.067	0.0014	----	----	----	----
1638	120	0.151	0.0004	----	----	----	----
1639	85	----	----	----	----	----	----
1640	150	0.284	0.0462	0.022	----	----	----
1641	400	----	0.0705	0.157	----	----	51.6
1642	275	0.35	0.0355	0.101	----	----	----
1643	175	0.125	0.0019	0.036	----	----	----
1644	75	----	----	0.013	----	----	----
1645	----	----	0.0036	0.027	----	----	----
1646	60	----	0.0089	0.007	----	----	----
1647	45	----	----	0.002	----	----	----
1648	30	0.097	0.0021	----	----	----	----
1649	15	0.08	----	----	----	----	----
1650	100	0.251	0.0017	----	----	----	----
1651	75	----	0.0015	----	----	----	----
1652	50	0.104	0.0010	----	----	----	----
1653	25	----	0.0101	----	----	----	----
1654	----	----	0.0066	----	----	----	----
1655	----	----	0.0043	----	----	----	----
1656	----	----	0.0052	----	----	----	----
1657	----	----	0.0004	----	----	----	----
1658	----	----	0.0030	----	----	----	----
1659	----	----	0.0011	----	----	----	----
1660	340	----	0.0157	----	----	----	----
1661	255	0.341	0.0316	----	----	----	----
1662	170	----	----	0.013	----	----	----
1663	85	0.292	0.0024	0.004	----	----	----
1664	130	0.146	----	0.001	----	----	----
1665	100	----	0.0059	----	----	----	----
1666	65	0.112	0.0079	----	----	----	----

1667	30	0.089	0.0161	0.017	----	----	----
1668	----	----	0.0461	0.048	----	----	----
1669	----	----	----	0.011	----	----	----
1670	----	----	----	0.002	----	----	----
1671	----	----	0.0018	----	----	----	----
1672	200	----	0.0011	----	----	----	----
1673	150	0.168	0.0446	0.07	----	----	16.13
1674	100	----	0.0539	0.128	----	----	----
1675	50	----	0.0065	0.049	----	----	----
1676	----	----	0.0036	0.018	----	----	----
1677	----	----	----	0.007	----	----	----
1678	----	----	0.0001	0.001	----	----	----
1679	----	----	0.0051	----	----	----	----
1680	280	0.478	0.0008	0.021	----	----	----
1681	210	----	0.0001	0.018	----	----	----
1682	140	----	0.0007	0.007	----	----	----
1683	70	----	0.0065	0.002	----	----	----
1684	----	----	0.0009	0.001	----	----	----
1685	----	----	0.0019	----	----	----	----
1686	----	----	0.0080	0.006	----	----	----
1687	----	----	0.0020	0.003	----	----	----
1688	----	----	----	0.002	----	----	----
1689	----	----	0.0010	0.001	----	----	----
1690	----	----	----	----	----	----	----
1691	----	----	0.0005	----	----	----	----
1692	----	----	0.0106	----	----	----	----
1693	140	0.151	0.0563	----	----	----	27.1
1694	285	----	0.0777	0.105	----	----	----
1695	205	----	0.1405	0.158	----	----	----
1696	105	0.104	0.0395	0.171	----	----	----
1697	45	----	0.0028	0.075	----	----	----
1698	----	----	----	0.033	----	----	----
1699	----	----	0.0022	0.009	----	----	----
1700	----	----	0.0026	0.004	----	----	----
1701	----	----	0.0010	0.001	----	----	----
1702	----	----	----	0.002	----	----	----

1703	----	----	0.0003	----	----	----	----
1704	----	----	----	0.005	----	----	----
1705	----	----	0.0126	0.002	----	----	----
1706	----	----	0.0040	0.004	----	----	----
1707	300	----	----	0.001	----	----	----
1708	225	----	----	----	----	----	----
1709	150	----	----	----	----	----	----
1710	75	0.104	0.0031	----	----	----	----
1711	----	----	0.0078	----	----	----	3.86
1712	80	----	0.0022	----	----	----	----
1713	60	----	0.0207	----	----	----	----
1714	40	----	0.0007	----	----	----	----
1715	20	----	0.0025	0.001	----	----	----
1716	----	----	0.0027	----	----	----	----
1717	120	----	0.0003	----	----	----	----
1718	90	0.13	0.0006	----	----	----	----
1719	60	----	0.0023	----	----	----	31.48
1720	30	0.058	0.0066	0.005	----	----	----
1721	100	----	0.0091	0.001	----	----	----
1722	75	----	0.0042	----	----	----	----
1723	50	----	0.0011	0.003	----	----	----
1724	55	----	----	0.001	----	----	----
1725	15	----	----	----	----	----	----
1726	15	----	0.0032	----	----	----	----
1727	15	0.087	0.0112	----	----	----	----
1728	15	----	0.0270	----	----	----	----
1729	15	----	0.0043	----	----	----	12.02
1730	160	0.126	0.0319	----	----	----	----
1731	130	----	0.0854	0.024	----	----	----
1732	90	----	0.0088	0.008	----	----	----
1733	50	----	----	0.002	----	----	----
1734	----	----	0.0002	----	----	----	----
1735	----	----	0.0012	----	----	----	----
1736	----	----	0.0006	----	----	----	----
1737	----	----	0.0044	----	----	----	----
1738	----	----	0.0122	----	----	----	3.34

1739	----	----	0.0167	0.017	----	----	----
1740	----	----	0.0359	0.035	----	----	----
1741	----	----	0.0032	0.008	----	----	----
1742	----	----	----	0.002	----	----	----
1743	----	----	----	----	----	----	----
1744	60	----	0.0012	----	----	----	----
1745	45	----	0.0079	----	----	----	----
1746	30	0.067	0.0009	----	----	----	----
1747	15	----	0.0200	0.005	----	----	----
1748	----	----	0.0001	0.001	----	----	----
1749	----	----	0.0154	----	----	----	----
1750	----	----	----	----	----	----	----
1751	----	----	0.0083	----	----	----	----
1752	200	----	0.0026	----	----	----	----
1753	150	0.167	0.0018	----	----	----	----
1754	160	----	0.0018	----	----	----	----
1755	255	----	0.0113	----	----	----	7.96
1756	150	----	0.0063	----	----	----	----
1757	95	----	0.0045	----	----	----	----
1758	40	----	0.0077	----	----	----	----
1759	80	----	0.0029	----	----	----	----
1760	110	0.138	0.0015	0.005	----	----	----
1761	77	----	0.0072	0.001	----	----	12.91
1762	45	----	0.0116	0.024	----	----	----
1763	13	----	0.0074	0.007	----	----	----
1764	----	----	0.0028	0.002	----	----	----
1765	----	----	0.0028	----	----	----	----
1766	----	----	0.0136	----	----	----	----
1767	----	----	0.0035	----	----	----	----
1768	----	----	0.0002	----	----	----	----
1769	----	----	0.0056	----	----	----	----
1770	----	----	0.0041	----	----	----	----
1771	----	----	0.0012	----	----	----	----
1772	50	0.067	0.0029	0.006	----	----	----
1773	37	----	0.0034	0.002	----	----	----
1774	25	----	0.0003	----	----	----	----

1775	13	----	0.0051	----	----	----	----
1776	----	----	0.0032	----	----	----	----
1777	----	----	0.0002	----	----	----	----
1778	----	----	0.0011	0.005	----	----	----
1779	180	----	0.0015	0.006	----	----	----
1780	135	----	0.0019	0.001	----	----	----
1781	90	0.094	0.0092	----	----	----	----
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	----	----	----
1821	----	----	0.0070	----	----	----	----
1822	200	----	0.0075	----	----	----	----
1823	150	----	0.0002	----	----	----	----
1824	100	----	0.0035	----	----	----	----
1825	70	0.104	0.0003	----	----	----	----
1826	80	0.15	0.0055	----	----	----	----
1827	65	0.143	0.0003	----	----	----	----
1828	50	0.147	0.0040	----	----	----	----
1829	75	0.147	0.0005	----	----	----	----
1830	50	0.069	0.0062	----	----	----	----
1831	200	0.293	0.0570	0.01	----	----	16.97
1832	130	0.284	0.0570	0.098	----	----	----
1833	80	0.16	----	0.048	----	----	----
1834	40	0.059	0.0081	0.018	----	----	----
1835	525	0.52	0.1300	0.127	----	----	40.16
1836	450	----	0.1527	0.116	----	----	----
1837	375	----	0.0218	0.042	----	----	----
1838	300	----	0.0091	0.015	----	----	----
1839	225	0.178	----	0.006	----	----	----
1840	150	0.185	0.0004	0.004	----	----	----
1841	75	0.11	0.0030	0.001	----	----	----
1842	----	----	0.0012	----	----	----	----
1843	----	----	0.0007	0.004	----	----	----
1844	----	----	0.0022	0.001	----	----	----
1845	100	0.145	0.0071	----	----	----	----
1846	205	----	0.0036	0.006	----	----	----

1847	140	----	0.0006	0.002	----	----	----
1848	90	----	0.0029	----	----	----	----
1849	30	----	0.0039	----	----	----	----
1850	----	----	----	----	0.0036	----	----
1851	----	----	----	----	0.0025	----	----
1852	----	----	0.0017	----	0.0014	----	----
1853	----	----	0.0075	----	0.0006	----	----
1854	----	----	0.0032	0.009	0.0003	----	----
1855	----	----	0.0043	0.004	0.0020	----	----
1856	140	----	0.0033	0.001	0.0387	----	----
1857	105	----	0.0014	----	0.0602	----	----
1858	70	0.098	0.0013	----	0.0290	----	----
1859	35	0.083	0.0001	----	0.0112	----	----
1860	----	----	----	0.003	0.0046	----	----
1861	160	0.164	0.0077	0.002	0.0034	----	4.23
1862	120	----	0.0075	0.054	0.0137	----	----
1863	80	----	0.0063	0.033	0.0100	----	----
1864	40	0.081	0.0067	0.012	0.0046	----	----
1865	----	----	0.0037	0.005	0.0020	----	----
1866	----	----	0.0021	0.001	0.0008	----	----
1867	----	----	0.0018	----	0.0004	----	----
1868	160	0.204	0.0020	----	0.0002	----	----
1869	120	0.196	0.0013	----	0.0006	----	----
1870	80	----	0.0084	----	0.0006	----	----
1871	40	0.097	0.0009	----	0.0006	----	----
1872	----	----	0.0091	0.001	0.0013	----	----
1873	----	----	0.0033	0.008	0.0030	----	----
1874	----	----	0.0035	0.002	0.0020	----	----
1875	120	0.241	0.0012	0.01	0.0013	----	----
1876	90	----	0.0102	0.003	0.0062	----	----
1877	60	----	0.0130	0.001	0.0053	----	----
1878	30	0.143	0.0023	----	0.0032	----	----
1879	----	----	0.0009	----	0.0020	----	----
1880	----	----	----	----	0.0011	----	----
1881	----	----	----	----	0.0007	----	----
1882	----	----	----	----	0.0006	----	----

1883	400	0.56	0.0410	0.02	0.0473	0.096	21.87
1884	300	0.46	0.0897	0.157	0.1429	0.192	----
1885	240	0.361	0.0138	0.073	0.0635	0.071	----
1886	170	0.37	0.0302	0.045	0.0364	0.026	1.93
1887	50	0.21	0.0325	0.016	0.0371	----	----
1888	170	0.31	0.0036	0.004	0.0219	----	----
1889	125	----	0.0019	----	0.0285	----	----
1890	85	0.132	0.0031	0.004	0.0391	0.026	----
1891	45	0.101	0.0128	0.001	0.0300	0.048	----
1892	20	0.094	0.0090	0.004	0.0217	0.018	----
1893	15	0.108	0.0047	0.001	0.0094	----	----
1894	10	0.069	0.0007	----	0.0035	----	----
1895	5	----	0.0005	----	0.0014	----	----
1896	----	----	0.0011	----	0.0183	----	----
1897	----	----	0.0001	----	0.0169	----	----
1898	30	0.084	0.0041	0.007	0.0121	----	----
1899	25	0.084	0.0014	0.002	0.0046	----	----
1900	15	0.13	0.0027	----	0.0018	----	----
1901	5	----	0.0021	----	0.0007	----	----
1902	180	0.27	0.0094	0.004	0.0202	0.014	3.77
1903	135	----	0.0478	0.069	0.0715	0.118	----
1904	90	0.118	0.0092	0.038	0.0318	0.061	----
1905	45	----	0.0032	0.014	0.0126	----	----
1906	----	0.17	0.0049	0.005	0.0073	----	----
1907	60	0.2655	0.0078	0.013	0.0092	0.01	----
1908	45	0.2	0.0056	0.006	0.0103	0.004	----
1909	30	0.13	----	0.001	0.0040	----	----
1910	15	----	0.0008	----	0.0031	----	----
1911	----	----	0.0518	----	0.0017	----	----
1912	60	0.163	0.0161	0.031	0.0193	0.028	11.04
1913	45	0.16	0.0120	0.029	0.0241	0.019	----
1914	30	0.168	0.0048	0.006	0.0099	0.007	----
1915	15	0.106	0.0055	0.001	0.0039	----	----
1916	----	0.177	0.0040	0.009	0.0027	----	----
1917	----	0.122	0.0016	0.003	0.0022	----	----
1918	----	0.12	0.0036	0.001	0.0020	----	----

1919	----	0.195	0.0072	----	0.0020	----	----
1920	----	0.16	0.0014	----	0.0094	----	----
1921	----	0.156	0.0012	0.005	0.0077	----	----
1922	----	0.2	0.0052	0.001	0.0029	0.008	----
1923	----	0.13	0.0031	----	0.0011	0.004	----
1924	----	----	0.0102	0.011	0.0034	----	----
1925	----	0.15	0.0106	0.005	0.0029	----	11.15
1926	----	----	0.0126	0.001	0.0023	----	----
1927	----	0.175	0.0029	----	0.0015	----	----
1928	----	0.195	0.0036	----	0.0053	0.002	----
1929	----	----	0.0029	0.002	0.0098	0.014	----
1930	----	----	0.0002	0.002	0.0062	----	----
1931	----	----	0.0075	0.006	0.0047	----	----
1932	----	0.161	0.0005	0.01	0.0082	0.012	----
1933	----	0.172	0.0026	0.003	0.0067	0.002	----
1934	----	----	0.0028	0.001	0.0038	----	----
1935	----	0.116	0.0058	----	0.0042	----	----
1936	----	0.122	0.0021	----	0.0033	----	----
1937	----	----	0.0278	----	0.0028	----	----
1938	----	0.136	0.0044	----	0.0049	----	----
1939	----	----	0.0054	----	0.0041	----	----
1940	----	0.094	0.0004	----	0.0032	----	----
1941	----	----	0.0050	----	0.0019	----	----
1942	----	----	0.0036	----	0.0042	----	----
1943	----	0.094	0.0728	----	0.0044	----	6.61
1944	----	0.21	0.0499	----	0.0024	----	----
1945	----	----	0.0012	----	0.0022	----	----
1946	----	----	0.0033	----	0.0018	----	----
1947	----	----	0.0056	----	0.0023	----	----
1948	----	----	0.0033	----	0.0017	----	----
1949	----	----	0.0029	----	0.0033	----	----
1950	----	----	0.0027	----	0.0029	----	----
1951	----	----	0.0507	----	0.0020	----	----
1952	----	0.167	0.0559	----	0.0037	----	----
1953	----	0.268	0.0056	----	0.0034	----	----
1954	----	----	0.0006	----	0.0036	----	----

1955	----	----	0.0038	----	0.0018	----	----
1956	----	----	0.0068	0.005	0.0011	----	----
1957	----	----	0.0053	0.001	0.0005	----	----
1958	----	0.293	0.0008	----	0.0003	----	----
1959	----	----	0.0029	----	0.0002	----	----
1960	----	----	0.0005	----	0.0046	----	----
1961	----	----	0.0053	----	0.0108	----	----
1962	----	----	0.0024	----	0.0133	0.012	----
1963	160	----	0.0502	0.04	0.0460	0.066	17
1964	120	----	0.0389	0.055	0.0717	0.051	----
1965	80	----	0.0149	0.03	0.0432	0.031	----
1966	40	----	0.0027	0.01	0.0232	0.014	----
1967	31.4	0.138	0.0053	0.003	0.0145	0.019	----
1968	60.7	0.32	0.0164	0.001	0.0274	0.011	----
1969	40	----	0.0388	----	0.0344	0.006	----
1970	32.4	----	0.0275	----	0.0166	0.006	----
1971	23.7	----	0.0141	----	0.0065	0.015	----
1972	9.5	----	0.0135	----	0.0039	0.008	----
1973	9.3	----	0.0047	----	0.0078	0.001	----
1974	56.1	----	0.0055	----	0.0127	0.007	----
1975	41	----	0.0071	0.024	0.0301	0.024	----
1976	67	----	0.0080	0.015	0.0136	0.007	4.72
1977	45.4	----	----	0.006	0.0051	0.003	----
1978	25.8	----	0.0051	0.002	0.0075	0.001	----
1979	25.4	0.19	0.0019	0.001	0.0092	----	----
1980	51	----	0.0010	----	0.0047	----	----
1981	41	----	0.0098	----	0.0050	----	----
1982	366.1	----	0.0492	0.048	0.0525	----	14
1983	267.2	----	0.0370	0.079	0.0752	----	----
1984	171.1	0.19	----	0.03	0.0302	----	----
1985	85	----	----	0.011	0.0126	----	----
1986	----	----	----	0.004	0.0136	----	----
1987	----	----	----	----	0.0103	----	----
1988	----	----	----	----	0.0076	----	----
1989	----	----	----	----	0.0061	----	----
1990	----	----	----	----	0.0061	----	----

1991	----	0.15	----	0.037	0.0539	----	30.1
1992	----	----	----	0.131	0.1211	----	----
1993	----	----	----	0.053	0.0490	----	----
1994	----	----	----	0.02	0.0200	----	----
1995	----	----	----	0.007	0.0096	----	----
1996	----	0.22	----	0.001	0.0065	----	----
1997	----	----	----	----	0.0052	----	----
1998	----	----	----	----	0.0028	----	----
1999	----	----	----	----	0.0021	----	----
2000	----	----	----	----	0.0021	----	----