Climate of the Past Discussions

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Comment on cp-2021-78

Fred Prata (Referee)

Referee comment on "The blue suns of 1831: was the eruption of Ferdinandea, near Sicily, one of the largest volcanic climate forcing events of the nineteenth century?" by Christopher Garrison et al., Clim. Past Discuss., https://doi.org/10.5194/cp-2021-78-RC2, 2021

General Comments

This paper presents the hypothesis that an important climate forcing event in the 19th century and seen in the records of Greenland ice cores, was due to the eruption of an undersea volcano (Ferdinandea) off the coast of Sicily that occurred in 1831.

This is an innovative, interesting and scholarly research paper and it should be published. It is innovative in its use of "eye-witness" observations of certain atmospheric optical phenomena associated with volcanic aerosols to estimate size, composition, transport and even the amount of S in a little known volcanic eruption. It is interesting because it reveals new information on processes affecting the injection of aerosols into the stratosphere as well as perhaps solving the mystery of a sulphate signal in the Greenland ice core record thought to be from an 1831 tropical eruption. It is scholarly (there are > 120 references) as it involves collection and research of historical documents and records in several different languages, as well as covering topics in volcanology, atmospheric optical physics and dynamics and even some radiative transfer.

Specific Comments

The hypothesis presented relies on three key points:

- That a small (VEI 3) volcanic eruption could inject aerosols into the stratosphere.
- That the event injected sufficient SO2 to register a signal in the Greenland ice core.
- That the aerosols were transported westwards in agreement with the (indirect) observations presented.

I cannot comment on point 2 as I am not sufficiently expert to assist the discussion, but I can provide some thoughts on points 1 and 3.

Point 1. The idea that an undersea, relatively minor eruption could produce stratospheric aerosols seems surprising. However, as the authors note, the eruption of Krakatau in December 2018 did just that. More recently, the 12 August 2021 eruption of the undersea volcano Fukutoku-Okanoba, off Japan generated a column that reached up to 18 km (in the stratosphere). These eruptions were monitored by modern satellite instruments and provide unambiguous evidence of stratospheric injection. The 1963 eruption of Surtsey was reported to have generated a column up >9000 m which is stratospheric at the high latitude of Surtsey. Thus there is evidence that near sea-surface volcanic eruptions can generate tall columns, even if the amount of solid-rock material is not large. The mechanism for this is thought to be due to a combination of tropospheric convective instability and the interaction of hot material with sea water, generating additional convective available potential energy (CAPE) which drives the buoyancy of the column. I think the authors should perhaps describe this in more detail as they must convince readers that a small VEI eruption can generate a stratospheric aerosol – crucial to their hypothesis.

Point 3. The authors estimate the zonal transport of the aerosol to be ~20 m/s westwards. This is quite fast. There are no detailed vertical wind profiles available for 1831 but there are modern climatologies and also good knowledge of the atmospheric circulation based on solid meteorological foundations. Eruptions from Mt Etna (a volcano close to Empedocles/Ferdinandea) generate volcanic plumes that predominantly move eastwards and sometimes northwards and southwards, but rarely westwards. This is because these eruptions are mostly tropospheric where the winds in summer are from the west. Modern climatologies of the vertical zonal winds suggest that up to the tropopause at 40 N during the NH summer winds are from the west. Above the tropopause the winds gradually shift to the east in accordance with thermal winds caused by the vertical gradient of temperature. As the sign of the gradient changes from negative to positive the winds change from eastwards to westwards. But, according to modern zonal wind climatologies for midlatitude NH summers, the magnitude of the westward winds is much less than 20 m/s. At 70 hPa (~18 km) it is generally <10 m/s and does not reach ~20 m/s until 10 hPa (~30 km). It is possible that in August 1831 the stratospheric winds were anomalously high, but that would be somewhat speculative and convenient. I wonder then whether the authors should re-evaluate the speed of transport or perhaps put an error range on their estimate to allow for this inconsistency.

None of these points are serious enough for me to suggest a revision is needed and I am happy to recommend publication subject to technical corrections. Indeed I found the paper so interesting that I wondered whether the authors had exhausted all observations, such as reports from ships logs (perhaps too scant?), were pumice rafts observed? or could the possibility that the aerosols reached the upper stratosphere be sustained (where

there are stronger winds), in which case one might expect observations of PSCs during the NH winter. I believe the earliest documented evidence for PSCs dates back only to the 1870s.

Minor comments

These are really quite minor.

- I don't think it is necessary to have a full-stop after the longitude/latitude directions (e.g. N. should be N)
- Extinction coefficient and extinction efficiency factor are both acceptable but just use one. I think extinction efficiency is most commonly used.
- I suppose that sometimes observations were hampered by cloudiness. One cannot expect a particularly complete set of observations of the Sun so I think some inconsistencies could be explained by lack of visibility.
- Were there any lunar observations? (The Moon was 43% illuminated and 23 days old on 14 August 1831).
- I noticed in Table 1 A22 that there was mention of a "black dot" observed on the Sun. Could this be a sunspot? If so,it adds weight to the drastic diminution of light from the Sun, as observing sunspots requires considerable rejection of sunlight. There are > 200 observations of sunspots made in 1831 (see: https://onlinelibrary.wiley.com/doi/abs/10.1002/asna.201111601) some with notes. These records are held at the archives of the Royal Astronomical Society in London, so it might be possible for one of the authors to view them and investigate whether anything unusual was noted on solar observations during August 1831.