Authors' response to Anonymous Reviewer #3

This is an interesting paper that comes up with a new hypothesis concerning the now-unknown (previously attributed to Babuyan Claro) 1831 eruption. The volcanic signature seen in ice cores is attributed to an eruption in the vicinity of Sicily, which according to its assigned VEI should not have had a big impact on the stratosphere. However, associated cross-tropopause exchange could have injected sulfur from this plume into the stratosphere. The authors present a detailed study of sightings of coloured sun, which beautifully align. They are consistent with a plume that travelled around the globe form East to West in the lower stratosphere. The paper is very interesting and thought-provoking. I think this is the sort of papers that play an important role in the discussions in the community. Combining historical documentary sources and scholarly expertise with scientific reasoning is interesting. This is fascinating and should be published with some minor revisions.

[R3,1] Thank you. We are grateful for your helpful and detailed comments.

However, at some instances this reasoning should be strengthened, as is outlined below.

- The time (and space) between the eruption and the first observations is very small. Sightings of coloured suns were made immediately (days) after the eruption and near the location of the eruption. This sound plausible, but is this to be expected? We read that a radius of ca. 0.5 um is required for the volcanic aerosols to have this effect. I am not a microphysicist, but in the case of tropical eruptions, sulfate aerosols, forming from the gas phase, need some time to grow to that size. This could take 2-3 months. During that time the cloud would long have circled the globe. Perhaps this is different in this case, but I would appreciate a discussion of the aerosol formation and growth process.

[R3,2] Yes, this is indeed an interesting point but one which we had decided could not be satisfactorily addressed in this paper. It is also raised by reviewer # 1. Rather than what would be a lengthy and speculative discussion at this stage, we have therefore revised the manuscript at line 570 to raise the issue for future work in the following way:

> **"Analysis of reported observations of unusual atmospheric optical phenomena both in 1831 and in 1883 may also support further investigation in a number of additional directions. For example, the first observation of a blue$^{(+)}$ sun in the equivalent connected sequence following the onset of the most explosive phase of the 1883 Krakatau eruption occurred of the order of one day later (Symons *et al.*, 1888). This suggests the rapid formation of a stratospheric aerosol whose size distribution is dominated by particles with a radius of the order of 0.5 μm (Table 2). The close co-incidence between the substantial increase in the intensity of phreatomagmatic activity during the Ferdinandea eruption between 6 and 11 August 1831 and the first observation of a blue$^{(+)}$ sun in the connected sequence on 8 August 1831 (sect. 4.1) suggests that a similarly rapid stratospheric aerosol formation occurred in that case too. Given that, for example, the stratospheric aerosol produced by the 1991 Pinatubo eruption took several months to grow to a typical size between 0.3 and 0.5 μm (Self *et al.*, 1993), it would be interesting to consider the nature of the atypical microphysical processes that could be involved in these two rare cases. Further…"**

Is there a role of ash or is ash too large anyway for that?

[R3,3] Phreatomagmatic eruptions do, of course, produce fine ash. However, it is not possible to infer the composition of the aerosol particles from the blue(+) sun observations so we cannot say what role it might have played either in terms of optical properties or aerosol particle nucleation. The vast majority of phreatomagmatic eruptions do not produce blue(+) sun aerosols of the type produced in 1831 and 1883.

- How likely is it that "tropospheric" plumes at these latitudes reach the stratosphere due to trop-strat exchange? There are examples from other locations, but is there also evidence from this region, e.g., from Etna eruptions?

[R3,4] We are not aware of any significant quantities of aerosol being injected into the stratosphere from eruptions at Etna whether by direct injection or other troposphere / stratosphere exchange mechanisms. The only significant sulphate peak identified in Greenland ice-cores which has so far been attributed to an eruption in the region appears to be the 79 AD / CE eruption of Vesuvius (Sigl et al., 2013), which is assigned a VEI of 5 (associated with definite (direct) stratospheric injection) (Global Volcanism Program, 2013).

20 m/s is superfast. Perhaps you can provide some context for this?

[R3,5] Please see our response 3 to Reviewer #2.

You mention 20CRv3, but then do not show it. I agree that for this region and time period, this data set might not show much, but a plot would still be nice (the data go back to 1806 on NCAR's website).

[R3,6] We are aware of data available for the 1830s for both 20CR V2 and V3, however data pre-1836 is not yet part of the official release. We are currently working on how we might be able to use 20CR data to investigate hypothesis H2 but prefer to leave this to 'future research'.