

This article employs paleoclimate modelling to investigate the impacts of volcanic eruptions on hydroclimate, particularly the African monsoon and Nile flow, and thereby to assess whether and how historical eruptions may have been responsible for revolts in Ptolemaic Egypt. The study represents a valuable step in integrating historical research and paleoclimate modelling. However, the article could benefit from substantial reorganization, and it requires a clearer discussion of whether and how to attribute historical societal impacts to volcanic eruptions and climatic variability.

I would recommend substantially reducing and reorganizing the introduction for greater precision, clarity, and a logical flow. Currently, this section is very long and shifts among a number of topics. The introduction needs to establish only the following contexts and in the following order: (1) Volcanic eruptions are a major driver of historical climatic variability. (2) This includes suppression of precipitation, the ITCZ, and the African monsoon. (3) Thus, volcanic eruptions probably reduced the flow of the Nile. (4) Nile flood levels were historically crucial for Egyptian agriculture and thus the populations and states that relied on that agriculture. (5) There is a correlation between the timing of volcanic eruptions and timing of revolts in Ptolemaic Egypt but not sufficient historical records to demonstrate that there was a low Nile flow during those years. (6) Therefore, this study uses paleoclimate modelling to determine to what extent volcanic eruptions such as those experienced in the Ptolemaic period were sufficient to suppress the flow of the Nile. (7) This study can enhance our understanding of volcanic forcing of the climate, as well as the study of Egyptian history and the integration of paleoclimate and historical research.

Most of the other material currently in the introduction, including the discussion of climate as a causal factor in Egyptian history, should be edited out or moved to the discussion section.

The introduction should also acknowledge previous research on volcanic eruptions, Nile flood levels, and famines in during recent centuries, for which there are Nilometer measurements and abundant historical records—see especially Alan Mikhail, ‘Ottoman Iceland: A Climate History,’ *Environmental History* 20 (2015): 262–84. <https://doi.org/10.1093/envhis/emv006>. This research, particularly for the Ottoman era, already makes a strong case that volcanic eruptions have had major historical impacts on Egyptian society by causing low Nile flow, shortages, epidemics, and political instability (indeed, a stronger case, with richer detail, than is possible for ancient history). The real question is whether this was also the case in Ptolemaic period.

The article’s arguments regarding attribution of societal impacts to volcanic eruptions are often imprecise. I would stress that the attribution of societal impacts to climate variability should be as clear and logical as the attribution of climate impacts to climatic forcings. In this case, the authors aim to evaluate whether and to what extent volcanic eruptions were responsible for revolts in Ptolemaic Egypt. They have made a *prima facie* case for a causal connection in previous research, which demonstrated a correlation between the timing of eruptions and timing of revolts. Now they are taking this causal argument one step further.

In this regard, the article should first specify its causal argument(s), preferably in contrastive terms. (For more on this issue, see e.g., S. White and Q. Pei. ‘Attribution of Historical Societal Impacts and Adaptations to Climate and Extreme Events: Integrating Quantitative and Qualitative Perspectives’. *Past Global Changes Magazine* 28, no. 2 (2020): 44–45. <https://doi.org/10.22498/pages.28.2.44>) Do the authors mean to argue that the *presence* (rather than absence) of volcanic eruptions caused the *occurrence* (rather than non-

occurrence) of revolts? Or do they mean to argue that the *timing* of the volcanic eruptions explains the *timing* of the revolts (which may have occurred anyway but in different years)? Or is it some other distinction about the eruptions or climate forcing that explains some other difference in societal impacts? I would stress that these are each very different arguments (though not mutually exclusive). They each require different evidence and each have different implications for Egyptian history. Until the authors specify which causal argument(s) they are making, it is difficult to determine whether they have succeeded or failed.

If the article intends to determine whether and to what extent the *occurrence* of eruptions were responsible for the *occurrence* of revolts in Egypt, then that will require a more clear and rigorous approach to causation. To clarify this problem, and to avoid some of the confusion that often clouds discussions of climate impacts on human societies, it may help to use a simple analogy. Let us suppose a doctor prescribes vicodin (v) to a bus driver without offering appropriate warnings about its side effects. The bus driver subsequently causes a road accident in which another driver is injured. The injured party sues the doctor on the basis that the negligent prescription (v) caused erratic driving (d) and therefore the accident (a) and the injury (i). In common law, to demonstrate the doctor's responsibility for the injury the injured party would have to demonstrate with a preponderance of evidence at least the following two points: First, that the negligent prescription for vicodin was specifically necessary for the injury to occur (i.e., the "but-for" test). Second, that negligently prescribing medication is somewhat sufficient to cause injuries in general (i.e., the "harm within risk" standard). We could also express these two causal chains as two sets of conditional probabilities that would have to meet a reasonable threshold: first, $p(v|d)$, $p(d|a)$, $p(a|i)$ and second, $p(D|V)$, $p(A|D)$, $p(I|A)$, where lowercase letters stand for specific real-world events and the capital letters stand for a type of event in general. These legal standards capture everyday understandings of causation and responsibility as well as centuries of philosophical discussion and legal experience.

While all this might seem a long way from volcanoes and instability in Ptolemaic Egypt, the issue of attribution here is basically the same. To what extent was a volcanic eruption (v) responsible for political instability (i), throughout the mechanisms of drought (d) and famine (a)? To attribute the political instability to the eruption, a preponderance of evidence should demonstrate a strong chain of specific necessity and at a least a weak chain of general sufficiency from (v) to (d) to (a) to (i). If there were alternative sufficient causes and the eruption was not necessary for the outcome—let's say another climatic event would have caused a drought even in the absence of an eruption—then we cannot attribute the societal impact to the volcano at all. If the chain of causation depended on extraordinary contributory factors—let's say the Ptolemaic empire was unusually reckless or vulnerable to instability (not wearing its seatbelt, metaphorically speaking)—then the causal responsibility of the eruption would be much diminished, and it would be misleading to refer to the eruption, rather than weaknesses within the empire, as "the cause" or even "a cause" of the occurrence of revolts. Much of the historical discussion in the paper suggests this may have been the case.

What this study has done is to take a one small but important step toward demonstrating potential causal responsibility of volcanic eruptions for Egyptian instability by demonstrating the causal sufficiency of eruptions for Nile droughts in general: $p(D|V)$. The paper needs to put this contribution in perspective and not claim to do either more or less. It should neither

hide nor exaggerate the significance of this contribution with vague language about volcanoes “playing a role” or an “environmental context” for the disaster. It is entirely possible that we could one day demonstrate that volcanoes were causally responsible for revolts in Egypt, with similar standards and rigor that courts use to assign legal responsibility for damages. This is more than “playing a role”: it is causal responsibility. However, this would require further research into other steps in those causal chains, including comparisons with better documented episodes during the medieval and Ottoman eras. On the other hand, if there were alternative sufficient causes of the drought, famine, or instability, or if Ptolemaic Egypt only faced problems because it was extraordinarily vulnerable, then it does not make sense to talk about the eruption as the cause of revolts at all (except perhaps as a trigger for the *timing* of the revolts). Talk about “a role” for the eruptions would be more misleading than helpful.

Nor does it help to include additional historical context (i.e., lines 795-843) if that context is not clearly addressed to a causal argument. If the authors intend to state that there were (or were not) alternative sufficient causes for Egyptian revolts besides eruption-induced droughts, then they should state that clearly. If they intend to state that changes in Egyptian leadership explain why some eruptions were followed by revolts but other were not, then they should also state that clearly. Otherwise, readers are left to infer causal arguments where the authors may not have intended them and where they may not be warranted. I can see that the authors are aiming for greater subtlety and sophistication; however, additional information that is not clearly tied to the causal argument(s) creates more confusion than clarity. Clearly, this study cannot yet provide a definite answer to the question of causal responsibility of volcanic eruptions for the occurrence (or is it timing?) of Egyptian revolts—nor does it need to. However, the authors need to be clear what contributions they *can* make to this question: that is, how we may update our assessments of the probabilities of necessity and sufficiency along relevant chains of causation. They may also explain what questions remain to be answered and how further research might address them.

The sections on climate modelling are mostly beyond my area of expertise to evaluate. However, with respect to evaluating historical societal impacts, I would question the emphasis on mean precipitation anomalies. To evaluate whether eruptions were a sufficient cause of a low Nile flow, what I really want to know is how much more probable a low Nile flow would be with an eruption vs. without an eruption: $p(D|V)/p(D|\neg V)$. That is, I need some help in assessing the counterfactual scenario: if there hadn't been those eruptions, would there probably have been droughts in Ptolemaic Egypt anyway? The conclusion on lines 578-580 (“likely to have strongly influenced”) is too vague. The crucial issue in attributing societal impacts to volcanoes is just how likely it was that deficient Nile flows occurred due to eruptions.

Much of the material currently in the introduction and results sections reads more like discussion. I would encourage the authors to create a larger discussion section in two parts: one for the discussion of volcanic forcing and hydroclimate anomalies and another for discussion of societal impacts. The article would also benefit from a real conclusion that summarizes findings and returns to issues raised in the introduction. The authors may also wish to address the methodological significance of the work and, in particular, make proposals for further integration of paleoclimatology, climate modelling, and human history.

Specific issues:

Line 15: The phrase “sometimes widespread” is confusing. Based on context, I would suggest “both local protests and widespread revolts”.

Line 24: I assume that “observe” here refers to finding an average in the simulations, not an actual observation of the real climate. Please clarify.

Line 55: This statement already presupposes the conclusion.

Line 56: The phrase “potentially climatically effective” is awkward. I would recommend perhaps “eruptions that may have had regional or global climatic impacts.”

Line 57-58: Again, this statement presupposes the conclusion.

Line 146-152: I do not find that this example supports the authors’ arguments. Instead, it serves as a reminder that there were, at times, other sufficient causes of political change in Egypt besides climatic variability, such as conflicts with neighbouring empires.