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Reconstructing the tephra dispersal pattern from the Bronze Age eruption of Santorini using an advection-diffusion model

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The advection-diffusion model TEPHRA2 has been used in conjunction with a multivariate inversion (the downhill simplex method) and a sensitivity analysis (the misfit function) to reconstruct the eruption conditions and seasonality consistent with the deposit patterns from the Bronze Age eruption of Santorini. The misfit function is defined as the Root Mean Square Error (RMSE) between observed and calculated deposit accumulation values at individual locations). The eruption deposit information has been compiled which was used to provide three datasets for the model inversion (proximal terrestrial, distal terrestrial and deep-sea core). These were used in the model to constrain source conditions and recreate the tephra fall deposit from the Plinian, co-ignimbrite and combined eruptive phases respectively.

The procedure of conducting the misfit differs from that typically employed in previous sensitivity analyses. It was found that iterating the misfit hierarchically (i.e. applied to eruption parameters in the order that they have most influence on mass accumulation), for a predefined range of parameters yields an improved match to the recorded deposits than the standard approach. It is suggested that this approach is adopted in similar future studies.

The results of the inversion and misfit agreed adequately well with each other for parameters such as erupted mass, plume height and grain-size distribution. It is known that empirical parameters (diffusion coefficient and fall-time threshold) cannot be well calibrated which is further supported by findings from this study. Both approaches were able to successfully recreate the Plinian deposit which was the direct consequence of it having the most detailed, preserved and studied dataset. In contrast, constraining conditions that created the co-ignimbrite and deep-sea core dataset were less successful. Typically, eruption parameters such as erupted mass and median grain-size were overestimated. It is concluded that the poor agreement is the result of the low quantity (six to 28 deposit points) and quality (inconsistent deposit depths at localities adjacent to each other) of the datasets. Different sampling methods between archaeological and volcanological disciplines and post-depositional processes which have acted on the tephra deposits since the Bronze Age can largely explain the discrepancy between these computed and observed deposits.

The seasonality of the Minoan eruption was investigated by using pseudo-arbitrary seasonal wind profiles for winter, spring, summer and autumn. Results of this study suggest that the Bronze Age eruption of Santorini is likely to have occurred between the spring and summer with a main dispersal axis aligned East from the volcano. Therefore, Crete would have received very little ash fall and it is concluded that the eruption would not have caused the direct decline of the Minoan civilization as has been previously hypothesized by some members of the archaeological community. Further work will include an archaeological assessment of the impact of the eruption on the Cycladic civilizations to the East of the volcano.