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Comment on "No consistent ENSO response to volcanic forcing over the last millennium"

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Dee *et al.* (Reports, 27 March 2020, p. 1477) claimed that large volcanic eruptions do not produce a detectable El Niño response. However, they come to the wrong conclusion because they have ignored the fundamental climate response to large volcanic eruptions: Volcanic eruptions cool the surface, thus masking the relative El Niño warming.

The recent report by Dee *et al.* (*1*) claims that large volcanic eruptions do not produce a detectable El Niño response. However, they come to the wrong conclusion because the coral temperature reconstructions they use measure actual sea surface temperature (SST) and not the temperature relative to the rest of the tropics. Volcanic eruptions cool the surface, thus masking the relative El Niño warming, if expressed in absolute temperature changes. El Niño is a dynamical ocean response, which warms the eastern and central tropical Pacific with respect to the surrounding water. When the entire tropics cools in response to stratospheric aerosols from volcanic eruptions, the absolute temperature in the El Niño region will cool, too, and the impact will only be clear with respect to the surrounding region. This is called the relative SST (RSST), as shown by Khodri *et al.* (*2*).

Dee *et al.* have produced a valuable climate record by using oxygen isotope records from Palmyra corals to give a record of SST near the center of the region in the central Pacific Ocean that warms during an El Niño relative to the regions around it. But this SST is affected both by large-scale climate change and by local El Niños. Whereas Dee *et al.* used RSST in their analysis of climate model simulations in their figure S8, the basic results in figure 4 consider only raw SST, without accounting for the cooling effects of the volcanic eruptions. This is because they do not have a reliable way to calculate the tropical average temperature from proxies, so it is important to interpret the actual SST record they have produced. In this comment I am only addressing the interpretations from the Palmyra $\delta^{18}O$ temperature reconstructions, and not the climate model results, because climate models still imperfectly simulate the El Niño response to volcanic eruptions, as can be seen by the large differences in the climate model simulations shown in figure 4.

The smaller eruptions, shown in figure 4, A and B, would not be expected to show a strong El Niño signal because of the small radiative forcing. Figure 4D shows the signal from the largest eruption in their study, the 1257 CE Samalas eruption. Rather than showing the expected large cooling in year 1 after the eruption, they found basically no signal, which I interpret as an El Niño, counteracted by the volcanic cooling. In fact, if there had not been an El Niño, we would expect to see significant cooling. The dynamical response of the climate system that triggers El Niños does not in general produce larger El Niños for larger eruptions, so the El Niño after this largest eruption would be expected to show a weaker absolute SST warming signal than that from smaller eruptions, because the volcanic cooling would be larger.

Timmreck *et al.* (*3*) have suggested that larger aerosol particles from larger SO_2 stratospheric injections from larger eruptions would make the radiative forcing less than linear as a function of SO_2 input. Still, the radiative forcing as shown in figure 1 of Dee *et al.* for Samalas is approximately twice that of the average of the next three largest eruptions, and therefore we should expect twice as much cooling from that eruption. Guillet *et al.* (*4*) examined Northern Hemisphere responses to the Samalas eruption and found "that 1258 and 1259 experienced some of the coldest Northern Hemisphere summers of the past millennium." They also found that "in North America, volcanic radiative forcing was modulated by a positive phase of the El Niño–Southern Oscillation," evidence indeed that the Samalas eruption produced an El Niño.

Figure 4C of Dee *et al.* shows the SST signal averaged for the four largest eruptions, including Samalas. Even with the 0.0‰ signal from Samalas at lag 1 year, figure 4C shows a strong El Niño signal, significant at close to the 95% significance level. If the 0.0‰ value from Samalas had not been included in this average, the signal would have been higher by one-third of the signal and would have been 0.13‰, not the current 0.10‰ at lag 1 year, and would certainly have been significant at a 95% level.

If we take into account the expected cooling from volcanic eruptions, the results from Dee *et al.* show a clear El Niño signal from the largest eruptions they considered. The El Niño SST signal for the largest eruption is obscured by the cooling effect of the eruption. The El Niño SST signal from the next three largest eruptions is clear even when looking at the absolute SST signal.

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