Analyzing the Influence of Pre-Eruption Conditions on Post-Eruption ENSO Variability

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1. Introduction

- As one of the largest natural perturbations, volcanic eruptions inject sulfate aerosols and particulate matter into the stratosphere that reduces surface shortwave radiation, causing cooling anomalies and significant climate variability. These eruptions can influence oceanic responses and potentially disrupt the normal El Niño Southern Oscillation (ENSO) cycle in the central and eastern tropical Pacific Ocean.
- ENSO consists of three phases, the two opposites being "El Niño" and "La Niña" with "Neutral" being the middle of the continuum, in which El Niño is a warming of the ocean's surface or above average sea surface temperature (SST), while La Niña signifies the cooling of the ocean surface/below average SST.
- To further study these effects and differences in how pre-conditions can potentially influence the post eruption responses, we utilize the high-top version of the Community Earth System Model (CESM2-WACCM6), with the integration of the Paleoclimate Model Intercomparison Project (PMIP), which contributes to the sixth phase of the Coupled Model Intercomparison Project (CMIP6) and the fourth phase of PMIP (PMIP4).

2. Methods

- The 10 volcanoes chosen were based on information provided in Toohey and Sigl (2017), which run from 500 BCE to 1900 CE, showing the largest eruptions in the last millennium in terms of volcanic stratospheric sulfur injections (VSSI) in the eVolv2k reconstruction.
- Based on the El Niño state definitions given in Trenberth (1997), we used a 5-month running mean of sea surface temperature (SST) in the Niño 3.4 region (5ºN - 5ºS, 120ºW - 170ºW), in which each eruption that exceeded 0.5 ºC will be classified as an El Niño response, and each eruption that was less than -0.5 ºC will be classified as a La Niña response.
- Instead of using modern definitions which are based on 1950 to 1979, we used a 30-year period from 1000 CE to 1030 CE as a base of monthly sea surface temperature comparison. These comparisons were made for both pre-eruption and post-eruption analysis with a 5-month running mean to determine whether the conditions are El Niño, La Niña, or neutral.

Research questions:
- Do pre-eruption conditions consistently change the post-eruption response regarding ENSO conditions?
- What is the ocean sea surface temperature response following the chosen volcanic eruptions in the post 3 years?

3. Pre and Post Eruption Analysis

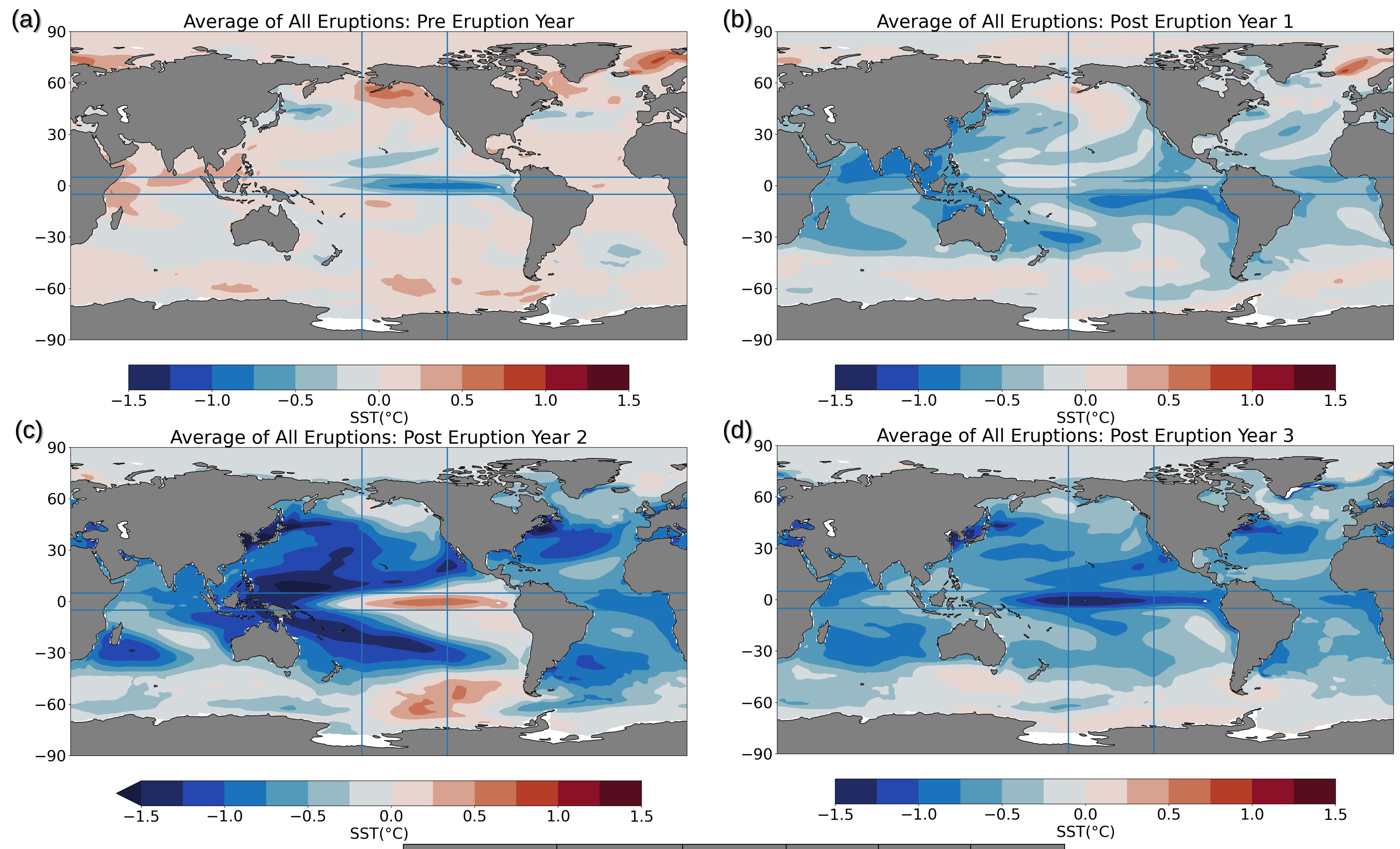

Figure 1(a)-(d): Averaged temperature anomalies (ºC) for all volcanoes shown on *Table 1*, using a 5-month running mean of sea surface temperature (SST) in the Niño 3.4 region (5ºN - 5ºS, 120ºW - 170ºW),

Volcanoes	Eruption Date	Pre-Eruption	Post Year 1	Post Year 2	Post Year 3
(1) Unidentified	January 1108	Neutral	La Niña	La Niña	La Niña
(2) Unidentified	January 1171	Neutral	Neutral	La Niña	Neutral
(3) Unidentified	July 1230	Neutral	Neutral	El Niño	Neutral
(4) Samalas	July 1257	El Niño	La Niña	La Niña	La Niña
(5) Unidentified	July 1458	La Niña	La Niña	Neutral	La Niña
(6) Huaynaputina	February 1600	La Niña	La Niña	El Niño	Neutral
(7) Parker	December 1640	El Niño	Neutral	Neutral	La Niña
(8) Grimsvotn (Laki)	June 1783	La Niña	El Niño	El Niño	La Niña
(9) Unidentified	October 1809	Neutral	El Niño	La Niña	El Niño
(10) Tambora	April 1815	La Niña	La Niña	Neutral	La Niña

Table 1. The top 10 volcanic eruptions chosen based on years after 850 CE from the past 2500 years, in terms of volcanic stratospheric sulfur injection (VSSI) in the eVolv2k reconstructed (Toohey and Sigl, 2017)

4. Last Millennium El Niño 3.4 Index

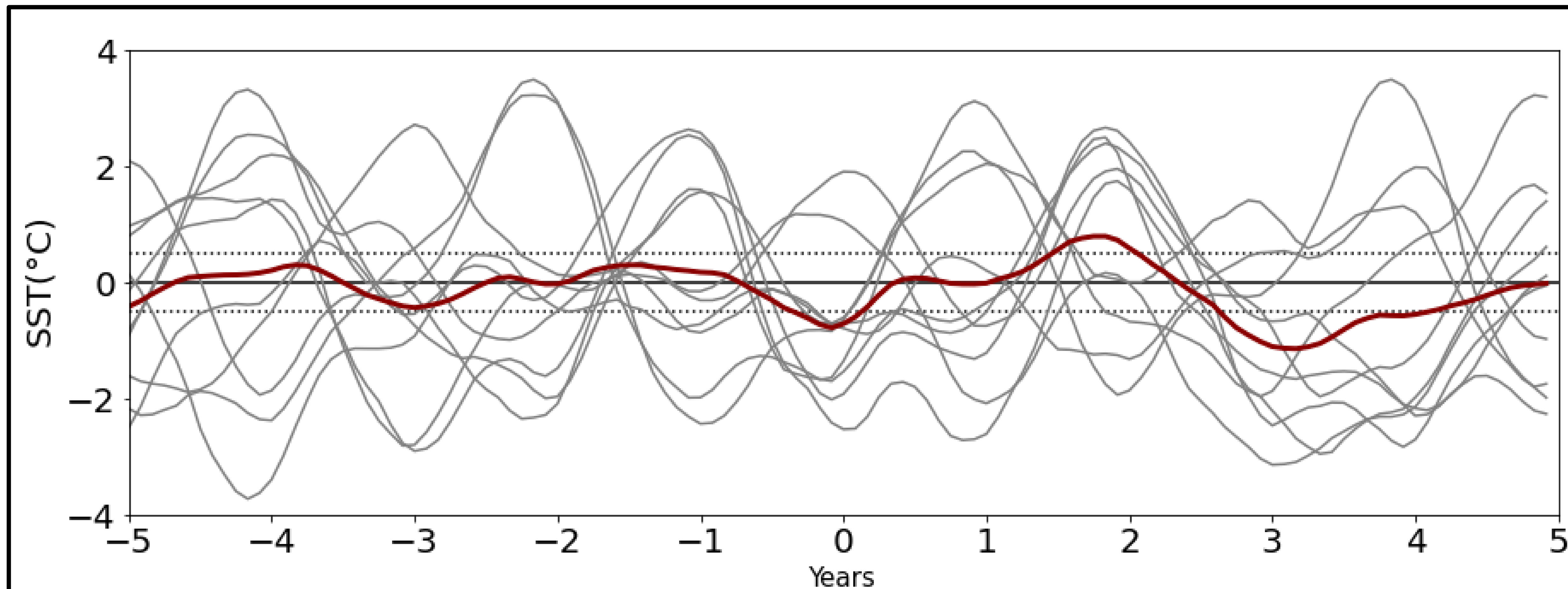

Figure 2. Time series of Niño-3.4 SST index, highlighting selected 10 volcanic eruption years and (+/-) five years of observed temperature anomalies, with the eruption year being year 0. El Niño phase is measured by being greater that 0.5 ºC while La Niña is measured by being less than 0.5 ºC, in which the dashed lines represent the threshold of the ENSO continuum. Red bolded line signifies the average of all volcanic eruptions for the chosen timescale.

5. Conclusion

- Significant El Niño response shown on year 2 averages, demonstrating cooling everywhere except in the East Equatorial Pacific, due to volcanic cooling and possible suppressed convection over the Western Pacific warm pool, which weakens the Walker Circulation, relaxing trade winds over the entire Pacific, triggering El Niño events shown in year 2.
- Since most of these eruptions occurred during a La Niña event, El Niño may have been a part of the cyclic nature of ENSO for year 2.

6. Future Work

- Analyze pre-eruption and post-eruption nitrate, phosphate, carbon dioxide and oxygen concentrations for the same time frame to use as comparison.
- Further examine patterns in ENSO responses differentiating in Northern, Southern, and tropical eruptions.
- Observe atmospheric/wind circulation anomaly patterns and precipitation responses for the eruptions.

7. References

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8. Acknowledgments

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