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Fingerprint of volcanic forcing on the ENSO–Indian monsoon coupling

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The coupling between the El Niño–Southern Oscillation (ENSO) and Indian Monsoon (IM) plays a significant role in the summer rainfall over the Indian subcontinent. In this study, we provide insights into the IM variability with regard to the degree of ENSO variability and radiative forcing from large volcanic eruptions (LVEs). Volcanic dust and gas injected into the stratosphere during major eruptions influence the ENSO from seasonal to interannual timescales. However, the effects of LVEs on the ENSO-IM coupling remain unclear. The relationship between ENSO and IM systems in the context of LVEs is examined using a panoply of datasets and advanced statistical analysis techniques in this study. We find that there is a significant enhancement of the phase-synchronization between ENSO and IM oscillations due to increase in angular frequency of ENSO in the last millennium. Twin surrogates-based statistical significance testing is also used to affirm this result and similar evidence is found in the combinations of 14 ENSO and 11 IM paleoclimate proxy records in the last millennium. Bayesian probabilities conditioned with and without LVEs show LVEs lead to a strong ENSO-IM phase-coupling, with the probabilities remaining higher till the fourth year from the eruption. A large-ensemble climate model experiment with and without the 1883 Krakatoa eruption is conducted using the IITM-ESM, and also with varied volcanic radiative forcing (VRF) depending on the evolved state of ENSO. The simulations show that LVEs force the ENSO-IM systems into a coupled state, and increase (decrease) in the VRF leads to an enhanced (decreased) probability of the phase synchronisation of ENSO-IM systems with a high chance of El Niño-IM drought in the year following the LVE. Our results promisingly pave a way not only for improving the seasonal monsoon prediction improvements but also for the regional impact assessment from the proposed geo-engineering activities over the South Asian region.