



# Fingerprint of volcanic forcing on the ENSO-Indian monsoon coupling



M. Singh, R. Krishnan\*, B. Goswami, A.D. Choudhury, P. Swapna, R. Vellore, A.G. Prajeesh, N. Sandeep, C. Venkataraman, R.V. Donner, N. Marwan and J. Kurths

## Abstract

- Coupling between ENSO and Indian Monsoon plays a significant role in the summer rainfall over the Indian subcontinent.
- Role of volcanic radiative forcing (VRF) on ENSO-IM coupling is studied. VRF known to influence ENSO, but role on ENSO-IM coupling unclear.
- Significant enhancement of the phase synchronization between ENSO and IM oscillations due to increase in angular frequency of ENSO in the last millennium found using panoply of datasets and advanced statistical analysis techniques.
- 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.

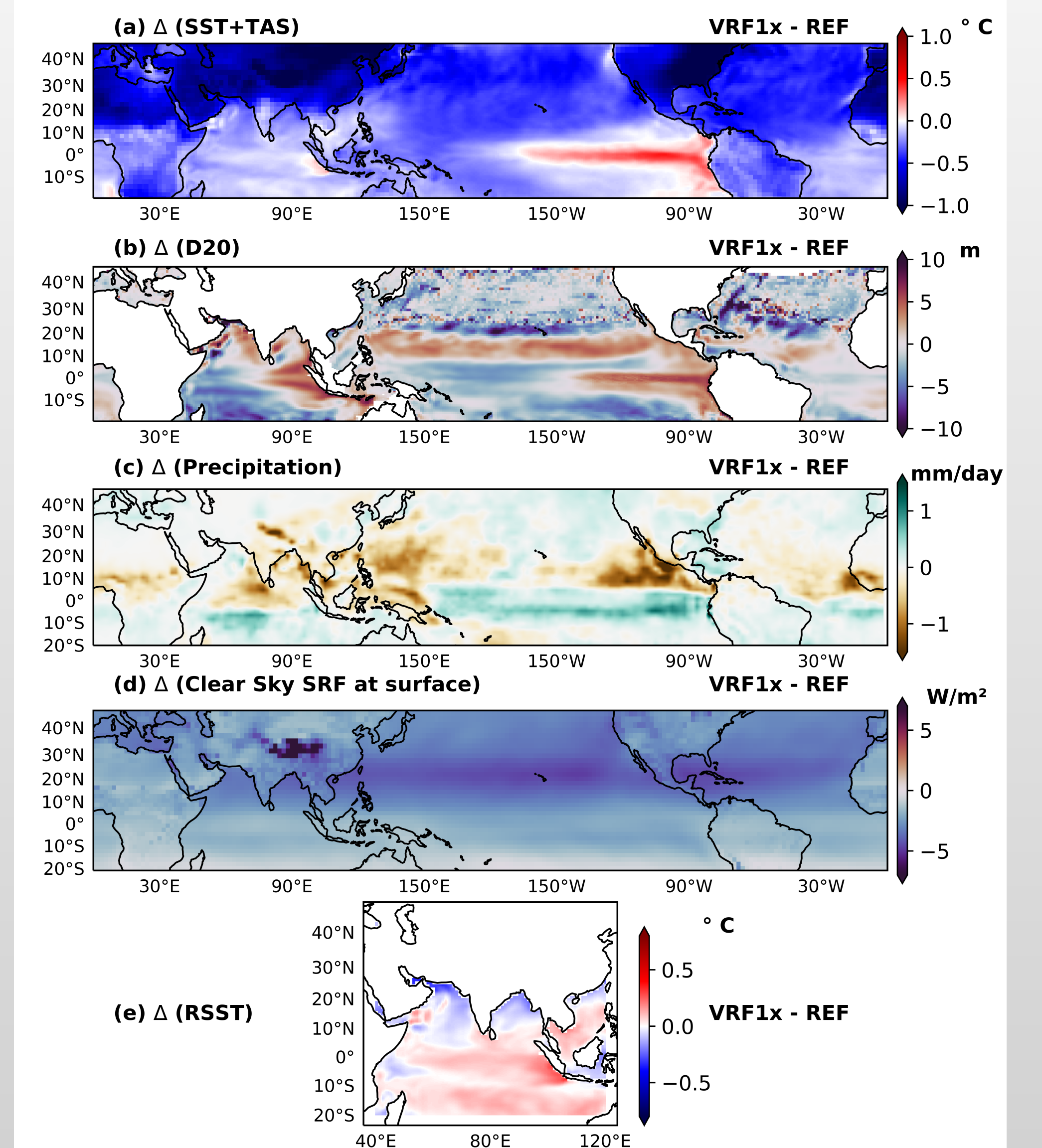
## Datasets used

Monthly Paleoclimatic Model Intercomparison Project (PMIP3) simulations outputs from 8 models for the period 850 - 1850 AD  
 Paleoclimatic reconstructions for ENSO(14), IM(11), PDO(4) and Volcanic eruptions(1) from 29 published studies  
 Suite of targeted Climate Model sensitivity simulations using IITM-ESM, observational datasets of ENSO, IM since 1871 AD

## Methods

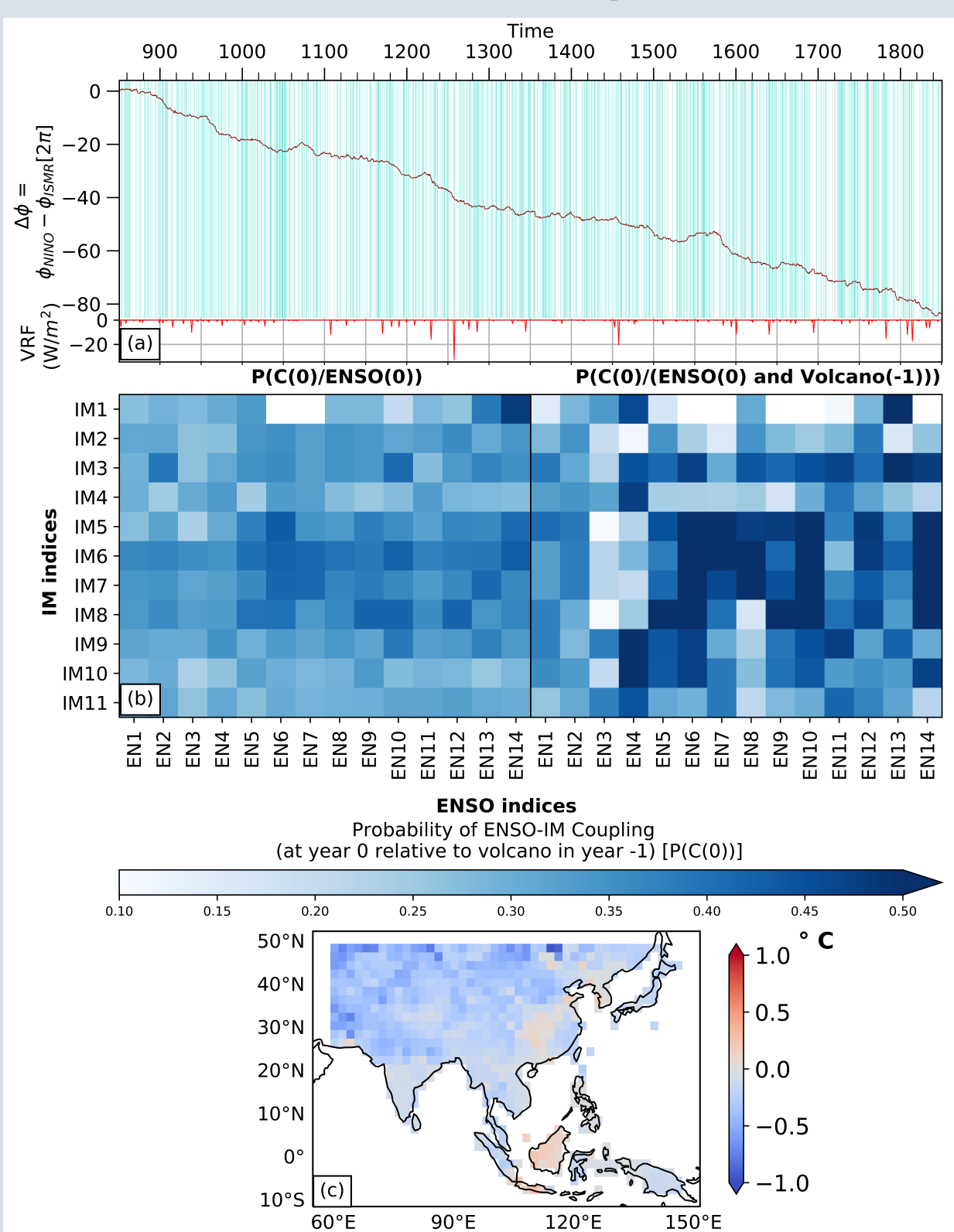
Phase Coherence Analysis  
 Event Synchronization Analysis  
 Twin Surrogates for statistical significance testing  
 Bayesian analysis based conditional probabilities  
 Large-ensemble experiment with and without 1883 Krakatoa eruption using IITM-ESM, and also with varied VRF depending on the evolved state of ENSO.

## Volc - Novolc ensemble (100 members)

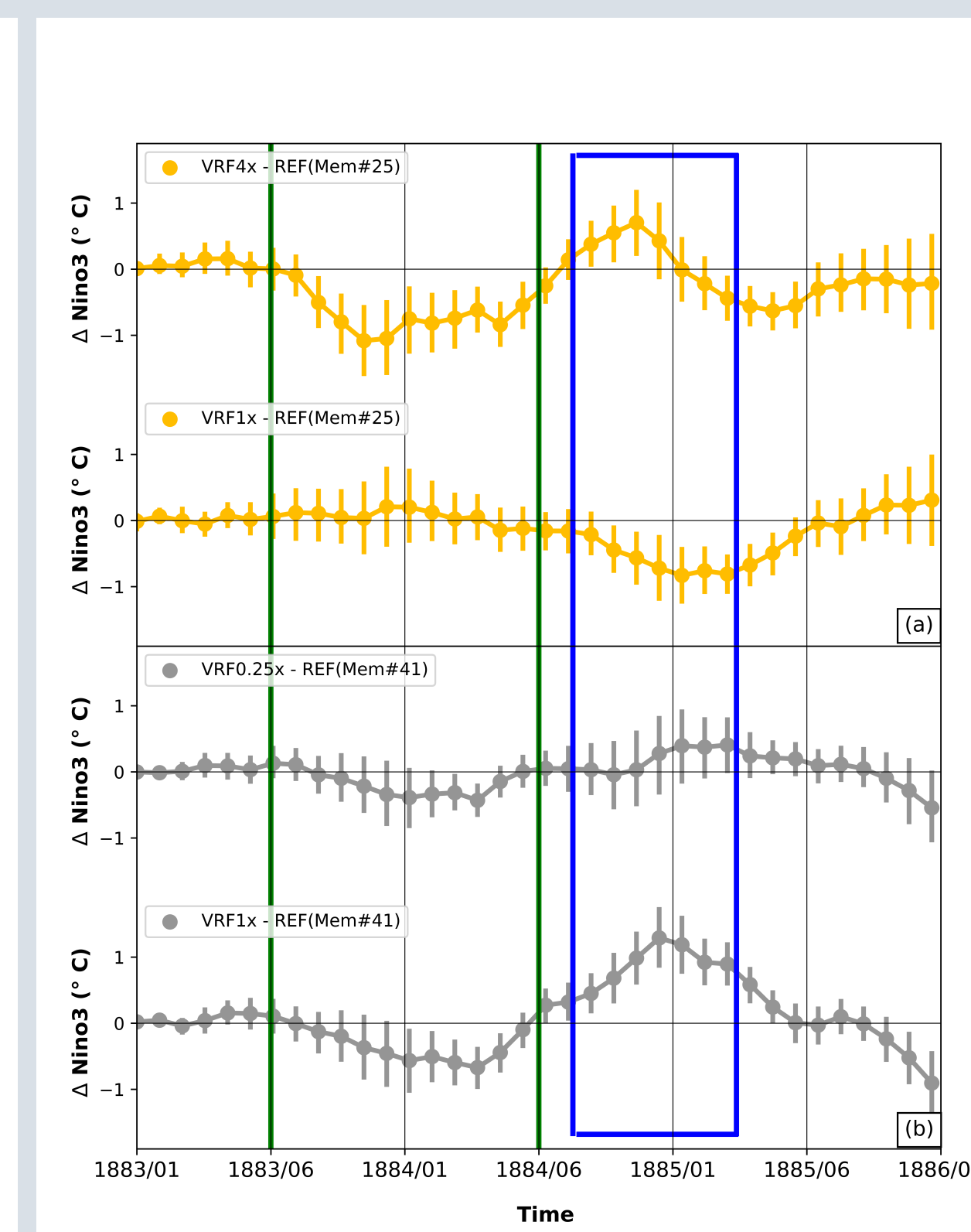


## Results and Discussion

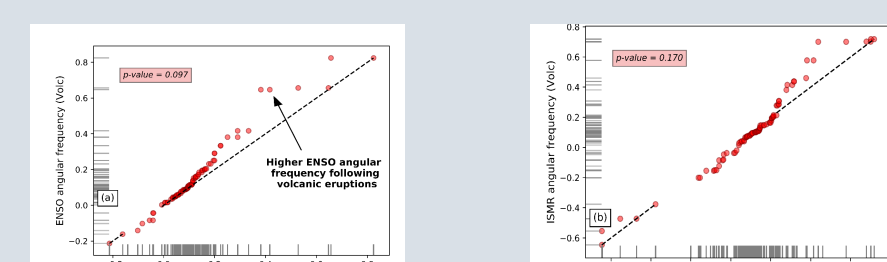
### Phase Coherence Analysis using last-millennium IPSL data and composite of Northern-hemispheric



### ENSO response to change in VRF



Statistically significant Increase in angular velocity of ENSO and insignificant change in angular velocity of IM



## Conclusions

- Phase-coherence analysis shows volcanically-induced ENSO-IM coupling. 5000 twin surrogates based statistical significance and event synchronization on IPSL-PMIP3 data for 850-1850 AD.
- Similar evidence is found using conditional Bayesian probabilities in the combinations of 14 ENSO and 11 IM paleoclimate proxy records in the last millennium. Enhanced probabilities until 4th year from eruption
- IITM-ESM simulations show LVEs force ENSO-IM systems into coupling, and increase (decrease) in VRF leads to enhanced (decreased) synchronisation.

[1] <https://github.com/manmeet3591/fingerprint-volcano-enso-im>  
 [2] Maraun, D. and Kurths, J., 2005. Epochs of phase coherence between El Nino/Southern Oscillation and Indian monsoon. Geophysical Research Letters, 32(15).

