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Nonlinear forced change and nonergodicity: The case of ENSO-Indian monsoon and global precipitation teleconnections

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We study the forced response of the teleconnection between the El Niño–Southern Oscillation (ENSO) and the Indian summer monsoon (IM) in the Max Planck Institute Grand Ensemble, a set of Earth system ensemble simulations under historical and RCP forcing. The forced response of the teleconnection, or a characteristic of it, is defined as the time dependence of a correlation coefficient evaluated over the ensemble. We consider the temporal variability of spatial averages and that with respect to dominant spatial modes in the sense of Maximal Covariance Analysis, Canonical Correlation Analysis and Empirical Orthogonal Function analysis across the ensemble. A further representation of the teleconnection that we define here takes the point of view of the predictability of the complete spatiotemporal variability of the Indian summer monsoon. We find that the strengthening of the ENSO-IM teleconnection is robustly or consistently featured in view of various teleconnection representations, whether sea surface temperature (SST) or sea level pressure (SLP) is used to characterise ENSO, and both in the historical period and under the RCP8.5 forcing scenario. It is found to be associated dominantly with the principal mode of ENSO variability. Concerning representations that involve an autonomous characterisation of the Pacific, in terms of a linear regression model, the main contributor to the strengthening} is the regression coefficient, which can outcompete even a declining ENSO variability when it is represented by SLP. We also find that the forced change of the teleconnection is typically nonlinear by (1) formally rejecting the hypothesis that ergodicity holds, i.e., that expected values of temporal correlation coefficients with respect to the ensemble equal the ensemble-wise correlation coefficient itself, and also showing that (2) the trivial contributions of the forced changes in means and standard deviations are insignificant here. We also provide, in terms of the test statistics, global maps of the degree of nonlinearity/nonergodicity of the forced change of the teleconnection between local precipitation and ENSO.