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Synchronizaton and causality across time-scales of observed and modelled ENSO dynamics

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Phase-phase and phase-amplitude interactions between dynamics on different temporal scales has been observed in ENSO dynamics, captured by the $NINO_3.4$ index, using the approach for identification of cross-scale interactions introduced recently by Paluš [1]. The most pronounced interactions across scales are phase coherence and phase-phase causality in which the annual cycle influences the dynamics on the quasibiennial scale. The phase of slower phenomena on the scale 4-6 years influences not only the combination frequencies around the period one year, but also the phase of the annual cycle and also the amplitude of the oscillations in the quasibiennial range. In order to understand these nonlinear phenomena we investigate cross-scale interactions in synthetic, modelled $NINO_3.4$ time series. The models taken into account were a selection of 96 historic runs from CMIP5 project, and two low-dimensional models - parametric recharge oscillator (PRO) [2], which is a two-dimensional dynamical model and a data-driven model based on the idea of linear inverse models [3]. The latter is a statistical model, in our setting 25-dimensional. While the two dimensions of the PRO model are not enough to capture all the cross-scale interactions, the results from the data-driven model are more promising and they resemble the interactions found in $NINO_3.4$ measured data set. We believe that combination of models of different complexity will help to uncover mechanisms of the cross-scale interactions which might be the key for better understanding of the irregularities in the ENSO dynamics.

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