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Bicovariance and Bispectrum of ENSO index and its impact in nonlinear predictability

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El Niño Southern Oscillation (ENSO) index has been shown as a non-Gaussian and nonlinear stochastic process. Here we assess the statistical significance of non-Gaussianity and non-linearity through the analysis of third-order statistics of El Niño 3.4 index in the period 1870–2018, namely the bicovariance (lagged third-order moments) and bispectrum (its 2D Fourier transform). The analysis of bicovariance reveals a tendency for extreme (weak) ENSO signal in the Boreal Spring to be followed by la Niñas (El Niños) in the forthcoming Boreal Winter, thus contributing for a nonlinear attenuation of the ENSO Spring Predictability Barrier. The bispectrum provides a spectral decomposition of skewness in a similar way of the spectral decomposition of variance. Positive and negative real bispectrum values identify triadic phase synchronizations (at frequencies f1, f2 and f1+f2, mostly in the period range 2–6 years) contributing respectively to extreme El Niños and La Niñas. The known positive ENSO skewness and the main features of the ENSO bicovariance and bispectrum are shown to be well reproduced by fitting a bilinear stochastic model where the influence of non-observed variables is simulated by a delayed multiplicative noise, being able to generate non-Gaussianity and non-linearity. The model shows improved forecasts, with respect to benchmark linear models, up to four trimesters ahead, especially of the amplitude of extreme El Niños. The authors would like to acknowledge MISU (Meteorological Institute at Stockholm University) and the financial support FCT through project UIDB/50019/2020 – IDL and project JPIOCEANS/0001/2019 (ROADMAP: 'The Role of ocean dynamics and Ocean–Atmosphere interactions in Driving cliMAte variations and future Projections of impact–relevant extreme events').