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Non Gaussian and Non stationary characters of ENSO: the role of climate shifts and nonlinearities

J. Boucharel (1,3), B. Dewitte (1,2,3), B. Garel (4), Y. Du Penhoat (1,2)

(1) (Université de Toulouse; UPS (OMP); LEGOS; 14 Av, Edouard Belin, F-31400 Toulouse, France., (2) IRD; LEGOS, F-31400 Toulouse, France., (3) Instituto del MAR del Peru, Callao, Peru., (4) Université de Toulouse; INP-ENSEEIHT, Institut de Mathématiques de Toulouse (UPS) France.

ENSO is the dominant climate mode of variability in the Pacific, having socio-economical impacts on surrounding regions. ENSO exhibits a significant modulation at decadal to multidecadal timescales which is associated to changes of its characteristics (onset, amplitude, frequency, propagation, and predictability). Among these characteristics, some of them are generally ignored in ENSO studies, such as its asymmetry and the deviation of its statistics from those of the Gaussian distribution. These properties could be related to the ability of the current generation of coupled models to predict ENSO and its modulation.
Here, the non-Gaussian nature and asymmetry of ENSO is diagnosed from in situ data and a variety of models (from intermediate complexity models to full physics coupled general circulation models) using robust statistical tools. In particular -stable laws are used as theoretical background material to quantify the non-Gaussian character of ENSO time series. It is shown that the -stable character of ENSO may result from the presence of climate shifts inducing non stationnarity in the time series. Also, cool (warm) periods are associated with ENSO statistics having a larger (weaker) tendency towards Gaussianity and a weaker (larger) asymmetry. This supports the hypothesis of ENSO being rectified by changes in mean state through non-linear processes. The relationship between change in mean state and non-linearity is investigated both in the Zebiak and Cane model and the IPCC models, which indicate that the propensity of a model to reproduce extreme events is related to its tendency to emphasize the non-linear interaction between mean state and ENSO variability. More particularly, high statistical moments i.e high order nonlinearities seem to be involved in the feedback between extreme events occurrence and mean state shit triggering through energy cascade, emphasizing the ENSO multifractal nature.