NON GAUSSIAN AND NON STATIONARY CHARACTER OF ENSO

How these statistical properties allow diagnosing time scales variability interactions?

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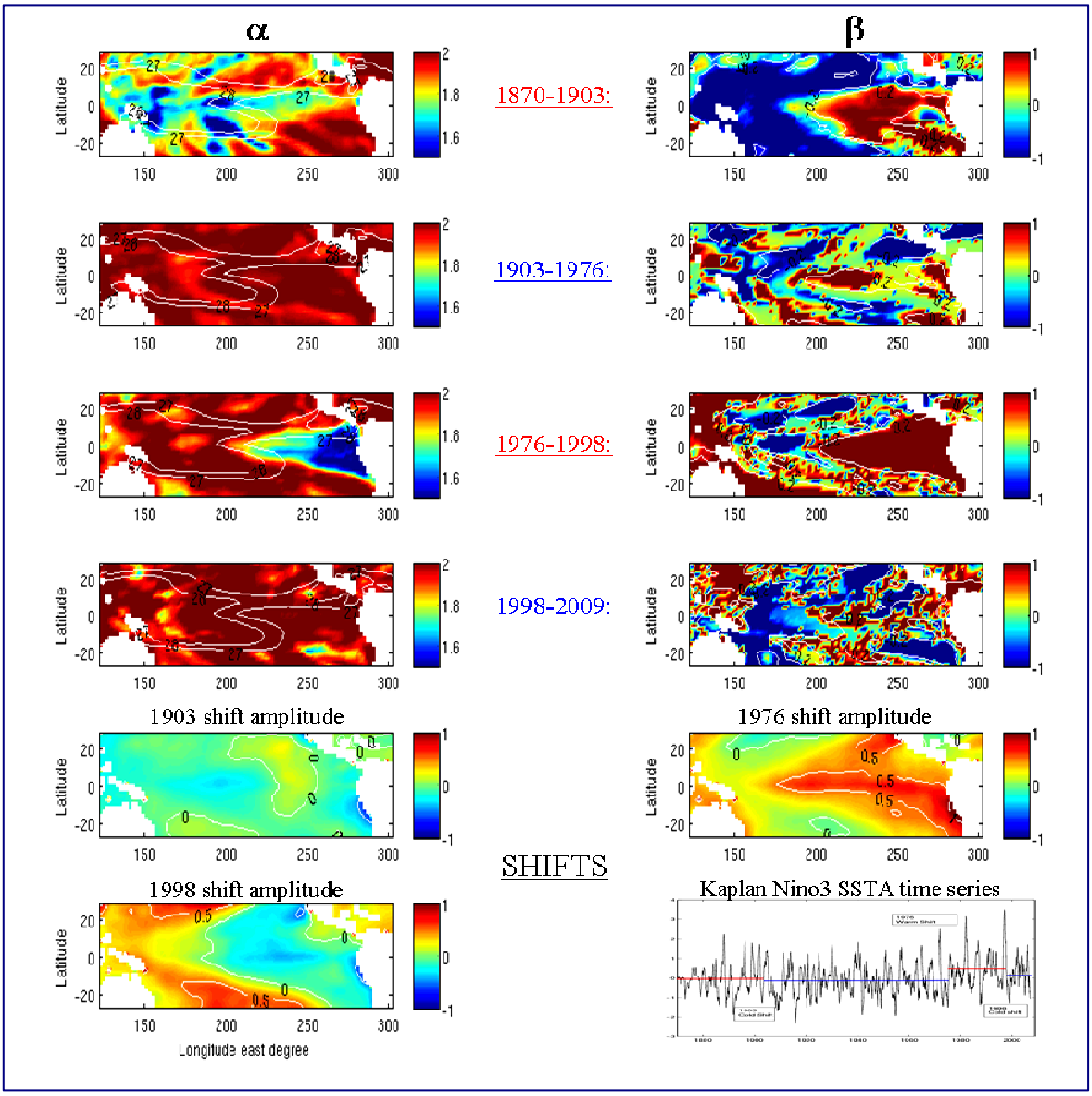
El Niño Southern Oscillation (ENSO) is the dominant mode of climate variability in the Pacific. Although our knowledge of the phenomenon has increased considerably in the last two decades, it remains difficult to predict, in particular, because its characteristics (frequency, amplitude…) vary with changes in the mean state of the tropical Pacific. These abrupt changes of the ocean background, as in 1903, 1976 and probably in 1998 and the specific associated dynamics are still unclear. The use of robust statistics, specifically designed for analysing this complex variability (from low frequency variability to burst of rapid Extreme Events (EE)), has not yet been fully achieved. We propose here an alternative to classic Gaussian statistics, namely the α-stable laws, to explicitly consider 2 main features of the Probability Density Function (PDF): the asymmetry and the weight of the distribution tail associated with warm strong El Niño episodes. In brief, non-Gaussian α-stable laws, (aka heavy tailed laws) are characterized by four main parameters. The main ones, $0 < \alpha \leq 2$ and $-1 \leq \alpha \leq 1$, respectively allow to diagnose the "non-Gaussian degree" (the PDF tails weight) and the asymmetry (~ skewness) of the set to be measured. In the same time, we applied a



bivariate test to detect shifts within the time series. By combining these two statistically rigorous methods, we were able to link the rectification of ENSO variability (burst of EE) with the tropical Pacific mean state. Over the inter-shift periods, the results of the estimation of α and β on distinct warm/cool periods (Figure 1) indicate that the ENSO statistics experienced significant changes. In particular, warm periods were characterised by stronger asymmetry and a greater deviation from Gaussianity (smaller α and $\beta \sim 1$) whereas the cool period exhibited a Gaussian symmetrical pattern on average over the tropical Pacific ($\alpha \approx 2$ and $\beta \sim 0$). A comparable tendency was found in the intermediate complexity Zebiak and Cane (ZC) model. In particular the ZC model had increased (reduced) nonlinearity quantified through nonlinear advection within the mixed layer (NDH) during warm (cool) periods. Consistently with recent studies, nonlinear dynamics is found to be responsible for rectification of ENSO variability through changes in ocean background. Although current measures of ENSO nonlinearities (through NDH) have provided meaningful information on the rectification of ENSO variability by changes in mean state, they may not fully account for the complexity of the rectified effect. In the light of the results, we can hypothesize that EE occurrences are part of the feedback loop linking changes in mean state and ENSO asymmetry. This hypothesis was tackled thanks to the CMIP3 IPCC database (pre industrial experiments). Significant correlations between different orders of running statistical moments (mean, standard deviation, skewness, kurtosis, and α as a proxy of higher statistical moment) indicated a propensity for α-stable models to link different timescales variability. Interestingly, these models which are found to represent accurately the typical ENSO time scale, as well as the decadal variability in previous models inter-comparison studies, emphasized scaling relations within different timescales. This provides further arguments to consider ENSO as a purely tropical mechanism, whose complex nonlinearity can transfer energy from low frequency variability to EE bursts and vice versa.

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