Large scale Geophysical phenomena as emerging properties from fast complex systems: the El Niño case.

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In geophysical fluid dynamics, and in particular in large scale oceanography, we always need to simplify the description of very complex phenomena, like El Niño-La Niña, the Gulf Stream, the MOC etc., introducing some approximations, while still preserving the qualitative (if not quantitative) features of the phenomenon of interest.

Typically, a Low Order Model (LOM) is thus obtained, which is a closed finite set of Ordinary Differential Equations. The LOM aims at describing the time smooth dynamics of the interesting slow part of the whole system, while the interaction with the fast part (usually some external variables, like the atmosphere and/or some internal ones, like the chaotic part of the advection process) are included by hand as a white or a correlated noise. In this way, for example, is obtained the famous Recharge Oscillator Model (ROM), mimicking the slow part of the dynamics of the El Niõ Southern Oscillation (ENSO), forced by a noise. This approach, however, overlooks some relevant details and it is open to pitfalls, from which the underlying assumption (usually not verified in this context) of the validity of the central limit theorem. Here we change the point of view. First of all we assume that it is possible to simplify the description, arriving to a LOM for the *whole* system. However, we do not make explicit the equation of motion of the fast non interesting part, because we shall see that we dont need to know it. Then, we apply a Zwanzig projection approach to obtain the large scale dynamics of the sole part of interest, that emerges as a universal property of the system, weakly dependent on the details of the fast part. We present here some results stemming from the implementation of this approach to the ENSO. In particular we obtain analytic results for the stationary probability density function of the NINO3 index (East equatorial Pacific sea surface temperature anomaly), and for the recurrence timing of strong El Niño events.

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