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Another look at low-frequency variability in climate dynamics, from the ergodic theory of dynamical systems

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Climate variability, oceanic currents, and geophysical turbulent flows in general exhibit recurrent large-scale patterns which although evolving irregularly in time, exhibit characteristic dominant frequencies across a large range of time-scales from intraseasonal through seasonal-interannual up to interdecadal. The understanding of the associated low-frequency variability (LFV) is essential for simulation and prediction of the irregularly occurring events in each of these bands. In the case of El-Niño-Southern Oscillation (ENSO), Chekroun et al. (PNAS, 108, 2011) showed that a better understanding of these modes — and their interactions with higher-frequency variability — allows an extension of predictability for a stochastic model exhibiting the appropriate LFV (for ENSO, the quasi-biennial and quasi-quadrennial modes essentially).

Several approaches have been proposed to explain the origin of such LFV over the past decades such as the mechanisms of nonlinear resonance or the ones of noise-sustained oscillations from non-normal modes, to name a few. In this talk, new perspectives stemming from the ergodic theory of dynamical systems will be presented which will point out other mathematical representations of LFV as arising in dissipative chaotic systems subject to random disturbance or not. The theory of time-dependent Sinaï-Ruelle-Bowen measures (Chekroun et al., Physica D, 240, 2011) and the theory of Koopman operator will serve us in that perspective. Idealized models of intermediate complexity will illustrate our theoretical approach and challenges for more realistic models will be discussed.