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Oscillatory Climate Modes in the Indian Monsoon, North Atlantic and Tropical Pacific

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In this presentation, we concentrate on potential teleconnections among the Indian monsoon, Tropical Pacific Ocean, and the North Atlantic. Most teleconnection studies so far were based on correlations between climatic time series from the regions of interest; often the correlations found in this way were no larger in absolute magnitude than 0.6, and they did not clarify in which frequency band the teleconnection under investigation was most active. To explore in greater depth the commonalities between the well-documented records of the North Atlantic Oscillation (NAO) index, the Southern Oscillation Index (SOI) and the Indian monsoon rain records we adopt here the viewpoint of synchronization between chaotic oscillators.

Our synchronization analysis is based on singular spectrum analysis (SSA) and it is partly described in (Feliks 2010). It differs from that of previous studies that relied on SSA and on multichannel SSA (M-SSA) inasmuch as we rely upon the recently proposed varimax rotation of M-SSA eigenvectors (Groth & Ghil 2011) in order to improve the separation of oscillations and the identification of synchronized oscillators. With no need for any a priori phase definition for each of the subsystems, M-SSA is able to automatically identify multiple oscillatory modes and detect whether these modes are shared by phase- and frequency-locked oscillators; even if the oscillatory behavior is getting swamped by the observational noise. Given the presence of high stochasticity in the system's dynamics, we raise in particular the question of a reasonable spectral resolution as well as the robustness and reliability of M-SSA results with respect to parameter changes.

In this study we show that interannual oscillatory modes exist in all the climatic records at hand, with statistically significant oscillatory modes having periods of 2.2-2.7 yr, 3.2-3.6 yr, 5 yr and 6-8 yr. Such a clustering of periodicities raises the possibility of teleconnection between these regions. A key result is that the 7-8-yr and 2.7-yr oscillatory modes in all three regions are strongly synchronized, and the energy ratio analysis suggests that the NAO induces these modes in the other two regions. Both these modes in the NAO appear to be connected to intrinsic modes of variability of the Gulf Stream front. In agreement with some recent studies, it was found here that the South Asian monsoon is not slaved to forcing from the equatorial Pacific, although it does interact strongly with it. The energy-ratio analysis pinpointed this to be the case in particular for the quasi-biennial oscillatory modes.

Feliks, Ghil, and Robertson (2010), Oscillatory climate modes in the Eastern Mediterranean and their synchronization with the North Atlantic Oscillation. J. Climate, 23 (15), 4060–4079.

Groth and Ghil (2011), Multivariate singular spectrum analysis and the road to phase synchronization. Phys. Rev. E, 84, 036206