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Information transfer and synchronization among the scales of climate variability: clues for understanding anomalies and extreme events?

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Deeper understanding of complex dynamics of the Earth atmosphere and climate is inevitable for sustainable development, mitigation and adaptation strategies for global change and for prediction of and resilience against extreme events. Traditional (linear) approaches cannot explain or even detect nonlinear interactions of dynamical processes evolving on multiple spatial and temporal scales. Combination of nonlinear dynamics and information theory explains synchronization as a process of adjustment of information rates [1] and causal relations (à la Granger) as information transfer [2]. Information born in dynamical complexity or information transferred among systems on a way to synchronization might appear as an abstract quantity, however, information transfer is tied to a transfer of mass and energy, as demonstrated in a recent study using directed (causal) climate networks [2]. Recently, an information transfer across scales of atmospheric dynamics has been observed [3]. In particular, a climate oscillation with the period around 7–8 years has been identified as a factor influencing variability of surface air temperature (SAT) on shorter time scales. Its influence on the amplitude of the SAT annual cycle was estimated in the range 0.7–1.4 °C and the effect on the overall variability of the SAT anomalies (SATA) leads to the changes 1.5–1.7 °C in the annual SATA means. The strongest effect of the 7–8 year cycle was observed in the winter SATA means where it reaches 4–5 °C in central European station and reanalysis data [4]. In the dynamics of El Niño-Southern Oscillation, three principal time scales have been identified: the annual cycle (AC), the quasibiennial (QB) mode(s) and the low-frequency (LF) variability. An intricate causal network of information flows among these modes helps to understand the occurrence of extreme El Niño events, characterized by synchronization of the QB modes and AC, and modulation of the QB amplitude by the LF mode. The latter also influences the phase of the AC and QB modes.

These examples provide an inspiration for a discussion how novel data analysis methods, based on topics from nonlinear dynamical systems, their synchronization, (Granger) causality and information transfer, in combination with dynamical and statistical models of different complexity, can help in understanding and prediction of climate variability on different scales and in estimating probability of occurrence of extreme climate events.

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