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Discriminating different El Niño and La Niña phases by evolving climate networks

Marc Wiedermann (1,2), Alexander Radebach (2,3), Reik V. Donner (1), Jonathan F. Donges (1,4), Jürgen Kurths (1,2,5)

(1) Potsdam Institute for Climate Impact Research, Potsdam, Germany, (2) Department of Physics, Humboldt University, Berlin, Germany, (3) Mercator Research Institute on Global Commons and Climate Change, Berlin, Germany, (4) Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden, (5) Institute for Complex Systems and Mathematical Biology, University of Aberdeen, Aberdeen, United Kingdom

The El Niño Southern Oscillation (ENSO) can be observed, for example, in terms of surface air temperature anomalies in the Central and East Pacific Ocean and has a large impact on the global climate system. Its variability can roughly be categorized into El Niño (anomalously warm), La Niña (anomalously cold) and normal periods. In addition, the El Niño exhibits into two different types (Eastern-Pacific (EP) and central-Pacific (CP) type) which may be distinguished from each other by different signatures in the first empirical orthogonal function (EOF) computed over the respective years of its appearance. A similar proposition has been made recently regarding the existence of two different types of La Niña phases [1]. However, no generally applicable criterion to distinguish these different phases has been introduced so far.

Here, we construct time-evolving climate networks from anomalized daily global surface air temperature fields and investigate the dynamics of their structural properties. For the El Niño phases, global network measures have been shown to naturally discriminate between the presence of EP and CP type [2]. Local network measures found during either of the two periods show high similarity with the results from classical EOF analysis with respect to their spatial patterns which strongly depend on the El Niño type. If the same concept is applied to La Niña periods, we find that an analogous categorization of events into two types is possible. Here, the spatial patterns of local network measures prove to be equivalent to those found for El Niño events. Our findings imply that each of the four different types of ENSO events displays unique signatures in the SAT field's correlation structure, which can be discriminated objectively with the tools of complex network theory at hand.

Our findings demonstrate that evolving climate networks provide a powerful formalism to systematically detect and categorize different types of ENSO periods while at the same time highlighting dynamical equivalences between them. With our tools we derive generally applicable criteria for discriminating Eastern-Pacific and Central-Pacific ENSO events purely based on the structural properties of the underlying climate network, which complements existing methods of pattern based statistical analysis.

[1] J.-S. Kug et at., Geophys. Res. Lett., 2011
[2] A. Radebach et al., Phys. Rev. E, 2013