Forecasting El Niño well before the spring predictability barrier

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The El Niño Southern Oscillation (ENSO) is the most important driver of interannual global climate variability and can trigger extreme weather events and disasters in various parts of the world. Existing operational El Niño predictions have been particularly hampered by the so-called spring predictability barrier, which limits the reliable pre-warning time before an El Niño to about six months.

Recently [1,2], we have developed a dynamical climate network approach for predicting the onset of El Niño events well before the spring barrier. In this network, the nodes are reanalysis grid points in the Pacific, and the strengths of the links between them are derived from the cross-correlations of the atmospheric surface temperatures at the grid points. In the year before an El Niño event, the links between the eastern equatorial Pacific and the rest of the tropical Pacific tend to strengthen such that the average link strength exceeds a certain threshold. Predictions based on this feature for the presence or absence of an El Niño onset in the following year are correct with 73% and 90% probability, respectively. The p-value of the hindcasting and forecasting phase (1981-2022) for this performance based on random guessing with the climatological average is $3.5*10^{-5}$.

We complement the climate network approach with additional forecasting methods, which can also cross the spring barrier for obtaining more specific predictions. We found that information entropy in the Niño3.4 area in the central Pacific strongly correlates with the magnitude of an El Niño that starts in the following year [3]. Additionally, the temperature gradient between the western and central Pacific provides an early predictor for the type of an El Niño event. Depending on the region of maximal warming, El Niño events can be partitioned into 2 types, Eastern Pacific and Central Pacific. The type of an El Niño has a significant influence on its impact and can even lead to dry or wet conditions in the same areas on the globe, however its prediction is currently even more limited than that of the El Niño event itself. Combining the different approaches allows not only more specific forecasts but mutually agreeing predictions increase the forecast certainty. The approaches here presented about double the pre-warning time before an El Niño and can enable early and more targeted mitigation measures.

References

[1] J. Ludescher et al., PNAS 110, 11742 (2013).
[2] J. Ludescher et al., PNAS 111, 2064 (2014).
[3] J. Meng et al., PNAS 117, 177 (2020).
[4] J. Ludescher et al., PNAS 118, e1922872118 (2021).