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Complexity-based approach for El Niño magnitude forecasting before the spring predictability barrier

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The El Niño Southern Oscillation (ENSO) is one of the most prominent interannual climate phenomena. An early and reliable ENSO forecasting remains a crucial goal, due to its serious implications for economy, society, and ecosystem. Despite the development of various dynamical and statistical prediction models in the recent decades, the “spring predictability barrier” (SPB) remains a great challenge for long (over 6-month) lead-time forecasting. To overcome this barrier, here we develop an analysis tool, the System Sample Entropy (SysSampEn), to measure the complexity (disorder) of the system composed of temperature anomaly time series in the Niño 3.4 region. When applying this tool to several near surface air temperature and sea surface temperature datasets, we find that in all datasets a strong positive correlation exists between the magnitude of El Niño and the previous calendar year’s SysSampEn (complexity). We show that this correlation allows to forecast the magnitude of an El Niño with a prediction horizon of 1 year and high accuracy (i.e., Root Mean Square Error = 0.23°C for the average of the individual datasets forecasts). For the 2018 El Niño event, our method forecasts a weak El Niño with a magnitude of $1.11 \pm 0.23^\circ\text{C}$. Our framework presented here not only facilitates a long-term forecasting of the El Niño magnitude but can potentially also be used as a measure for the complexity of other natural or engineering complex systems.