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

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Abstract—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). After we have finished this work in 2017, for the 2018 El Niño event of 0.9°C magnitude, our method forecasts a weak El Niño with a magnitude of 1.11 ± 0.23°C. We also forecast non-El Niñosituation for the year 2020. 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.

1. Introduction

Although El Niño events characterized by anomalous episodic warmings of the eastern equatorial Pacific can trigger disasters in various parts of the globe, reliable/robust forecasts of their magnitude are still limited to about six months ahead. A significant extension of this prewarning time would be instrumental for mitigating some of the worst damages. Here we introduce a new approach relying on information entropy, which achieves some doubling of the prewarning time. The approach is based on our finding that the entropy in one calendar year exhibits a strong correlation with the magnitude of an El Niño that starts in the following year, and thus allows to forecast the onset and the magnitude of El Niño event one year in advance.

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