Geophysical Research Abstracts
Vol. 20, EGU2018-9521, 2018
EGU General Assembly 2018

From Critical Fluctuations to Prediction of Indian Summer Monsoon

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The critical phenomena appear in the vicinity of the critical point. Those phenomena are indicators of upcoming critical transition. Earlier methods were dealing with the critical phenomena as early warning signals. However, they do not yet show an example where early warning signals were used to avert an upcoming shift. They have been used in models, experiments or retroactively.
In our study, we make a step forward in this direction. In contrast to traditional approaches, which use precursors for prediction of the time of the critical transition (which in fact work retrospectively only), we discovered how to use precursors in a new way – to find regions where the critical conditions for a transition originate. We use the phenomenon of critical growth of fluctuations [1] to detect such regions.
We have found the evidence in observational data of the Indian Summer monsoon that we can consider the onset of monsoon as a critical transition - a sudden transition to the monsoon when critical thresholds (in particular, in near-surface air temperature, relative humidity) are reached. This finding allows us using the critical transition theory for a prediction of onset and withdrawal dates of the Indian summer monsoon.
Our prediction relies on observations of near-surface air temperature and relative humidity from both the ERA-40 and NCEP/NCAR re-analyzes.
Using the phenomenon of critical growth of fluctuations we revealed two geographical areas - the Eastern Ghats (EG) and North Pakistan (NP), which we defined as origins of critical conditions or Tipping Elements of Indian Summer Monsoon. We have found the regularities between the Tipping Elements allow us predicting the timing of the upcoming monsoon onset and withdrawal for 40 and 70 days in advance respectively.
Our results show that our method allows predicting the monsoon not only retrospectively (over the period 1951-2015, [2]) but also in the future. In 2016 and 2017 we successfully predicted the onset and withdrawal dates. Hence, we proved that such early prediction of the monsoon timing is possible [3].
The proposed approach is applicable for systems of different nature, thereby offers a general framework for predicting critical transitions in spatial-temporal systems.

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[2] Stolbova, V., E. Surovyatkina, B. Bookhagen, and J. Kurths (2016): Tipping elements of the Indian monsoon: Prediction of onset and withdrawal. GRL 43, 1–9 [doi:10.1002/2016GL068392]
[3] https://www.pik-potsdam.de/services/infodesk/forecasting-indian-monsoon