



## **Predicting Indian Summer Monsoon onset through variations of surface air temperature and relative humidity**

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Indian Summer Monsoon (ISM) rainfall has an enormous effect on Indian agriculture, economy, and, as a consequence, life and prosperity of more than one billion people. Variability of the monsoonal rainfall and its onset have a huge influence on food production, agricultural planning and GDP of the country, which on 22% is determined by agriculture. Consequently, successful forecasting of the ISM onset is a big challenge and large efforts are being put into it.

Here, we propose a novel approach for predictability of the ISM onset, based on critical transition theory. The ISM onset is defined as an abrupt transition from sporadic rainfall to spatially organized and temporally sustained rainfall. Taking this into account, we consider the ISM onset as a critical transition from pre-monsoon to monsoon, which take place in time and also in space. It allows us to suggest that before the onset of ISM on the Indian subcontinent should be areas of critical behavior where indicators of the critical transitions can be detected through an analysis of observational data. First, we identify areas with such critical behavior. Second, we use detected areas as reference points for observation locations for the ISM onset prediction. Third, we derive a precursor for the ISM onset based on the analysis of surface air temperature and relative humidity variations in these reference points. Finally, we demonstrate the performance of this precursor on two observational data sets.

The proposed approach allows to determine ISM onset in advance in 67% of all considered years. Our proposed approach is less effective during the anomalous years, which are associated with weak/strong monsoons, e.g. El-Nino, La-Nina or positive Indian Ocean Dipole events. The ISM onset is predicted for 23 out of 27 normal monsoon years (85%) during the past 6 decades. In the anomalous years, we show that time series analysis in both areas during the pre-monsoon period reveals indicators whether the forthcoming ISM will be normal or weaker/stronger.