



## **Predicting onset and withdrawal of Indian Summer Monsoon in 2016: results of Tipping elements approach**

Elena Surovyatkina (1,2), Veronika Stolbova (1,3,4), Jurgen Kurths (1,4)

(1) Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany (elena.surovyatkina@gmail.com), (2) Space Research Institute of Russian Academy of Sciences, Moscow, Russia, (3) University of Zürich, Zürich, Switzerland, (4) Institute of Applied Physics of Russian Academy of Sciences, Nizhny Novgorod, Russia

The monsoon is the season of rain caused by a global seasonal reverse in winds direction and a change in pressure distribution. The Southwest winds bring summer monsoon to India. The economy of India is able to maintain its GDP in the wake of a good monsoon. However, if monsoon gets delayed by even two weeks, it can spell disaster because the high population depending on agriculture - 70% of its people directly related to farming. Agriculture, in turn, is dependent on the monsoon.

Although the rainy season happens annually between June and September, the time of monsoon season's onset and withdrawal varies within a month from year to year. The important feature of the monsoon is that it starts and ends suddenly. Hence, despite enormous progress having been made in predicting monsoon since 1886, it remains a significant scientific challenge.

To make predictions of monsoon timing in 2016, we applied our recently developed method [1]. Our approach is based on a teleconnection between the Eastern Ghats (EG) and North Pakistan (NP) - Tipping Elements of Indian Summer Monsoon. Both our predictions - for monsoon onset and withdrawal - were made for the Eastern Ghats region (EG-20N,80E) in the central part of India, while the Indian Meteorological Department forecasts monsoon over Kerala - a state at the southern tip of the Indian subcontinent.

Our prediction for monsoon onset was published on May 6-th, 2016 [2]. We predicted the monsoon arrival to the EG on the 13th of June with a deviation of +/-4 days. In fact, monsoon onset was on June 17-th, that was confirmed by information from meteorological stations located around the EG-region. Hence, our prediction of monsoon onset (made 40 days in advance) was correct.

We delivered the prediction of monsoon withdrawal on July 27, 2016 [3], announcing the monsoon withdrawal from the EG on October 5-th with a deviation of +/-5 days. The actual monsoon withdrawal started on October 10-th when the relative humidity in the region started to decrease, and after two days meteorological stations reported 'No rain' in the EG and also in areas located across the subcontinent in the direction from the North Pakistan to the Bay of Bengal. Hence, the date of monsoon withdrawal - October 10-th, predicted 70 days in advance, lies within our prediction interval.

Our results show that our method allows predicting a future monsoon, and not only retrospectively or hindcast. In 2016 we predicted of the onset and withdrawal dates of the Southwest monsoon over the Eastern Ghats region in Central India for 40 and 70 days in advance respectively. Our general framework for predicting spatial-temporal critical transitions is applicable for systems of different nature. It allows predicting future from observational data only, when the model of a transition does not exist yet.

[1] Stolbova, V., E. Surovyatkina, B. Bookhagen, and J. Kurths (2016): Tipping elements of the Indian monsoon: Prediction of onset and withdrawal. *Geophys. Res. Lett.*, 43, 1–9.

[2] [https://www.pik-potsdam.de/news/press-releases/indian-monsoon-novel-approach-allows-early-forecasting?set\\_language=en](https://www.pik-potsdam.de/news/press-releases/indian-monsoon-novel-approach-allows-early-forecasting?set_language=en)

[3] <https://www.pik-potsdam.de/kontakt/pressebuero/fotos/monsoon-withdrawal/view>