

Elena Surovyatkina



Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany

Space Research Institute (IKI), Russian Academy of Sciences, Moscow, Russia

Tipping Elements Approach for Forecasting Monsoon in Central India: Result 2016-2018

Outline

 Critical Transition & Critical phenomena
Spatially organized critical transitions.
Tipping Elements approach for prediction of the Indian Summer Monsoon

- 3.Forecasting upcoming monsoon: observational evidences
- 4. Climate change effects

«The onset of monsoon.. Is not a transition from a regime of no rain to rain; it is a transition from a regime of sporadic rainfall to spatially organized and temporally sustained rainfall...»

R. Ananthakrishnan and M.K. Soman, 1990

The Treasure of San Gennaro (1966)

Operazione San Gennaro (original title)





An American gangster in Italy enlists a local gang to help him steal the treasure of Naples' patron saint.





Is it a critical transition from a regime of sporadic rainfall to spatially organized and temporally sustained rainfal?



Critical fluctuations



Pre-bifurcation growth of fluctuations in the nonlinear oscillator



[Surovyatkina et al. (2005), Phys. Rev. E, 72, 046125; Surovyatkina, Phys. Lett. A 329, (2004) 169 ; 9 Kravtsov, Surovyatkina, Phys. Lett. A , (2003), 319 (3–4), 348.]

Critical phenomena

• Pre-bifurcation growth and saturation of fluctuations

Kravtsov Yu.A., Surovyatkina E.D., Phys. Lett. A 319 (3–4), (2003) 348. Surovyatkina E.D., Kravtsov Yu. A. and Kurths Jü., Phys. Rev. E, 72, 046125 (2005)

 Pre-bifurcation rise and saturation of the correlation time of fluctuations

Surovyatkina E.D., Phys. Lett. A 329, (2004) 169.

• Rate-depended critical phenomena

Majumdar Apala , Ockendon John , Howell Peter and Surovyatkina Elena. Transitions through Critical Temperatures in Nematic Liquid Crystals. Phys. Rev. E. 88, 022501 (2013)

Early warning indicators



Fully 3-D dynamical model test

Lenton et al. (2009) Phil. Trans. A 367: 871-884



August 24, 2010

GENIE-2 model

"We do not yet have an example where early warning signals were used to avert an upcoming shift (they have been used in models, experiments or retroactively)".

> Early Warning Signals of Ecological Transitions: Methods for Spatial Patterns. [Kefi et al.(2014)]

In our study, we make a step forward in this direction. In contrast to traditional approaches to use precursors for a prediction of the time of the critical transition, we use precursors to find regions where conditions for a critical transition originate.

- Where (geographically) do critical conditions originate?
- How do the critical conditions propagate in space?

2. Spatially organized critical transitions: Tipping Elements approach for prediction of the Indian Summer Monsoon

What does the term 'tipping' mean?

One of the definitions of tip

- overbalance or
- cause to overbalance

"The hay caught fire when the candle tipped over....."



- \checkmark The candle is an origin of the problem a tipping element of the system.
- \checkmark The time when the candle tipped over is *a tipping point*.
- ✓ An open window which gives the direction of flame propagation is the second *tipping element of the system*.

Tipping elements and prediction of monsoon



 Stolbova V., Surovyatkina E., Bookhagen B., Kurths J., Tipping elements of the Indian monsoon: prediction of onset and withdrawal. Geophysical Research Letters 43, 1–9, 2016, 2016

• Surovyatkina E.D., Kravtsov Yu. A. and Kurths Jü., Phys. Rev. E, 72, 046125 (2005)



https://earth.nullschool.net/#2016/06/17/0300Z/wind/isobaric/1000hPa/orthographic=78.74,8.05,626/loc=80,20



North Pakistan (32.5N,72.5E) is the tipping element of ISM where the ISM ceases to exist.

The Eastern Ghats (20N, 80E)

is the tipping element of the ISM where we deliver our forecast of monsoon onset on **May 6**.

Stolbova V., Surovyatkina E., Bookhagen B., Kurths J., Tipping elements of the Indian monsoon: prediction of onset and withdrawal. *GRL*, *43*, *1–9*, *April 20*, 2016

Networks analysis

Stolbova V.et al., NPG, 2014.

Temperature & wind fields



Figure 3. Links between a set of 153 reference grid points to other grid points and surface wind vector mean 1998-2012.



Figure 4. Wind fields and near-surface temperature: before, during and after the onset of monsoon

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DATA: NCEP/NCAR reanalysis, 2.5 °, near –surface air temperature, (1951-2015)

How can we use obtained result for the predictability of the onset of monsoon?

Prediction scheme for monsoon onset and withdrawal over the Eastern Ghats (20N,80E)



Performance of prediction scheme



3. Forecasting upcoming monsoon:
observational evidences

https://www.pikpotsdam.de/services/infodesk/forecasting-indian-



Indian Summer Monsoon - 2017

The PIK- monsoon onset monitor news

May 08, 2017

Forecast of the Onset date of the Indian Summer Monsoon - 2017 over the central part of India

The Indian Summer Monsoon (the Southwest Monsoon) is likely (with a 73% probability) to set over the central part of India, the Eastern Ghats region (20°N,80°E) on or around 18th June (+/- 4 days).

The region of our forecast locates in the central part of India in the area of the Easter Ghats (EG).

https://www.pik-potsdam.de/services/infodesk/forecasting-indian-monsoon





Daily mean near-surface air temperature till **May 8, 2017**, for the Eastern Ghats (red) and North Pakistan (blue).Violet and gray lines- past 5-years average for same regions. The tipping point (red) indicates the critical temperature and the forecasted onset date. The forecasted withdrawal dates are from 7th to 17th October.

The Evidence for successful PIK-Monsoon onset forecast - 2017 Onset forecast: June 18+/-4 days



The Map of Advance of Southwest Monsoon by the Indian Meteorological Department (<u>http://www.imd.gov.in/pages/allindiawxfcbulletin.php)</u>

Indian Summer Monsoon - 2017

The PIK- monsoon onset monitor news



July 30, 2017

Earliest Forecast of the Withdrawal Date of Indian Summer Monsoon - 2017 from the Central part of India.

The Indian Summer Monsoon (Southwest Monsoon) is likely (with an 84% probability) to withdraw from the Central part of India (20N, 80E) around 12th October (+/- 5 days), namely between 7th and 17th October 2017.

https://www.pik-potsdam.de/services/infodesk/forecasting-indian-monsoon



Indian Monsoon Monitor, 2017



Indian Summer Monsoon - 2018

The PIK- monsoon onset monitor news

May 07, 2017

Forecast of the Onset date of the Indian Summer Monsoon - 2017 over the central part of India

The Indian Summer Monsoon (the Southwest Monsoon) is likely to set over the central part of India, the Eastern Ghats region (20°N,80°E) around 15th June (+/- 4 days) namely between 11th to 19th June 2018.

The region of our forecast locates in the central part of India in the area of the Easter Ghats (EG).

https://www.pik-potsdam.de/services/infodesk/forecasting-indian-monsoon





Daily mean near-surface air temperature till **May 7, 2018**, for the Eastern Ghats (red) and North Pakistan (blue).Violet and gray lines - past 5-years average for same regions. The tipping point (red) indicates the critical temperature and the forecasted onset date.





Daily mean near-surface air temperature till **June 15**, **2018**, for the Eastern Ghats (red) and North Pakistan (blue).Violet and gray lines - past 5-years average for same regions. The tipping point (red) indicates the critical temperature and the forecasted onset date.

18 June 2018



4. Climate change effect

Climate change affects the Indian Summer Monsoon in several aspects:

- 1. In the last decade, the intensity of monsoon rainfalls in the central part of India has increased.
- 2. Local Overheating Premature Release Bogus.
- 3. The delay of withdrawal of the monsoon.
- In Central India, the variability of Monsoon is quite high due to local changes such as rapid urbanization, industrialization.

The forecasting of monsoon is a challenge mostly because of there is no recent historical precedent for such changing in the climate system.



- Our approach is based on a teleconnection between two geographical areas - the Eastern Ghats (EG) and North Pakistan (NP), which we defined as Tipping Elements of Indian Summer Monsoon.
- We have found the Tipping Elements approach allows 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) but also in the future. In 2016 and 2017, we proved that such early prediction of the monsoon timing is possible.
- The proposed approach is applicable to different kind of season, which exhibits properties of critical transition. Our prediction is based on observational data only when the model cannot accurately anticipate the transition or does not exist yet.

References

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IITM, Climate Change Center, Pune

Amirta University, Coimbatore

Dynamic case: the effect of the rate of change of the bifurcation parameter $\frac{dS}{dt} = S(S^2 - 2S + A(t))$

Transcritical bifurcation:

backward transition through $A_T = 0$

Saddle-node bifurcation:

forward transition through

$A(t) = A_0 + \mathcal{E}t$ $A(t) = A_0 - \varepsilon t$ 3 3 S(A), S(A(t)) S(A), S(A(t))2.5 2.5 $O(\mathcal{E}^{2/3})$ $-\varepsilon = 0.5$ 1.5 1.5 $-\varepsilon = 0.25$ 1 $-\varepsilon = 0.125$ $\epsilon = 0.0625$ 0.5 0.5 $O(\mathcal{E})$ 0 L -3 0 L -3 2 -2 Ò. З -2 -1 2 З A_{SN} A_0 $-A_0$ A_{T} A_0 $O(-\varepsilon \log \varepsilon)$

The delay in stability exchange is **independent** The dynamic transition overshoots the static of \mathcal{E} and proportional to the initial value of A [1]. value A =1 and this overshoot is **dependent** on

[1] Apala Majumdar, John Ockendon, Peter Howell, Elena Surovyatkina. Phys. Rev. E. 88, 022501 (2013)

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 $A_{SN} = 1$