Elena Surovyatkina

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

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

Network-Based Monsoon Forecasts: Tipping Elements Approach

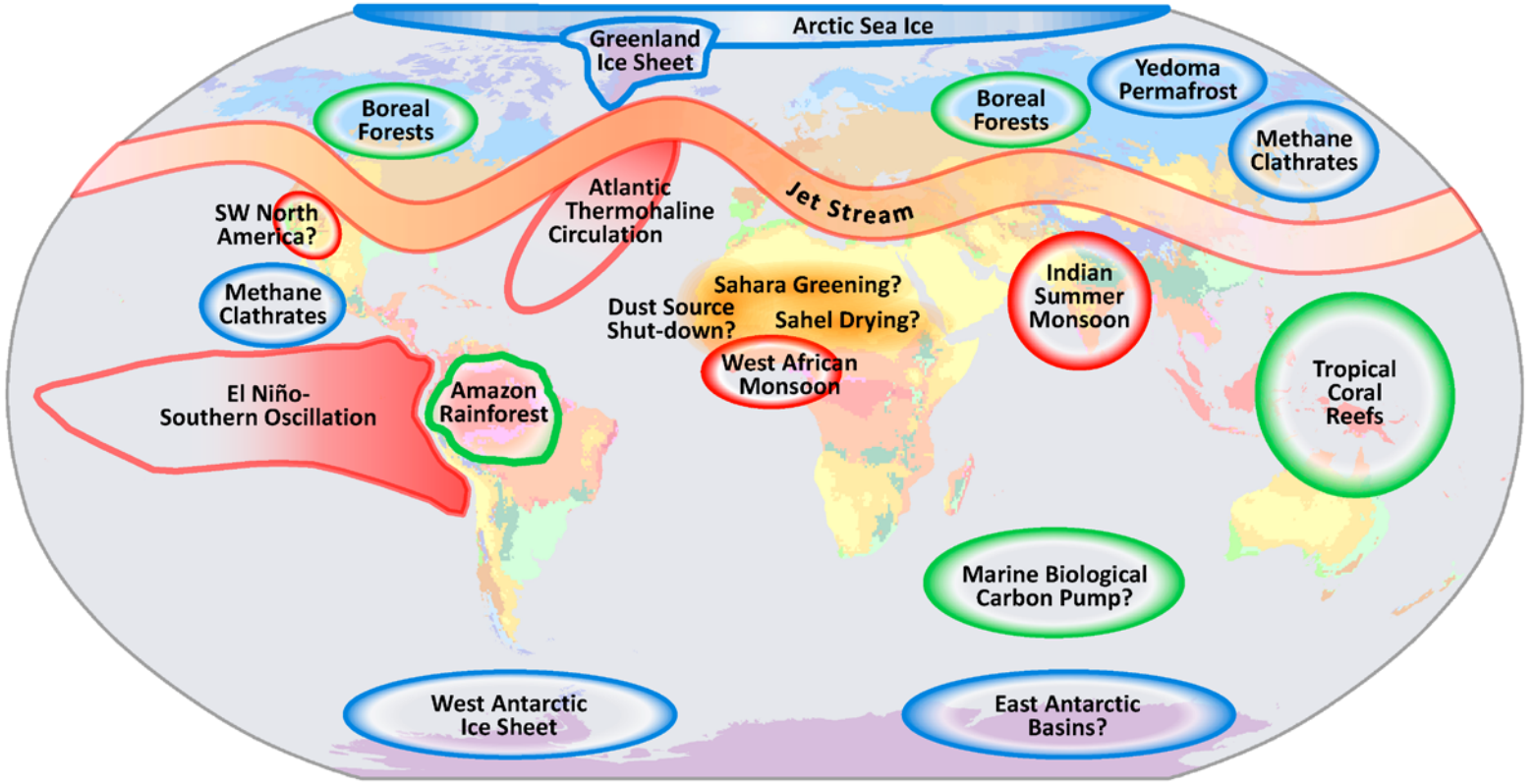
Veronika Stolbova, Bodo Bookhagen, Jürgen Kurths



University of Alaska Fairbanks | GOTHAM Summer School

18th - 22th Sep, 2017

Tipping elements are components of the Earth System that are sub-continental in scale. A rapid and often irreversible qualitative change its state might have dramatic consequences on the system as a whole [Lenton et al. 2008].



[https://www.pik-potsdam.de/services/infodesk/tipping-elements]

What does the term 'tipping' mean?

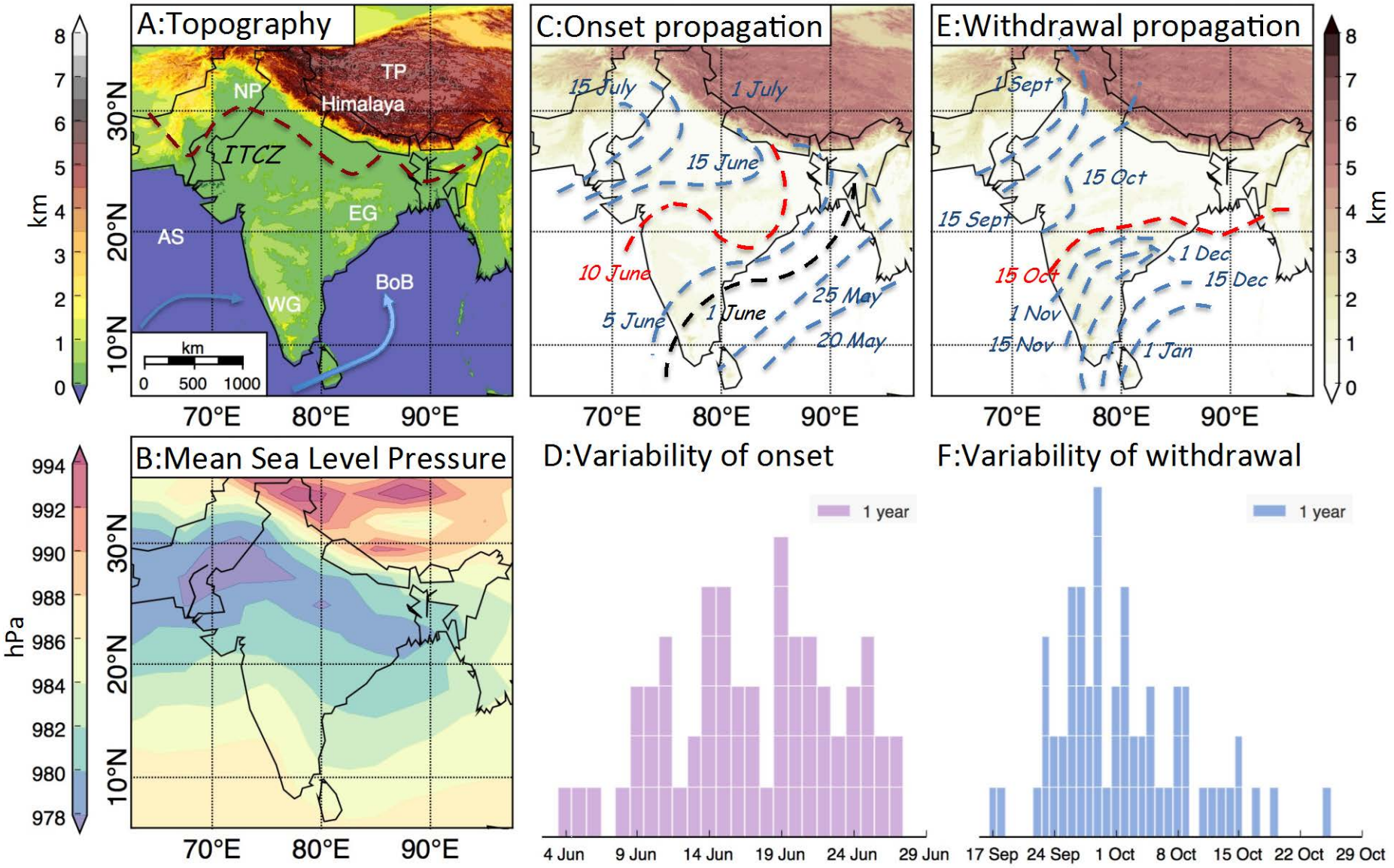
One of the definitions of tip

- *overbalance or*
- *cause to overbalance*

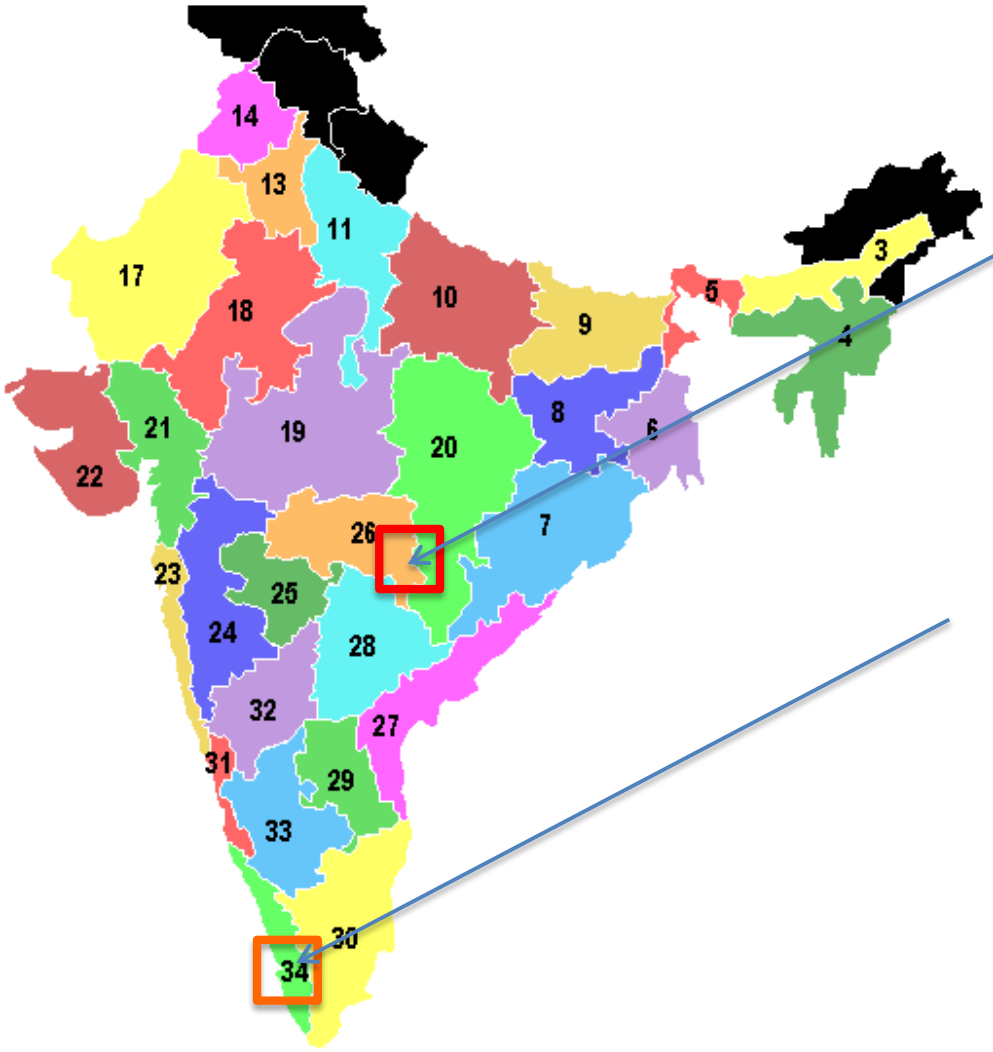
"The hay caught fire when the candle tipped over….."

- ✓ The candle is an origin of the problem – *a tipping element of the system*.
- ✓ 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*.

Advance and withdrawal of monsoon



How far in advance can the monsoon be realistically predicted?



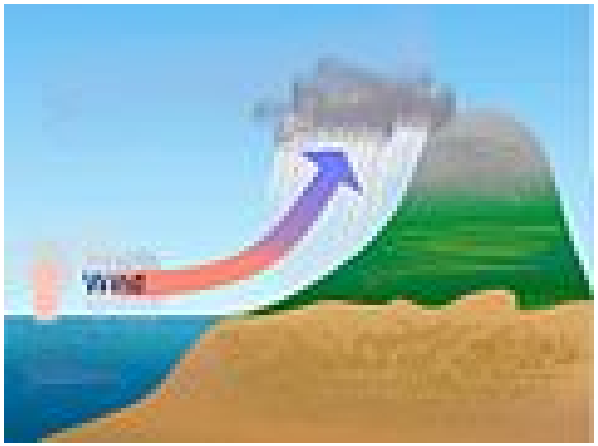
The Eastern Ghats (20N, 80E) is the Tipping element of the ISM where we deliver our forecast of monsoon onset on **May 6**.

Kerala state is the region where the IMD delivers the forecast of onset of monsoon on **May 15**.

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

The theories of monsoon

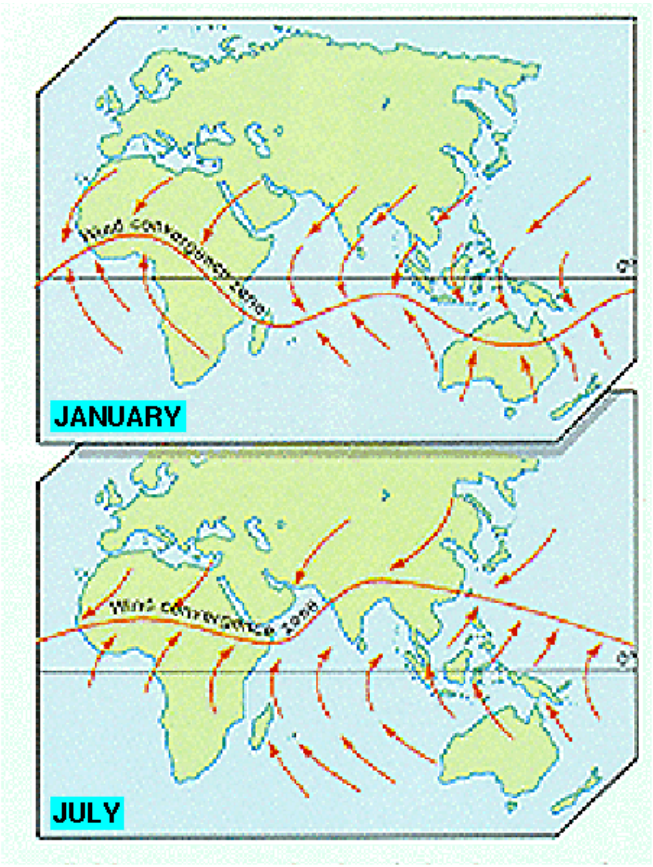
Differential heating theory



Mausim - season

1686 - English astronomer and mathematician Edmond Halley gave first explanation of the monsoon.

ITCZ fluctuations theory



The Intertropical Convergence Zone (ITCZ) is the area encircling the earth near the equator where the northeast and southeast trade winds come together.

«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…»

critical

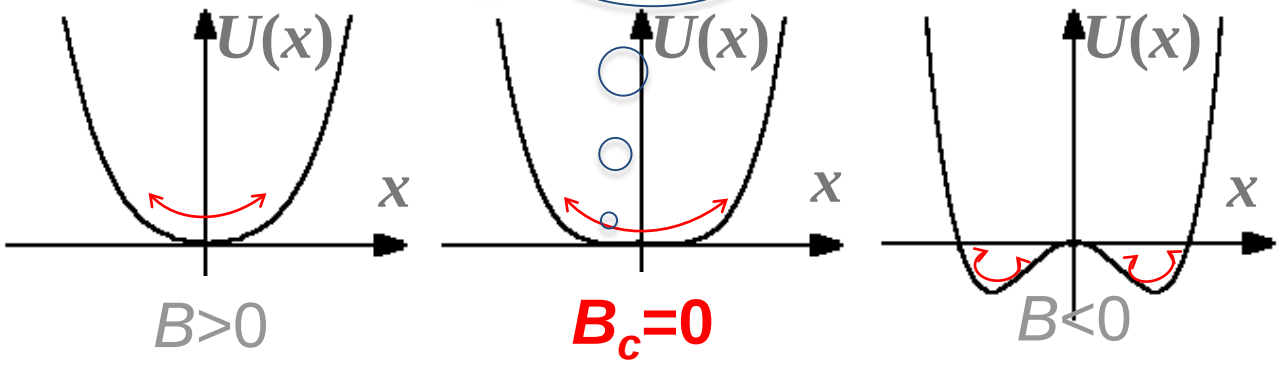
R. Ananthakrishnan and M.K. Soman, 1990

Critical transition in the Nonlinear Oscillator

$$\ddot{x} + 2\gamma\dot{x} + \frac{dU}{dx} = f(t),$$

$$U(x) = \frac{1}{2}Bx^2 + \frac{1}{4}Ax^4$$

Pre-bifurcation growth of fluctuations



Pitchfork Bifurcation

How the growth of fluctuation depends on the distance to the bifurcation point?

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)

"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)".

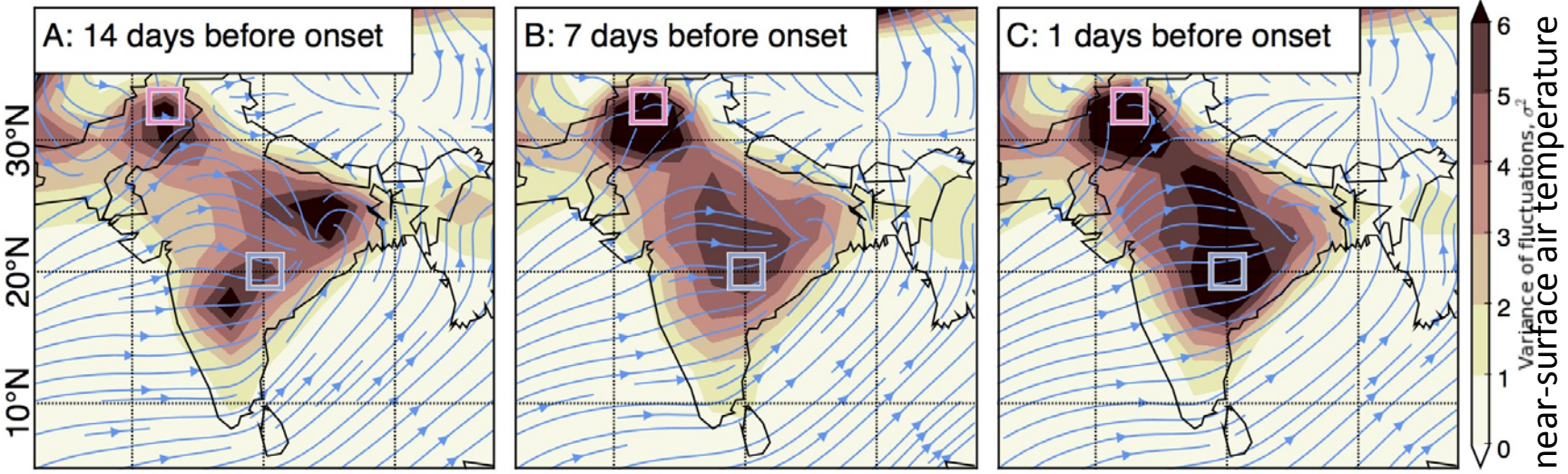
Early Warning Signals of Ecological Transitions: Methods for Spatial Patterns. [Kefi et al.(2014)]

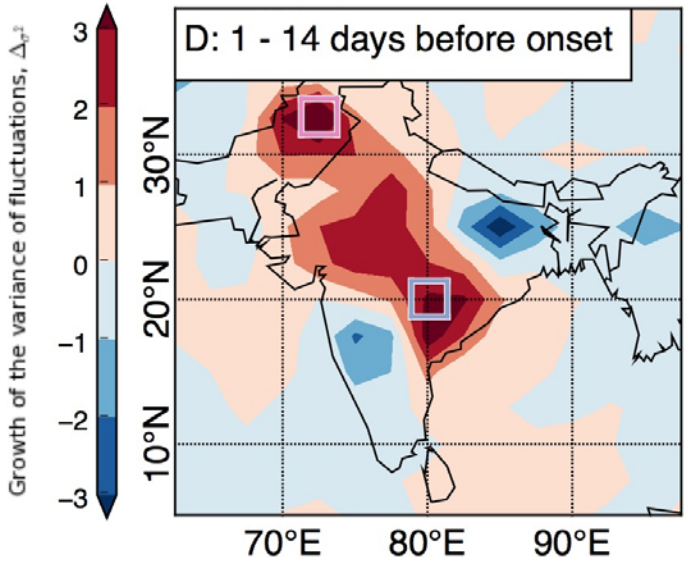
In our study, we make a step forward in this direction. In contrast to traditional approaches to use precursors for a prediction of the time of the critical transition, we use precursors to find regions where conditions for a critical transition originate.

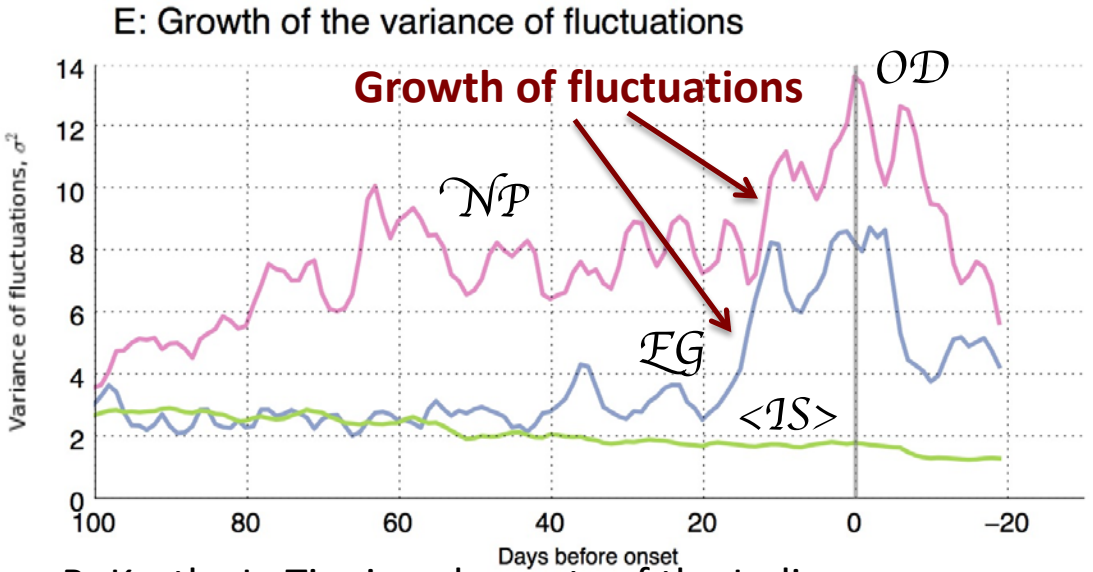
- Where (geographically) do critical conditions originate?
- How do the critical conditions propagate in space?

Tipping elements and prediction of monsoon

DATA: ERA40: near –surface air temperature, 0.25 °/0.25° resolution, (1958-2001)







- Stolbova V., Surovyatkina E., Bookhagen B.,Kurths J., Tipping elements of the Indian monsoon: prediction of onset and withdrawal. Geophysical Research Letters43, 1–9, 2016, 2016
- Surovyatkina E.D. , Kravtsov Yu. A. and Kurths Jü., Phys. Rev. E, 72, 046125 (2005)

Networks analysis

Stolbova V.et al., NPG, 2014.

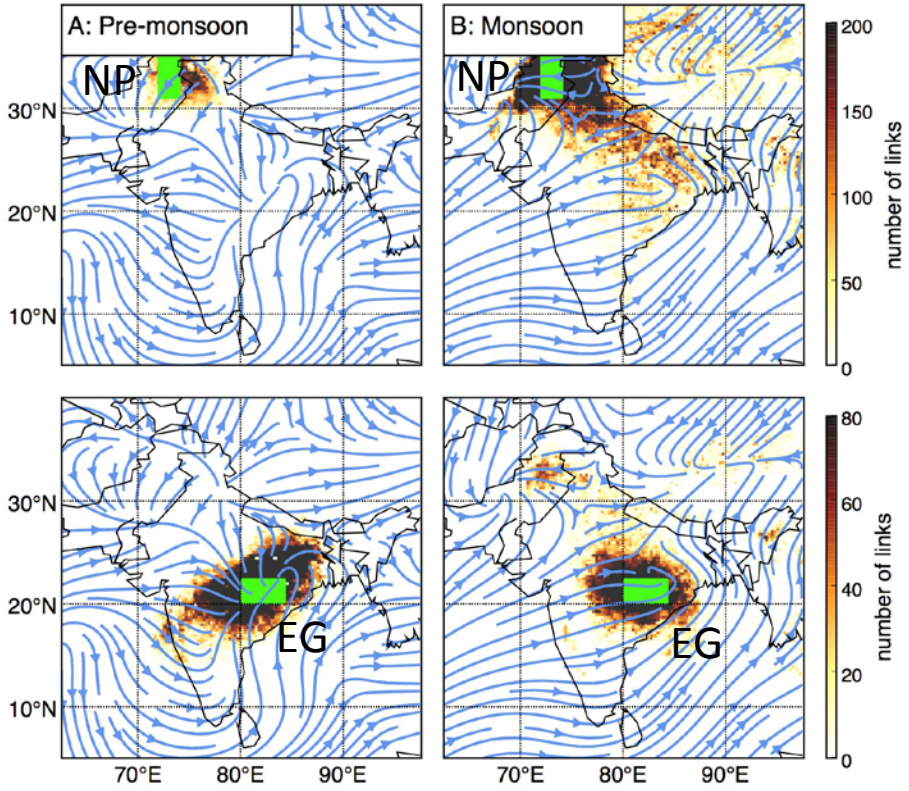


Figure 3. Links between a set of 153 reference grid points to other grid points and surface wind vector mean 1998-2012.

Temperature & wind fields

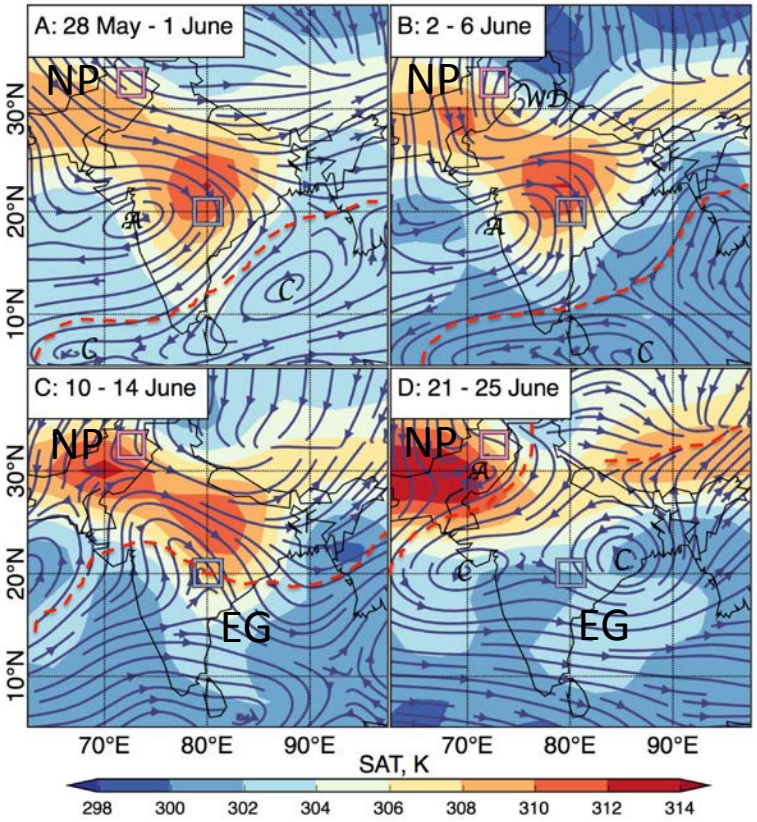


Figure 4. Wind fields and near-surface temperature: before, during and after the onset of monsoon

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?

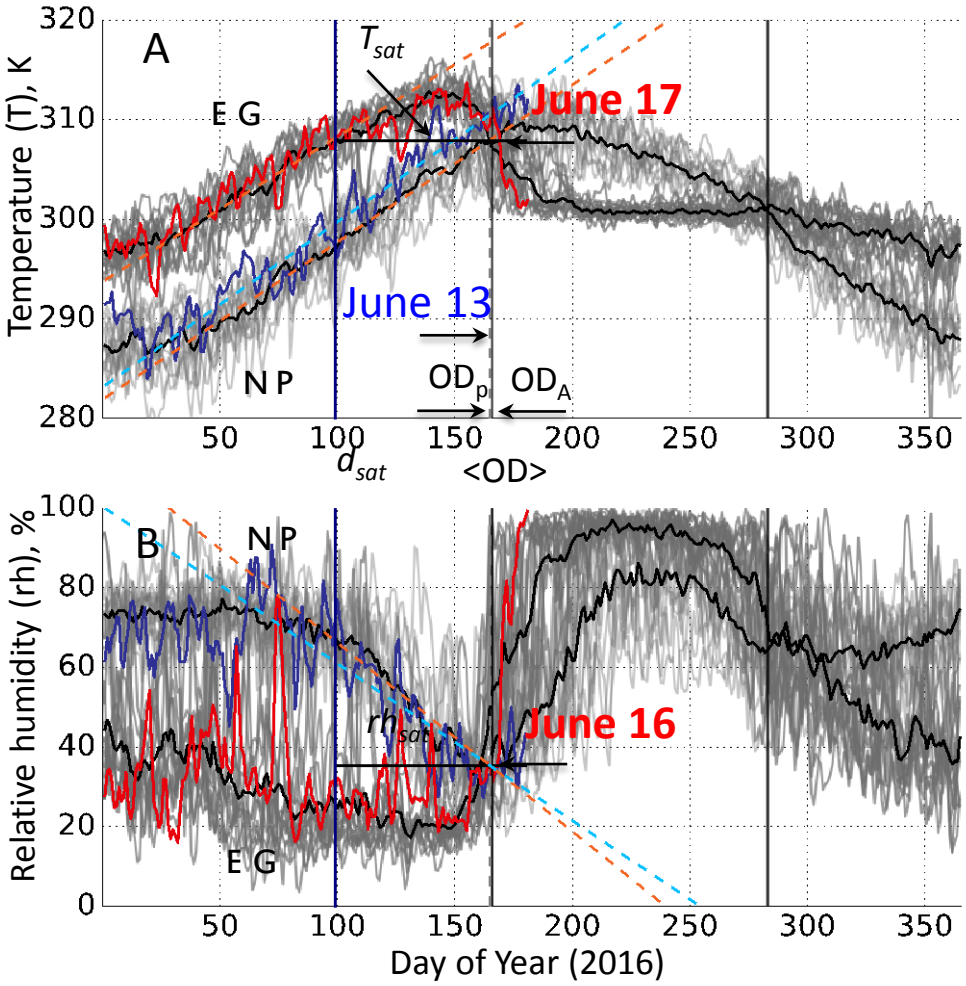
PREDICTION OF INDIAN SUMMER MONSOON for Eastern Ghats (20N, 80E), 2016

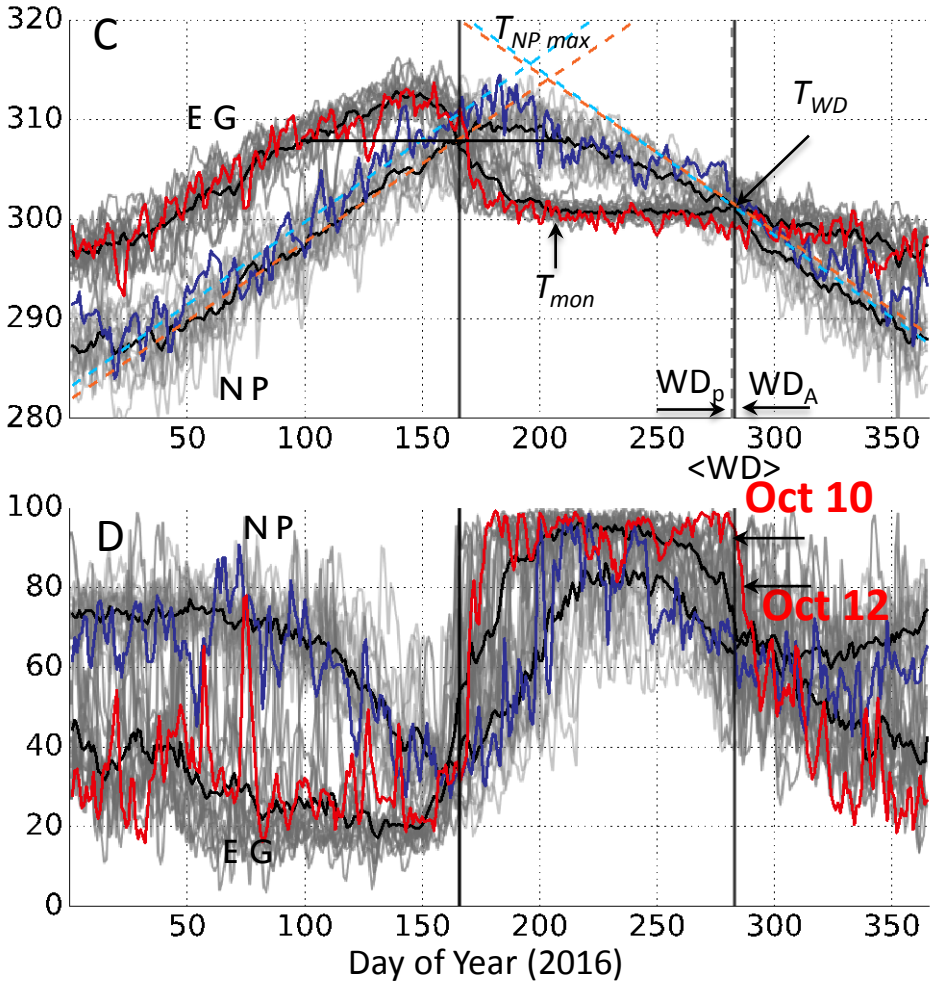
Onset Date Forecast: June 13+/-4 days

Actual Onset Date: June 17

Withdrawal Date Forecast: October 5 +/-5 days

Actual Withdrawal Date: October 10-12





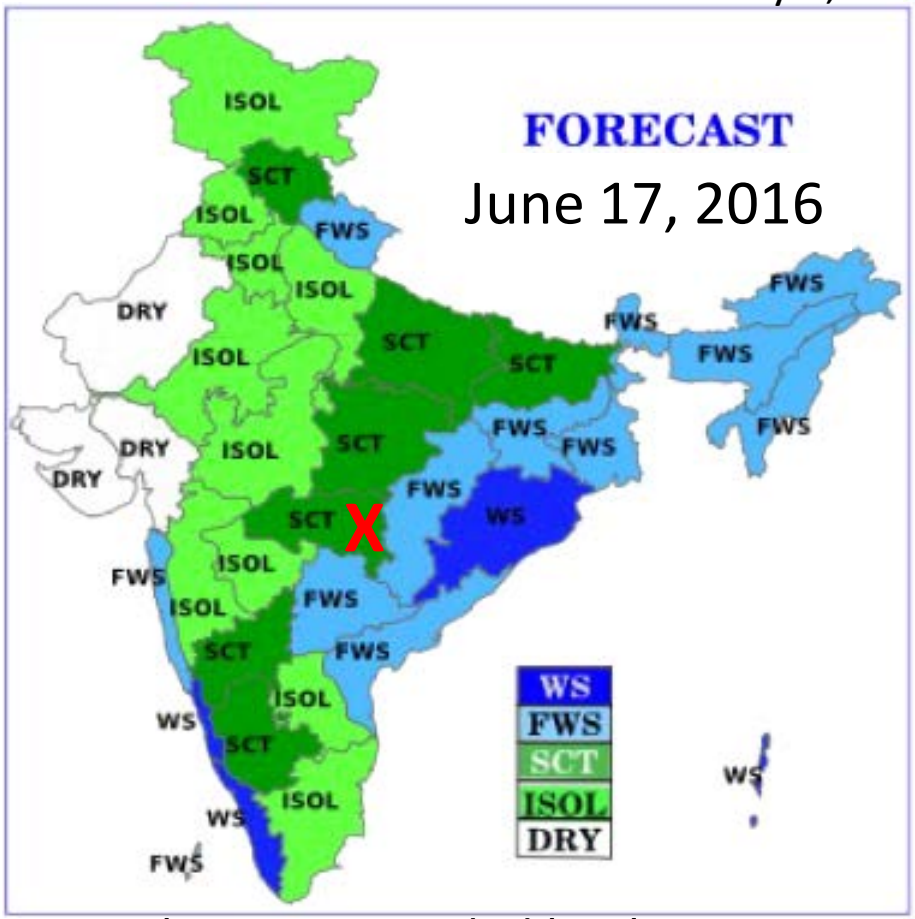
Prediction of onset date (OD) made on May 6, 2016 (**40 days in advance**)

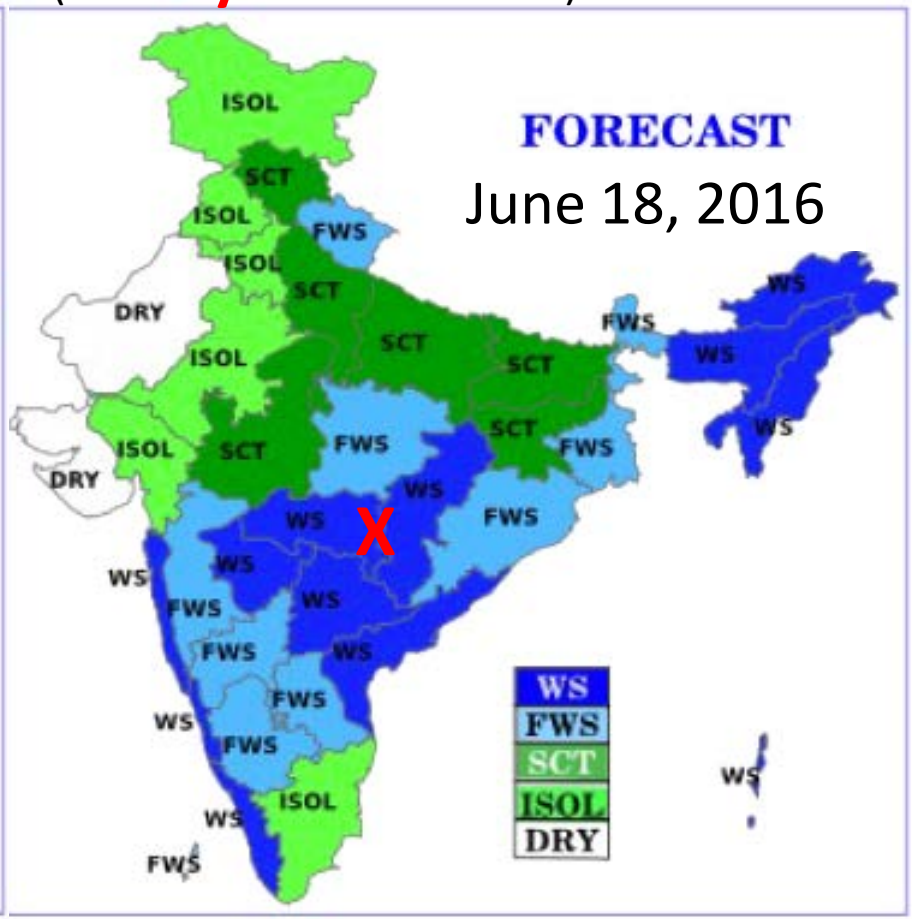
Prediction of withdrawal date (WD) made on July 27, 2016 (**70 days in advance**)

PREDICTION OF INDIAN SUMMER MONSOON for Eastern Ghats (20N, 80E), 2016

Onset Date Forecast: June 13+/-4 days **Actual Onset Date: June 17**

Prediction made on May 6, 2016 (**40 days in advance**)





Daily Maps provided by the IMD

% Station Reporting Rainfall

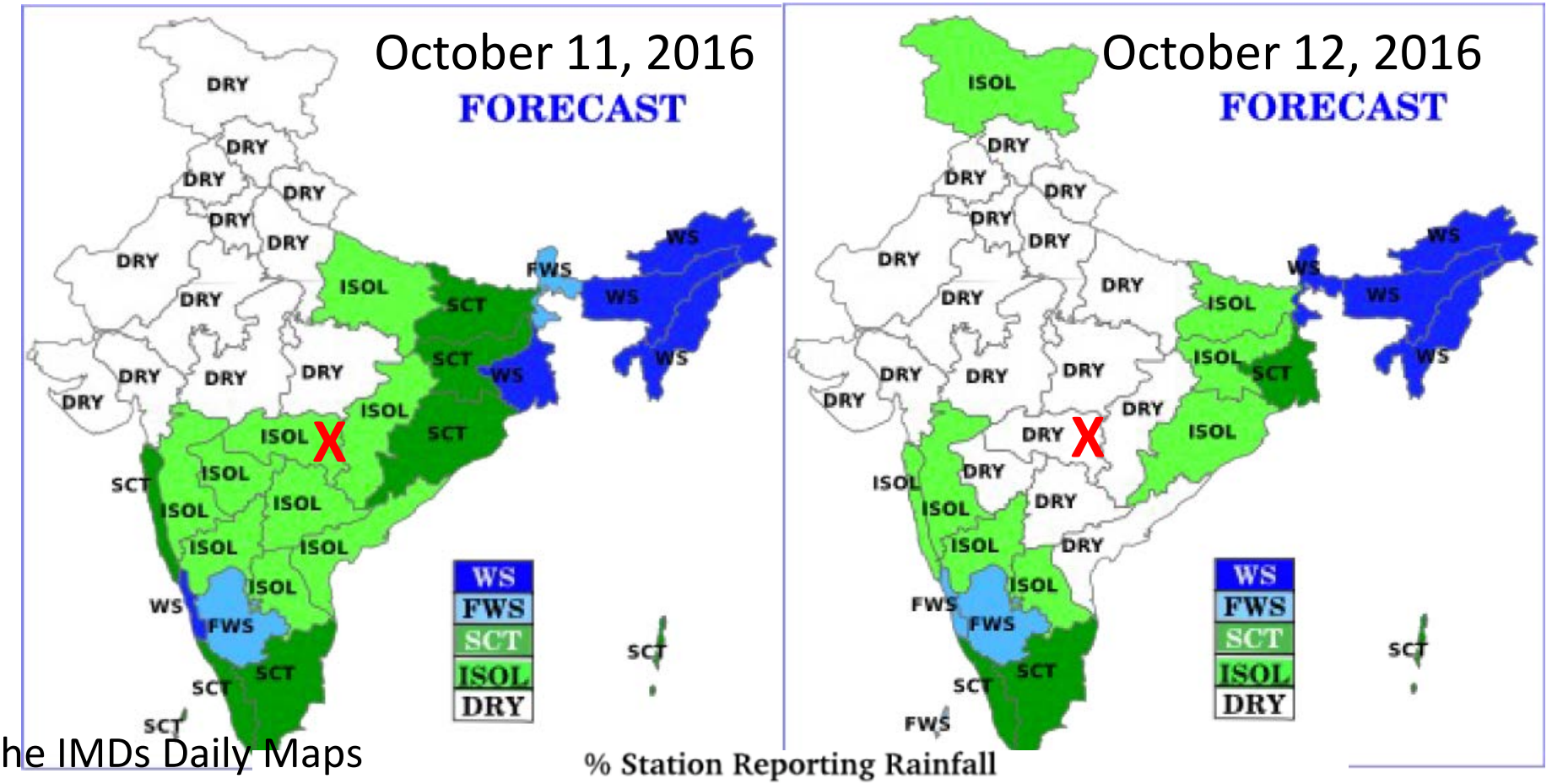
% Stations	Category	% Stations	Category
76-100	Widespread (WS/Most Places)	26-50	Scattered (SCT/ A Few Places)
51-75	Fairly Widespred (FWS/ Many Places)	1-25	Isolated (ISOL)
No Rain	Dry		

PREDICTION OF INDIAN SUMMER MONSOON for Eastern Ghats (20N, 80E), 2016

Withdrawal Date Forecast: October 5 +/-5 days

Actual Withdrawal Date: October 10-12

Prediction made on July 27, 2016 (**70 days in advance**)



the IMDs Daily Maps

% Station Reporting Rainfall

% Stations	Category	% Stations	Category
76-100	Widespread (WS/Most Places)	26-50	Scattered (SCT/ A Few Places)
51-75	Fairly Widespred (FWS/ Many Places)	1-25	Isolated (ISOL)
No Rain	Dry		

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).

June 18, 2017

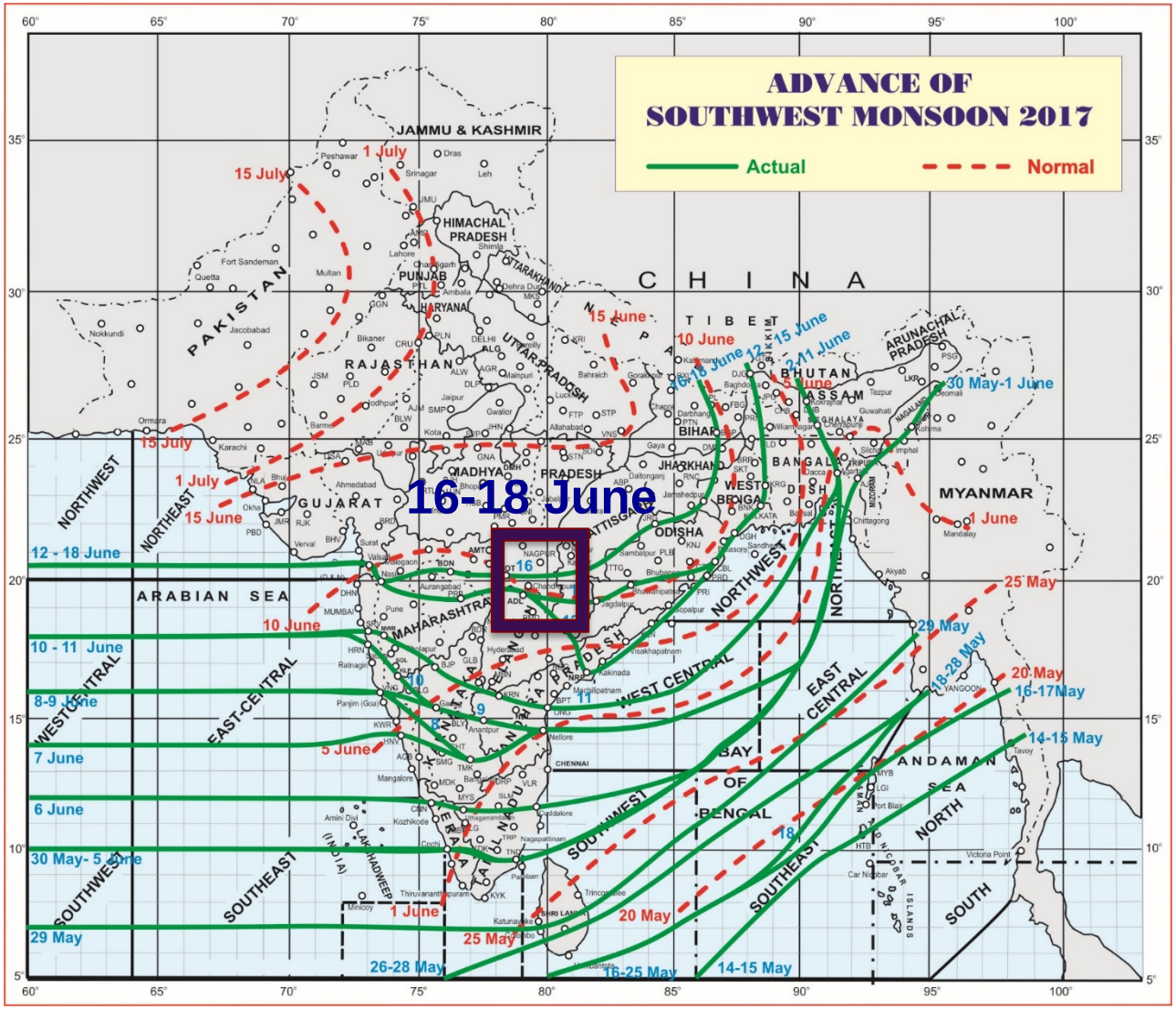
Successful earliest forecast of the onset of Southwest Monsoon 2017 over the central part of India

The Indian Summer Monsoon (the Southwest Monsoon) has set in over the central part of India, the Eastern Ghats region (20°N,80°E) **16-th June 2017**.

Hence, our prediction made 40 days in advance was correct.

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

The Evidence for successful PIK-Monsoon onset forecast - 2017



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

German modelling to crack monsoon code

IIT-Madras associates itself with Potsdam Institute for Climate Impact Research's project, IMD kept in the loop

శుక్రవారం గోల్కొండ హోటల్‌లో 'ప్రెడిక్షన్ ఆఫ్ మాన్‌సూన్ ఫర్ ఇండియా, తెలంగాణ' సదస్సులో మాట్లాడుతున్న జర్మనీ ప్రొఫెసర్ సబీనా. చిత్రంలో మంత్రులు జోగు రామన్న, పోచారం శ్రీనివాస్‌రెడ్డి, ఈటల రాజేందర్, ఎమ్మెల్యే చెన్నమనేని రమేశ్

10న రాష్ట్రానికి రుతుపవనాలు

(మొదటిపేజీ తరువాయి) పరిశోధనలు చేస్తున్నదని, తెలంగాణ రాష్ట్ర ప్రయోజనాల దృష్ట్యా ఇక్కడికి వచ్చి ఆ పరిశోధనా వాసరెడ్డి మాట్లాడుతూ.. జర్మనీ ప్రొఫెసర్ అందించిన వివరాలు ఎంతో ఉపయుక్తంగా ఉన్నాయన్నారు. తాను విదేశాలో పర్య

Eastern Ghats, North Pakistan serve as tipping elements in monsoon prediction

DC CORRESPONDENT
CHENNAI JUNE 9

The key to their research is in finding the regions where conditions for an occurrence of Indian monsoon originate

A team of researchers led by the Potsdam Institute for Climate Impact Research (PIK) in Germany has identified two regions — the Eastern Ghats and North Pakistan — that serve as tipping elements in accurately predicting the arrival and departure of southwest monsoon.

As per their research, analysing air temperatures and relative humidity in these areas predict the arrival and departure of the monsoon earlier. "The tipping point is critical to predicting the onset of monsoon. Once it is onset, it's difficult to change," said professor Elena Surovyatkina from Russian Academy of Sciences' Space Research Institute.

"This year, we predicted as early as May 6 that monsoon will hit India on June 13 with plus or minus four days. India Meteorological Department had announced only on May 15 that monsoon will onset over Kerala on June 7," she said.

"We predicted well before 30 days when monsoon would hit central India. It will surely help the farmers in these regions. Based on our method we can predict the withdrawal of monsoon by July 15 based on the observations from the same regions," she added.

The key to their research is in finding the regions where conditions for an occurrence of Indian monsoon originate.

"We can see a pattern before the onset of monsoon. We use the precursors not to predict the time but to predict places where the critical transition originates. We take air surface temperature and calculate fluctuation."

"We applied our method for data from 1957 to 2015. Our prediction about the onset of monsoon was 74 per cent successful and withdrawal of monsoon 84 per cent correct. Even for El Nino years our predictions were nearly 60 per cent correct," she said.

When asked whether they had discussions with the IMD about using their new method to predict the southwest monsoon she said formal discussion is yet to take place.

Germans develop new method to predict India's monsoon

AFP
Berlin

Climate researchers in Germany said yesterday they had found a way to more accurately predict the Indian monsoon, which could help maximise the subcontinent's food and hydro-power supplies.

Improved forecasts of when the heavy summer rains start and end could help millions of farmers plant crops at the right time, and allow energy providers to estimate when dams and reservoirs fill up, they said.

Global warming already affects monsoon stability and will make accurate forecasting ever more important, as deviations can spark droughts and floods, said the Potsdam Institute for Climate Impact Research (PIK).

"The timing of Indian summer monsoons, on which the livelihoods of many millions of people depend, is likely becoming more erratic," said project leader Juergen Kurths. "This makes early and accurate forecasting ever more crucial."

The scientists said they had developed a novel prediction method based on a network analysis of regional weather data, and would propose their model to the Indian Meteorological Department.

"We can predict the beginning of the Indian monsoon two weeks earlier, and the end of it even six weeks earlier than before - which is quite a breakthrough, given that for the farmers, every day counts," said Veronika Stolbova of PIK and Zurich University.

"We found that in North Pakistan and the Eastern Ghats, a mountain range close to the Indian Ocean, changes of temperatures and humidity mark a critical transition to monsoon," said Stolbova in a statement.

Usually the focus has been on Kerala region, said Stolbova, lead author of the study published in the scientific journal the Geophysical Research Letters.

The team said it used an advanced mathematical approach called network analysis of complex non-linear systems, combined with subtle statistical analyses of the early warning signals for the monsoon onset and withdrawal.

"These precursor phenomena are often buried by huge piles of weather data and hence get overlooked," said PIK guest scientist Elena Surovyatkina of the Russian Academy of Sciences' Space Research Institute.

Kurths said they had looked at the climate system "as a network, just like the social networks so many people are using in their everyday life".

"On Facebook or Twitter, you can follow how news is spreading, one posting leading to many others. In the climate system, not people but geographical regions are communicating - admittedly in a quite complex way."

Like Facebook postings or tweets that get shared again and again, the scientists explained, temperature and humidity get transported from one place to another by atmospheric flows such as winds.

Information about monsoon timing is key for Indian farmers, who usually grow all-important crops like rice, soybean and cotton during the June-September monsoon season.

The scientists said they had tested their method with historical monsoon data and achieved correct predictions in more than 70% of cases for the start of the monsoon, and in more than 80% for its withdrawal.

The authors said their method could improve the time horizon of monsoon prediction compared to that now used in India - both during relatively normal times, and in years when the El Nino phenomenon affects the rainy season.

limitations. Now, a group of scien- dras. "However, we are glad to get cation on various sectors like ag- However, the most relevant infor- (Arabian Sea and Bay of Bengal)

The Indian Summer monsoon case

1. We have developed a prediction scheme for long-range forecasting (30+ days) of onset and withdrawal dates of the monsoon.

- The proposed scheme allows to predict onset dates 40 days in advance with a range of 7 days.
- Also, it allows to predict the withdrawal date 70 days in advance with a range of 10 days.
- Our results show that our method allows predicting a future monsoon, and not only retrospectively or hindcast.

2. 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.

References

- 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
- Stolbova V., Martin P., Bookhagen B., Marwan N. and Kurths J., Nonlinear Processes in Geophysics, 2014.
- Kravtsov Yu.A. , Surovyatkina E.D. , Phys. Lett. A 319 (3–4), (2003) 348.
- Surovyatkina E.D. , Phys. Lett. A 329, (2004) 169.
- Surovyatkina E.D. , Kravtsov Yu. A. and Kurths Jü., Phys. Rev. E, 72, 046125 (2005)
- Surovyatkina E., Nonlinear Processes in Geophysics,(2005), 12, 25-29.
- Majumdar Apala , Ockendon John , Howell Peter and Surovyatkina Elena. Transitions through Critical Temperatures in Nematic Liquid Crystals. Phys. Rev. E. 88, 022501 (2013)

P I K

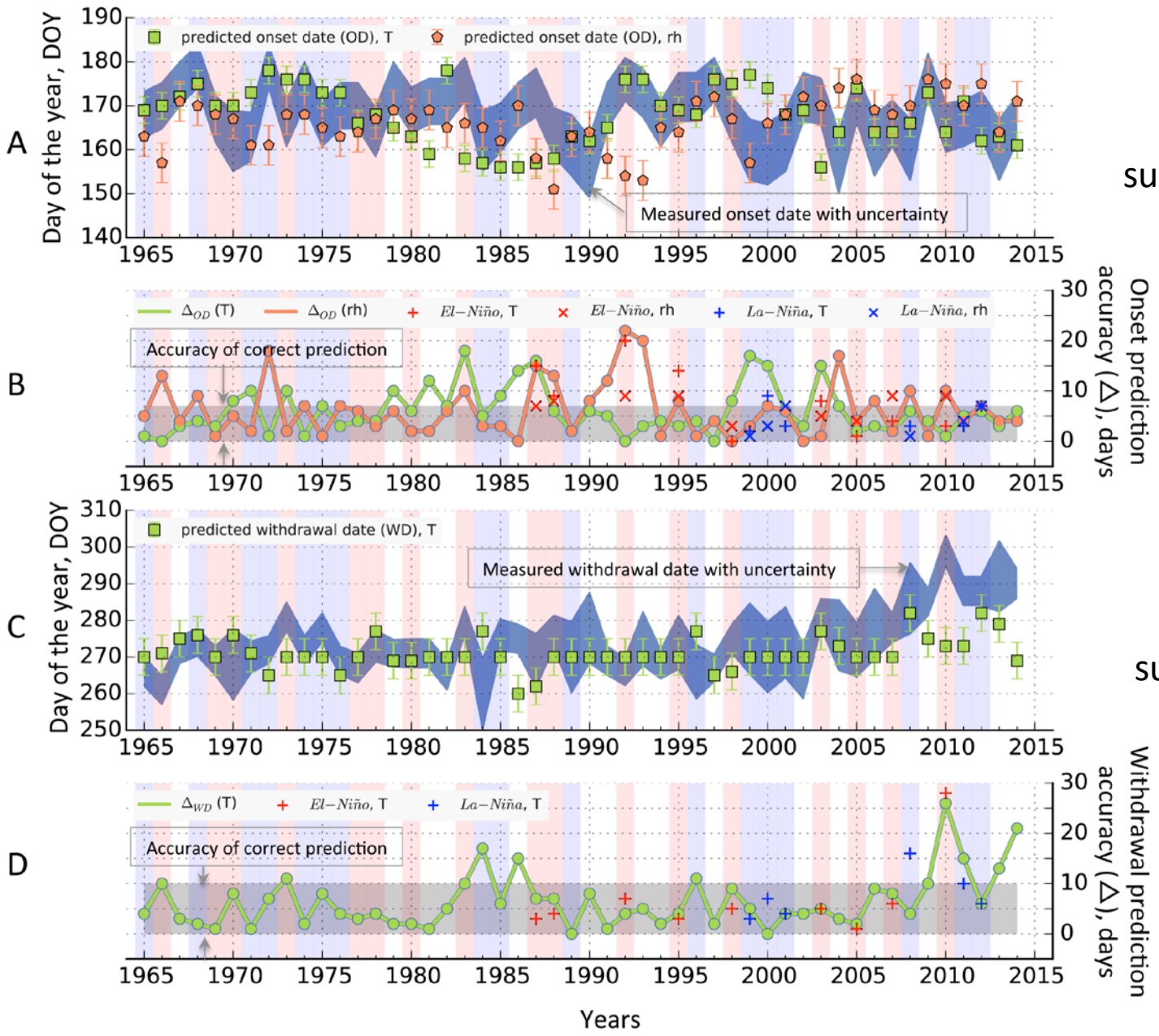
UNIVERSITY OF OXFORD Mathematical Institute

ИКИ

Performance of prediction scheme

ONSET

WITHDRAWAL



74% of success rate

84% of success rate