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

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

Prediction of Indian summer monsoon: from Complex Network to Tipping elements approach

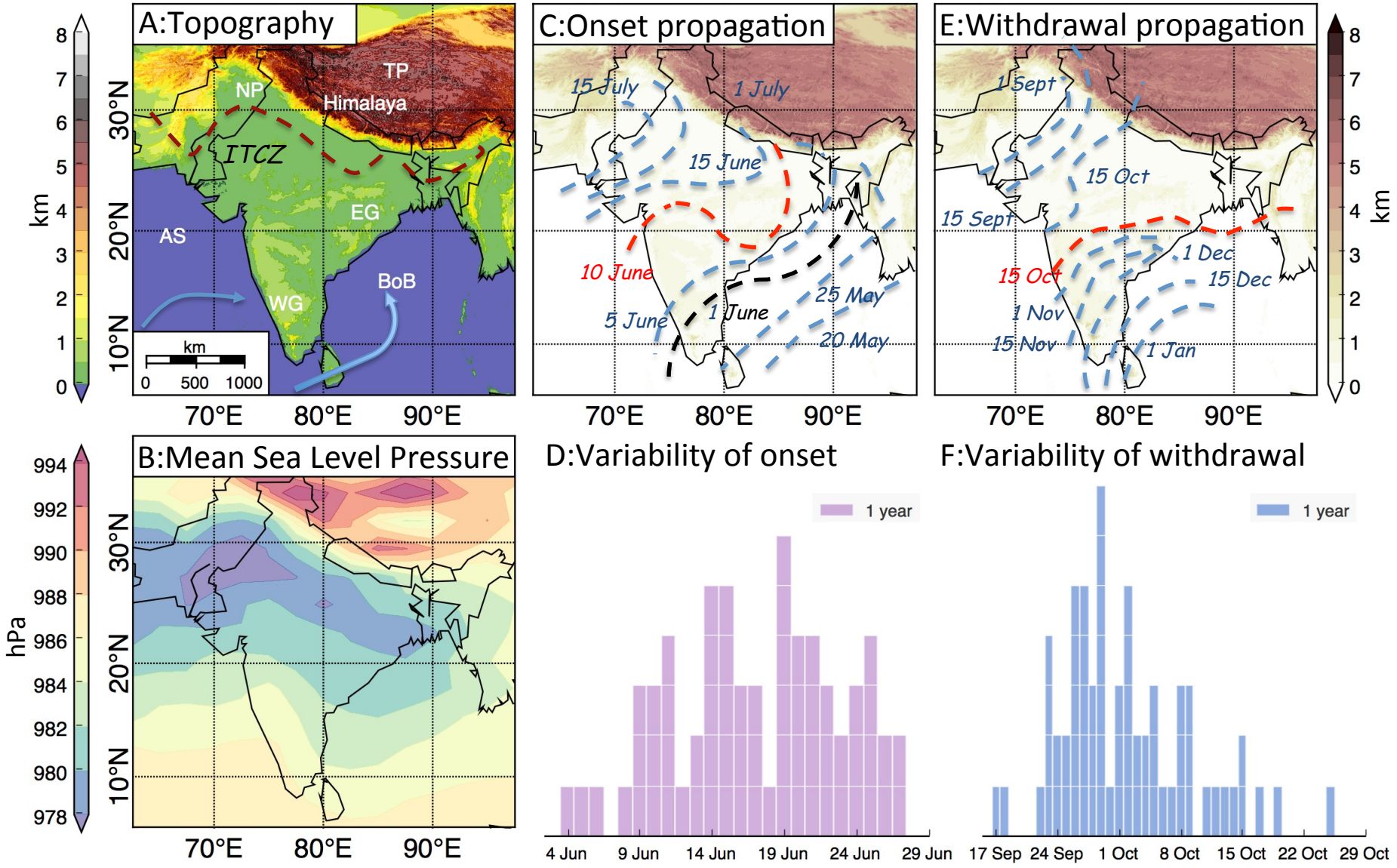
EPICC - East Africa Peru India Climate Capacities funded by BMUB (18_II_149_Global_A_Risikovorhersage)

ICTS, Bangalore, 26th June, 2018

Seasonal variability implies two aspects:

1. The seasons do not begin at fixed dates but must be determined by observation and are **known only after the fact;**
2. A new season begins **at different dates** in different parts of the country and over the world.

Advance and withdrawal of monsoon



Numerical Weather Prediction has a limit to forecast the weather for **up to approximately 10 days** in the future.
Other long-term prediction provide the statistical summary only such as whether the temperature averaged over the next summer will be warmer or colder than average over some number of years before.
Hence, the seasonal prediction is a considerable scientific challenge with great importance for society.

Outline

1. Network of extreme precipitation over the Indian subcontinent.
2. Critical Transition & Critical phenomena
3. Spatially organized critical transitions. Tipping Elements approach for prediction of the Indian Summer Monsoon
4. Forecasting upcoming monsoon: observational evidences

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.

1. Network of extreme precipitation over the Indian subcontinent.

METHOD

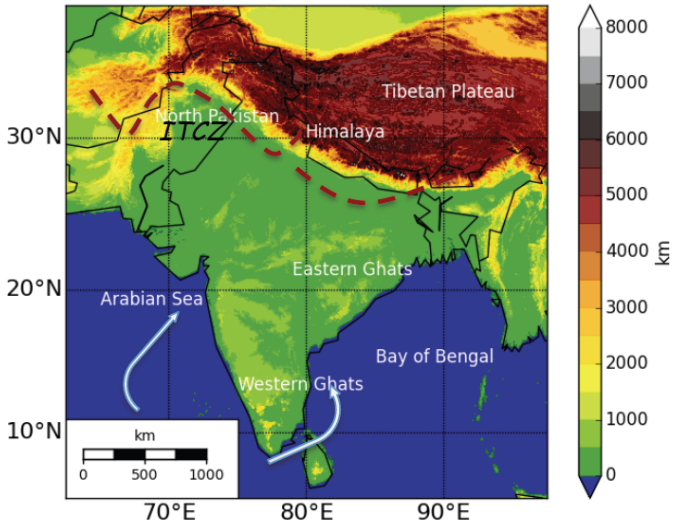
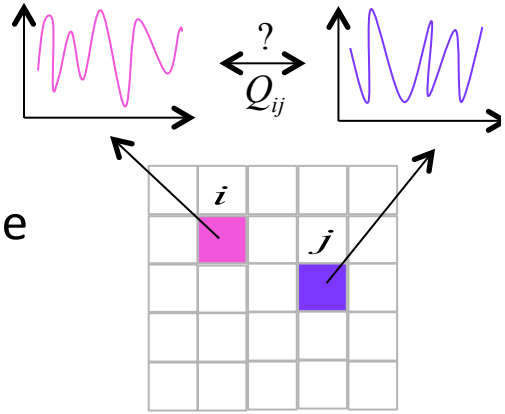


Figure 1. Indian subcontinent with its main topographical features, Intertropical Convergence zone and branches of monsoon.

1. Network Approach

Nodes: geographical locations

Links: synchronization of extreme rainfall events between nodes



Data:

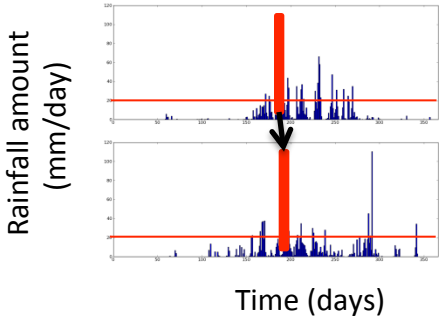
- ***APHRODITE:*** daily rainfall, rain-gauge interpolated, 0.5 °/0.25° resolution (1951-2007)
- ***TRMM:*** daily rainfall, satellite-derived, 0.25° (1998-2013)
- ***NCEP/NCAR:*** reanalysis, 2.5 °, T, P, winds, vorticity, divergency

2. Event synchronization

Step 1. Apply a threshold to time series of each grid point to obtain extreme event series

Step 2. Event synchronization – use time lags to compare individual events between two grid points

Step 3. Construct the network by creating links between points with the highest synchronization values



Stolbova, V., P. Martin, B. Bookhagen, N. Marwan, and J. Kurths (2014),NPG, 21, 901–917.

Network analysis of the extreme events

Degree

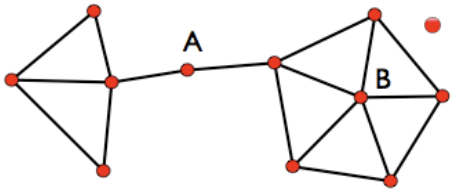
$$D_j = \frac{\sum_{n=1}^{N} A_{ij}}{N-1},$$

Betweeness

$$B_v = \sum_{i \neq j \neq v \in \{V\}}^{N} \frac{\sigma_v(i,j)}{\sigma(i,j)},$$

Average link distance

$$L_j = \langle L_{ij} \rangle_i = \langle \alpha_{ij} A_{ij} R \rangle,$$



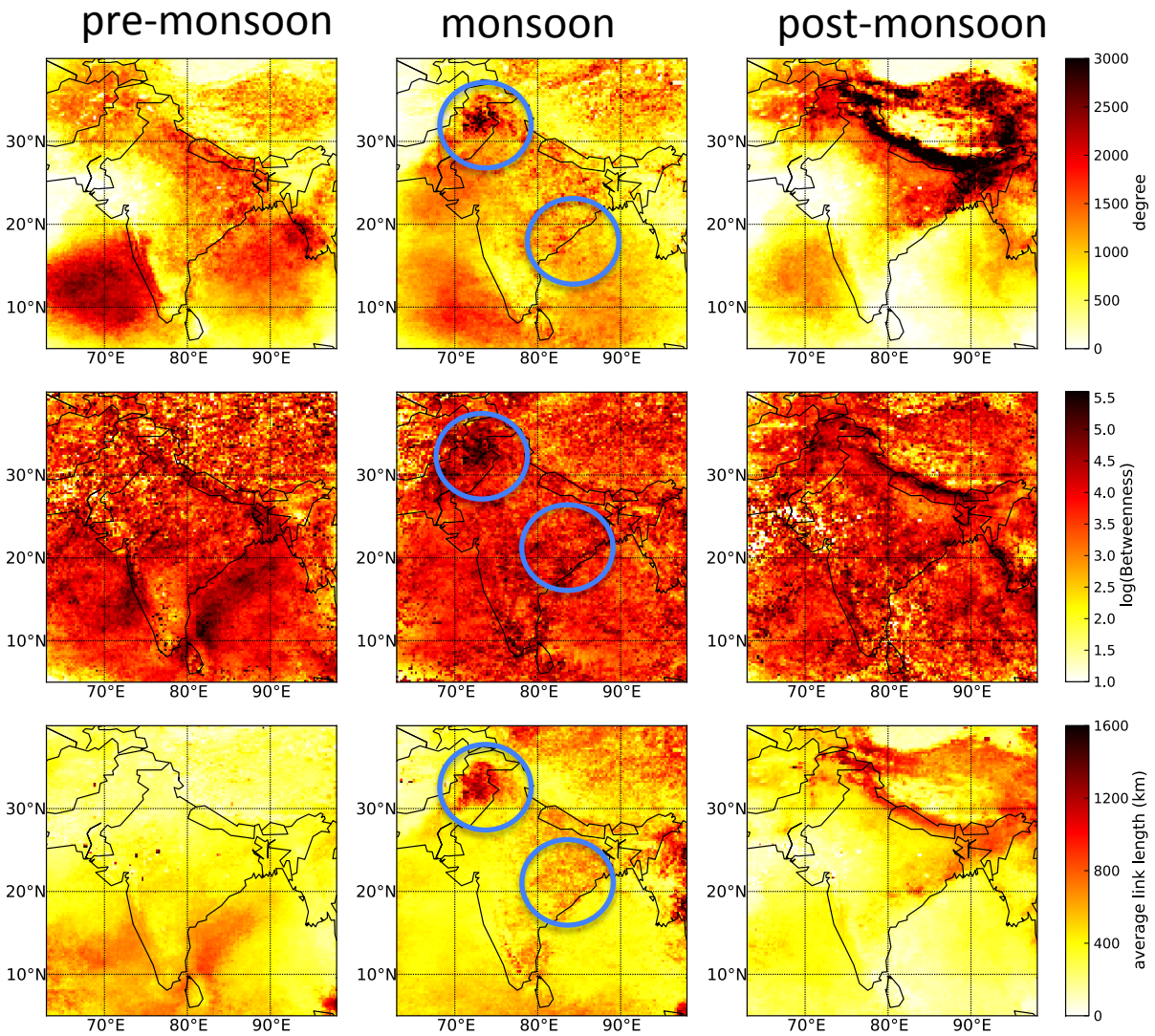


Figure 2. Network measures of the extreme rainfall network: degree, avl, btw – from top to bottom, during the pre-monsoon, monsoon, and post-monsoon – left – right.

Stolbova, V., P. Martin, B. Bookhagen, N. Marwan, and J. Kurths (2014), Nonlinear Process. Geophys., 21, 901–917, doi:10.5194/npg-21-901-2014.

Why are these regions so special?

Networks → Mechanism of transition to monsoon

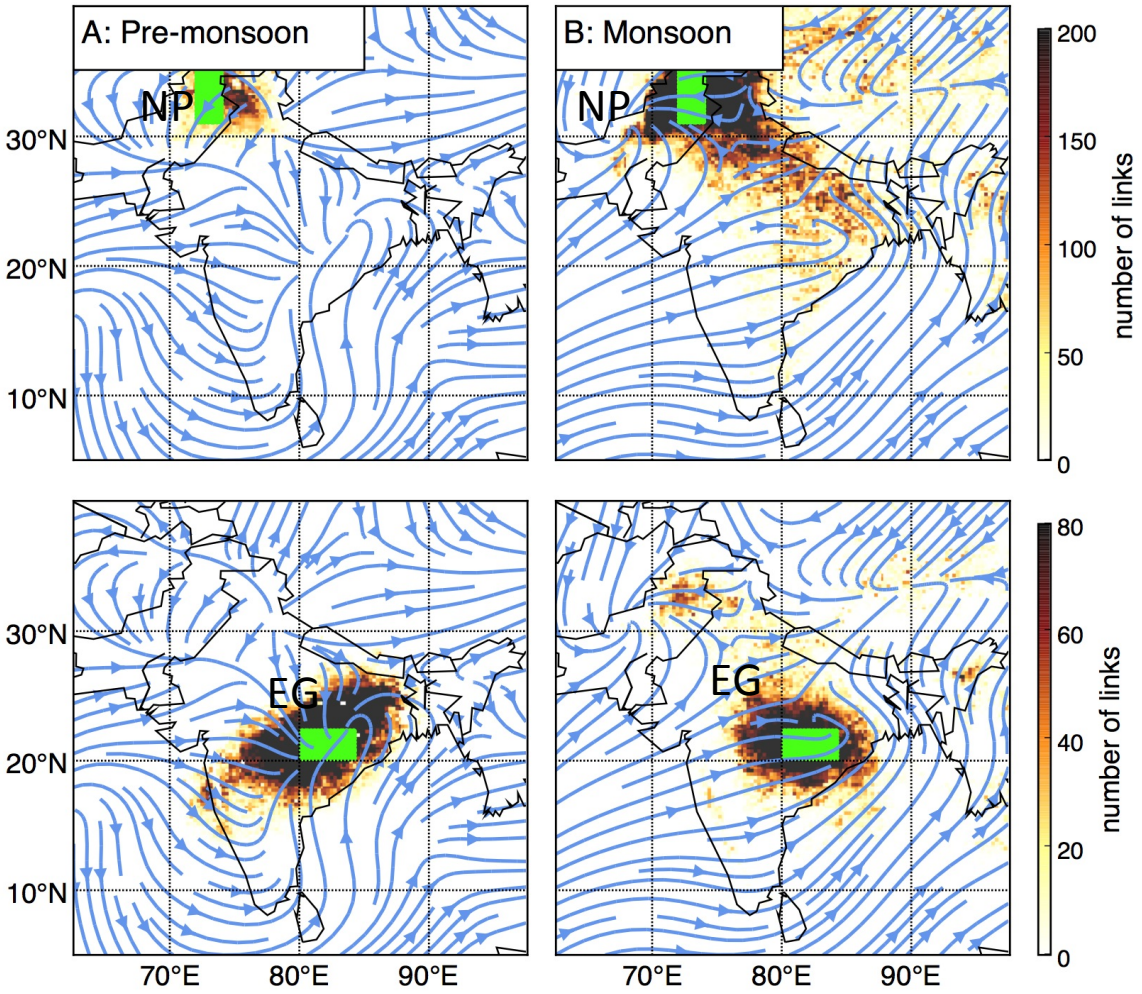


Figure 3. Links between a set of 153 reference grid points to other grid points and surface wind vector mean 1998-2012.

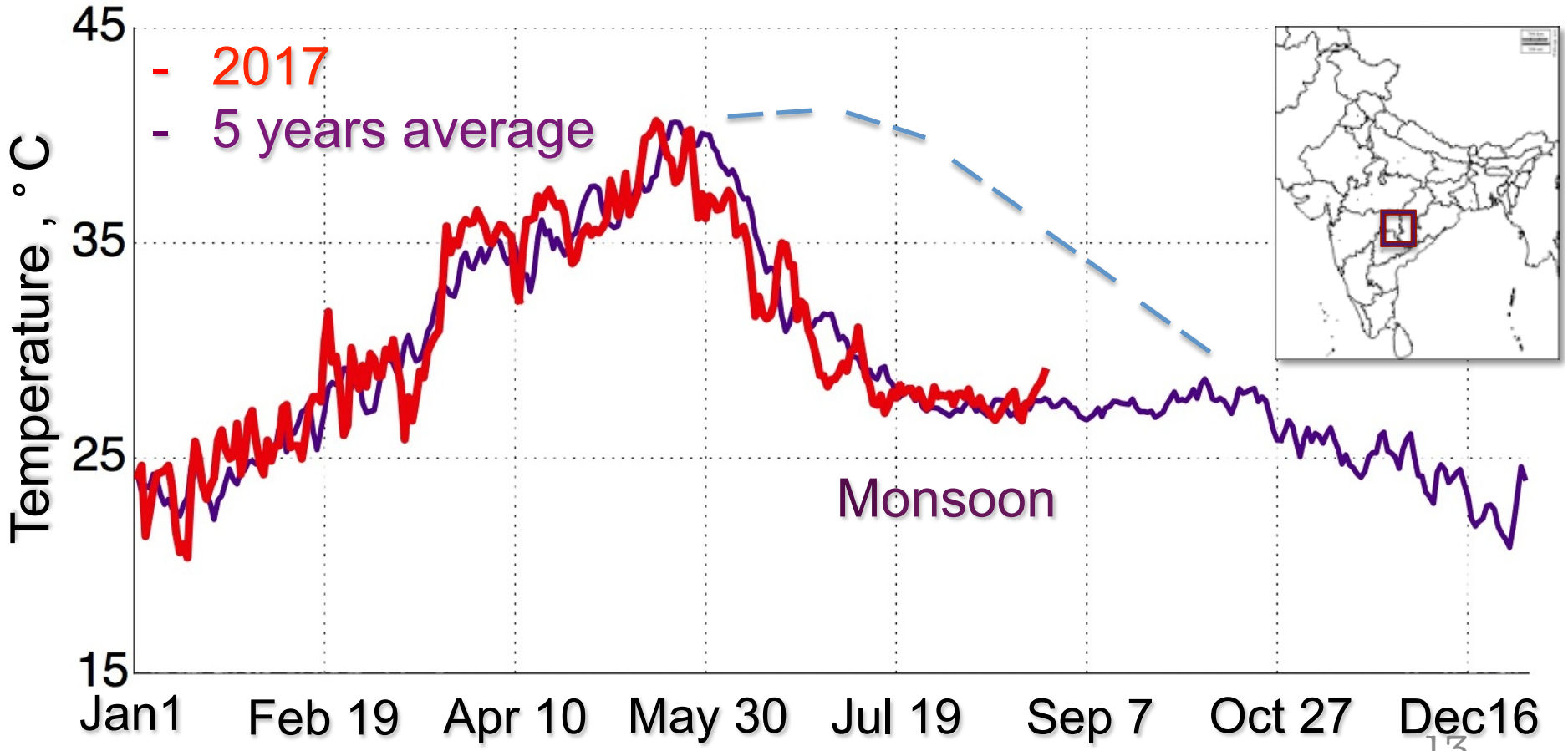
Stolbova V.et al., NPG, 2014.

2. Critical Transition & Critical phenomena

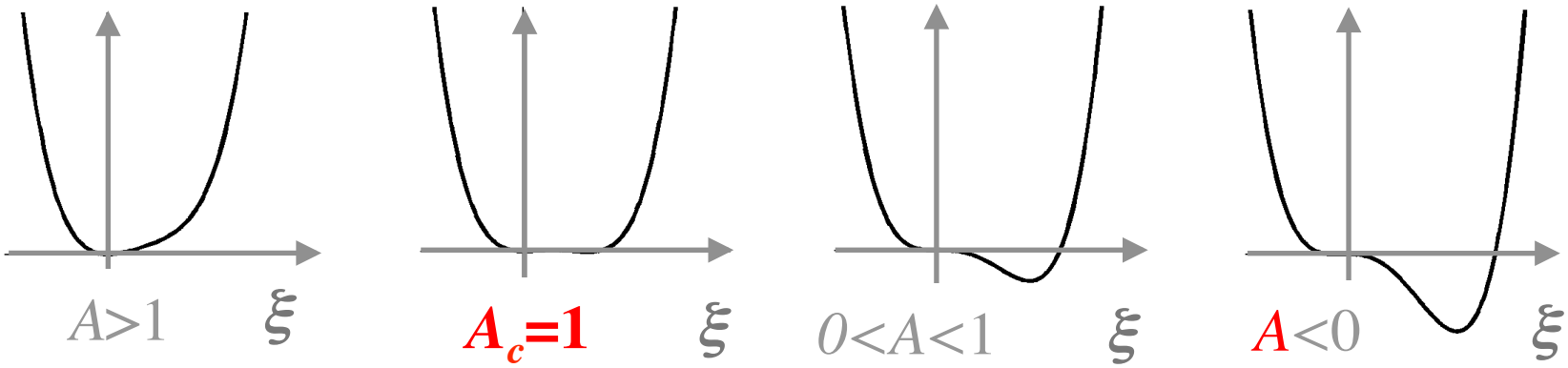
«The onset of monsoon.. Is not a transition from a regime of no rain to rain; it is a critical transition from a regime of sporadic rainfall to spatially organized and temporally sustained rainfall…»

R. Ananthakrishnan and M.K. Soman, 1990

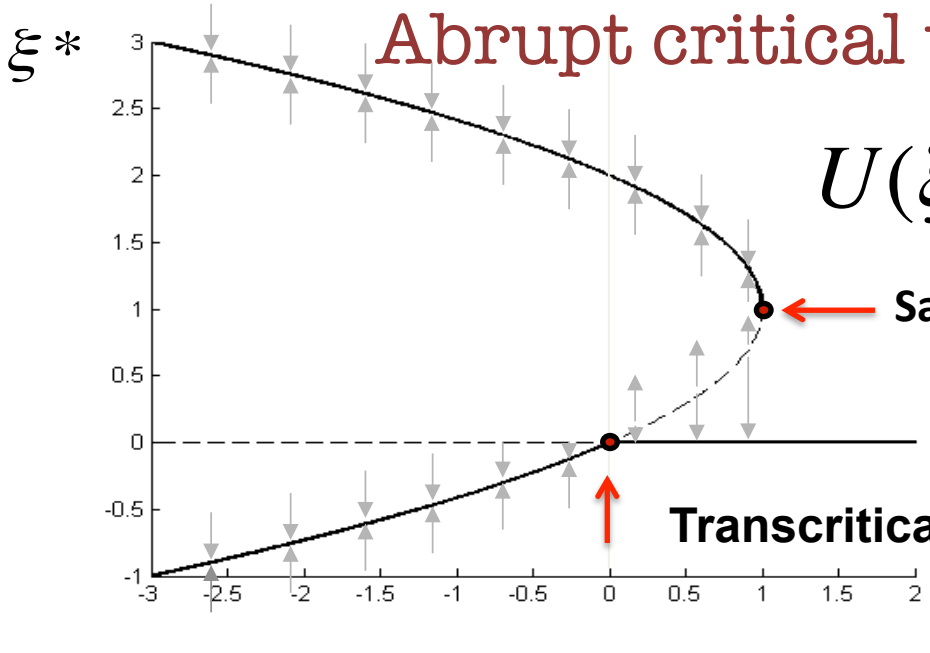
Is it a critical transition from a regime of sporadic rainfall to spatially organized and temporally sustained rainfal?



$$\ddot{\xi} + 2\gamma\dot{\xi} + \frac{dU}{d\xi} = 0$$



Abrupt critical transition



$$U(\xi) = A\xi - \frac{1}{3}B\xi^2 + \frac{2}{3}C\xi^4$$

Saddle-Node bifurcation

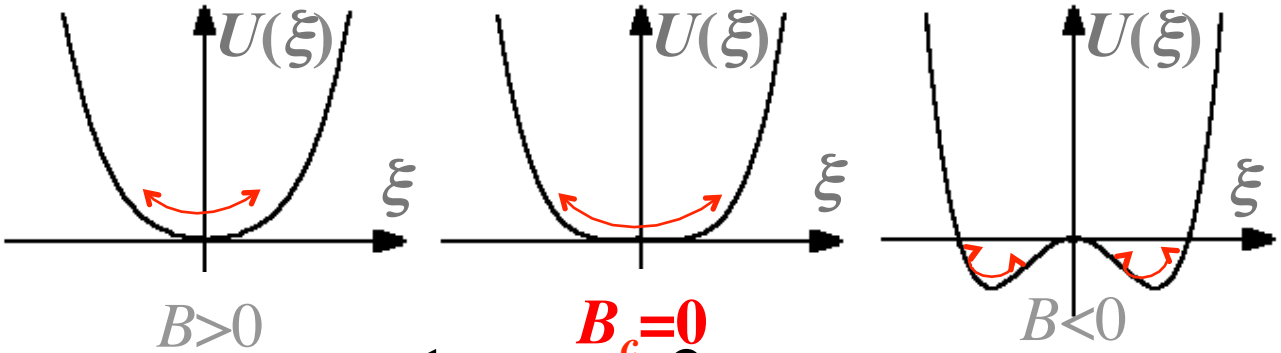
Transcritical bifurcation

14

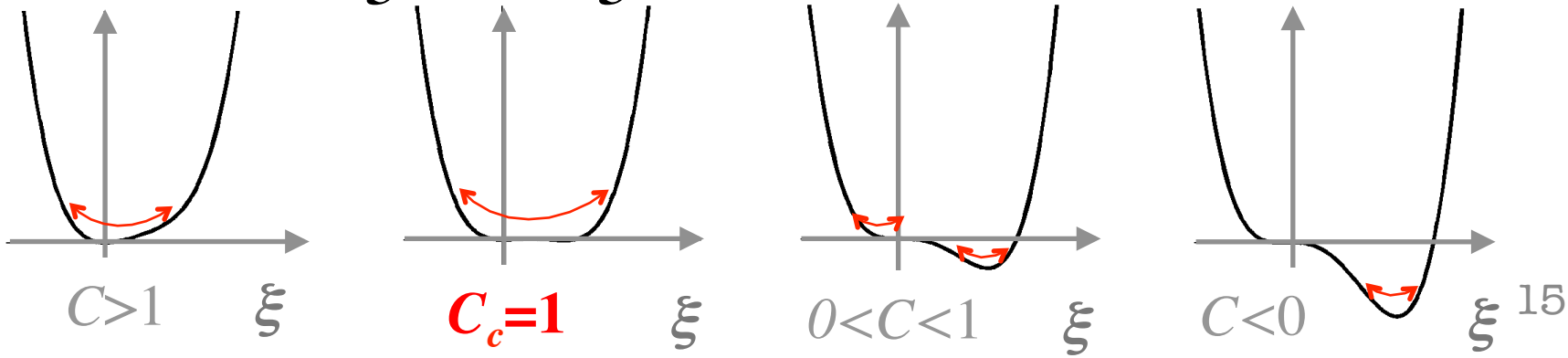
Critical fluctuations

$$\ddot{\xi} + 2\gamma\dot{\xi} + \frac{dU}{d\xi} = f(t)$$ -noise

$$U(\xi) = \frac{1}{2}B\xi^2 + \frac{1}{4}A\xi^4$$

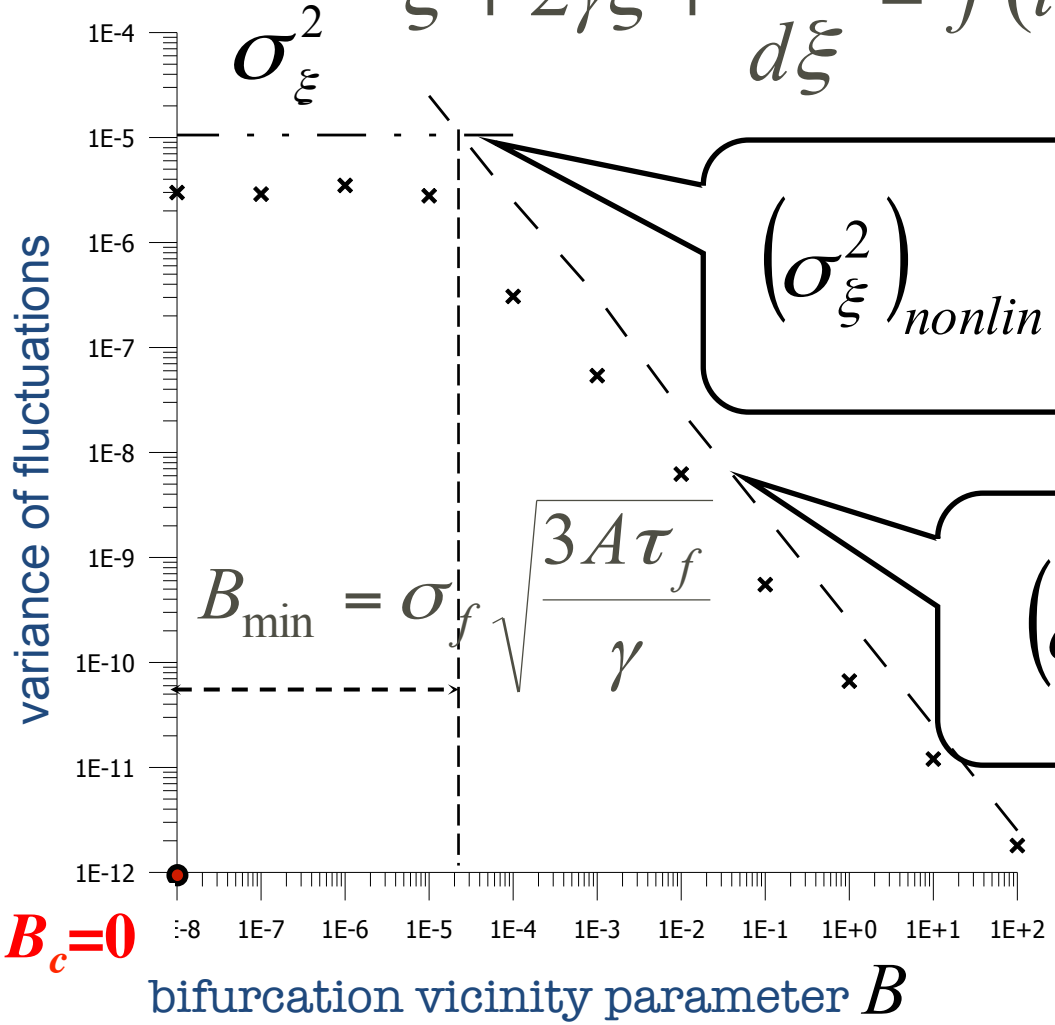


$$U(\xi) = C\xi - \frac{1}{3}B\xi^2 + \frac{2}{3}A\xi^4$$



Pre-bifurcation growth of fluctuations in the nonlinear oscillator

$$\ddot{\xi} + 2\gamma\dot{\xi} + \frac{dU}{d\xi} = f(t), U(\xi) = \frac{1}{2}B\xi^2 + \frac{1}{4}A\xi^4$$



$$\left(\sigma_\xi^2\right)_{nonlin} \approx \sigma_f \sqrt{\frac{\tau_f}{12A\gamma}}$$

$$\left(\sigma_\xi^2\right)_{lin} = \frac{\sigma_f^2\tau_f}{2\gamma B}$$

$$\sigma_f^2 = 10^{-8}, \gamma = 1,$$
$$\tau_f = 3.5\times10^{-3}, A = 0.5$$

[Surovyatkina et al. (2005), Phys. Rev. E, 72, 046125; Surovyatkina, Phys. Lett. A 329, (2004) 169 ; 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

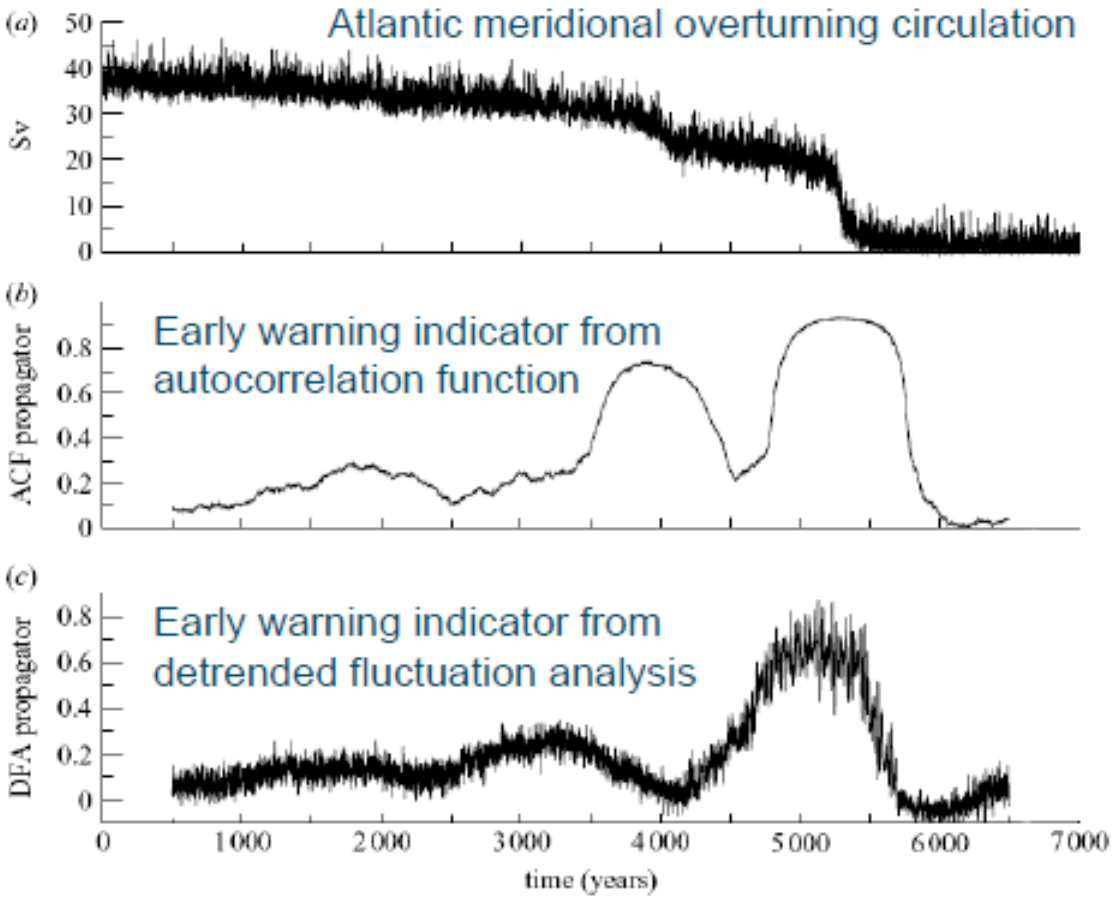
  Majumdar Apala , Ockendon John , Howell Peter and Surovyatkina Elena. Transitions through Critical Temperatures in Nematic Liquid Crystals. Phys. Rev. E. 88, 022501 (2013)

Early warning indicators

Fully 3-D dynamical model test

University of East Anglia

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



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?

3. 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

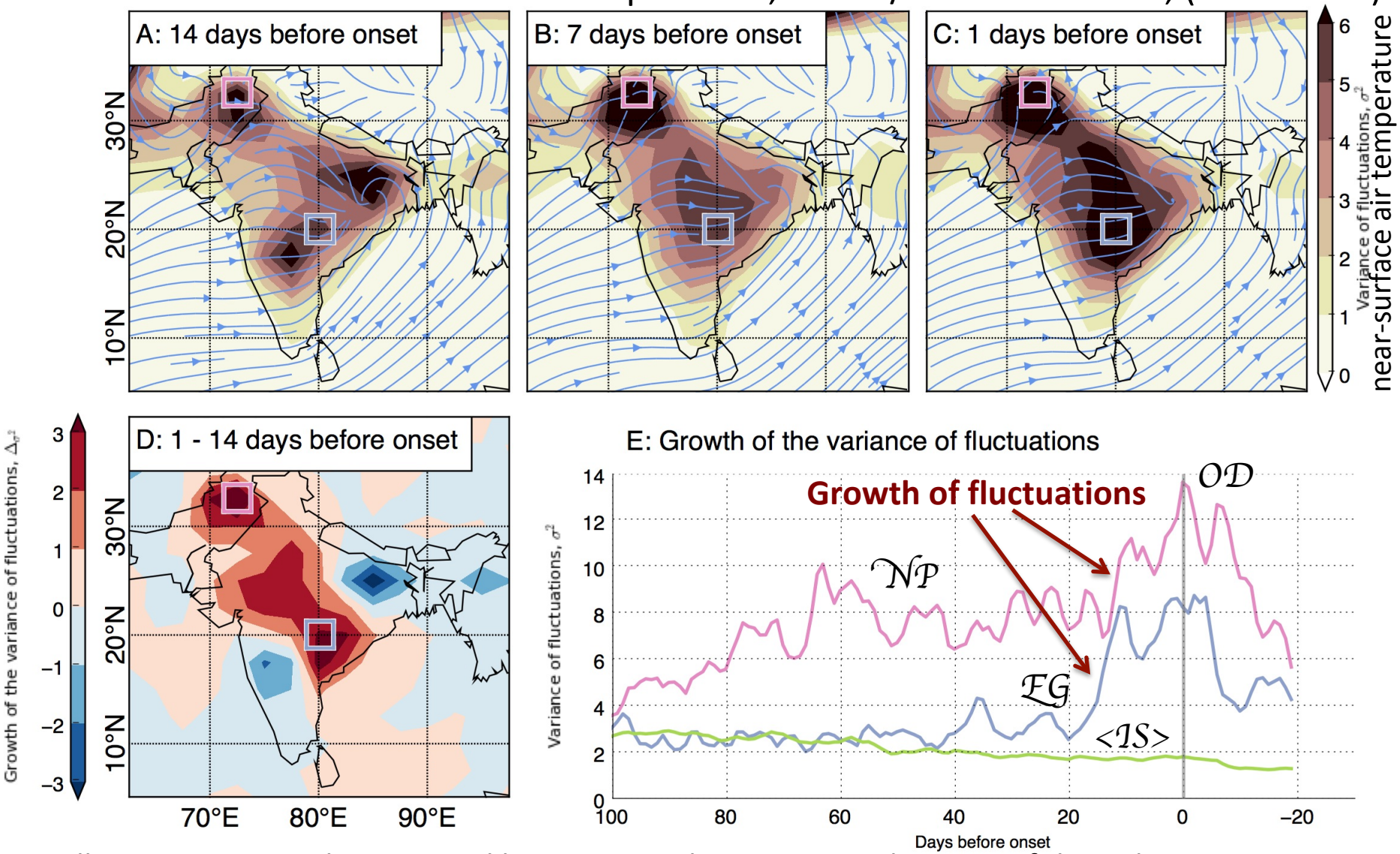
- *overbalance or*
- *cause to overbalance*

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

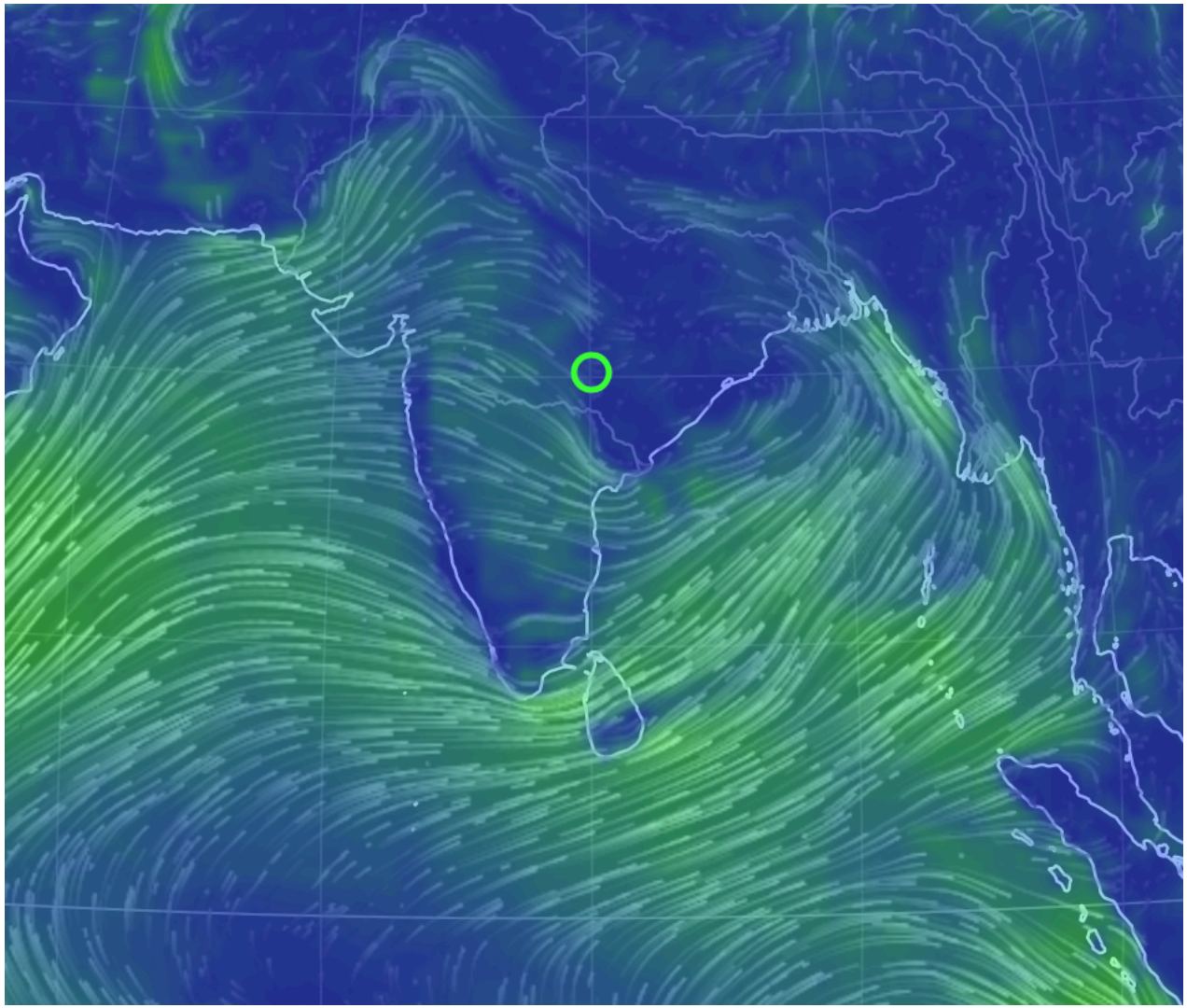
- ✓ The candle is an origin of the problem – *a tipping element of the system*.
- ✓ The time when the candle tipped over is *a tipping point*.
- ✓ An open window which gives the direction of flame propagation is the second *tipping element of the system*.

Tipping elements and prediction of monsoon

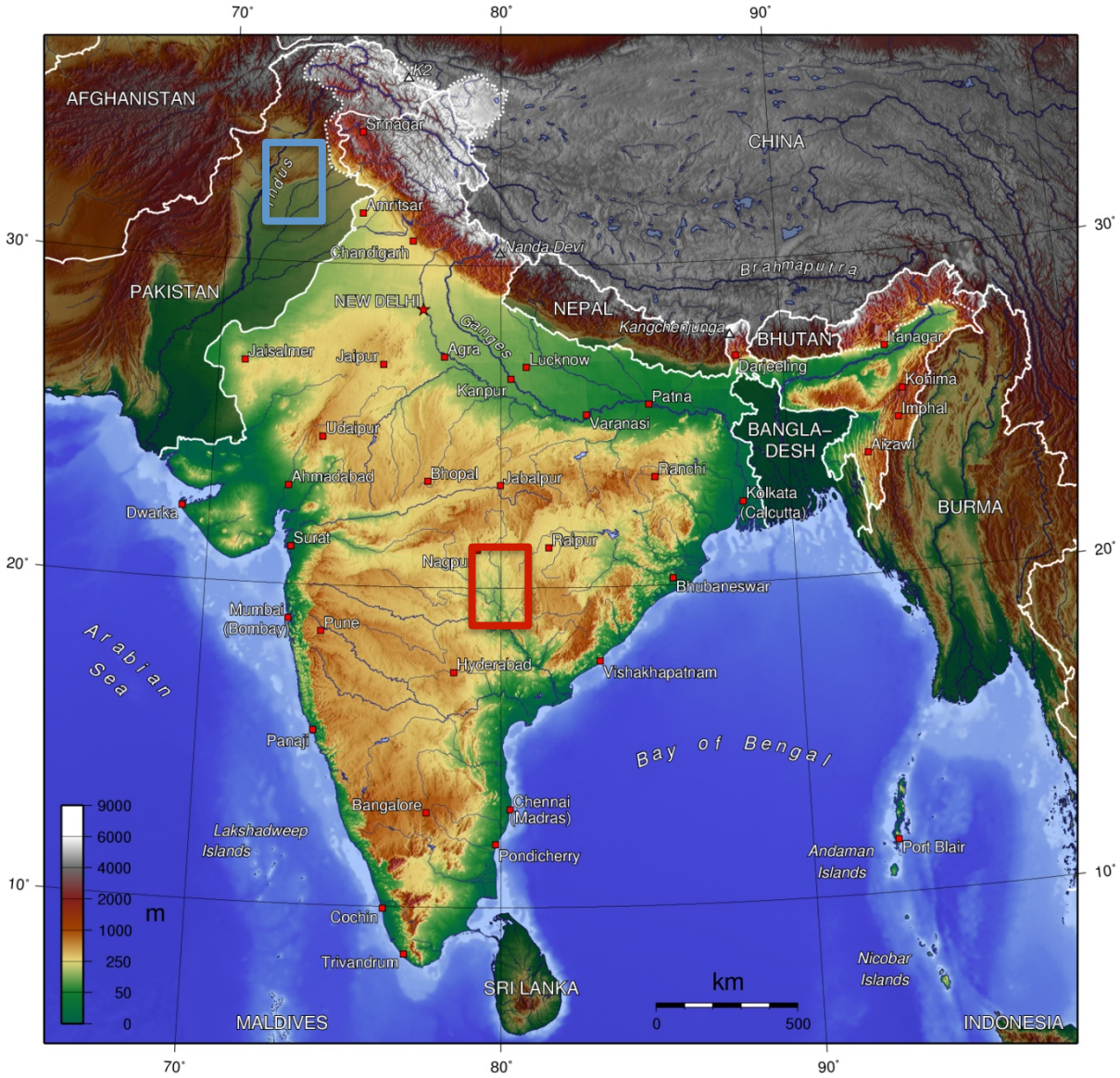
DATA: ERA40: near –surface air temperature, 0.25 °/0.25° resolution, (1958-2001)



- 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)



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.

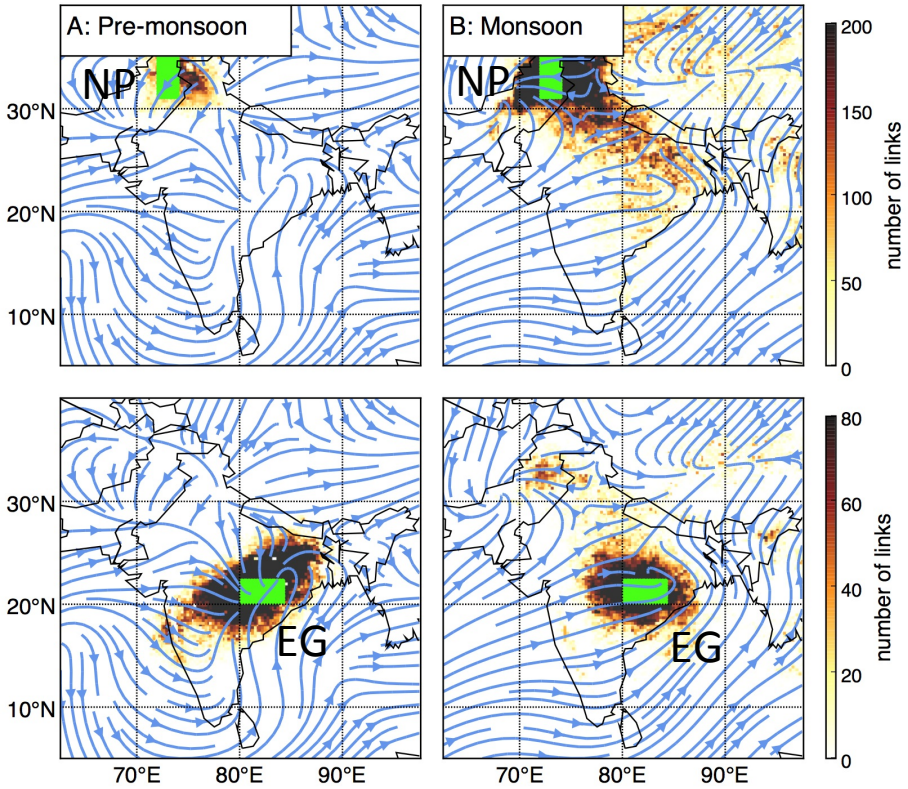


Figure 3. Links between a set of 153 reference grid points to other grid points and surface wind vector mean 1998-2012.

Temperature & wind fields

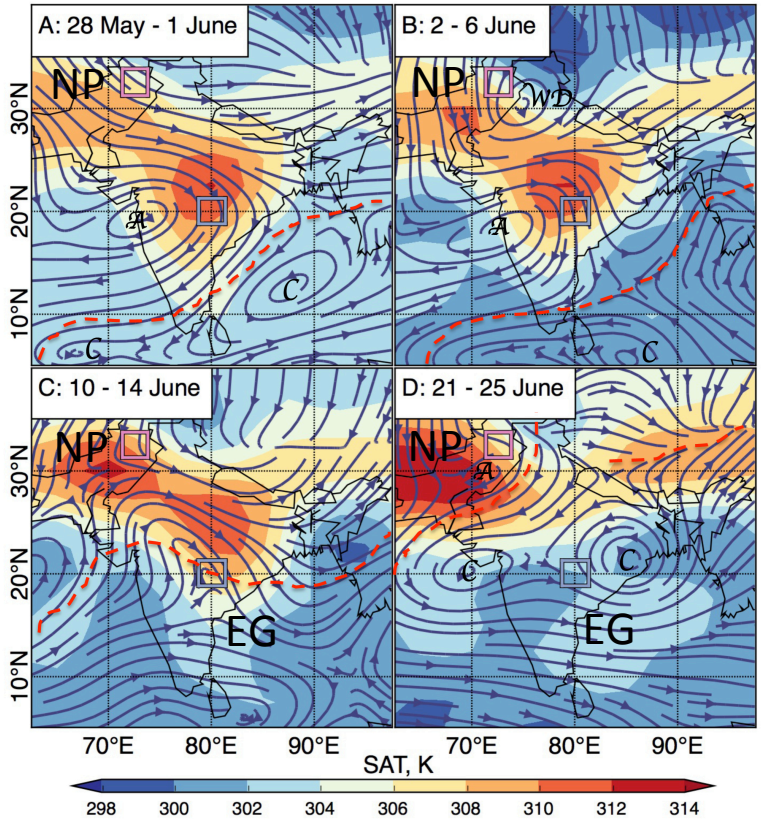
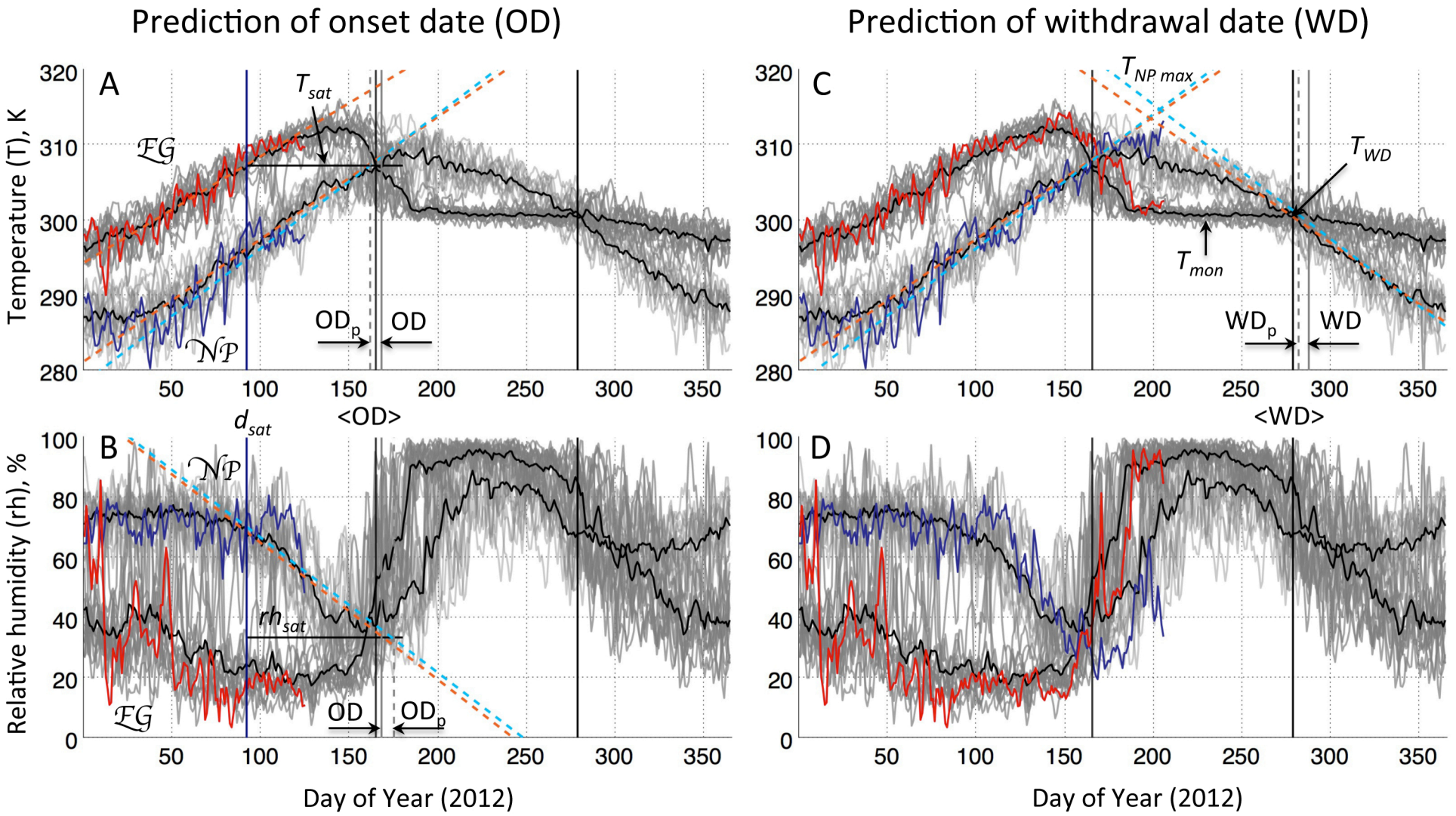


Figure 4. Wind fields and near-surface temperature: before, during and after the onset of monsoon

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?

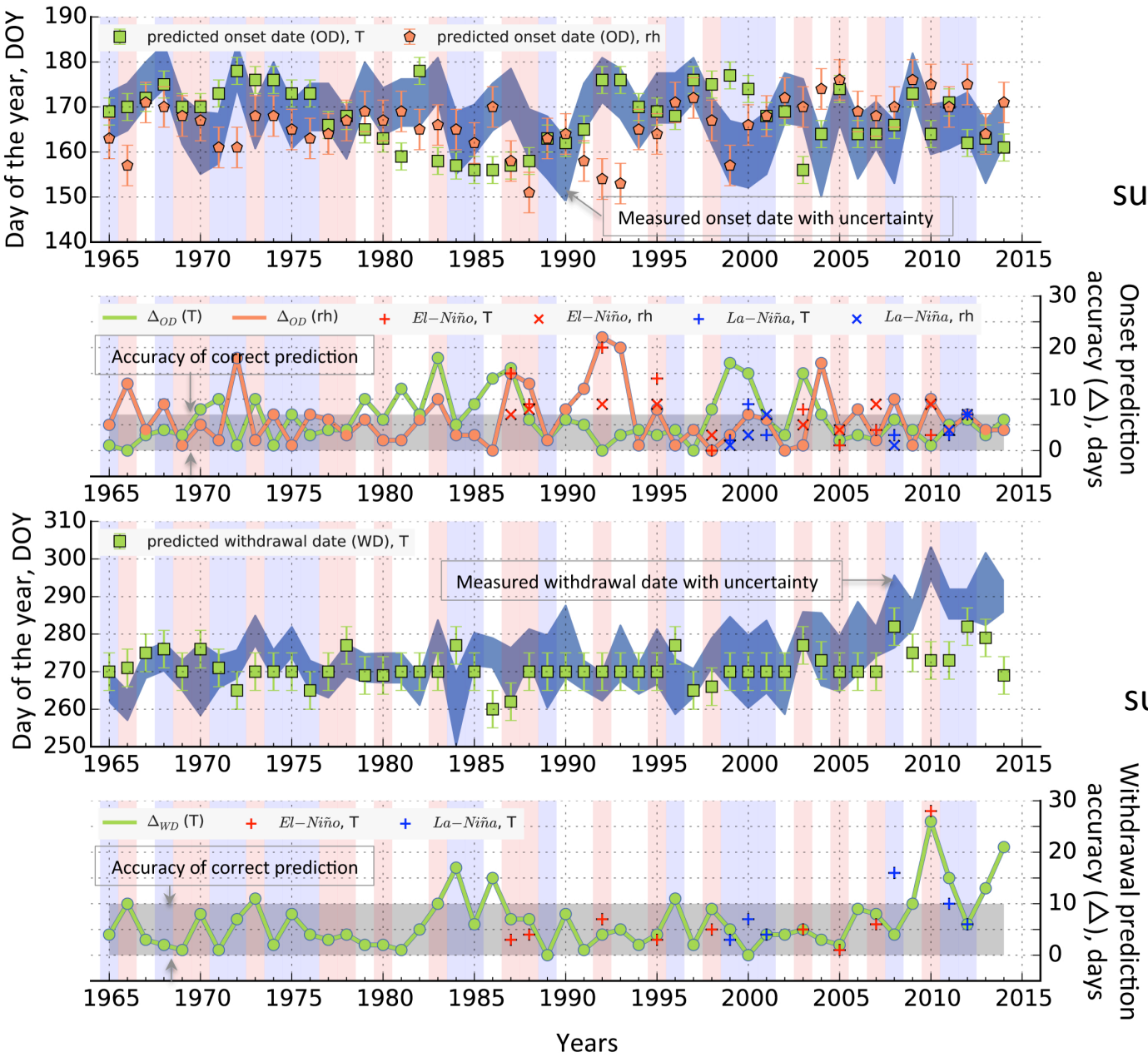
Prediction scheme for monsoon onset and withdrawal over the Eastern Ghats (20N,80E)



Performance of prediction scheme

ONSET

WITHDRAWAL



74% of success rate

84% of success rate

Stolbova V., Surovyatkina E., Bookhagen B.,Kurths J.*GRL, 43, 1–9, April 20,* 2016

3. Forecasting upcoming monsoon: observational evidences

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

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you are here: home › services › info desk › forecasting of indian monsoon

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  - Telegraphenberg
  - Museum "weather factory"
  - PIKee/PIKeeBB-Environmental education
  - Forecasting of Indian Monsoon
    - News about Monsoons

Welcome to the PIK monsoon page!

This web page provides a long-term forecast of the onset and withdrawal of the Indian Summer Monsoon (the Southwest Monsoon) for the central part of India. The long-term forecast means 40 days in advance for the onset date, and 70 days in advance for the withdrawal date. Our approach is based on a teleconnection between the Eastern Ghats (EG) and North Pakistan (NP) - Tipping Elements of Indian Summer Monsoon. The forecasts are performed by Elena Surovyatkina.

LATEST NEWS

October 16, 2017
Successful earliest forecast of the Withdrawal Date of Indian Summer Monsoon from the Central part of India.

Daily mean near-surface air temperature till May 5,2017 for EG(red) and NP(blue).Violet and

NEWS

- Successful earliest forecast of onset and withdrawal of the Indian Summer Monsoon
- New forecast method predicts 2017 Indian Summer Monsoon onset
- Successful forecast of onset and withdrawal of the Indian Summer Monsoon
- Prediction of Monsoon withdrawal

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

You are here: Home » National » Monsoon to hit central India between June 14-22

Monsoon to hit central India between June 14-22

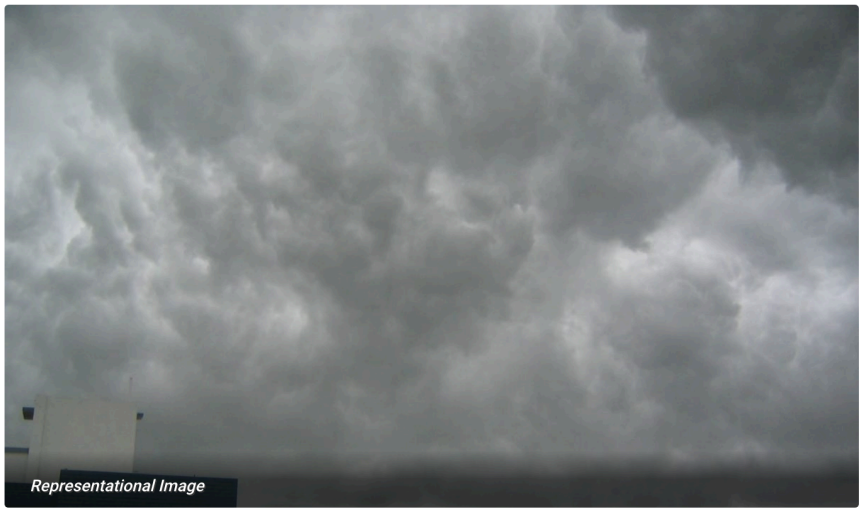
New Delhi, DH News Service, May 9 2017, 1:35 IST

Since last year, the German institute began forecasting the onset and withdrawal of monsoon using its own weather model.

Monsoon to hit TS on June 18

Scientists from Germany develop forecast method which predicts accurately.

By TelanganaToday | Published: 14th May 2017 10:50 pm



Representational Image

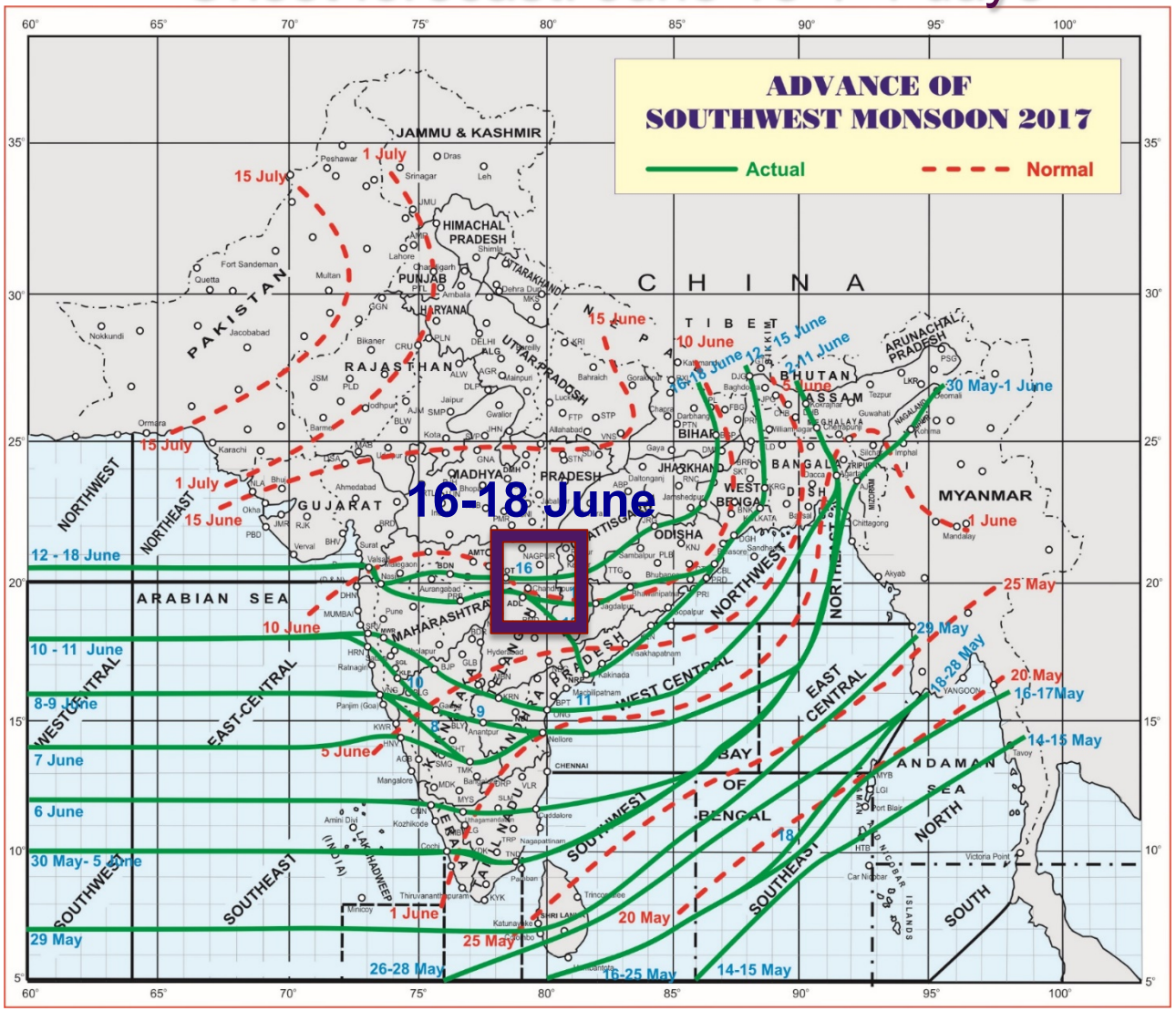
Hyderabad: The southwest monsoons will hit Telangana and other parts of Central India on or around June 18, according to an early forecast method developed by weather scientists from Potsdam Institute for Climate Impact Research (PIK), Germany.

The forecast method is based on analysis of observational data that allows predicting monsoon onset date more than a month in advance in the central part of India where early forecasting has never been made, Elena Surovyatkina, the research scientist from PIK, who led this study said.

Meanwhile, an early forecast method at the Potsdam Institute for Climate Impact Research said that the mosoon would reach Central India between June 14 and 22.

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 (http://www.imd.gov.in/pages/allindiawxfcbulletin.php)

Indian Summer Monsoon - 2017

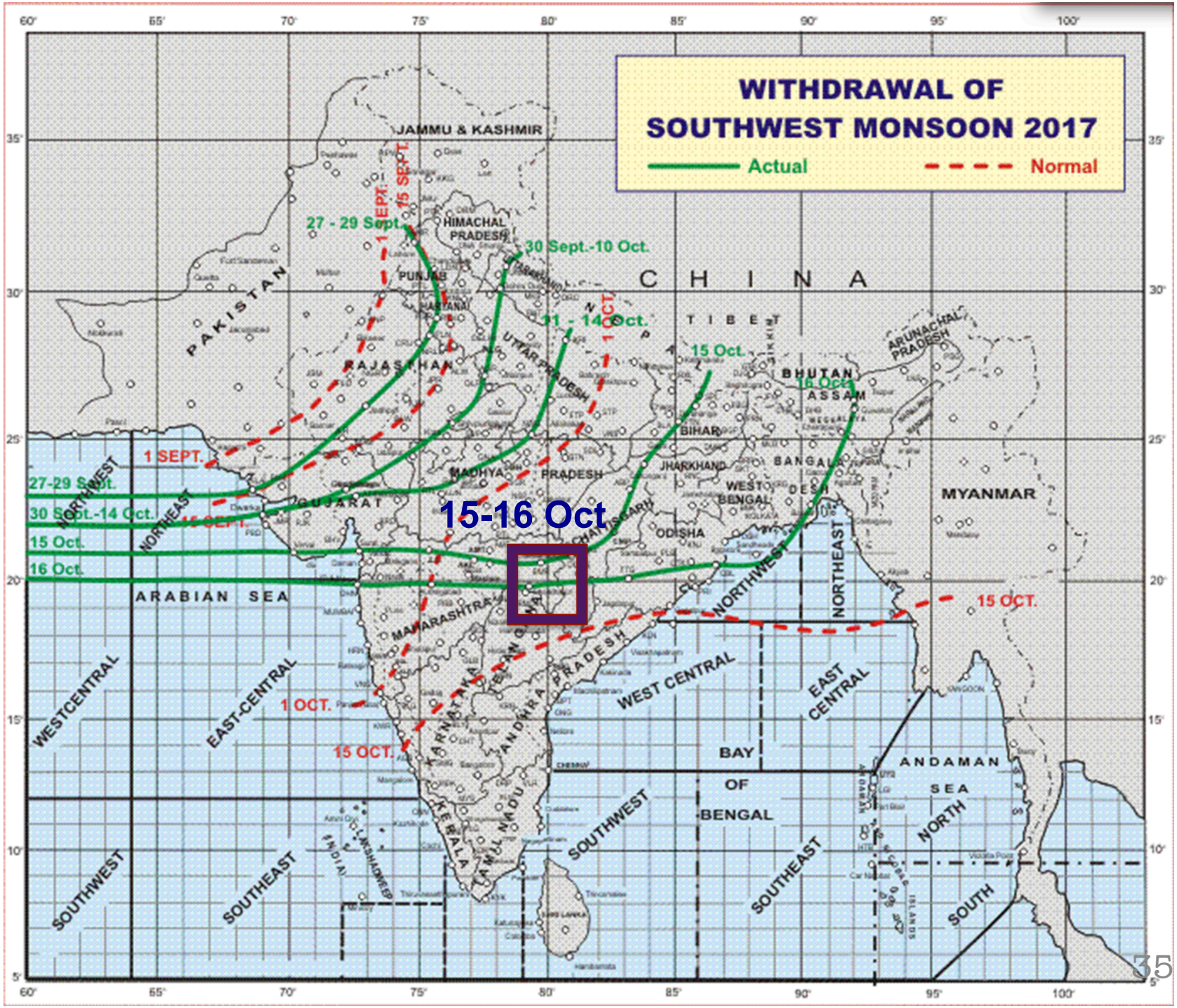
The PIK- monsoon onset monitor news

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.

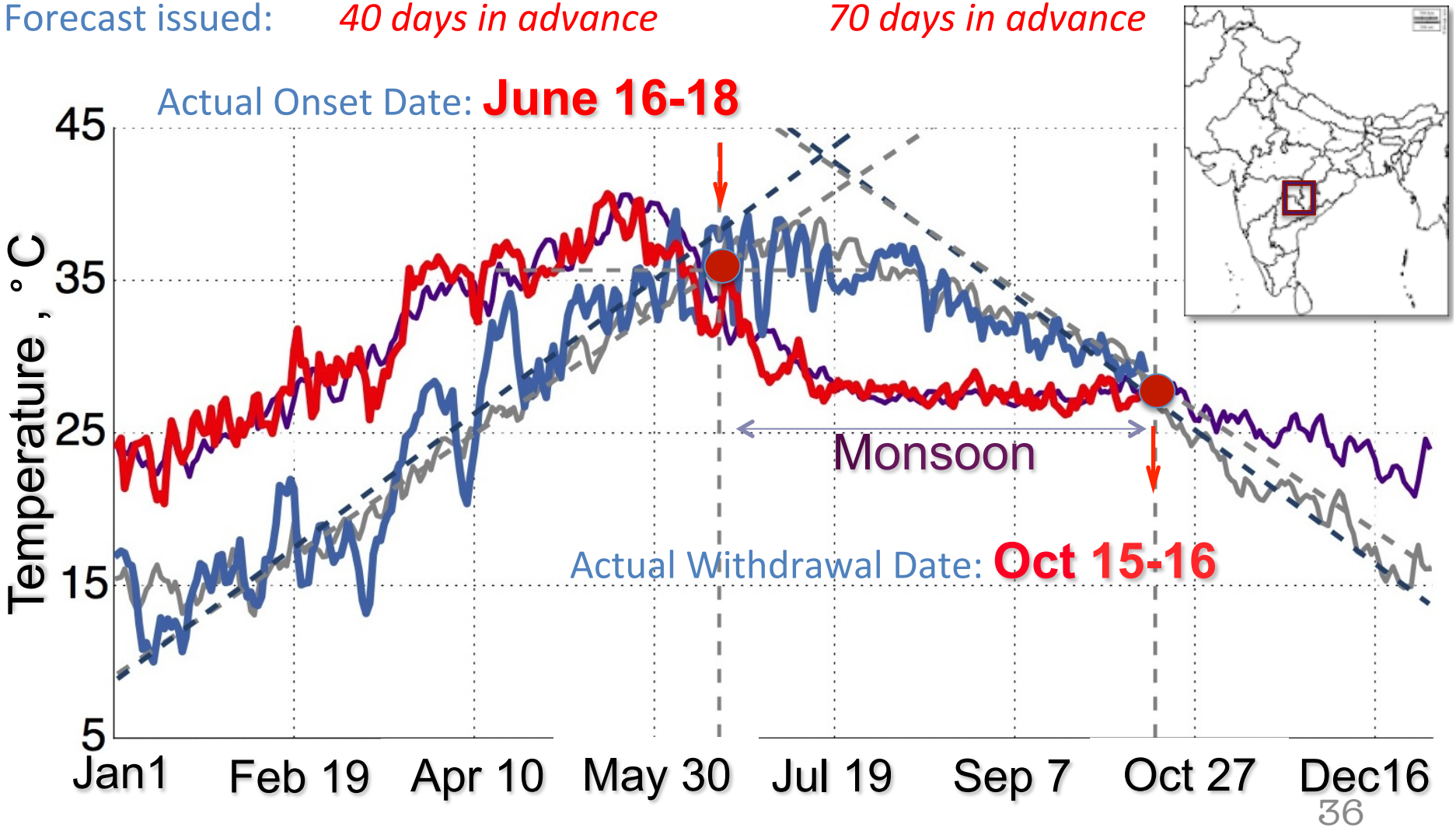
https://www.pik-potsdam.de/services/infodesk/forecasting-indian-monsoon


WITHDRAWAL OF
SOUTHWEST MONSOON 2017
Actual
Normal
15-16 Oct
27 - 29 Sept.
30 Sept.-10 Oct.
11 - 14 Oct.
15 Oct.
16 Oct.
1 SEPT.
15 SEPT.
1 OCT.
15 OCT.
JAMMU & KASHMIR
HIMACHAL PRADESH
PUNJAB
HARYANA
RAJASTHAN
UTTAR PRADESH
BIHAR
SIKKIM
ARUNACHAL PRADESH
BHUTAN
ASSAM
MADHYA PRADESH
JHARKHAND
WEST BENGAL
ODISHA
CHHATTISGARH
GUJARAT
MAHARASHTRA
KARNATAKA
ANDHRA PRADESH
TAMIL NADU
KERALA
MYANMAR
PAKISTAN
CHINA
TIBET
ARABIAN SEA
BAY OF BENGAL
ANDAMAN SEA
NORTHWEST
NORTHEAST
WESTCENTRAL
EAST-CENTRAL
WEST CENTRAL
EAST CENTRAL
SOUTHWEST
SOUTHEAST
NORTH
SOUTH

Indian Monsoon Monitor, 2017

Onset Date Forecast: **June 18 +/-4 days** Withdrawal Date Forecast: **Oct 12 +/-5 days**

Forecast issued: *40 days in advance* *70 days in advance*



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

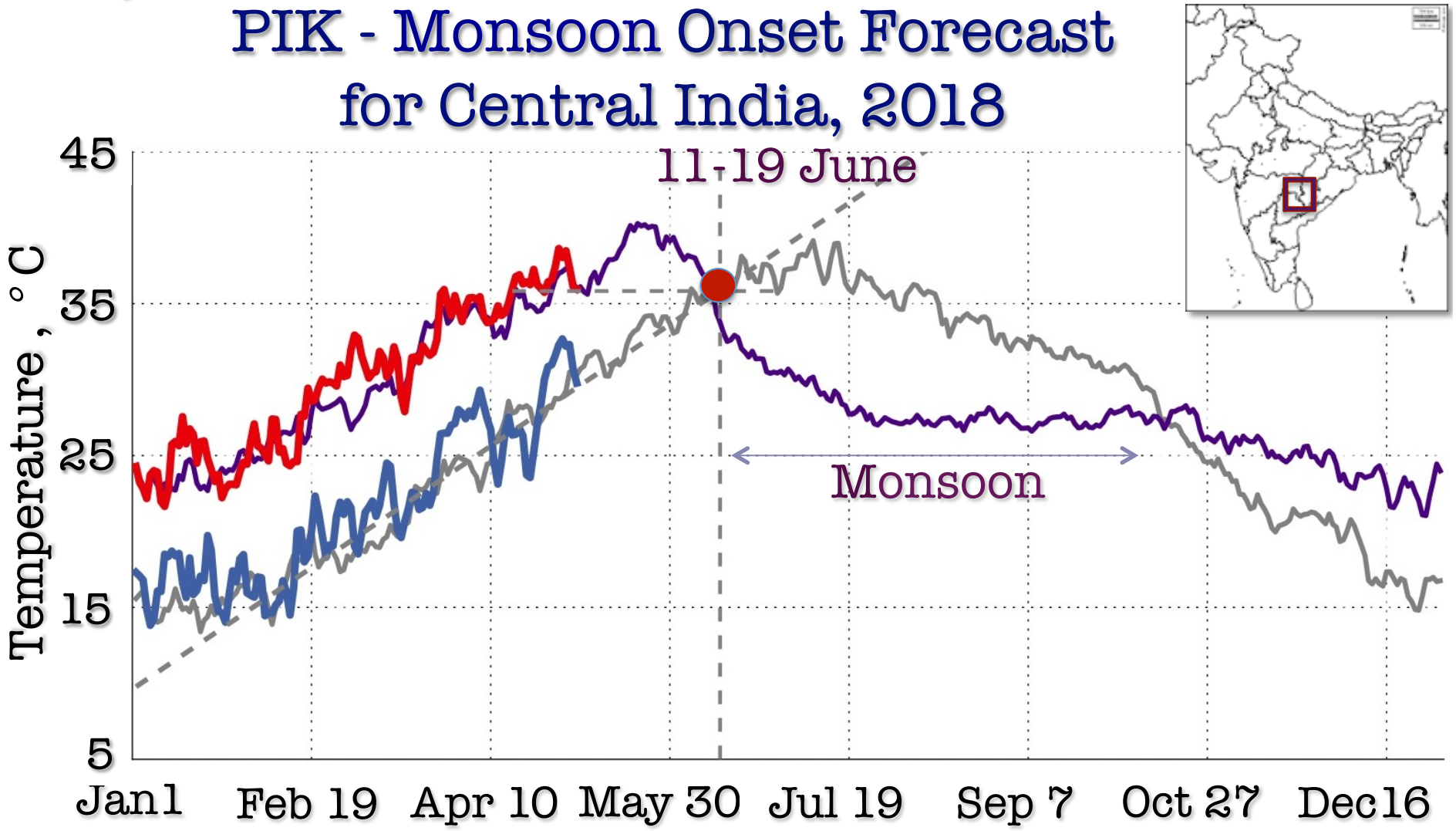
The Indian Summer Monsoon (the Southwest Monsoon) is likely to set over the central part of India, the Eastern Ghats region (20°N,80°E) around 15th June (+/- 4 days) namely between 11th to 19th June 2018.

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

7 May 2018

PIK - Monsoon Onset Forecast for Central India, 2018



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.

Sakal Times

Friday, May 25, 2018, 1:15 AM | e-paper

hindustantimes

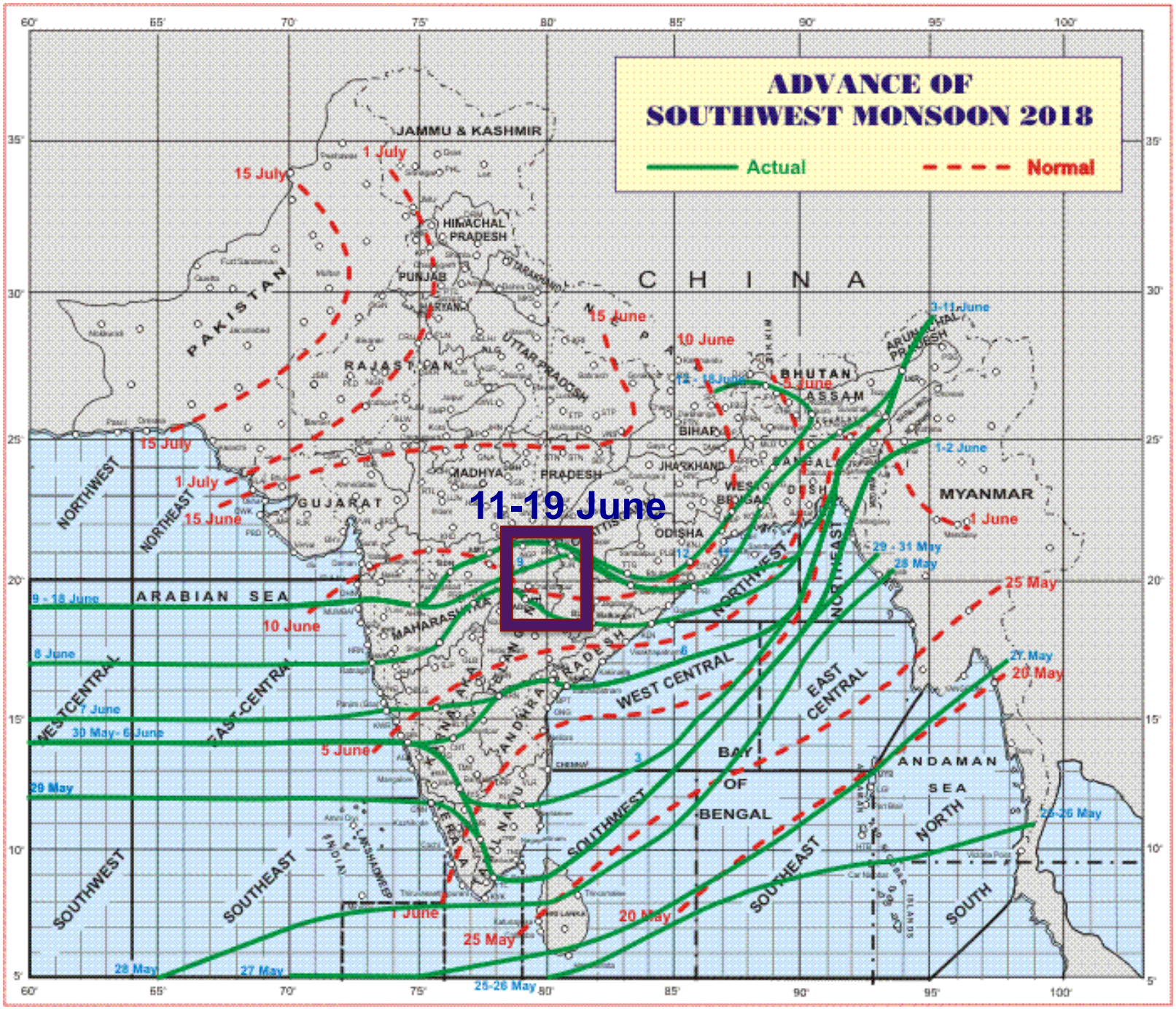
Monday,

Monsoon in Pune from June 11, but heat to continue

According to Elena Surovyatkina, a researcher from the Potsdam institute for climate impact research (PIK), the Indian summer monsoon (the Southwest monsoon) is likely to engulf the central part of India, the Eastern Ghats region (20°N,80°E), around June 15 (+/- 4 days), between June 11 and June 19.

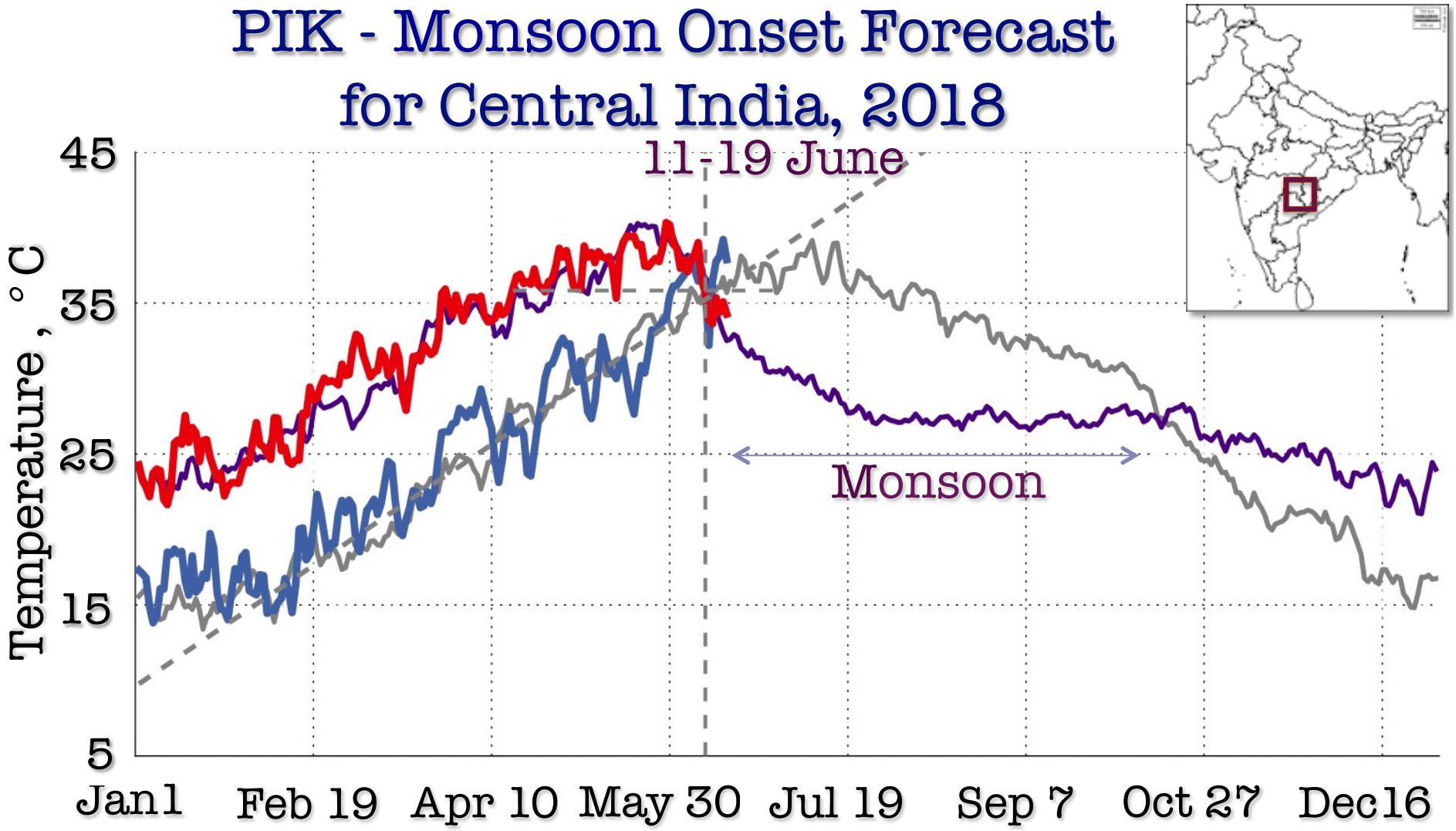
PUNE Updated: May 15, 2018 14:32 IST

ht Ananya Barua
Hindustan Times, Pune


ADVANCE OF
SOUTHWEST MONSOON 2018
Actual
Normal
JAMMU & KASHMIR
HIMACHAL PRADESH
PUNJAB
HARYANA
RAJASTHAN
UTTAR PRADESH
BIHAR
JHARKHAND
WEST BENGAL
SIKKIM
BHUTAN
ARUNACHAL PRADESH
ASSAM
MYANMAR
MADHYA PRADESH
GUJARAT
ODISHA
MAHARASHTRA
ANDHRA PRADESH
TELANGANA
KARNATAKA
TAMIL NADU
KERALA
PUDUCHERRY
ANDAMAN & NICOBAR ISLANDS
PAKISTAN
CHINA
SRI LANKA
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
11-19 June
1 July
15 July
15 June
10 June
5 June
3-11 June
1-2 June
1 June
29 - 31 May
28 May
25 May
20 May
9 - 18 June
8 June
7 June
30 May - 6 June
29 May
1 June
28 May
27 May
25-26 May
NORTHWEST
NORTHEAST
WEST CENTRAL
EAST CENTRAL
SOUTHWEST
SOUTHEAST
NORTH
SOUTH

15 June 2018

PIK - Monsoon Onset Forecast for Central India, 2018



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.

Conclusion

- 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

- Stolbova V., Surovyatkina E., Bookhagen B.,Kurths J., Tipping elements of the Indian monsoon: prediction of onset and withdrawal. GRL43, 1–9, 2016, 2016
- 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)
- J. Tony, S Subarna, K. S. Syamkumar, G. Sudha, S. Akshay, E. A. Gopalakrishnan, E. Surovyatkina & R. I. Sujith. Experimental investigation on preconditioned rate induced tipping in a thermoacoustic system . Scientific Reports, 2017, 7(1), 5414.

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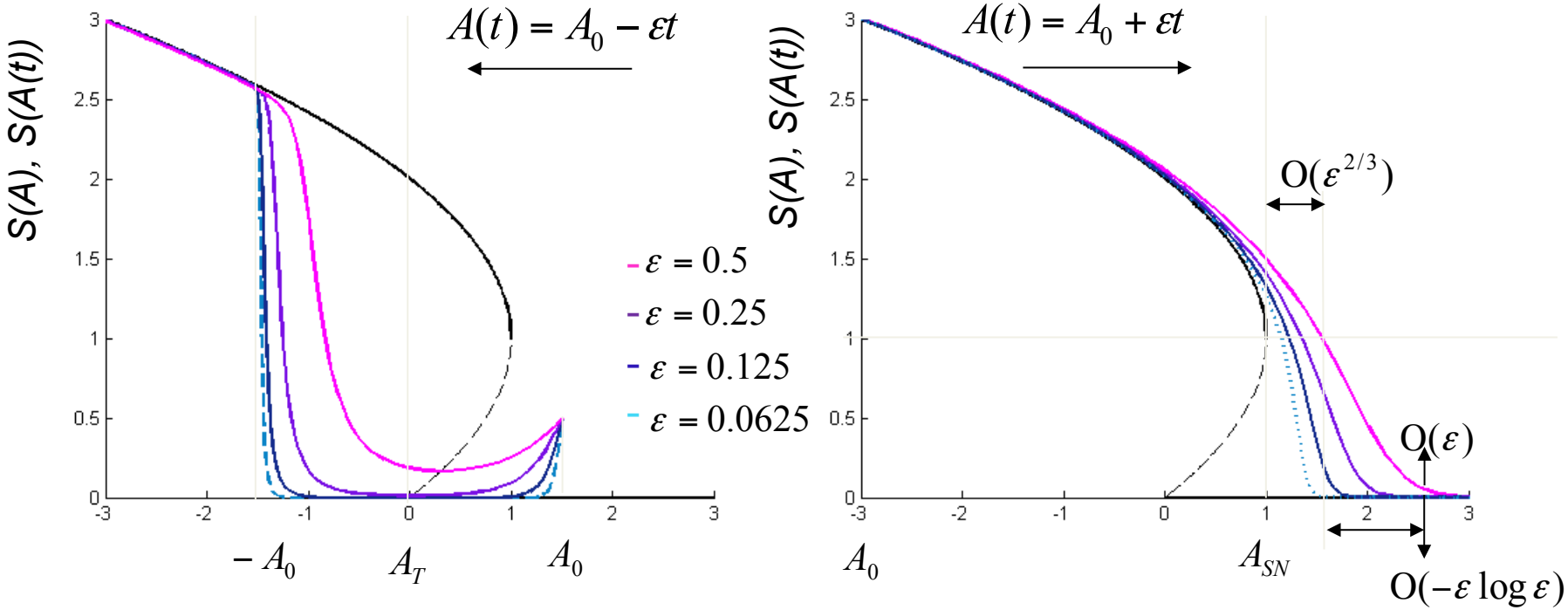
Dynamic case: the effect of the rate of change of the bifurcation parameter

$$\frac{dS}{dt} = S\left(S^2 - 2S + A(t)\right)$$

Transcritical bifurcation:
backward transition through $A_T = 0$

Saddle-node bifurcation:
forward transition through $A_{SN} = 1$



The delay in stability exchange is **independent** of ε and proportional to the initial value of A [1].

The dynamic transition overshoots the static value A =1 and this overshoot is **dependent** on ε

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

18 June 2018

17.5 N ,
72.5E