POTSDAM INSTITUTE FOR
CLIMATE IMPACT RESEARCH (PIK)

SPACE RESEARCH INSTITUTE
RUSSIAN ACADEMY OF SCIENCES

Elena Surovyatkina

Monsoon Prediction under Climate Change: South American Monsoon Case

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety
B-EPICC project
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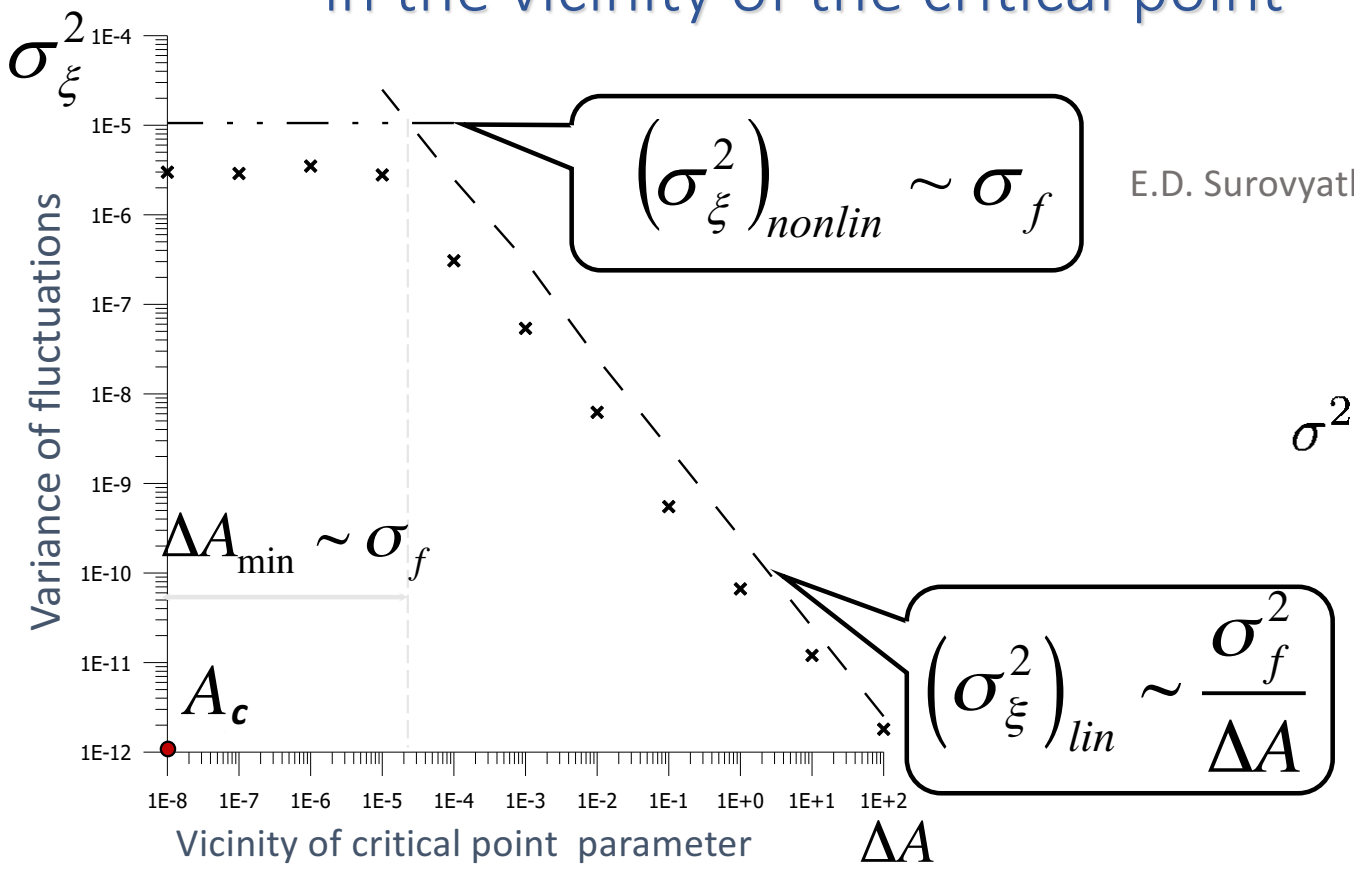
INTERNATIONALE
KLIMASCHUTZINITIATIVE (IKI)

23 August, 2022, São Paulo, Brazil

Contents

- Theoretical background: critical phenomena and transition to monsoon.
- The main principles of the prediction of monsoon timing.
- Future perspective for the extension of monsoon forecast worldwide.

The nonlinear saturation of the fluctuation's growth in the vicinity of the critical point



E.D. Surovyatkina [1,2]

$$\sigma^2 = \frac{\sum_{i=1}^{n} (X_i - \mu)^2}{n}$$

K. Weisenfeld, J. Stat. Phys. 38 (1985) 1071.

1. E.D. Surovyatkina, Phenomenon of Prebifurcation Rise and Saturation of the Correlation Time, Phys. Lett. A 329, 2004, 169.

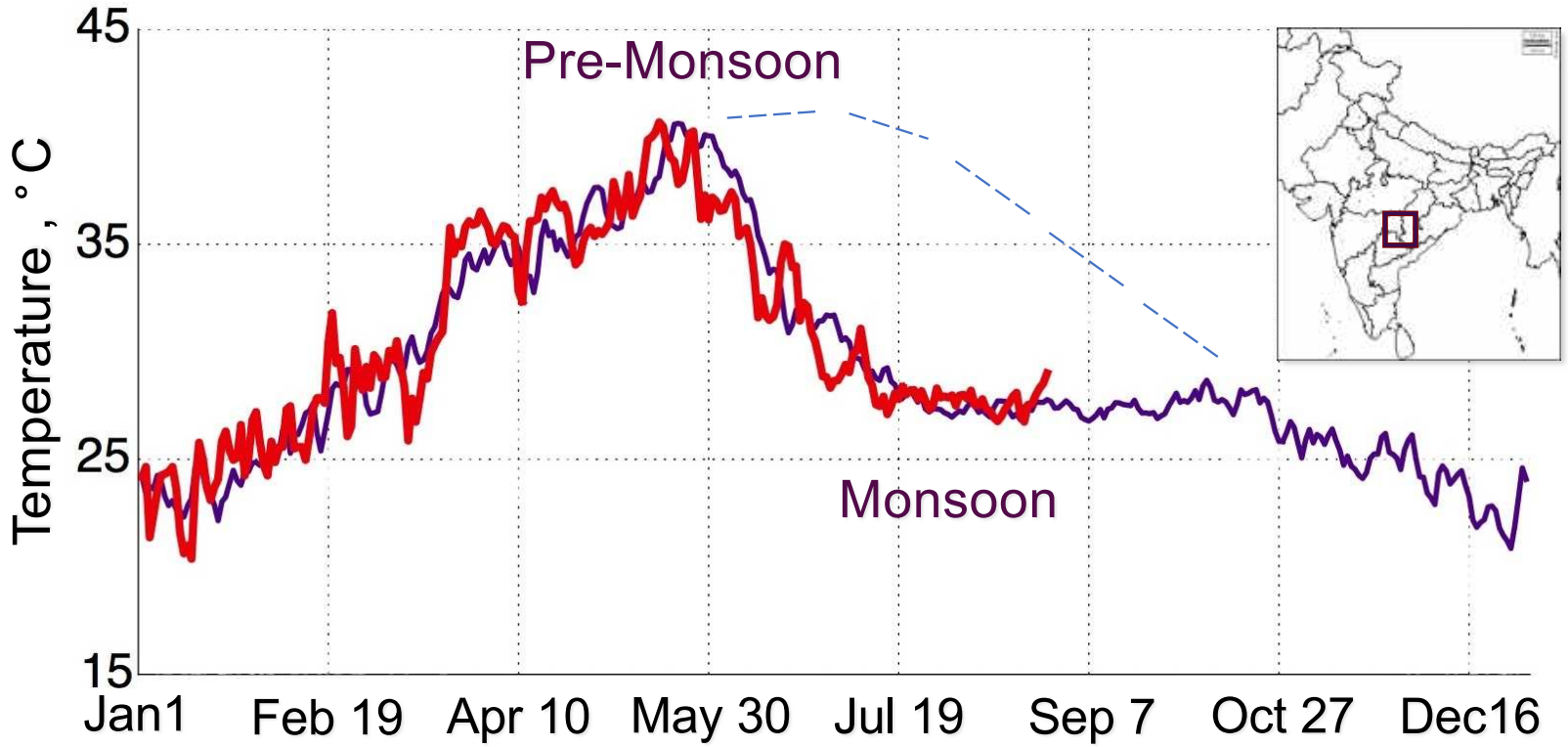
2. E.D. Surovyatkina, Yu. A. Kravtsov and J. Kurths, Fluctuation growth and saturation in nonlinear oscillator on the threshold of bifurcation of spontaneous symmetry breaking, Phys. Rev. E, 72, 2005, 046125

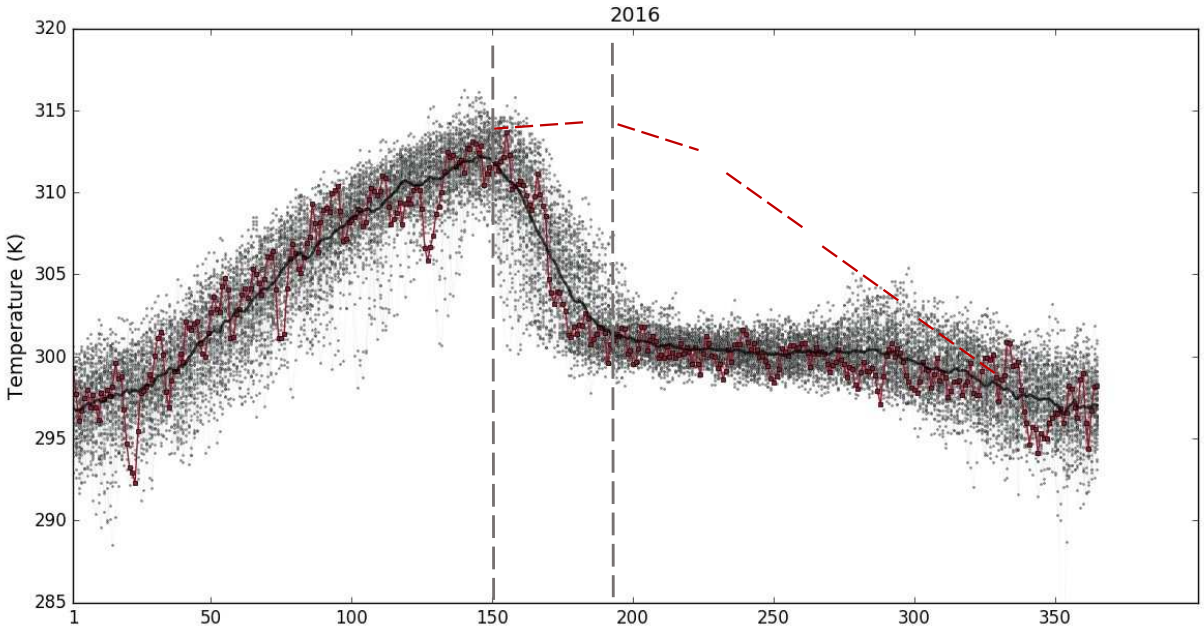
«The onset of monsoon… Is not a transition from a regime of no rain to rain; it is a transition from a regime of sporadic rainfall to spatially organized and temporally sustained rainfall…»

critical

R. Ananthakrishnan and M.K. Soman, 1990

Is it a critical transition?





Daily mean near-surface air temperature over the Eastern Ghats (1950-2020)

The numerical weather model **cannot reproduce the abrupt transition** common in the tropics.

Major limitations in numerical weather prediction

- Numerical Weather Prediction has a limit to forecast the weather for **up to 5 days** in the future.
- Existing observation networks have poor coverage in some regions (for example, over the Pacific Ocean), which introduces uncertainty into the true initial state of the atmosphere. These uncertainties limit forecast model accuracy to about **five or six days** into the future [Weickmann et al. 2001], [Chakraborty, Arindam, 2010].
- General Circulation Model (GCM) includes an inadequate description of basic processes like **cloud formation, moist convection, and mixing** is what climate models **miss most** [Stevens and Bony, 2013].

The limitations of current models prevent further progress. A new strategy is desperately needed in weather and climate sciences [Stevens and Bony, Science 31 May 2013]

Once we accept our limits,
we go beyond them.

Albert Einstein

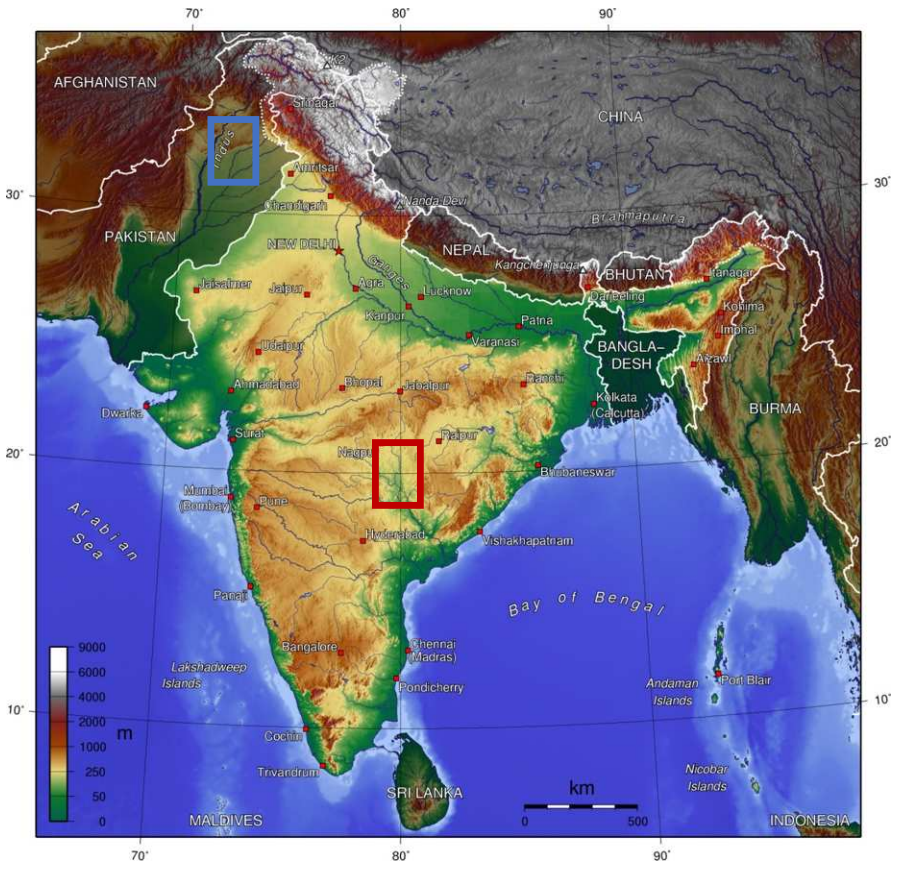
Forecasting Monsoon Timing: Tipping Elements approach

The approach is fundamentally different from the numerical weather and climate models; it is based on the following ground rules:

- statistical physics principles,
- spatial-temporal regularities (or teleconnections between Tipping Elements) in monsoon system.

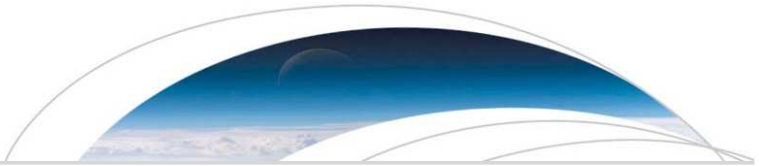
The forecasting method relies on the analysis of observational data.

Such a strategy opens a new chapter in meteorology and climate phenomena predictions. It applies to cases when the GCM fails, particularly the monsoon timing or the sea ice season forecasts.



AGU PUBLICATIONS

Geophysical Research Letters



RESEARCH LETTER
10.1002/2016GL068392

Key Points:
- We identify geographic regions of critical behavior as tipping elements
- We use critical fluctuations in air temperature as a precursor of monsoon timing
- We improve the time scale of monsoon onset and withdrawal forecasting

Supporting Information:
- Supporting Information S1

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Tipping elements of the Indian monsoon: Prediction of onset and withdrawal

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Abstract Forecasting the onset and withdrawal of the Indian summer monsoon is crucial for the life and prosperity of more than one billion inhabitants of the Indian subcontinent. However, accurate prediction of monsoon timing remains a challenge, despite numerous efforts. Here we present a method for prediction of monsoon timing based on a critical transition precursor. We identify geographic regions—tipping elements of the monsoon—and use them as observation locations for predicting onset and withdrawal dates. Unlike

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*.

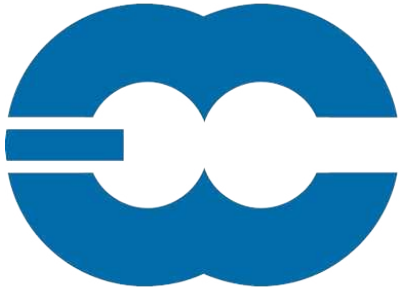
- Where (geographically) do the critical conditions originate?
- How do the critical conditions propagate in space?
- How to predict a future transition?

DATA

NCEP/NCAR Reanalysis 1

- 4-times daily, daily and monthly values for 1948/01/01 to present
- 2.5 degree latitude x 2.5 degree longitude global grid (144x73)

https://downloads.psl.noaa.gov/Datasets/ncep.reanalysis/Dailies/pressure/



ERA-Interim

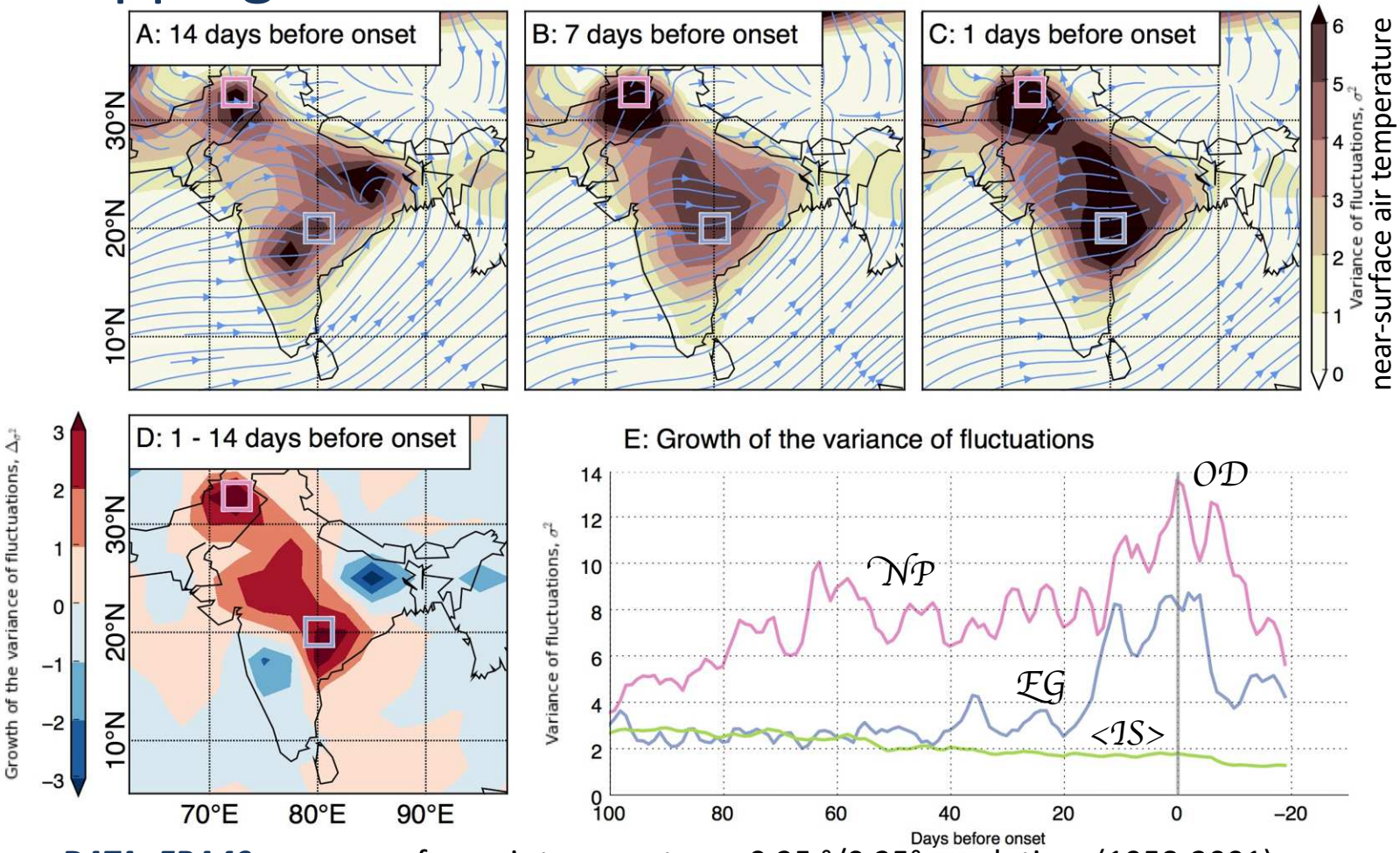
- 4-times daily, daily and monthly values for 1979/01/01 to present (delay 2m)
- 0.125 degree latitude x 0.125 degree longitude global grid

https://www.ecmwf.int/en/forecasts/datasets/archive-datasets/reanalysis-datasets/era-interim

The Indian Summer Monsoon

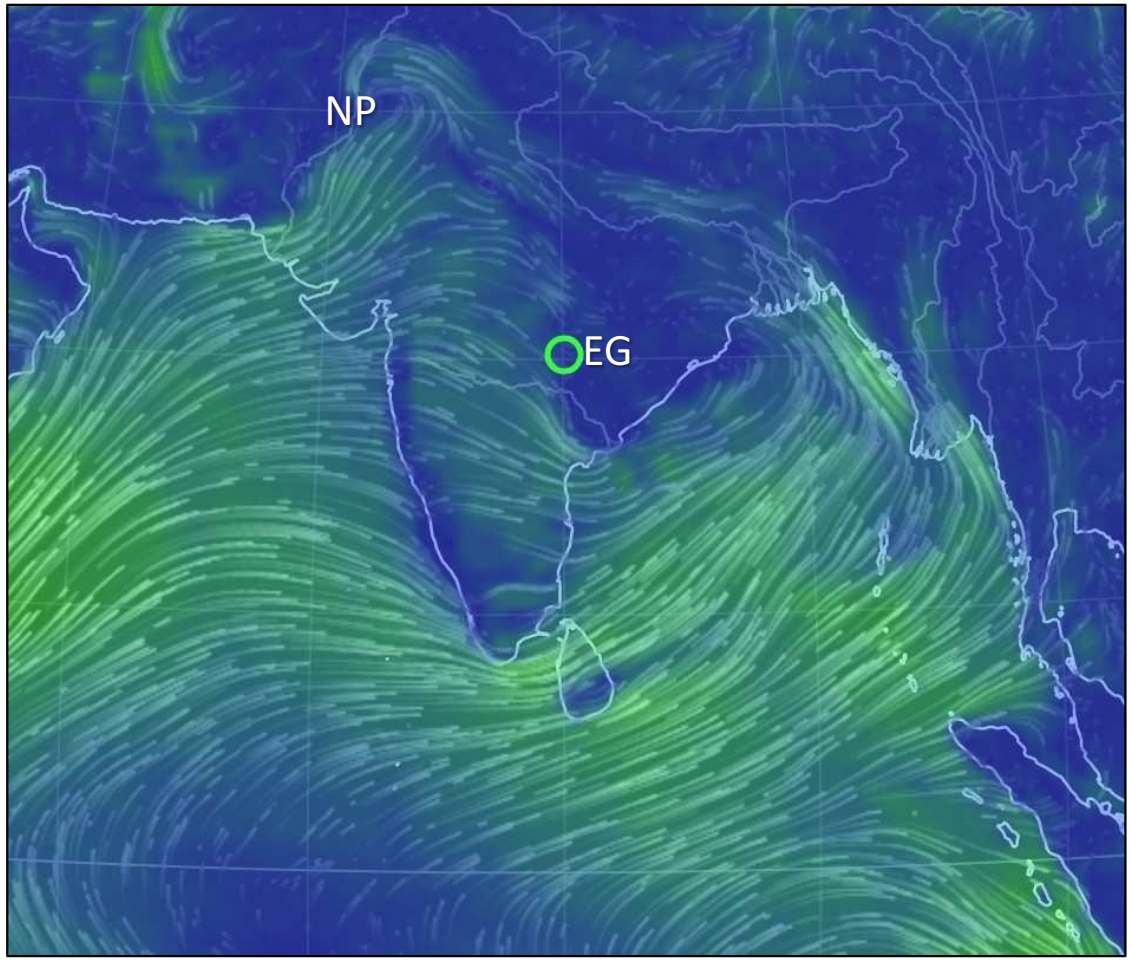
Where (geographically) do the critical conditions originate?

Tipping elements of Indian Summer Monsoon



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

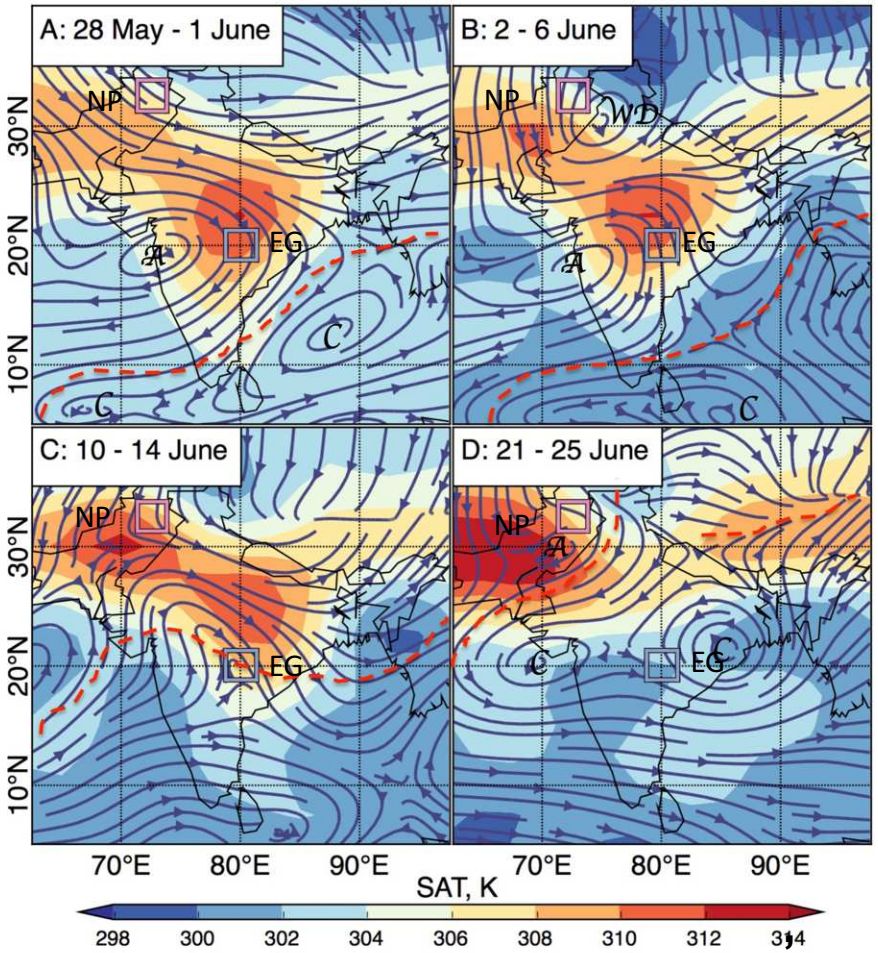
How do the critical conditions propagate in space?



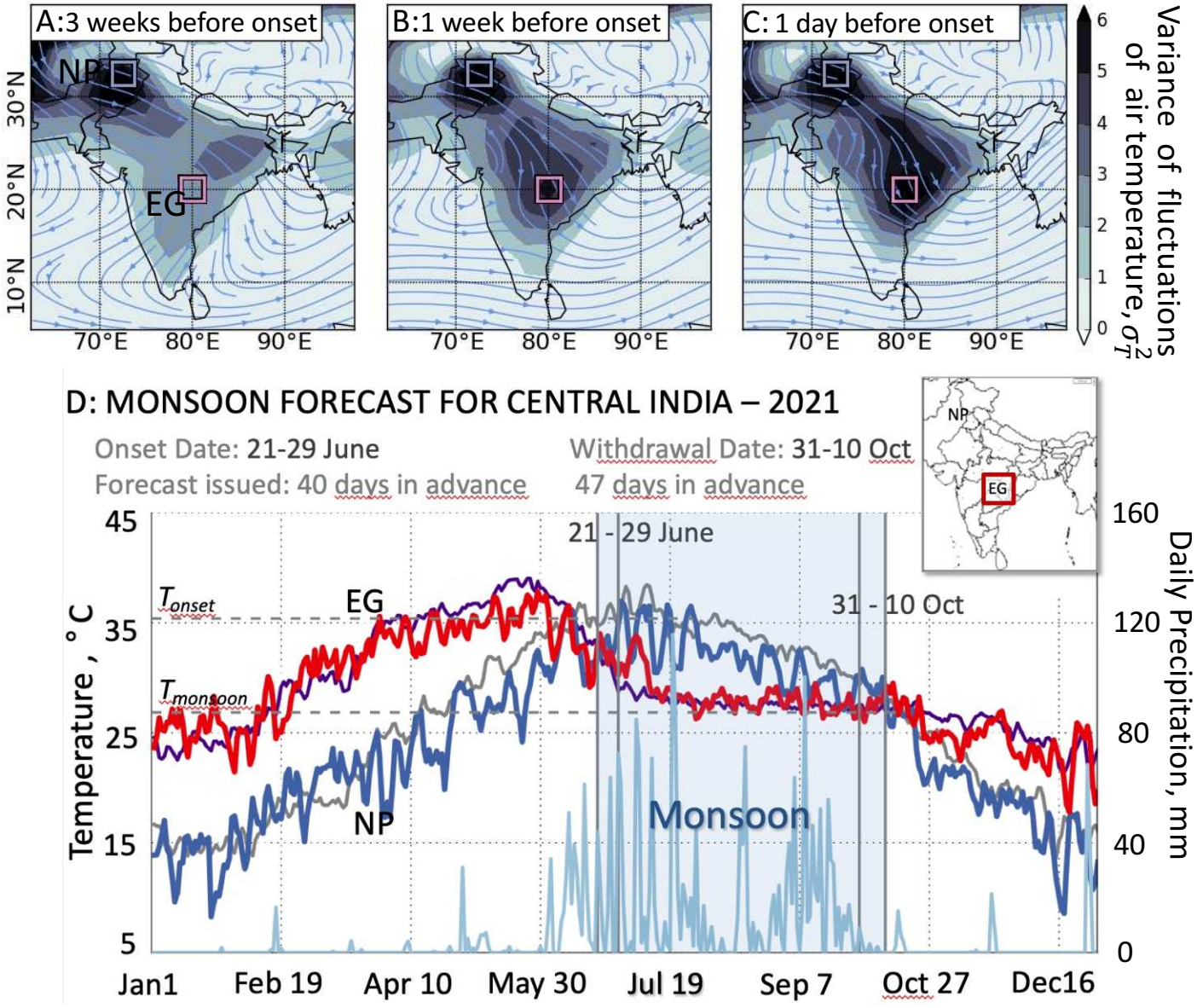
https://earth.nullschool.net/#2016/06/17/0300Z/wind/isobaric/1000hPa/orthographic=78.74,8.05,626/loc=80,20

The onset of monsoon in the EG appears when the conditions in two regions NP and EG equalizes.

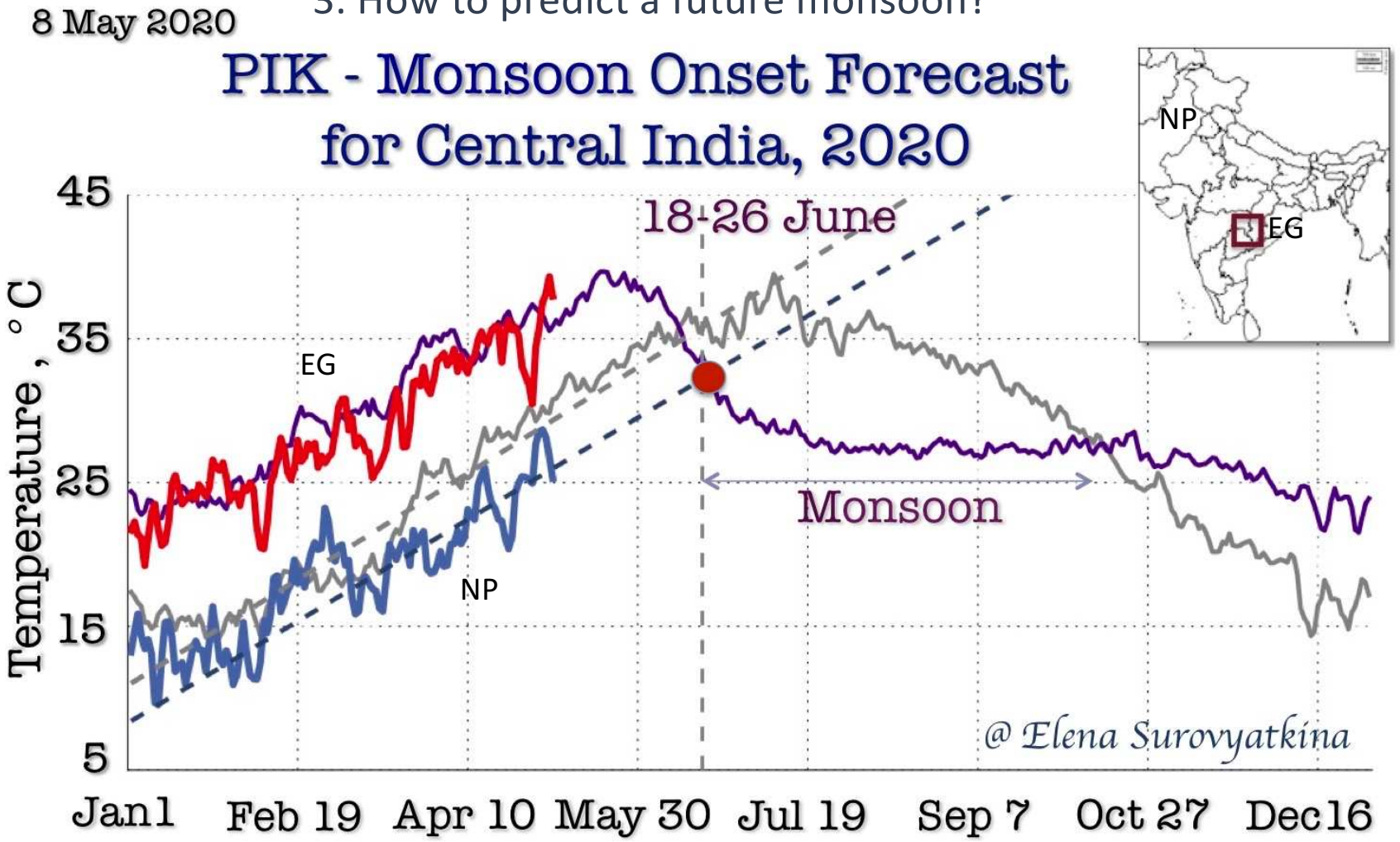
Temperature & wind fields



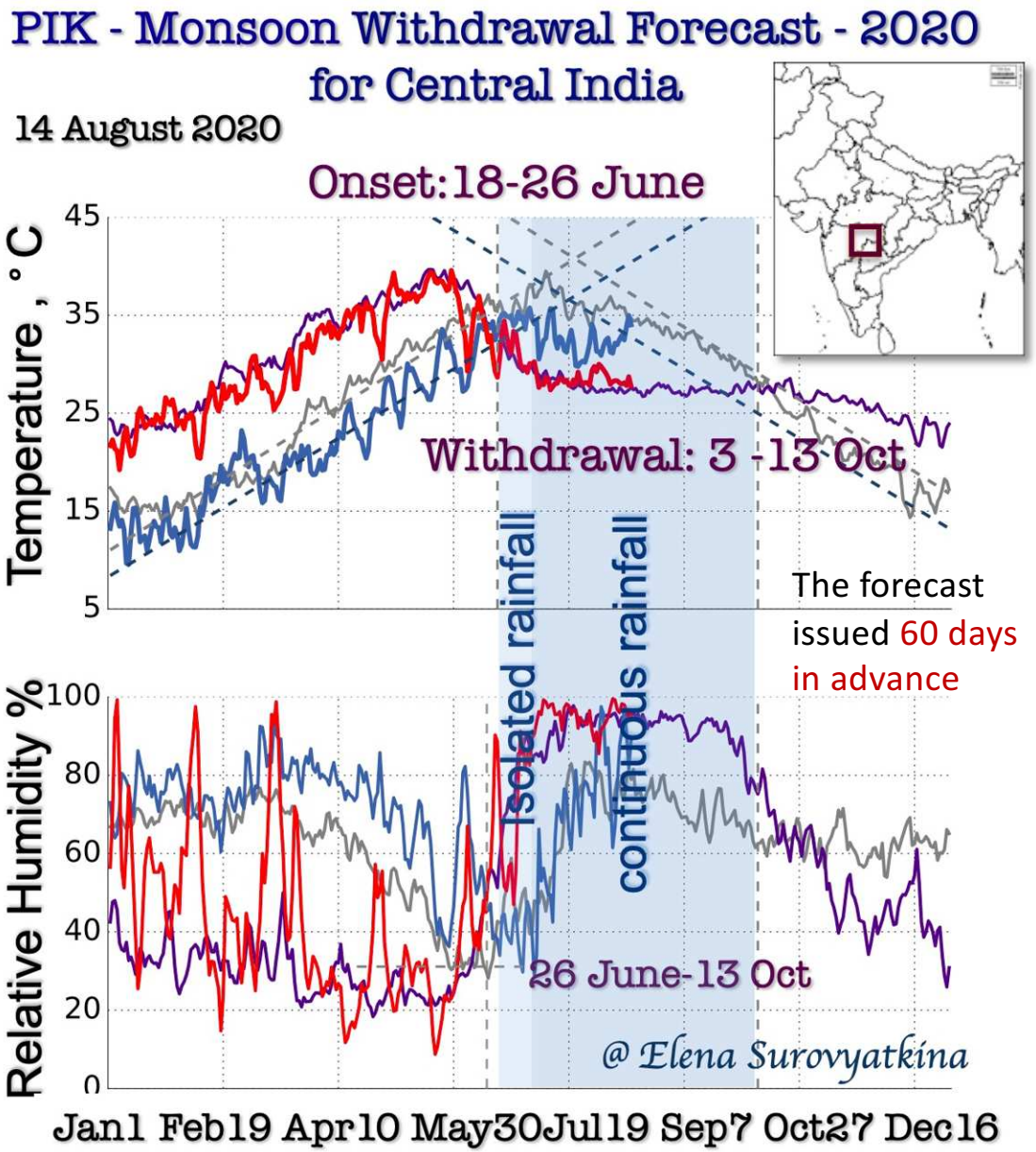
DATA: NCEP/NCAR reanalysis, 2.5°, near –surface air temperature, (1951-2015)


A:3 weeks before onset
B:1 week before onset
C: 1 day before onset
NP
EG
30°N
20°N
10°N
70°E
80°E
90°E
Variance of fluctuations of air temperature, σ_T^2
0
1
2
3
4
5
6
D: MONSOON FORECAST FOR CENTRAL INDIA – 2021
Onset Date: 21-29 June
Withdrawal Date: 31-10 Oct
Forecast issued: 40 days in advance
47 days in advance
21 - 29 June
31 - 10 Oct
T_{onset}
$T_{monsoon}$
EG
NP
Monsoon
Temperature , °C
Daily Precipitation, mm
45
35
25
15
5
160
120
80
40
0
Jan1
Feb 19
Apr 10
May 30
Jul 19
Sep 7
Oct 27
Dec16

3. How to predict a future monsoon?



Daily mean near-surface air temperature till **May 8, 2020**, 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 forecast issued 40 days in advance



Summer Monsoon 2020 in Central India began on the 26th of June.

The Indian Summer Monsoon (Southwest Monsoon) is likely to withdraw from the Central part of India (20N, 80E) between 3rd and 13th of October 2020.

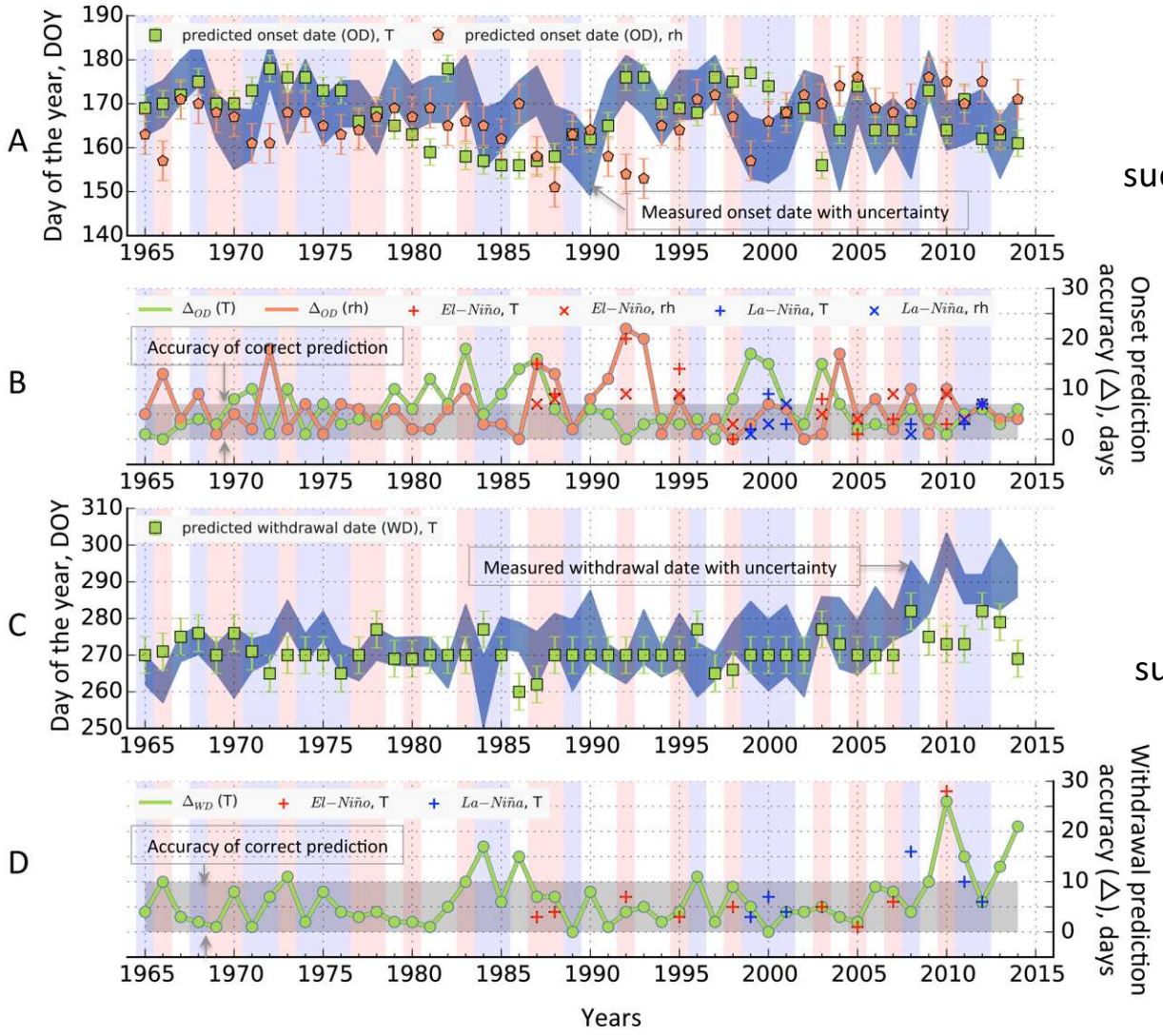
Temperature anomaly in North Pakistan shrinks the duration of the monsoon season.

Nevertheless, after the monsoon withdrawal date in October, others post-monsoon rainfalls might appear over the central & northwest India.

Performance of prediction scheme

ONSET

WITHDRAWAL



74% of success rate

84% of success rate

INDIAN SUMMER MONSOON FORECASTS (Central India, Eastern Ghats)

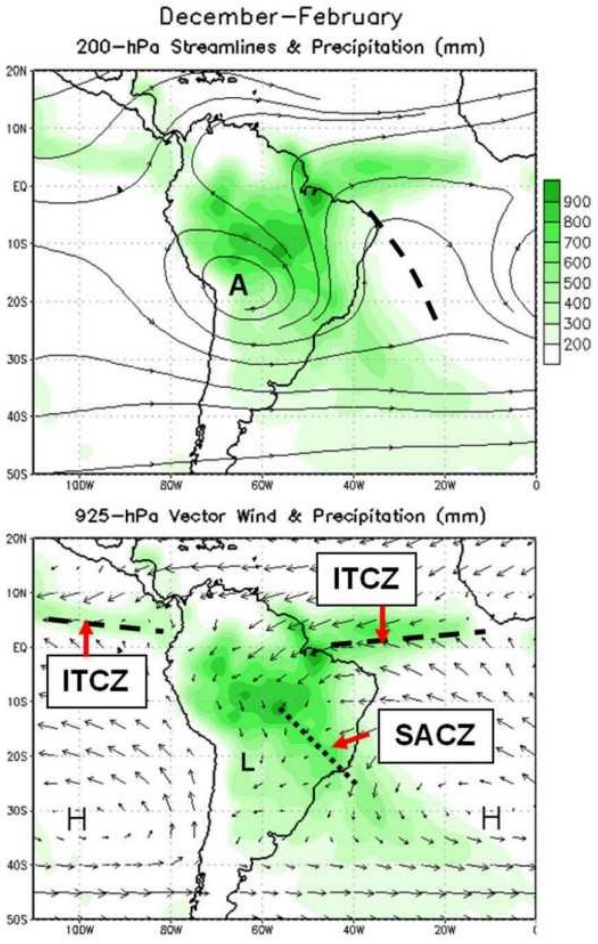
	ONSET OF MONSOON		WITHDRAWAL OF MONSOON	
Year	FORECAST 40 DAYS IN ADVANCE	OBSERVATION	FORECAST 70 DAYS IN ADVANCE	OBSERVATION
2016	9-17 June	17 June	1-10 October	10-12 October
2017	14-22 June	16-18 June	7-17 October	15-16 October
2018	11-19 June	9-19 June	13-23 October	18-21 October
2019	10-18 June	18-19 June	14-24 October	14-24 October
2020	18-26 June	26 June	3-13 October	7-13 October
2021	21-29 June	29 June	31-10 October	8-10 October

https://www.pik-potsdam.de/en/output/infodesk/forecasting-indian-monsoon/welcome-to-the-pik-monsoon-page-1

The South American Monsoon

The development of the South American Monsoon

The development of the South American warm season Monsoon System during the austral spring is **characterized by a rapid southward shift of the region of intense convection** from northwestern South America to the southern Amazon Basin and Brazilian highlands (Altiplano) (Kousky, 1988; Horel et al., 1989; Marengo et al., 2001, Liebmann & Marengo, 2001, Nogués-Paegle et al. 2002).



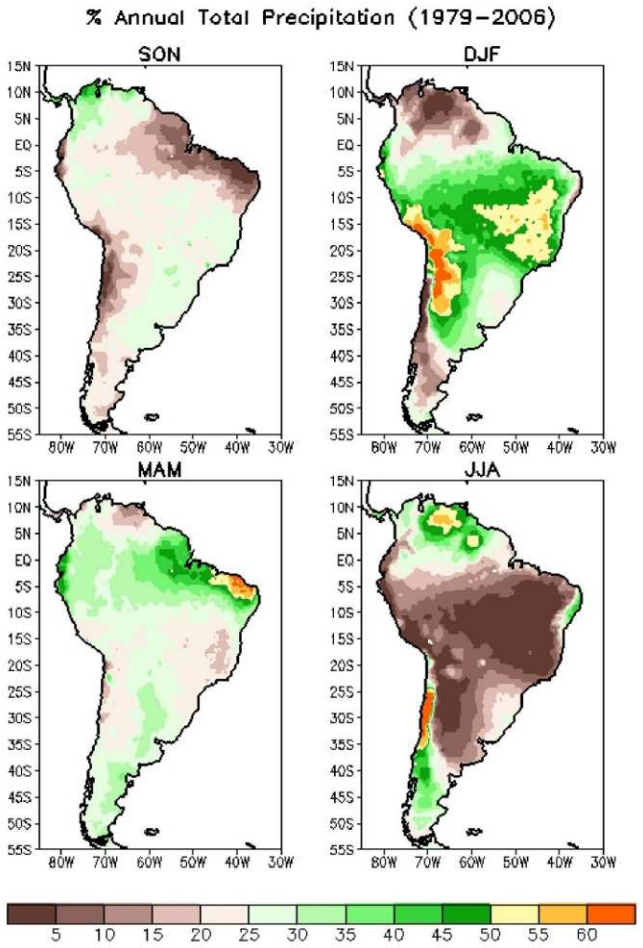


Fig. 5. Percent of observed mean (1979-2006) annual precipitation for each season.

Vernon E. Kousky,; Viviane B. S. Silva,. The South American Monsoon System: Climatology and Variability. INTECH Open Access Publisher, 2012. Edition/Format: eBook

South American monsoon indices

”Several studies have been made to define the onset and demise dates of monsoon systems, e.g. Fasullo and Webster (2003) for the Indian monsoon and Gan et al. (2004) and Wang and Fu (2002) for the South American monsoon. Kousky (1988), Liebmann and Marengo (2001) and Marengo et al. (2001) used either **outgoing long wave radiation** (OLR) or **precipitation data to define the onset of rainy season** over South America. In these studies, different criteria, mostly based on rainfall or OLR, were used to identify the monsoon onset and demise dates over differen monsoon regions. However, monsoon indices based on wind changes are important because the skill of the climatic models to predict **the wind components** is better than to predict the precipitation” [Gan et al, 2006]

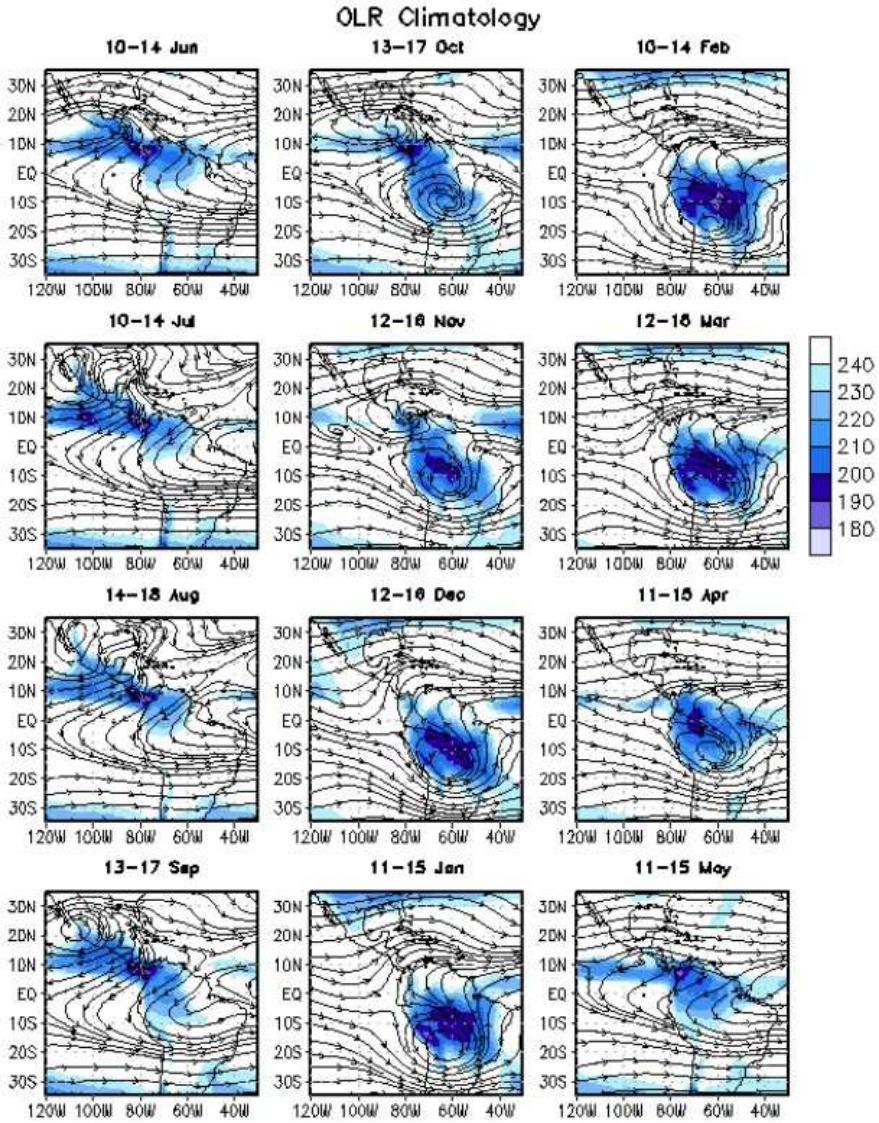


Fig. 8. Mean (1979-1995) seasonal cycle of OLR and 200-hPa streamlines. Units for OLR are W m-2. Low values of OLR indicate cold cloud tops (deep convection) in the Tropics.

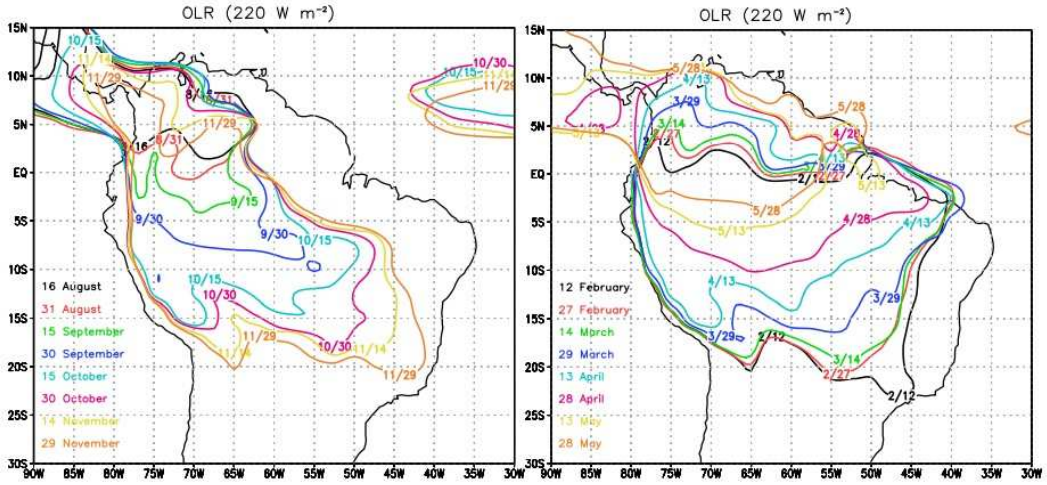


Fig. 10. Time onset and end dates for the wet season in the monsoon core region (Central Brazil) based on OLR less than 220 W m-2.

Kousky (1988)

Vernon E. Kousky,; Viviane B. S. Silva,. The South American Monsoon System: Climatology and Variability. INTECH Open Access Publisher, 2012. Edition/Format: eBook

Climate change impacts on heat stress in Brazil

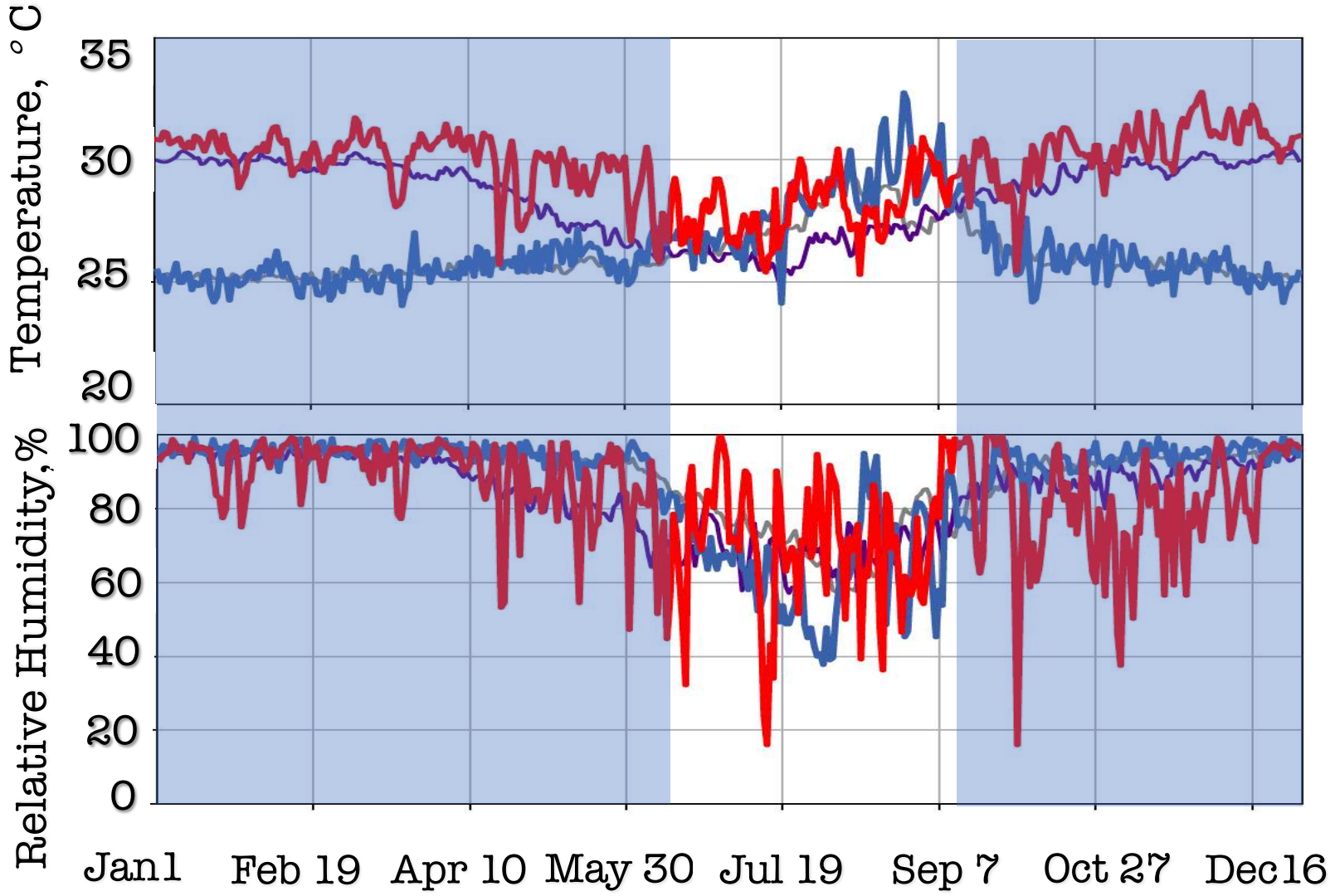
“Climate change has caused an increased occurrence of heat waves. As a result of rising temperatures, implications for health and the environment have been more frequently reported. Outdoor labour activities deserve special attention, as is the case with agricultural and construction workers exposed to extreme weather conditions, including intense heat”.

Daniel Pires Bitencourt, Lincoln Muniz Alves, Elisa Kayo Shibuya, Irlon de Angelo da Cunha, Joao Paulo Estevam de Souza. International Journal of Climatology, 2021/1

Tipping Elements approach forecasting the South American Monsoon

Preliminary estimations

South American Monsoon, Brazil,2017



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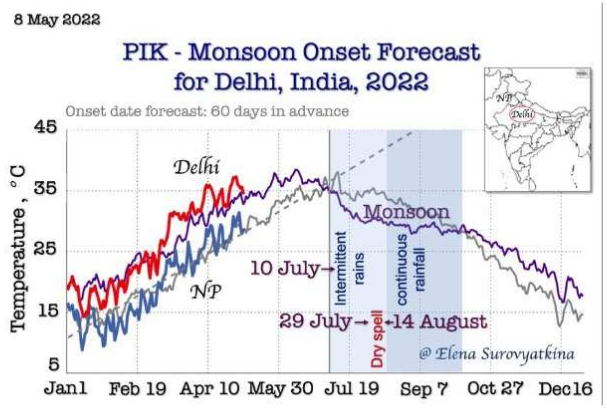
HOME › OUTPUT › INFO DESK

Welcome to the PIK monsoon page!

Menu

This web page provides a long-term forecast of the onset and withdrawal of the Indian Summer Monsoon (the Southwest Monsoon) in the central part of India and the Msimu rains in southern Tanzania. 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 Tipping Elements of Monsoon. The forecasts are performed by Elena Surovyatkina.

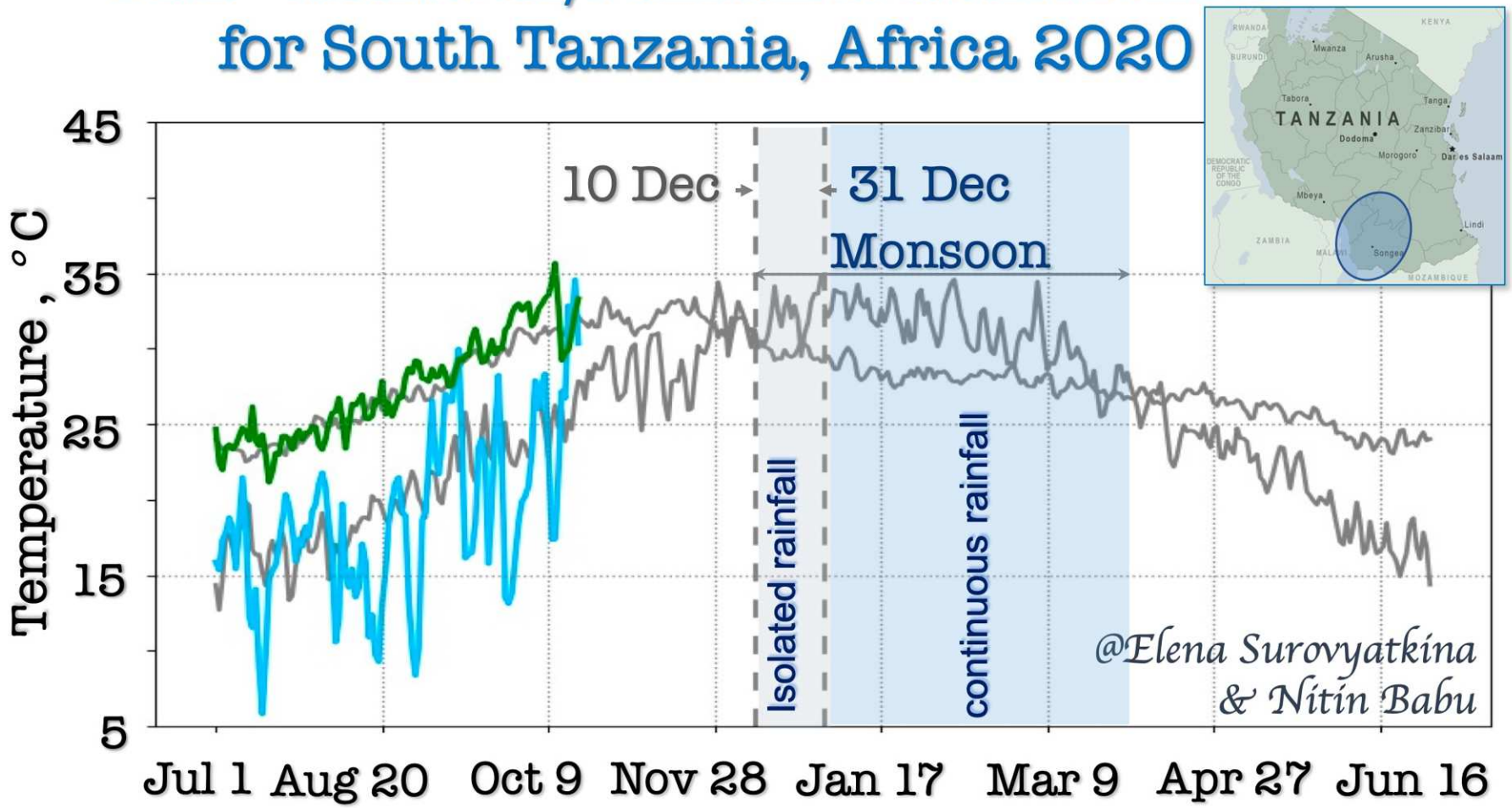


Daily mean near-surface air temperature till May 5 ,2022 for Delhi and North Pakistan (NP). Violet and grey lines are past 5-years average for the same regions. The vertical line indicates the beginning of monsoon season.

https://www.pik-potsdam.de/en/output/infodesk/forecasting-indian-monsoon/welcome-to-the-pik-monsoon-page-1

20 October 2020

PIK – Monsoon/rainfall season monitor for South Tanzania, Africa 2020

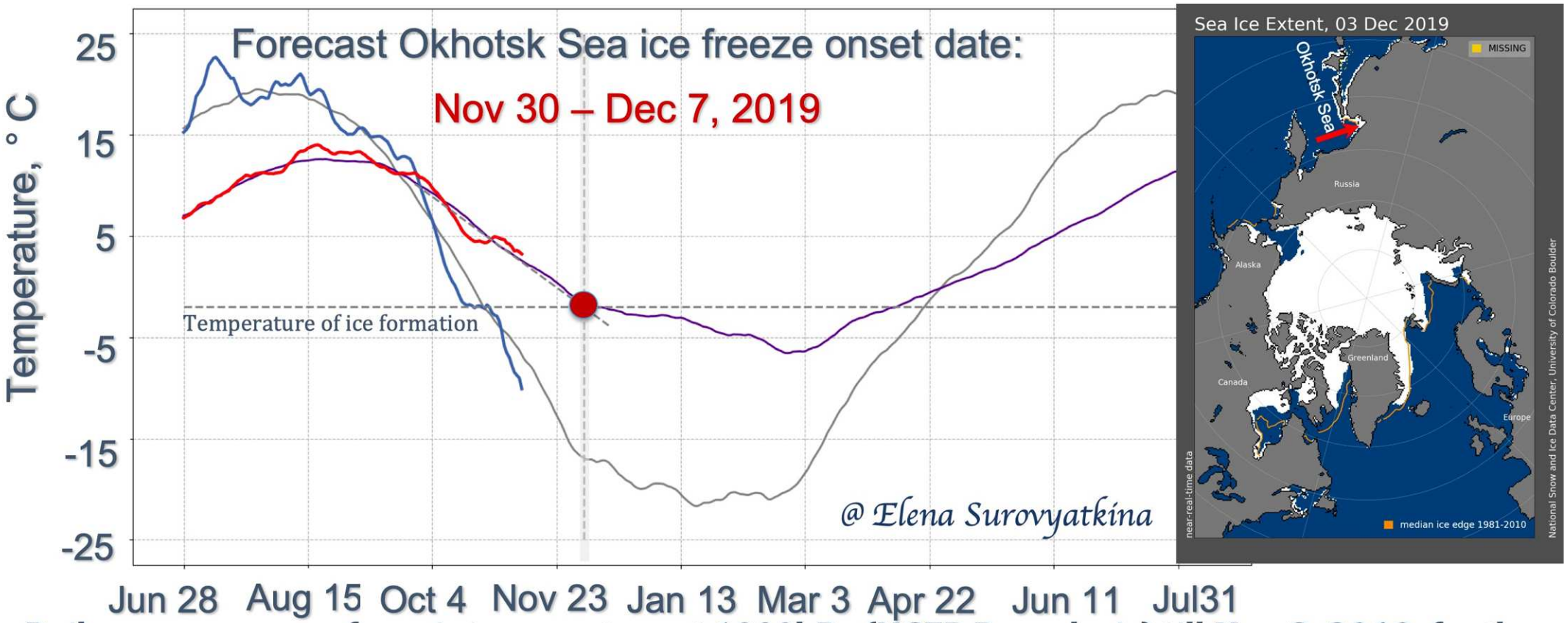


https://www.pik-potsdam.de/en/output/infodesk/forecasting-indian-monsoon

Forecasting scheme of sea ice advance date

Abstract ID: 20073

Evidence from observations



Daily mean near-surface air temperature at 1000hPa (NCEP Reanalysis) till **Nov 8, 2019** for the western (red) and eastern parts (blue). Violet and gray lines - past 19-years average for same regions. The tipping point (red) indicates the critical temperature and the forecasted onset date.

Current Progress:

I offer the following forecasts both
in North and South hemispheres:

- in India: summer monsoon in Central India and Telangana state;
- in Africa: a rainfall season in Tanzania
- in Russia and Japan Sea Ice Season in the Sea of Okhotsk.

Possible Extensions:

- Eurasia: South Asia, South China, Japan, the Arctic Circle;
- Africa: Ethiopia, Congo;
- South and North America.

Conclusion

The new methodology offers the following advances:

1. Predicting the date of the upcoming monsoon onset for 40 days in advance, that is unprecedently early.
2. Forecasting withdrawal date for 70 days in advance, and it is the only one available withdrawal forecast in India.
3. The applicability of the methodology is not limited by specific location; it works for different parts of India, Africa and South America.

The six years tests (2016-2021) show successful results.

References

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Thanks my co-authors

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