Large-scale assessment of climate suitability for wheat blast in Asia

Carlo Montes

Agricultural Climatologist
Sustainable Intensification Program
International Maize and Wheat Improvement Center (CIMMYT)
Mexico

CIMMYT[MR]
International Maize and Wheat Improvement Center

CGIAR

Outline

1) Motivation

2) Objectives, methods and data used

3) Results
   - Spatial and interannual patterns
   - Drivers of interannual variability
   - Uncertainties and limitations

4) Concluding remarks

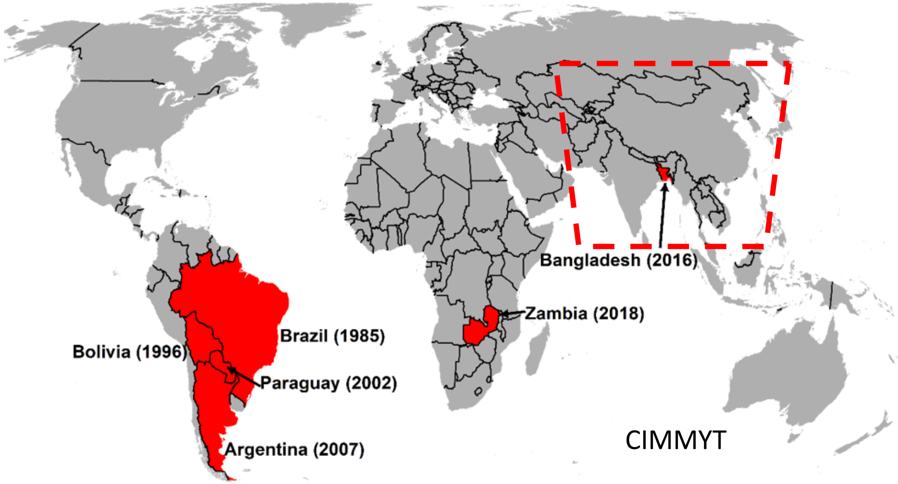
Motivation

Wheat blast today

- *Magnaporthe oryzae Triticum* (MoT)
- Spike infection during heading stage
- Partial to total grain loss (e.g. up to 90%)

Serious threat for food security in developing countries

Spread pattern?

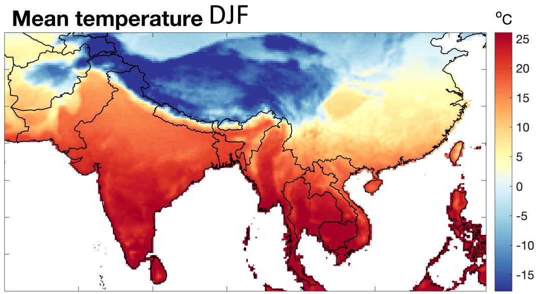


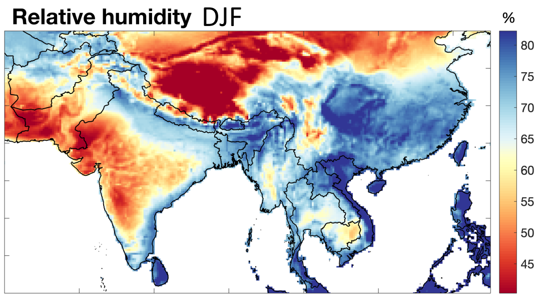
- South America 1985 (3M ha)
- Bangladesh 2016 (15,000 ha)
- Zambia 2018

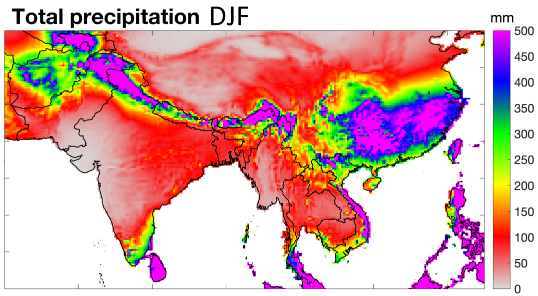
Cultural versus biophysical factors

Motivation

A big picture…



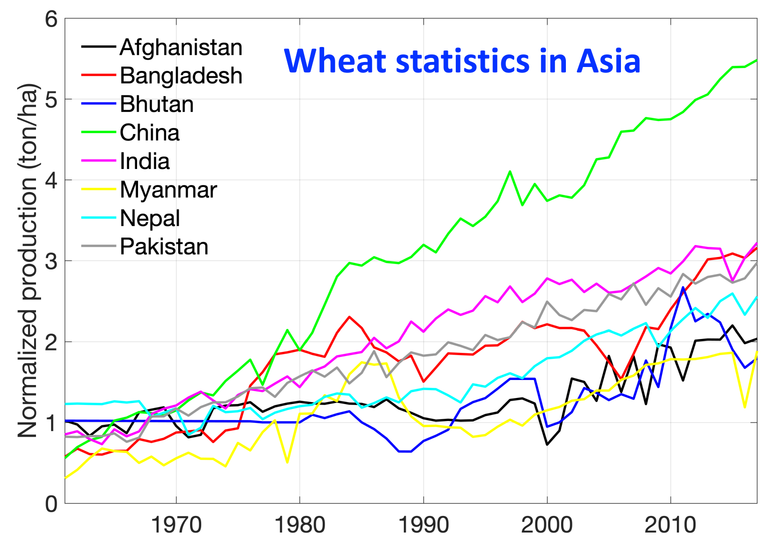




Climate (weather) a major driver of fungal diseases

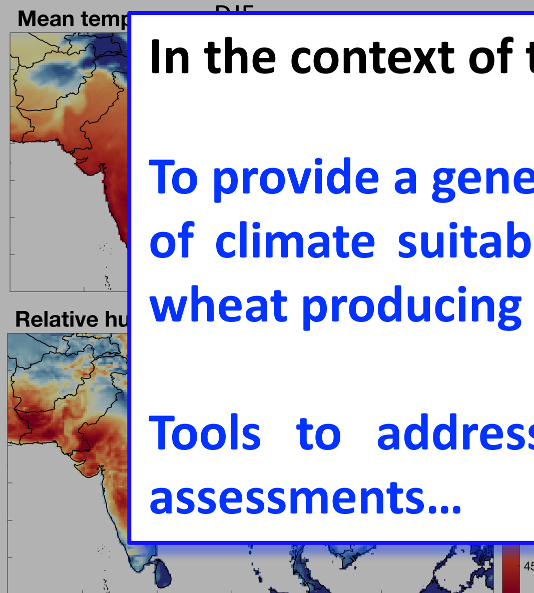
How suitable are ***background*** conditions?

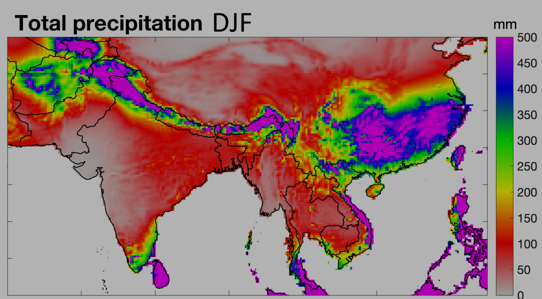
Increasing wheat yields and production



Motivation

A big picture…

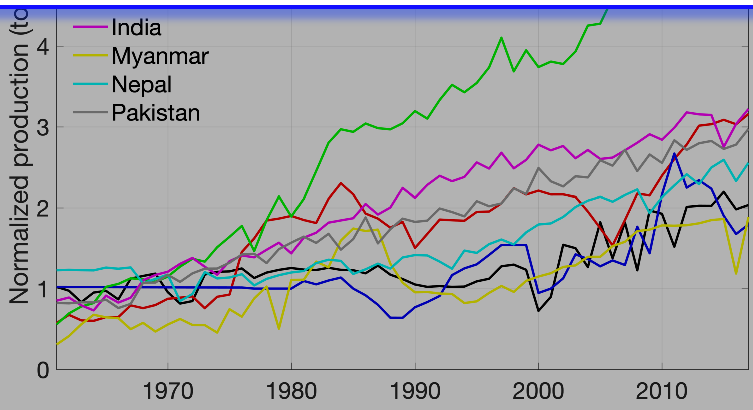




In the context of the development of climate information servives:

To provide a general overview of the spatial and temporal variability of climate suitability for the development of wheat blast in asian wheat producing countries

Tools to address potential threat, research prioritization, risks assessments…



Approach

- Generic infection model
- Wheat phenology model
- Climate forcing data
- Boundary conditions data

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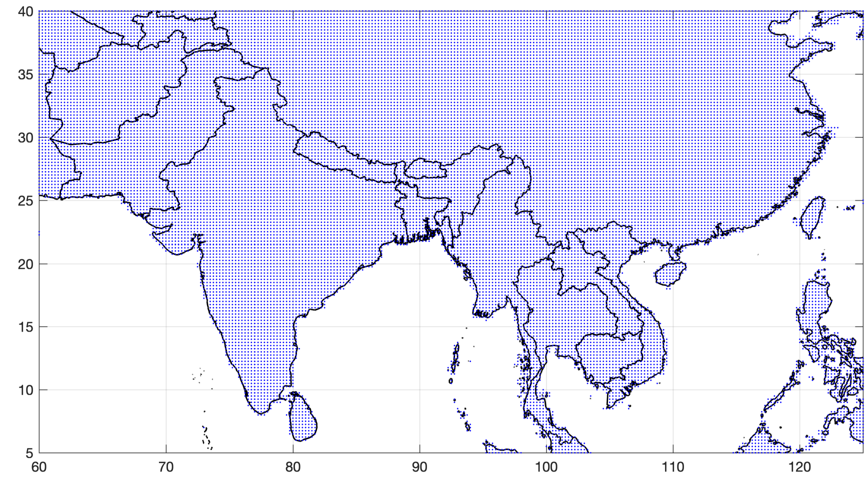
Seasonal (heading stage) number of potential wheat blast infections (NPI)

Analysis: variability and drivers

Grid 31 km x 31 km

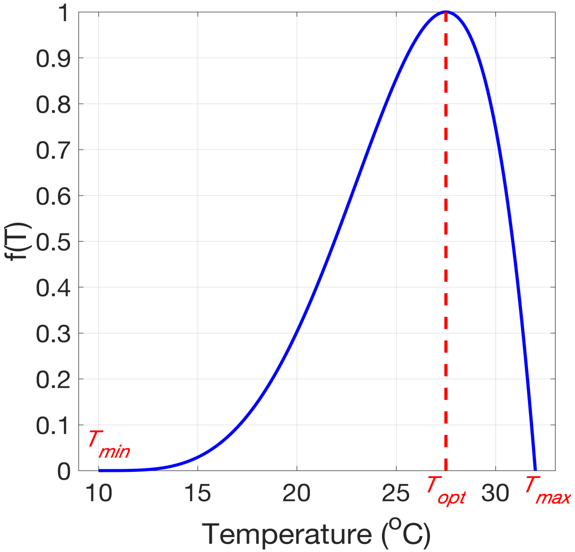


Infection model

Generic fungal infection model* of potential wheat blast outbreaks

- **Temperature** response function

$$f(T) = \left(\frac{T_{max} - T}{T_{max} - T_{opt}}\right)\left(\frac{T - T_{min}}{T_{opt} - T_{min}}\right)^{(T_{opt} - T_{min})/(T_{max} - T_{opt})}$$



- *f*(T) scaled to **wetness duration** requirements *W*(T)

$$W(T) = \begin{cases} \dfrac{WD_{min}}{f(T)}, if \ \dfrac{WD_{min}}{f(T)} < WD_{max} \\ 0, \ \ elsewhere \end{cases}$$

- Impact of critical **dry periods** (*D*50)

$$W_{sum} = \begin{cases} W_1 + W_2, & if \ D \leq D50 \\ W_1, W_2, & elsewhere \end{cases}$$

W_{sum}: sum of the wetting periods

***D*50**: duration of a dry period with relative humidity < 95% that will result in a 50% reduction in disease compared with a continuous wetness period

RH > 95%, *f*(T) > 0 → infection event

*Magarey *et al*. 2005

Phenology model

Heading stage timing and duration: Wang and Engel (1998) model

Wheat phenology using only air temperature as forcing variable

- **Emergence day**: constant thermal time of 125 GDD after sowing date
- **Phenology** calculated as daily developmental rate for vegetative and reproductive phases

Response functions for **temperature** (*T*), **photoperiod** (*p*) and **vernalization** (*v*)

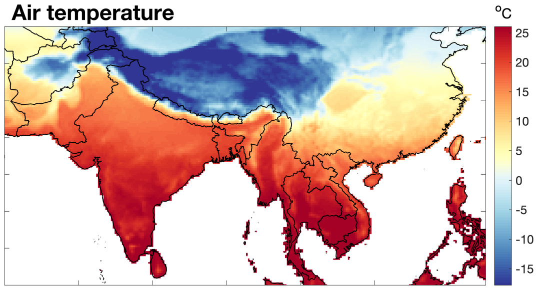
$$R_v = R_{max,v} f(T) f(P) f(v)$$ $\Rightarrow$ Winter wheat varieties

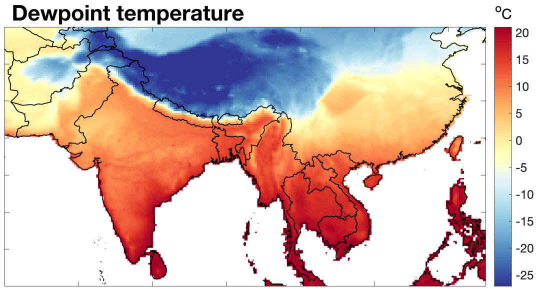
$$R_v = R_{max,v} f(T) f(P)$$ $\Rightarrow$ Spring wheat varieties

Data used: model forcing

ERA5 atmospheric reanalysis: hourly forcing, 1980 through 2019

- European Center for Medium Range Weather Forecasting (ECMWF)
- 31 km x 31 km spatial resolution, 137 vertical levels
- 4D-Var data assimilation scheme to combine climate model outputs and multiple observations sources



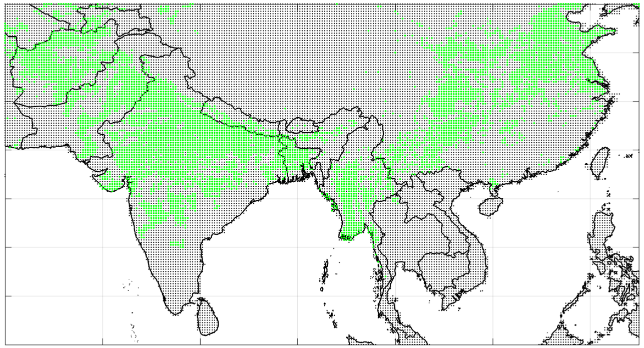


Air and dewpoint temperature for infection model

Air temperature for phenology model

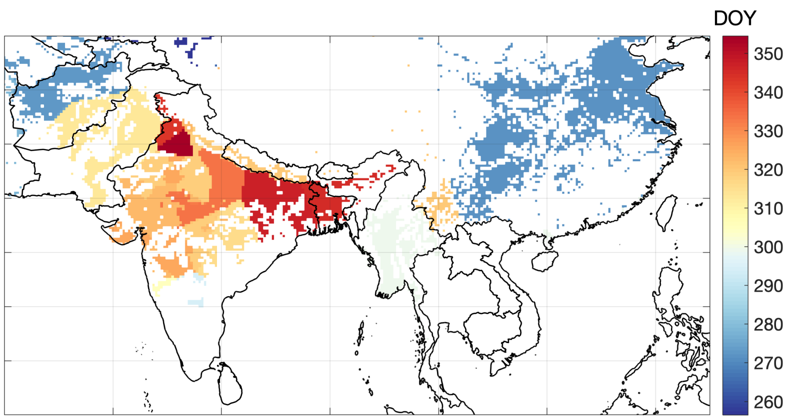
Data used: boundary conditions

Spatial Production Allocation Model SPAM 2010 v1.0 global data

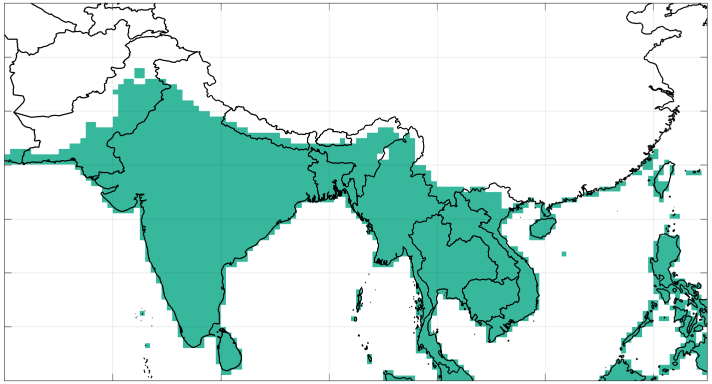


⇨ Wheat production to wheat grid presence

Crop Calendar Dataset of Sacks *et al*. (2010)

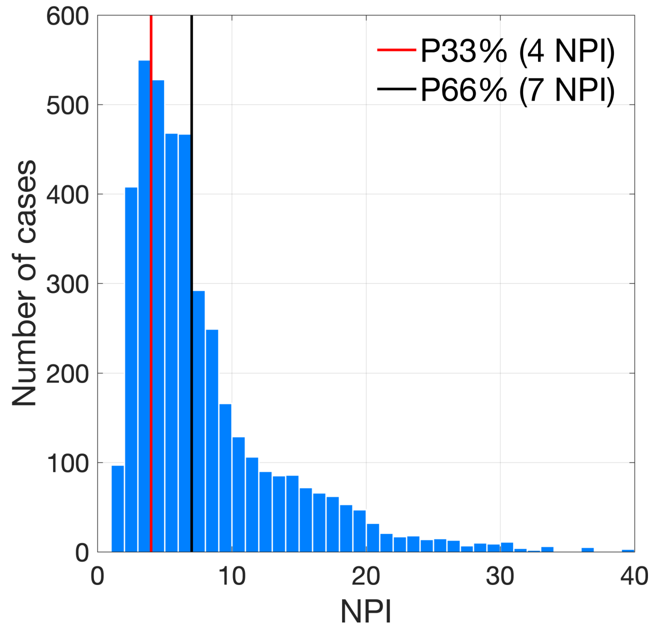


Spring wheat derived from Iizumi *et al*. (2019)
Probabilities of winter wheat = 0

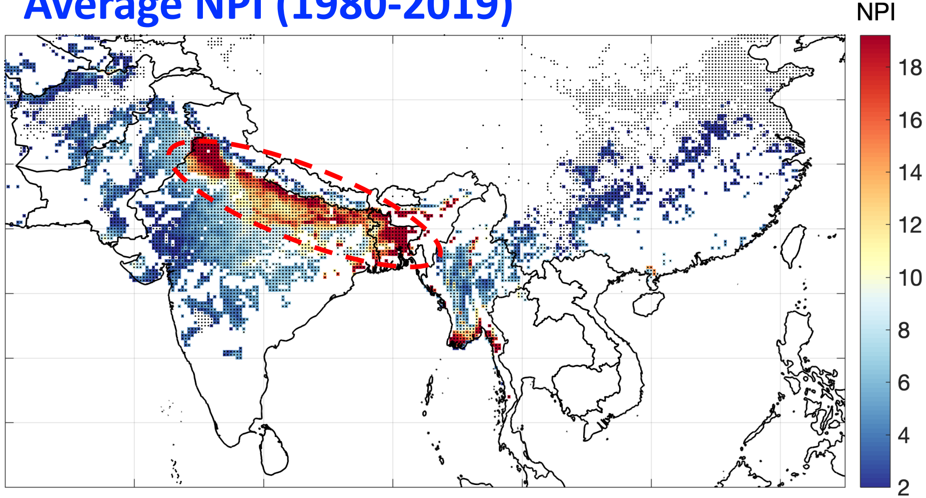


Results: climatology of NPI

- From *low* to *high* pressure
- Range 1 (min) to 55 (max) NPI
- High spatial variability
- Hotspots of climate suitability



Average NPI (1980-2019)

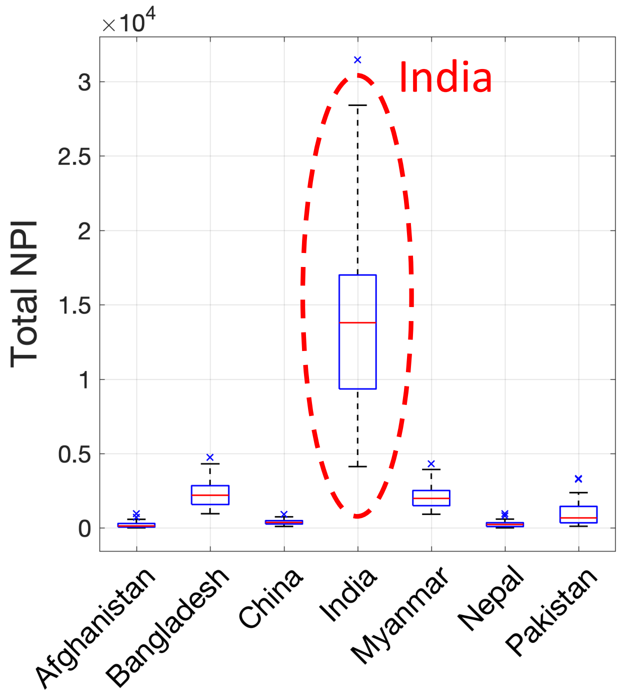


- Indian *breadbasket* Indo Gangetic Plains
- Bangladesh

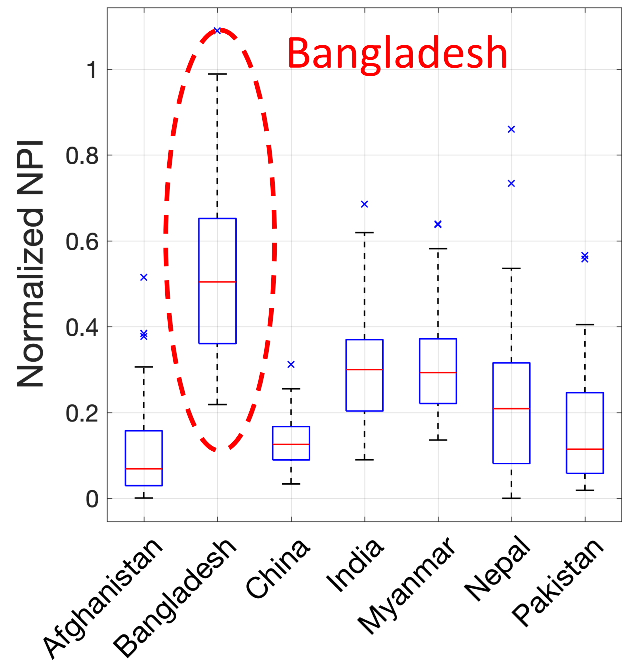
Results: climatology of NPI

Interannual variability by country

Total annual number of NPI by country

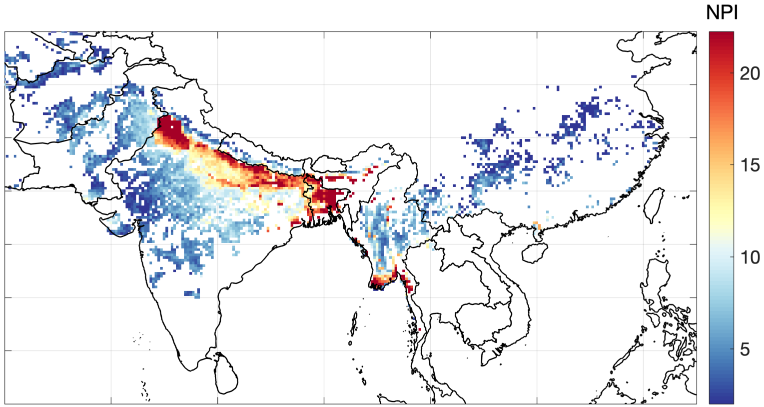


Normalized by area of the country



Results: the relationship with climate anomalies

Percentile 66% of NPI



- Association with temperature not very clear
- Relative humidity: positive anomalies
- Precipitation: dry season

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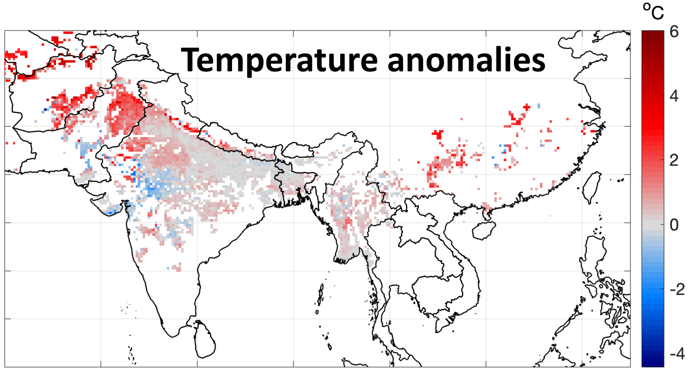
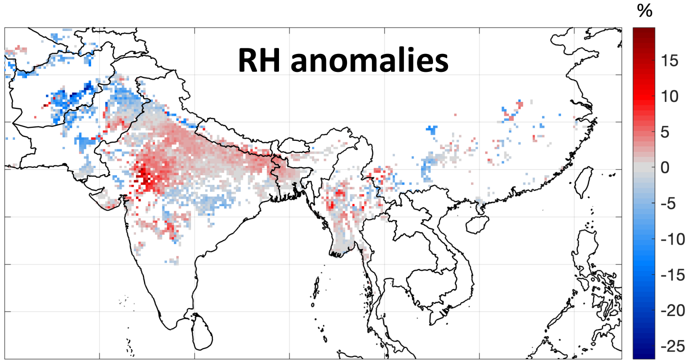
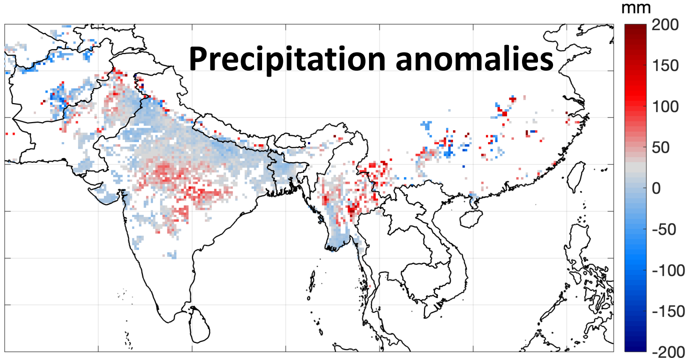
- Temperature response function (non linear)
- Air water content

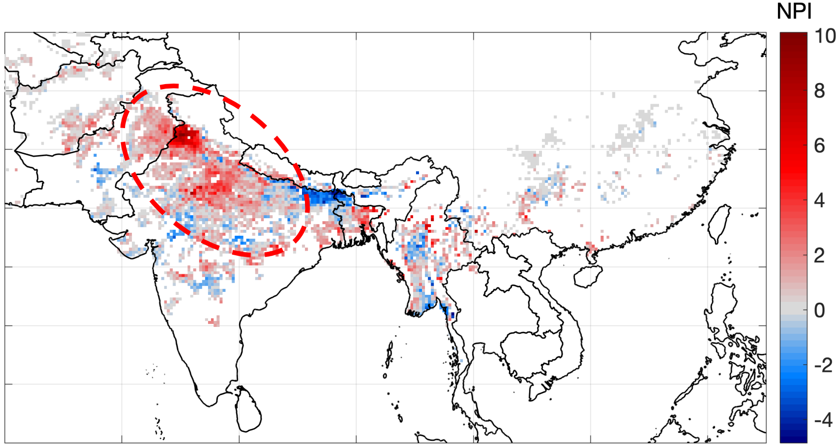






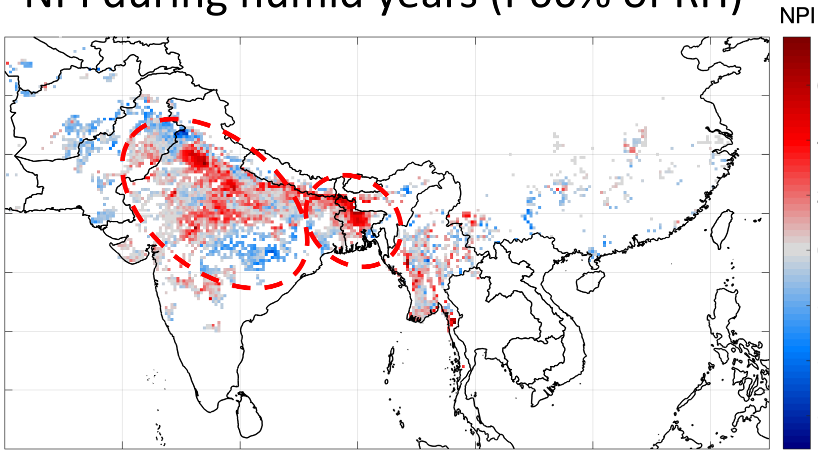
Results: the relationship with climate anomalies

NPI during warm years (P66% of temperature)



Large area in India and Bangladesh with positive anomalies in NPI

NPI during humid years (P66% of RH)

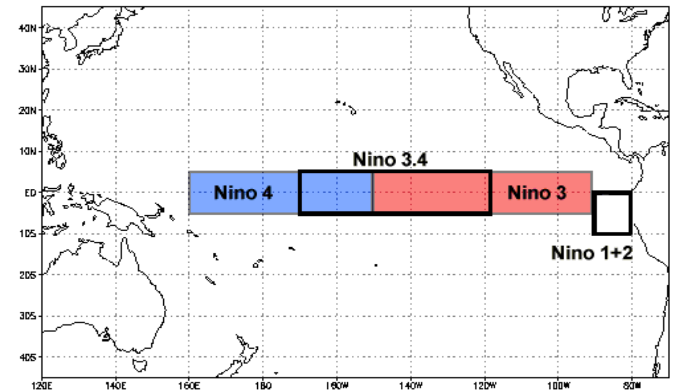


Associated dynamical factors?

Results: the relationship with global drivers

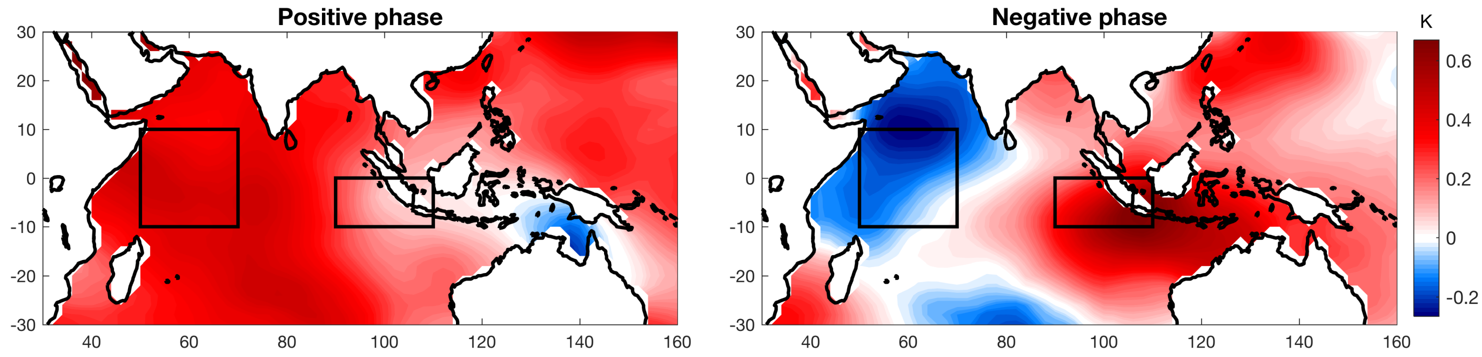
El Niño - Southern Oscillation (ENSO)

Periodic **fluctuation** in **sea surface temperature** (El Niño) and **atmospheric pressure** (Southern Oscillation) across the **equatorial Pacific Ocean**



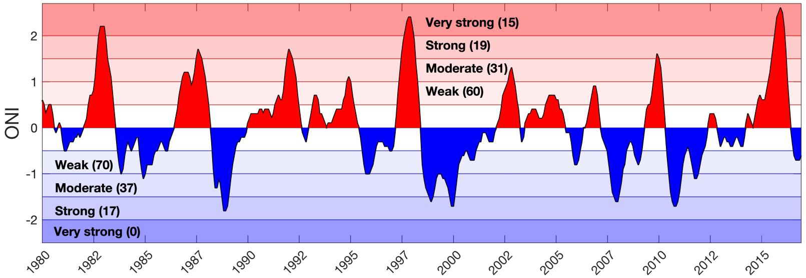
The Indian Ocean Dipole (IOD)

Anomalous **SST gradient** between **western** equatorial and **south eastern** equatorial Indian Ocean

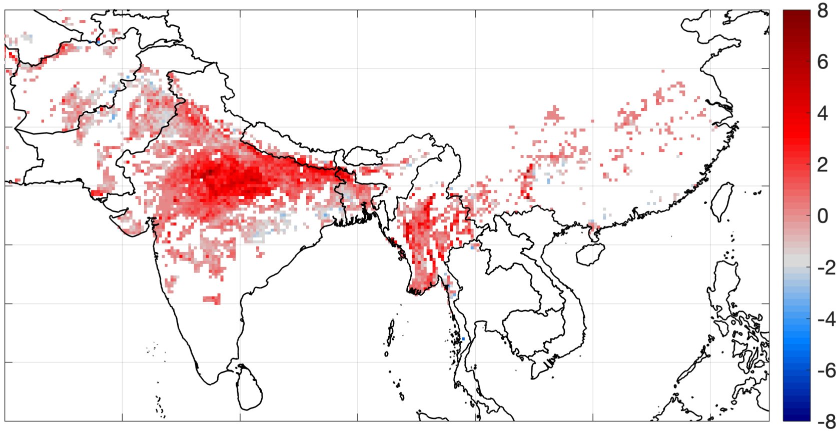


Results: the relationship with global drivers

Oceanic ENSO index (ONI)

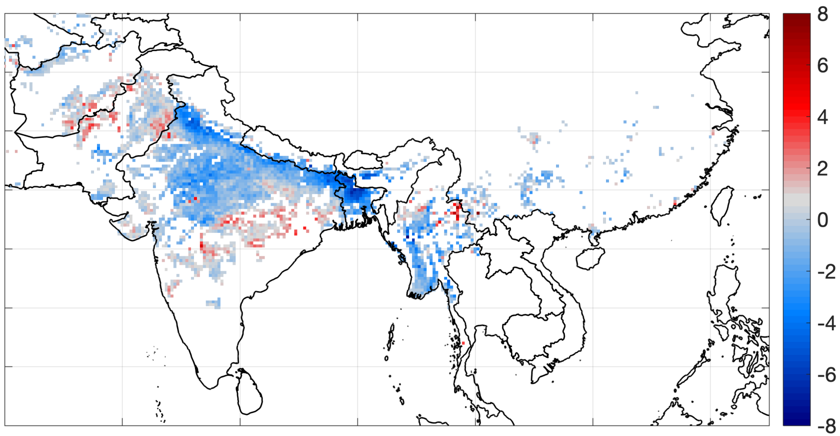


El Niño years



(+) anomalies in NPI

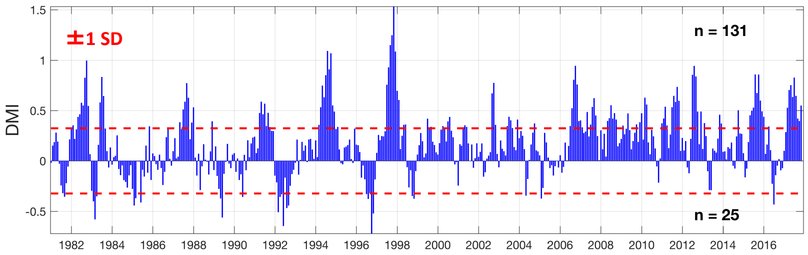
La Niña years



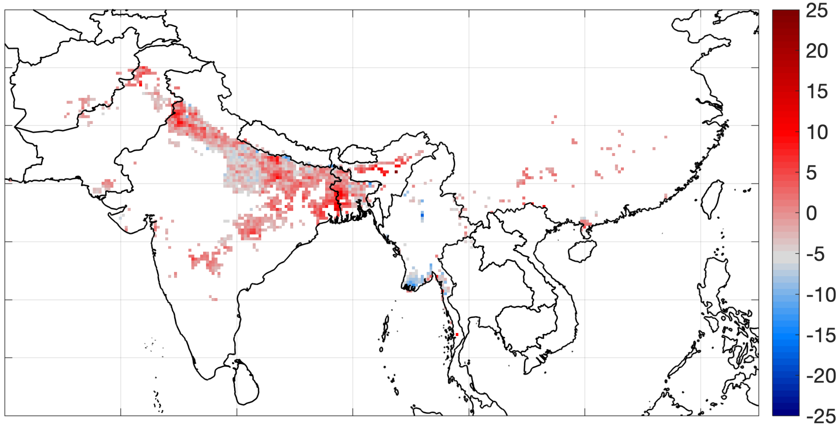
(–) anomalies in NPI

Results: the relationship with global drivers

Dipole Mode Index (DMI)

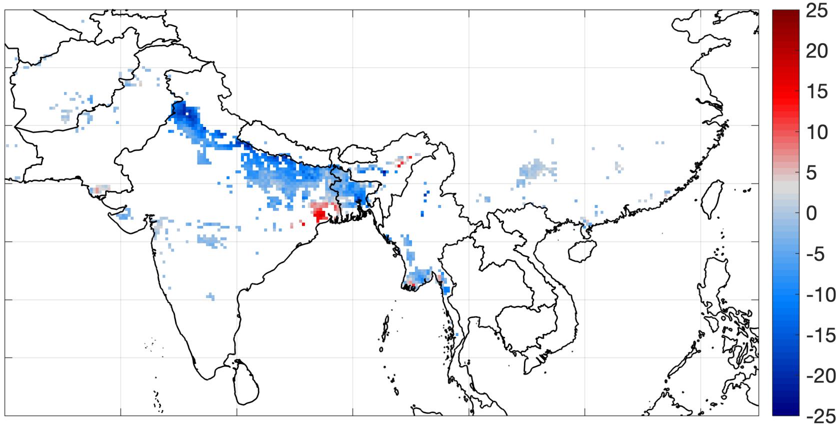


Positive years



(+) anomalies in NPI

Negative years



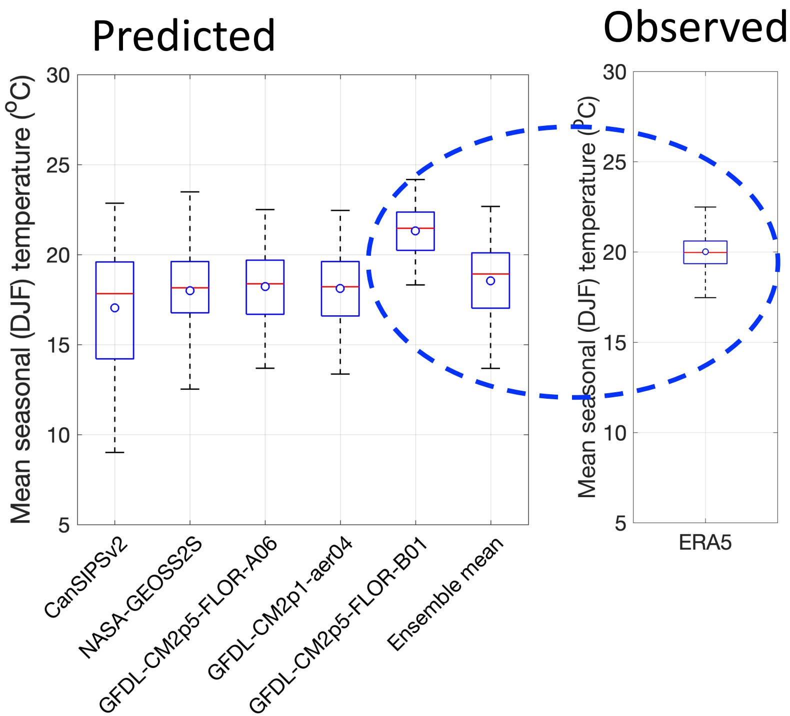
(–) anomalies in NPI

Results: potential seasonal predictability

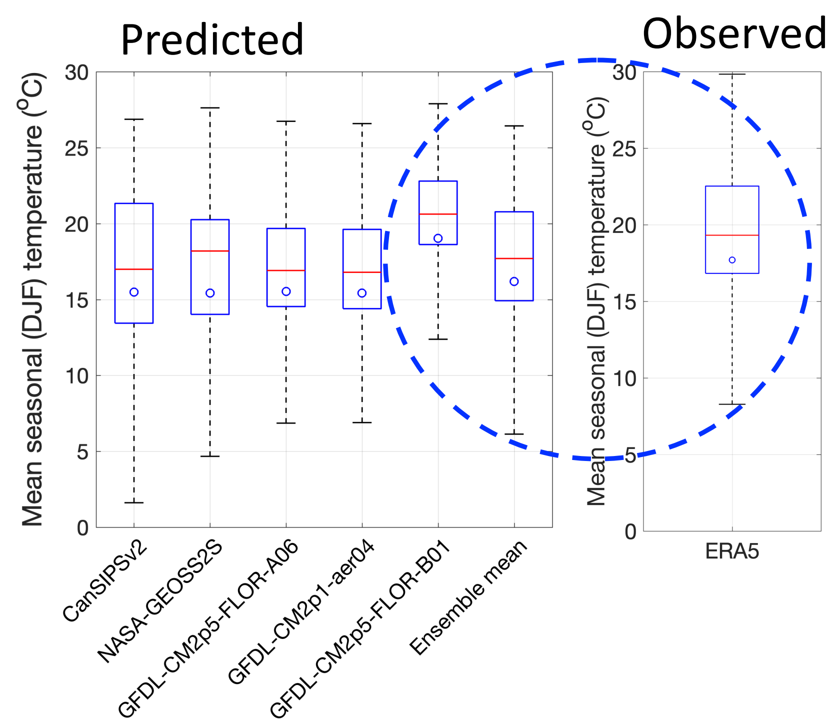
Can the *background* seasonal conditions be predicted?

North American Multi-Model Ensemble **NMME** hindcasts (1982-2016): 5 opeational models

Bangladesh, mean DJF temperature



India, mean DJF temperature



Uncertainties and limitations

Some relevant parameters not easy to measure or not available in the literature

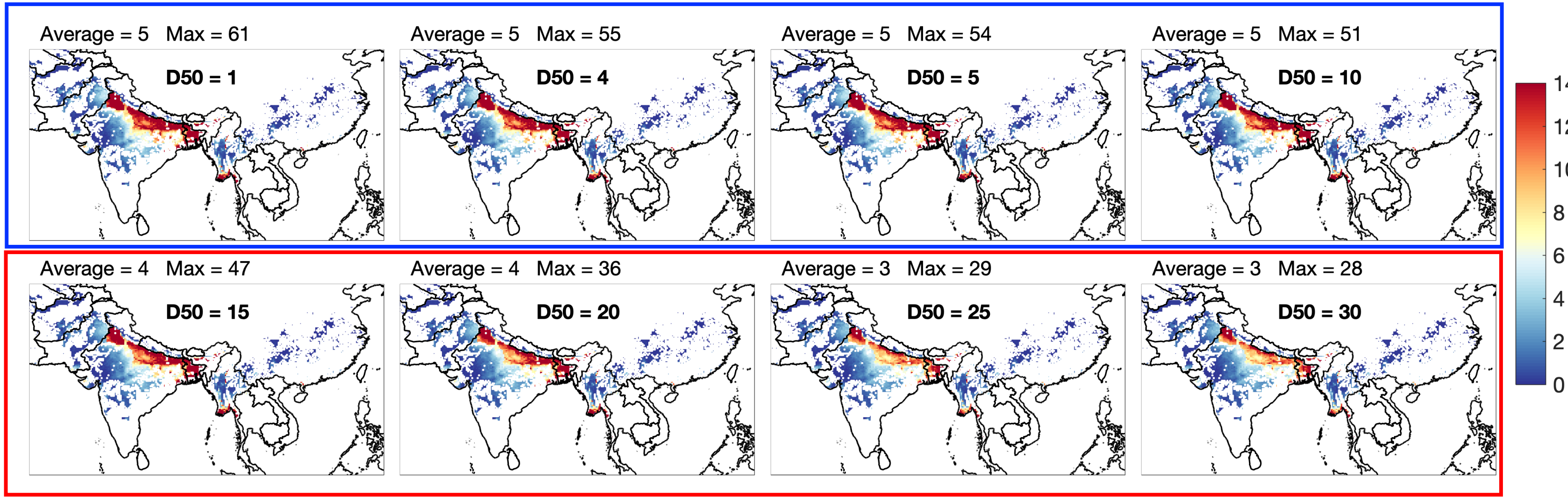
D50: duration of a dry period that will result in a 50% reduction in infections

Sensitivity to dry interruption: **Sensitive: 1-2 h** **Moderate: 4-20h** **Insensitive: >= 24 h**

D50 = 1 to 10-15

Reliable range of values?

D50 = 15 to 30



Uncertainties and limitations

Other sources of uncertainties:

- Other parameters for infection model
  - Sensitivity analysis
- Parameters for phenological model
  - Large domain, high uncertainty
  - Most parameters generated for other latitudes
- Fixed planting dates

Conclusions

- High **spatial and temporal variability** in climate suitability for wheat blast
- **Hotspots** concentrate in India and Bangladesh
- High interannual variability: variable suitable conditions
- Clear relationship with **ENSO and IOD anomalies**
- **ENSO** influences NPI anomalies over an area larger than IOD
- NPI anomalies associated with **IOD** phases are stronger
- Potential seasonal **prediction** of favorable conditions
    - Bias correction of GCMs (NMME)
    - Empirical statistical forecasting of NPI using SST indices

Thank you

Carlo Montes

c.montes@cgiar.org