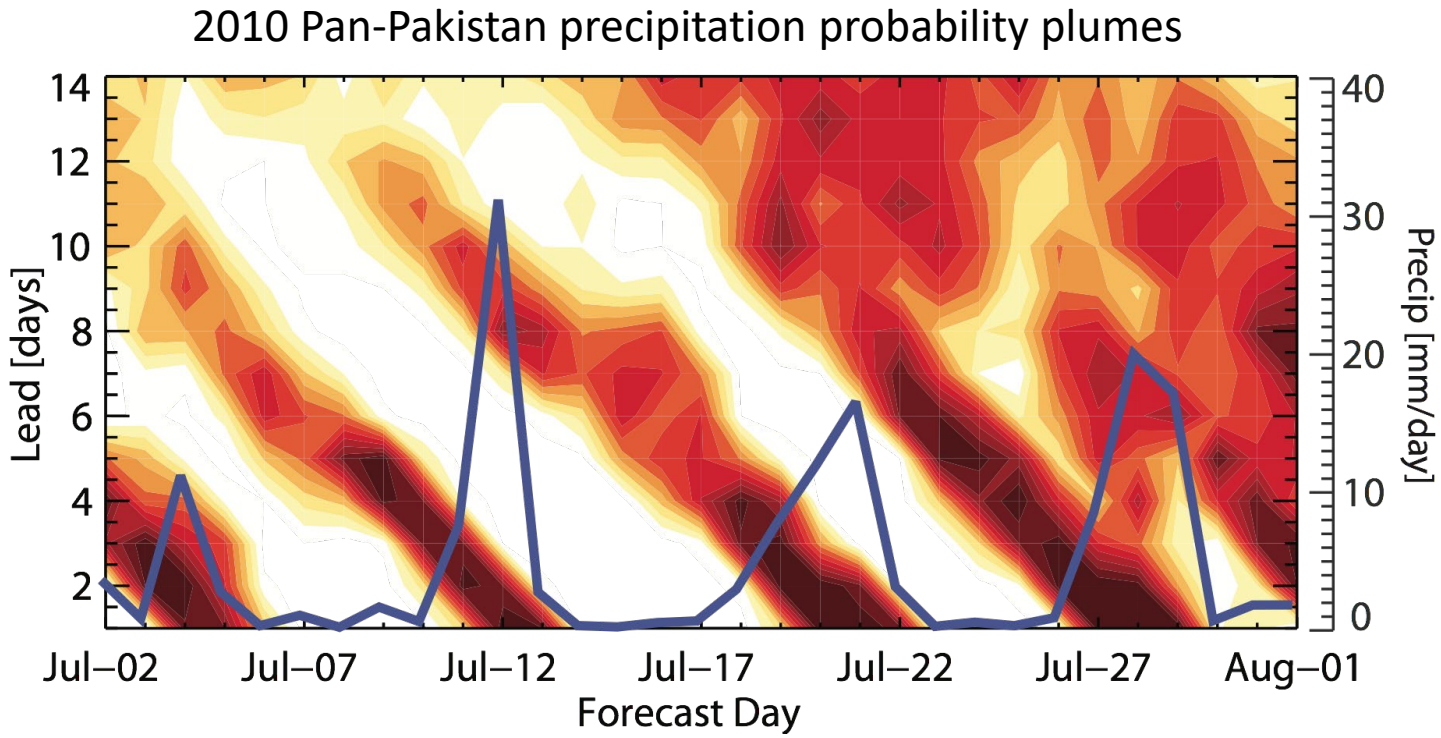
From Hazard Anticipation & Mitigation to Increasing Food Security: Utilizing Ensemble Forecasts in a Changing World



- Overview:
  (1) Utility of ensemble forecasts, especially in the developing world
  (2) Communication of Probabilistic Forecasts: Are they useful?

- Problems of poverty and food Insecurity in a changing world
  (1) United Nations sustainability list
  (2) The rain-fed farming issue
  (3) Building a “staircase of sustainability” to accommodate the impacts of climate change

30 Years of Ensemble Forecasting & the Tim Palmer Symposium

- In the early 1990s, Tim Palmer invited me to spend a year's sabbatical to spend with his group at ECMWF.

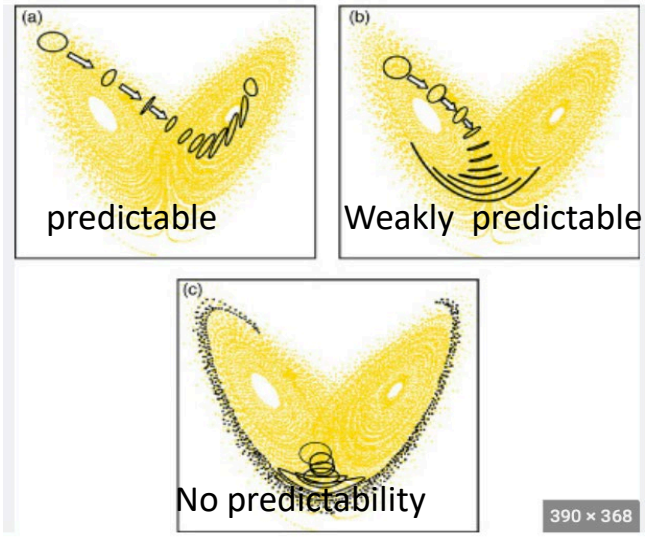
  A sabbatical definition: *".....But in the seventh year shall be a sabbath of rest unto the land, a sabbath for the Lord: thou shalt neither sow thy field, nor prune thy vineyard....."*

- Despite the biblical origins of the word "sabbatical" my sabbatical far from a fallow year and a lot of personal weeding, pruning and replanting took place.
- It was an exciting, invigorating and productive year working with Tim's group and turned out to be instrumental in setting personal goals for the next 3 decades in which we have collectively (maybe) done a little good.
- So, thanks to Tim, and ECMWF, and to Prof. Brian Hoskins at University of Reading for making me welcome.

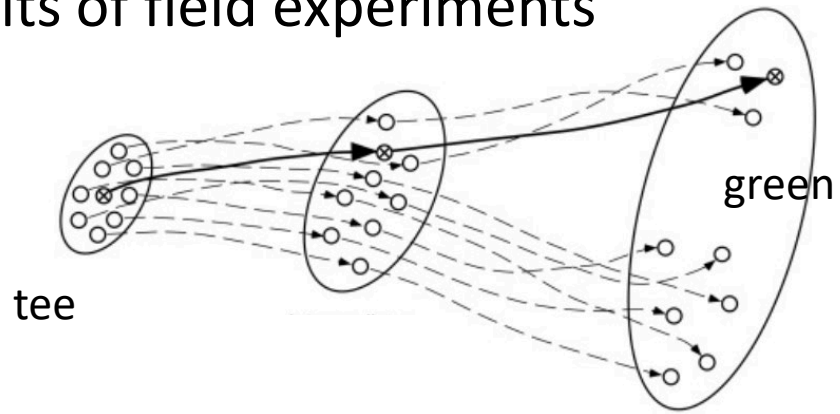
The sabbatical year was also a time for family and the development of friendships

- My sabbatical also involved considerable field work in ascertaining degrees of uncertainty.
- The hours were long, and the conditions were often tough, but our team persisted.
- Well, someone had to do it!

Summary of experimental results



Results of field experiments



Experiment: 196/10-16-1991, Wales UK

Haven't you often wondered where the data for Tim's famous diagram came from?

The First UN Goal for a Sustainable World…..

1. *"…..the eradication of poverty everywhere….."*.

   Poverty entails more than the lack of income and productive resources to ensure sustainable livelihoods. Its manifestations include hunger and malnutrition, limited access to education and other basic services, social discrimination and exclusion, as well as the lack of participation in decision-making.

- 85% of global citizens live on <$30/day, 65%< $10/day, 10% <$2/day (absolute poverty)
- About 85% of the impoverished reside in rural areas
- Rate of population growth rate declining except in certain regions (Central, Sub-Saharan Africa). Overall population is increasing.

The Second UN Goal for a Sustainable world

2. *"….the establishment of global food security….."*

UN resolves "…that all societies, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life….".

- To match population growth, UN has calculated that to meet food security goals a 70% increase in food production is required by 2050
- Most of this increase has to come from rainfed farming (80% global agriculture)

The UN goals are inextricably linked and interdependent

Silva (2021) encapsulates the challenges that have faced humanity through the ages:

"...one can prepare, one can strive, one can make a choice, but ultimately life is an elaborate game of providence and probability...".

- "*Providence*" is what a society encounters. Successful "*striving*" and "*preparation*" are only useful if the probability of an event is known.
- Food abundance, availability and affordability is still challenged by the susceptibility of agriculture to the vagaries of weather and climate,
- The use of an Ensemble Prediction System (EPS) products allows the estimation of the probability of weather events => adaptation and mitigation.

30 Years of Ensemble Forecasting & Tim Palmer Symposium

A number of critical questions had emerged from FGGE, TOGA and other WCRP program field experiments and modelling programmes.

- **Deterministic forecasts** (<2000 BP) offered limited utility in weather dependent regions (esp. for rain-fed agriculture).
- Why does there exist a **"springtime predictability barrier"** that has proved troublesome for understanding ENSO evolution and its relationship to the monsoon *and*
- Why did ENSO and monsoon variability **change ascendancy interannually** as noted (and largely forgotten) in the research of Normand (1953) and Troup (1961, 1965)?

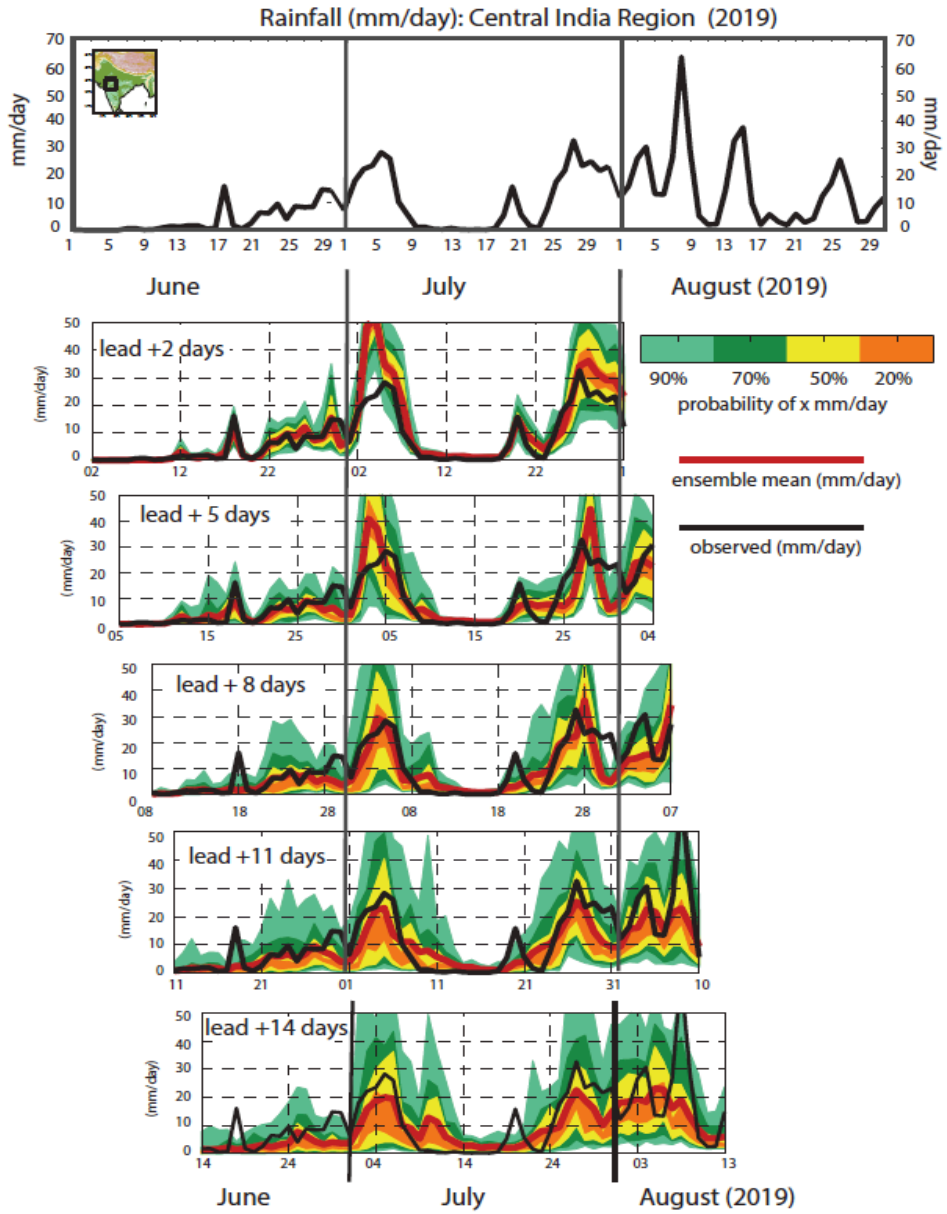
These questions seemed important to us as we viewed seasonal prediction with some some anticipation (and trepidation)

Tim had advice about dealing with the inadequacies of deterministic prediction:

Use the new results of coming from EC's experimental Ensemble Forecasting System as:

- They could provide a *probability* of a weather event allowing cost-benefit decisions to be made in the field
- Noting that a deterministic forecast has no greater statistical significance than any one of the ensemble members

Tim's suggestions led to probabilistic forecasts of tropical weather, tropical cyclones and severe events and the establishment of warning systems.

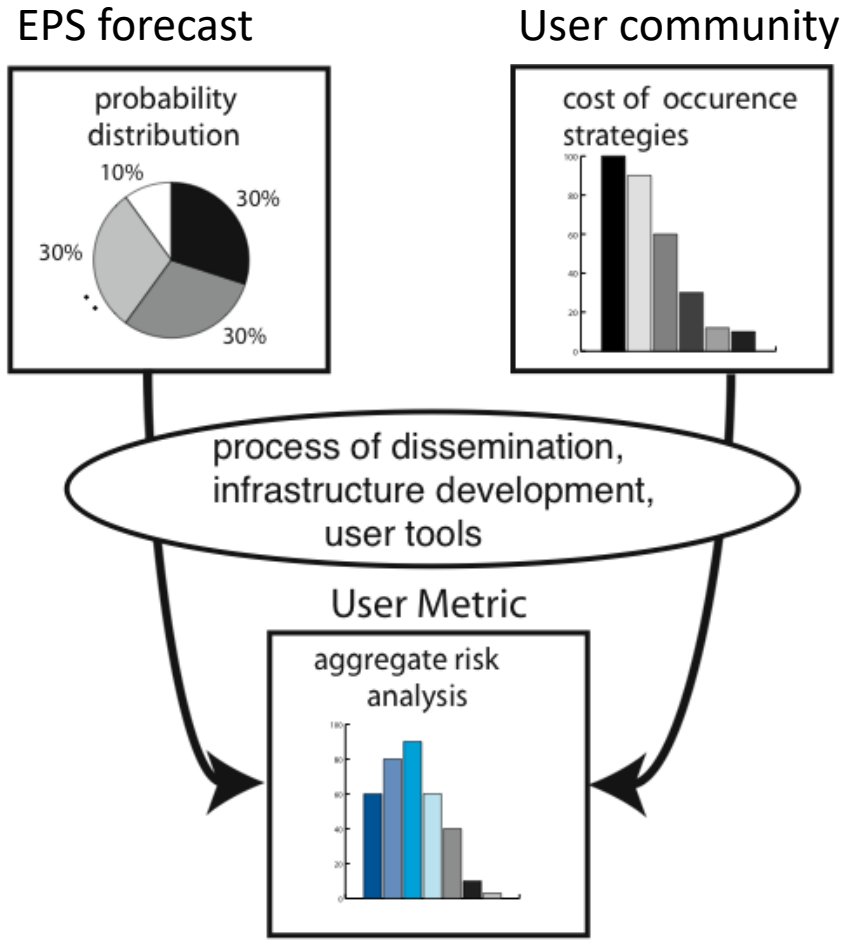


Raw precipitation plumes from EPS for Central India (June-August, 2019).

Use EPS results in the developing world where the need is greatest

- We initially concentrated on floods in Bangladesh (Brahmaputra and Ganges) and then Pakistan (Indus)
- Use of ECMWF's Extreme Forecast Index for intense rain events, heat waves.
- Use of EPS products for rain-fed regions (work with NGO Precision Agriculture for Development: PxD)

Methodology



Risk = cost x probability

But would a probabilistic forecast be understood?

Paraphrasing a conversation with a Bangladeshi farmer:

"We hope to provide you with flood forecasts to help you plan ahead"

FARMER: "That would be good, I think".

"But we will not always be correct: Maybe 8 times out of 10."

FARMER: (after some thought): "That is fine*!* Only God knows 100% what will happen, and he is not telling, and you are not God!

Right now, floods just turn up. Your forecast means I am ahead*!* "

Lesson: Don't underestimate…!

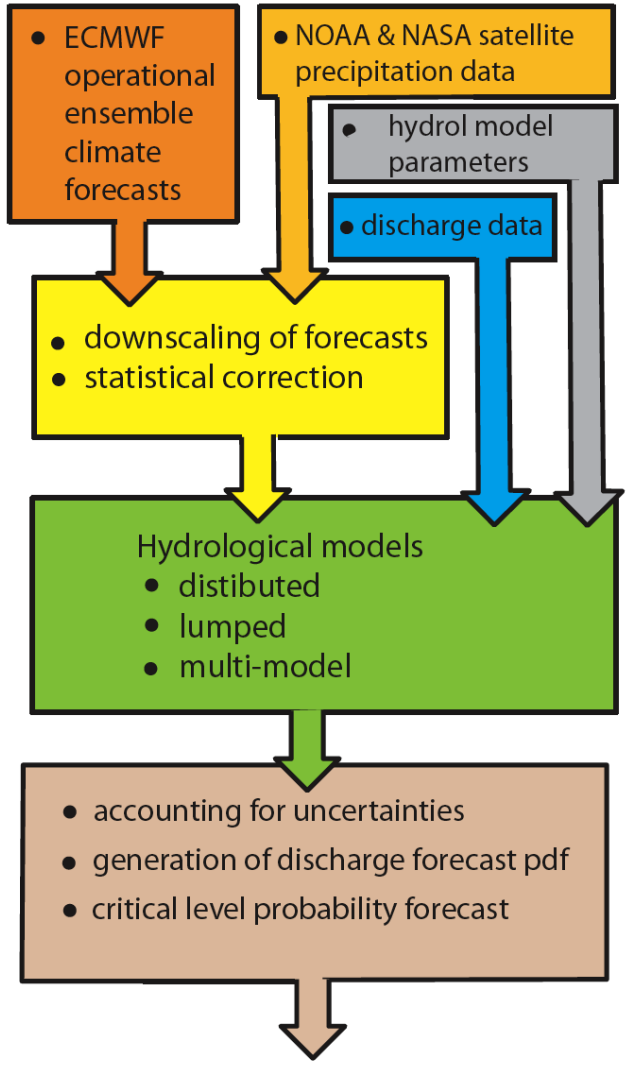
Bangladesh Flood Transboundary Forecasting System

(I) Initial Data Input

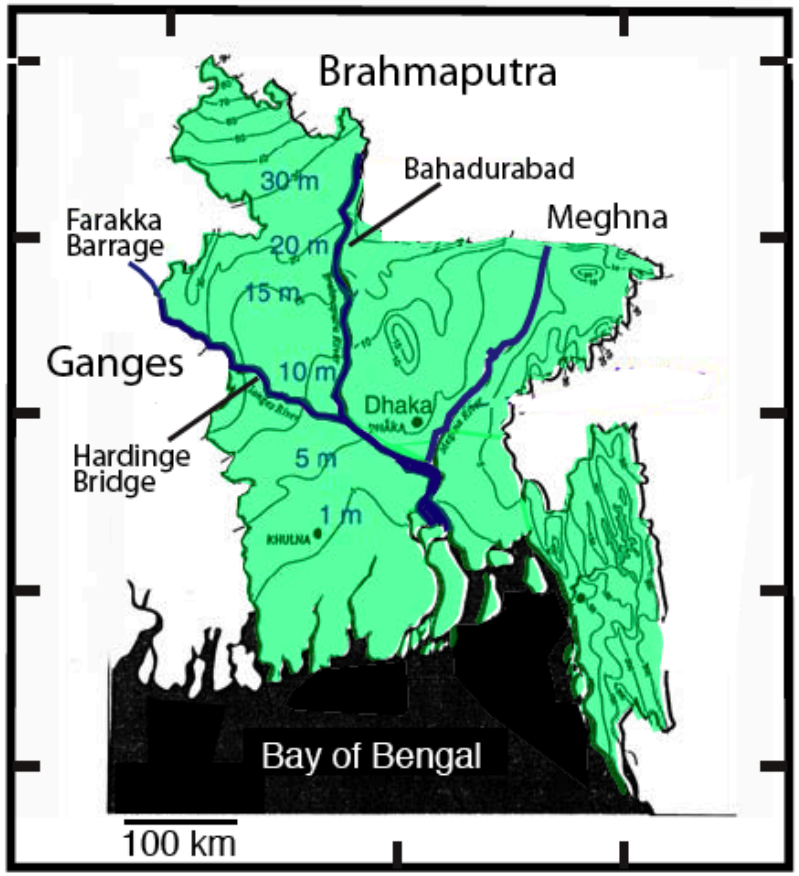
(II) Statistical Rendering

(III) Hydrological Modeling

(IV) Generation of Probabilistic Forecasts

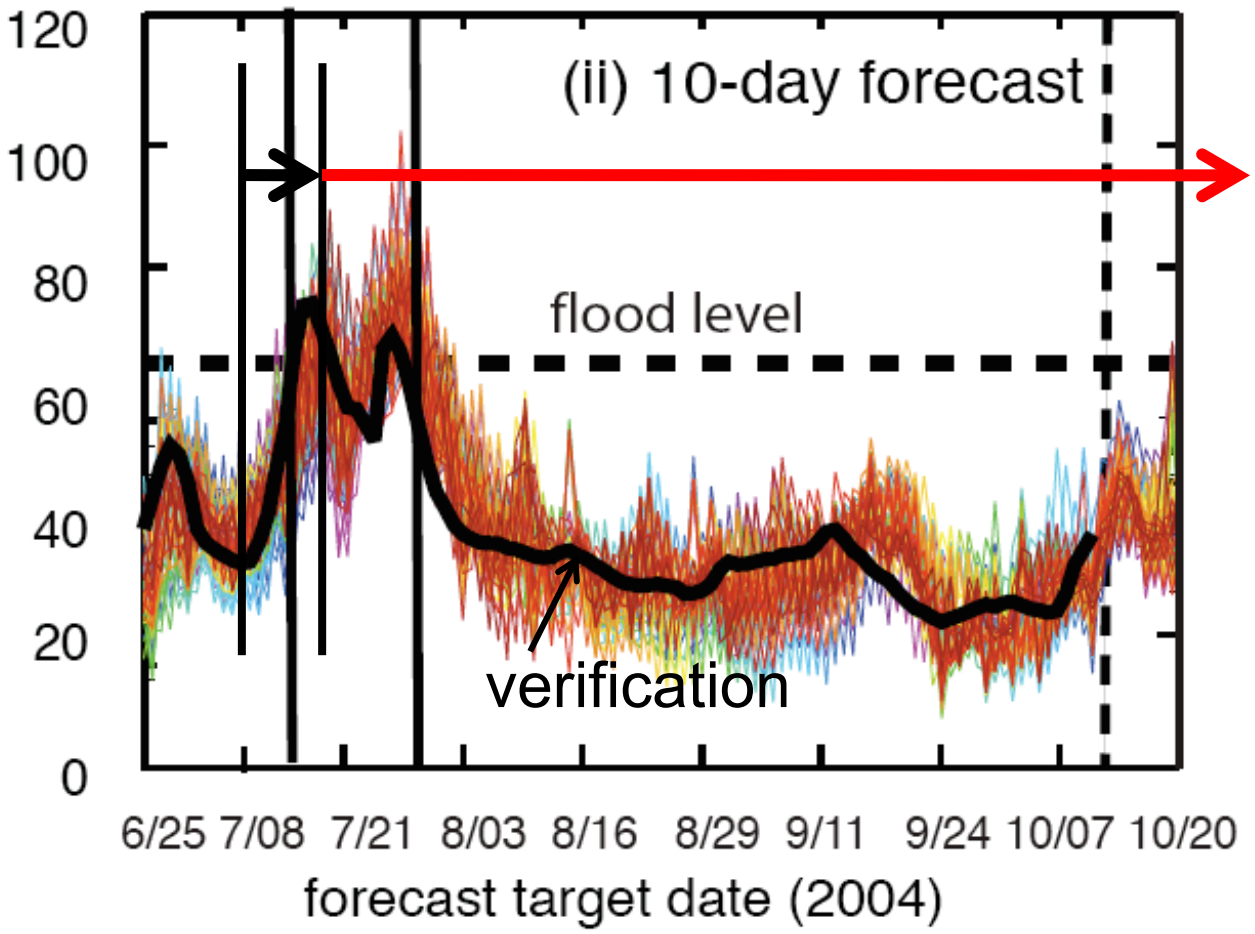


(V) Dissemination

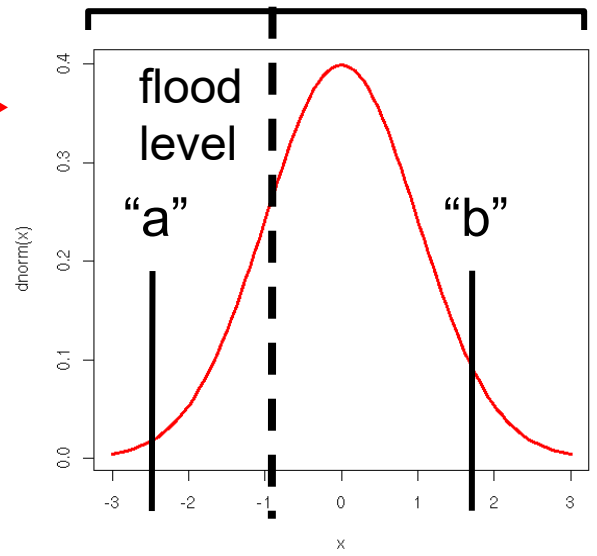


Hopson and Webster (2010)
Webster, Palmer, et al (2010)
Webster and Jian (2011)

First experimental Brahmaputra Flood forecasts 2004



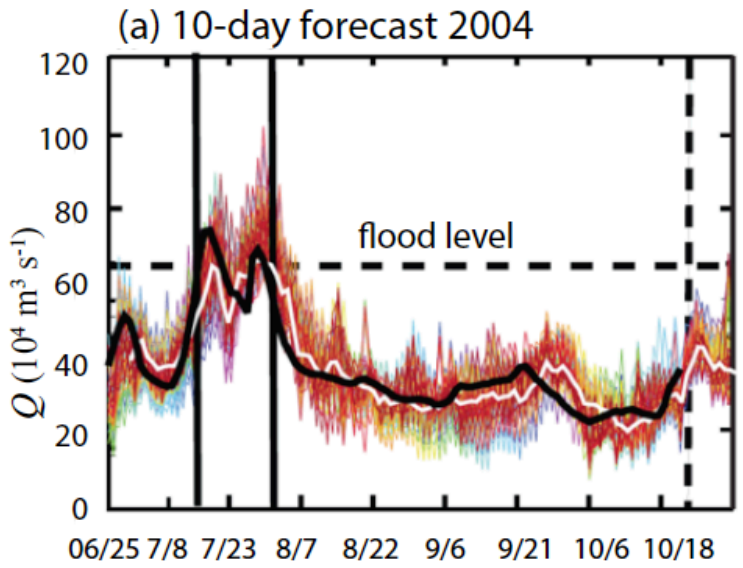
For forecast made
July 08 for 17, 2004

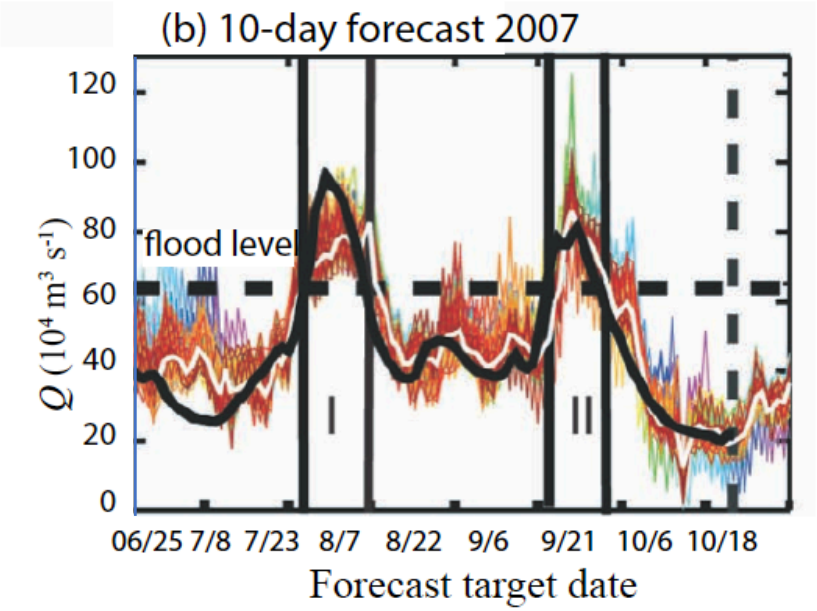


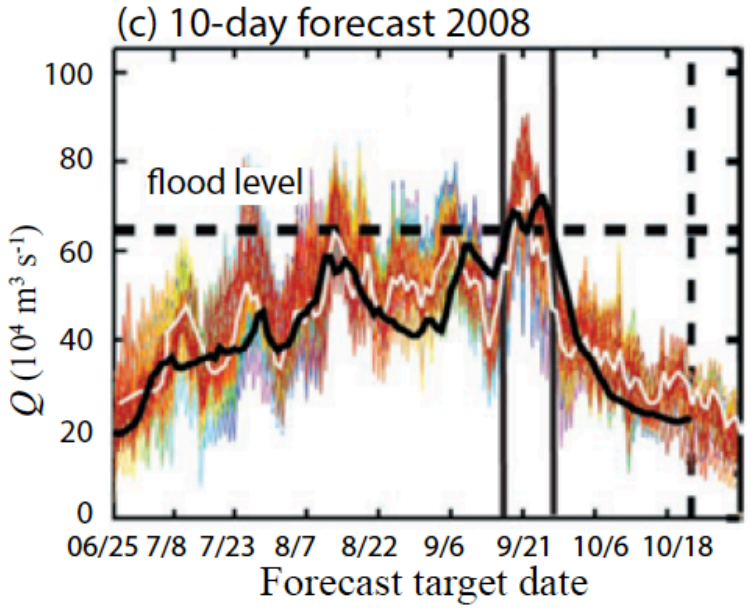
Probability of exceeding flood level 10-days in advance calculated from ensemble spread

Note: If a deterministic forecast had been made, rather than an ensemble of forecasts, "a: no flood" or "b: flood" would have been equally likely and there would be limited trust in the forecast

Bangladesh Ganges/Brahmaputra Forecasts Became Operational 2007/08

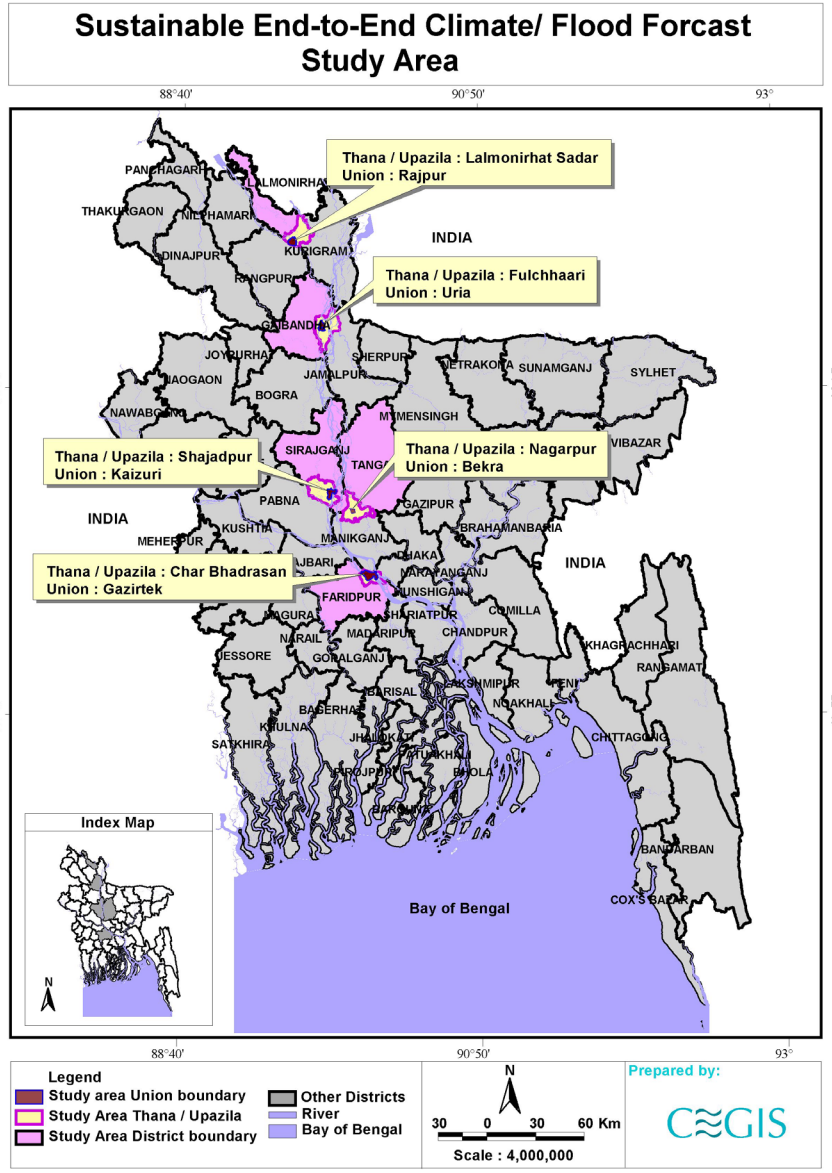






- Summer of 2007, the EPS flood forecasting became operational and were disseminated throughout Bangladesh.
- Model now run by RIMES (Regional Integrated Multi-Hazard Early Warning System (Director: Sri A. Subbiah) and results passed to the Bangladesh Flood Forecast and Warning Centre

During 2007 and 2008, the forecasts were communicated across Bangladesh



- A number of “counties” or “unions” were designated as test regions and the forecasts transmitted (via cell phone) to district leaders and, from there, to the village level.
- Advice for evacuation, livestock safety, early harvest, safe drinking water by Bangladeshi authorities ahead of high probability forecast of floods

Floods, instead of arriving as a disastrous surprise, were proceeded by warnings and actions throughout the country

The Imam from the Mosquein Koijuri Union of Sirajgong District in Bangladesh relating how forecasts were disseminated and how the flood forecasts were used and disseminated:

"We disseminate the forecast information and how to read the flag and flood pillar to understand the risk during the prayer time. In my field, T. Aman was at seedling and transplanting stage, I used the flood forecast information for harvesting crops and making decision for seedling and transplantation of T. Aman. Also we saved household assets."

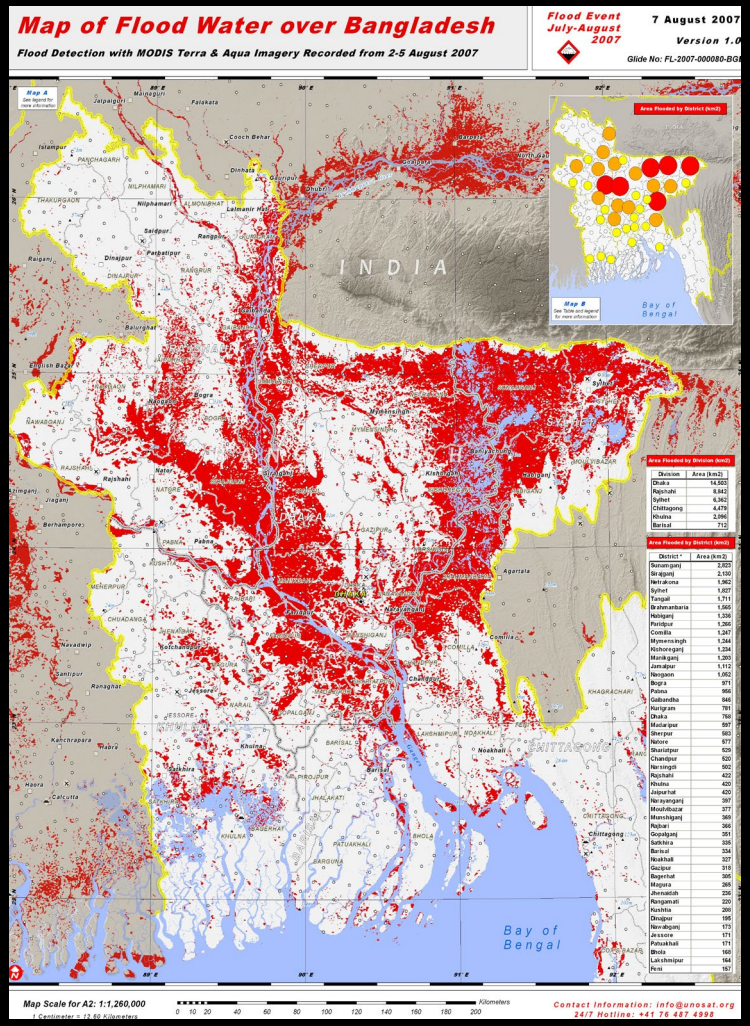
Bangladesh CEGIS (Centre for Environmental Information Services) estimated the savings (reduced loss) of using the 10-day flood forecast information)

Household effects: $130 (4 months labor based on $350/year rural labor)

Agricultural $190 (6 months ….)

Household effects $270 (10 months….)

Livestock $500/cattle (2 years …)



- Minimize loss
- Accelerate recovery

Slow rise floods:

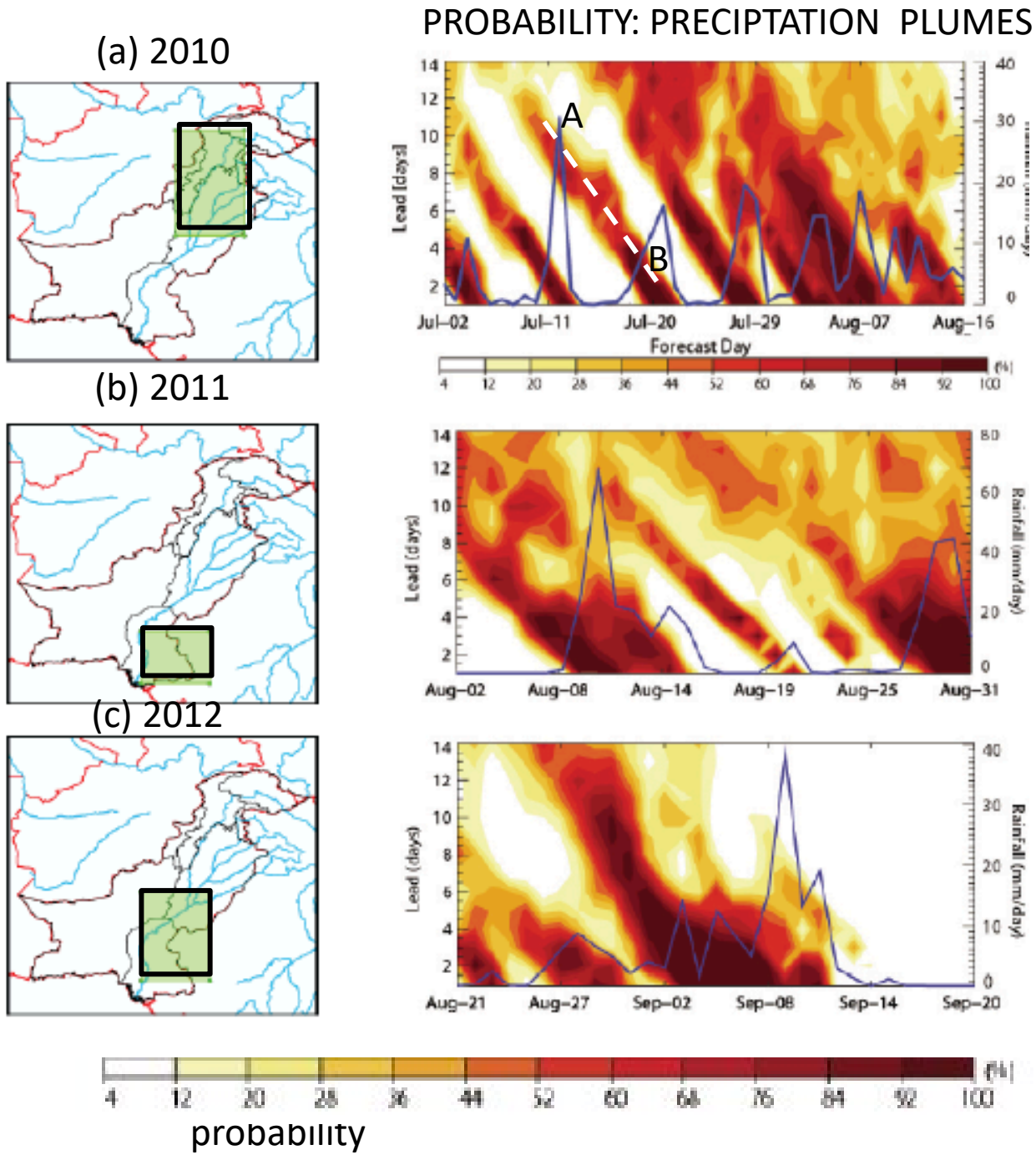
- long-lived
- large scale
- devastating

But predictable!

PAKISTAN FLOODING 2010/11/12:

Alas, different outcome.

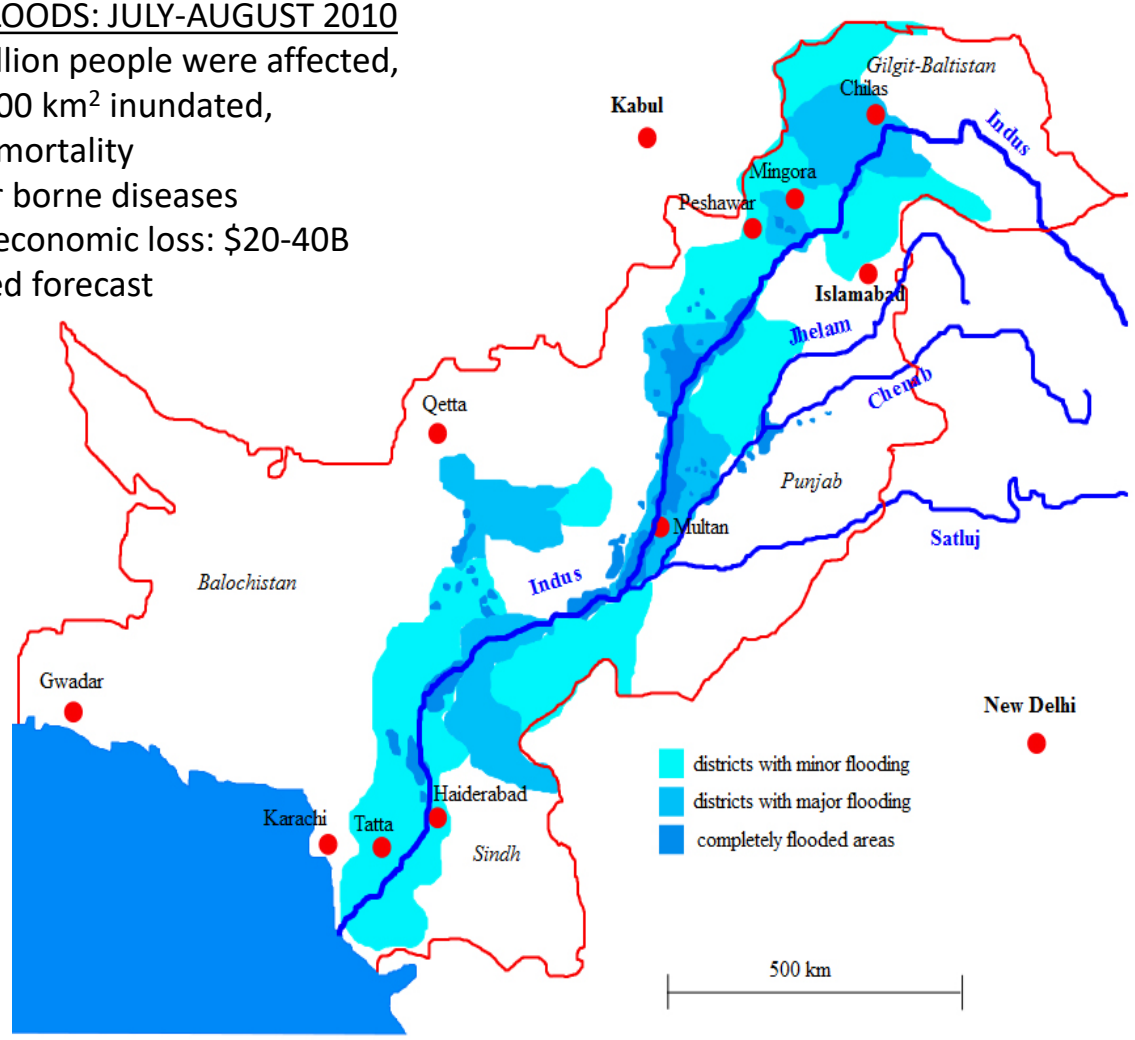
- Good flood forecasts for the three flood years of 2010, 2011 and 2012 including inundation
- Pakistani government not interested
- 2022?

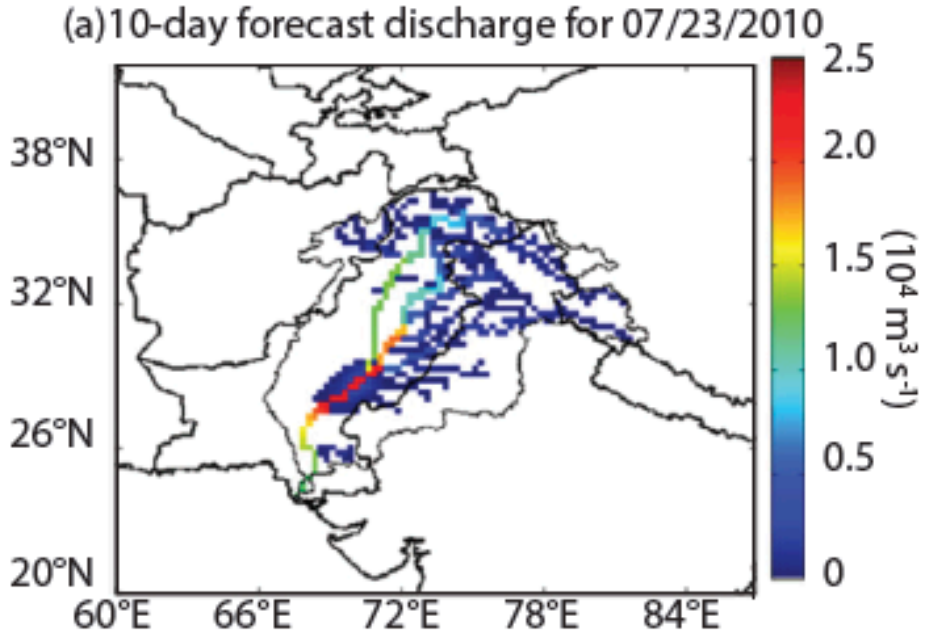


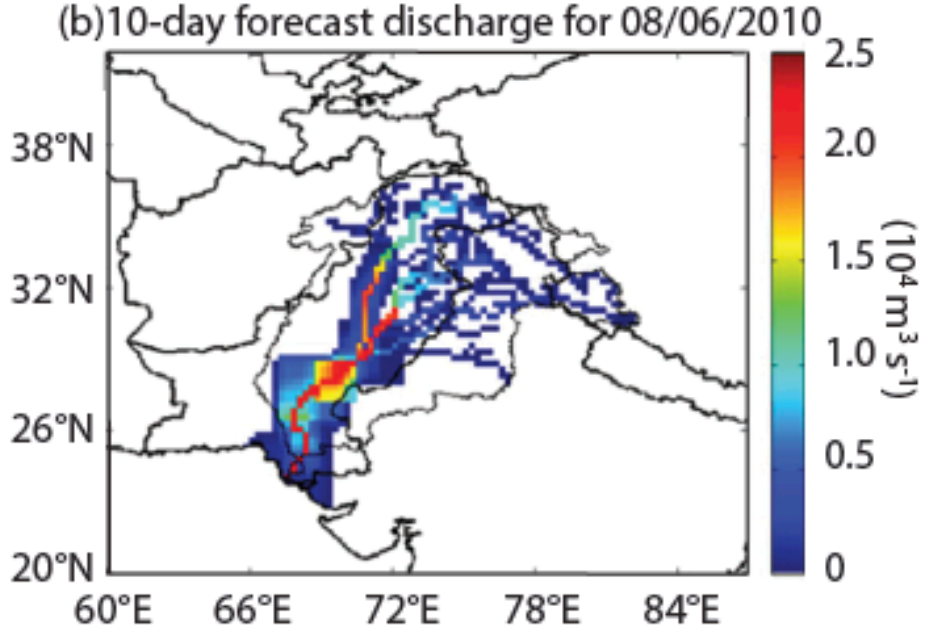
Inundation forecast Pakistan June & August 2010

MAJOR FLOODS: JULY-AUGUST 2010

- 20 million people were affected,
- 160,000 km^2 inundated,
- 2000 mortality
- Water borne diseases
- Total economic loss: $20-40B
- Limited forecast







A flood affectee in Multan reaches out for water bottles being distributed by relief workers.

The flood forecast model developed at the Georgia Institute of Technology can predict rain very accurately, even when it is dealing with anomalous storm patterns. But, in order to predict streamflows at precise locations, it needs river flow data from each of the hydrological structures on the Indus river system. However, the government of Pakistan is not willing to share this data with the creators of the model.

Inside: Keeping schools open in Panjgur

October 2014

Herald

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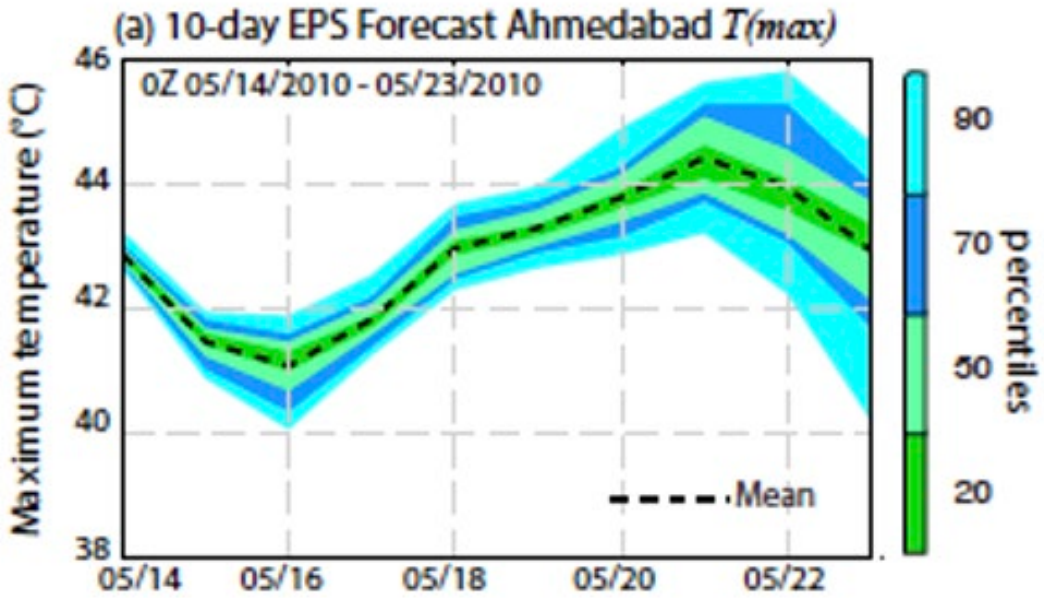
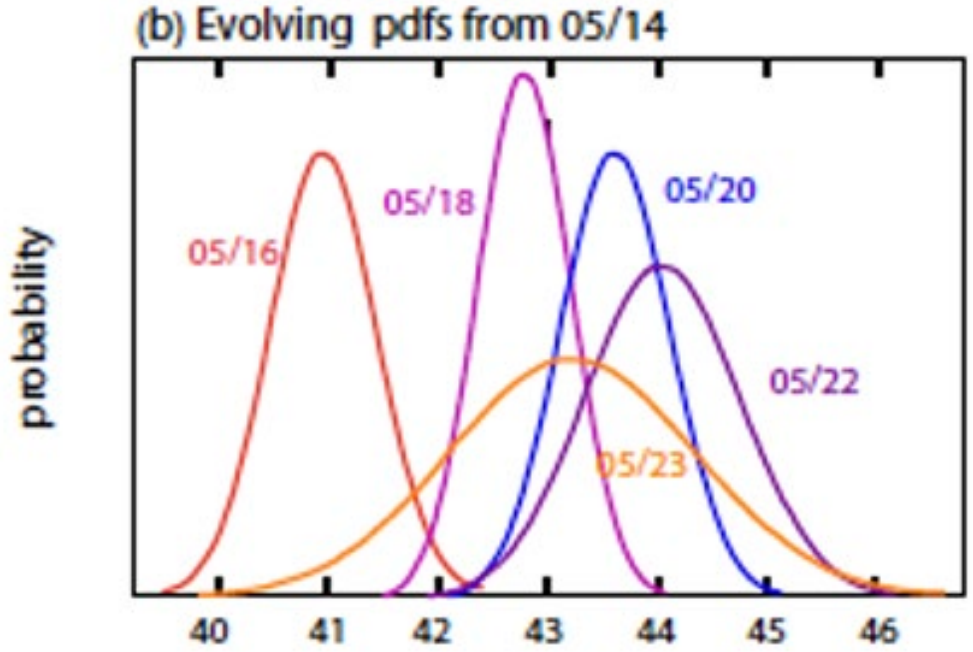
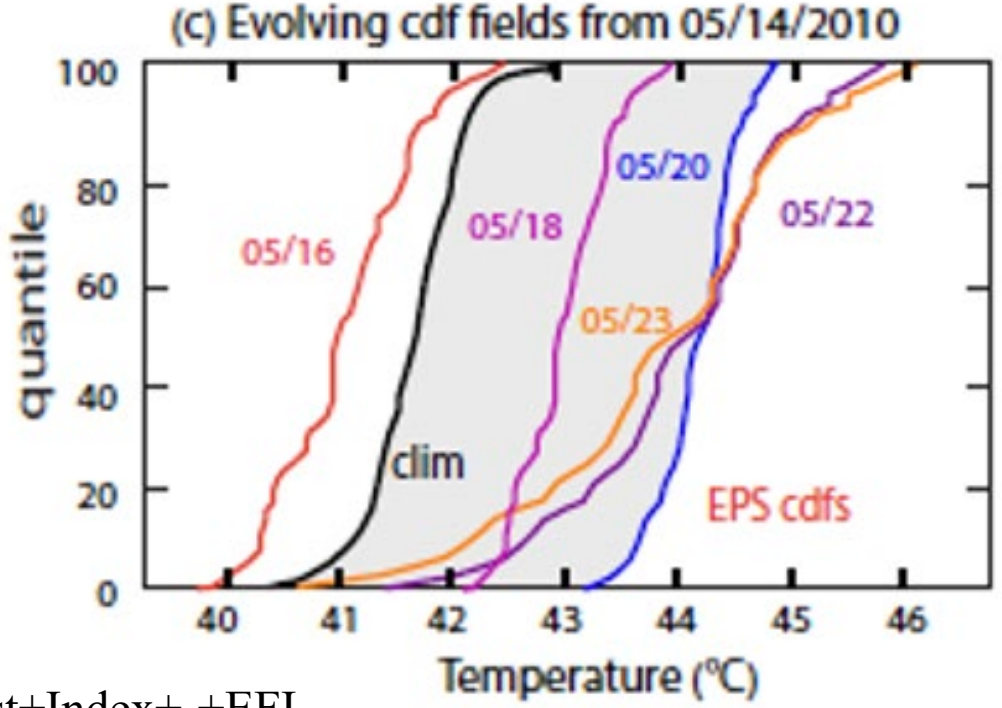
A ValuableNerw ECMWF Tool

The probability of extreme events can be determined at a point, or using ECMWF's Extreme Forecast Index (EFI) as an evolving (x, y, t) field



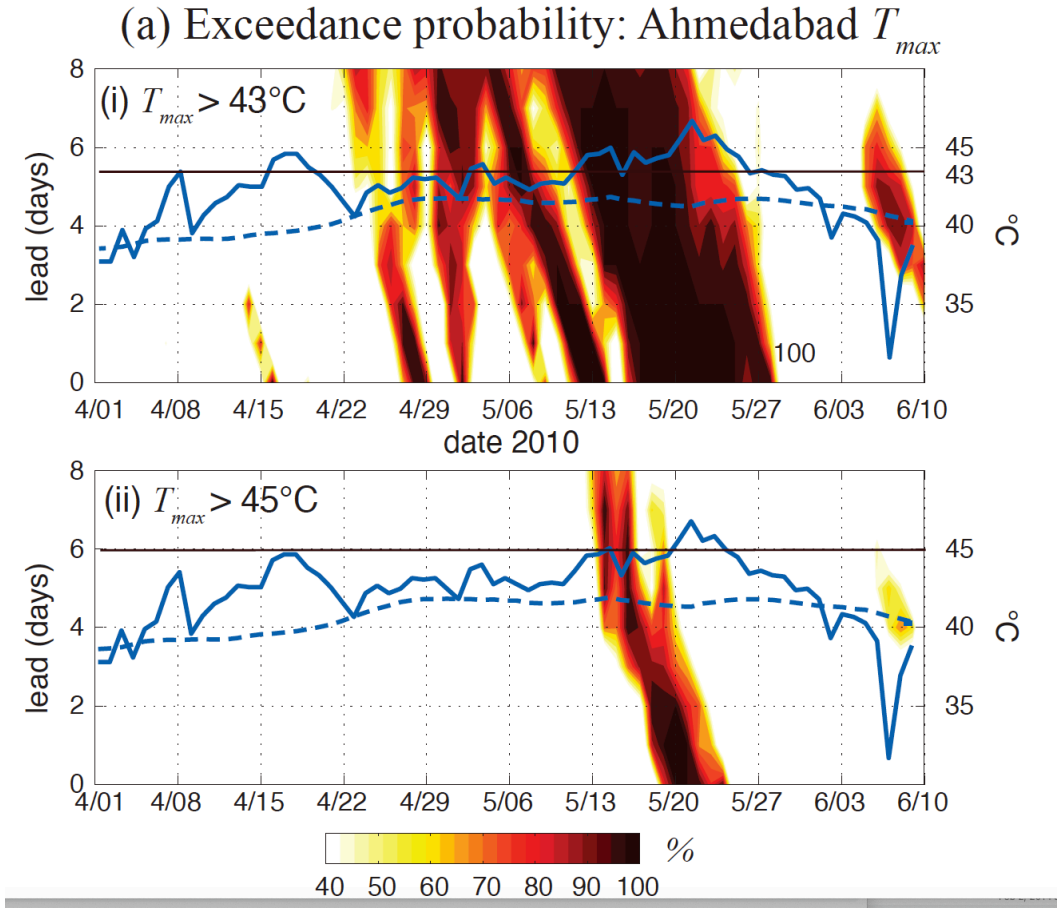




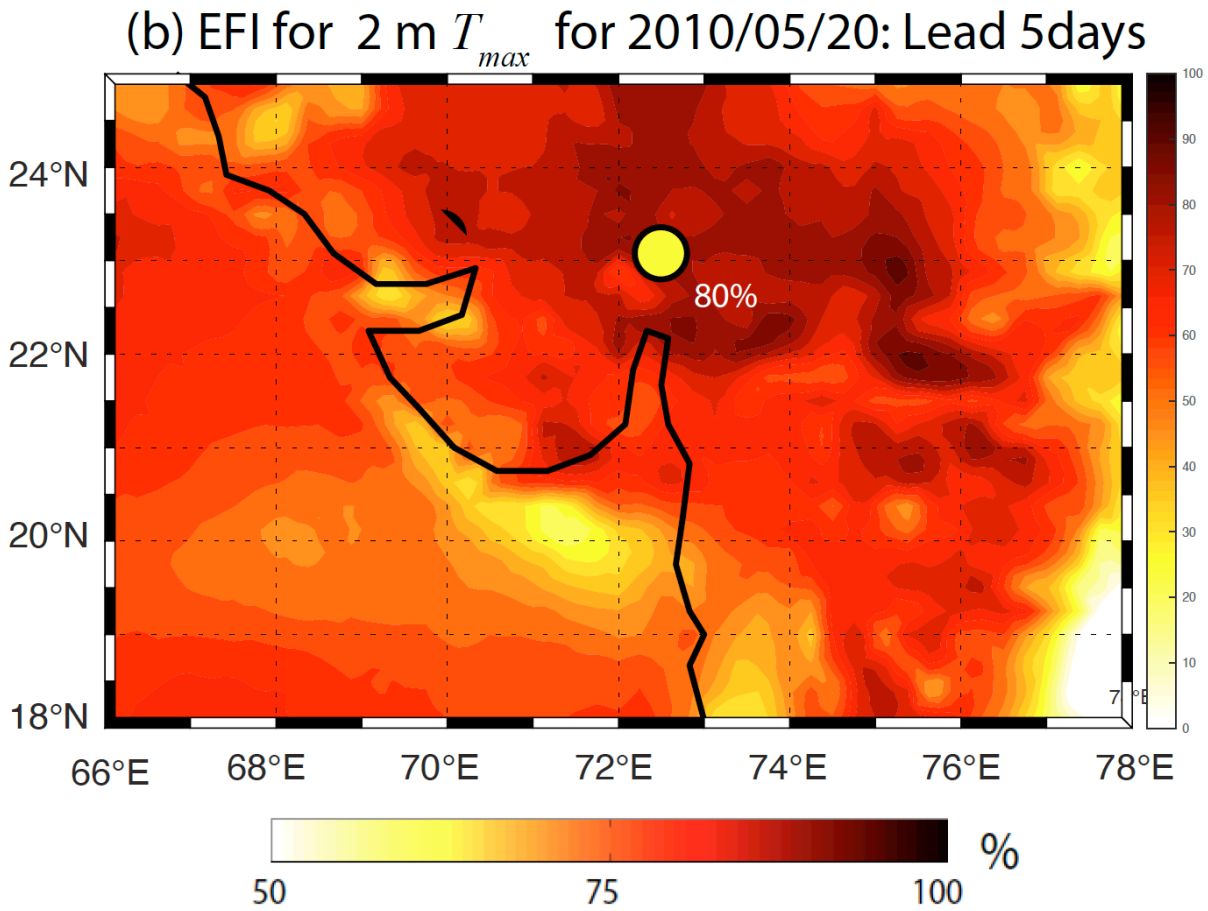
* https://confluence.ecmwf.int/display/FUG/Extreme+Forecast+Index+-+EFI

Heat wave forecast for Ahmedabad: Plumes and EFI

Plumes lags 0-8 days



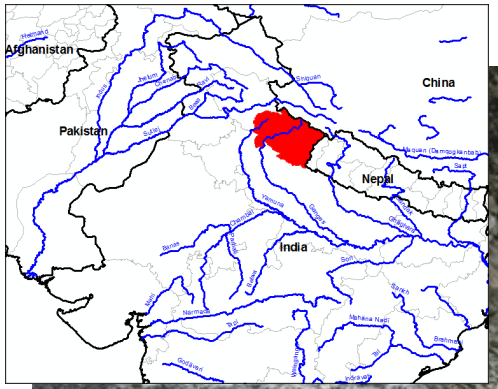
Regional *EFI* lag 5 days

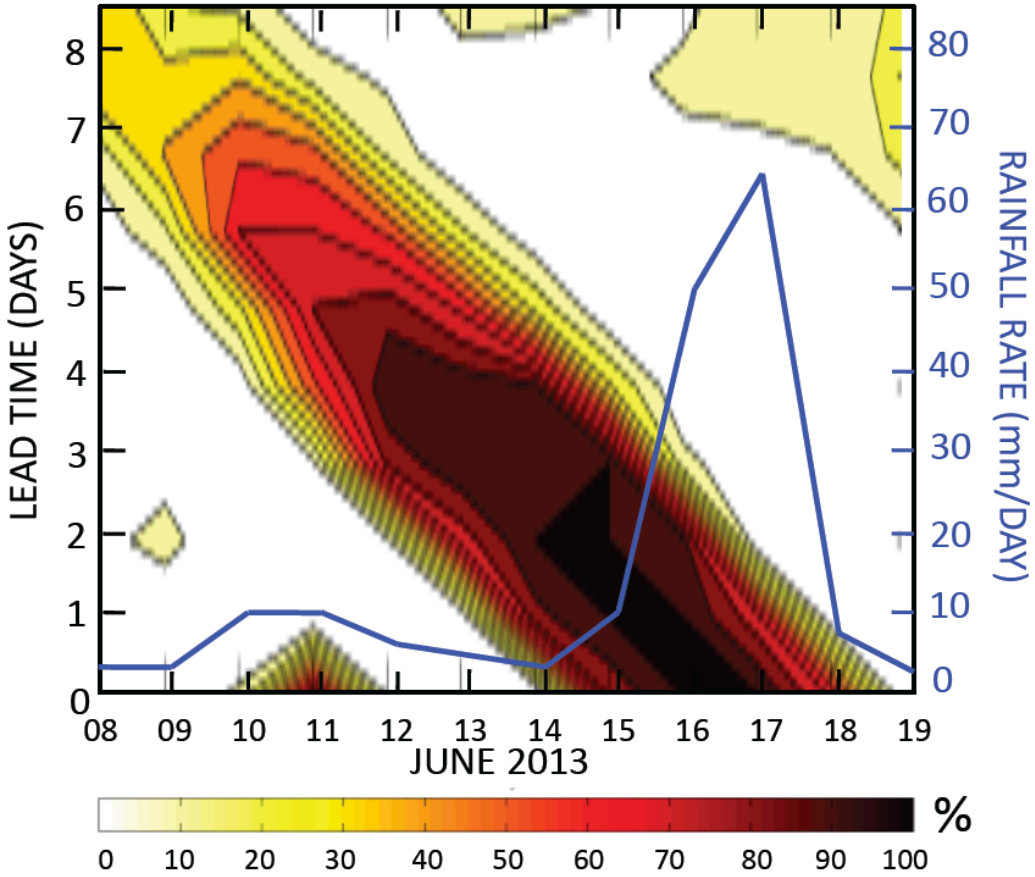


Knowlton et al. 2014.

Uttarakhand Floods (June 2013)

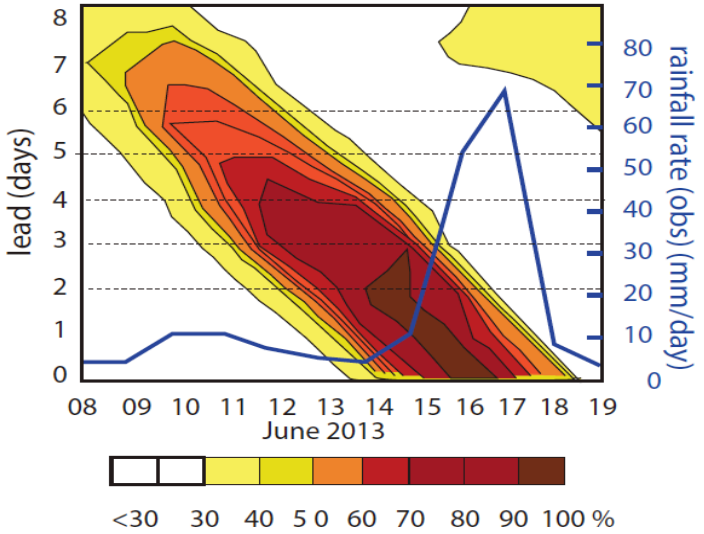
July 9: Authorities estimate >6000 (mainly pilgrims) may have died in Uttarakhand floods.





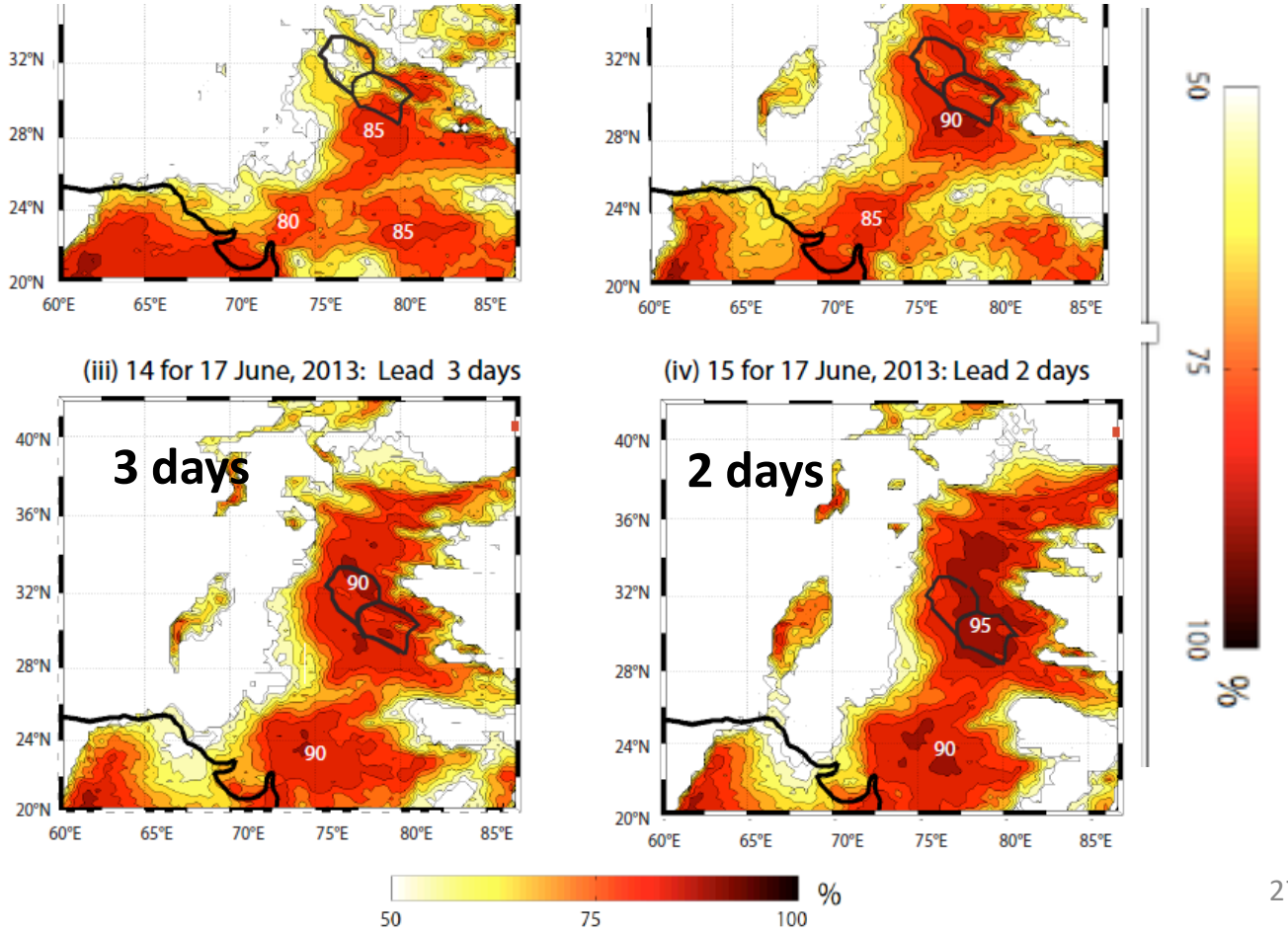
Uttarakhand flooding: June 2013: Plumes and *EFI*

Uttarakhand precipitation plume



An EFI field has the advantage of looking at the evolution in time and space of a field (T, precipitation…)

EFI distribution of excessive rainfall relative climate
long-term expectations(11-15 June 2013)



Towards the future (1)

- ECMWF, and other national and international groups, continue to produce global ensemble products. These are continually improving , especially on the 1-14 day time scales, and at 14-24 days.
- EPS provides important information of severe events and hazards (e.g., floods, intense rainfall..) Increasingly, these forecasts are being used by communities across that planet.
- As put by Bob Grossman (2022):

"….It is not the average climate that reduces crop yield and induces poverty and food insecurity but unanticipated variability…."

- EPS has the capability of helping anticipate such variability and the possibility of greater yield reduced loss.

(2) Creating bridges to a sustainable future

We can wait to find out if there are regional climate changes in 50-100 years and hope that carbon emissions will temper them..

or

We can improve our shorter prediction skills to anticipate variability for agriculture on the assumption that the average climate changes slowly.

Our optimism for the future is based on the belief *"….A society that learns to deal with present era hazards will be best equipped to adapt to and mitigate hazards that may be encountered in a changing climate…"*

(3) Achieving the first UN imperatives:
Increasing food production by 70% by 2050

- 80% of global agriculture is "rain-fed" often with minimal irrigation and limited or decreasing artesian water supplies.
- Rainfed farming distributed across all continents largely by small-hold farmers.
- Rain-fed areas are often collocated with poverty.
- Communicating EPS products to all rain-fed regions will allow the UN goal to be approached and consequently help reduce poverty
- Of course, we do not know if rainfed precipitation will increase/decrease regionally in 50 years with any certainty.

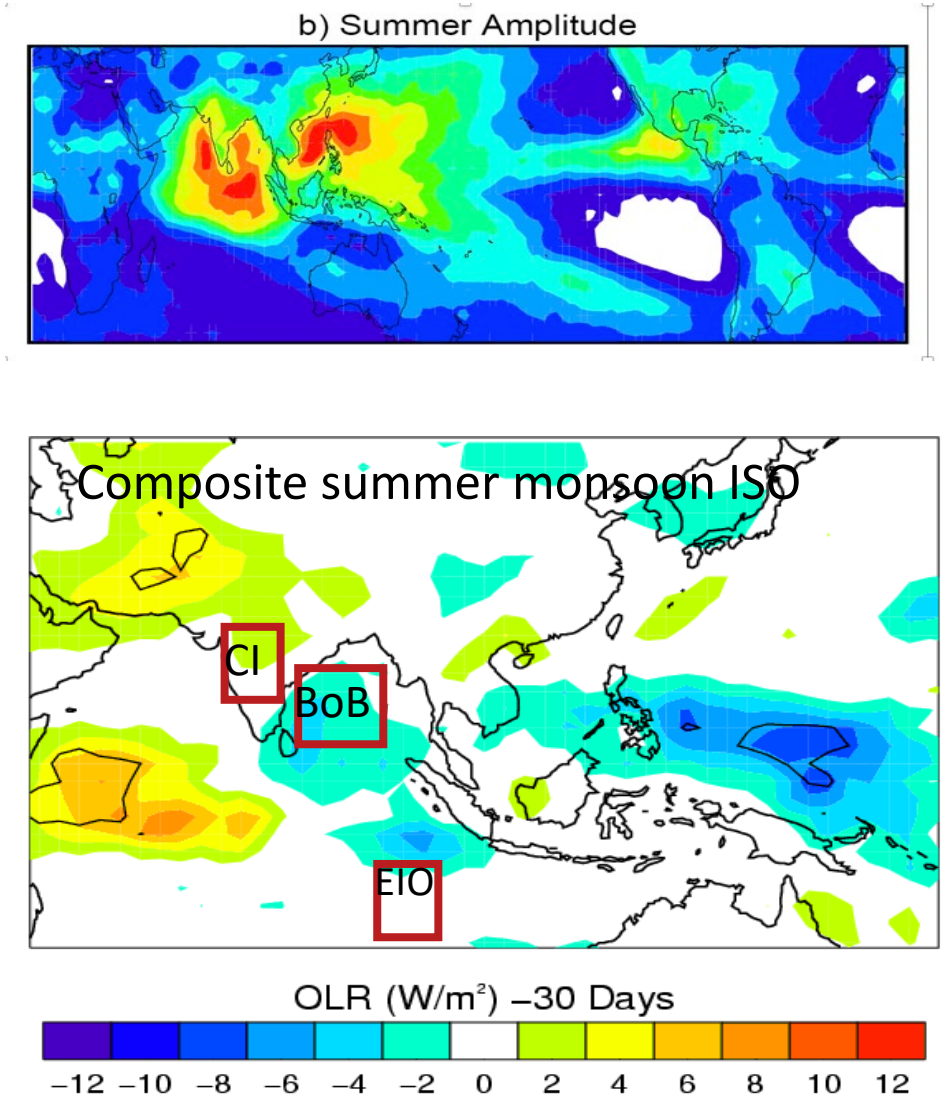
However, EPS will provide useful probabilistic skill in weather and extremes, irrespective of the base climate

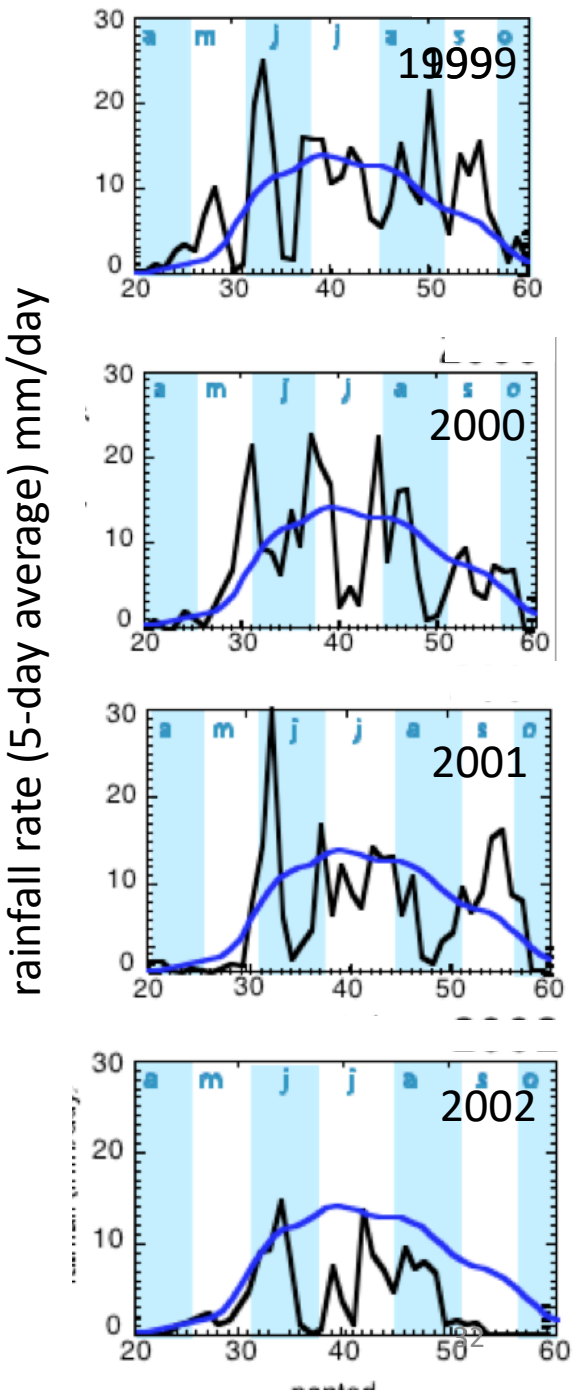
Creating an UN Global System?

- National Weather Services, intergovernmental institutions (e.g., RIMES), NGOs (e.g., PxD) directly with the Ag sectors. But do all have access to EPS products that will allow them to determine future risk?
- One can envision a UN entity ensuring availability and usage of all EPS products for all nations and groups
- Such an entity would act as the consolidator and disseminate of multi-model ensembles products and global EFI fields to governments, institutions and user-groups world-wide.
- Such access would allow national and regional tailoring of EPS products for their own specific consumer groups.
- Could this be part of the CERN-like organization that Tim Palmer has been suggesting for a number of years?

Some gaols: (1) Variability within a forecast of the mean seasonal climate

- Collectively, these subseasonal systems are those that bring critical variability to sectors of the globe.
- How well can we anticipate them with our current EPS systems?
- How predictable are they?

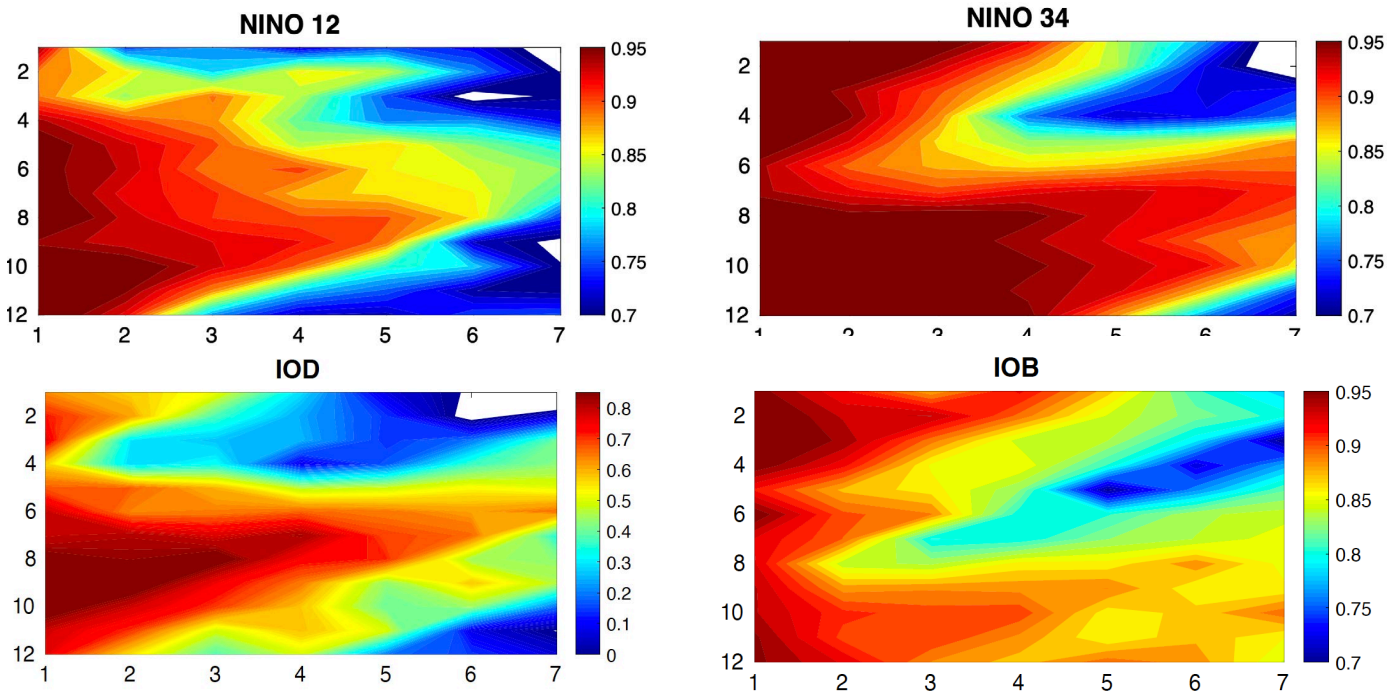




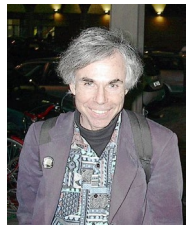
Hoyos & Webster 2007

Another goal: (2) Spring predictability decrease?

SST predictability

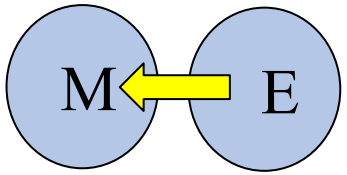


- Is the system tangled system (Hofstadter) with little or no predictability on seasonal/annual time scales?
- Notice very different predictability patterns for each of these four regions
- Even though these systems are regionally related, drop off of predictability occurs at somewhat different times

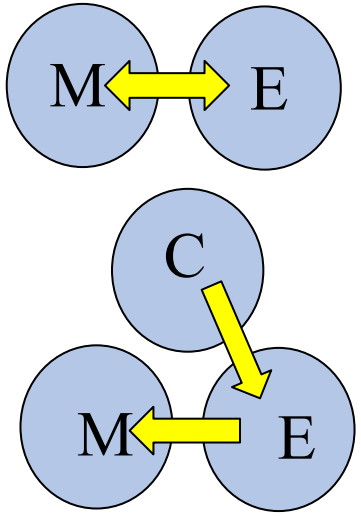


Tim's comment about dealing with the so-called "springtime predictability barrier" - the "bane" of seasonal prediction"

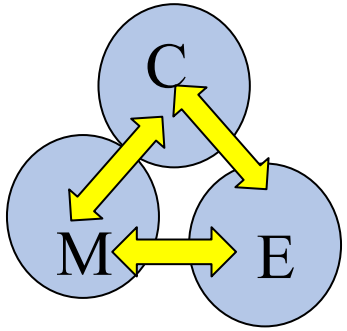
- Read Hofstadter (1979! "Gödel, Escher, Bach: An Eternal Golden Braid") defined three system stages of predictability



Simple: High predictability

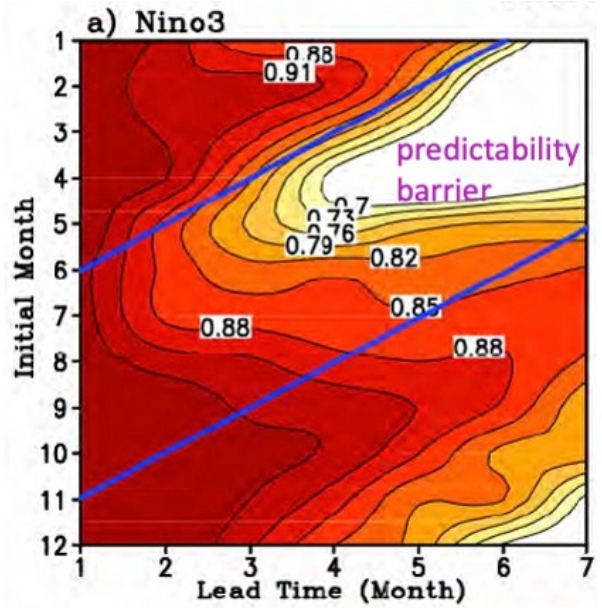


Complex: moderate predictability



Tangled: Low/no predictability

SST JJA => +0.8 SST DJF
SST DJF => -0.2 SST JJA



- Complex or tangled?
- Is there a mysterious "C" or "C's"
- Or at times of low variance of E does a "C" have a greater influence?

Another goal (3) Probability of regional climate change on interannual/decadal time scales

- Model simulations need to provide ambiguous estimates of changes in regional precipitations, beyond global means.
- However, without reliable regional information (i.e., probabilities of (say) rainfall in the Ganges Valley in the period 2050-2060) it is difficult to plan for large scale changes in agriculture.
- Can multi- high-resolution climate models, run in ensemble mode, ascertain probabilities of regional climate on the decadal time scales.
- Creation of Tim Palmer's climate CERN or a UN centre mentioned above?

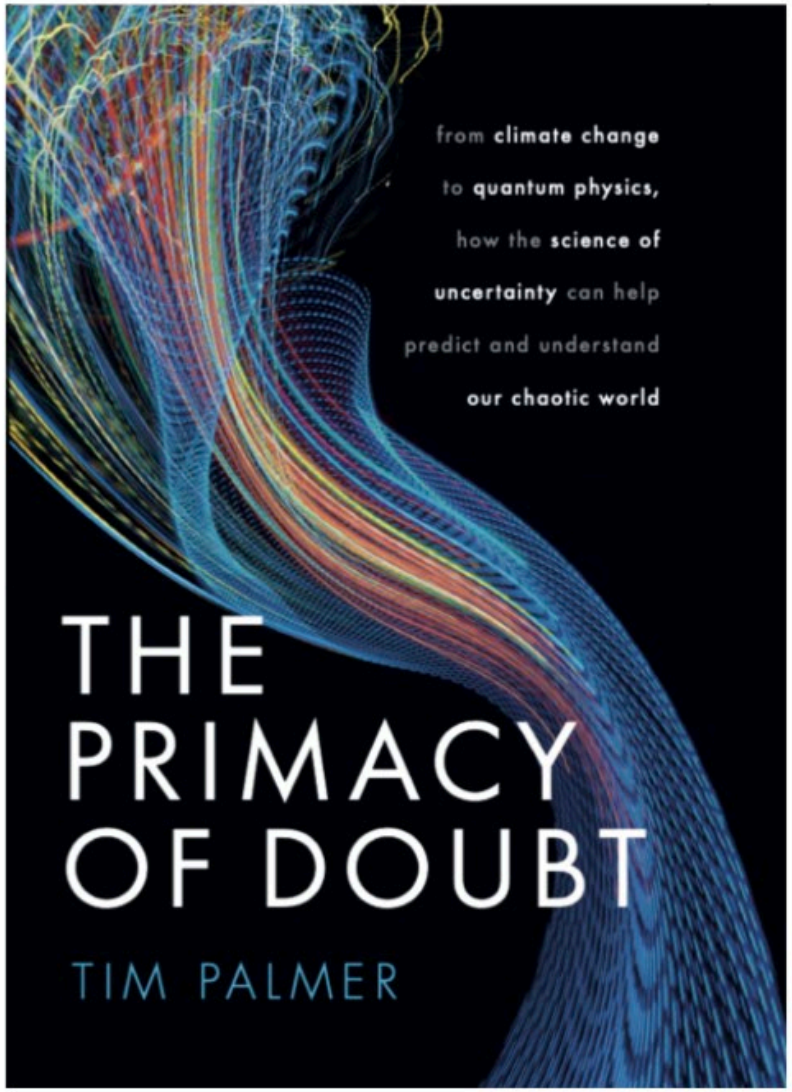
Back to Professor Tim Palmer

Orion giant with his servant Cedalion

- In a letter to Robert Hooke in 1675, Isaac Newton made a memorable statement:

"If I have seen further, it is by standing *on the shoulders of giants …….*"

- Considering the predictability and the furtherment of economics and welfare of society, we ask are there current giants leading studies of these existential topics?

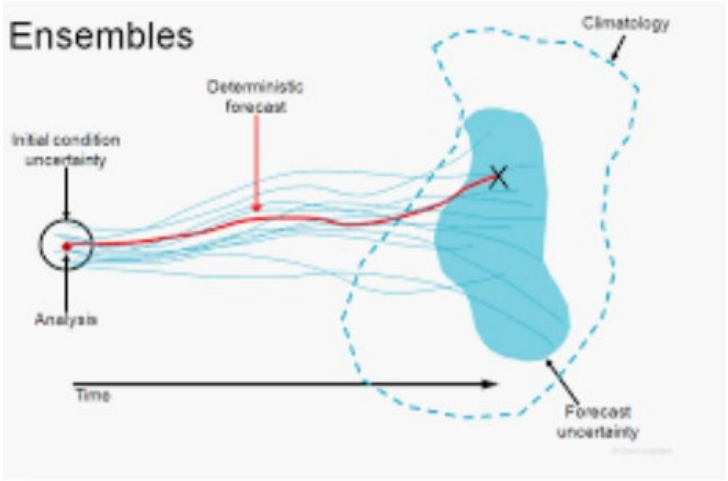


What more can be said?

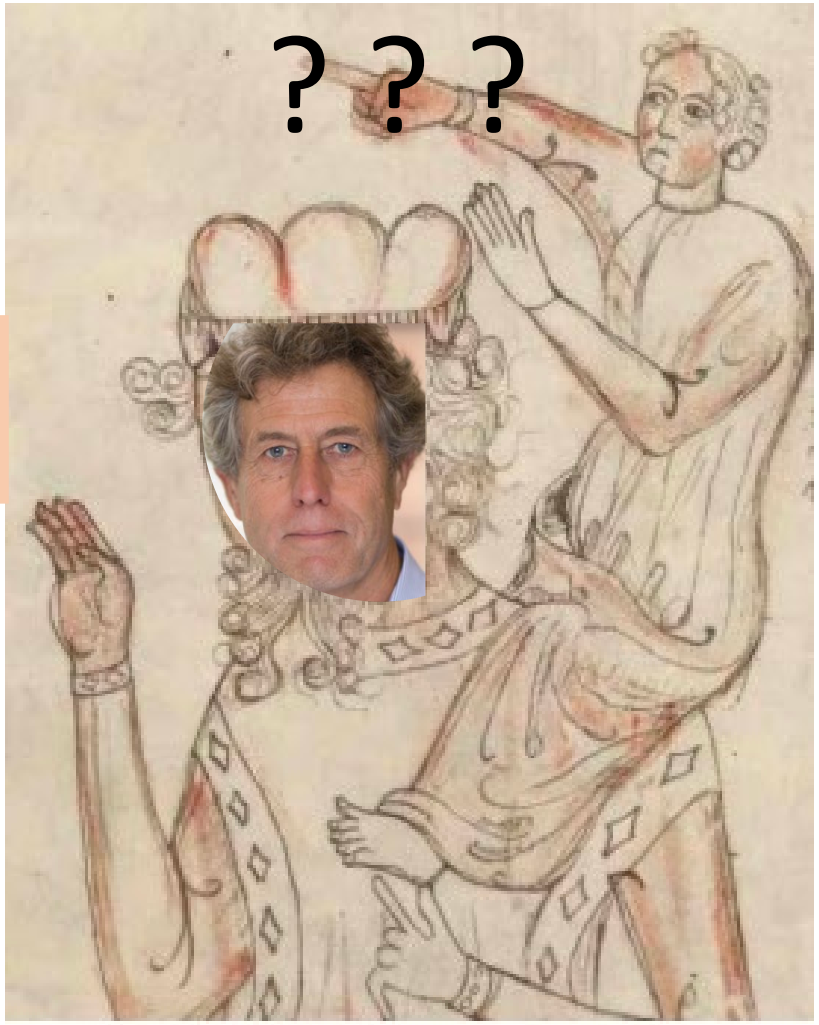
Tim's new book suggests that there is at least one giant in our field!

I strongly suggest that you read his book!

Ensemble prediction system and predictability



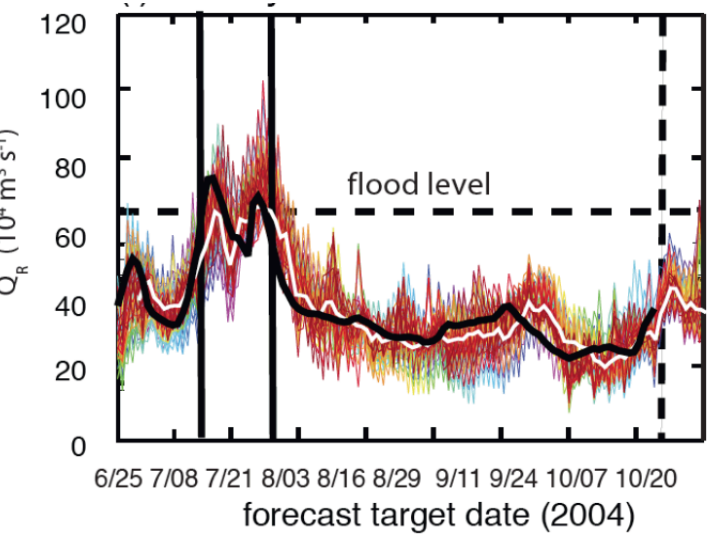
Much of what we know about useful predictability and its utility comes from the inspiration of Tim Palmer and his work at ECMWF and later Oxford



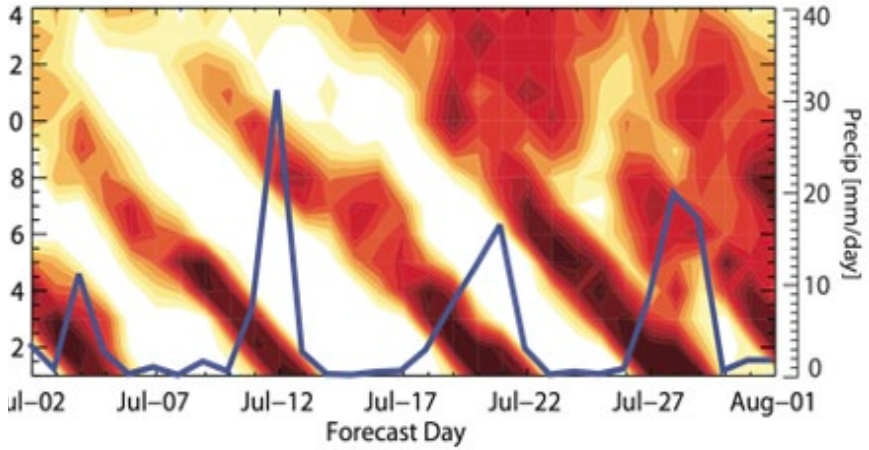
Why the degree of predictability dependency on initial conditions

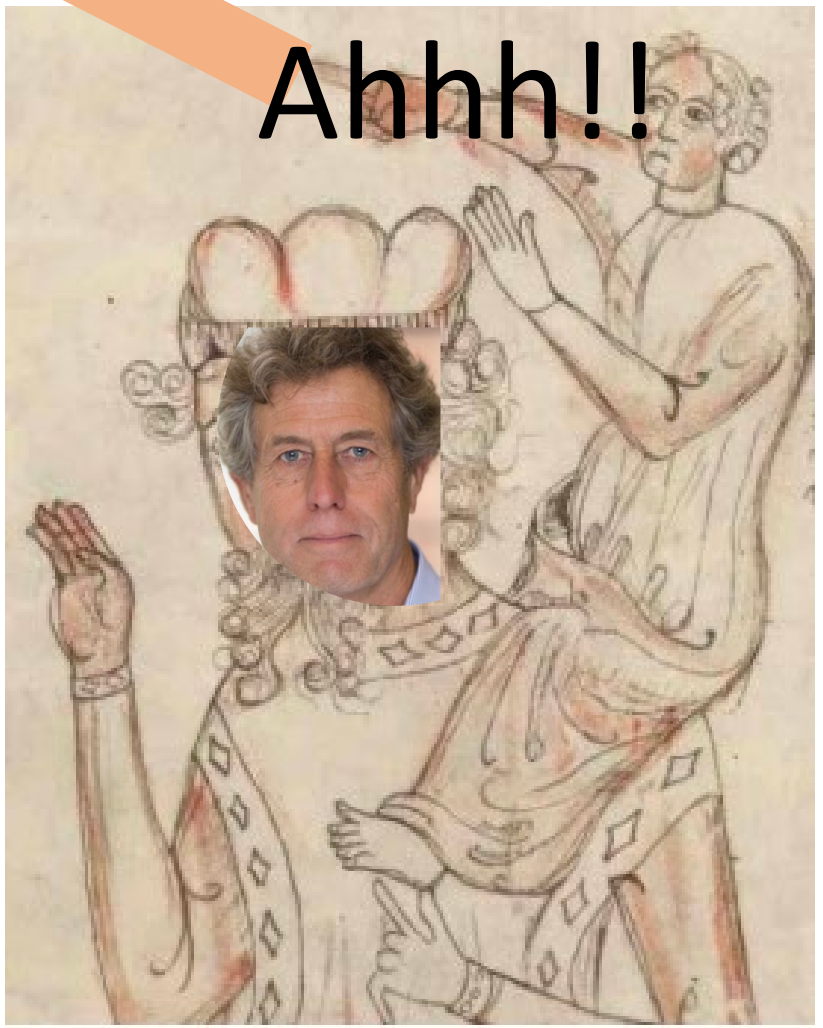
"From the shoulders of this giant…"

(i) Brahmaputra 10-day forecasts

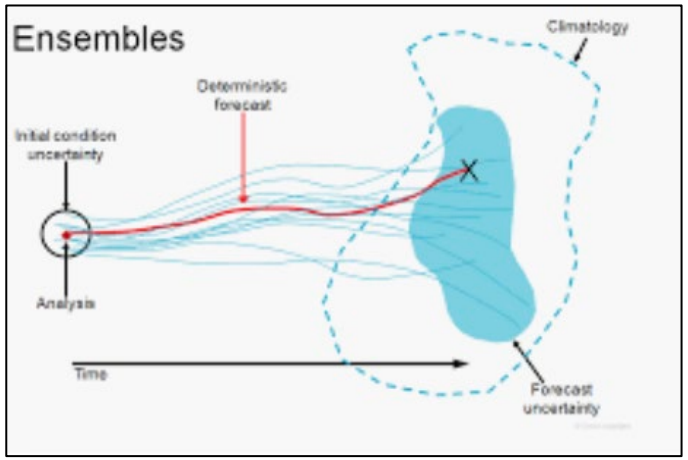


(ii) Pakistan prediction plumes 2010

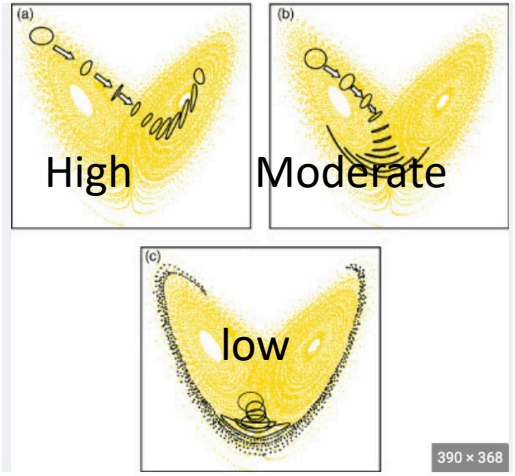




Ensemble prediction system



Initial conditions and predictability



Thank you, Tim, for your leadership, inspiration and friendship