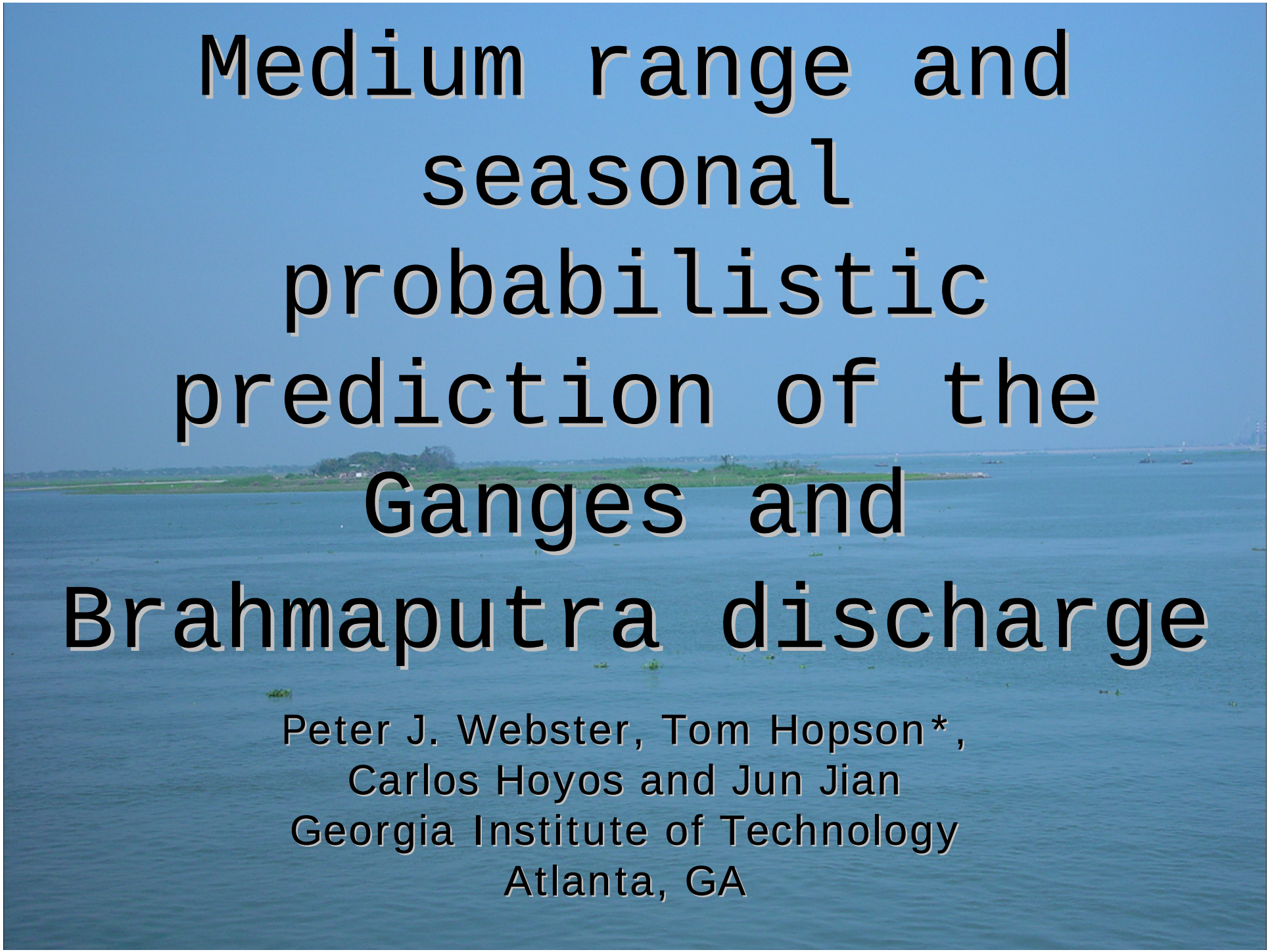

Medium range and seasonal probabilistic prediction of the Ganges and Brahmaputra discharge

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Partners

Georgia Tech

ECMWF

adpc CFAN

Funding Agencies

care

USAID

National Science Foundation

THREE-TIER FLOOD AND PRECIPITATION FORECASTING SCHEME

for South-East Asia

http://cfab2.eas.gatech.edu

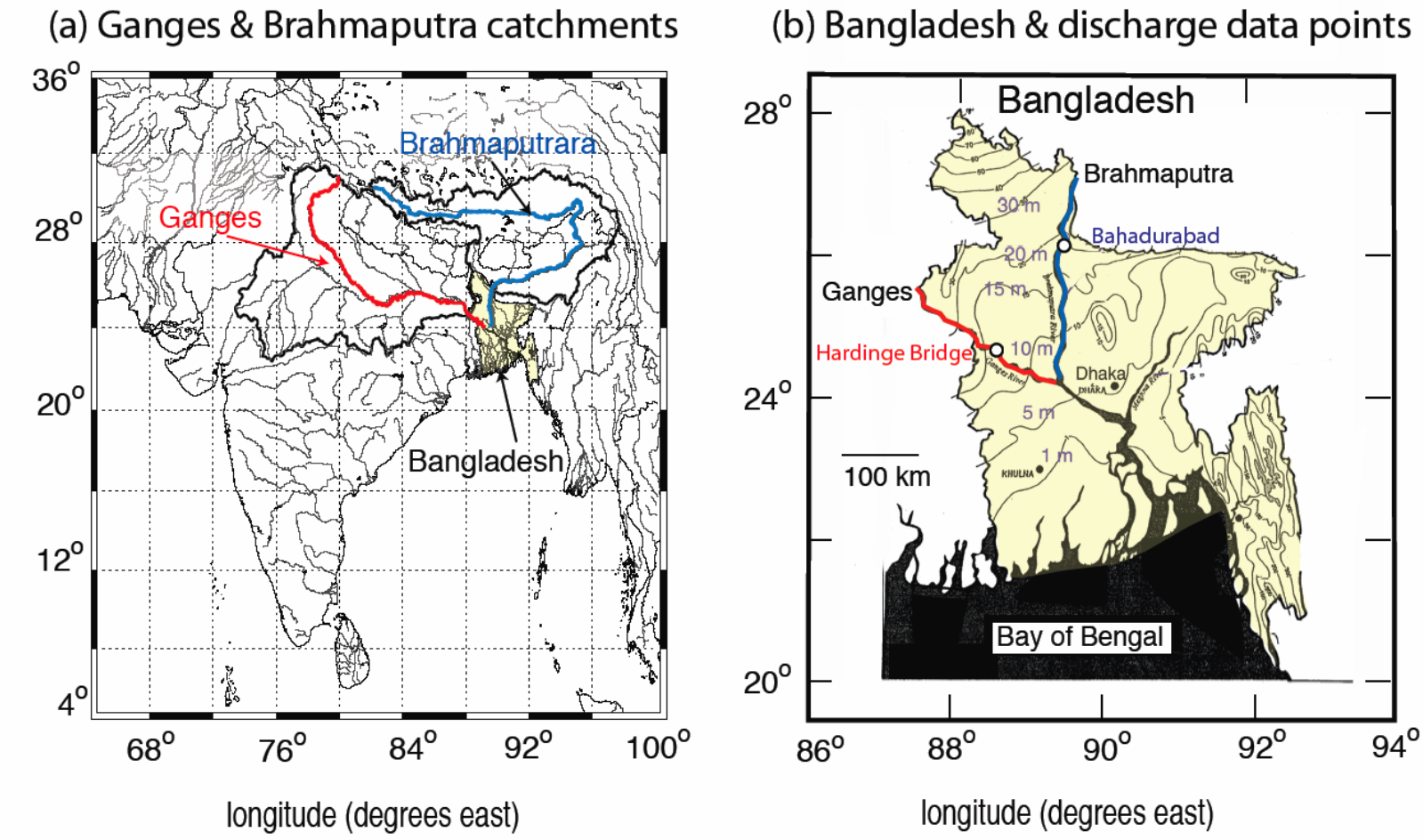
http://pjw.eas.gatech.edu

Overview:

- The Bangladesh situation
- Data issues:
  - Available in situ data
  - Forecast versus in situ information
- Why probabilistic forecasts for Bangladesh
- 3-tierred overlapping forecast system
- Ganges and Brahmaputra forecasts for 2003 and 2004
- Seasonal and medium range forecasts for 2007
- Use of the 2007 forecasts
- Extensions

SITUATION:

- Ganges and the Brahmaputra exist within two of the largest catchment basins in the world



The Project:

- Following the disastrous 1998 flooding in Bangladesh when, without warning, flooding from both the Ganges and Brahmaputra covered 60% of Bangladesh for 3 months, the Bangladesh project was instigated.
- Also motivated by shorter term flooding that occurs most years but with sufficiently irregularity to be very disruptive
- India provides no upstream data to Bangladesh
- Bangladesh, like India has today, had only a 2-day river forecast horizon
- Purpose, extend the 2-day forecasts produced by the Government of Bangladesh to 1-10 days, 20-30 days and seasonal.
- Partnership with ECMWF and GoB

3-tiered forecasting

Provide: Overlapping forecasts that to allow both strategic and tactical decisions for disaster mitigation, water resource management and agricultural optimization:

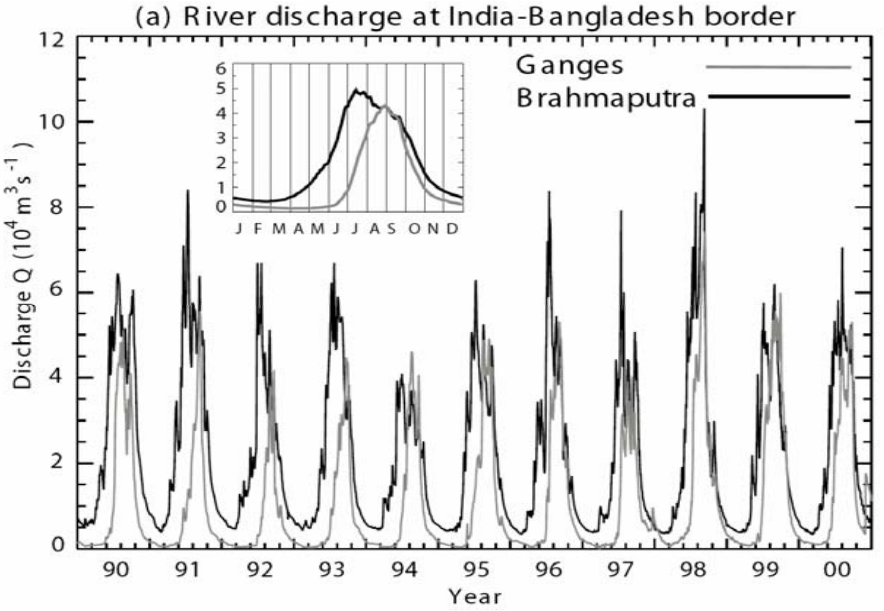
Seasonal:	1-6 months	STRATEGIC
Intraseasonal:	15-30 days	STRATEGIC/TACTICAL
Short-term:	1-15 days	TACTICAL

Produce: A system that takes developed world technologies and interfaces them with the needs and abilities of developing world infrastructures

Probabilistic forecasts to allow proper risk assessment

A system that is useable and adaptable throughout the developing world

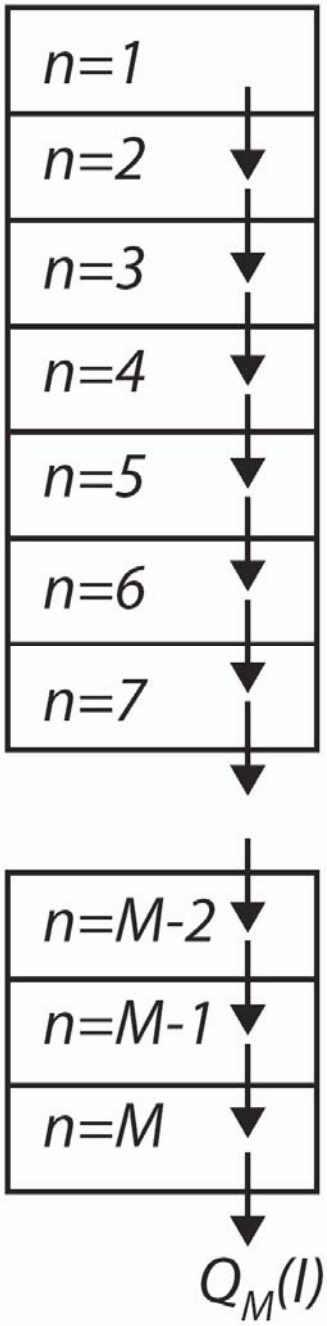
Data Issues:



- Hydrological streamflow data collected at the borders of India and Bangladesh
- Satellite data and derived precipitation products from NASA and NOAA
- ECMWF products (EPS and System 3)

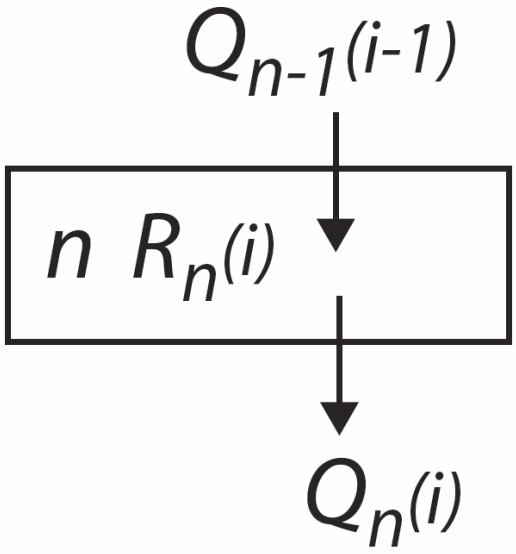
Question: Is it possible to produce forecasts with an absence of data from within the Brahmaputra and Ganges catchments?

This will turn out to depend on the length of the forecast and the size of the basin.



Consider a simple linear catchment system consisting of *M* equally area 1-day sub-basins

sub-basin budget day *i* :

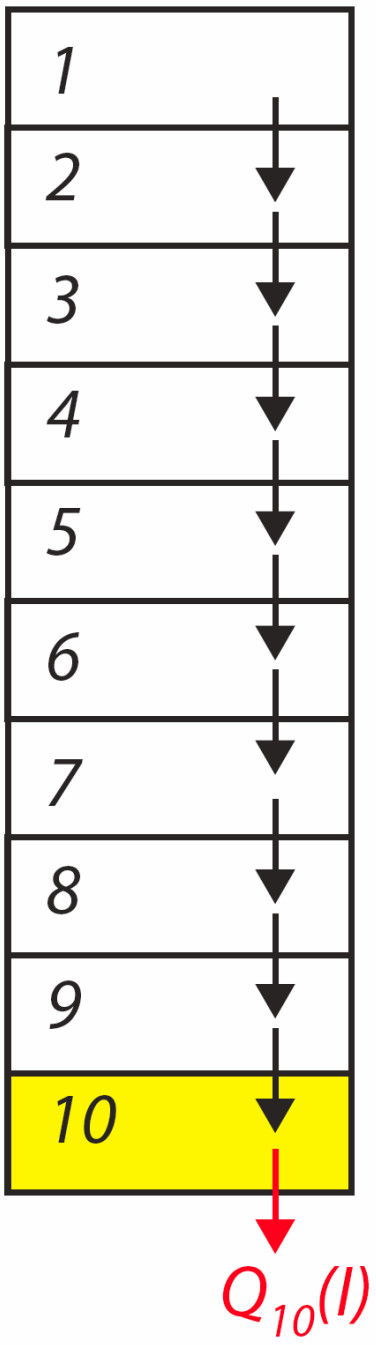


sub-basin discharge:

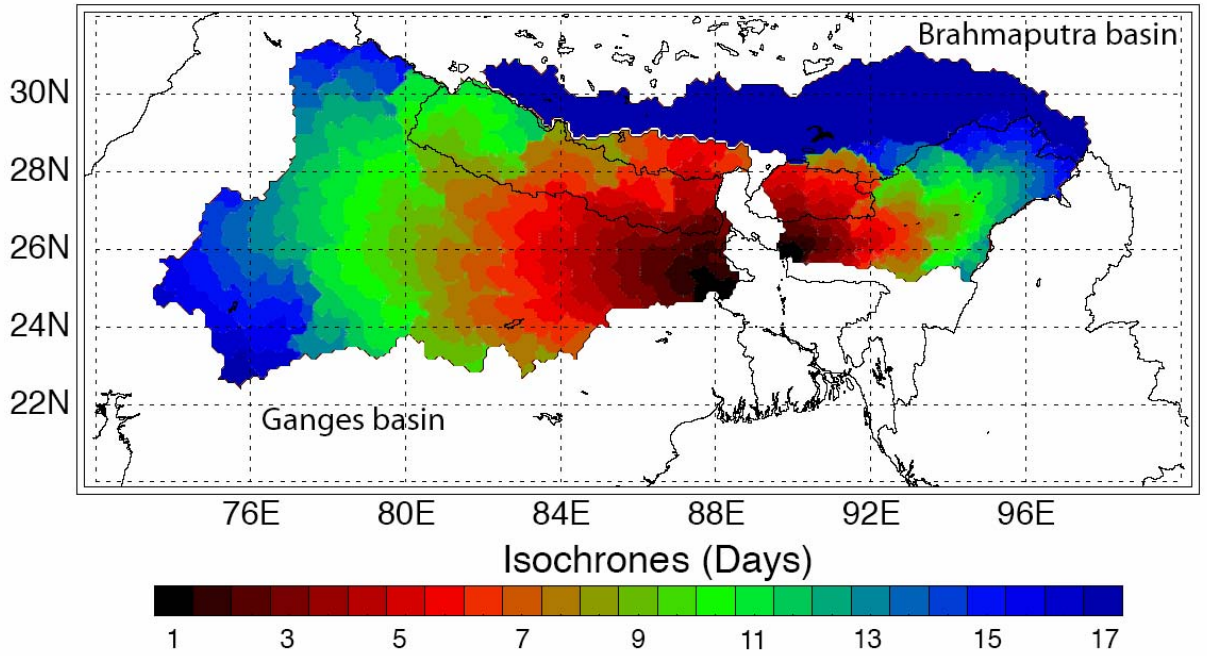
$$Q_n(i)=R_n(i)+Q_{n-1}(i-1)$$

sub-basin rainfall:

$$R_n(i)=\int_A \frac{P_n(i)+P_n(i-1)}{2}dA$$



Assume an *M*=10 linear system approximating the Ganges and Brahmaputra



For a given forecast of I days, how important is observed upstream discharge data relative to information that has to be forecast?

Relative importance of in situ versus forecasts data in an *M*=10 basin in a 1-(>*M*) day forecast

In general: $$Q_{10}(I) = \left[\sum_{i=0}^{I-i} R_{10-i}(I-i)\right] + Q_{10-I}(0)$$

forecast | observed

1-day forecast: $I = 1$: $Q_{10}(1) = R_{10}(1) + Q_9(0)$ [50% forecast, 50% in situ]

2-day forecast: $I = 2$: $Q_{10}(2) = R_{10}(2) + Q_9(1)$

$= R_{10}(2) + R_9(1) + Q_8(0)$ [66% forecast, 33% in situ]

. . . . . .

9-day forecast: $I = 9$: $Q_{10}(9) = R_{10}(9) + R_9(8) + ...R_8(1) + Q_2(0)$ [90% forecast, 10% in situ]

10-day forecast: $I = 10$: $Q_{10}(10) = \left[\sum_{i=0}^{10-i} R_{10-i}(10-i)\right]$ [100% forecast, 0% in situ]

In summary: For extended prediction of discharge, in situ data provides increasingly less information compared to forecasts. Degree of importance of in situ/predictions depends on how important precipitation is in basin

Probabilistic forecasting and the developing world: A conversation (January 2003)

PJW: We hope to provide you with seasonal forecasts to help you plan your agricultural activities

HUSSEIN: That would be good.

PJW: But we will not always be correct: Perhaps 7 times out of 10.

HUSSEIN: (after some thought): That is fine. Only God knows 100% what will happen and you are not God!

Riight now, we guess each year and that means we are right as often as wrong.

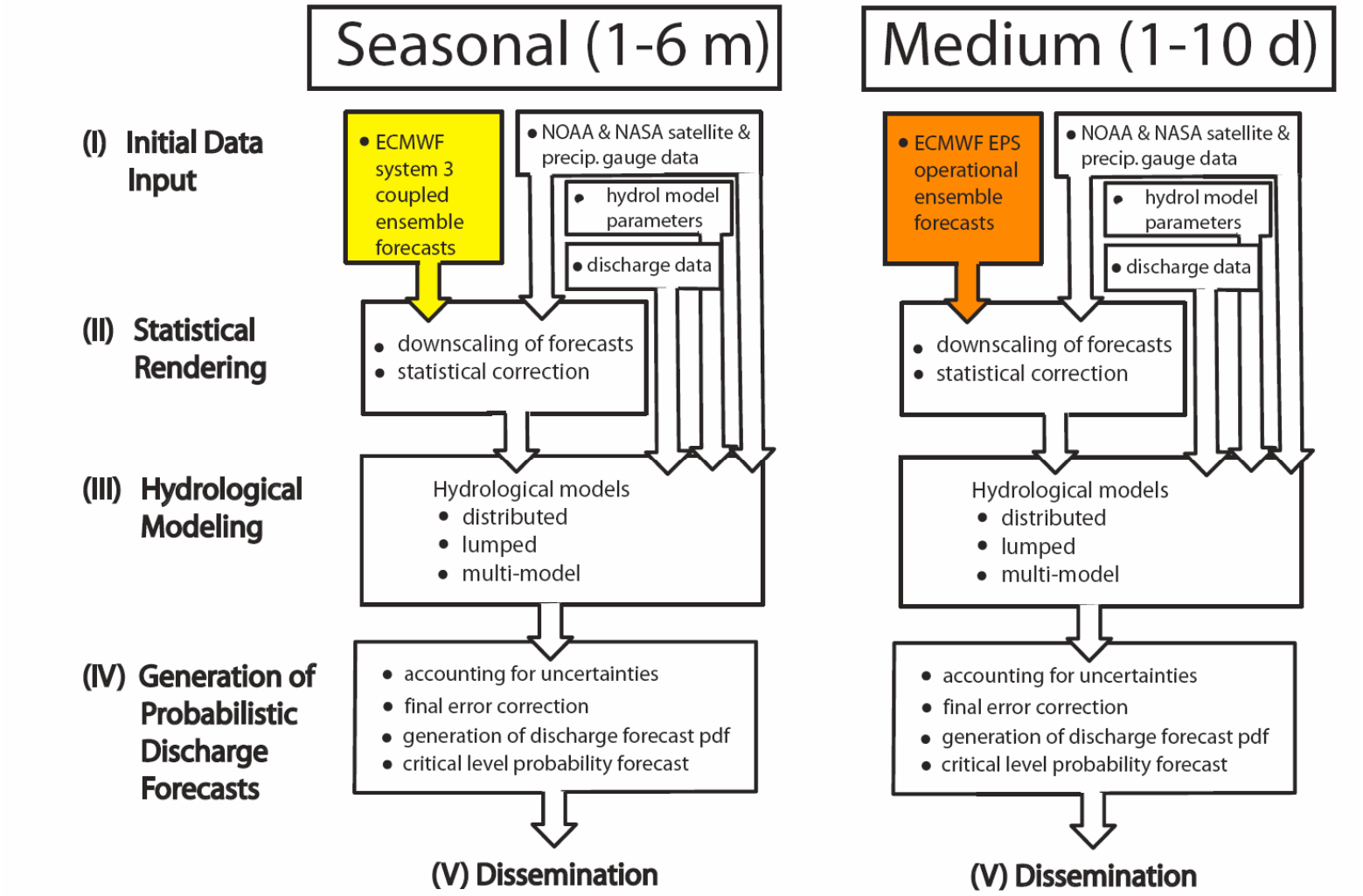
70% means I am ahead!

Data Conclusions:

- Very short-term forecasts would benefit from Indian data
- Ganges and Brahmaputra basins have to be treated as ungauged. (Largest ungauged basins on planet!)
- Extended forecasts needed to allow anticipation of flooding for evacuation and minimization of impact.
- Extended forecasts require very good precipitation forecasts
- To obtain estimates of precipitation out to 10 days (or for seasonal time scales) requires considerable statistical rendering and use of auxiliary data

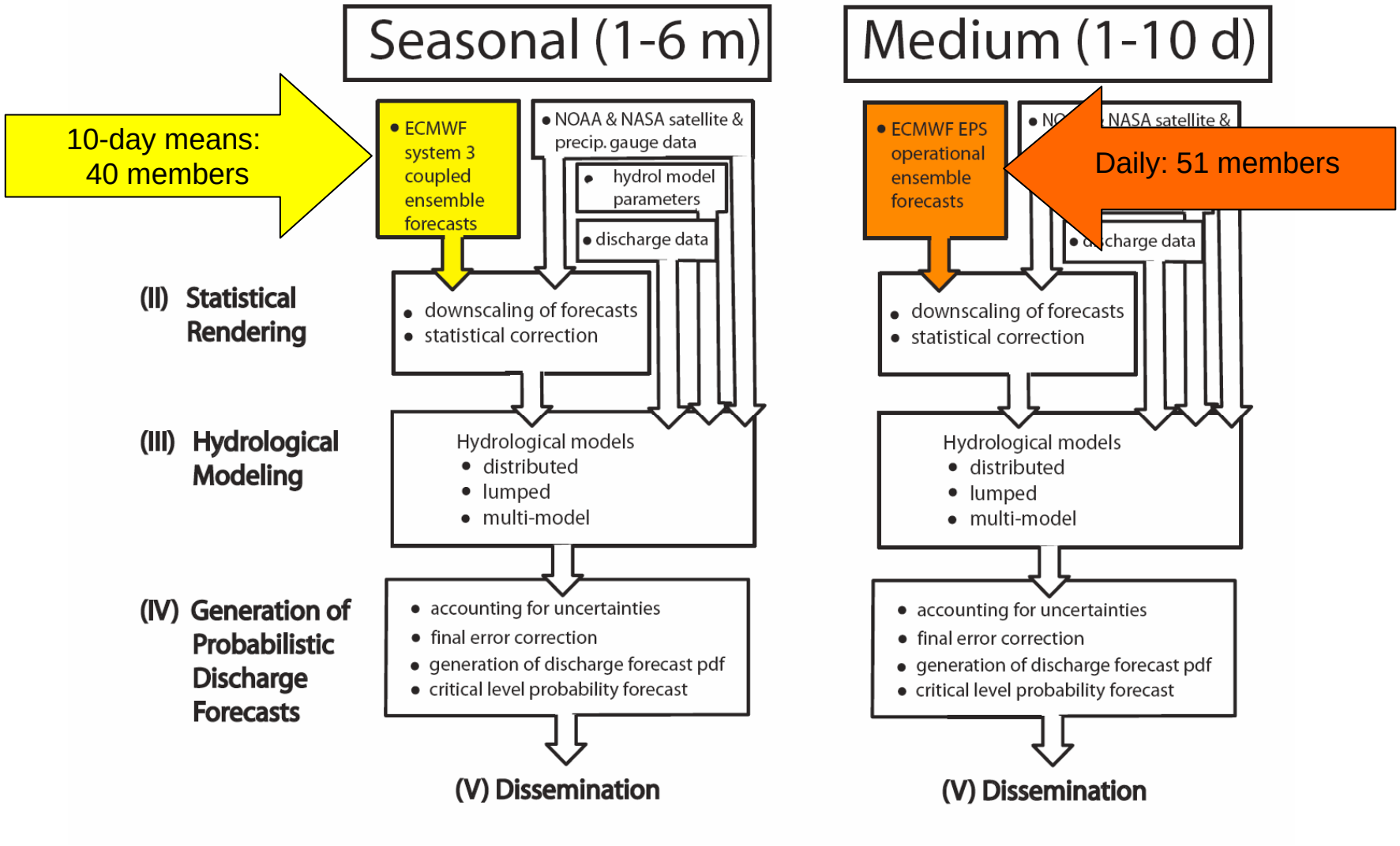
Discharge Forecast Schemes:

Hopson & Webster 2007a
Hopson & Webster 2007b
Webster et al. 2007



Seasonal and medium-range schemes are essentially the same, differing in details not discussed here (Hopson & Webster 2007a,b)

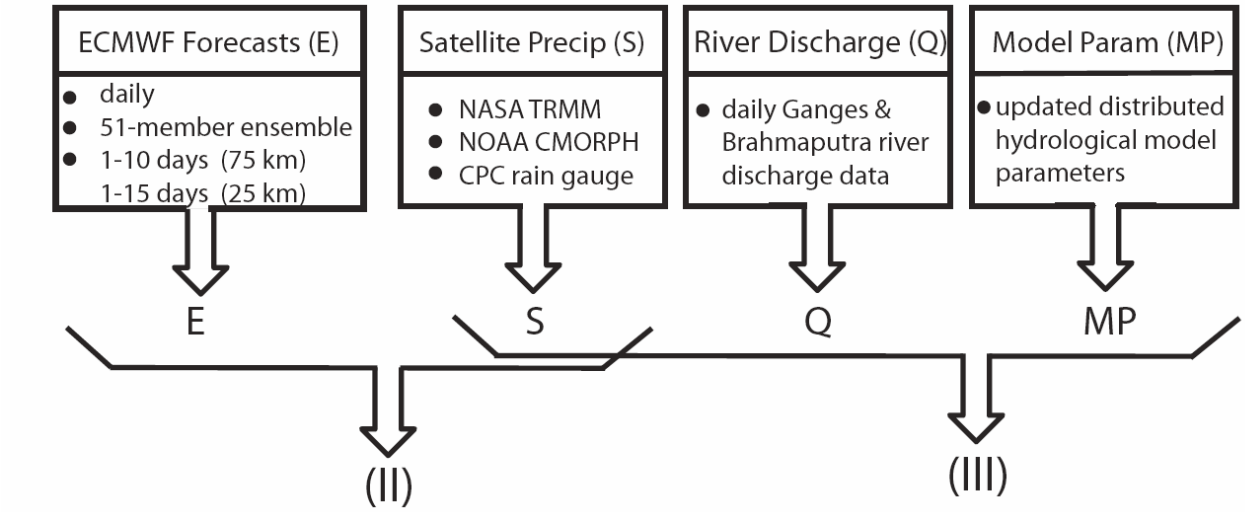
Discharge Forecast Schemes:

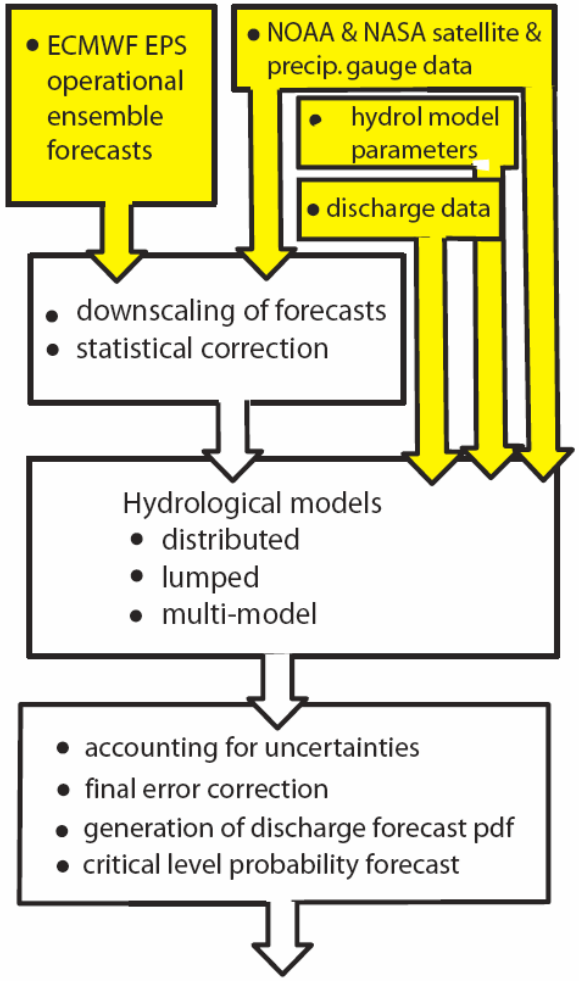


Seasonal and medium-range schemes are essentially the same, differing in details not discussed here.

Details of the initial data

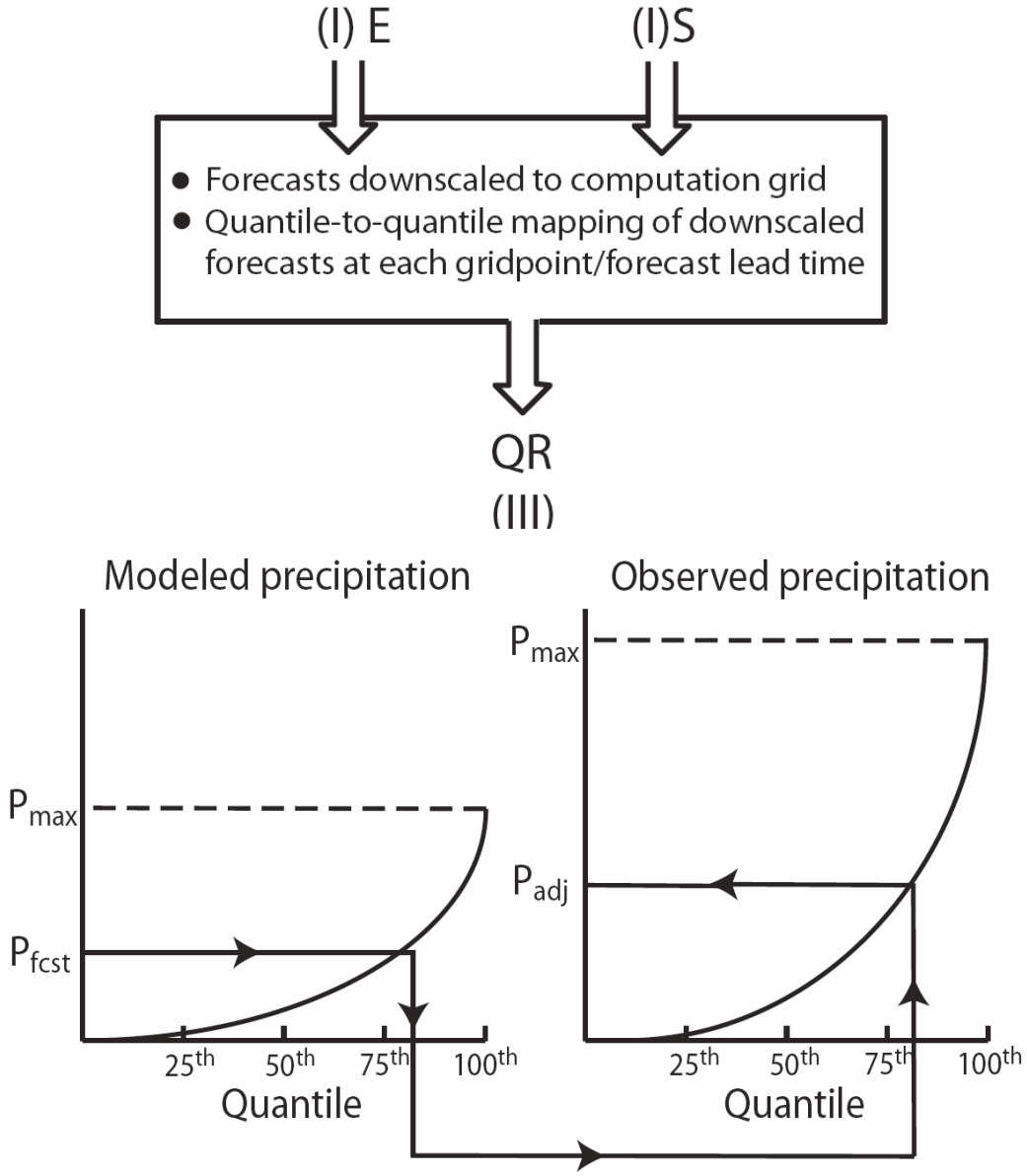
Initial data comes from a number of sources and is used to either drive the forecasts (e.g.,ECMWF EPS), correct the forecasts and provide calibration of the basin discharge



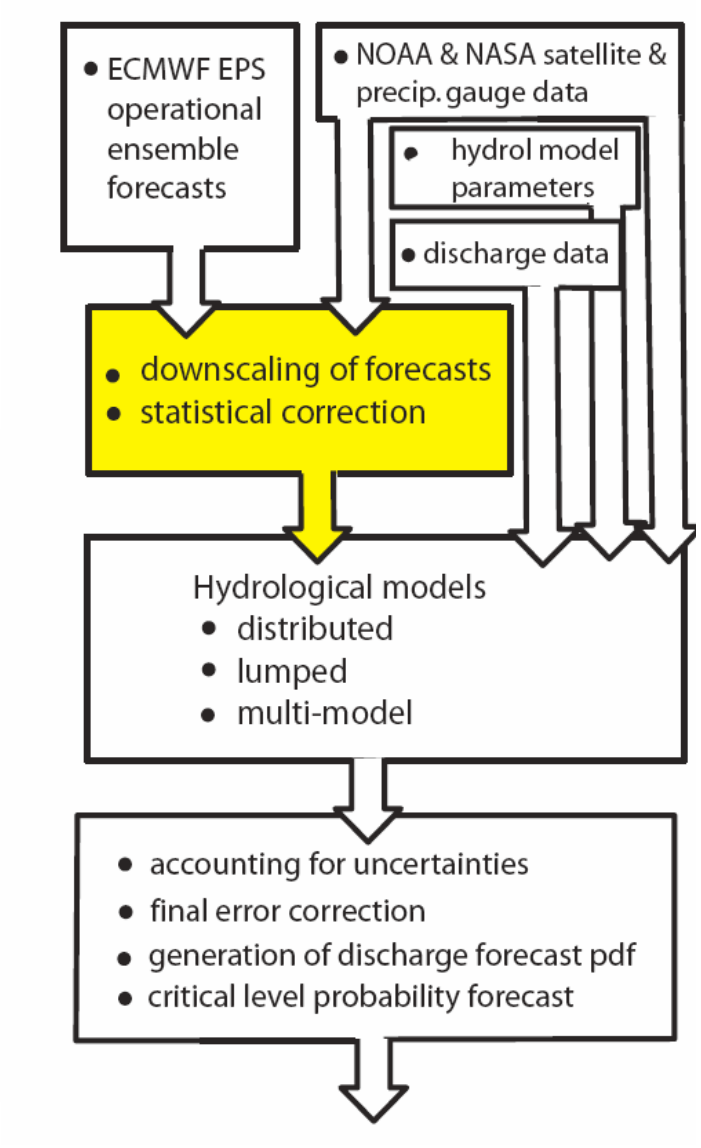


Data is passed on for statistical rendering and to force the hydrological models

Statistical Rendering: Correction of EPS systematic error

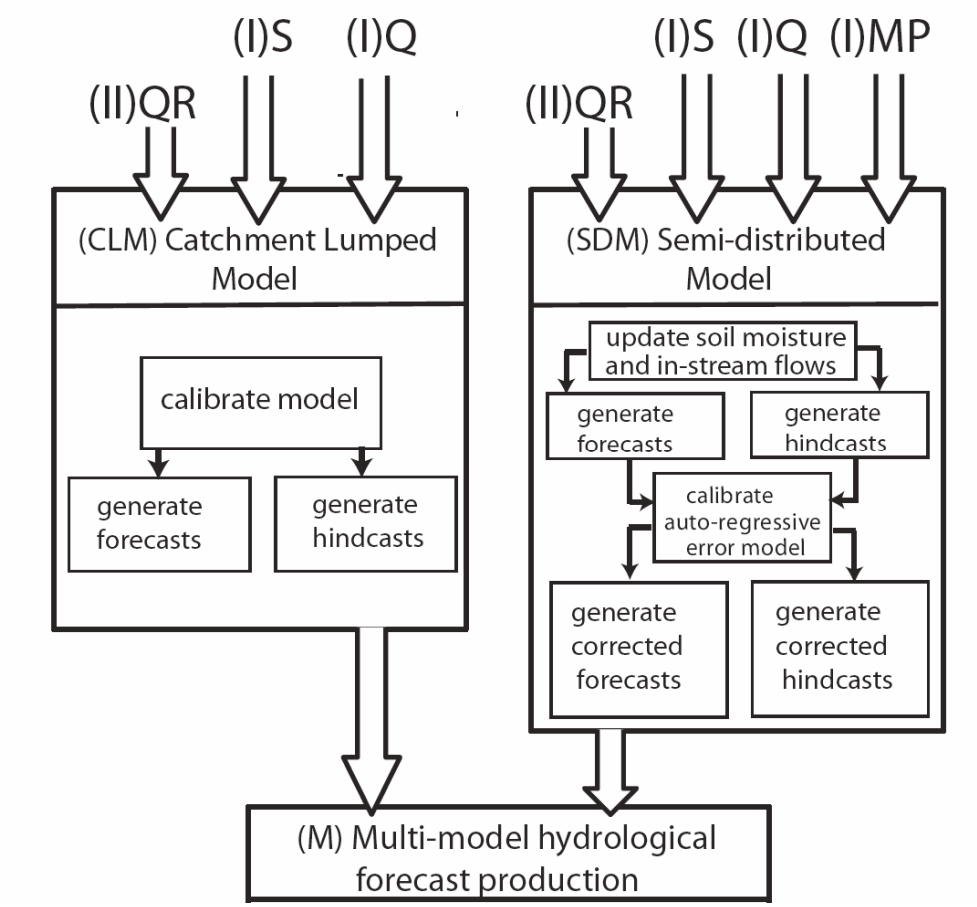


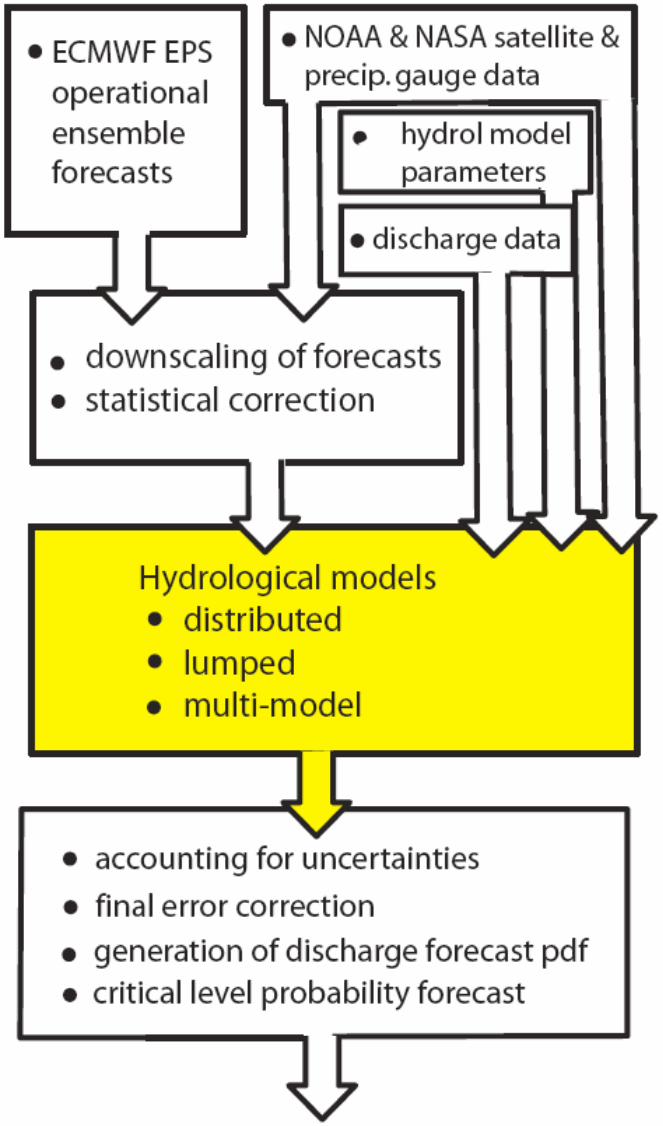
Quantile to quantile correction of model ppt



Hopson & Webster 2007a

Details of the hydrological model

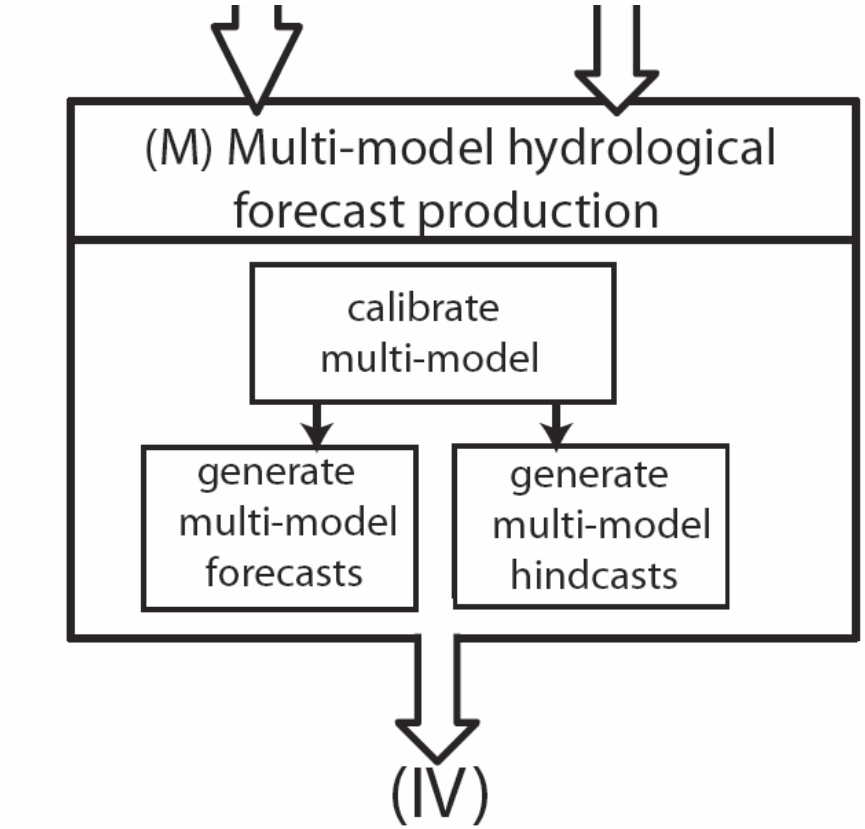




Hopson & Webster 2007b

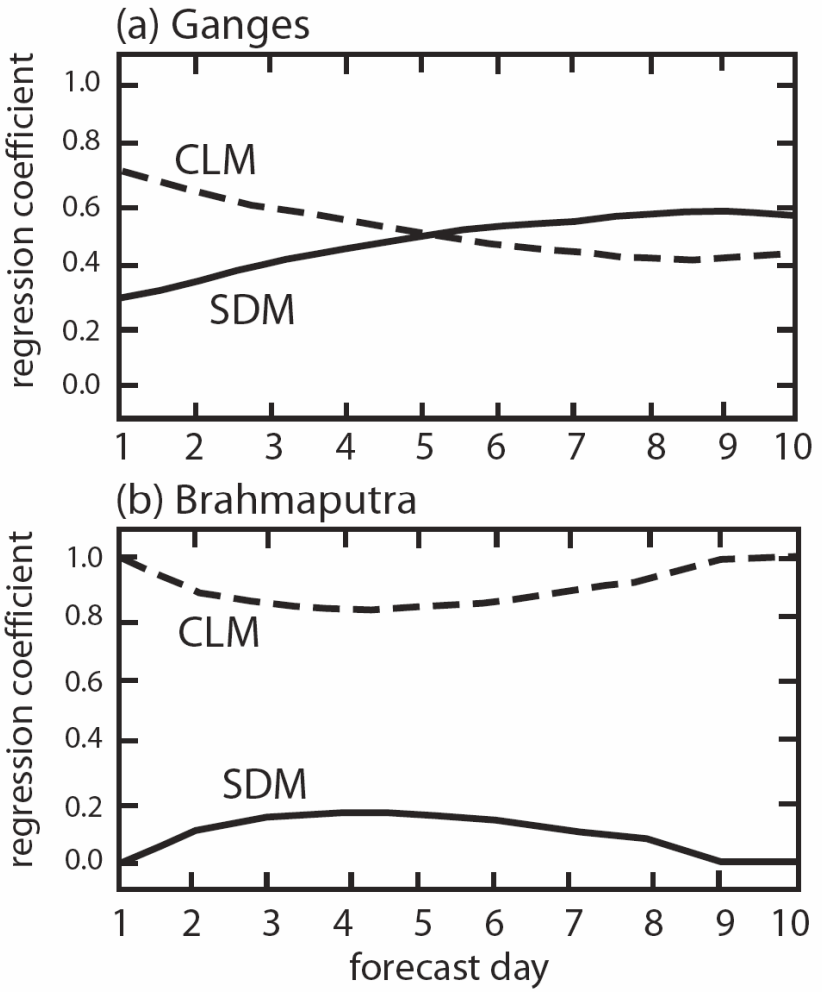
The Multi-Model Hydrology System:

Hopson & Webster 2007a

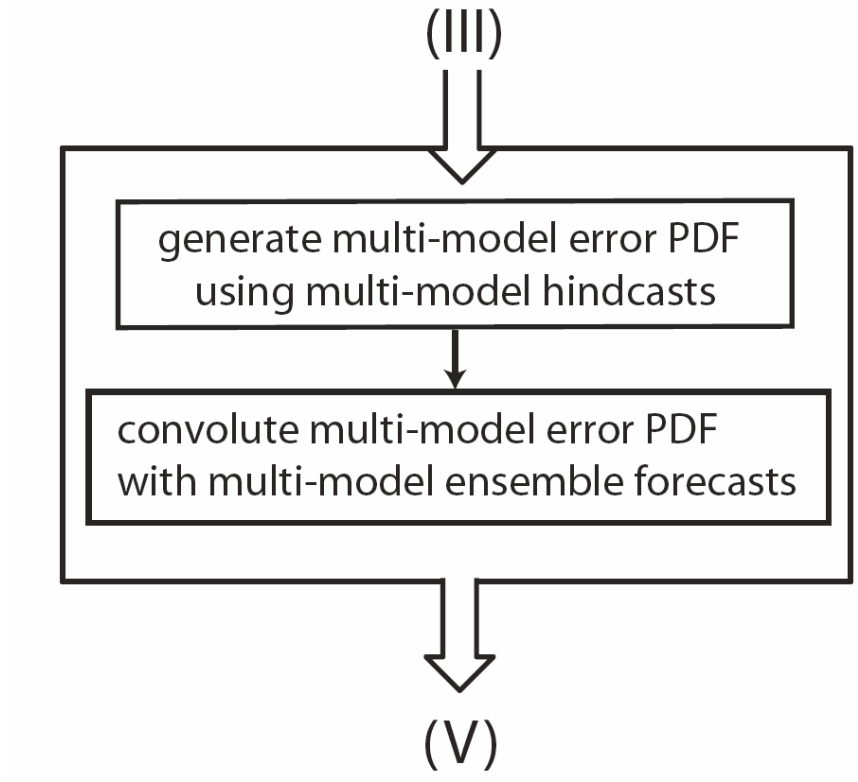


Hydrological models behave differently depending on basin characteristics or meteorological situations. Multi-model allows possibility of daily switching

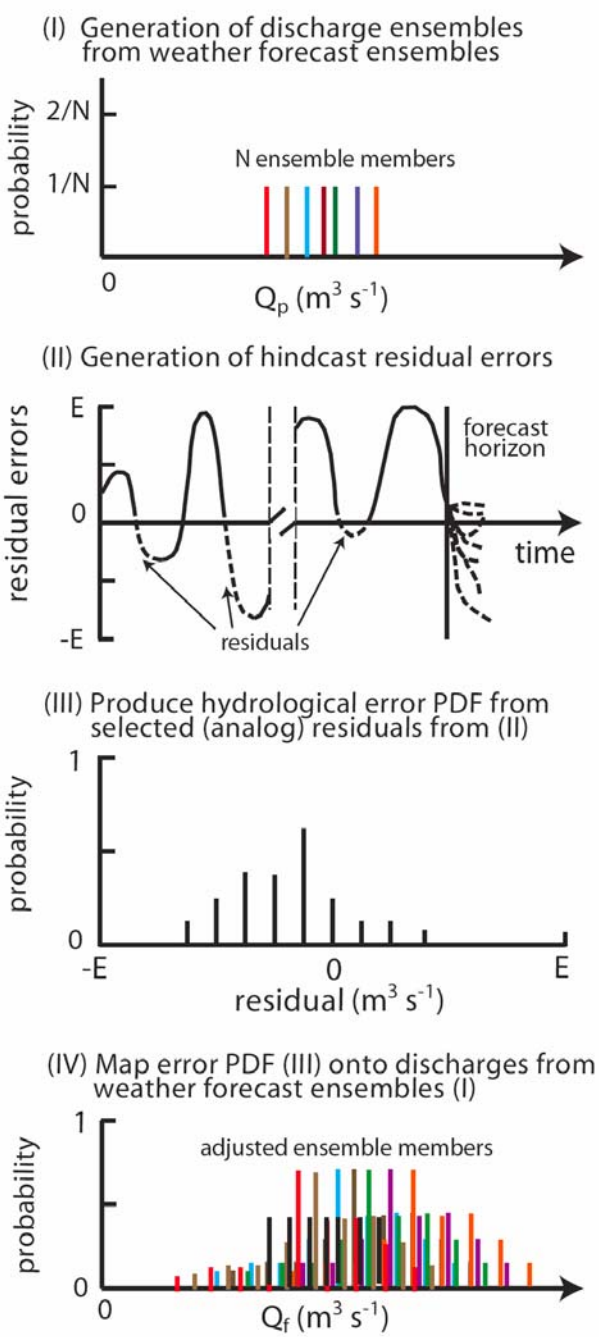
Comparison of the two models (clumped and distributed) against observations and lead-time



Final corrections and use of analogues



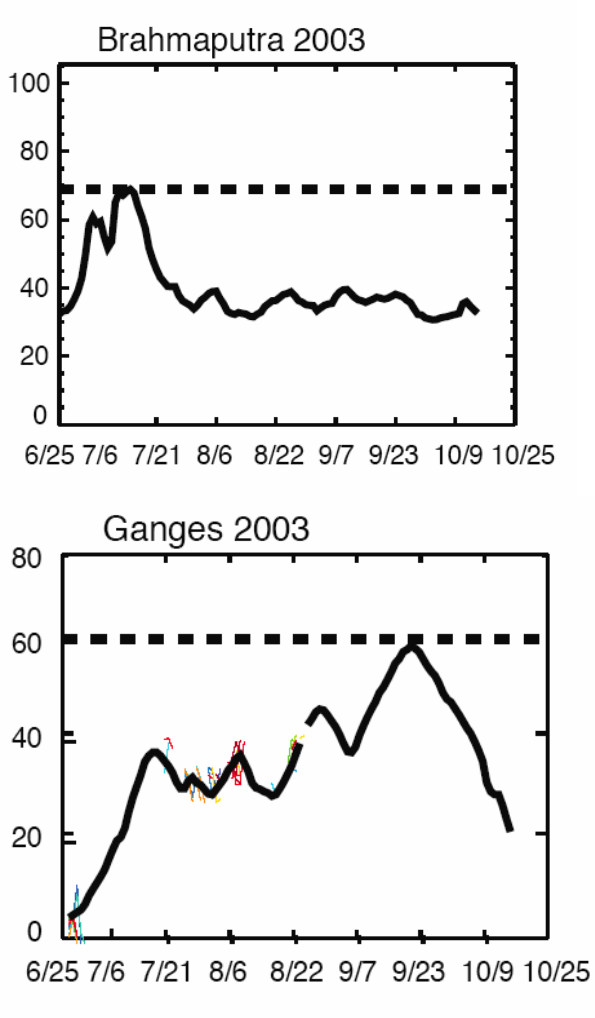
System uses analogues from hindcasts and past data to make a final correction to system



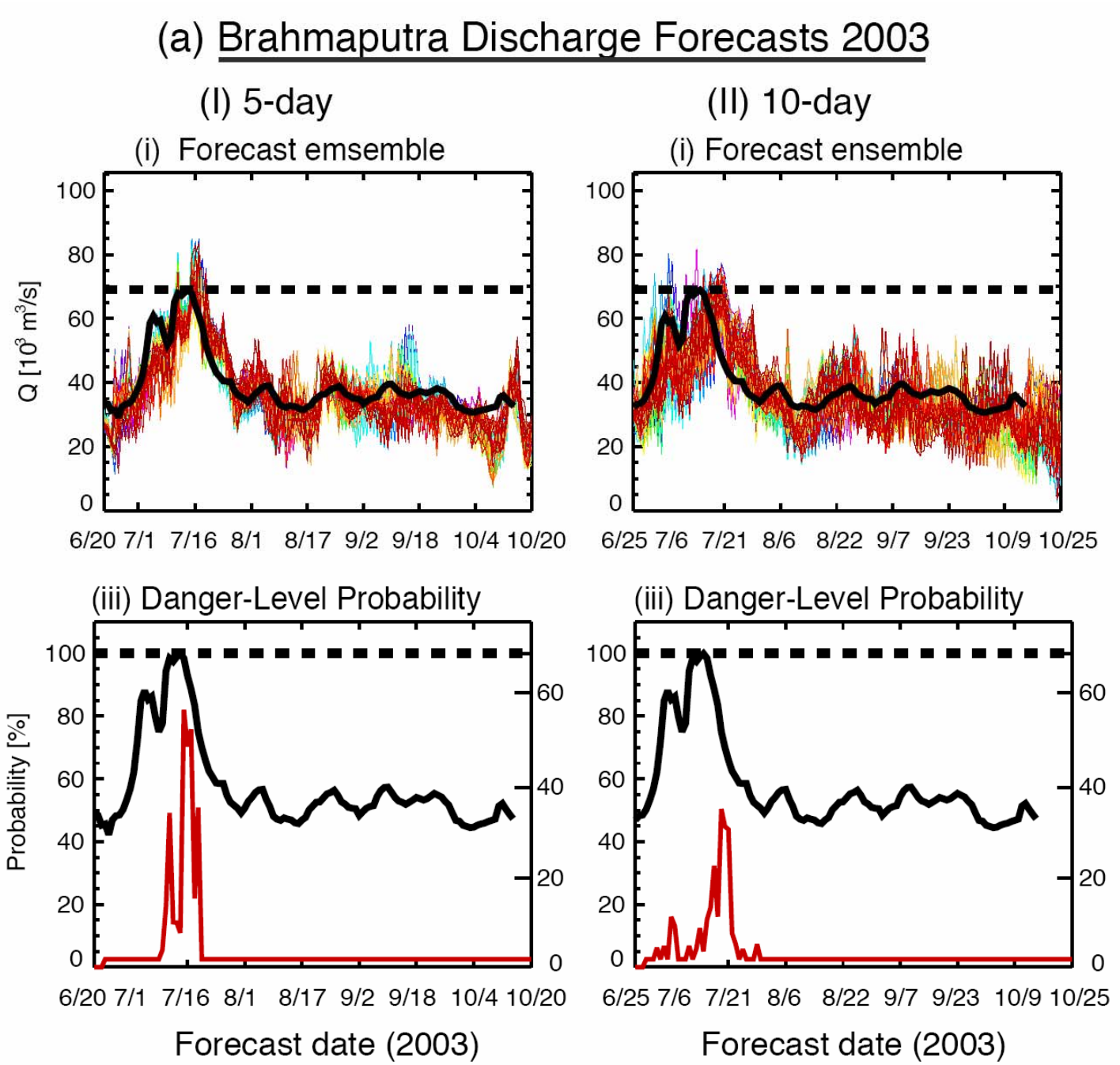
Hopson & Webster 2007a

2003 Forecasts (Quiet year)

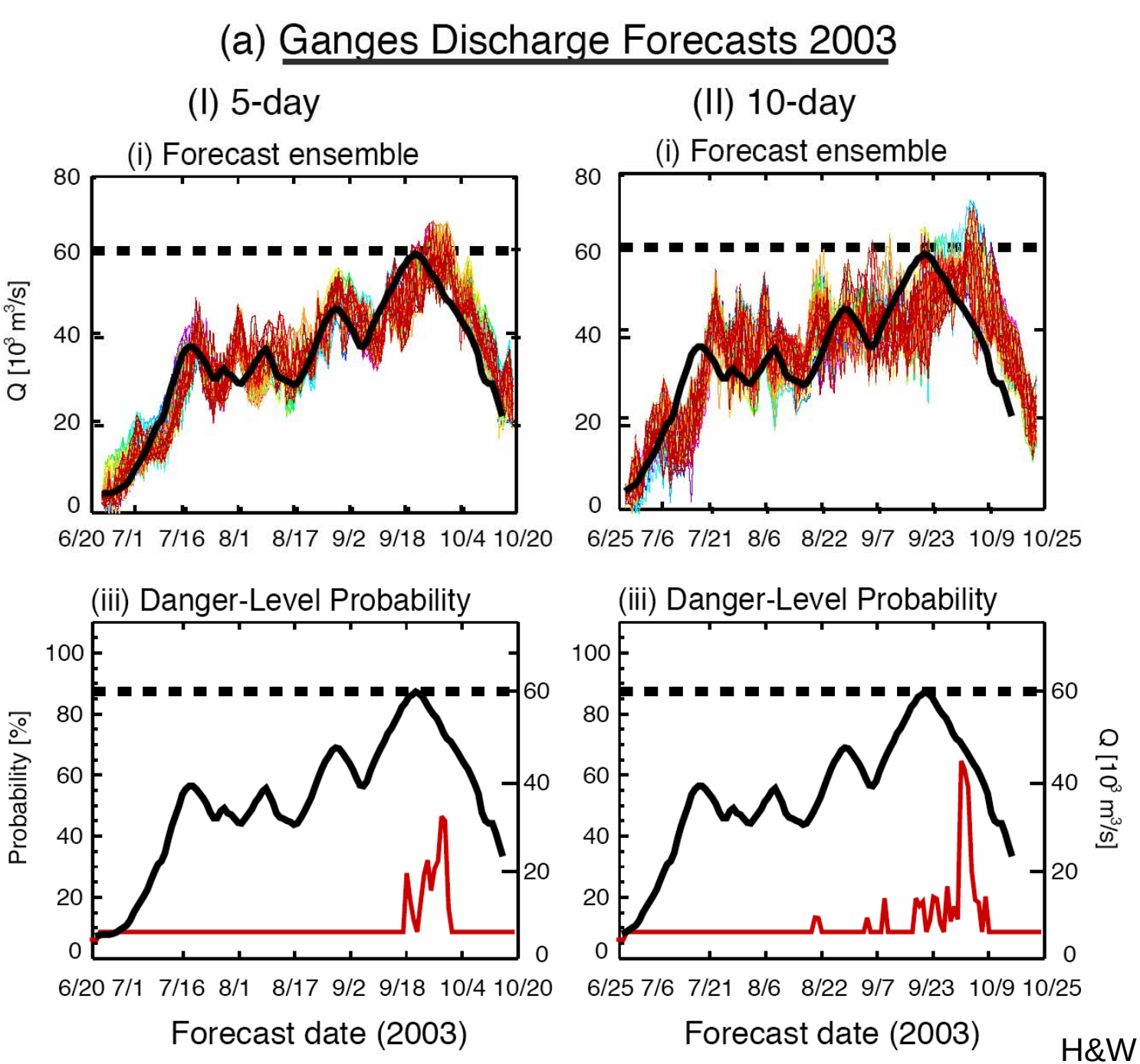
- No flooding in either Ganges or Brahmaputra
- Early rising of the Brahmaputra and late rising of the Ganges
- Only lumped catchment model was used
- Final error correction system introduced in medium range system
- Seasonal system under development



http://cfab2.eas.gatech.edu


(a) Brahmaputra Discharge Forecasts 2003
(I) 5-day
(II) 10-day
(i) Forecast emsemble
(i) Forecast ensemble
Q [10³ m³/s]
100
80
60
40
20
0
6/20 7/1 7/16 8/1 8/17 9/2 9/18 10/4 10/20
6/25 7/6 7/21 8/6 8/22 9/7 9/23 10/9 10/25
(iii) Danger-Level Probability
(iii) Danger-Level Probability
Probability [%]
60
40
20
0
Forecast date (2003)
Forecast date (2003)

H&W 20007a


(a) Ganges Discharge Forecasts 2003
(I) 5-day
(II) 10-day
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Q [10³ m³/s]
80
60
40
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0
6/20 7/1 7/16 8/1 8/17 9/2 9/18 10/4 10/20
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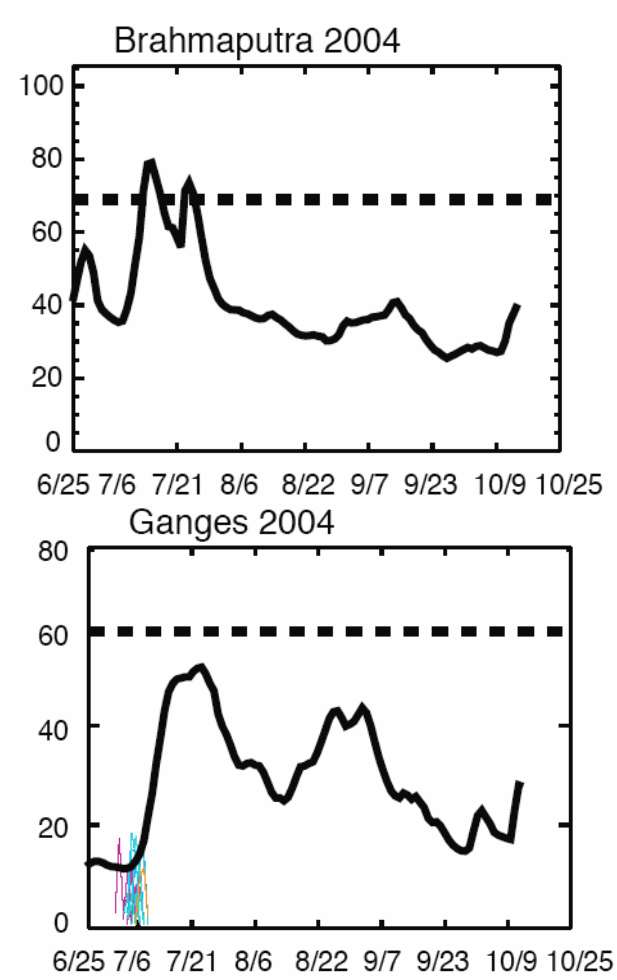
100
80
60
40
20
0
60
40
20
0
Q [10³ m³/s]
Forecast date (2003)
Forecast date (2003)

H&W 20007a

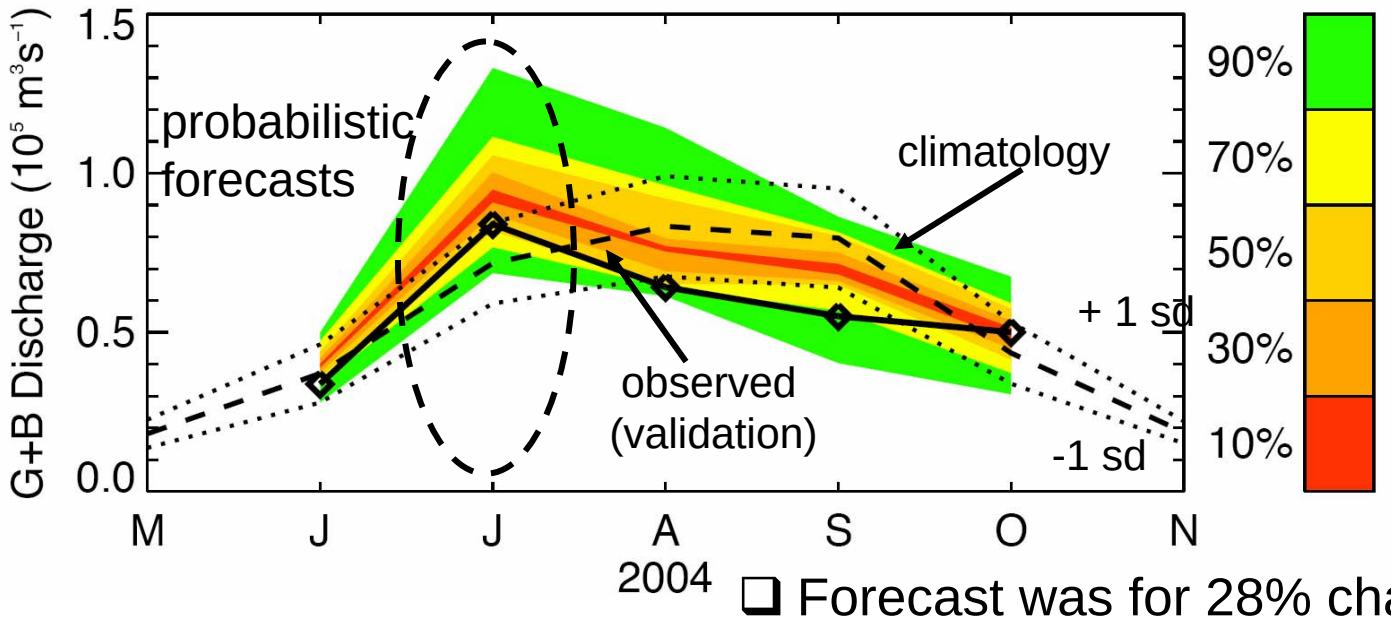
2004 Forecasts (serious July Brahmaputra flooding)

- Extensive flooding of Brahmaputra during July
- Ganges quiet all season
- Distributed catchment model added to lumped catchment model to produce multi-hydrological model
- Seasonal system introduced but was used to provide combined Brahmaputra+Ganges forecast

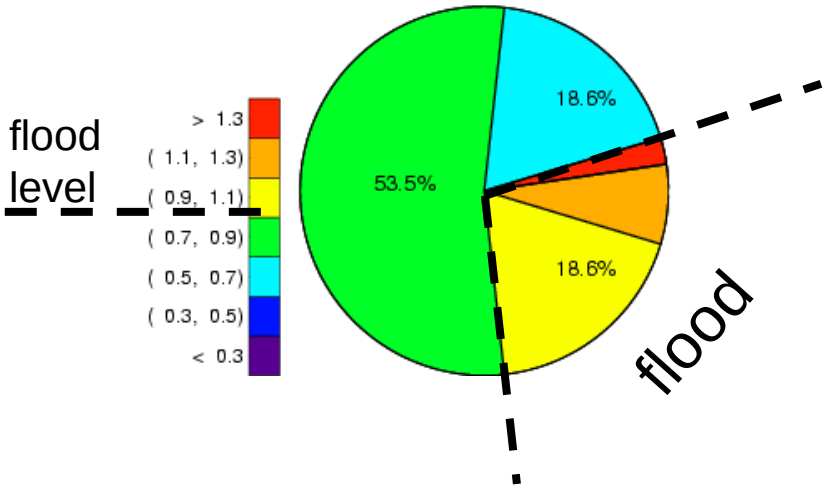


http://cfab2.eas.gatech.edu

2004: Seasonal (1-6 months) Ganges/Brahma forecast

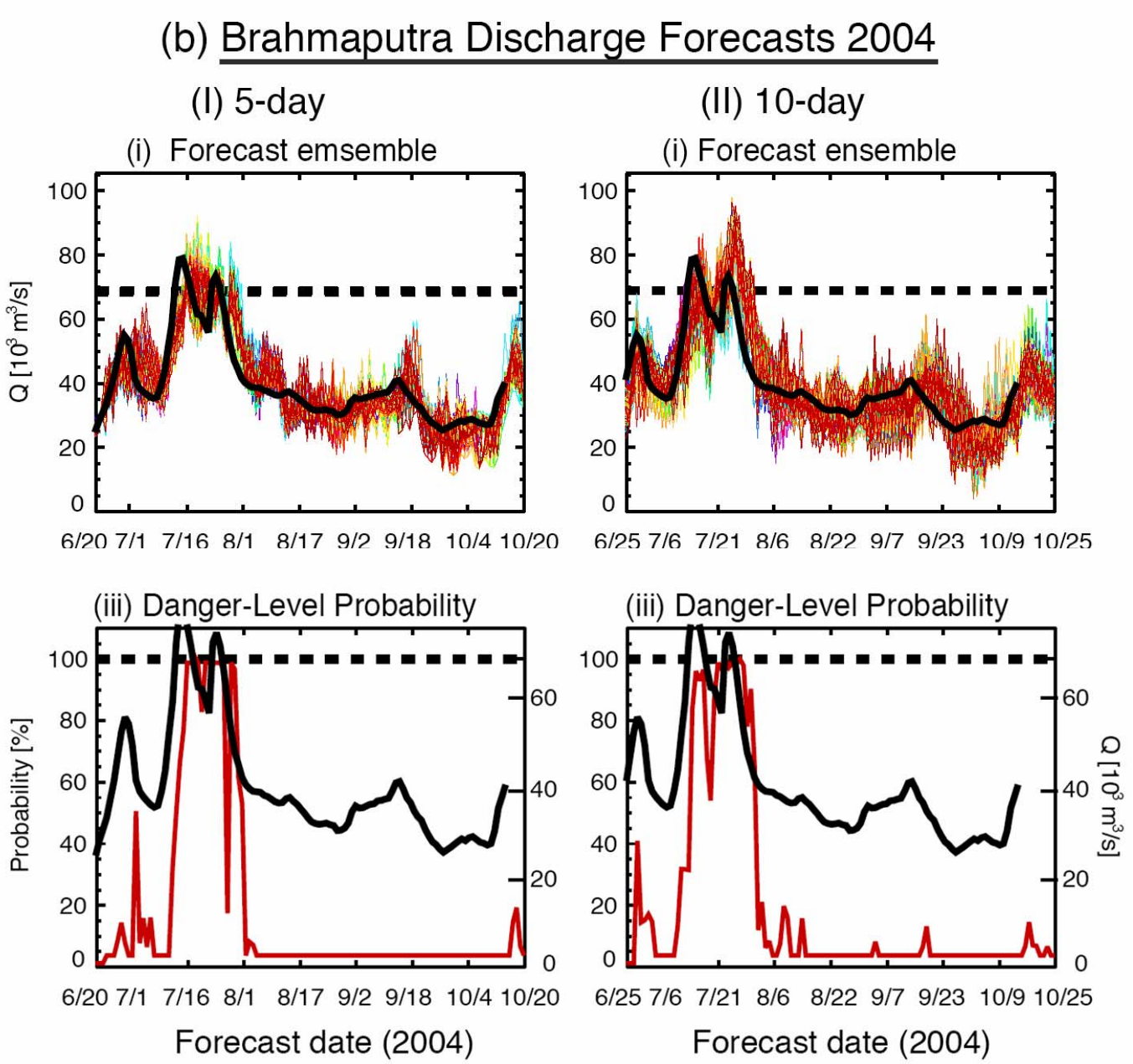


May forecast for July



- Forecast was for 28% chance of flooding over entire month of July with risk reducing thereafter.
- 28% chance of flood for entire month translates to very high probability of shorter term floods. But diffiucult to differentiate between G&B.

(More on downscaling later)


(b) Brahmaputra Discharge Forecasts 2004
(I) 5-day
(II) 10-day
(i) Forecast emsemble
(i) Forecast ensemble
Q [10³ m³/s]
100
80
60
40
20
0
6/20 7/1 7/16 8/1 8/17 9/2 9/18 10/4 10/20
6/25 7/6 7/21 8/6 8/22 9/7 9/23 10/9 10/25
(iii) Danger-Level Probability
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Probability [%]
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60
40
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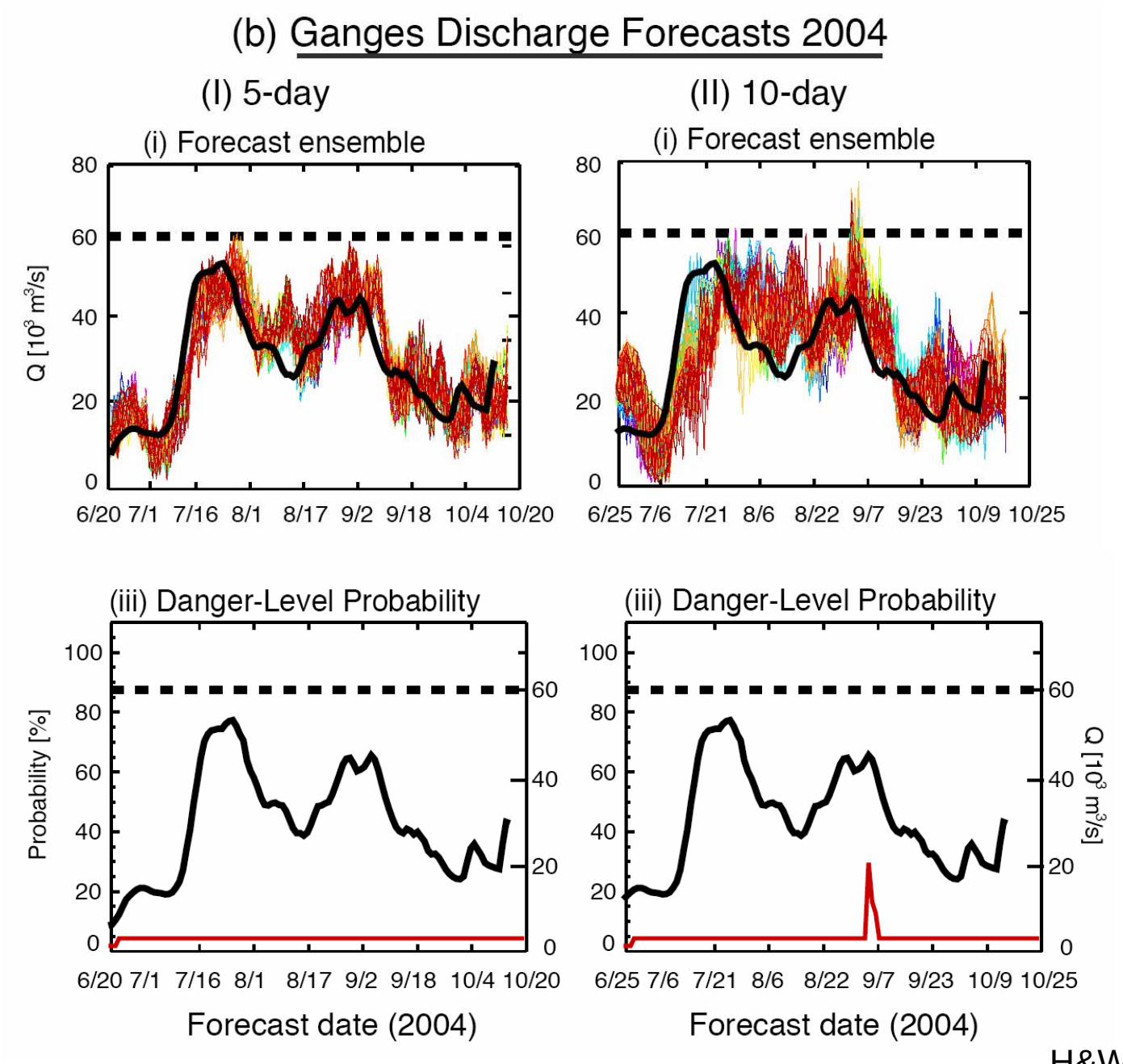
0
Forecast date (2004)
Forecast date (2004)

H&W 20007a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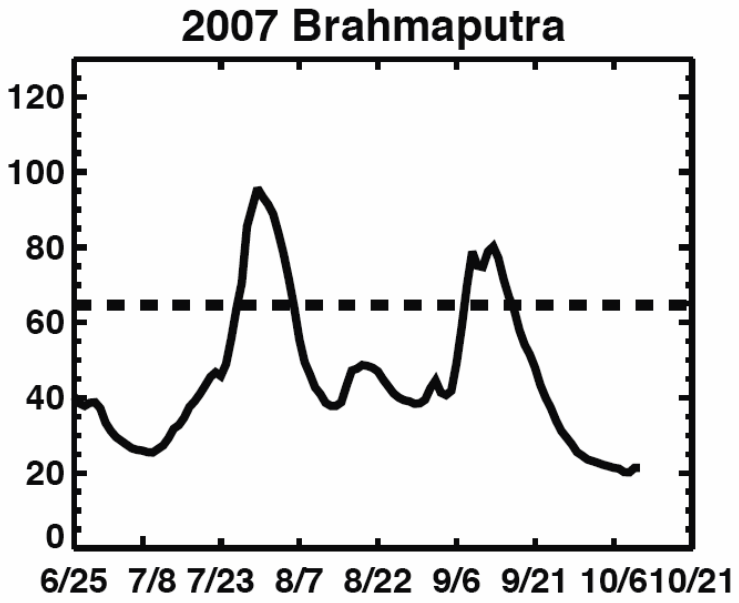
6/25 7/6 7/21 8/6 8/22 9/7 9/23 10/9 10/25
Forecast date (2004)
Forecast date (2004)

H&W 20007a

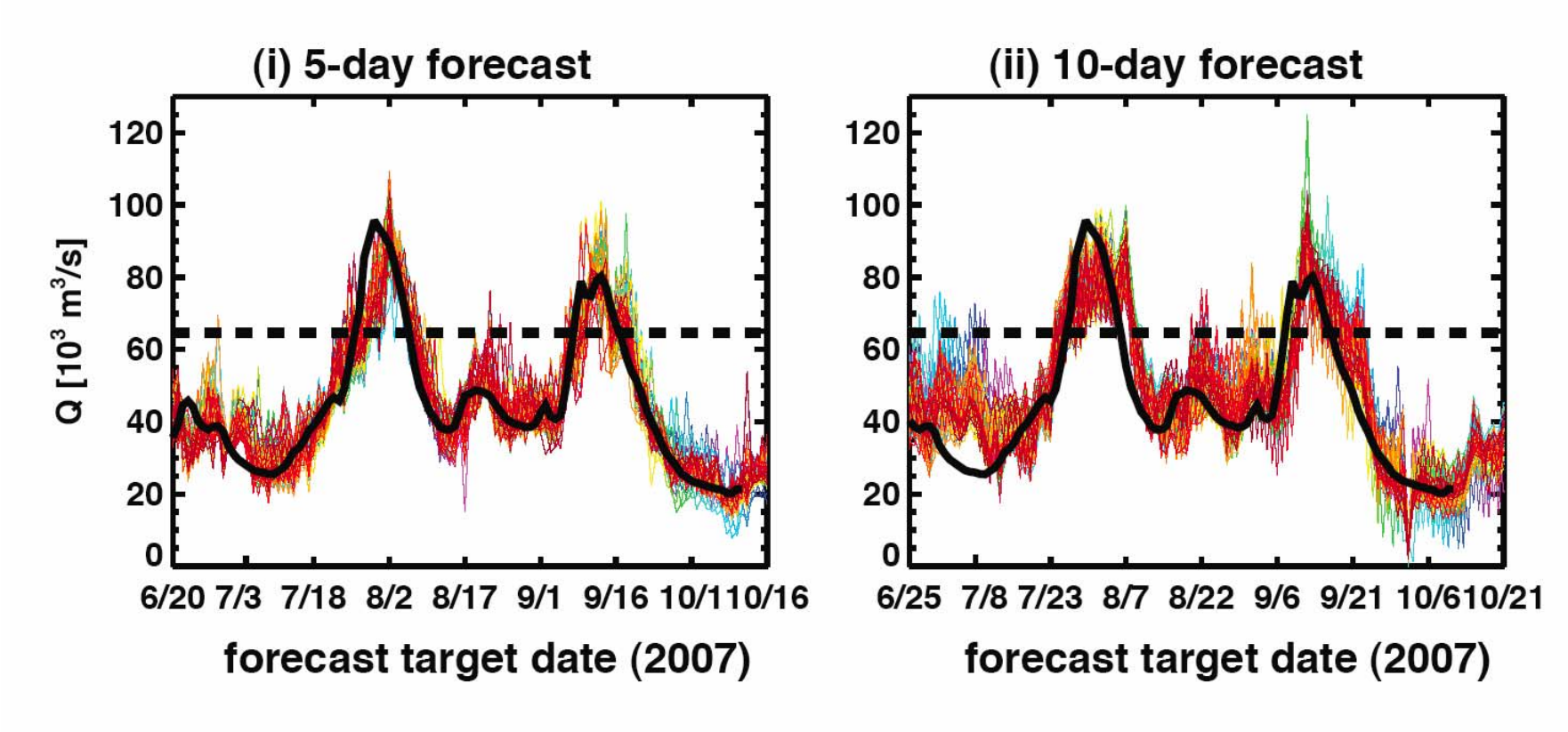
2007 Forecasts (2 periods of extensive Brahmaputra flooding)

- Extensive flooding of Brahmaputra during July/August and September
- Ganges quiet all season
- Seasonal system issues both Ganges and Brahmaputra forecasts.
- Downscaling of seasonal forecasts introduced



http://cfab2.eas.gatech.edu

The 5-day and 10-day Brahmaputra forecasts for 2007

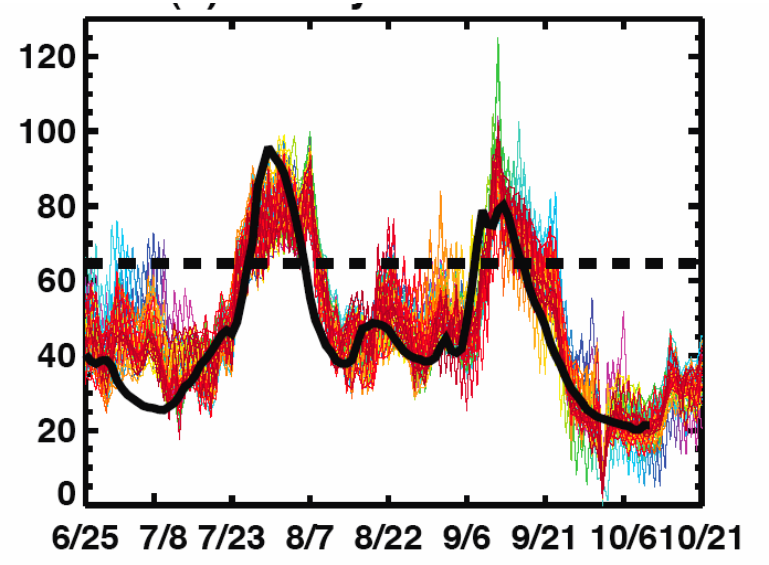


Ganges (which did not flood) are not shown and can be found at http://cfab2.eas.gatech.edu (“short-term”)

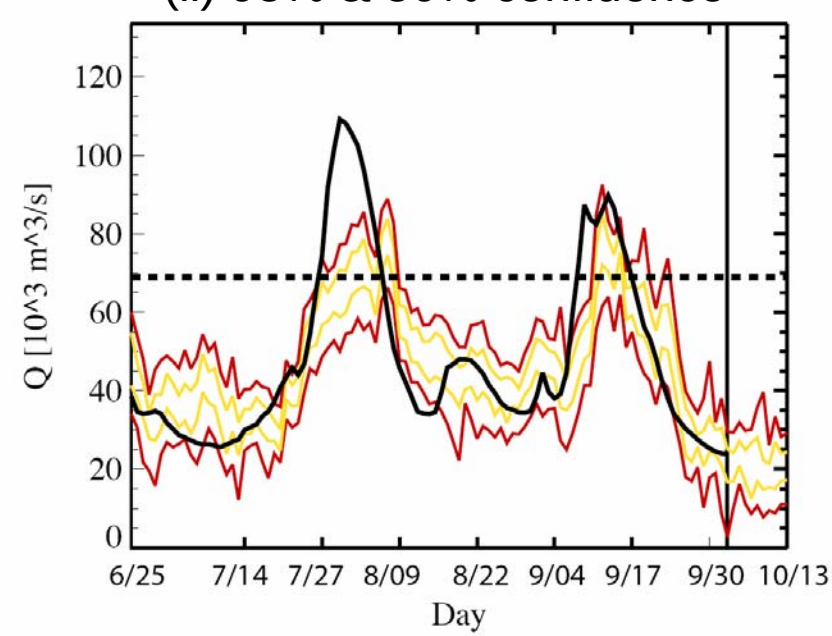
Webster et al. 2007

2007 10-day Brahmaputra Forecast

(i) Forecast ensemble

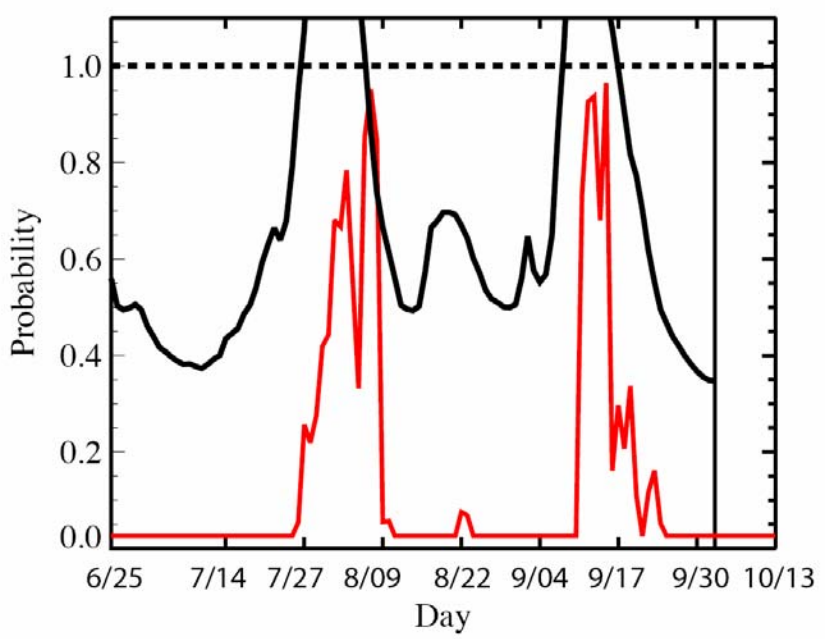


(ii) 95% & 50% confidence

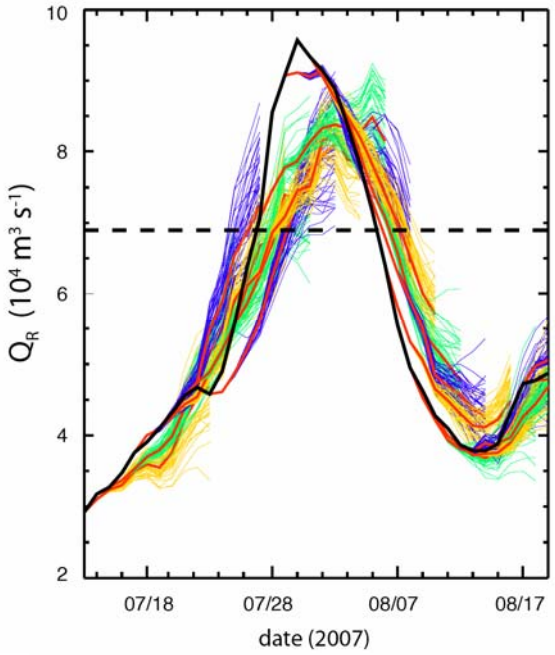


- Both the July-August and September flood events were forecast with some accuracy 10 days ahead.
- For the first time, the national Disaster Emergency Response Group was proactive, evacuating and planning ahead of the flooding

(iii) Danger level probability

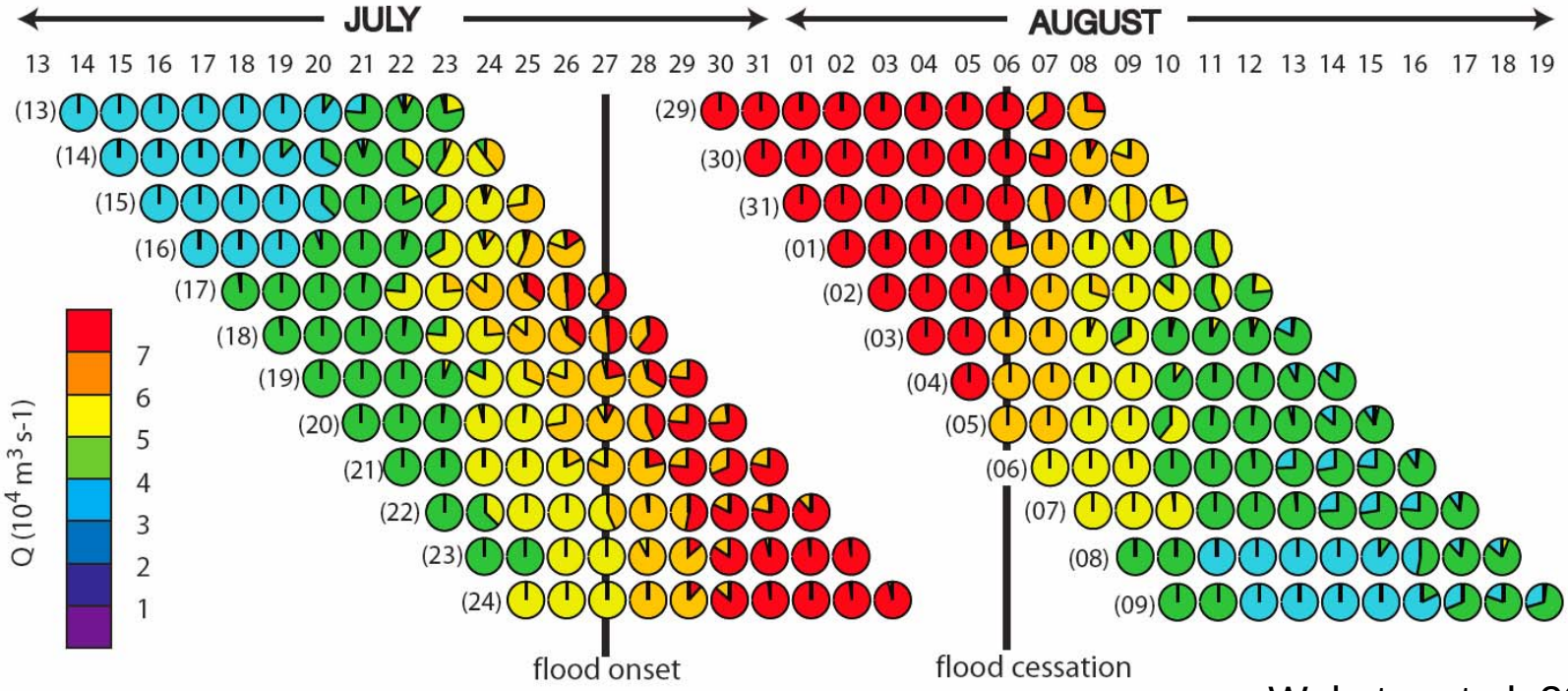


Webster et al. 2007

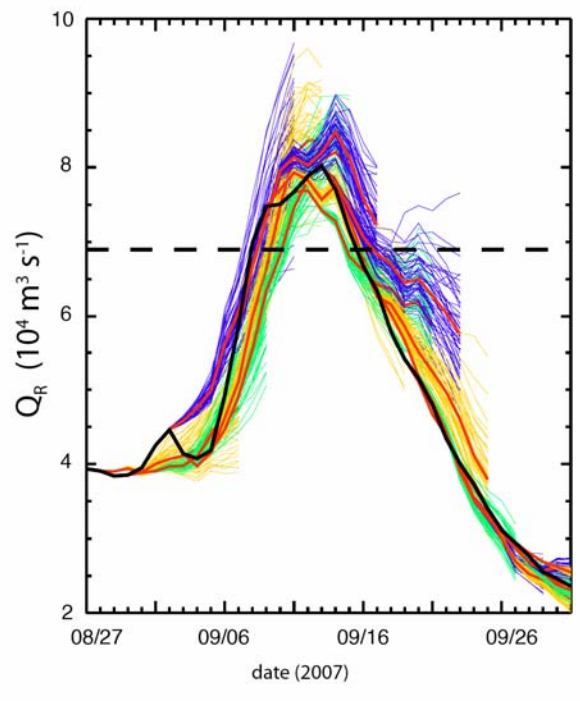


Plumes and probability pies for the first Brahmaputra flood July 28-August 6

- Short-term system was successful in providing high probabilities of exceedance of the danger level by the Brahmaputra at the India-Bangladesh border
- The forecasts were used for evacuation and etc

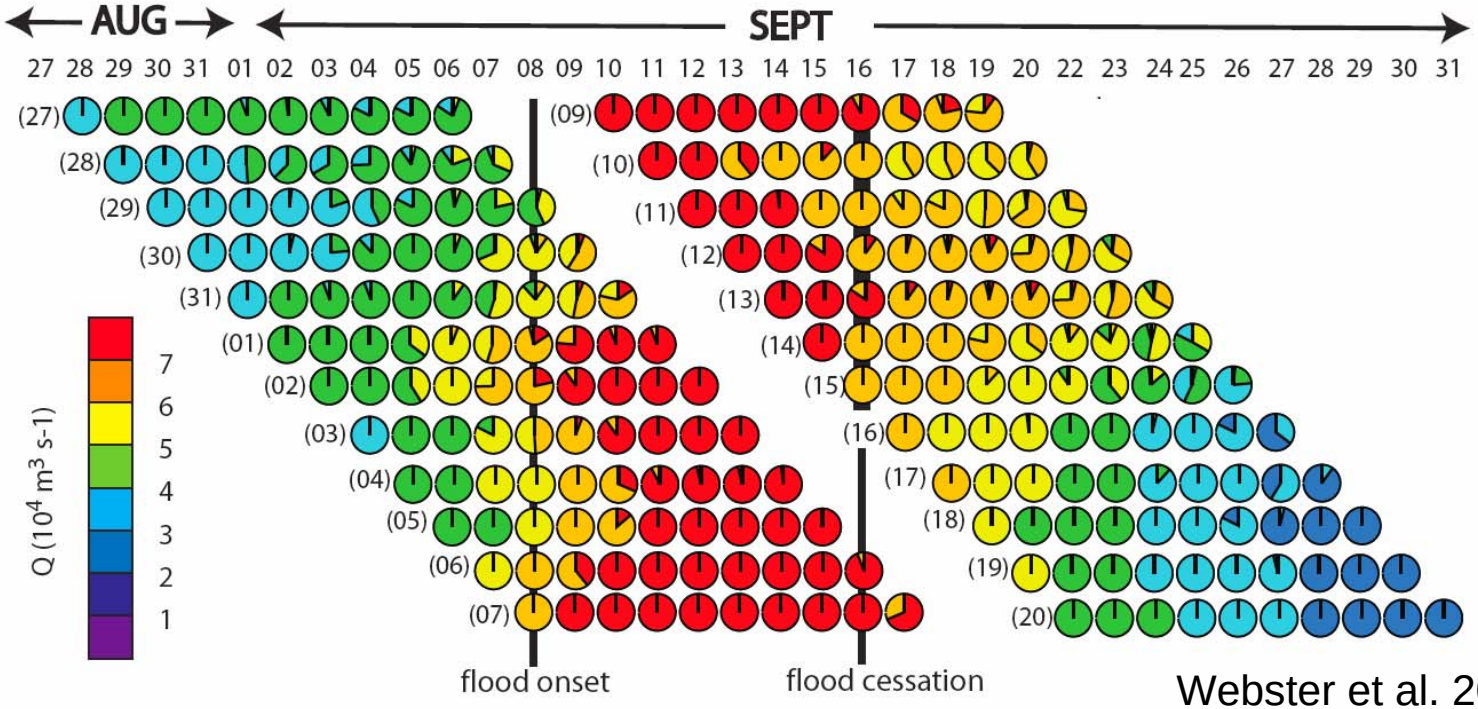


Webster et al. 2007



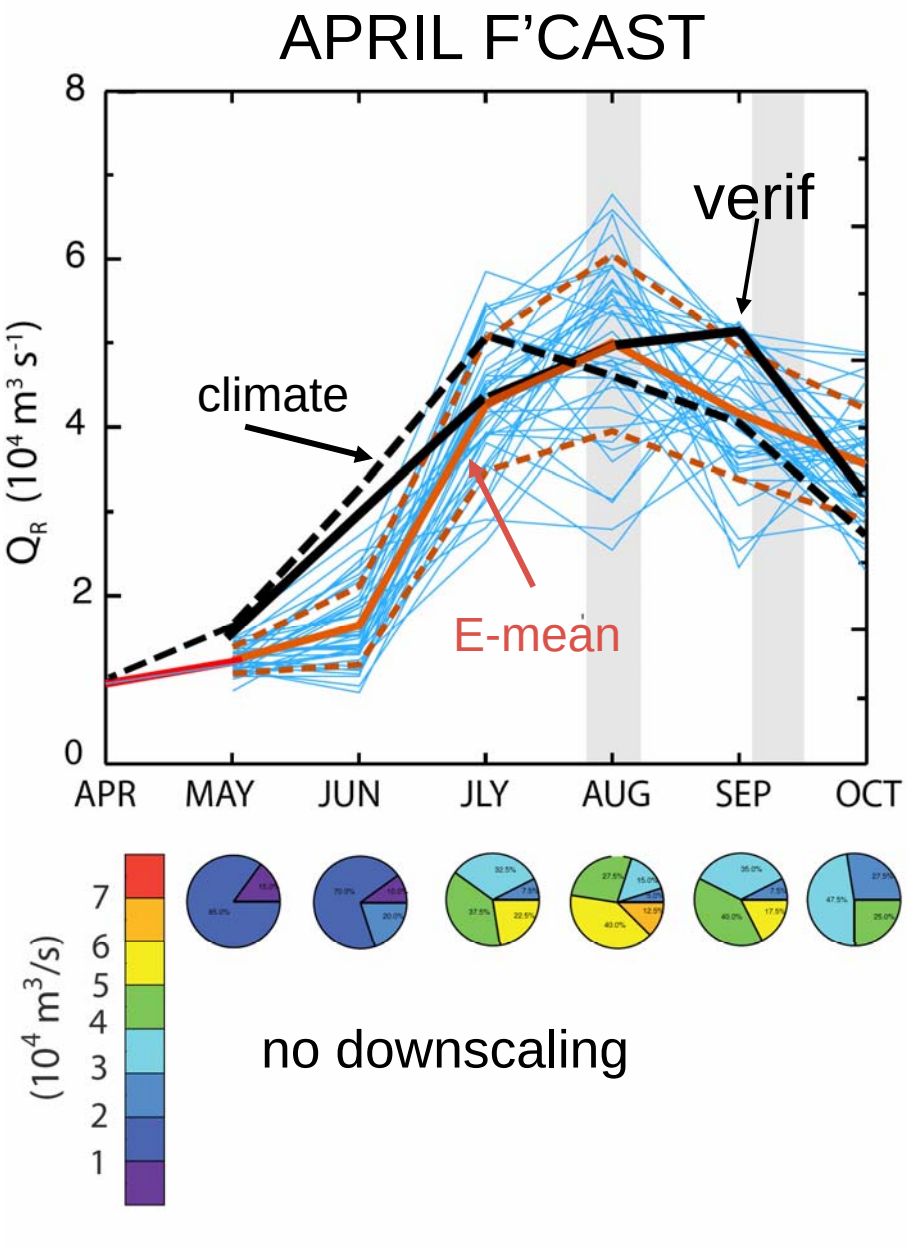
Plumes and probability pies for the second Brahmaputra flood Sept 8-16

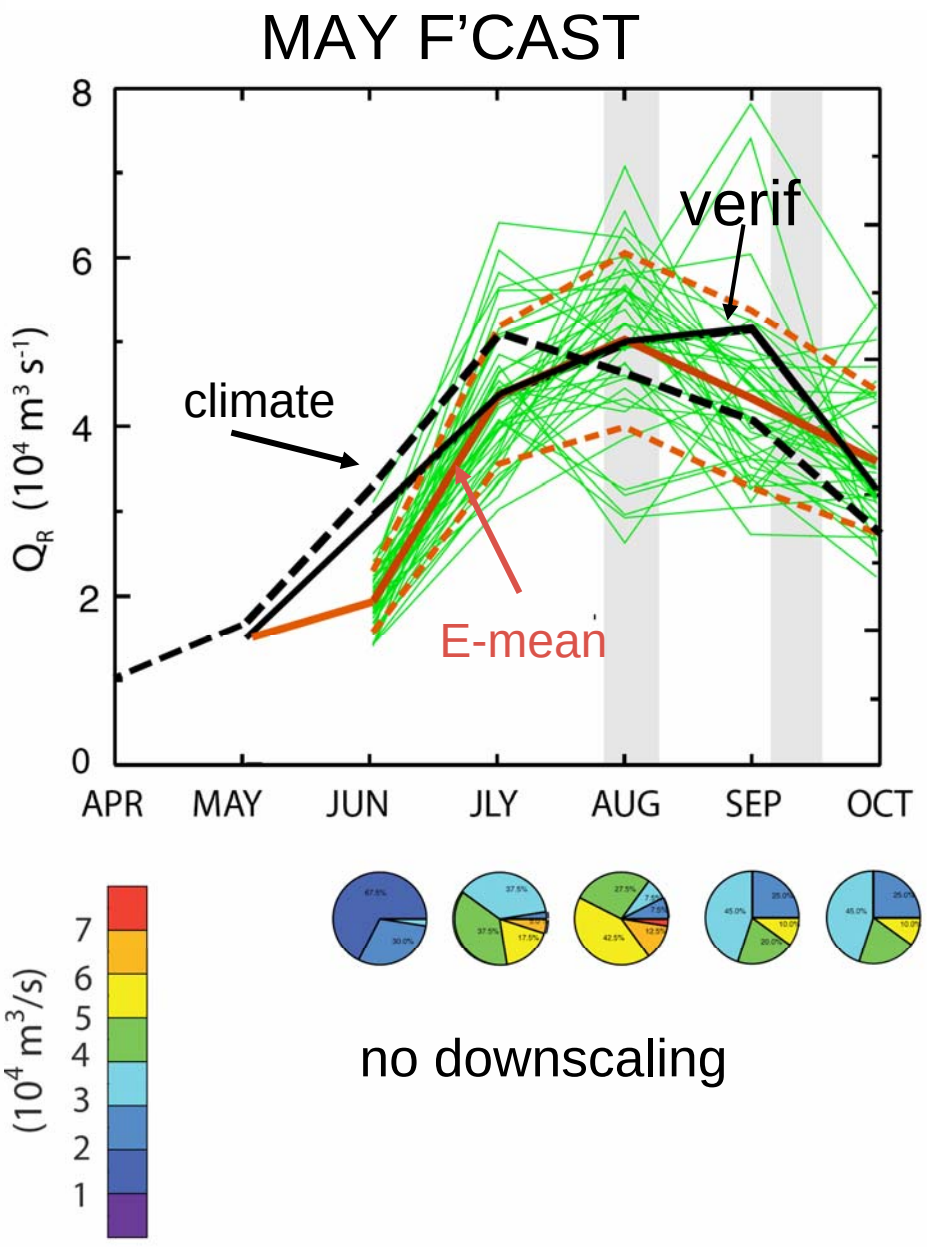
- For the second flooding, short-term system was successful in providing high probabilities of exceedance of the danger level by the Brahmaputra at the India-Bangladesh border
- The forecasts were also used for evacuation and etc



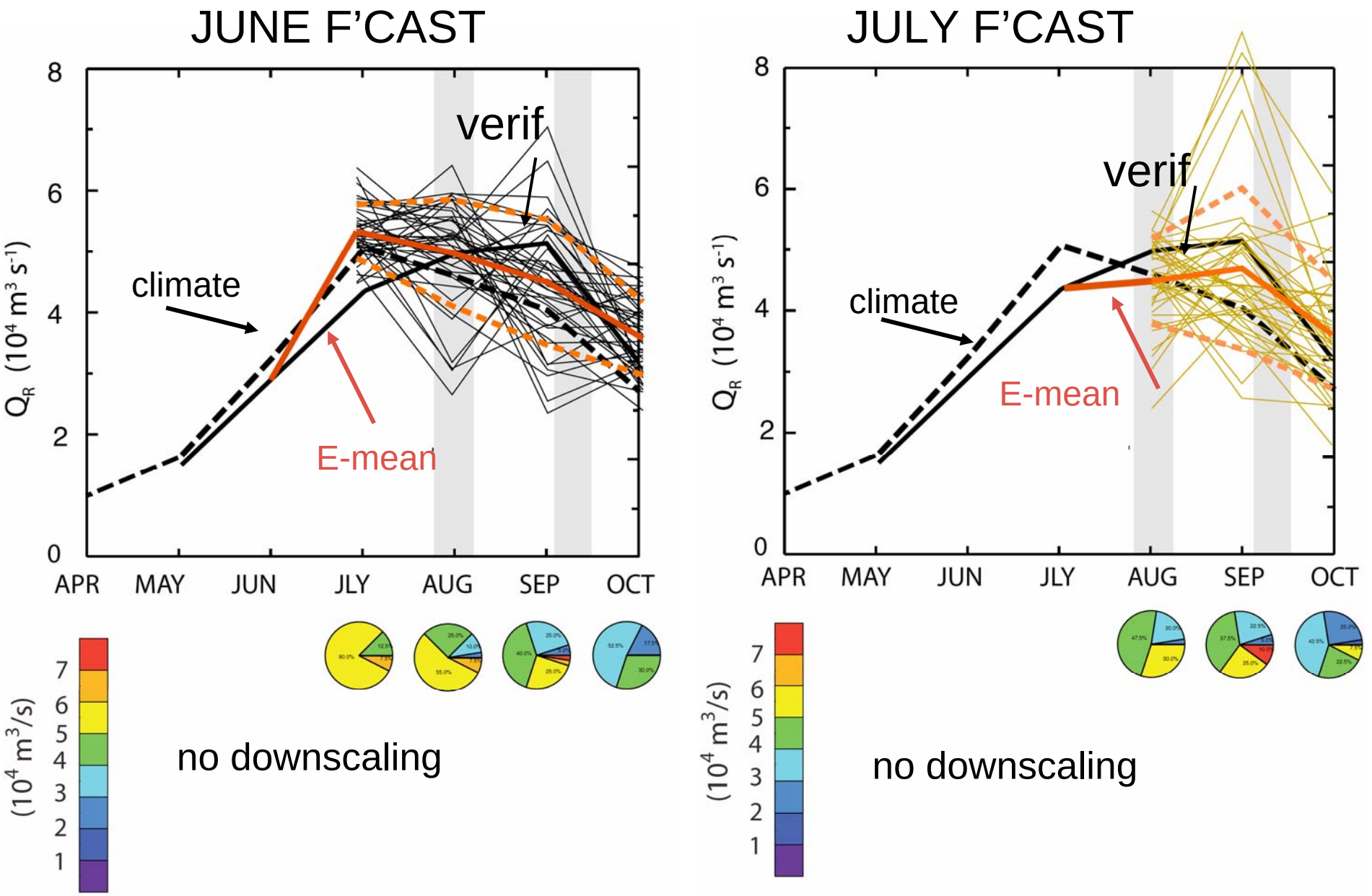
Webster et al. 2007

Seasonal (1-6 months) Brahmaputra 2007

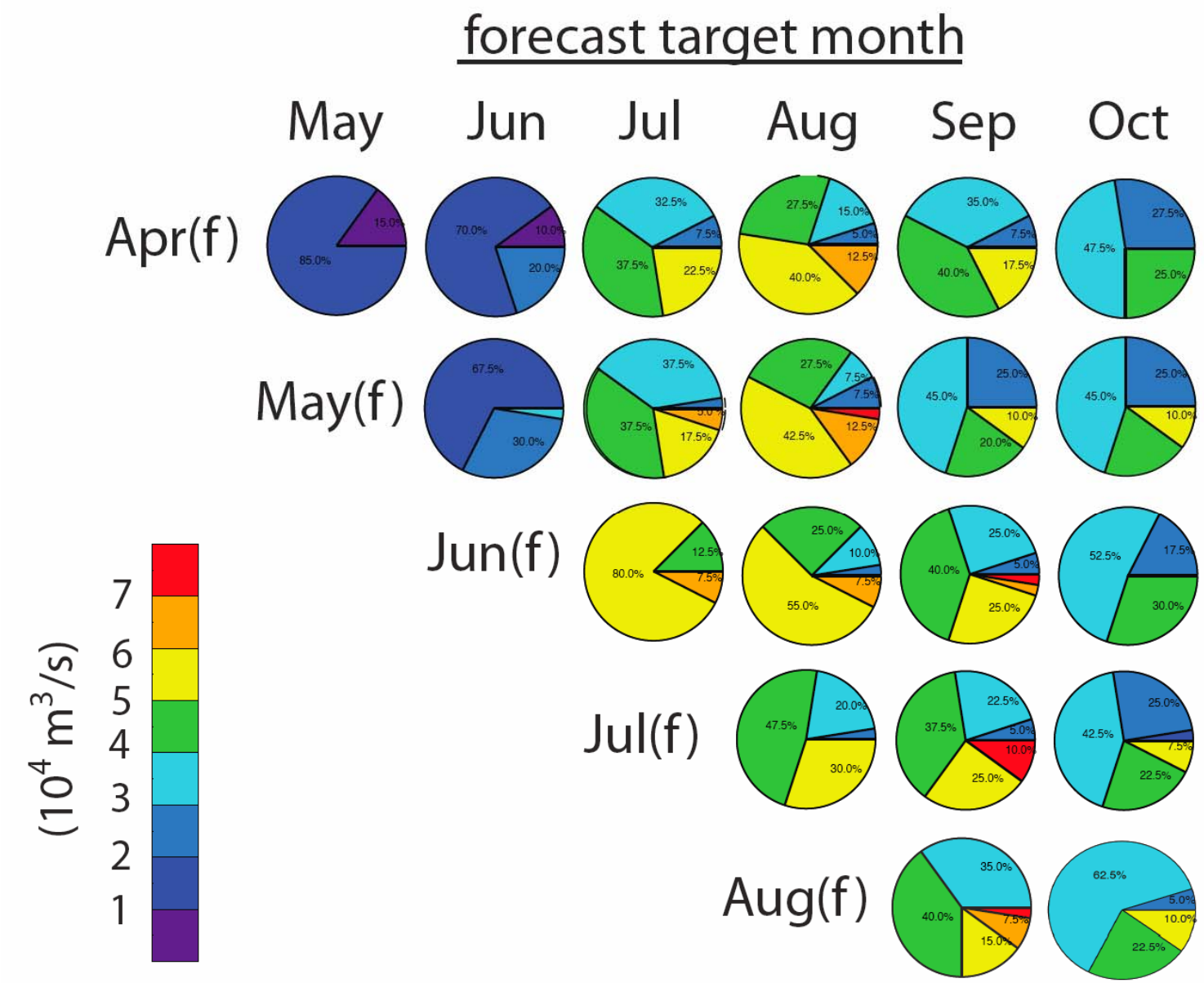




Seasonal (1-6 months) Brahmaputra 2007

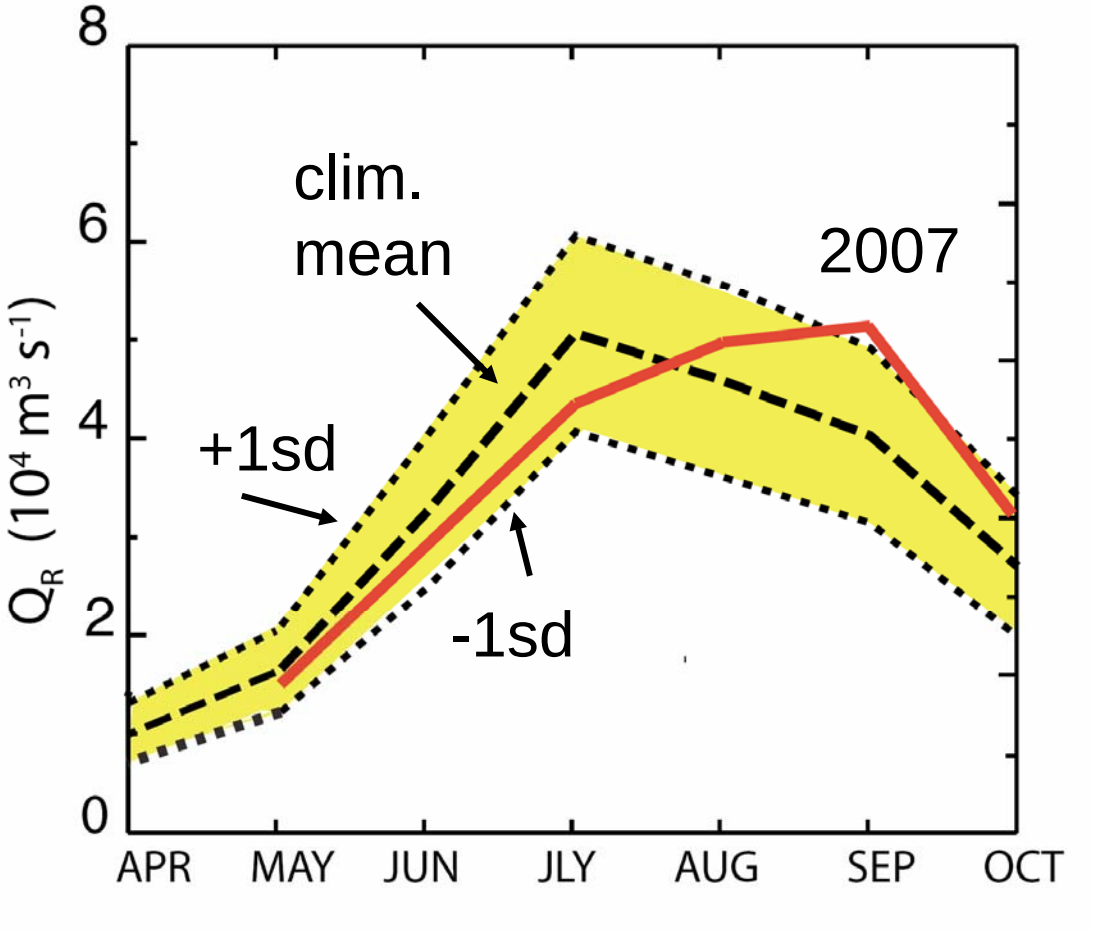


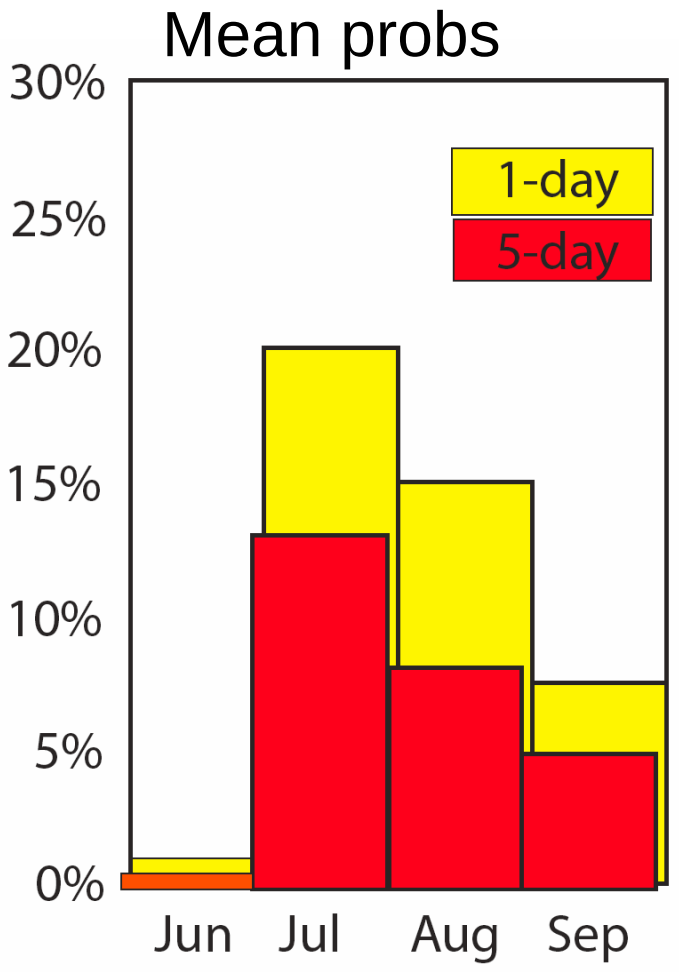
Summary of the non-downscaled 2007 Brahma Forecasts

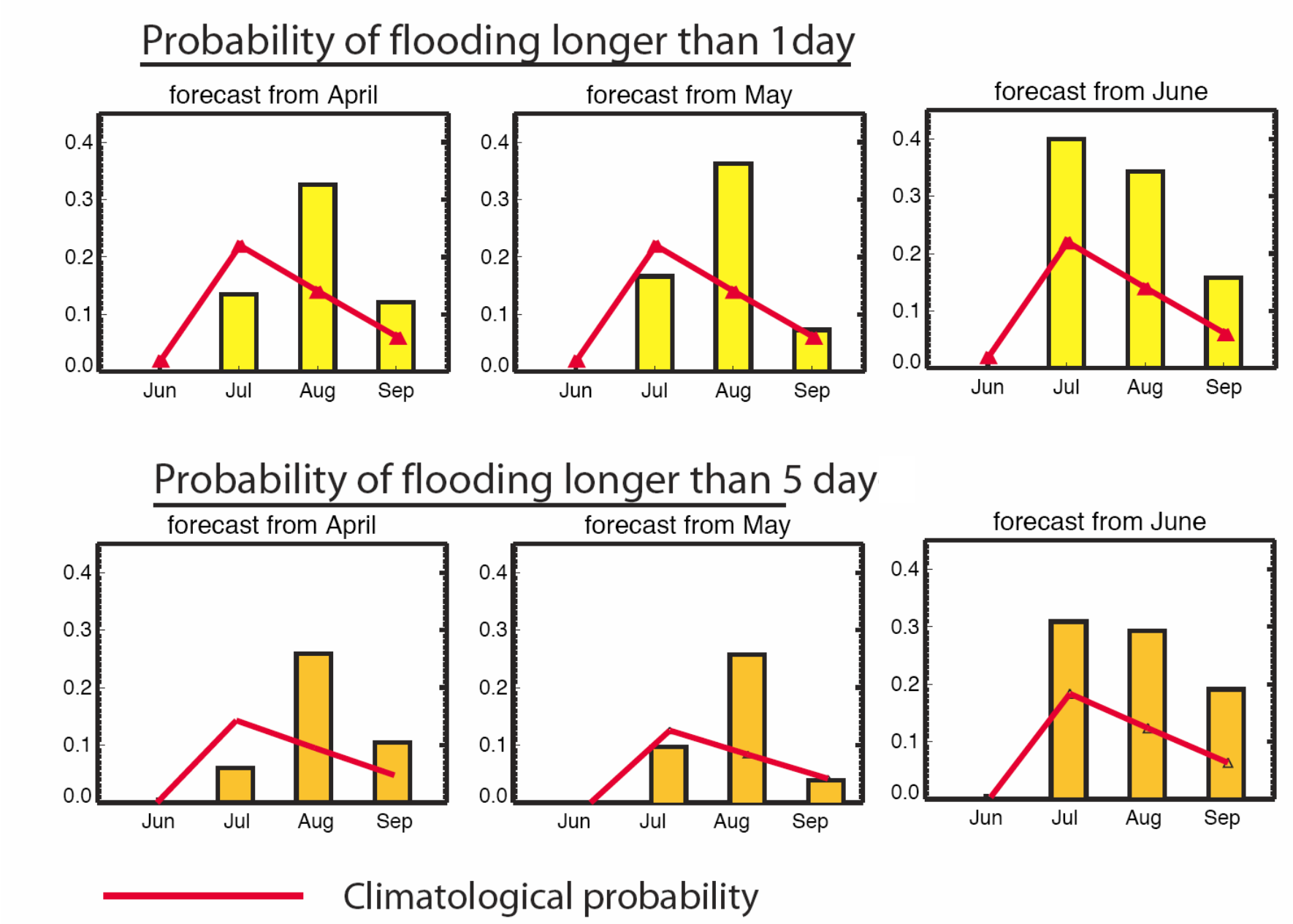


Downscaling:

Seasonal system provides monthly average river discharge. Can we use climatology to determine occurrence of multi-day flooding within this month?






Probability of flooding longer than 1day
forecast from April
forecast from May
forecast from June
0.4
0.3
0.2
0.1
0.0
Jun
Jul
Aug
Sep
Probability of flooding longer than 5 day
forecast from April
forecast from May
forecast from June
Climatological probability

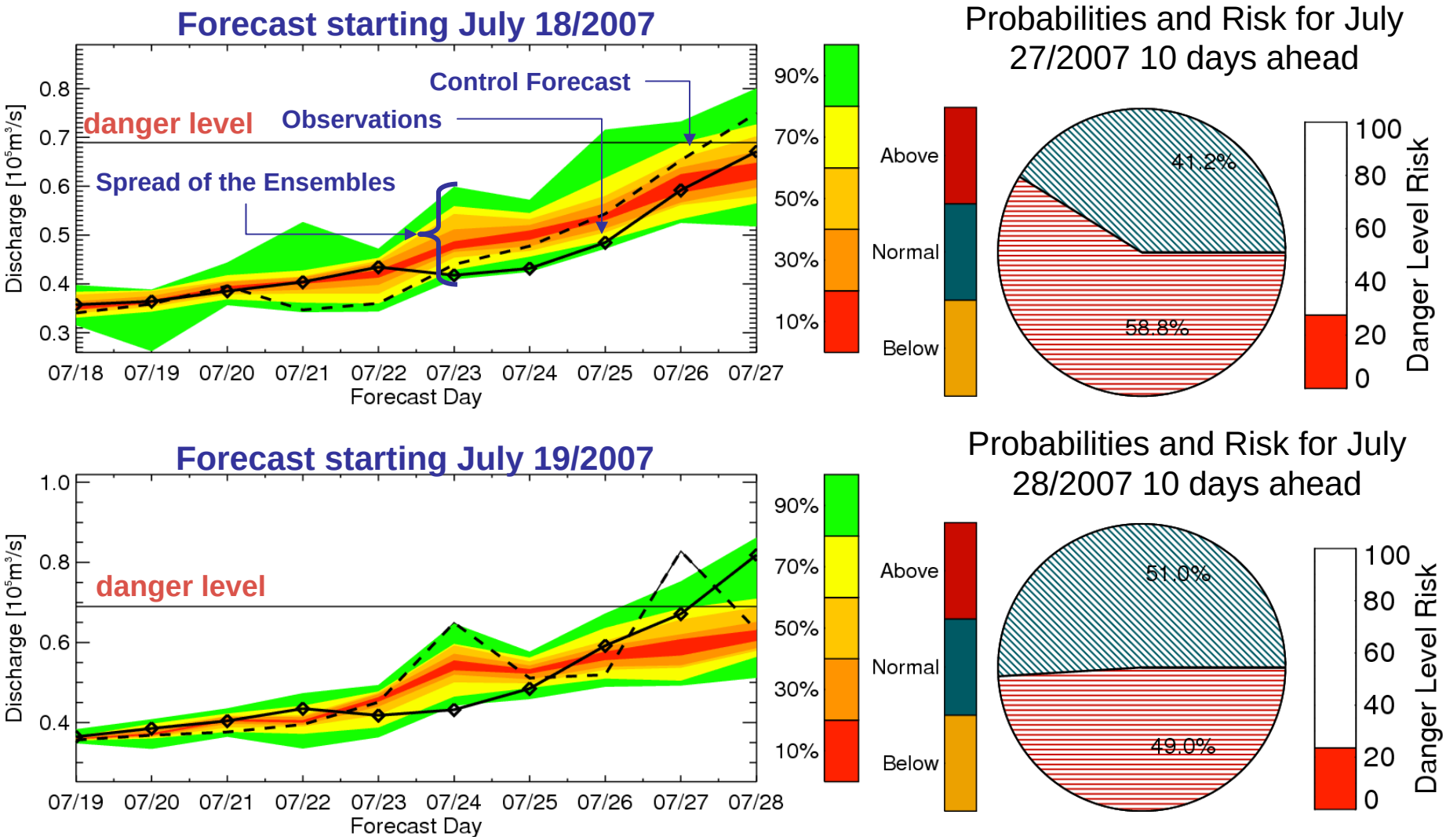
Conclusions:

- Considerable skill exists at both the medium range and the seasonal (and on the intraseasonal: not discussed here)
- The forecasts were used: The Bangladesh Disaster Response Committee was pre-emptive for the first time. It normally is recative
- The ECMWF EPS precipitation forecasts are excellent but still require considerable “rendering.
- The scheme that we have developed is designed for use where there I s little data and infrastructure
- The CFAB system may act as a template for other regions of the world

Forecast implementation

- By comparison, developing forecasting techniques and making forecast is the easy part compared to getting the forecasts used.
- We have produced forecast for the last 3 years.
- This was the first year that the forecasts were used!

Actual forecast 8 days in advance of floods appearing on the CFAN website http://cfab2.eas.gatech.edu. These forecasts were used by Bangladesh Flood Forecast and Warning Centre for forecasts and by the disaster managers in Bangladesh to change agricultural cropping/planting and evacuate those in danger.



Example of Bangladesh Flood Forecast & Warning Centre's use of the CFAN forecasts in 2007

Traditional 2 day forecast

Forecasts extended to 10-days

Forecast made on: 15-09-2007

			today	1-day forecast	2-day forecast	3-day forecast	4-day forecast	5-day forecast	6-day forecast	7-day forecast	8-day forecast	9-day forecast	10-day forecast	
Water Level in [m]			15-09	16-09	17-09	18-09	19-09	20-09	21-09	22-09	23-09	24-09	25-09	Forecast type
River	Station	D.L	0600	0600	0600	0600	0600	0600	0600	0600	0600	0600	0600	
Jamuna	Serajganj	13.75	14.64	14.48	14.37	14.28	14.20	14.14	14.06	13.88	13.65	13.43	13.23	Upper Range
				14.44	14.24	14.04	13.88	13.71	13.47	13.12	12.80	12.47	12.24	Lower Range
				14.46	14.31	14.19	14.05	13.93	13.77	13.53	13.23	12.93	12.81	Mean
Jamuna	Aricha	9.40	10.02	9.94	9.88	9.84	9.79	9.71	9.72	9.62	9.47	9.33	9.15	Upper Range
				9.91	9.78	9.66	9.53	9.36	9.23	9.02	8.76	8.59	8.43	Lower Range
				9.92	9.83	9.77	9.67	9.53	9.47	9.33	9.19	9.00	8.81	Mean
Tongi Khal	Tongi	6.08	5.55	5.62	5.69	5.77	5.84	5.90	5.95	6.00	6.03	6.04	6.03	Upper Range
				5.62	5.69	5.76	5.82	5.87	5.90	5.91	5.92	5.91	5.90	Lower Range
				5.62	5.69	5.76	5.83	5.89	5.93	5.96	5.97	5.97	5.96	Mean
Turag	Mirpur	5.94	5.85	5.92	5.99	6.05	6.12	6.18	6.22	6.26	6.28	6.27	6.25	Upper Range
				5.92	5.98	6.04	6.10	6.13	6.14	6.14	6.14	6.13	6.10	Lower Range
				5.92	5.98	6.05	6.11	6.15	6.19	6.20	6.20	6.19	6.18	Mean
Buriganga	Dhaka	6.00	5.05	5.12	5.18	5.25	5.32	5.37	5.41	5.45	5.46	5.44	5.42	Upper Range
				5.12	5.18	5.23	5.28	5.31	5.31	5.31	5.30	5.29	5.26	Lower Range
				5.12	5.18	5.24	5.30	5.34	5.37	5.37	5.37	5.36	5.34	Mean
Balu	Demra	5.03	5.60	5.67	5.74	5.81	5.89	5.95	6.01	6.06	6.10	6.12	6.12	Upper Range
				5.67	5.74	5.81	5.88	5.93	5.97	5.99	6.01	6.01	6.00	Lower Range
				5.67	5.74	5.81	5.89	5.94	5.99	6.03	6.05	6.06	6.06	Mean

Traditional 2 day forecast

Response of National Institutions for 2007 flood forecasts

- Flood Forecasting and Warning Center (FFWC) incorporated the CFAB forecasts to produce water level forecasts for many locations along Brahmaputra and Ganges well in advance
- Localised flood inundation maps were prepared by FFWC engineers and communicated to local partners in Rangpur and Sirajganj
- National level Disaster Emergency Response Group consisting of INGOs, Ministry of Food and Disaster Management and International Organisations prepared emergency response plans, logistics for preparedness and relief in advance
- National level NGO network (NIRAPAD) and INGOs prepared localised warning messages and disseminated to their counterparts at local level
- National level service organisations like Department of Agriculture Extension prepared rehabilitation plans in advance

Response of local institutions for 2007 flood forecasts

- Upazilla level service organisations in partnership with NGOs communicated 1-10 days forecast to the communities in advance
- Local NGOs and implementing partners prepared evacuation and response plans to protect lives and livelihoods (Lalmunihat and Gaibandha)
- Local project partners used community vulnerability maps to assess the risk of flooding
- District level relief and emergency organisations plan to mobilise resources for relief activities
- Local NGOs, Government organisations and CBOs mobilise mechanised and manual boats to rescue people and livestock from the “char” areas
- Local NGOs and Department of Agriculture Extension prepared work plan for relief and rehabilitation activities
- Union Parishad chairman in Gaichuri (Sirajganj) and Fulchuri (Gaibandha) prepared evacuation plans in partnership with community based organisations,

Selvaraju (ADPC)

Community level decision responses for 2007 flood forecasts (Low lands)

- Local people planned to store dry food and safe drinking water for about 10 days knowing that relief will start only 7 days after initial flooding.
- Secured cattle, poultry birds, homestead vegetables, protected fishery by putting nets in advance
- Secured cooking stove, small vessels, firewood and animal dry fodder and transported it to highlands and embankments
- Planed to evacuate and identified high grounds with adequate communication and sanitation facilities
- Farmers in land areas harvested their jute crop, but had problems with transporting
- Planed for alternative livelihood options immediately after flooding (small scale fishing, boat making, seedling raising, jute retting)

Community level decision responses for 2007 flood forecasts (High lands)

- Abandoned *T. aman* transplanting temporarily anticipating floods in Mohipur in Gangachara upazilla
- Secured additional seedlings for double planting of rice after the first floods, but the establishment was affected due to continuous water stagnation
- Protected homestead vegetables by creating adequate drainage facilities
- Reserved seeds of flood tolerant crops for the subsequent seasons
- Planned for growing seedlings in high lands in Rajpur union of Lalmunirhat district
- Planed for alternative off-farm employment during floods
- Early harvesting of B.aman rice and jute anticipating floods in Gaibandha and Sirajganj, respectively.
- Livestock was protected in high lands with additional dry fodder (paddy straw)

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Key lessons from 2007 flood forecast application

- Floods exceeded danger level about a day earlier than forecasted date and it was generally observed by the local stakeholders that that observed discharge was higher than forecast in Bahadurabad transit
- Conflicting community perception slow down the local actions.
- Community level risk and vulnerability maps are the appropriate tools to incorporate flood information and prepare localized impact outlooks involving Community Based Organisations (CBOs), local networks
- Preparedness plans by local institutions are driven by response from local Disaster Management Committee (DMC) members and require capacity building initiatives
- The relief activities are slow due to sequence of lengthy procedures with district administration and Thana Nivahi Officers are interested to use the flood forecasts to facilitate quick response activities

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Key lessons from 2007 flood forecast application..

- Response to forecasts in low lying areas and “char” regions are related to saving lives and securing small household assets (dry food, drinking water, fire wood, animal fodder, barrowing credit from micro-financing institutions)
- Response to flood forecasts in high lands are mostly related to preparedness activities like reserving seedlings for double planting, protecting fisheries, early harvesting, abandoning early planting, protecting livestock and preserving fodder
- Local institutions during 2007 in pilot unions are well informed and prepared for floods in advance, but need to strengthen local institutions and coordination among them
- Local level infrastructure facilities (high lands, flood shelters, sanitation etc.,) are not sufficient to carry out preparedness and response actions in most of the unions

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