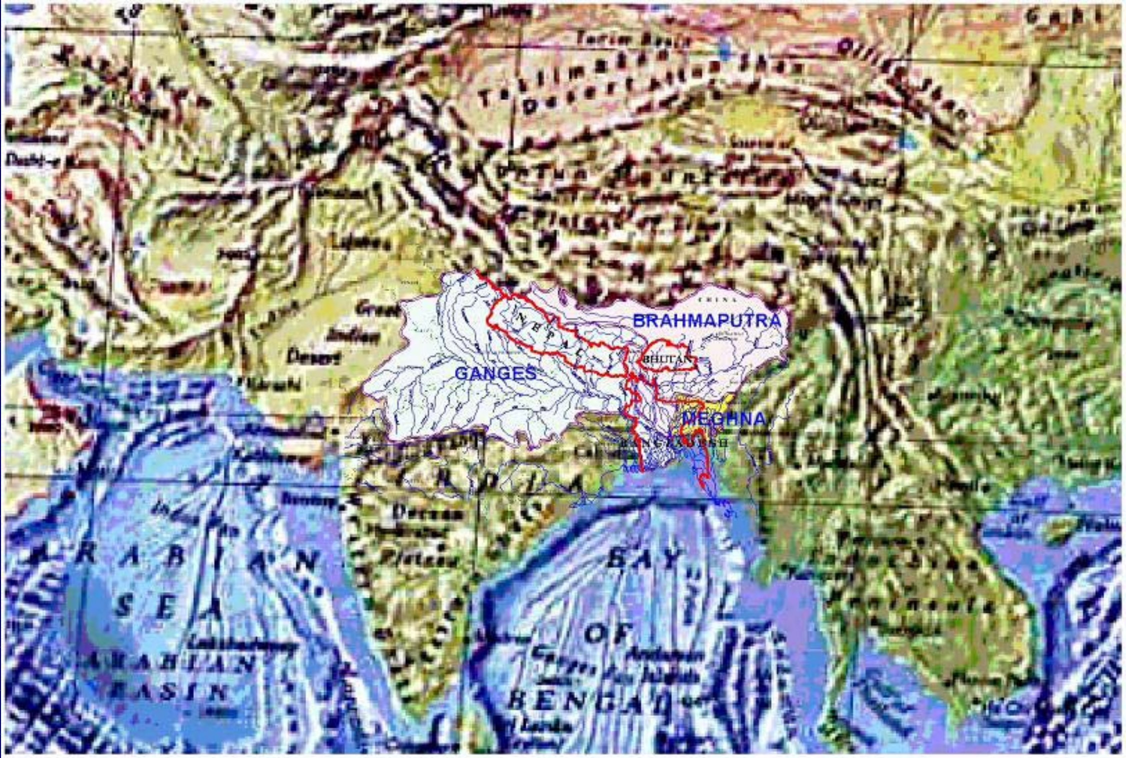
Operational Short-Term Flood Forecasting for Bangladesh:

Application of ECMWF Ensemble Precipitation Forecasts

Tom Hopson   Peter Webster

Climate Forecast Applications for Bangladesh (CFAB):
USAID/CU/GT/ADPC/ECMWF

The Climate Forecast Applications Project CFAB

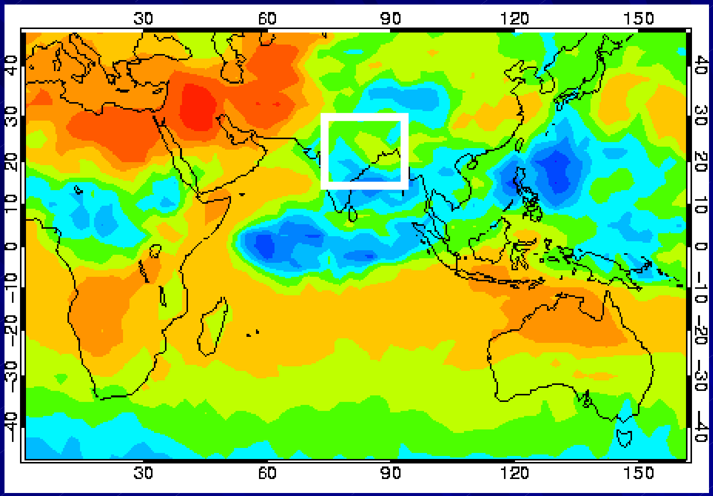


- Bangladesh at confluence of: Meghna, Brahmaputra and Ganges
- Limited upstream river discharge data provided to Bangladesh
- However, good quality border daily discharge measurements
  => utilize in forecasting

CFAB's GOAL: Provide operational upper catchment flood-stage discharge warning and precipitation forecasts at differing time-scales

Overview:

Short-term flood forecasting



1. Multi-Model Ensemble Discharge Forecasting: Combining Data-Based and Distributed Modeling Techniques

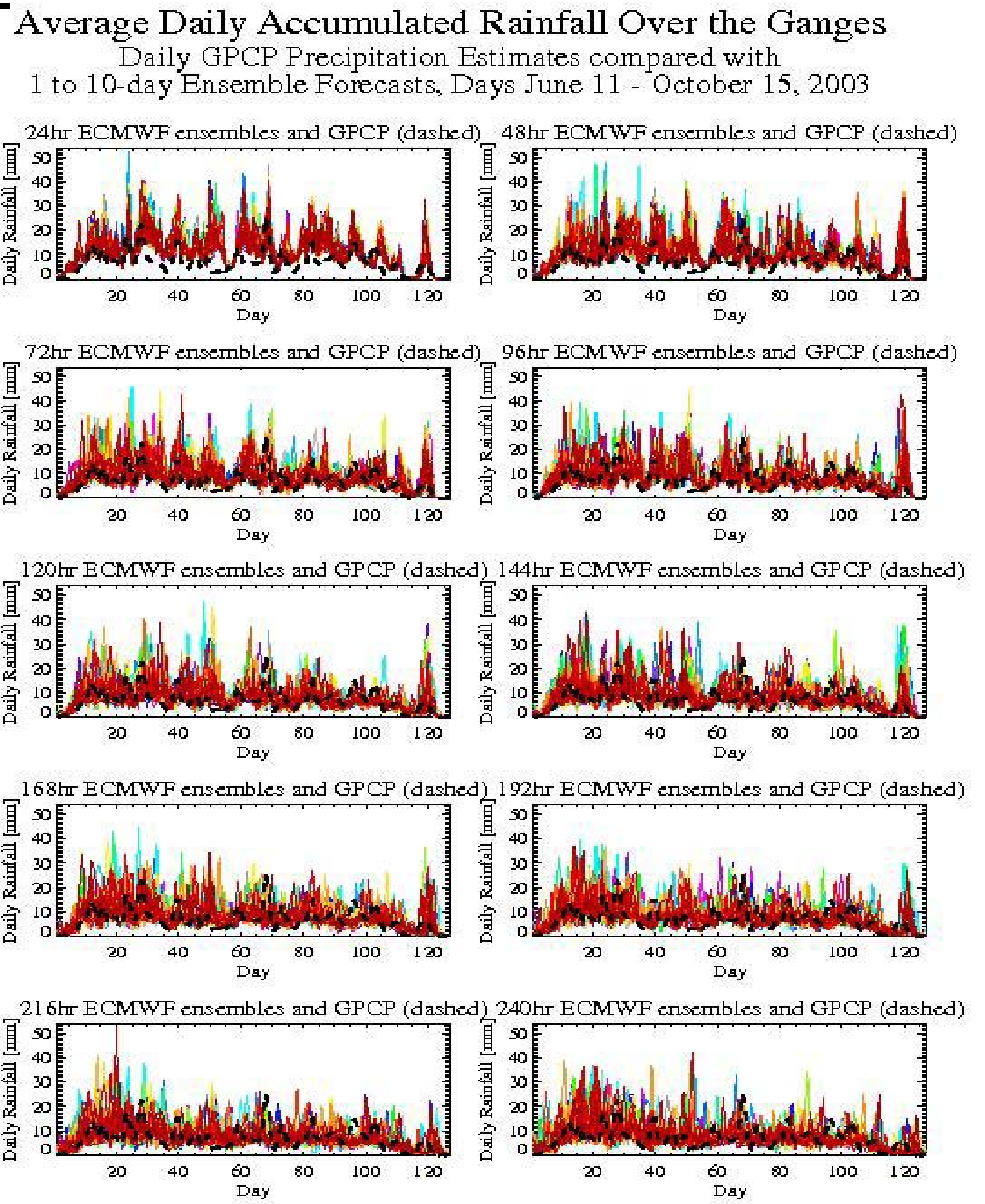
2. "Dressing" Precipitation-derived Discharge Ensembles with Model Error Estimates: "Truer" Discharge Probabilities

3. Conclusions, and Future Work

Ganges catchment-averaged ECMWF 51 member 1-10 day Precipitation Forecasts

-- comparisons to the Global Precipitation Climatology Project (GPCP) precipitation estimates

• GPCP and CMORPH used as “truth”
 => used to calibrate models
 => initializes soil-moisture
• bias and spread corrections of ECMWF “catchment-averaged” forecasts done similar to Hamill and Colucci, 1997



Discharge Multi-Model-Ensemble

Krishnamurti (2001): combining (via regression) multiple NWP model outputs significantly improves weather forecasts => apply to 2 discharge models to generate 'multi-model-ensemble' discharge forecasts

Data-Based Modeling (Beven, 2002)

-- Linear Store / Linear Transfer Function Approach.

• Benefits: recalibrate to specific conditions => ;
maximizes data-assimilation (discharge measurements)

• Drawbacks: basin lumped model; limited slow time-scale response

Distributed Model (US NWS River Forecast System)

-- subcatchment gridded 2 soil-layer model

• Benefits: ET/soil-storage/water-balance explicitly modeled

• Drawbacks: Model recalibration and data-assimilation inflexible

Discharge Multi-Model Ensemble (cont)

Multi-Model-Ensemble Approach:

• Rank models based on historic residual error using current model calibration and “observed” precipitation

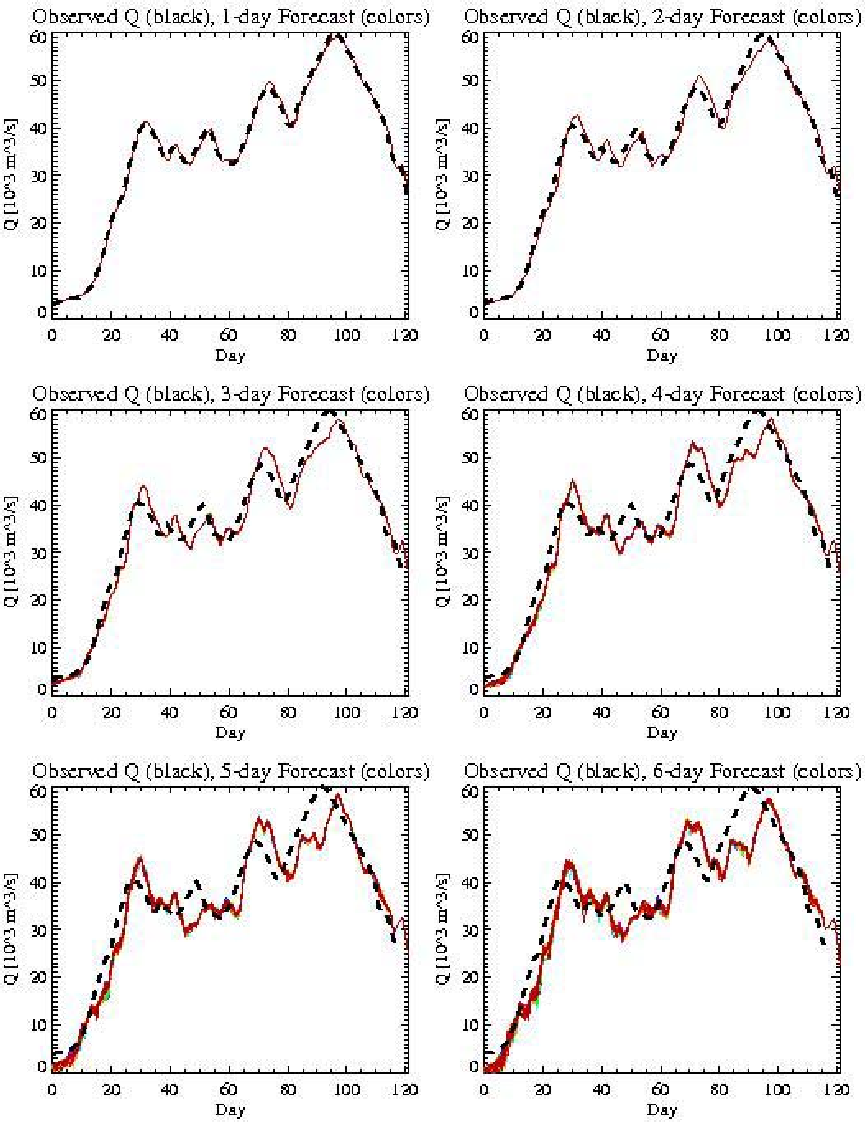
•Regress models’ historic discharges to minimize historic residuals with observed discharge

•To avoid over-calibration, evaluate resultant residuals using Akaike Information Criteria (AIC)

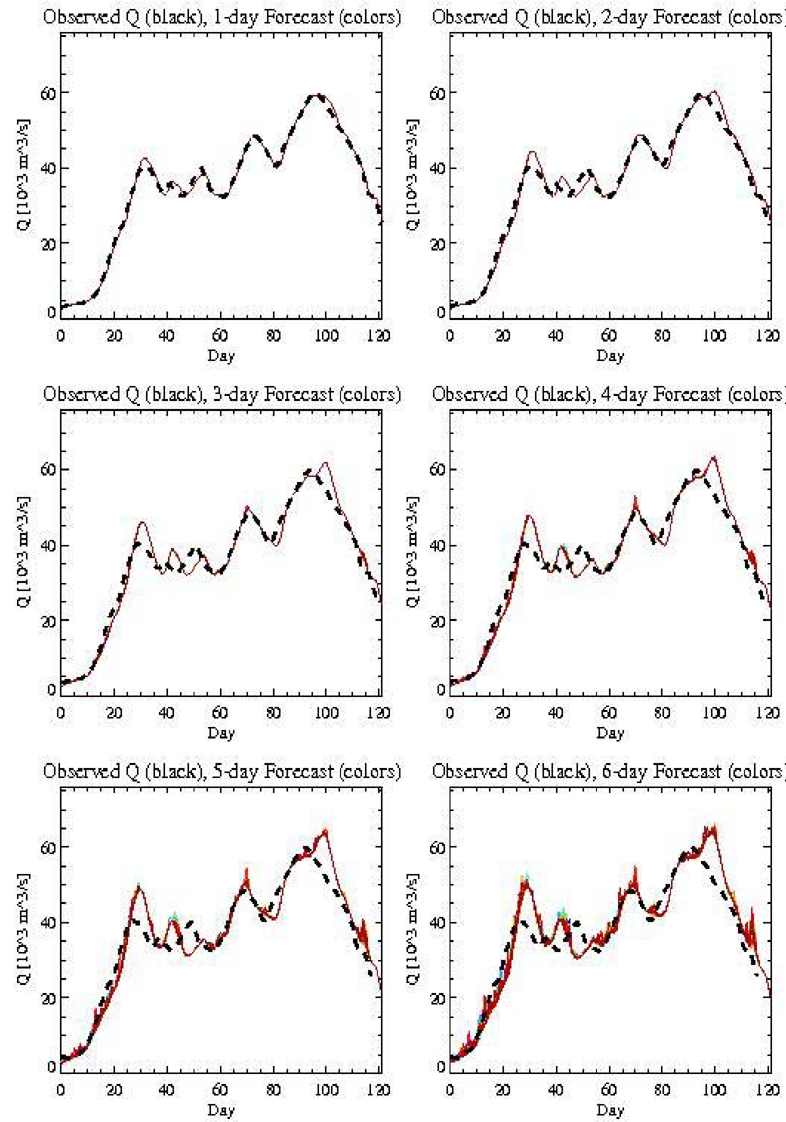
•If AIC minimized, use regression coefficients to generate “multi-model” forecast; otherwise use highest-ranked model => “win-win” situation!

Model Comparisons for the Ganges

TFM Ganges Discharge Forecasts
1-6 day using ECMWF Precipitation Forecasts
June 15 - October 15, 2003



Distributed S-G Ganges Discharge Forecasts
1-6 day using ECMWF Precipitation Forecasts
June 15 - October 15, 2003

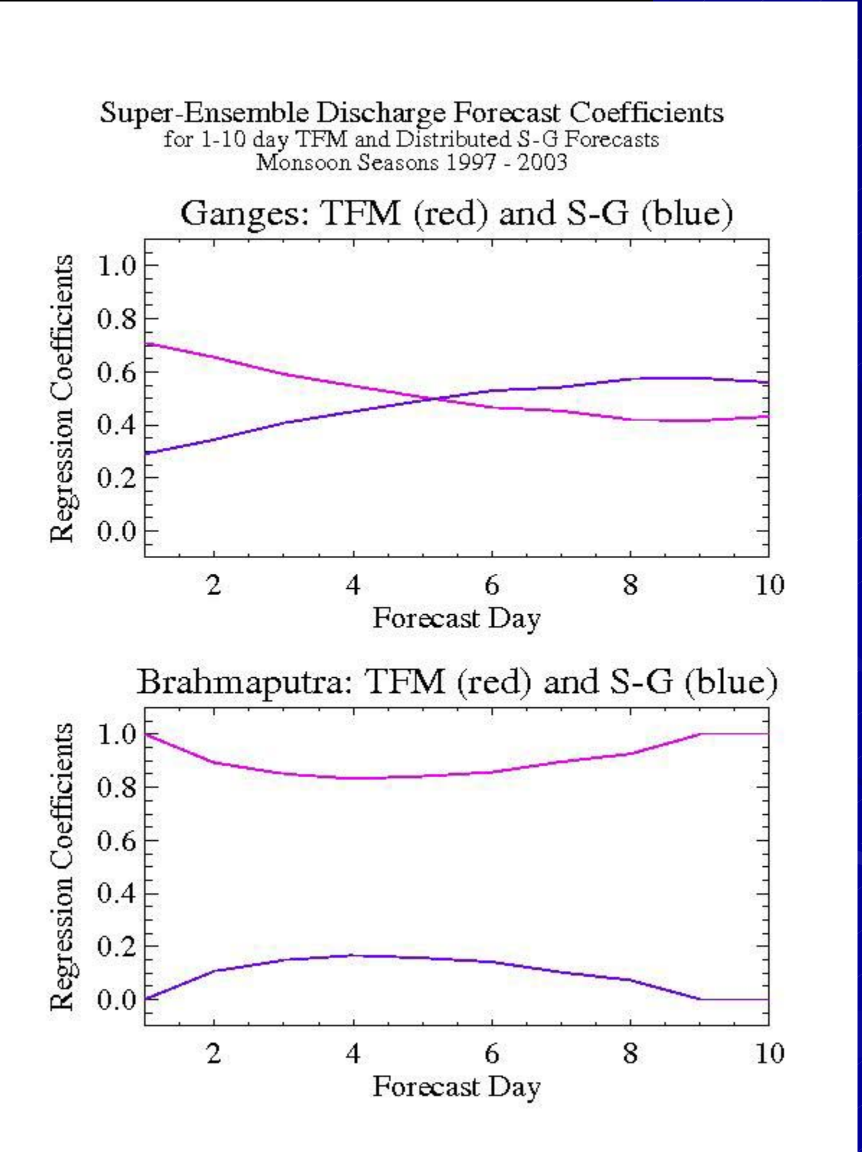


Multi-Model Ensemble Regression Coefficients

- DBM-TFM model (red)
- Distributed Model (blue)

- Significant catchment variation
- Coefficients vary with the forecast lead-time

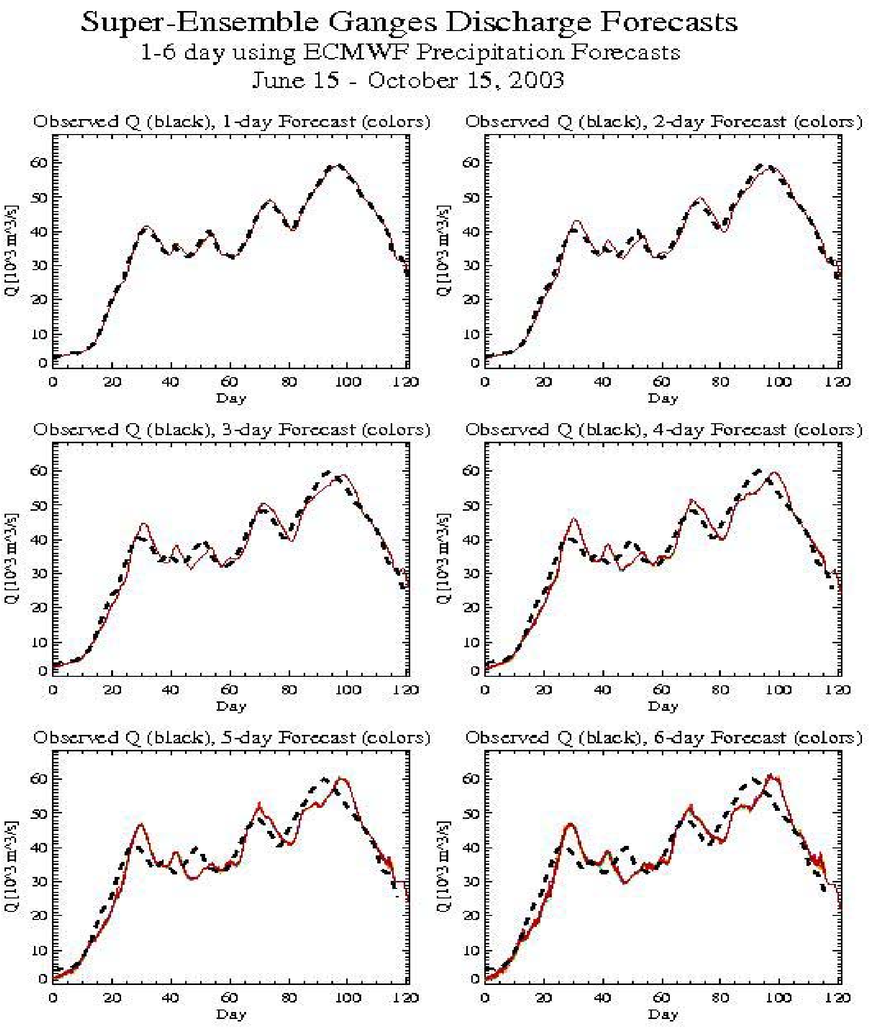
⇒ Representative of the
⇒ each basin's hydrology
⇒ -- Ganges slower time-scale response
⇒ -- Brahmaputra "flashier"



Multi-Model Ensemble Forecasts

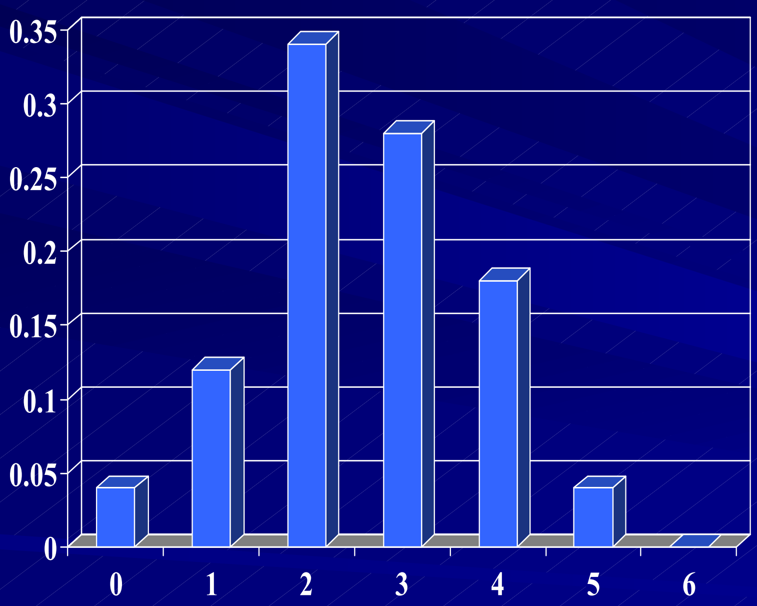
Results:
-- show improvements
-- but compromise timing (distributed) with amplitude (DBM)
=> use of different error measure in selection process

Future:
-- structure allows incorporating other models – MMS/PRMS
-- KNN technique to select based on current precipitation/discharge conditions



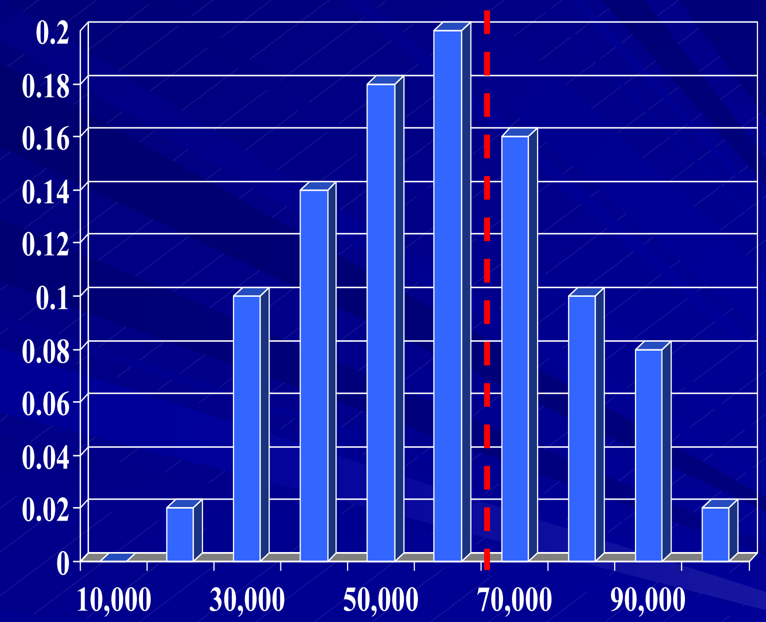
Combining Precipitation (Ensemble) Probability with Model Error: Forecasting "Truer" Discharge Probabilities

Rainfall Probability



Rainfall [mm]

Discharge Probability



Discharge [m^3/s]

Above danger level probability 36%
Greater than climatological seasonal risk?

A More Complete Discharge Probability Forecast

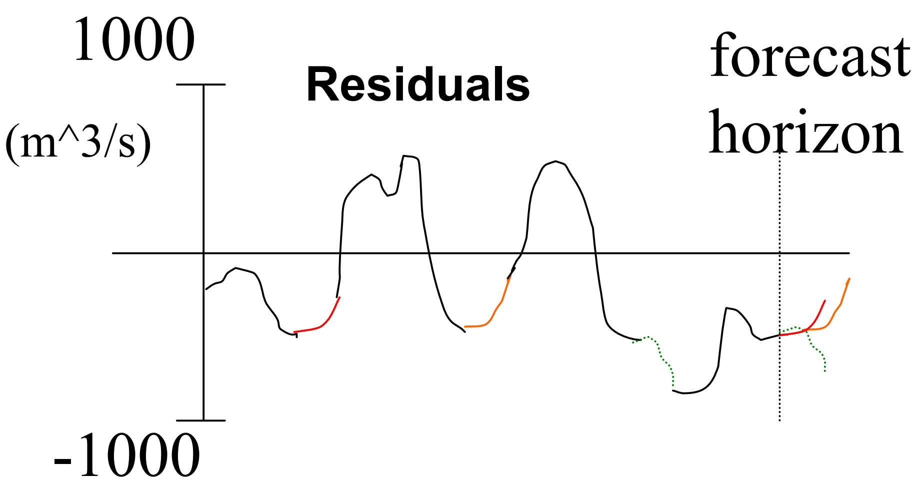
Step 1: generate model error PDF

(discharge model/rating curve/observed precipitation)

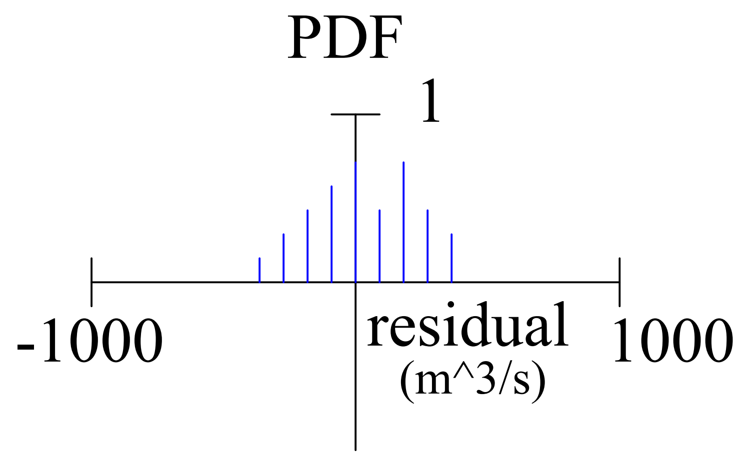
-- historically generate residual time series for each day's re-calibrated hydrologic model (multi-model) using "observed" precipitation

-- use K-Nearest-Neighbor (KNN) technique to select "nearest-neighbor" residuals (selection: values/slope/curvature)

-- use Mahalanobis Distance to weight and create model-error PDF

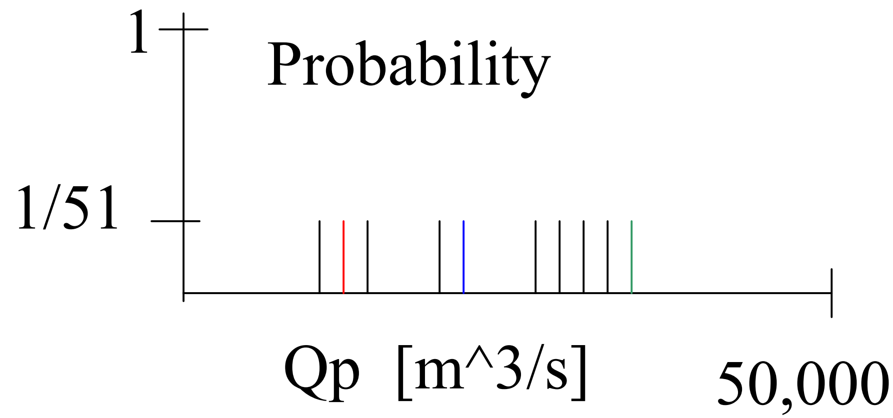


=>



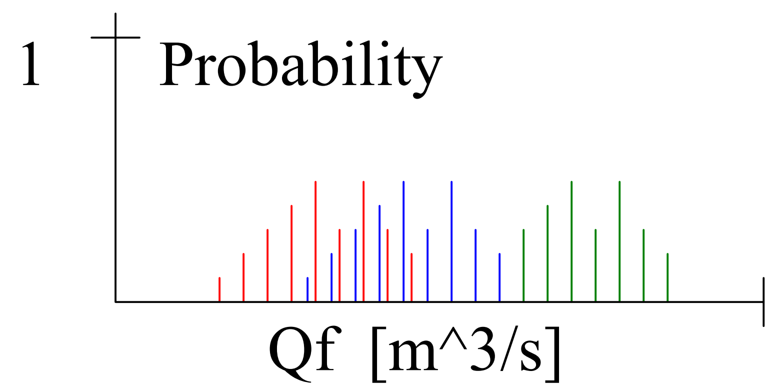
Combining Model / Precipitation Error (cont)

<u>Step 2:</u> generate precipitation-ensemble-generated discharge PDF

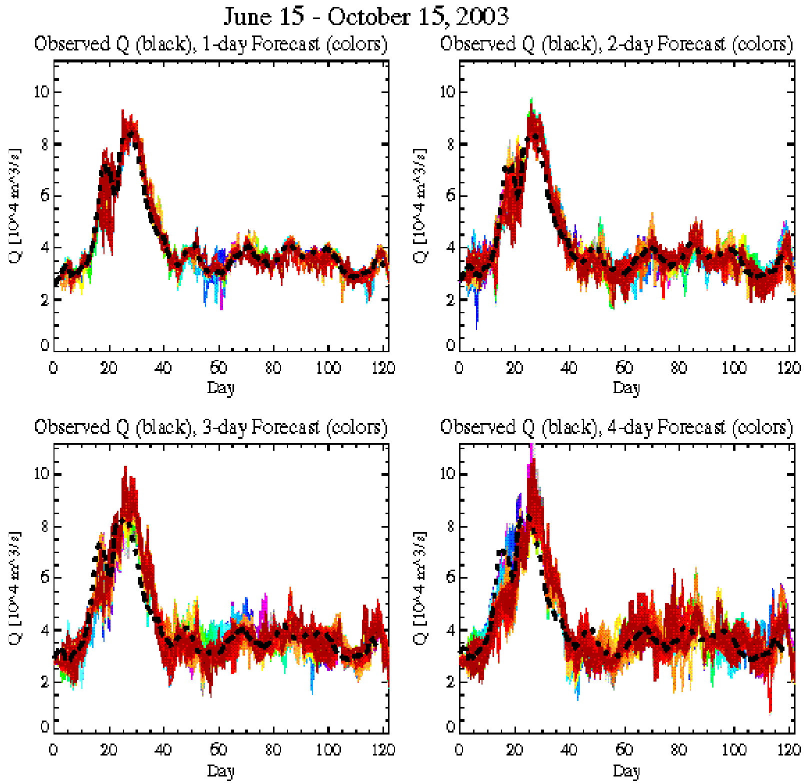


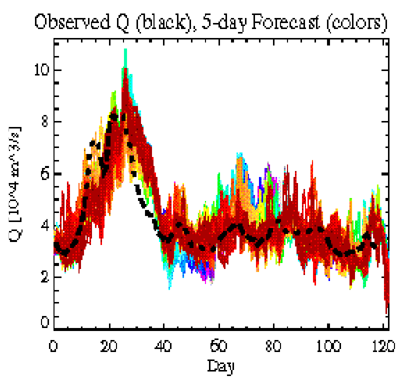
<u>Step 3:</u> combine model error PDF with the above to generate a "new-and-improved" more complete PDF for forecasting:

Result



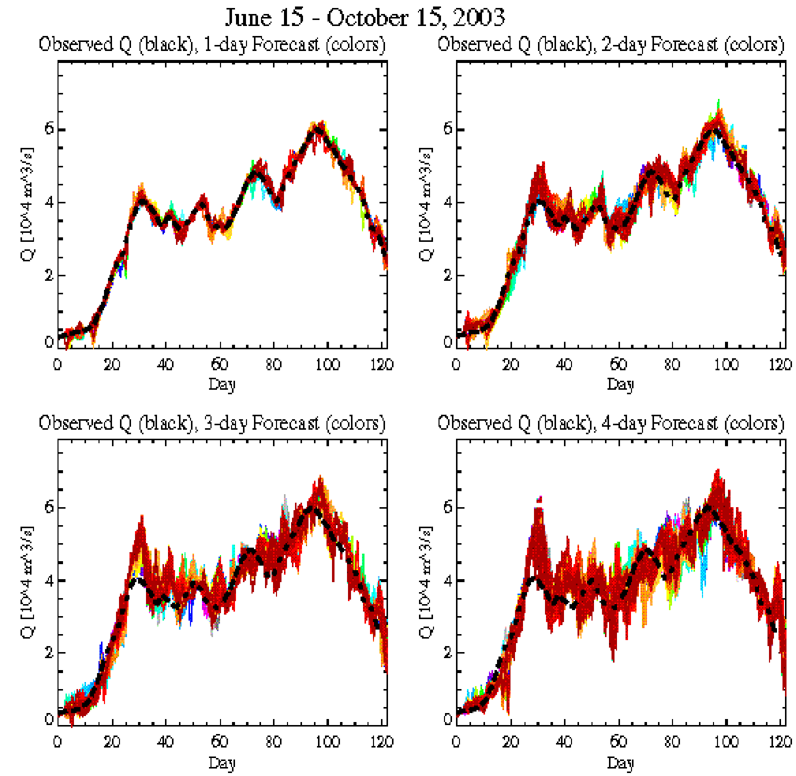
Brahmaputra Discharge

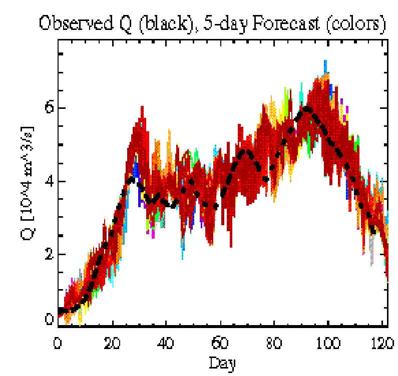




51 ensemble
Members in color

Ganges Discharge

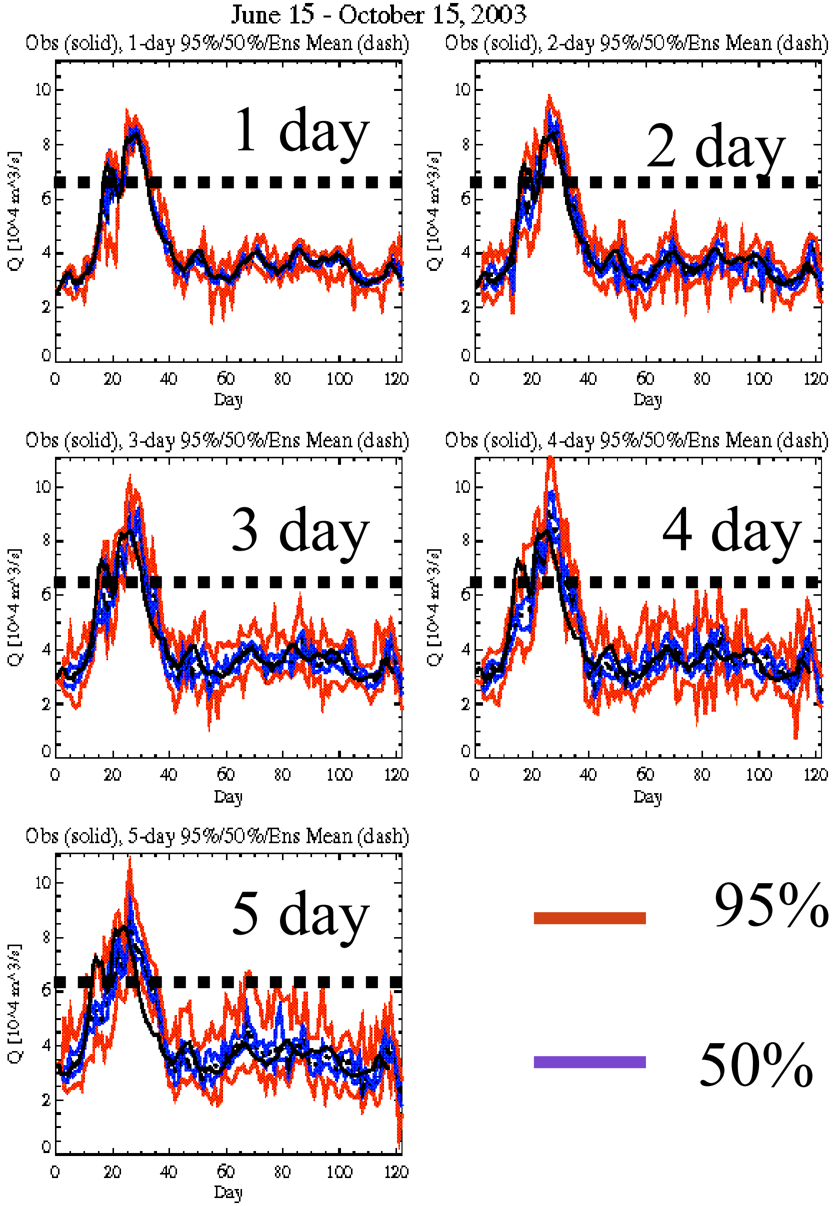




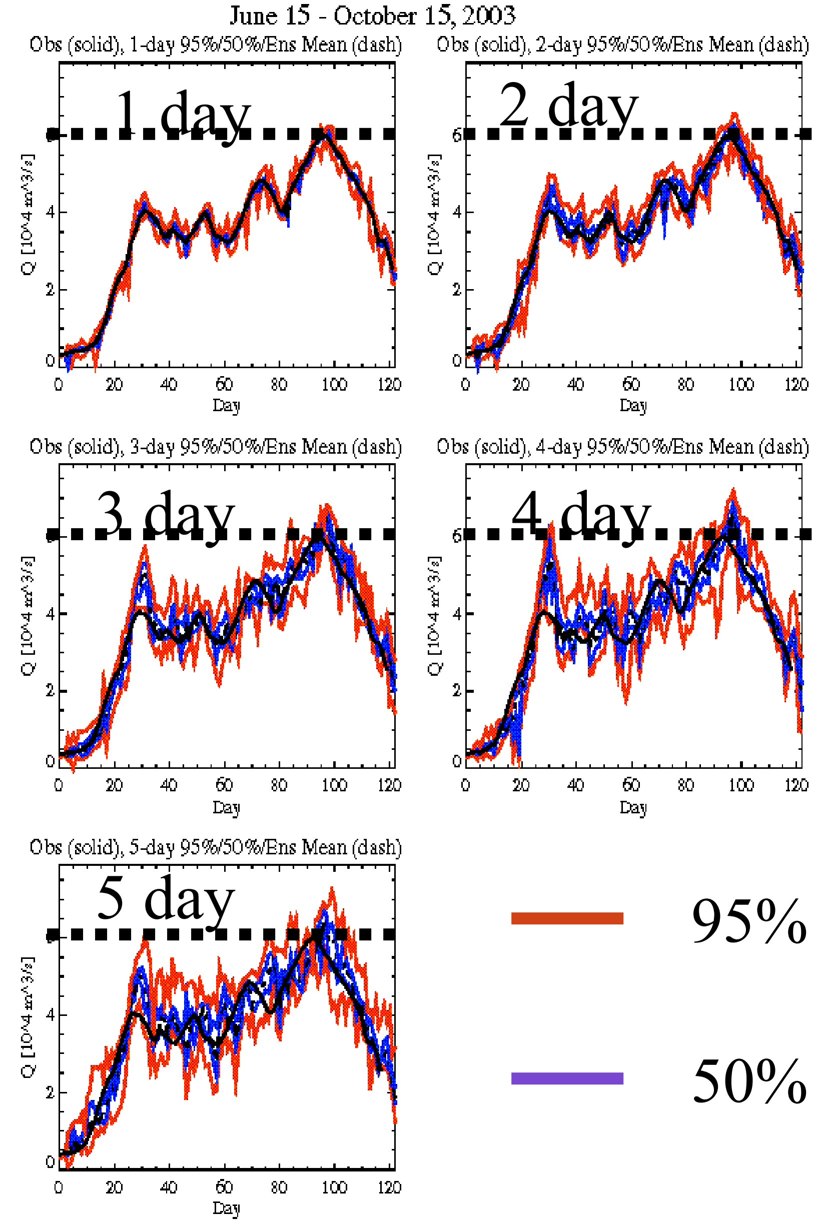
Observed Q
Black dash

Br

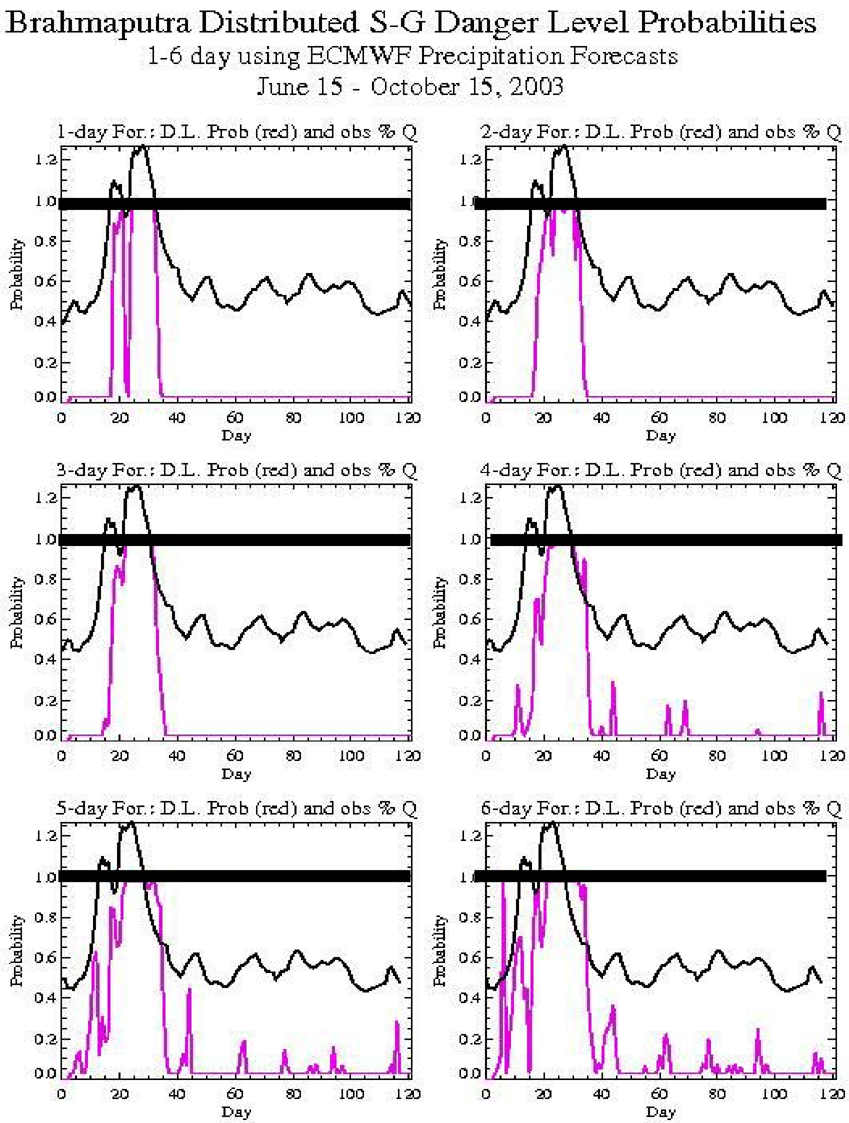
Brahmaputra Flood Probability

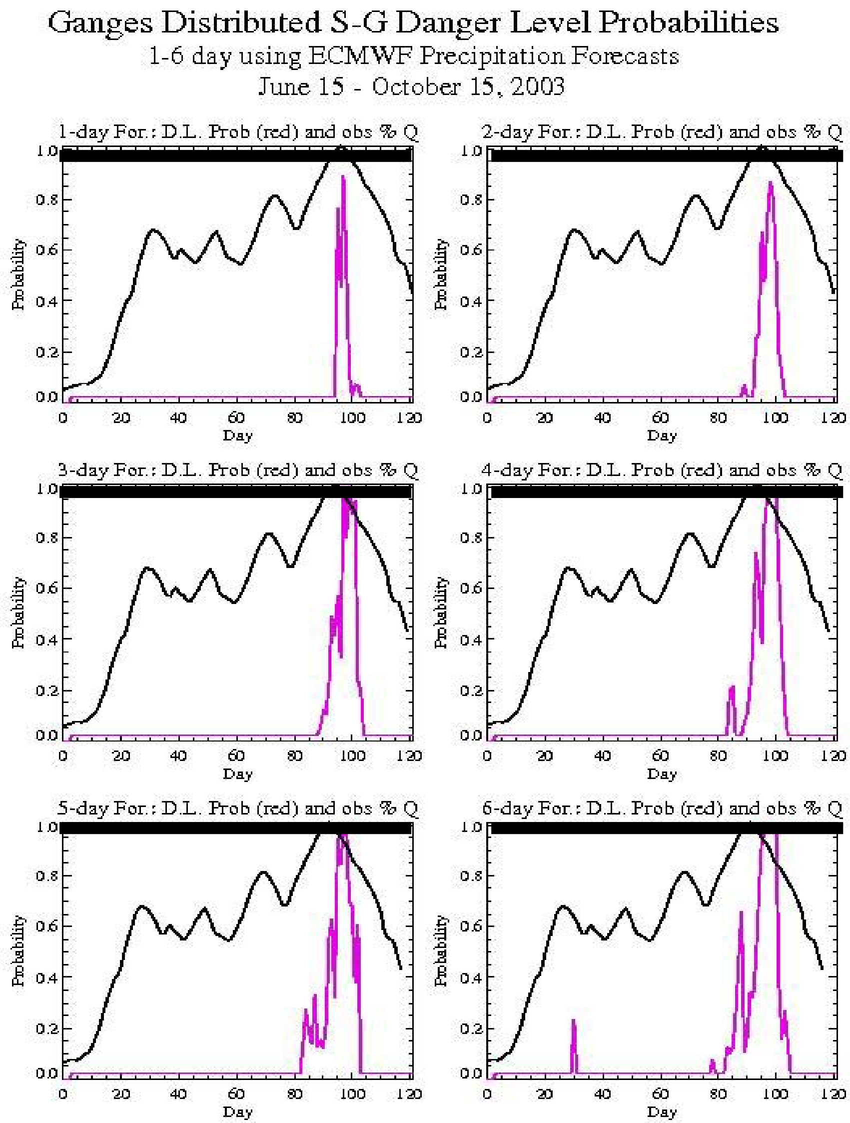


Ganges Flood Probability



Danger Level Probabilities





Conclusions

- Incorporated operationally into Bangladesh flood warning program
- Forecasts based on ECMWF 51-member forecasts and “observed” near-real-time precipitation estimates
- Shows good skill out to 5-7 days (“useful” skill out to 10-days)
- Extends Bangladeshi forecasts to 7-9 days

Future Work: combine ECMWF EPS precipitation with longer time-scale statistical-derived precipitation forecasts for a “seam-less” extension