Operational Short-Term Flood Forecasting for Bangladesh:

Application of ECMWF Ensemble Precipitation Forecasts

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


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

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)

**Step 2:** generate precipitation-ensemble-generated discharge PDF

**Step 3:** combine model error PDF with the above to generate a “new-and-improved” more complete PDF for forecasting:
Brahmaputra Discharge

Ganges Discharge

51 ensemble Members in color

Observed Q Black dash
Brahmaputra Flood Probability

June 15 - October 15, 2003

Obs (solid), 1-day 95%-50% Ens Mean (dash)

1 day

Obs (solid), 2-day 95%-50% Ens Mean (dash)

2 day

Obs (solid), 3-day 95%-50% Ens Mean (dash)

3 day

Obs (solid), 4-day 95%-50% Ens Mean (dash)

4 day

Obs (solid), 5-day 95%-50% Ens Mean (dash)

5 day

Ganges Flood Probability

June 15 - October 15, 2003

Obs (solid), 1-day 95%-50% Ens Mean (dash)

1 day

Obs (solid), 2-day 95%-50% Ens Mean (dash)

2 day

Obs (solid), 3-day 95%-50% Ens Mean (dash)

3 day

Obs (solid), 4-day 95%-50% Ens Mean (dash)

4 day

Obs (solid), 5-day 95%-50% Ens Mean (dash)

5 day
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