HEPEX Bangladesh Brahmaputra and Ganges River Testbed

1. Project Purpose

The data sets and models of the two proposed HEPEX test-beds of the Brahmaputra and Ganges river basins presented below are part of the project Climate Forecasting Applications for Bangladesh (CFAB) which provides operational real-time forecasts of river discharge into Bangladesh at daily, weekly, monthly, and seasonal time-scales (see http://cfab.eas.gatech.edu/cfab/cfab.html for further details) in support of national and international flood mitigation efforts for this country. As part of this project, short-term (1 to 10 day) forecasts of severe flood-stage discharges in the catchments of the Ganges and Brahmaputra Basins were developed and began operational dissemination during the monsoon season of 2003, continuing to the present. In order to generate probabilistic river discharge forecasts, the forecasting scheme utilizes the European Centre for Medium-Range Weather Forecasts (ECMWF) ensemble weather forecasts, near-real-time satellite and rain gauge precipitation estimates, and near-real-time discharge estimates from the Bangladesh Flood Forecasting and Warning Centre (FFWC).

2. Accomplishments during the past year

a) Beginning in May 2006, 1- to 10-day discharge forecasts for the Ganges and Brahmaputra went operational once again, after a one year pause in 2005 while funding was reauthorized (operational forecasts originally began 2003; see http://cfab.eas.gatech.edu/shortterm/ for the current daily-updated operational forecasts).

Other activities during the last year:

b) improved upon the "quantile-to-quantile" mapping technique we developed in 2004 for the ECMWF weather and seasonal forecast bias removal. These improvements significantly improve forecast skill and reliability. The improved technique is employed for ECMWF weather and seasonal forecasts, and also for the operational discharge forecasts (publication in process);

c) developed a new skill score that measures the relationship between ensemble spread and forecast skill; this new measure removes the inadequacies in the traditional spread-skill correlation measure (publication under review).

3. Plans for the coming year

operationally test data assimilation techniques

Data assimilation techniques hold promise for making significant improvements in operational discharge forecast model state estimation and thus leading to improvements in overall forecast performance. As well, these techniques can provide accurate forecast error estimates, as well as having the potential to reduce hydrologic model parameter uncertainty as well as improve model structural calibration in rain-fed through snow-melt-

dominated basins (ref: Moradkhani, 2005; Slater and Clark, 2005; Vrugt, 2005).

It is proposed that the focus of the Brahmaputra and Ganges test-beds presented here be to provide an opportunity to compare the performance of a variety of different data assimilation techniques within this data-sparse operational setting. In particular, these two basins are primarily ungauged, except at the forecast location itself, where near-real-time discharge estimates (rating curve derived) are available. As well, the only "observation-based" data inputs are "forcing" precipitation data provided by two semi-independent near-real-time satellite-derived estimates (6 to 12 hour lags) as well as sparse rain gauge estimates (36 hour lag).

As part of the data assimilation technique inter-comparison, the current operational discharge forecast methodology for these basins includes an analogue-based data assimilation and forecast correction technique. This technique was developed to provide real-time estimates of discharge forecast uncertainty by utilizing the near-real-time discharge estimates. This technique has shown good skill, and has its own strengths and weaknesses not inherent in other data-assimilation techniques.

5. Data sets available to HEPEX

Note: because we are under a licensing agreement with ECMWF, who provides for us their operational 1- to 10-day ensemble weather forecasts as part of a specific humanitarian need (Bangladesh flood forecasting), their data could only be made available for HEPEX users in collaboration with this specific project.

Data sets:

Daily River Discharge of the Brahmaputra and Ganges Rivers derived from rating curves from the late 1950's to the present;

ECMWF ensemble forecast weather variables [10U 10V 2D 2T CP LSP SLHF SSHF SSR STR SWVL1 SWVL2 SWVL3 SWVL4] over the region 30E to 160E, 40S to 45N, nominally 1degX1deg, but linearly interpolated down to 0.5degX0.5deg, 51 members, initialized 12:00GMT, with forecast interval times every 12 hours out to 10 days from 2003 to the present;

Satellite observed precipitation from the Global Precipitation Climatology Project (GPCP) and the NOAA CPC Morphing Technique ("CMORPH"), 3hourly, nominally 1997 to the present;

Gridded rain gauge data, 1979 to the present, provided by the National Oceanic and Atmospheric Administration's Climate Prediction Center, which were derived from the daily-reporting GTS rain gauge network;

The satellite and rain gauge estimates are also combined into one product and are interpolated to the same grid (0.5degX0.5deg) and time window as the ECMWF forecasts for operational use;

Digital Elevation Map over the region from the EROS Data Center.

6. Community Hydrologic Prediction System (CHPS)

The following techniques were developed as part of this project, which could be made available to a CHPS:

a) A method to correct precipitation forecasts to remove model biases and other discrepancies with "observations" (while retaining spatial and temporal covariances). Our improved technique builds upon our previous operational quantile-to-quantile mapping technique, but increases both forecast reliability and skill;

b) The issue of appropriate hydrologic model selection for this particular forecasting application was dealt with through the implementation of a flexible multi-model discharge forecasting approach which tries to capture the "best of both worlds" of the lumped and distributed hydrologic modeling techniques;

c) An analogue technique to account for all aspects of discharge forecasting error (while simultaneously making a model correction) so that statistically correct probabilistic discharge forecasts are made which account for all sources of uncertainty.

4. List of web sites, presentations, and publications

Web sites

CFAB web site: http://cfab.eas.gatech.edu/cfab/cfab.html

CFAB shortterm forecasts: http://cfab.eas.gatech.edu/shortterm/

Presentations

"Verifying the Relationship between Ensemble Forecast Spread and Skill", poster presentation at the 2nd International Symposium on Quantitative Precipitation Forecasting and Hydrology, 4-8 June 2006, Boulder, CO.

"Operational Flood Forecasting for Bangladesh", NOAA-CIRES Climate Diagnostic Center Seminar, June 22 2005, Boulder, CO.

Hopson, T. M., Operational Short-Term Flood Forecasting for Bangladesh, invited talk at MONEX 25 International Conference, New Delhi, India, 3 - 7 Feb. 2005.

Hopson, T. M., P.J. Webster, Operational Short-Term Flood Forecasting for Bangladesh: Application of ECMWF Ensemble Precipitation Forecasts, talk at AGU Fall Meeting, San Francisco, CA, 13 - 17 Dec. 2004.

"A Three tier precipitation and flood forecasting system for South Asia and Bangladesh", ECMWF seminar (with P.J. Webster), 17 May 2004, Reading, UK.

Hopson, T. M., P.J. Webster, R.L. Grossman, Operational Short-Term Flood Forecasting for Bangladesh using ECMWF Ensemble Precipitation Forecasts,

talk at 20th Conference on IIPS, 84th AMS Annual Meeting, Seattle, WA, 11 - 15 Jan. 2004.

Webster. P.J., A.R. Subbiah, T.M. Hopson, C. Hoyos, R.L. Grossman, H.-R Chang, K. Sahami, T.N. Palmer, D.L.T. Anderson, A. Hossain, Forecasting Rainfall and Floods in Bangladesh on Weekly to Seasonal Time Scales: Climate Forecast Applications in Bangladesh, talk at 14th Conference on Applied Climatology, 84th AMS Annual Meeting, Seattle, WA, 11 - 15 Jan. 2004.

P. J. Webster, R. Grossman, T. Hopson, T.N. Palmer, D.L.T. Anderson, Prediction of Floods in the Bangladesh Delta, Invited Talk at 25th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, April 29-May 3, 2002.

Book chapter

Webster, P. J., T. Hopson, C. Hoyos, A. Subbiah, H-. R. Chang, R. Grossman, 2006: A three-tier overlapping prediction scheme: Tools for strategic and tactical decisions in the developing world. In Predictability of Weather and Climate, Ed. T. N. Palmer, Cambridge University Press.

Journal Articles

Hopson, T. M. and P. J. Webster, Operational Probabilistic Flood-Forecasting for Bangladesh: Application of ECMWF Ensemble Forecasts, J. of Hydromet., (in review).

Hopson, T. M., Verifying the Relationship between Ensemble Forecast Spread and Skill, Mon. Weath. Rev. (in review).

Hopson, T. M. and P. J. Webster, A Multi-Model Ensemble Approach to Discharge Forecasting: Application to Operational Flood-Forecasting for Bangladesh, J. of Hydrol., (in process).

Hopson, T. M. and P. J. Webster, Using Quantile Techniques to Improve Bias, Skill, and Reliability of Forecasts: Application to Operational Flood-Forecasting for Bangladesh, J. Clim., (in process).

Hopson, T. M. and P. J. Webster, Accounting for Forecast Uncertainty: A Technique for Ensemble Discharge Forecasts, Water Resour. Res., (in process).

Hopson, T., Operational Flood-Forecasting for Bangladesh, University of Colorado Ph.D. Dissertation, Department of Astrophysical, Planetary, and Atmospheric Science, 2005.

Moradkhani, H., K. L. Hsu, H. Gupta, S. Sorooshian, "Uncertainty assessment of hydrologic model states and parameters: Sequential data assimilation using the particle filter", Water Resour. Res., 2005.

Moradkhani, H., S. Sorooshian, H. V. Gupta, P. R. Houser, "Dual state-parameter estimation of hydrological models using ensemble Kalman filter", Adv. Water Resour. 28 (2): 135-147, 2005.

Slater, A., and M. Clark, 2005 (in review).

Vrugt, J. A., C. G. H. Diks, H. V. Gupta, W. Bouten, J. M. Verstraten, "Improved treatment of uncertainty in hydrologic modeling: Combining the strengths of global optimization and data assimilation", Water Resour. Res., 41 (1): Art. No. W01017, 2005.

Webster, P. J., T. M. Hopson, C. Hoyos, A. Subbiah, H-. R. Chang, R. Grossman, Weather to Climate: A Holistic Approach to Environmental Prediction and Decisions, Bulletin of the American Meteorological Society (in process).