Title of Grant	A New Statistical Model of Streamflow Forecast Error
Type of Report	Final Report
Name of Principal Investigator	Mekonnen Gebremichael (PI from 05/2010 to 07/2014) Richard Anyah (PI from 03/2015 to 10/2015)
Period Covered by Report	05/01/2011 -
Name and Address of Recipient's Institution	University of Connecticut, Storrs (PI) University of California, Los Angeles (Sub-award recipient: from 03/2015 to 10/2015)
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Major Findings

Several findings have resulted from this work. Samples of major findings are listed below:

1. **A new statistical model of streamflow error has been developed.**

- We have developed a conditional probabilistic model for river level given a point forecast and other information (e.g., lag-1 observed river level) available at the time of the forecast. The conditional distribution is a skewed t-distribution, whose four parameters (location, scale, skewness, and df), are all characterized by smooth functions of the point forecast and lag-1 observed river level, both available at the time when the point forecast is issued. The model is intuitive and can be fitted with existing software.

- With an entire distribution of forecasts, our model provides uncertainty information to accompany each point forecast. The conditional distribution of the forecast error given the covariate information at the time the forecast is just the conditional distribution of river level shifted to the left by an amount of the point forecast level. This conditional forecast error distribution characterizes the uncertainty in the point forecast river level. It can be issued along with the point forecast river level. For instance, if a 90% prediction interval is issued with a point forecast river level, then users of the forecast will have clearer understanding of the forecast uncertainty. This can be especially useful when it is infeasible or too expensive to obtain ensembles of forecast from ensemble hydrologic models and ensemble precipitation forecasts.

2. **A method has been developed for improving the streamflow simulation accuracy. The method assimilates satellite soil moisture observations.**

- Surface and root-zone satellite soil moisture retrievals from passive and active microwave sensors were separately assimilated to the SAC-SMA hydrologic model, and their contribution to river discharge improvement was evaluated. The passive microwave sensor is the AMSR-E radiometer onboard the Aqua satellite, and the active microwave sensor is the ASCAT onboard the MetOp satellite. A CDF matching approach was applied to remove the mismatch between the remotely sensed and model soil moisture and to convert the satellite retrievals to the model space (accumulation in mm). Two separate data assimilation experiments were carried out and compared: soil moisture state updating and dual soil moisture and total channel inflow correction. All the satellite soil moisture datasets considered **(**AMSR-E and ASCAT) improved streamflow forecast compared to the open loop (without data assimilation). The best result was obtained when dual soil moisture and TCI (STU) update was carried out, compared to soil-moisture-only state update (SMU).

Publications and Presentations Resulting from the Work Supported by this Grant

(a) Journal Publications

Yan, J., G.-Y. Liao, M. **Gebremichael**, R. Shedd, and D.R. Vallee, 2012: Characterizing the Uncertainty in River Stage Forecasts conditional on Point Forecast Values, *Water Resources Research*, 48, W12509, DOI: 10.1029/2012WR011818.

(b) Book Chapters

Hirpa, F.A., M. **Gebremichael**, T.M. Hopson, R. Wojcik, and H. Lee, 2014: Assimilation of Satellite Soil Moisture Retrievals into Hydrologic Model for Improving River Discharge, In: Remote Sensing of the Terrestrial Water Cycle, *Geophysical Monograph 206*. First Edition, Lakshmi, V. (Ed.), American Geophysical Union, John Wiley & Sons, Inc., 319-329.

(c) Presentations

Hirpa, F.A., M. **Gebremichael**, H.S. Lee, and T.M. Hopson, "H23C-1369. Comparative evaluation of ensemble Kalman filter, particle filter and variational techniques for river discharge forecast," American Geophysical Union, Fall Meeting, San Francisco, CA, USA, December 2012.

Yan, J., G.Y. Liao, M. **Gebremichael**, R. Shedd, and D. Vallee, "H42B-06. Semiparametric Model for Uncertainty in River Stage Forecasts Conditional on Point Forecast Values," American Geophysical Union, Fall Meeting, San Francisco, CA, USA, December 2012.

Hirpa, F.A., M**. Gebremichael**, T. Hopson, and R. Wojcik, "Assimilation of satellite soil moisture observations in a hydrologic model for improving streamflow forecast accuracy," AGU Chapman Conference on Remote Sensing of the Terrestrial Water Cycle, Kona, Hawaii, February 2012.

Hirpa, F.A., M. **Gebremichael**, T.M. Hopson, and R. Wojick, "Ensemble Data Assimilation for Streamflow Forecasting: Experiments with Ensemble Kalman Filter and Particle Filter," Eos Trans. AGU, Fall Meet. Suppl., Abstract, San Francisco, CA, USA, December 2011.