Report as of FY2008 for 2007WY40B: "Weather Modification Impacts and Forecasting of Streamflow"

Publications

- Articles in Refereed Scientific Journals:
  - Soukup, T., O., Aziz, G. Tootle, S. Wulff and T. Piechota, 2009. Incorporating Climate into a Long Lead-Time Non-parametric Streamflow Forecast. Journal of Hydrology, 368(2009), 131-142.
- Conference Proceedings:
  - Moser, C., T. Soukup, G. Tootle and T. Piechota, 2008. An Expert System Approach to Improve Streamflow Forecasting in the North Platte River Basin, Wyoming, USA. Proceedings of the ASCE World Water & Environmental Resources Congress 2008, May 11-17, 2008, Honolulu, HI.

Report Follows

Weather Modification Impacts and Forecasting of Streamflow

PIs: Glenn Tootle (UW and Univ. of Tennessee) and Tom Piechota (Univ. of Nevada)
Graduate Students (UW and Univ. of Tennessee): Cody Moser, Ty Soukup, and Oubeid Aziz
Post-Doctoral Research Assistant (Univ. of Nevada): Haroon Stephen

Year 2 Annual Report

Objectives:

The scientific objectives of the proposed three-year research project are to:

1. Identify and evaluate snowpack, unimpaired streamflow, soil moisture and air temperature datasets in weather modification target areas within the state of Wyoming.
2. Examine relationships between snowpack and streamflow, including the impacts from the previous Fall season soil moisture (antecedent moisture conditions) and following Spring-Summer season air temperature on resulting streamflow from snowpack. This includes determining the optimum (i.e., highest correlation) relationships (period and lag time) between snowpack and streamflow.
3. Utilizing the optimum relationships, develop statistically based models (regression) for snowpack and resulting streamflow and apply the models to quantify streamflow increase due to snowpack increase as a result of weather modification.
4. Utilizing relationships between snowpack and streamflow in Task 3, evaluate statistically based models, including regression and non-parametric approaches, and develop forecasts of streamflow including exceedance probability, forecast skill and uncertainties.

Current Progress:

Cody Moser and Ty Soukup (Master's students in Civil and Arch. Eng.) completed their coursework and successfully defended their master's thesis in April 2008. Cody's thesis was entitled *Incorporating Antecedent Soil Moisture Into Streamflow Forecasting Within the North Platte River Basin, Wyoming* and Ty's thesis was entitled *Long Lead-time Streamflow Forecasting of the North Platte River Incorporating Oceanic-Atmospheric Climate Variability*. Each thesis directly addresses the four scientific objectives of the proposal. Cody presented the results of his research at the American Society of Civil Engineers (ASCE) Environmental Water Resources Institute (EWRI) Conference in May 2008. Cody published the results of his research in the 2008 ASCE EWRI proceedings. Ty presented the results of his research at the American Geophysical Union (AGU) Fall Meeting in December 2008. Ty published the results of his research in the *Journal of Hydrology*. Both Cody and Ty have made local presentations at the WY State Engineer's Water Forum and the University of Wyoming Graduate Seminars. Ty has accepted a position with Tri-Hydro in Laramie while Cody is pursuing a PhD at the University of Tennessee.

Preliminary Results:

Cody utilized existing Natural Resource Conservation Service (NRCS) methods (Principal Component Stepwise Linear Regression) in an attempt improve forecast skill. This was accomplished by including Antecedent Soil Moisture (ASM) as a streamflow predictor (in addition to snowpack, precipitation and streamflow persistence) and the development of an expert system based on ASM conditions (wet, normal, dry). During meetings with the NRCS (Tom Pagano, Portland, OR), they stressed the need to improve their "bad year" forecasts (i.e., years in which their forecast are significantly off). Cody determined the eight "bad years" of

NRCS forecasts for the two North Platte River basin streamflow stations of which he was developing forecasts. For the first station, Cody's model "beat" the NRCS forecast six out of eight and for the second station, seven out of eight (Figure 1).

Ty was successful in generating a skillful long lead-time (3 to 6 months) forecast of North Platte River basin streamflow utilizing climate (Sea Surface Temperatures and 500mb Geopotentials). He utilized a non-parametric modeling approach (Kernel Density Estimator) and developed Exceedance Probability Forecasts (Figure 2) for four USGS streamflow stations in the North Platte River basin. He reported good to excellent skill for the forecasts.

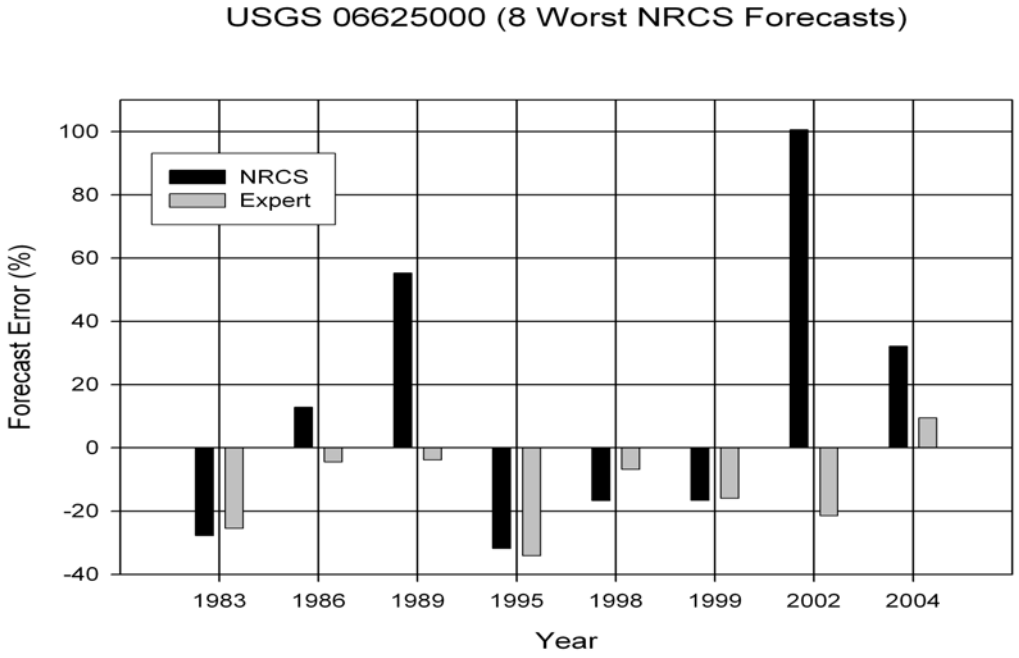

Figure 1: Plot of NRCS % difference forecasted valued versus the % difference Expert System forecast for the 8 worst NRCS forecast years for USGS Station 06625000.

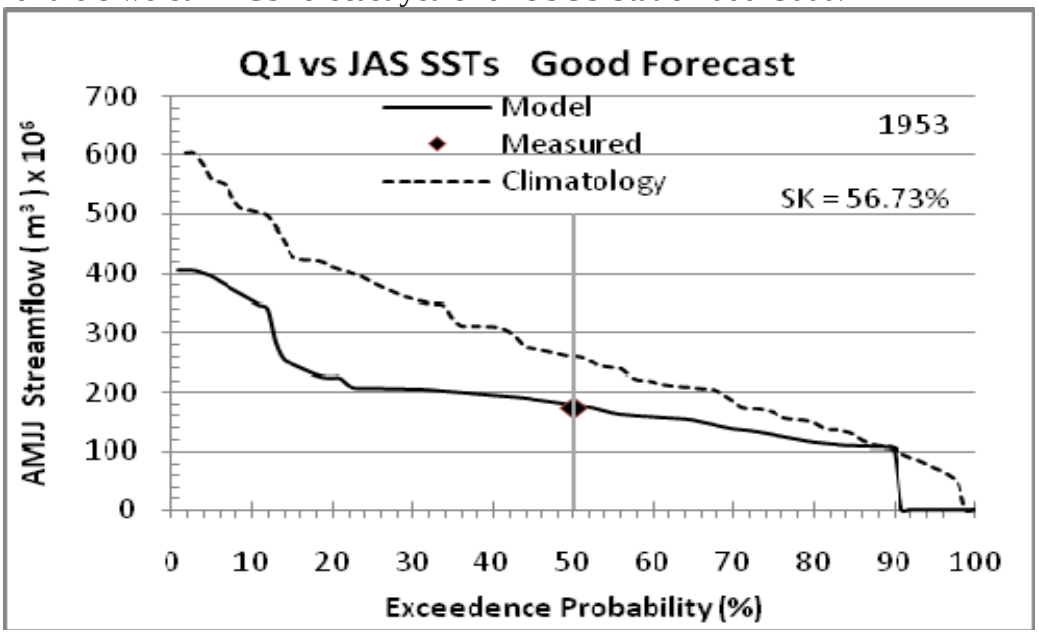

Figure 2: Example of Exceedance Probability Forecast.

Future Work:

Per meetings with Barry Lawrence (WWDO) and the Weather Modification Technical Advisory Group, it was concluded that the development of a physically based hydrologic model of the North Platte River basin would be of great benefit. Therefore, through cooperation with the University of Nevada, Las Vegas Department of Civil and Environmental Engineering and the University of Nevada, Las Vegas National Supercomputing Center for Energy and the Environment (NSCEE), we are developing a physical model (Variable Infiltration Capacity model) of the North Platte River basin. The lead investigators are Haroon Stephen, Cody Moser and Oubeid Aziz. We are evaluating various scenarios for the North Platte River basin. These scenarios include: What are the impacts of Weather Modification (cloud seeding) on streamflow? What are the environmental impacts (due to climate change) of massive high elevation deforestation due to the pine bark beetle? What does the incorporation of Global Circulation/Climate Models (GCMs) reveal for the future of North Platte River basin streamflow? Haroon plans to attend the American Water Resources Association (AWRA) spring meeting in May 2009 and present preliminary results of his research. He also plans to submit a paper (proceedings) for the AWRA meeting.

Cody is investigating differences in Snow Water Equivalent (SWE) measurements, comparing land-based (in-situ) SNOTEL data collections systems and satellite (NASA AMSR-E) collection systems. He is evaluating this data in western U.S. watersheds including the North Platte River Basin. Ty is continuing his research on using climate to develop a long lead-time streamflow forecast in the North Platte River Basin. He is currently improving upon his published work in the *Journal of Hydrology* by developing an operational streamflow forecast. Ultimately, he hopes to provide an experimental forecast website in which long lead-time forecasts (exeedance probabilities) are provided in advance of snowpack forecasts which begin on January 1st.

Invited presentations:

Soukup, T., O. Aziz, C. Moser and G. Tootle, 2008. Incorporating Climate into a Long Lead-Time Non-parametric Streamflow Forecast. Presentation at *American Geophysical Union (AGU) Fall Meeting*, December 13-18, 2008, San Francisco, California.

Moser, C., T. Soukup, G. Tootle and T. Piechota, 2008. An Expert System Approach to Improve Streamflow Forecasting in the North Platte River Basin, Wyoming, USA. Presentation at *ASCE World Water & Environmental Resources Congress 2008*, May 11-17, 2008, Honolulu, HI.