Summary of SARP Kickoff Workshop – 10/1/2012-10/2/2012

On October 1st a kickoff meeting for the 'Integrating Climate Forecasts and Reforecasts into Decision Making' SARP project was held in Salt Lake City at the Colorado Basin River Forecasting Center, bringing together researchers from UMass-Amherst, National Weather Service team leads, and project partners from Dallas Water Utilities, Public Utility District #1 of Snohomish County (SnoPUD), Salt Lake City Department of Public Utilities (SLC), and PacifiCorp. The overarching goal of the project is to *demonstrate the potential usefulness of climate forecasts and creating an appropriate framework for their application in water resources decision making.*

The workshop provided a forum to:

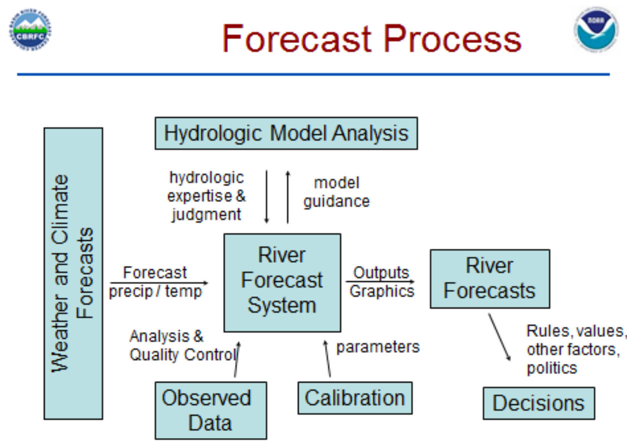
- Inform and educate each other on general and specific needs of each water management system,
- Learn about current and proposed NWS products,
- Understand operational challenges and metrics for each system, and
- Brainstorm methods for engaging the larger water community in the use and evaluation of forecasts.

A number of presentations were made throughout the day by NWS, UMass, and project partners spanning a myriad of topics. Below are the presentation highlights and important conversation notes, followed by an expanded description of each item.

- Hydrologic forecasts and reforecasts for this study will be produced by NWRFC and CBRFC, with assistance from these RFCs provided to the WGRFC for reforecast production for the Dallas system,
- Three types of streamflow forecast/reforecast products based on NCEP weather and climate model predictions will be produced and evaluated in this research: ESP, coupled GFS/ESP, and coupled GFS/CFSv2 forecasts,
- The UMass team is creating simulation and optimization models for each project partner system and will be using these to evaluate the usefulness of forecasts in decision making,
- The team is currently creating a project website that will be online by the end of November and will serve as an initial tool for information dissemination. Project meetings will be held quarterly or as needed,
- Metrics for assessing the value of forecasting for decision making and also critical operating periods were determined for each project partner. Models and forecast/reforecast development will focus on addressing these periods and objectives.

Hydrologic Forecasting with RFC models, Short & Long term

Kevin Werner of the Colorado Basin River Forecasting Center (CBRFC) presented on the operational production of short and long lead forecasts and ensemble streamflow prediction (ESP) methods. Most of these methods are common to RFC's throughout the country, though some of the tools and products discussed were specific to CBRFC. In general, the RFC forecasting process follows the figure below, with each RFC integrating and ingesting a variety of meteorological forecasts and on-the-ground products, including weather and streamflow observations, to produce meteorological forcings. These forcings are then processed through a series of models to generate a forecast of streamflow for a specific location. Hydrologists at each RFC are responsible for diagnosing potential issues in the forecast system and, if warranted, correcting them through adjustments to forcing datasets, model states, or the forecast time series. Once the RFC team feels comfortable with the forcings, model states, and forecast, a forecast is issued for each location of interest within an RFC domain. RFC forecasts are typically updated daily with some longer lead forecasts updated less frequently. RFCs also generate ensemble forecasts (ESP) with multiple forecast time series (ensemble members) meant to convey forecast confidence information. Daily forecasts are currently issued for the majority of inflow locations required in the systems models for the study sites identified in this project.



NWS Ensemble Forecasting and Reforecasting: Weather, Climate, and Flow

Dr. Andy Wood from the Northwest RFC (NWRFC) presented a summary of NWS ensemble forecasting and reforecasting procedures at the RFCs. After long discussion, three types of reforecasts products were chosen to be evaluated. The figure below provides an illustration of the three reforecast types:

- ESP/Climatology – This historical time series make up both short and long lead forecasts,
- Global Forecast System (GFS) and Climatology - Ensembles based on numerical weather prediction (NWP) drives forecast forcings for the first 14 days of the forecast period followed by climatology, and

Type of Forecast	Forcings	Streamflow
ESP/Climatology	Historic	Climatology
HEFS	GFS and Climatology	GFS and Climatology
HEFS	GFS and CFSv2	GFS and CFSv2

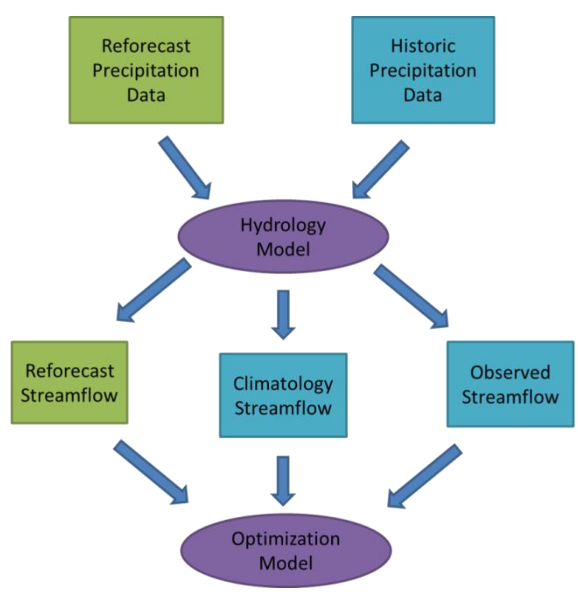
- ESP - Ensemble Streamflow Prediction
- HEFS – Hydrologic Ensemble Forecast System
- CFS – Climate Forecast System
- GFS – Global Forecast System

- GFS and Climate Forecast System version 2 (CFSv2) - In addition to GFS, forcing ensembles are driven by CFS based forecasts from day 15 through the end of the forecast period.

The RFCs directly involved in this research will soon be capable of producing ESP/Climatology traces and the GFS/Climatology traces using the Hydrologic Ensemble Forecasting System. These will be produced operationally at NWRFC and CBRFC by WY2014. We similarly anticipate WGRFC will be able to produce HEFS based forecasts though communication regarding this is ongoing. Operational production of GFS/CFSv2 forecasts and reforecasts are in initial stages of operational production at CBRFC and NWRFC. These RFCs will serve as the testbed for operational production and evaluation of these forecasts and reforecasts as part of this project. This methodology will expand to other RFCs as the framework is developed and finalized.

Presentation of Past UMass DSS Systems and Proposed Modeling Framework

UMass presented previous work which involved incorporating different types of forecast products into decision support systems (DSS). Previous work with the SnoPUD provided a case study that demonstrated how the use of forecasts improves operational performance and ensures all system constraints are met through optimizing desired metrics. In this case study, the objective was increasing avoided costs incurred by the customer base (i.e. generating hydropower to offset power purchased). The DSS (a combined simulation and optimization model) was used to evaluate avoided cost gains in three hydrologically different years (Alemu et al. 2010). The forecast information scenarios were compared to the rule of thumb scenario. There was significant improvement from the rule of thumb scenario when forecasts were used in the operating process.



A second study built on the work of Alemu, investigating insights provided by climate informed forecasts. The same three hydrologically diverse years were analyzed using the process outlined in the Figure shown to the right. Using the methods of Hamill (2006), CFSv2 data were downscaled and used as the climate forcings to generate streamflow instead of climatology as was the case in Alemu et al. (2010). The study found that while the CFSv2 forecasts show promise as a potential tool to improve operational forecasts, further research is needed to fully understand its potential applications and periods where the forecast exhibits useful skill. Exploring a range of streamflow conditions could help define when it is most appropriate to apply the reforecast data and a more refined method of downscaling could improve the usefulness of the reforecast products.

Proposed Simulation and Optimization Modeling

For this project, the team will use iSee's Stella simulation software and LINDO's Lingo optimization software. Previous work with SnoPUD used GoldSim and Stella to model the 112 MW Henry M. Jackson Hydroelectric Project. The simulation and optimization models incorporate system constraints, operating policies, and environmental flow requirements. Simulation models tend to be rule based and reflect operating policies of a system. Optimization models are objective based and try to maximize or minimize targets determined important by the user. Each provides a unique view of the system and its operating policies.

Constructing each water system simulation model facilitates information transfer between partners and UMass regarding operating rules and constraints and model limitations with respect to replicating historic operations. Simulation models can also provide a two way mechanism to interact with optimization models. For instance, simulation models can develop targets that constrain the optimization models via standard operating policies. Optimization models provide optimal operations given certain objectives; these may be used to craft new rules that are implemented in the simulation model.

Project Timeline

The proposed project timeline is captured in the figure shown to the right. Task 1 involves generation of the reforecast data for use in system evaluation. This task is currently in progress and will continue through December of 2013. The NWRFC and CBRFC will work to identify collaborators at the WGRFC to create reforecasts for the Dallas system. Model development is currently underway, with the workshop providing significant insight for Task 2.1, which identifies critical periods and operational metrics to evaluate system performance. This is detailed below in the Metrics section. Task 2.2, incorporating climate forecast skill, will begin with an evaluation of the SnoPUD system as both simulation and optimization models are completed and a framework for generating and transferring reforecast data is almost in place. Next, Bear Lake and the Salt Lake City system will be evaluated because modeling is underway and reforecast generation methods are almost in place at CBRFC. The Dallas system will follow shortly behind these as the WGRFC is brought up to speed on reforecast generation and the simulation and optimization models are constructed. Task 2.3, evaluating short and long lead time skill, will occur concurrently with Task 2.2.

	Year 1				Year 2			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1	Ensemble Streamflow Forecast generation (Hindcast and Real-time) for project locations							
Task 2.1	Framework to identify critical periods where climate forecasts cross the threshold of utility							
Task 2.2		Climate forecast skill in dynamic – evaluating system performance and risk using reforecast data						
Task 2.3			Influence of short and long lead time skill to system performance					
Task 3				Disseminating climate data to end users				

Information dissemination to end users is currently happening, though the task will begin in earnest once initial results are generated and the PNWRFC and CBRFC are able to communicate their framework to other RFCs. This is described below in the Information Dissemination Section.

Information Dissemination

Given the success of this workshop, the project team determined that another workshop should be held in one year. Although some funds are available in the SARP budget, the team will pursue additional funding to conduct this workshop.

The project team agreed that construction of a project website will serve as an initial means for information dissemination. The project website is currently under construction and will be made public by the end of November. The project site will showcase initial results, model development, and updates on project progress. The website will be used to transfer data and project status to NIDIS and the NOAA SARP program.

The team decided that initially quarterly meetings would be held via Skype or Google Hangouts. This would allow face-to-face dialog among team members and the ability to share results though presentations and actual running of models via screenshare and web applications. UMass and NWS team members will meet as needed (more frequently) to discuss production of reforecast data and model handshaking. The UMass team will use Trello to track model development and testing. The NWS expressed some interest in using Trello as well to help with workflow management.

A number of items were generically discussed regarding information dissemination, including data formats, best ways to reach end users, and dissemination of project results and reports. It was concluded that although the conversation was fruitful it was better to wait to discuss this once tangible results and products were in the pipeline. Team members brainstormed a number of important meetings to present results at next year. Everyone agreed this would be one of the most effective ways to disseminate results nationally and regionally.

Project Partner Presentations

Project partners each presented an overview of their respective systems, detailing general system information as well as highlighting operational constraints and objectives. The presentations will be available online at the project website. During the discussion of each system, the project team brainstormed with the partner regarding the usefulness of system forecasts, and whether any operational products are currently used in decision making. It was found that all of the partners actively use both short lead and long forecasts in decision making. SnoPUD currently processes forecasts through a DSS to generate weekly operating policies. Salt Lake City and PacifiCorp use both short term forecasts during spring flood seasons and long lead climate forecasts to make decisions regarding water supply such as allocation or refill timing and quantity. Dallas uses long lead forecasts to look at drought probability and short term forecasts in storm water and flood management.

System Metrics and Critical Operating Periods

The project team formulated important operational metrics and critical operating periods for each system. A complete list of metrics, constraints, and critical periods are found in the accompanying workshop PowerPoint. The corresponding figure provides a matrix of operating objectives as described by project partners for three management uses. An important outcome of the workshop was populating this matrix with system specific objectives and metrics as each use was discussed in detail. The UMass team is collaboratively developing systems models with each project partner based around this information. The discussion highlighted the potential usefulness of the models in decision making as well as what challenges exist in correctly modeling a partner's system.

Partner	Hydropower	Water Supply	Environmental Flows
Dallas	None	• Firm yield • Frequency of instituting voluntary or mandatory restrictions • Total revenues generated • Minimum storages in reservoirs	None
PacifiCorp Bear Lake	• Energy production lost relative to baseline	• Volume of water provided to irrigation • Annual allocation of water • Accuracy of forecast of water to be allocated • Irrigation supply lost	None
Salt Lake City	• Potential hydropower out of Little Dell	• Appropriate storage level at the beginning of water supply season • Balancing water sources and supplies	• Cannot divert into pipeline until >5 cfs at Lamb's Diversion
SnoPUD	• Mega-watts hours produced per year • Total avoided costs from other purchases • Annual energy value	• Prioritize water supply to Everett per agreements	• Meet Minimum Instream flows • Minimizing peak releases that harm fish • Provide a range of process flows

References

Alemu, Eset T., Richard N. Palmer, Austin Polebitski, and Bruce Meaker. "A Decision Support System for Optimizing Reservoir Operations Using Ensemble Streamflow Predictions." *Journal of Water Resources Planning and Management* 137.1 (2010): 72-82.

Hamill, Thomas M., and Jeffrey S. Whitaker. "Probabilistic Quantitative Precipitation Forecasts Based on Reforecast Analogs: Theory and Application." *Monthly Weather Review* 134.11 (2006): 3209-229.