Workshop Summary:
Climate Change Modeling Workshop for Front Range Water Providers
February 1, 2008 Denver, Colorado

Climate change has the potential to affect water supplies and water management in the Intermountain West. Water managers are beginning to explore ways to quantify and adapt to potential changes. Several Front Range water providers are working together to fund a study of the potential impacts of climate change on water resources in Colorado. The water providers will use a variety of downscaled GCM projections in two different hydrology models to identify streamflow changes through out the 21st century. WWA is serving on an advisory committee to help the group select GCMs, emissions scenarios, climate variables, and data sets. WWA will also provide guidance on adaptation strategies and communicating the results to governing bodies and the public.

In February, WWA organized an education workshop for the water providers were four presenters explained the fundamentals and differences of GCMs, emissions scenarios, downscaling techniques, and hydrologic modeling. See http://wwa.colorado.edu/resources/climate_change_modeling.html for presentations and other background information. The following are short summaries of each presentation from the workshop.

Climate Models and Emissions Scenarios

Joe Barsugli, CIRES/University of Colorado, affiliated with NOAA Earth system Research Lab, Physical Sciences Division

Dr. Barsugli provided background on three topics: climate sci ence, emissions scenarios, and climate models.

1)The *science of climate change* can be simplified by stating that as humans increase carbon dioxide emissions, we affect the carbon cycle, which changes the energy balance of the earth. The earth heats up, which causes increased evaporation, which also affects the energy balance. Because the energy balance and the water cycle involve the winds and ocean currents, they are changed as well, potentially changing all aspects of climate.

2) *Emissions scenarios* refer to the projected amount of change or increase in carbon dioxide emissions and other drivers of climate change during the 21st century. The scenarios differ mainly in the rate of carbon dioxide increase and in whether or not they lead to a stabilization of greenhouse gas concentrations during the 21st century. The rate of carbon dioxide increase depends on assumptions regarding demographic development, socio-economic development, and technological change. These scenarios are used as inputs to the climate models, and typically, each climate model is run with several emissions scenarios. Three emissions scenarios (B1, A1B, A2) were chosen for intensive climate modeling studies used in the IPCC Fourth Assessment Report, though other scenarios were also considered. It is important to note that emissions scenarios are useful tools, but they are not forecasts.

3) *General Circulation Models (GCMs*), or climate models, simulate all the processes that affect the climate on a global scale, including atmospheric chemistry, ocean circulations, clouds, terrestrial ecology, and large river systems. These models use mathematical equations to represent physical processes to varying degrees of approximation. Different modeling centers make different choices in how to represent these processes. There are 22 GCMs in the IPCC Fourth Assessment Report, and each has its own biases and uncertainties. Often the same model will be run with different initial conditions (the starting state of the physical processes that affect climate), and so there are multiple runs from the same models. Climate models produce output for many parameters and at various time scales. Typically, temperature and precipitation changes for the mid and late 21st century are referenced in articles.

An Overview of Downscaling Techniques Used in Climate Change Science

Christopher J. Anderson, NOAA Earth System Research Lab, Global Services Division

Climate models have a large resolution (limited by computing power), and this resolution is most often larger than both the physical processes that affect climate and the spatial scale of river basins. Therefore, in order to get temperature and precipitation projections that are relevant to river basin scales for water management, one must downscale the results and attempt to remove some of the model biases. Dr. Anderson explained two types of downscaling: dynamical and statistical.

1) *Dynamical downscaling* uses a regional climate model to provide climate change projections based on smaller scale physical processes. These models incorporate GCM output and provide an extra modeling step. Regional climate models require very large amounts of data and computing power, so only a small number of regional climate simulations are generated when downscaling. The results of regional climate models provide additional details but may also contain biases that need correction by statistical techniques. Regional climate models are well suited for understanding processes.

2) *Statistical downscaling* identifies statistical relationships between observations and model simulations of past climate. This method then uses these relationships to remove the bias from GCM output and to provide climate projections on a smaller scale that better reflect the regional differences in climate. The advantage of statistical downscaling is that a large data set can be generated. However, it is impossible to account for changes in statistical parameters in the climate projections since the observations needed to make such corrections do not yet exist.

K-Nearest Neighbor Resampling Technique

Balaji Rajagopalan, University of Colorado, Department of Civil, Environmental and Architectural Engineering

Many water managers make long-range water supply projections based on observed streamflow or weather conditions. The K-NN approach resamples past weather or streamflows to create scenarios for the future. The resampling is based on 'K' historical years that are 'analogs' to the 'current condition'. Thus simulated scenarios have the same statistical properties as the historical data, but they also provide a rich variety of sequences and variability. This framework can be easily modified to generate scenarios based on any user-defined condition. For example, seasonal climate forecast can be used as a condition to generate flow or weather scenarios thus, providing a seasonal ensemble forecast. Or the method can preferentially choose streamflow from years that were below average to simulate a long-term drought. This approach has been applied to a variety of water resources problems especially in Western US.

Dr. Rajagopalan presented two examples of using the Knn method: (1) stochastic weather generation that can be used in hydrologic or agriculture or other process models to provide long term simulation or seasonal forecast and (2) quantifying influent water quality variability to understand regulatory compliance risk in drinking water utilities.

Hydrology Modeling for Climate Change Impacts Studies

Levi Brekke, USBR Water Resources Planning and Operations, Technical Service Center

Hydrologic models can be used to "convert" downscaled temperature and precipitation data from climate models into streamflows. These models simulate the hydrologic system, including rivers, soil moisture, and ground water storage, and the effect of snow, rain and temperature on the resulting runoff. Dr. Brekke described the similarities and differences between three hydrology models: WEAP21, SAC-SMA/Snow17, and VIC. The models tend to produce different runoff responses for a given climate change assumption. One reason is that each model "structure" features a slightly different approach for representing soil moisture storage and distribution, groundwater interaction with surface water, watershed elevation influences, and other water cycle processes (e.g., evapotranspiration). Beyond model "structure" differences, the differences in runoff results can also be caused when the models are not calibrated in a consistent fashion, built to consistent spatial scales, or simulated on consistent time steps.

Dr. Brekke advised the group to consider using multiple hydrologic models in their impacts investigations. If the goal is to determine model preference, he suggested that it may be useful to re-calibrate and validate the models on pairs of historical periods featuring contrasting climates (e.g., earlier wet/cool period for calibration followed by recent warmer/drier period for validation). This would hopefully indicate whether some model(s) may be more confidently applied to a future climate that differs from the "calibration" climate.

On the Web

The workshop agenda, presentations, references, and key terms are available at:

- http://wwa.colorado.edu/resources/climate_change_modeling.html.