A Integrated Hydrometeorological Observation and Prediction Network, What is it? What could it Do?

John Pomeroy* and Chris Spence**

+Centre for Hydrology
University of Saskatchewan

*Water Science and Technology Directorate
Environment Canada

Bow River at Banff, Mean Annual Flow

Trend -11.5% since 1910, Statistically Significant at 99% Probability
We Need to Know the Details

Late summer flows large and dropping rapidly

Bow River at Banff, Mean August Flow

Trend -24.9% since 1910, Statistically Significant at 99.9% Probability
Winter flows small and rising somewhat

Bow River at Banff, Mean March Flow

Trend +15.2% since 1910, Statistically Significant at 99.9% Probability
Decline in Natural Flows from the Rockies \textit{and} Increase in Downstream Consumption is \textbf{Not Sustainable}

\textit{Natural and Actual Flow} of South Saskatchewan River leaving Alberta

- Natural flow: Decline of 1.2 billion $\text{m}^3$ over 90 years (-12%)
- Actual flow: Decline of 4 billion $\text{m}^3$ over 90 years (-40%)
- Note: 70\% of decline due to consumption, 30\% due to hydrology
- Upstream consumption: 7\%-42\% of naturalized flows in last 15 years
Implications of Changing Water Supply

- Loss of hydrological “stationarity” means that policy and infrastructure can no longer be based on traditional risk management analyses.

- Requires predictive modelling based on data assimilation, enhanced observations, continuing process research and model improvements to deal with rapidly evolving unknowns.
How to Answer the Questions

- **Observations** answer “Where?” and “How Fast?” and improve Understanding and Prediction
- **Understanding** answers “Why?” and improves Prediction
- Integration of observations and prediction with a research program to develop better understanding can efficiently and effectively answer our major questions regarding water resources
Hydrometeorological Observations

- To predict water resources in cold regions we need to know
  - Inputs: rainfall, snowfall, radiation, wind, temperature, humidity
  - Storage: groundwater, soil moisture, snowpack, glaciers, lakes, wetlands
  - Flows: streamflow, evaporation, blowing snow
Meteorological Stations
Hydrological Observation
Observations Clustered in Small Basins Improve Understanding
Observations are Not Enough!

- Data itself is not understanding or prediction
- Problem of retrieving, archiving, change in media
- QA/QC essential
- Observational data needs interpretation, interpolation, assimilation to be useful
Energy and Water are closely linked in cold regions
Regional climate change predictions 2080-2089 relative to 1980-1999

Annual

Winter - DJF

Summer - JJA

IPCC 2007

Warmer and Wetter in North; Drier in South; Winter enhancement
Canadian Rockies are the Hydrological Apex of North America
Mountain Runoff is Mostly Snowmelt and Glacier Melt

Snow and Glacier Melt in Mountains

Flow rate (m³/s)
How Much Snow is There?

Less and Less.....
US NOAA satellite measured average change (days/yr) in snow cover duration (Feb.-Jul.) over the period 1972-2000.

Cordillera: 1 to 2 month decrease!

NOAA
Temperature Trends at High Elevation in Marmot Creek, Kananaskis

Winters are warmer by 3 to 4 °C since 1962

Harder & Pomeroy
Warmer winters = less snowfall
Warmer winters = more rainfall

Harder & Pomeroy
Middle Creek June Streamflow cubic metres/second

Land use changes did not occur in this sub-basin

Harder & Pomeroy
Global Trend towards Glacial Decline

Mountain Glacier Changes Since 1970

Effective Glacier Thinning (m/yr)
Glacier Retreat – Rocky Mountains

Mapped from NASA LANDSAT satellite

Glaciers are fed by alpine snow

36% loss of glaciated area of South Sask River Basin 1975-1998

22% loss of glaciated area of North Sask River Basin 1975-1998

Demuth & Pietroniro
Glacier Wastage Contribution to Streamflow as a Function of Glaciation of a River Basin

\[ R^2 = 0.7169^* \]

\[ R^2 = 0.8014^* \]
20% decline in natural flow of the South Saskatchewan River over 1912 to 2070
BUT GREAT UNCERTAINTY IN THESE PRELIMINARY RESULTS!

Al Pietroniro, Environment Canada

Red Deer at Bindloss
-13%
(-32% to 13%)

South Sask at Diefenbaker
-8.5%
(-22% to 8%)

Bow River at mouth
-10%
(-19% to 1%)

Oldman at mouth
- 4%
(-13% to 8%)

2039-2070 Mean, Change from Current Natural
A Framework for Integrated Research and Monitoring (FIRM)

- A Framework for Integrated Research and Monitoring, or FIRM, has been developed in response to recommendations from a series of scientist-user workshops and proposed to the Water Survey of Canada and other groups.

- Application of the FIRM concept to any specific research or policy question is via a cluster of activities including short and long term monitoring sites and process research.

- These clusters are designed to provide information, improve knowledge and develop predictive tools for practitioners, for policy development and/or to respond to priority issues such as climate change, secure water resources, or biodiversity.
FIRM Concept

- Cluster research and observations
  - High quality and collaborative
  - Strategic
  - Relevant
  - Worthy
  - Scale appropriate
  - Representative
- Provide prediction and information
High quality and collaborative

- High quality collaborative monitoring and research need to be present in each cluster.
Strategic

- Research strategies are needed to develop understanding for the creation and evaluation of predictive models.
- Research strategies need explicit environmental prediction and/or engineering design goals.
- Goals should include a quantified reduction in uncertainty from present predictive tools.
Relevant

- Focus on activities that address current needs and emerging issues
Worthy

- Demonstrable benefits for the environment and economy.
Scale appropriate

- Research and monitoring in FIRM clusters needs to exhibit demonstrated synergy in a nested manner.
- The time and space scales of individual cluster outputs must be defined.
The suite of clusters must be representative of the country’s environmental diversity.
Rocky Mountain Integrated Hydrometeorological Observation and Prediction Network

- Focused Observation and Prediction Area to couple key issues
  - Mountain snow and glacier dynamics
  - Downstream drought and water supply
  - Climate change impacts on water supply
    - International Waters

- Integrated Research and Monitoring
  - Surface water, groundwater, snow & ice
    - Remote sensing
    - Research basins
    - Major river basins

- Regional Data Assimilation & Prediction
  - Information Portal
  - Information Interpretation

- Strategic Prediction of Water Resources for
  - Infrastructure Design
  - Hydroelectricity
  - Food Security
  - Ecosystem Preservation
Possible Goals of the Network

- Establish the critical importance of maintaining and improving the hydrometeorological monitoring network.
- Advance our understanding and prediction of water resources in the western mountains and downstream areas.
- Improve our ability to assess hydrological changes and associated predictive uncertainty that arise from changing climate and land use.

**Ultimately** –
- contribute to the assessment of the long term sustainability of western and northern Canadian water resources.
- enhance our collective ability to assure water and related energy and food security in this region.
International Linkages

- CliC – Climate and Cryosphere Project of World Climate Research Program
- PUB – Decade for Prediction of Ungauged Basins, International Association of Hydrological Sciences
- GEO- Group on Earth Observations
- GEWEX – Global Energy and Water Cycling Experiment, World Climate Research Program
Activities for the Network?

- Understanding and Describing Processes:
  - Improve our understanding through field and modelling studies
  - Develop improved numerical descriptions of processes

- Observing and Monitoring
  - Design and help implement improved observation networks
  - Advance observation methods and practises
  - Integrate and assimilate surface and remote sensing data into information products

- Improving Models
  - Improve hydrological models for this region
  - Develop scale and purpose appropriate predictive modelling

- Predicting Impacts:
  - Predict impacts of changing climate and land use on water and climate using the improved models,
  - Reconstruct historical records and climate model and land use scenarios
  - Predict water resources in ungauged basins

- Applying Knowledge:
  - Demonstrate water resource applications and improved forecast accuracy with collaborators
  - Provide policy makers with information they can use
Possible Methodologies

- Establish intensive clusters of observations in research basins
- Enhance networks of hydrometeorological observations around clusters
- Integrate remote sensing with basin observations through data assimilation.
- Use explicit modular model development strategies to rapidly incorporate new algorithms and structures into purpose built predictive models.
- Use a nested modelling strategy employing the European Union, “Open MI” standards [http://www.openmi.org](http://www.openmi.org) to move information from large to small scale and in reverse.
- Use dynamical and statistical scaling to downscale and upscale between climate models, observations and hydrological models.
- Develop assessments of the uncertainty in hydrological predictions for climate and water resources.
- Demonstrate water resource and climate predictions with user groups for key basins.
Expected Results

- More accurate estimates of current water resources
- More accurate predictions of changes to water resources.
- Incorporation of this information into infrastructure design and ecosystem conservation strategies.
How Might We Measure Success?

- Greater hydrometeorological information sharing and collaboration among affiliated organizations
- Improved water resource information delivery to all users
- Provision of high end water resource prediction information to users so that they can improve program delivery
Take Care in Your Discussions