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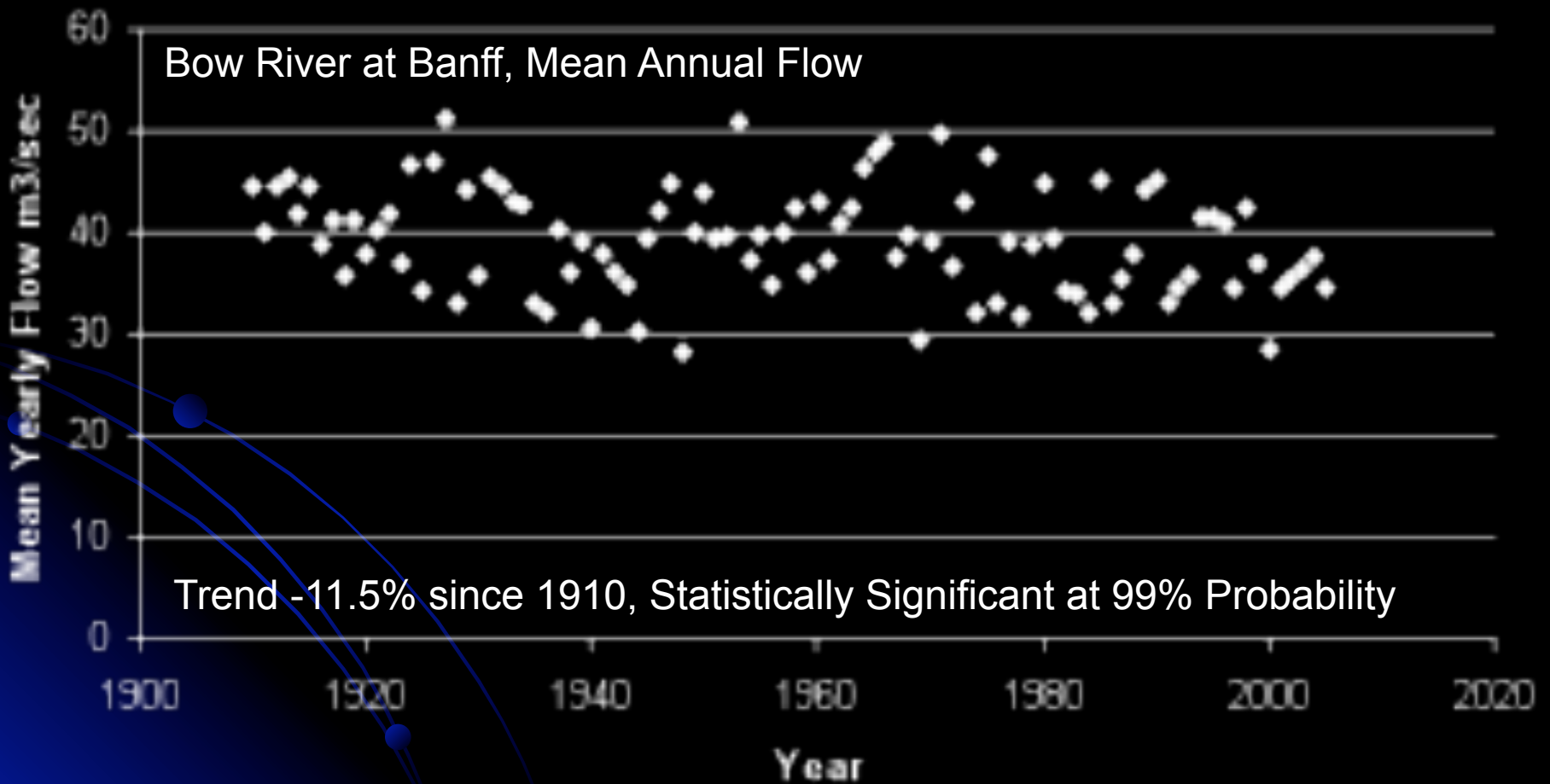

IP3
Improved Processes & Parameterisation
for Prediction in Cold Regions
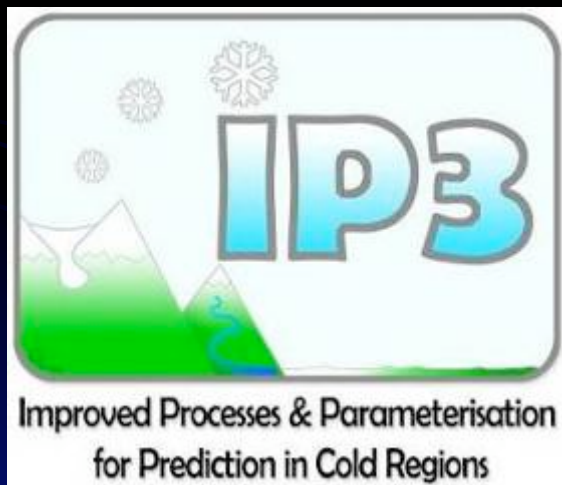
John Pomeroy[+] and Chris Spence[*+]

[+]Centre for Hydrology
University of Saskatchewan

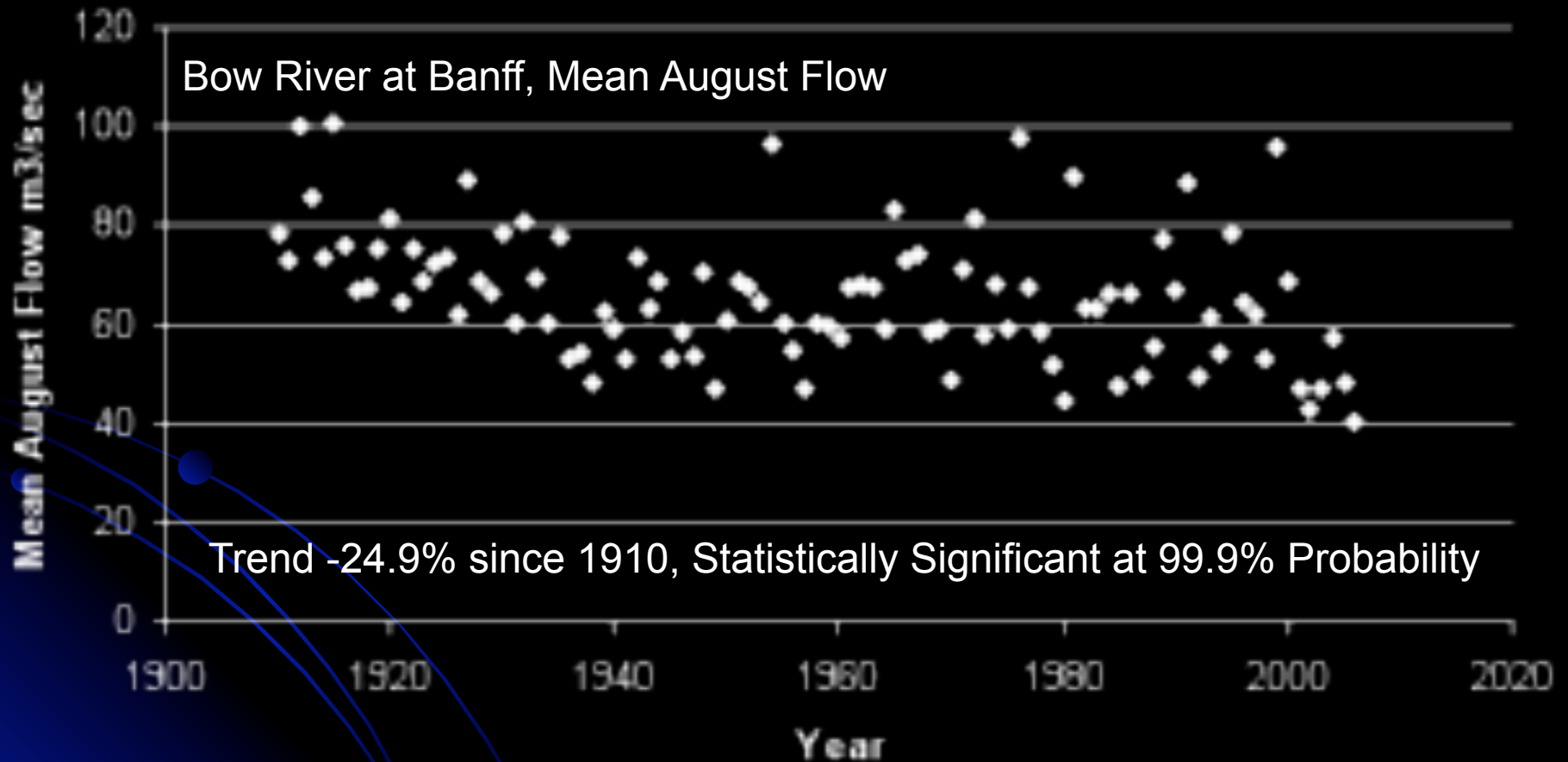[*]Water Science and Technology Directorate
Environment Canada

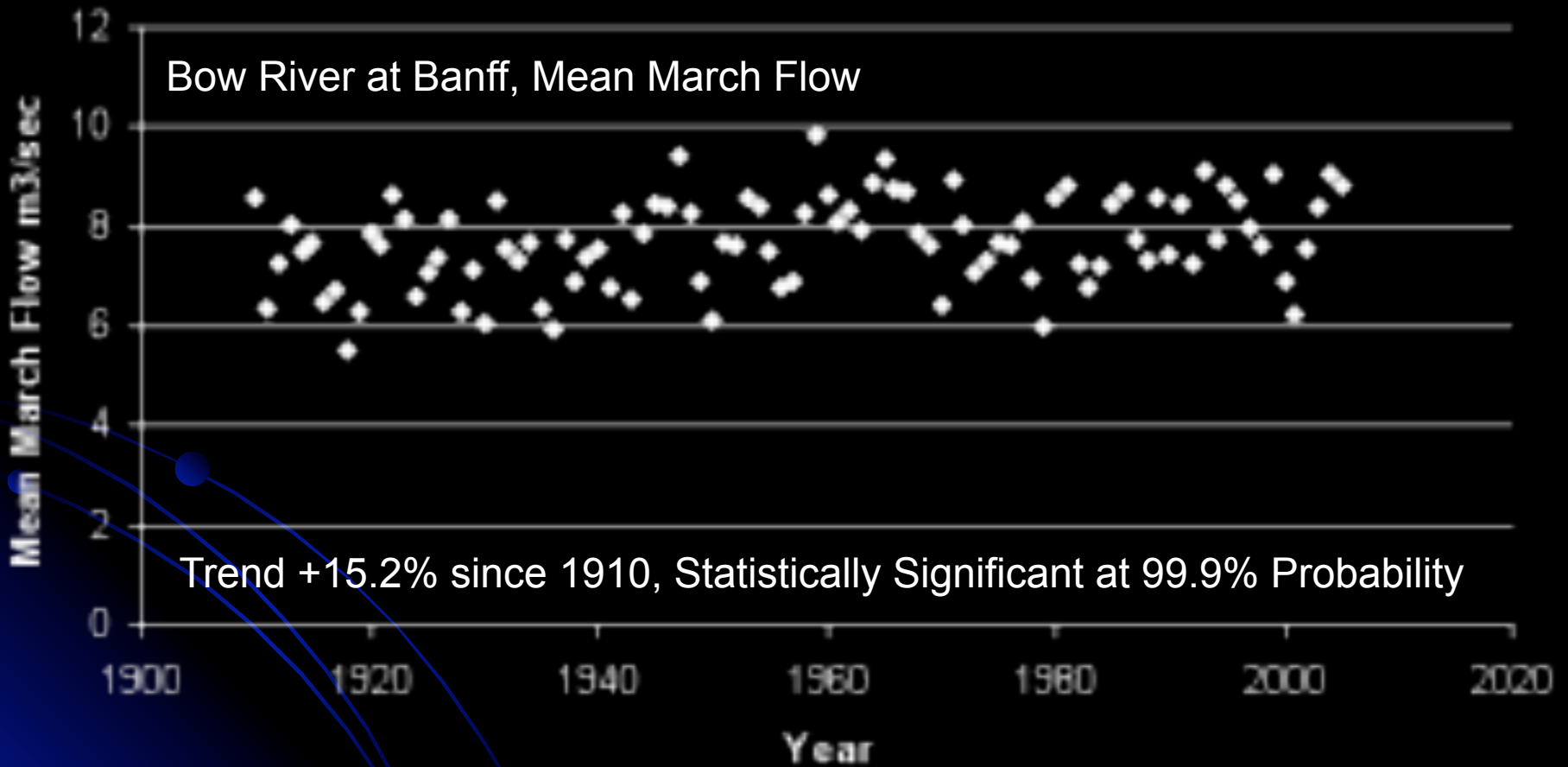# Problem: Water Resources are Changing. Where, How Fast, Why, How Much More?

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

Mean August Flow m3/sec

Year

All the Details

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 *and*
Increase in Downstream Consumption is Not Sustainable

Natural and Actual Flow of South Saskatchewan River leaving Alberta
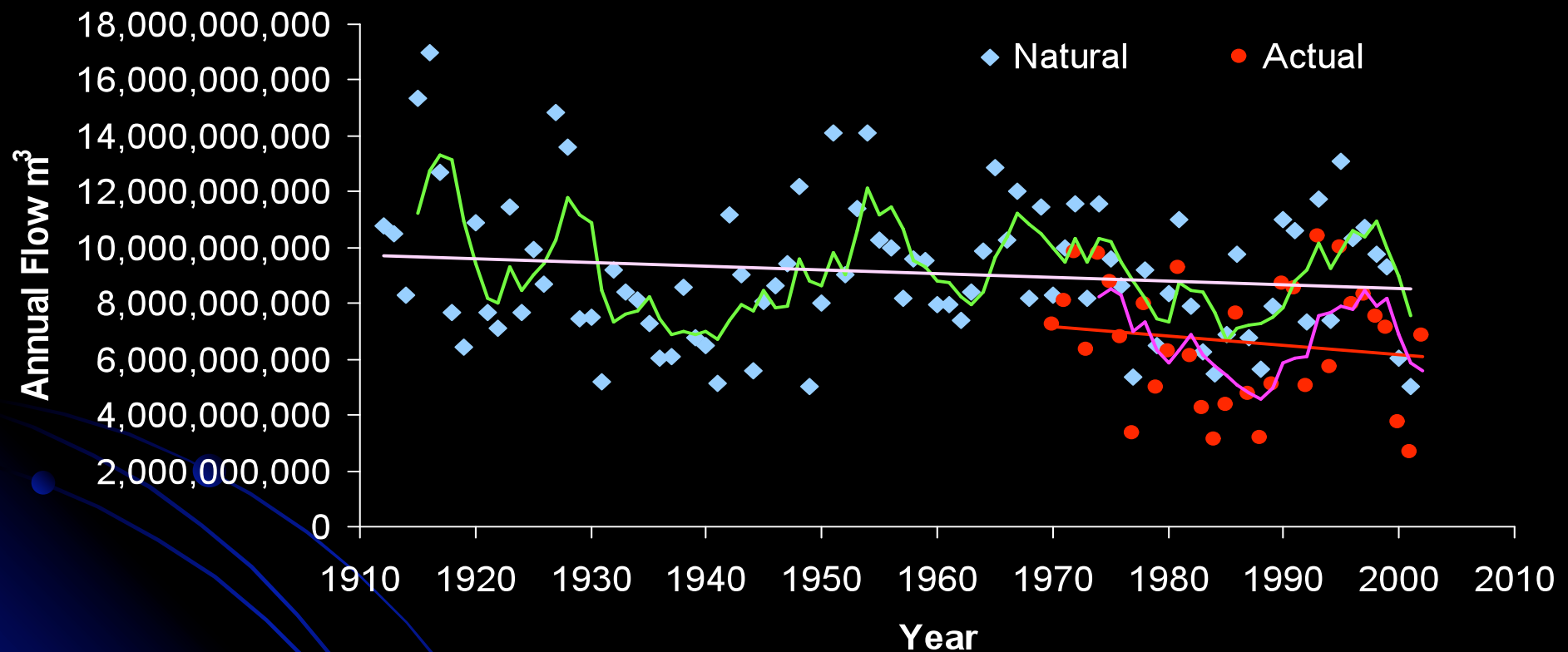
Natural flow: Decline of 1.2 billion m^3 over 90 years (-12%)
Actual flow: Decline of 4 billion m^3 over 90 years (-40%)
Note: 70% of decline due to consumption, 30% due to hydrology
Upstream consumption: 7%-42% of naturalized flows in last 15 years

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
- **Prediction** answers "How Much More?" but also helps answer "Where?", "How Fast?" and "Why?"
- 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**
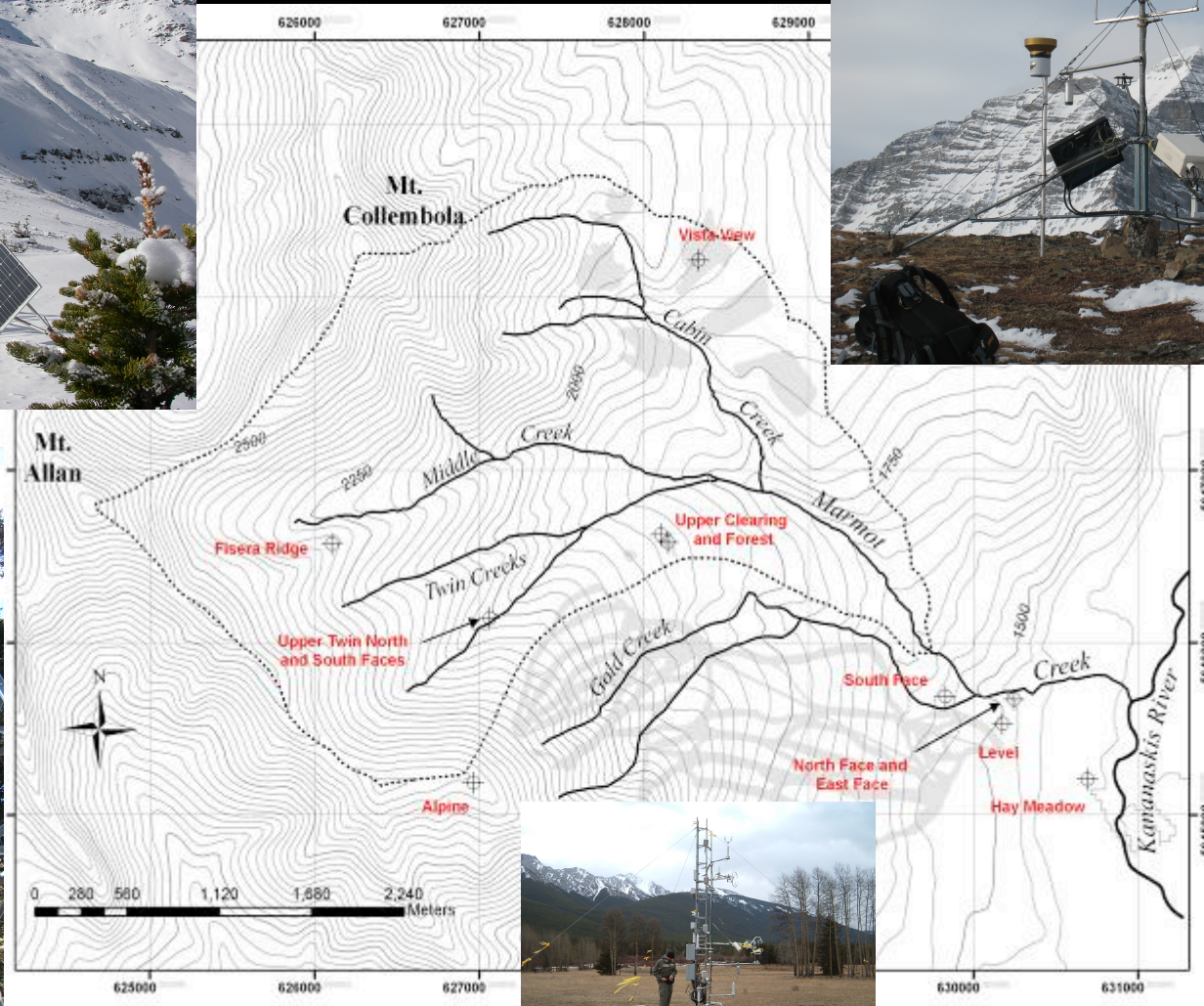 - **Flows: streamflow, evaporation, blowing snow**

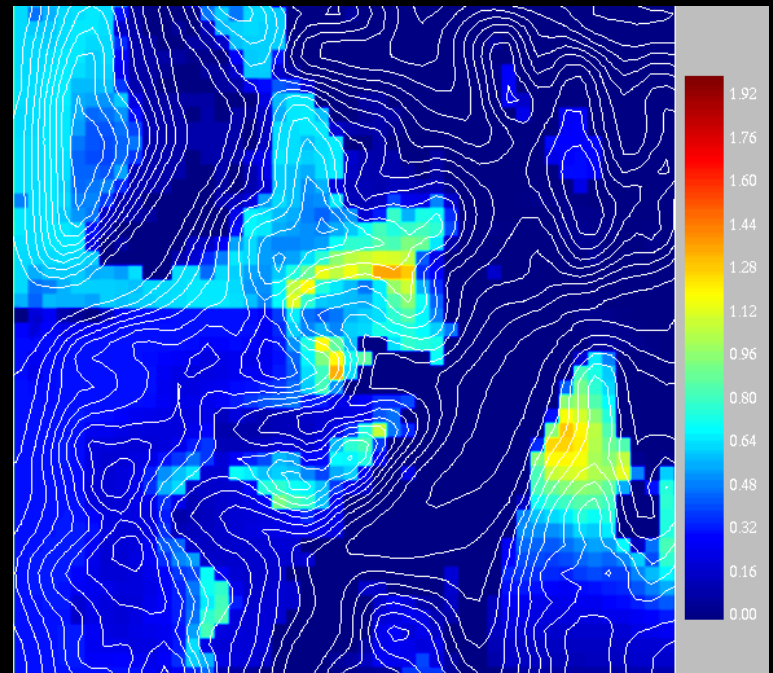# Meteorological Stations

Hydrological Observation
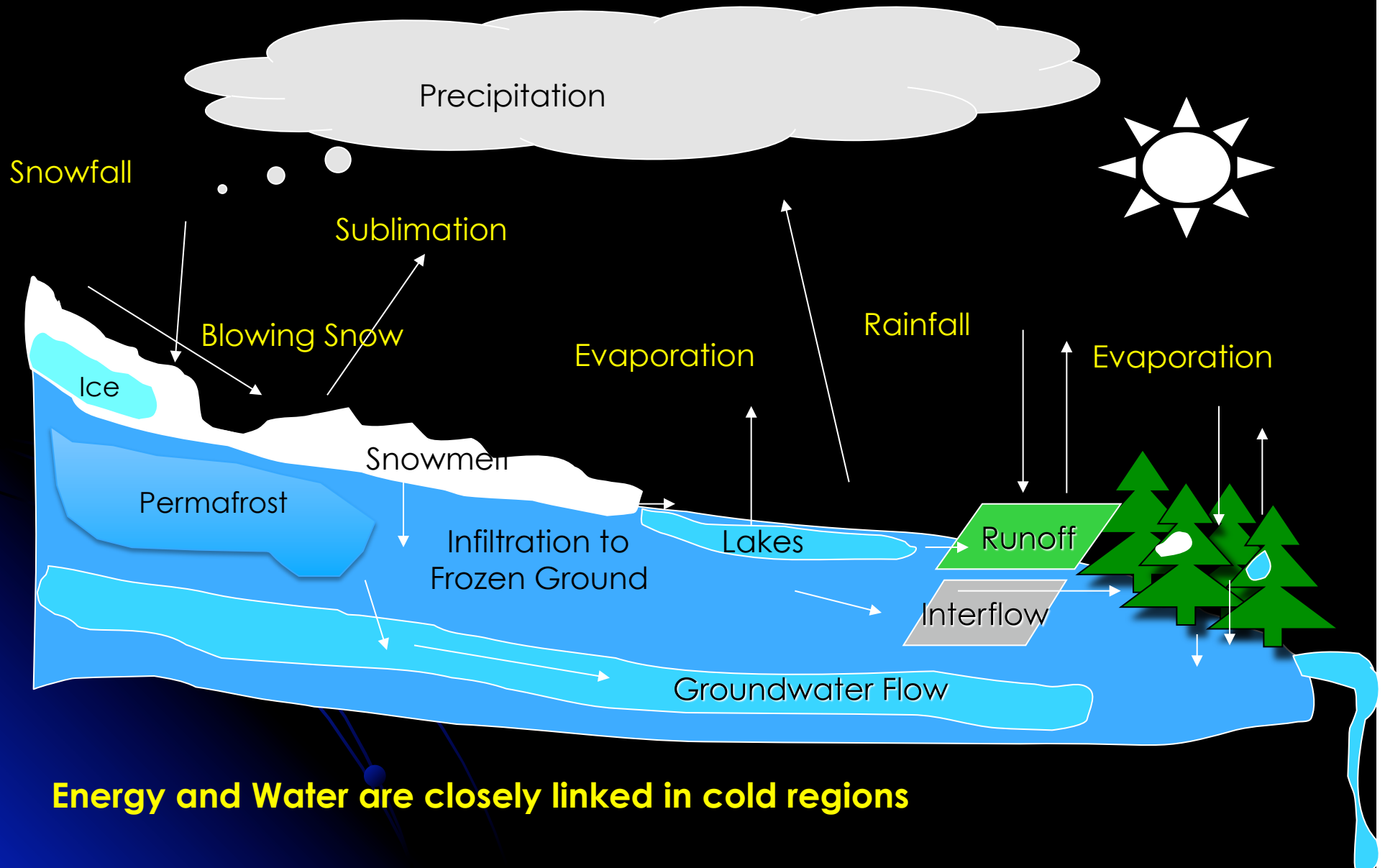
Observations Clustered in Small Basins Improve Understanding
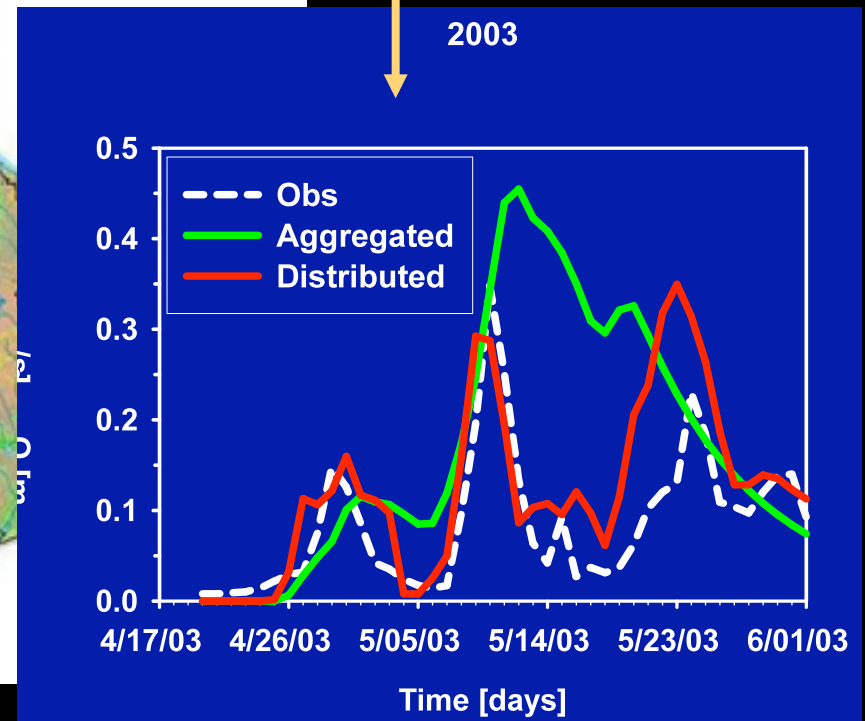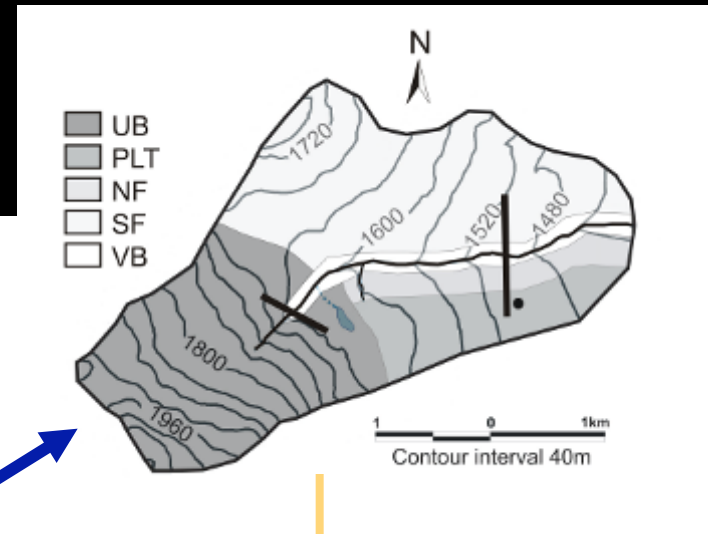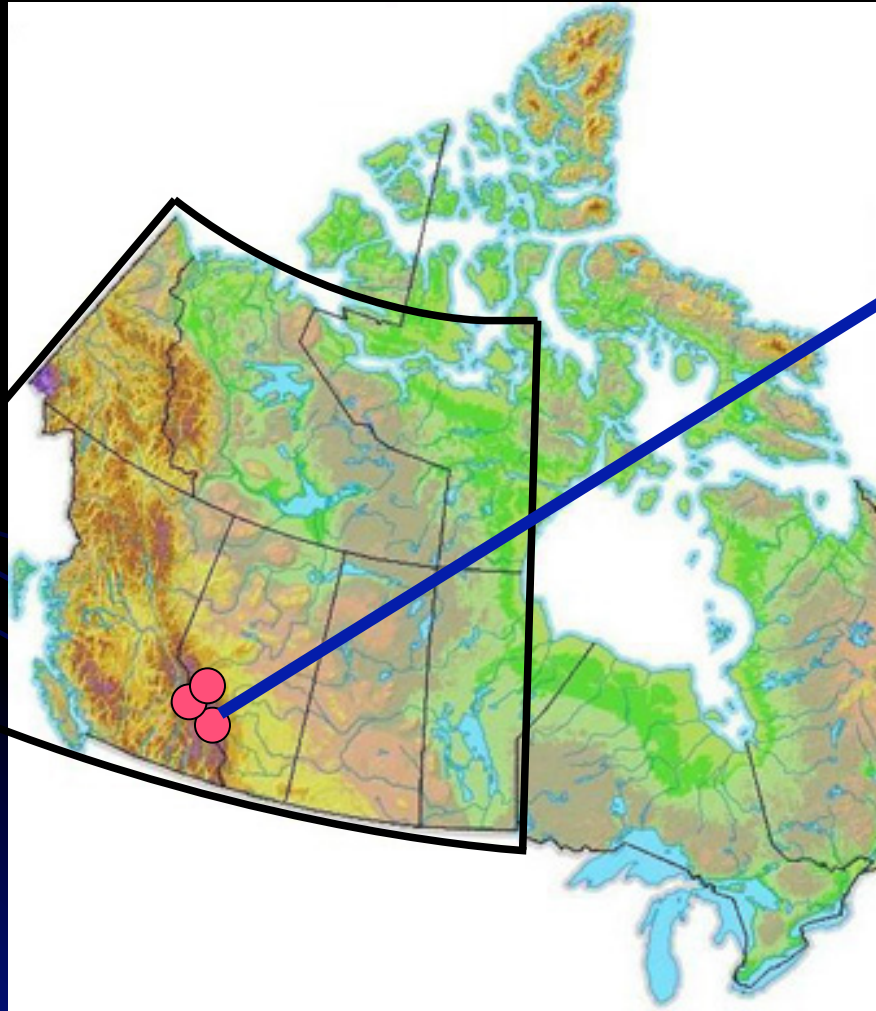
Observations are Not Enough!

- Data itself is not understanding or prediction
- Problem of retrieving, archiving, change in media
- QA/QC essential
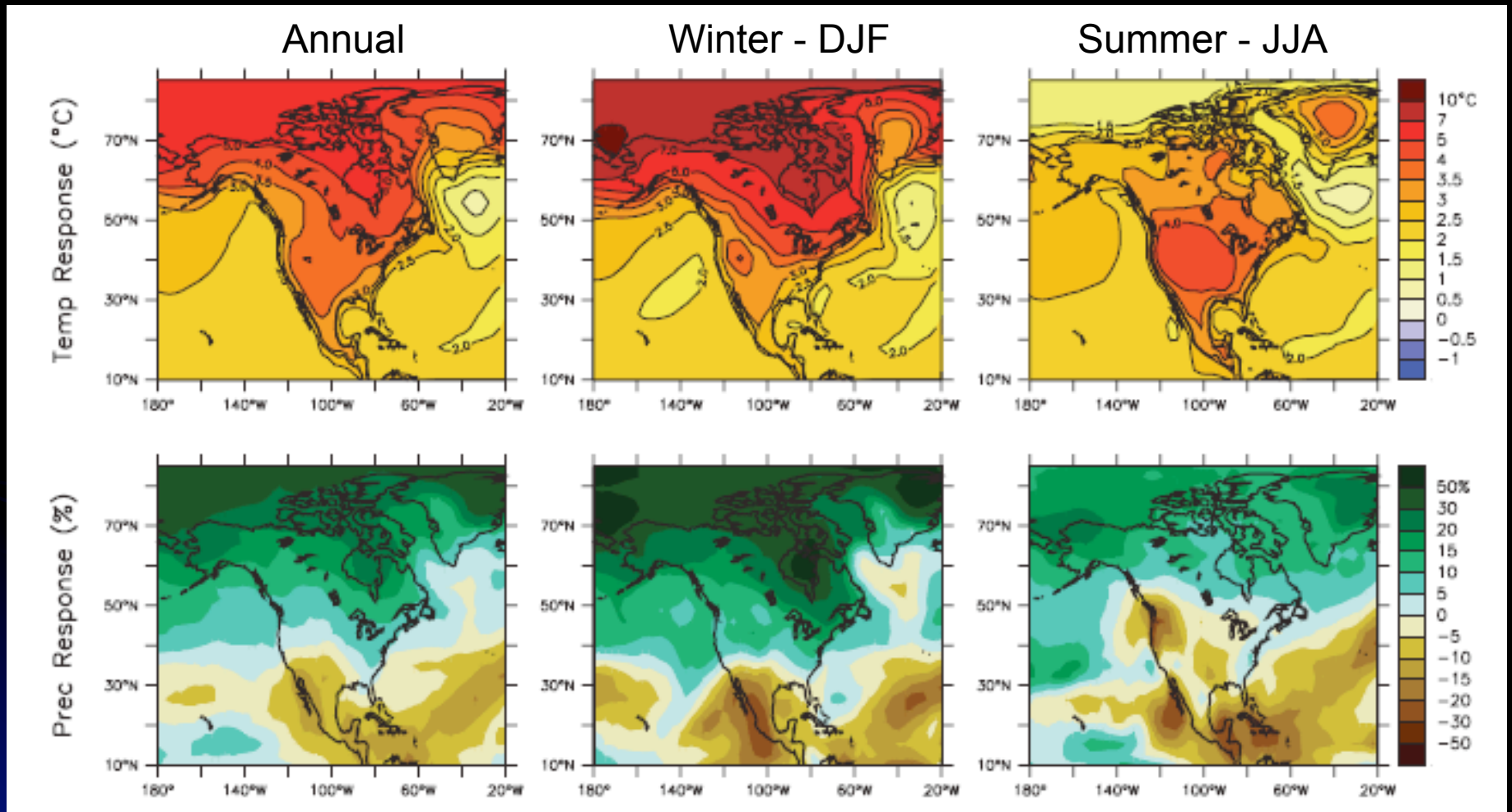- Observational data needs interpretation, interpolation, assimilation to be useful

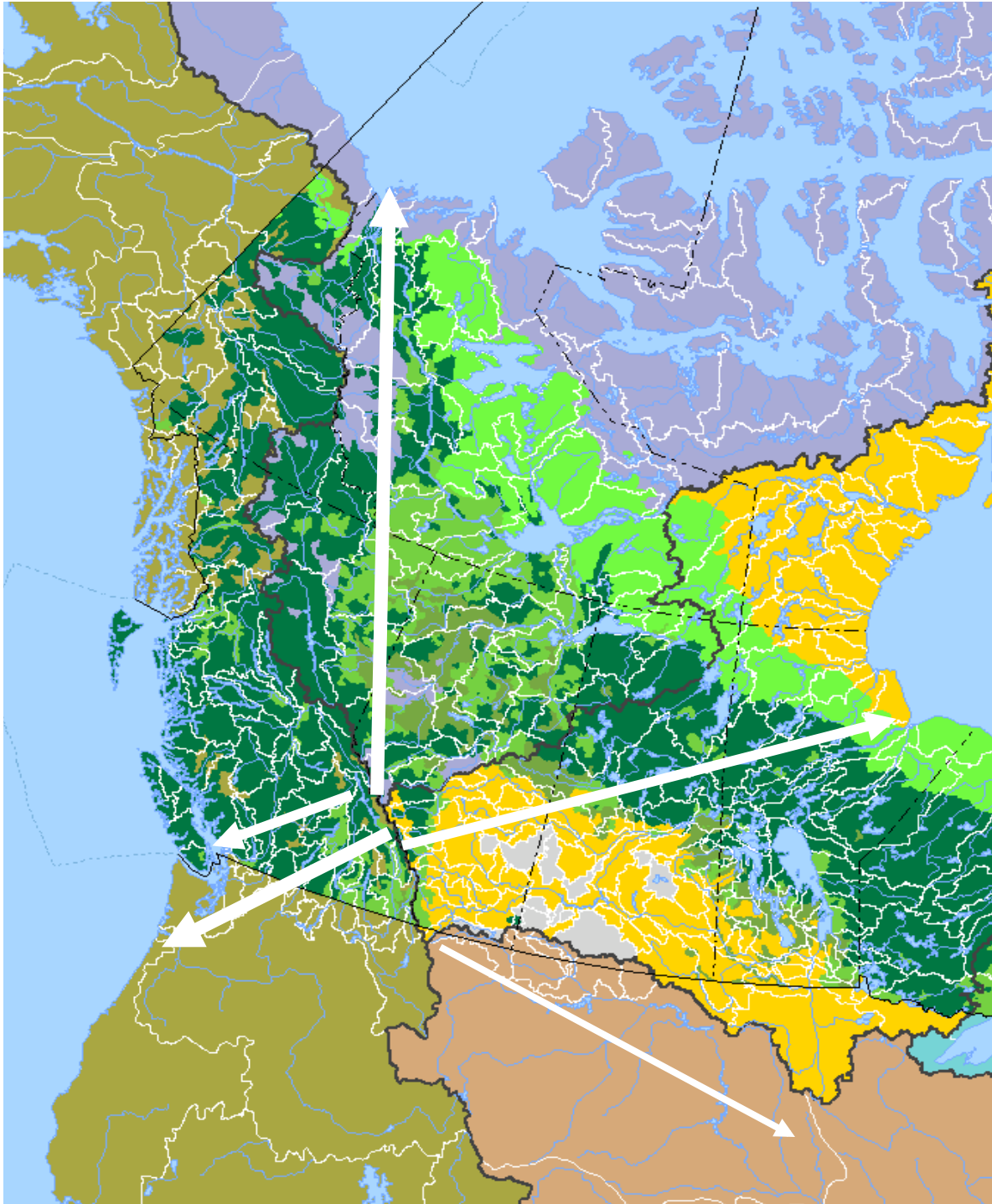# Hydrological Cycle in Western Canada

Prediction

Regional climate change predictions 2080-2089 relative to 1980-1999

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) vs date
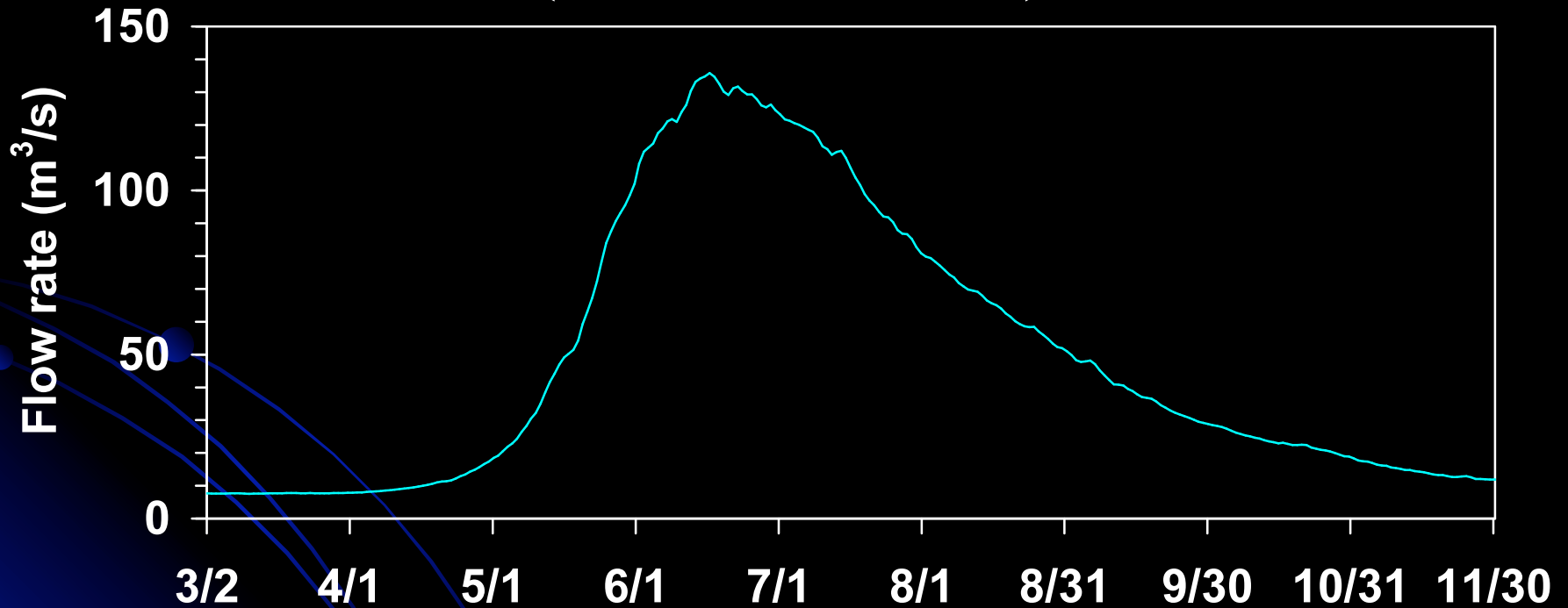
Bow River

Hayashi

How Much Snow is There?
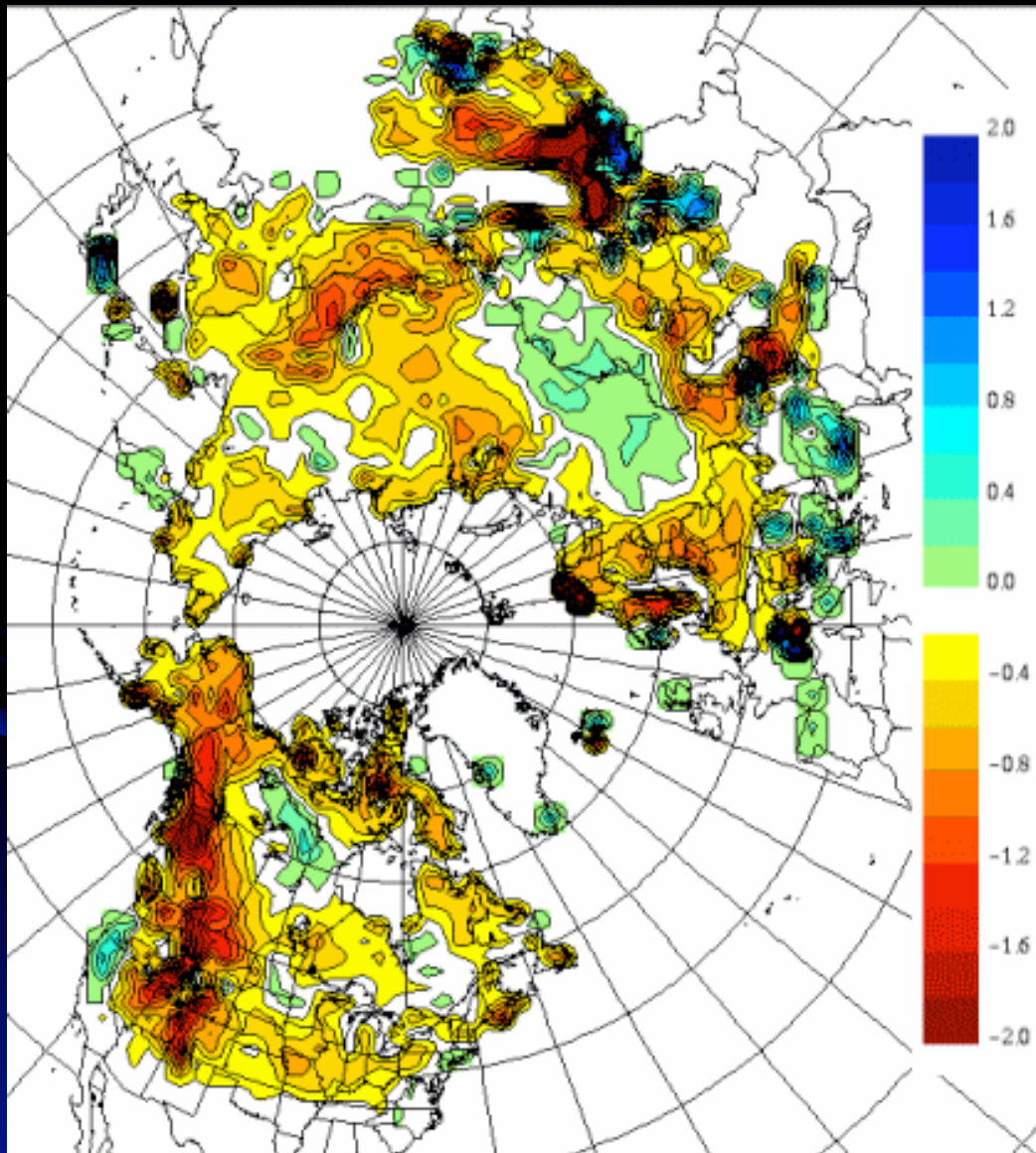
Less and Less…..
US NOAA satellite measured average change (days/yr) in snow cover duration (Feb.-Jul.) over the period 1972-2000.

Cordillera: 1 to 2 month decrease!

NOAA

Temperature Trends at High Elevation in Marmot Creek, Kananaskis
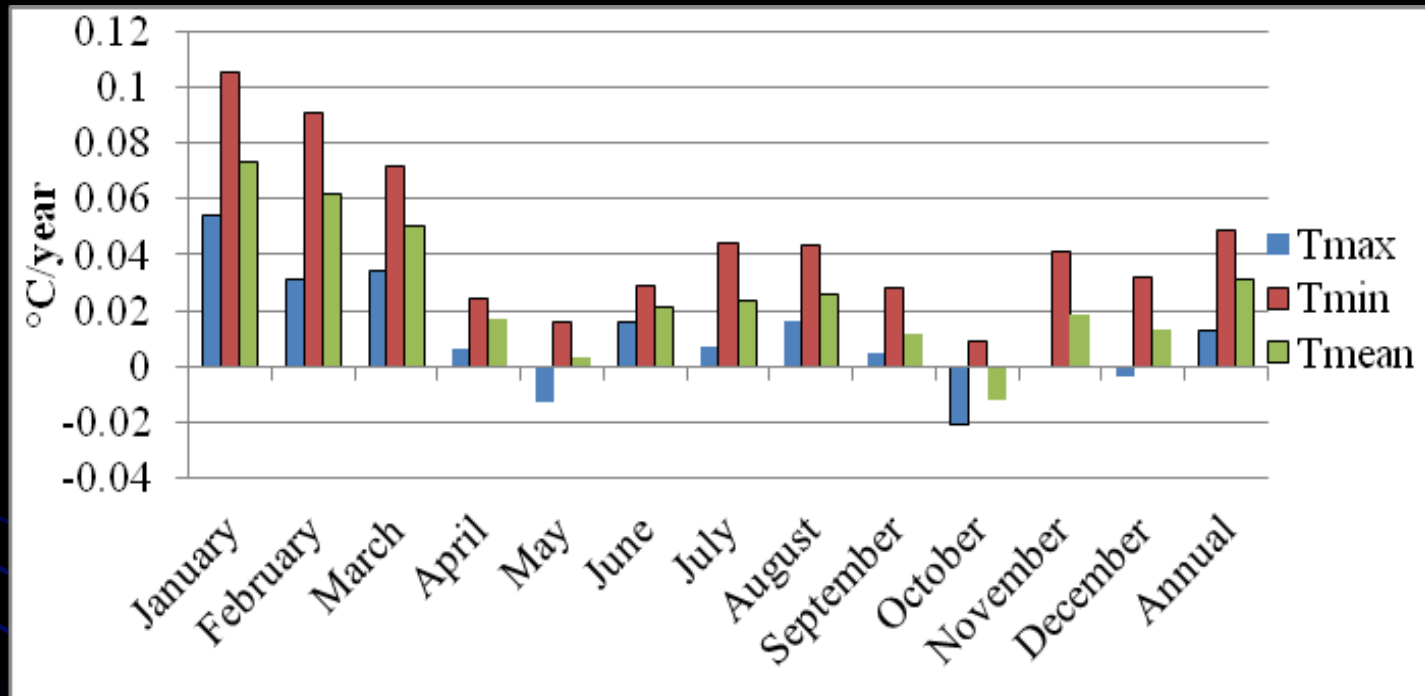
Winters are warmer by 3 to 4 ºC since 1962

Harder & Pomeroy

Rainfall versus Snowfall, Kananaskis Valley
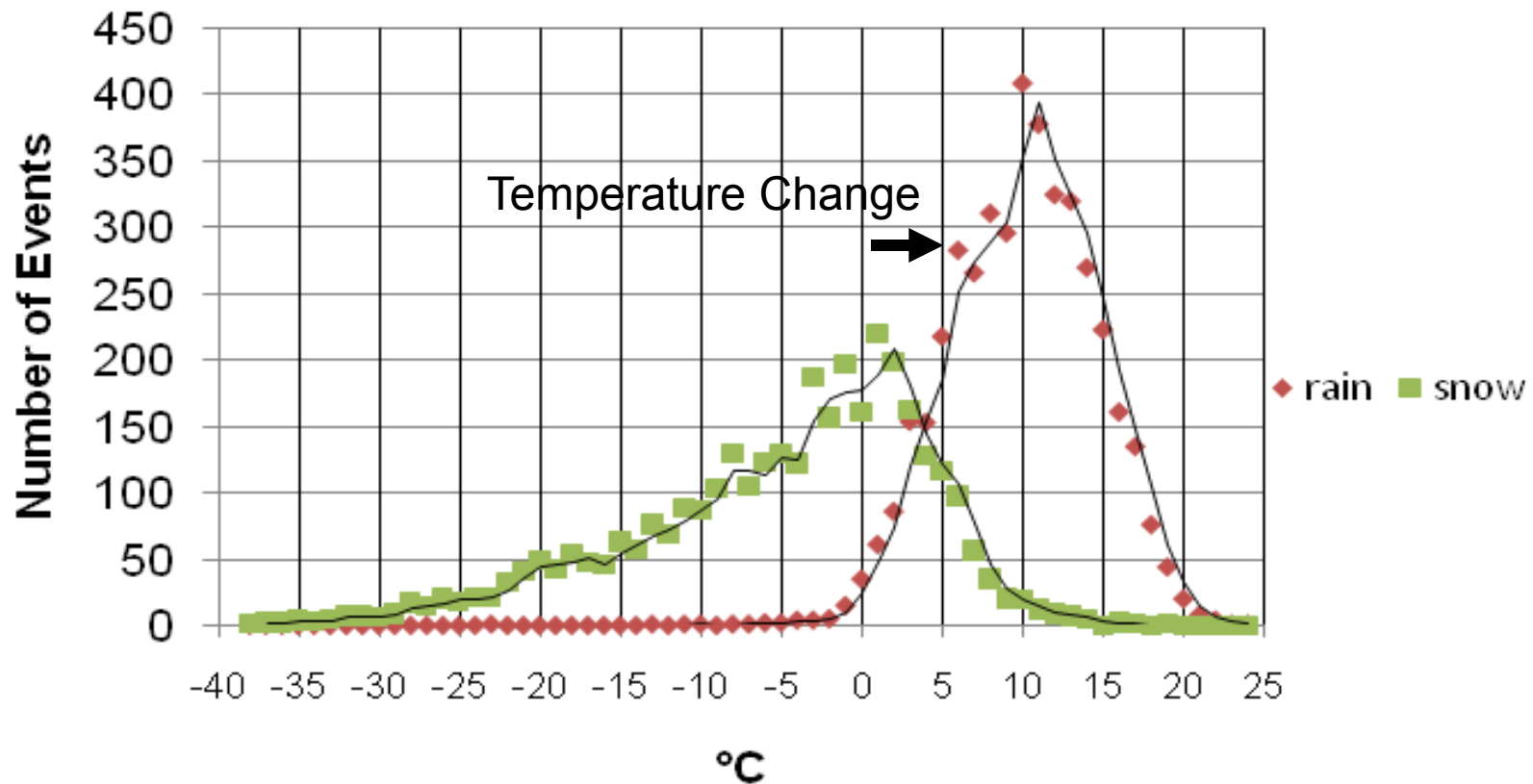
Warmer winters = less snowfall
Warmer winters = more rainfall

Harder & Pomeroy

Marmot Creek Spring Peak Flow and Annual Streamflow Decline of ~30%

Middle Creek June Streamflow cubic metres/second
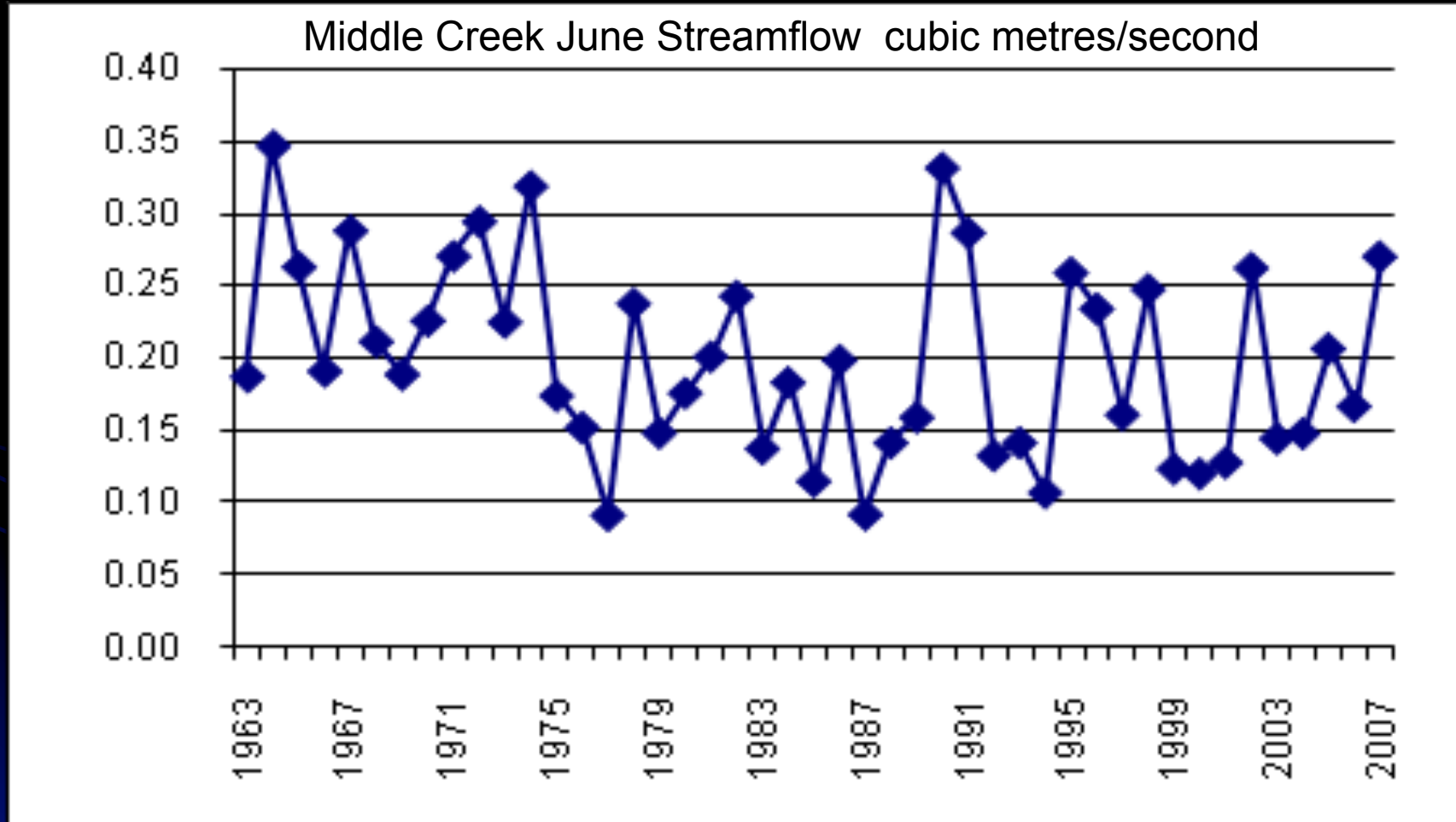
Land use changes did not occur in this sub-basin

Harder & Pomeroy

Global Trend towards Glacial Decline

Mountain Glacier Changes Since 1970
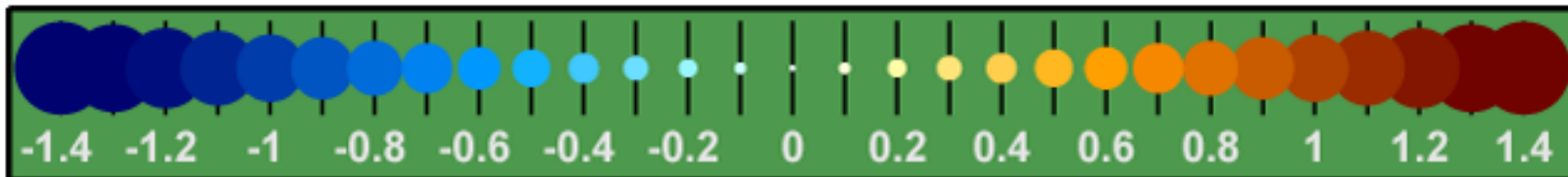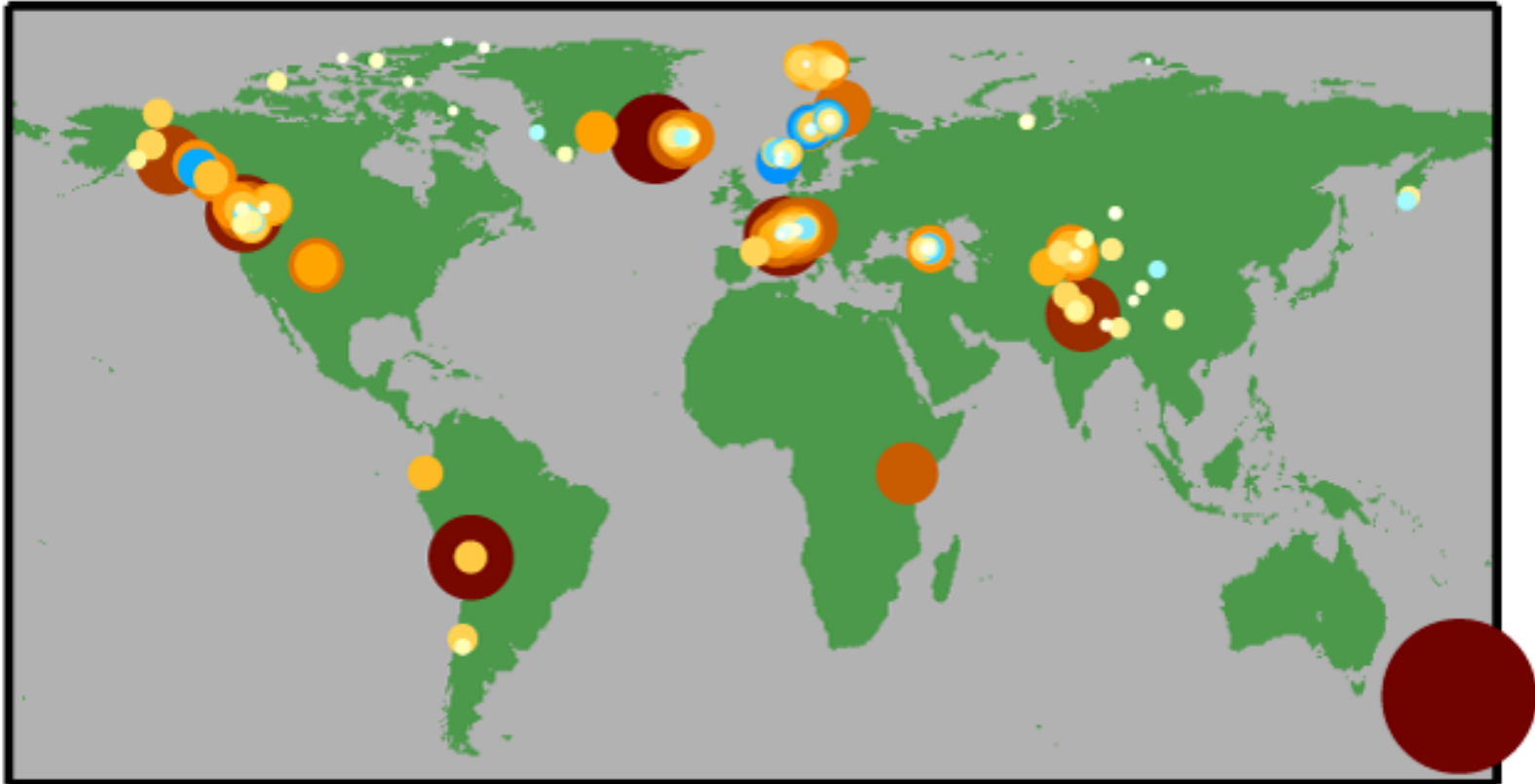
Effective Glacier Thinning (m / yr)

-1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4

Glacier Retreat – Rocky Mountains

Saskatchewan Glacier

— 1975
— 1998
— 2001

0 500 1000 m

N
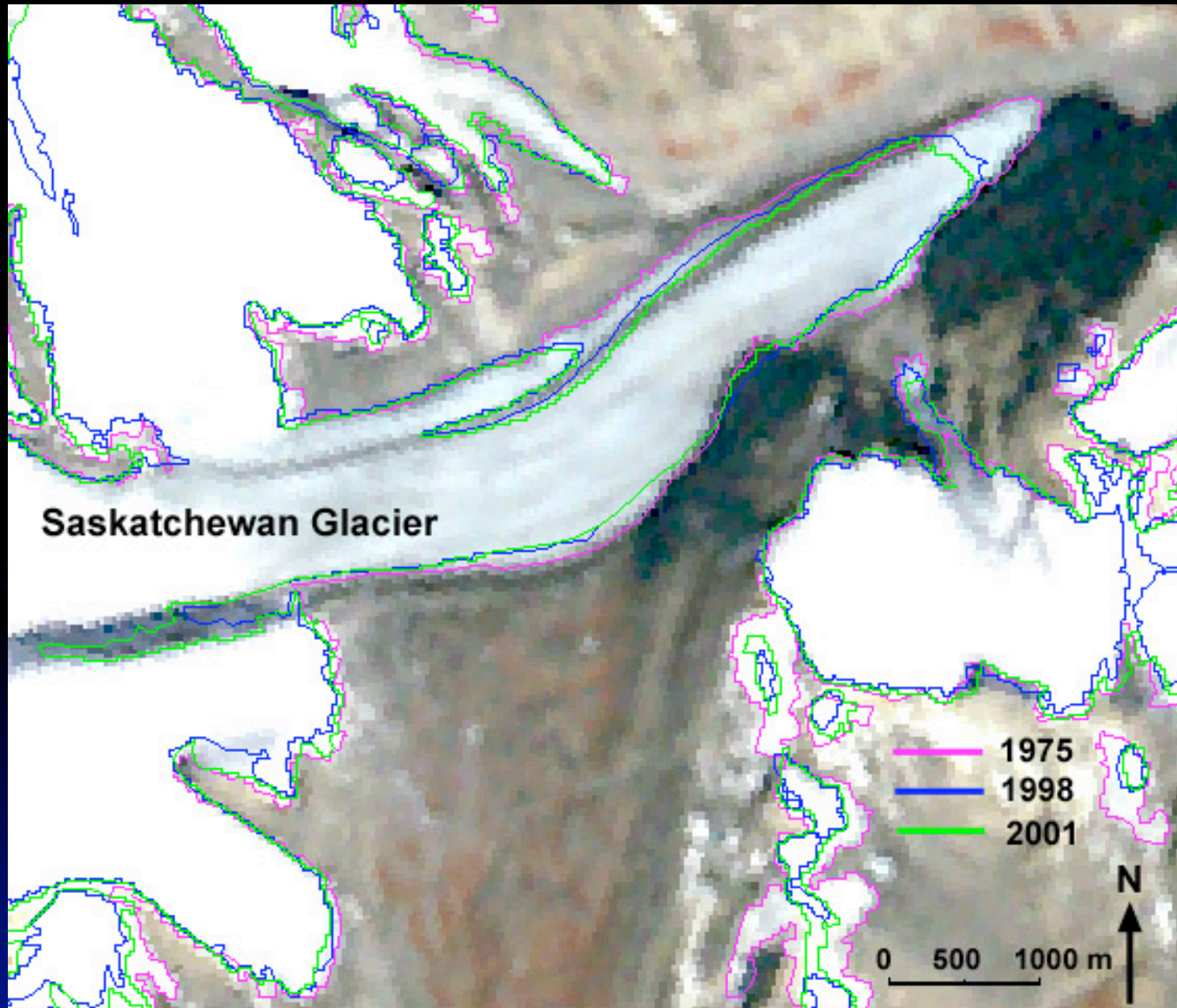
Mapped from NASA LANDSAT satellite

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

Comeau, 2008
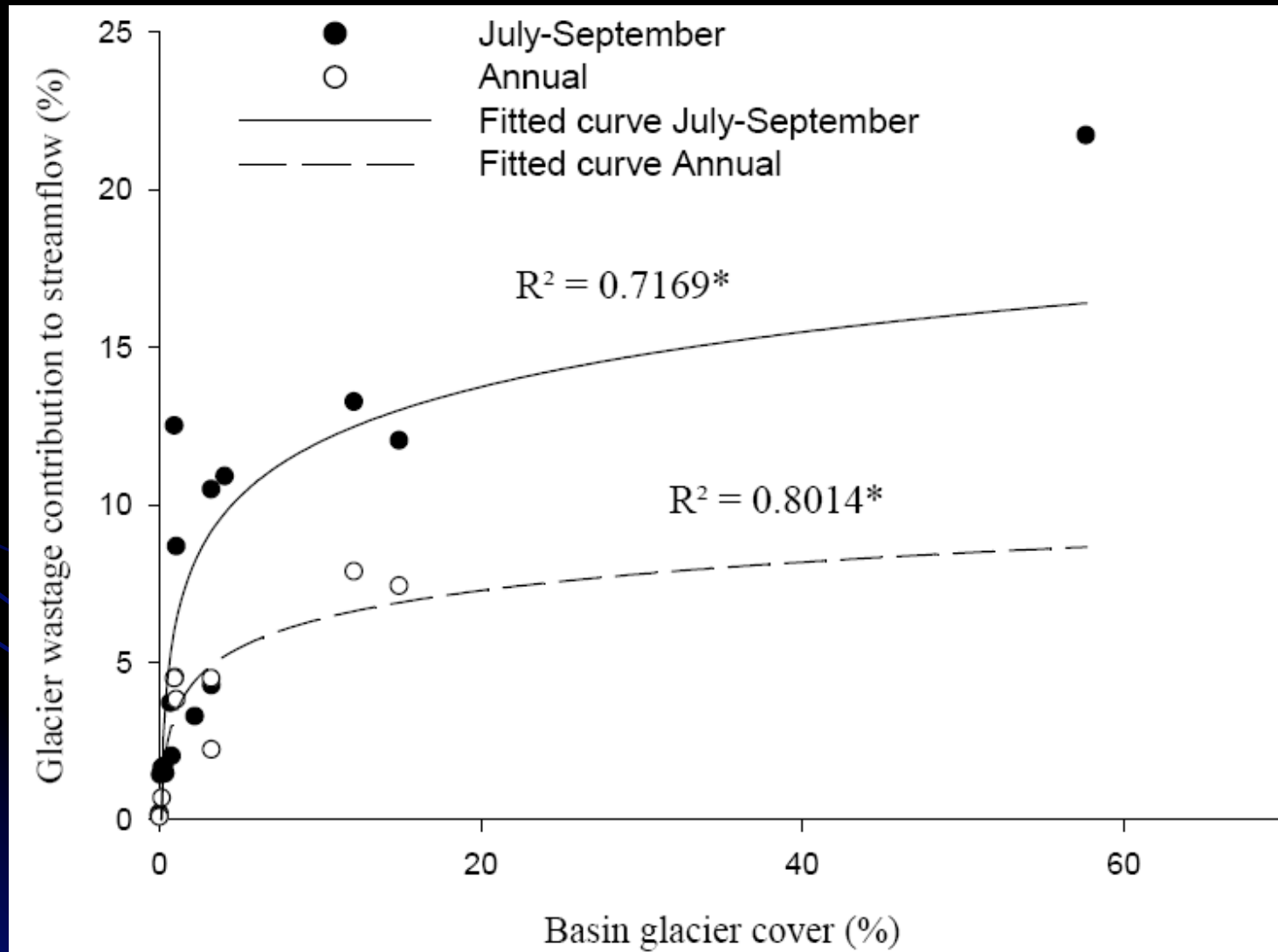
Prediction Models Required to Assess Future Water Resources in Changing Climate

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%)
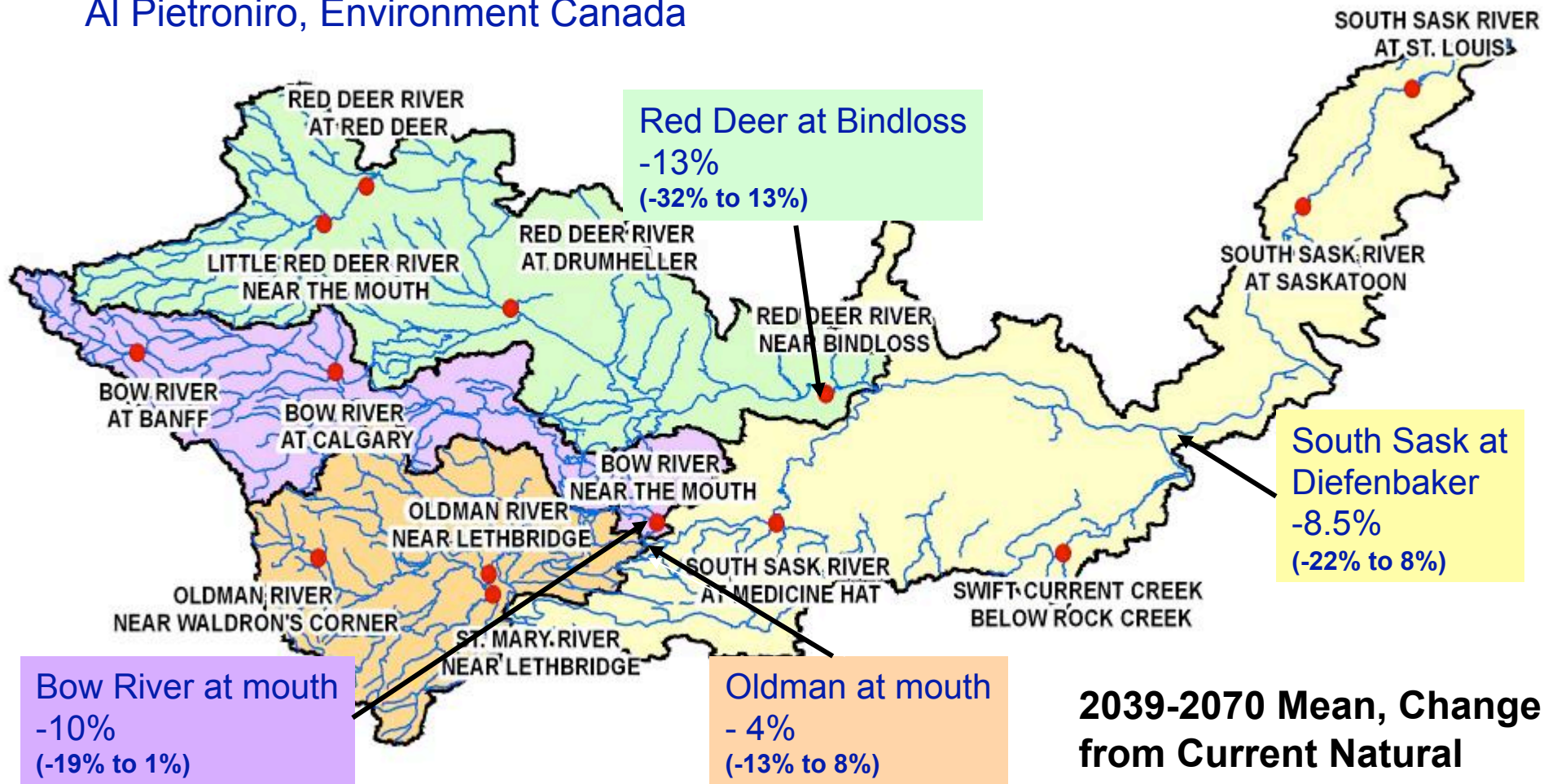
2039-2070 Mean, Change from Current Natural

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.
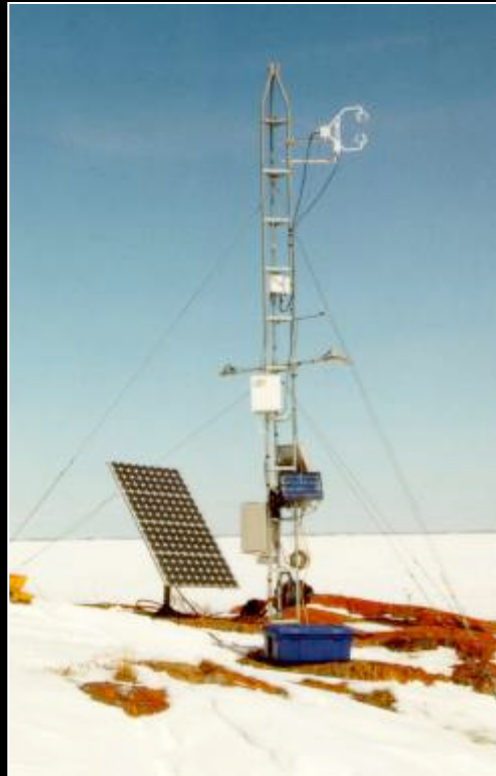
Strategic

- Research strategies are needed to develop understanding for the creation and evaluation of predictive models.
- Research strategies need <u>explicit</u> 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
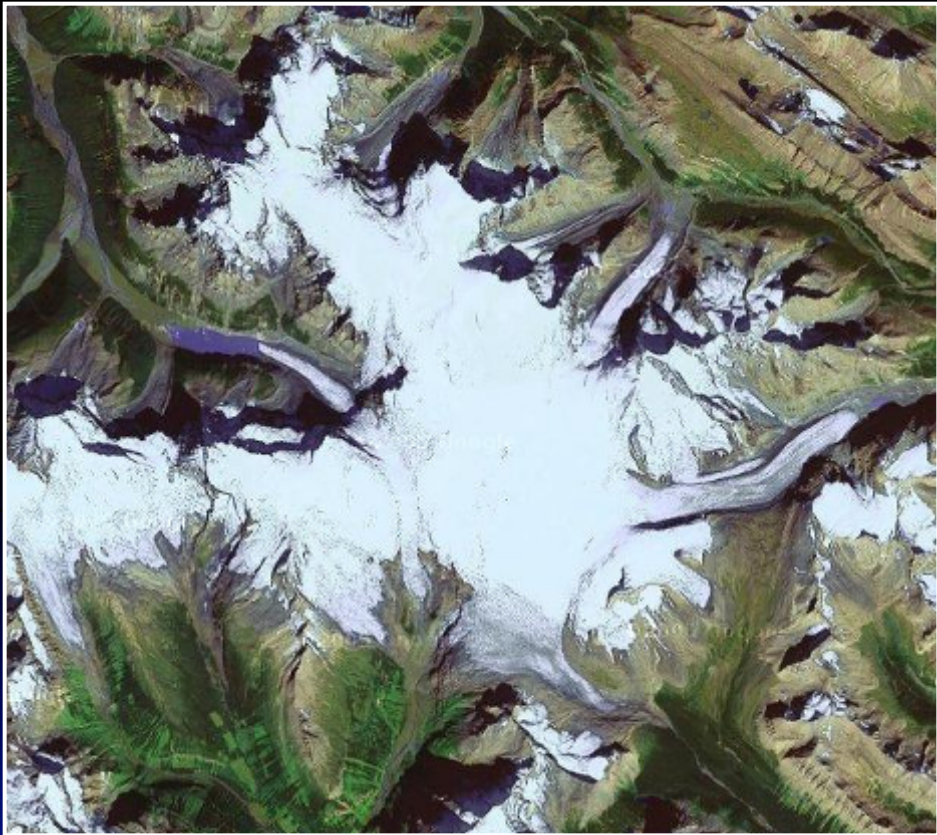
Worthy

- Demonstrable benefits for the environment and economy.
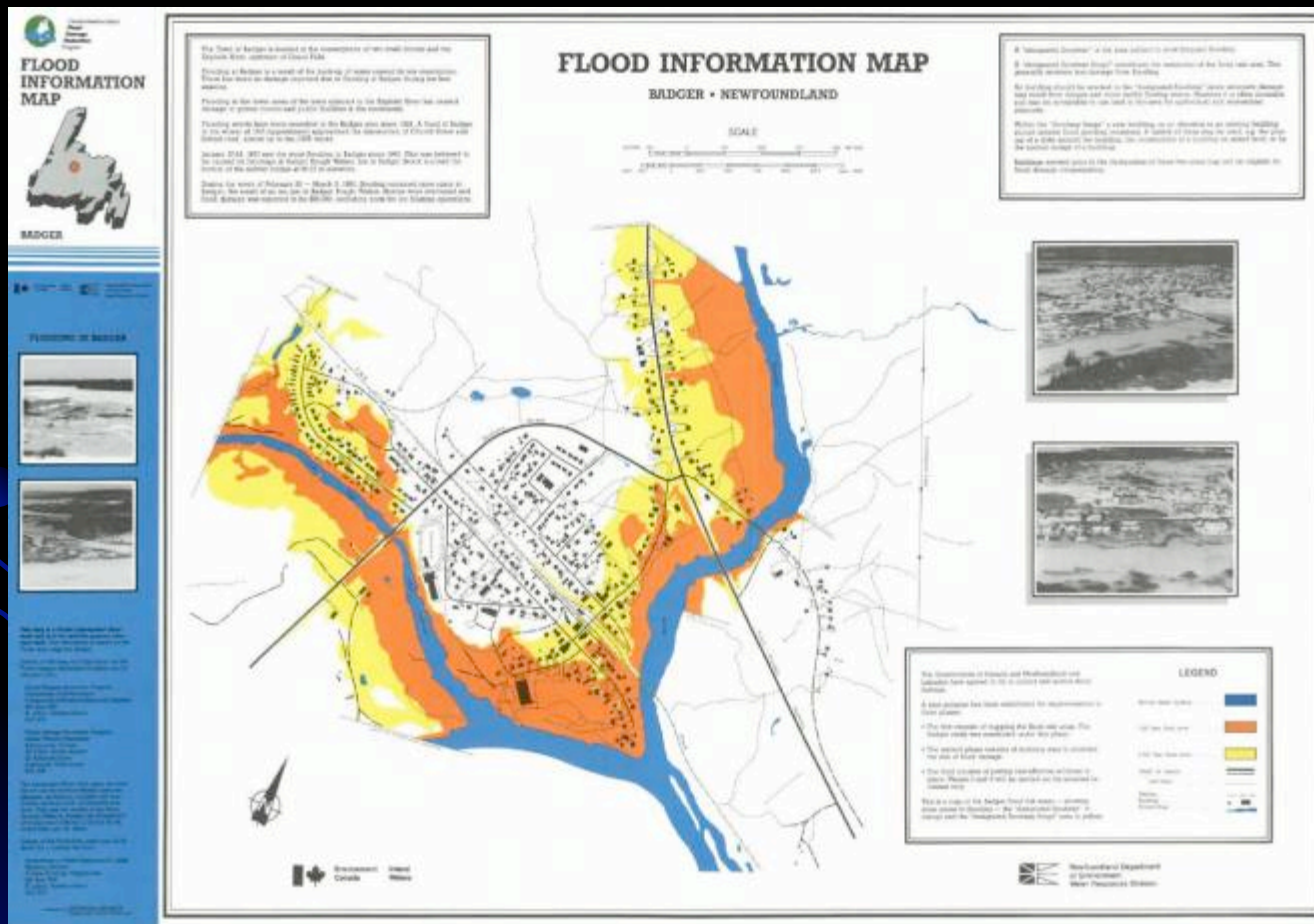
Scale appropriate

- 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.
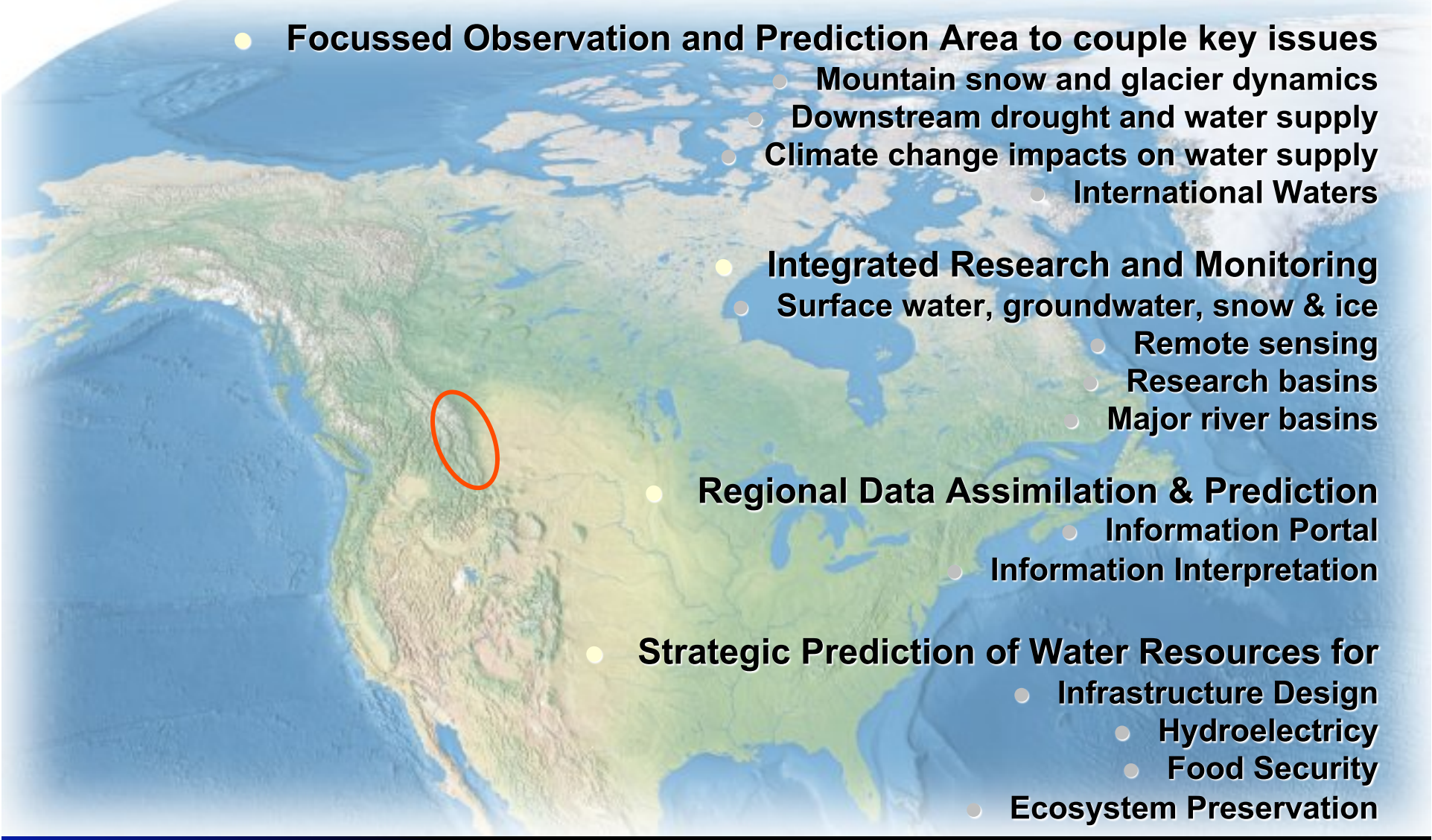
Representative

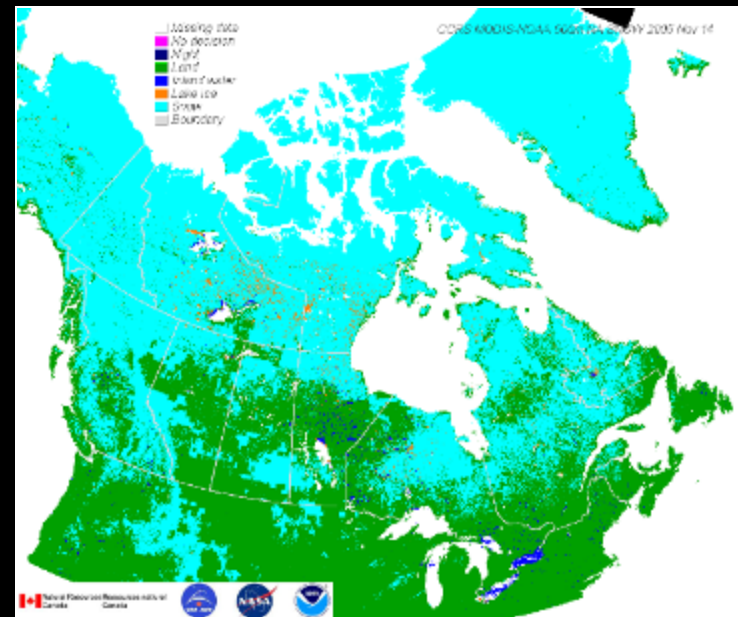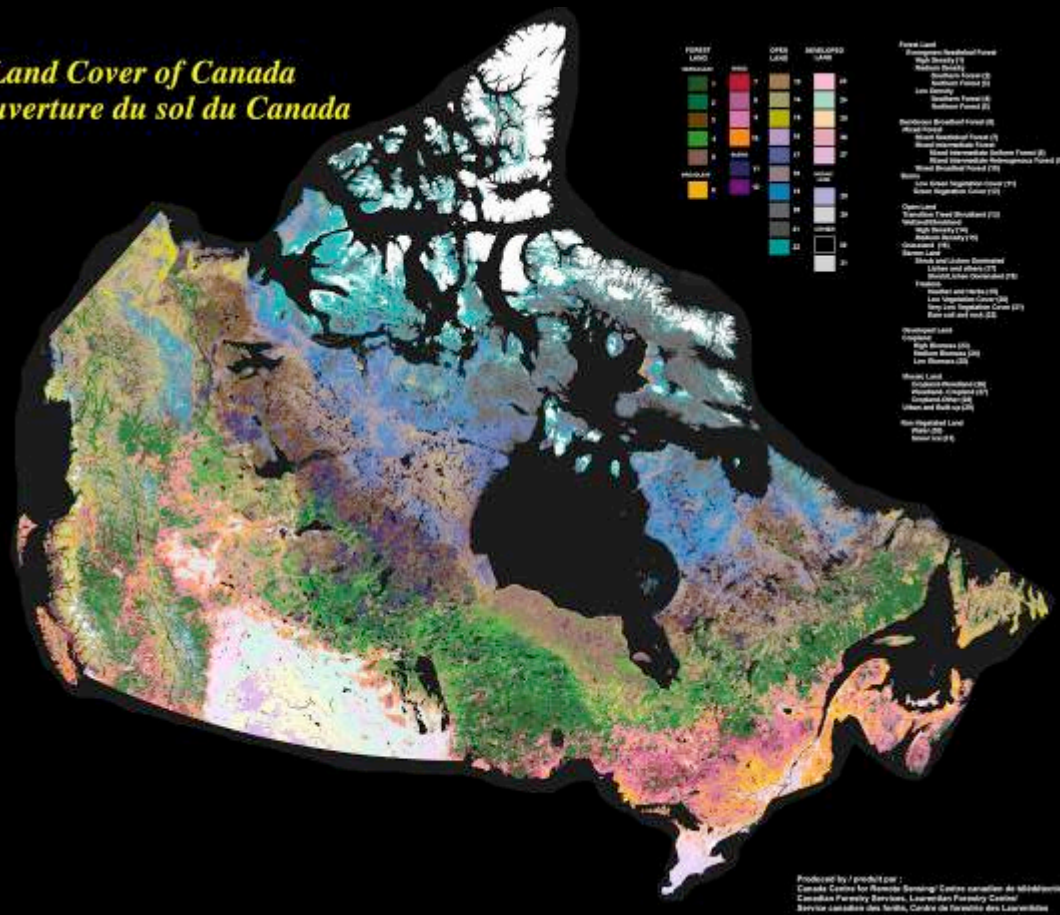- The suite of clusters must be representative of the country's environmental diversity.

Rocky Mountain Integrated Hydrometeorological Observation and Prediction Network

- **Focussed 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
    - Hydroelectricy
    - 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 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