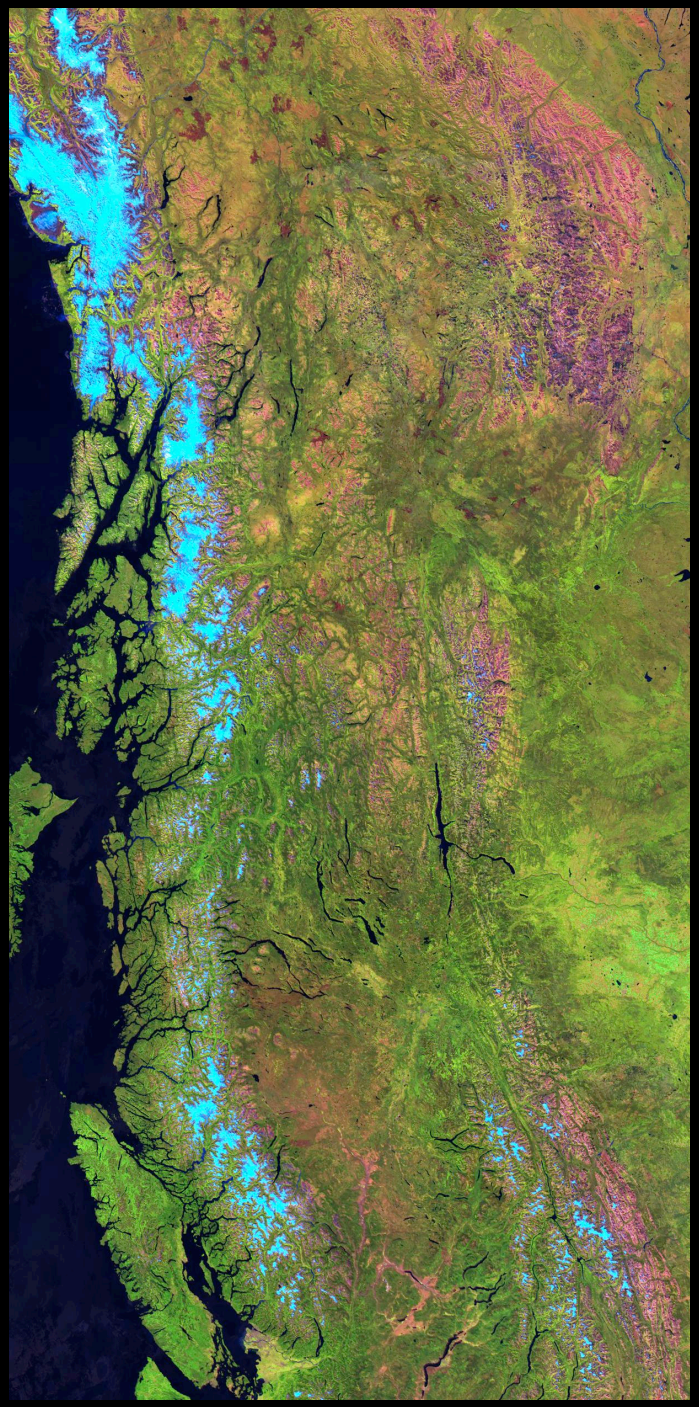
Calgary's Water in a Changing Climate ?

*– **Look upstream** –*

Michael N. Demuth, Alain Pietroniro, Steve Grasby and Chris Spence
with John Pomeroy, Bob Sandford, Masaki Hyashi and Shawn Marshall

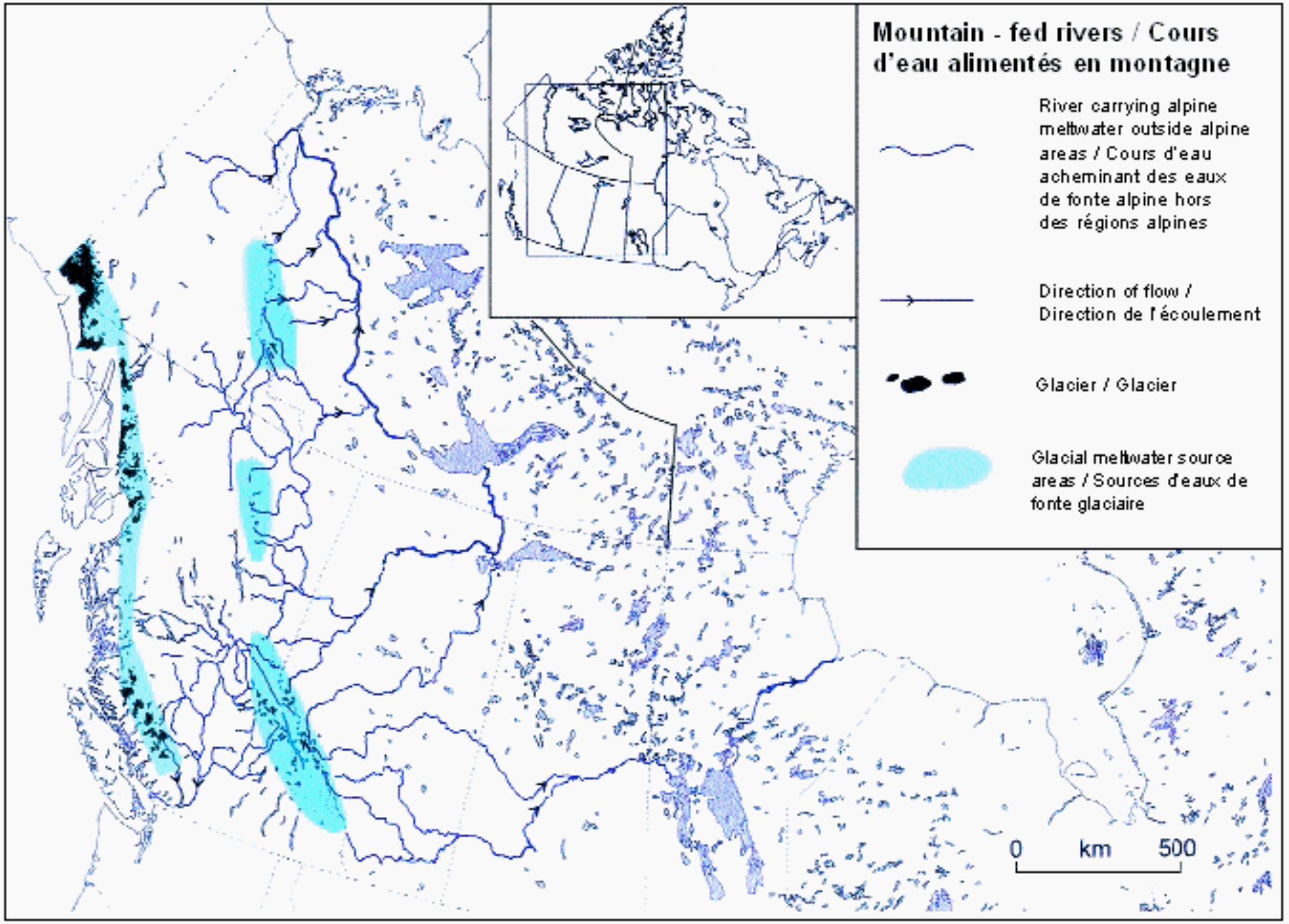
Outline

- Calgary with respect to the mountain West
- Regional climate projections
- Regional and thematic synthesis of what has been happening to the climate and hydrology upstream: snow, glaciers
- Research needs pertaining to climate change, weather prediction, the Bow River and Calgary
- Reducing vulnerability – Integrated Monitoring and Research
- Summary points to take away

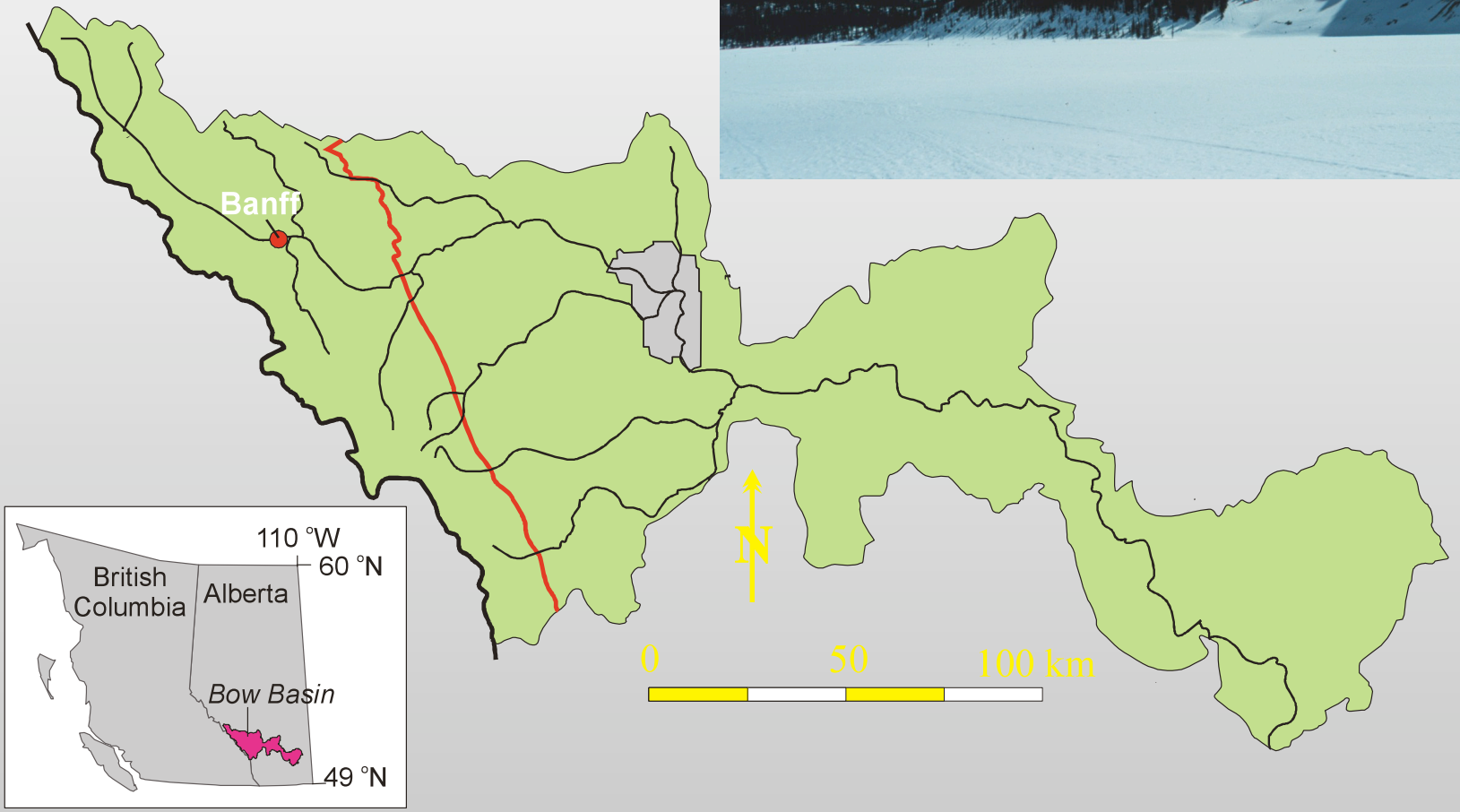


ModIS mosaic courtesy
Alex Trichtchenko, NRCan

Map 7 – Carte 7

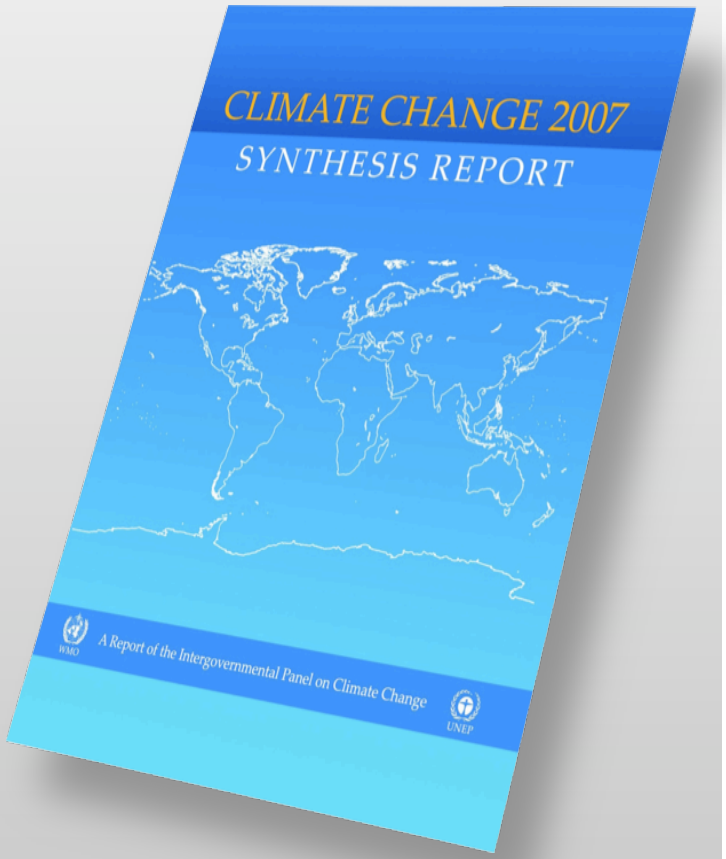

Mountain - fed rivers / Cours d'eau alimentés en montagne
River carrying alpine meltwater outside alpine areas / Cours d'eau acheminant des eaux de fonte alpine hors des régions alpines
Direction of flow / Direction de l'écoulement
Glacier / Glacier
Glacial meltwater source areas / Sources d'eaux de fonte glaciaire
0
km
500


Annual Precipitation (mm)
300-400
400-600
600-800
800 +
Alberta
Saskatchewan
Edmonton
Jasper
North Saskatchewan R.
Saskatoon
Red Deer River
Banff
Bow River
Calgary
Regina
South Saskatchewan R.
STUDY AREA
60°
135°
125°
115°
55°
50°
Alberta
British Columbia
Pacific Ocean
U.S.A.


Banff
110 °W
60 °N
British Columbia
Alberta
Bow Basin
49 °N
N
0
50
100 km

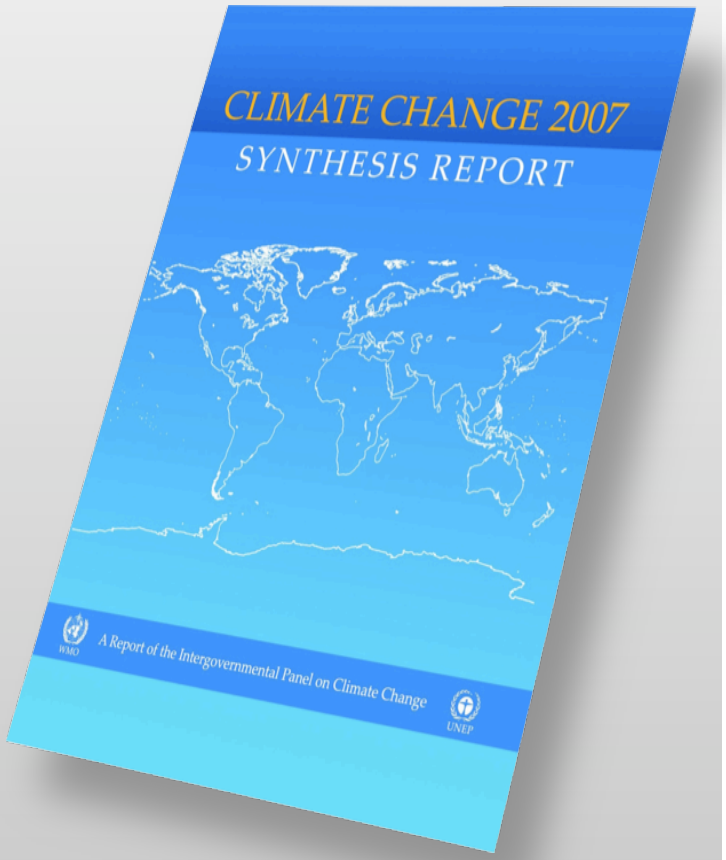
Observational evidence

"... increased run-off and earlier spring peak discharge in many glacier- and snow-fed rivers [on all continents]."



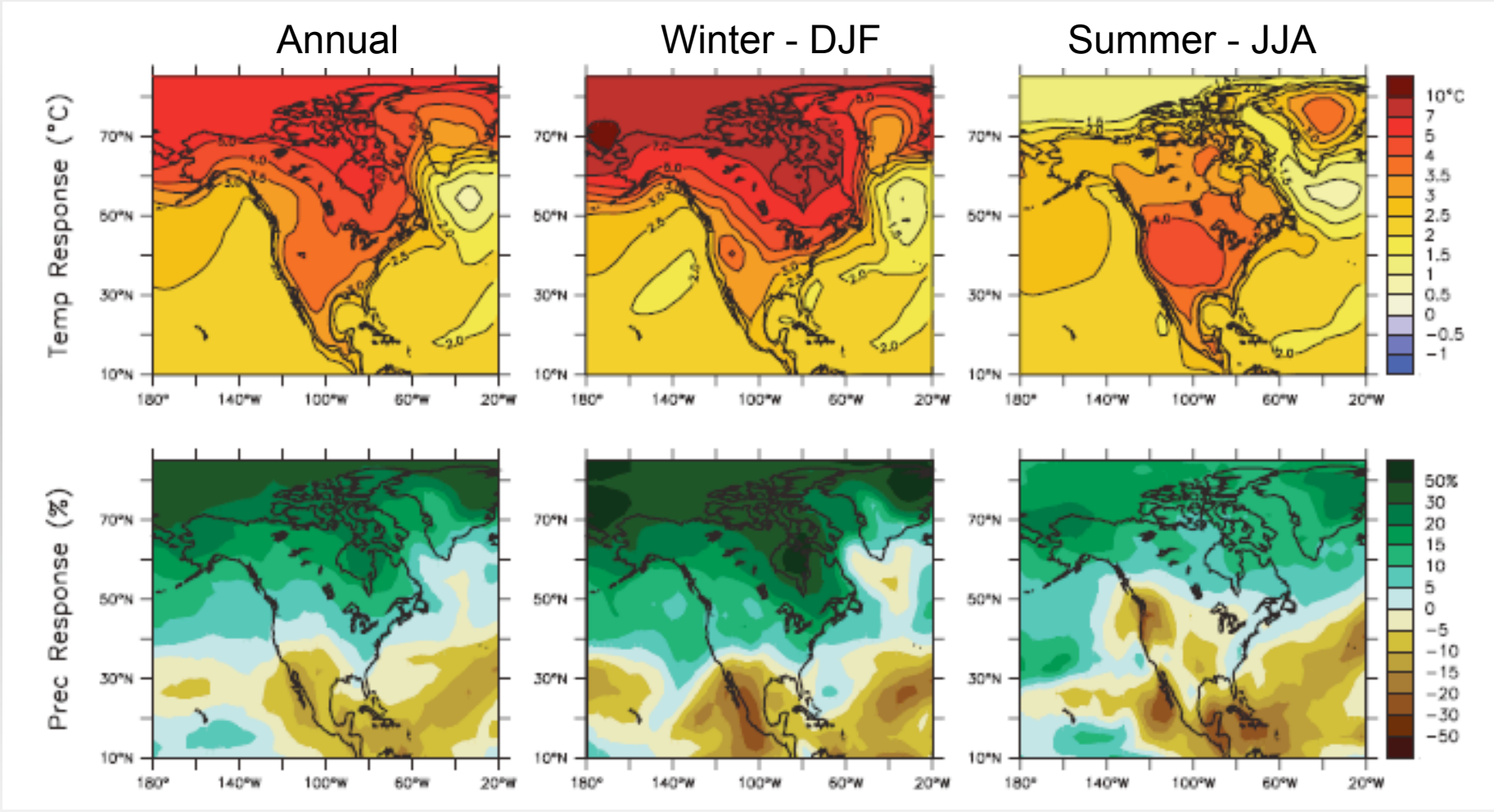
Knowledge of future impacts

"Water supplies stored in glaciers and snow cover are projected to decline, reducing water availability in regions supplied by meltwater."



Regional climate change predictions

2080-2089 relative to 1980-1999

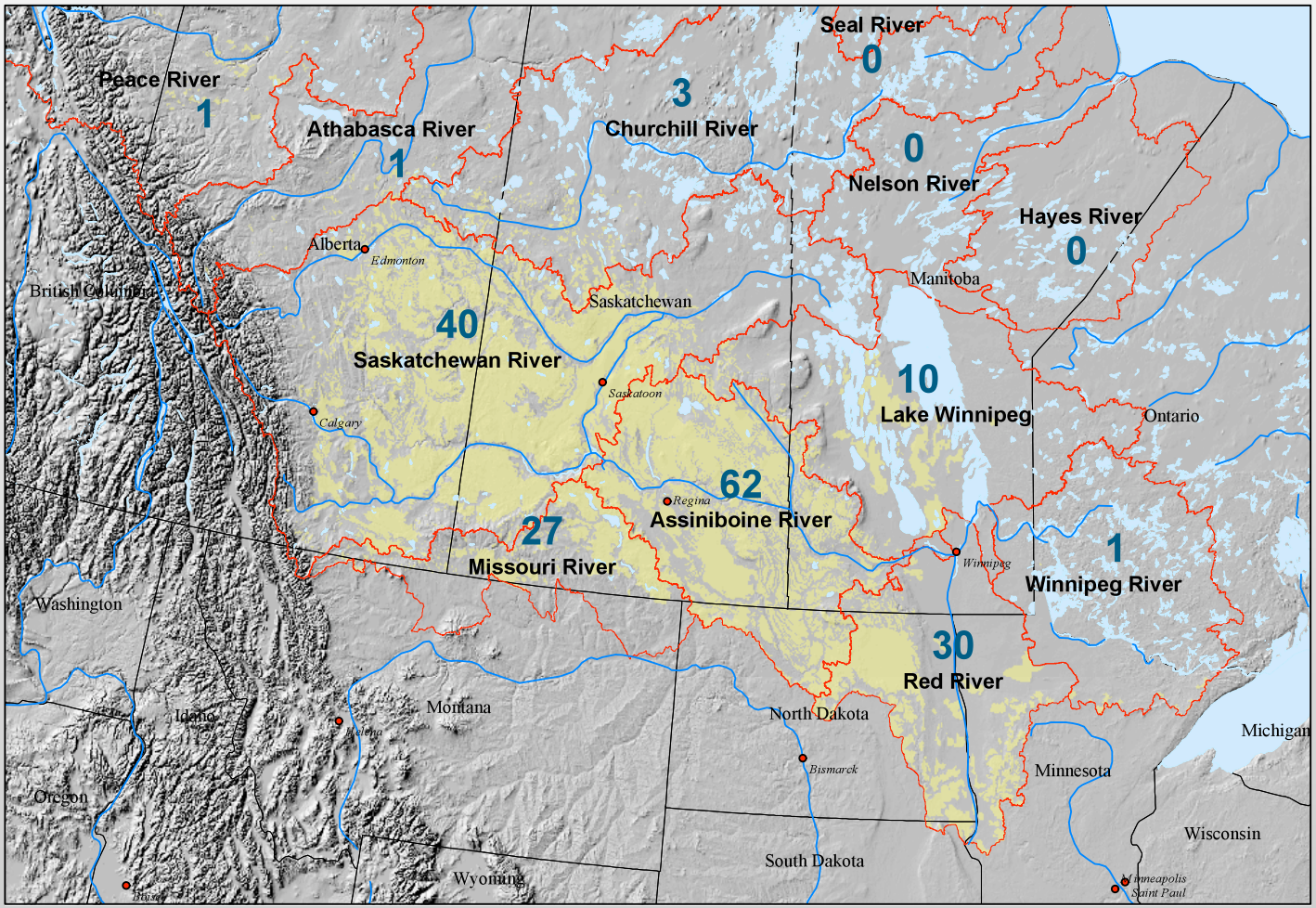


IPCC 2007

Warmer and Wetter generally; Drier regionally !

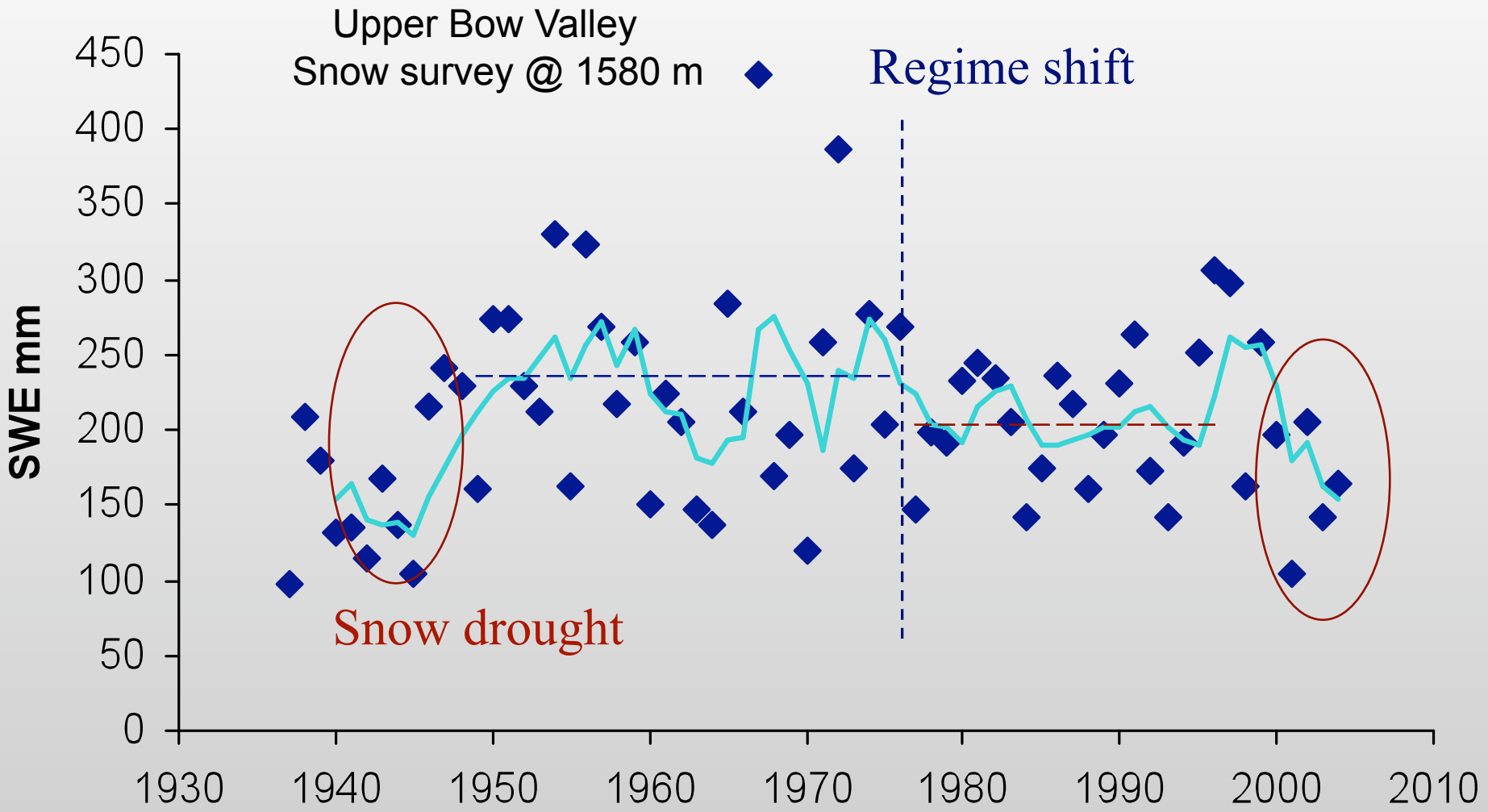
Look upstream

90% of the streamflow in the South Saskatchewan River Basin originates in the Rocky Mountain eastern slopes

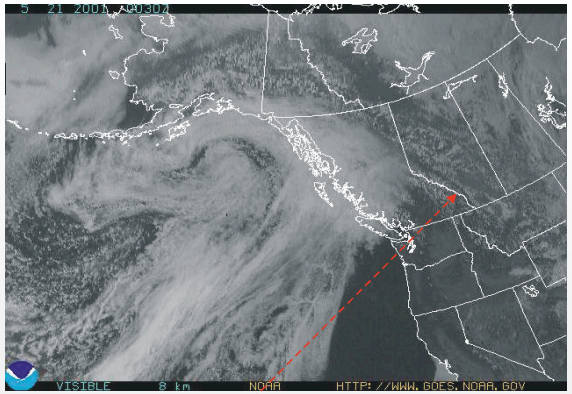


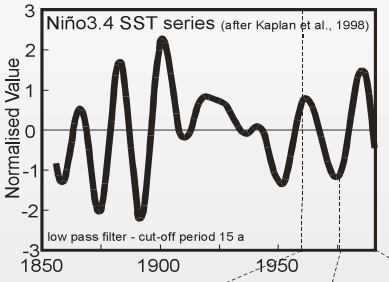
Source: Non-contributing area - Agriculture and Agri-Food Canada, P.F.R.A.
Elevation data - Environmental Systems Research Institute

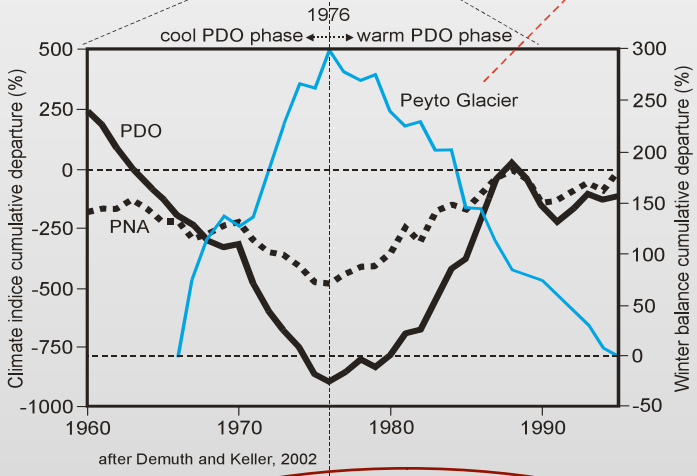
High Elevation Snow Accumulation

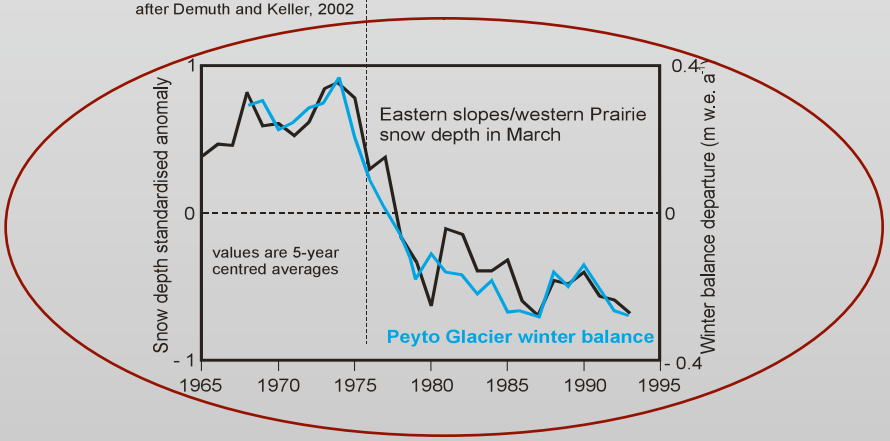


Snow nourishes glaciers

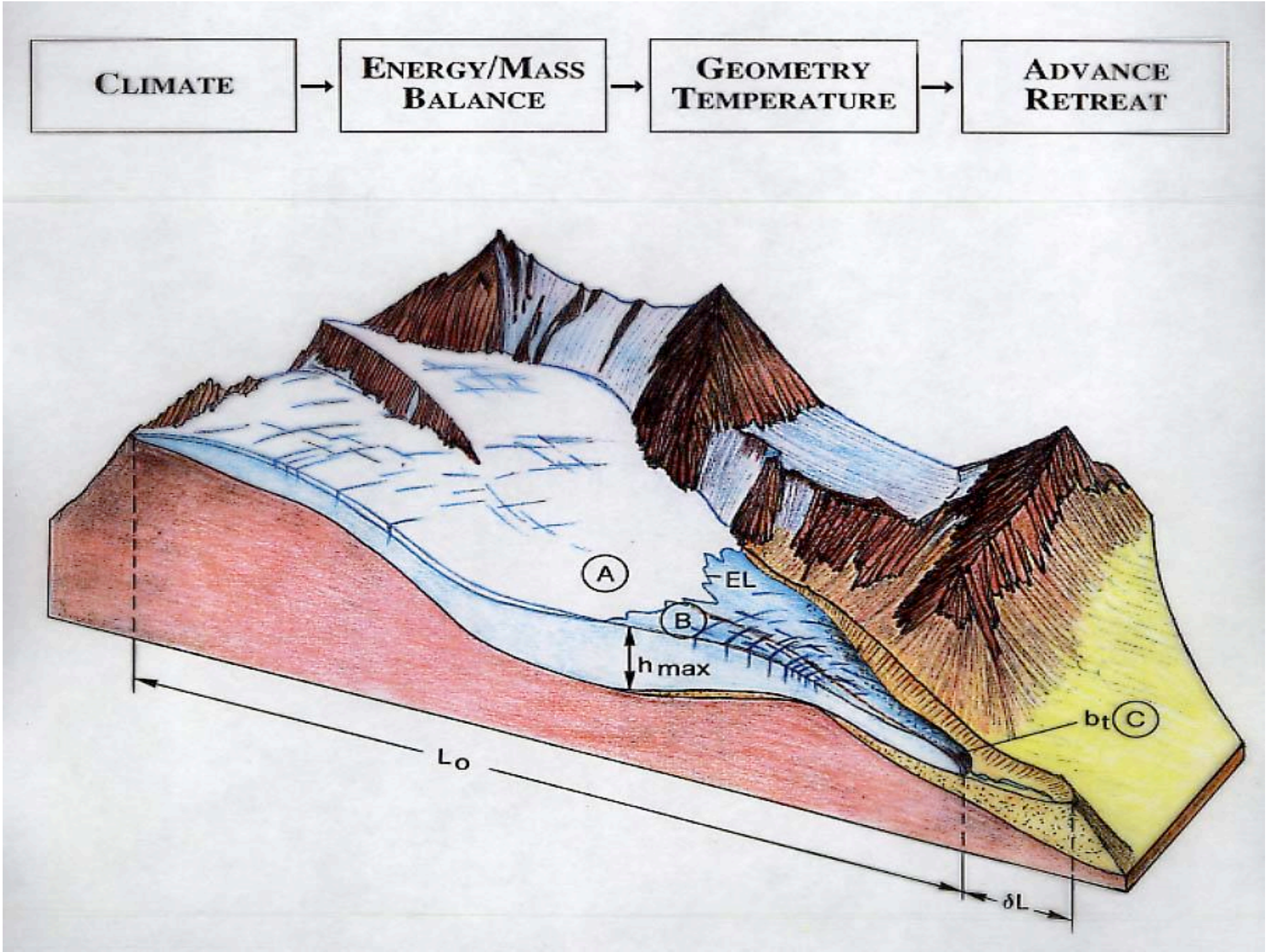






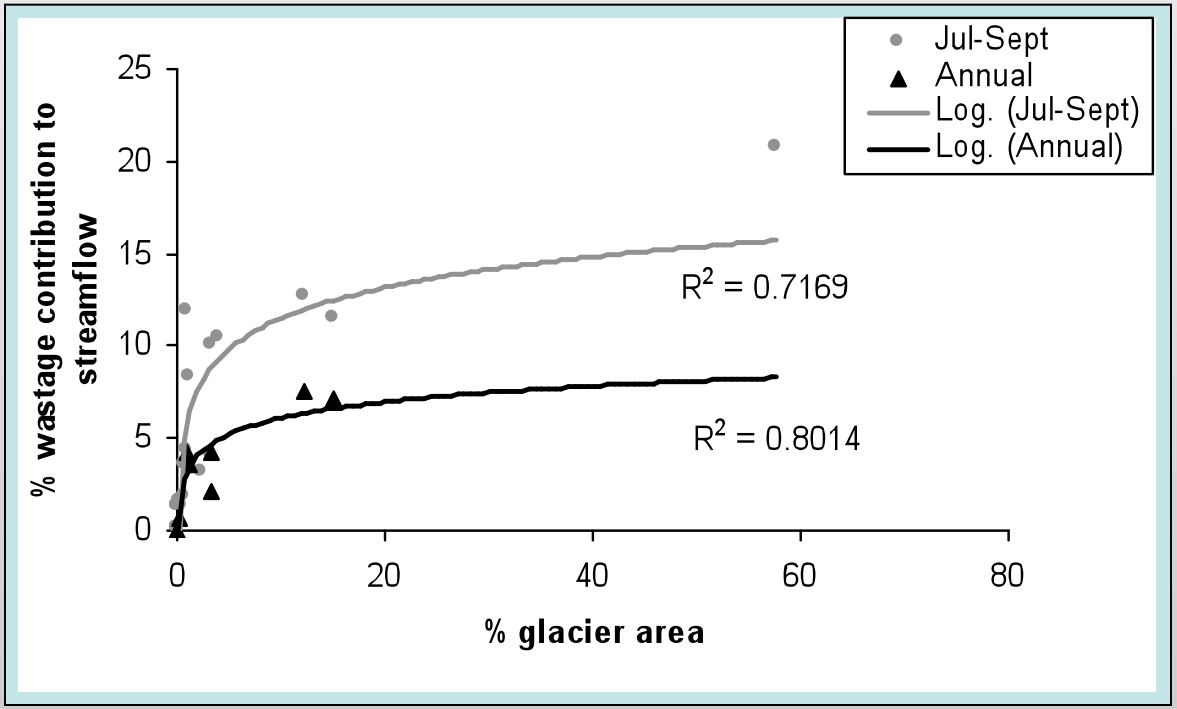


CLIMATE → ENERGY/MASS BALANCE → GEOMETRY TEMPERATURE → ADVANCE RETREAT



Snow and glaciers nourish river flow and groundwater

- Snowmelt is the most significant contributor
- **Annual** glacier contribution is relatively small
- Seasonal contribution is more significant:

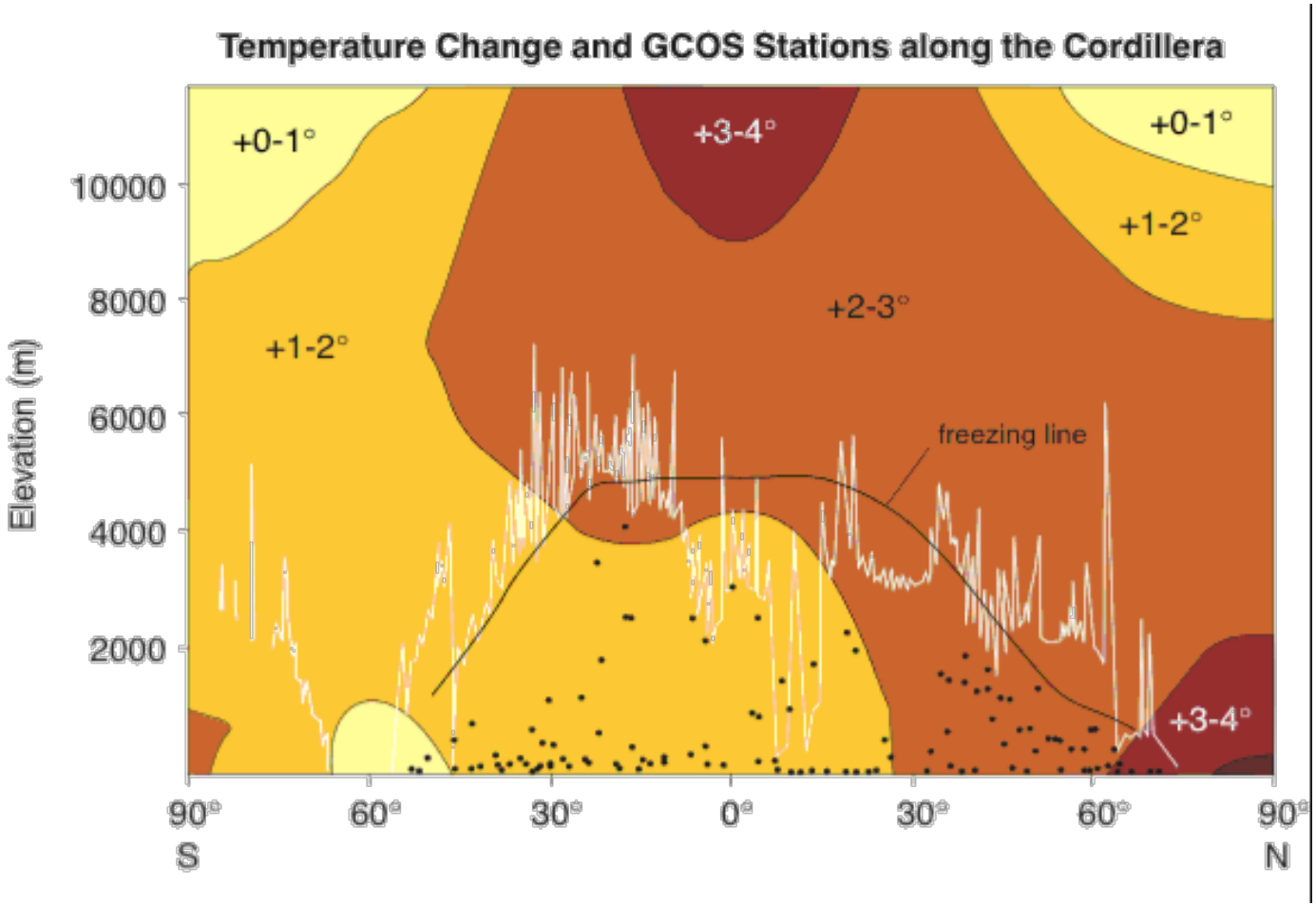


Rocky Mountain headwaters
Nelson Drainage Basin

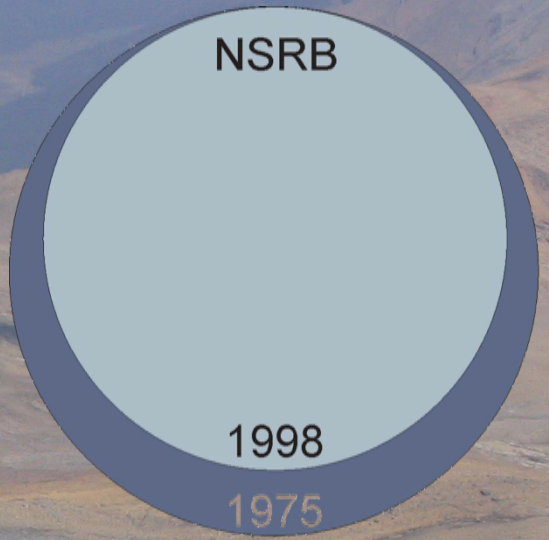
Demuth et al. 2008 *Terra Glacialis*

Comeau et al. submitted

Mountain regions are changing

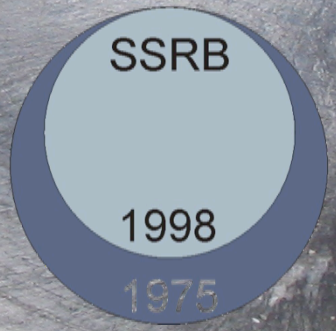


Recent glacier diminution !



FAC = - 22 %

484 > 450
(147 lost)

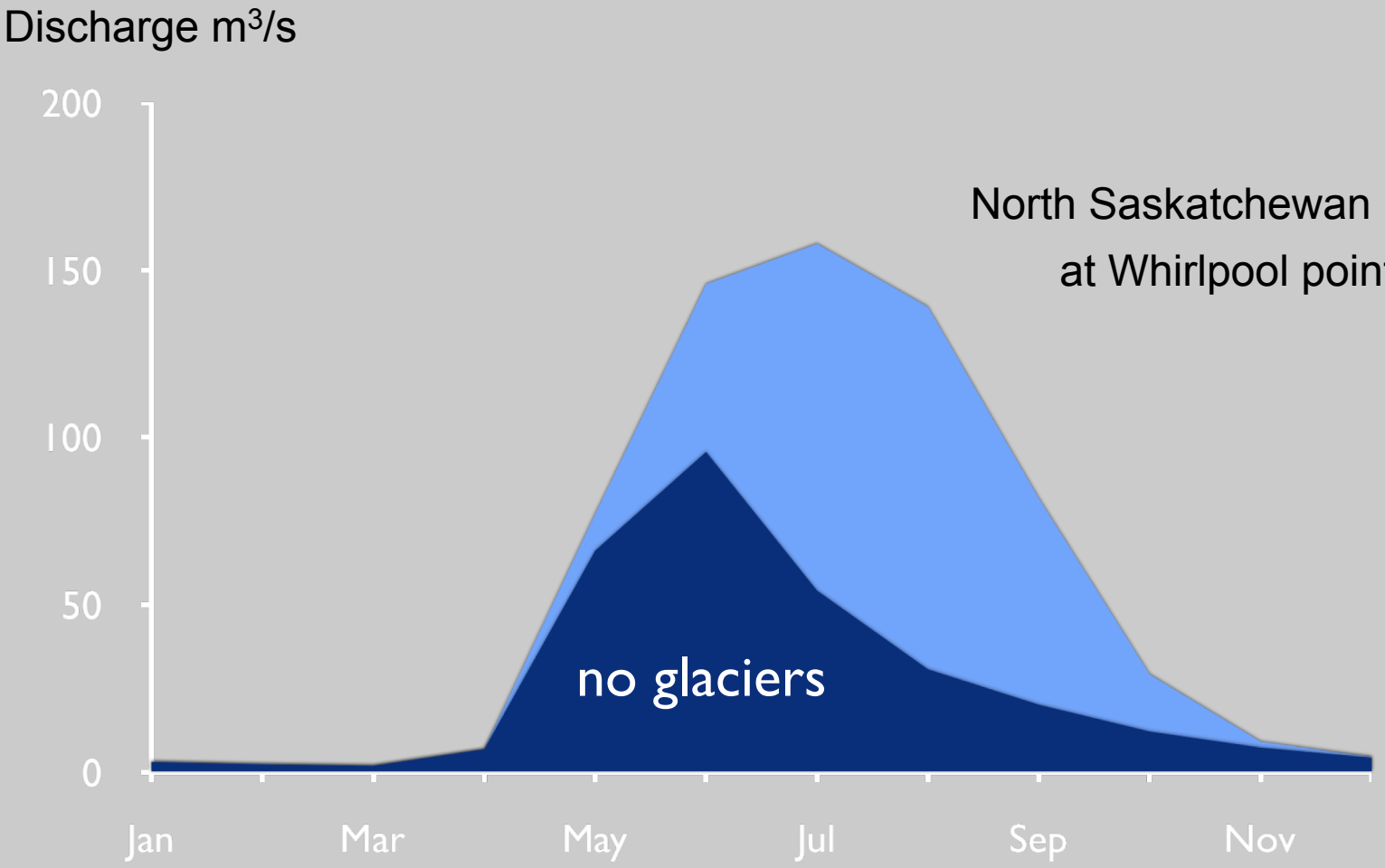


FAC = - 36 %

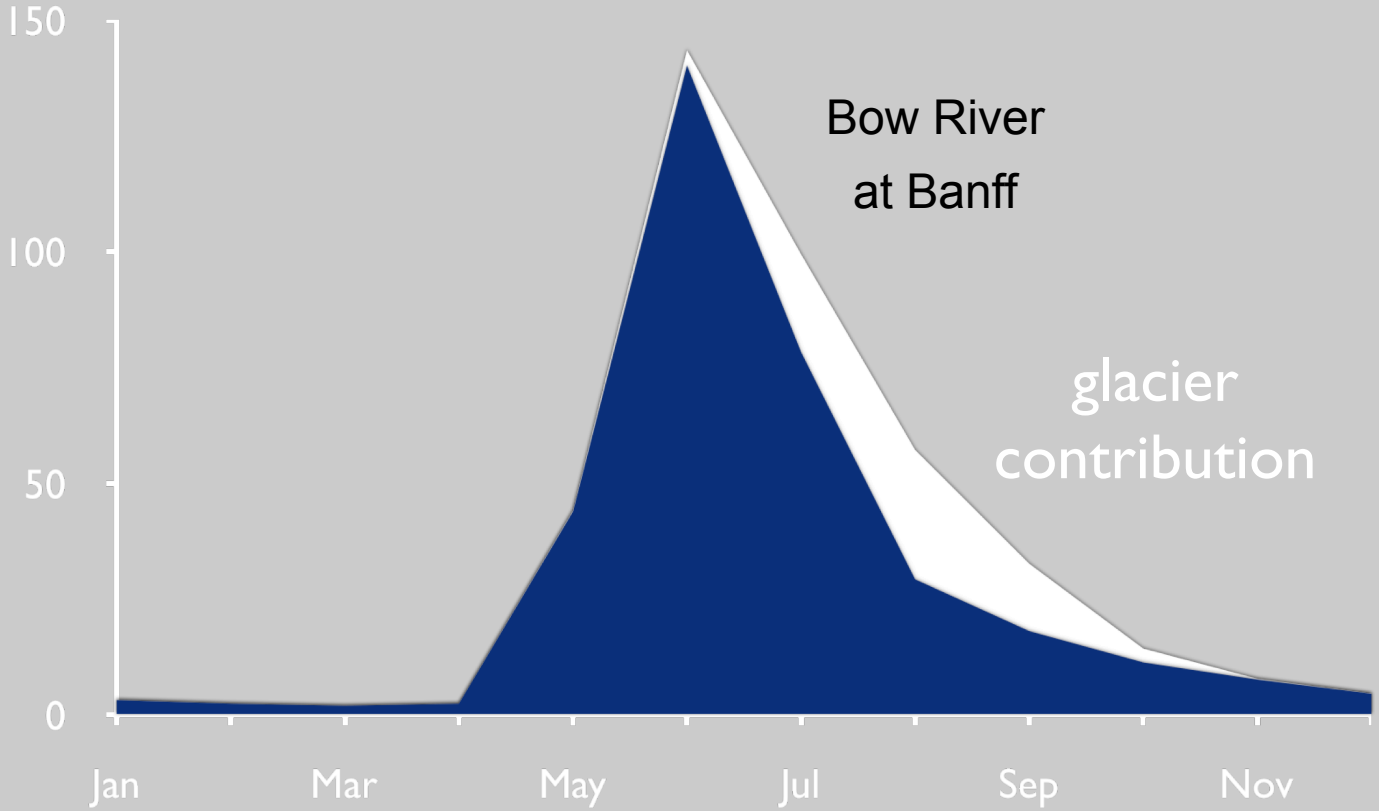
369 > 291
(181 lost)

Demuth et al. 2008 *Terra Glacialis*

Streamflow without glaciers



Pietroniro et al. 2008 Alta. Env. CCRUG



Dornes et al. 2008 in prep

- Some regions are already experiencing reduced streamflows predicted by the IPCC – *increased flow phase already past*:

  Rocky Mountain eastern slopes

  Demuth and Pietroniro 2003 CCAF-PARC

  Demuth et al. 2008 *Terra Glacialis*

  South-central British Columbia

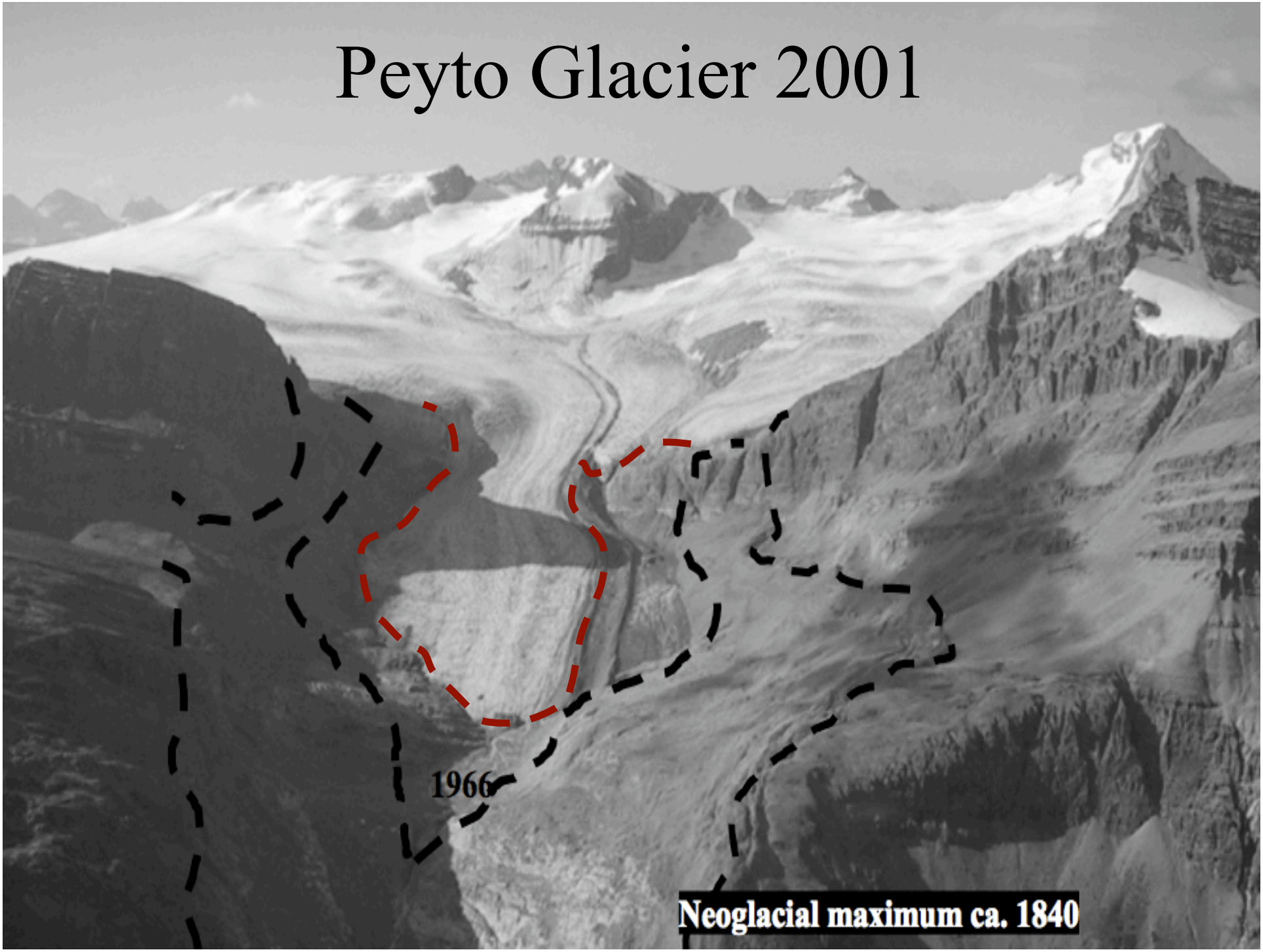
  Moore and Demuth 2001 *Hydrological Processes*

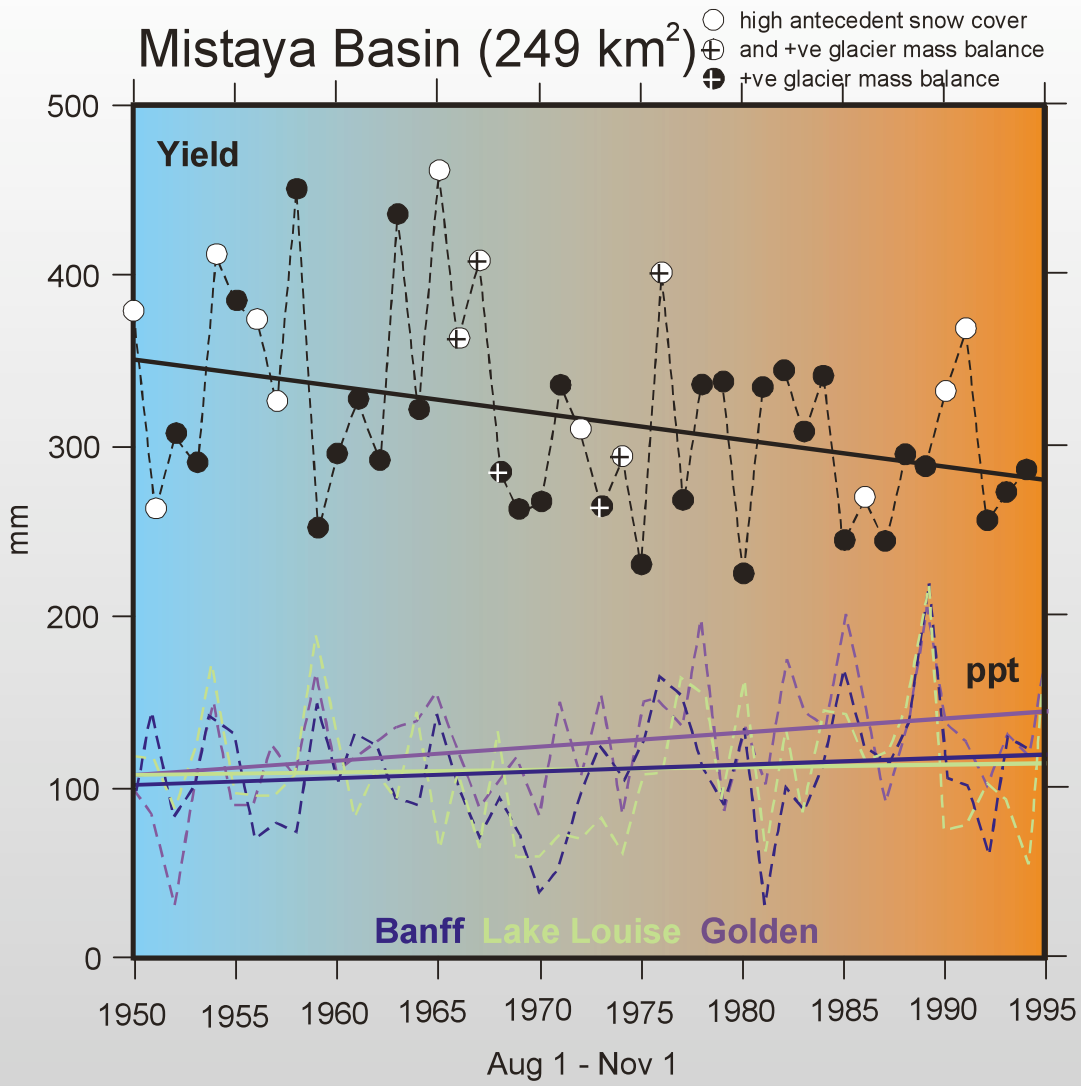
  Stahl and Moore 2006 *Water Resources Research*

- Glacier cover *contraction* over the last Century has been fuelled by regional warming and reduced nourishment – *there is simply much less glacier cover, resulting in reduced contribution when other sources may be absent or are know to be in decline*

- The *regulatory effect* over small and large time scales is muted

Peyto Glacier 2001

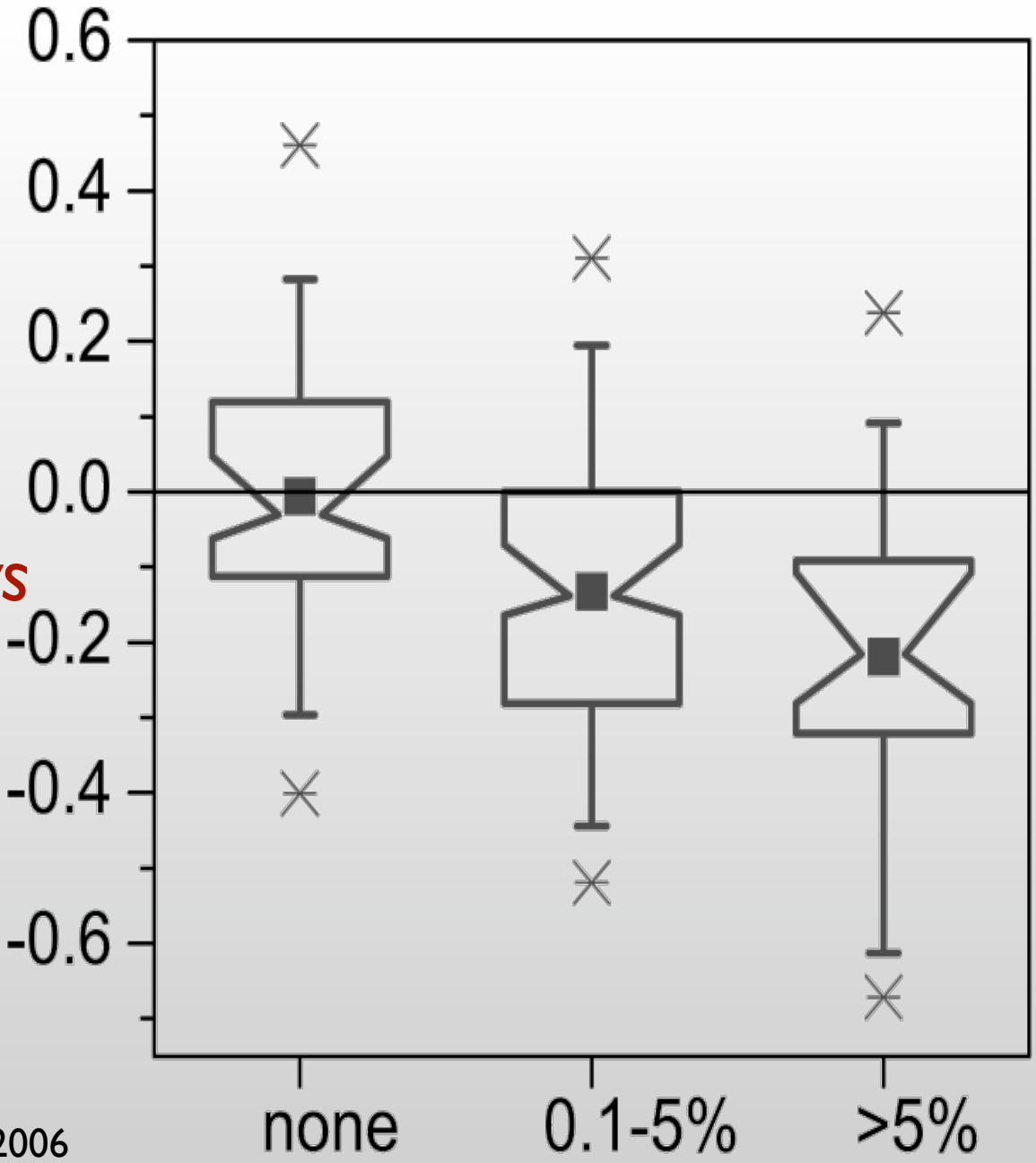




Demuth and Pietroniro 2003
CCAF - PARC

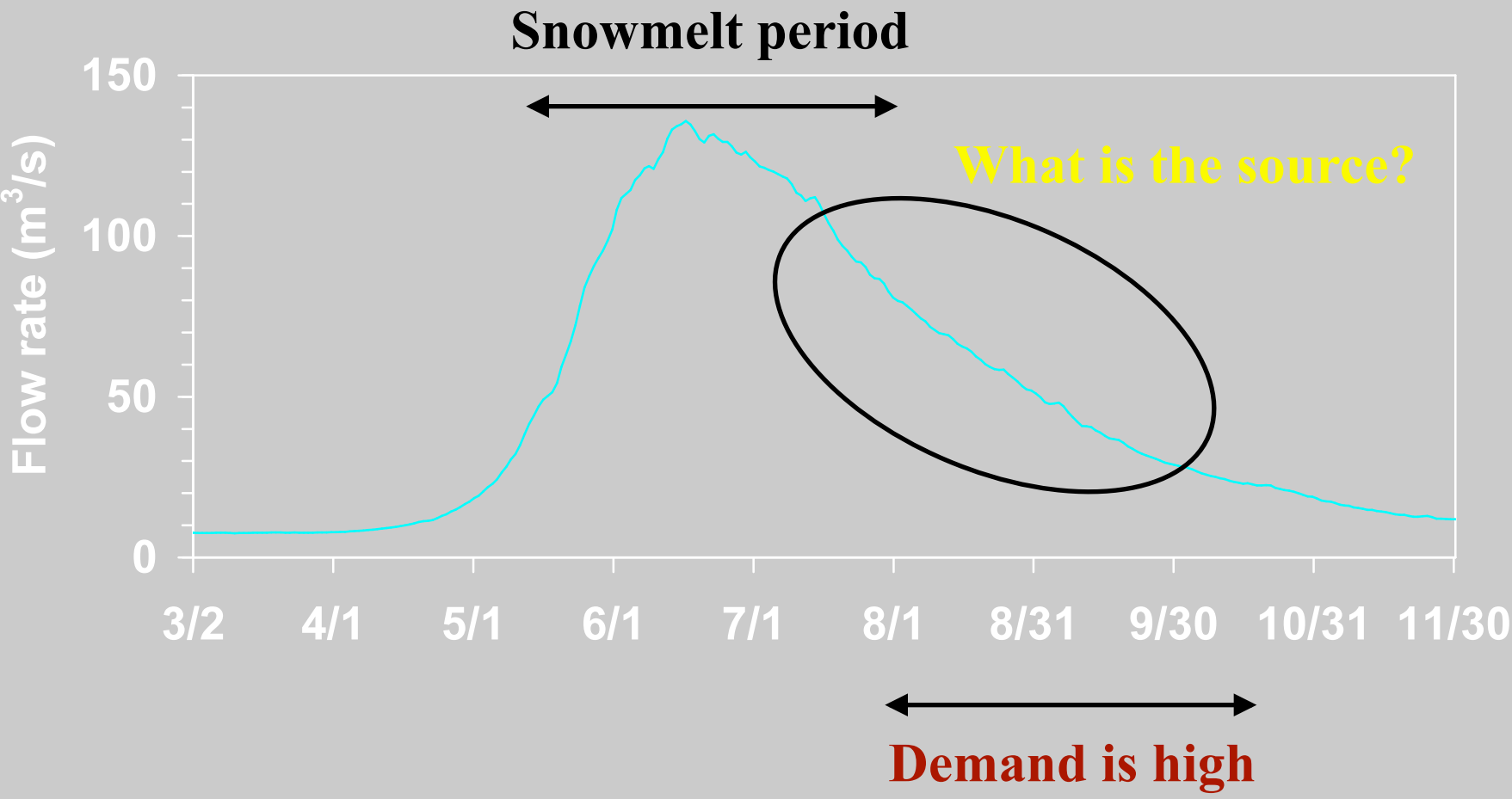
Basin yield

Declining August flows



Stahl and Moore 2006
Water Resources Research

Average Flow: Bow River at Banff

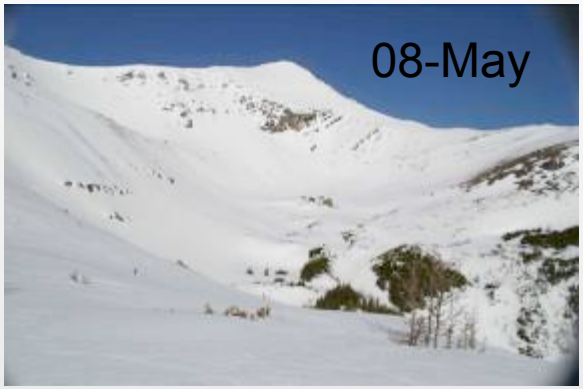


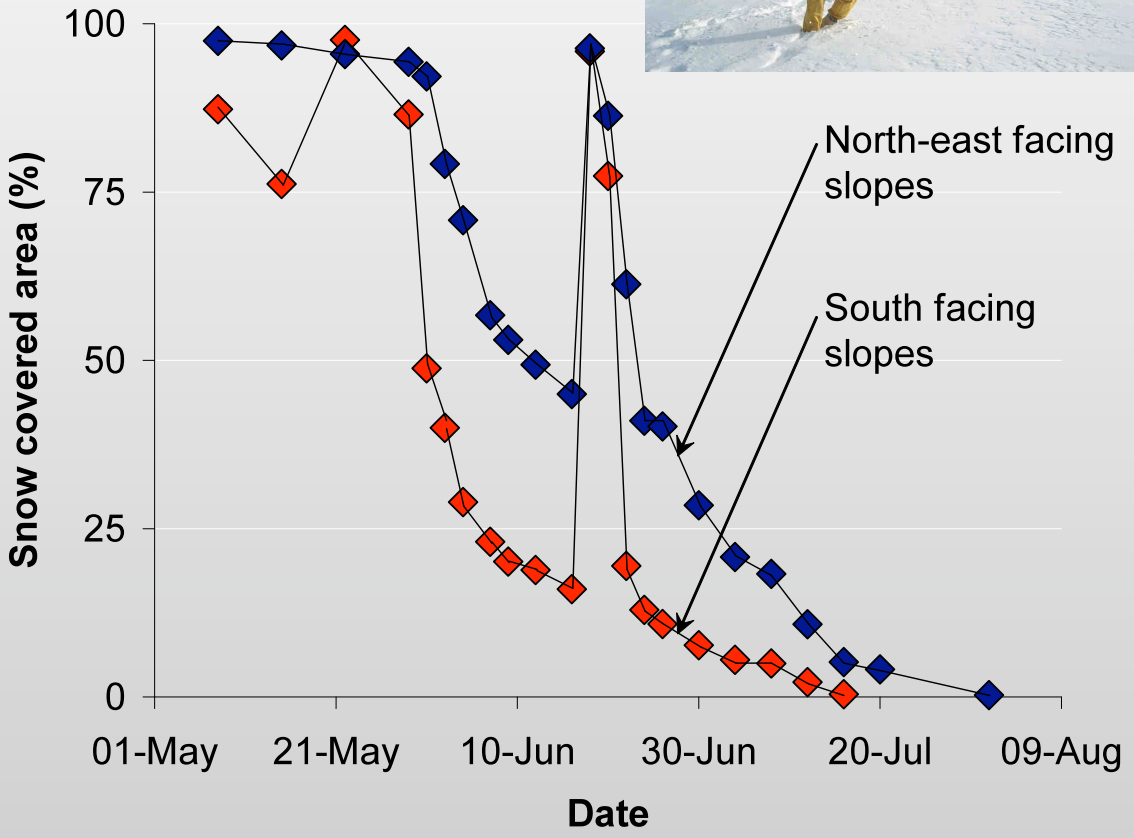
Prof. John Pomeroy

- Because temporal snow cover depletion patterns differ considerably between slopes within typical cirque-type basins found in the Bow Basin, a single snow cover depletion curve cannot be applied

- The role of *Chinook* events on snow-cover depletion and the countering role of transient Spring *upslope* precipitation events in the mountain headwaters is poorly understood

Snowcover Depletion in Alpine Basins





Dr Masaki Hyashi

UNIVERSITY OF CALGARY

- The role of groundwater in mountain headwater basins has received little attention, but needs to be incorporated in the prediction of river flow regimes
- The headwater basins in the Rockies have an enormous capacity to store snowmelt, rain, and glacier melt for a short period of time (e.g. a few months)
- This short-term storage may ameliorate hydrologically significant reductions in direct surface water contributions

IP3
Improved Processes & Parameterisation for Prediction in Cold Regions

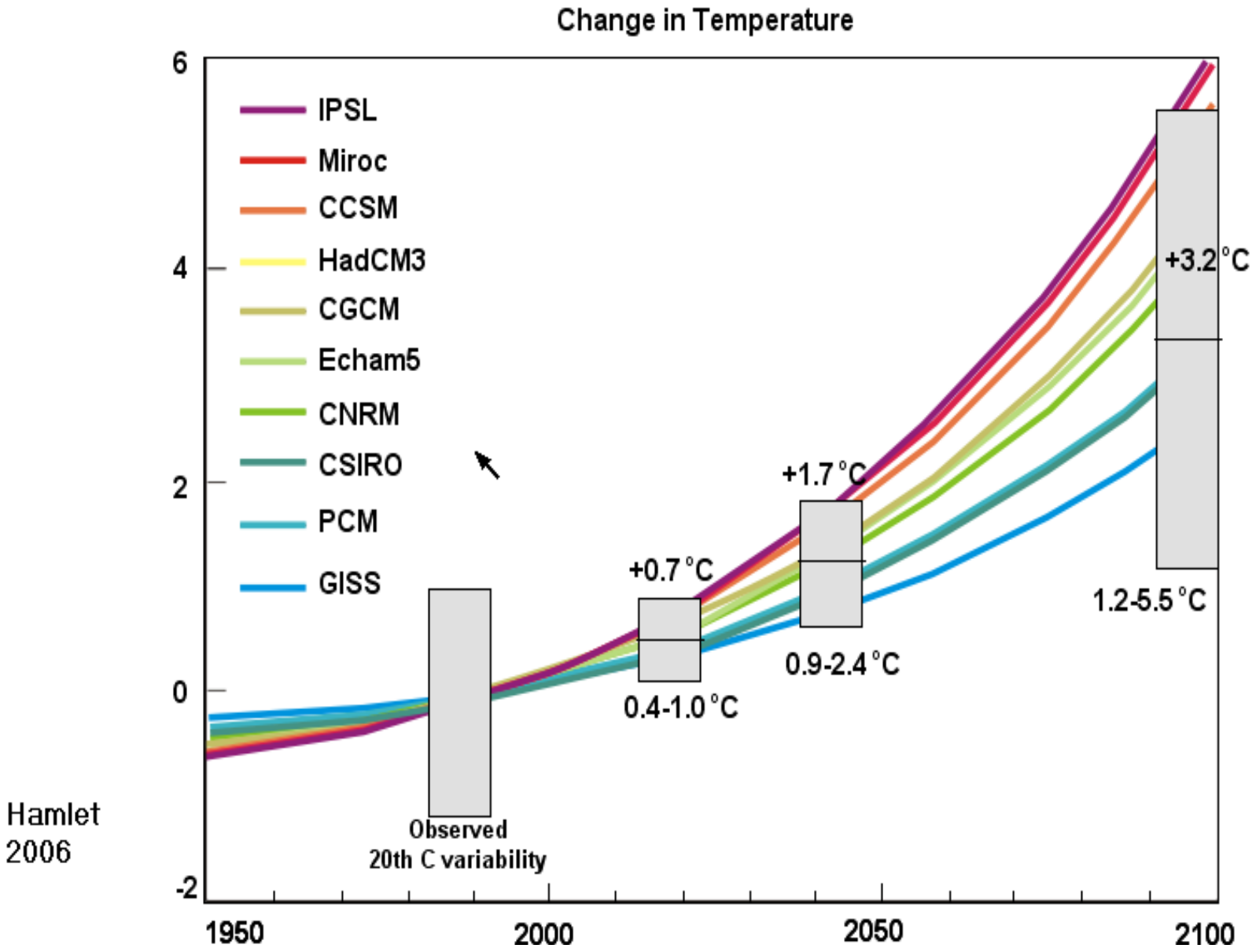
NSERC CRSNG

Geophysical (50 MHz GPR) investigations of loose materials as possible reservoirs of groundwater –

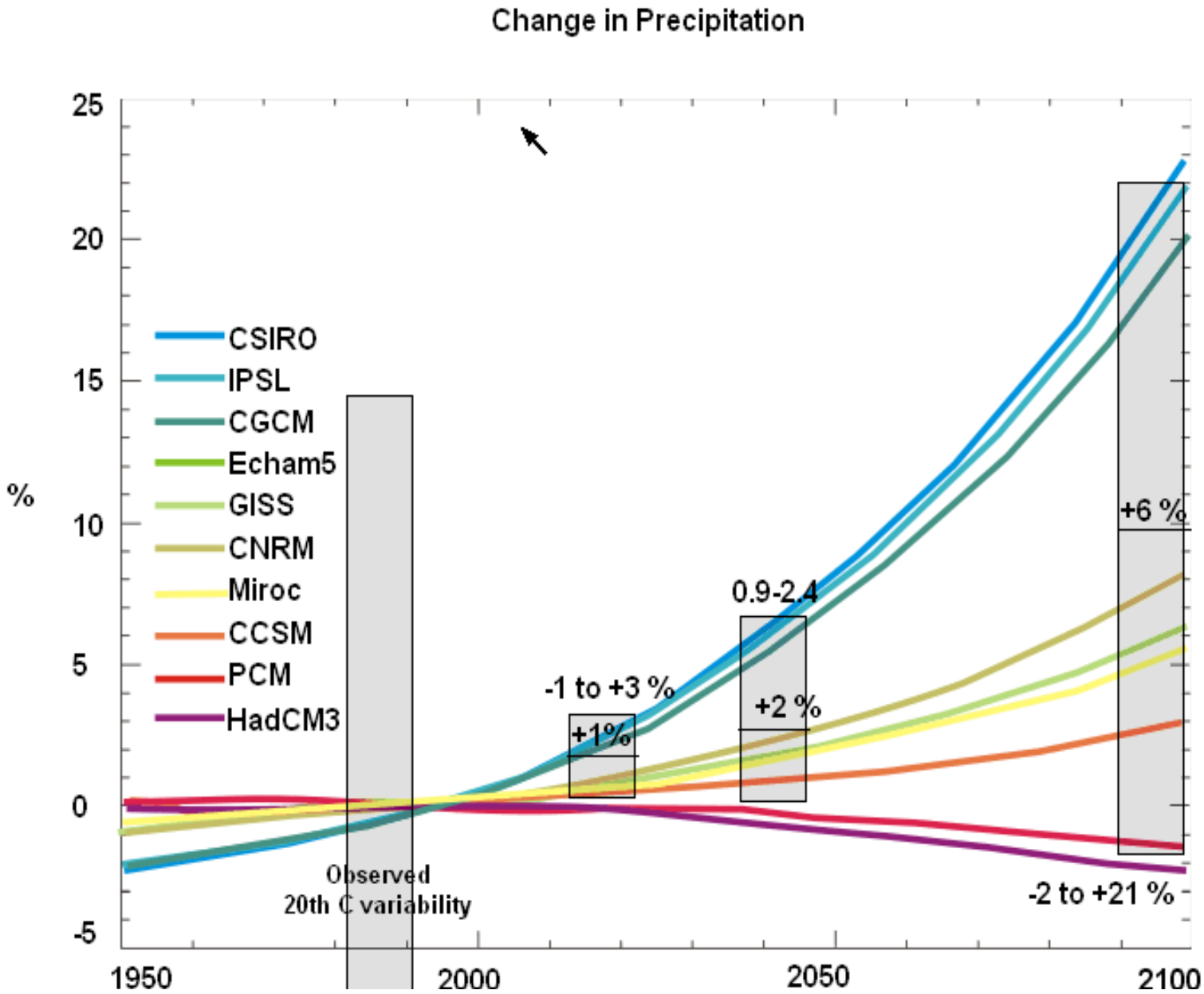
temporary storage

slow release during summer

Climate prediction in the mountains



Hamlet
2006

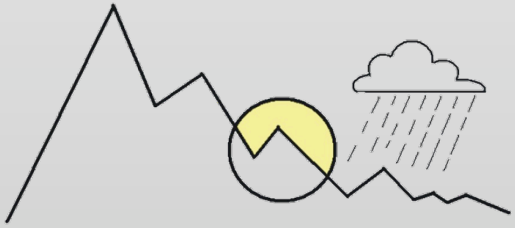

Change in Precipitation
25
20
15
10
5
0
-5
%
1950
2000
2050
2100
CSIRO
IPSL
CGCM
Echam5
GISS
CNRM
Miroc
CCSM
PCM
HadCM3
Observed
20th C variability
-1 to +3 %
+1%
0.9-2.4
+2 %
+6 %
-2 to +21 %

Dr Shawn Marshall

UNIVERSITY OF CALGARY

- To foster improved environmental and hydrological prediction, there is a pressing need to understand climate and hydrological processes at numerous scales.

- To achieve this requires a *co-ordinated enhanced observing period* during which meteorological measurements are made at a high spatial and temporal density:



Foothills Climate Array

WC²N

NSERC CRSNG

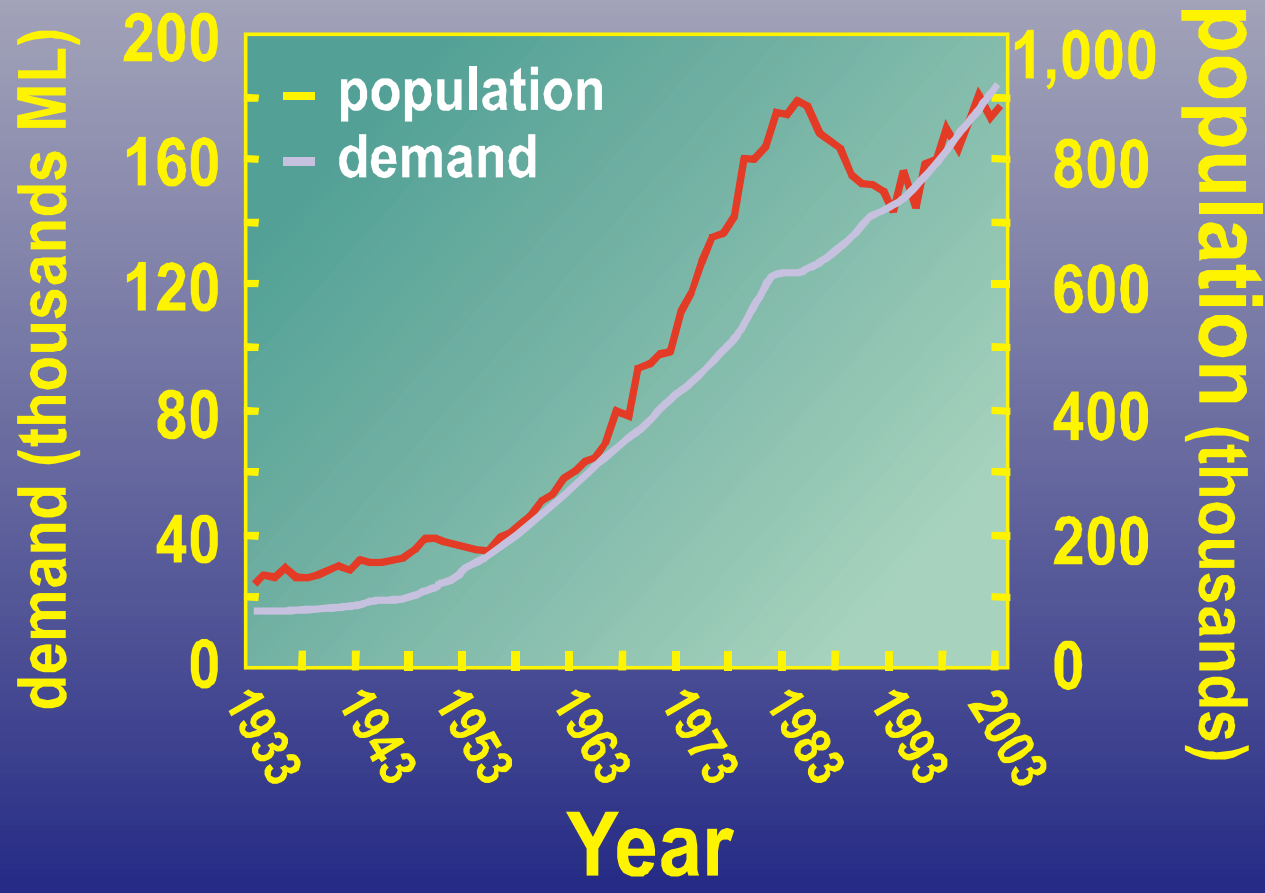
Dr Steve Grasby

- For Calgary, population growth is the largest factor in characterizing water stress
- Conservation needed to meet future growth
- Even then climate change may cause periods of demand greater than supply

Canada

CANADA 1842 GEOLOGICAL SURVEY - COMMISSION GÉOLOGIQUE

Annual demand controlled by population growth



Courtesy Chen, Grasby and Fesco

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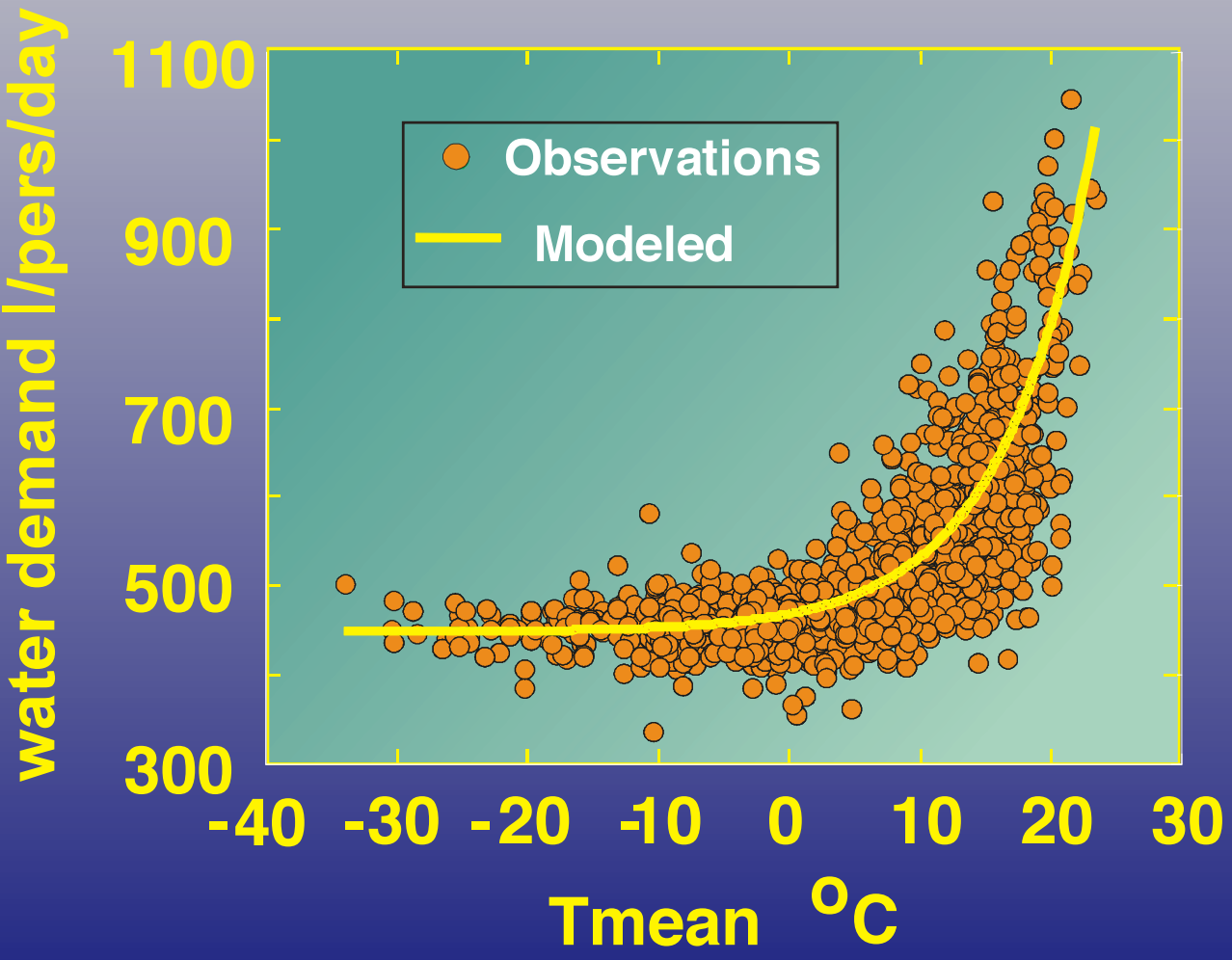
CANADA 1842 GEOLOGICAL SURVEY - COMMISSION GÉOLOGIQUE

Peak demand controlled by temperature



Courtesy Chen, Grasby and Fesco

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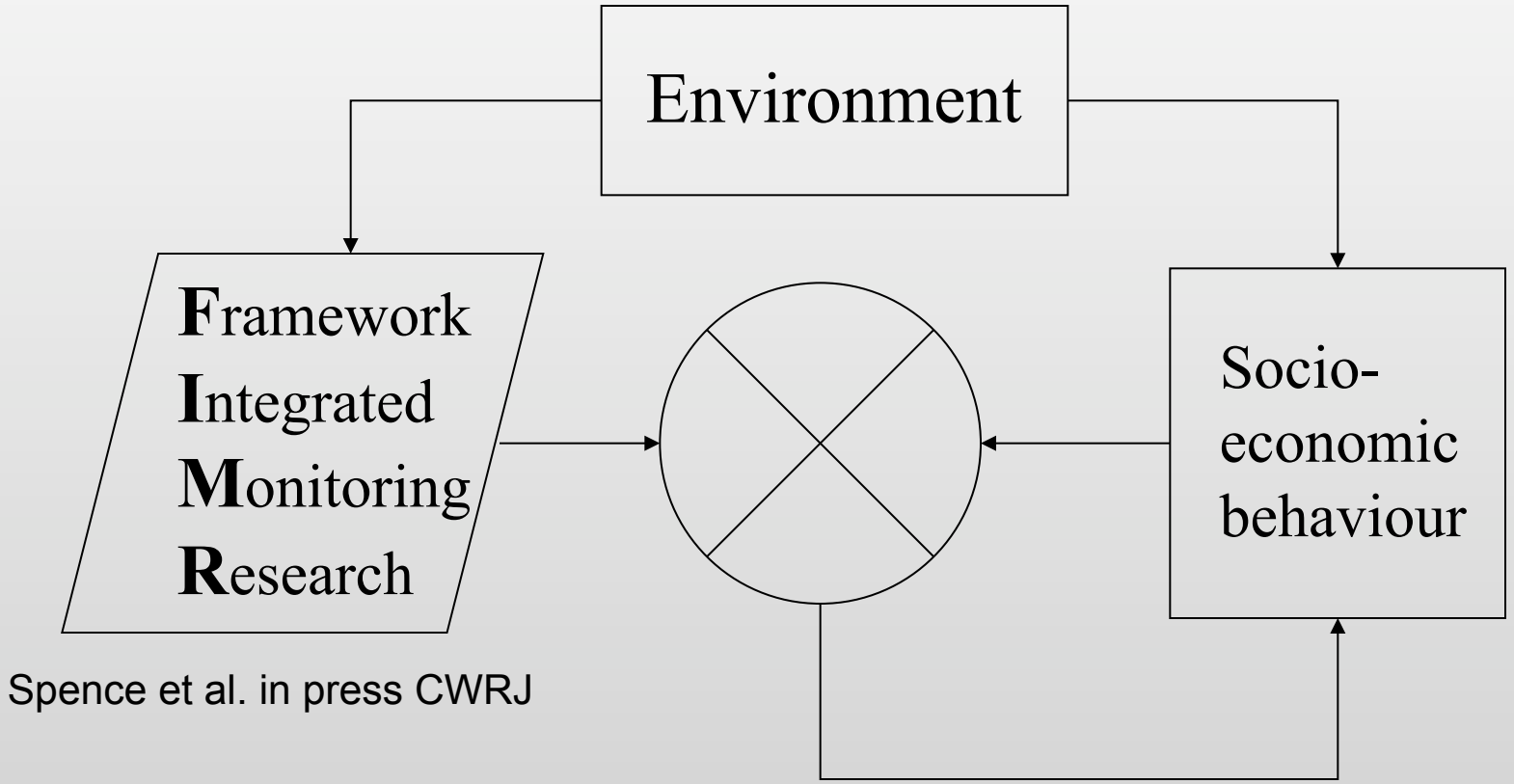
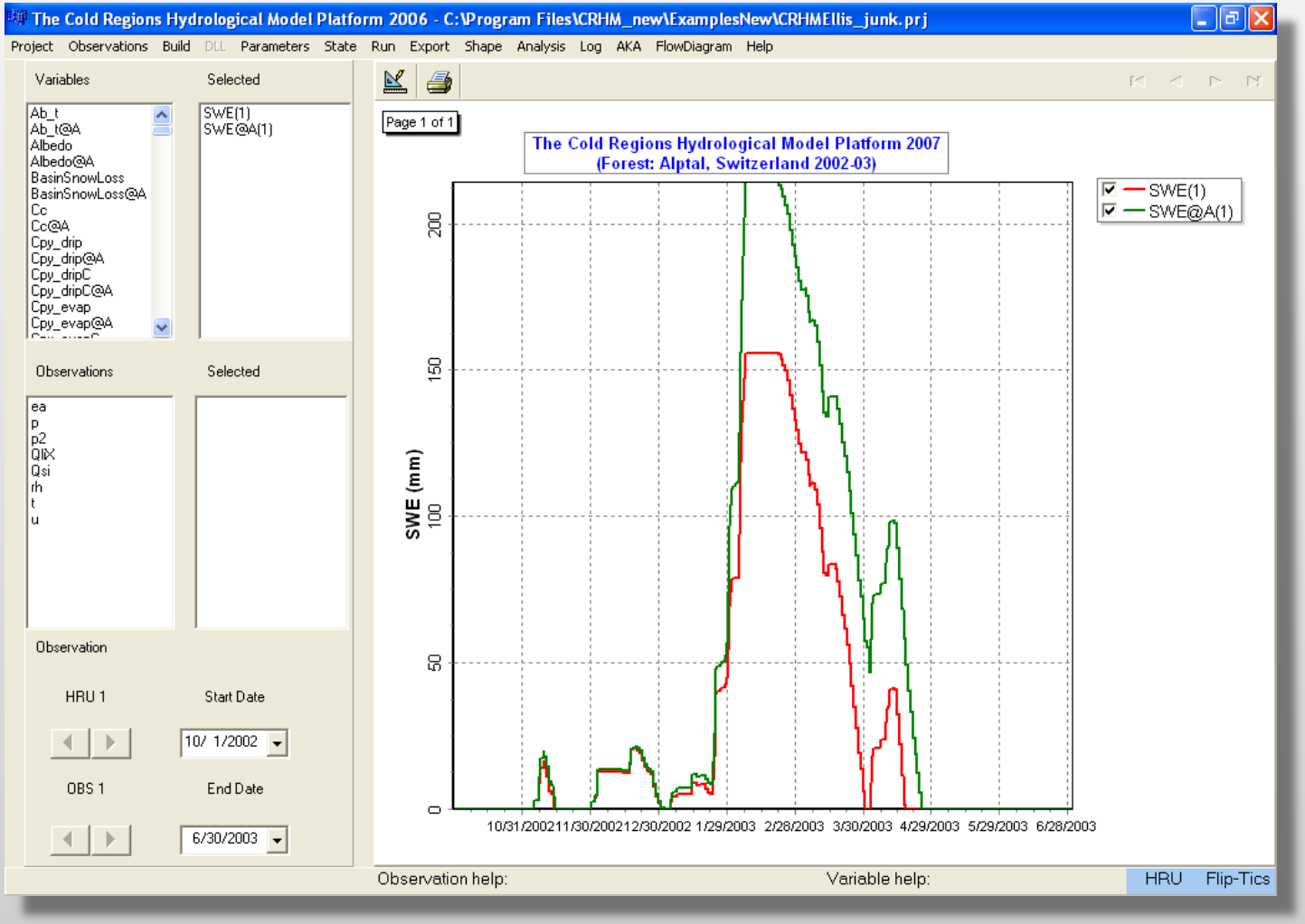
CANADA 1842 GEOLOGICAL SURVEY - COMMISSION GÉOLOGIQUE

Reducing vulnerability

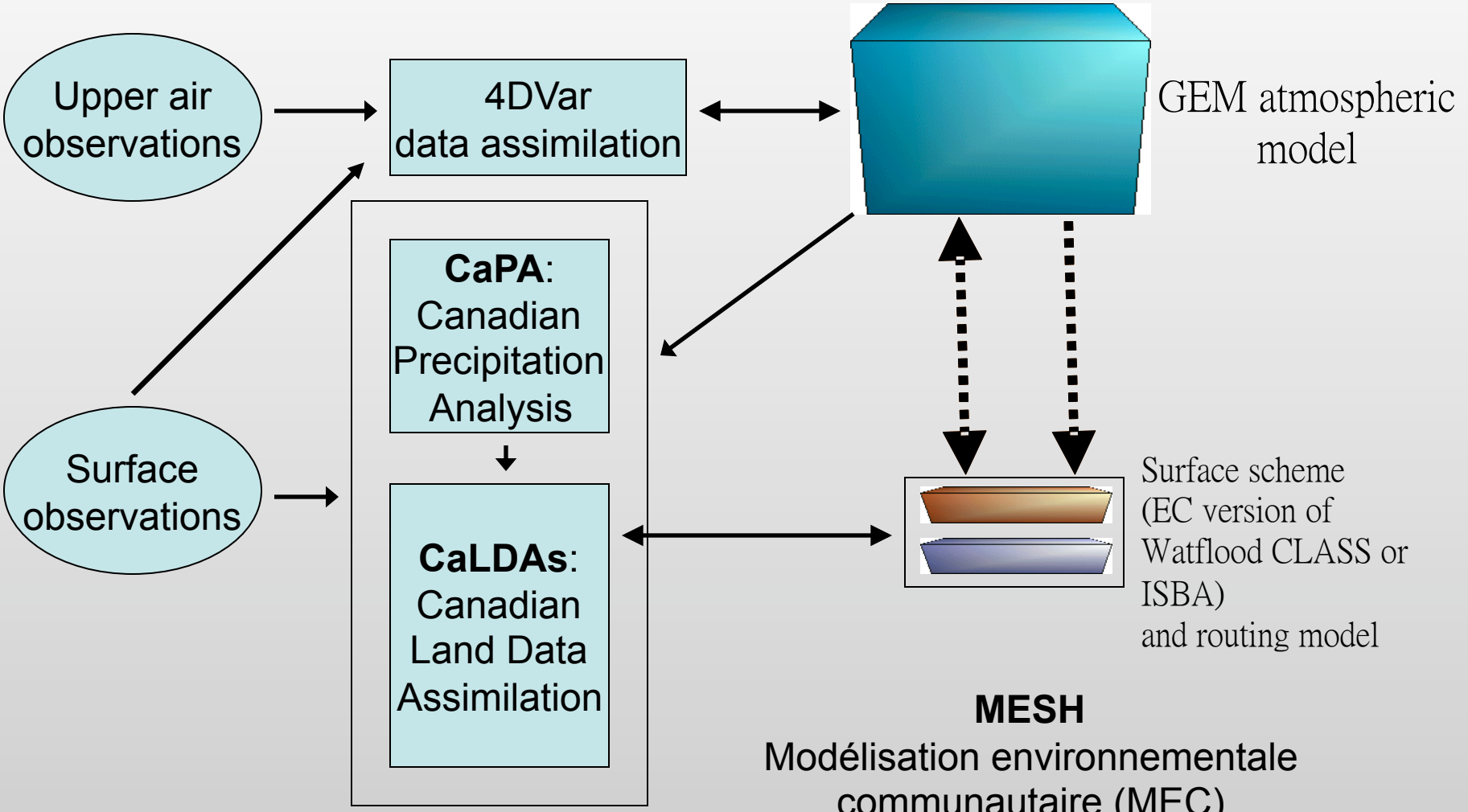


Spence et al. in press CWRJ

Physically-based Hydrological Modeling



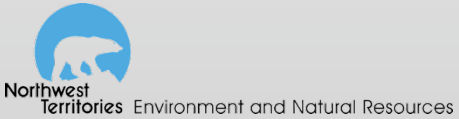
EC Environmental Prediction Framework

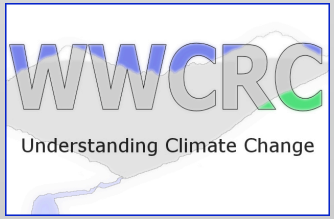


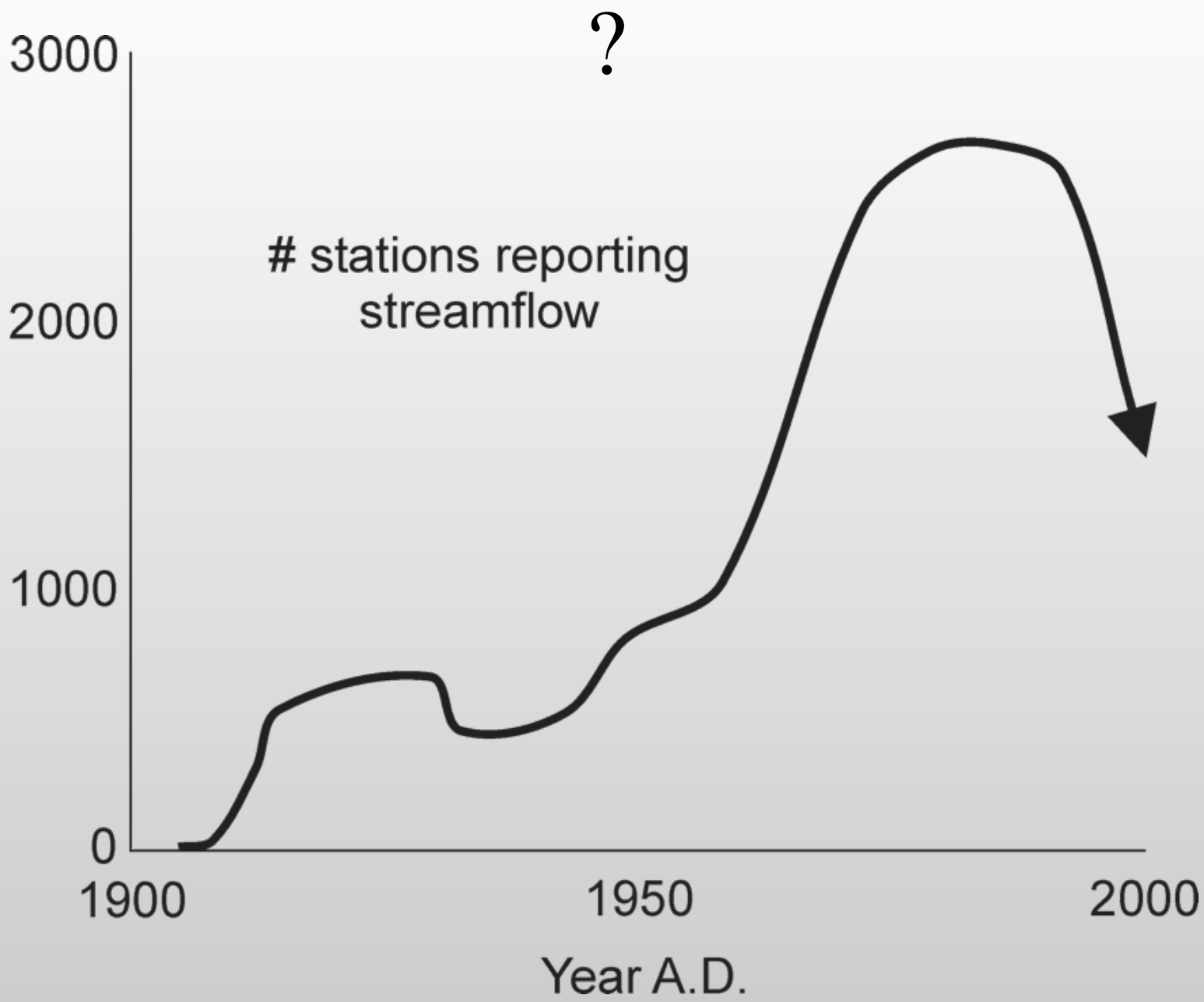
Canada

Observatory concept

- An *Observatory* is a region of relatively intensive hydro-meteorological observations associated with developing improved water and weather prediction
- Workshop (Canmore, December 8-10). Objective: permit a diverse partnership group of water resources experts to assist water and energy stakeholders in fostering improved forecasting and predictive modeling capacity in service of current and future energy and water supply security






?
3000
2000
1000
0
stations reporting
streamflow
1900
1950
2000
Year A.D.

Summary Points 1

- Climate and hydrology are *not stationary*; that regime shifts and (changing means and variance) make redundant traditional statistical approaches based on the concept of "normal"
- Hydro-climatic data contain trends, cycles and noise, requiring adequate length (*monitoring !*) and decomposition (analysis)
- Move from *annual/mean* constructs to those that foster adaptation to shifting *seasonality* and *extremes*
- The regulatory role of glaciers is in decline in several regions including the Bow River Basin headwaters
- The nuances of snow accumulation and snowmelt needs further attention

Summary points 2

- The role of groundwater requires further study – Surface-ground water interaction is poorly understood

- Risk management and adaptation to a changing climate requires improved forecasts of weather, climate and river flow (and estimates of uncertainty) – *a **F**ramework for **I**ntegrated **R**esearch and **M**onitoring fostered in part by the proposed **"Mountain West Weather and Water Observatory"***

- Encourage exploration "upstream" to foster increased awareness of environmental change and water stress – ***citizen awareness***

Thank you

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