

Global Water Futures: Overview, Core Modelling Program and Forecasting Potential

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Canada's Water Crisis: Regional Examples

Conflicts between water and land users, typically arising over resource development pressures threatens our financial stability while transitioning to a low carbon economy.

Ecological collapse in significant freshwater systems through cumulative effects of water quality stressors on iconic and at-risk species is threatening food sources and livelihoods.

Extreme swings in water quantity between floods and droughts are fundamentally altering the ability to use our waterways and are threatening critical infrastructure and lives.

Inadequate source water for First Nations threatens our ability to provide all citizens of Canada with equitable access to safe and clean drinking water.



15/17 measures of environmental health in decline Wood Buffalo National Park



Fort McMurray Forest Fires 2016
$8.9M



Long-term water advisories for **84** First Nations[2]



Rocky Mountain Floods 2013
$6B and **100,000** Evacuated



>$50M already dedicated to restoring Lake Winnipeg



Ring of Fire Mining Protests over land and water rights



TransMountain Pipeline delays cost **$15B/year**



Ontario/ Quebec Floods 2017
$223M



Nestle groundwater mining **90%** of Six Nations lacks drinking water



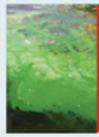
Record BC Floods & Fires 2017-2018



Prairie Droughts 1999-2004
$6B



Prairie Summer Floods 2014
$1.5B



Lake Erie Algae Blooms 2014
$65M USD in lost economic benefits



Toronto Floods 2013
$1B



St. John River Flood 2018
$80M

Global Water Futures: Solutions to Water Threats in an Era of Global Change

GWF aims:

a) to **place Canada as a global leader in water science for cold regions**,

b) to **address the strategic needs of the Canadian economy** in adapting to change and managing the risks of uncertain water futures and extreme events.











Global Water Futures - Mission

- **Improve disaster warning** – develop:
  - scientific knowledge, monitoring and modelling technologies,
  - national forecasting capacity to predict the risk and severity of extreme events
- **Predict water futures** –
  - use Big Data to make informed decisions,
  - Develop better models to assess change in human/natural land and water systems
- **Inform adaptation to change and risk management** – to reduce the risk of water threats, design adaptive strategies, and enhance economic opportunities, propose
  - governance mechanisms,
  - management strategies,
  - policy tools





GWF Today

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Awarded
$ 77.84 M

over 7 years
7 2016 - 2023

from
CANADA FIRST RESEARCH EXCELLENCE FUND | APOGÉE CANADA FONDS D'EXCELLENCE EN RECHERCHE

GWF supports
3 Global Programs

UNESCO
WCRP World Climate Research Programme
futureearth research for global sustainability

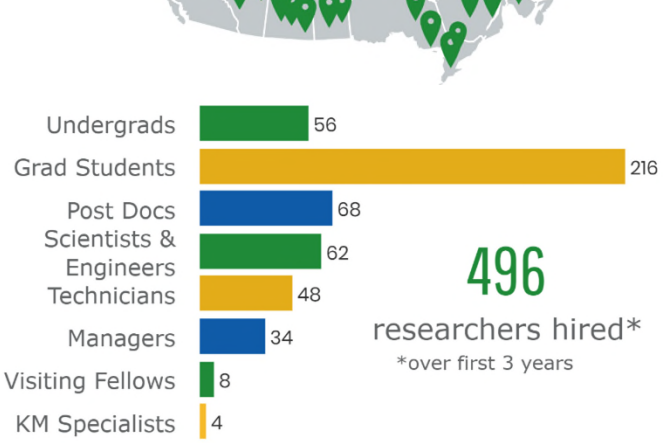
GWF
39 projects
funded across Canada

15
universities

60
observatories



162
faculty investigators



335
partners

496
researchers hired*
*over first 3 years

$292.6 M
in GWF project & core team funding

$115.8 M
In-kind

$176.8 M
Cash

Transformative Science Projects

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- 21 transformative research, big data and decision support tool projects













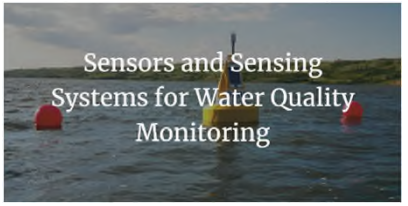






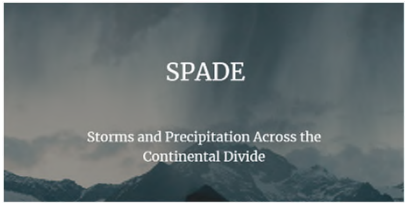






















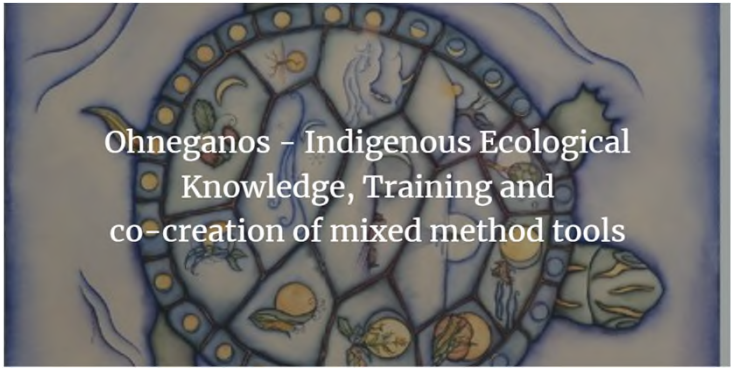


Indigenous Community Water Research Projects – 6 co-designed, co-led projects

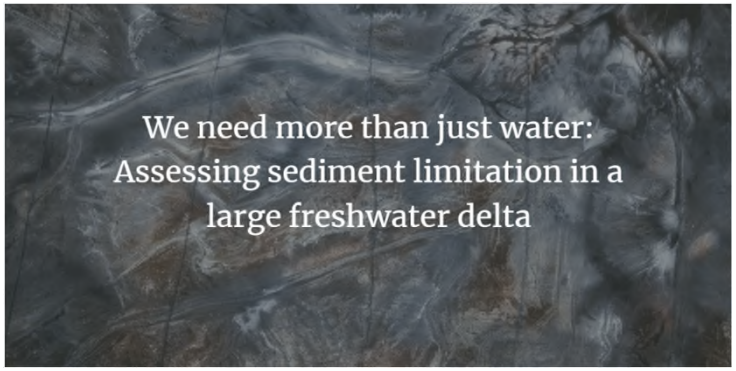
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Designing Solutions for Users

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- 12 user-question led projects

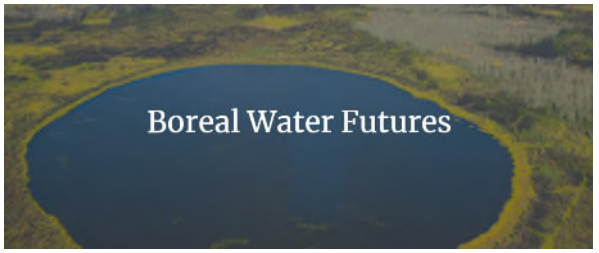
























GWF Canada and Policy Initiatives

- Increased engagement with ECCC – lead water department for Government of Canada
  - National Hydrological Service
  - Meteorological Service of Canada
  - Science and Technology
- MOU with NRCan – river basins, remote sensing, groundwater, climate change, glaciers, forestry
  - November 2018 science summit with NRCan in Ottawa
- Water, Peace and Security
- Canada Water Security Initiative
  - Climate change & extreme events, Indigenous water, Transboundary issues, Integrated River Basin Prediction and Assessment –
    FLOW, CIER, POLIS, UNU-INWEH





GWF International

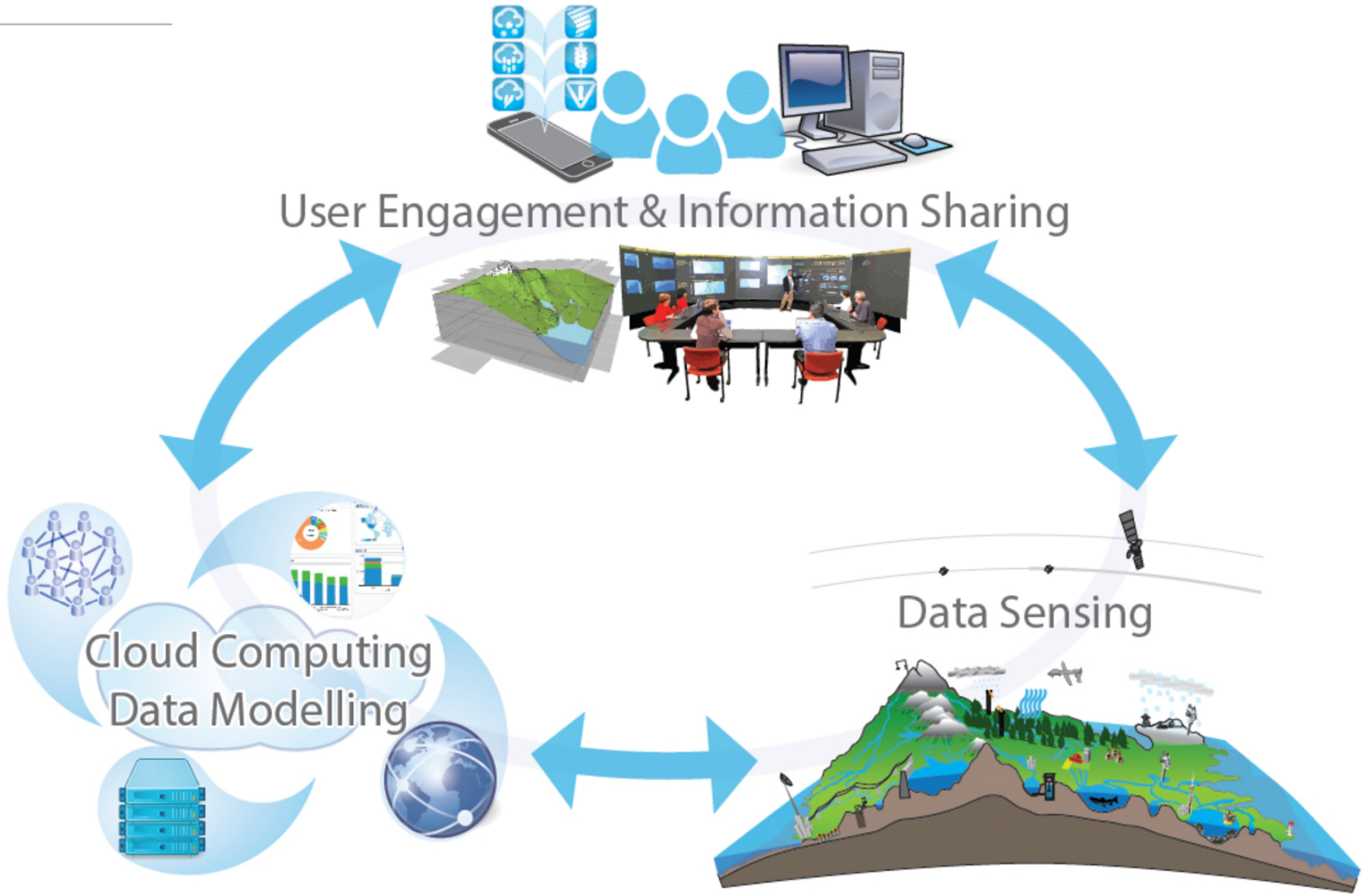
- INARCH – mountain hydrometeorology
- GEWEX –
  - GWF is a **Regional Hydroclimate Project**
  - Water for the Food Baskets of the World
- UN Water Action Decade
  - Collaboration with UN University
  - *Canada Water* - Strategy and Action Plan
- UNESCO
  - Global Environmental Facility - Central Asian Hydrology Project
  - GWF/UNESCO Joint Presentation to COP25, Santiago, Dec 2019
- Future Earth – Water Futures.
  - Sept. Conference, Bangalore
  - *Climate Impacts on Global Mountain Water Security Working Group*
- WMO – High Mountain Summit in Geneva, Oct 2019
- Modelling – Iran, India, Israel, Kazakhstan, Spain, Chile, Argentina, China
- Critical Zone Observatory – China-Siberia
- Third/Three Pole Environment – Chinese Academy of Sciences



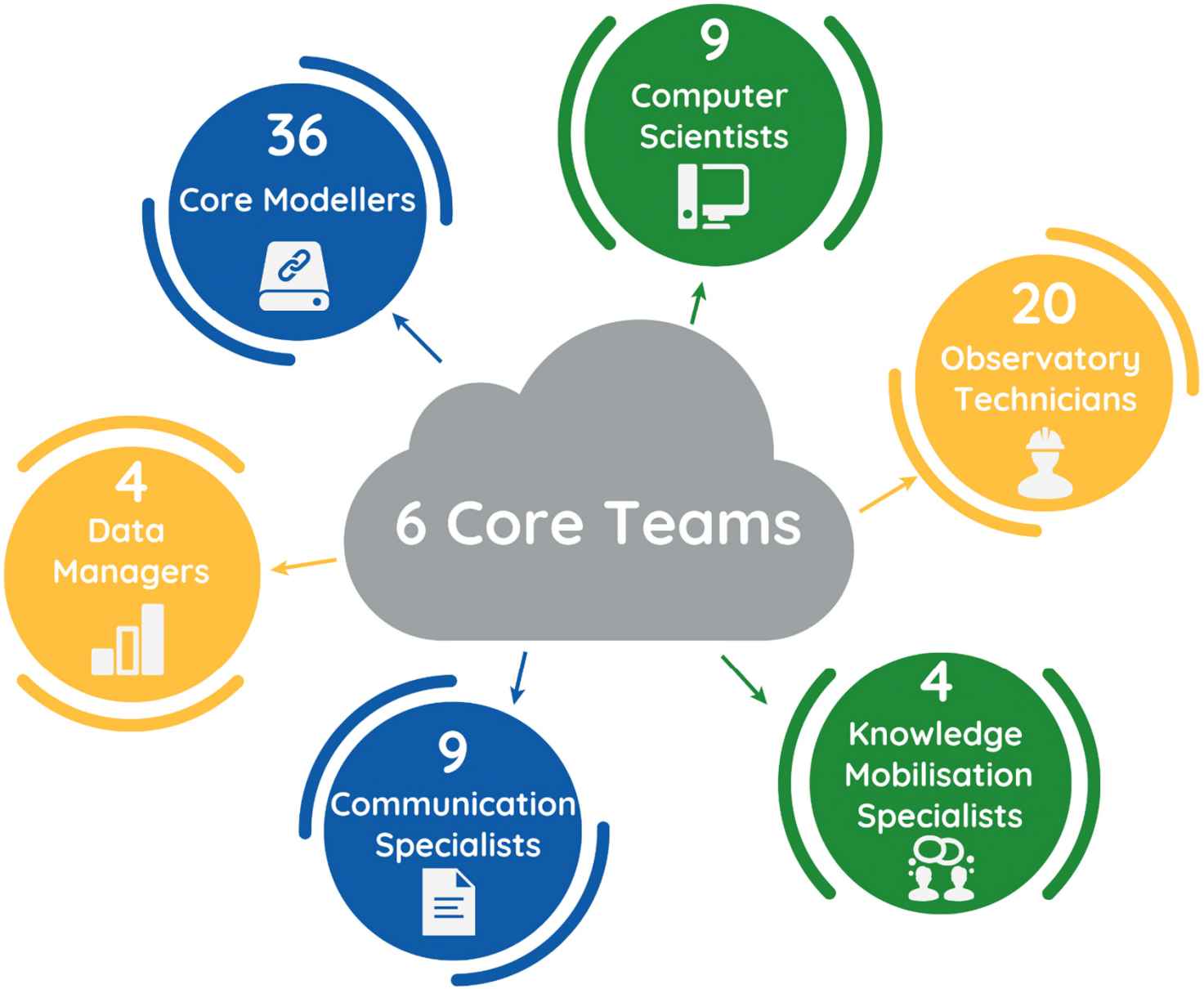
By 2023, GWF will contribute to

- *Improved scientific foundations* for solving water problems.
- National *water forecasting and prediction* system
- *Predictions of water futures* around the world
- *Water solutions* for food security, energy security, infrastructure, economic development, safe communities, ecosystem conservation, governance.
- *Decolonialization* of Indigenous water management in Canada.
- *Water, peace and security* around the world
- Revitalized *water strategy for Canada*
- Making Canada known as the ***water solutions country***.

GWF Water Observation, Prediction and Knowledge Mobilization Strategy



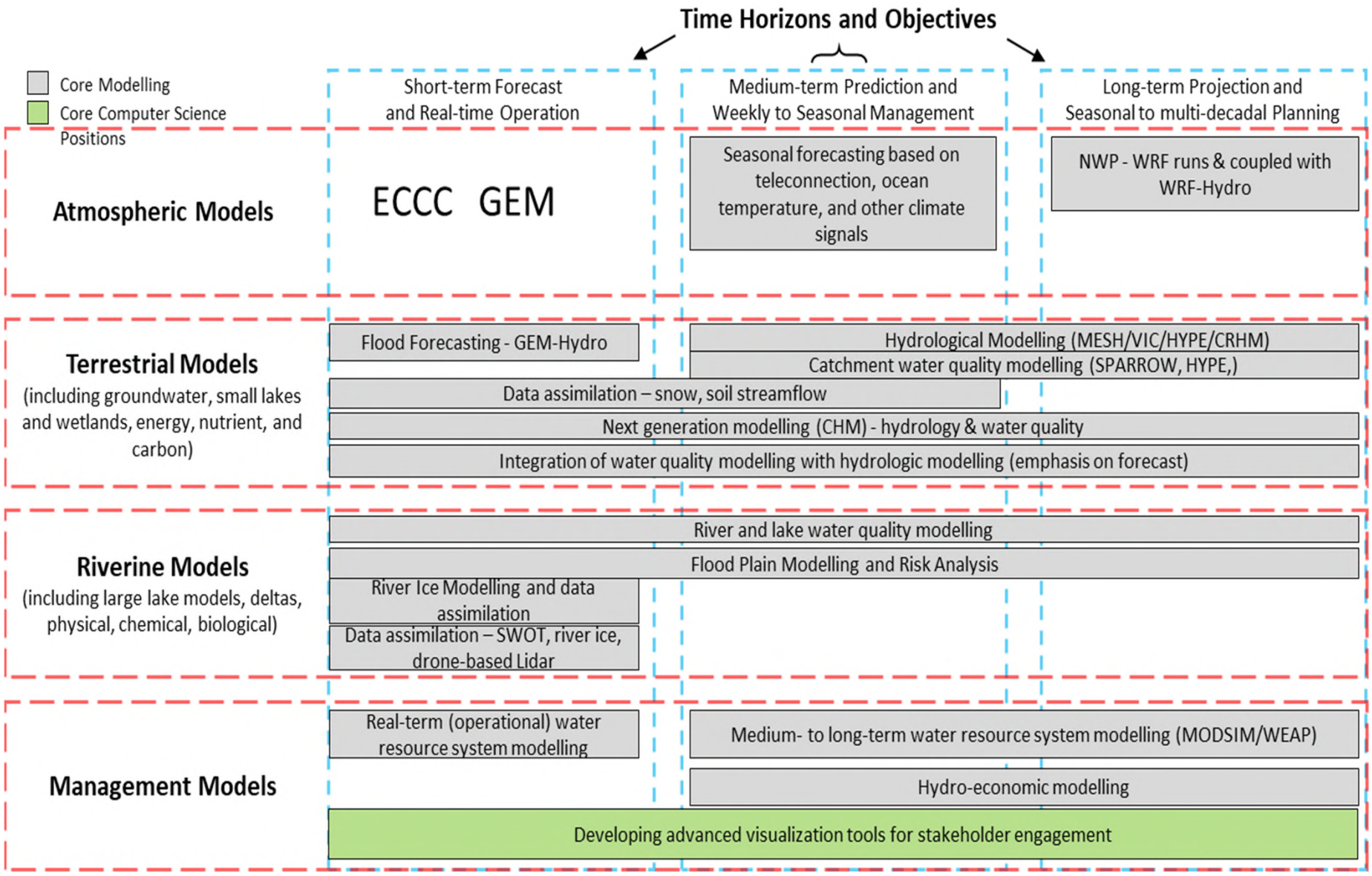
GWF Core Teams



GWF's 8 River Basins



Core Modelling Strategy

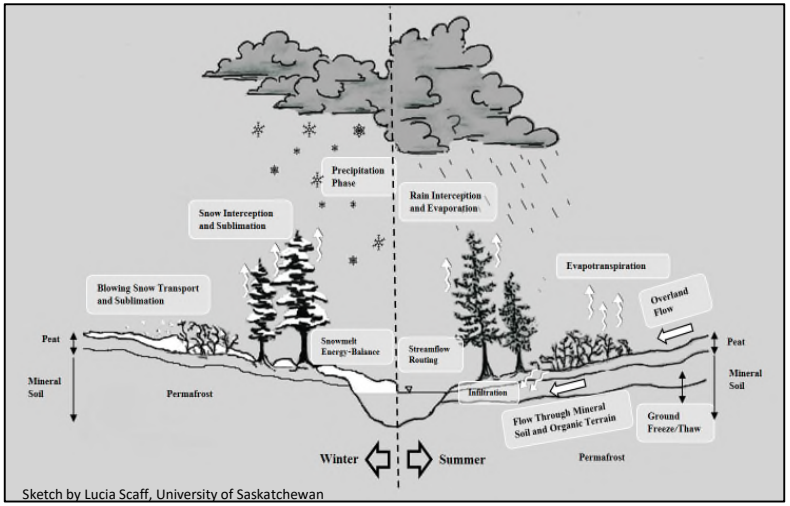


GWF Multi-modelling Strategy

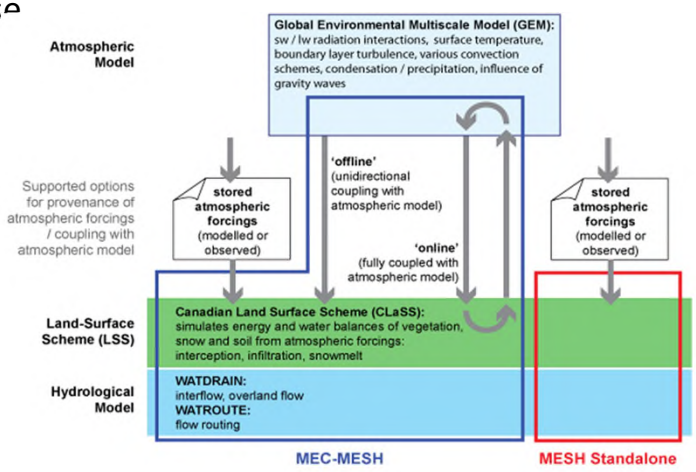
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Cold Regions Hydrological Modelling Platform (CRHM)

-modular, flexible, object oriented process modelling
-users select modules to create a custom model
-spatial discretization based on hydrological response units
-catchment applications



*Pomeroy et al., 1998; 2007, 2016

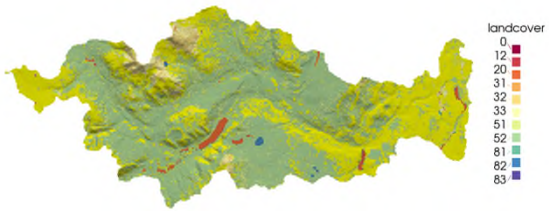


Pietroniro et al., 2007

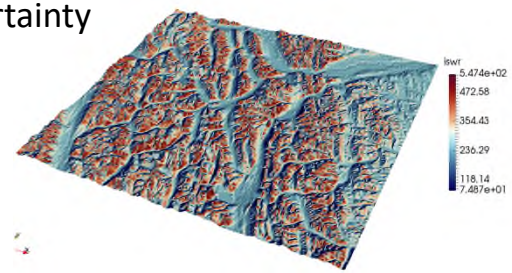
MESH -Coupled land surface hydrological model
-Feedback with atmospheric and groundwater models
-Water management
-Cold regions
-Flexible
-Large river basins

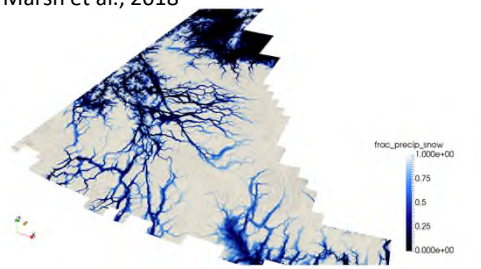
Canadian Hydrological Model (CHM)

Multi-scale, multi-physics, variable complexity and domain model
-Efficient TINS
-Assessment of model structural uncertainty



Marsh et al., 2018

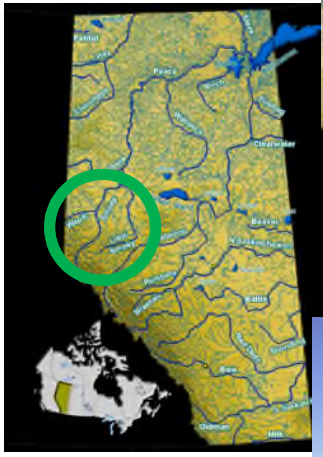




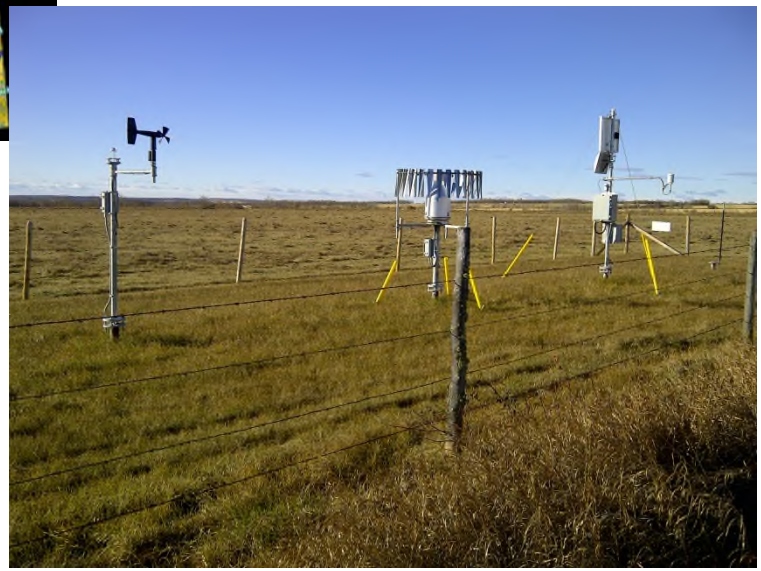
-GEM-Hydro – with ECCC
-VIC
-HYPE
-Various water quality models

Application: Operational Forecasting of Ungauged Snowmelt Runoff

- Smoky River Basin is 46% ungauged
- Need to simulate spring streamflow from the ungauged basin area (23,769 km^2) in order to forecast Smoky River contribution to the Peace River
  - Run model on a daily basis during flood forecast period – update ungauged flows
  - Use daily updates of meteorological model forecast data to run for the future
  - Route ungauged with gauged flows for forecast

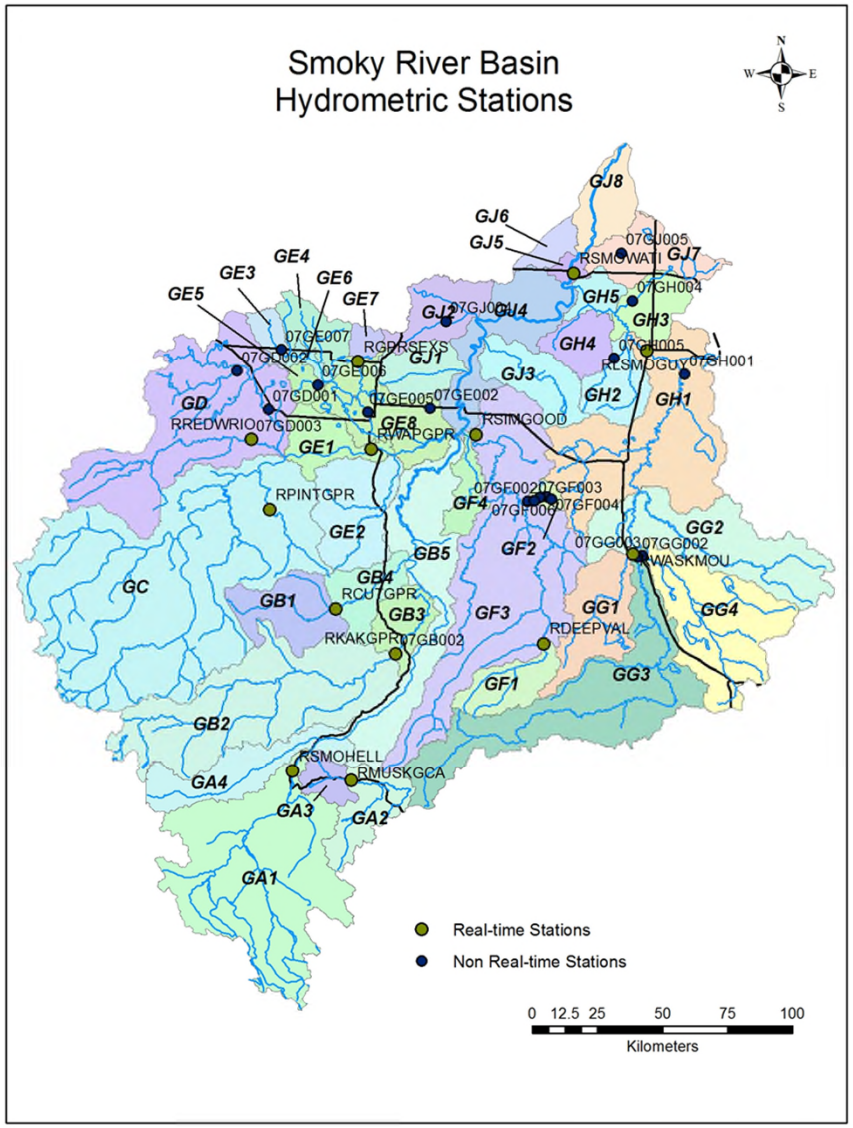


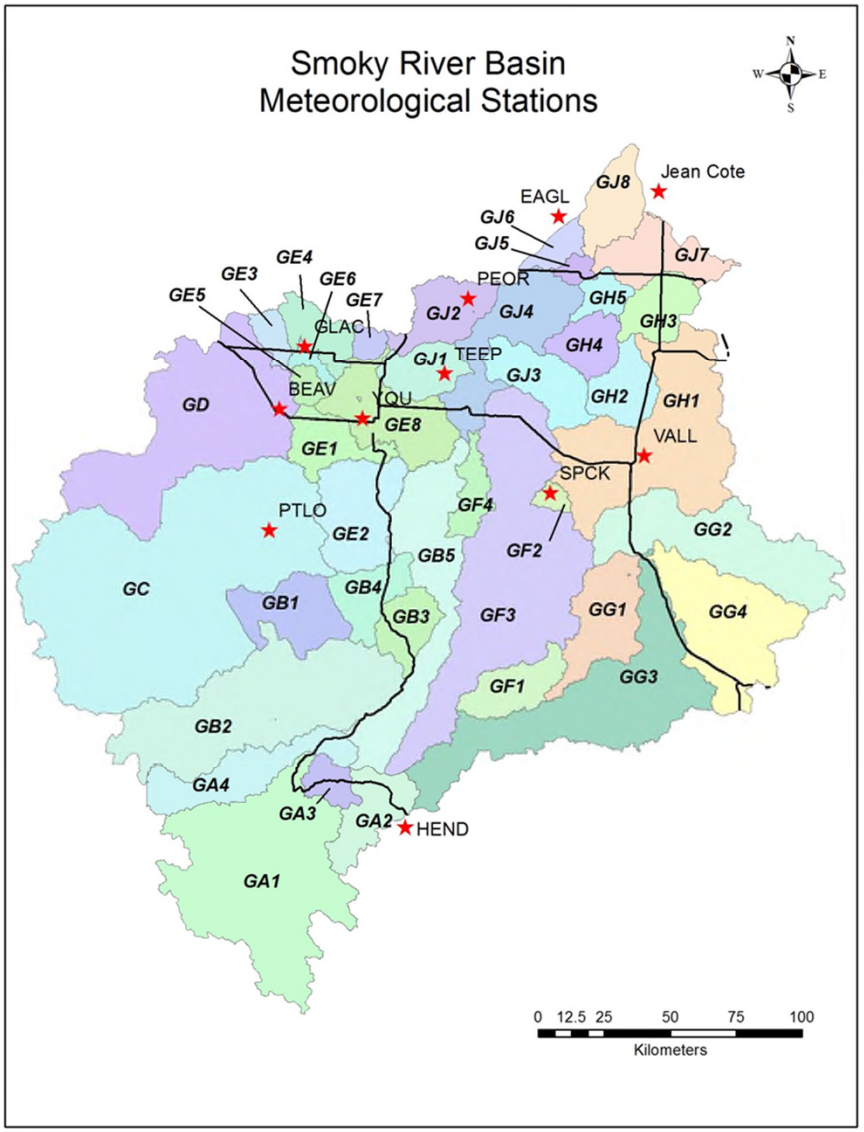




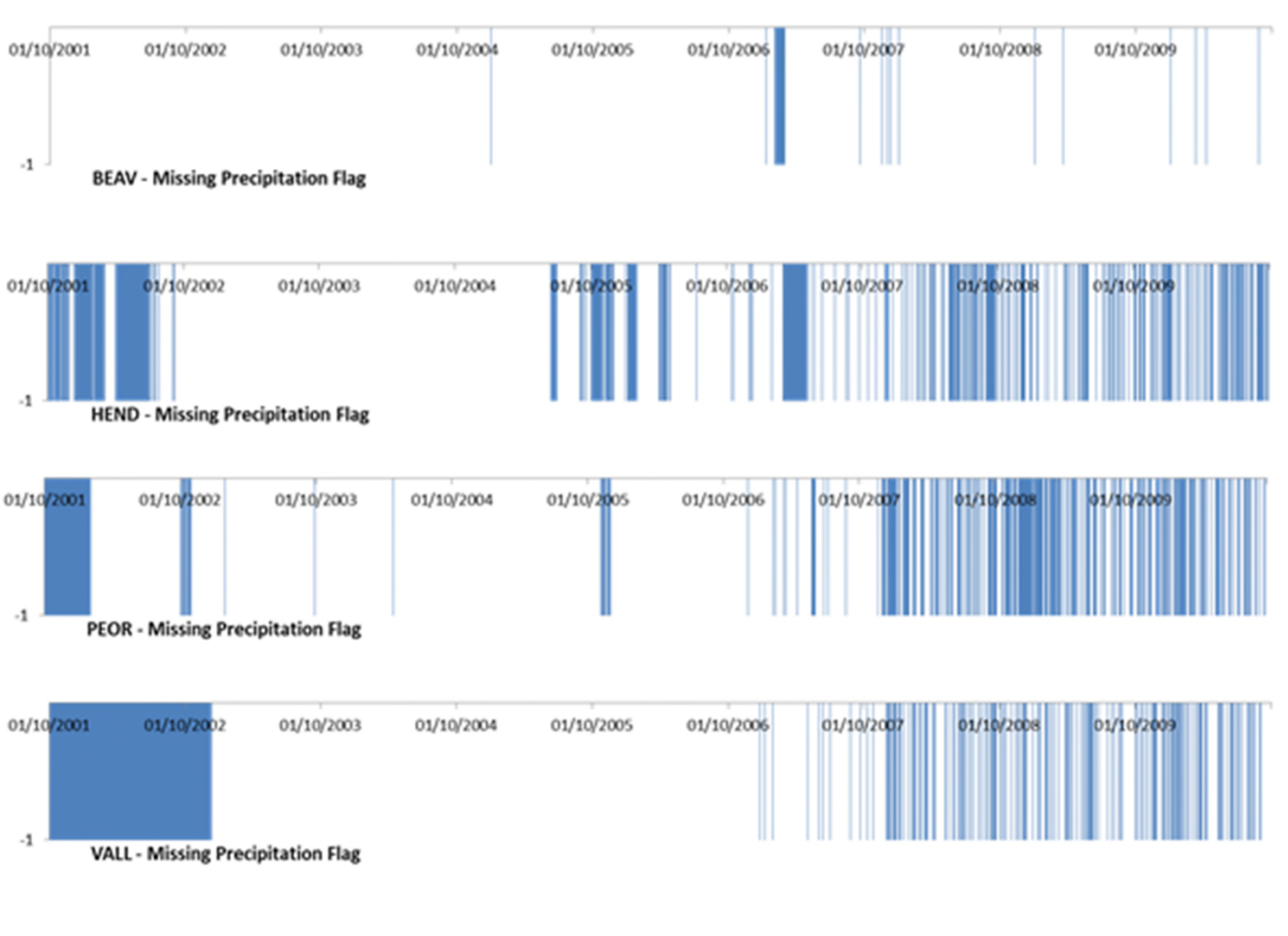
Pomeroy, Shook, Fang, Brown, Marsh, C4H Report No. 13

Smoky River Basin: 51,839 km^2



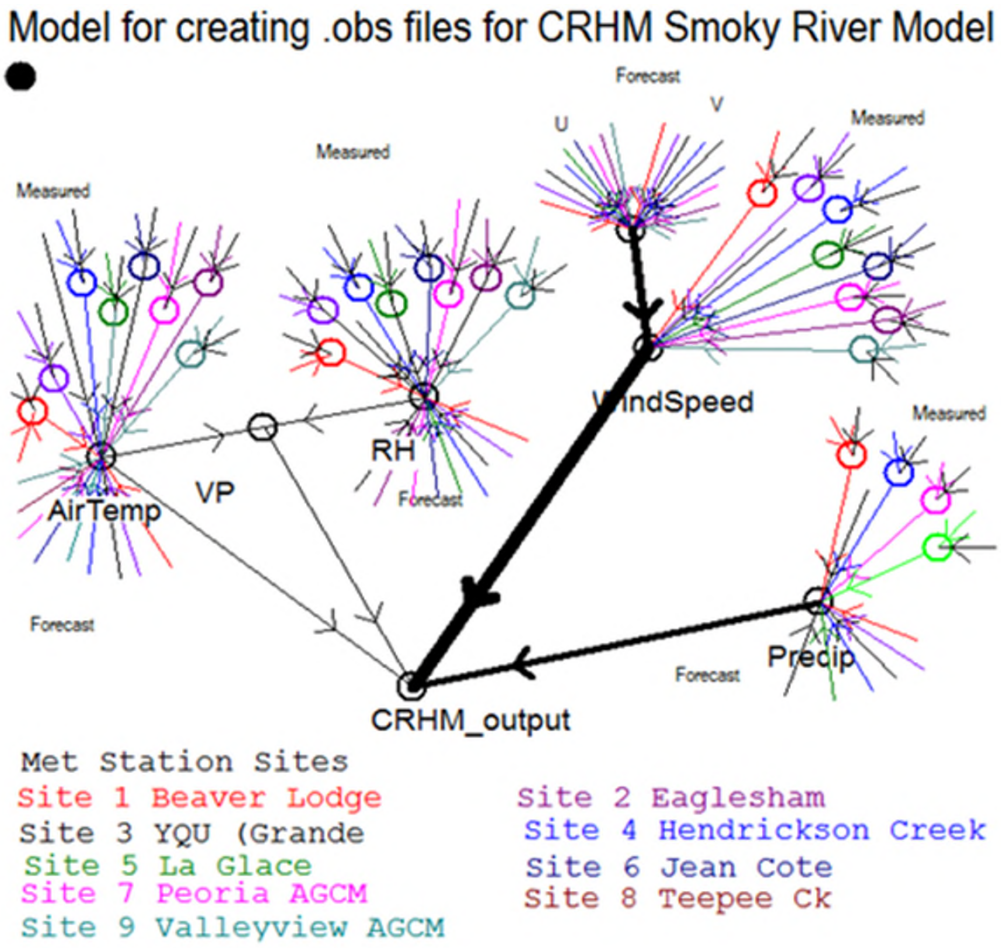


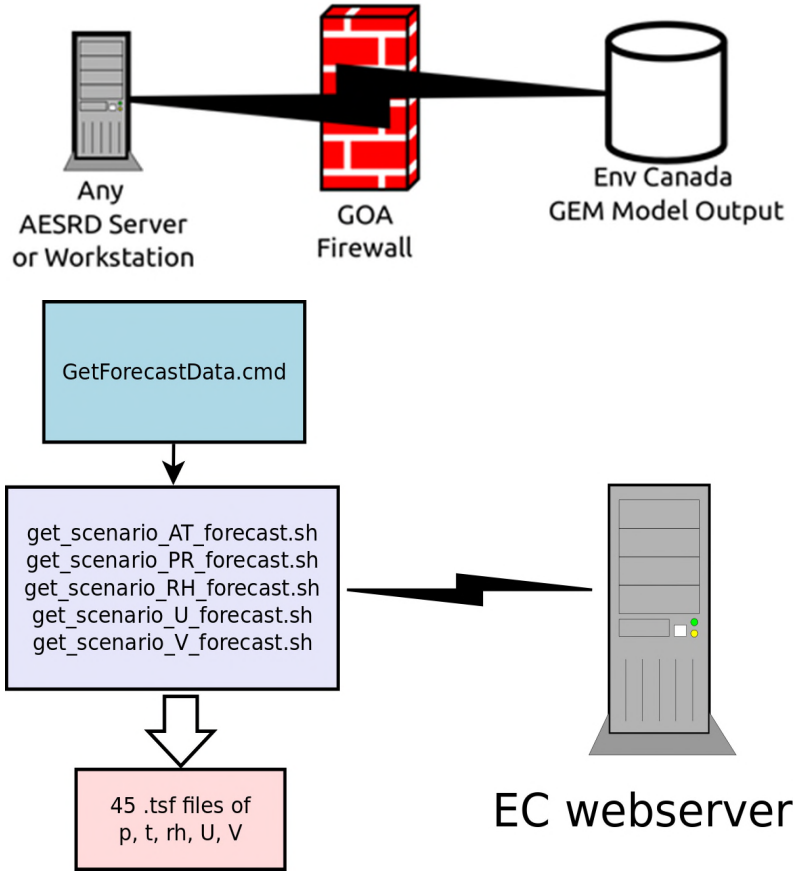
Challenge: Reliable Meteorological Observations and Forecasts



Interpolate, Predict, Forecast

GEM-WISKI-CRHM

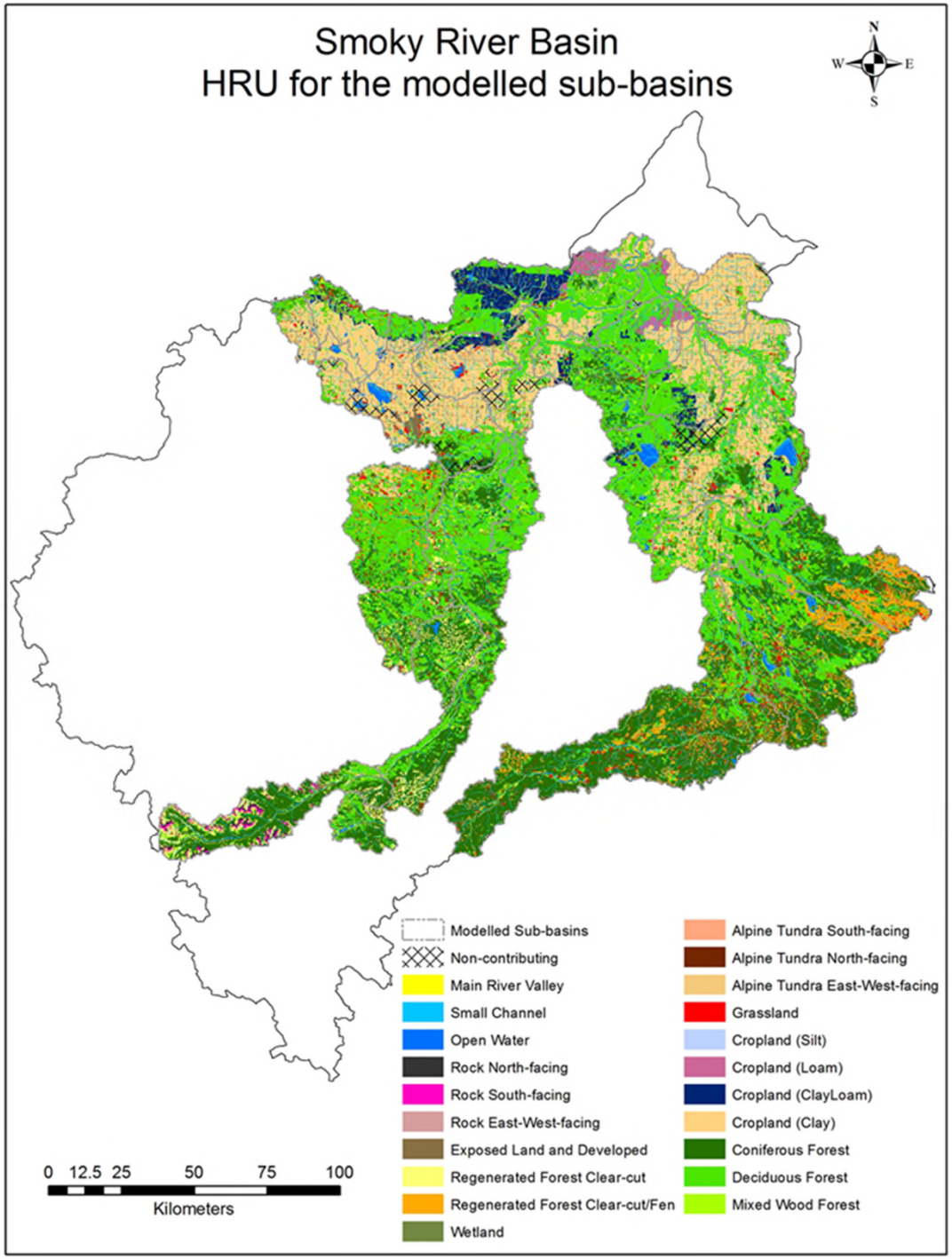




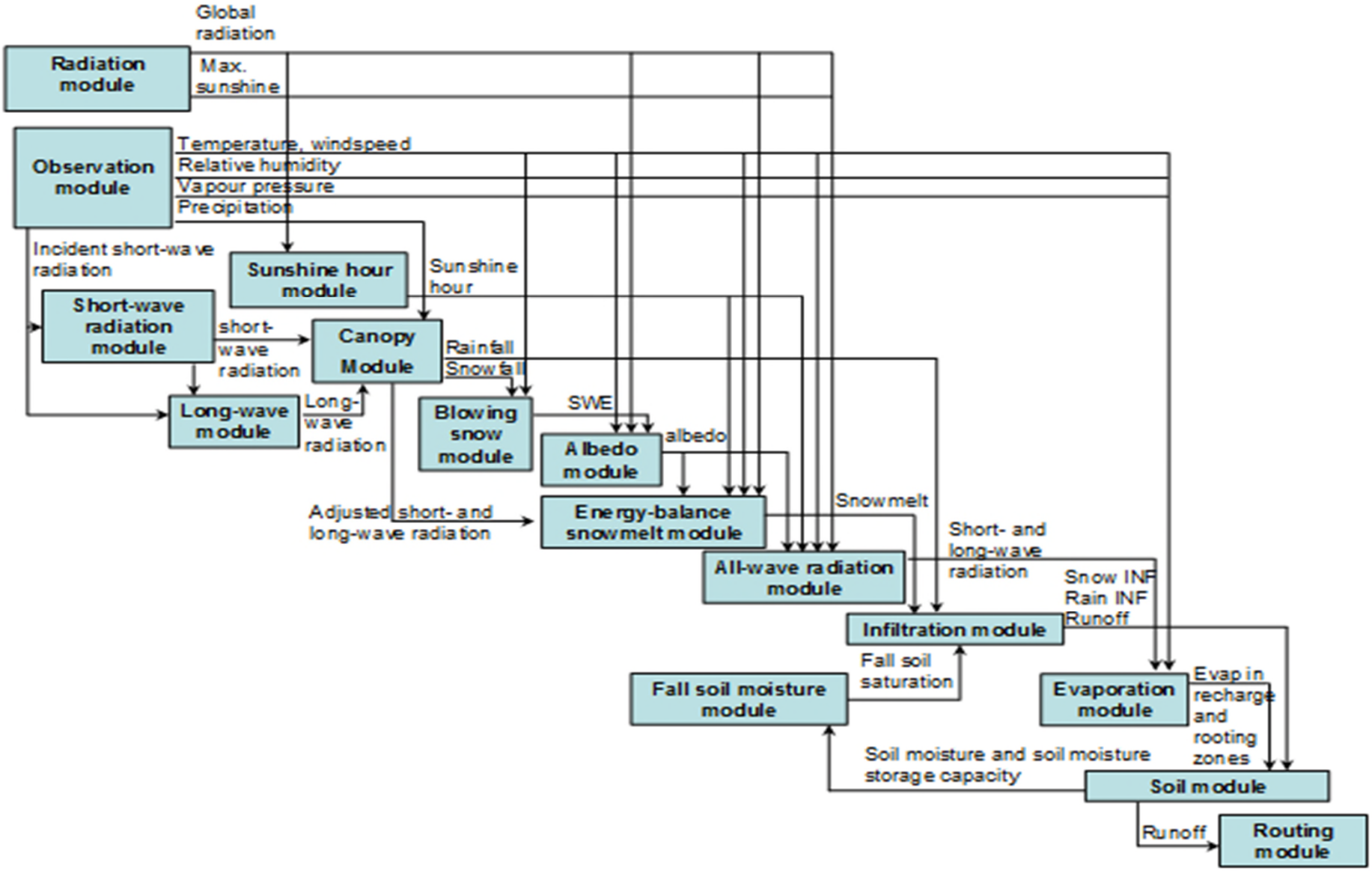
North America Ensemble Forecast System:
21 ensemble forecasts, 16 days in the future
Options to adjust forecast and run scenarios

Hydrological Response Units

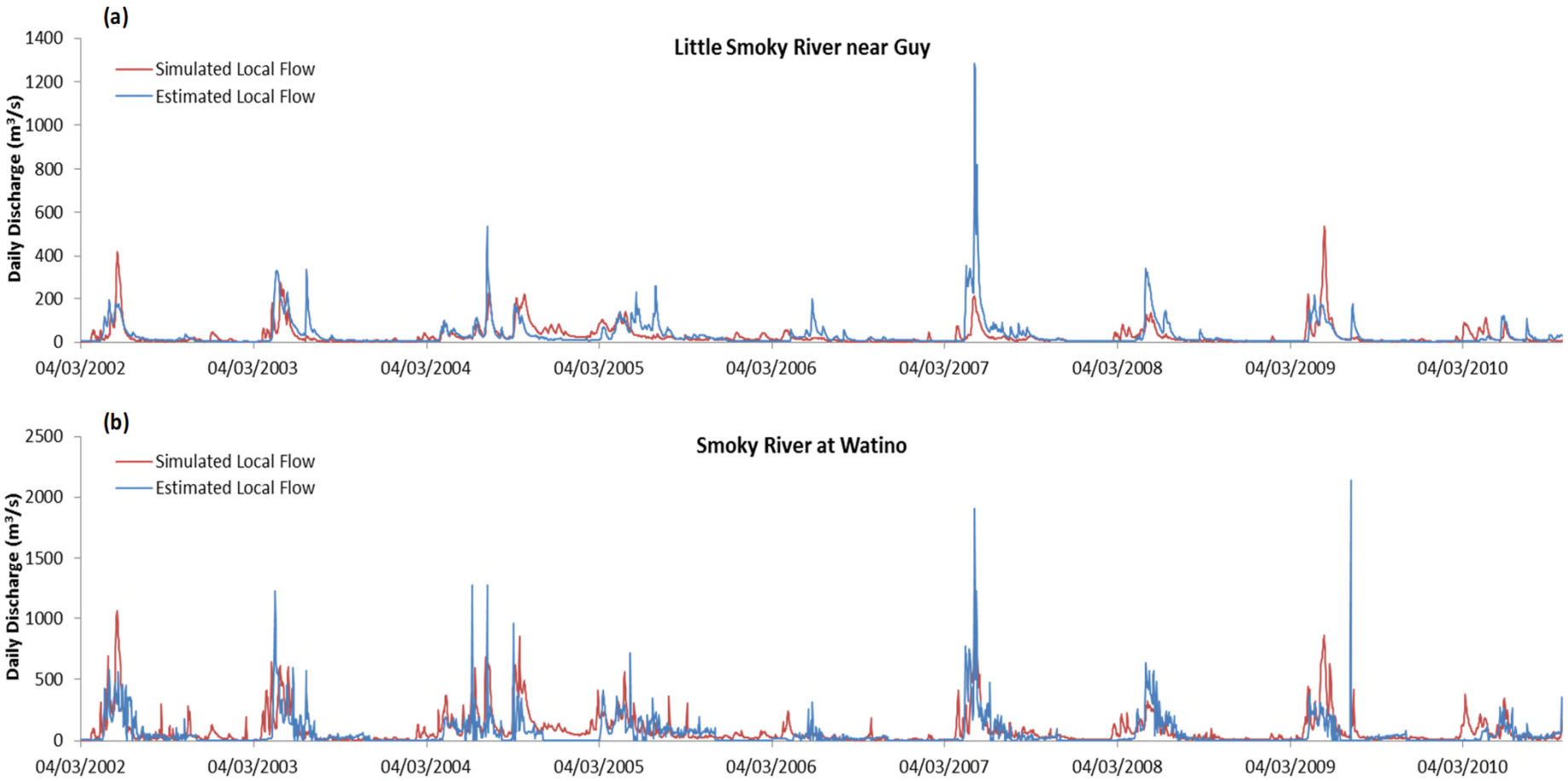
parameters estimated by ecoregion and interpolation from research basins



CRHM Module Structure within each HRU

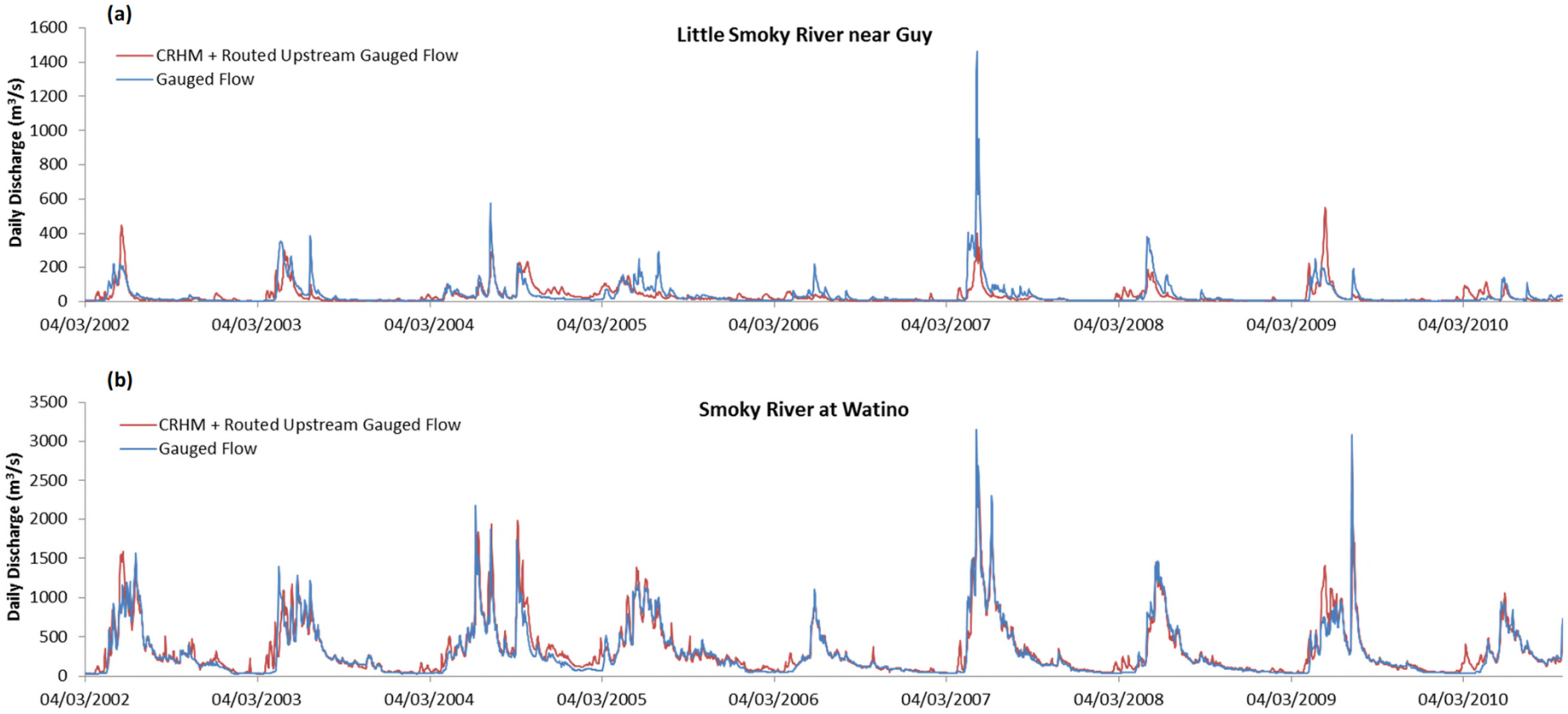


Basin-scale Ungauged Prediction



Great uncertainties in estimating local inflows for comparison to model results

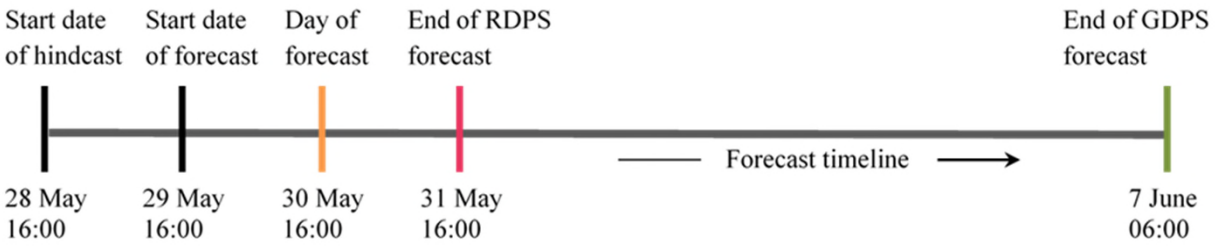
Basin-scale Prediction Evaluation



Predicted flows, Nash-Sutcliff Statistic: 0.41 (Little Smoky) and 0.87 (Smoky)

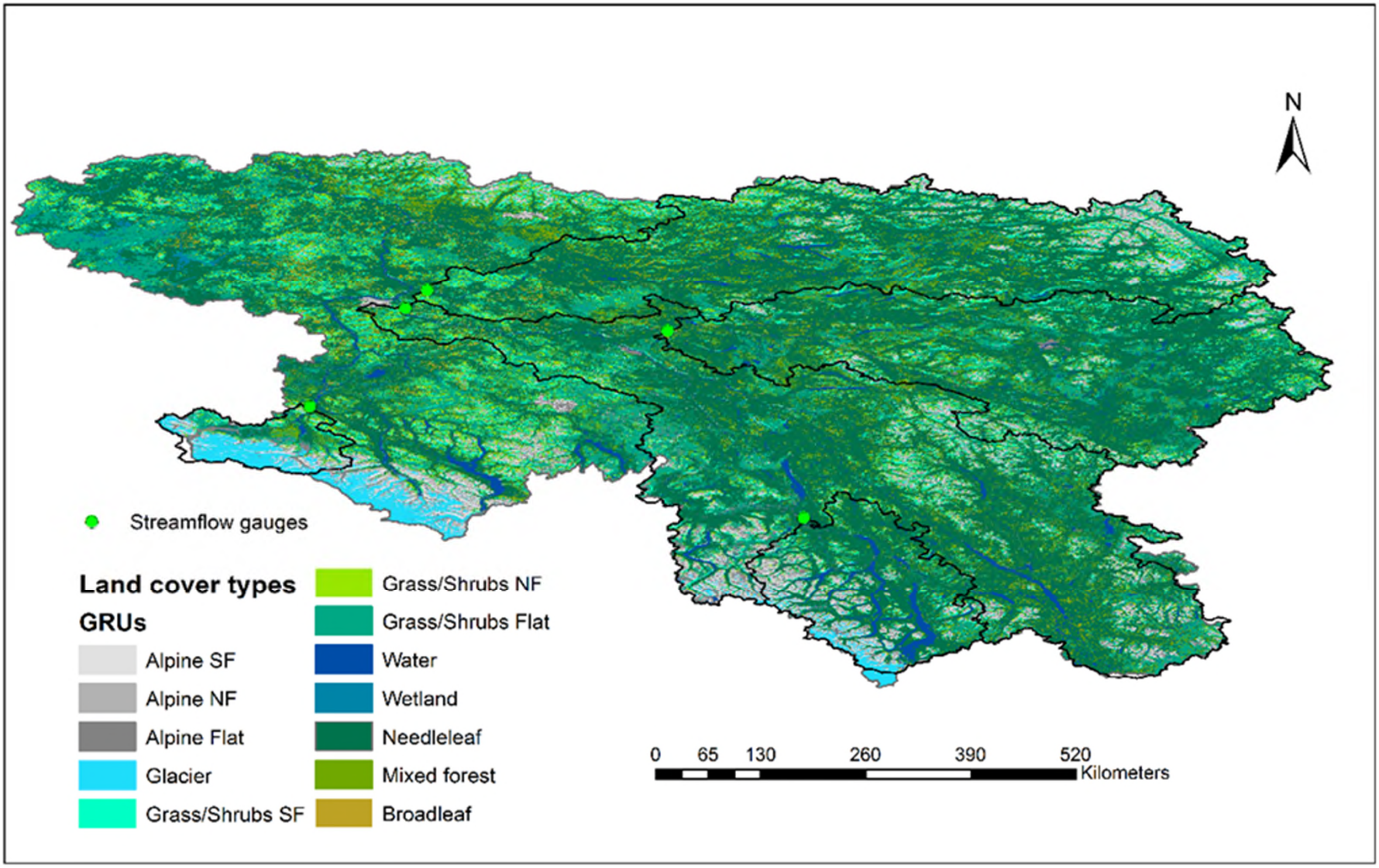
GEM-MESH for Yukon



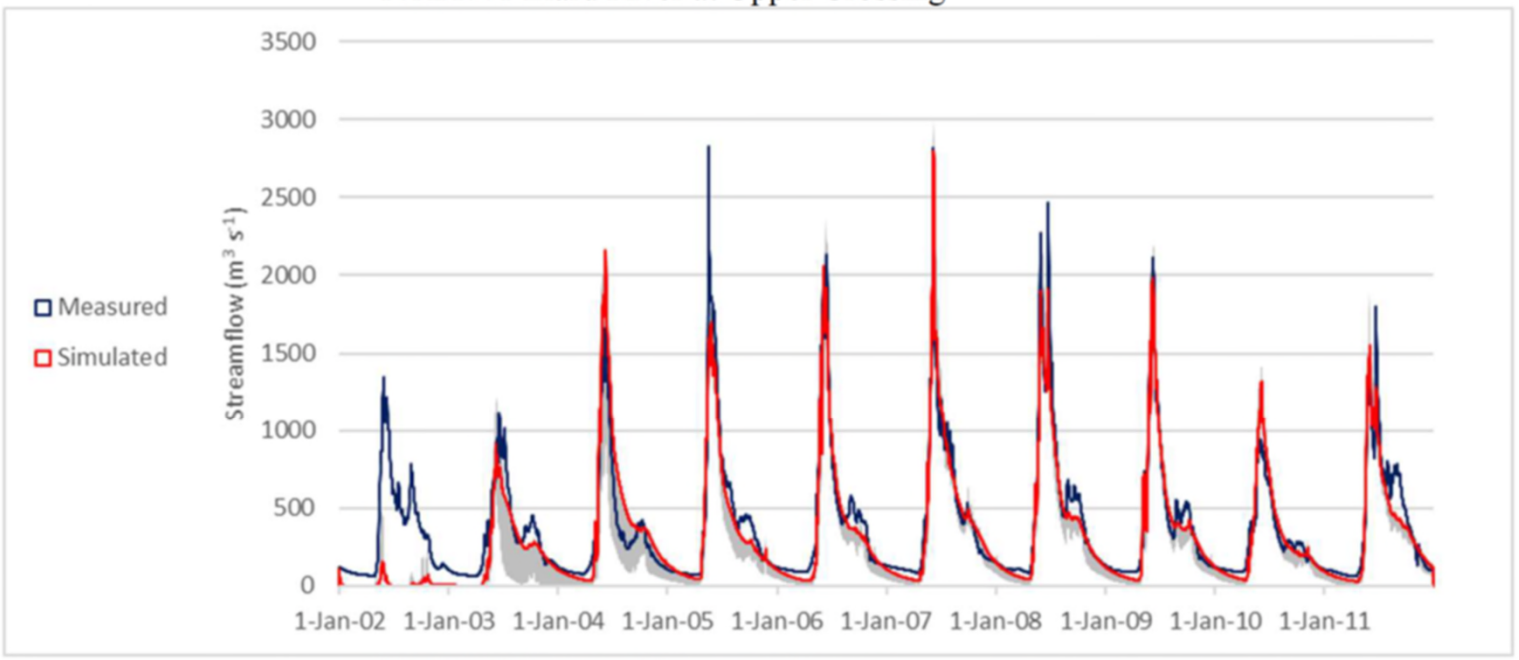


Richard, Pomeroy, Princz, Tesemma, Davison, Loukili, Shook, Elshamy, Pietroniro 2019

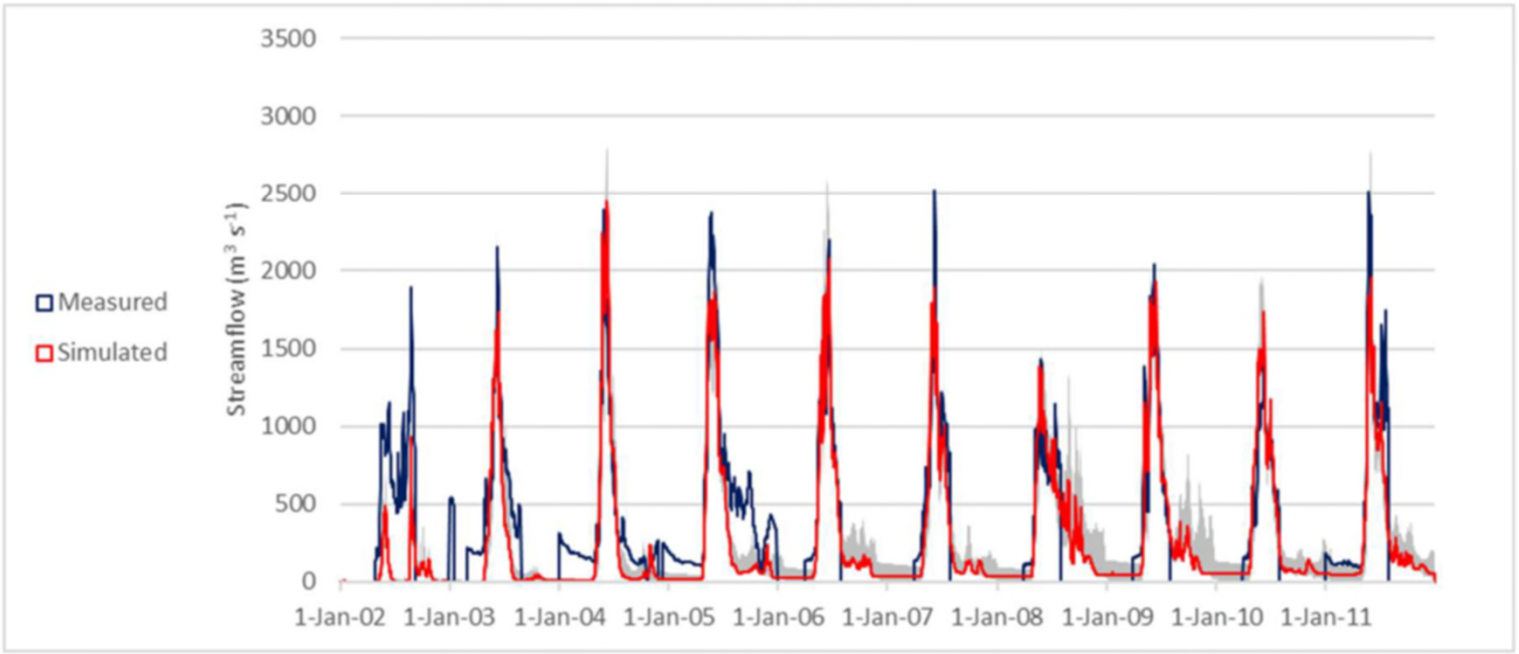
MESH Grouped Response Units



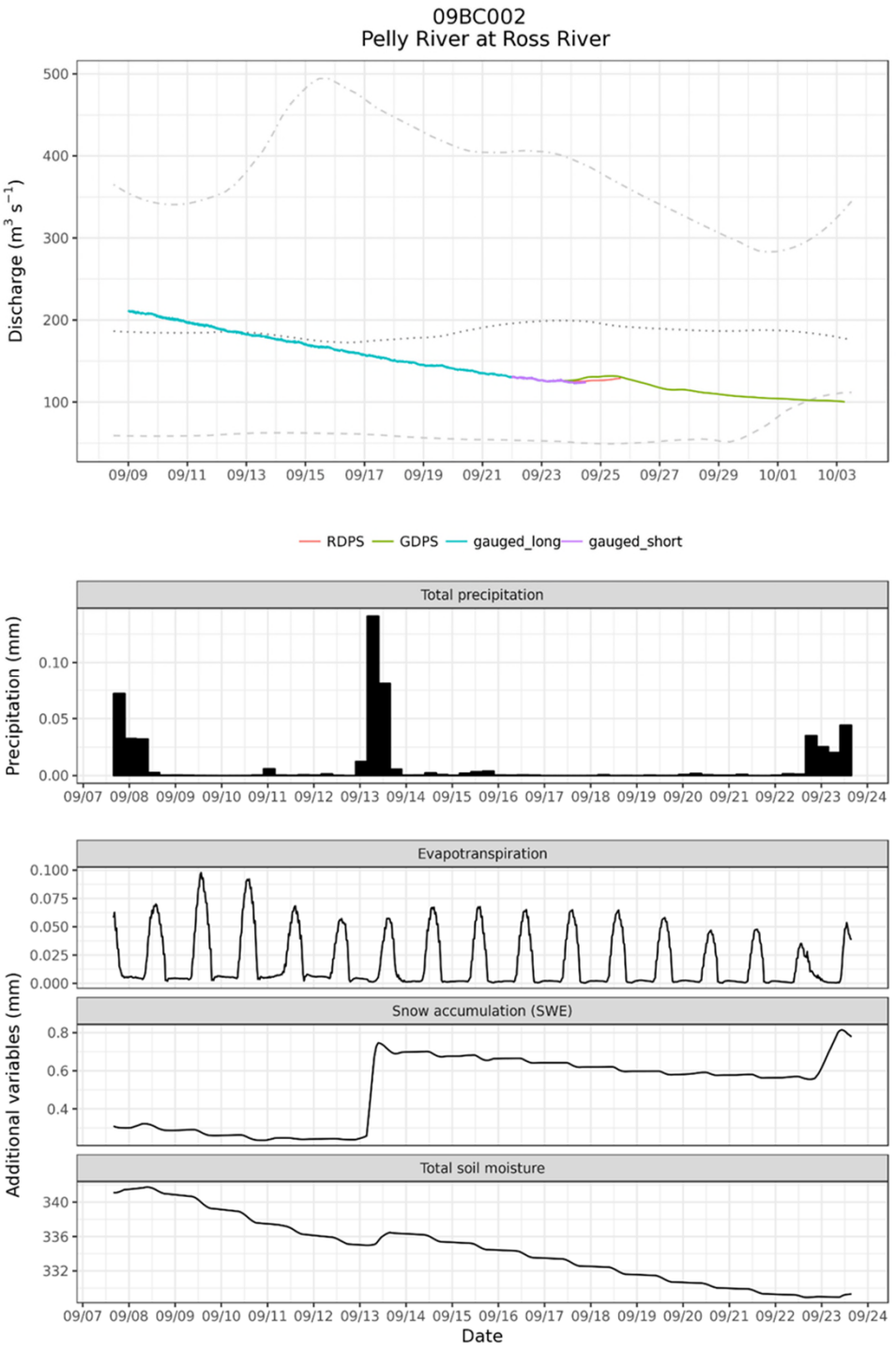
10AA001 Liard River at Upper Crossing



09DC006 Stewart River near Stewart

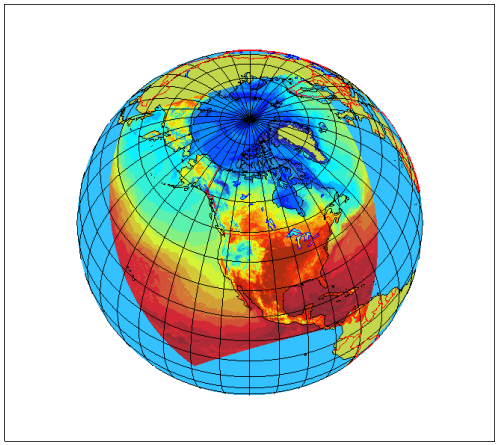


Forecasts


09BC002
Pelly River at Ross River
Discharge (m^3 s^{-1})
500
400
300
200
100
09/09 09/11 09/13 09/15 09/17 09/19 09/21 09/23 09/25 09/27 09/29 10/01 10/03
RDPS GDPS gauged_long gauged_short
Total precipitation
Precipitation (mm)
0.10
0.05
0.00
09/07 09/08 09/09 09/10 09/11 09/12 09/13 09/14 09/15 09/16 09/17 09/18 09/19 09/20 09/21 09/22 09/23 09/24
Evapotranspiration
0.100
0.075
0.050
0.025
0.000
Snow accumulation (SWE)
0.8
0.6
0.4
Total soil moisture
340
336
332
Additional variables (mm)
09/07 09/08 09/09 09/10 09/11 09/12 09/13 09/14 09/15 09/16 09/17 09/18 09/19 09/20 09/21 09/22 09/23 09/24
Date

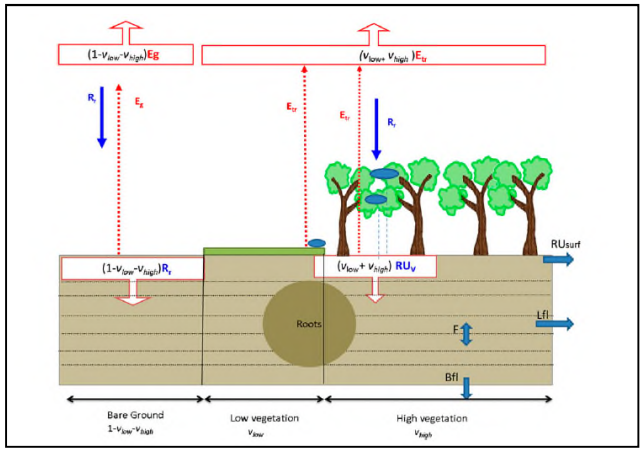
GEM-Hydro Modelling Platform

Atmospheric forcing



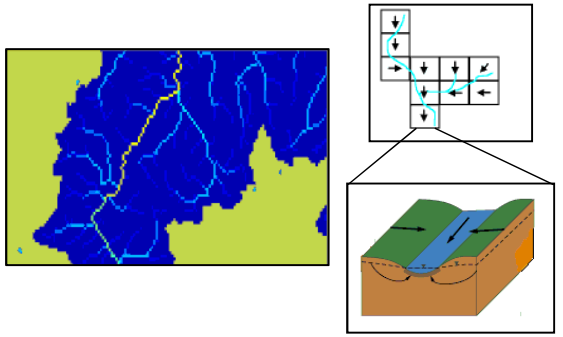
- Forecasts from the GEM model
- Canadian Precipitation Analysis (CaPA)

Land Surface Scheme
SVS (Soil Vegetation and Snow)



- Multiple energy budgets for bare ground, low and high vegetation
- Single layer snowpack scheme

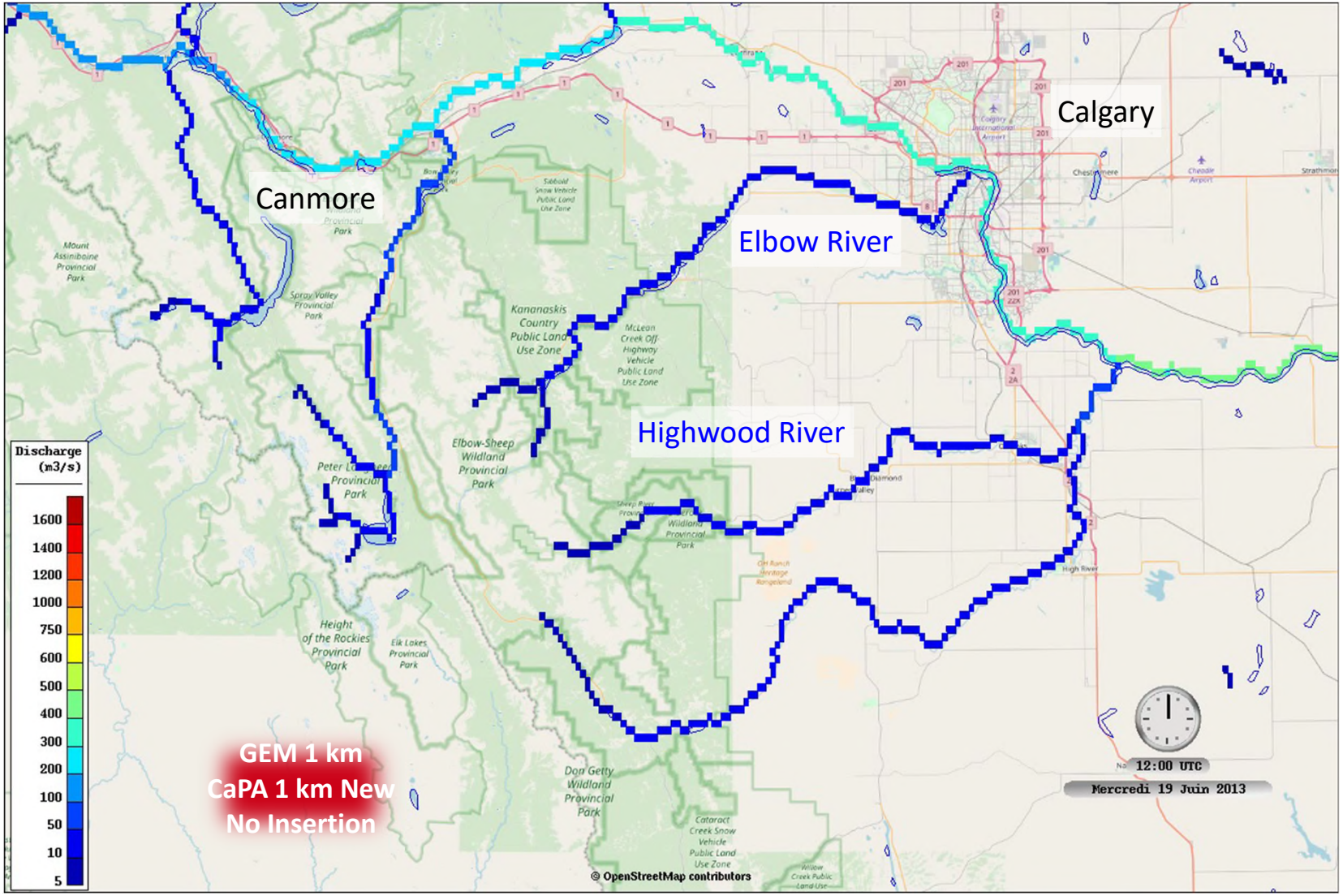
Routing
WATROUTE



- Hydrological routing of surface/lateral flows and drainage simulated by SVS

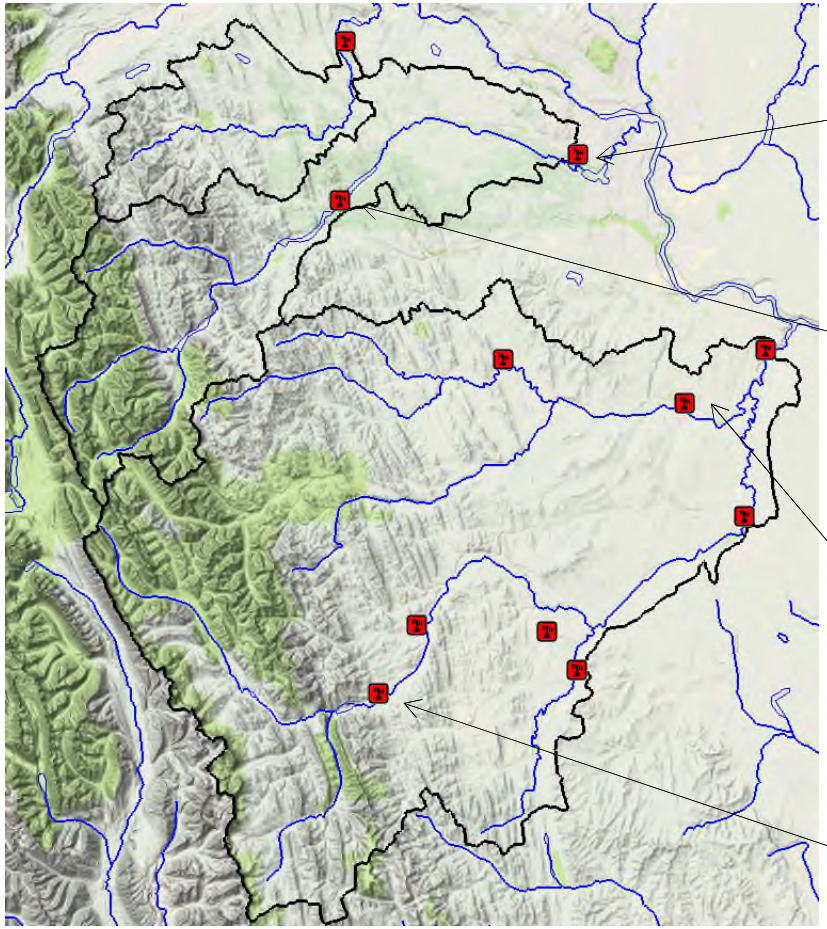
A collaboration between Environment and Climate Change Canada and Global Water Futures

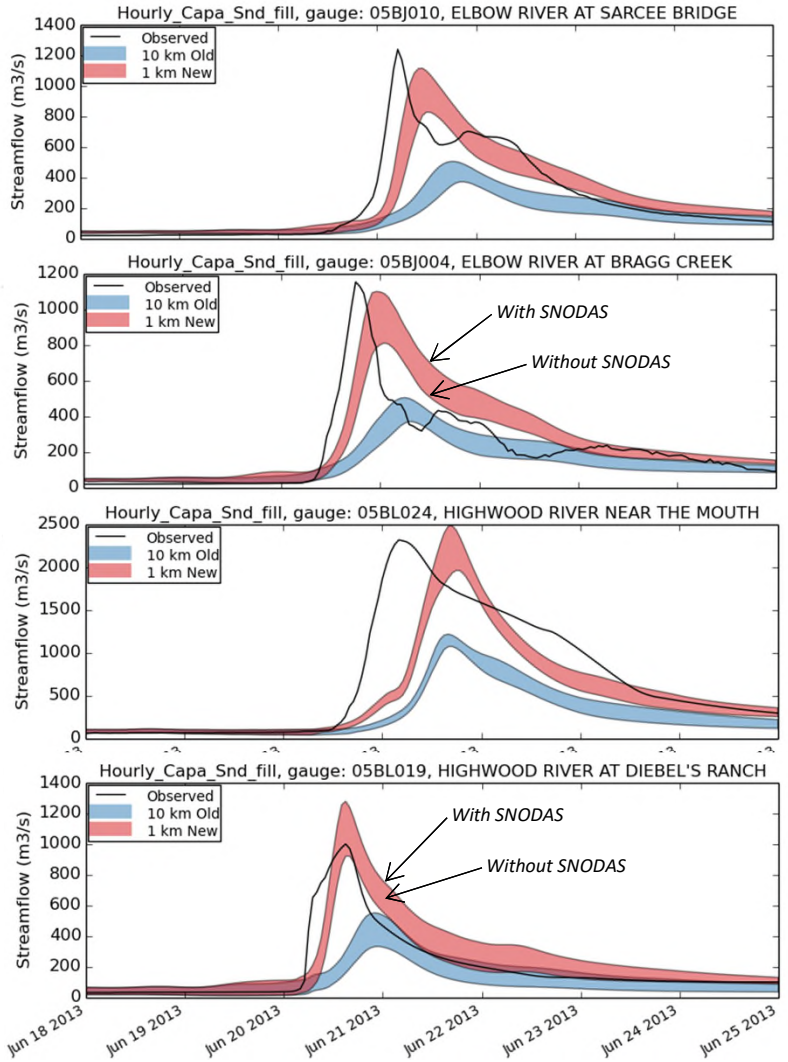
GEM-Hydro Simulation of 2013 Flood



Vincent Vionnet and CMC

Flood Dynamics

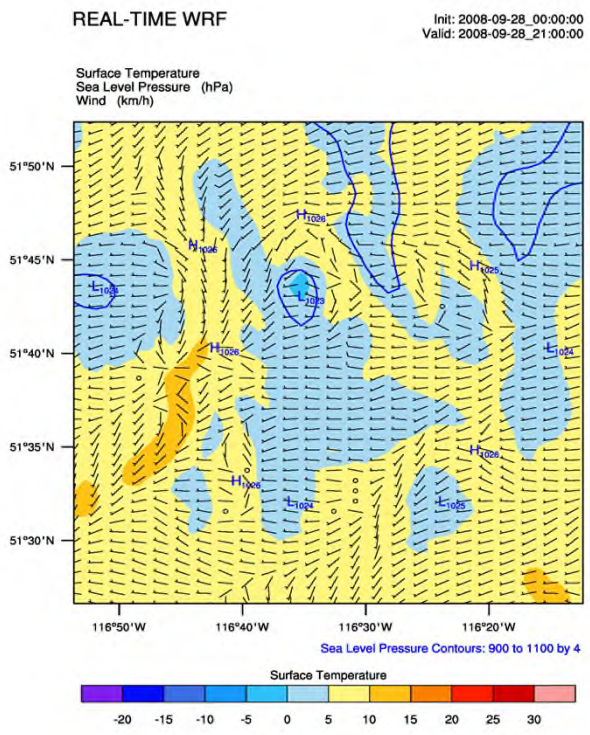




- **Better agreement** in terms **of peak flow** with GEM-CaPA 1km compared to GEM-CaPA 10km (Old)
- **Larger influence** of the **new pecip. analysis** than the insertion of **SNODAS**

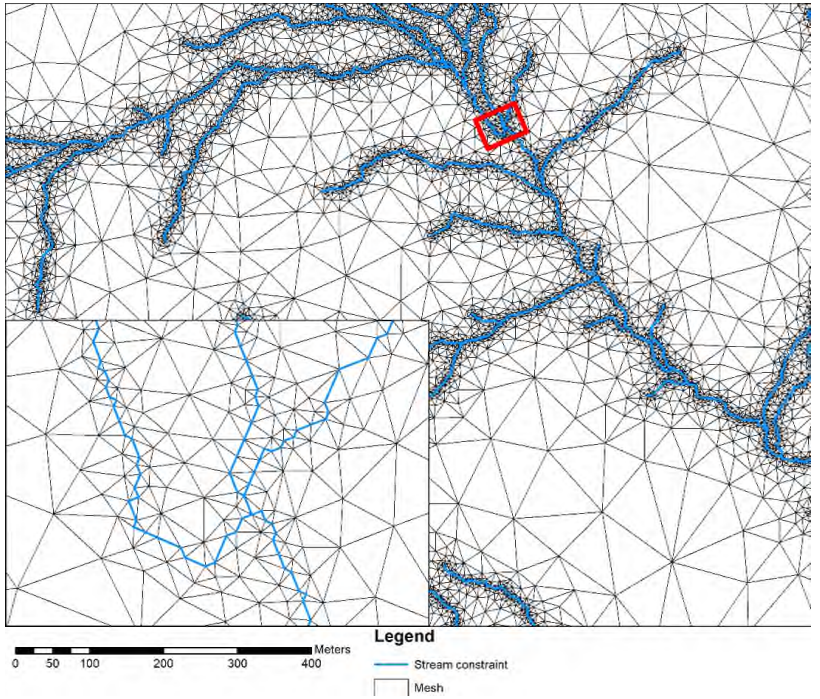
New High Resolution Modelling Approaches

High Resolution Atmospheric Models



Conway, Helgason, Pomeroy, 2018

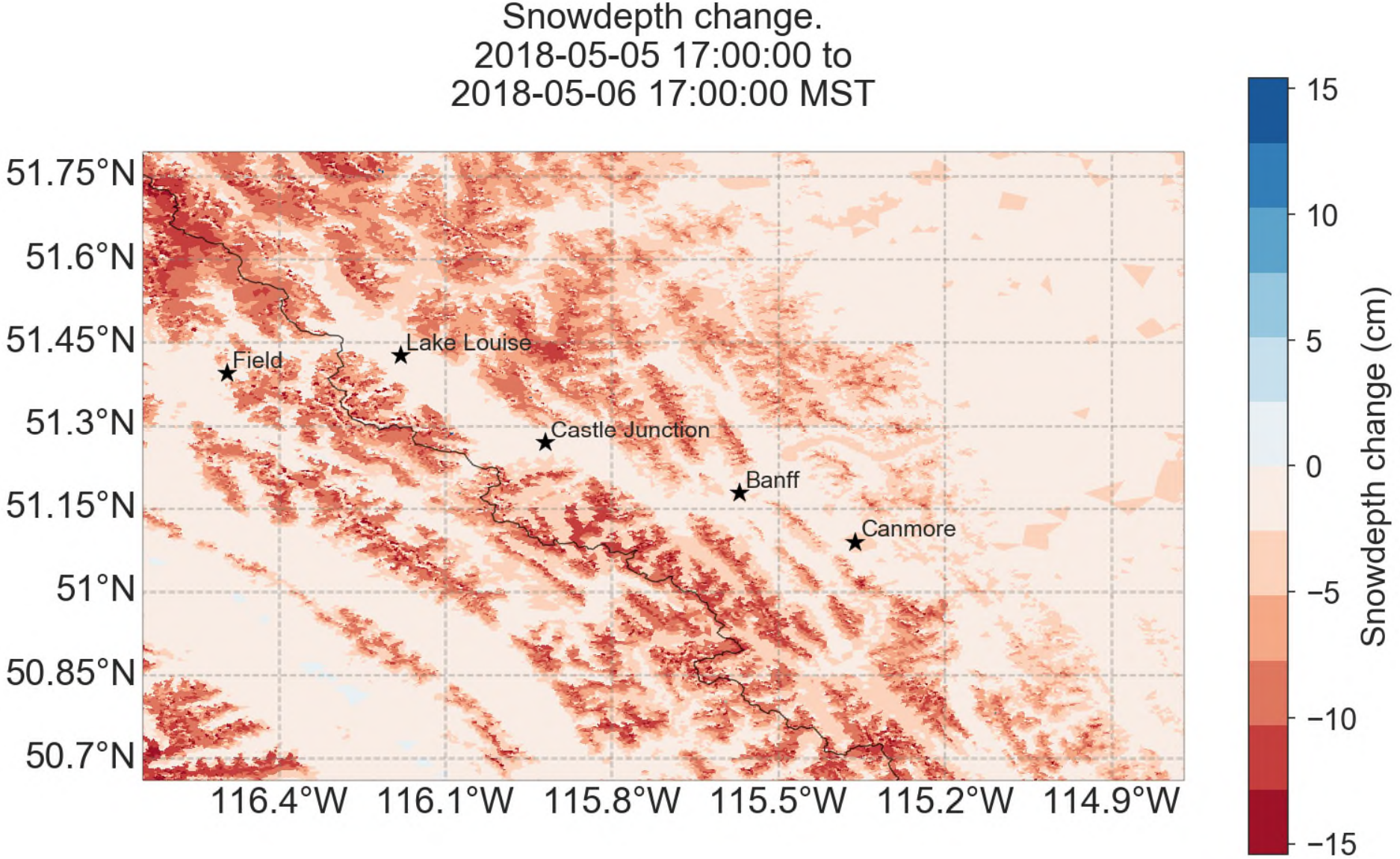
Variable Mesh, Physically Based, Multi-physics Hydrological Models



Coupling at hillslope-snowdrift scale

Marsh, Spiteri, Pomeroy, Wheater, 2018

SnowCast – Canada's Mountain Snow Forecast System



www.snowcast.ca

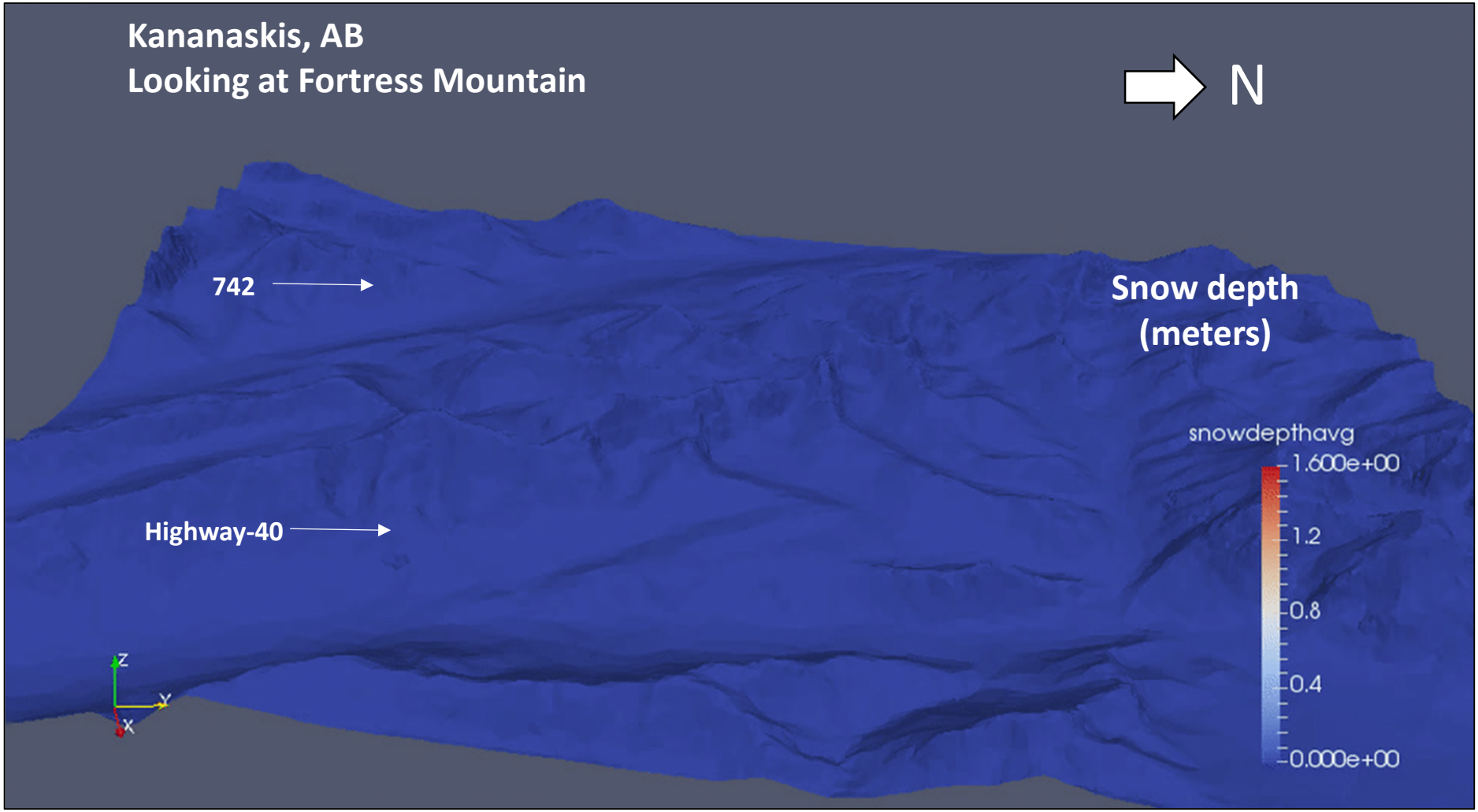
GEM-CHM

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GWF.USASK.CA

Mountain Snowpack Forecast – Kananaskis

GEM-Canadian Hydrological Model

www.snowcast.ca



GWF Upcoming Meetings

- Water Security Solutions for Canadians
  - Ottawa, April 11th, AM
  - Solutions and Policy Options for Dealing with the National Water Crisis

- GWF 2nd Annual Meeting
  - Saskatoon, May 15-17
  - Science update including prediction



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