Global Water Futures Core Modelling Efforts

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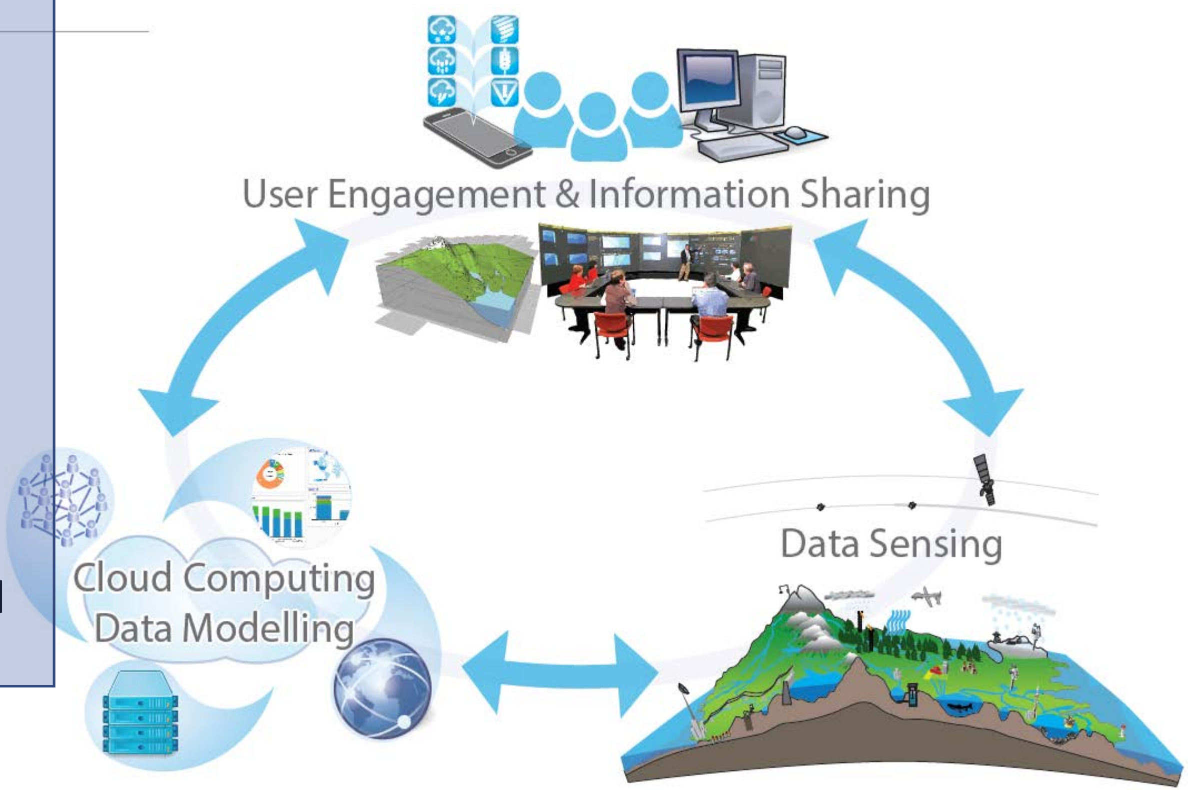
GWF National Water Prediction & Observation Strategy

GLOBAL WATER FUTURES
SOLUTIONS TO WATER THREATS IN AN ERA OF GLOBAL CHANGE

- **Core support teams to deliver:**
- **National modelling capability,**
  - Modelling Core Team (30)
    - Forecasting
    - Diagnostic modeling
    - Water resources modelling
  - Computer Science Core Team (3)
    - Human computer interface
    - Re-engineering model codes
- **New Observational Science**
  - Water observations (20)
  - Data management (3)
- **Knowledge Mobilization** (3)



National Water Prediction Strategy

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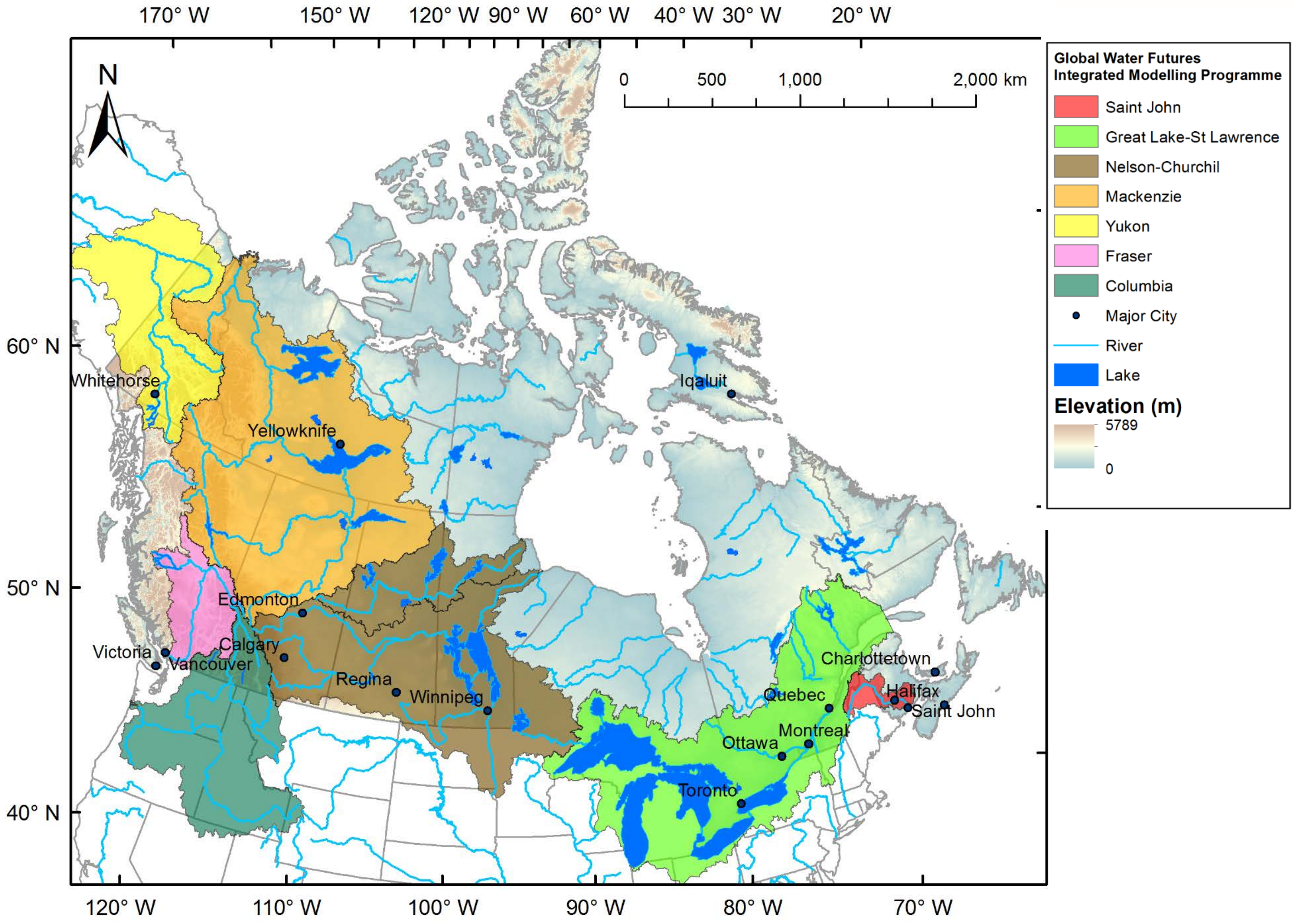
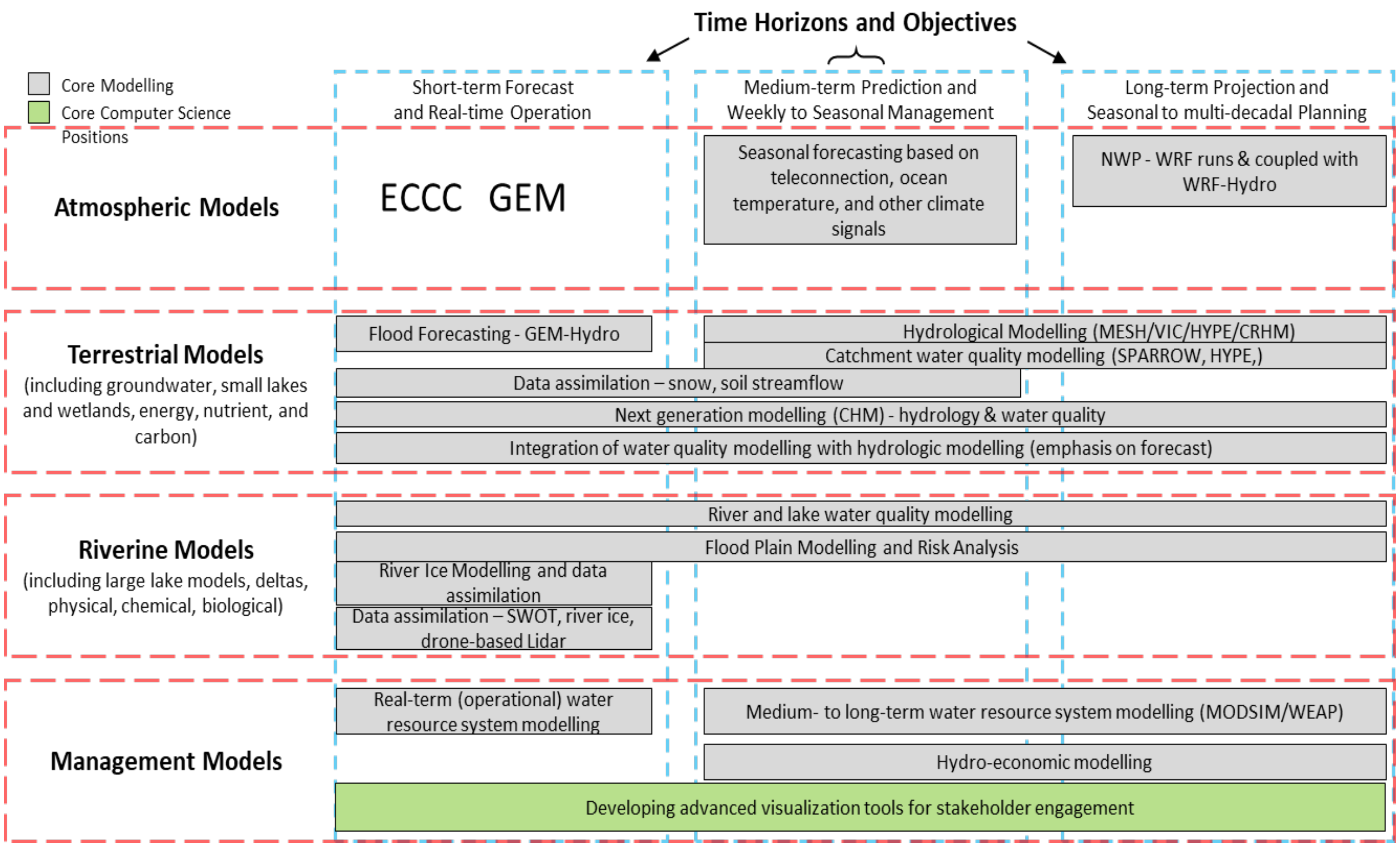


Why Core-Modelling ?

- The modelling strategy is based around a sequence of atmospheric driving models, linked to terrestrial, riverine and management models, with a hierarchy of time horizons and objectives that scale from short term/real time operations to medium term predictions at weekly to seasonal scales to long term predictions at seasonal to multi-decadal time scales as described in the diagram below.
- The core modelling team deals with most models and the core computer science team develops advanced visualisation methods and improved operations and software engineering of model architecture and operation to take advantage of high performance computing

Core Modelling Strategy



GWF Models

- **Atmospheric models or forcing**: A series of coupled, uncoupled, historical or re-analyzed forcing data are required to drive the water, ecosystem, and energy modelling systems. These data can be derived from numerical weather prediction models (NWP), NWP reanalysis models, and climate models using various forms of interpolation, ensemble outputs, statistical downscaling and dynamical downscaling.
- **Hydrological and Water Quality Models:** These are focused around hydrological models and land-surface schemes that can resolve the coupled energy and water budget of the land surface at multiple scales, including features pertinent to cold regions such as lakes, wetlands, snow, frozen ground and glaciers. These models are coupled to or may include detailed models of groundwater storage and flow, permafrost, glacier dynamics, ecosystem landscape dynamics, fire, crop growth and non-point nutrient/contaminant export.
- **River Models:** These models will be coupled physical/chemical/biological schemes dealing with flow, velocity, depths, energy (temperature and ice formation), ice break-up, biological attributes such as BOD, DOC and chemical components, nutrients and contaminants.
- **Small Lake/Large Lake/Reservoir Models:** These models will simulate inflow/outflow processes, storage, mixing, algal blooms, ice cover and temperature.
- **Water Management Models:** These models simulate anthropogenic impacts on water resulting from small and large storages, drainage, irrigation and other abstractions, including groundwater extractions. At a basic level, these effects will be represented in land surface schemes and hydrological models. More generally, integrated water management modelling is needed to address long term planning and short term operational management of water resource systems under varying hydroeconomic conditions. Decision-making must integrate climate change, land management, water quality and hydrological considerations to meet human and ecosystem needs. Water management models can provide a new level of integrated modelling to support Canada’s needs in these areas.
- These various modelling systems require consideration of time-prediction elements within their design and implementation. Prediction systems for watershed management require different consideration for short-term forecasting, seasonal or longer term forecasting and “open loop” simulations. The latter are characterized as either analysis of either past events or future climate projections.

Some GWF Models

- Atmospheric Models or Forcing
  - GEM (Canadian NWP), WRF, Capa
- Climate Models Outputs,
  - GCM, CRCM policy runs, Pseudo warming with WRF-Hydro
- Coupled Atmospheric –Hydrology Systems
  - GEM Hydro, MESH, WRF Hydro
- Non-point pollution models such as Sparrow
- Instream water quality models such as WASP
- Stand-alone Hydrology Models
  - Cold Regions Hydrology Model (CHRM), MESH (includes a variant of ISBA, CLASS) , CHM-next generation, VIC, HYPE
- Decision Support and Water Management Models

Forecasting vs Prediction

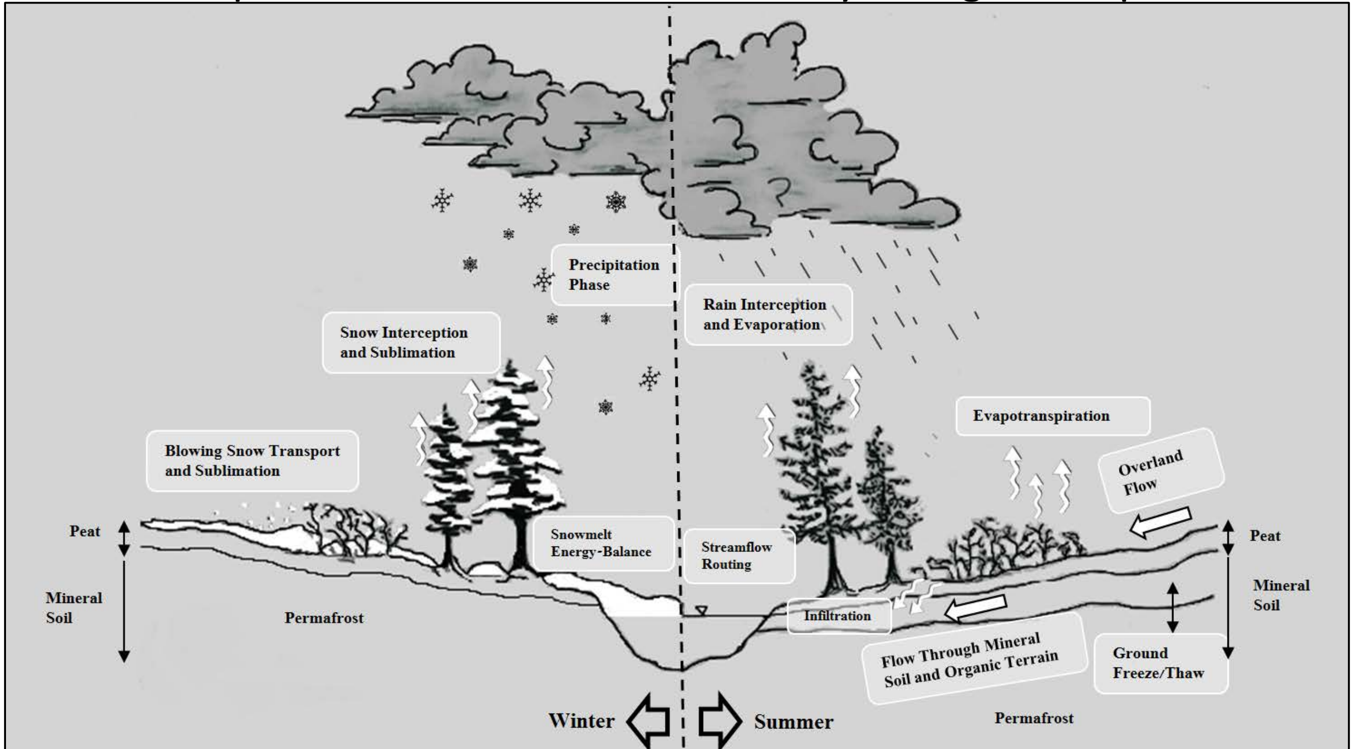
- **Now-casting and forecasting:** These use 0-14 day ensembles of simulations for assessing floods, high and low flows, snowcover and snowpacks, soil moisture, river ice breakup, wind-setup on large lakes, irrigation scheduling, reservoir operation, hydroelectricity production, in-stream flow needs, water quality, sediment transport, contaminant transport from spills, BOD and environmental flows. Day-0 simulations (now-casting) are typically required for assessing ungauged or unmeasured basins. Projections can be extended from 10 day to multiple months.
- **Open Loop Simulations:** Long-term simulations are used for planning, design and/or climate projections. In a hind-cast (historical model), these types of simulations are used for management studies, carrying out “what if scenarios”, assessing ungauged attributes, examining land and water management impacts, assessing future cryosphere, vegetation and water quality implications, calculating risk and probabilities and looking at trends. In a future climate context, these type of simulations are used to understand and ascribe future impacts on water and river basins and look at management implications including potential mitigation. Ideally these would be extended to include coupled modelling of land-atmosphere feedbacks.

Choosing a Model

- not straightforward and must consider;
  - choice of the appropriate model, parameterization and model setup;
  - reduction of problem dimensionality and choice of calibration parameters;
  - model calibration and model validation;
  - uncertainty assessment.
- Model identification involves the choice of the suitable model structure and degree of complexity
- Should result from the application considering
  - the phenomena to simulate (not just streamflow)
  - the availability of data.

Cold Regions Hydrological Modelling Platform (CRHM)

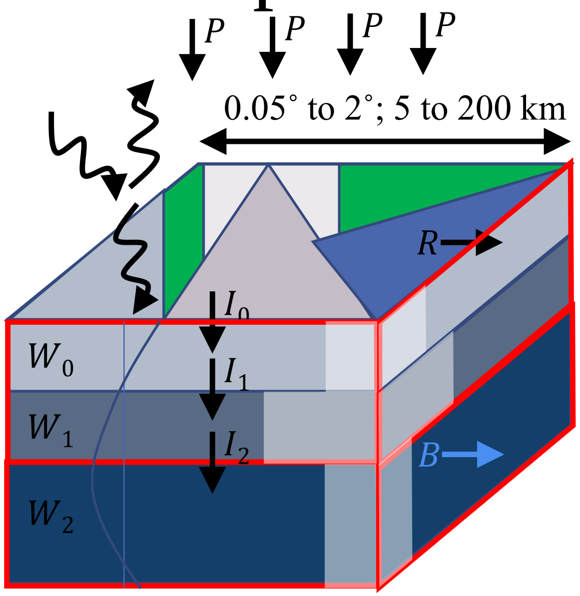
modular, flexible, object oriented process modelling
users select modules to create a custom model
spatial discretization based on hydrological response units

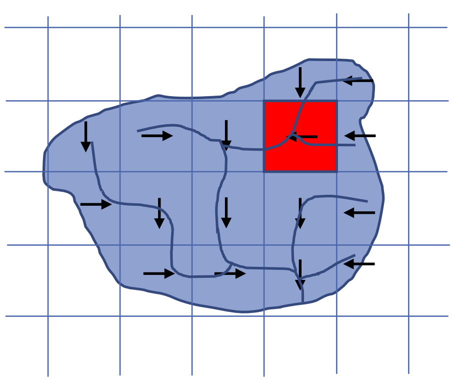


Sketch by Lucia Scaff, University of Saskatchewan

*Krogh, Pomeroy and Marsh, 2017. Journal of Hydrology, DOI: 10.1016/j.jhydrol.2017.05.042

The VIC Variable Infiltration Capacity LSS developed as a simple land surface et al.,1994).

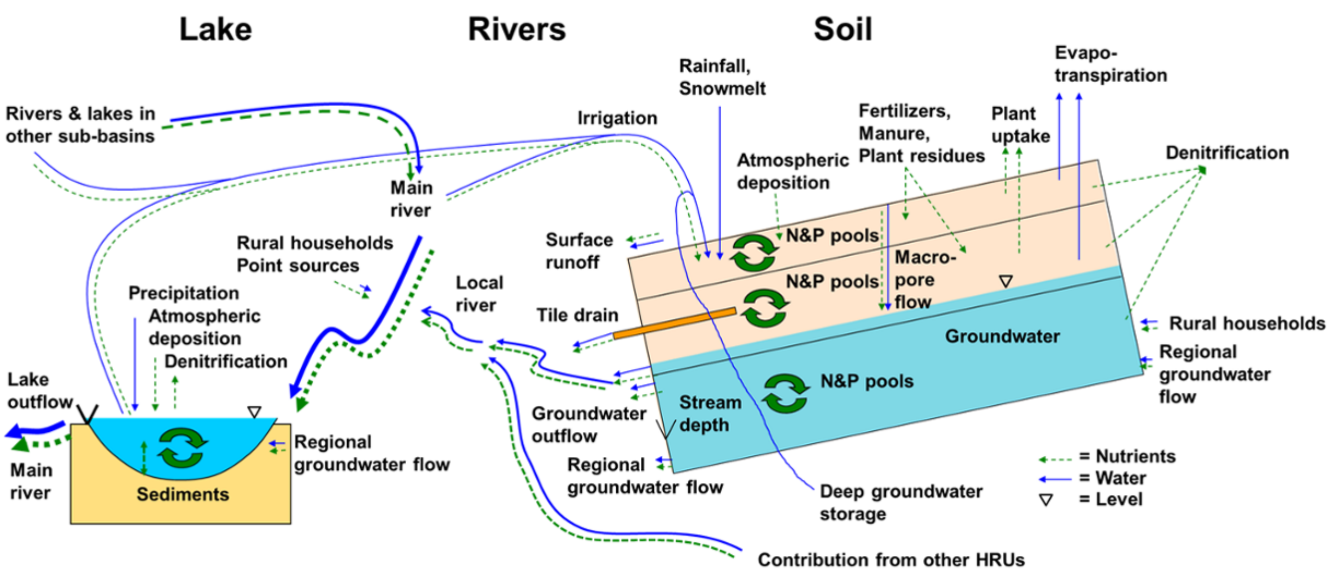




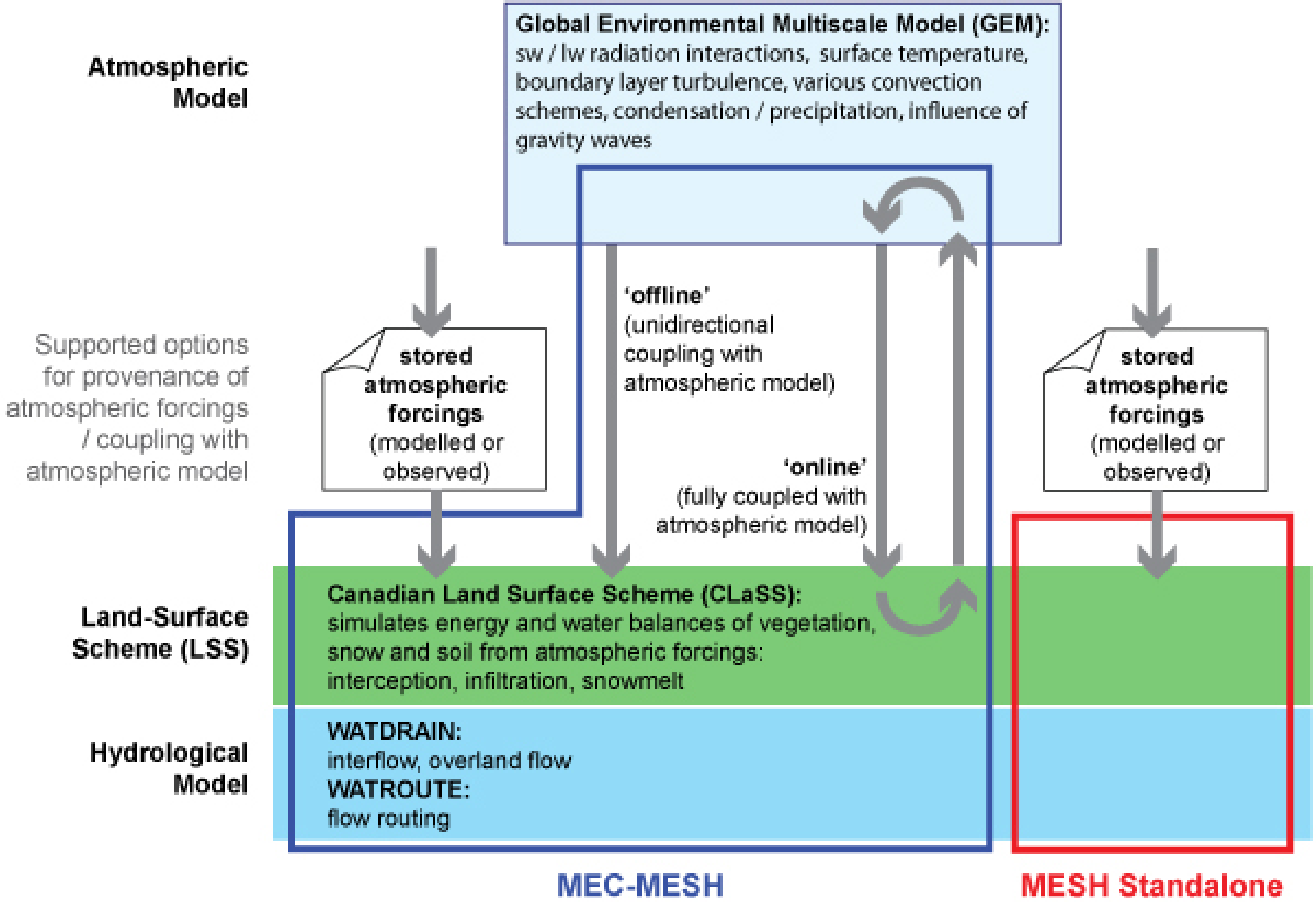
- VIC is a meso- to large- scale model at grid scale.
- VIC accounts for various land covers and lakes within a grid.
- Infiltration capacity varies based on a distribution of saturated areas define by *b* as infiltration shape parameter.
- $I_0 = f\,(W_0+W_1);\ R = P - I;$
- Base flow is calculated based on storage of the lowest soil layer as a nonlinear reservoir.
- B = $f\,(W_2)$
- Water flow between the layers are calculated by an approximation of Richards equation.
- VIC is able to calculate energy fluxes for soil profile, atmosphere and lake (1-D lake model).
- VIC is able to account for frozen soil and its impact on infiltration and transpiration.
- The routing model is consist of a unit hydrograph at a grid scale and linearized Saint-Venant equation based on velocity and diffusivity.

HYPE - SMHI

- The hydrological catchment model HYPE simulates water flow and substances on their way from precipitation through soil, river and lakes to the river outlet (Arheimer et al., 2008; Lindström et al., 2009).
- The catchment is divided into subbasins which in turn are divided into classes (calculation units) depending on land use, soil type and elevation (Figure 1).
- The classes can not be coupled to a geographic location within the subbasin but are given as part of its area. Typical land uses are forest, lake, open land, but also different crops, e.g. cereal and potatoes, are common. Elevation can be used to get temperature variations within a subbasin to influence the snow conditions.



MESH modelling system



Pietroniro A., Fortin V., Kouwen N., Neal C., Turcotte R., Davison B., Verseghy D., Soulis E. D., Caldwell R., Evora N., and Pellerin P. (2007). **Development of the MESH modelling system for hydrological ensemble forecasting of the Laurentian Great Lakes at the regional scale.** *Hydrol. Earth Syst. Sci.*, 11: pp 1279-1294.

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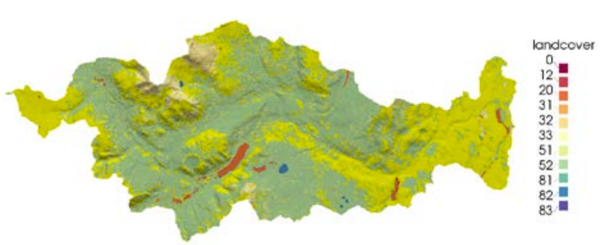
Canadian Hydrological Model

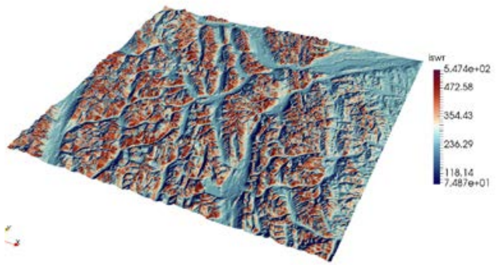
- Multi-scale, multi-physics, variable complexity and domain model
- Assessment of model structural, parameter, and data uncertainty
- Incorporates existing snow physics models (ex: **Snobal**, Snowpack)
- Sub-surface cold regions processes and land surface processes under development

Basin (100 km^2)



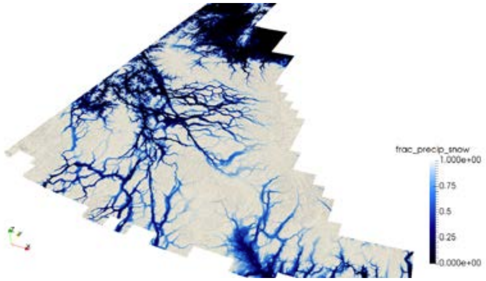
Wolf Creek

Regional (8000 km^2)



Canadian Rockies

State/Provincial (500 000 km^2)



Yukon

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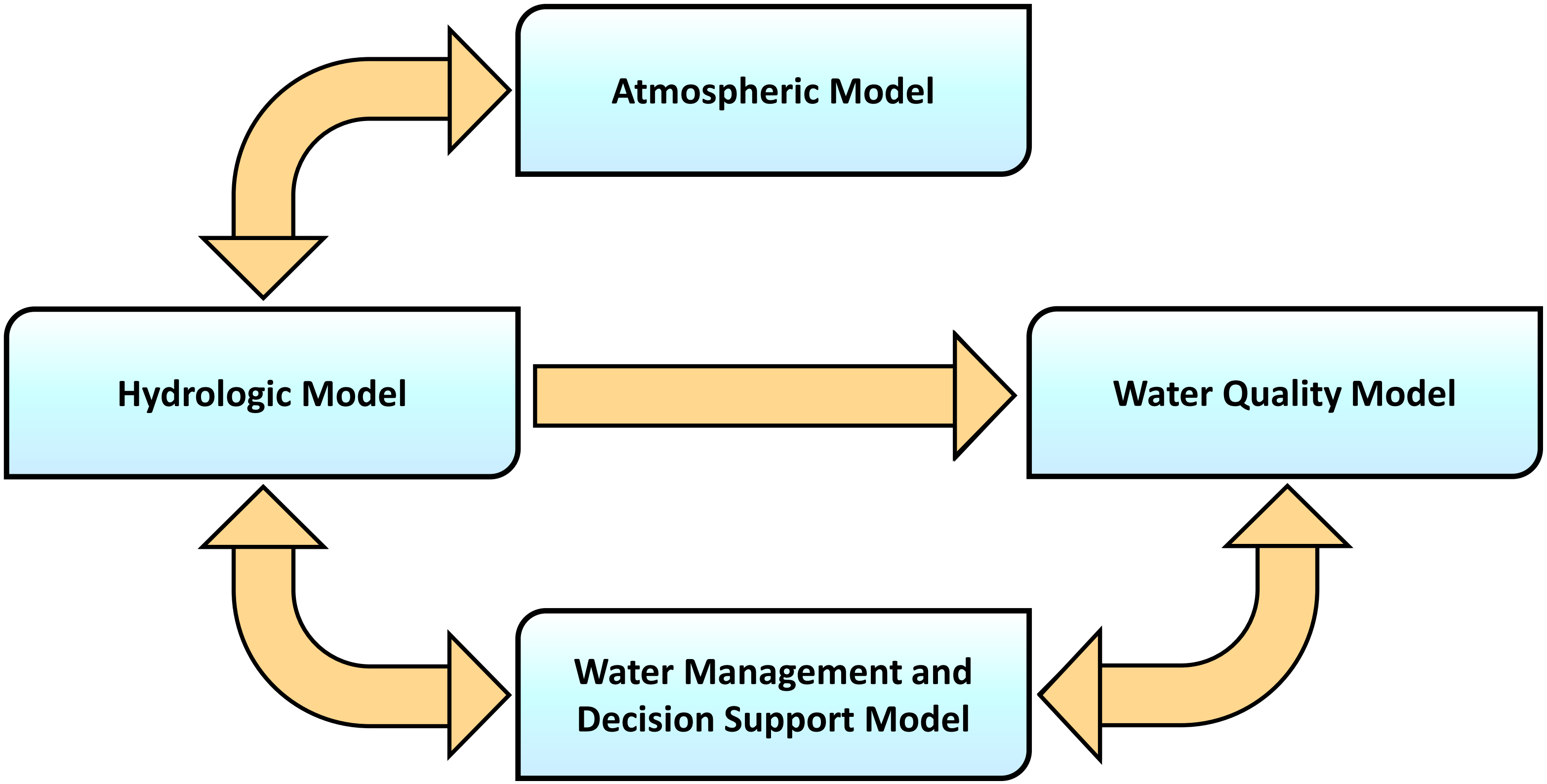
Model-Coupling Framework



Policy vs Experimental Runs

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- **Experimental Runs :** are the focus of the pillar 1 and 3 studies and it is expected that these runs will be conducted by funded investigators.
  - In some cases, there will be requirements for CORE modelling domains, expertise or assistance, depending on the nature of the pillar project being funded; and the scales at which the pillar 1 and 3 experiments are taking place.
  - Core modelling support is expected to assist in applying exiting models and testing new algorithms at the large scale as GWF expands policy runs to incorporate modelling details being vetted and evaluated in the pillar 1 and 3 programs.
- **Policy Runs :** are focused modelling runs for the larger scale systems where hydrograph and ancillary water balance variable are available for the purposes of model evaluation, boundary conditions for model testing, algorithms evaluation and policy runs for initial climate assessments.
  - In order to achieve more systematic approach to modelling, metadata associated with the modelling platform will need to be well-documented. As model improvement and testing refinements are established through the pillar 3,2 and 1 projects, policy runs can be re-assessed and re-run with improved forcing, improved basin representation and improved or modified physics, policy runs can be re-established and validated.

Name	Temporal resolution	Temporal extent	Spatial resolution	Spatial extent	Variables	Format
GEM (RDPS, HRDPS)	1-hour	2001/10-present	0.22 deg (~24 km): 2001/10-2004/05/17 0.1375 deg (~15 km): 2004/05/18-2012/10/02 10 km (likely 0.09 deg): 2012/10/03-present 0.0225 degree (~2.5 km): 2012/10/03-present	North America: 2016/09/08-present Canada, Mexico, conterminous US: 2010/11-present Canada, continental US: 2001/10-present	Precipitation, temperature, pressure, specific humidity, wind speed, downward SWR, downward LWR	fst (with rmnlib), ASCII, GRIB 2 (convertible to NetCDF)
CaPA (RDPA)	6-hour Daily	2002-present	10 km	Canada, Mexico, conterminous US: 2002/01-present	Precipitation	fst (with rmnlib), ASCII, GRIB 2 (convertible to NetCDF)
WFDEI	3-hour Daily	1979-2016	0.5 degree	Global	Rainfall-CRU, Snowfall-CRU, Rainfall-GPCC, Snowfall-GPCC, temperature, pressusr, specific humidity, wind speed, downward SWR, downward LWR	NetCDF
WFD	3-hour Dily	1901-2001 (updates?)	0.5 degree	Global	Rainfall-CRU, Snowfall-CRU, Rainfall-GPCC, Snowfall-GPCC, temperature, pressusr, specific humidity, wind speed, downward SWR, downward LWR	NetCDF
Princeton V.1 and V.2	3-hour Daily Monthly	V1: 1948-2008 (updates?) V2: 1901-2012 (updates?)	V1: 0.25, 0.5, 1.0 degree V2: 0.5, 1.0 degree	Global	Precipitation, temperature, Tmin, Tmax, Specific humidity, Donward SWR, downward LWR, Wind Seed, Surface Pressure.	NetCDF
NARR	3-hour Daily	1979-2015	0.3 degree	Lat: 15 to 90	Precipitation, temperature, pressure, specific humidity, wind speed, downward short	NetCDF

The following table provides a list of metadata information that will be required for the policy runs to ensure consistency and repeatability of the code and the model runs

Model Name and Version number : MESH(SVS), MESH(CLASS), CRHM, VIC……..

Model Domain and Sub-Domain: Mackenzie, Nelson-Souris, Great-Lakes-Grand River, ……..

Land-Cover : See appendix B

DEM : See appendix B

Soils : See appendix B

Model Run-Type and Simulation Period : Hindcast, Forecast, Climate \

Forcing Variables : See appendix B

Initial Conditions and state variables : Spin-up, Assimilation, Remote Sensing…..

Water Management : Reservoirs, irrigation, …….

Cold Regions Processes, Glaciers, Frozen Soil, Permafrost, Snow Sublimation, Snow redistributions

Lateral Flow : Interflow, Groundwater, Potholes….

Tested Outputs : Streamflow, peak flow, soil-moisture, SWE, snow-cover …..

Model Metadata Summary

BaySys Team 2 Meteorological & Hydrologic Forcing Data Summary

Based on what has been done/run up until now (January, 2018)

Period	Scenario	Atmospheric Forcing	Atmospheric Variables	Spatial domain Available	Spatial domain simulated	Atmospheric variable time period applied	Atmospheric temporal resolution availability	Bias Correction Data	Model Simulation Period (NEMO/HYPE)	Result Reporting Period	Output temporal resolution (simulated)	Output temporal resolution (analysis)	Calibration Data	Validation Data
Historical	Calibrated Regulation	SMHI-WFDEI (WFD/GFD hybrid)*	P, T	Arctic (>45°N)	HudBay	1961-2013	daily	GPCCv7, NRCan	1976-2010	1979-2010 OR 1981-2010	daily	daily	WSC, Dery et al. 2016	
		NARR		North America		1979-2013	3-hrly	None	1979-2010				Dery et al. 2016	
		WFDEI-GPCCv5		Global		1979-2013	daily	None						
		SMHI-WFDEI (WFD/GFD hybrid)*	P,T	Arctic (>45°N)	Arctic (>45°N)	1961-2013	daily	GPCCv7, Nrcan	1976-2010		daily	daily	Dai & Trenberth (non gap-filled), Dery et al. (2016)	
		ECCC	P, T, wind	Canada	LNRB	1979-2012	daily	None	1979-2009		hourly, daily	daily, monthly	WSC, Dery et al. 2016, MH gauges	
		NARR		North America		1979-2012	3 hrly		1979-2009					
		WFDEI-GPCCv5		Global		1979-2012	3 hrly		1979-2009					
	Naturalized	SMHI-WFDEI (WFD/GFD hybrid)*	P,T	Arctic (>45°N)	HudBay	1961-2013	daily	GPCCv7, NRCan	1976-2010		daily	daily	Dery et al (2016), MH unregulated (19 gauges)	
		Re-naturalized stage-discharge	WSL, Q	NCRB and LGRC (re-naturalized)	HudBay	1979-2017	daily	none	1979-2010				HQ, HQ unregulated (5 gauges)	
	Regulated	SMHI-WFDEI (WFD/GFD hybrid)*	P, T	Arctic domain (N of 45°)	HudBay	1961-2013	daily	GPCCv7, NRCan	1979-2010		daily	monthly	WSC, Dery et al. 2016, MH, HQ	
		MH regulated system rules	WSL, Q	NCRB	Nelson R	1979-2017	daily	WSC	1969-2017				MH, WSC	
Future	Calibrated Regulation	19 GCMs (CMIP5)	P, T	Global	N of 25°	1960-2070	daily (3-hrly available)	NRCan (Canada), Livneh 2013 (US)	2011-2070	2021-2070 (2030: 2021-2040, 2050: 2041-2070)	daily	monthly or 2030/50	--	--
	Naturalized												--	--
	Regulated												--	--

NOTE: does not include 2011-2020 period, however this will be derived for each scenario. Use combination of reanalysis data (TBD) and GCM data. Will update table once determined

Courtesy of Trish Stadnyk, U of Manitoba

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Dealing with Forecasting and Forcings

FloodNet NSERC

CaSPAr
Canadian Surface Prediction Archive

Juliane Mai, **Kurt Kornelsen**, David Schäfer, Bryan Tolson, Paulin Coulibaly, François Anctil, Vincent Fortin, Michael Leahy, Brent Hall

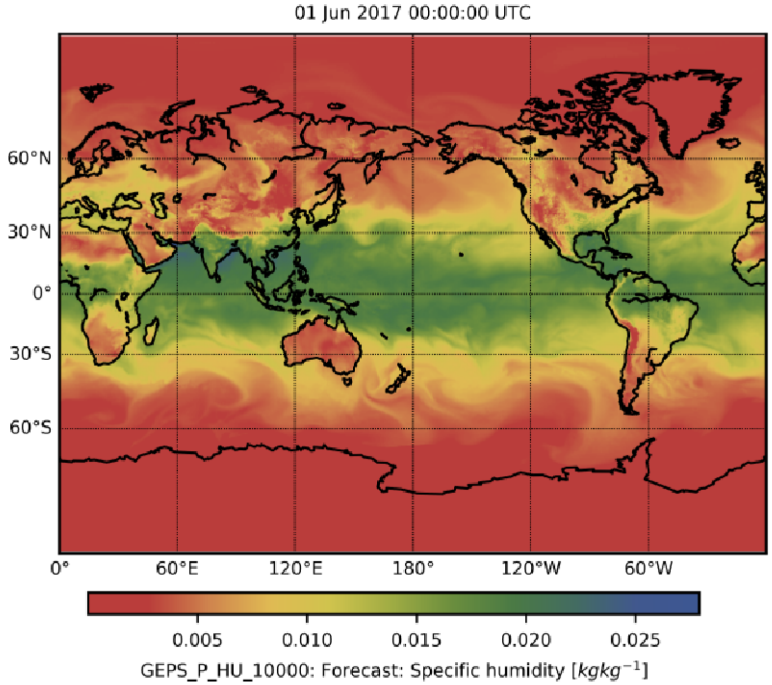
University of Waterloo
McMaster University
Université Laval
compute canada
Environment and Climate Change Canada
Environnement et Changement climatique Canada
HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ
esri
NSERC CRSNG

CaSPAr Status Report ECCC-CMC
October 24, 2017

Products

Products
– Status Quo –

1. GEPS



Forecasted time steps [h]:	1,2,..., 72, 96,..., 384
Issues:	2/day
Ensemble size:	21
Number of variables:	55
Resolution:	50km
Memory [GB/month]:	4662

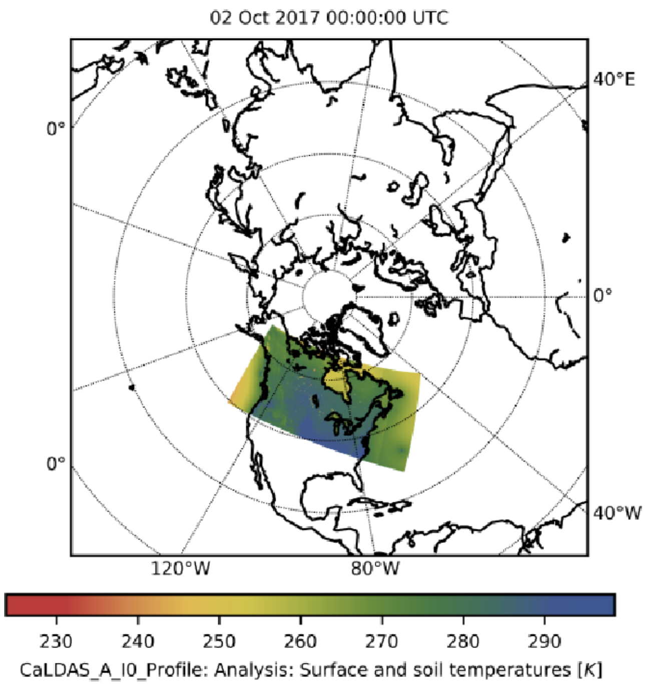
www.caspar-data.ca
caspar-data@uwaterloo.ca

Multiple scale and forecast ranges

Products

– Status Quo –

1. GEPS
2. GDPS
3. REPS
4. RDPS
5. HRDPS
6. CaPA_coarse
7. CaPA_fine
8. CaLDAS



Forecasted time steps [h]:	N/A
Issues:	8/day
Ensemble size:	25
Number of variables:	14
Resolution:	2.5km
Memory [GB/month]:	281

www.caspar-data.ca
caspar-data@uwaterloo.ca

Water Quality

CRHM/MESH-WINTRA.

WINTRA is a UofS-developed nutrient chemistry model, currently coupled to the Cold Regions Hydrological Model (CRHM) to provide hourly simulations of field-scale N and P release and transport during snowmelt (Costa et al., 2017). This physically based chemical release and runoff model is designed for cold continental climates where most N and P exports are in the dissolved form due to the limited erosive capacity of snowmelt runoff when compared to rainfall-runoff.

WASP

WASP (Water Quality Analysis Simulation Program) is one of the most widely used water quality models throughout the world . Because of the model's capabilities of handling multiple pollutant types it has been widely applied in the development of Total Maximum Daily Loads (TMDL).

WASP can link with hydrodynamic and river basin hydrological models to allow for multi-year analysis under varying meteorological and environmental conditions.

https://www.epa.gov/exposure-assessment-models/water-quality-analysis-simulation-program-wasp

HYPE

HYPE is a physically based, spatially aggregated conceptual model with a spatial resolution of 10 km^2. It was developed by the Swedish Meteorological Institute with focus on high spatial resolution, nutrient processes, predictions in ungauged basins and efficient computational structure.

https://www.smhi.se/en/research/research-departments/hydrology/hype-1.7994

Water Quality

SPARROW

- SPARROW is a USGS modeling tool for the regional interpretation of water-quality monitoring data. The model relates in-stream water-quality measurements to spatially referenced characteristics of watersheds, including contaminant sources and factors influencing terrestrial and aquatic transport. SPARROW empirically estimates the origin and fate of contaminants in river networks and quantifies uncertainties in model predictions. An empirically based model relying on water quality observations, the core of the model consists of a nonlinear regression equation for point and diffuse source in-stream contaminant transport. More information on SPARROW can be found here: https://water.usgs.gov/nawqa/sparrow/

MAGIC

- MAGIC is a process-oriented intermediate-complexity dynamic model by which long-term trends in soil and water acidification can be reconstructed and predicted at the catchment scale. MAGIC consists of two groups of equations. (1) Soil-soil solution equilibria equations in which the chemical composition of soil solution is assumed to be governed by simultaneous reactions involving sulphate adsorption, cation exchange, dissolution and precipitation of aluminium, and dissolution and speciation of inorganic and organic carbon. (2) Mass balance equations in which the fluxes of major ions to and from the soil and surface waters are assumed to be governed by atmospheric inputs, mineral weathering, net uptake in biomass, and loss in runoff. MAGIC produces long-term reconstructions and predictions of soil and streamwater chemistry in response to scenarios of acid deposition and land use. MAGIC uses a lumped approach in two ways. (1) A myriad of chemical and biological processes active in catchments are aggregated into a few readily described processes. (2) The spatial heterogeneity of soil properties within the catchment is lumped into one set of soil parameters.

MyLake Model Suite

- MyLake (Multi-year Lake simulation model) has been developed at Norwegian Institute for Water Research in collaboration with Ecohydrology group in Waterloo within various projects, and is freely available. MyLake is a one-dimensional process based model for simulation of daily vertical distribution of lake water temperature, density stratification and mixing, evolution of seasonal lake ice and snow cover, temporal and spatial variability of phytoplankton, nutrients, and algal blooms. Continuous (i.e., in water column and sediment) reaction network in the coupled model include microbially mediated redox reactions, aqueous speciation, mineral dissolution, and precipitation. Microbially mediated organic matter degradation (e.g., oxic respiration, denitrification, iron and sulfate reduction, methanogenesis) are implemented using Michaelis-Menten rate laws with inhibition terms. Bimolecular reaction rate laws are used for secondary redox reactions (e.g., oxidation of Fe^{2+}, NH_4^+, and HS^-). The reaction network is parametrized according to previous studies. The model is suitable for sensitivity and uncertainty Monte-Carlo analyses.

Water Quality

PorousMediaLab

- PorousMediaLab is one dimensional reactive transport modeling toolbox developed in Ecohydrology group In Waterloo. The toolbox is designed for variably saturated soils during freezing and thawing cycles and simulates microbially mediated redox reactions, aqueous speciation, mineral dissolution and precipitation reactions under variable boundary conditions. The toolbox includes built-in calibration and sensitivity analysis tools. More information and examples can be found here: https://github.com/biogeochemistry/PorousMediaLab

MatSedLab

- MATSEDLAB is a biogeochemical model of the early diagenesis, which calculates the concentration of different species at each depth for a specific time period, based on the reaction framework, transport processes, and boundary conditions specified by the users. It does so by forming a system of partial differential equations based on the early diagenesis equation, and using the MATLAB built-in solver *pdepe* to solve the system (Couture, 2015).

ELCOM-CAEDYM (Lake Model)

- ELCOM-CAEDYM is a three-dimensional (3-D) hydrodynamic and bio-geochemical model that consists of two coupled models: a 3-D hydrodynamic model - the Estuary, Lake and Coastal Ocean Model (ELCOM), and a bio-geochemical model - the Computational Aquatic Ecosystem Dynamics Model (CAEDYM). The hydrodynamic model (ELCOM) can simulate water transport, temperatures, salinity, mixing intensities, ice-cover, and up to 10 different numerical conservative or non-conservative tracers. The bio-geochemical model (CAEDYM) can simulate many important water quality variables including dissolved oxygen, carbon and nutrients (phosphorus, nitrogen, and silica) including their major fractions (dissolved and particulate, organic and inorganic, liable and refractory), suspended sediments (particulate and colloidal fractions). It can simulate up to seven phytoplankton groups, five zooplankton groups, and three groups of mussels. There is a flexibility for a user in choosing which species to include in the simulations. ELCOM-CAEDYM and/or ELCOM models have shown a great potential for modelling of physical and biochemical processes and been successfully used for in-depth investigations into variable hydrodynamic and biochemical processes in Canadian lakes of different sizes ranging from mid-sized lakes (Lake St. Clair and Lake Simcoe) to very large lakes such as Laurentian Great Lakes (Erie and Ontario) and other North American Great Lakes (Winnipeg, Great Slave and Great Bear). For example, in Lake Erie, ELCOM-CAEDYM has been used to study nutrient and phytoplankton dynamics, the effect of mussel grazing on phytoplankton biomass, the sensitivity of thermal structure to variations in meteorological parameters, the effect of ice on hydrodynamics and water quality parameters. Other application of ELCOM-CAEDYM to Lake Erie included the estimation of the effects of external nutrient controls on low dissolved oxygen concentrations (hypoxia) and integration with statistical models for more accurate predictions of spatial extent of hypoxia to improve lake management.

Water Management

MODSIM-DSS

- MODSIM is a generalized river basin management decision support system (DSS) developed at the Colorado State University as a computer-aided tool for developing improved basin wide and regional strategies for short-term water management, long-term operational planning, drought contingency planning, water rights analysis and resolving conflicts between urban, agricultural, and environmental concerns. MODSIM is designed to aid stakeholders in developing a shared vision of planning and management goals, while gaining a better understanding of the need for coordinated operations in complex river basin systems that may impact multiple jurisdictional entities. MODSIM provides for integrated evaluation of hydrologic, economic, environmental, and institutional/legal impacts as related to alternative development and management scenarios, including the conjunctive use of surface water and groundwater resources. As a robust river basin management DSS, MODSIM provides both a planning framework for integrated river basin development and management, as well as aid in real-time river basin operations and control. The basic solver in MODSIM is a state-of-the-art network flow optimization algorithm that is more than an order of magnitude faster than solvers currently in use in other river basin modeling packages and capable of modeling extremely large-scale networks. Details are available at http://modsim.engr.colostate.edu/.

WEAP

- The Water Evaluation and Planning (WEAP) Integrated Water Resource Management (IWRM) model has been developed and maintained by the Stockholm Environment Institute (SEI). It seamlessly integrates water supplies generated through watershed-scale hydrologic processes with a water management model driven by water demands and environmental requirements and is governed by the natural watershed and physical network of reservoirs, canals, and diversions. It includes the concept of demand priorities and supply preferences, which are used in a linear programming heuristic to solve the water allocation problem as an alternative to multi-criteria weighting or rule-based logic approaches. WEAP can address a wide range of issues, e.g., sectoral demand analyses, water conservation, water rights and allocation priorities, groundwater and streamflow simulations, reservoir operations, hydropower generation, pollution tracking, ecosystem requirements, vulnerability assessments, and project benefit-cost analyses. Details are available at http://www.weap21.org/index.asp?action=200.

Other Considerations…

- Remote Sensing
  - Land-surface
    - (SWE, Soil Moisture, Glaciers vegetation and change….
  - Water Bodies
    - Water level (SWOT), water extent, wetland extent….
  - Water Quality
    - Algal blooms, colour, temperature………

- Initial Conditions
- Assimilation
- Verification

Principles

- Open-Source models if possible
- Consistent meta-data approaches to model runs
- Strong version control
- “Digestible “ by use community
- Linking and coupling of various modelling sytems
  - Common formats between models if possible
  - Shared tools

CORE OUTCOMES

GLOBAL WATER FUTURES
SOLUTIONS TO WATER THREATS IN AN ERA OF GLOBAL CHANGE

- The modelling core project will focus on creating a common platform for scientists from various disciplines and different universities/institutes to work together. The focus on the first 3 years will
  - Develop and apply new coupled modeling systems that integrate regional climate, land management, hydrology and water management over climate change sensitive regions.
  - Improve models with the capability to explore and assess how changes in population, economic development, and land use will impact water resource management and water quality, in addition to climate change.
  - Determine how state-of-the-art model scenarios and predictions can be best framed to inform decision making, policy and adaptive governance for the management of risks from hydrological change to water resources.

Next Steps

- Collate all ancillary data (Land-cover, DEM etc..)
- Collate all Forcing and work with CasPAR team.
- Develop metadata standard for model runs
- Finalize policy runs and domains/sub domains.

- Communication will be key
  - Meet with core managers
  - Meet with pillar PIs

MESH system progress and developments

GWF

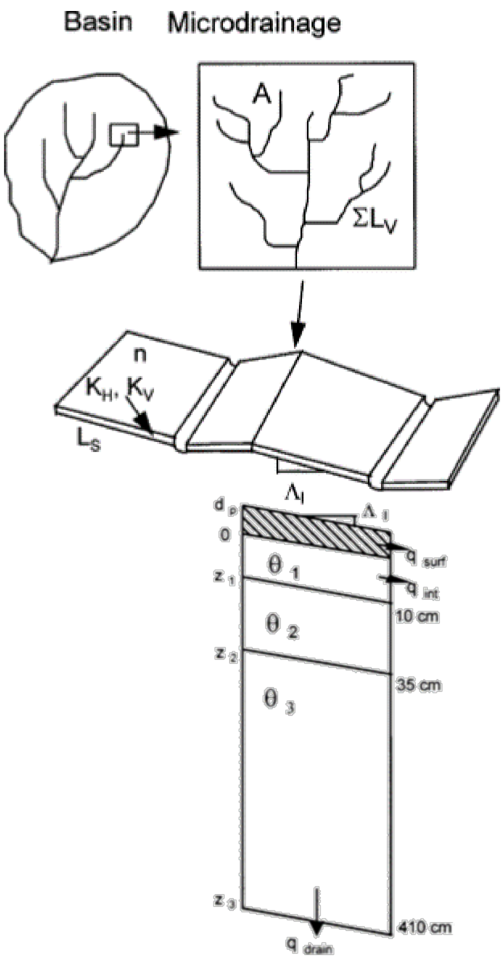
GLOBAL WATER FUTURES

SOLUTIONS TO WATER THREATS IN AN ERA OF GLOBAL CHANGE

Standalone MESH

(Modélisation Environnementale communautaire – Surface Hydrology)

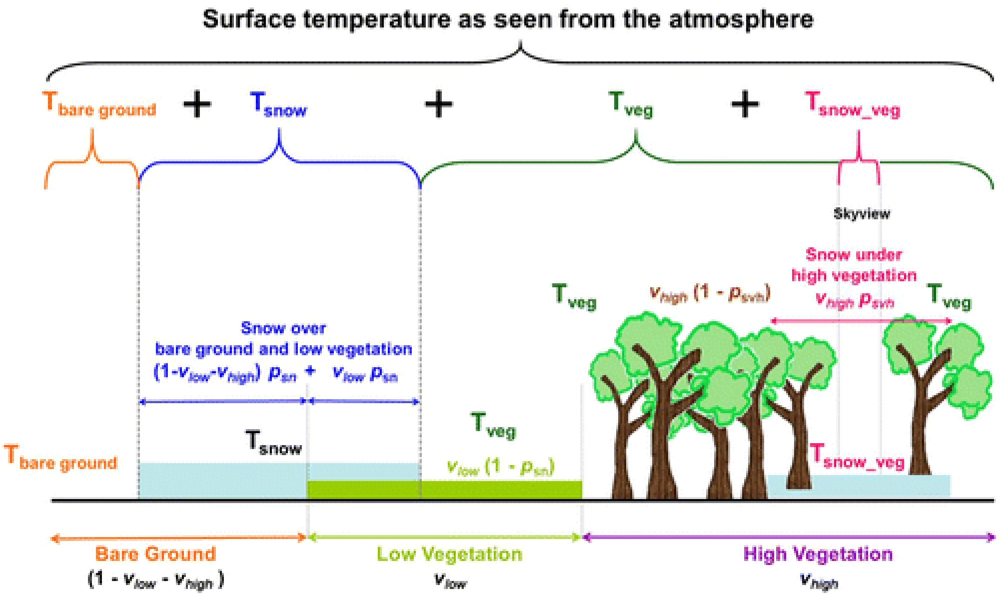
- 2000-2005 WATCLASS with CLASS 2.7 + sloped soil column with interflow (WATROF) + simple channel routing adopted from Watflood (WF_ROUTE)
- 2007 "Standalone MESH" with CLASS 3.3.1
- 2009 MESH 1.2 with support for R2C input files (e.g., Watflood compatible)
- 2011-2012 MESH 1.3 with CLASS 3.5, infiltration into frozen soils (hind-cast), > 3 soil layers, gridded parameters, prairie pothole model (PDMROF), gridded output files to run Watflood
- 2014 MESH 1.3 with CLASS 3.6, including new snow cover dynamics
- 2015 prairie blowing snow model (PBSM), binary file format for large-scale modelling, simulation metrics at gauge locations + spin-up period
- 2017 MESH 1.4 with MPI parallelization, SVS, critical bug fixes to WF_ROUTE and time-stepping

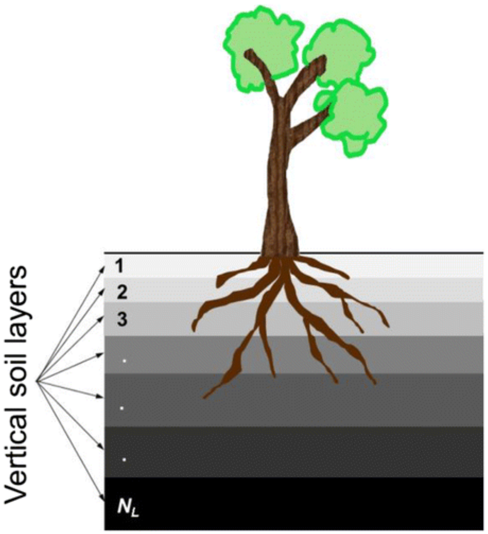


Soulis et al., 2000

The SVS land-surface model

- Multi-tile surface model and multi-layer soil model
    - Alavi et al. (2016). Warm Season Evaluation of Soil Moisture Prediction in the Soil, Vegetation and Snow (SVS) Scheme, *J. Hydromet.*, 17: 2315–2332.
    - Husain et al. (2016). The Multi-Budget Soil, Vegetation, and Snow (SVS) Scheme for Land Surface Parameterization: Offline Warm Season Evaluation, *J. Hydromet.*, 2293–2313.





Land surface schemes available in both GEM and MESH

SVS 1

- Force-restore model for snow and soil temperature (similar to ISBA)

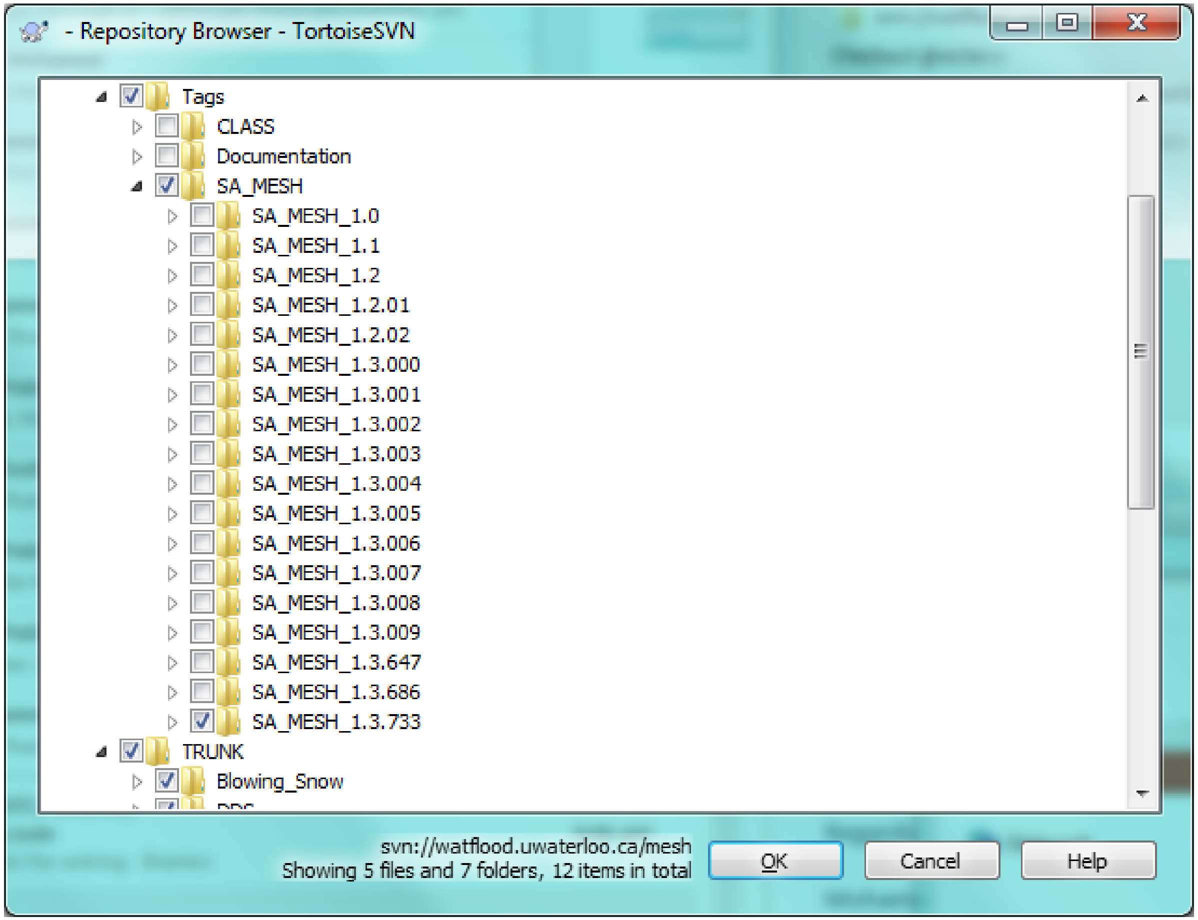
SVS 2

- Multilayer « Explicit Snow » (ES) model (Boon and Etchevers, 2001) used in SURFEX (Meteo-France)
- Diffusion equation for soil temperature and freeze/thaw coupled with soil moisture model (similar to CLASS)

- Explicit representation of bare ground, low vegetation and high vegetation tiles (different surface temperature and snowpack)
- Richards equations for soil moisture (single column for the grid cell)
- WATDRAIN interflow parameterization

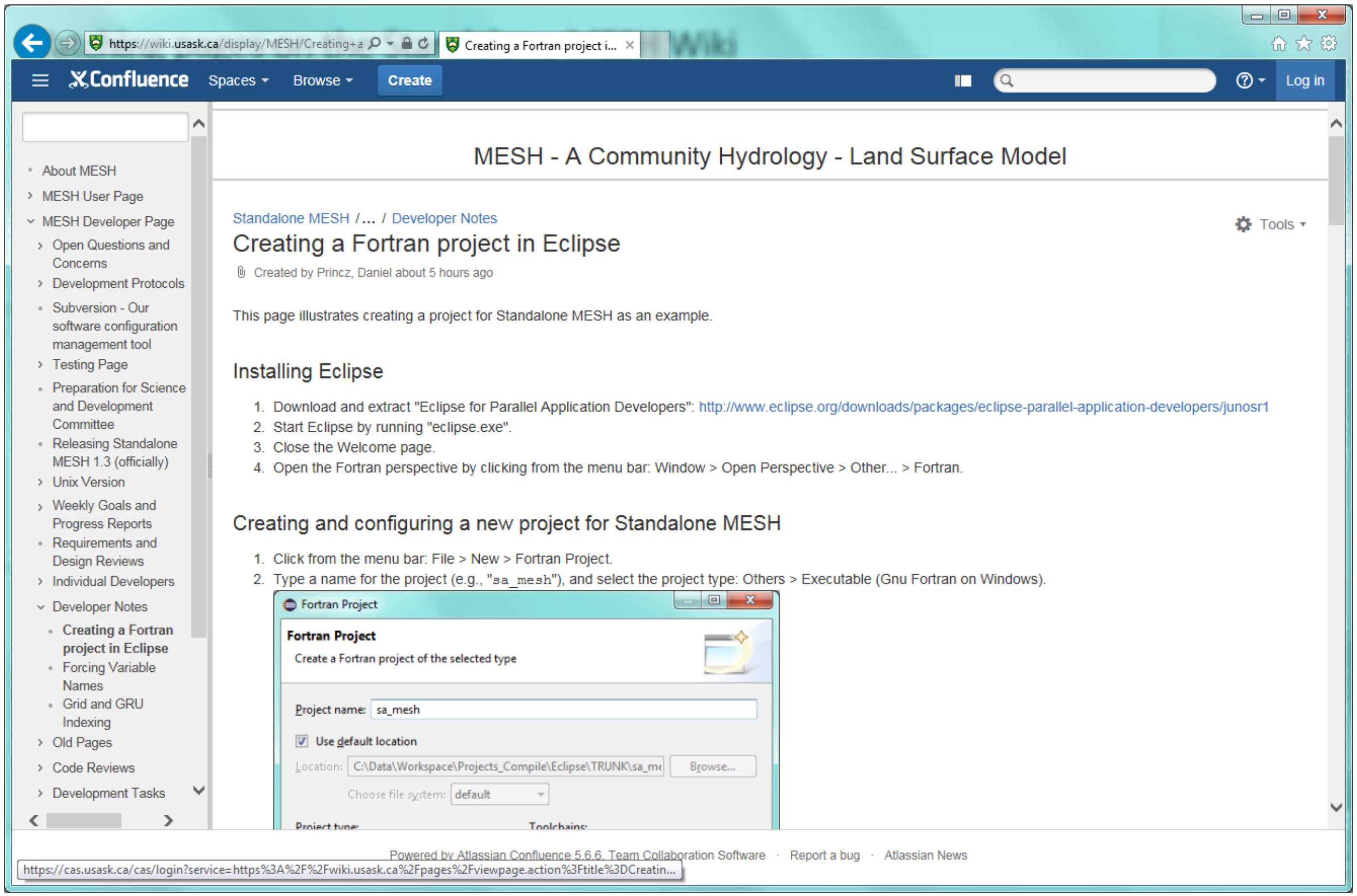
Working with the Repository

- Select the most recent tag from the tree-view: Tags > SA_MESH > SA_MESH_1.3.733
- Select: TRUNK
- Click “OK” to close the window



Interacting with the Standalone MESH Wiki

- Log in via PAWS CAS or using the guest login page



GLOBAL WATER FUTURES
SOLUTIONS TO WATER THREATS IN AN ERA OF GLOBAL CHANGE

Similar streamflow predictions obtained with SVS. CLASS and WATFLOOD

É. Gaborit et al.: A hydrological prediction system based on the SVS land-surface scheme

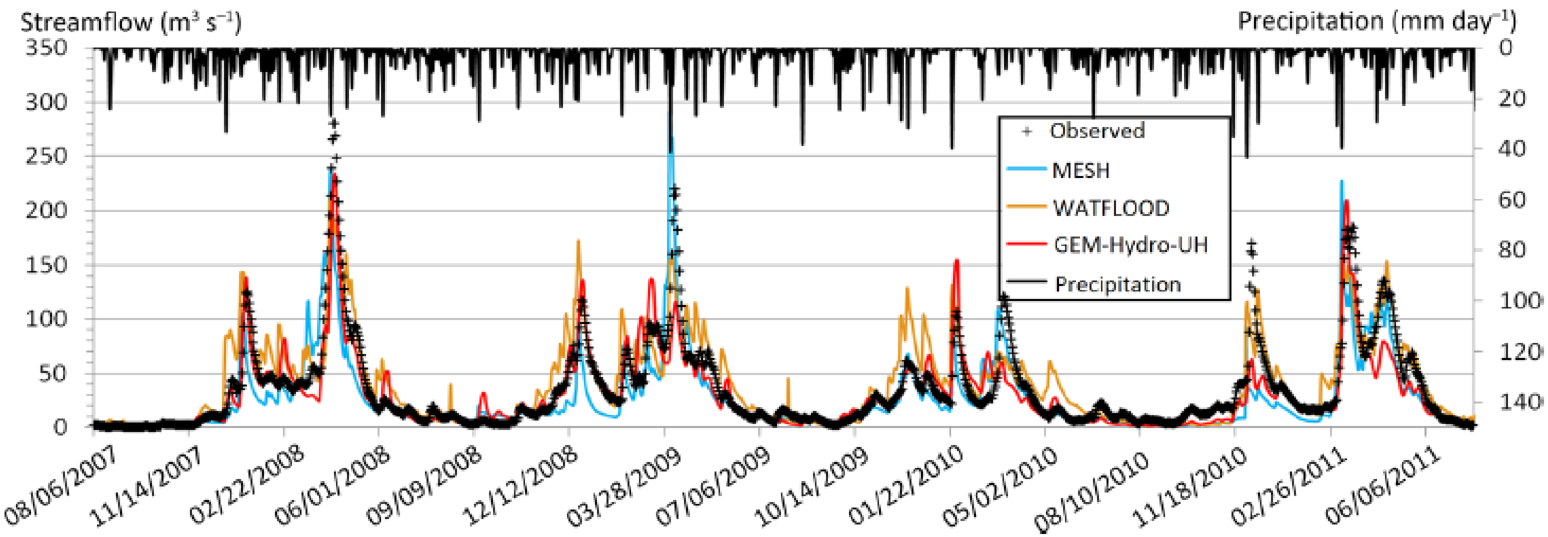
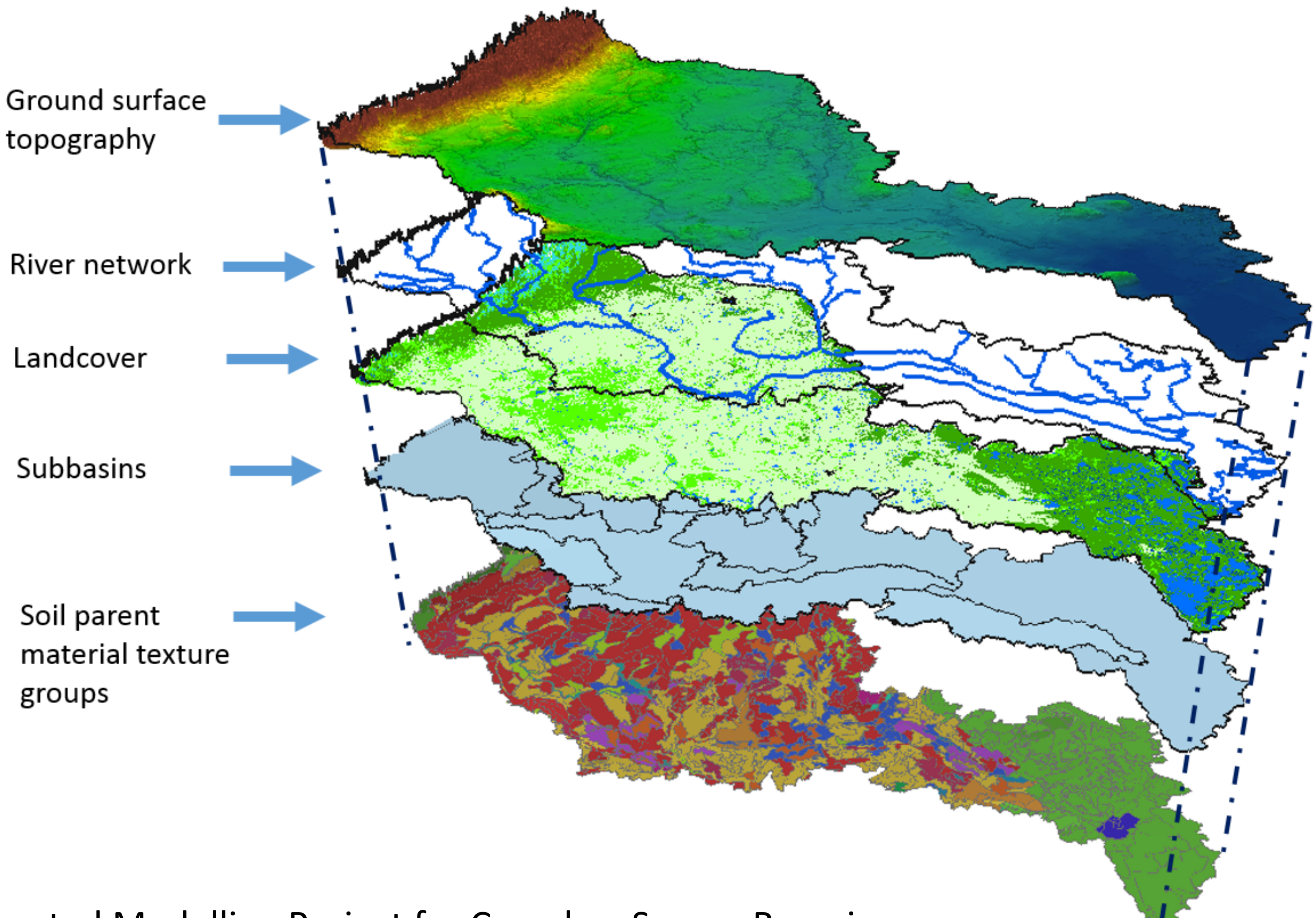


Figure 6. Intercomparison for the Moira River (calibration period, CaPA precipitation).

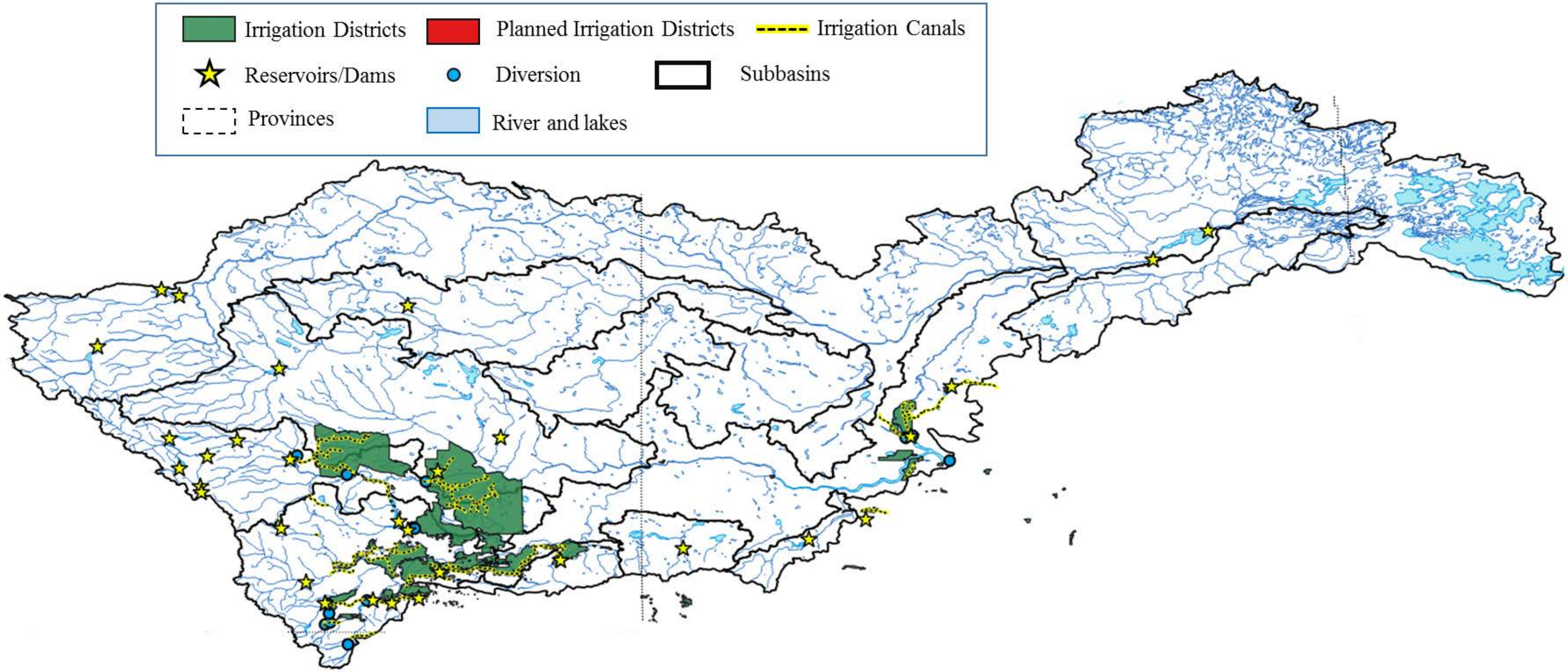
Gaborit, É., V. Fortin**, X. Xu, F. Seglenieks, B. Tolson, L.M. Fry, T. Hunter, F. Anctil et A.D. Gronewold (2017).** A Hydrological Prediction System Based on the SVS Land-Surface Scheme: Implementation and Evaluation of the GEM-Hydro platform on the watershed of Lake Ontario**.** *Hydrology and Earth System Sciences***. 21: 4825–4839.**

MESH Modelling of the Saskatchewan River Basin



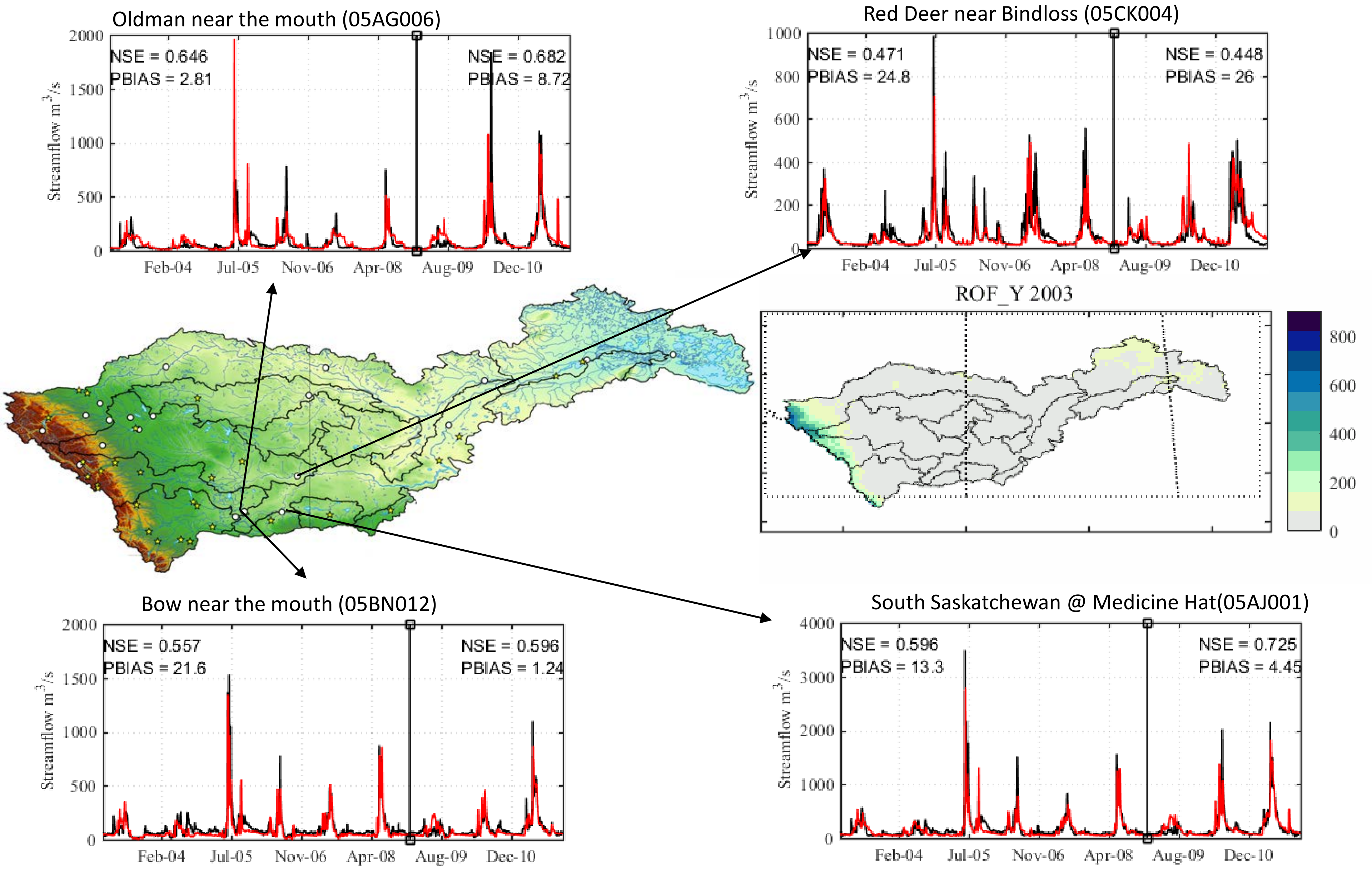
Integrated Modelling Project for Canada – Saman Razavi

Irrigation and Diversion in SRB

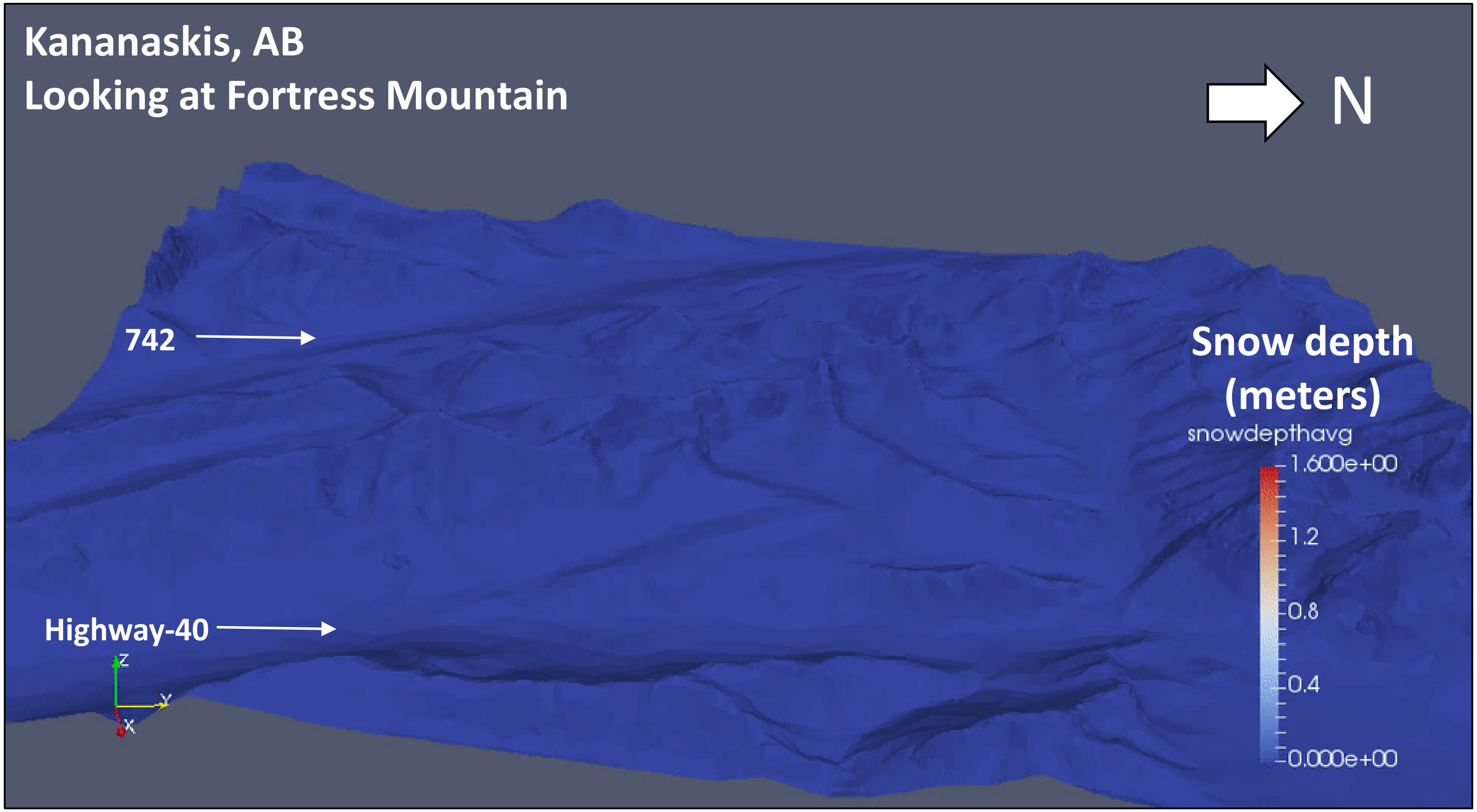


- In Southern Alberta, there are 13 irrigation districts providing water to 1,412,836 acres of farmland
- In Saskatchewan Lake Diefenbaker supplies water to 11 irrigation districts with total area of some 80,000acres

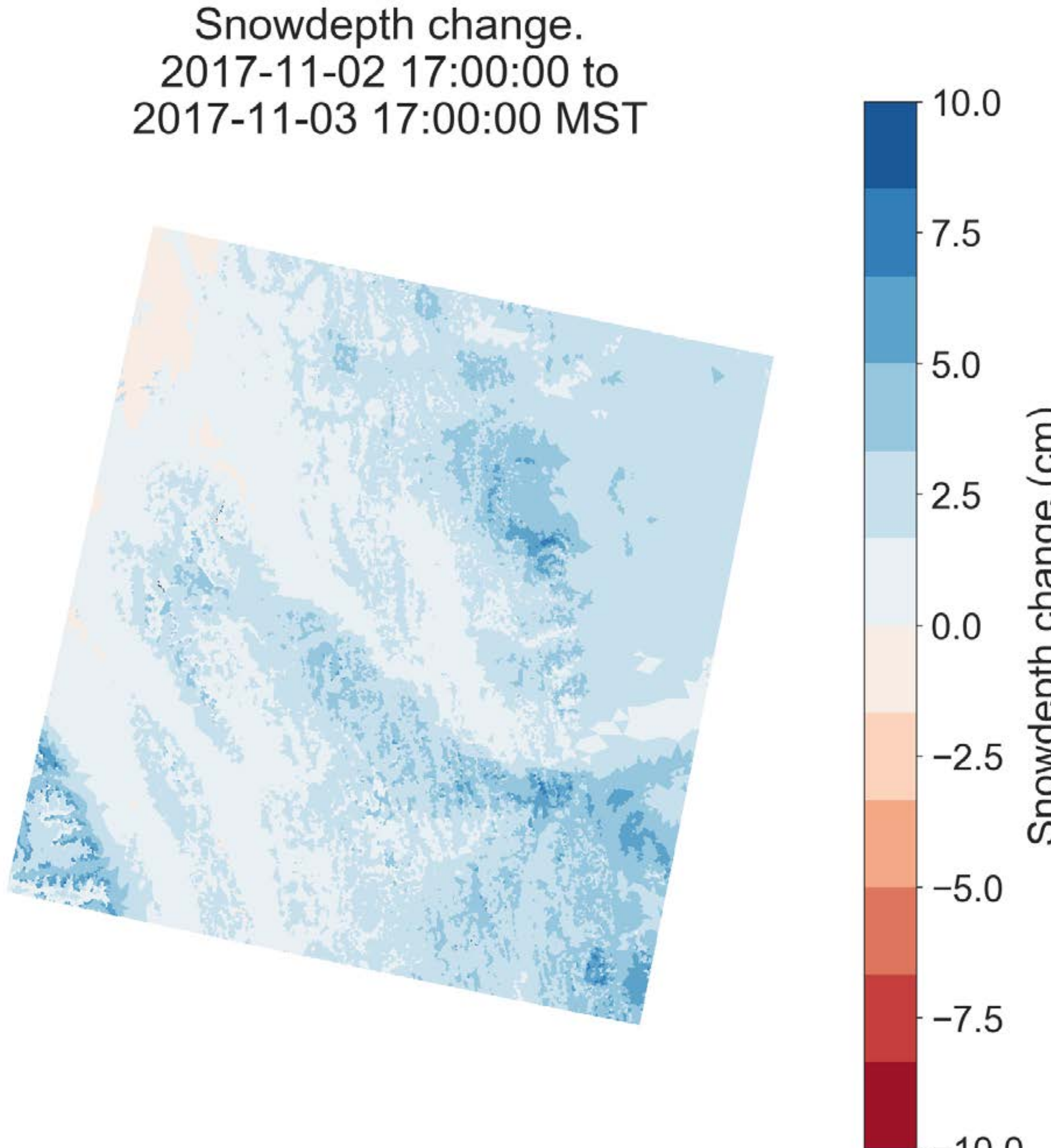
Model Calibration and Validation



CHM - Mountain Snowpack Forecast Simulation - Kananaskis



SnowCast – C



www.snowcast.ca

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