Core Modelling Update

Alain Pietroniro, Executive Director, National Hydrological Service, Meteorological Service of Canada and Lead - Global Water Futures Core Modelling Program

GWF

GLOBAL WATER FUTURES

SOLUTIONS TO WATER THREATS IN AN ERA OF GLOBAL CHANGE

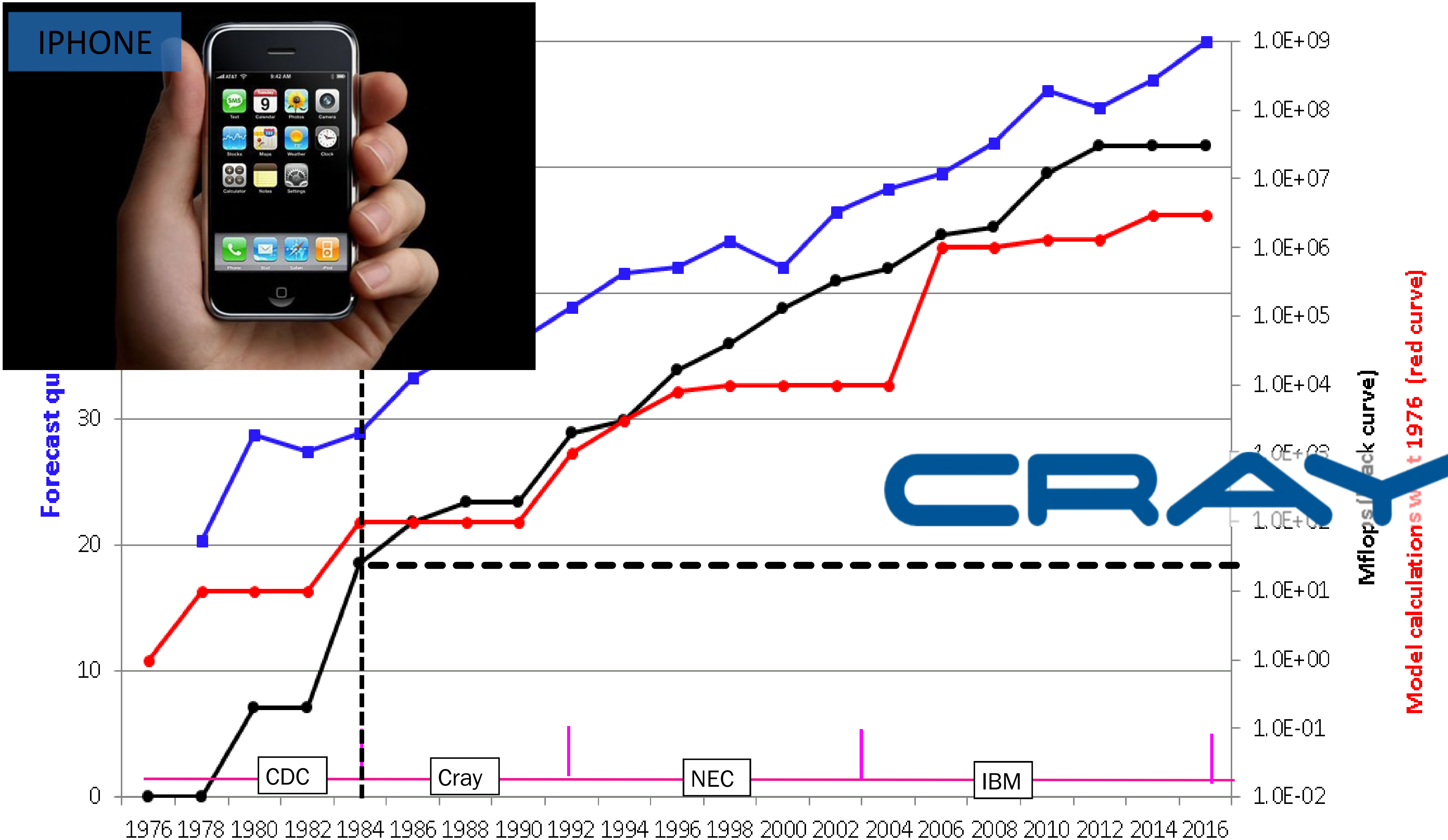
Outline

- Review of Core modelling activity and modelling within GWF
- Selected updates on core modelling team efforts
- CASPar Update (Julie Mai)
- NEXT STEPS

Drivers for a Change in Approach

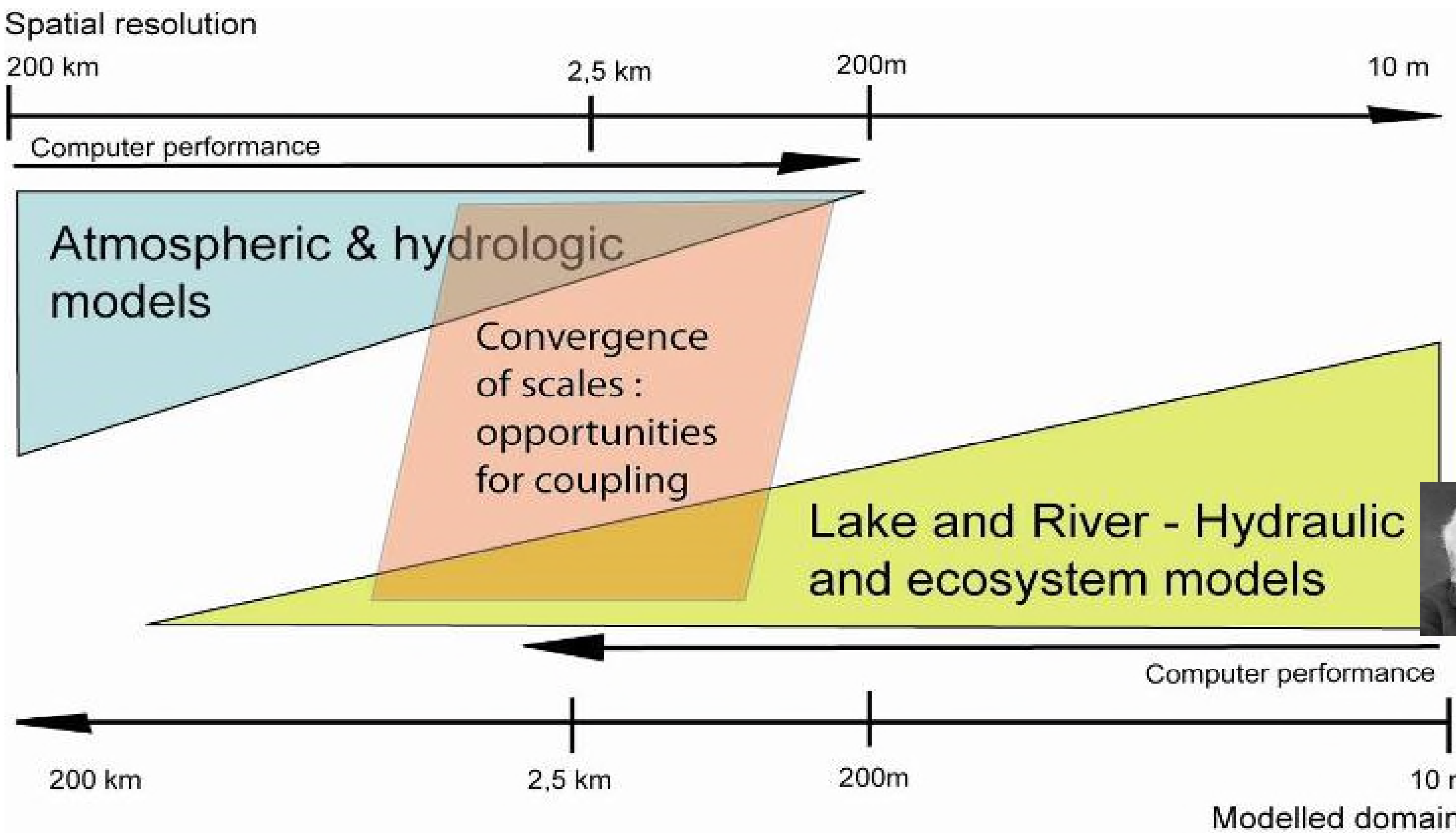
- *Climate Change and Resilience*
  - Demands for more reliable and accessible localized predictions and longer lead times of hydro-meteorological extremes are being accentuated by a changing climate.
- *Technology*
  - Today's technological environment is radically different than 10 years ago, providing tremendous potential for innovating and improving program delivery including new investments in technological developments such as upgraded supercomputing platform.
- *Digital Age*
  - As digital innovation permeates society to a greater and greater extent clients and stakeholders expectations' evolve accordingly.
  - New methods are arising to decipher through artificial intelligence, the relevant information in this big data environment with the potential for applications in a weather and climate forecasting.
- *Open Government*
  - Today's governments are placing a much stronger emphasis on being an open data and services as well as seeking to stimulate the Canadian economy through partnerships

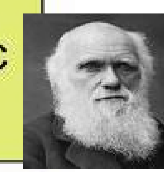
Model calculations – HPC power – Forecast quality



Why hydrologic, lake, river and ecosystem model applications are emerging?

- Established models exist for most components
- Modelling scales are converging





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Why GWF Core Modelling

- Hydrology still not completely defined, particularly Cold Regions
  - Dealing with spares data systems, incorporating cold regions processes, basin segmentations and physics, data assimilations …. Hydro-Mythology
- No systematic water quality models have been implemented
  - No In-stream quality systems e.g. (WASP)
  - No non-point pollutions models operational
  - No lake quality modelling systems
- Hydraulic models currently limited in ECCC systems
- No DSS implemented
- No water management

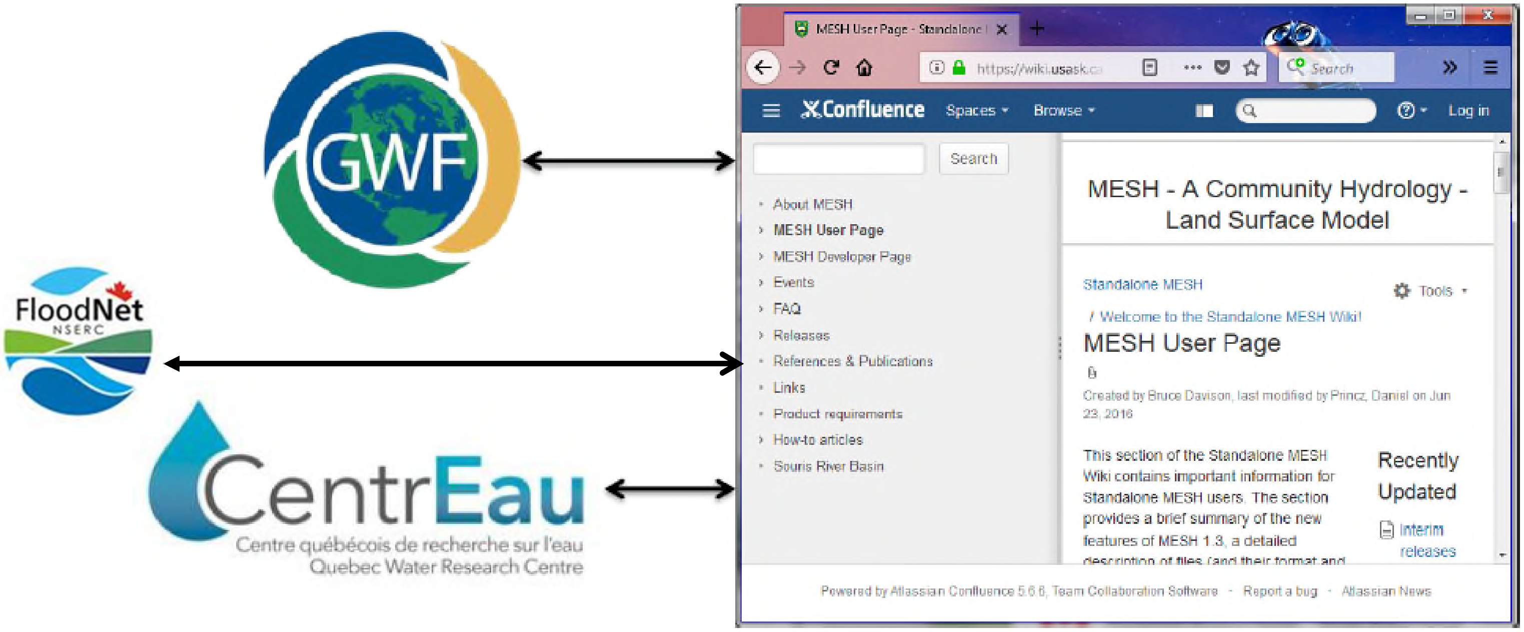
Current Hydrological Approaches are Limited

- Hydro-mythology : *Concepts that have been dismissed by scientific investigation but persist in hydrological model* (Pomeroy)
- Examples:
  - Radiation is difficult to estimate with normal meteorological data
    - Evapotranspiration can be estimated by temperature and wind functions
    - Temperature index melt of snow and soil thaw
  - Snowfall determines snow available for melt
    - Sublimation = 0
    - Snowfall gauge correction = snow redistribution loss
  - Soils can be represented as uniform porous media and subjected to clever mathematical manipulations
    - Macropores = 0
    - Green-Ampt or Richard's Eq. can work "as is" or are still physically based when heavily calibrated from streamflow
  - All land surfaces drain freely to streams with quick flow at overland flow velocities
    - Hortonian overland flow
    - Contributing area = 100%
  - Frozen soils behave like unfrozen soils
    - Calibration of unfrozen soil infiltration for frozen conditions

Some GWF Models

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

Advantages of MESH and future plans



MESH is a modelling Framework tying systems together. Right now focused on H-LSS and routing. Sediment, NPP and water temperature components have been added

- Evaluating other routing models
- Adding SVS and SUMA, CRHM algorithms
- Compatible with FEWS (forecasting system wrapper)
- Linked with WASP, HEC-RAS, HEC-RESIM, possibly CHM, SNOWCAST system
- Able to run on Amazon Cloud in hindcast, climate or forecast mode.
- Compatible with OSTRICH and VARS

GWF Model 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 systems
  - Common formats between models if possible
  - Shared tools

- Core modelling team starting to work closely with Core computing team

CORE OUTCOMES

- 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.

Core Team – Modelling & Forecasting

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- Hydrological and Water Quality Forecasting
  - **Flood Forecasting**
  - **Seasonal and Drought Forecasting**
  - **Floodplains**
  - **Data Assimilation**
  - **River Ice Modelling**
  - **Water Quality**
- Climate and Diagnostic Hydrology and Water Quality Modelling
  - **Climate - high resolution pan-Canadian**
  - **Hydrological Modelling**
  - **Next Generation Water Modelling**
  - **Catchment, River and Lake Water Quality**
- Water Resources Systems

ECCC Grant

- Vacant – MESH community model development
- Nassim Hosseini – SWOT and Hydraulic model development

Center for Hydrology

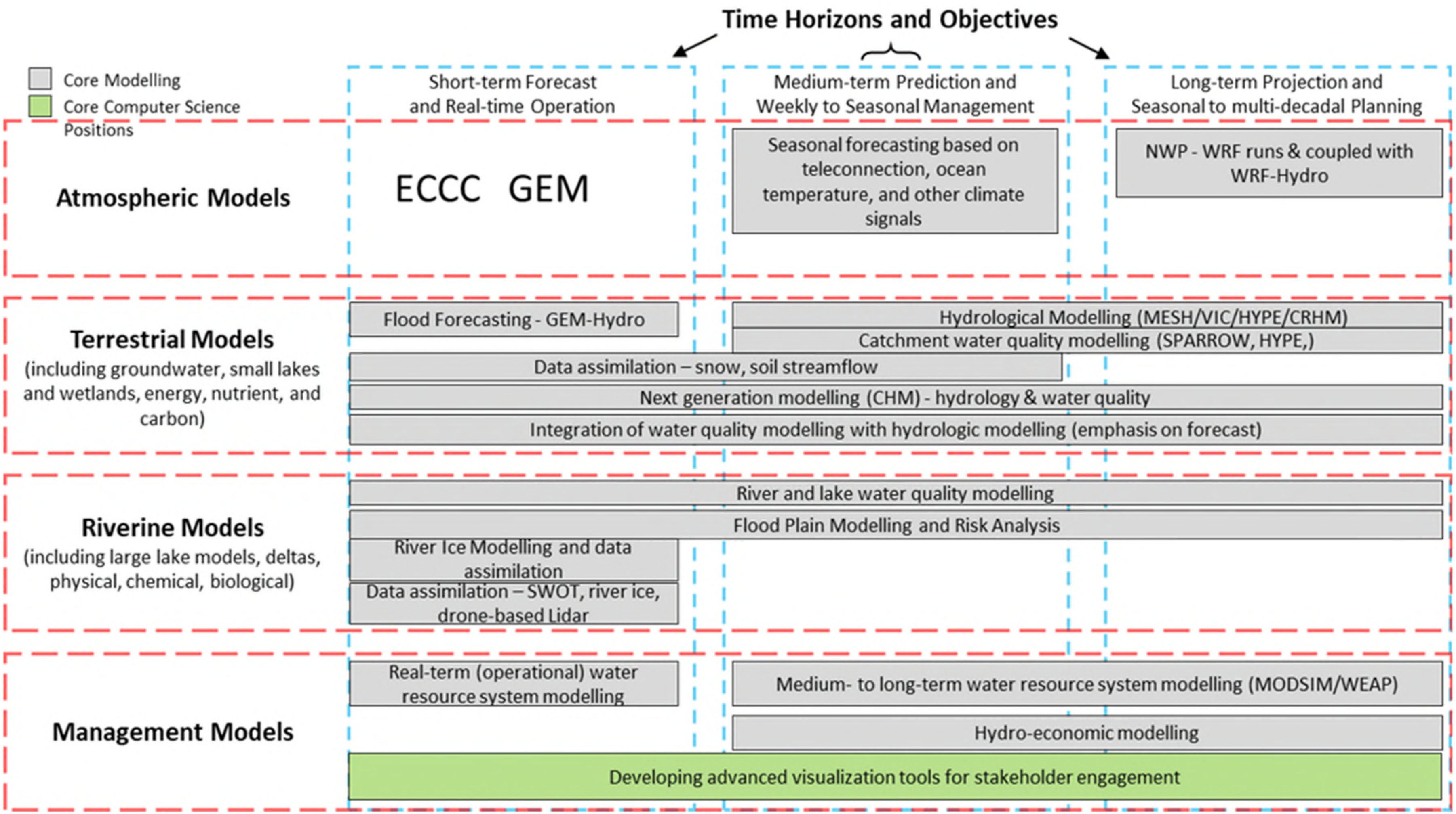
-Tom Brown – CRHM development
- Dominique Richard – MESH forecasting and testing – Yukon and Bow

ECCC modelling Team

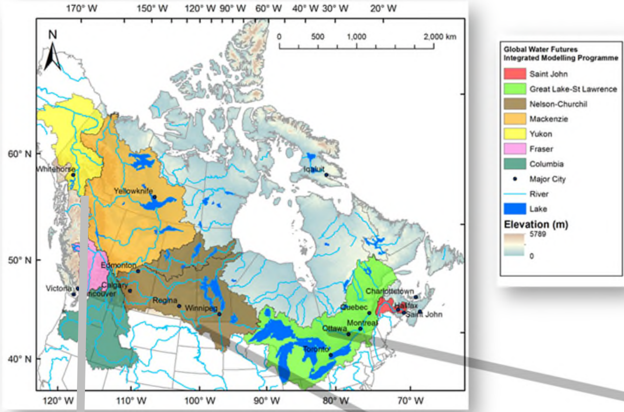
- Fortin, Gaborit, Dunford, others GEM Hydro development
- Bruce Davison/Dan Princz/Anthony Liu /Frank Seglenieks– MESH development
- Mogus – Souris Study

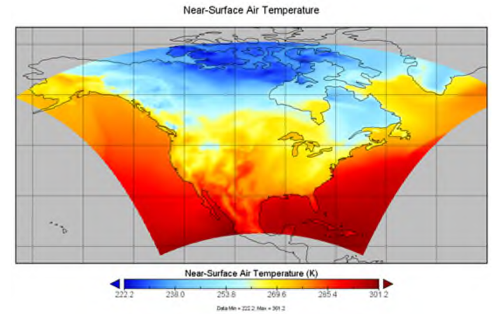
University Teams

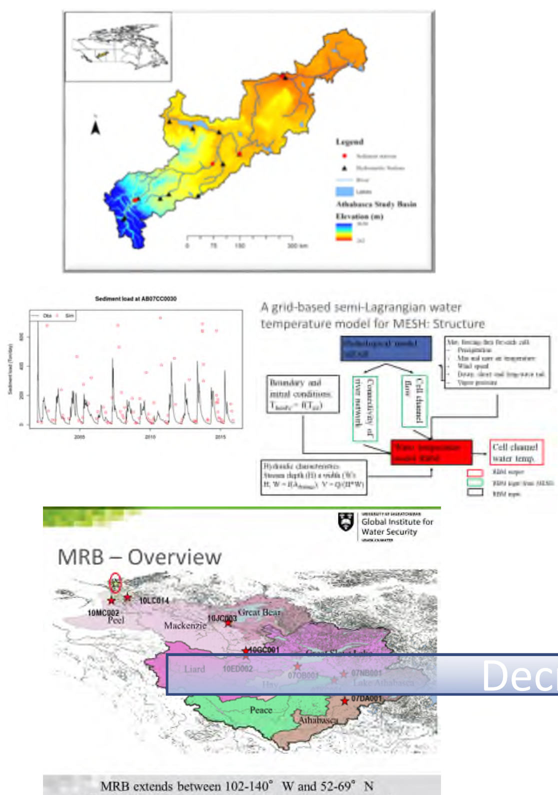
- Saman Razavi – VIC/MESH development and IMPC
- Bryan Tolson – IMPC inter-comparison
- Trish Stadnyk – IMPC, HYPE, Isotopes



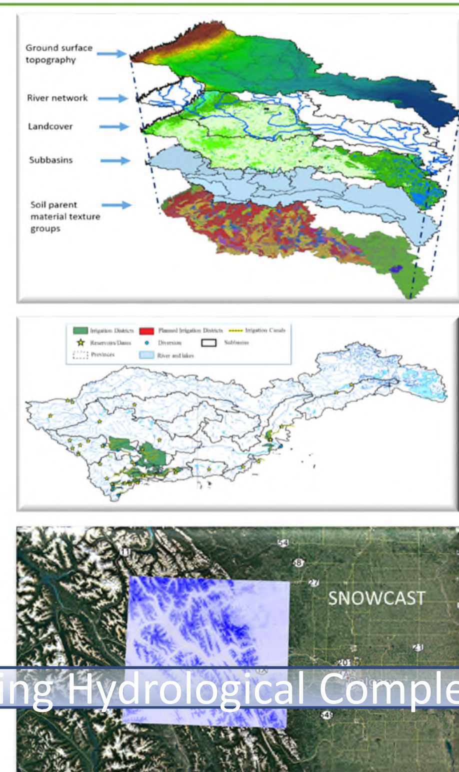
Time Horizons and Objectives
Core Modelling
Core Computer Science Positions
Short-term Forecast and Real-time Operation
Medium-term Prediction and Weekly to Seasonal Management
Long-term Projection and Seasonal to multi-decadal Planning
Atmospheric Models
ECCC GEM
Seasonal forecasting based on teleconnection, ocean temperature, and other climate signals
NWP - WRF runs & coupled with WRF-Hydro
Terrestrial Models
(including groundwater, small lakes and wetlands, energy, nutrient, and carbon)
Flood Forecasting - GEM-Hydro
Hydrological Modelling (MESH/VIC/HYPE/CRHM)
Catchment water quality modelling (SPARROW, HYPE,)
Data assimilation – snow, soil streamflow
Next generation modelling (CHM) - hydrology & water quality
Integration of water quality modelling with hydrologic modelling (emphasis on forecast)
Riverine Models
(including large lake models, deltas, physical, chemical, biological)
River and lake water quality modelling
Flood Plain Modelling and Risk Analysis
River Ice Modelling and data assimilation
Data assimilation – SWOT, river ice, drone-based Lidar
Management Models
Real-term (operational) water resource system modelling
Medium- to long-term water resource system modelling (MODSIM/WEAP)
Hydro-economic modelling
Developing advanced visualization tools for stakeholder engagement



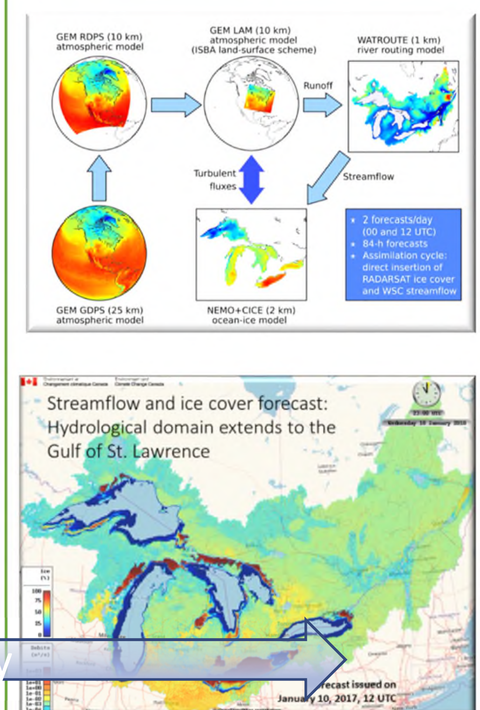




a) MESH development on Athabasca (T, Sed, Ice) b) Scenario runs for CC includes glaciers and permafrost



a) MESH Model Setup for the Saskatchewan River Basin; b) Incorporating reservoirs and water management in MESH; c) New model developments (TIN based) for snow forecasting in the Rocky Mountain Head-waterrs using CHM (Canadian Hydrological Model)



GEM-Hydro and NEMO operational system for Environment and Climate Change Canada's Great lakes Prediction System

Scenario 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.
- **SCENARIO 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.

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

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

Survey

- A survey asking core modellers and supervisor (SK only at this point) was conducted and results collated.
- Questions focused on accomplishments in the last year and proposed work for upcoming calendar year.
- 25 responses (only 3 still waiting)
- Propose to conduct same survey with core teams in UW, WLU and Mac.
- Included pillar project scientist doing focused d modelling work.

Survey Results

- Clear Point of collaboration are occurring at a variety of levels.
  - Geographic (i.e. similar or nested watersheds)
  - Model Synergy (e.g. non-point pollution models, temperature models, Snow and glacier model testing etc..)
  - Tool Development and needs (e.g. CRHM-R, MESH-R, Caspar)
  - New Process models (e.g. moving CRHM model processes into MESH)
  - Others as well.
  - Tying into pillar projects
- 25 responses (only 3 still waiting) from SK
- Propose to conduct same survey with core teams in UW, WLU and Mac next week.
- Excellent Progress but lots left to do….

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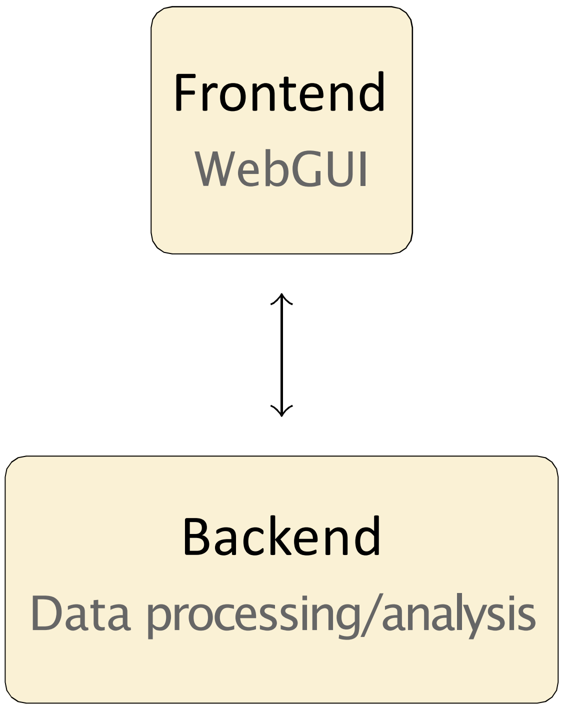
Caspar – Example of cooperative tool development

Juliane Mai, Jimmy Lin, Zhenhua Li, Homa Kheyrollah Pour, Martin Gauch, Yixin (Ethan) Wang, Luchen Tan, Yanping Li, Alain Pietroniro

GWF data Cuizinart – General Architecture – Advancing Visualization



meta-data browsing

region, time period, variable selection

slicing & dicing of large NetCDF datasets

GWF data Cuizinart
– Current Implementations –

already exists

CaSPAr
Canadian Surface Prediction Archive

FloodNet
NSERC

ArcGIS Frontend

↕

SLURM Backend

proprietary = bad

Graham

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GWF data Cuizinart – Current Implementations –

already exists		Demo/ Prototype	
ArcGIS Frontend	proprietary = bad	React Frontend	open-source = good
↕		↕	
SLURM Backend	Graham	SLURM Backend	same as CaSPAr

CaSPAr Canadian Surface Prediction Archive
FloodNet NSERC
GWF

GWF data Cuizinart – Current Implementations –

already exists

CaSPAr
Canadian Surface Prediction Archive

FloodNet
NSERC

ArcGIS Frontend

↕

SLURM Backend

proprietary = bad

Graham

Demo/ Prototype

GWF

React Frontend

↕

SLURM Backend

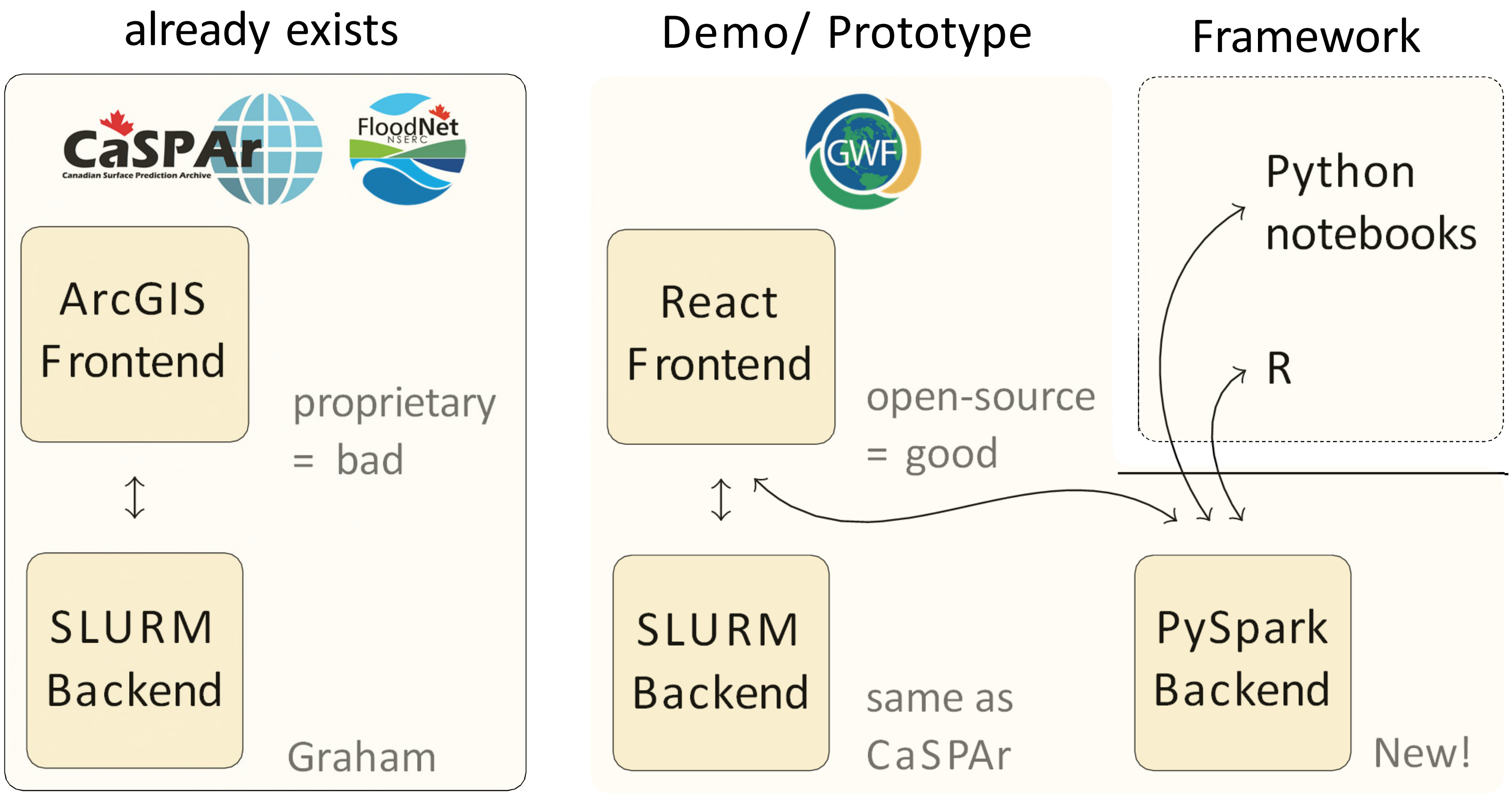
PySpark Backend

open-source = good

same as CaSPAr

New!

GWF data Cuizinart
– Current Implementations –



GWF data Cuizinart

GLOBAL WATER FUTURES
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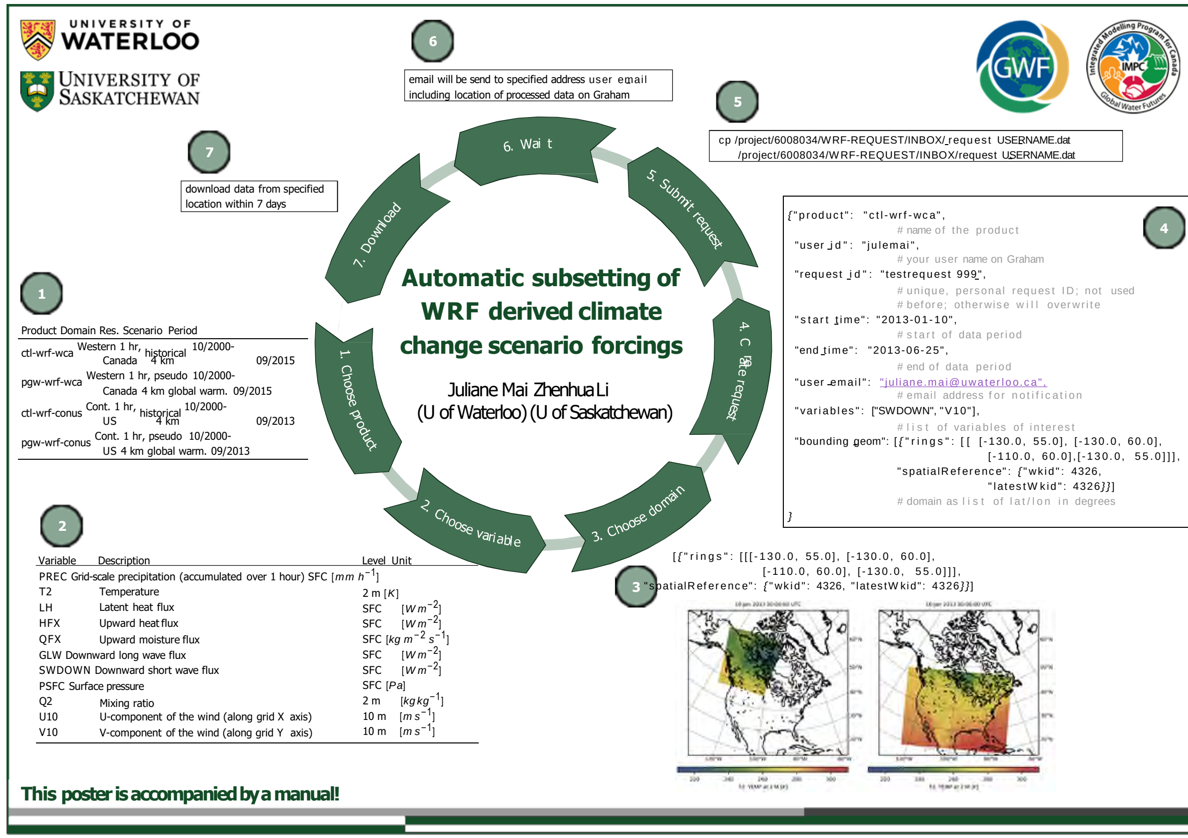
– Dissemination of Large Gridded Datasets Within and Beyond GWF –

- **Team**: Juliane Mai, Jimmy Lin, Zhenhua Li, Al Pietroniro, +
- **CaSPAr-like tool** to archive, distribute and publish large gridded datasets
- **Data** available at the moment are 4 different version of WRF runs
- **Backend** presented July 2018 (no data)



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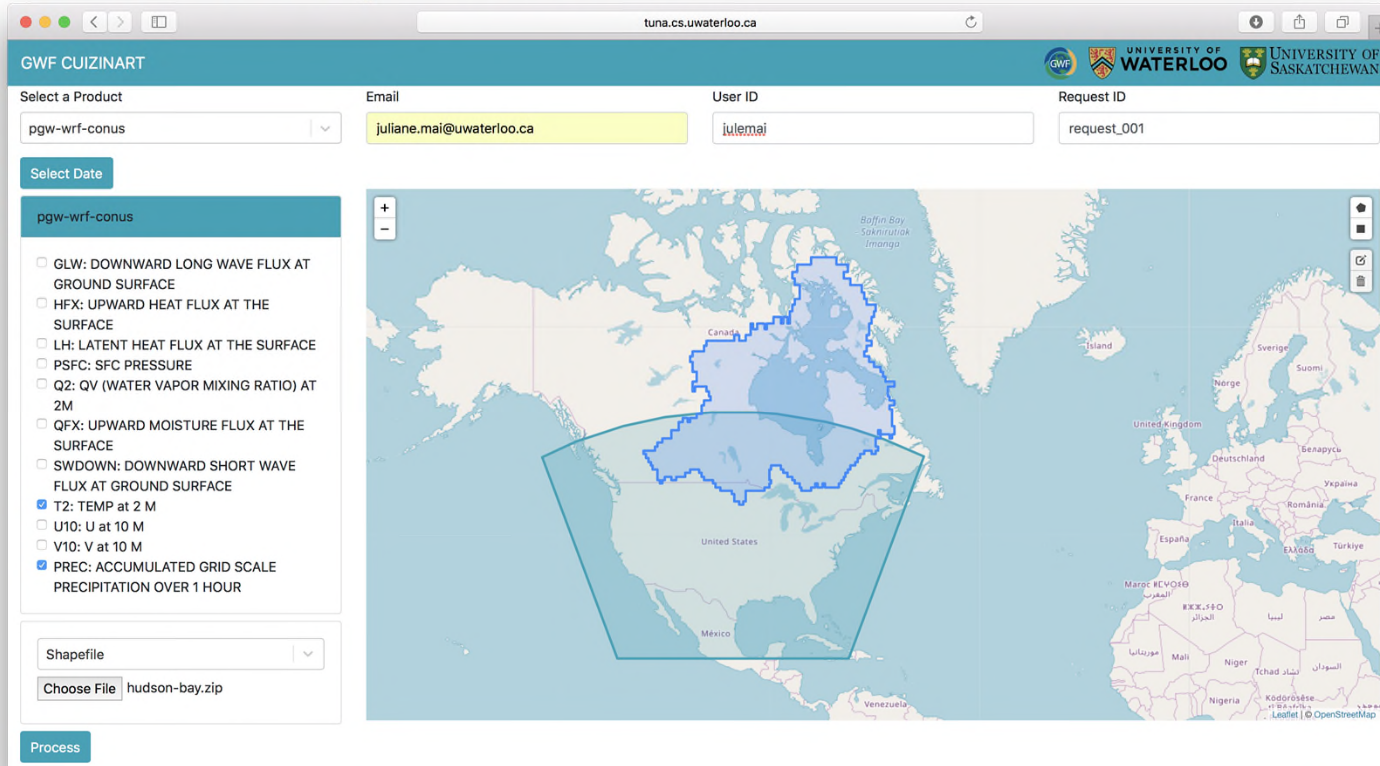
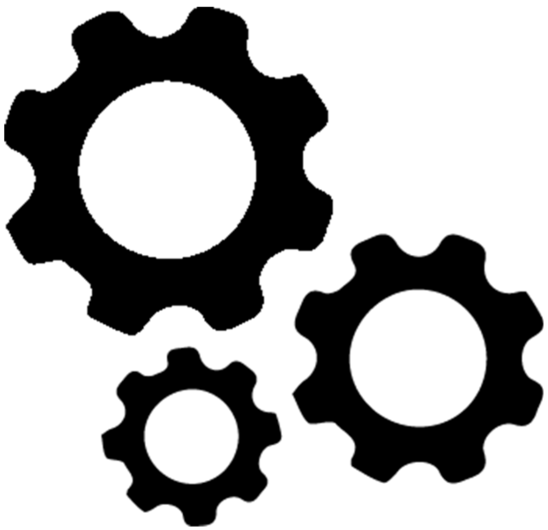
GWF data Cuizinart – Dissemination of Large Gridded Datasets Within and Beyond GWF –



Frontend of GWF Cuizinart with domain selected by shapefile upload (or GeoJSON or drawing)

GWF data Cuizinart – Dissemination of Large Gridded Datasets Within and Beyond GWF –



Backend processing on Graham based on Python and GDAL (Julie)

Second backend under development based on PySpark (Jimmy)

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GWF data Cuizinart – Dissemination of Large Gridded Datasets Within and Beyond GWF –

```
Downloads — ssh ◂ scp -r julemai@gra-platform.computecanada.ca:/project/6008034/WRF-REQUEST/OUTBOX/julemai_reque...
Last login: Fri Jan 18 13:25:42 on ttys000
[j6mai@v1020-wn-220-182:/Users/j6mai/Downloads/]:
[scp -r julemai@gra-platform.computecanada.ca:/project/6008034/WRF-REQUEST/OUTBOX/julemai_request_001 .  ]
CHECKED                                                                    100%  261     5.6KB/s   00:00
report.check                                                               100%   40     0.8KB/s   00:00
REQUEST                                                                    100%   11KB 232.8KB/s   00:00
request.check                                                              100%   40     0.8KB/s   00:00
201001.nc                                                                    3%   16MB 724.5KB/s   09:39 ETA_
```

Data retrieval via SCP (requires Graham account)

r.-ToDo: Will be changed to Globus to enable retrieval for everybody

GWF data Cuizinart – Dissemination of Large Gridded Datasets Within and Beyond GWF –

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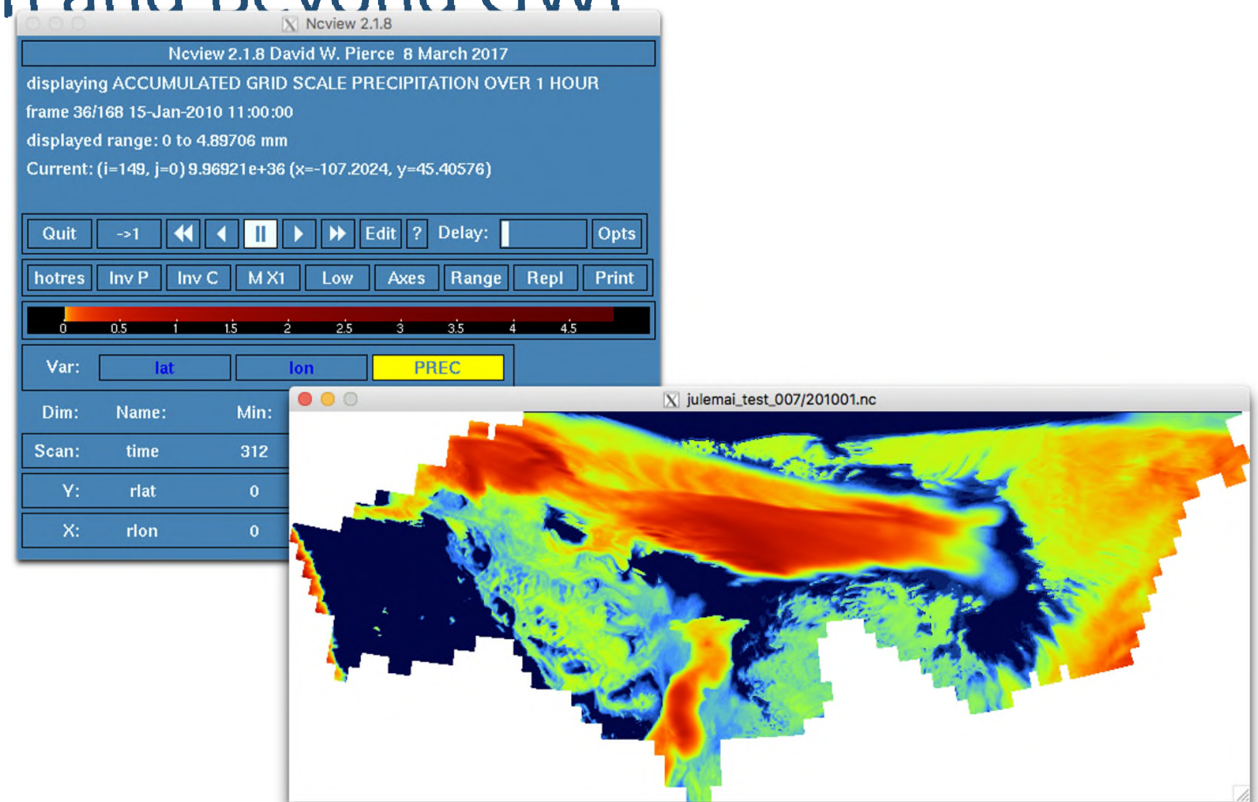

Cropped data in CF-1.6 compliant NetCDF format

Global Water Futures

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