Improved Processes & Parameterisation for Prediction in Cold Regions

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A Network of the

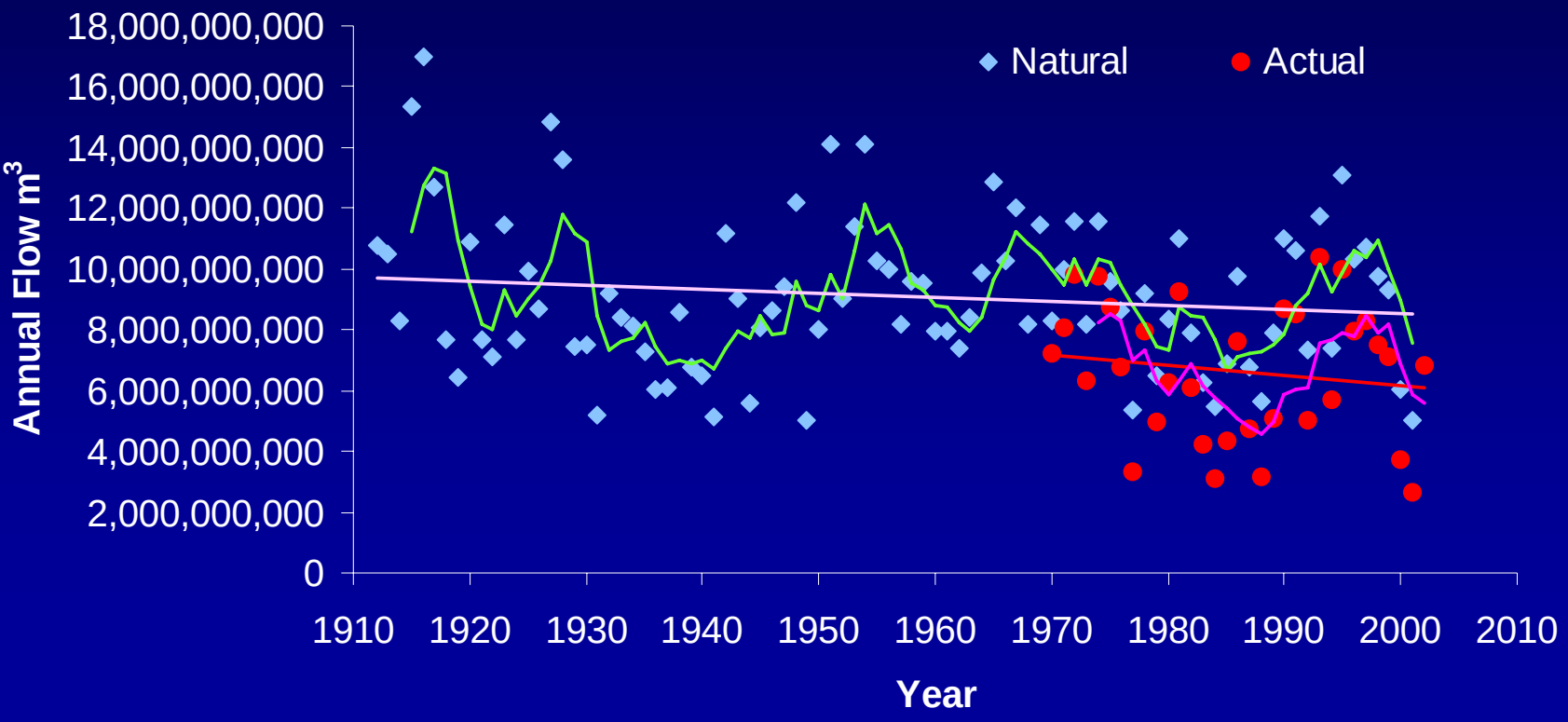
Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)

Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

Background

- Declining annual or earlier peak discharge in many cold regions streams and rivers (Rockies and Northern Canada)
- Increasing consumptive use of Rocky Mountain water in Prairie Provinces
- Uncertainty in engineering design for small to medium size ‘ungauged’ basins undergoing resource development and restoration (oil & gas, diamond mines, other mines)
- Opportunity to couple atmospheric-hydrological models with cold regions components for forecasting weather generation, streamflow to Arctic Ocean, flooding, improved climatology

Naturalized Flow of South Saskatchewan River entering Lake Diefenbaker

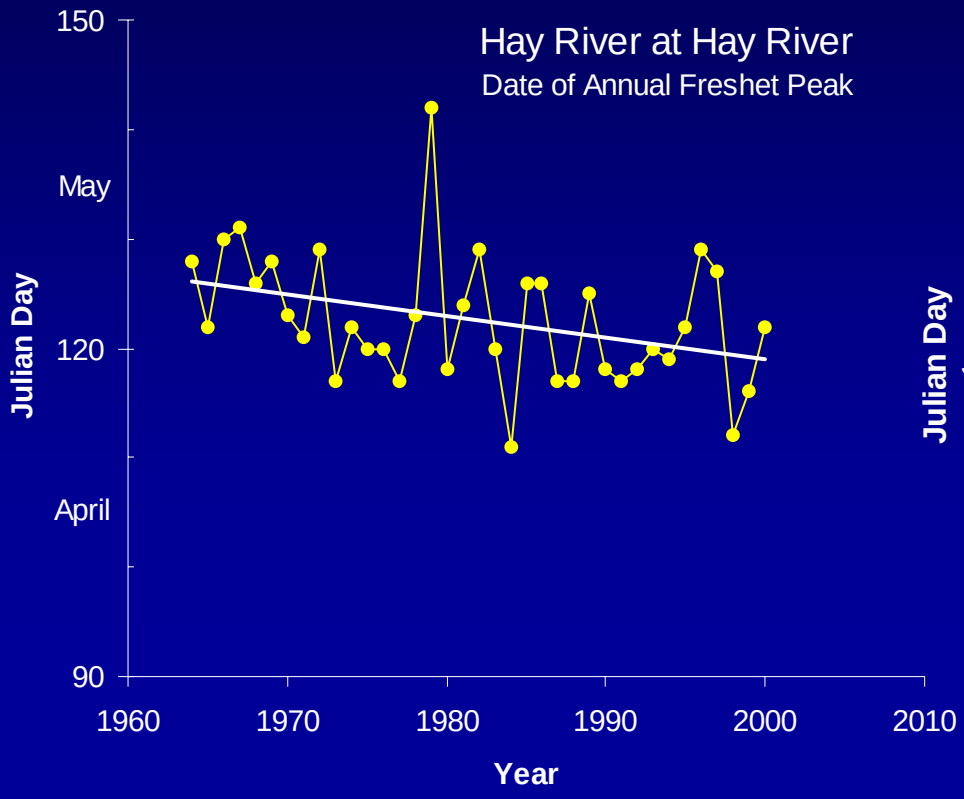


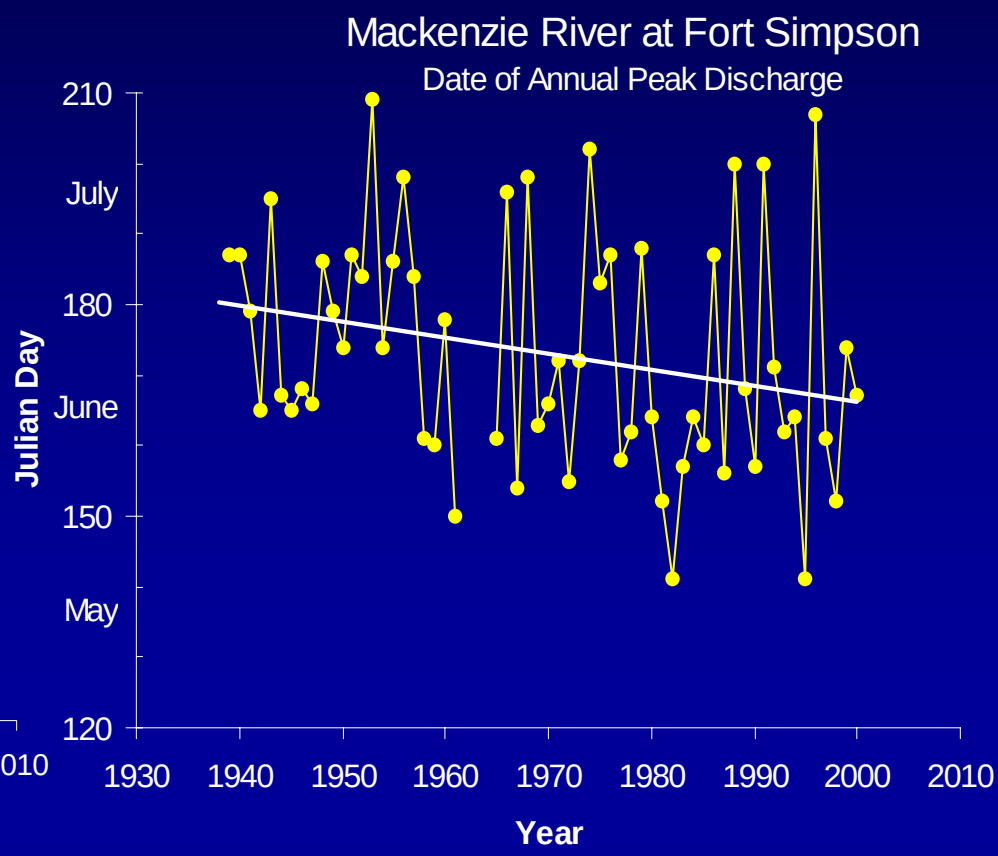
Decline of ~1.5 billion m^3 over ~90 years (~ -15%) in natural flow

Decline of ~1.1 billion m^3 over ~30 years (~ -15%) in actual flow

Upstream consumption of naturalized flows up to 7%-42% in last 15 years

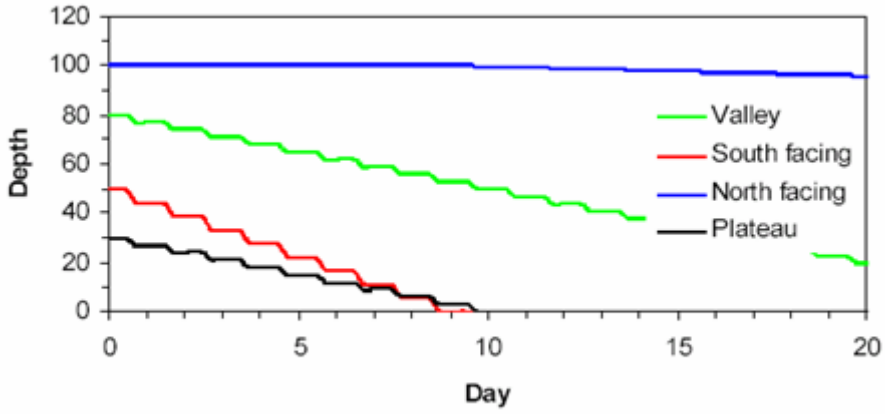
Date of Spring Freshet

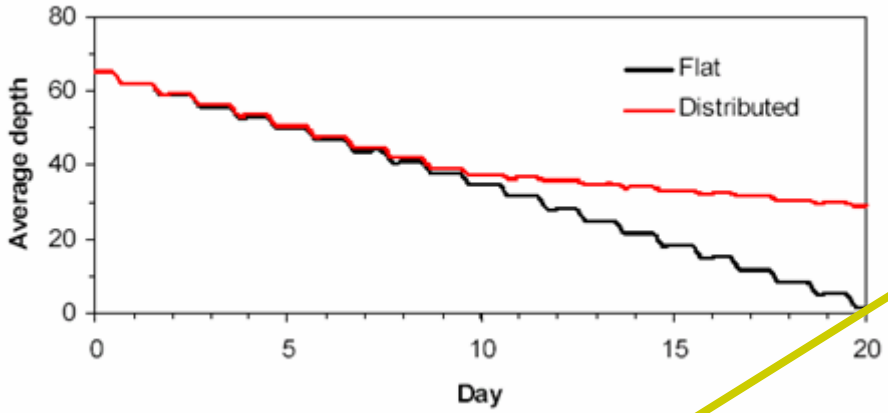


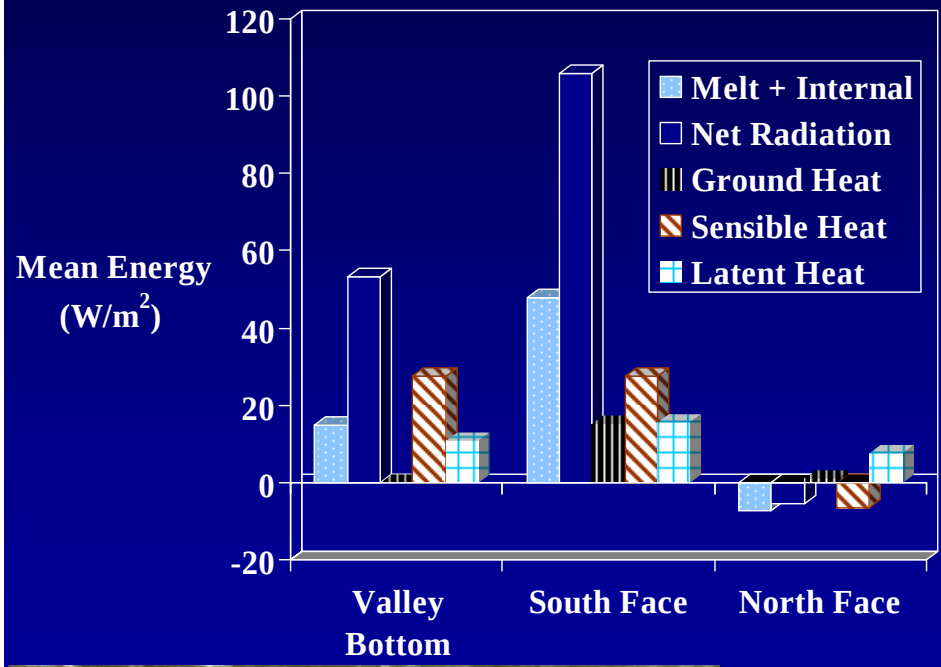


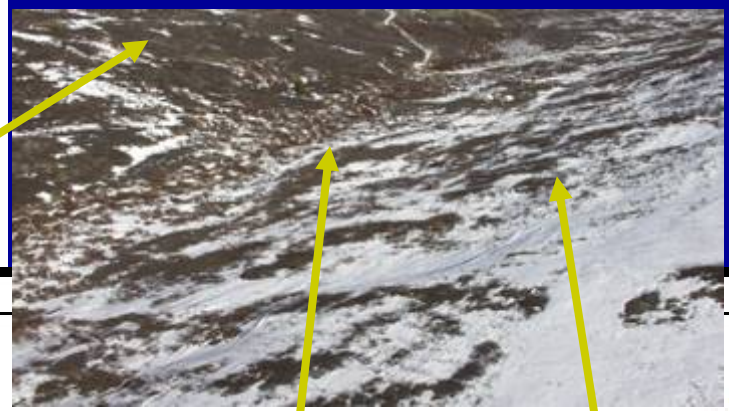
Courtesy Derek Faria, INAC

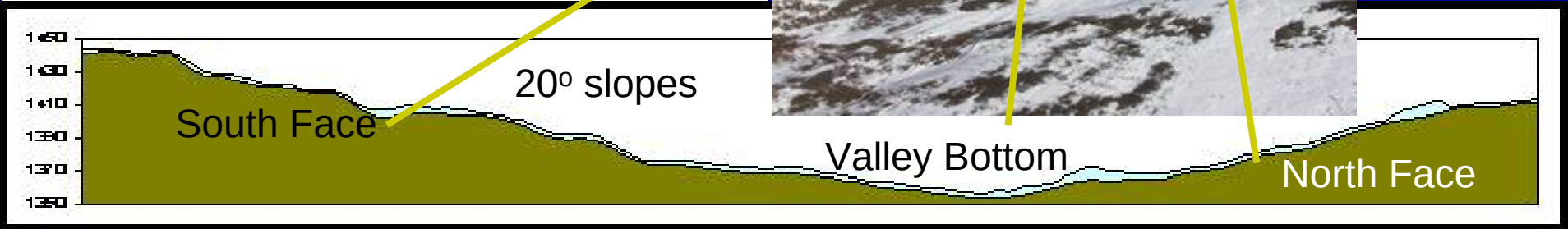
Cold Regions Hydrology on Complex Terrain



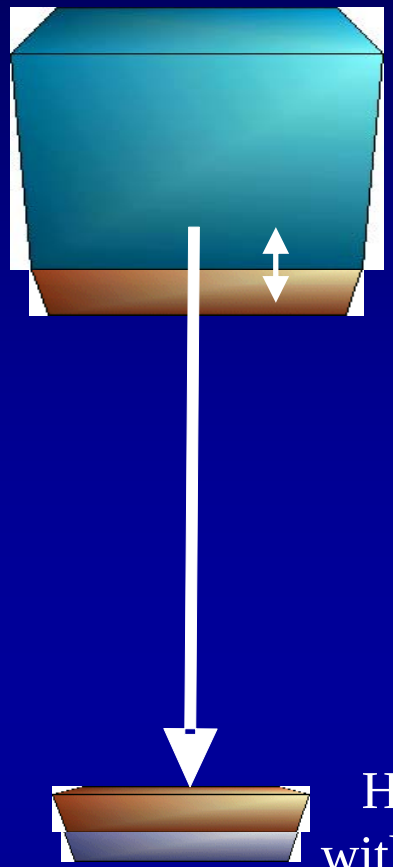








Hydrometeorological Prediction: Current Paradigm - uncoupled



Atmospheric
model (3D)
with its own
surface scheme (1D)

Extracted atmospheric
model forcing

Hydrological model (lumped or 2D)
with its own land-surface scheme (LSS)

IP3 Targets

- Understanding key climate system processes relating to the hydrometeorology of cold regions,
- Parameterizing the land surface hydro-meteorological processes that control the coupled atmospheric-hydrological system in cold regions;
- Validating and improving models for weather, water and climate systems leading to better prediction and simulation of related atmospheric impacts on water resources and surface climates in cold regions.

IP3 – Goals and Theme Structure

- ***Theme 1 Processes:*** Advance our understanding of cold regions hydrometeorological processes
- ***Theme 2 Parameterisation*** Develop mathematical parameterisation of cold regions processes for small to medium scales
- ***Theme 3 Prediction*** Evaluate and demonstrate improved hydrological and atmospheric prediction at regional and smaller scales in the cold regions of Canada
- *Ultimately* – contribute to multiscale assessment of coupled climate system, weather and water resources in cold regions

IP3 Methodology

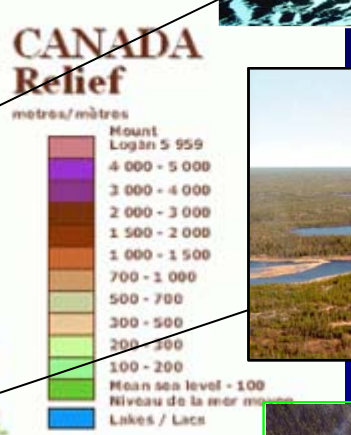
- Multiple-scale near-surface observations of snow, water body, frozen soil and permafrost mass and energy fluxes at IP3 research basins.
- Development of improved process algorithms for small to medium scales, evaluated at IP3 research basins
- Incorporation of improved process parameterisations into coupled land surface – hydrology models
- Simulation of water resources and the near-surface atmospheric fluxes at multiple scales in cold regions
- Evaluation of progress in coupled model predictions of discharge, water storage, water balance, snow cover, soil moisture, soil frost, evaporation at IP3 research basins and in larger domains.

Processes and Parameterisation of

- Cold Regions Terrestrial System
  - Drainage network connectivity
  - Frozen soil infiltration and drainage
- Cold Regions Open Water
  - Ice growth and decay, snow on lake ice
  - Advection of energy to small lakes
- Snow and Ice Processes
  - Snow Redistribution
  - Spatial variability of snowmelt
  - Improved turbulent transfer in complex terrain
  - Glacier-scale katabatic cooling effects
  - Upscaling turbulent transfer relationships

IP3 Research Basins – multiscale observations of cold regions hydrology and meteorology

IP3 Research Basins



Havikpak Creek,
taiga woodland

Trail Valley Creek,
arctic tundra

Baker Creek,
Subarctic shield lakes

Wolf Creek,
subarctic tundra cordillera

Scotty Creek,
permafrost wetlands

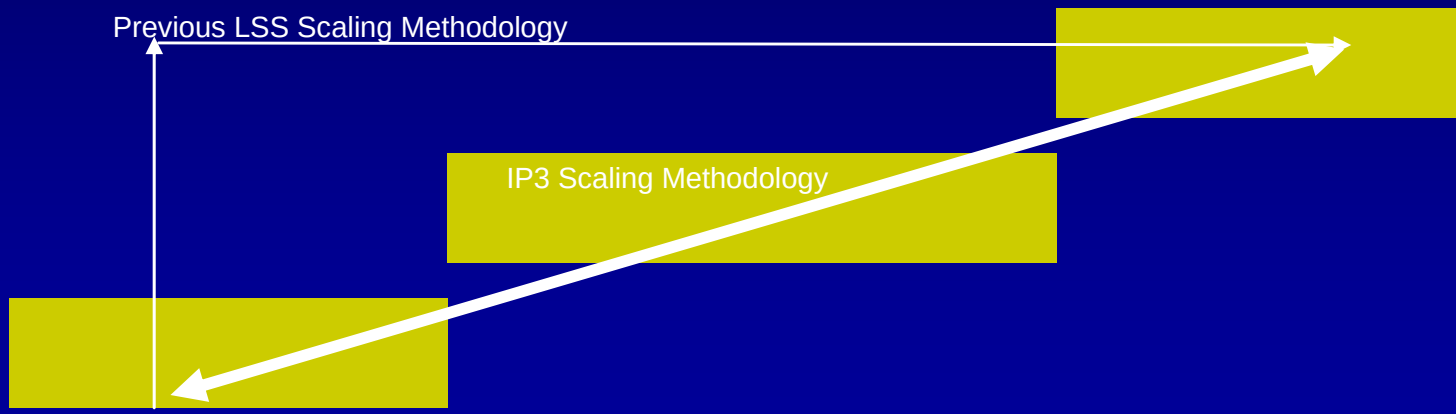
Peyto Creek,
glacierized alpine

Lake O'Hara,
wet alpine

Marmot Creek,
Dry subalpine

Scaling

	Resolution	1 m	100 m	100 m - 2 km	2 - 10 km	10 km -	10 km
			Landscape type	Pattern/tile			
		Tile/HRU	Tile/HRU	Grid/small basin	Multi-grid/medium basin	Multi-grid	
		Point	Hillslope	Sub-basin	Basin	Mesoscale	Regional;
Prediction	Terrestrial						
	Open Water						
	Snow and Ice						
Parametrization	Terrestrial						
	Open Water						
	Snow and Ice						
Process	Terrestrial						
	Open Water						
	Snow and Ice						
MODELS		CHRM	CHRM	MESH CHRM CEOP Hydrology	MESH CHRM CEOP Hydrology	MESH	MESH



Quinton CFCAS Study---------->

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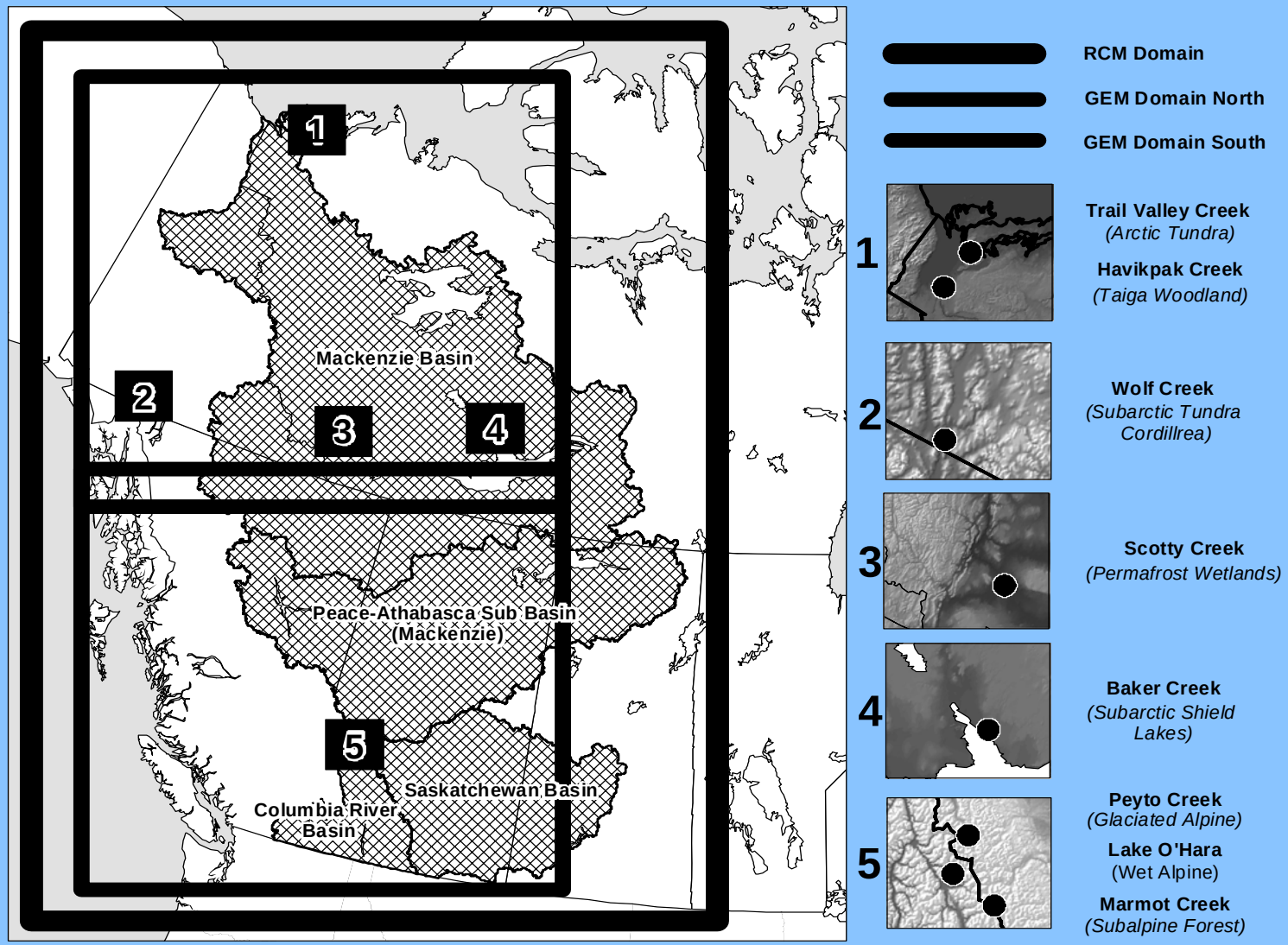
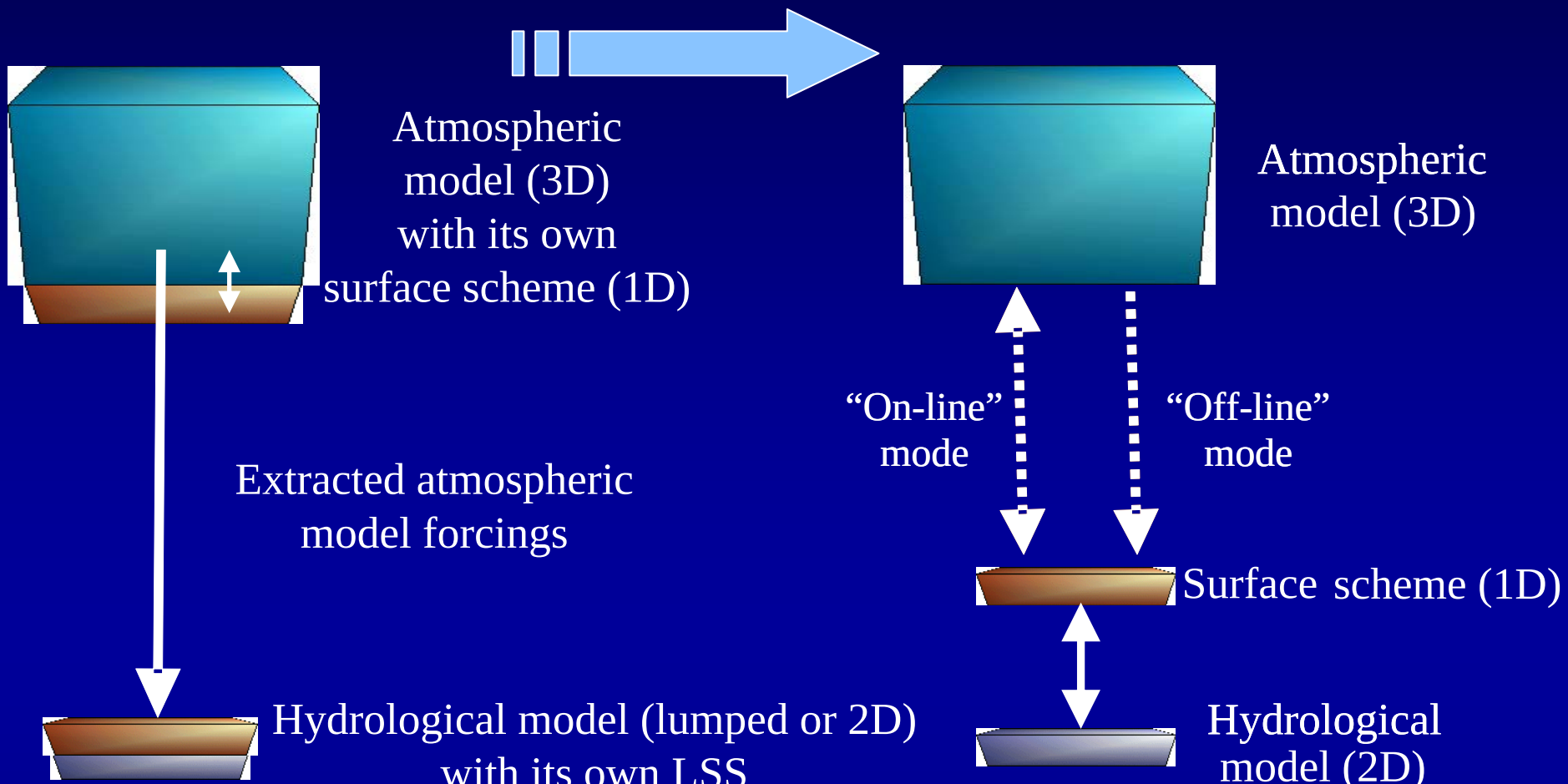
Integrating the TOP DOWN and BOTTOM UP approaches

Prediction

- Cold Regions Hydrology Model at basin scale
- Land surface hydrology model evaluation and development
- Evaluation of GEM-LAM and CRCM



Modélisation Environnementale Communautaire, MEC



Anticipated Results: Processes

- New soil physics parameters for organic and frozen soils
- Control of lateral flow established for various cold regions environments
- Influence of glaciers on regional climate fields
- Improved turbulent transfer relationships over snow and glacier ice in complex terrain
- Improved short and longwave relationships for vegetation canopies on snow-covered slopes

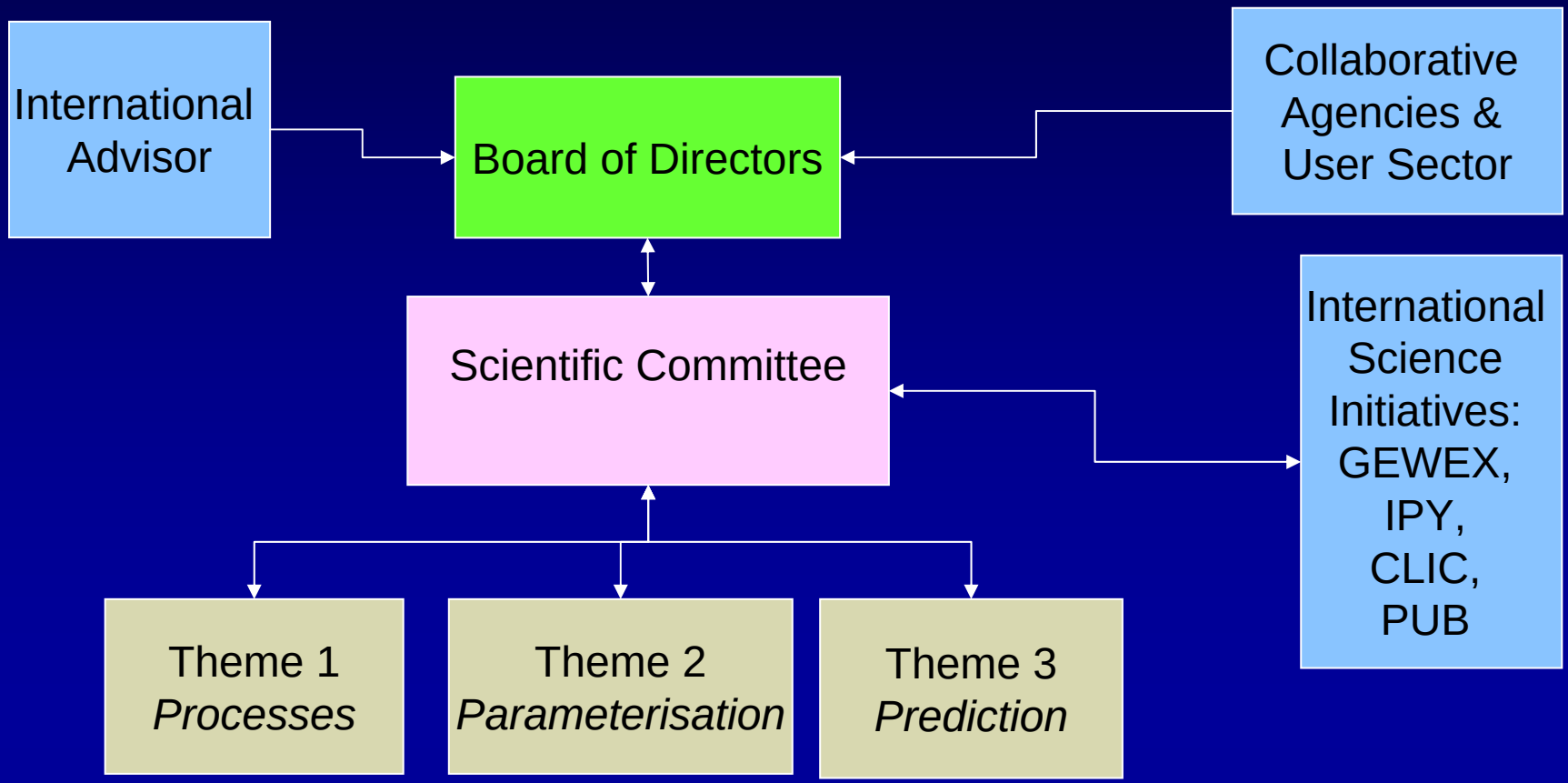
Anticipated Results: Parameterisation

- Runoff and streamflow – variable contributing area based on energy and moisture state, ‘fill and spill’ runoff
- Small lakes – advection, evaporation and lake ice effects
- Mass change, phase change, radiation and turbulent fluxes from snow – upscaled radiation and turbulent fluxes, snow covered area depletion, blowing snow redistribution

Anticipated Results: Prediction

- MESH for cold regions – developed and tested
- CRHM for small northern and mountain basins
- Improved prediction in ungauged basins – streamflow prediction with less calibration of model parameters from gauged flows
- Improved weather prediction – quantify importance of land-atmosphere feedback in cold regions
- Improved climate prediction – benefits to improved land surface scheme physics and parameterisation

IP3 Organisational Structure



IP3 Scientific Committee

- John Pomeroy, Chair
- Sean Carey, Theme 1, Processes
- Bill Quinton, Theme 2, Parameterisation
- Al Pietroniro, Theme 3, Prediction
- Diana Verseghy, member at large
- Network Manager, Secretary

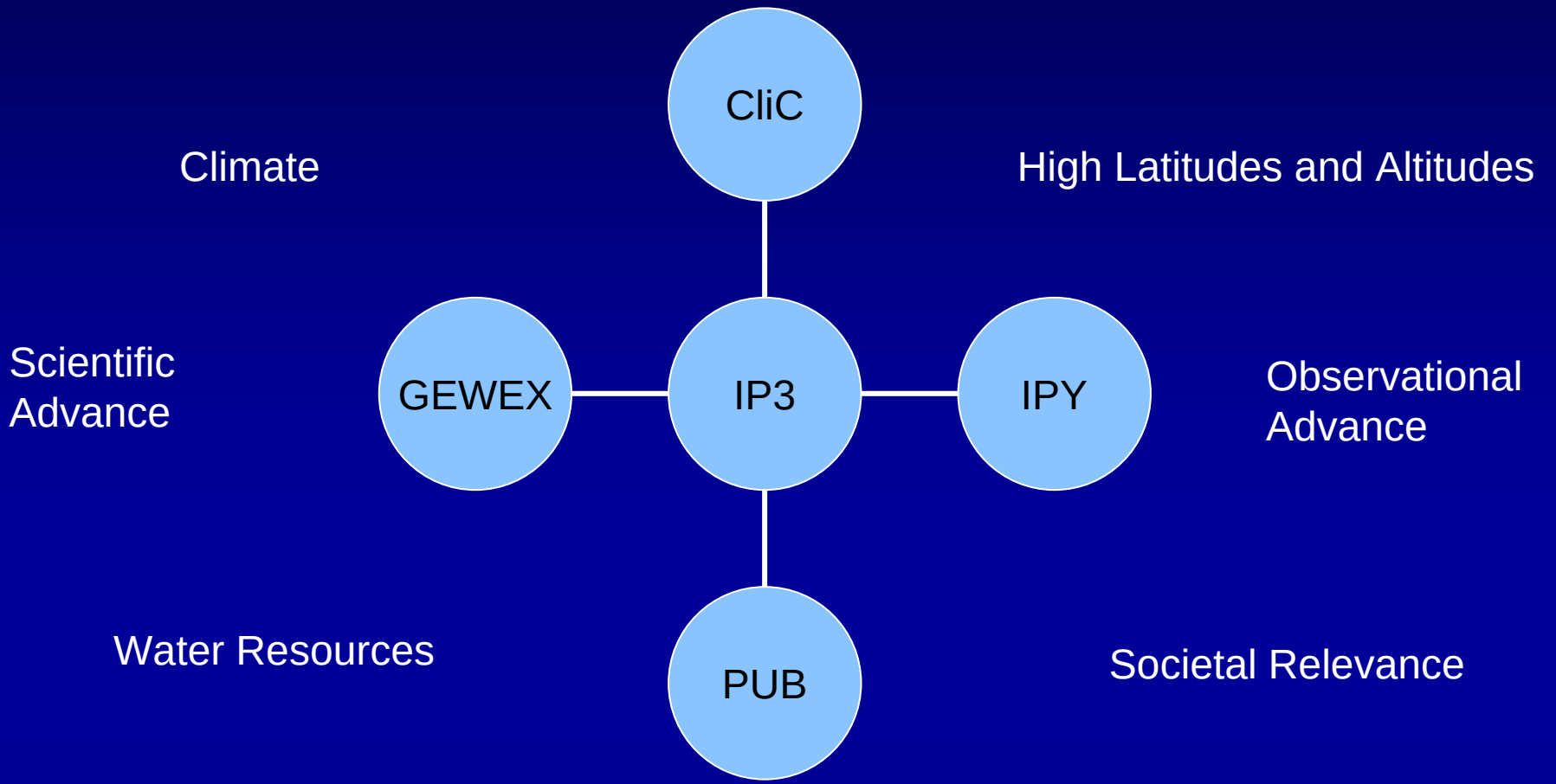
IP3 Board of Directors

- Hok Woo, Chair, McMaster Univ.
- Tim Aston, CFCAS
- Dan Moore, UBC
- John Pomeroy, PI
- Bob Reid, INAC, Yellowknife
- Vincent Fortin, EC, Montreal
- Network Manager, Secretary

IP3 Secretariat

- Network and Information Manager
  - Network Management
  - Finances
  - Web
  - Data
- GEM Modeller – NWP modeling for domains around study basins, coupled modelling
- CRHM Modeller – develop CRHM platform for general application in parameterisation studies

IP3 International Science Linkages



IP3 Outputs

- Improved understanding of cold regions hydrology at scales that were poorly understood
- Improved environmental predictive capability in cold regions at *requested spatial scales* by inclusion of improved processes, snow and ice, spatial patterns, frozen ground, drainage => CRHM, MESH
- Improved hydrological and atmospheric model performance at multiple scales, e.g. CRCM, GEM, MEC, ultimately GCM
- Unique observational dataset archive
- Enhanced Canadian capacity in cold regions hydrology and meteorology in response to greater water resource demands.