UNIVERSITY OF SASKATCHEWAN

Global Institute for Water Security

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Impact of climate and associated land cover changes on the hydrology of the Mackenzie River Basin

Mohamed Elshamy, Alain Pietroniro, and Howard Wheater

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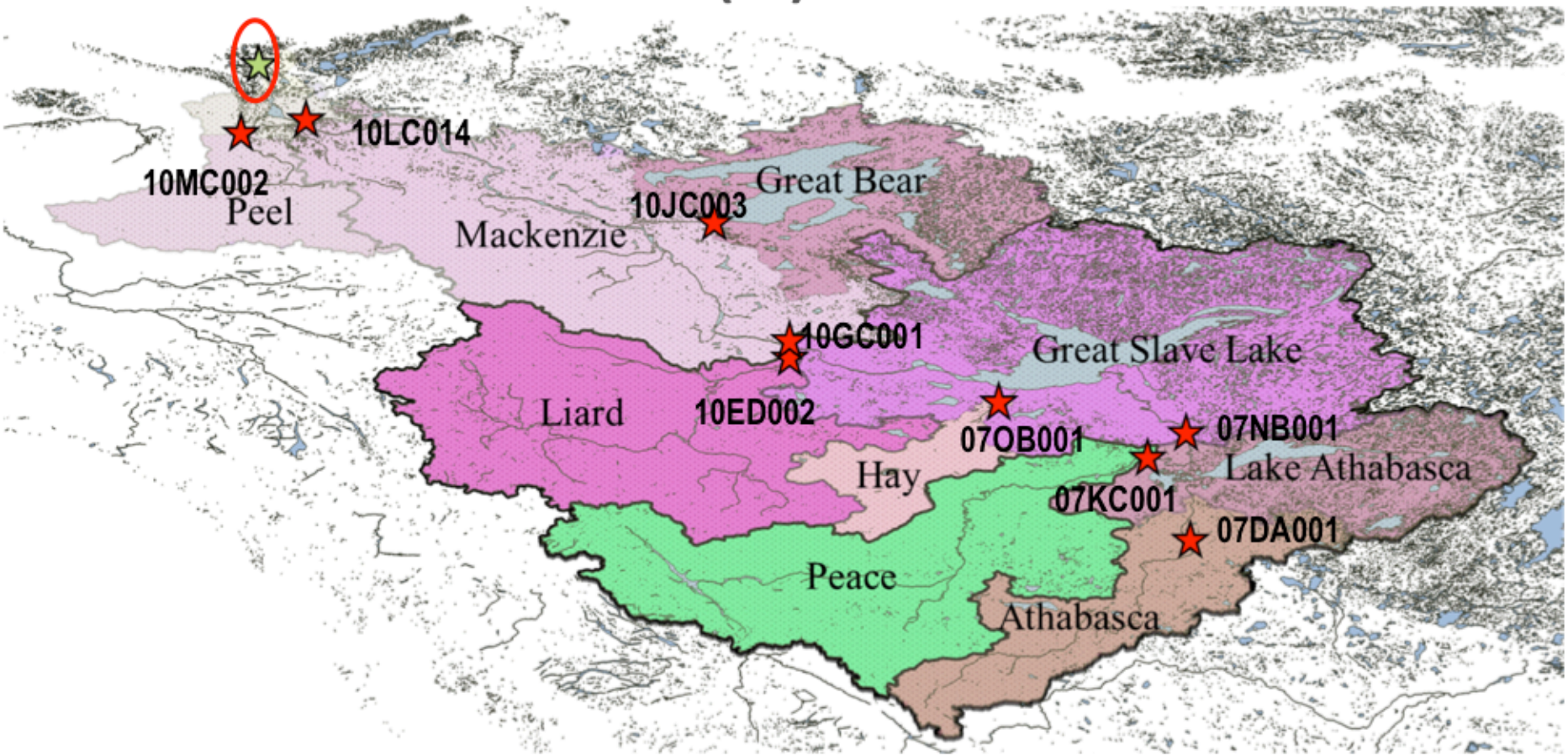
Outline

- Objectives
- MRB – Overview
- Model Configuration and Validation for MRB
- Permafrost
- Future Scenarios
- Preliminary Results – Impacts on Streamflow and ALD
- Conclusions and Way Forward

MRB MODELLING: OBJECTIVES

1. To improve large scale modelling for operational management and transboundary water resource planning
2. To simulate scenarios of changing flow regimes under climate and land use/cover change
3. To Investigate the uncertainty of hydrological simulations to climatic forcing (Current and Future)

MRB – Overview (1)



MRB extends between 102-140° W and 52-69° N

MRB Model 19,598 grid cells, 11/12 GRUs, 1.755 M Km^2

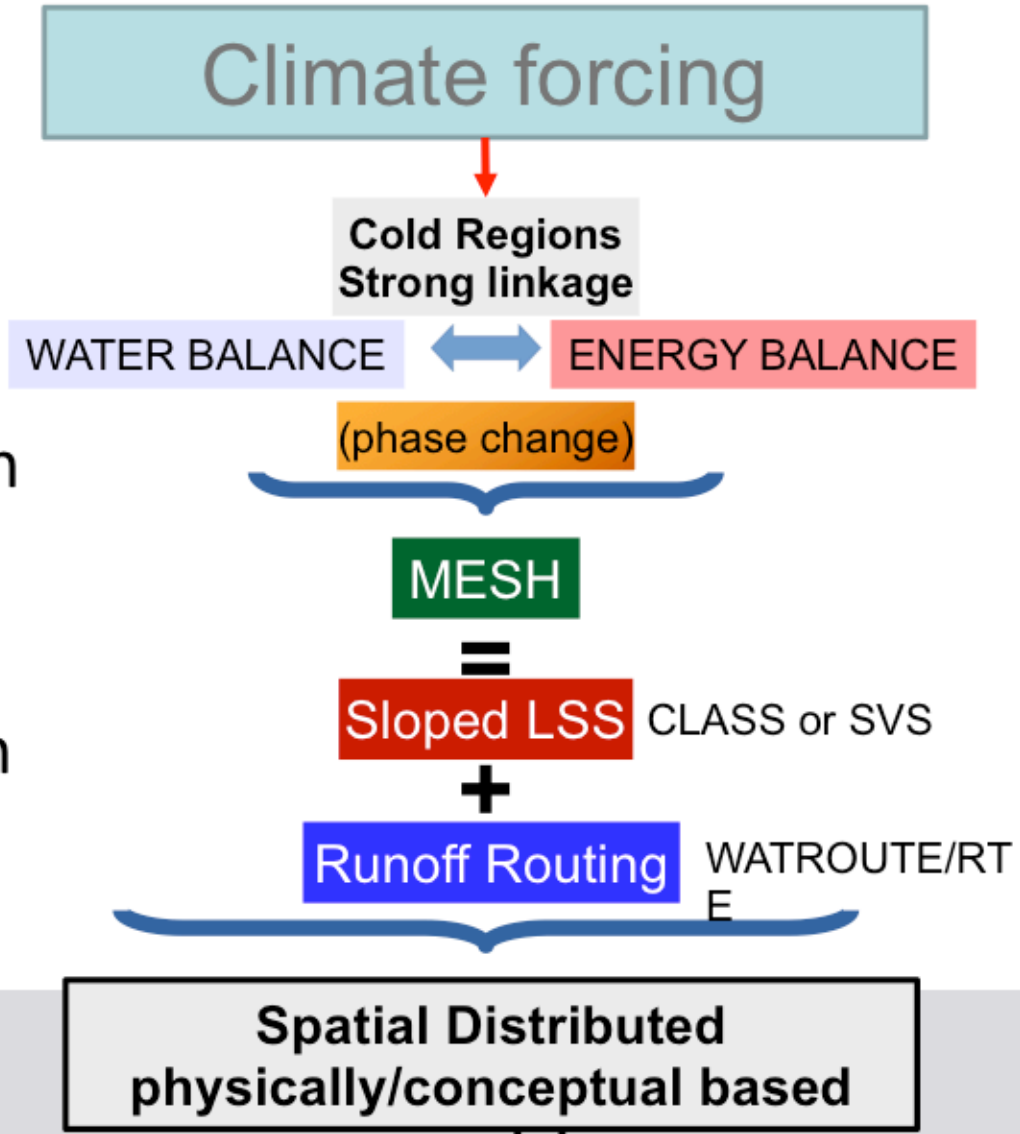
MRB – OVERVIEW (2)

Sub-basin	Outlet Station	Area (km^2)	Flow (BCM/yr)	MAP (mm/yr)	RF
Athabasca	Athabasca@Fort McMurray	132,057	17.37	504	26%
Peace	Peace@Peace Point	300,360	61.96	553	37%
Lake Athabasca*	Slave@Fitzgerald	597,219 164,802	100.76 21.43	512 444	33% 29%
Hay	Hay@Hay River	51,531	3.78	428	17%
Liard	Liard nr Mouth	272,956	85.64	613	51%
Great Slave Lake+	Mackenzie@Fort Simpson	1,294,903 373,197	224.07 33.89	490 373	35% 24%
Great Bear Lake	Great Bear River@outlet	146,629	18.62	338	38%
Mackenzie#	Mackenzie@Artic Red River	1,685,073 243,541	305.24 62.55	474 471	38% 55%
Peel	Peel above Fort McPherson	70,748	21.15	535	56%
Whole Mackenzie!	Outlet	1,775,101 19,280	332.11 5.72	475 535	39% 55%

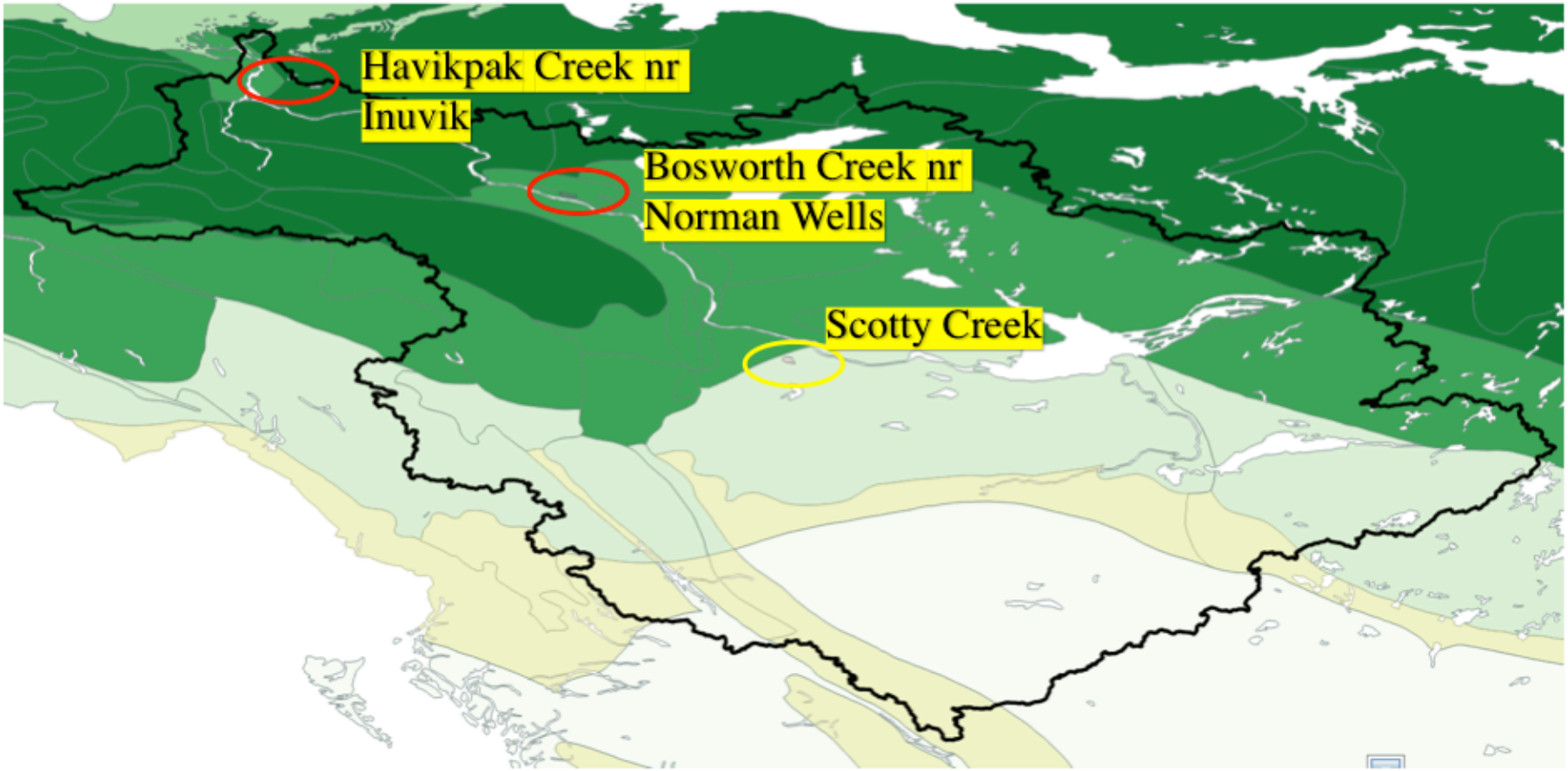
Using CaPA Precipitation and Observed Flows for

MESH Framework

- Requires detailed climate Forcing (7 variables – Subdaily)
- Requires information about drainage between different cells (derived from DEM)
- Requires information on Soil and land use/cover



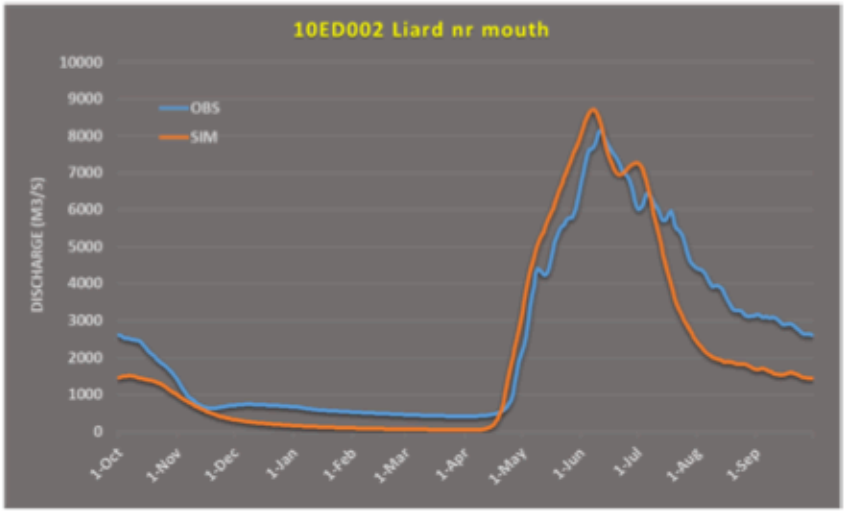
Permafrost – Importance & Study Locations

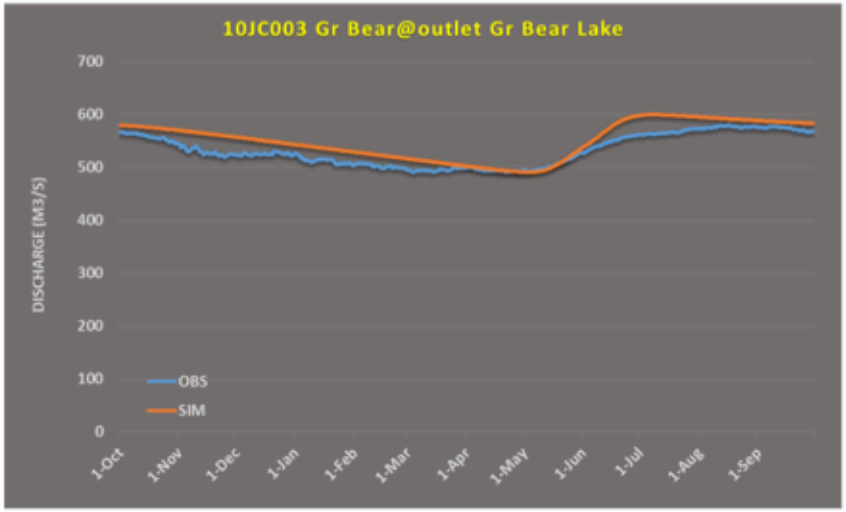


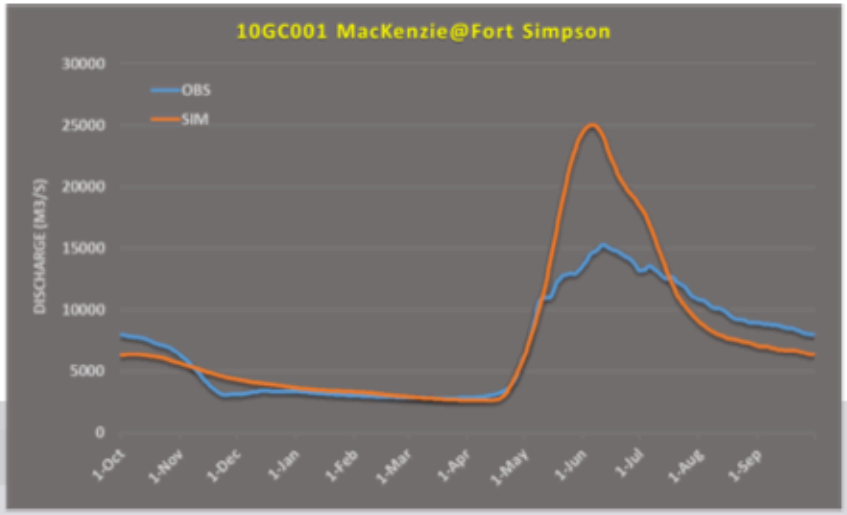
Model Configuration & Validation

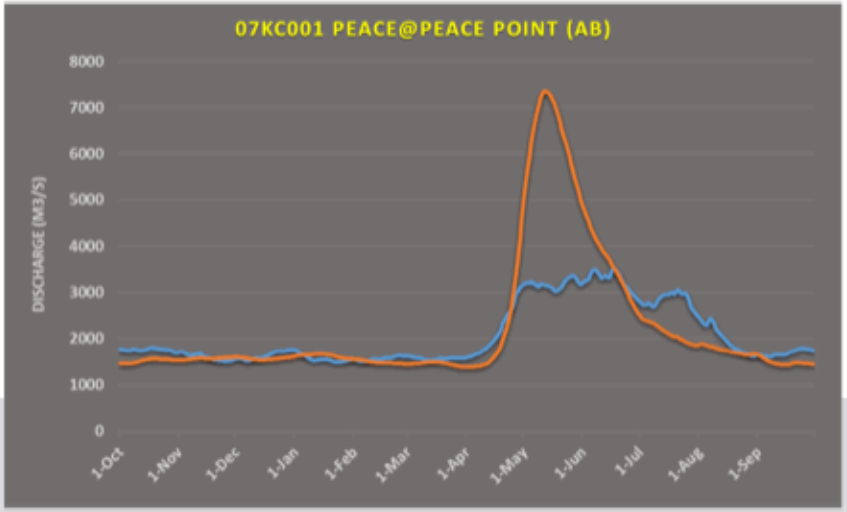
- Spatial resolution: 0.125° ≈ 10 km
- Checked drainage directions such that sub-basin areas/shapes are compatible with WSC shapes for about 270 gauges
- 11 GRUs (12 after splitting East/West)
- 21 Natural Lakes are explicitly included + Dynamically Zoned Reservoir Scheme for Bennet Dam
- Distributed Soil Texture & Depth to Bedrock
- Deep soil profile (24L – 50m) to represent Permafrost
- Calibration of two major sub-basins (Liard and Great Bear) and the generalization of parameters for others
- Validation of Active Layer Depth and Temperature Profiles at few points with Permafrost observations
- Spinning Strategy was devised for Permafrost initialization

Model Performance (2)

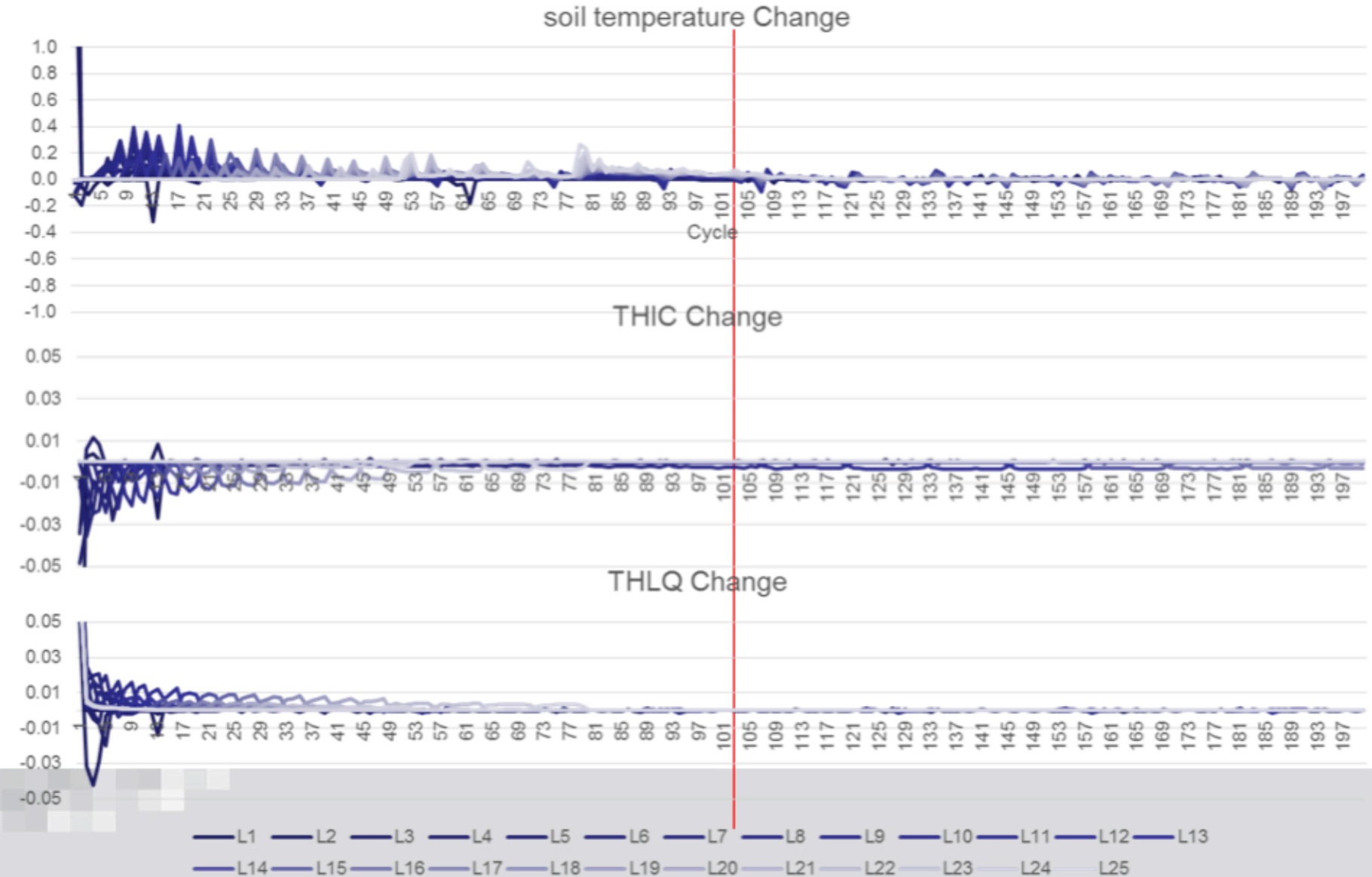




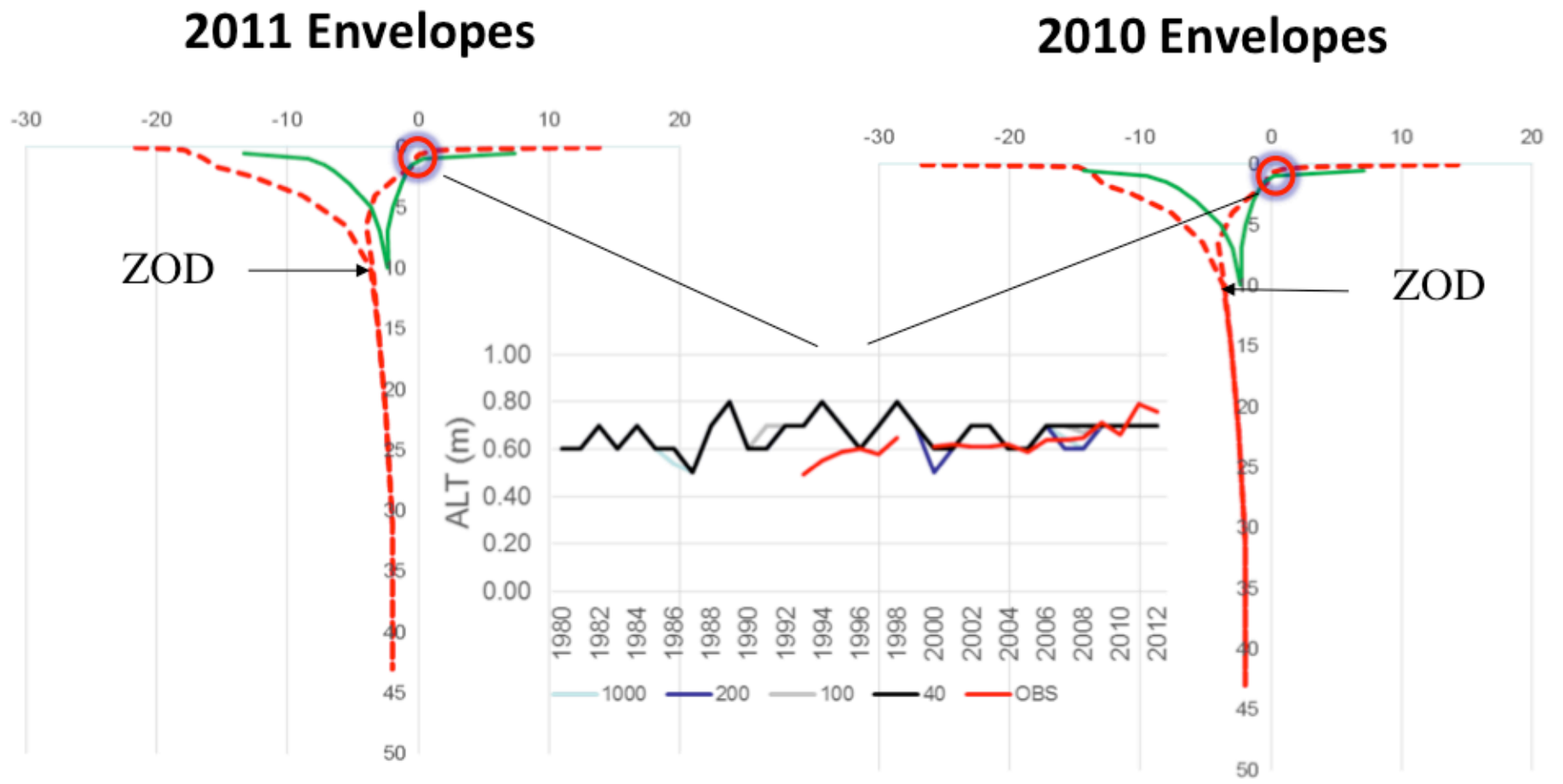




HavikPak Creek (HPC) – Spinning



HPC Forest GRU - Permafrost



Simulations: HPC forced with WFDEI 1979-2012 + Inuvik Temp, spun 200 cycles using 1/10/1979-30/9/1980 and run 1/10/1979-31/12/2012 - FOREST
Temp Observations: Inuvik Airport Site 01TC2 (Tree) – just outside the basin

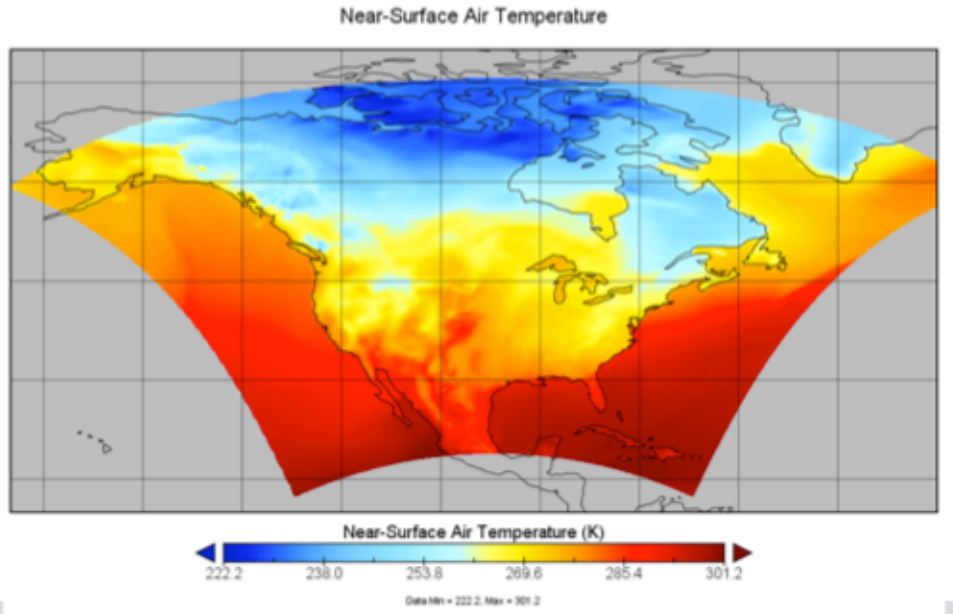
Mapping Active Layer Depth 1980-2010

Future Scenarios

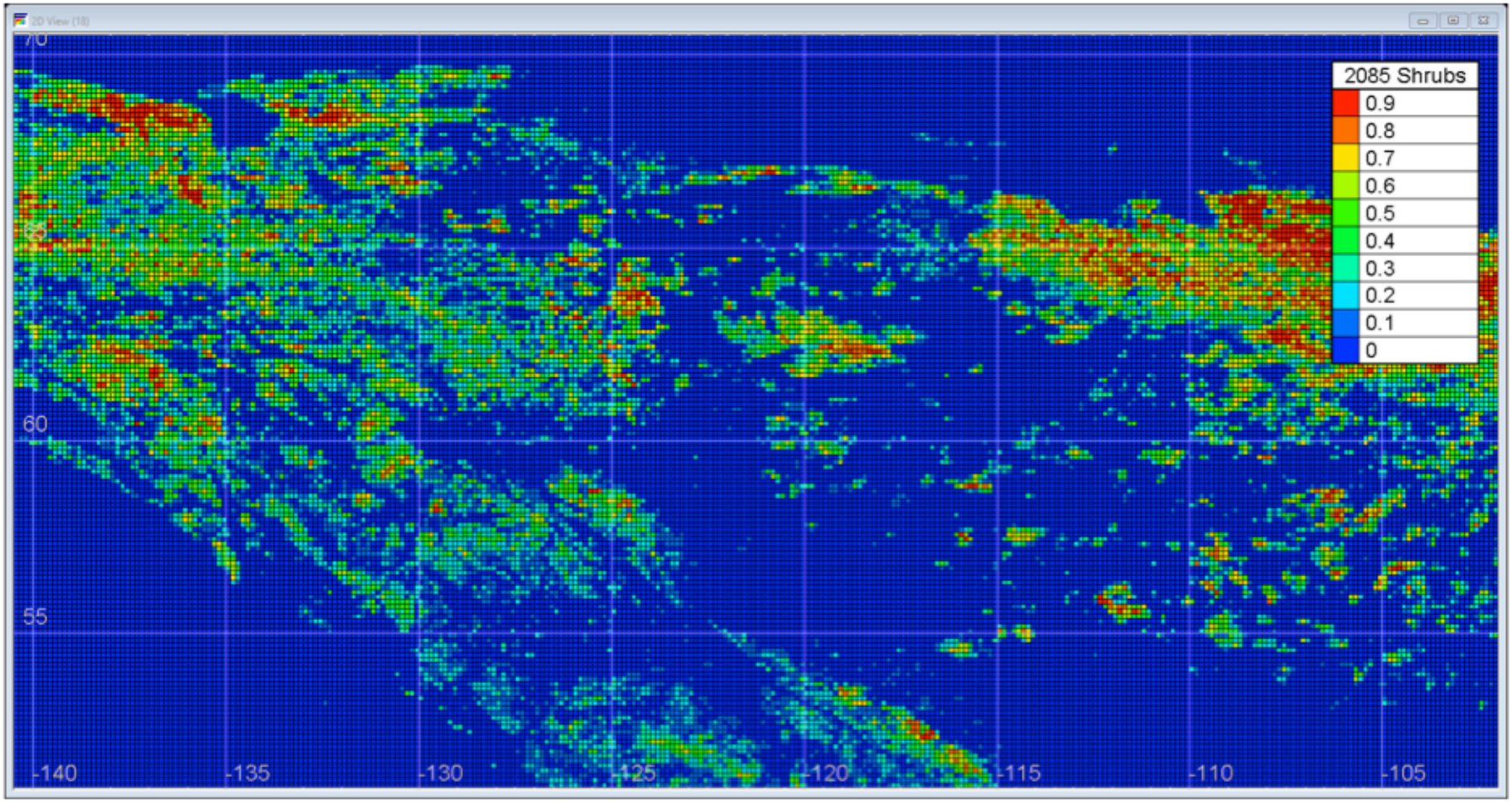
- Climate Change only (CC)
  - CanRCM4 – Bias Corrected by WFDEI-GPCC
- Climate Change + Land Cover/Use Change (CC+LC)
  - Land cover changed in 2040 and 2085
  - Glacier retreat based on Garry Clarke (2015) results uner CanESM2-RCP8.5
- Climate Change + Land Cover/Use Change + Water Management (CC+LC+WM)
  - Site C Dam
  - Activate Irrigation & Diversions

Future Scenarios – Climate

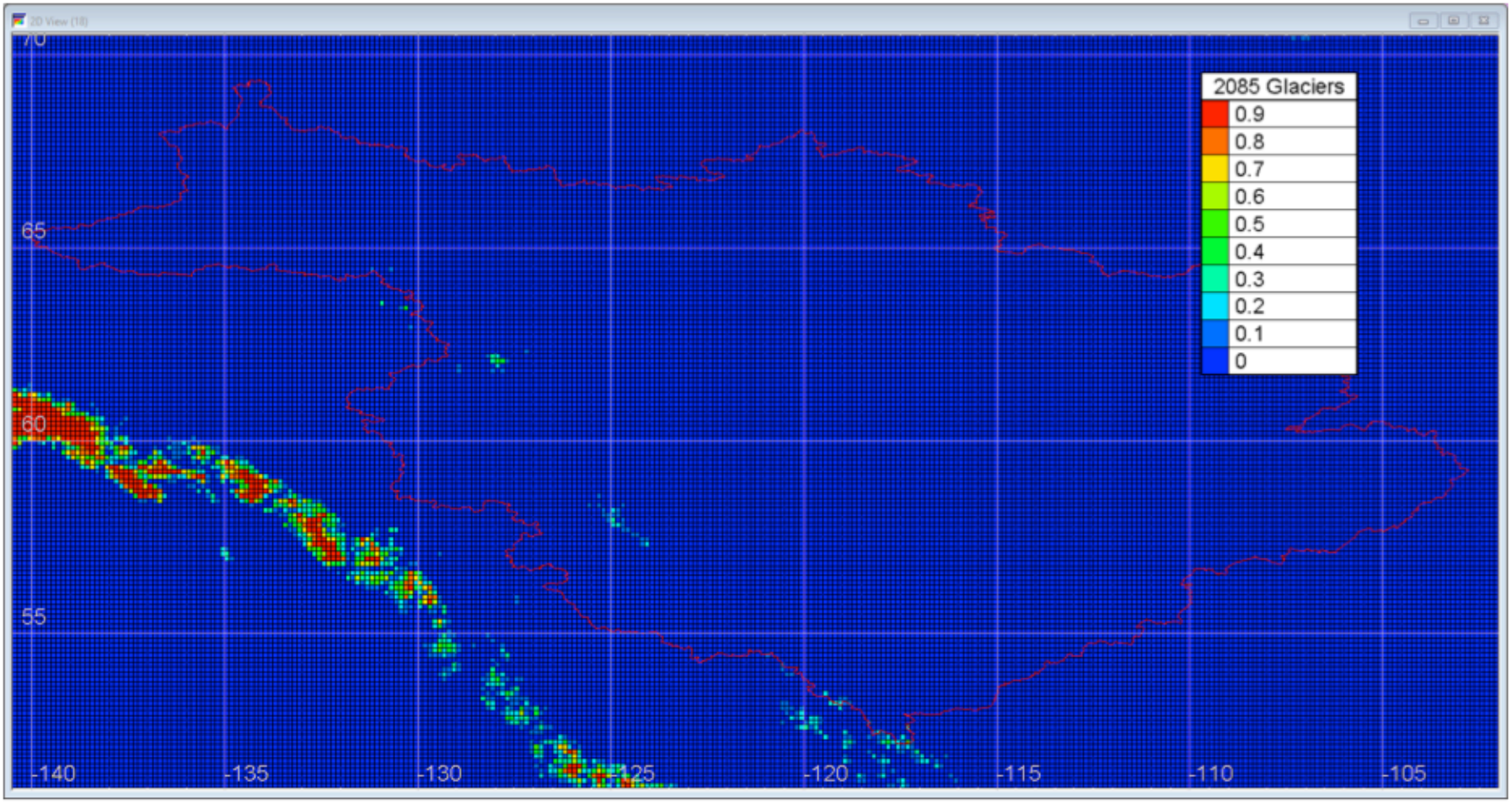
- 15 simulations of 0.44˚ (~50 km) + 1 finer resolution (0.22˚ ~25 km) over North American Domain run (Historical 1950-2005 then RCP 8.5 for 2006-2100) – CanESM2 downscaled by CanRCM4
- Hourly data for 21 Variables downloaded (32 TB) for all members
- Scripts developed to extract desired basin, all members were processed for MRB and 1 is being run through
- 1st scenario has been BIAS Corrected (all 7 variables) based on WFDEI-GPCC (correction is under progress for GEM-CaPA)



Future Scenarios – Land Cover/Use



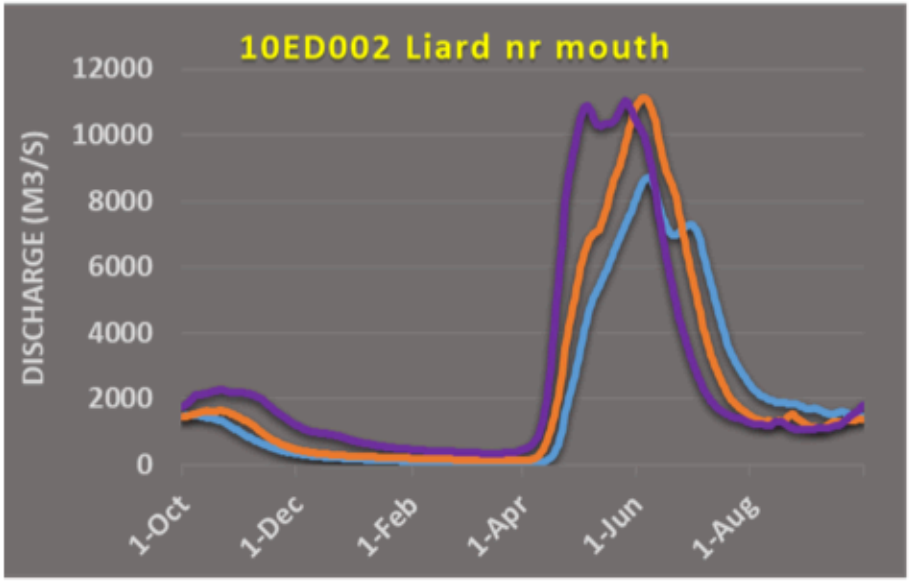
Future Scenarios - Glaciers

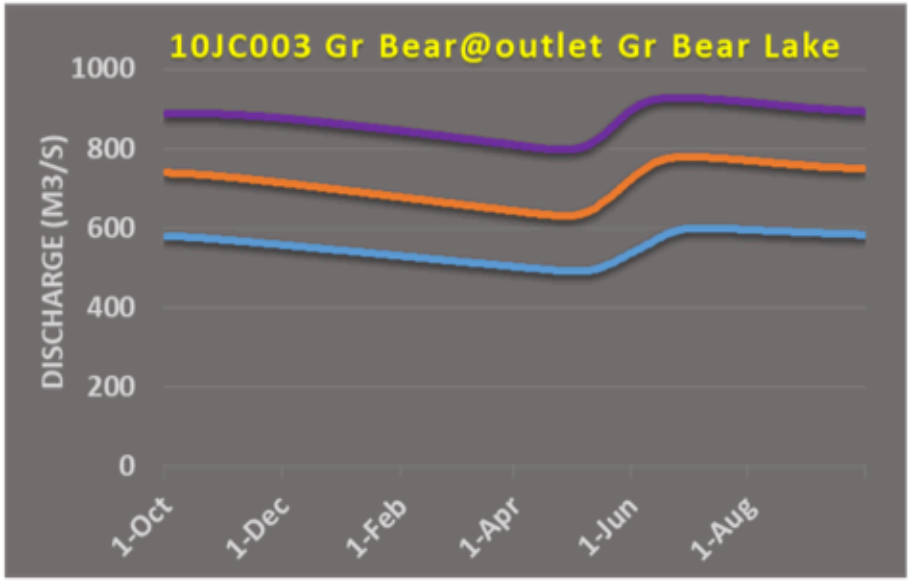


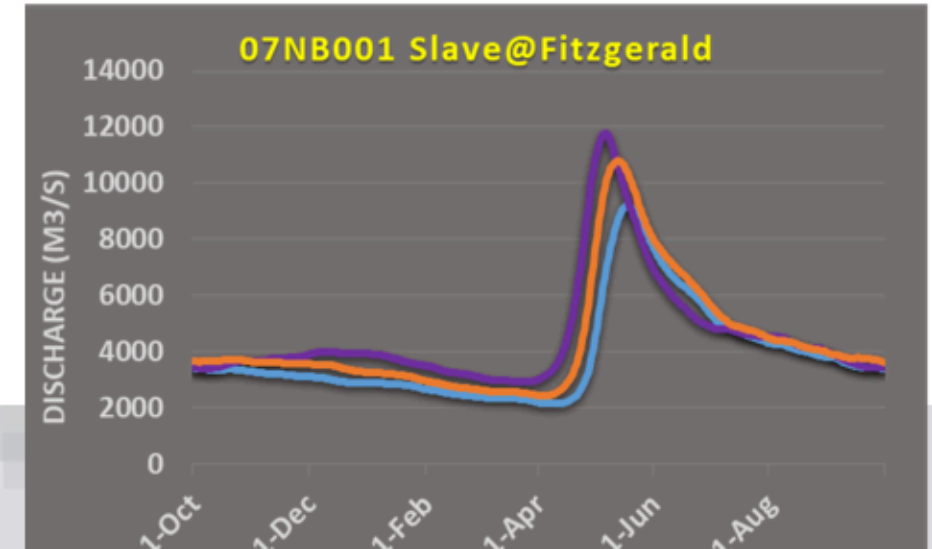
Simulation Timeline

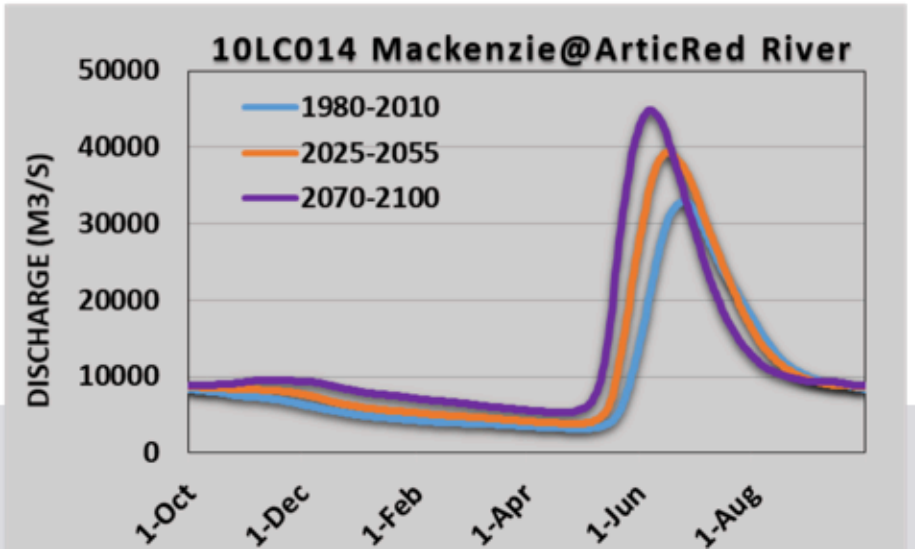
Date/Period	Type
1. Oct 1979 – Sep 1980	Spin-up (50-100 Cycles)
2. Oct 1979 – Sep 2010 Oct 1980 – Sep 2010	Open Loop Analysis – Baseline Period
3. Oct 2010 – Sep 2020	Open Loop
Oct 2020	Land Use 2040 Introduced
4. Oct 2020 – Sep 2025	Open Loop - Land Use 2040 Smoothing
5. Oct 2025 – Sep 2055	Open Loop Analysis – Near Future
6. Oct 2055 – Sep 2065	Open Loop
Oct 2065	Land Use 2085 Introduced
7. Oct 2065 – Sep 2070	Open Loop - Land Use 2085 Smoothing
8. Oct 2070 – Sep 2100	Open Loop Analysis – Far Future

Average Hydrographs – CC Only

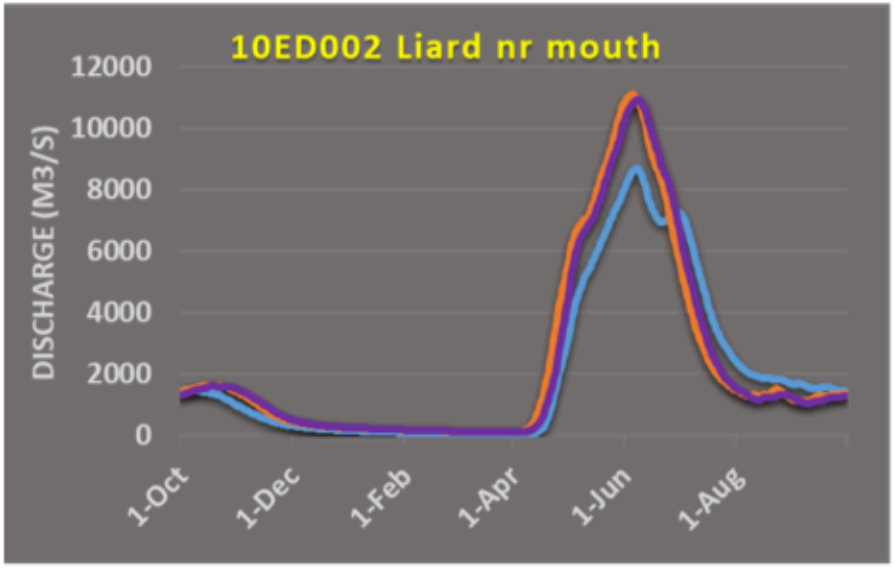


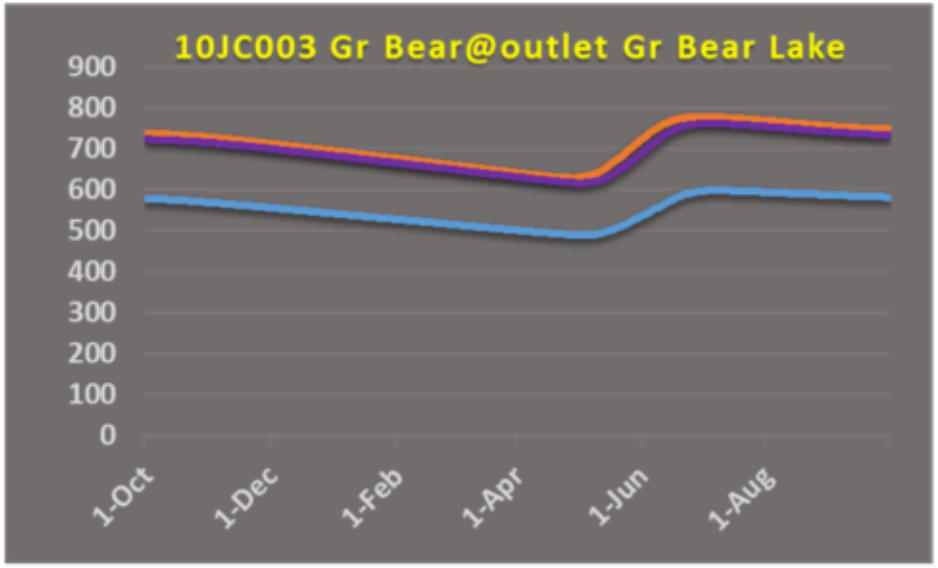


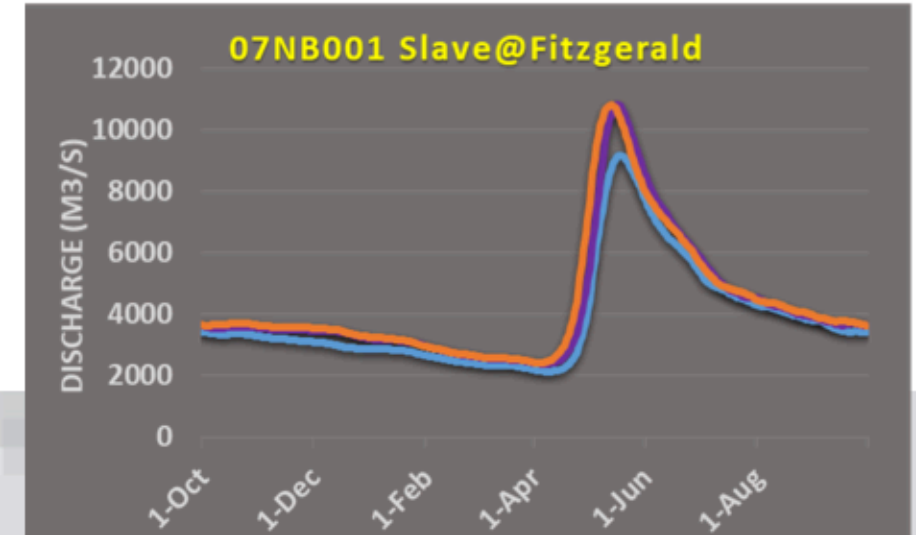


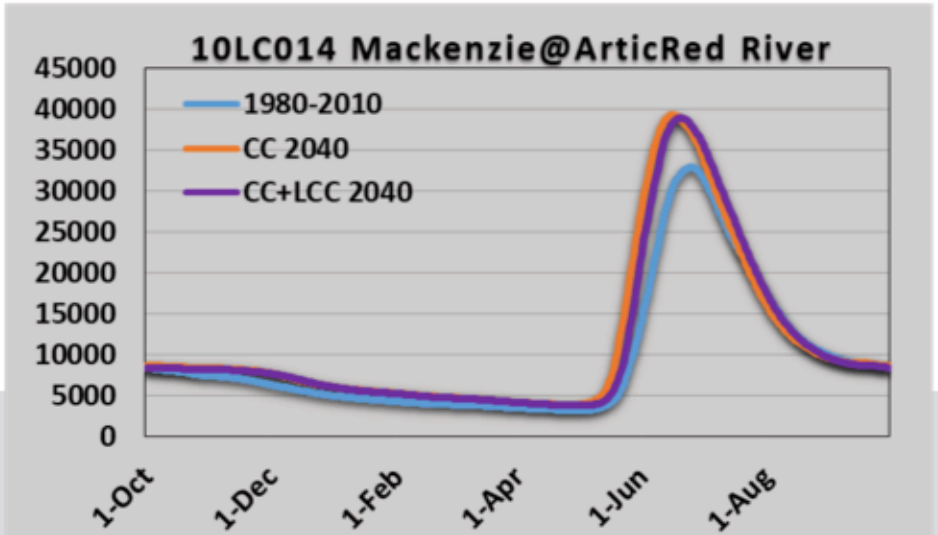


Average Hydrographs CC+LCC 2040









Summary for flow changes (CC only)

Sub-basin	Outlet Station	2025-2055				2070-2100			
		Precip (mm/yr)	% Change	Flow (BCM/yr)	% Change	Precip (mm/yr)	% Change	Flow (BCM/yr)	% Change
Athabasca	Athabasca@Fort McMurray	606	14%	22.6	15%	665	25%	24.1	22%
Peace	Peace@Peace Point	623	13%	76.0	8%	697	27%	80.1	14%
Lake Athabasca*	Slave@Fitzgerald	598	14%	137.0	12%	661	26%	143.5	18%
		547	17%	38.4	20%	591	26%	39.2	22%
Hay	Hay@Hay River	547	15%	8.5	11%	620	30%	10.0	30%
Liard	Liard nr Mouth	573	12%	73.1	11%	660	29%	84.0	28%
Great Slave Lake+	Mackenzie@Fort Simpson	545	15%	280.7	15%	612	29%	311.7	27%
		440	19%	62.1	26%	500	35%	74.2	51%
Great Bear Lake	Great Bear River@outlet	404	22%	22.4	29%	468	41%	27.4	58%
Mackenzie#	Mackenzie@Artic Red River	520	16%	355.1	17%	588	31%	400.4	32%
		456	19%	52.0	24%	533	39%	61.3	47%

Impacts on Permafrost – Mid 21st Century

Impacts of Permafrost – End of 21st Century

Summary & Way Forward

- Earlier snow melt, higher peaks at most locations → high risk of flooding
- Low flows are mostly unchanged but become more variable
- Widespread permafrost thaw → connectivity and land from impacts need to be studied further
- Uncertainty due to Forcing and Parameters - underway
- Future Uncertainty due to RCPs & GCMs/RCMs – underway

Thank you

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