Environment Canada | Environnement Canada

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Canada

Hydrology Tool Set (HTS): open science through online applications

Serban Danielescu

Environment and Climate Change Canada &
Agriculture and Agri-Food Canada

National Dialogue on Groundwater
September 13, 2023

Hydrology Tool Set (HTS)

- ECCC, AAFC, UNB & CRI collaborative effort
- First tool launched in 2017
- Several tools for various hydrological analyses
  - local and watershed scale hydrological processes
  - assess the impact of agricultural practices, urbanization, climate change, etc
- Encourage easier and open access to science

https://www.hydrotools.tech

Hydrology Tool Set (HTS)

Developed using the following principles:

- User-friendly / streamlined interface
- Minimal input data requirements
- Required input data publicly available
- Offer a choice of methods when applicable
- Customizable parameters
- Freely available
- Integrate graphical and tabular tools and import/export functions
- Include built-in test datasets

Hydrology Tool Set (HTS)

All tools:

- have daily data requirement
- include error-checking utilities
- include a User reference manual and a User Guide

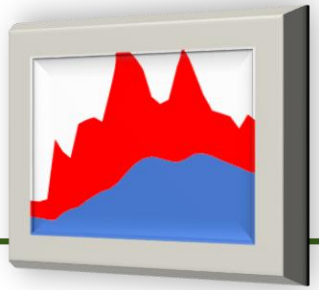
- Can be used:
  - as standalone tools/models
  - to provide input to more complex models (e.g. commercial software)
  - for development and testing of scenarios
  - for scientific research & education

ETCalc (2022)

- Estimation of Potential Evapotranspiration (PET), Reference Evapotranspiration (ETR) and Actual Evapotranspiration (ETA)
- Requires meteorological data (PET and ETR) and crop coefficients (ETA).
- The tool currently integrates:

Penman-Monteith	Priestley-Taylor
Thornthwaite	Hargreaves
Blaney-Criddle	Jensen-Haise
Turc	Abtew

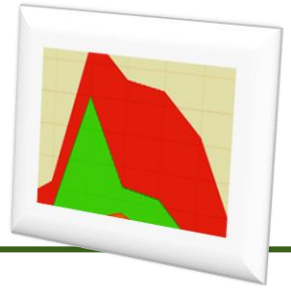
SepHydro (2017)



- Conduct hydrograph separation (i.e. surface runoff and groundwater contributions to streamflow) using several customizable digital filtering algorithms
- Requires streamflow data.

Lyne & Hollick	TR-55
Chapman	Szilagyi (long and short)
Eckhardt	Boughton (AWBM)
Pettyjohn & Henning (Fixed Interval, Sliding Interval, Local Minimum)	Furey & Gupta
	Chapman & Maxwell

SWIB (2021)



- Soil Water Stress, Irrigation Requirement and Water Balance Model (SWIB)

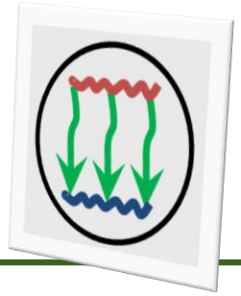
- Estimate daily crop / soil water stress, crop irrigation requirements and the impact of irrigation on aquifer storage, water balance components.

- Requires soil moisture and precipitation

SNOSWAB (2022)

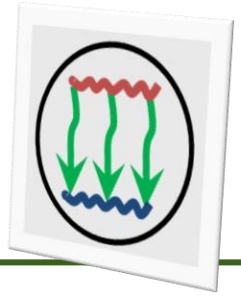
- SNOSWAB (Snow, Soil Water and Water Balance Model)
- Most complex tool / model
- Estimate dynamics of snow-related processes (snowfall, snow accumulation, snowmelt), soil water content and water balance components (infiltration, drainage and surface runoff)
- Requires air temperature, precipitation, rainfall and evapotranspiration.

Recharge Buddy (2023)



- Groundwater Recharge Estimation Tool (RECHARGE BUDDY)
- Estimation of groundwater recharge, groundwater discharge and change in aquifer storage
- Uses a modified Water Table Fluctuation (WTF) method
- Requires specific yield and water table elevations.

Snow Buddy (2023)



- Snowfall and rainfall estimation tool (SNOW BUDDY)
- Estimation of daily snowfall and rainfall amounts
- Requires air temperature and total precipitation

Online demo…

- https://www.hydrotools.tech

HTS Usage Stats

Unique visitors (all tools)	24100
Data sets loaded to the tools	17000
No. of analyses conducted by users	40400

Spatial distribution of HTS users (example for SepHydro)

References

- ***[SepHydro]*** *Danielescu S, MacQuarrie KTB, Popa A (2018) SEPHYDRO: A Customizable Online Tool for Hydrograph Separation. Groundwater 56: 589-593. DOI: https://doi.org/10.1111/gwat.12792*

- ***[SWIB]*** *Danielescu S, MacQuarrie K, Zebarth B, Nyiraneza J, Grimmett M, Levesque M (2022). Crop water deficit and supplemental irrigation requirements for potato production in a temperate humid region (Prince Edward Island, Canada). Water 14, 2748. DOI: https://doi.org/10.3390/w14172748*

- ***[SWIB]*** *Danielescu S (2023) SWIB - An Online Model to Estimate Daily Crop Water Stress, Irrigation Needs, and Soil Water Budget. Groundwater 61:296-300. DOI: https://doi.org/10.1111/gwat.13278*

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Acknowledgements

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  - Stephanie Merrill
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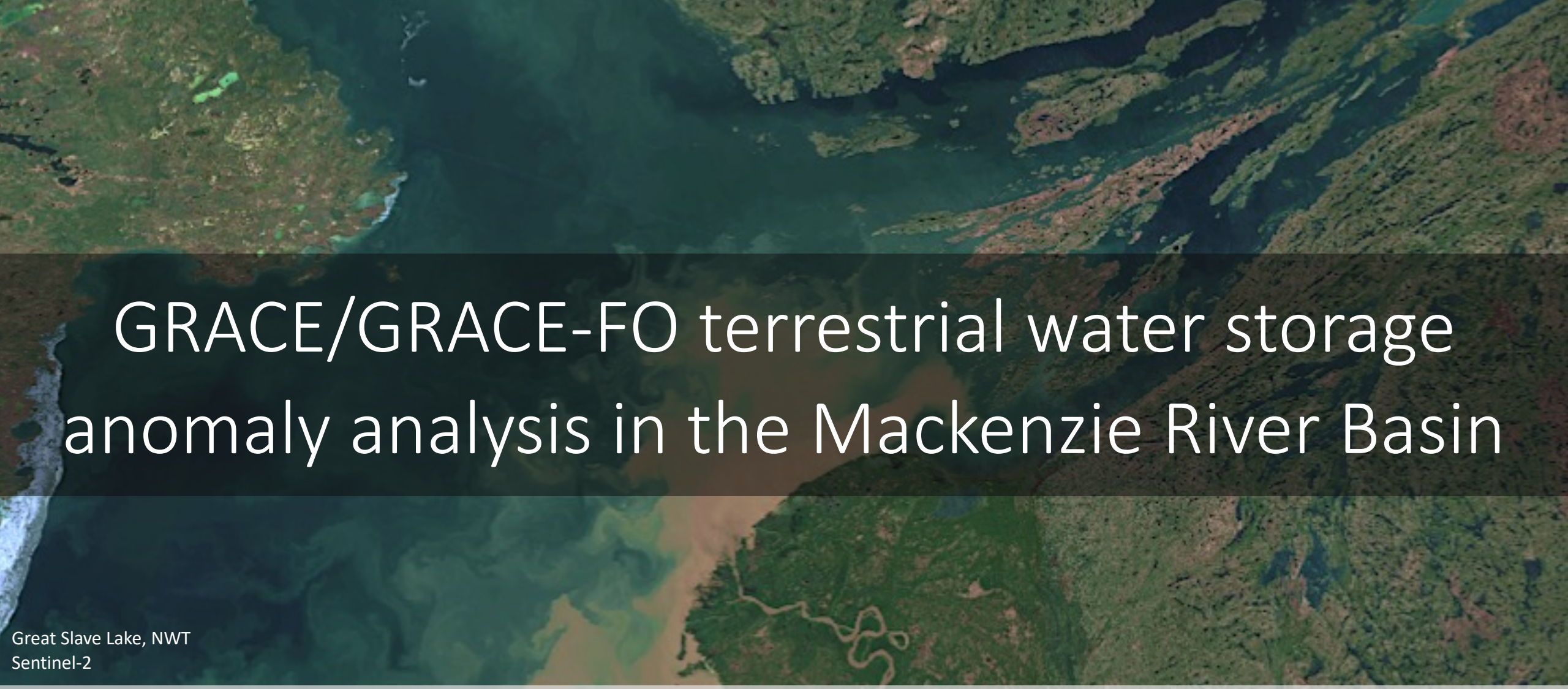
  - Richard Hardin
  - Tanya Dykens
- ECCC:
  - John Spoelstra
  - Dale van Stempvoort
- Reviewers
- Users
- Funding
  - AAFC: GF2, LL
  - ECCC

GRACE/GRACE-FO terrestrial water storage anomaly analysis in the Mackenzie River Basin



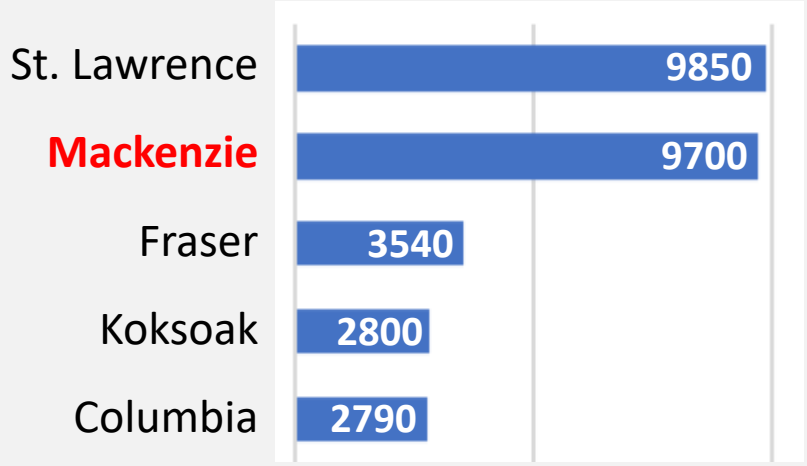
Great Slave Lake, NWT
Sentinel-2

Stephanie Bringeland & Georgia Fotopoulos
Queen's University
Department of Geological Sciences & Geological Engineering

The Mackenzie River Basin

- Canada's **largest** hydrologic basin: 1,743,058 km^2
- **7%** of Arctic Ocean freshwater influx

Canadian Rivers (m^3/s)



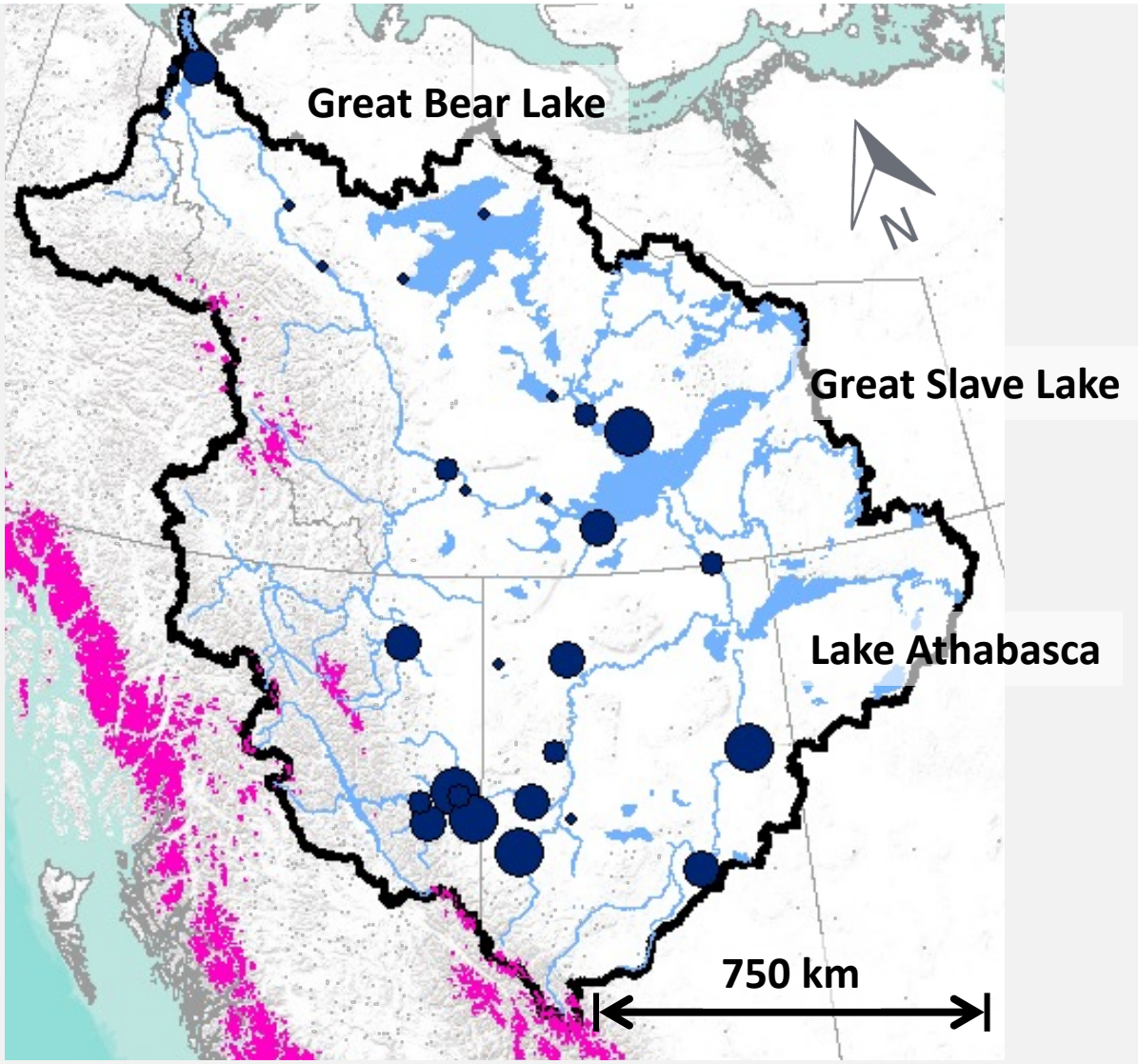
The Mackenzie River Basin

Municipalities
[population]

- 0 – 1,000
- 1,001 – 10,000
- 10,001 – 25,000
- 25,001 – 68,000

Glaciers/ice sheets

Major lakes/rivers



Sources: Esri, USGS, NOAA, RGI

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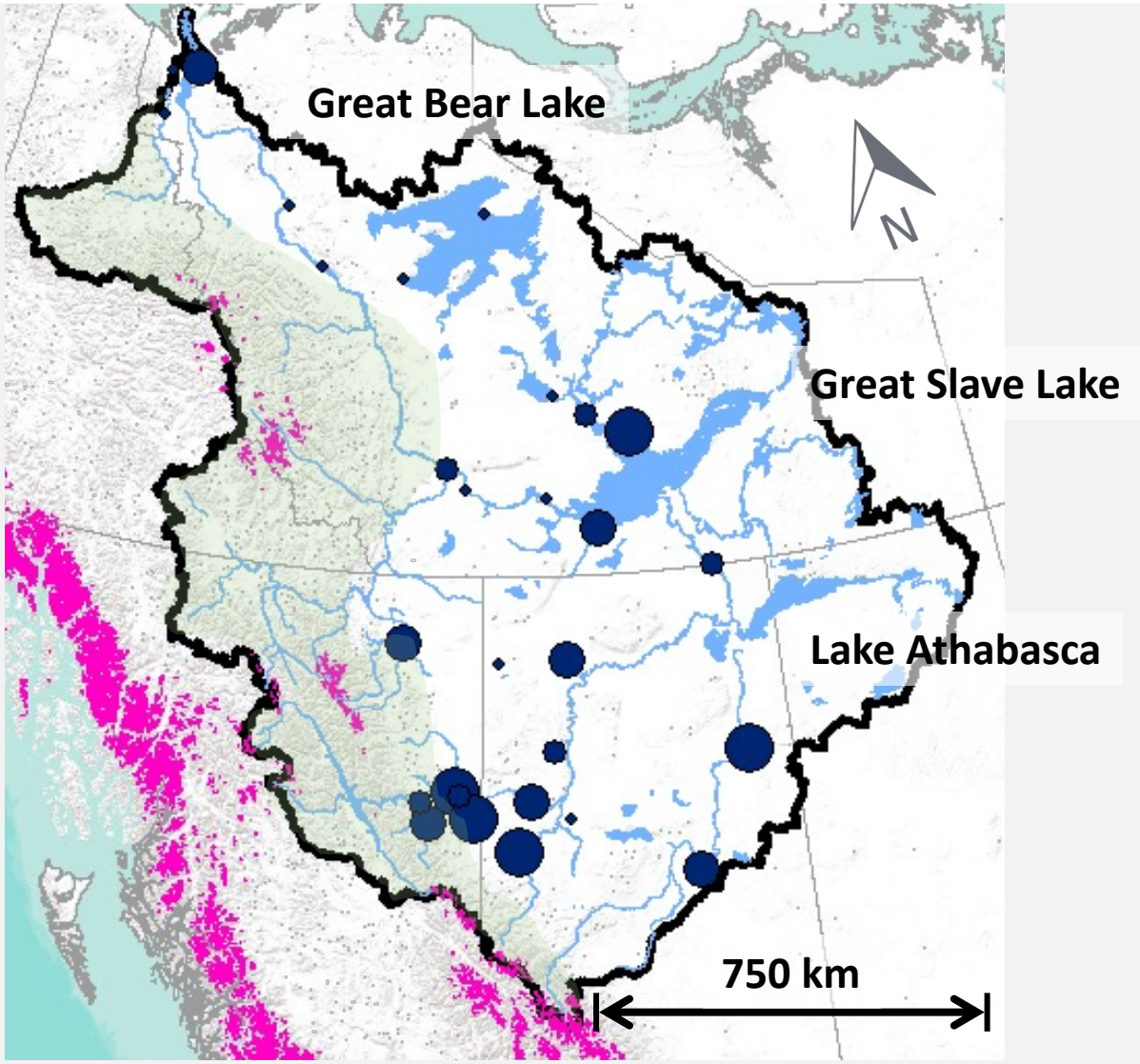

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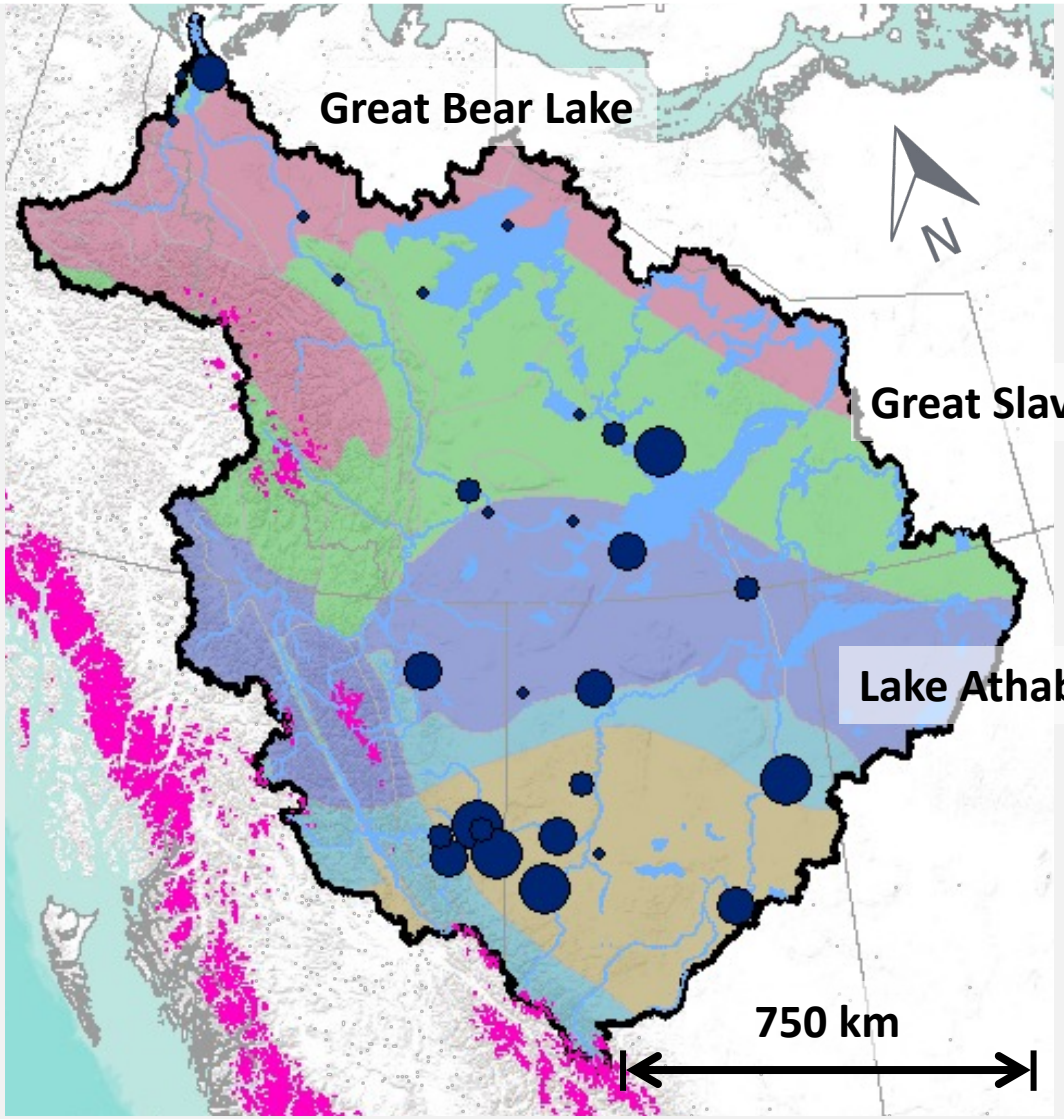
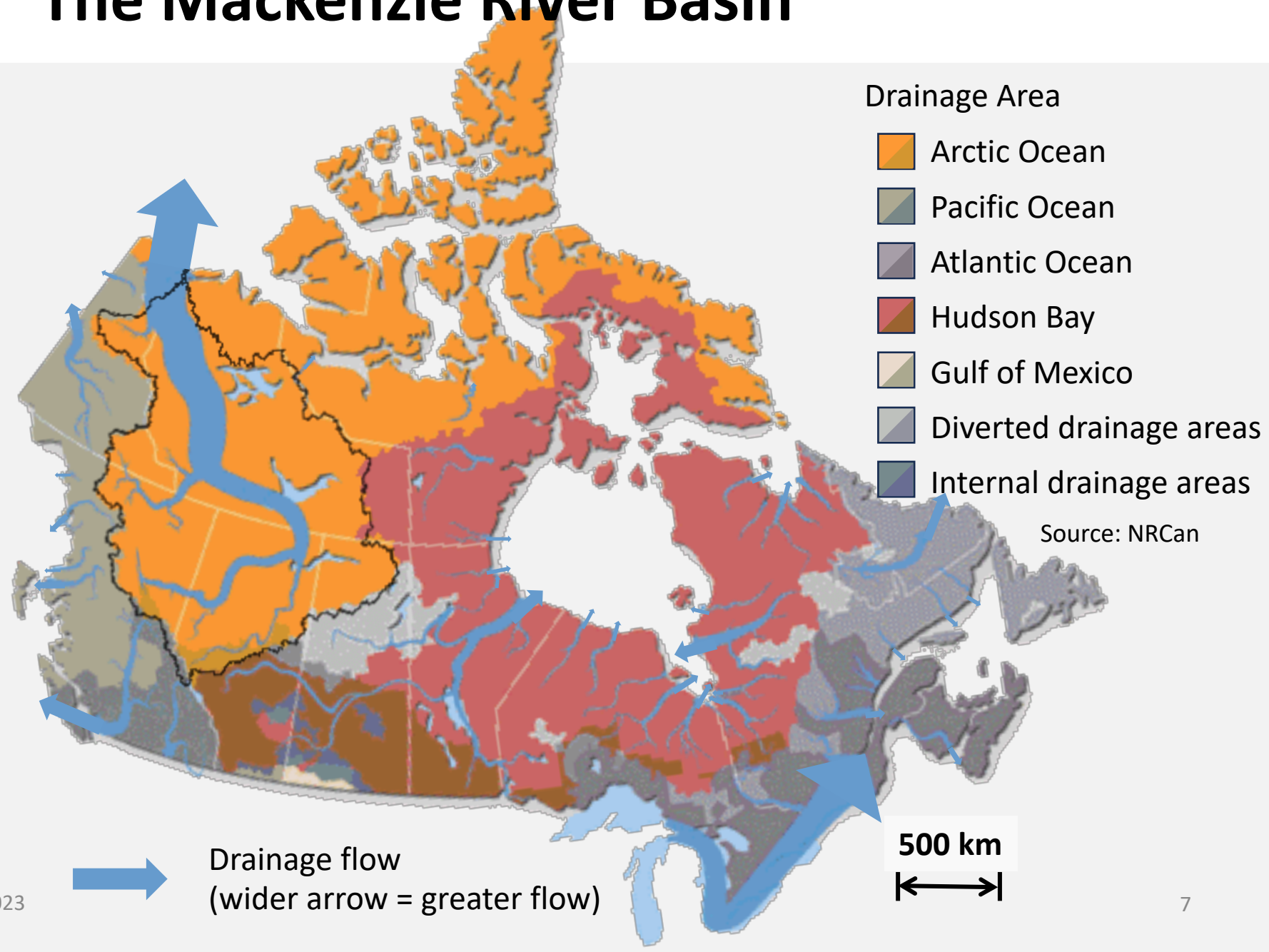


Permafrost extent (1995)

- Continuous
- Extensive
- Sporadic/discontinuous
- Isolated Patches
- No permafrost

Sources: Esri, USGS, NOAA, RGI, NRCan

The Mackenzie River Basin



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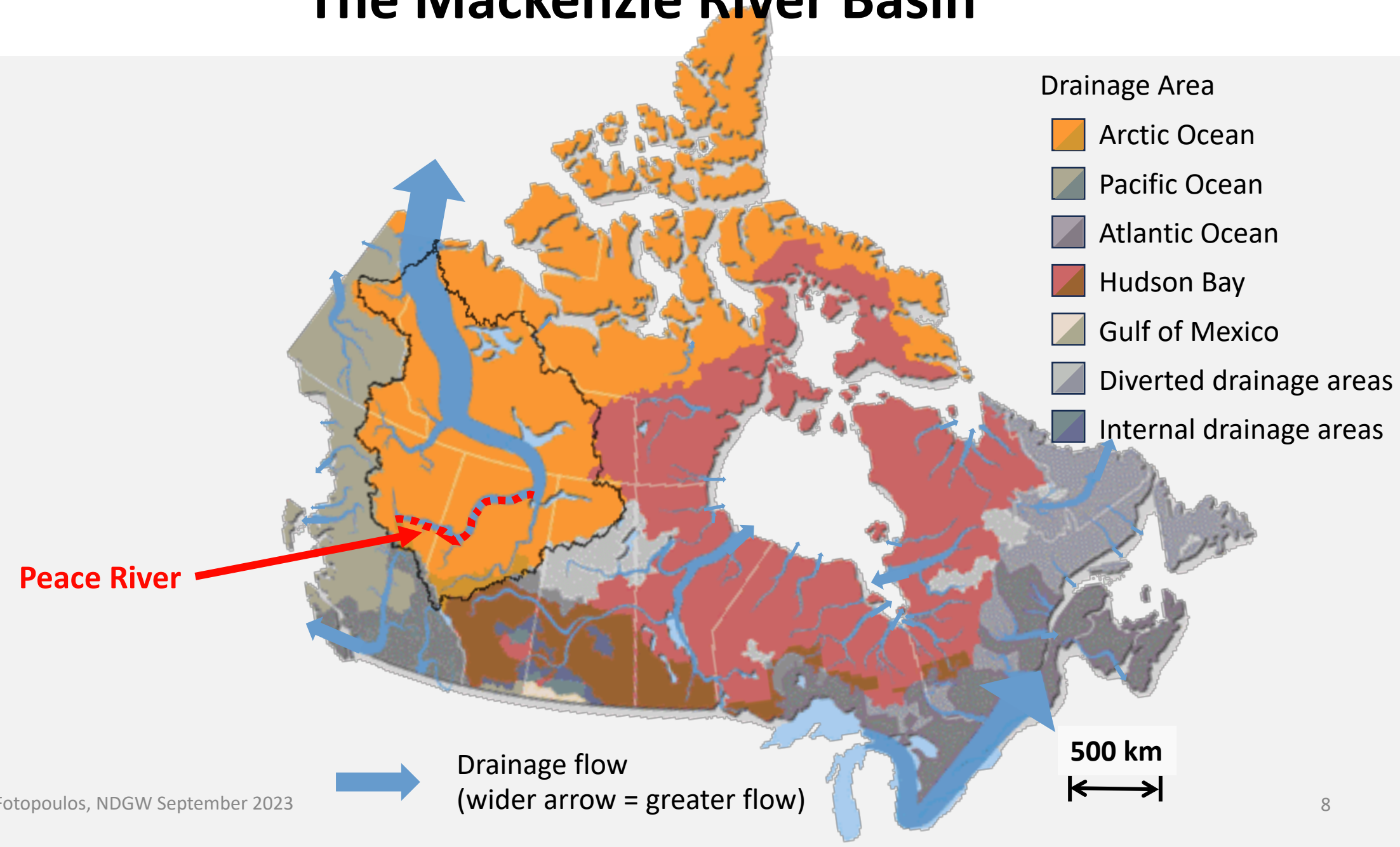

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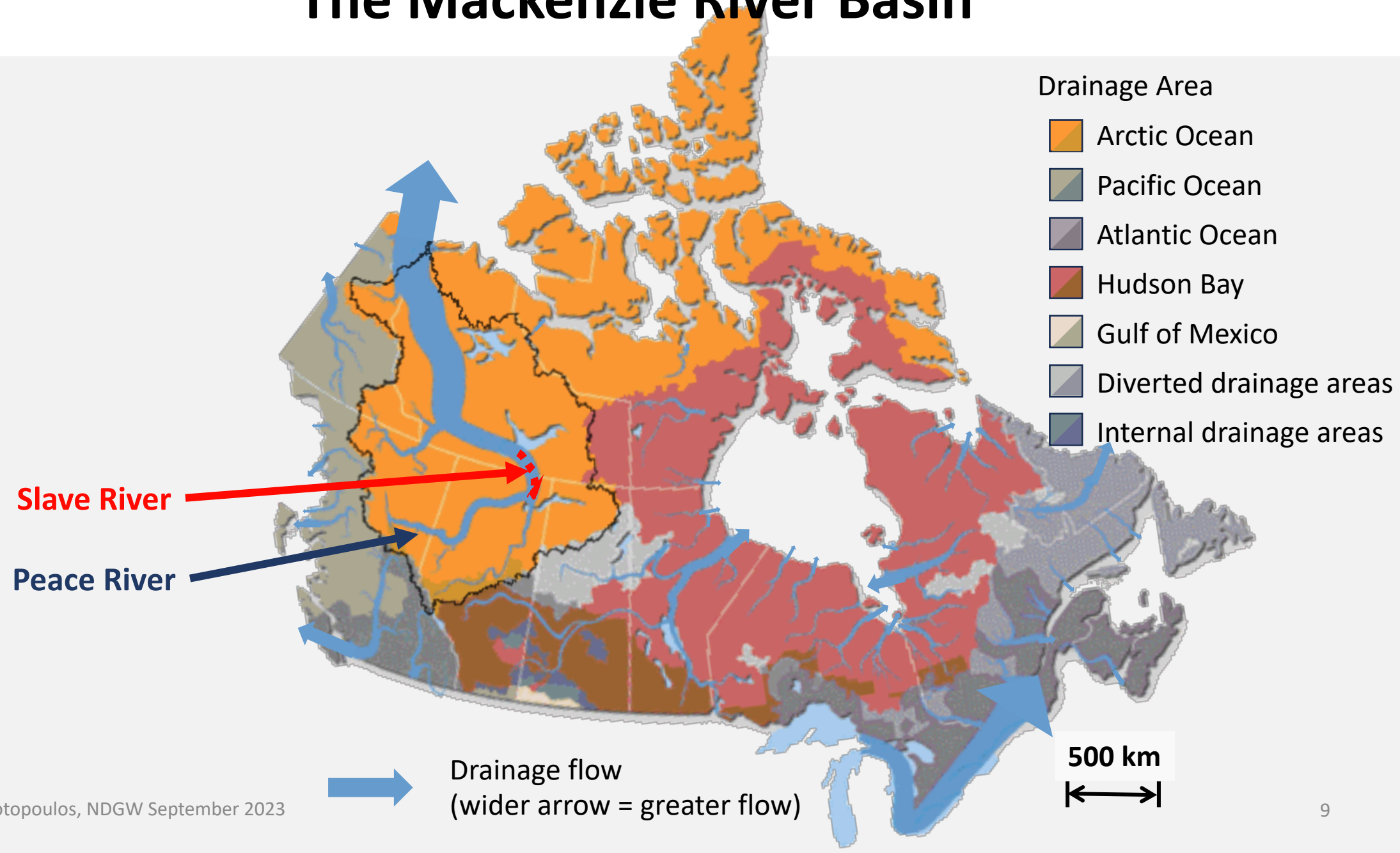

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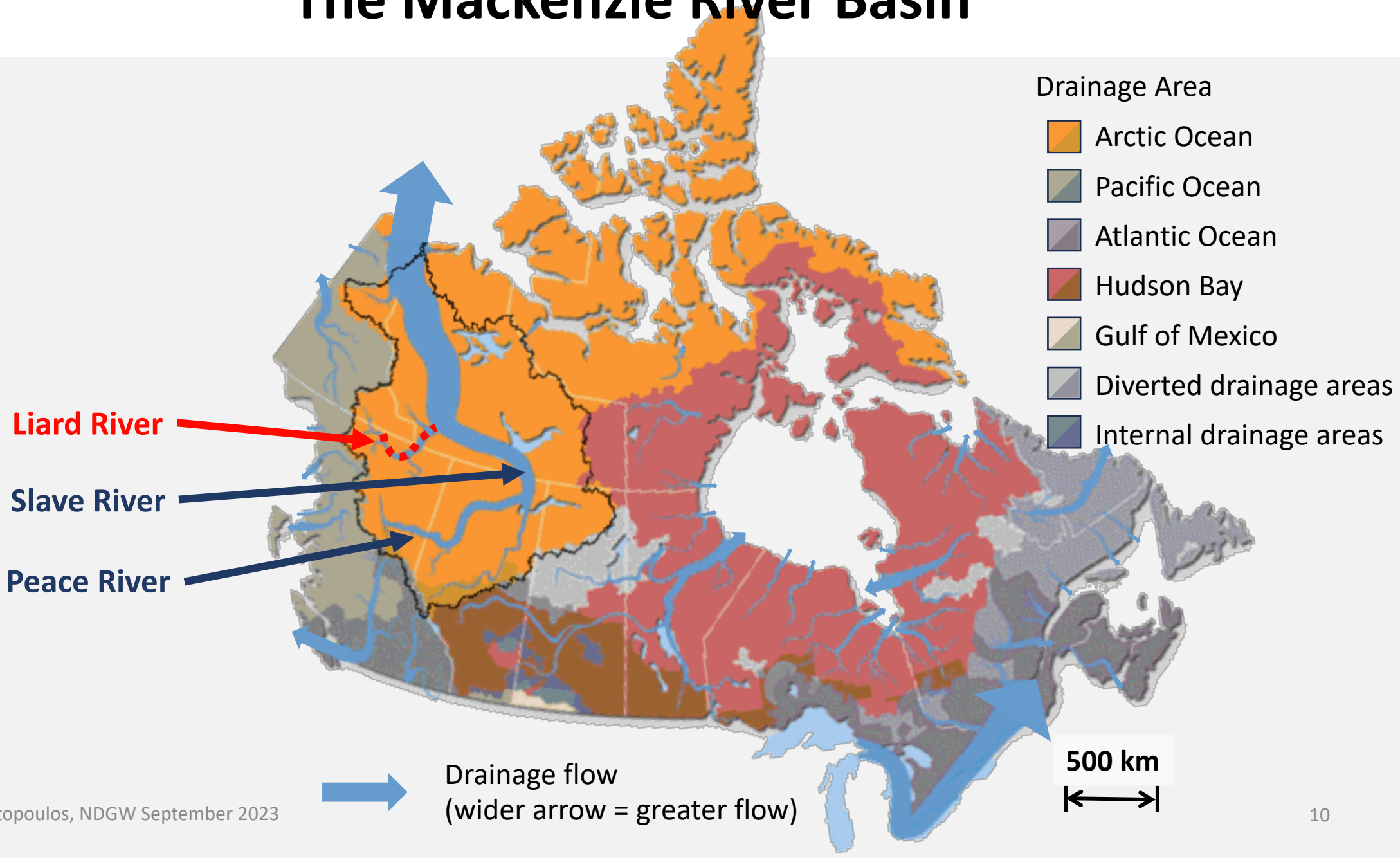

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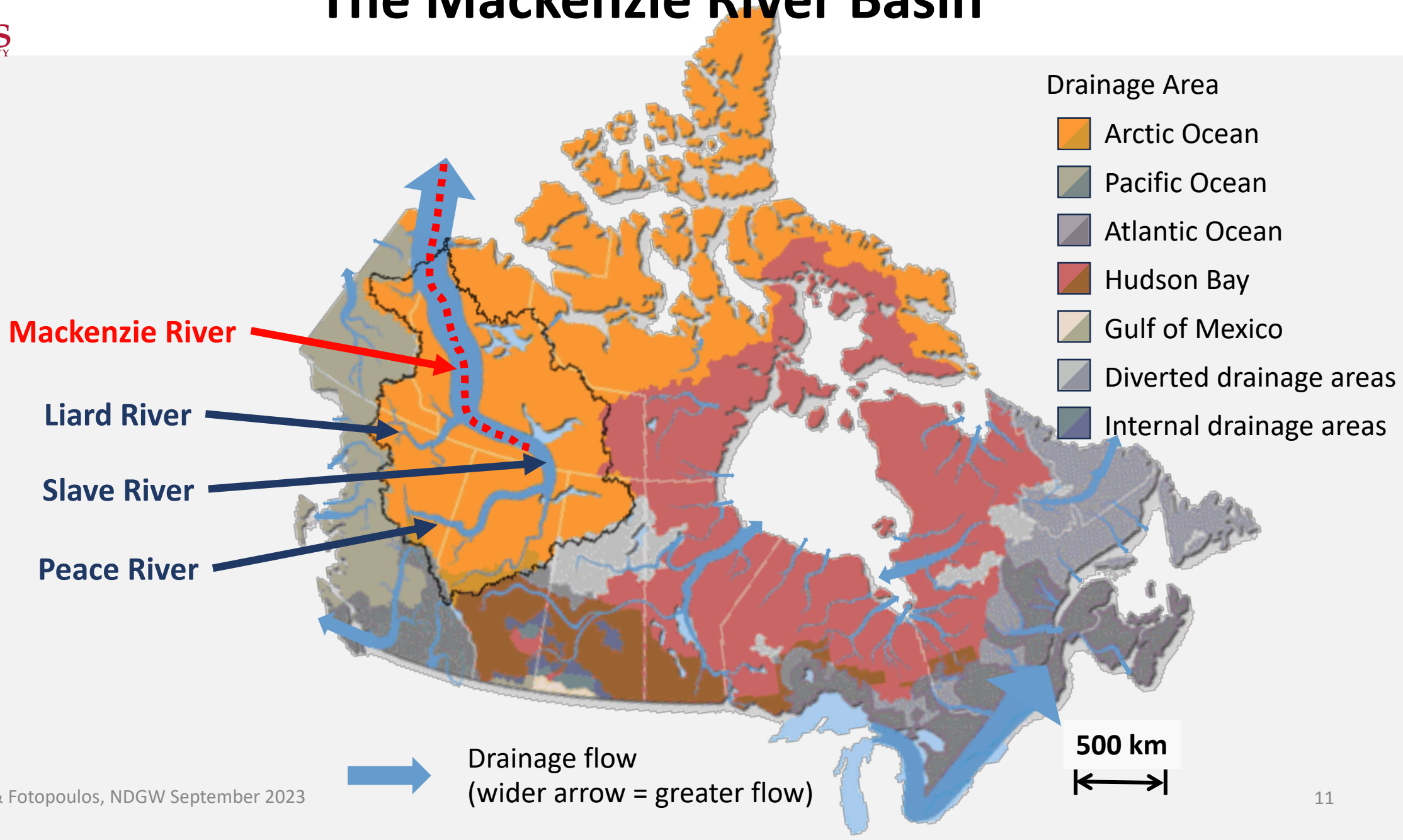


Mackenzie River Basin: Great Slave Lake Flooding Event

Jean Marie River, NWT
Source: Eden Maury, CBC (May 2021)

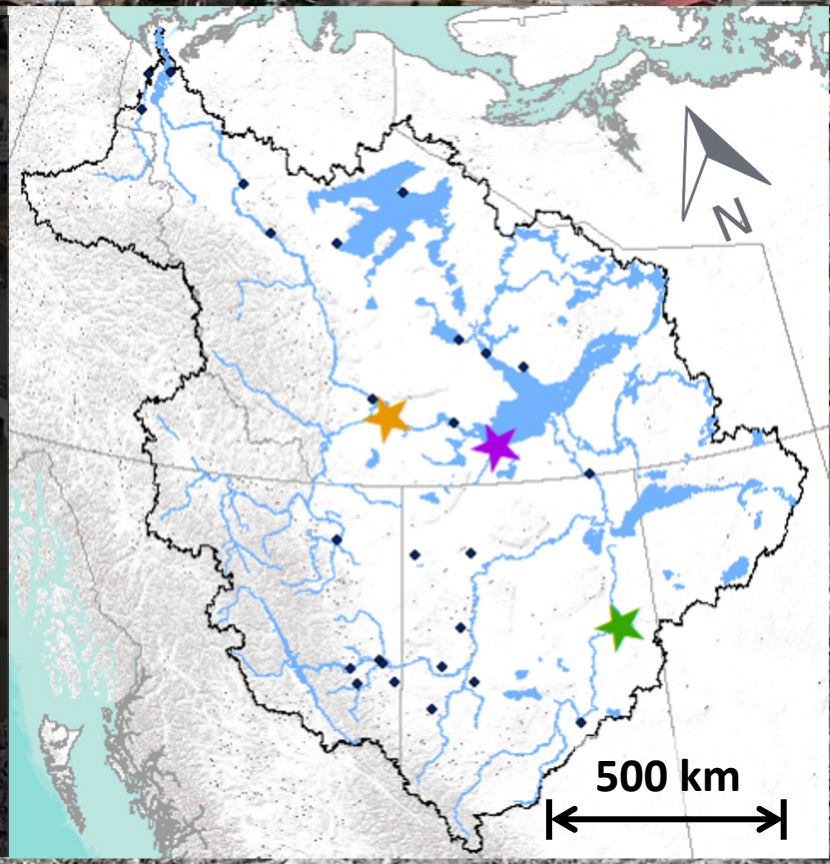
Mackenzie River Basin: Great Slave Lake Flooding Event

"Flooding in Fort MacMurray forces thousands to evacuate" April, 2020

"'Half the airport is gone' in flood-threatened Jean Marie River, NWT" May, 2021

"Hay River and KFN evacuate, thousands displaced" May, 2022

"Fort McPherson declares flooding state of emergency" May 2023



Jean Marie River, NWT
Source: Eden Maury, CBC (May 2021)

Objectives

- Examine the flooding events through the lens of **GRACE/GRACE-FO**
- Assess **hydrological drivers** of the flooding event using ERA5-Land Reanalysis data
- Evaluate the **spatial variability** of trends in terrestrial water storage within the Mackenzie River Basin
- Establish a **workflow** that can be adapted to analyze other Canadian river basins

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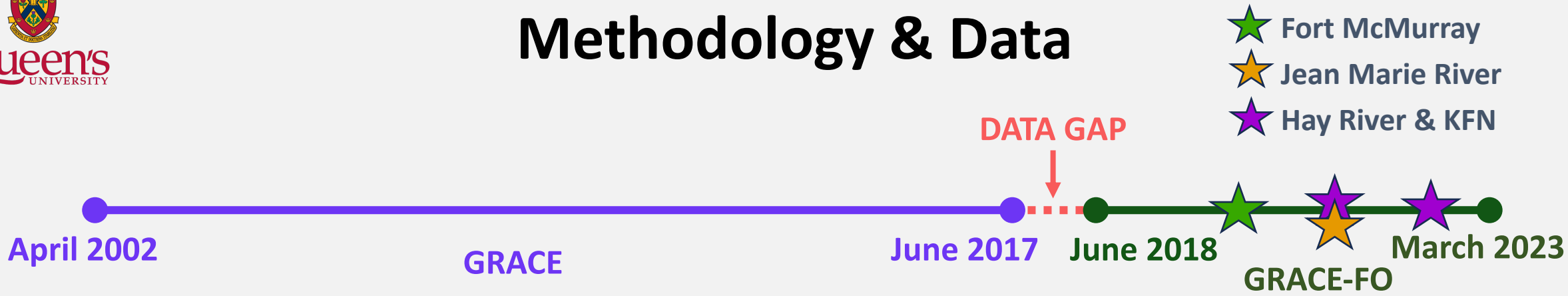
Can GRACE observe the historic high water levels of the Mackenzie River Basin?

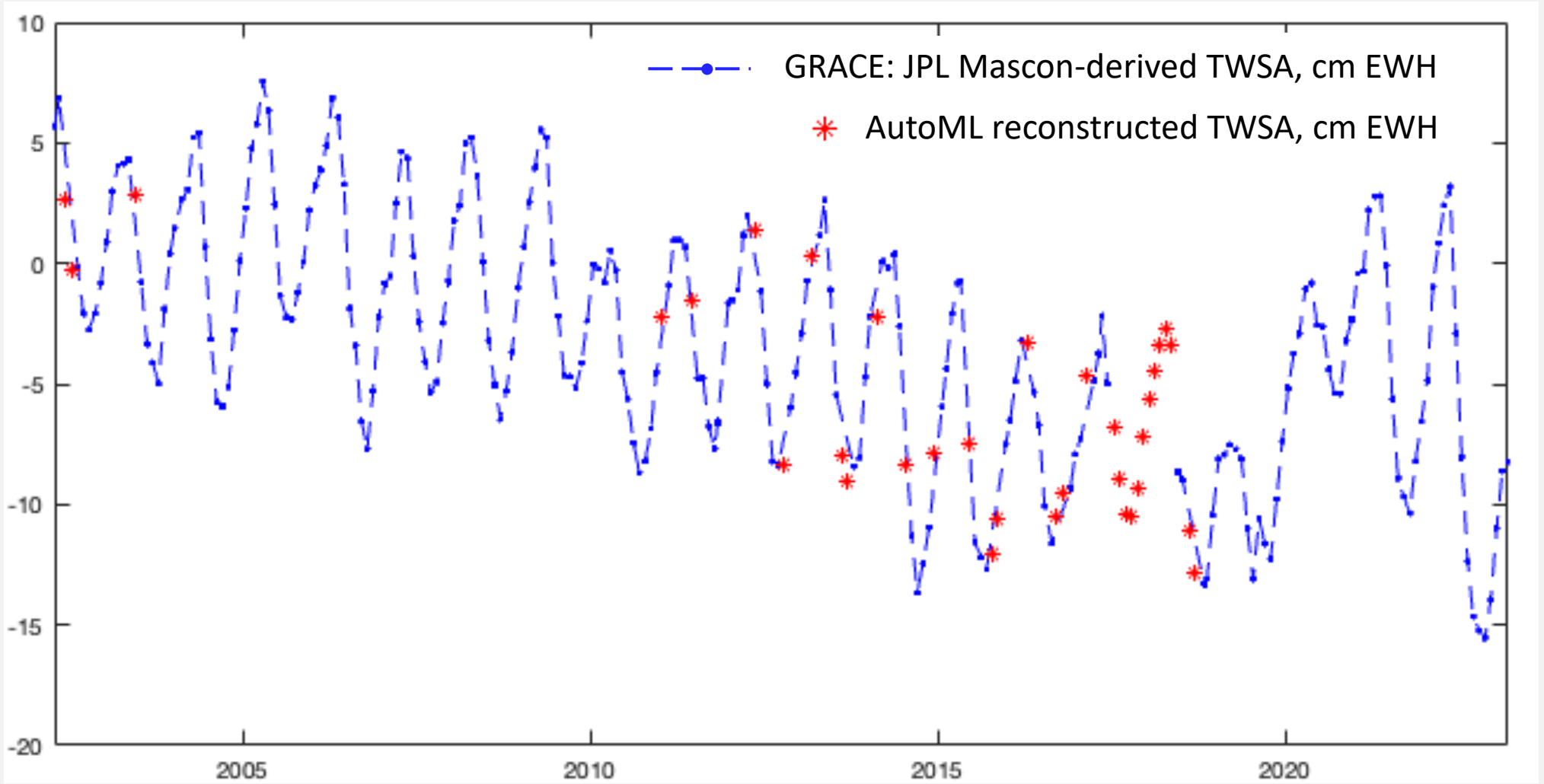
Methodology & Data



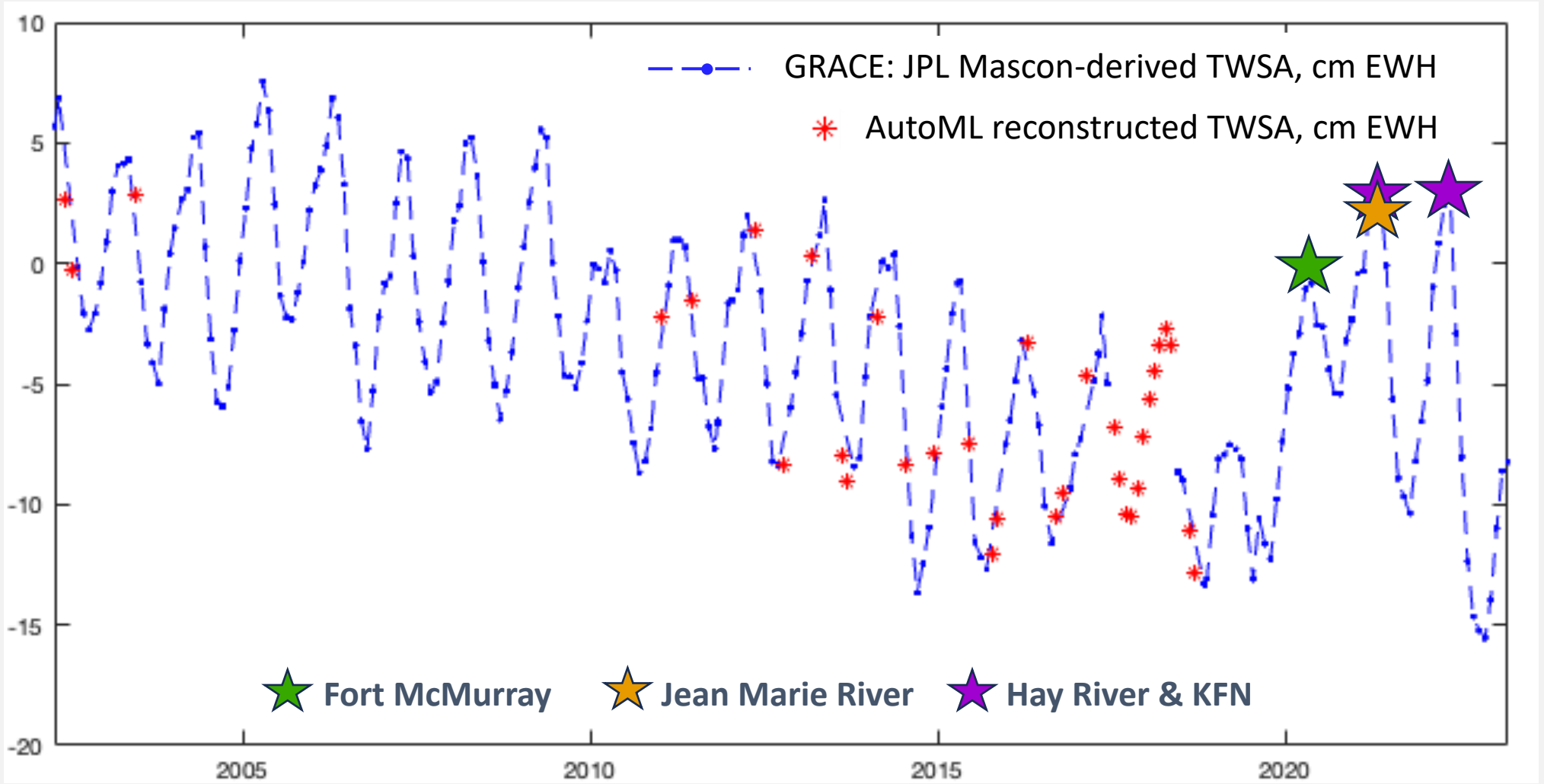
- **Level-3** Mass concentration **('Mascon')** products produced by the Jet Propulsion Laboratory (JPL) (RL06.1M.MSCNv03CRI)
- **ERA5-Land** total precipitation, total evaporation, 2-metre air temperature
- **April 2002 to March 2023 timespan** for all datasets
- Gaps within GRACE/GRACE-FO missions filled using machine learning*

*Bringeland & Fotopoulos (2023), "Analysis of gap filling techniques for GRACE/GRACE-FO terrestrial water storage anomalies in Canada", *Journal of Hydrology* (under review)

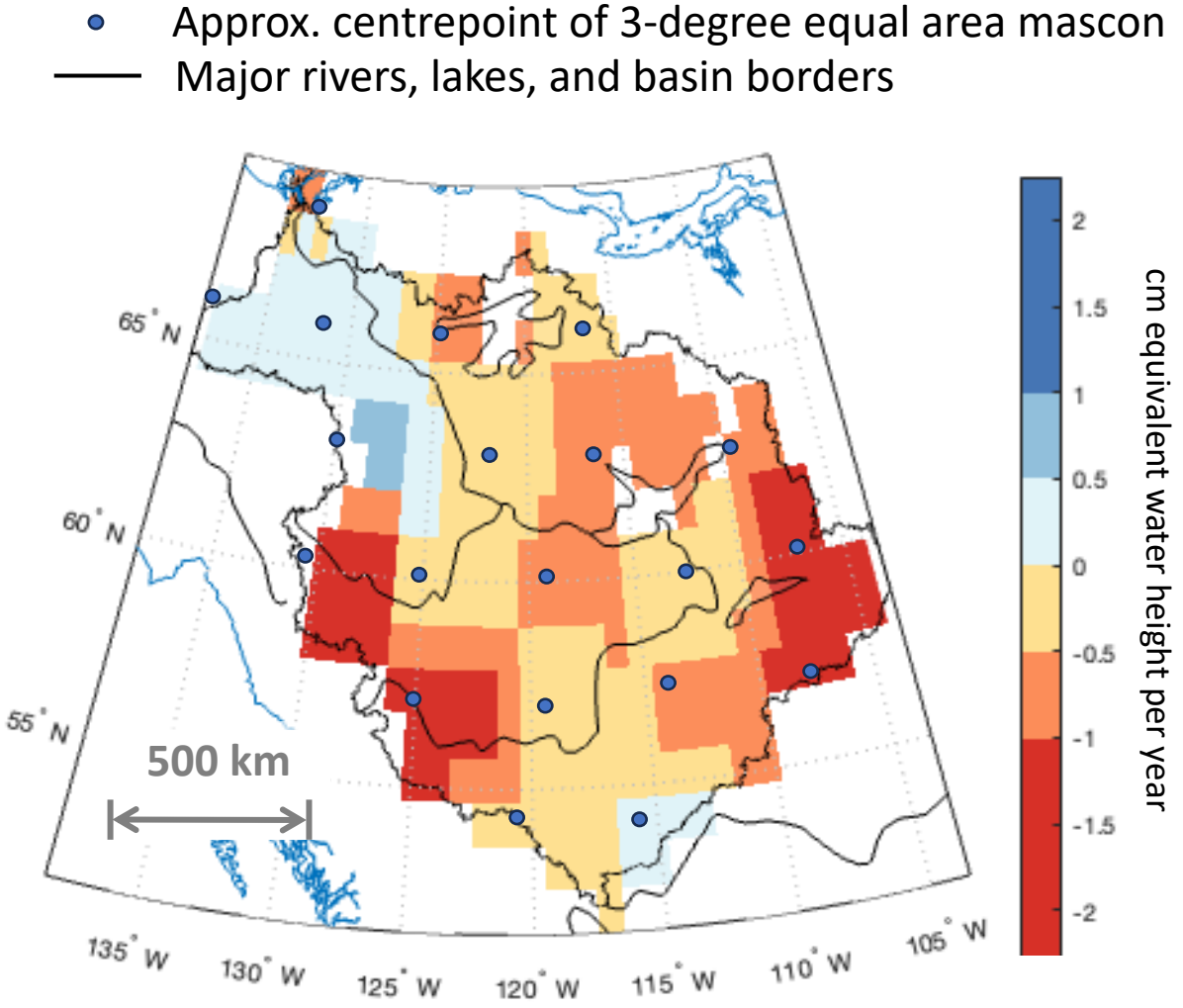
Results – GRACE/GRACE-FO in the MRB



Results – GRACE/GRACE-FO in the MRB



TWSA trend variability



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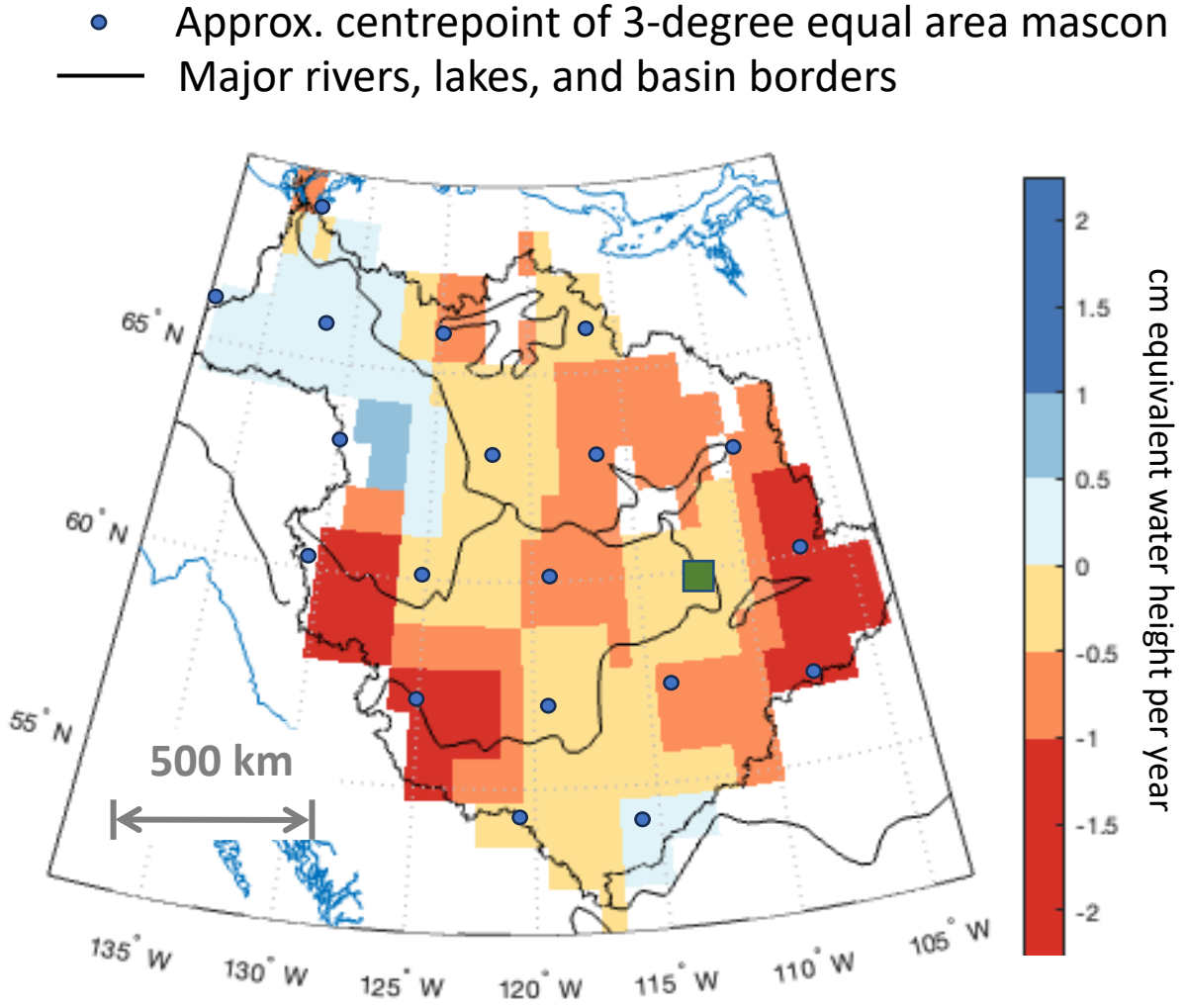

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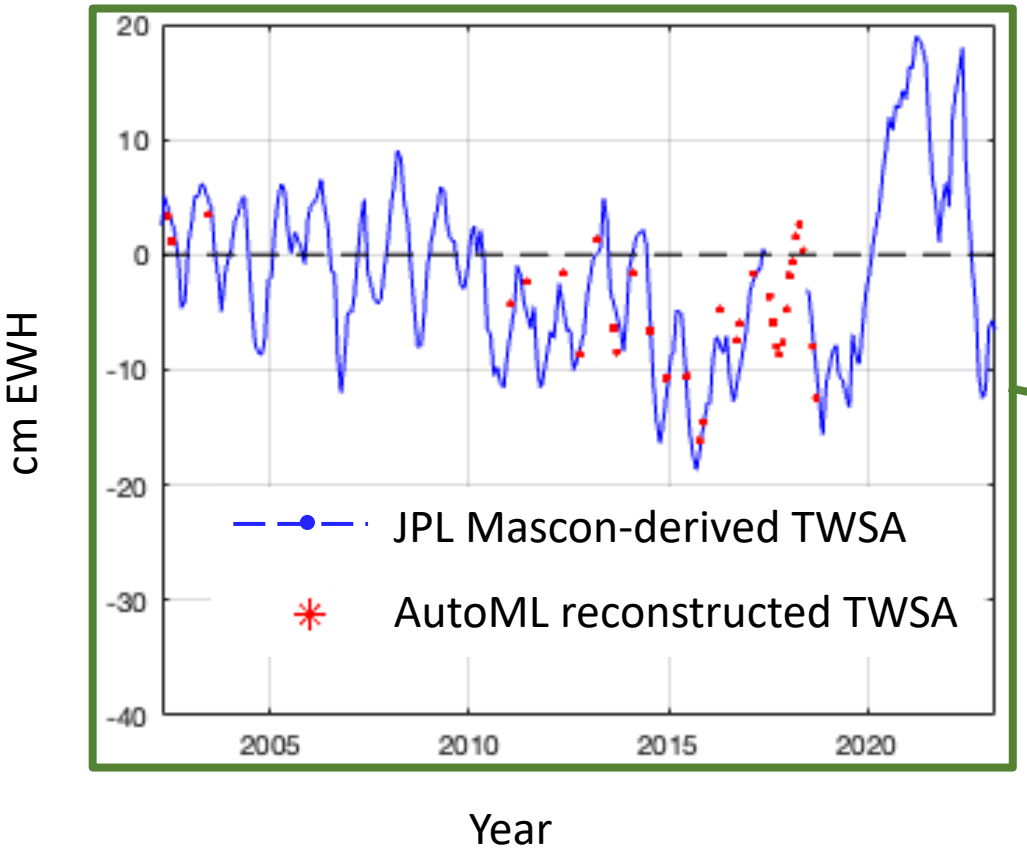

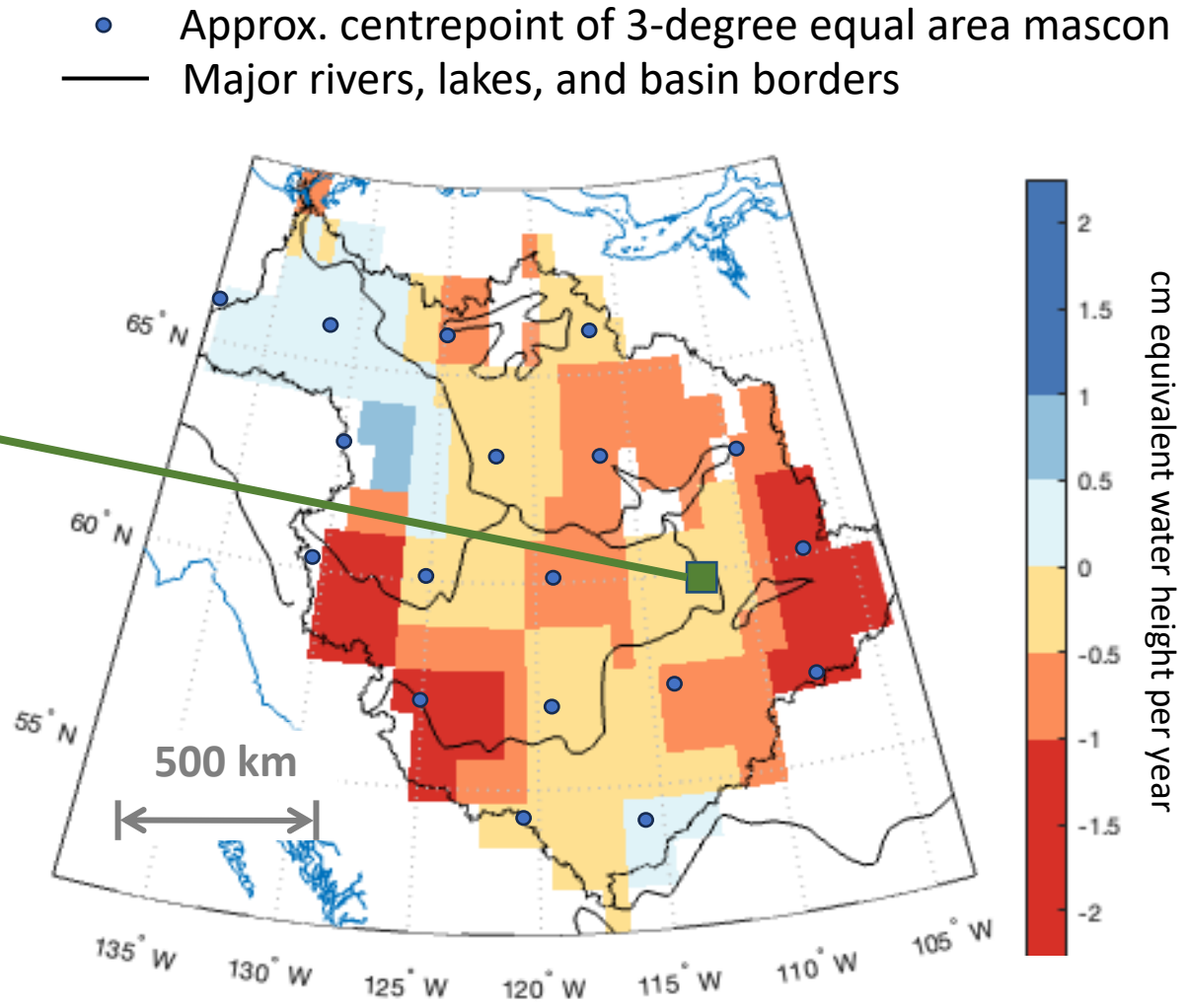

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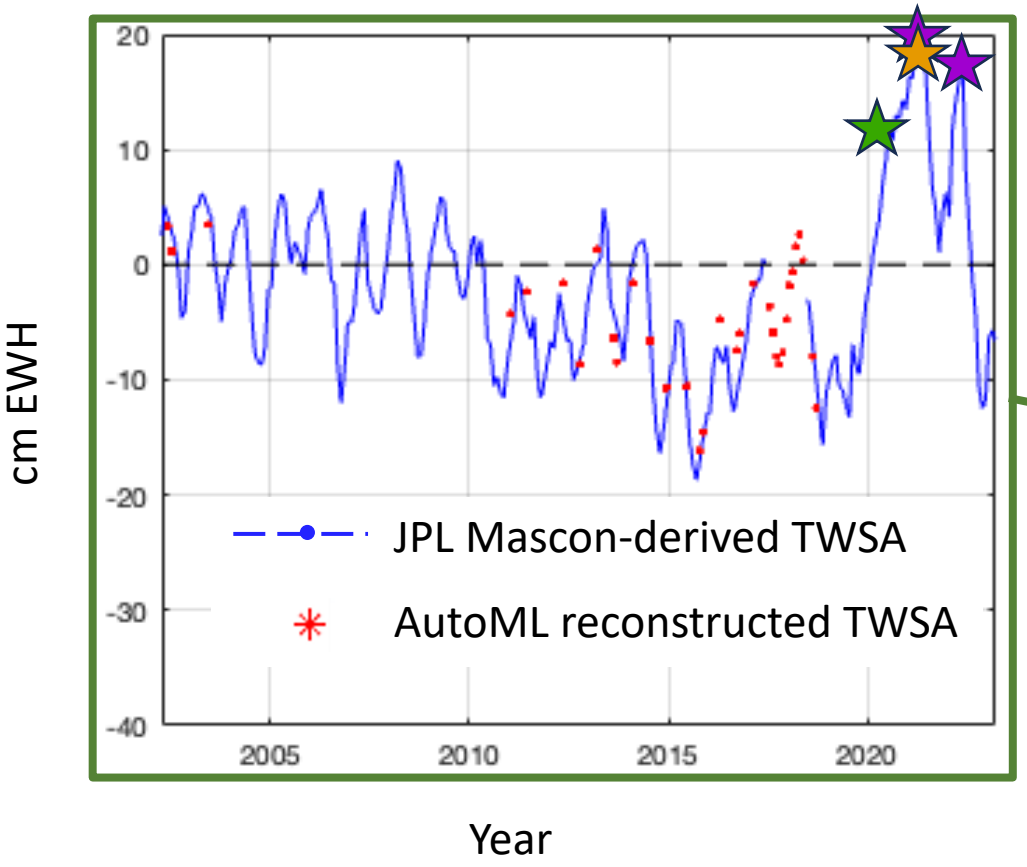
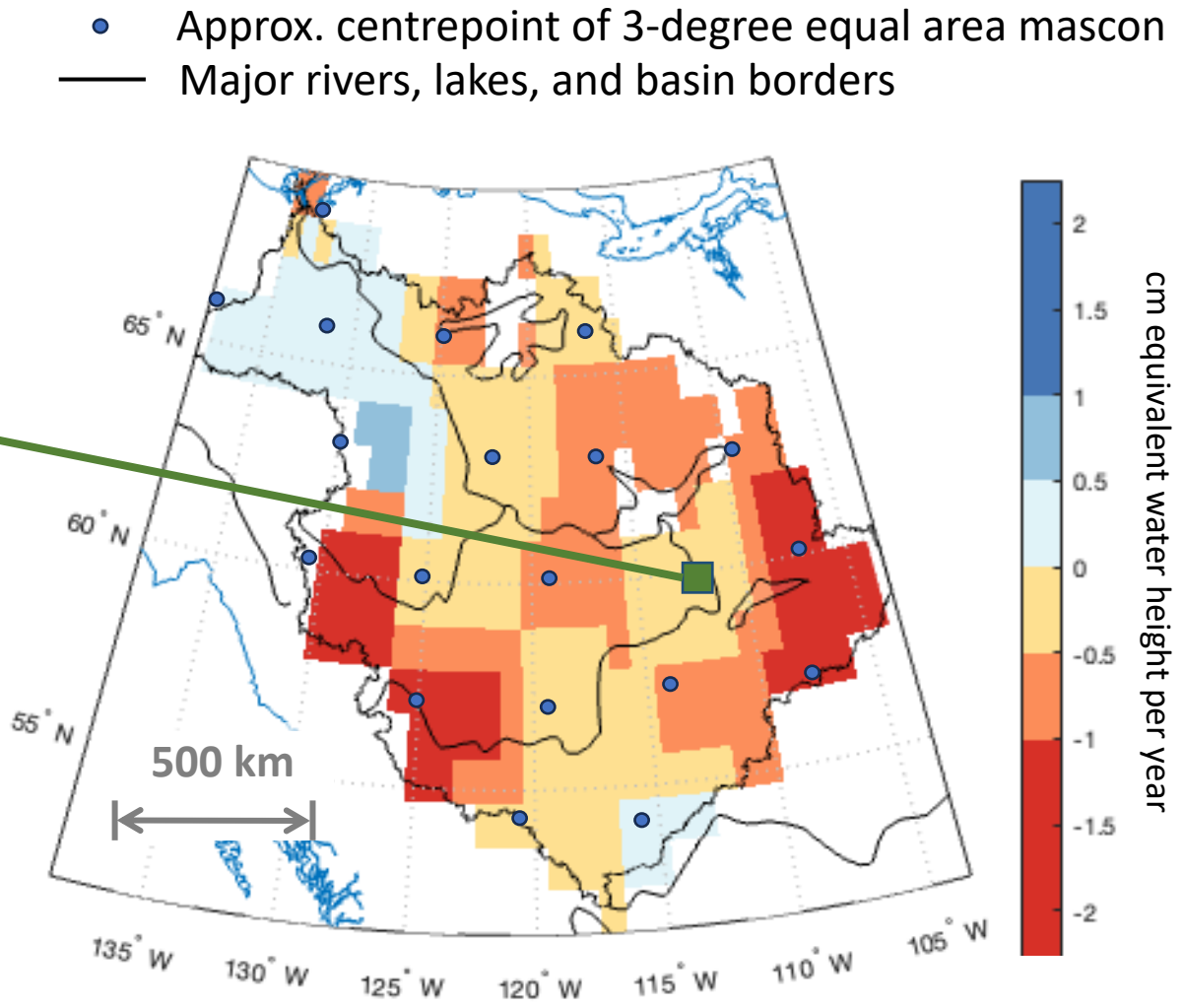
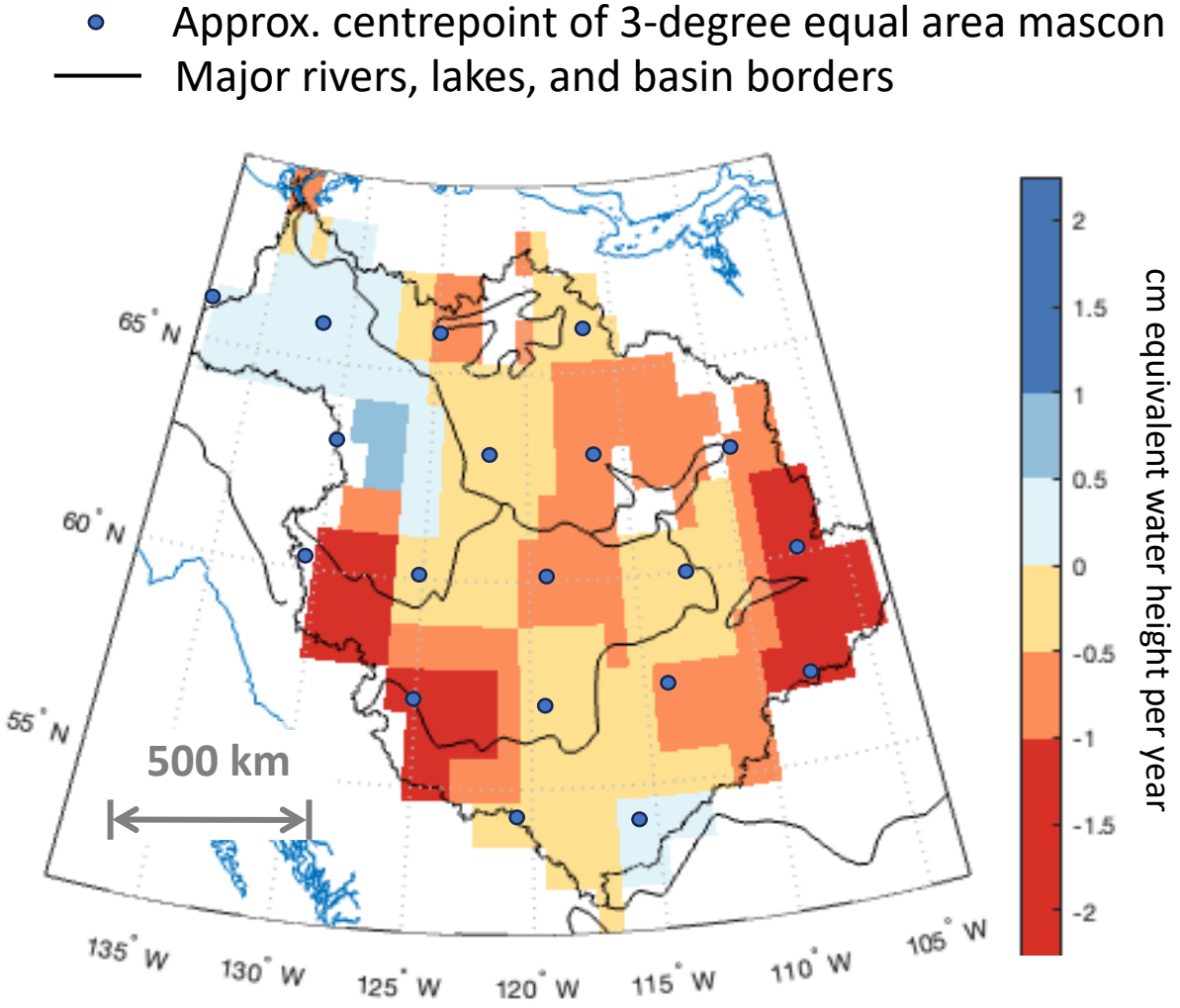


★ Fort McMurray ★ Jean Marie River ★ Hay River & KFN



TWSA trend variability

Can we observe heterogeneity throughout the basin during the flood event?



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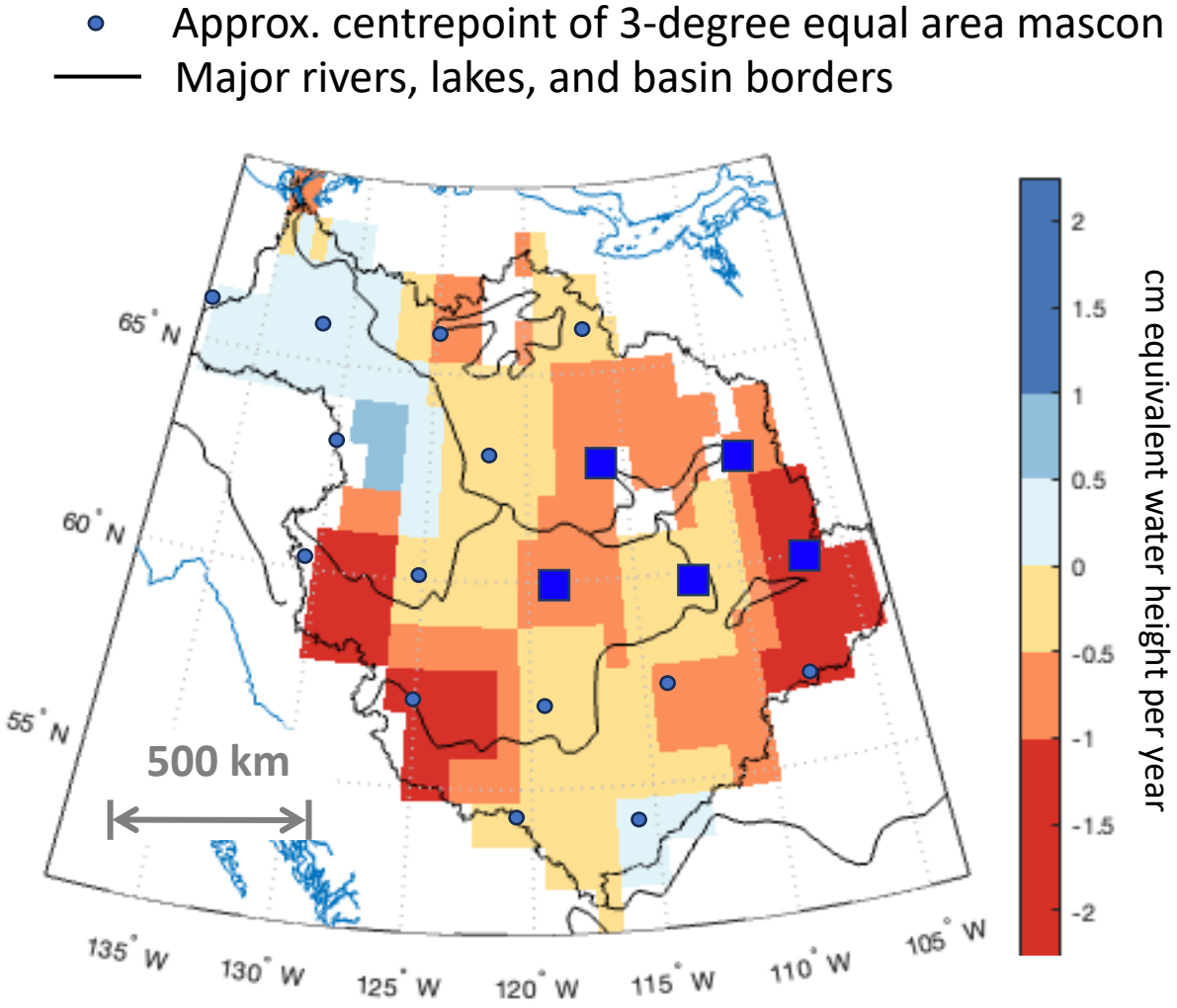
Can we observe heterogeneity throughout the basin during the flood event?

- **Great Slave Lake/Lake Athabasca**



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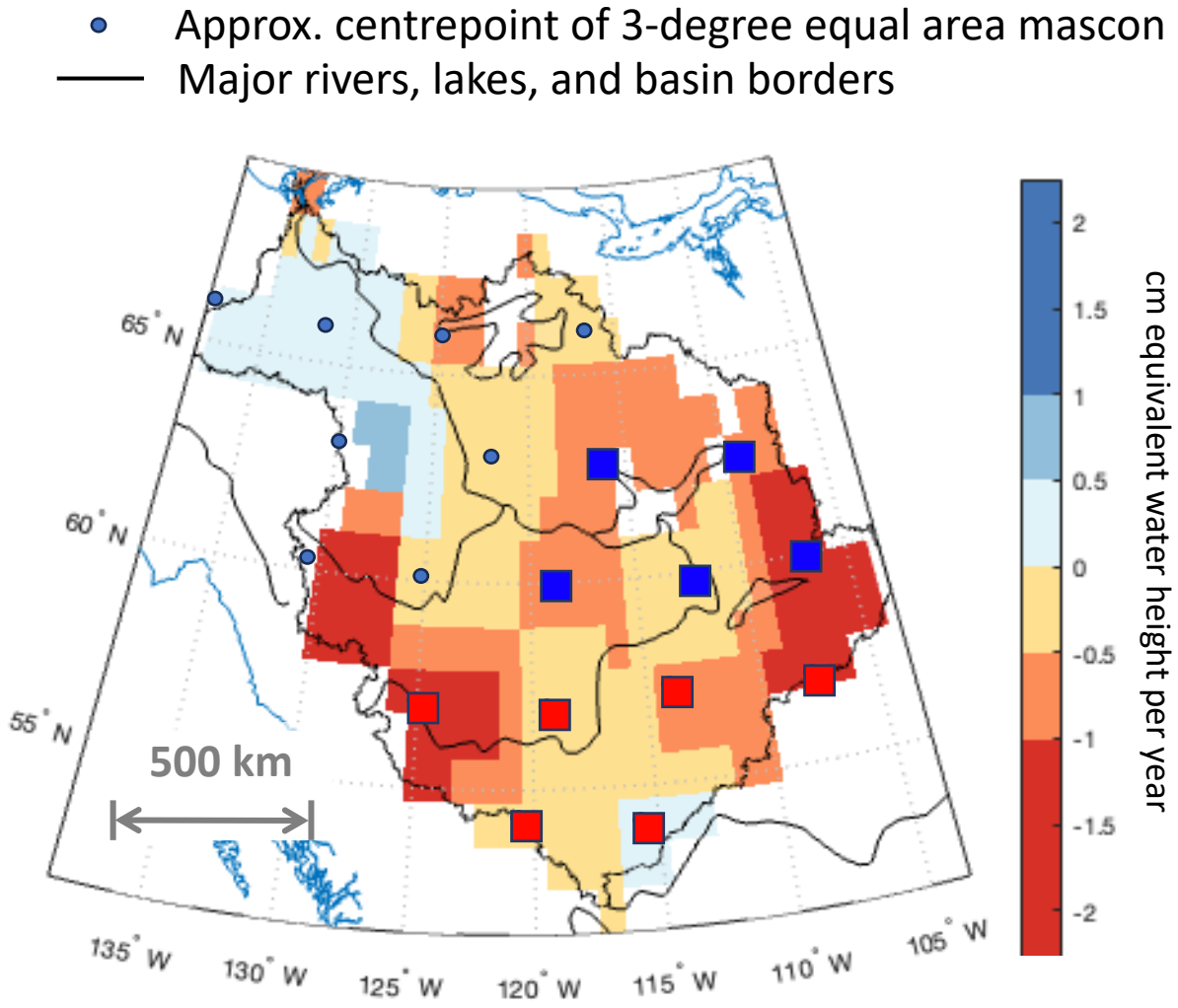
Can we observe heterogeneity throughout the basin during the flood event?

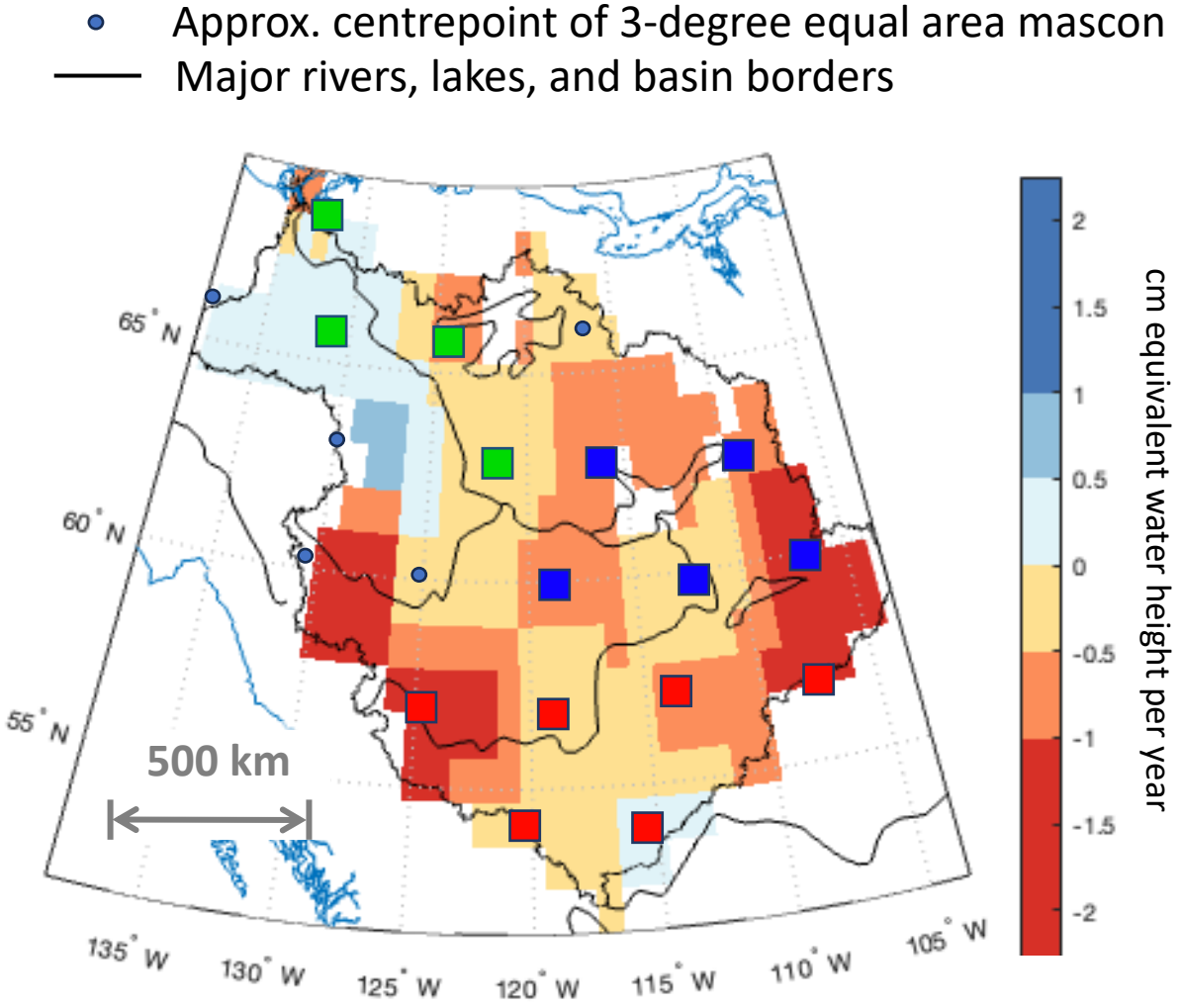
- **Great Slave Lake/Lake Athabasca**
- **Upstream**



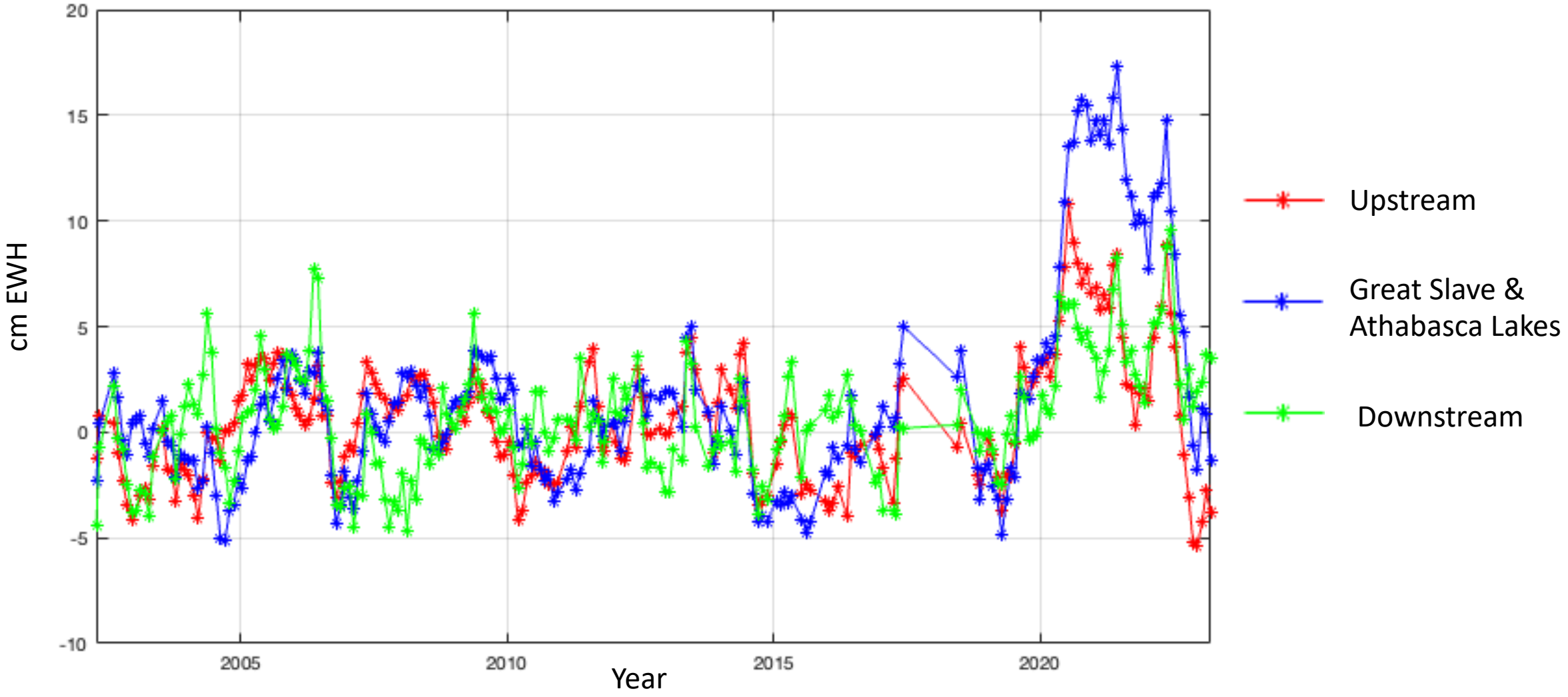
TWSA trend variability

Can we observe heterogeneity throughout the basin during the flood event?

- **Great Slave Lake/Lake Athabasca**
- **Upstream**
- **Downstream**



TWSA by Region: Annual & Linear Trend Removed



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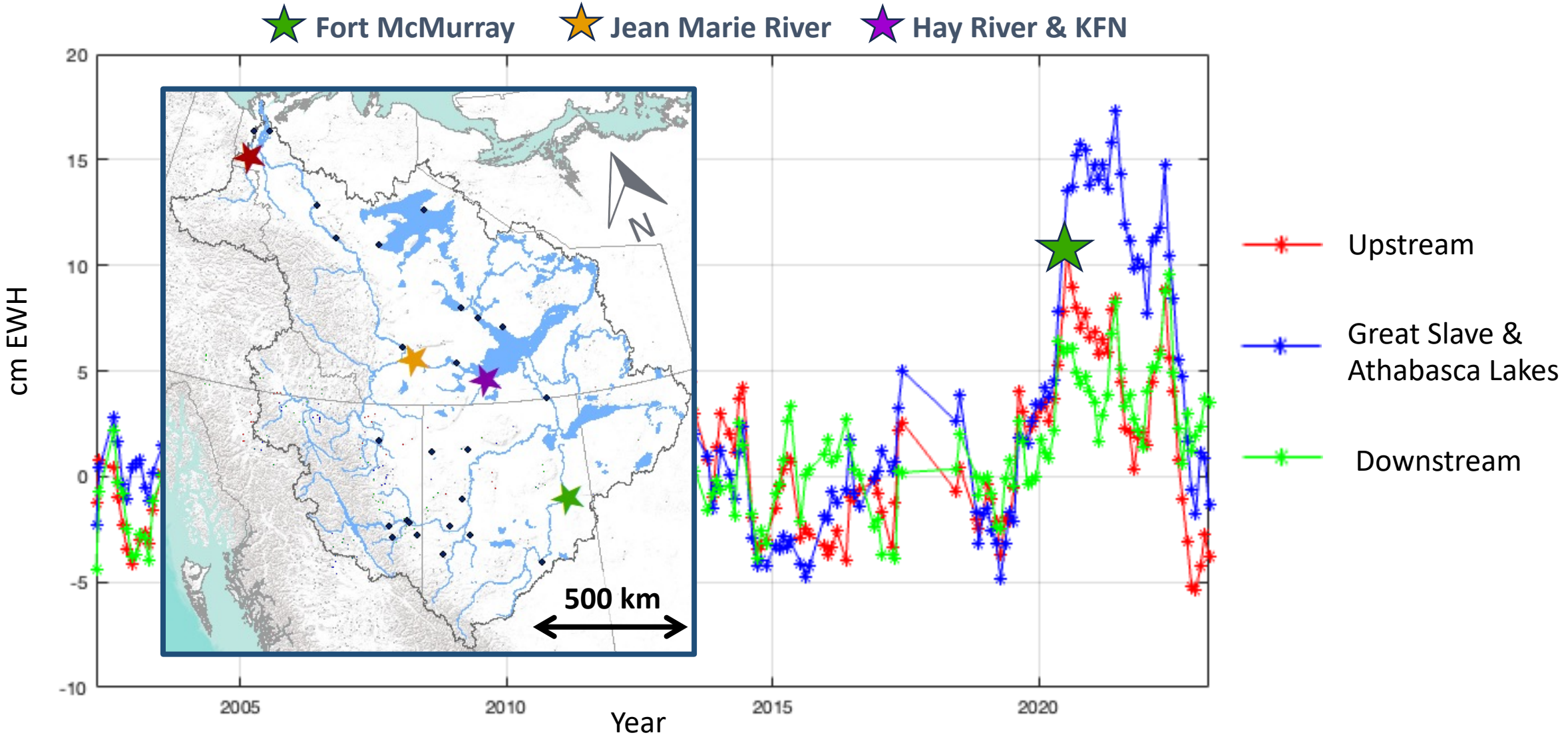

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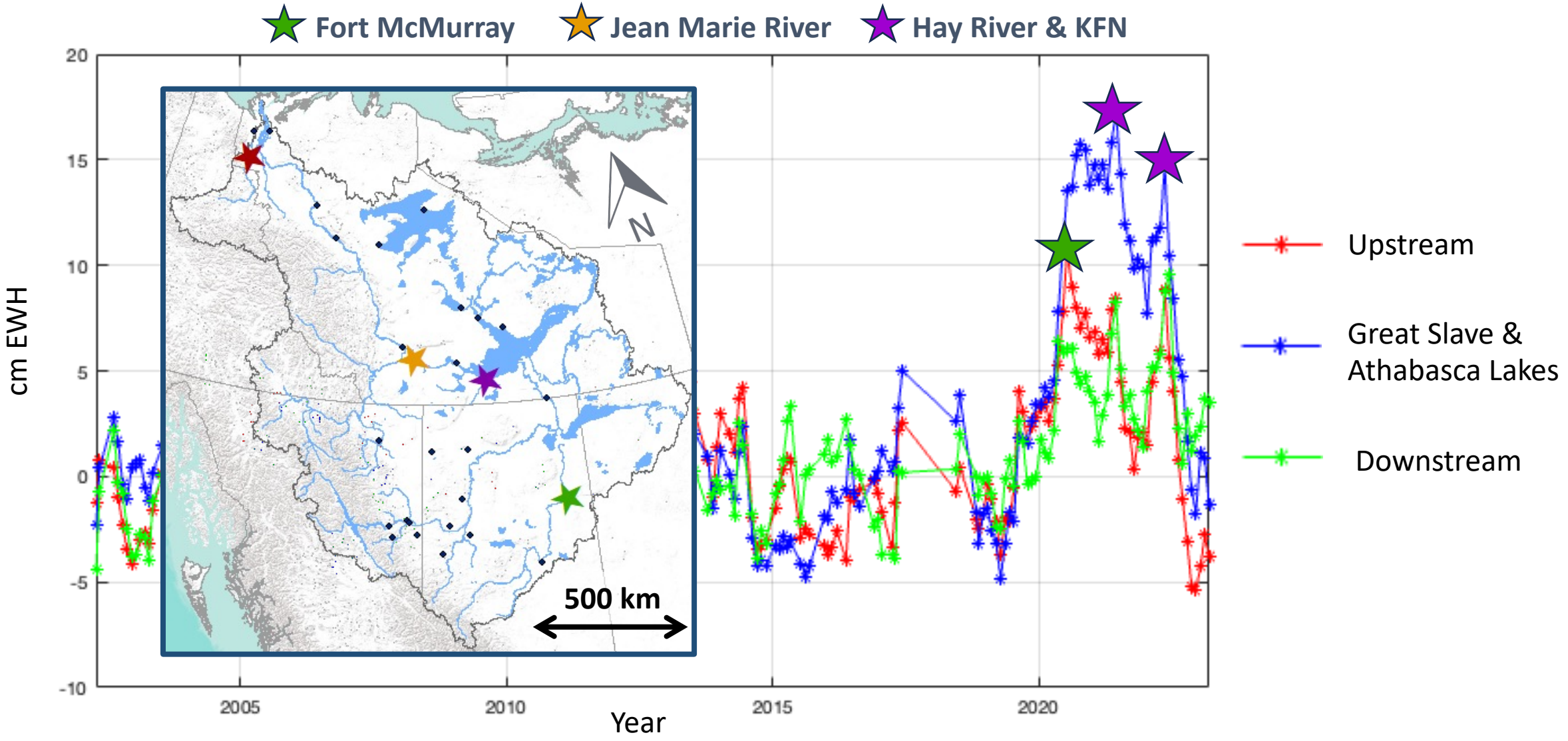

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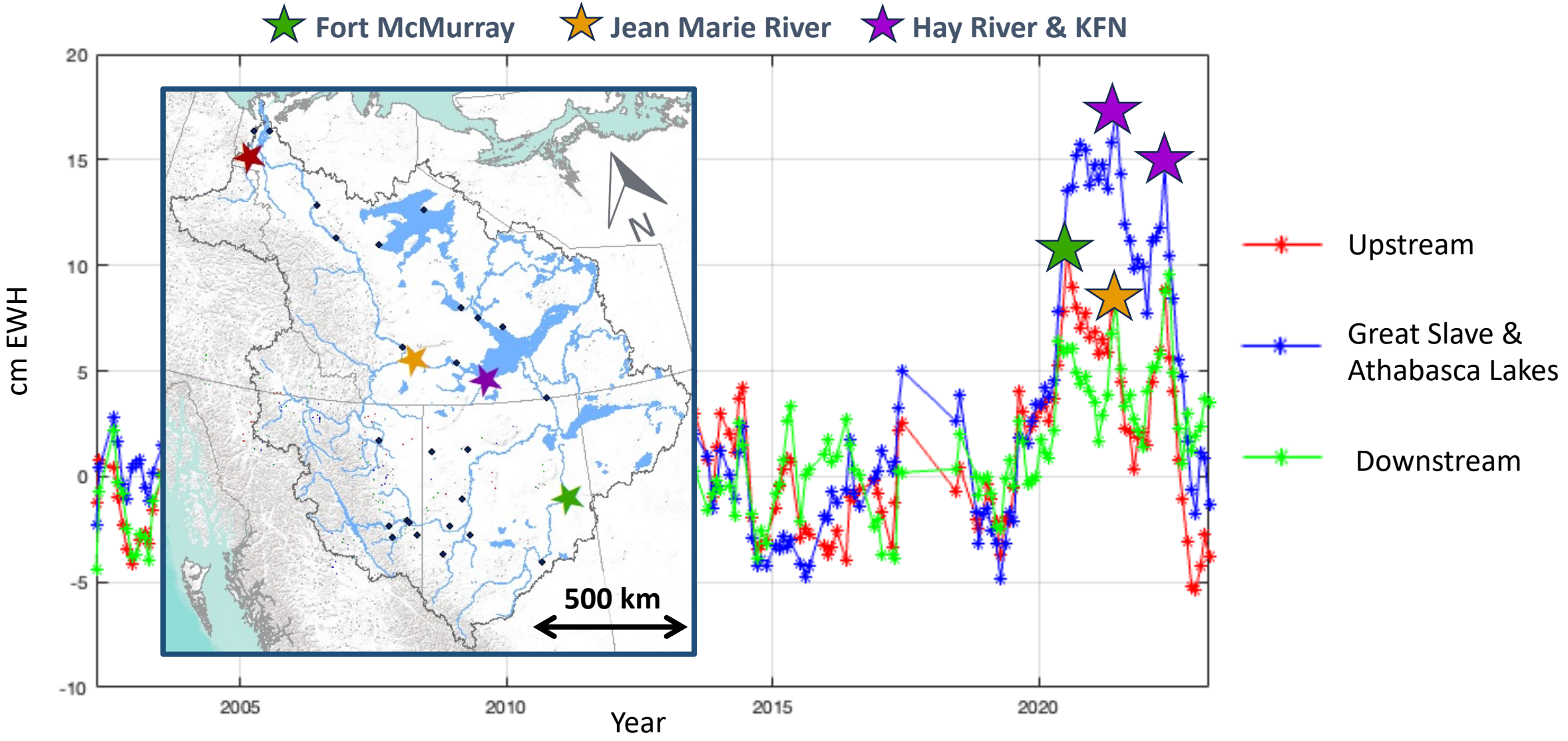
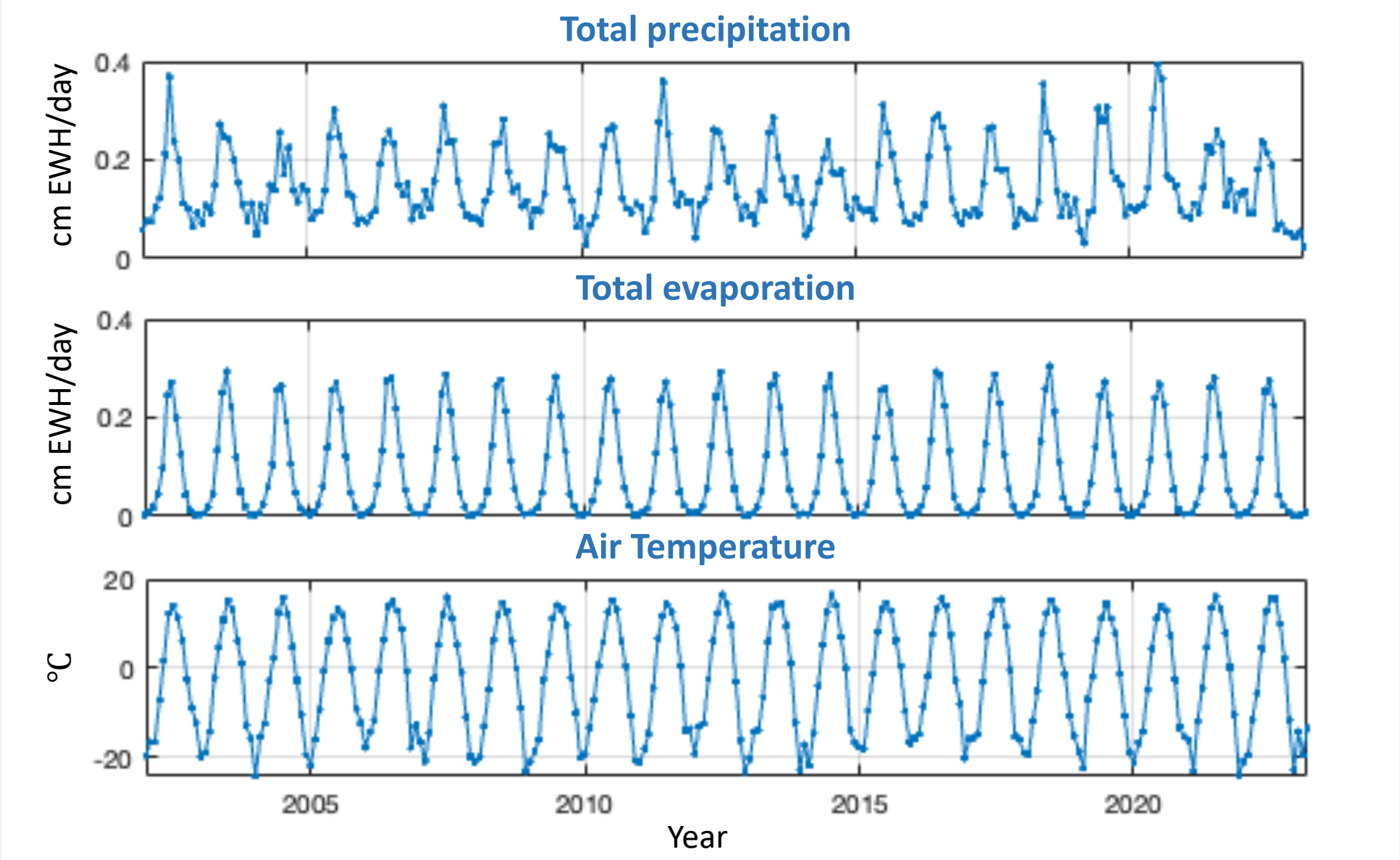
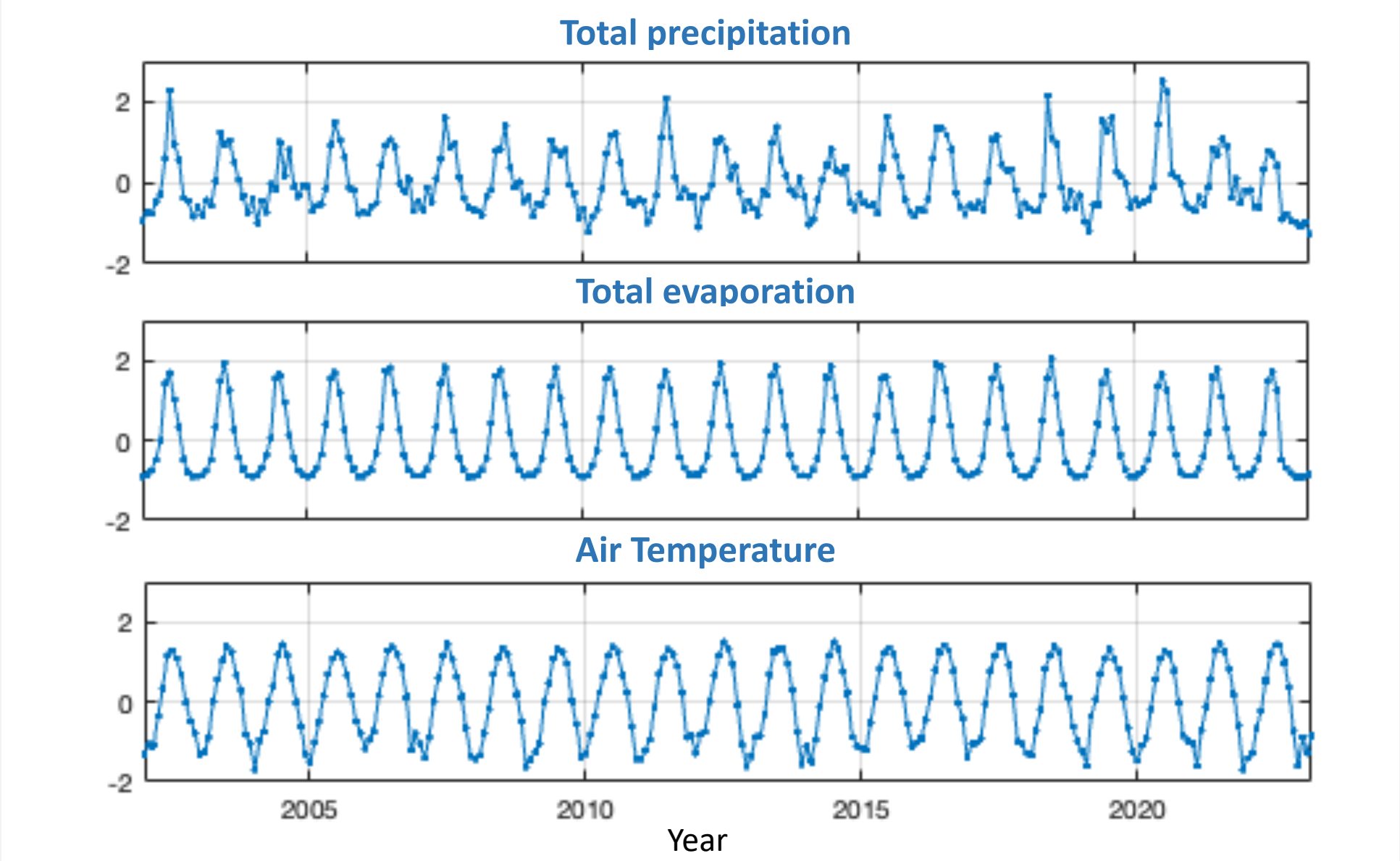


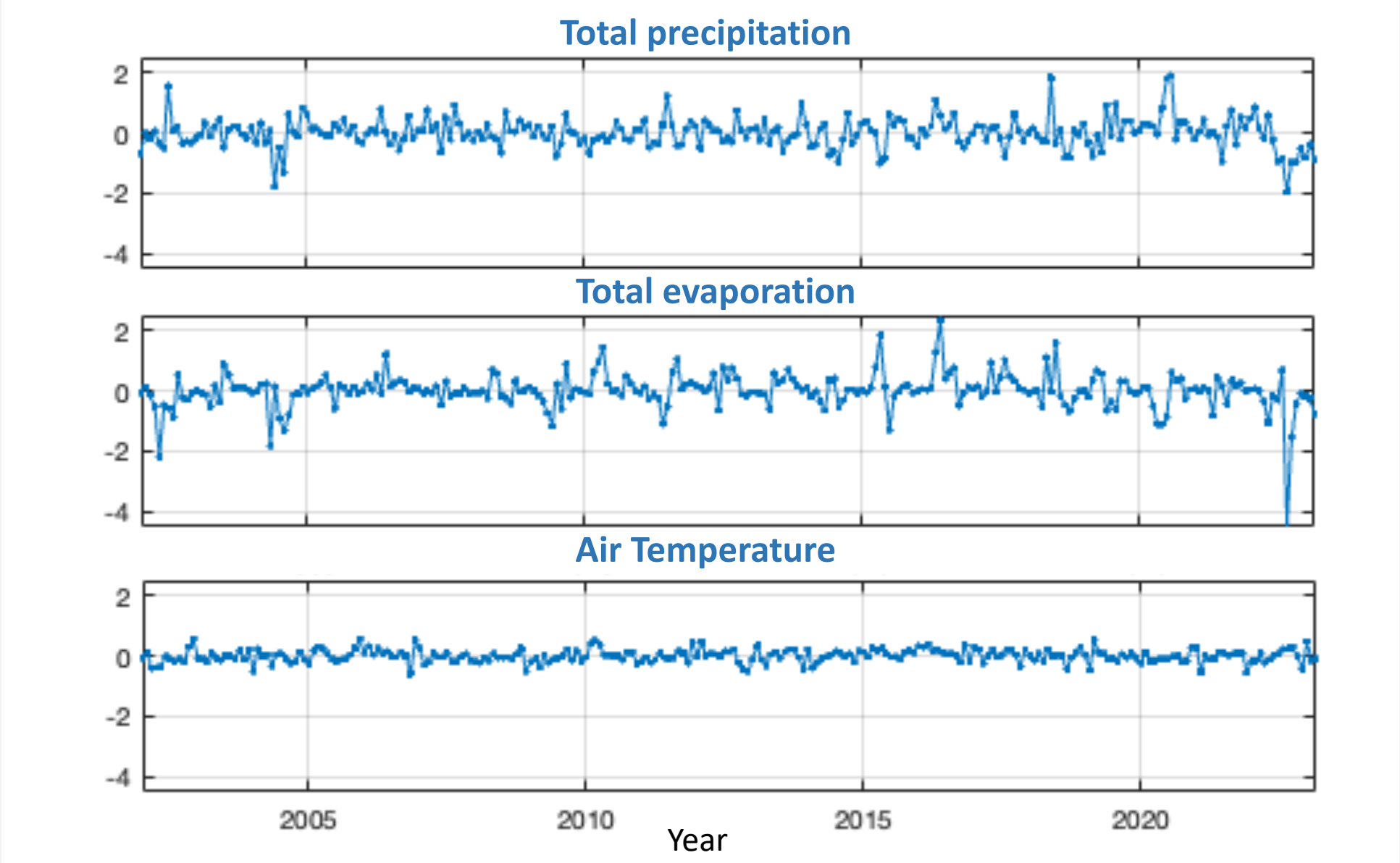
Average monthly values for ERA5-Land total precipitation, evaporation, and air temperature in the Mackenzie River Basin (Jan 2002 - March 2023)



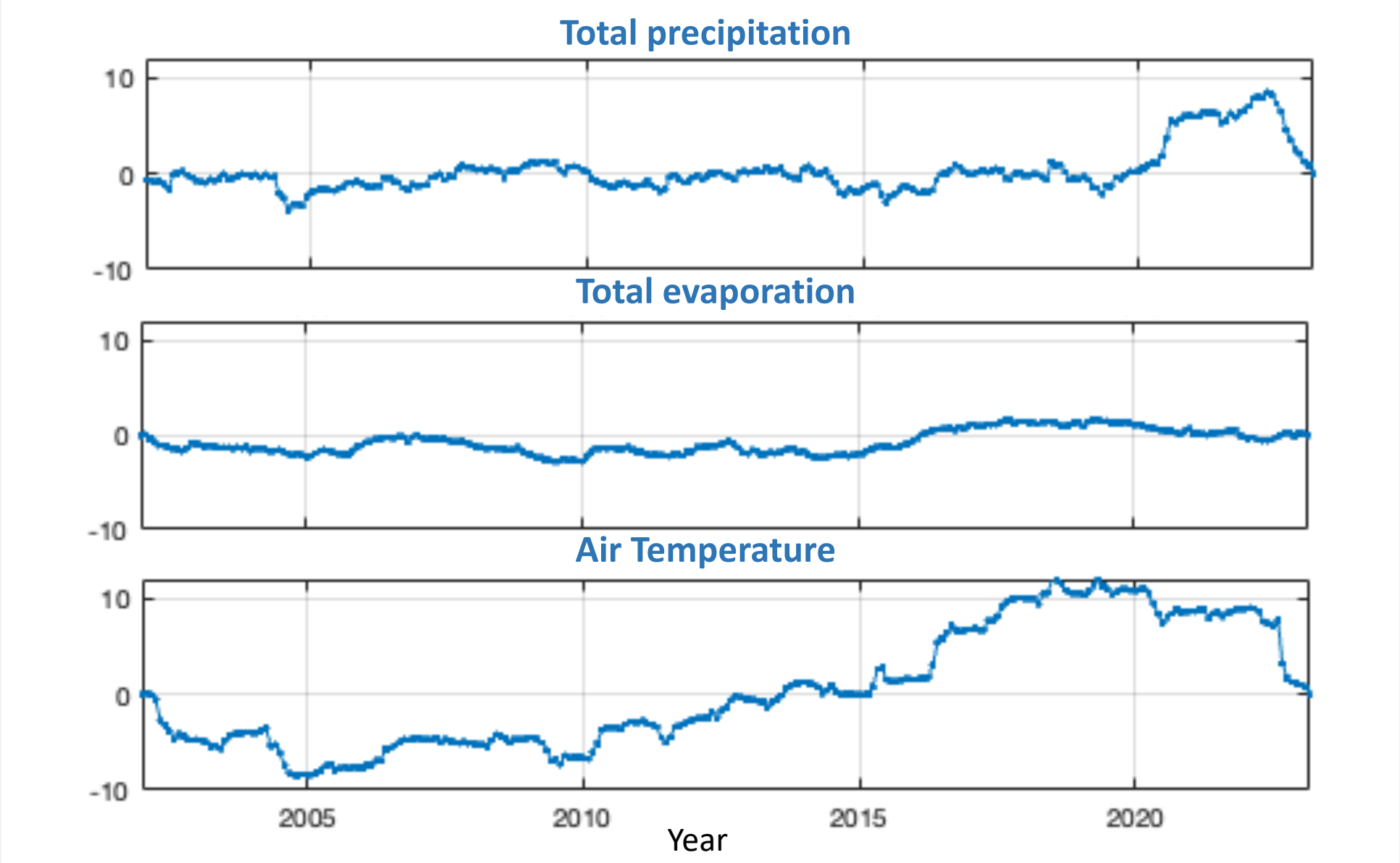
Normalized monthly value for ERA5-Land total precipitation, evaporation and air temperature in the Mackenzie River Basin (Jan 2002 - March 2023)



Normalized monthly value for ERA5-Land total precipitation, evaporation and air temperature in the Mackenzie River Basin (Jan. 2002 - March 2023), average seasonal signal removed



Cumulative sum of the normalized monthly value for ERA5-Land precipitation, evaporation and air temperature in the Mackenzie River Basin (Jan 2002 - March 2023), average seasonal signal removed



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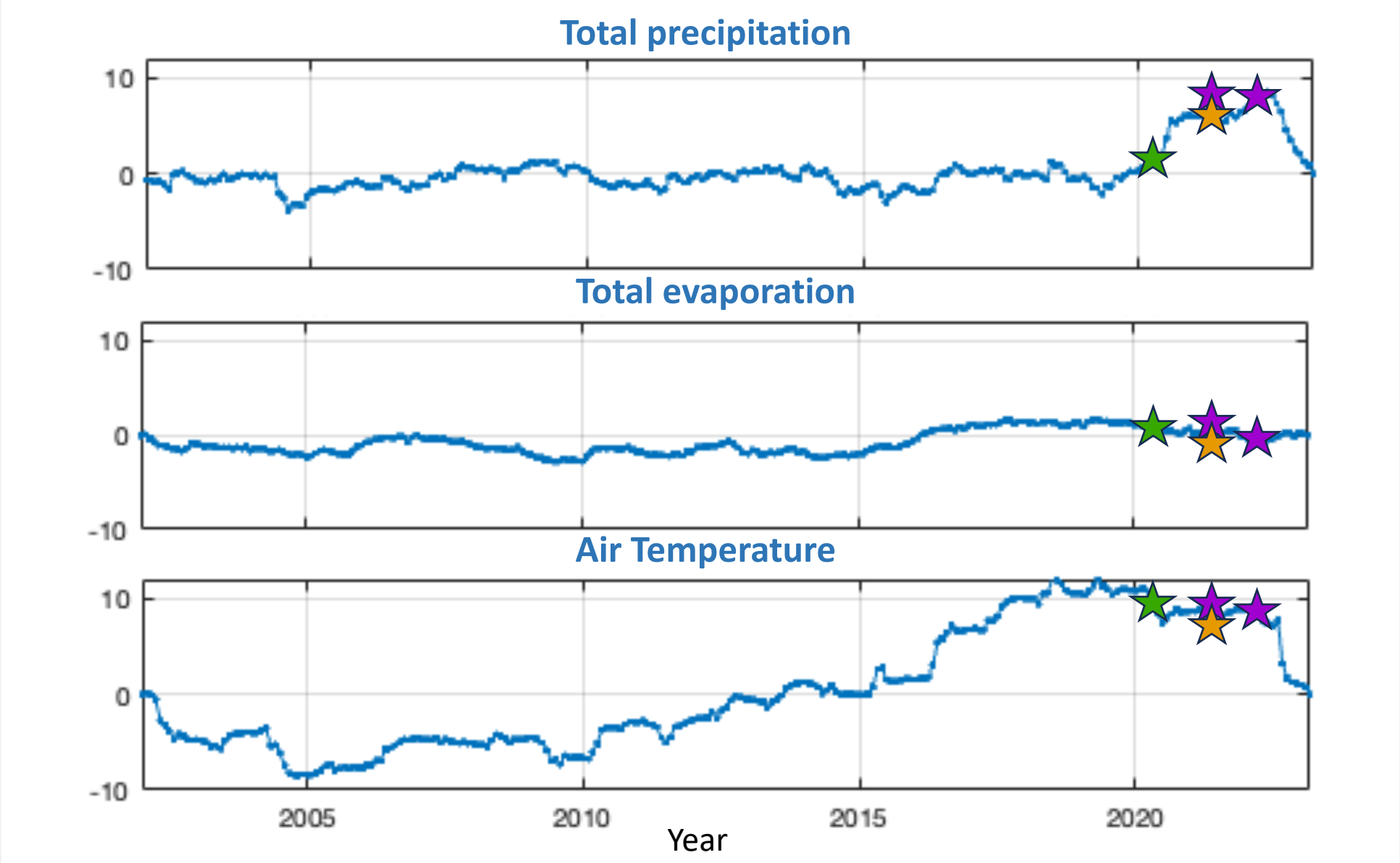

Conclusions & Future Work

- TWSA from **GRACE/GRACE-FO** suggests flooding event occurred **despite** overall declining TWSA trend, though anomalous precipitation events may become more frequent with climate change
- Increased **precipitation** upstream from Great Slave Lake caused historical high water levels
- Evaluating trends at the **mascon scale** reveals spatial variability of the flood within the Mackenzie River Basin
- Workflow for TWSA analysis **adapted** to other Canadian river basins

Thank you!

Natural Resources Canada - Canadian Geodetic Survey
Geological Survey of Canada - Groundwater Division

Geodesy & Geophysics Research Group

15smb14@queensu.ca

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