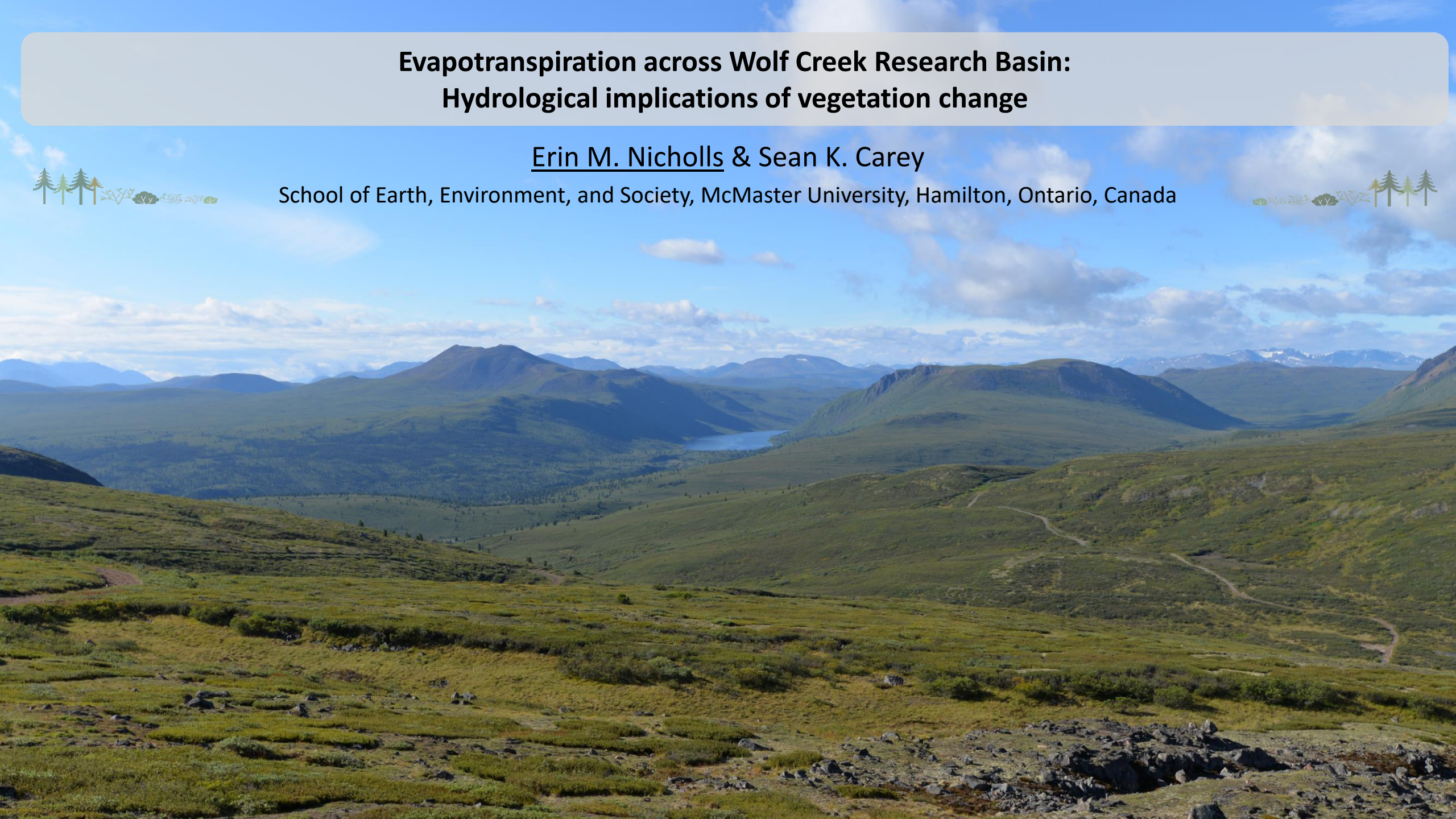
Evapotranspiration across Wolf Creek Research Basin: Hydrological implications of vegetation change

Erin M. Nicholls & Sean K. Carey

School of Earth, Environment, and Society, McMaster University, Hamilton, Ontario, Canada



Acknowledgments

CCRN
Changing Cold Regions Network

Water Resources Branch –Yukon Government
Dr. Gordon Drewitt
David Barrett
Tyler de Jong
Arsh Grewal
Sean Leipe
Joseph Desmarais
Fiona Chapman
Dr. Mike Treberg
Elysia Fuller-Thompson
Dr. Chrstoforos Pappas
Dr. Nadine Shatilla
Alanna Bodo
Nia Perron

Yukon

NSERC
CRSNG

Watershed Hydrology Group
McMaster University

GWF

International Polar Year 2007-2008

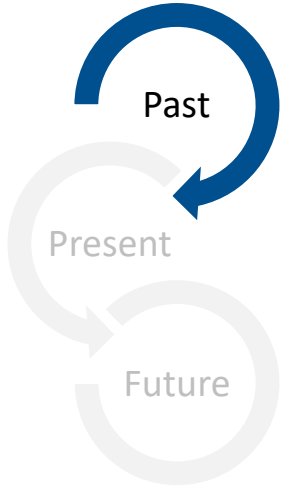
Mackenzie GEWEX Study MAGS

IP3
Improved Processes & Parameterisation for Prediction in Cold Regions

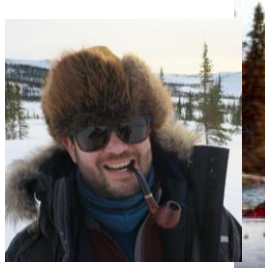
Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

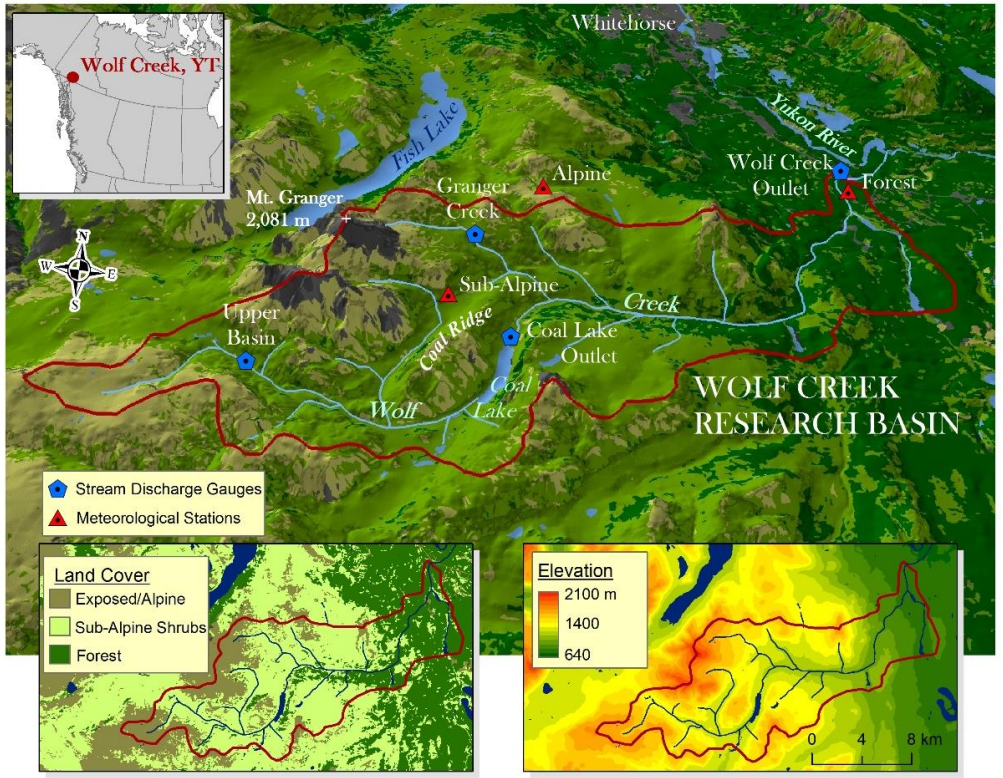
Weston Family Foundation

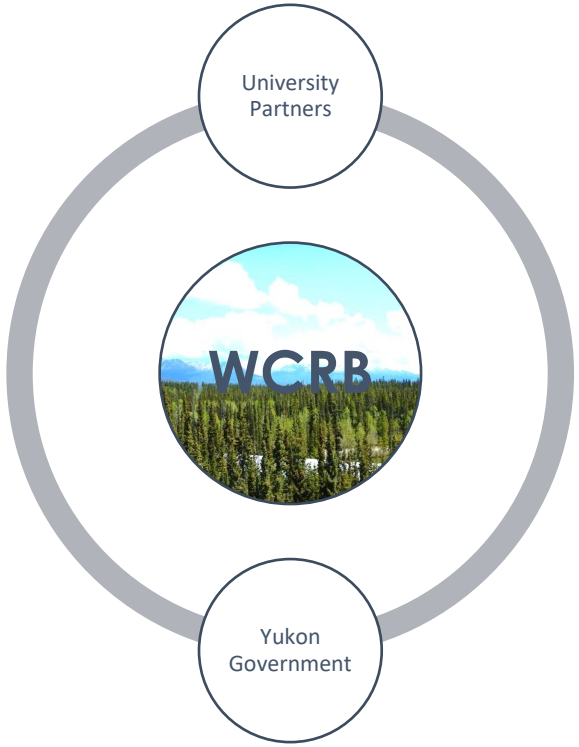
Canada First Research Excellence Fund
Apogée Canada
Fonds d'excellence en recherche

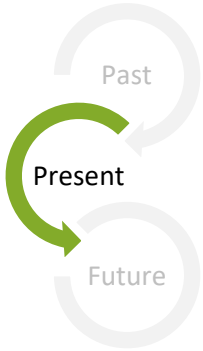


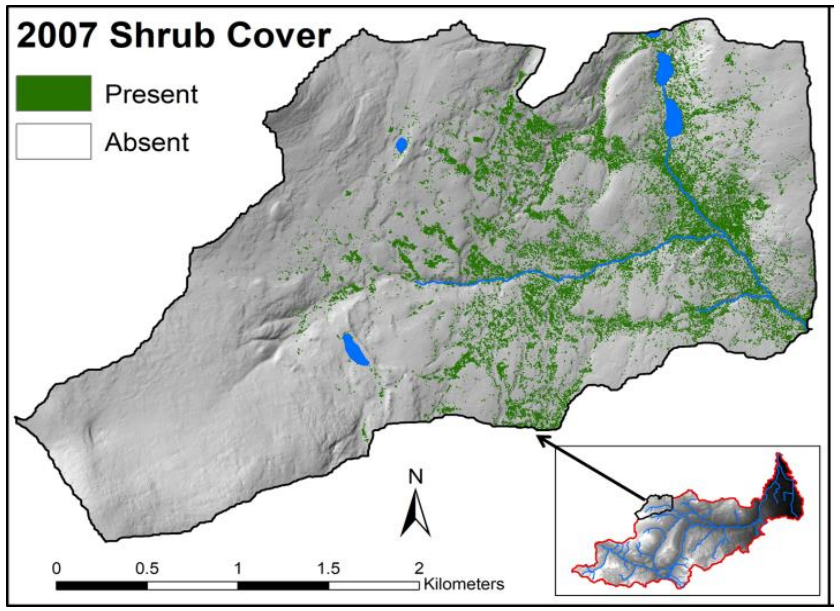
- In 1992, the Wolf Creek Research Basin (WCRB) was established in the sub-arctic mountainous headwaters of the Yukon River, as a representative basin for the northern reaches of the North American Cordillera.
- WCRB was established to **provide science-based evidence for decision making across the areas of water, climate and the biosphere** and to provide a test-bed to help resolve deficiencies in hydrological models in cold climates.

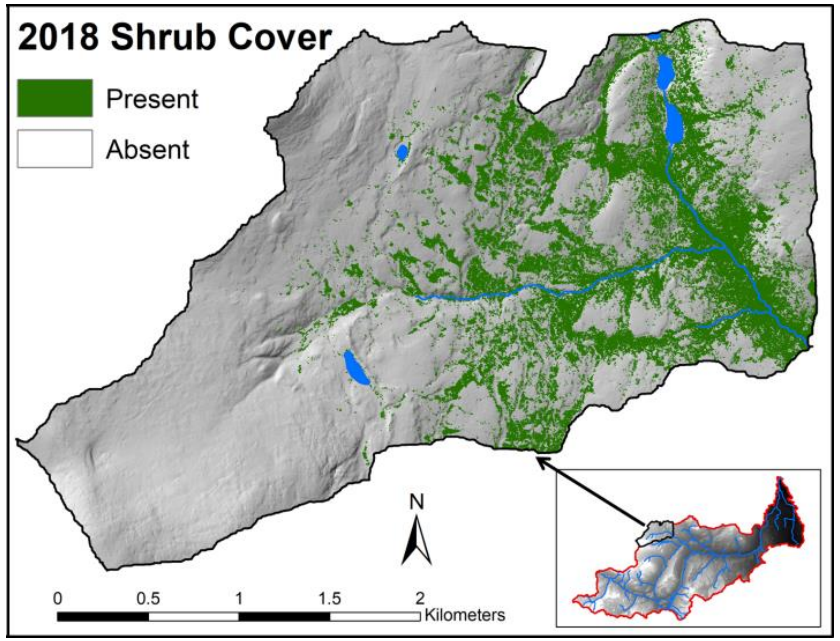










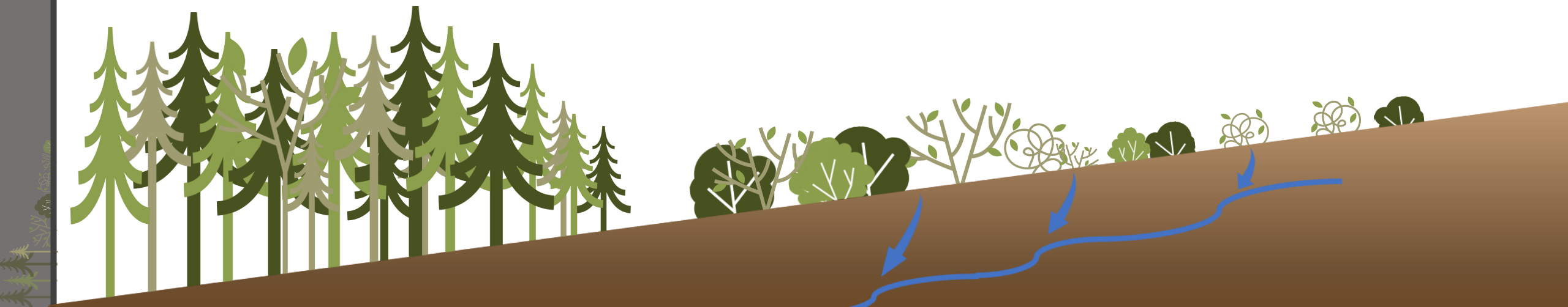


(Leipe and Carey, 2021)

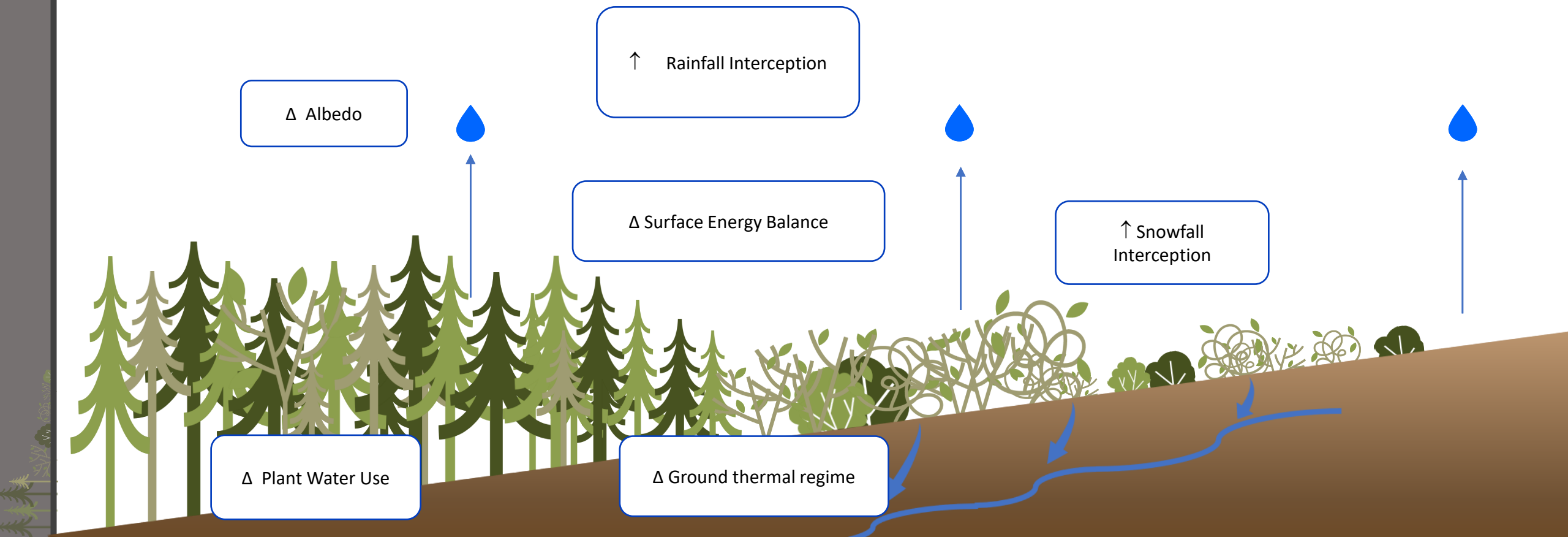
- Tree and shrub migration at increasing altitude and latitude
- Shifts in land classifications
- Increases in shrub height, extent and density

(Credit: NASA's Goddard Space Flight Center/Cindy Starr)

What hydrological changes will occur with a shift in treeline and increased shrub abundance?



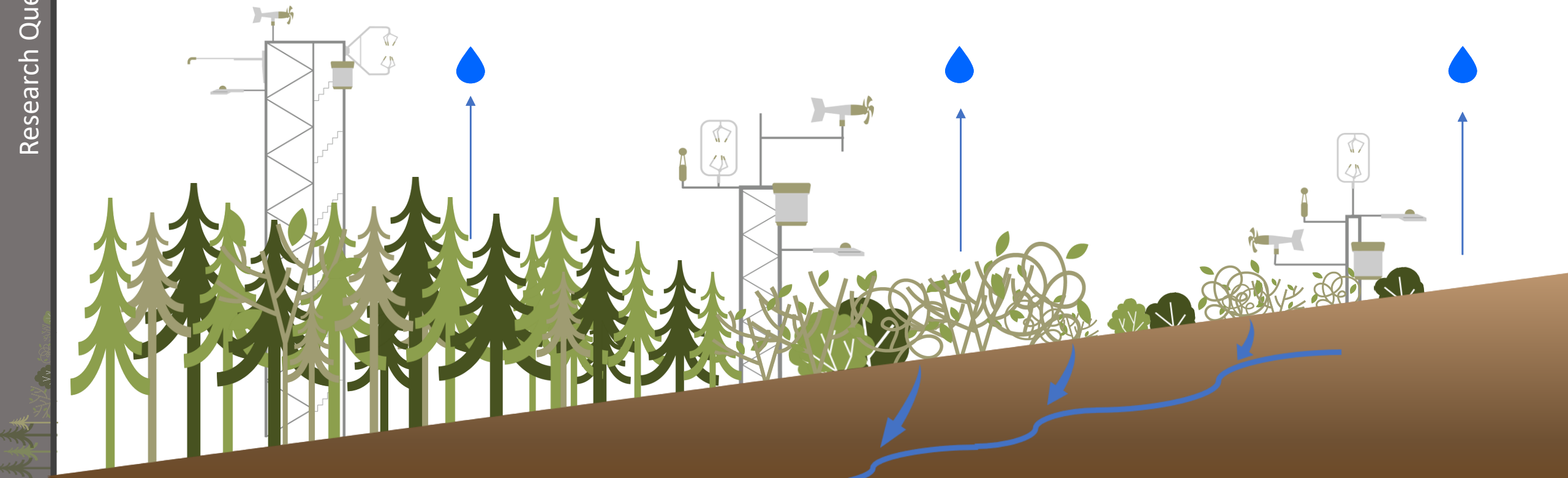
What hydrological changes will occur with a shift in treeline and increased shrub abundance?



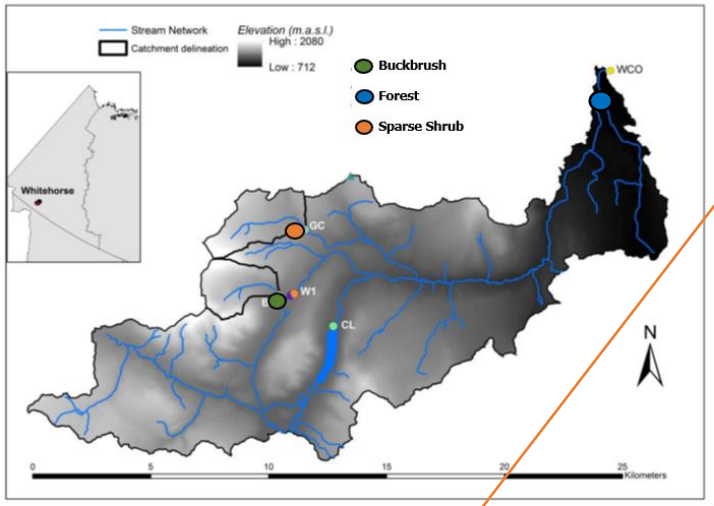
Research Questions

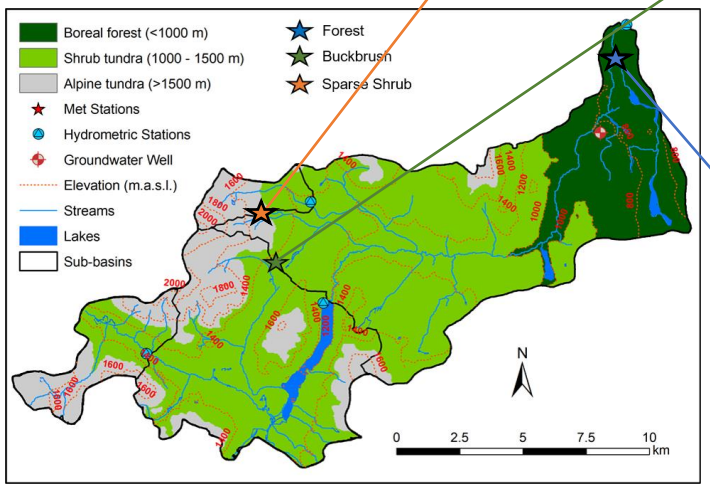
What hydrological changes will occur with a shift in treeline and increased shrub abundance?

What role does vegetation play in regulating these hydrological shifts?



Wolf Creek Research Basin, Yukon Territory





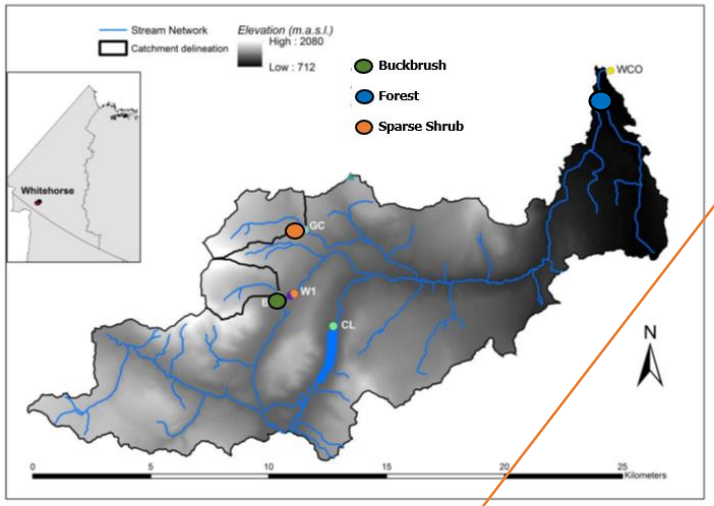
Increasing Elevation

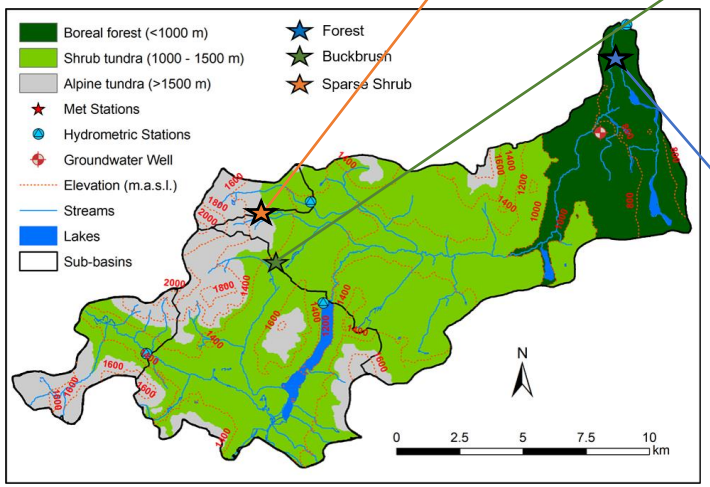
Sparse Shrub
1450 masl
Willow and Birch Shrubs
<~0.5m

Buckbrush
1250 masl
Willow and Birch Shrubs
<~1-3 m

Forest
750 masl
White Spruce
~12-20 m

Wolf Creek Research Basin, Yukon Territory





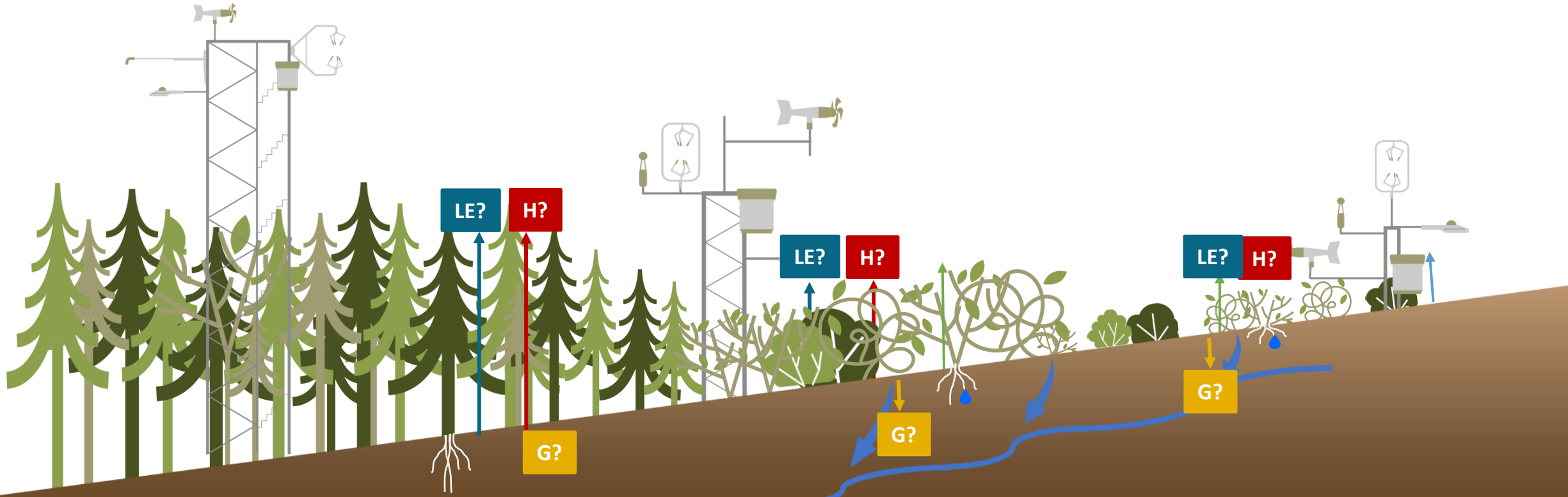
Increasing Elevation

Sap Flow Sensors

- Dynamax EXO-Skin Sensors
- 2019-2020
- 4 Birch
- 4 Willow

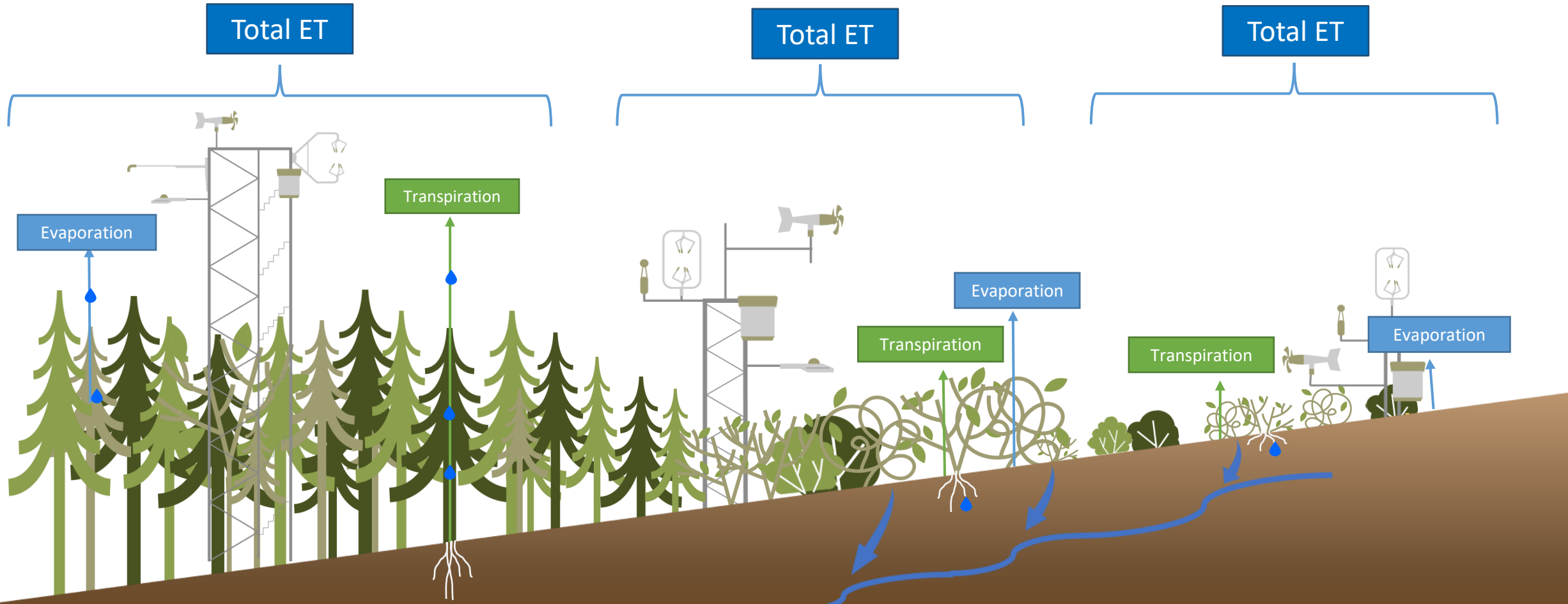
- Granier Style Thermal Dissipation Probes
- 2018-2020
- 22 White Spruce

How does surface energy partitioning vary across these ecosystems?



How does surface energy partitioning vary across these ecosystems?

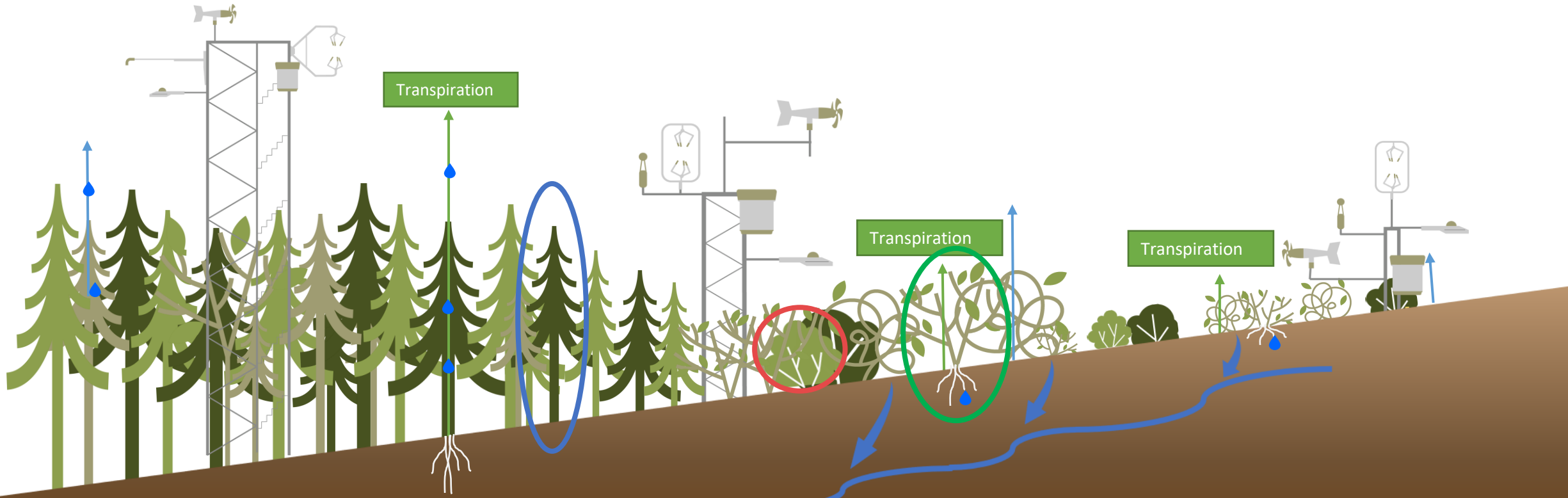
How does T:ET vary across sites and seasons?



How does surface energy partitioning vary across these ecosystems?

How does T:ET vary across sites and seasons?

Species-specific response: Does plant composition matter?

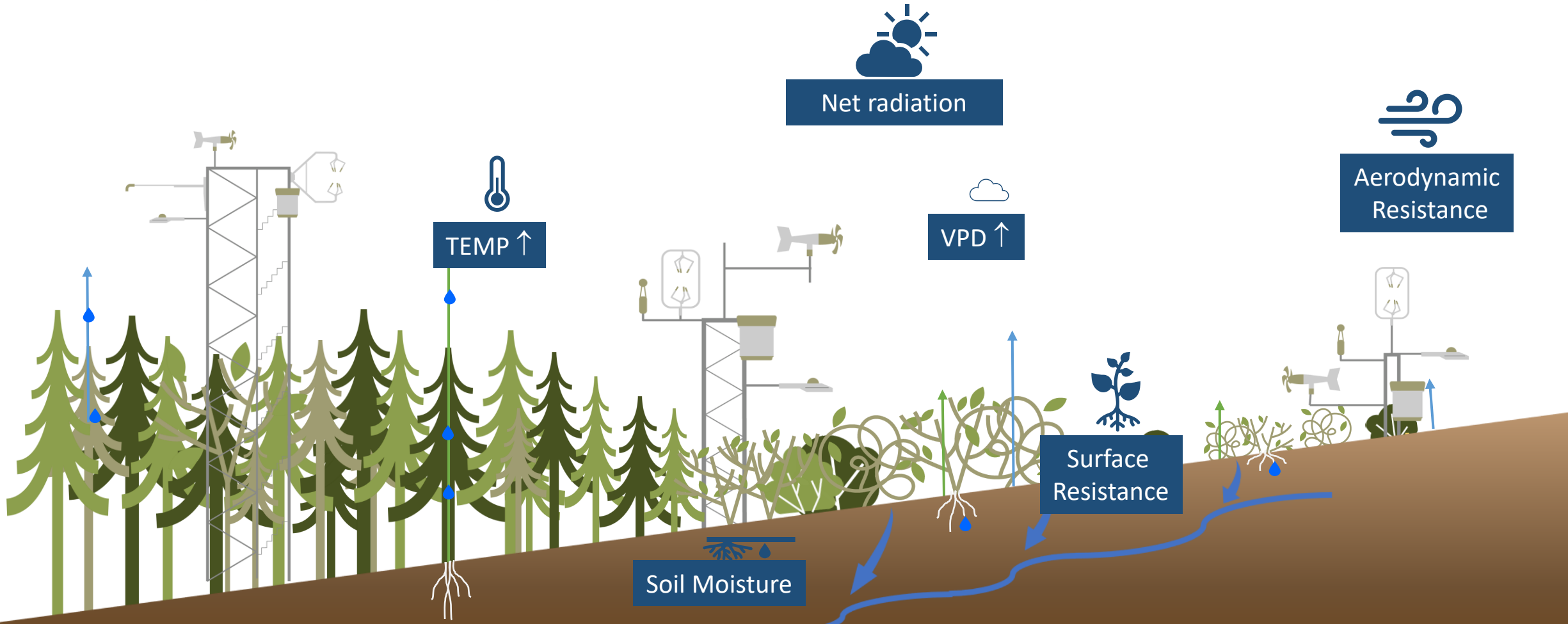


How does surface energy partitioning vary across these ecosystems?

How does T:ET vary across sites and seasons?

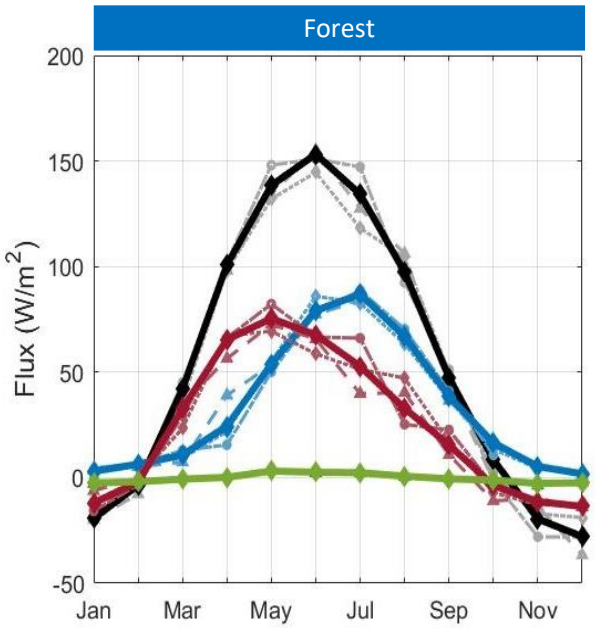
Species-specific response: Does plant composition matter?

What is driving ET and T?

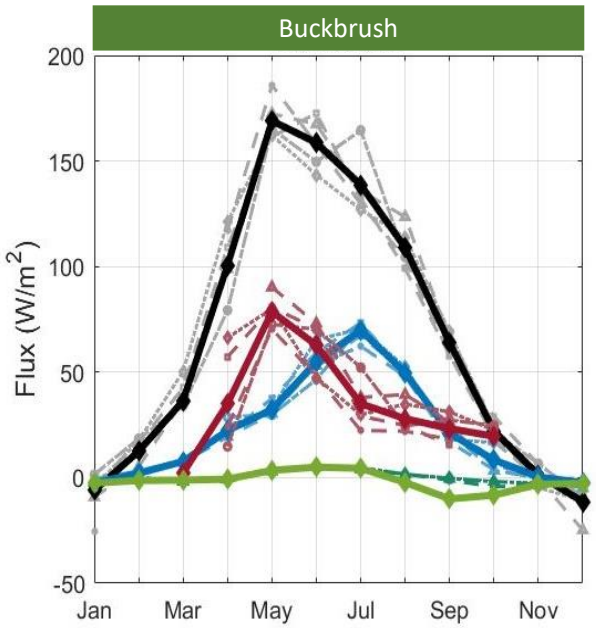


How does surface energy partitioning vary across these ecosystems?

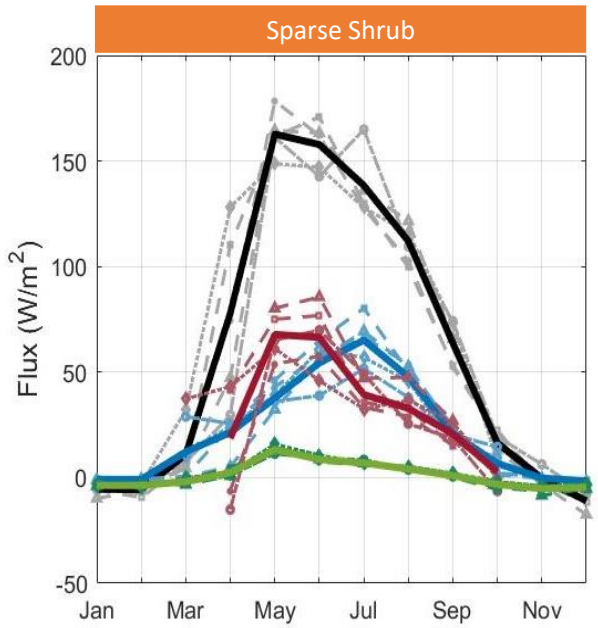
- All sites were dominated by sensible heat early in the season and shifted to latent heat later in the season. This transitioned occurred later in the year with increasing elevation
- Variability in all interannual energy balance terms increased with elevation and reduced vegetation



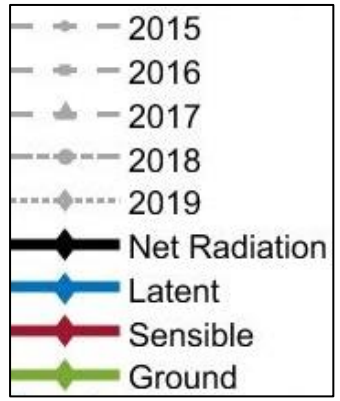
May to Sept
β= 0.81 (±0.12)



May to Sept
β= 1.31 (±0.12)

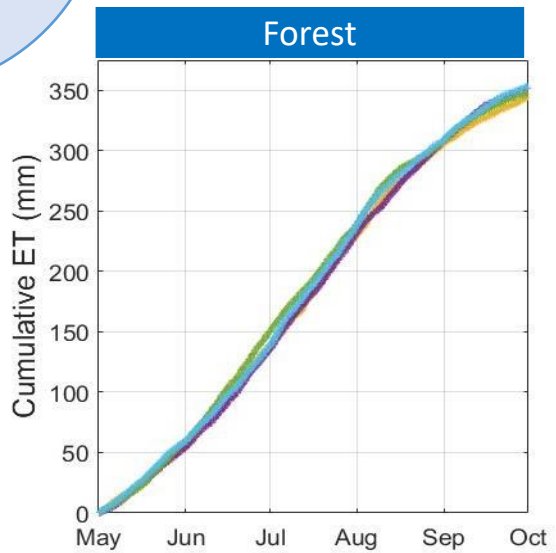


May to Sept
β= 1.12 (±0.31)

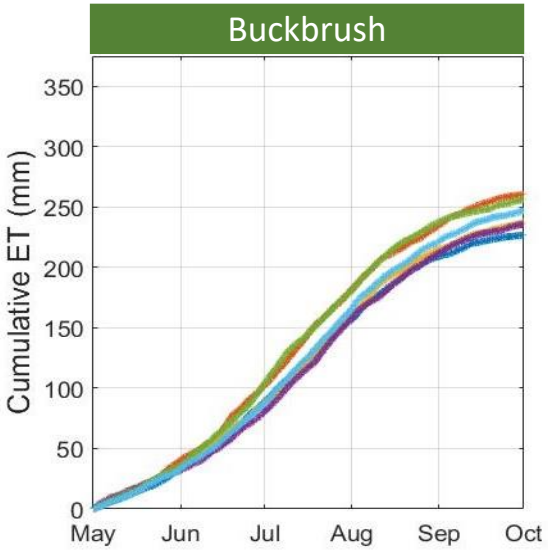


How does ET vary across sites and seasons?

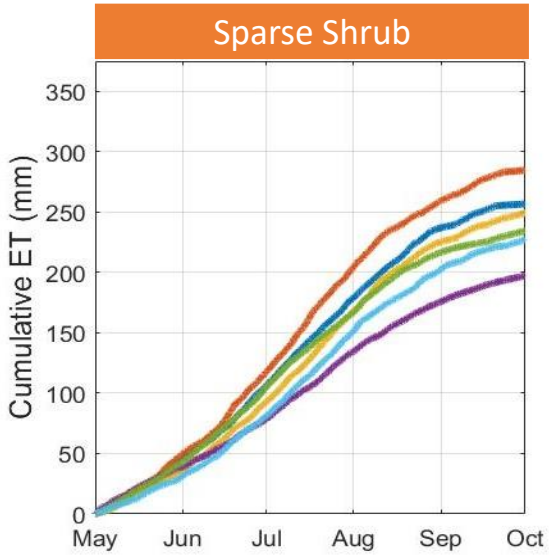
Increasing interannual variability with decreasing vegetation cover



349 (±4) mm
2.3 mm/day



244 (±10) mm
1.6 mm/day



226 (±22) mm
1.5 mm/day

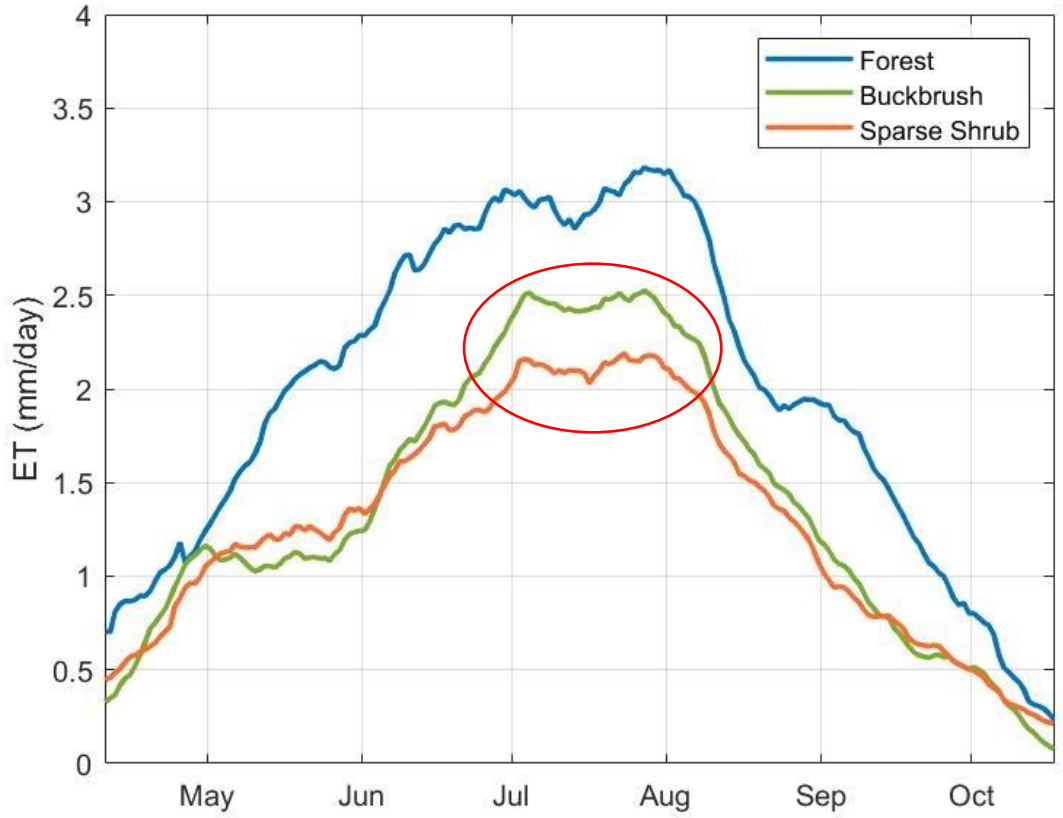
Treeline advance:
Increased May to September ET

Shrubification:
Similar total May to September ET

Nicholls and Carey, 2021. *Journal of Hydrology*.

How does ET vary across sites and seasons?

Increasing interannual variability with decreasing vegetation cover



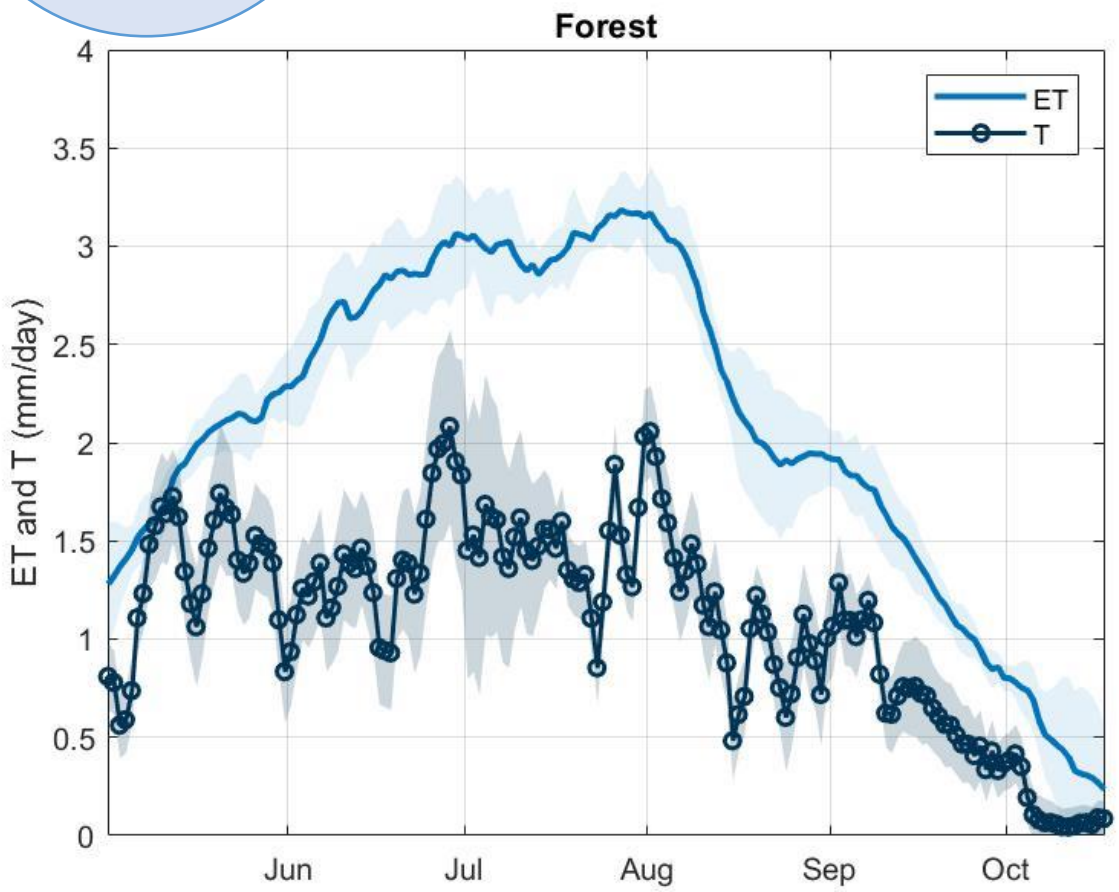
Treeline advance:
Increased May to September ET

Shrubification:
Similar total May to September ET

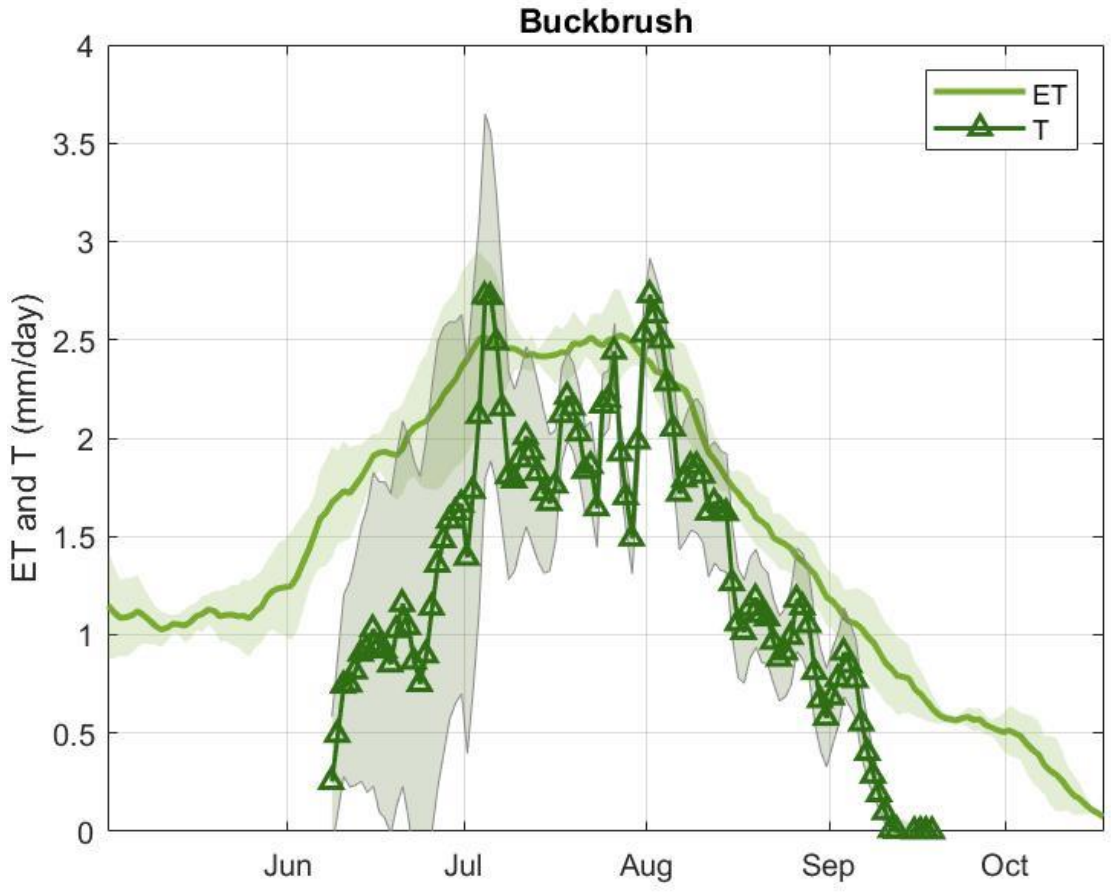
Nicholls and Carey, 2021. *Journal of Hydrology*.

How do T rates vary across sites and seasons?

- Mean T rates higher in willow and birch shrubs than white spruce forest
- Forest T follows a more seasonal trend with net radiation, beginning earlier in the spring and sustained later in the Fall
- Interannual and seasonal variability in T higher at Buckbrush than Forest



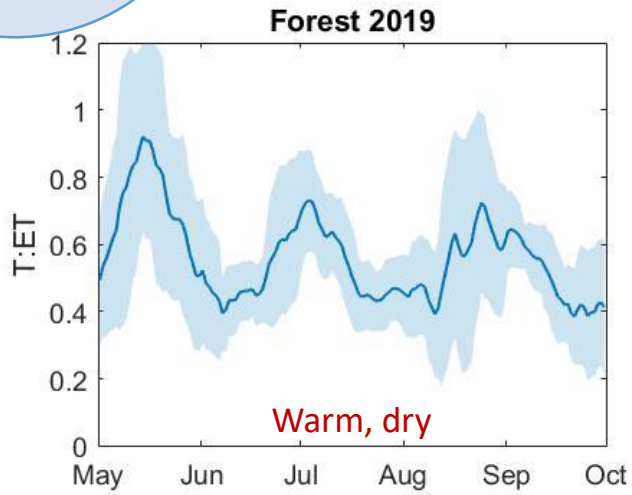
July to Sept T:
1.1 (± 0.58) mm/day

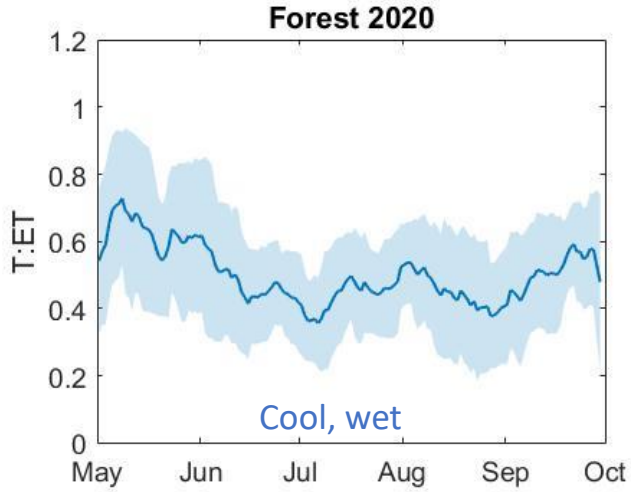


July to Sept T:
1.65 (± 1) mm/day

How do T:ET rates vary across sites and seasons?

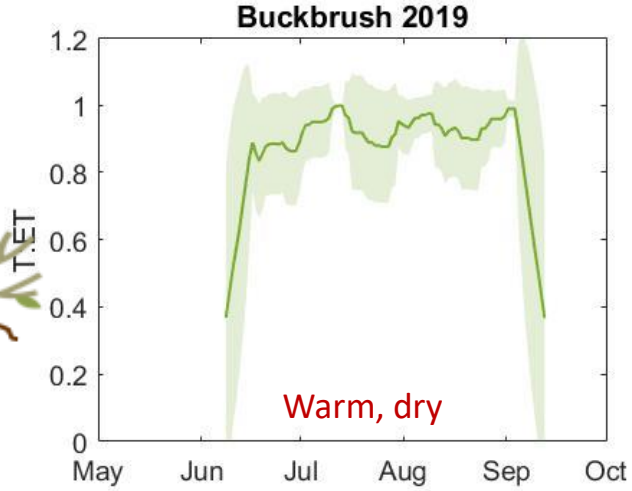
- **Forest**: T:ET was highest in the early season, when T had started but ET was still low
- **Buckbrush**: T:ET was high in the mid-growing season, with distinct shoulder season thresholds
- During the warm, dry growing season of 2019, T:ET was controlled by rainfall (moisture deficit)

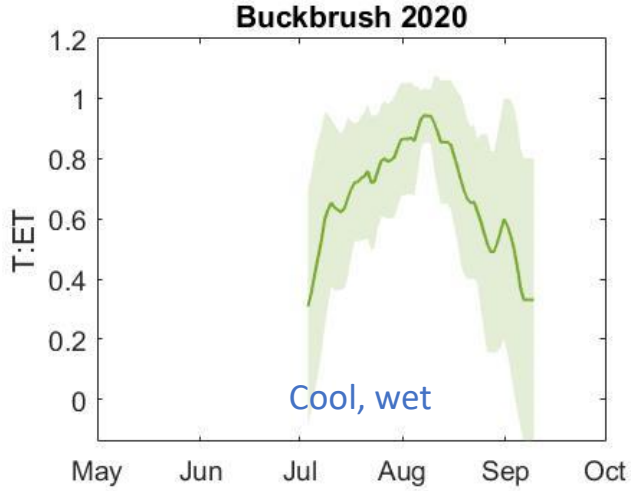




Forest:

- Peak growing season (July), T:ET =
  - 53% (2019)
  - 43% (2020)





Buckbrush:

- Peak growing season (July), T:ET =
  - 92% (2019)
  - 68% (2020)

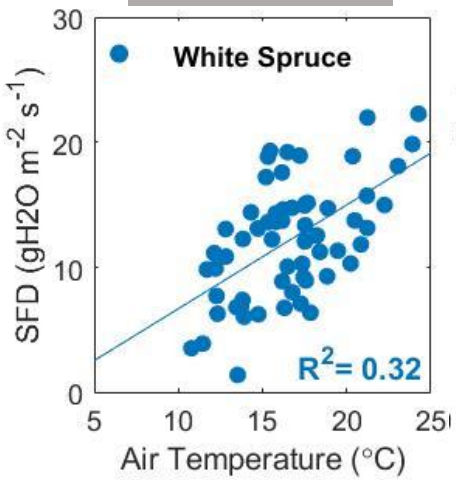
What is driving ET and T?

- Shrub T more sensitive to changes in VPD than White Spruce
- Changes in air temperature result in larger increases in Shrub T than White Spruce T
- Soil moisture controlled T at White Spruce but not at Shrubs

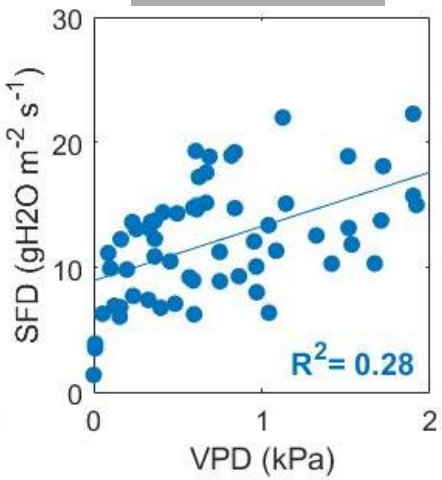
White Spruce

Shrubs

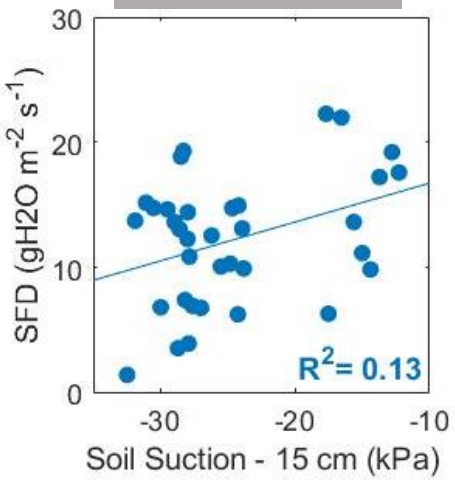
Air Temperature

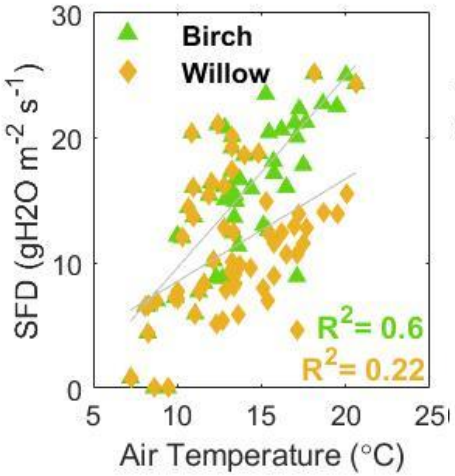


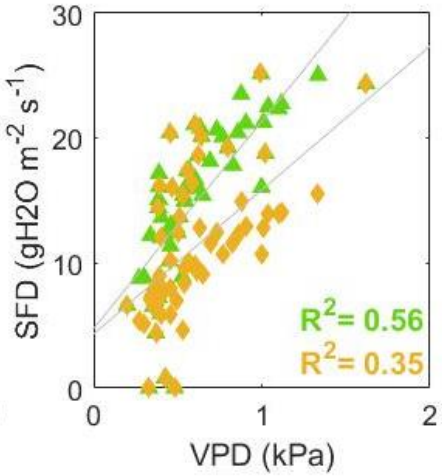
VPD

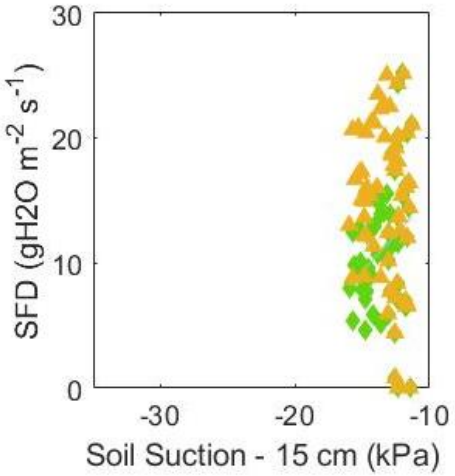


Soil Moisture







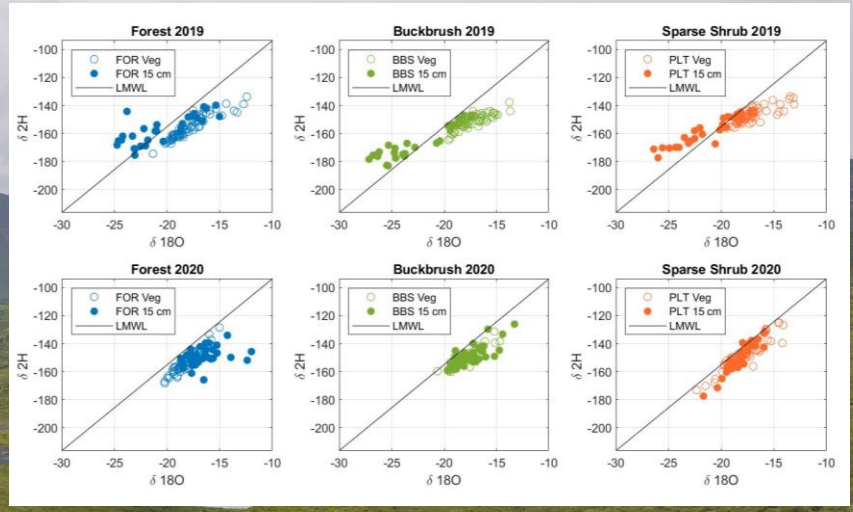


Treeline Advance		Shrubification
Large ↑ total ET	↑ Total ET	Small ↑, July only
↓ Albedo		
ET controlled by net radiation		Strong stomatal control in shoulder seasons
Strong reliance on snow inputs (large deficit)		Not moisture limited (small deficit)
White Spruce ~50% T:ET		Shrubs > 80% T:ET
Slow – Sensitive to disturbance and drought		Rapid – Sensitive to changes in temp and shoulder season length

nicholem@mcmaster.ca

Treeline Advance		Shrubification
Large ↑ total ET	↑ Total ET	Small ↑, July only
↓ Albedo		
ET controlled by net radiation		Strong stomatal control in shoulder seasons
Strong reliance on snow inputs (large deficit)		Not moisture limited (small deficit)
White Spruce ~50% T:ET		Shrubs > 80% T:ET
Slow – Sensitive to disturbance and drought		Rapid – Sensitive to changes in temp and shoulder season length

Ongoing: soil and vegetation stable water isotopes



nicholem@mcmaster.ca

Past

Present

Future

Other projects within WCRB and beyond

Cold Regions Runoff Processes

Wetland Hydrology

Vegetation Change and ET

Groundwater

University Partners

Long Term Water Balance of WCRB

Snow Hydrology

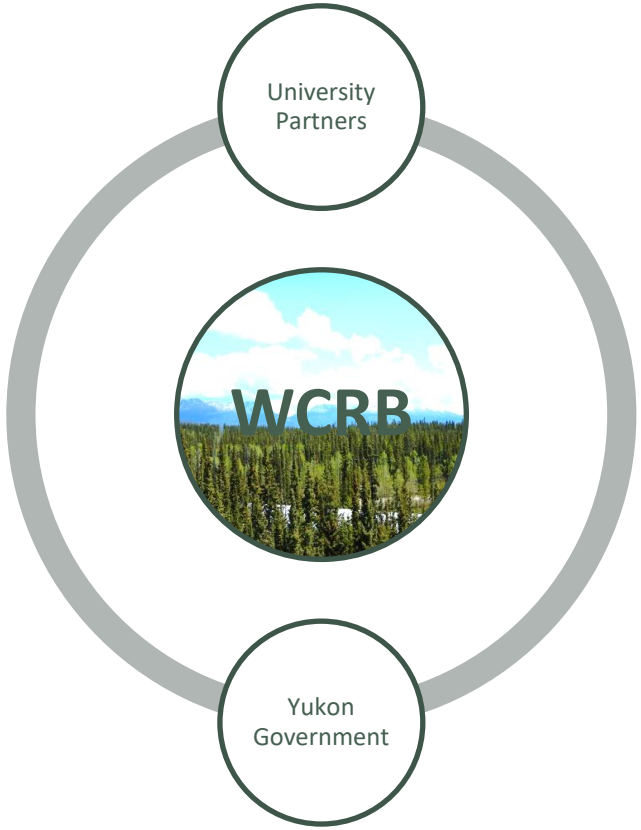
Stream Temperature Dynamics

Past

Present

Future

Wolf Creek Website, Newsletter & Storytelling

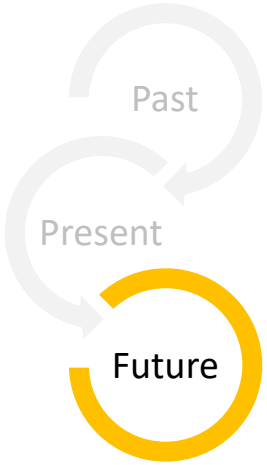


Website:

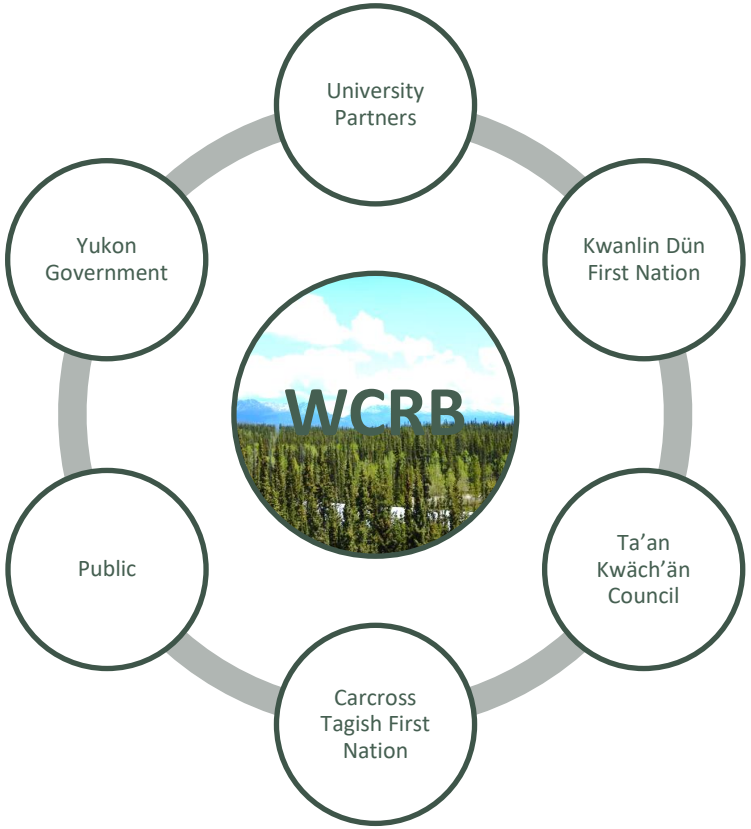
www.wolfcreekresearchbasin.ca

- *Publications*
- *Data*
- *Stories of Wolf Creek Watershed*

- Contextualize 25+ years of cold regions hydrological research
- Seek to include more voices in Wolf Creek Watershed
- Serve as a platform for information-sharing for academics, government, First Nations and the public



Wolf Creek Website, Newsletter & Storytelling



Website:

www.wolfcreekresearchbasin.ca

- *Publications*
- *Data*
- *Stories of Wolf Creek Watershed*

- Contextualize 25+ years of cold regions hydrological research
- Seek to include more voices in Wolf Creek Watershed
- Serve as a platform for information-sharing for academics, government, First Nations and the public

Past

Present

Future

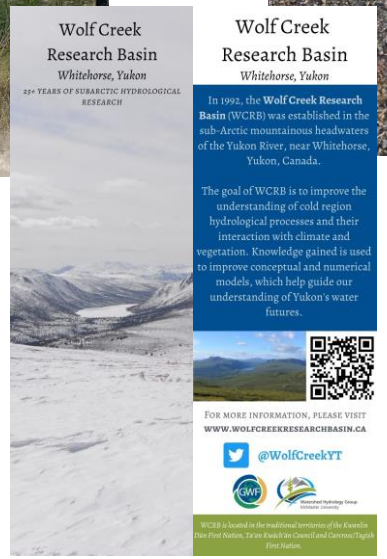
Wolf Creek Website, Newsletter & Storytelling

Annual Newsletter:
Join email list on website!

Twitter: @WolfCreekYT

Interpretive Signage

Fireside Chats



Pamphlets and Bookmarks

For more information on this research or Wolf Creek Research Basin:

nicholem@mcmaster.ca

@Erin_Nicholls_

wolfcreekresearchbasin@gmail.com

@WolfCreekYT