



The Effects of Chinook (Foehn) Winds on Alpine Forest Transpiration

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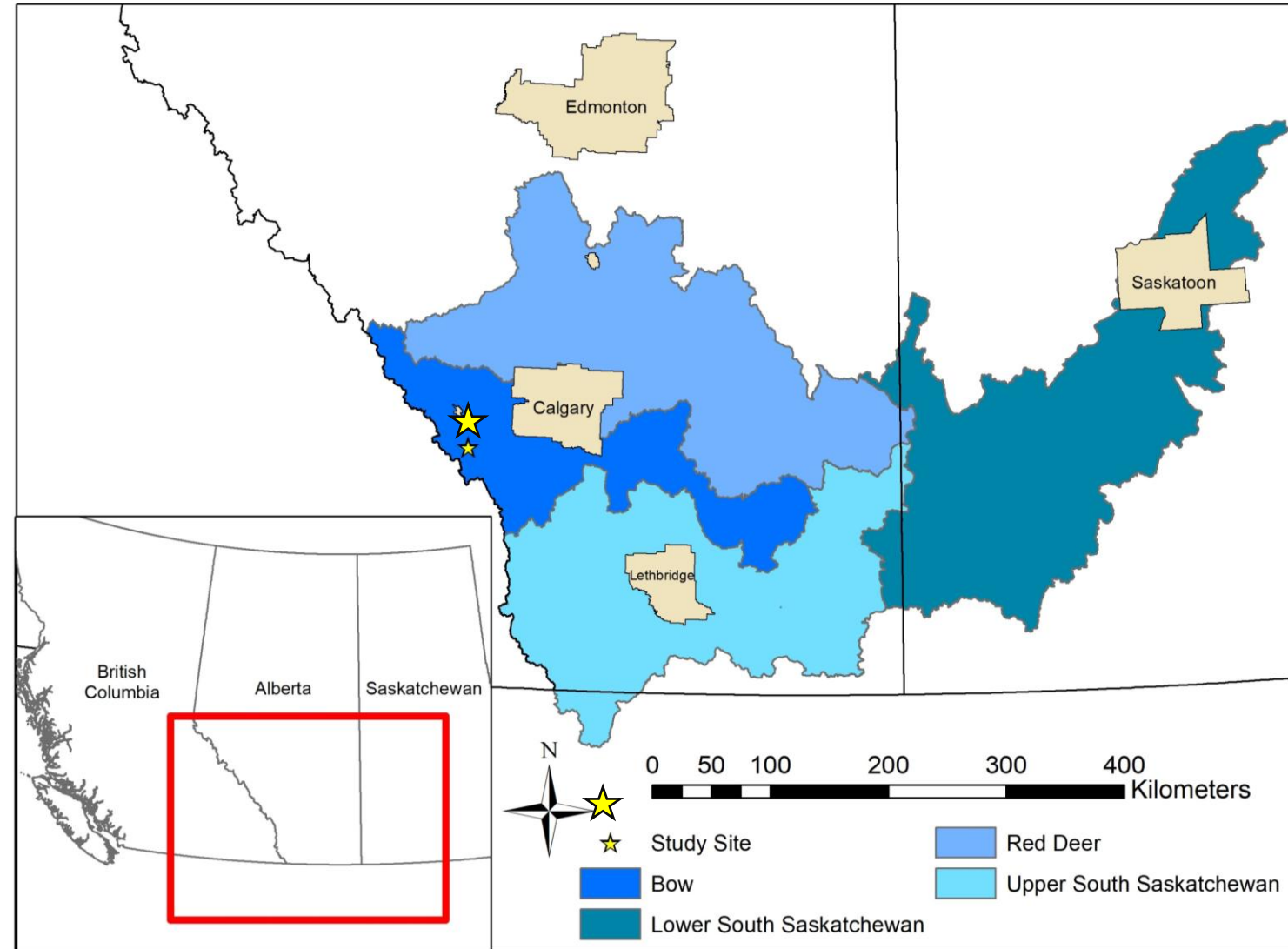


UNIVERSITY OF
WATERLOO



Western Canada's Water Tower

- Water source for 13 million people
- Headwaters for industry



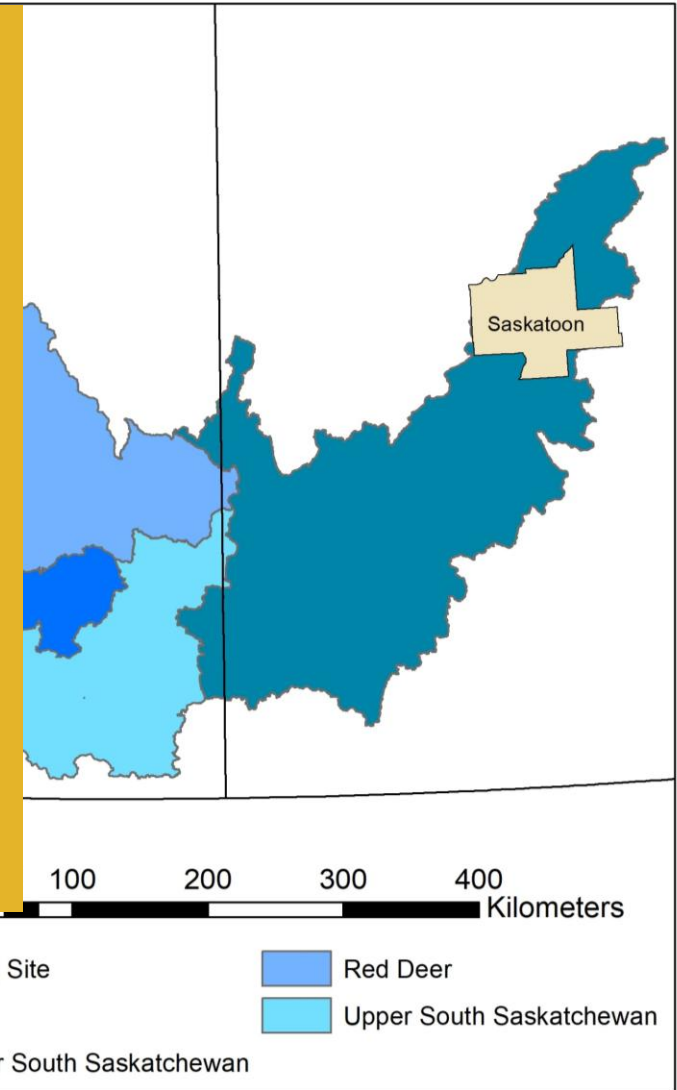
Western Canada's Water Tower

- Water source for 10 million people
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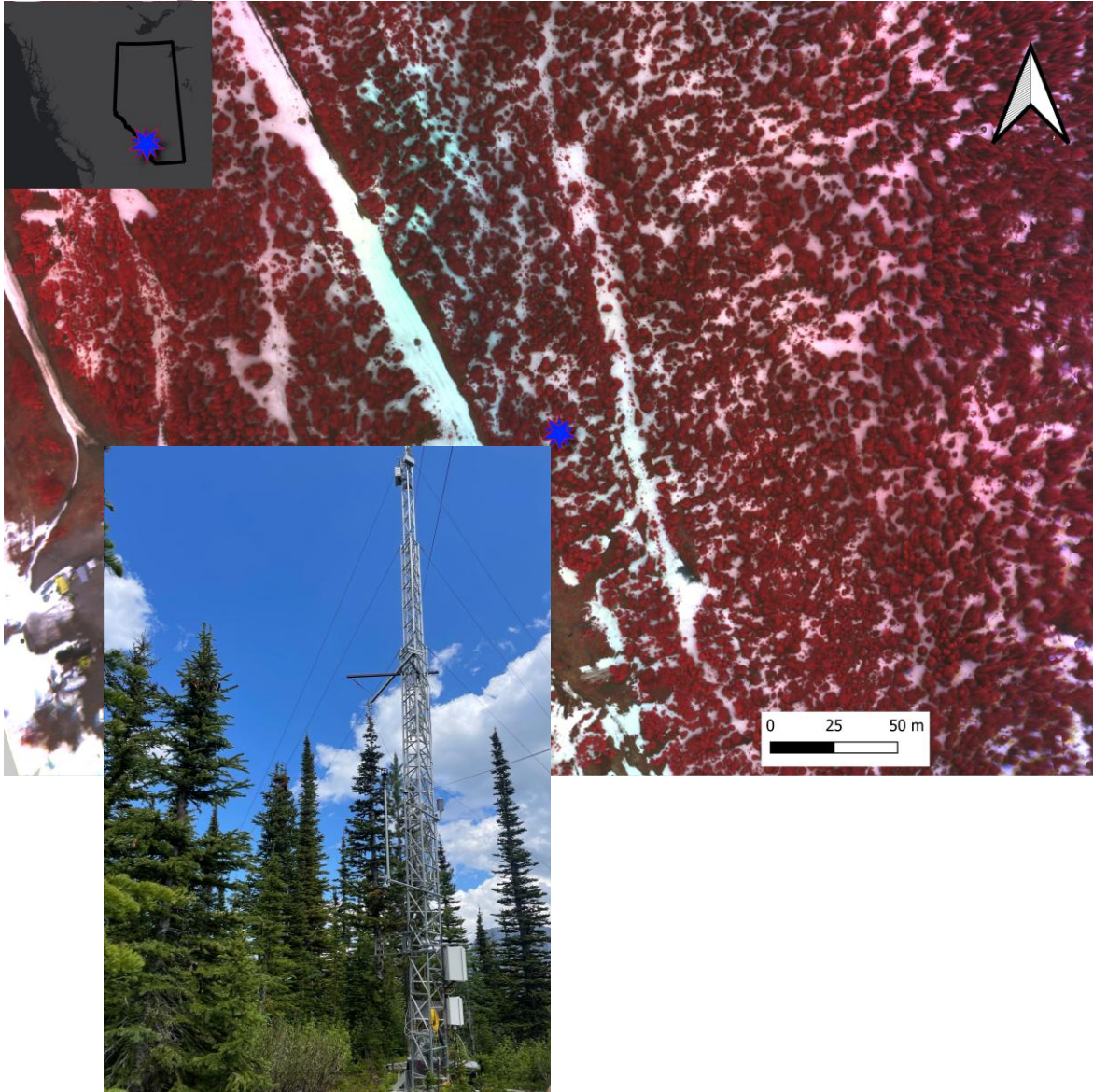
How headwater Forests
use water



water supply resiliency &
vulnerability



Study Location & Methods



- Fortress Mountain Research Basin (FMRB) located in Kananaskis, Alberta, Canada
- Sub-alpine Forest @ 2079 masl
 - *Picea engelmannii* (Engelmann spruce), *Abies lasioscarpa* (Subalpine fir), and limited numbers of *Pinus contorta* (Lodgepole pine) and *Larix lyalli* (Larch) (4 – 9m)
- 15 m tall tower
- Eddy Covariance → ET & T
- Climate Data: T_a , RH, Q^* , Q_G , T_s & VMC arrays, P, Snow Depth

Transpiration Estimation Algorithm

Nelson et al. (2018): infer plant water use by coupling carbon uptake and water loss

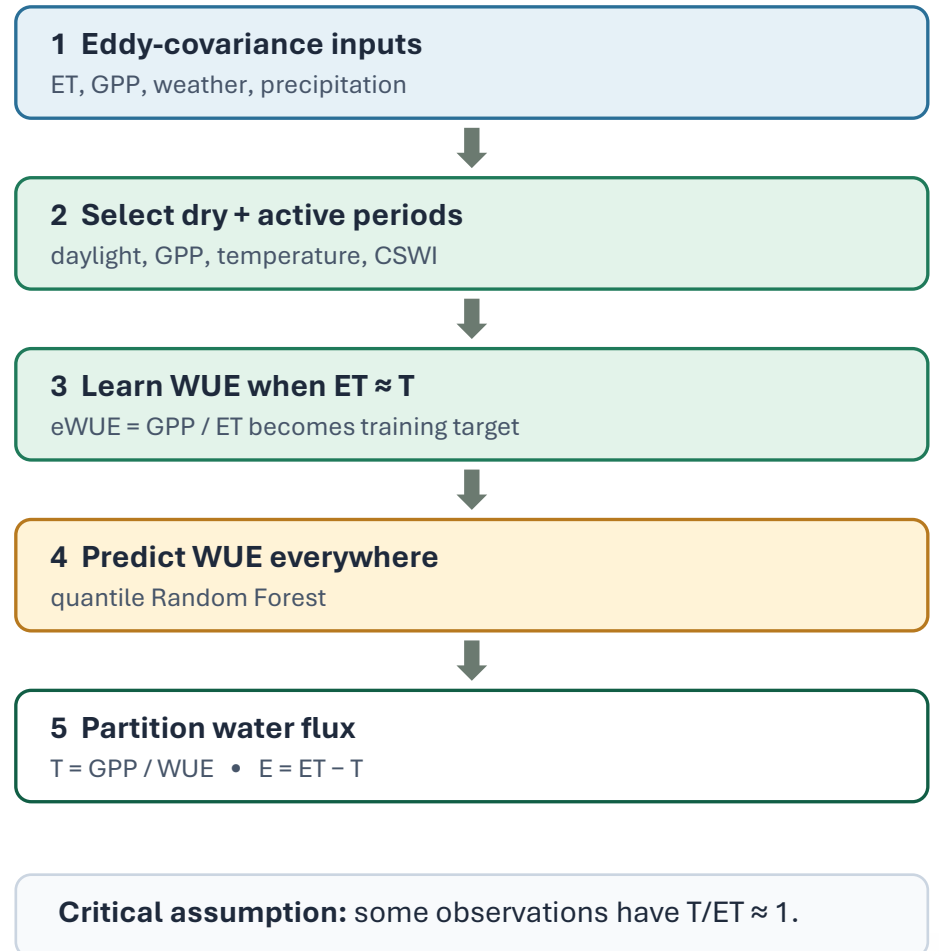
- **TEA estimates transpiration by using the link between photosynthesis and water loss**
 - During dry, actively photosynthesizing periods, it assumes most evapotranspiration is transpiration
→ $ET \approx T$
and $GPP/ET \sim$ plant water-use efficiency

- **Random Forest model learns how water-use efficiency changes with environmental conditions**
- That model is then applied to the full dataset to estimate transpiration as

$$T = \frac{GPP}{WUE}$$

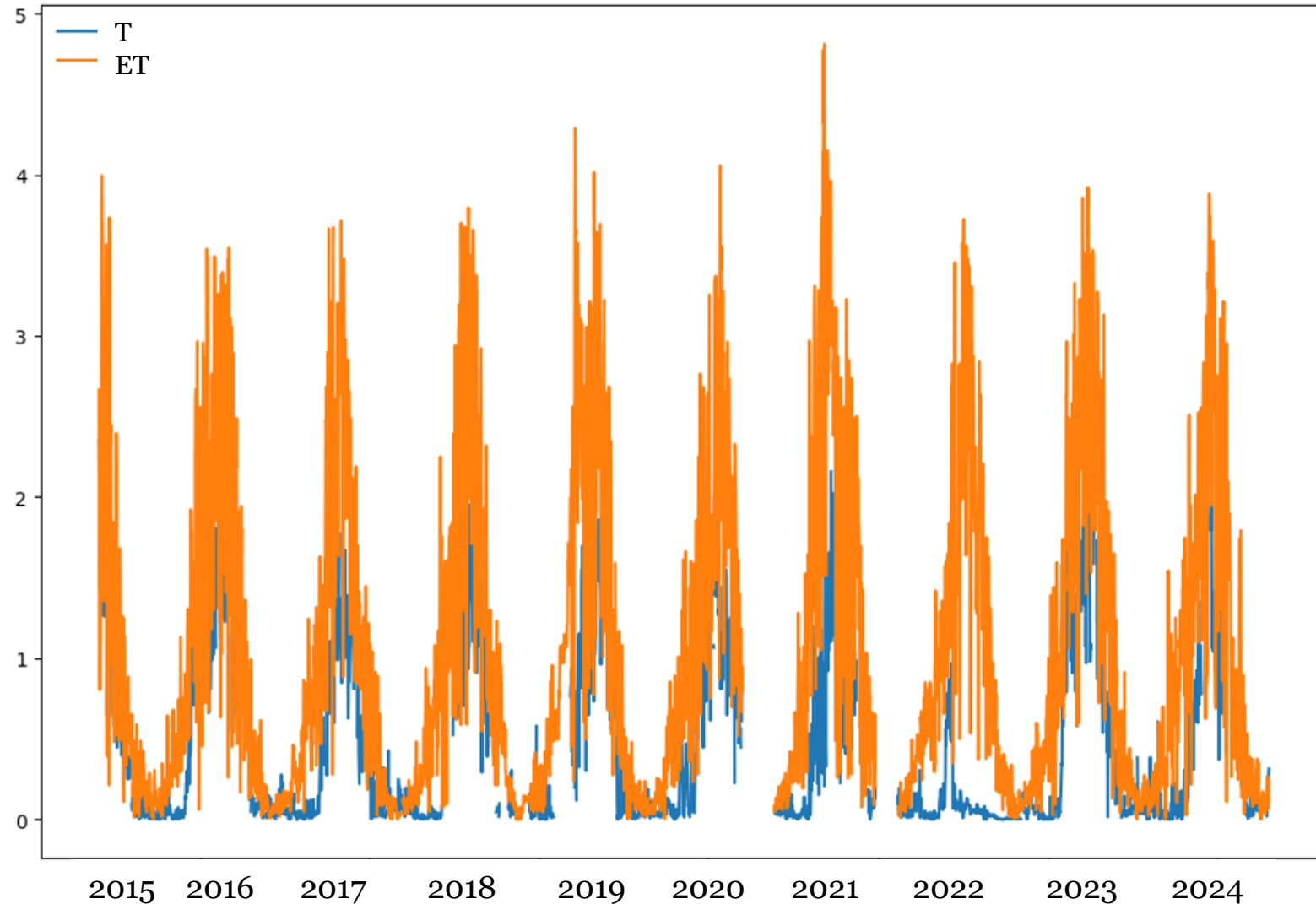
- **The main limitation is residual evaporation during the “dry” training periods**
 - If evaporation is still occurring, WUE is underestimated and transpiration can be overestimated.

Schematic workflow



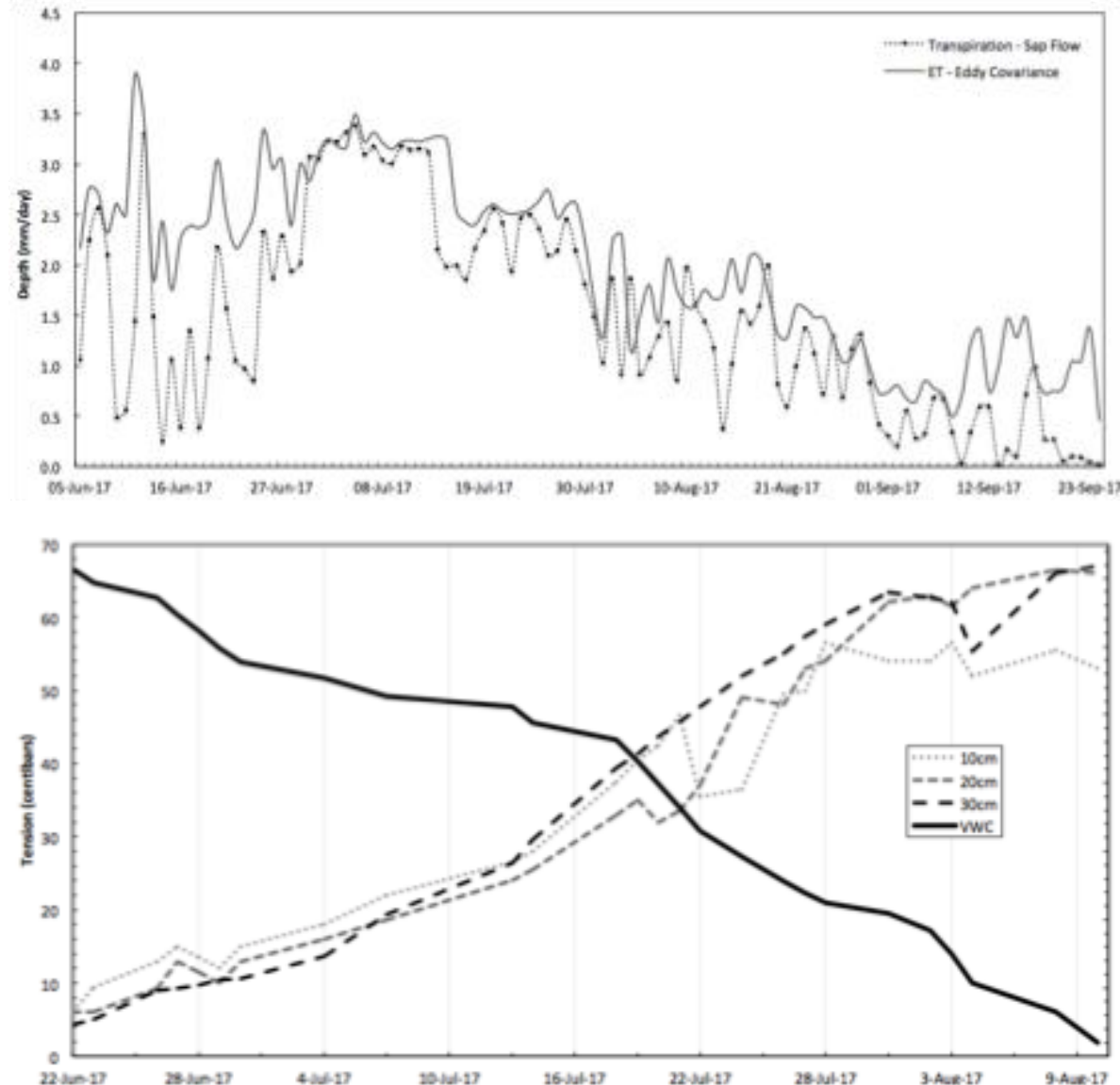
Forest Evapotranspiration

- 10 years (2015 – 2024)
- T ranges from 105 to 191 mm annually
- On average T ~ 75% of ET during the snow free period
- Annually, daily T averages from 0.3 to 0.5 mm/d over the study period



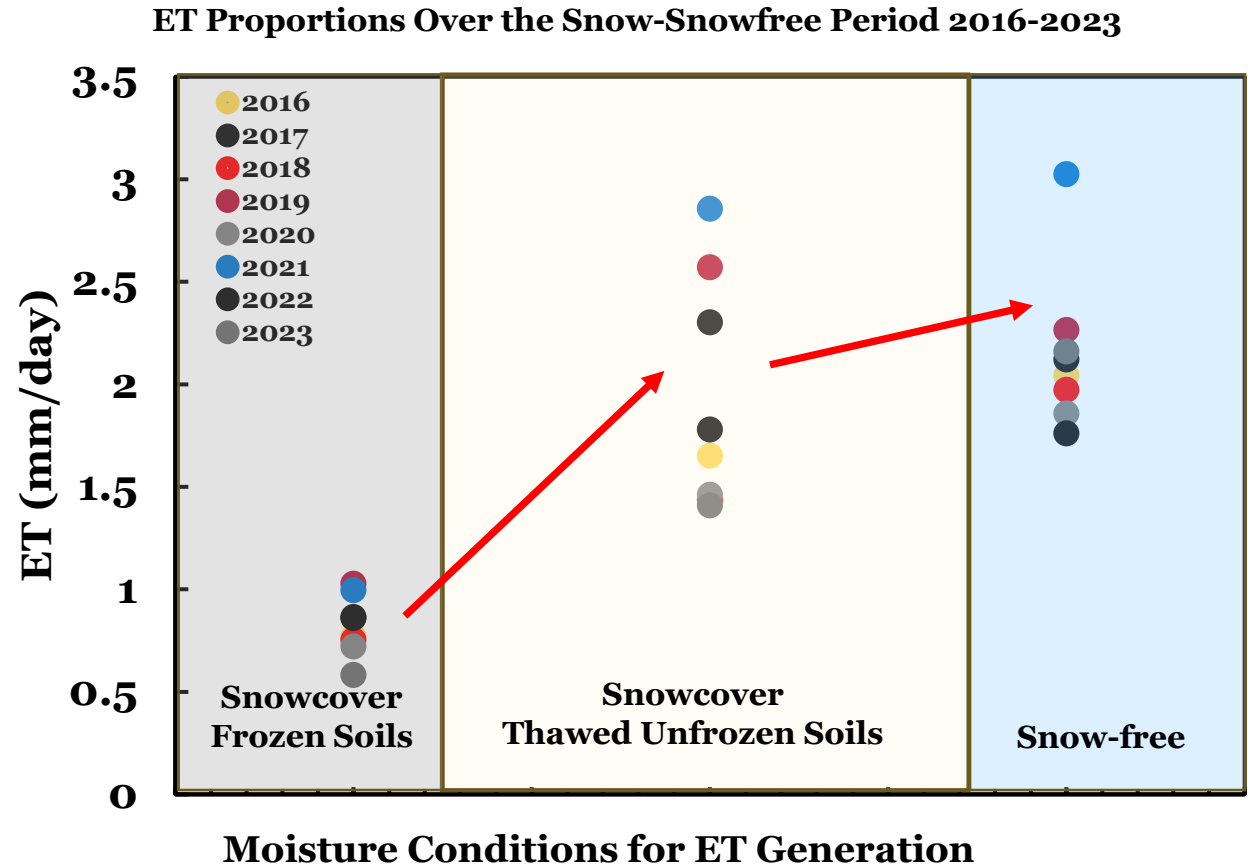
Forest Evapotranspiration

- During snow-free period T dominates ET
 - Higher ET rates in spring
- **Snowmelt governs early-season moisture & transpiration** → high ET even before summer rains
- As season progresses, **soil drying limits ET**, particularly under lower-rainfall conditions
- **Rainfall mainly recharges the shallow soil** → short-lived effects on ET

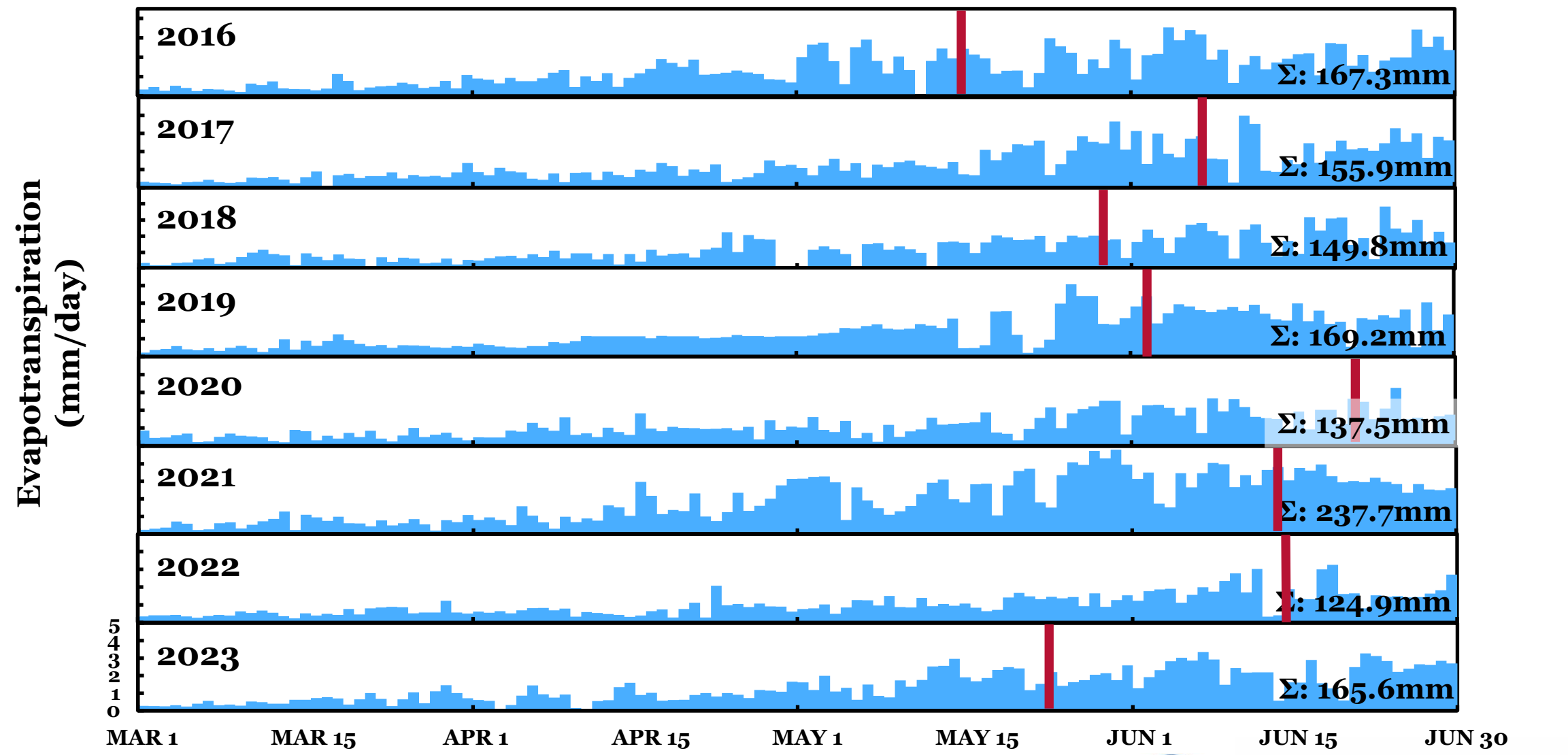


Forest Water Use Timing

- **ET during Snowcover/Frozen soils** largely sublimation
- **BUT T turns on** once soils thaw regardless of snowpack
 - Thawing soils → moisture into shallow soil zone – easily accessed by tree roots
- By peak growing season – WT is below soil layer
→ trees rely on P events

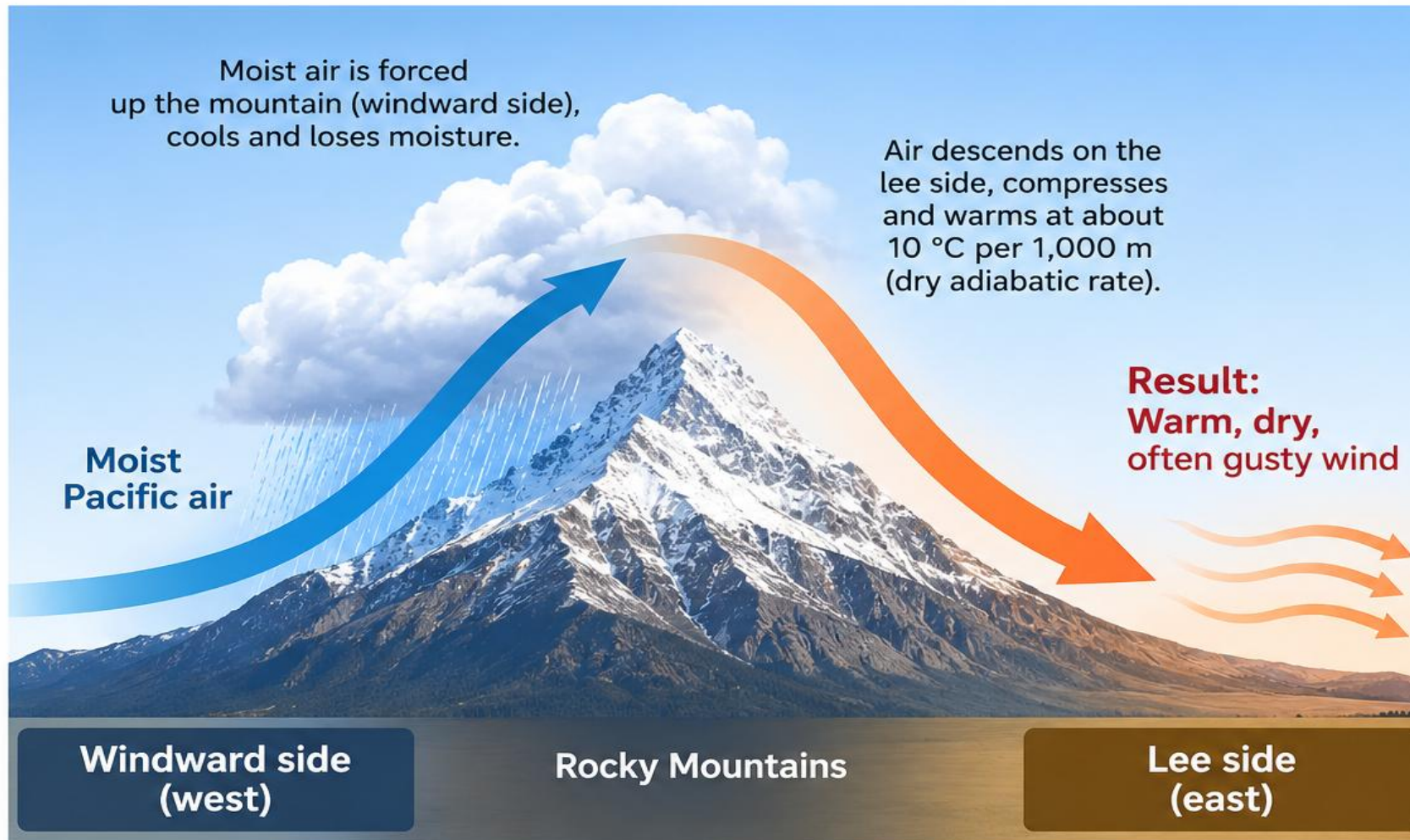


ET over the Winter – Greenup Transition (March – June)



What is a Chinook Wind?

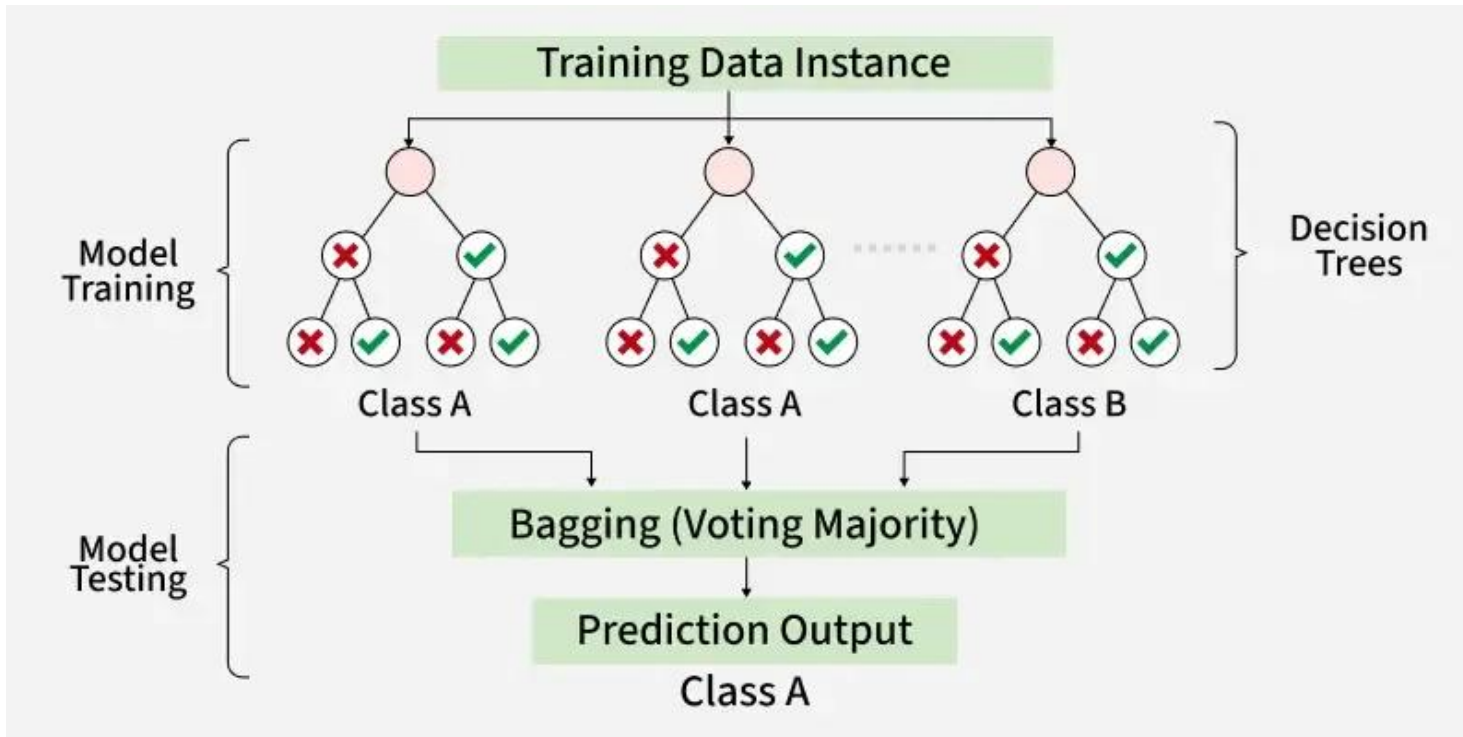
A Chinook wind is a warm, dry, downslope wind that occurs on the lee (east) side of the Rocky Mountains when moist air crosses the mountains and descends, warming by compression.



Key characteristics:

- Warm and dry downslope wind
- Occurs on the lee side of mountain ranges (e.g., eastern slopes of the Rockies)
- Can cause rapid temperature rises (10–20+ °C in hours)
- Often strong and gusty
- Can quickly melt snow and reduce humidity

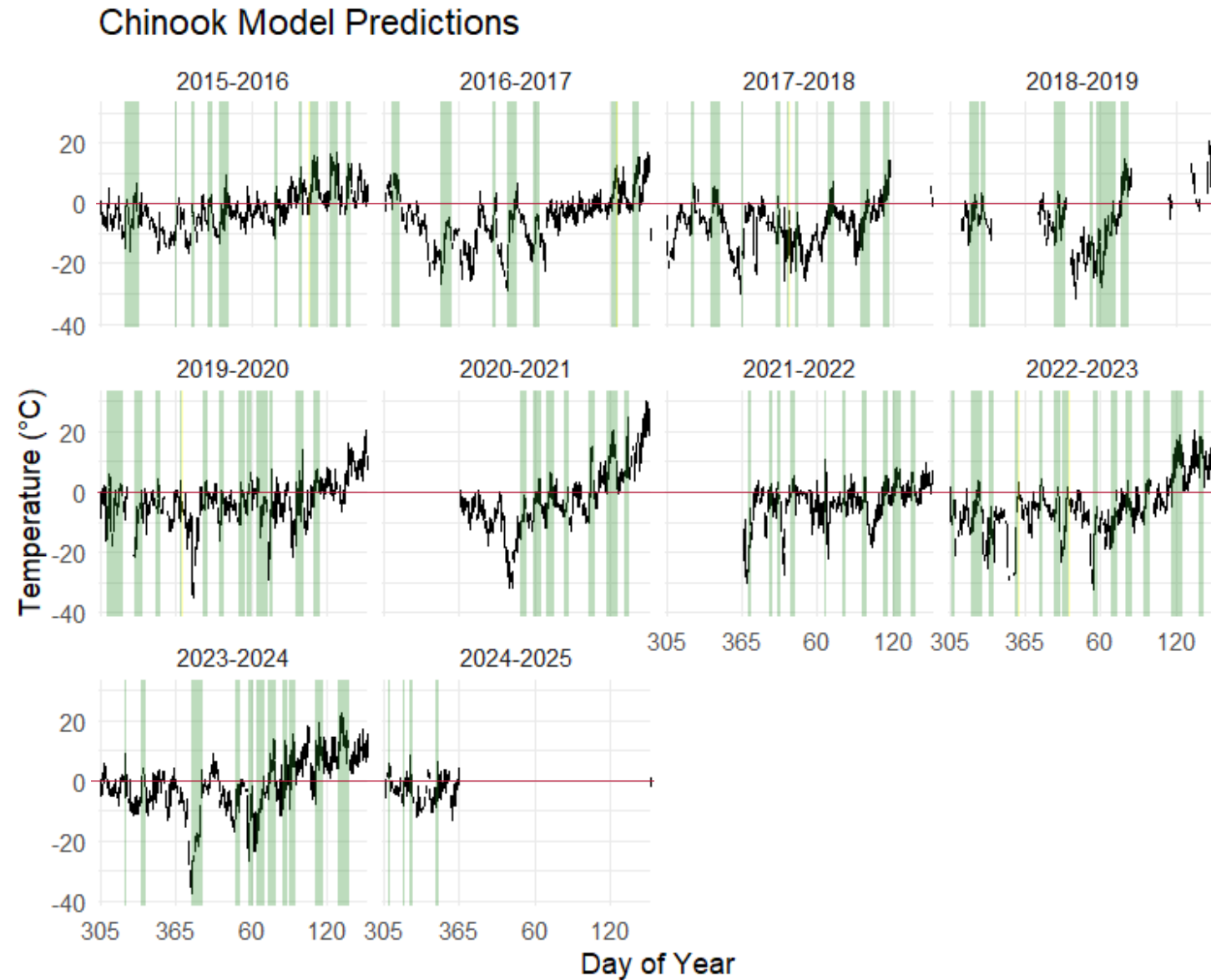
Chinook Detection & Classification



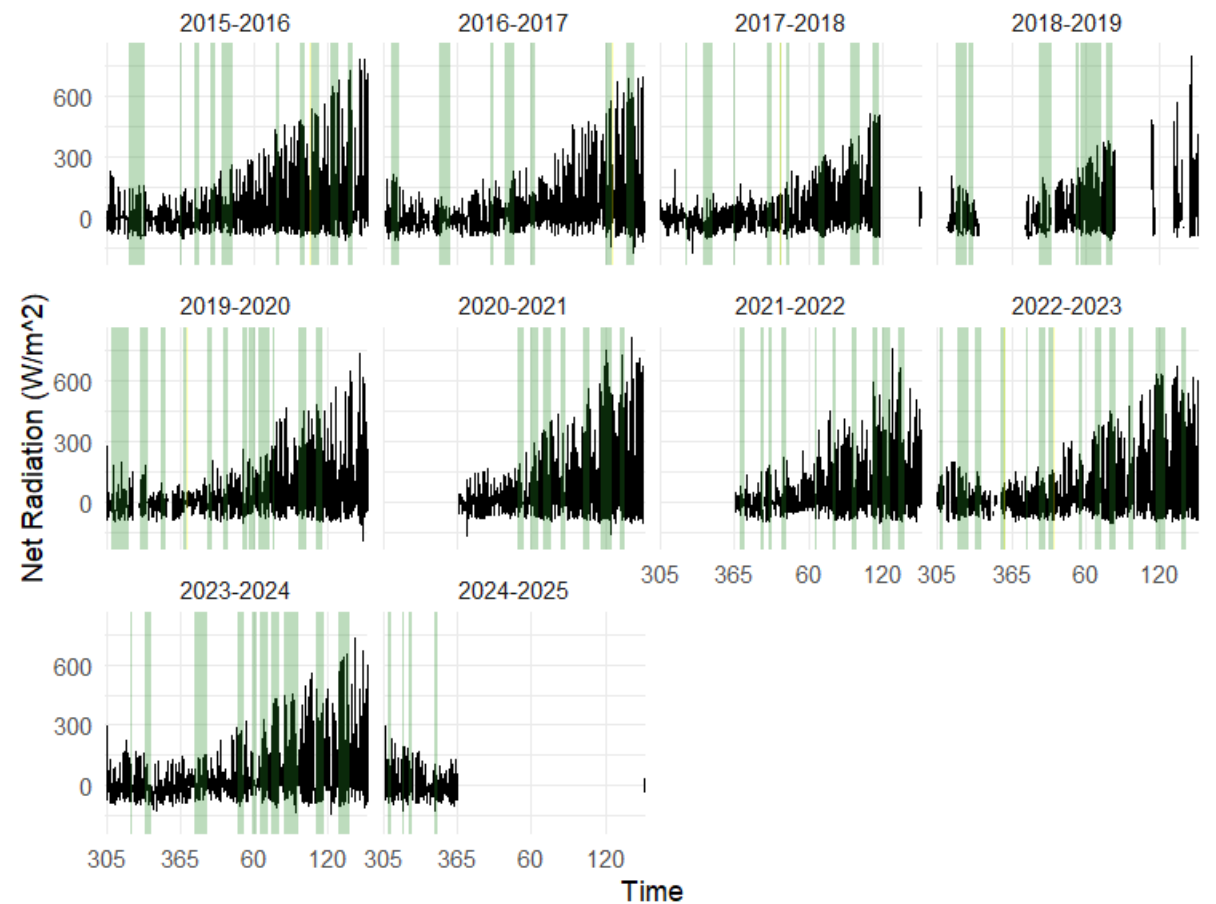
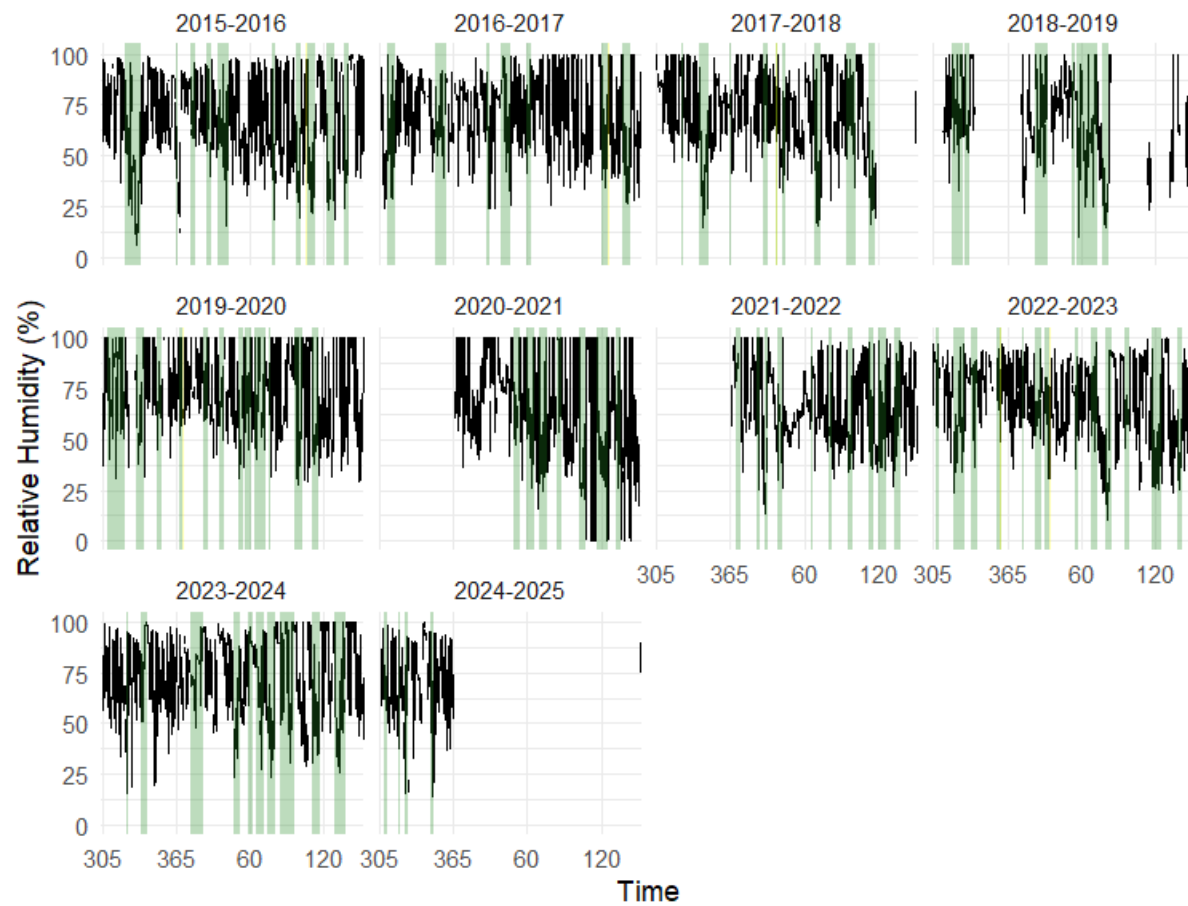
- Based on Calgary Airport and Forest Tower data each year (10 yr)
- Initial Manual classification - between November and May :
 - Periods with sharply rising Ta, decreasing RH, westerly winds, and an increasing trend in wind speeds.
- Manual classification → training data, a machine learning model was created using the *randomForest* package in R to automatically identify chinooks
- Based on 3-hour moving averages of:
 - Ta, wind speed, wind direction, and RH throughout the winter
 - 24-hour trends in the moving averages of the same four variables (i.e. if they were increasing, decreasing, or stable from one data cell to another data cell 24 hours later)
- Model identified chinooks with 94% accuracy relative to manual classification

Chinook Conditions

- 2015 - 2025
- 7 – 17 Chinook events classified per year
 - Durations range from ~48 – 153 hrs
- Significant increase in Ta with each event, especially into transition season
 - Also periods outside of classified Chinooks with increased Ta



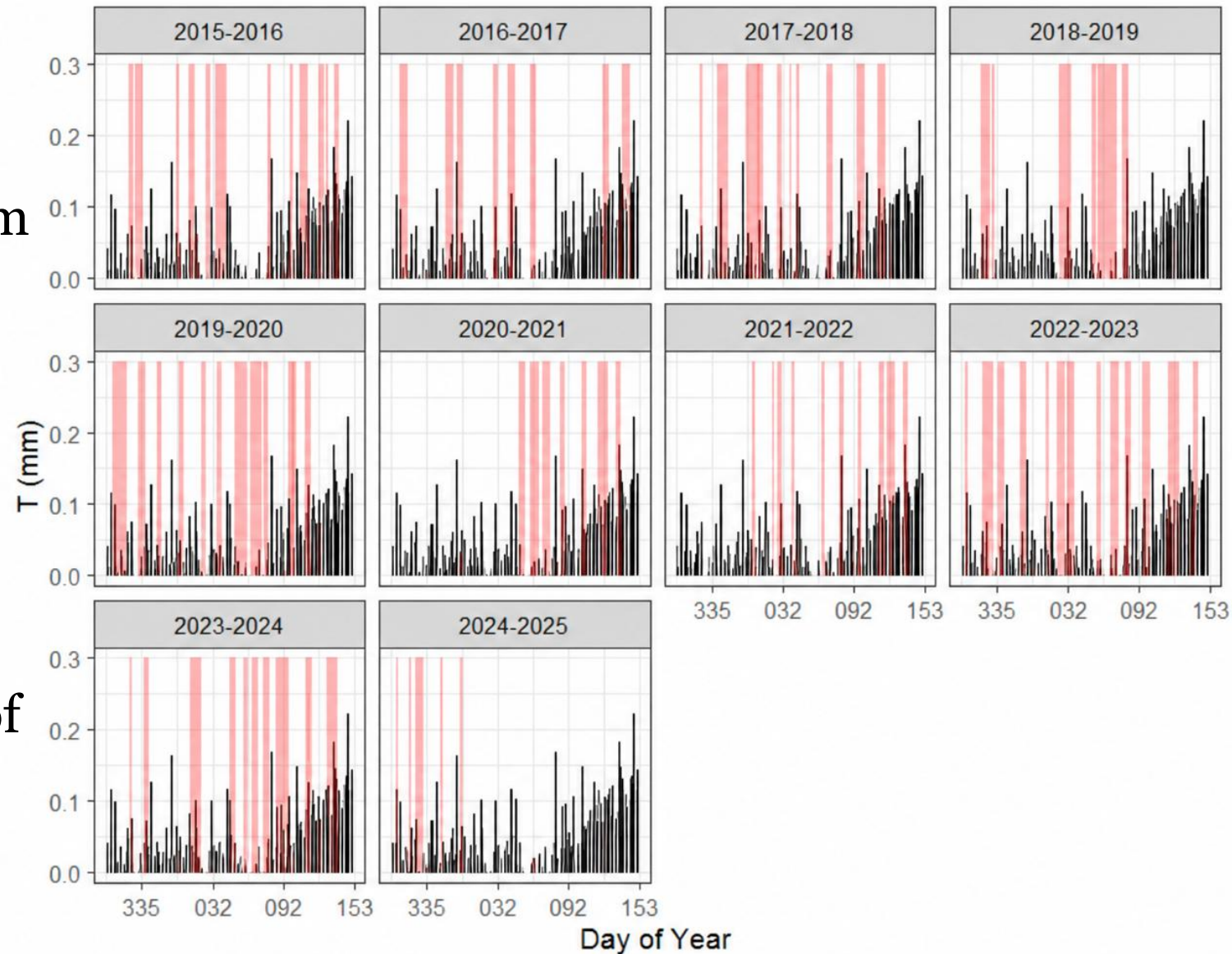
Chinook Conditions



- Significant temporal variability
- General decrease in RH
- General increase in Q^*

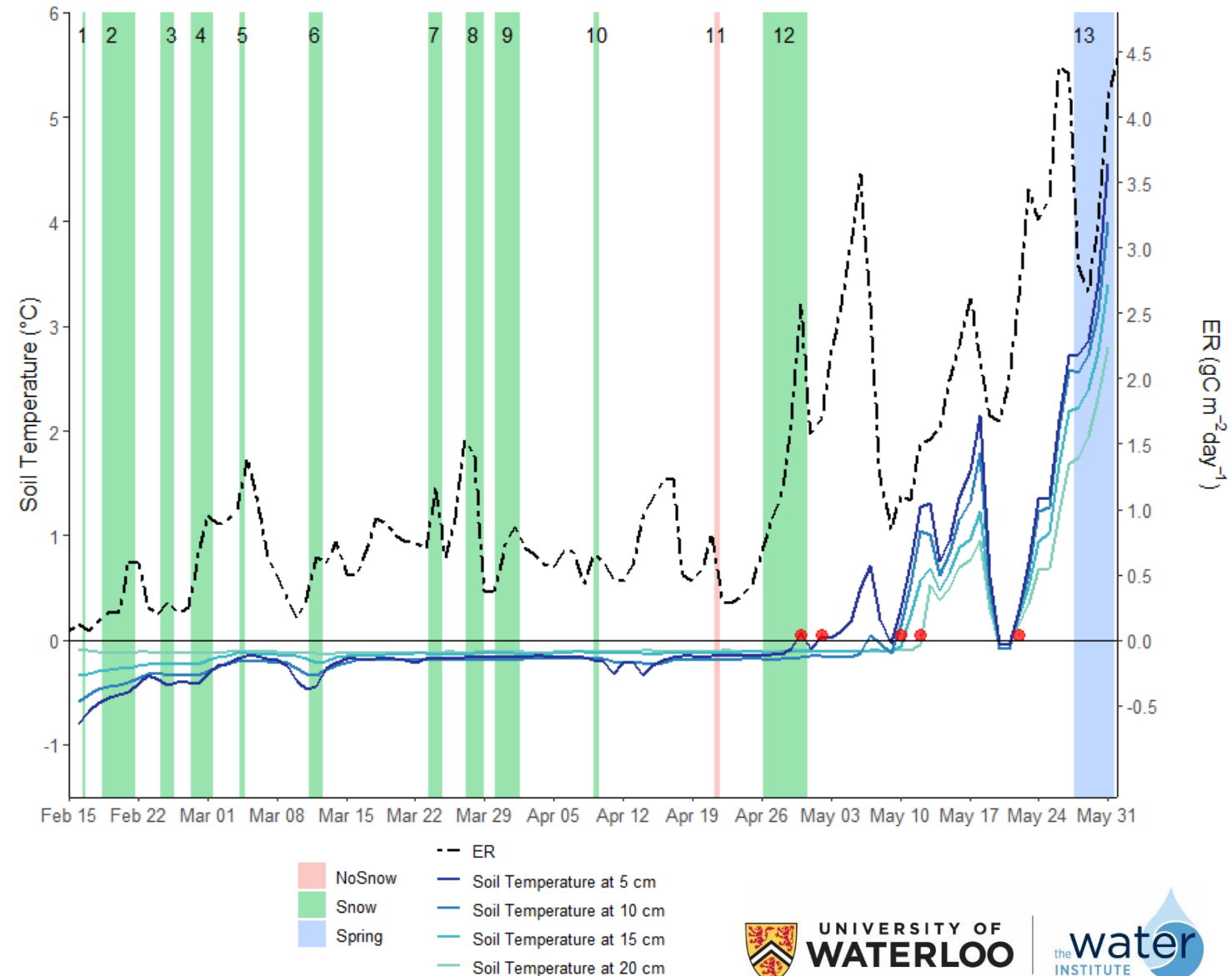
Chinook Transpiration

- Winter T ranges from 11 – 45 mm
- Average Winter T ~27 mm
- T is occurring during classified Chinooks
 - Periods where T seems to be occurring outside of Chinooks
- T not really related to duration of classified Chinook events
 - Larger magnitude fluxes are not observed during longer events



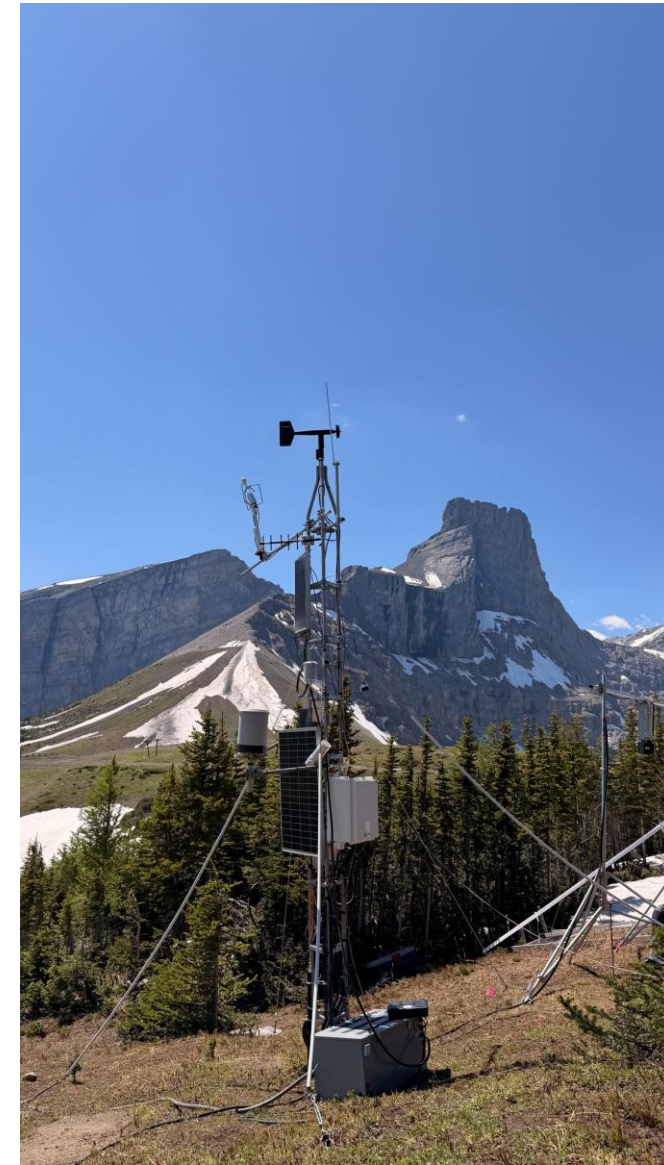
Chinooks and Mid-Winter Thaws

- 1 Yr (2021) – Montane Peatland
- Evidence does exist of biological activity...
- ER responds quickly to these short warm events
- Vegetation processes turn on
- T will begin to increase during periods of warmer temperatures



Summary

- Mid-winter warm events have the potential to increase E and T losses
- If thaw events increase with the increased duration of shoulder season periods – potential to decrease moisture stores
- Need to better understand how the frequency and duration of Chinook events will change with climate → implications for overall annual forest water use
- More closely examine non-Chinook T in winter
 - Drivers?
 - Artifacts of partitioning?
 - Classification?



Acknowledgements

- Matthew Woodward, Lindsey Langs, Eric Murray, Aiden Luckett, Jessica Williamson, Dylan Hrach, Julia Hathaway, Abby Wang, Savanna Cherry, Sheryl Chau, Rulan Xiao, Myroslava Khomik, Adam Green, Eric Kessel

