Effects of Soil Frost on Streamflow Generation Processes in Minnesota Headwater Catchments

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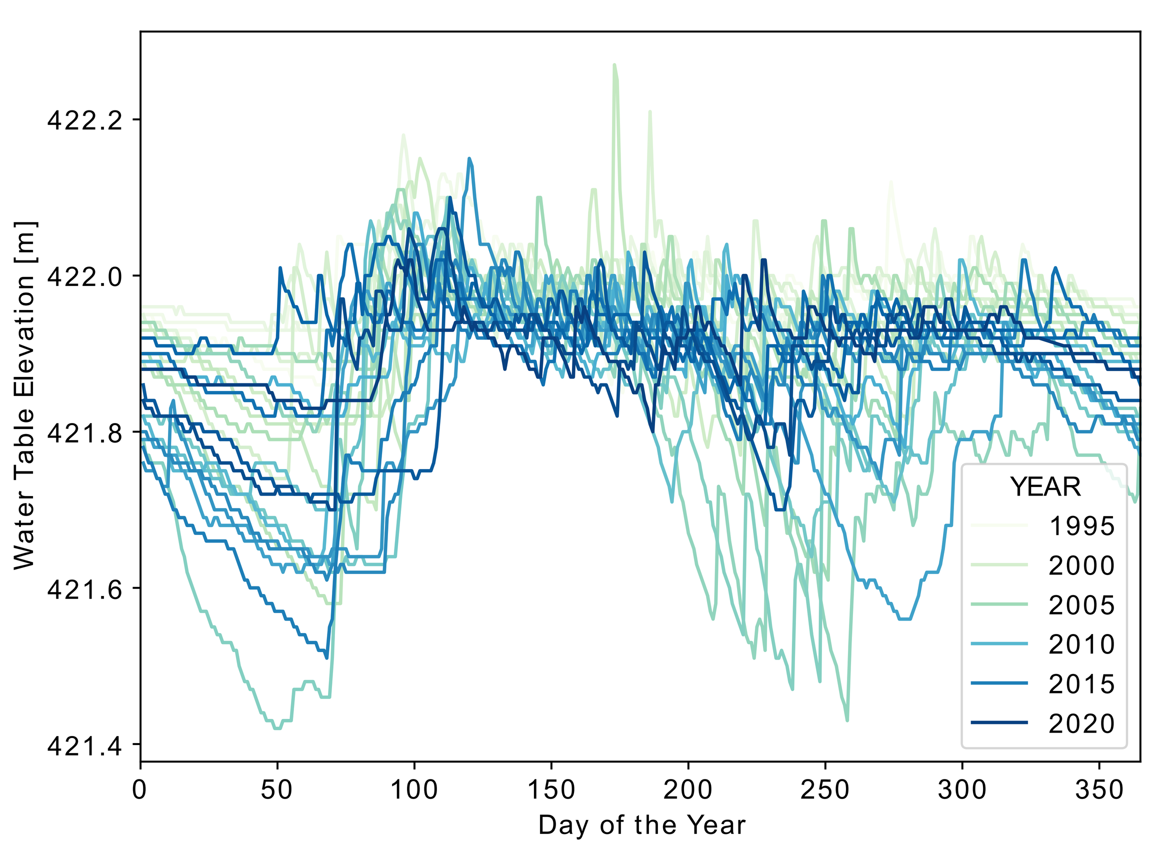
In snow-dominated catchments, the timing and magnitude of spring streamflow are changing with our warming climate. On the one hand streamflow has been shown to decrease due to decreasing snowpack size[1] and precipitation shifts from snow to rain[2,3] while on the other hand streamflow has increased due to shorter spring warming periods[4]. These discrepancies are likely explained by the different ways that the landscape mediates the flow of water using storage components like the snowpack or surface wetlands. Understanding the flow of water through these storage components will be integral to understanding the behavior of spring streamflow under climate change.

Research Questions

In peatland dominated catchments, what is the flow path that precipitation takes to generate spring streamflow?
What hydrologic, climactic, and landscape variables most control the magnitude of streamflow?

Data Synthesis

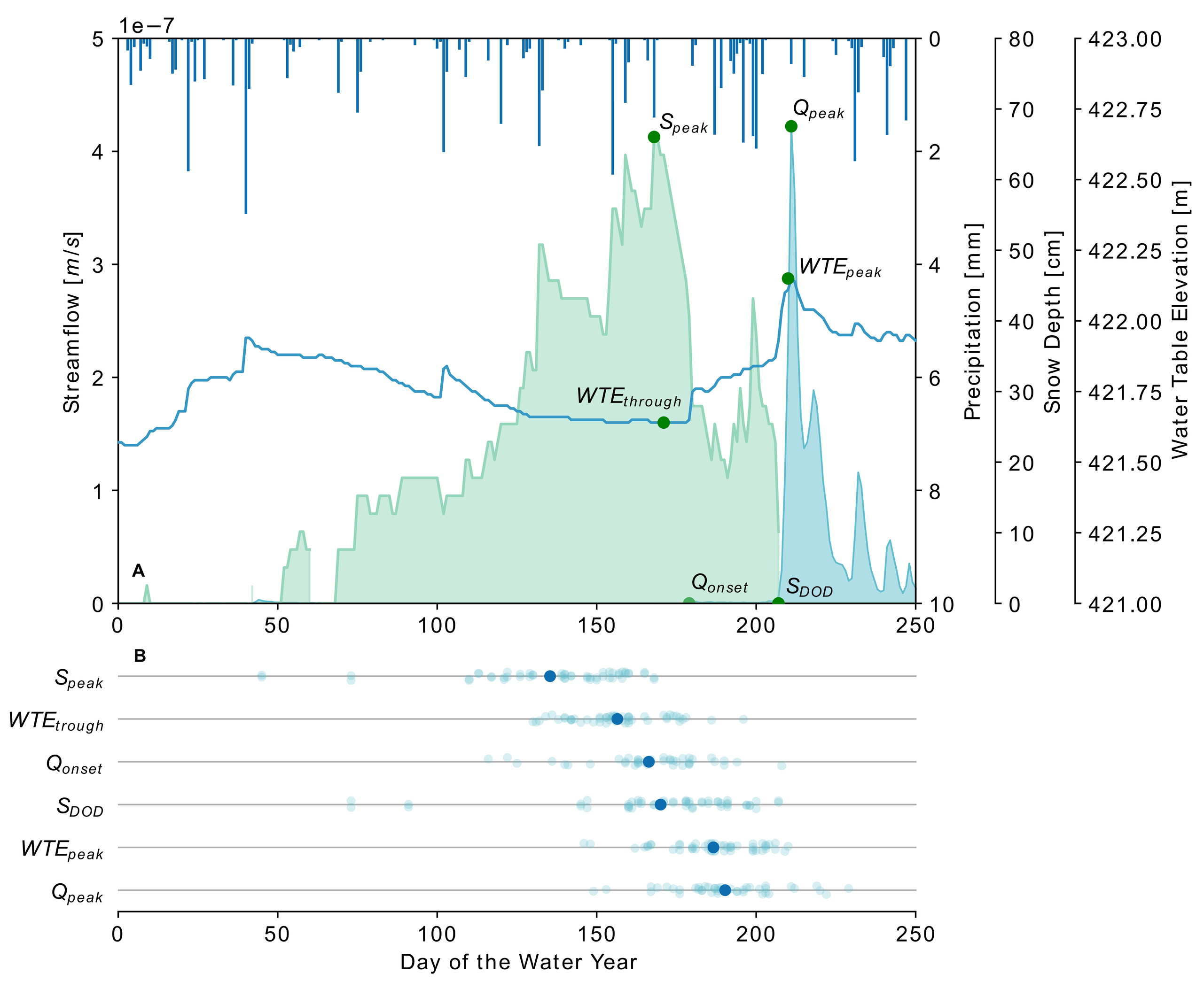


Research was done using data from the S2 and S5 peatland watersheds at the Marcell Experimental Forest in North-Central Minnesota

Each watershed has a central peatland surrounded by wooded uplands and a moat like lagg zone that regulates water table elevation.

Consistent water table recession over the last 25 years marked by strong declines in spring recharge

Water table, snowpack, and streamflow time series were parametrized to pull out key water events in the winter-spring transition season. Events show a cascade from snow to water table to stream.

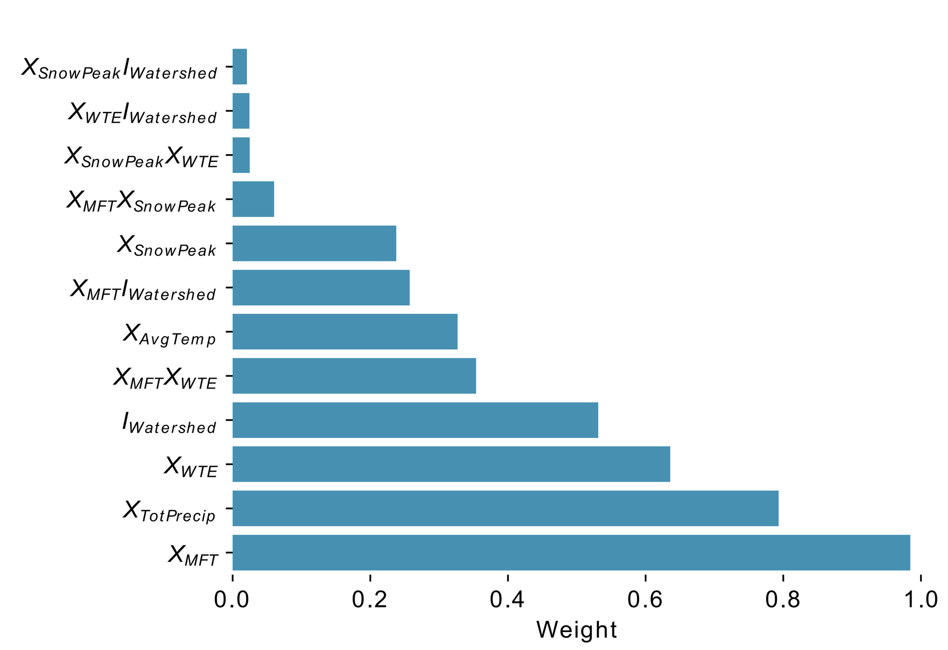


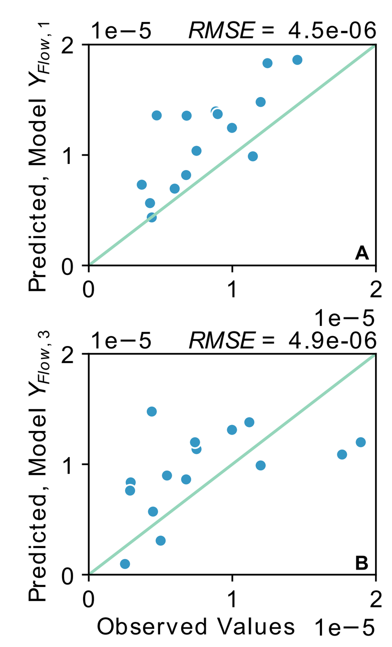
Model Analysis

A step-wise multiple regression model was used to determine which hydrologic ($X_{SnowPeak}$, X_{MFT}, X_{WTE}, $X_{TotPrecip}$), climactic ($X_{AvgTemp}$), or landscape characteristics ($I_{Watershed}$) were the best descriptors of peak spring streamflow and average annual streamflow.

668 possible models were run and ranked by a bias corrected Aikake Information Criteron (AICc)

$$Y_{Flow} \sim \beta_0 + \beta_1 X_{SnowPeak} X_{MFT} X_{WTE} I_{Watershed} + \beta_2 X_{AvgTemp} + \beta_3 X_{TotPrecip}$$





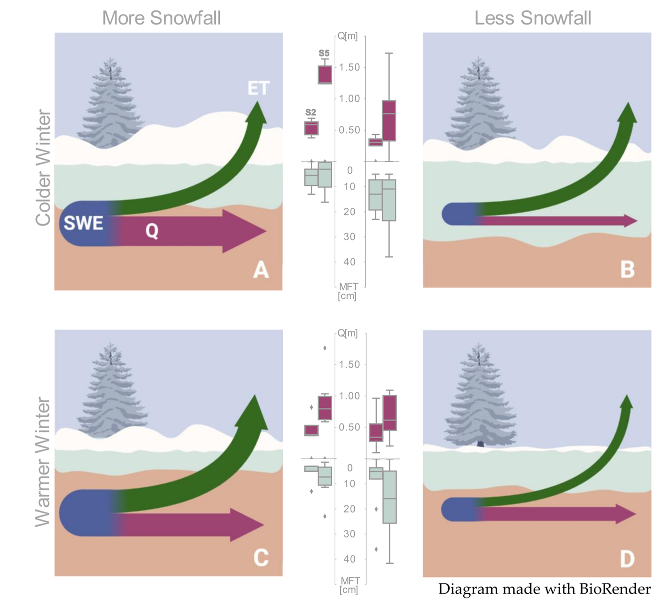
Of the 17 possible individual or interaction terms, **frost depth** was present in the largest number of highly weighted (best fit) models.

Importantly, frost was the one of the worst variables when used alone to predict streamflow. Water table elevation was best here, then precipitation.

Conclusions

There exists a clear flow path of water between the snowpack, water table, frost layer, and streamflow during the winter-spring transition.

Frost depth provides key insight into the magnitude of spring streamflow but is not a good individual predictor of streamflow.



The dynamic relationship between temperature, snow, and frost may dictate the partitioning of snowmelt into subsurface storage (which will make it available to plants) and overland runoff.

References

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