The Effects of Climate Variables on Average Stream Flow for Canadian Watersheds

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Background:

A watershed or catchment is an area of land that drains all the rainfall, snowmelt and streams to an outlet point such as reservoirs, bays, and the ocean. Understanding the mechanism and predicting the catchment streamflow is crucial for water resources management, e.g., irrigation, hydroelectric power, and flood control. In this project, we study the annual average stream flow, denoted by Q_{mean}. Our goal is to understand the relationship between stream flow and other climate variables.

Experimental Design & Data:

In this prospective study, we have collected historical climate data from a small number of catchments in Canada. We consider data from 1980 to 2018, for a small number of medium sized catchments, i.e., catchments between 50 km^2 and 1000 km^2. We collected the annual averages for the following variables:

1. Mean daily stream flow (mm/day)
2. Mean Evaporation (m/year)
3. Mean Snow Density (kg/m^3)
4. Mean Snow Depth (m)
5. Mean Snowfall (m/year)
6. Mean Snowmelt (m/year)
7. Mean Temperature (°C)
8. Mean Total Precipitation (m/year)

Statistical Questions:

I would appreciate advice on the following:

1. **(Data visualization)** Having multiple predictors, measured over many years, poses an interesting problem for how to best present our data. I would appreciate any ideas on best visual summaries of my data, ideally showing some relationship between my predictors and response.

2. **(Predicting stream flow)** Is there a statistical model we can use to predict the average stream flow from the climate variables? I am interested in both predicting & extrapolating. In greater detail, some catchments have missing stream flow values which I would like to predict. Additionally, I am curious if data from one catchment can be used to extrapolate stream flow in another catchment given climate variables. Finally, I am also interested in modeling average stream flow values beyond 2018. I am also interested in reporting the uncertainty in my estimates, e.g., standard error, confidence intervals.

3. **(Finding important predictors)** The relationship between climate variables and streamflow is complex, I am interested in finding important the most important climate variable(s). For this variable, I would like to determine the effect of said variable(s), directly/inversely proportional, U-shaped or plateaued.

4. **(Detecting outliers)** Unusual steam flow activity can lead to severe adverse effects for the nearby ecosystem and populated areas. For instance, in extreme cases unusual stream flow can lead to water scarcity or flooding. Is it possible to detect outliers in the average stream flow values?