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Modeling Long-Term Streamflow Response to Precipitation Change Using an Ecohydrologic Model

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Introduction

Climate change may be producing an intensification of the global hydrologic cycle that may result in an increasing or decreasing precipitation trend over western Montana. Streamflow records integrate the effects of land use and climate change on watershed hydrology. Although direct detection of a small change in precipitation may be difficult, it's effects in the streamflow record should be detectable and differentiable from other impacts. **In this study, we utilize an ecohydrologic model to test whether the effect of precipitation change is detectable and differentiable from other land use disturbances**

Hypothesis

The effect of a precipitation trend on runoff is greater in the 25% wettest years (75th percentile) than in the 25% driest years.

This is the opposite of what is expected from other human impacts, such as water diversions or land-use change, which should have a greater effect on the 25% driest years.

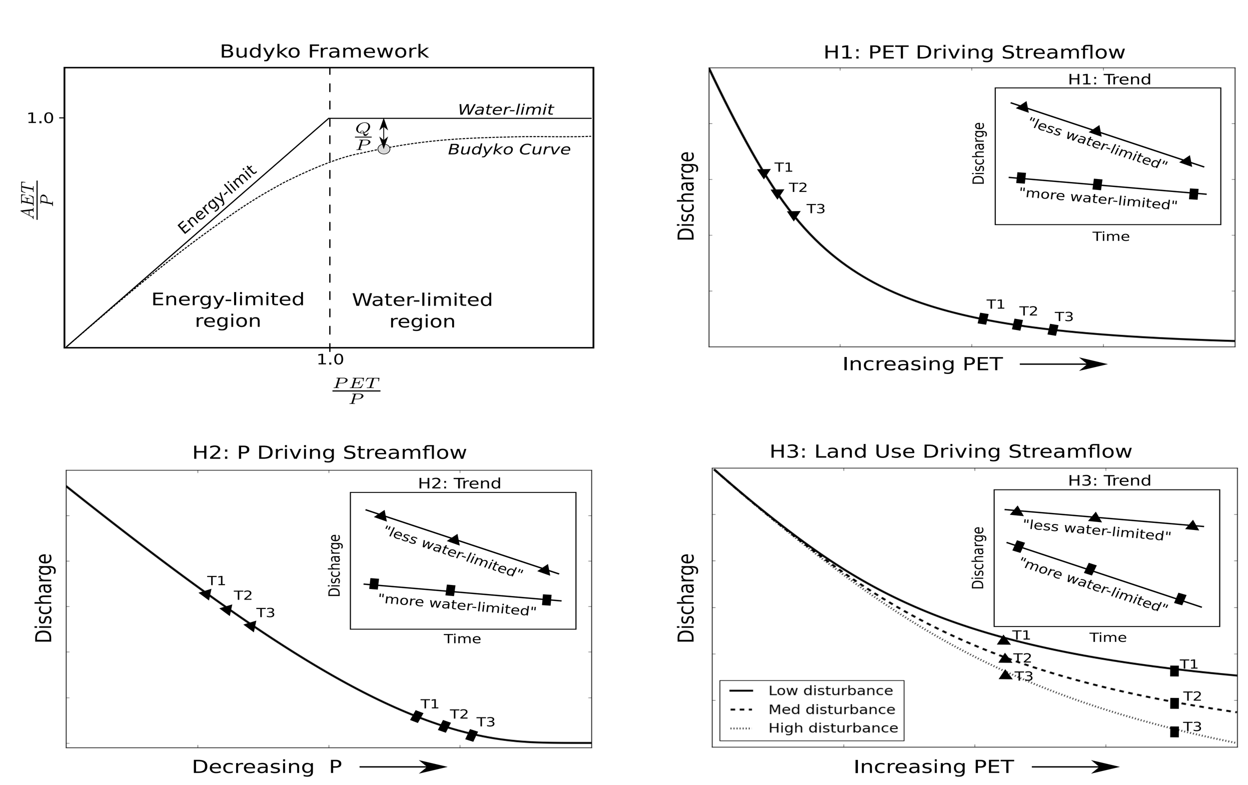
Analytical framework

We use Zhang's (2001) representation of the Budyko framework to explore the relationships between actual evapotranspiration (AET), potential evapotranspiration (PET), precipitation (P), streamflow (Q), and land use (ω). Zhang's equation is as follows:

$$\frac{AET}{P} = \frac{1+\omega\frac{PET}{P}}{1+\omega\frac{PET}{P}+\left(\frac{PET}{P}\right)^{-1}}$$

and the complimentary equation is:

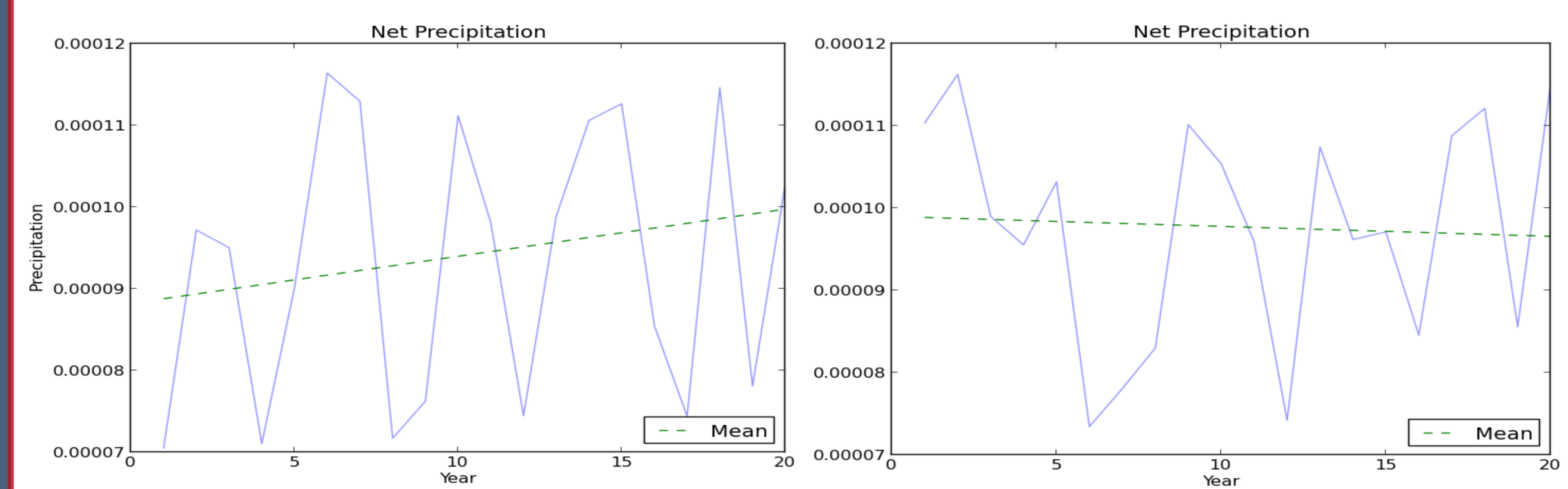
$$\frac{Q}{P} = 1 - \frac{1+\omega\frac{PET}{P}}{1+\omega\frac{PET}{P}+\frac{PET}{P}^{-1}}$$



Methods

We created two treatments to run through the ECH2O watershed model. In our first treatment, **mean precipitation was increased by about six percent over a twenty year period.** We adjusted the yearly precipitation data to create dry and wet years by shifting the annual precipitation by a constant selected from a normal distribution between 0.75 and 1.25. All other climate inputs were the same for the twenty year period. In our second treatment we created dry and wet years with a normal distribution but the mean precipitation trend showed no increase over 20 years. **We deccreased the canopy water use efficency by one percent each year** to simulate land use changes. All other climate inputs were held constant.

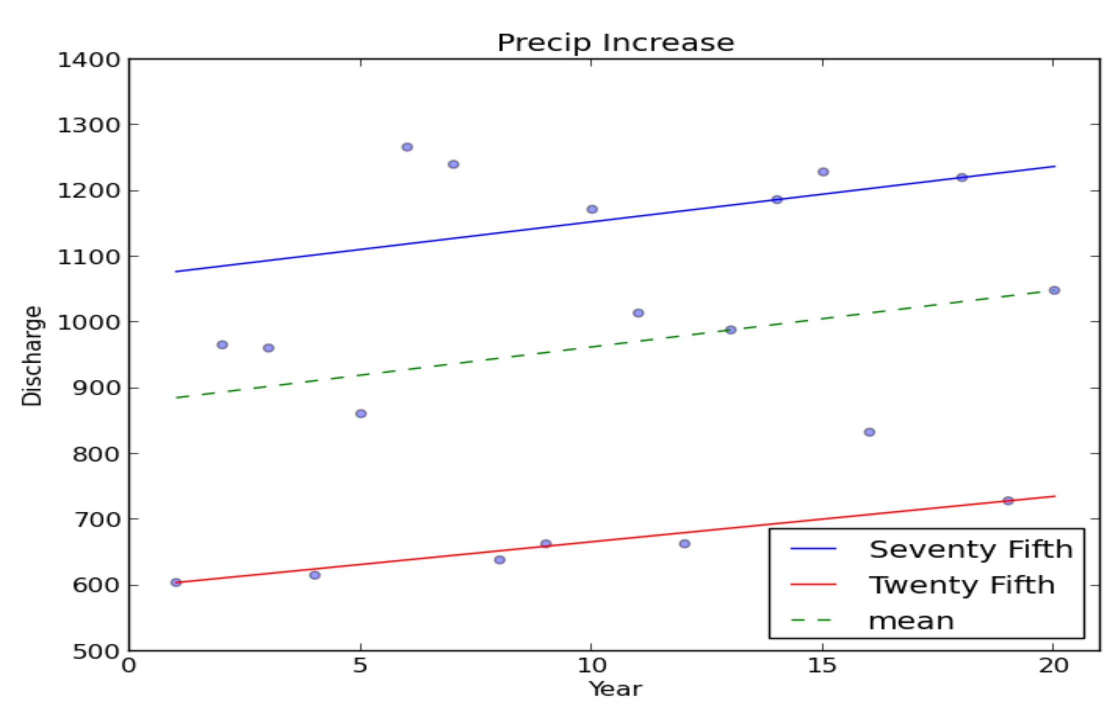
Precipitation inputs



The figure on the left shows the annual precipitation input for our first treatment where precipitation is increased. The mean is calculated from the 0.5 quantile of the data. The mean shows an increasing trend of about 6% over the twenty year period.

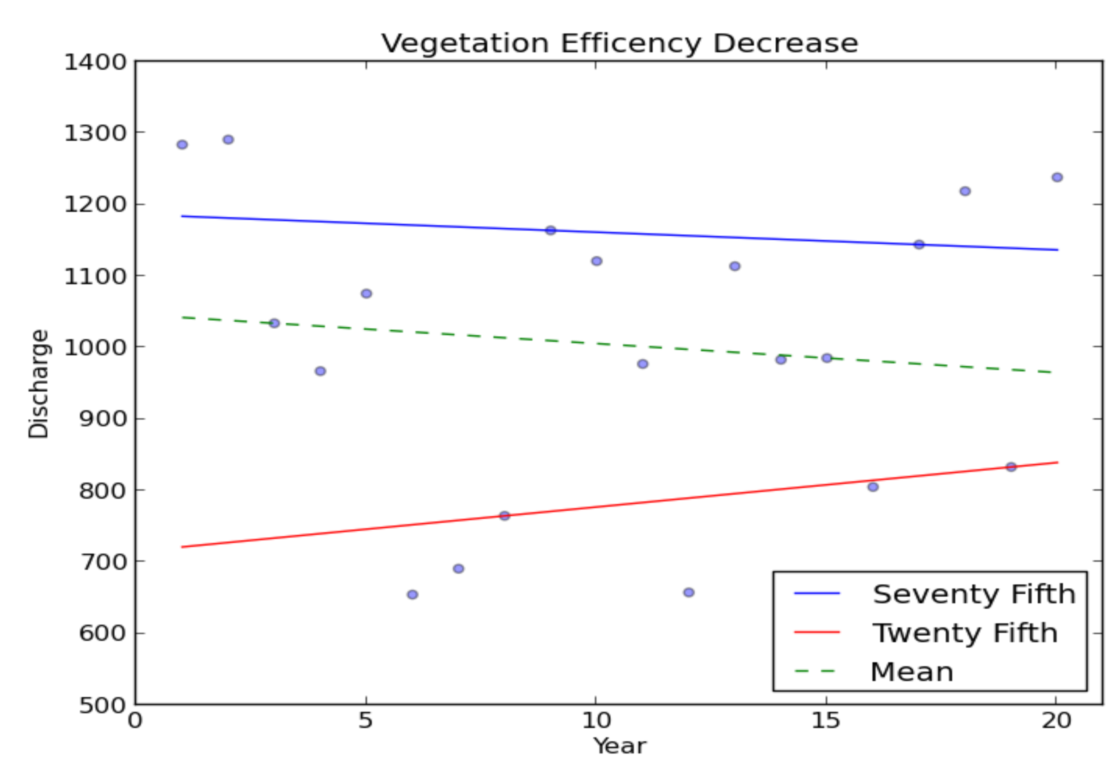
The figure on the right shows the precipitation input for the second treatment where precipitation remains constant. The mean decreases by about 1% over the twenty year period.

Results



Yearly discharge with precipitation increasing about 6% over the twenty year period.

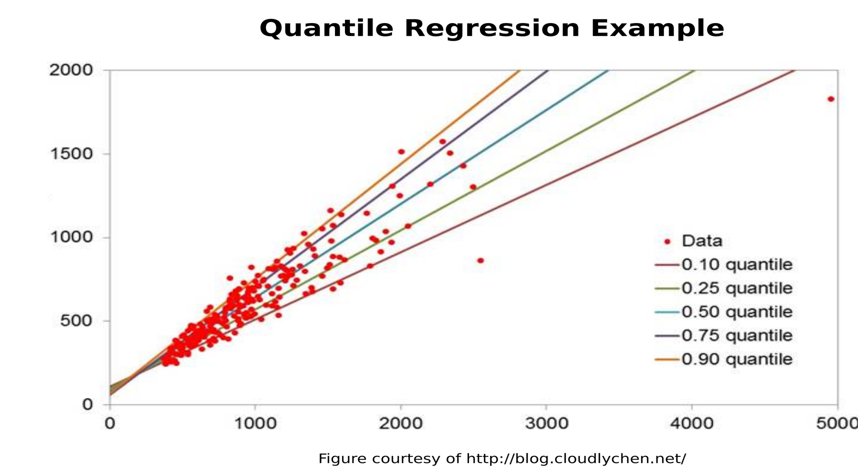
Slope of 75% = 8.0
Slope of 25% = 6.6
Slope of 50% = 8.2



Yearly discharge with vegetation efficeny decreasing 1% each year.

Slope of 75% = -2.3
Slope of 25% = 5.9
Slope of 50% = -3.9

Experimental setup



Quantile regression fits a line to a specifc percentile of the dataset

- Robust to outliers and non-normal distributions
- 75th percentile = wet years
- 25 percentile = dry years
- 50th percentile = mean

Discussion

For the precipitation increase treatment the slope of the 75% line is greater than the slope of the 25% line indicating an increase in precipitation affects wet years more than dry years.

For the vegetation efficency decrease treatment the slope of the 25% line is greater than the mean and the 75% line indicating a change in land use affects dry years more than wet years.

Implications

- We confirm the effect of precipitation change is detectable and differentiable from other disturbances.
- My approach to this problem utilized an advanced watershed model to generate knowledge about processes hard to observe in actual data.
- This study provides a framework to analyze the streamflow record and infer if streamflow change is due to changes in precipitation or in land use.

Reference

Zhang, L, W Dawes, G Walker, "Response of mean annual evapotranspiration to vegetation changes at the catchment scale." Water Resources Research 37, 3 (2001).

Acknowledgements

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