RELATIONSHIP BETWEEN CLIMATE, HYDROLOGY, AND LANDUSE IN THE WINOOSKI RIVER BASIN OF NORTHERN VERMONT

A Thesis Proposal

William Redin Hackett

Committee Members:
Paul Bierman
Donna Rizzo
Leslie Morrissey
Outline

- Objectives
- Study Area
- Background
  - Climate
  - Natural Oscillations in climate
  - Hydrology of landuse
- Methods
  - Preliminary analysis
  - Further Analysis
- Putting it all together
- Timeline
Study Objectives

- Determine the nature of changing trends in discharge and weather data
  - Have precipitation, discharge, and temperature changed over time?

- Identify changing trends in storm frequency and intensity
  - Has storm intensity changed over the past 50 years? Has their frequency changed?

- Analysis of relationship between climate and discharge over time by establishing landuse and climate signatures in the record
  - Have precipitation and discharge changed in equivalent amounts over time or has this relationship changed? Can this be linked to landuse?
### Stations

<table>
<thead>
<tr>
<th>Weather Station</th>
<th>Years of Coverage</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essex Junction</td>
<td>1937-1960</td>
<td>104</td>
</tr>
<tr>
<td>Essex Junction</td>
<td>1971-2007</td>
<td>73</td>
</tr>
<tr>
<td>Waterbury 3</td>
<td>1941-1958</td>
<td>143</td>
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<tr>
<td>Waterbury 2</td>
<td>1958-1992</td>
<td>232</td>
</tr>
<tr>
<td>Montpelier 2</td>
<td>1999-2007</td>
<td>162</td>
</tr>
<tr>
<td>Barre Montpelier AP</td>
<td>1948-2007</td>
<td>343</td>
</tr>
<tr>
<td>Northfield</td>
<td>1923-1974, 1994-2007</td>
<td>204</td>
</tr>
<tr>
<td>Northfield 3</td>
<td>1974-1994</td>
<td>429</td>
</tr>
<tr>
<td>Mt. Mansfield</td>
<td>1954-2007</td>
<td>1204</td>
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<table>
<thead>
<tr>
<th>Discharge Gage</th>
<th>Years of Coverage</th>
<th>Basin Area (km²)</th>
<th>USGS Station ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winooski River at Essex Jct.</td>
<td>1929-2005</td>
<td>2,704</td>
<td>04290500</td>
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<tr>
<td>Winooski River at Montpelier</td>
<td>1915-1922 &amp; 1929-2005</td>
<td>1,028</td>
<td>04286000</td>
</tr>
<tr>
<td>Winooski River at Wrightsville</td>
<td>1934-2005</td>
<td>179</td>
<td>04285500</td>
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<tr>
<td>Little River at Waterbury</td>
<td>1936-2005</td>
<td>287</td>
<td>04289000</td>
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<tr>
<td>Mad River at Moretown</td>
<td>1929-2005</td>
<td>360</td>
<td>04288000</td>
</tr>
<tr>
<td>Dog River at Northfield Falls</td>
<td>1935-2005</td>
<td>197</td>
<td>04287000</td>
</tr>
</tbody>
</table>
Concept

Climate Periodicity

Precipitation → Landuse → Runoff into channels → River Discharge

Climate Change
Climate

Average annual/monthly/daily: precipitation, snow, rain, temperature, wind, humidity, solar energy

Short term periodicity in climate can effect the weather: El Nino

- Sea surface temperatures in the Pacific can bring mild and wet winters to northeastern U.S.

North Atlantic Oscillation (NAO)

- NAO signal fluctuates and can drastically effect winter weather.
- Difference between Azores High and Icelandic Low.
- More of an effect in Europe, but US winters can be mild and wet during positive NAO winters, and colder during negative winters.

Hydrology of Landuse

Images: google earth, Discharge data: USGS
Hydrology Continued

-Increasing agriculture in sub basins of the Mississippi have seen increased runoff compared to forested areas.

-Increasing urbanization in CA has led to increased discharge

-Contaminant transport, erosion and sediment transport
Compounding Variables

- Spatial variability of microclimate: elevation

- Landuse changes can interact or coincide with changes in climate

- Solution: treat each sub Basin independently and Test for variables one at a time (landuse, climate, etc.)
Methods

- Analyze yearly, monthly, daily data by station:
  - Discharge
  - Precipitation
  - Temperature
  - Wind speed; direction
  - Relative Humidity
  - Solar Input

- Analyze discharge and precipitation for storms and base flows

- Look for relationships between these using Spectral Analysis and ANN
Preliminary Analysis

- Decadal periodicity
- Increasing trend (not significant)

- Decadal periodicity
- Increasing trend (significant)

Dog River annual discharge 1935-2005
Linear $r^2 = 0.034$, Spline $r^2 = 0.616$
P value = 0.124

Mad River annual discharge 1929-2005
Linear $r^2 = 0.075$, Spline $r^2 = 0.611$
P value = 0.016
Preliminary Analysis

- ~decadal periodicity
- increasing trend (significant)

Lowest annual discharge event
Mad River
1929-2005
Linear r² = 0.214, spline r² = 0.561
P value = <0.0001

Second lowest annual discharge event
Mad River
1929-2005
Linear r² = 0.188, spline r² = 0.555
P value = <0.0001
Natural Oscillations and Periodicity

Correlate peaks and troughs in discharge record with those of the NAO signal over the same period.

Adapted from *Decade-to-Century-Scale Climate Variability and Change*, 1998.
Further Analysis
Directional Statistics

Days of the year (1-365) around circle (1°=.9 days)

Winooski River @ Montpelier
1960

Discharge (cfs)

Fall          Winter          Spring          Summer
Spectral Analysis

![Spectral Analysis Graph](image-url)
Artificial Neural Network
Analysis of Landuse

Methods:

- Point sampling of entire basin to choose sites
  - Randomly select from uplands and lowlands
- At each point, $4 \text{ km}^2$ subset of sample points
- Identify each point as road/structure, field, forest, or developed.

- Total percentages for each image set (year)
Analysis of Landuse

Taft Corners, Williston, VT:
Analysis of Landuse

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Analysis of Landuse

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Analysis of Landuse

Taft Corners, Williston, VT:
Analysis of Landuse

Taft Corners, Williston, VT:
Sampling Bias

Test subject: Matt Jungers

<table>
<thead>
<tr>
<th>Category</th>
<th>1974</th>
<th>MCJ test</th>
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<tbody>
<tr>
<td>Field</td>
<td>62%</td>
<td>53%</td>
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<tr>
<td>Forest</td>
<td>21%</td>
<td>19%</td>
</tr>
<tr>
<td>Road/Structure</td>
<td>9%</td>
<td>8%</td>
</tr>
<tr>
<td>Developed</td>
<td>9%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Historical Landuse - Taft Corners, VT

- **Field**: 1974 - 62%, MCJ test - 53%
- **Forest**: 1974 - 21%, MCJ test - 19%
- **Road/Structure**: 1974 - 9%, MCJ test - 8%
- **Developed**: 1974 - 9%, MCJ test - 20%
Summary

- Overall climatic trends
- Climatic oscillations ie: NAO, el nino

Data:
- Precipitation
- Wind
- Solar Input
- Temperature

-Landuse
-Evapotranspiration
-Runoff

-Identify climate signals within the weather and discharge data
- Then, attempt to correlate landuse changes (and timing) with data
## Timeline

<table>
<thead>
<tr>
<th>Task</th>
<th>Timing</th>
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<tbody>
<tr>
<td>Discharge and weather data analysis</td>
<td>Spring 2008</td>
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<tr>
<td>Thesis Proposal</td>
<td>Spring 2008</td>
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<tr>
<td>Landuse/historical imagery analysis, additional data analysis and</td>
<td>Summer-Fall 2008</td>
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<tr>
<td>model creation, paper writing</td>
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<tr>
<td>Progress Report, GSA Talk/Poster</td>
<td>Fall 2008</td>
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<tr>
<td>Write Thesis</td>
<td>Spring 2009</td>
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<td>Thesis Defense</td>
<td>Spring/Summer 2009</td>
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</table>
Acknowledgements

- Vermont EPSCOR (Spring ‘08 RA)
- Donna Rizzo and Lance Besaw
- Matt Jungers (For being a bias tester and pretending it was fun)

Questions?
Preliminary Analysis

- Decadal periodicity
- Increasing trend (not significant)

Dog River October discharge 1935-2005
Linear $r^2 = 0.081$, Spline $r^2 = 0.622$

Dog River November discharge 1935-2005
Linear $r^2 = 0.076$, Spline $r^2 = 0.493$