GLACIER VARIABILITY IN WYOMING'S WIND RIVER & TETON RANGES

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OUTLINE

- Background
- Research Objectives
- Results
- Future Research
- Conclusion
IMPORTANCE OF GLACIERS

- Glaciated Basins are more stable sources of water
- Glaciers have been compared to natural water reservoirs for downstream domestic and agricultural uses
- Heavily glaciated basins have been documented to provide up to 50% more runoff than non-glaciated basins (Fountain et.al. 1985)
- Glaciated basins exhibit less variability in annual streamflow
LOCATION MAP - Teton Range
TETON RANGE FACTS

- Early French voyageurs gave the name “les Trois Tétons” (The Three Breasts)
- 65 km barrier host to 10 named glaciers
- Of which Teton Glacier is the largest
- All glaciers are located on the east slope of the mountain range
- Grand Teton is the highest peak at 4,197 m (13,770 ft)
  & another eight peaks are all over 3,660 m (12,000 ft)
- Water is used for domestic and irrigation use
LOCATION MAP - Wind River Range

Glaciated Regions of the Western United States

Legend
- Streams
- Glaciers
- County Line
- Lakes

Cheesbrough et al. (2007)
Largest Concentration of Glaciers in the American Rocky Mountains
160 km barrier host to 63 total glaciers
Total 17 mi² of glaciers
Seven of the ten largest glaciers in the American Rockies
Serve as headwaters for three drainage basins
- Green-Colorado
- Missouri-Mississippi
- Snake-Columbia
Water is used for domestic and irrigation use
## CLIMATOLOGICAL DATA

<table>
<thead>
<tr>
<th>River Basin</th>
<th>Site Name</th>
<th>NRCS Site #</th>
<th>Period of Record (yrs)</th>
<th>Temp. Increase For July (°C)</th>
<th>Temp. Increase For August (°C)</th>
<th>Latitude / Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>New Fork Lakes, WY</td>
<td>661</td>
<td>23</td>
<td>4</td>
<td>1.5</td>
<td>43.11/-109.95</td>
</tr>
<tr>
<td>Green</td>
<td>Kendall R.S., WY</td>
<td>555</td>
<td>23</td>
<td>3.5</td>
<td>1</td>
<td>43.25/-110.02</td>
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<tr>
<td>Green</td>
<td>Elkhart Park G.S., WY</td>
<td>468</td>
<td>23</td>
<td>5</td>
<td>2</td>
<td>43.01/-109.76</td>
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<tr>
<td>Green</td>
<td>Big Sandy Opening, WY</td>
<td>342</td>
<td>22</td>
<td>2</td>
<td>3</td>
<td>42.65/-109.26</td>
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<tr>
<td>Wind</td>
<td>Little Warm, WY</td>
<td>585</td>
<td>19</td>
<td>4</td>
<td>3</td>
<td>43.50/-109.75</td>
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<tr>
<td>Wind</td>
<td>Cold Springs, WY</td>
<td>405</td>
<td>19</td>
<td>4</td>
<td>3</td>
<td>43.28/-109.45</td>
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<tr>
<td>Wind</td>
<td>Hobbs Park, WY</td>
<td>525</td>
<td>19</td>
<td>4</td>
<td>2</td>
<td>42.87/-109.09</td>
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<tr>
<td>Wind</td>
<td>South Pass, WY</td>
<td>775</td>
<td>23</td>
<td>4</td>
<td>1</td>
<td>42.57/-108.84</td>
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<tr>
<td>Snake</td>
<td>Phillips Bench, WY</td>
<td>689</td>
<td>20</td>
<td>3</td>
<td>2</td>
<td>43.52/-110.90</td>
</tr>
</tbody>
</table>

NRCS SNOTEL sites in the WRR used for April 1st Snow Water Equivalent (SWE) and temperature data.
CLIMATOLOGICAL DATA

- Standardized April 1st SWE for eight gage stations
- Multiple points of zero, meaning running average is at equilibrium
- Strong drought conditions starting near 2000-2001

- Average temperature increased in the period of record
- David Naftz et. al. of the USGS conducted an ice core study of Upper Fremont Glacier that showed temperatures increased by 3.5°C, which is supported by the SNOTEL data
OBJECTIVES

- Estimate glacier area/volume change in the Wind River Range (WRR) & Teton Range (TR) from 1966-2005 using:
  - Landsat Imagery
  - Aerial Photographs
  - Geographical Information System (GIS)
- Analyze glacial recession using field evaluation techniques
- Quantify climatological trends in the area
- Quantify glacial volume loss through Photogrammetry techniques
Digital Photographs

2006
Teton Glacier

2007
Middle Teton Glacier
### TETON GLACIER AREA (Km$^2$)

<table>
<thead>
<tr>
<th>Year</th>
<th>Size (km$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967</td>
<td>0.215</td>
</tr>
<tr>
<td>1983</td>
<td>0.186</td>
</tr>
<tr>
<td>2006</td>
<td>0.108</td>
</tr>
</tbody>
</table>

The map shows the changes in the glacier area from 1967 to 2006, with a terminal moraine indicated. The size of the glacier area decreased from 0.215 km$^2$ in 1967 to 0.108 km$^2$ in 2006.
Aerial Photo vs. Landsat Data

<table>
<thead>
<tr>
<th>Data</th>
<th>Size (km$^2$)</th>
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</thead>
<tbody>
<tr>
<td>2002 Aerial Photo</td>
<td>0.096</td>
</tr>
<tr>
<td>2002 Landsat Data</td>
<td>0.160</td>
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</table>
GLACIAL AREA CHANGES FROM 1967 TO 2006

The graph illustrates the changes in the area of the Teton and Middle Teton glaciers from 1967 to 2006. The area is measured in square kilometers (Km²) on a logarithmic scale. The data shows a significant decrease in the area of both glaciers over the years, indicating the effects of climate change on glacial retreat.
Dinwoody Glacier
1935
1988
2006
Dinwoody Glacier
1935
1988
2006
### DINWOODY GLACIER AREA (Km²)

<table>
<thead>
<tr>
<th>Year</th>
<th>Size (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966</td>
<td>4.24</td>
</tr>
<tr>
<td>1989</td>
<td>3.30</td>
</tr>
<tr>
<td>2001</td>
<td>2.38</td>
</tr>
</tbody>
</table>

# PROJECT DATA

**Period of Record:**
- 1966 to 2005 (39 years)
- 1985 to 2005 (20 years)

**Data Source:**
- USGS Aerial Photos
- Landsat Imagery

**Glaciers:**
- Green River Drainage
- Wind River Drainage
- Green River Drainage
- Wind River Drainage

<table>
<thead>
<tr>
<th></th>
<th>Mammoth</th>
<th>Dinwoody</th>
<th>Minor</th>
<th>Bull Lake Complex</th>
<th>12 Glacial Complexes</th>
<th>30 Glacial Complexes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sourdough</td>
<td>Knife Point</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Information Provided:**
- Volume Changes & Extended Period for Area Changes
- Area Changes for 42 Glacial Complexes Since 1985

Cheesbrough et al. (2007)
GLACIAL AREA (%) 1985 TO 2005 FOR 42 WRR GLACIERS

Glacier Area Changes Since 1985

% Change from 1985 Area

Year

Large Glaciers (> 0.5 km²)
Small Glaciers (< 0.5 km²)

Cheesbrough et al. (2007)
GLACIAL AREA CHANGES FROM 1966 TO 2001

Cheesbrough et al. (2007)
2001 glacial area divided by the 1985 baseline area, with the error envelope about the axis

No significant correlations were found between glacier area change and topographic characteristics

Smaller glaciers receded more than glaciers with larger surface area

1985 area change of 42 glacial complexes
STEREO PHOTOGRAMMETRY

- This technique is considered to be more accurate than the Bahr et. al. equation.
- The results may be used to develop an equation similar to Bahr’s specifically for WRR glaciers.
Dinwoody Glacier 2001

Surfer Software

Cheesbrough et al. (2007)
VOLUME ANALYSIS RESULTS

- Dinwoody Glacier lost 66 million cubic meters, approximately 53,500 acre-ft from 1983-2001 (based on photogrammetry). For a comparison:
  - Alcova Reservoir – 168,000 acre-feet (91% full)
  - Guernsey Reservoir – 46,300 acre-feet (100% full)
  - Glendo Reservoir – 142,000 acre-feet (28% full)

- Elevation data obtained through aerial photogrammetry and ERDAS Imagine analysis is not statistically different from GPS field measurements at the 90% level in a paired t-test
FUTURE RESEARCH

- Extend the period of record analyzed and the number of glacial bodies studied in the Wind River Range (WRR) & Teton Range (TR)
- Apply area/volume scaling techniques to calculate volume loss
  - Calculate glacial meltwater volumes to determine variability of downstream flow in late summer months between glacial and non-glacial basins
  - Determine area/volume relationship such as Bahr et. al. specifically for the WRR
- Analyze glacial contributions to downstream flow during drought years
- Estimate relationship between glacial area and measurement (pixel resolution)
  - By utilizing 2001 imagery from:
    - Color Inferred aerial photos, ASTER imagery, Landsat 7 imagery, MODIS imagery
CONCLUSION

- Glacial surface area/volume showed strong decline from 1966 to 2005 in the WRR and TR
  - Smaller glaciers were impacted more than larger glaciers
- Dinwoody lost 66 million cubic meters from 1983 to 2001
  - This measure is considered more accurate since the Bahr et al. equation underestimates the loss by 40%
ACKNOWLEDGEMENTS

Faculty Members
- Glenn Tootle
- Greg Kerr
- Larry Pochop
- Ramesh Sivanpillai

Graduate Students
- Derrick Thompson
- Jeb Bell
- Jake Edmunds
- Kyle Cheesbrough

Funded By
- Wyoming Water Development Commission
- USGS/State of Wyoming Water Research Program
- University of Wyoming, Office of Water Programs
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