Rivers and geomorphic/hydrological implications for permafrost dynamics

Joel C. Rowland
Arctic Rivers

• 10% of the global freshwater discharge enters the Arctic Ocean

• 79% of rivers in tundra and barren arctic not affected by river fragmentation of flow regulation

• Arctic and sub-arctic river sediment loads low compared to temperate rivers

• 2°C increase in temp may lead to 10% increase in water discharge and 32% increase in sediment discharge (Syvitski, 2002)
Permafrost Linked to River Systems

Regions of low gradient permafrost bounding rivers

North America: 60%
Asia: 40%

Northern Hemisphere
PF Distribution

PF associated with river floodplains
River mobility influences fate of materials stored in floodplains

Birch Creek, Alaska
2002
Thermal impact of rivers: talik and surface and groundwater interactions

Black River, AK, courtesy USGS

Smith & Hwang, 1973
Sediment and nutrient loading to coastal oceans

Yukon River delta, August 2008, MODIS, source: NASA-Earth Observatory
Drainage network expansion and linkages to hillslopes

Hills north of Fairbanks, AK, 2002
Controls on River Mobility in Arctic Rivers

- Bank strength
  - Cohesive sediments
  - Vegetation
  - Permafrost
  - Pore pressures – bank saturation
- Magnitude, frequency and duration of flows
- Sediment load – magnitude and character
- Ice damming, bed fast ice, and iced banks
Effect of Climate Change on River

• Bank strength

  • Cohesive sediments – not likely to change rapidly

  • Vegetation – likely to change but questionable if rooting depth change will be significant

  • Permafrost – active layer vs. bank thawing

Beaver Creek, AK 2008, courtesy of USGS
Impact of increase bank thawing uncertain
Maximum Q and thawing out of sync

Remote sensing analysis

• Few estimates on river mobility of arctic/permafrost systems

• Landsat, aerial photographs, high resolution imagery – Ikonos, Quickbird, Worldview

• Automated feature extraction software to identify channel

• Vectorize river features

• Quantitatively measure spatial and temporal trends in river mobility
Genie Pro

Training on select ROIs

Automated Classification

2007 Ikonos imagery Ft. Yukon
Preliminary Results for Yukon Flats
Maximum Erosion rates ~ 10 to 20 m/yr
Areas of considerable deposition and island growth
## Change in net balance over time?

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Erosion Rate (km²/yr)</th>
<th>Deposition (km²/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986-1994</td>
<td>7.6</td>
<td>6.3</td>
</tr>
<tr>
<td>1994-2002</td>
<td>6.1</td>
<td>3.6</td>
</tr>
<tr>
<td>2002-2008</td>
<td>5.0</td>
<td>11.7</td>
</tr>
</tbody>
</table>

### Caveats:
- Areas not volumes
- Landsat resolution 30 m pixels, 1 pixel difference along 300km can account for all of observed change
Lower Yukon 1985-2008
Substantial Mid-Channel Bar Growth

Yukon River delta, August 2008, MODIS,
source: NASA-Earth Observatory
Ongoing work

• Extend analysis further back in time
• Look for associations with high erosion rates and vegetation patterns – map vegetation patterns
• Explore relationship between high erosion and changes in surface water distributions such as lakes
• Focus on areas of known disturbance such as fires
• Look at different geographical regions with differing permafrost characteristics