Rivers and geomorphic/hydrological implications for permafrost dynamics

Los Alamos NATIONAL LABORATORY EST. 1943

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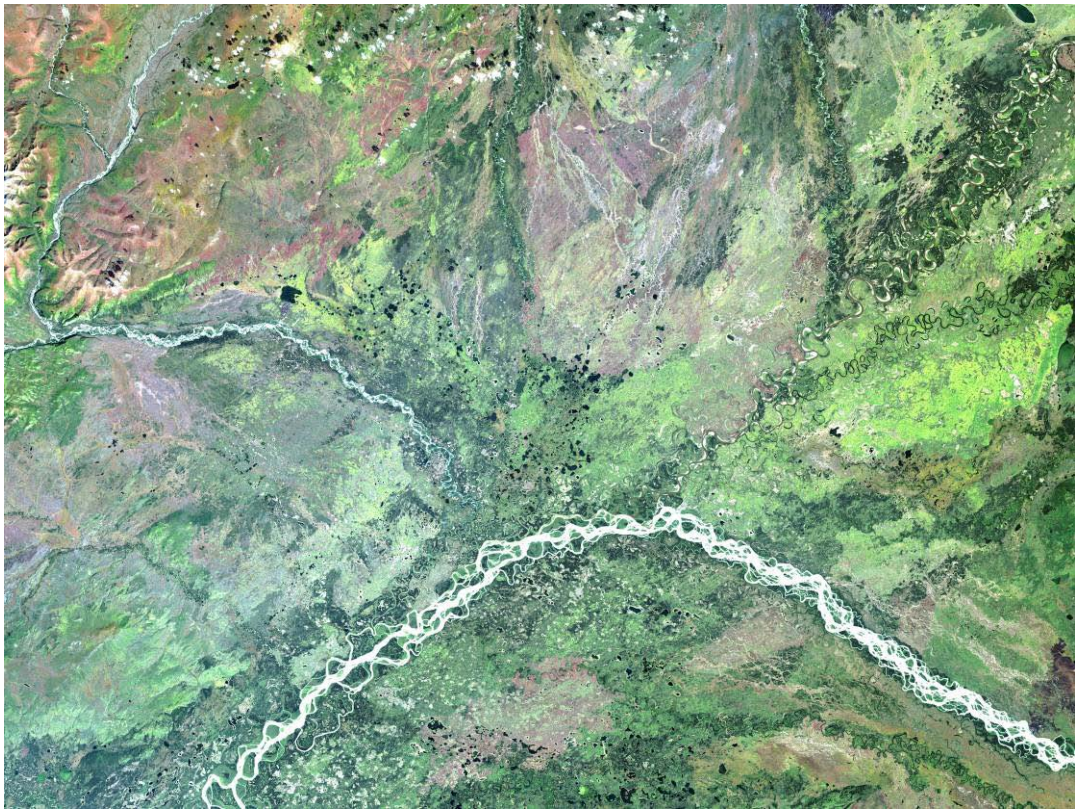
Arctic Rivers

•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)



Landsat 5, Yukon Flats 2008

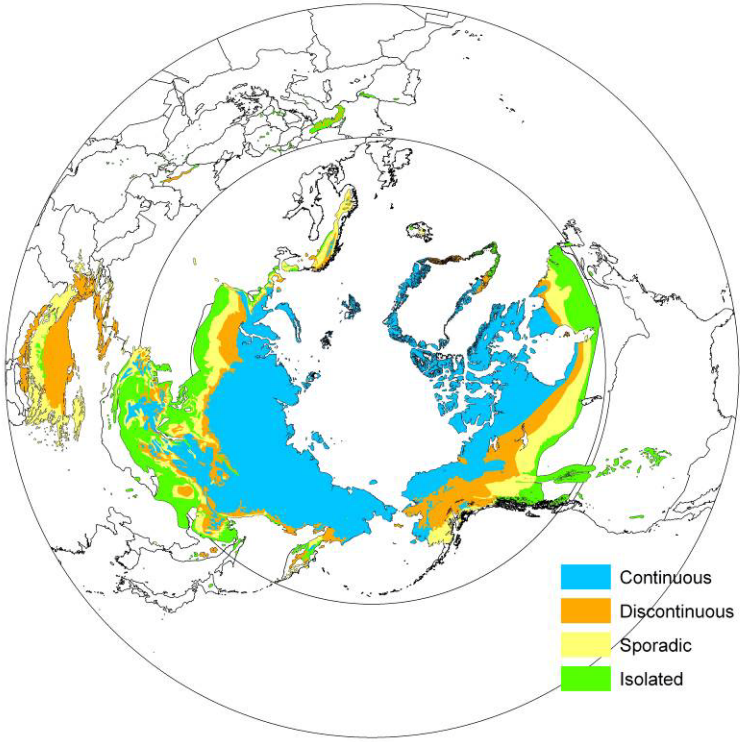
Permafrost Linked to River Systems

Regions of low gradient permafrost bounding rivers

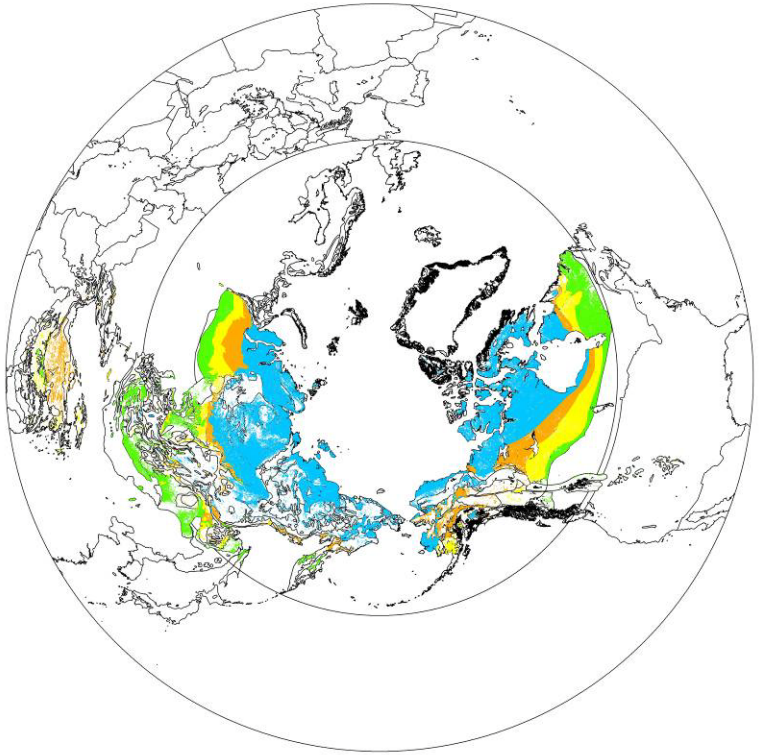
North America: 60%

Asia: 40%

Northern Hemisphere
PF Distribution



PF associated with
river floodplains



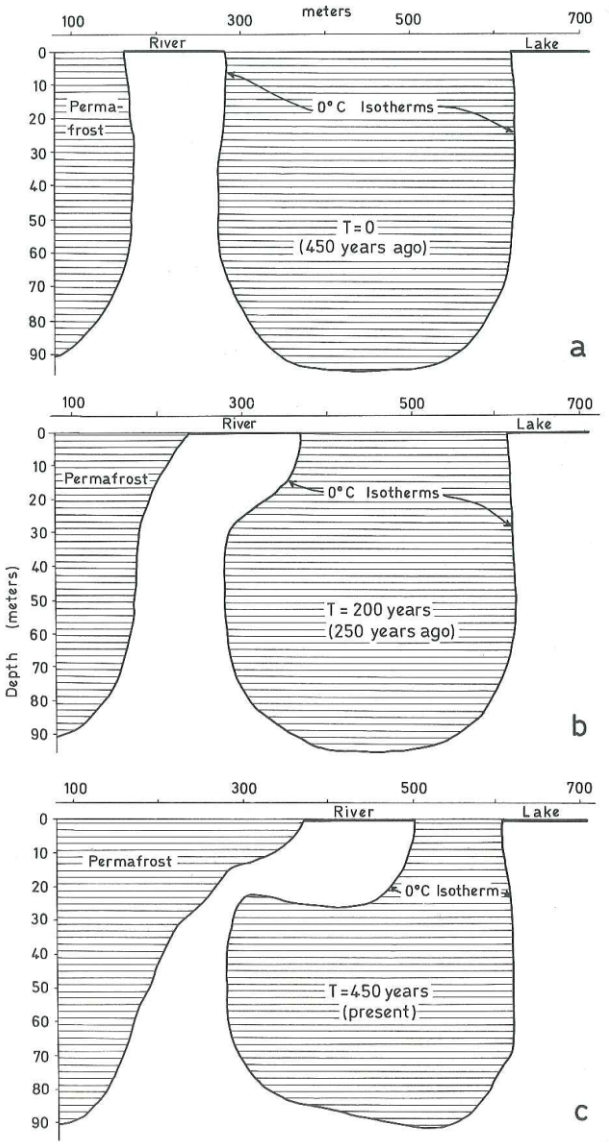
River mobility influences fate of materials stored in floodplains

Birch Creek, Alaska

2002

Thermal impact of rivers: talik and surface and groundwater interactions

Black River, AK, courtesy USGS

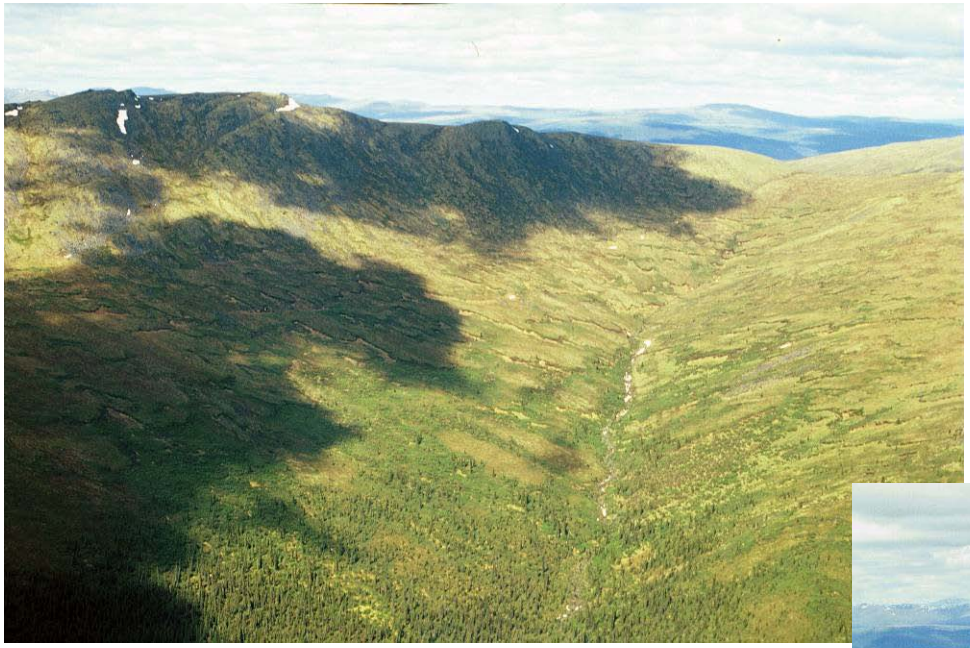


Smith & Hwang, 1973

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

Birch Creek, AK 2002

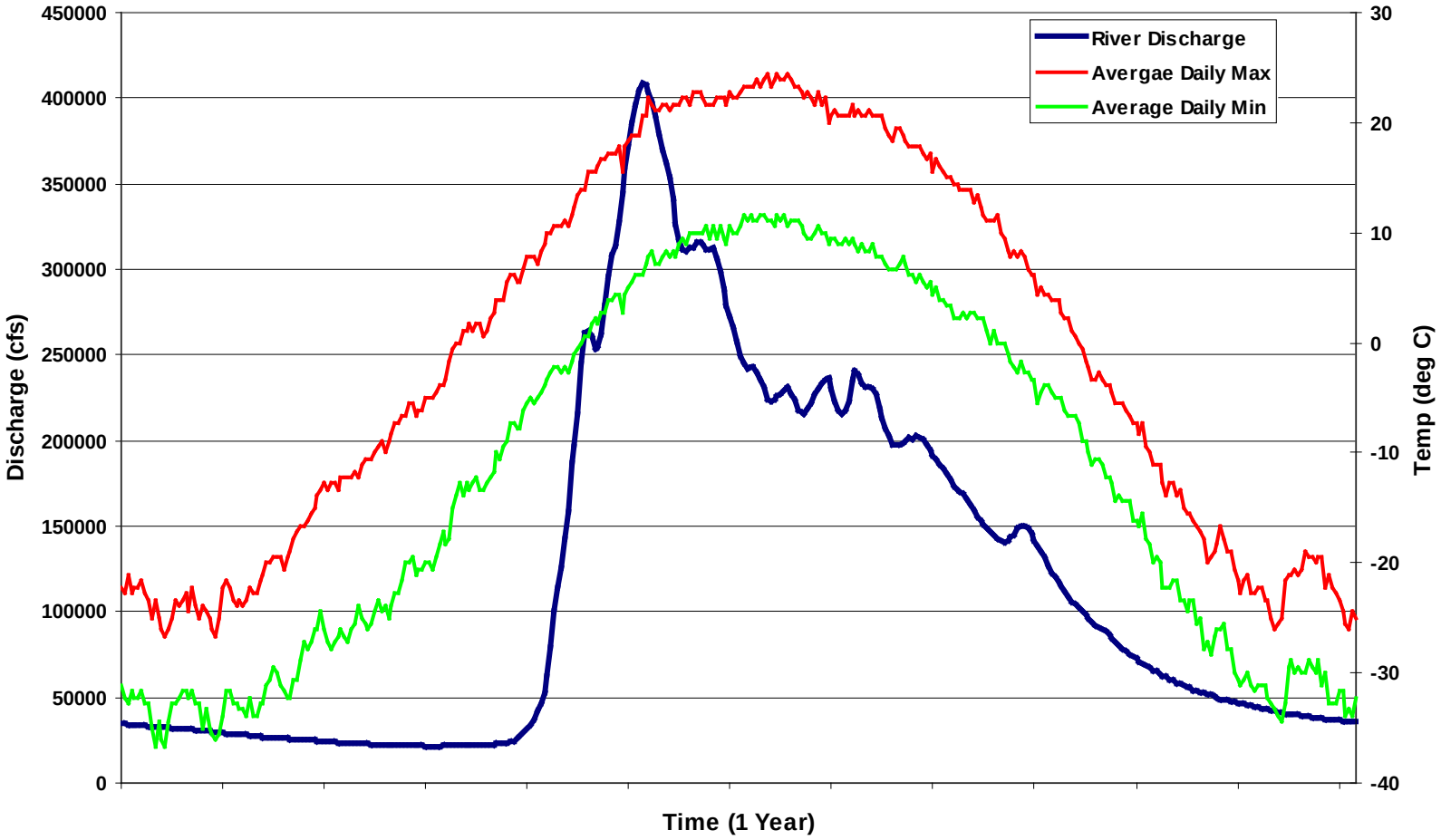
Effect of Climate Change on River

- **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



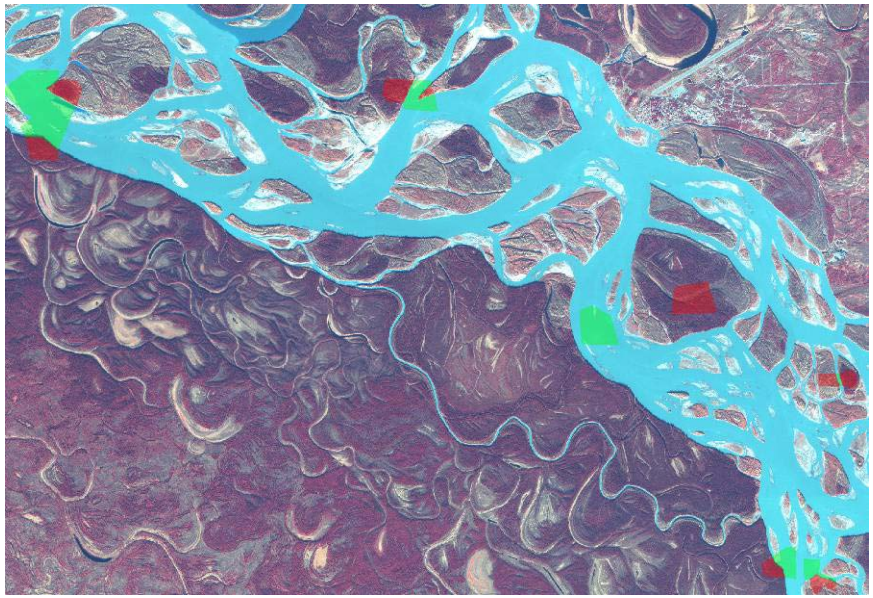
Flow at Stevens Village (1980-1984), Temp at Ft. Yukon (1938-1990)

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

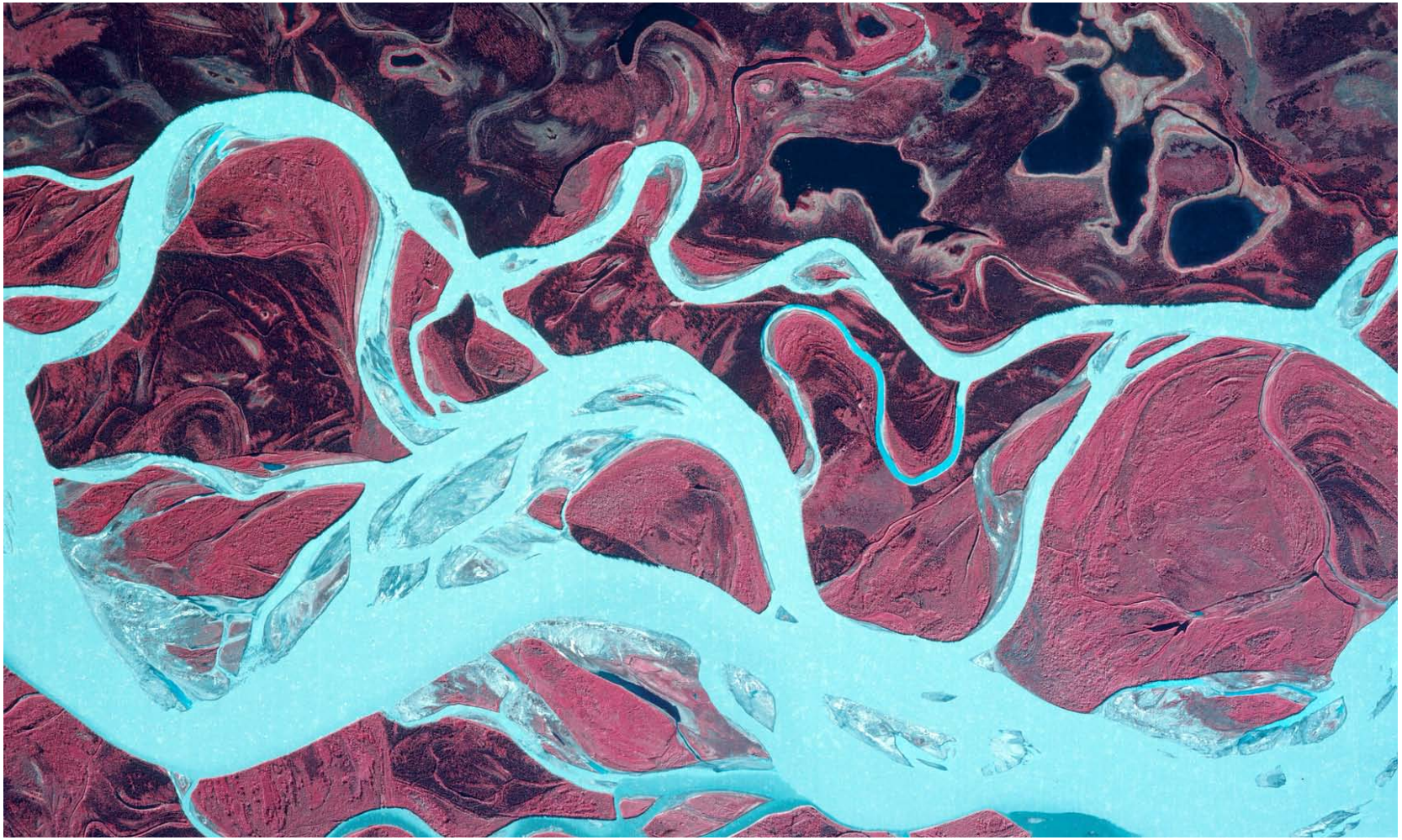
Training on select ROIs



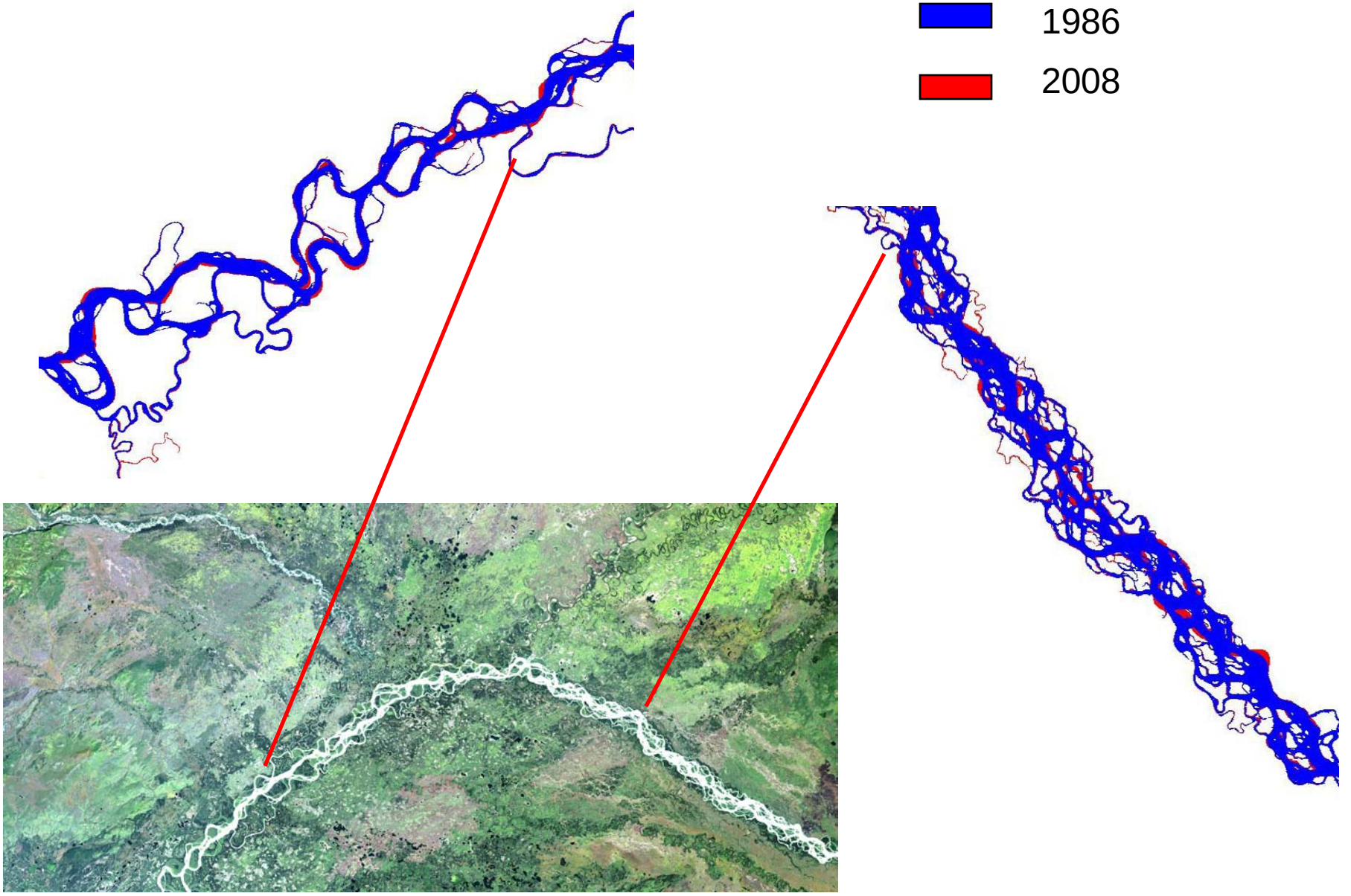
2007 Ikonos imagery Ft. Yukon

Automated Classification

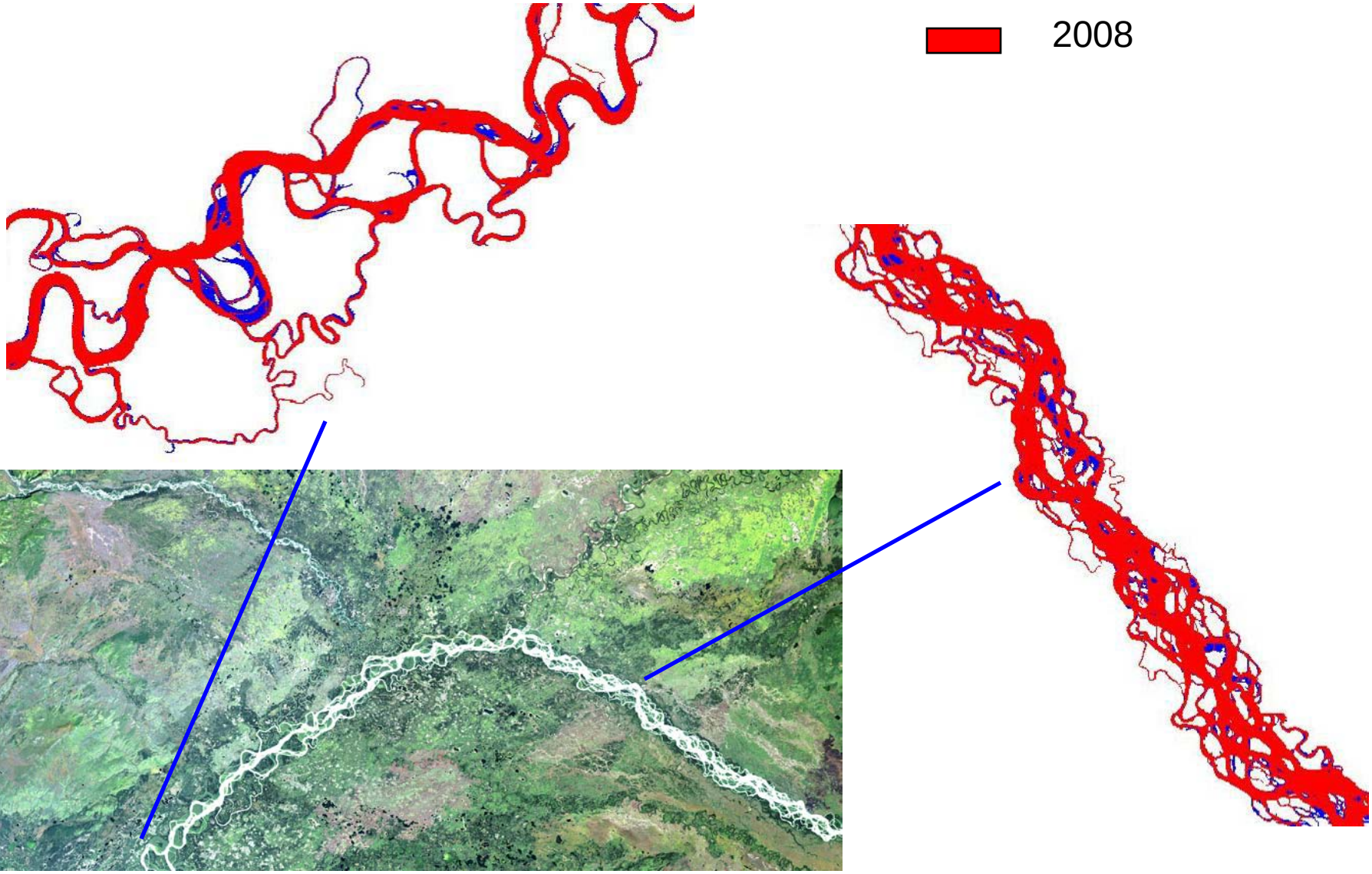
Preliminary Results for Yukon Flats



Maximum Erosion rates ~ 10 to 20 m/yr



Areas of considerable deposition and island growth



Change in net balance over time?

Time Period	Erosion Rate (km^2/yr)	Deposition (km^2/yr)
1986-1994	7.6	6.3
1994-2002	6.1	3.6
2002-2008	5.0	11.7

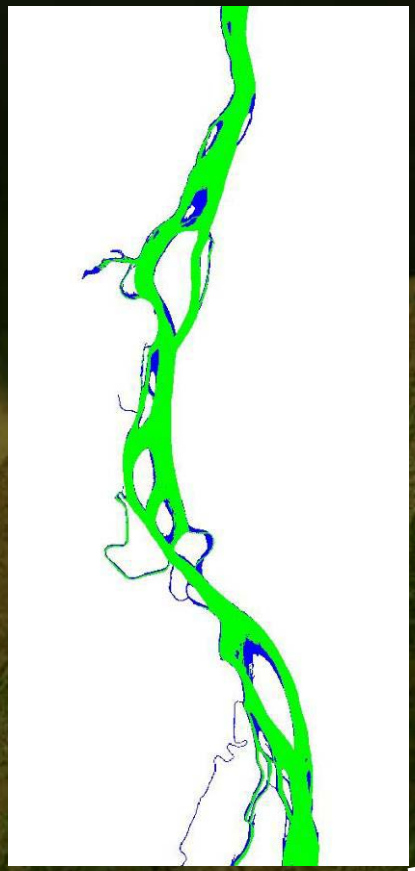
Caveats:

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