Evaluating climate-driven landscape changes and impacts on lakes and rivers in northern Yukon, Canada

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Dept. Geog. and Tour Studies
Dept. Earth Science

NASA ABoVE
5th Science Team Meeting

22-May-2019
Research in Yukon, Canada (other than in Old Crow Flats)

Sean Carey, McMaster University

Wolf Creek near Whitehorse
- 3 eddy covariance towers across different ecosystems
- Transpiration partitioning
- LiDAR 2018 compared to 2007 (vegetation differences)
- Updating land cover classifications

Dempster Highway (near NWT border)
- Headwater hydrology/snow study in area washing out road

Faro mine reclamation strategies and water flux
Yeendoo Nanh Nakhweenjit K’atr’ahanahtyaa
(Environmental change and traditional use of the Old Crow Flats in northern Canada – 2007-2010)
Old Crow Flats: Traditional territory of the Vuntut Gwitchin First Nation
ABoVE Airborne Campaign in Old Crow Flats

2017
• AVIRIS-NG
• UAVSAR
  • L and P bands
• LVIS
• AirSWOT

2018
• AVIRIS-NG
• UAVSAR
  • L band
Temperature trend across Canada

Environment and Climate Change Canada, 2019
(Figure updated from Vincent et al., 2015)

Porter and Pisaric, 2011

Tree rings
Old Crow Climate

- getting warmer and wetter
- longer ice-free season

Remote Sens. 2018, 9, x FOR PEER REVIEW

Based on the Landsat-derived land cover classification, the OCF basin comprises 8,335 km$^2$ of shrub vegetation, which was intersected with greening and browning pixels. Analysis revealed that significant greening occurred within 4.6% (384 km$^2$) of the shrub vegetation area (outside of drained lake basins) during the last 30 years (from 1985 to 2014). Browning was detected in 2.4% (202 km$^2$) shrub vegetation classified areas. Greening in shrub-classified areas was observed mostly across the peripheral headwater ecotone (i.e., 3.4%) compared to the greening within the flat lowland lake-rich portion (i.e., 1.2%) of the basin. Greening has been increasing in spatial coverage within areas classified as shrub vegetation an average of approximately 13.25 km$^2$ per year since 1985, which is higher compared to the increasing greening spatial coverage within other classified land cover types (i.e., approximately 11.50 km$^2$ per year).

Greening and browning trends were evaluated for individual subcatchments for OCF (see Figure 8), which were delineated based on locations of an ongoing drainage network monitoring project. BC subcatchment experienced the highest greening (7.58%) of total area in the catchment (see Figure 9) followed by OR8 (7.20%), TC (6.73%), OR5 (6.54%), SC1 (6.08%), JC6 (5.84%), OR3 (3.94%), OC12 (3.03%), SC10 (2.41%), JC9 (1.71%), and PC (1.07%). In contrast, shrub browning was predominantly observed in catchments JC9 (16.11%), PC (3.86%) and OC12 (3.62%). A small percentage of shrub browning was found across the subcatchments of OCF (see Figure 9).

Landscape Changes:

1) Vegetation Greening in the Old Crow Flats Basin, YK

How will this influence lake and river hydrology and biogeochemistry?
- Increased lake-river connectivity?
- More nutrient runoff?

Figure 8. Spatial dynamics of significant greening and browning of vegetation. Significant greening was observed in the northern and eastern ecotones, and in the southern locations of OCF. Browning predominantly situated in south and southeastern lowland to headwater ecotone, and few scattered in the western ecotone. The catchment boundary is shown as bold solid line, the bold dotted line is surrounds the former lakebed of Glacial Lake Old Crow, and the thin gray dotted line represent subcatchment boundaries divided up based on water sampling locations for ongoing studies.

Terrestrial NDVI and TC Greeness trends

Turner et al., in prep, Remote Sensing
Landscape Changes:

2) Lake drainage (rapid lake-river connectivity)

Zelma Lake drained during spring 2007. We've been monitoring it since.

*z*
Detecting hydrological responses of a drained thermokarst lake to drastic changes in catchment land cover

- using isotope tracers, water level and Landsat (NDVI, MNDWI, SWIR, NIR)

Comparison to DSWE
Detecting hydrological responses of a drained thermokarst lake to drastic changes in catchment land cover

- using isotope tracers, water level and Landsat

Summary figure

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<table>
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<th>p</th>
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Spring d-excess Mann Kendall trend analysis

Suggests encroaching shrub is increasing snowmelt input to lake. However, need to control for amount of precipitation.
Detecting hydrological responses of a drained thermokarst lake to drastic changes in catchment land cover

- using isotope tracers, water level and Landsat

Encroaching willow increases snowmelt input

Combine with land cover classification

Difference in snowmelt input to lake with and without (known amount of) shrub encroachment

AVIRIS-NG (July 2017)
Landscape Changes:

3) Permafrost retrogressive thaw slumps

- Are they increasing in frequency in Old Crow Flats?
- How will this influence lake and river biogeochemistry?
Monitoring permafrost retrogressive thaw slumps and downstream biogeochemical impacts

Turner et al., in prep.
Preliminary bulk density and carbon elemental and isotope analysis:

\[ n = 15 \]
\[ \text{mean } BD = 1.5 \text{ g/cm}^3 \]
\[ \text{range } BD = 1.3 - 1.6 \text{ g/cm}^3 \]
\[ \text{mean } %C = 1.1\% \]
\[ \text{mean } \delta^{13}\text{C} = -26.1\%\]

Preliminary values used to estimate total seasonal carbon export.

<table>
<thead>
<tr>
<th>Date</th>
<th>Volume (m$^3$)</th>
<th>% Volume</th>
<th>Area (m$^2$)</th>
<th>% Area</th>
<th># Dump Trucks</th>
<th># Football fields</th>
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<tbody>
<tr>
<td>29 Jul 16</td>
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<td>6,342</td>
<td></td>
<td>2,917</td>
<td>1.19</td>
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<tr>
<td>13 Jun 17</td>
<td>32,054</td>
<td>10</td>
<td>7,163</td>
<td>13</td>
<td>3,205</td>
<td>1.35</td>
</tr>
<tr>
<td>31 Aug 17</td>
<td>40,290</td>
<td>26</td>
<td>8,806</td>
<td>23</td>
<td>4,029</td>
<td>1.66</td>
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<tr>
<td>7 Jun 18</td>
<td>40,637</td>
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<td>9,006</td>
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<td>4,064</td>
<td>1.68</td>
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<tr>
<td>29 Aug 18</td>
<td>47,509</td>
<td>17</td>
<td>10,267</td>
<td>14</td>
<td>4,751</td>
<td>1.92</td>
</tr>
</tbody>
</table>
Daily Precipitation (mm)

Temperature (°C)

Year

# Days = 80
Tot. Rain = 114 mm
Avg. Temp = 15° C
Vol. exported = 8235 m³
C exported to river = ~131 t

# Days = 84
Tot. Rain = 138 mm
Avg. Temp = 12° C
Vol. exported = 6872 m³
C exported to river = ~109 t
Concentration (ppm)

DOC

DIC

Jul 2015

Jul 2016

Jul 2015

Jul 2016

Jun 2016

Slump is active

LVIS and UAVSAR
Want to inventory slumps and vulnerability to slumping along OC River
Landscape Changes:

4) Fire

June 8

2017

June 24

July 1

July 10

(Landsat quicklooks)

- How does fire influence lake and river biogeochemistry?
  - Direct and indirect (e.g., runoff from burn and shoreline slumping
Influence of fire on catchment and lake conditions

Thorne and Turner, in prep. (poster 3-49)
Old Crow Flats has experienced increasing temperature and precipitation

<table>
<thead>
<tr>
<th>change or disturbance</th>
<th>shrub growth</th>
<th>lake drainage</th>
<th>thaw slumps</th>
<th>fire</th>
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<tr>
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<tr>
<th>in-situ measurements</th>
<th>ALT depth</th>
<th>SWE water</th>
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<tr>
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<td>14 lakes</td>
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<td>14 lakes</td>
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<tr>
<td>24 creeks/rivers</td>
<td>24 creeks/rivers</td>
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</table>

Findings are providing key insight of relations among terrestrial and aquatic systems
Peter: ‘Seriously Kevin, you are done’
Kevin: ‘ok fine’

Mahsi’ choo
Megan Williams, Mary Jane Moses, James Linklader, Robert Kyikavichik, George Nagwan, Danny Kassi, Dougie Charlie, Joel Peter.

Students currently involved in the field research
- Brent Thorne, Josef Viscek, Michelle Pearce

Check out his poster 3-49 (and mine 3-50)
• Rainfall higher than average during last decade
• Old Crow River max discharge data agrees

[Graph showing cumulative precipitation and discharge over years with marked events such as Zelma Lake drained, Large thaw slump, and Fire]
Exploring changes in post-drainage water chemistry

Ions

- Wet conditions
- Normal conditions
- Dry conditions

Nutrients
Long-term perspective with paleolimnological approaches

Eutrophic conditions following drainage as indicated by pigments.
Surface water areal fluctuations

max = 12 km², min = 3 km²
Detecting hydrological responses of a drained thermokarst lake to drastic changes in catchment land cover

- using isotope tracers, water level and Landsat (NDVI, MNDWI, SWIR, NIR)
Sample hyperspectral data (AVIRIS)

Zelma Lake

John Charlie Lake

Plot

Slump

More slumps
Tracking slump volumetric changes using photogrammetry of UAV images

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<thead>
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<tr>
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<td>29,174</td>
</tr>
<tr>
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<td>2,917</td>
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<td>1.19</td>
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<tr>
<td>Date</td>
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<tr>
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<tr>
<td>area (m$^2$)</td>
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</tr>
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</table>
Concentration (ppm)

\[ \delta^{13}C \]‰VPDB

DOC

DIC

Jun

Aug

380 km downstream

2017

Jun

Aug

Jun

Aug
### Back of the Envelope

<table>
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<tr>
<th>Avg_Dry_Bulk_Density_g_cm3</th>
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<th>Nitrogen</th>
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<th>perc_N</th>
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<th>d15N</th>
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```r
## Convert bulk density units from g/cm3 to kg/m3 by multiplying by 1000
bulkD_kg_m3 <- Sed_data$Avg_Dry_Bulk_Density_g_cm3[Sed_data$Description=="sed"] * 1000
## Calculate kg C/m3 by multiplying by %C/100
C_kg_m3 <- bulkD_kg_m3 * Sed_data$perc_C[Sed_data$Description=="sed"] / 100
mean_C_kg_m3 = mean(C_kg_m3, na.rm = TRUE)
## Calculate total mass of carbon exported. (UAV volume in m3, which is multiplied by C kg/m3)
Total_C_export <- Volume_data$Volume_m3 * mean_C_kg_m3
## Convert amount of carbon from kg to tonnes
Tonnes_C_export <- Total_C_export * 0.001
#plot(Tonnes_C_export)
#lines(Tonnes_C_export)

Volume_C_data <- as.data.frame(cbind(Volume_data, Tonnes_C_export))
Volume_C_data$Date <- as.Date(Volume_C_data$Date, format="%d-%m-%Y")
```

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Arctic Vegetation Change