September 19-21, 2017

Supplemental Climate Information:
Dawson Historical Complex National Historic Site

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Parks Canada Parcs Canada

Contents

Preface

This is a supplement to the "Let's Talks about Climate Change: Northwest Region" report (Parker, 2017) and is intended to support a climate change adaptation workshop at the Dawson Historical Complex National Historic Site, Dawson City, Yukon on September 19-21, 2017.

Recommended reading:

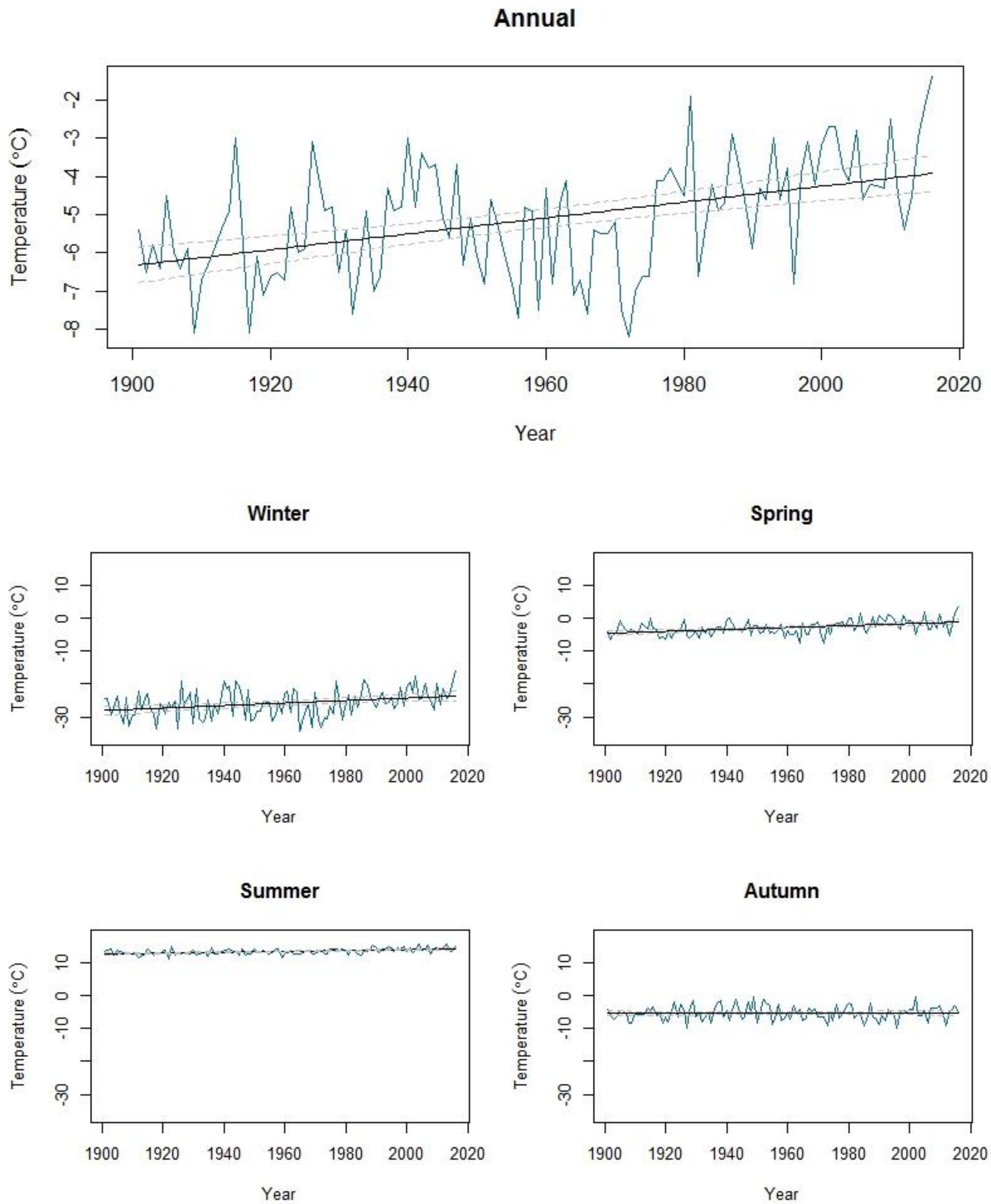
- Dawson Climate Change Adaptation Plan, Revised Edition (Hennessey *et al.*, 2011).
- Climate Change in Dawson City, YT: Summary of Past Trends and Future Projections (Werner *et al.*, 2009).
- Dawson City Landscape Hazards Geoscience Mapping for Climate Change Adaptation Planning (Benkert *et al.*, 2015).
- Yukon Water: An Assessment of Climate Change Vulnerabilities (Goulding, 2011).

Disclaimer

1. Observed Climate Trends

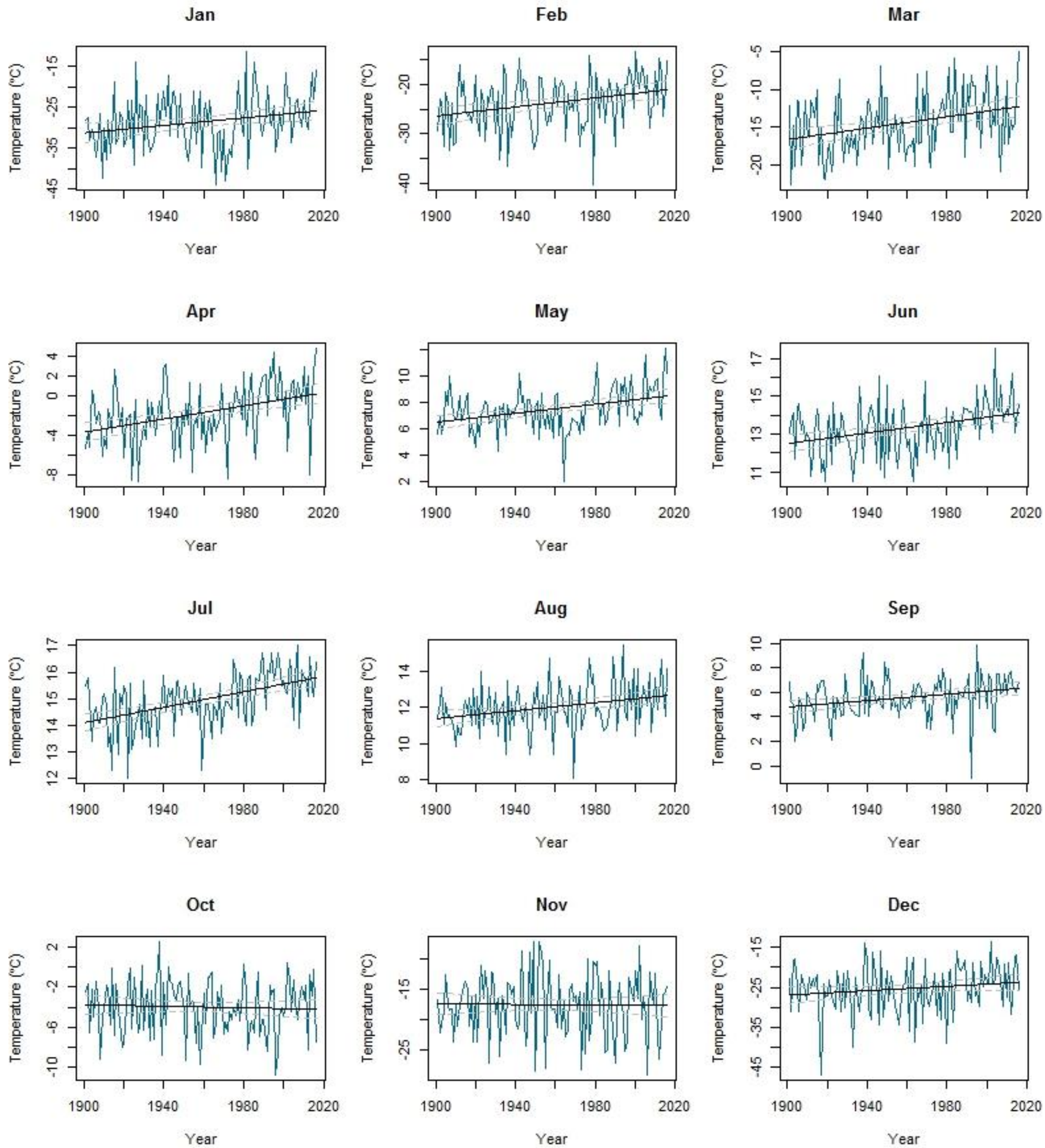
1.1 Temperature

Mean monthly temperature at Dawson City climatological station (2100402) from 1901 to 2016 (ECCC, 2017). Trend determined using a generalized linear model (R Core Team, 2014) including 95% confidence intervals.



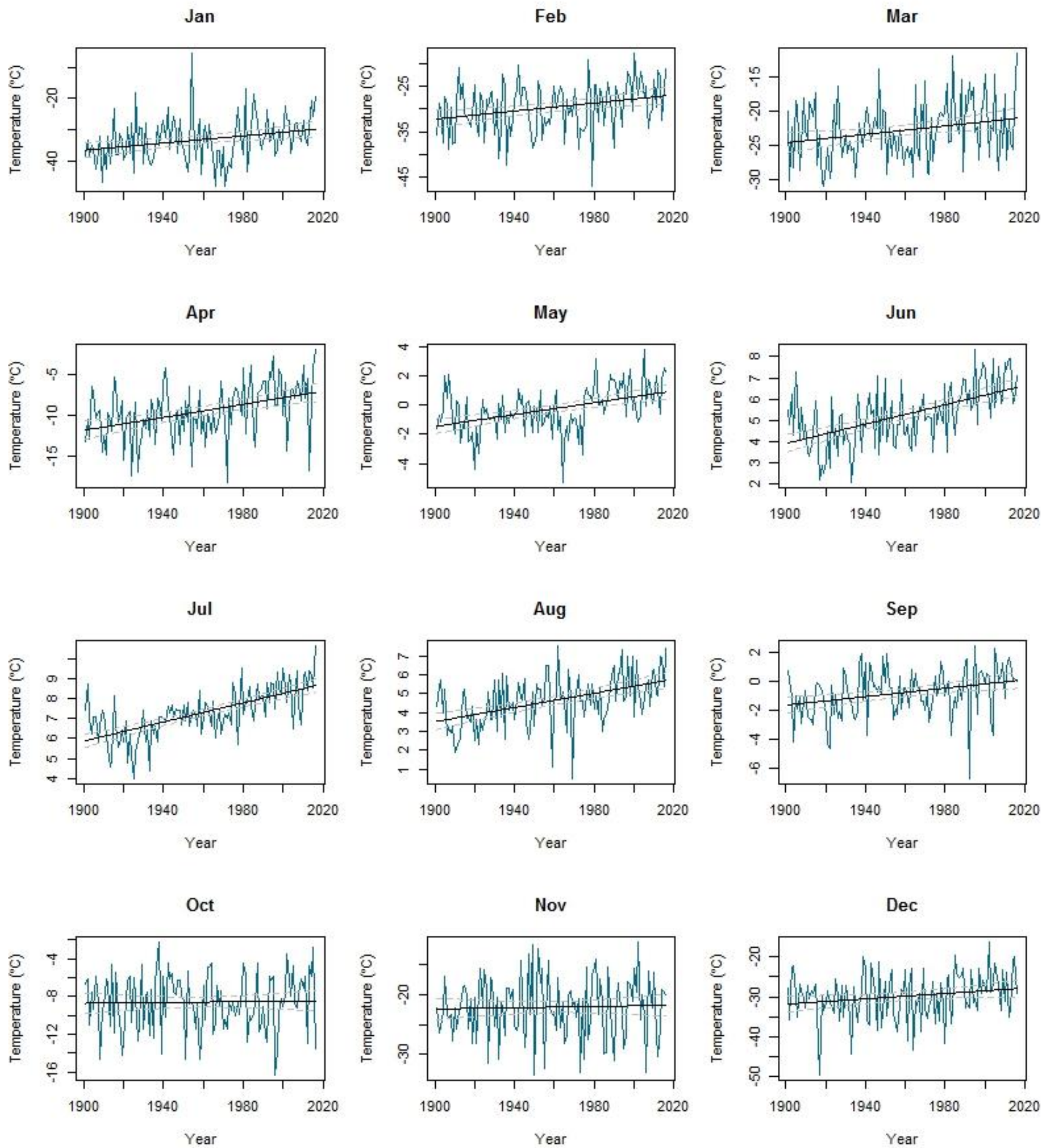
Significant increase ($P<0.05$) in mean annual temperature, ~2.4°C since 1901. All seasons, except autumn (Sep, Oct, Nov) demonstrated a significant increase, the greatest being observed for winter (Dec, Jan, Feb), ~4.4°C since 1901.

Mean Monthly Temperatures



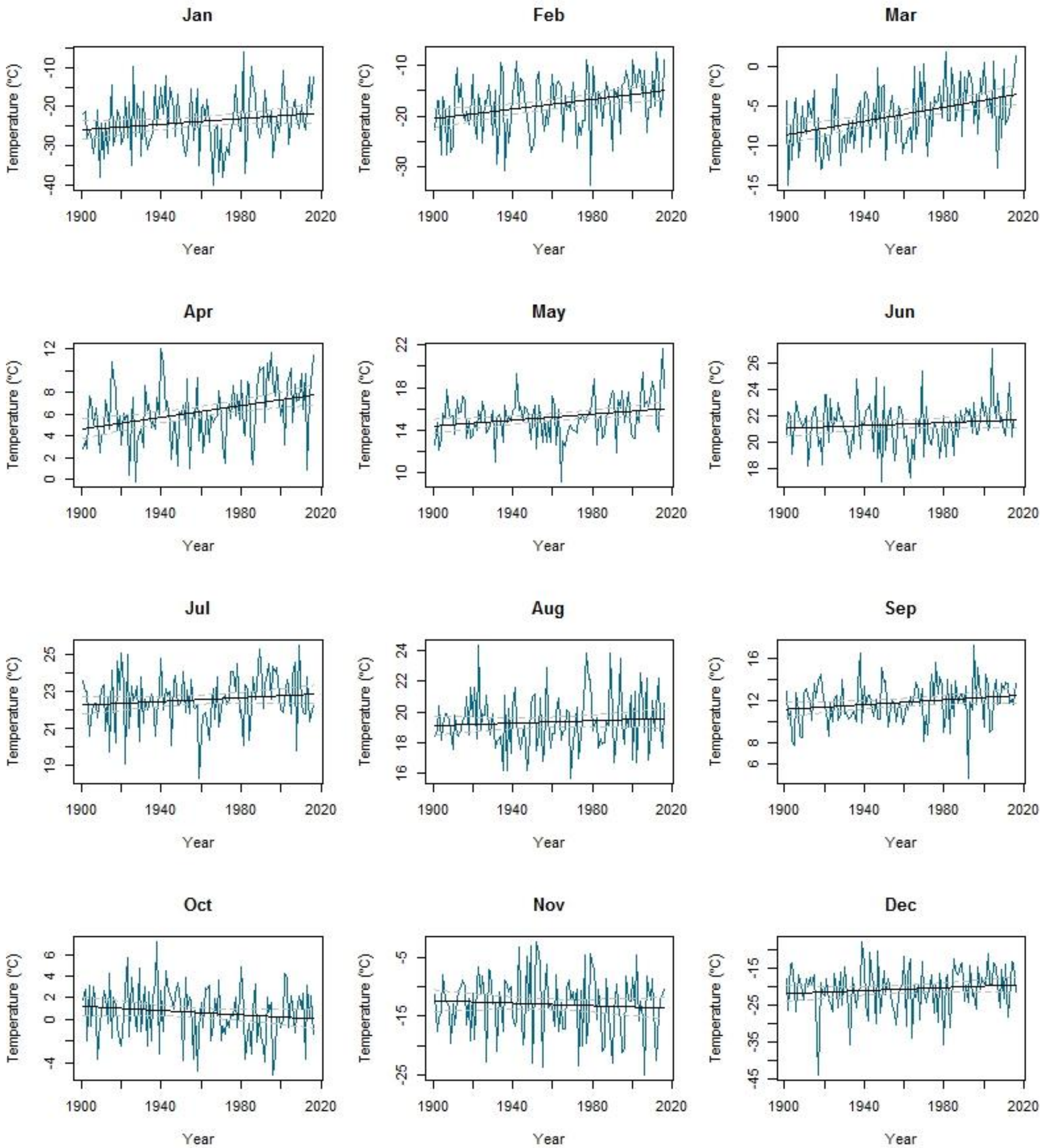
Significant increase (P<0.05) in mean monthly temperatures for all months except Oct, Nov, and Dec. Greatest increase observed for Jan and Feb, ~5.3°C since 1901. Jun and Jul demonstrated an increase by ~1.6°C since 1901.

Mean Minimum Monthly Temperatures



Significant increase (P<0.05) in mean monthly minimum temperatures for all months except Oct and Nov. Greatest increase observed for Jan, ~6.6°C since 1901. Jun and Jul demonstrated an increase by ~2.6°C since 1901.

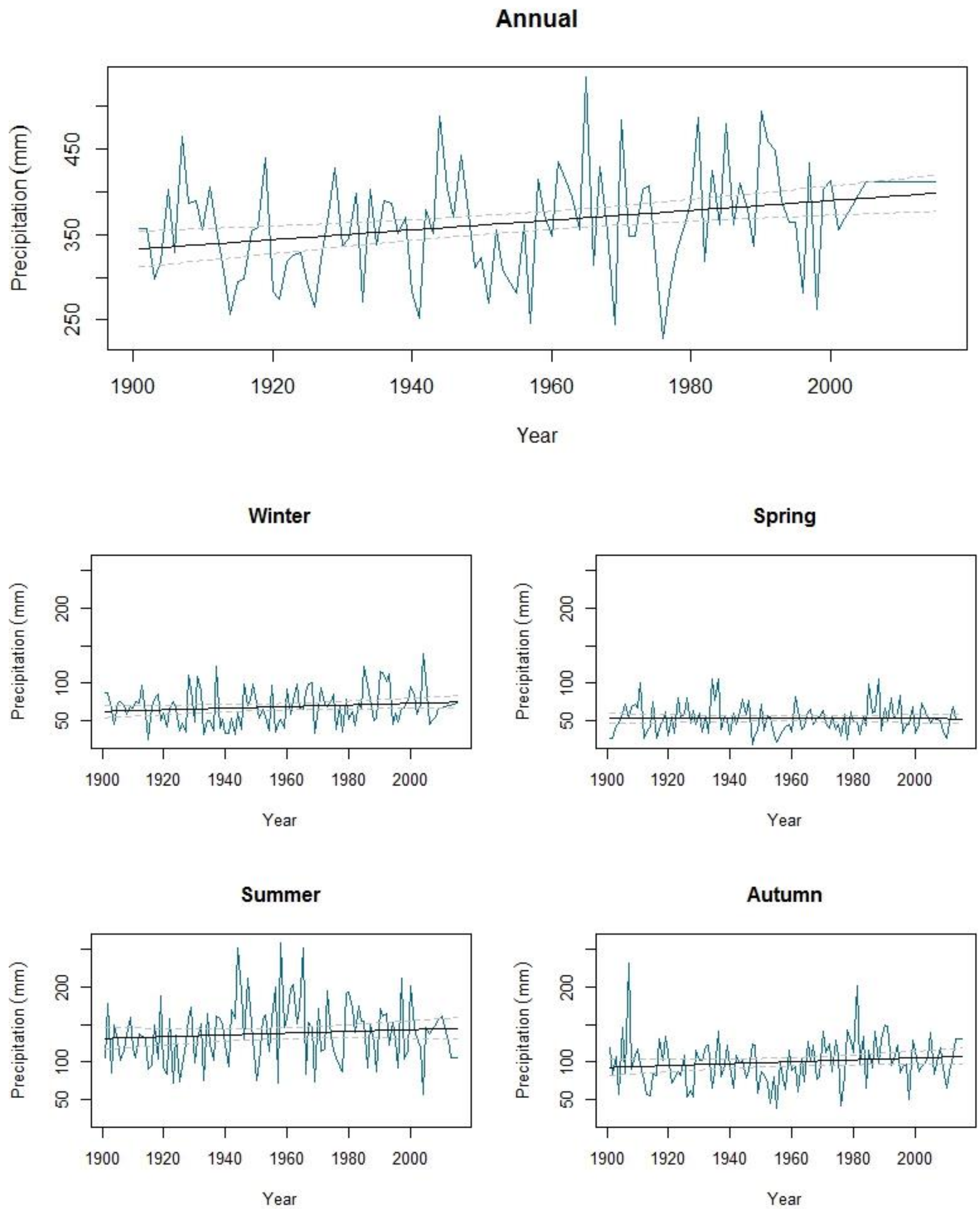
Mean Maximum Monthly Temperatures



Significant increase (P<0.05) in mean monthly maximum temperatures for all months except Oct, Nov and Dec. Greatest increase observed for Feb, ~5.5°C since 1901. Mar demonstrated an increase by ~5.1°C since 1901, and Jun and Jul demonstrated an increase by ~0.5°C since 1901.

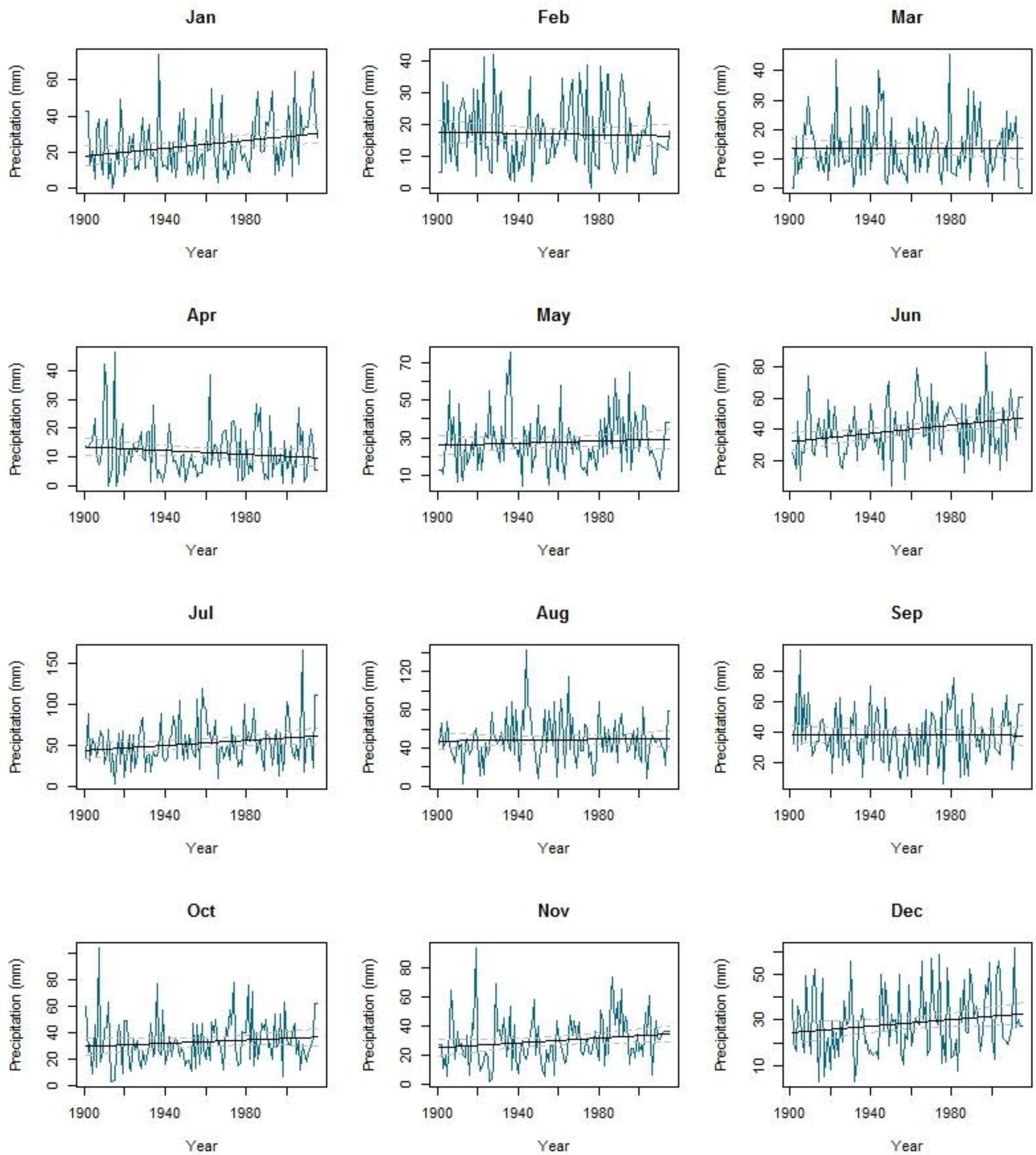
1.2 Precipitation

Total precipitation at Dawson City climatological station (2100402) from 1901 to 2015 (ECCC, 2017). Trend determined using a generalized linear model (R Core Team, 2014) including 95% confidence intervals.



Significant increase (P<0.05) in total annual precipitation, ~17% increase since 1901. No single season demonstrating a statistically significant increase, however increase appears more pronounced in winter.

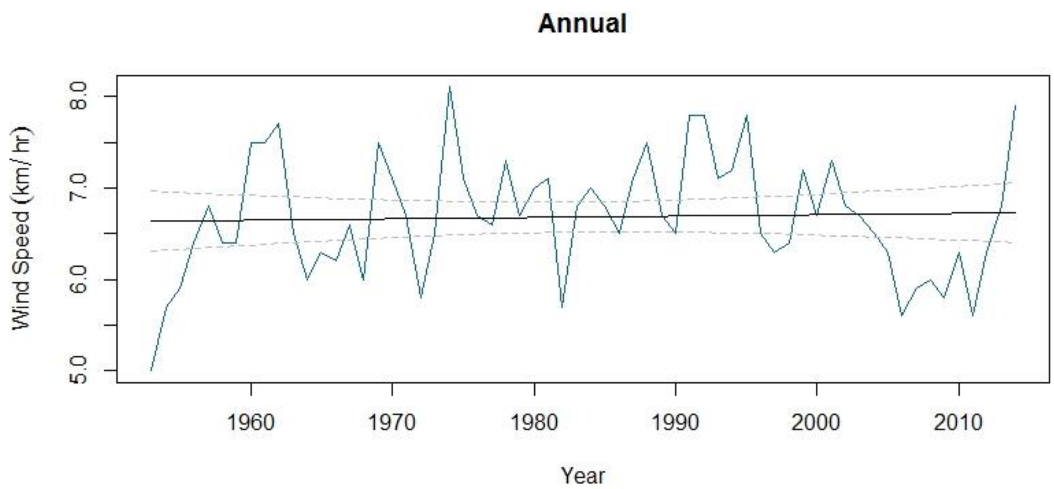
Monthly Total Precipitation

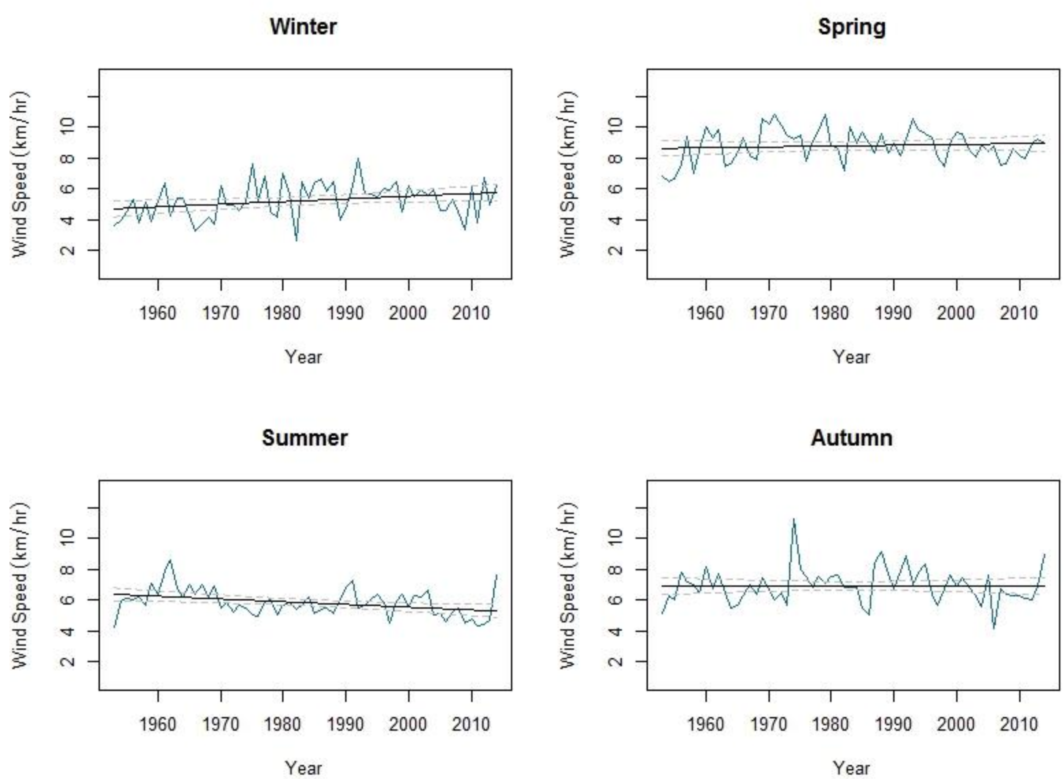


Significant increase (P<0.05) in total monthly precipitation for Jan, Jun and Jul. Greatest increase observed for Jun, ~40% since 1901, Jul experienced a 34% increase.

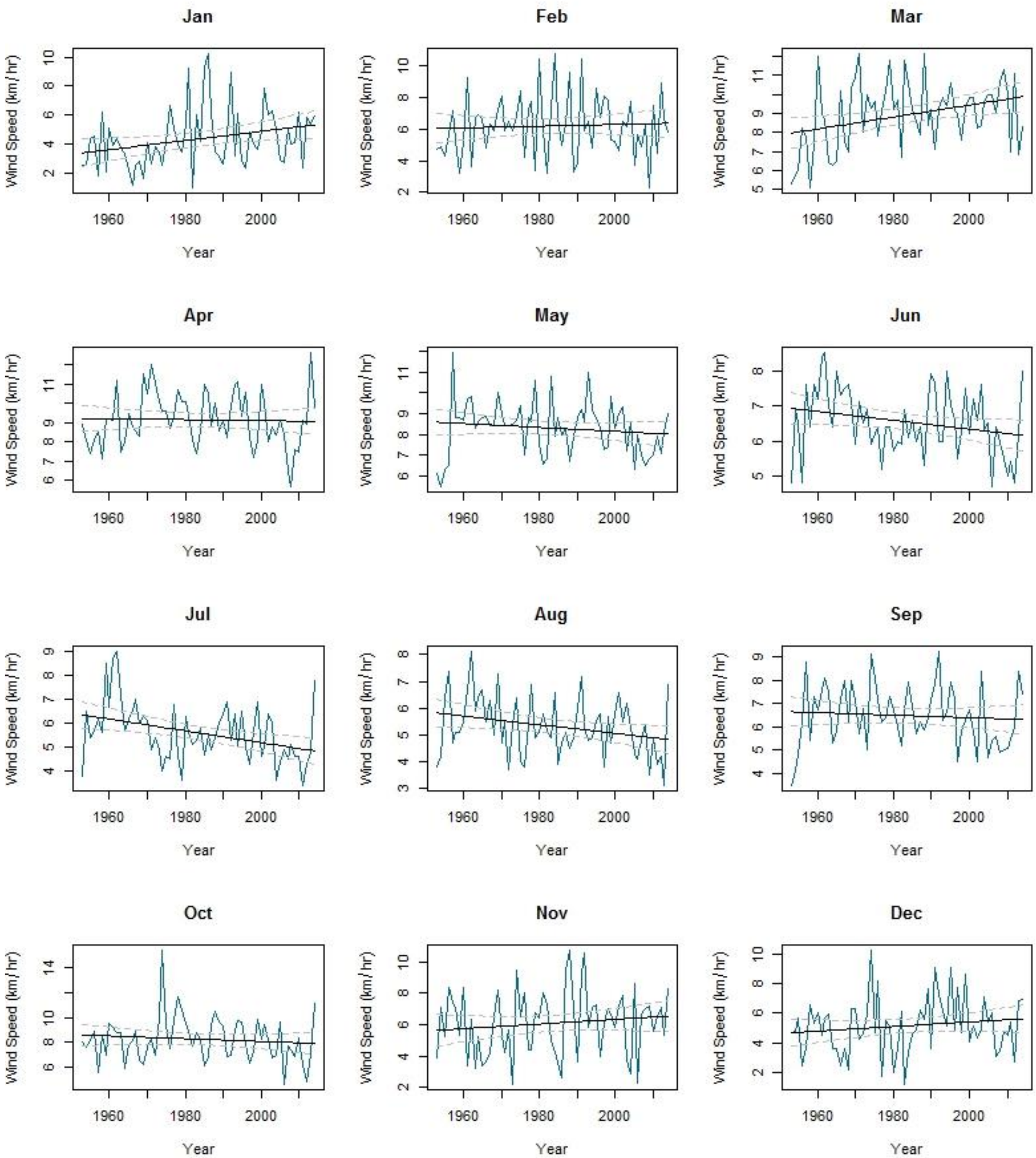
1.3 Surface Wind Speed

Mean monthly wind speeds at Mayo climatological station (2100700) from 1953 to 2014 (ECCC, 2017). Trend determined using a generalized linear model (R Core Team, 2014) including 95% confidence intervals.





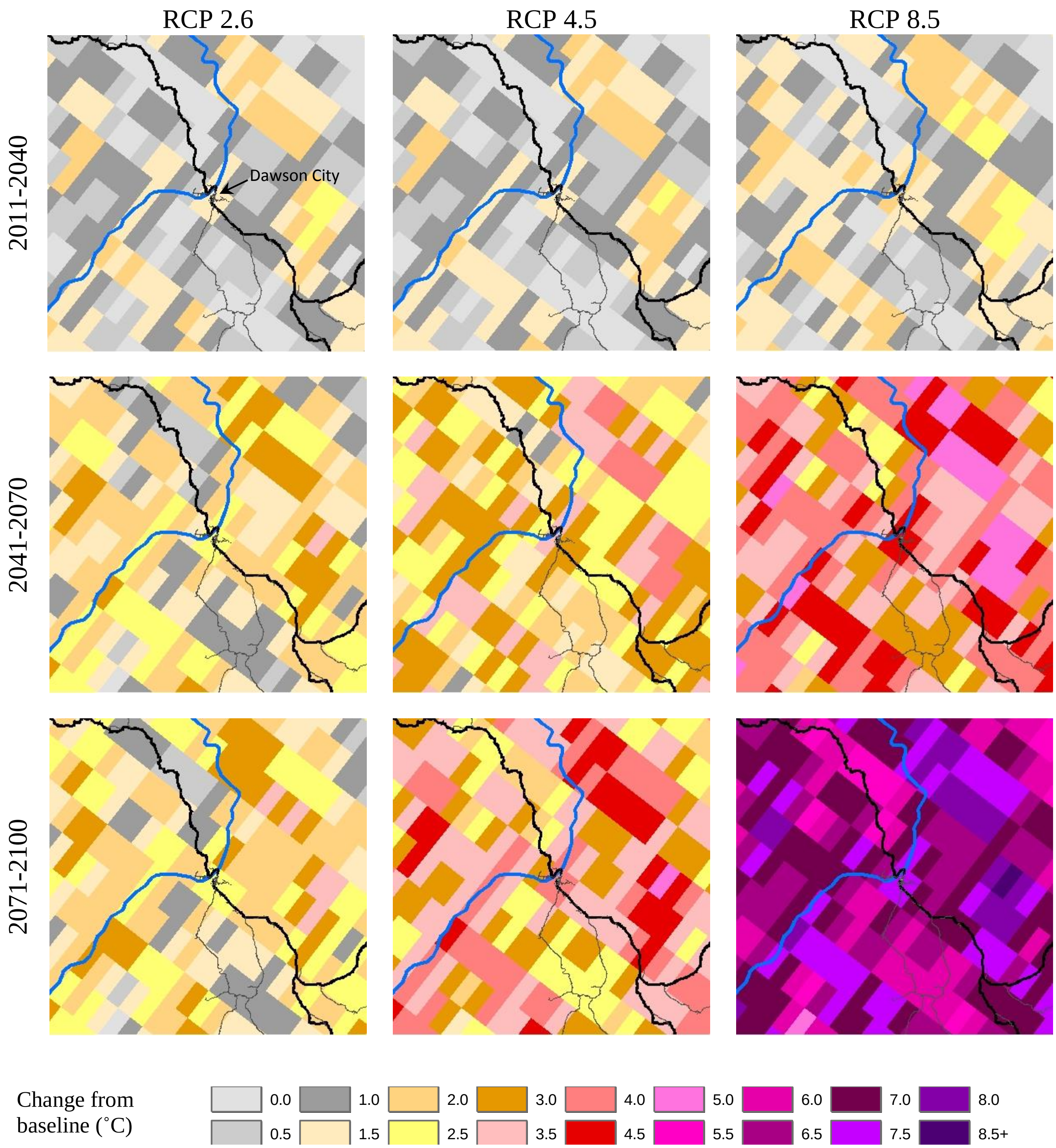
No significant increase (P<0.05) in annual mean wind speeds. Winter winds have increased by ~23% since 1953 and summer winds have decreased by ~17%.



Significant increase (P<0.05) in mean monthly wind speed for Jan and Mar and decrease for Jul and Aug since 1953 at the Mayo station.

2. Future Projected Climate Changes
2.1 Temperature

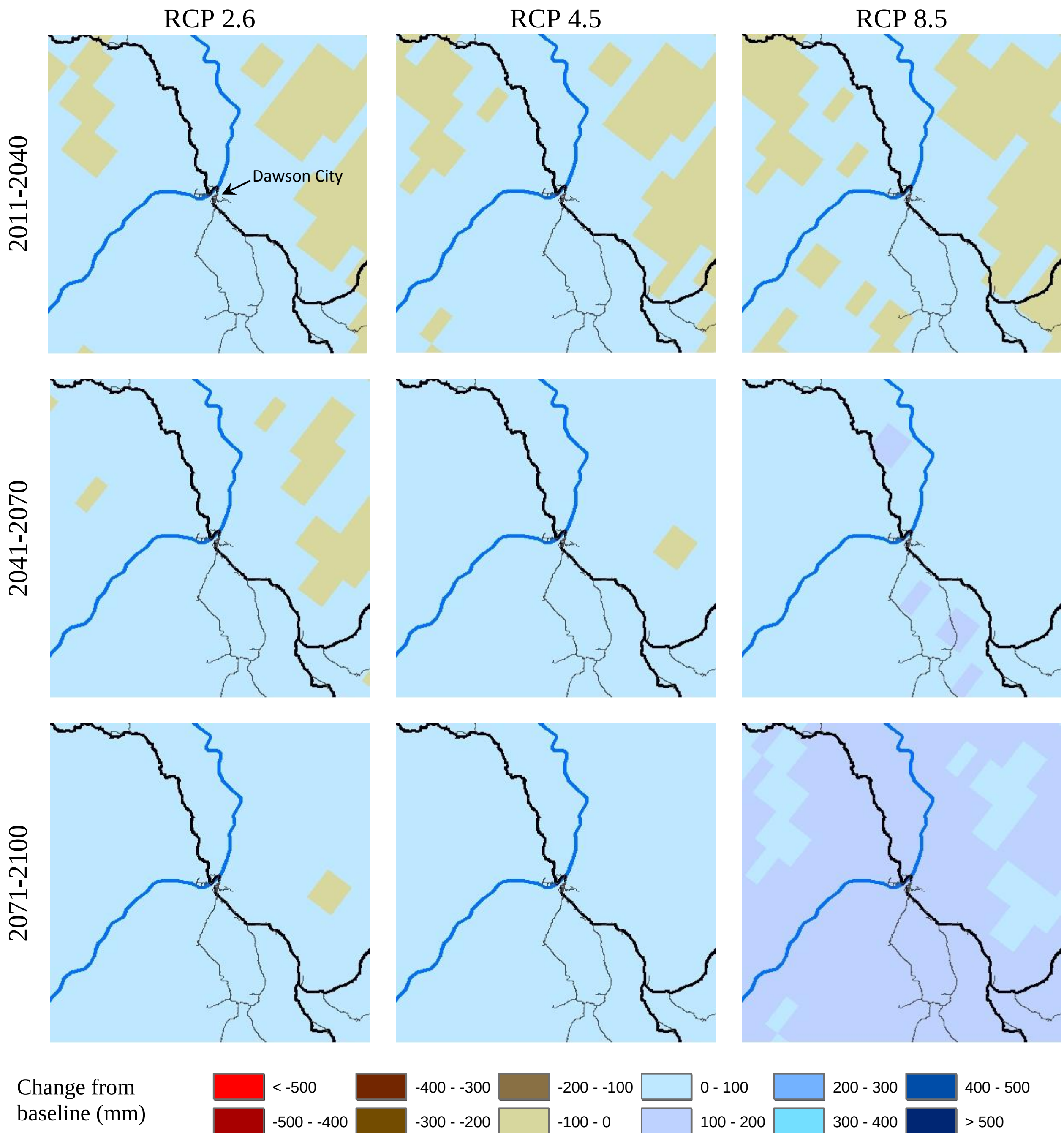
Werner et al. (2009) project a 2.5˚C to 3.5˚C increase in mean annual temperature for the region (2041-2070), with the greatest warming occurring for winter (4˚C to 6˚C).



Mean annual temperature increase for Dawson City area from 1980-2010 baseline. Composite projection of CanESM2, CESM1CAM5, HADGEM2ES and MIROCESM. Natural Resources Canada, Canadian Forest Service, http://cfs.nrcan.gc.ca/projects/3 (Price *et al.*, 2011).

2.2 Precipitation

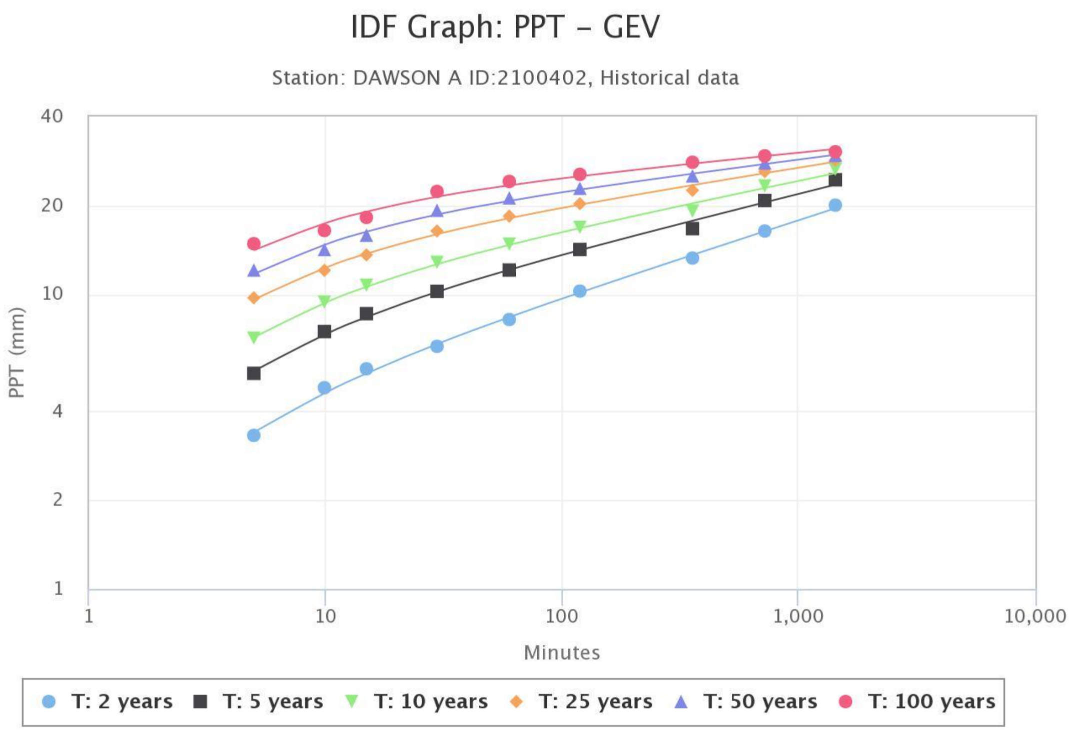
Werner et al. (2009) project a 10% to 40% increase in annual total precipitation for region (2041-2070), with the greatest increase during winter.



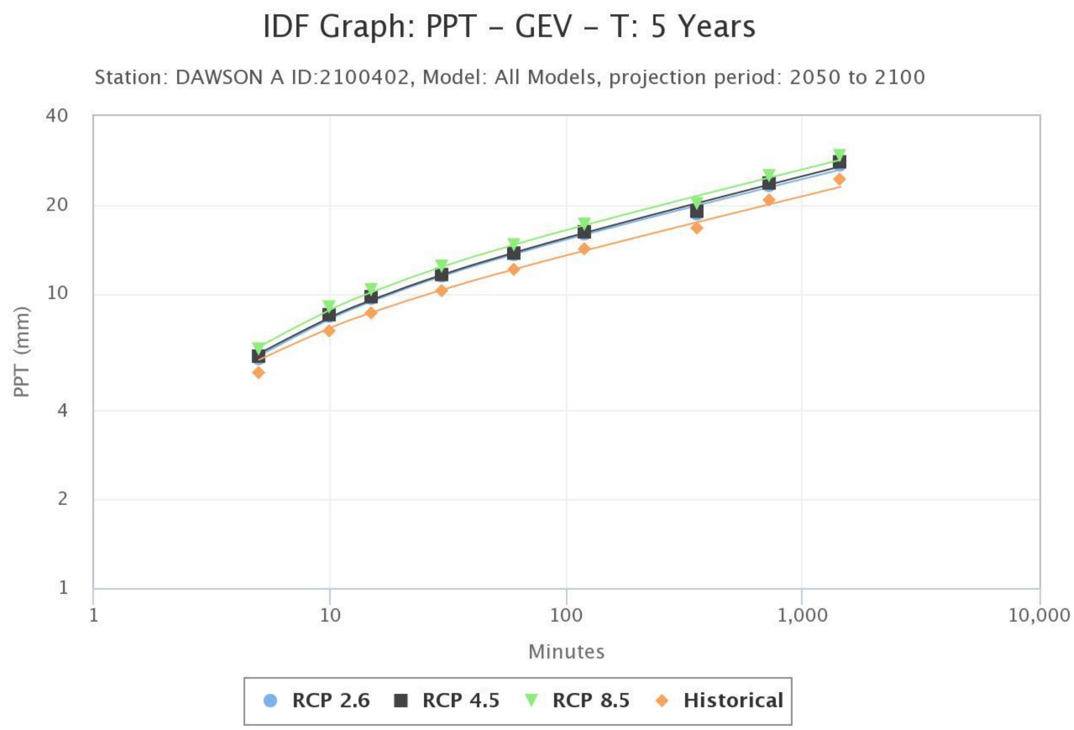
Total annual precipitation change for Dawson City area from 1980-2010 baseline. Composite projection of four spatially interpolated downscaled Global Circulation Models: CanESM2, CESM1CAM5, HADGEM2ES and MIROCESM. Data source Natural Resources Canada, Canadian Forest Service, http://cfs.nrcan.gc.ca/projects/3 (Price *et al.*, 2011).

2.3 Rainfall Intensity, Duration and Frequency (IDF)

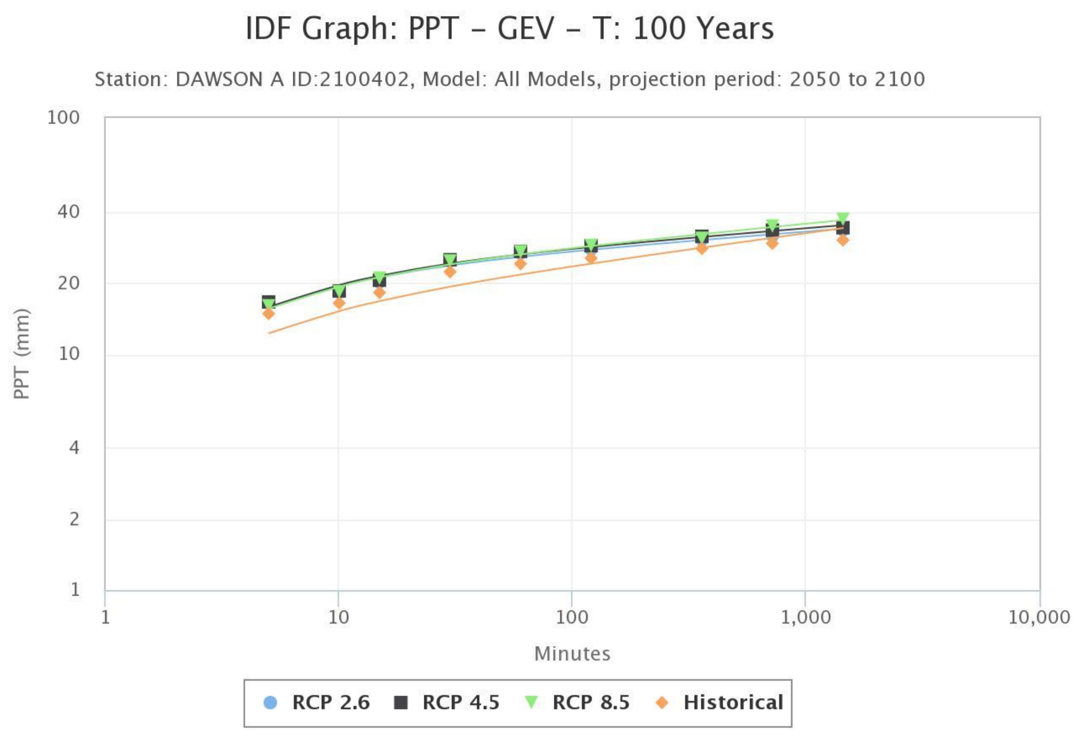
Extreme rainfalls calculated in IDF_CC Tool 2.0 (http://beta.idf-cc-uwo.ca/). The tool uses a Generalized Extreme Values (GEV) distribution. For more detail on extreme rainfall see Simonovic *et al.* (2017).



Baseline total precipitation amounts for Dawson City climatological station for 1976-2002 for the different return periods (T).



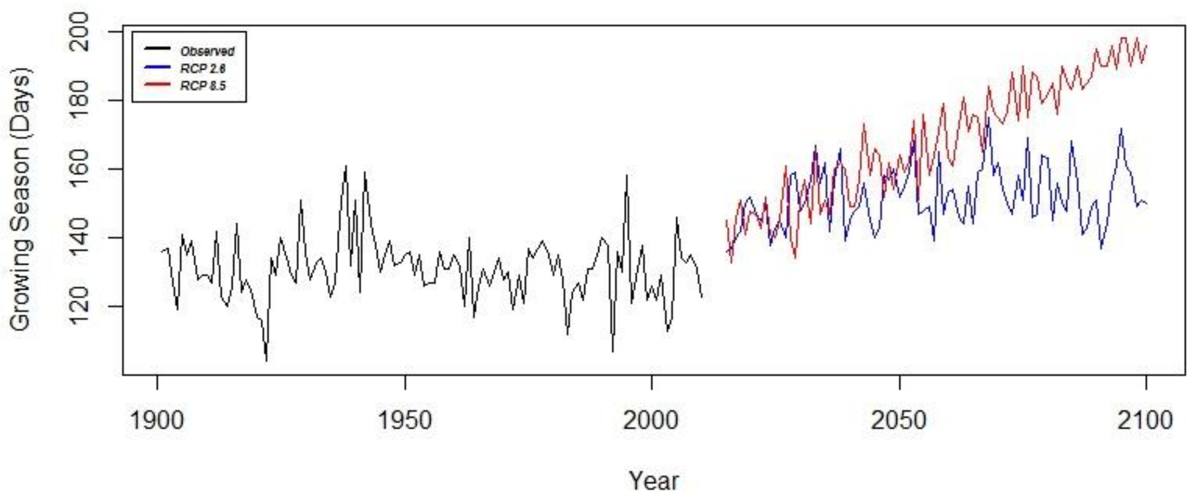
Projected total precipitation for **one in 5-year** events for the period 2050-2100 using ensemble of models.

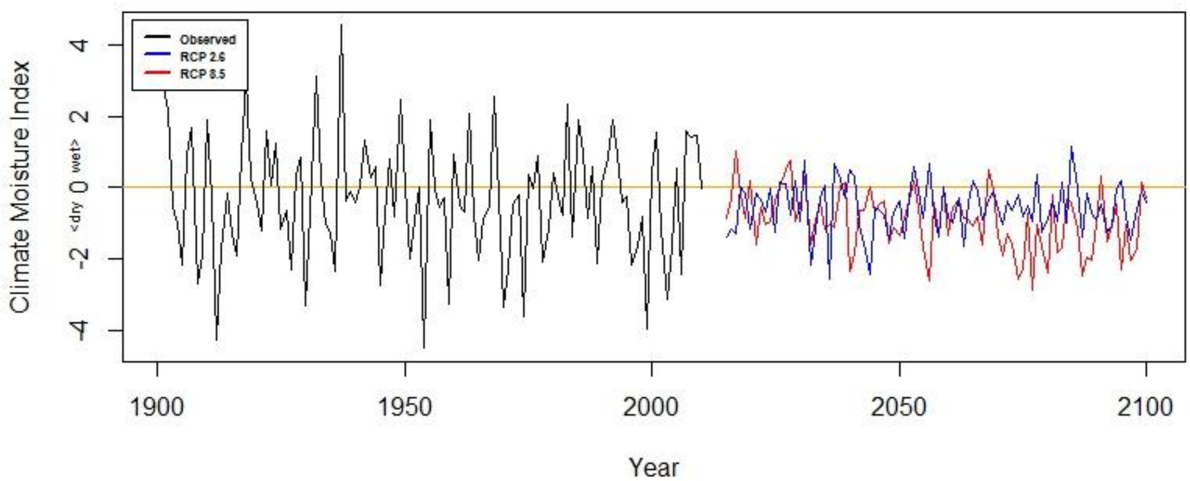


Projected total precipitation for **one in 100-year** events for the period 2050-2100 using ensemble of models

2.4 Growing Season and Climate Moisture Index

The Climate Moisture Index (CMI) is calculated as the difference between annual precipitation and potential evapotranspiration – the potential loss of water vapour from a landscape covered by vegetation (http://www.nrcan.gc.ca/forests/climate-change/forest-change/17772). A positive CMI value indicates wet or moist conditions and shows that precipitation is sufficient to sustain a closed canopy forest. A negative indicates dry conditions that, at best, can support discontinuous parkland-type forests.



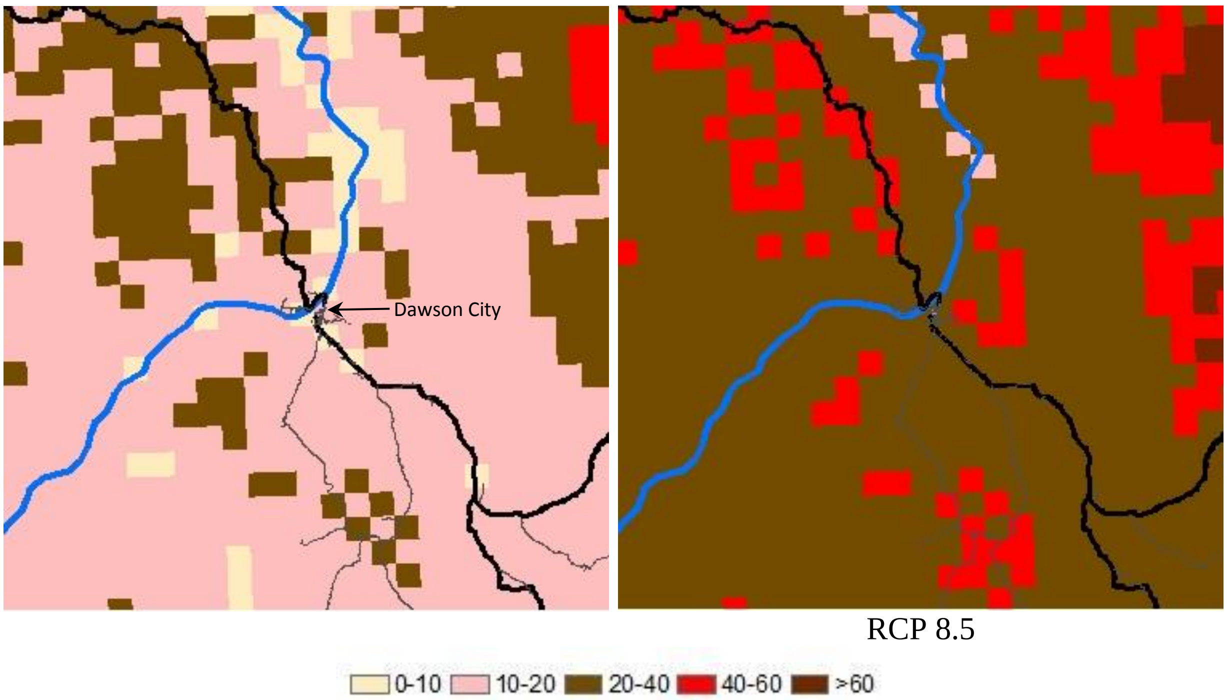


Observed and projected changes to growing season and climate moisture index under RCP 2.6 and 8.5 climate scenarios (Vuuren *et al.*, 2011) at the Dawson City climate station. Longer growing season and drier conditions are projected. Data provided by Canadian Forest Service.

2.5 Wildfire

While the annual area burned and the fire severity index have both reportedly increased in Yukon, the trends are not statistically significant (Streicker, 2016).

Area burned and numbered of wildfire occurrences are projected to increase for the region (McCoy and Burn, 2005).

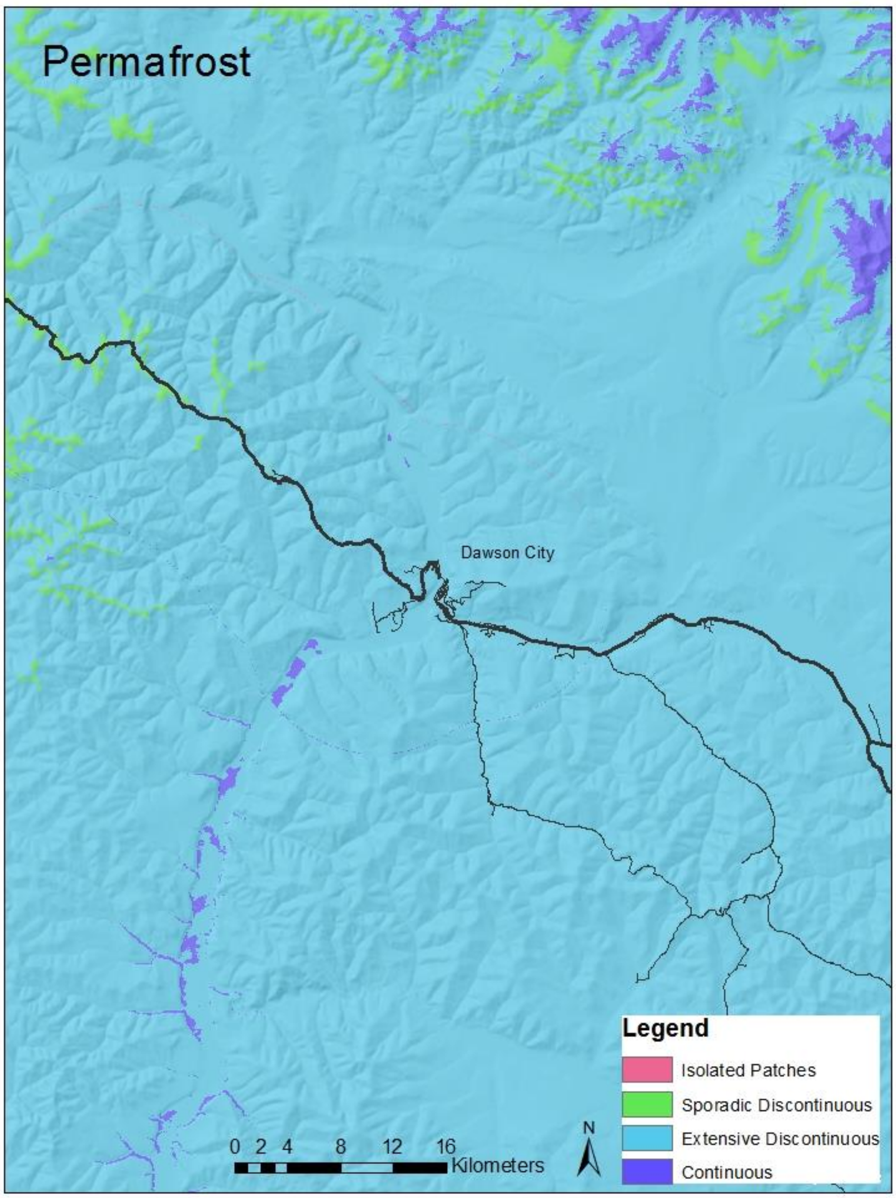


Projected increase in wildfire season for Dawson City area. Length in days from baseline (1981-2010) by 2071-2100 under RCP 2.6 and 8.5 scenarios. Data source Natural Resources Canada, http://cfs.nrcan.gc.ca/fc-data-catalogue.

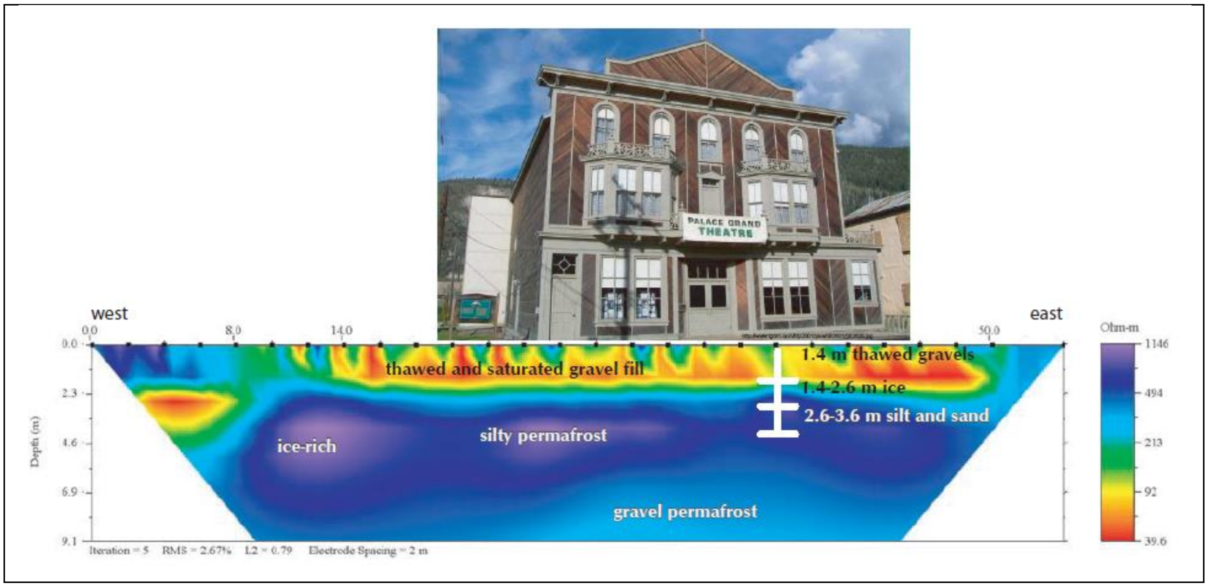
3. Permafrost

The current probability of permafrost at any point in the region is 77%, with valley bottoms having the highest probability (e.g., 90%). A 2˚C increase in mean annual temperature decreases the probability of permafrost distribution to 10%. The actual loss in permafrost may lag behind the climate changes by decades and even centuries if it is significantly thick (Benkert *et al.*, 2015; Bonnaventure and Lewkowicz, 2013). The Dawson-site has thinner, warmer permafrost.

Permafrost data for Dawson City is also found in Camels *et al.* (2014), Lipovsky (2014), Lipovsky and Yoshikawa (2009), and Laxton and Coates (2011).



Dawson region has extensive discontinuous permafrost. Data available from the Yukon Permafrost Network, http://permafrost.gov.yk.ca/data/arcgis/ (Bonnaventure and Lewkowicz, 2012).



The Palace Grand Theatre resistivity tomogram run on the north side of the building and borehole data. Image clipped from Laxton and Coates (2011).

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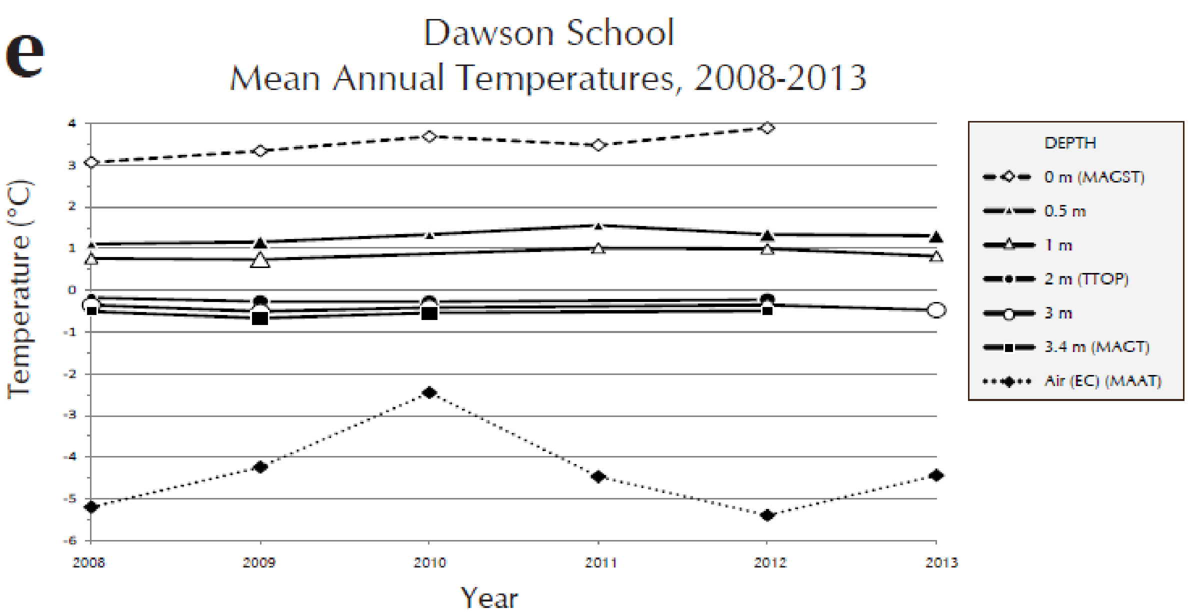
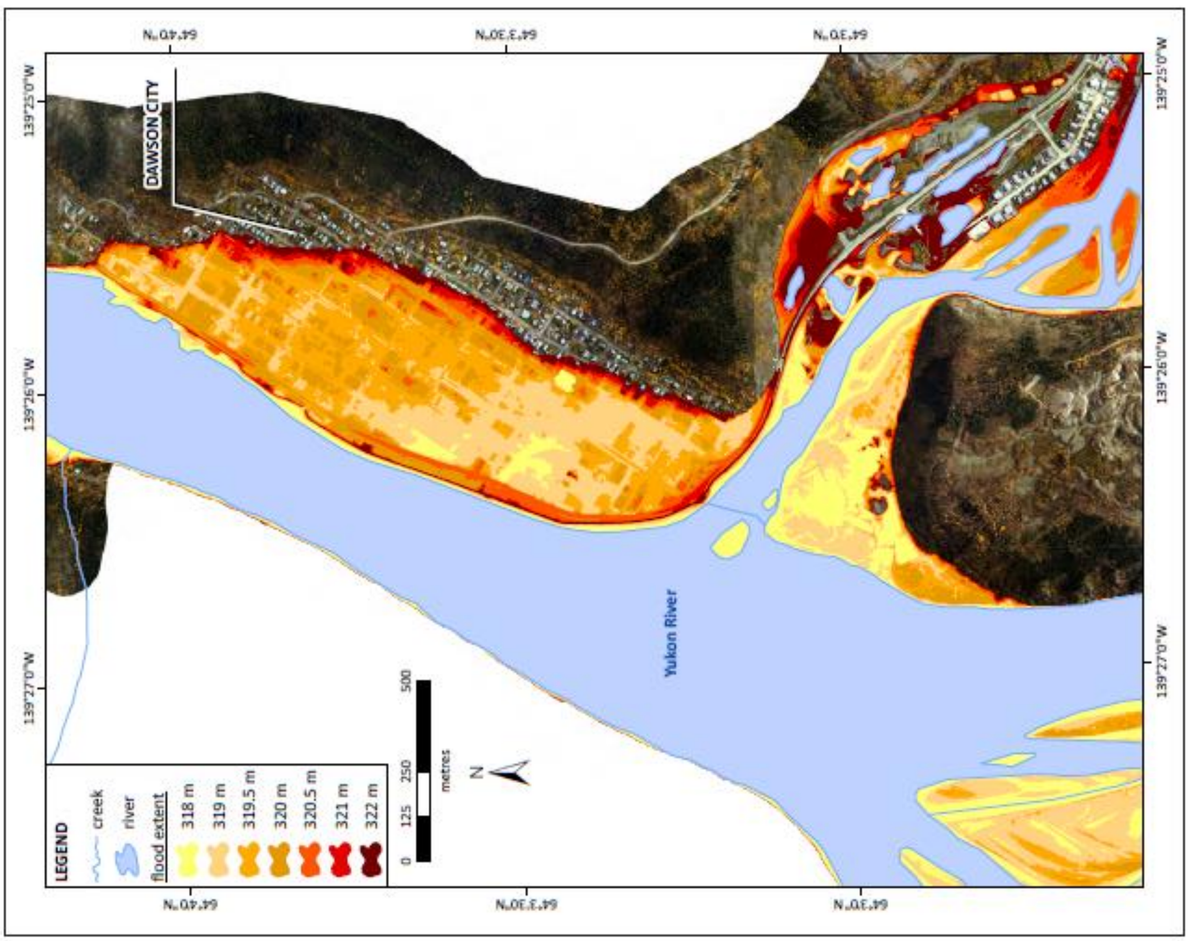


Permafrost monitoring at Robert Service School, very warm permafrost conditions (>-0.5˚C) exist. Times series shows variation in mean annual temperatures for various depths. Image clipped from Lipovsky (2014).

4. Flooding

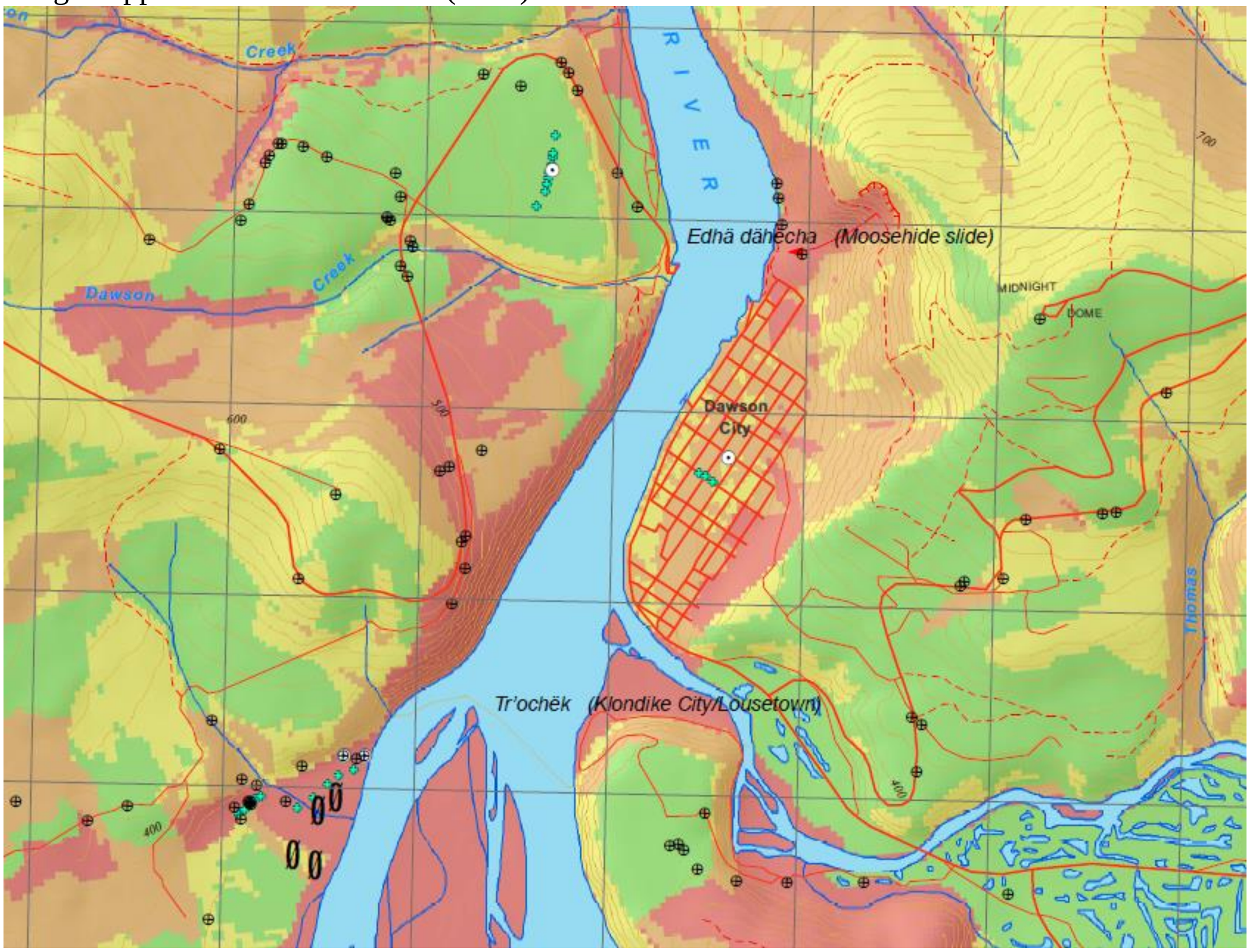
- Probability of an ice-jam flooding event is 3-5% in a given year (Beasley, 2010; Livingston *et al.*, 2009).
- On May 3rd, 1979 heavy snow fall and ice-jams resulted in a major flood in Dawson City. Low areas experienced >2m of water. Parks Canada's built heritage required extensive restoration.
- New dyke completed in 1987 with crown elevation (321m) to correspond to 1979 flood (320.6m). Reportedly this is a one in a 100 to 200 year event (Beasley, 2010).
- Breaching and/or over-topping of dyke is perceived as a risk (Beasley, 2010; Hennessey *et al.*, 2011).
- Warmer temperatures and increased precipitation will influence flooding regimes in region.
    - Degrading permafrost contributes to groundwater flow, e.g., increasing 0.7-0.9%/year (Dube *et al.*, 2013; Walvoord and Striegl, 2007).
    - River flow is projected to increase (Hay and McCabe, 2010)
    - Ice-jam frequency is known to increase with warmer temperatures (Livingston *et al.*, 2009). Seems contradictory, but freeze/thaw events can build ice thickness.



Modelled flood extents for Dawson City. Note that the dyke (321m) is not integrated as a barrier to flooding, however model depicts a breaching event. Image clipped from Benkert *et al.* (2015)

5. Landscape Hazard Risk

Image clipped from Benkert *et al.* (2015).



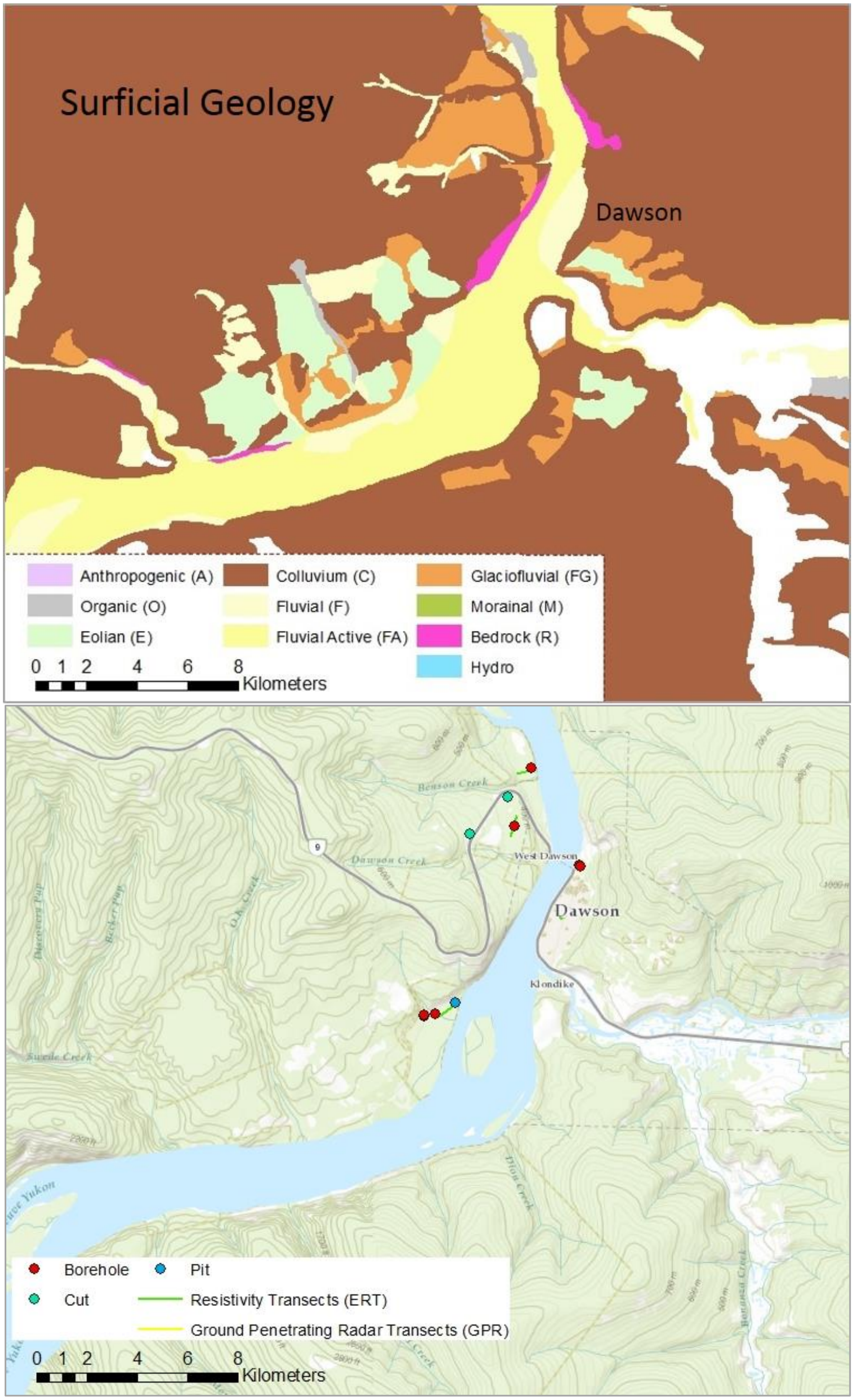
HAZARD CLASSIFICATIONS

Low risk. Characterized by flat to gently sloped terrain, with south and west-facing slopes. Low-risk terrain is found above modern floodplains, and is often comprised of well-drained gravel or weathered bedrock surface materials. Low-risk terrain may contain permafrost, but is less likely to be ice rich compared with more hazardous terrain.

Moderate risk. Characterized by gentle to moderate slopes, and occurs more commonly on west and south-facing slopes. Moderate-risk terrain is found on the steep edges and cold aspects of low-risk landforms (*i.e.* fluvial terraces and north-facing, high-elevation slopes). Moderate-risk terrain also occurs in coarse-grained (gravel) surficial materials that may be affected by ice-rich permafrost (*i.e.* downtown Dawson).

Moderately high risk. Characterized by moderate to steep slopes, and east to north-facing slopes. Moderately high-risk terrain is found on all aspects in the study area and is common in narrow, steep-sided valleys and on more gentle slopes where permafrost is more likely to be present. The difference between moderate and moderately high-risk terrain in the study area is often based on changes in slope angle and slope aspect.

High risk. Characterized by moderate to steep slopes and coldest east and north-facing slopes. Much of the high-risk terrain in the study area is defined by geological boundaries containing high-hazard processes such as landslides, thermokarst, and active floodplains that may be subject to flooding. High-risk terrain in the study area occurs in valley bottoms (flood risk and high permafrost probabilities), on steep north-facing valley slopes, and where landslide processes have affected large areas of terrain (*i.e.* landslides on the north side of the Klondike Valley).



Data from: http://data.geology.gov.yk.ca/Reference/DownloadProduct/49699

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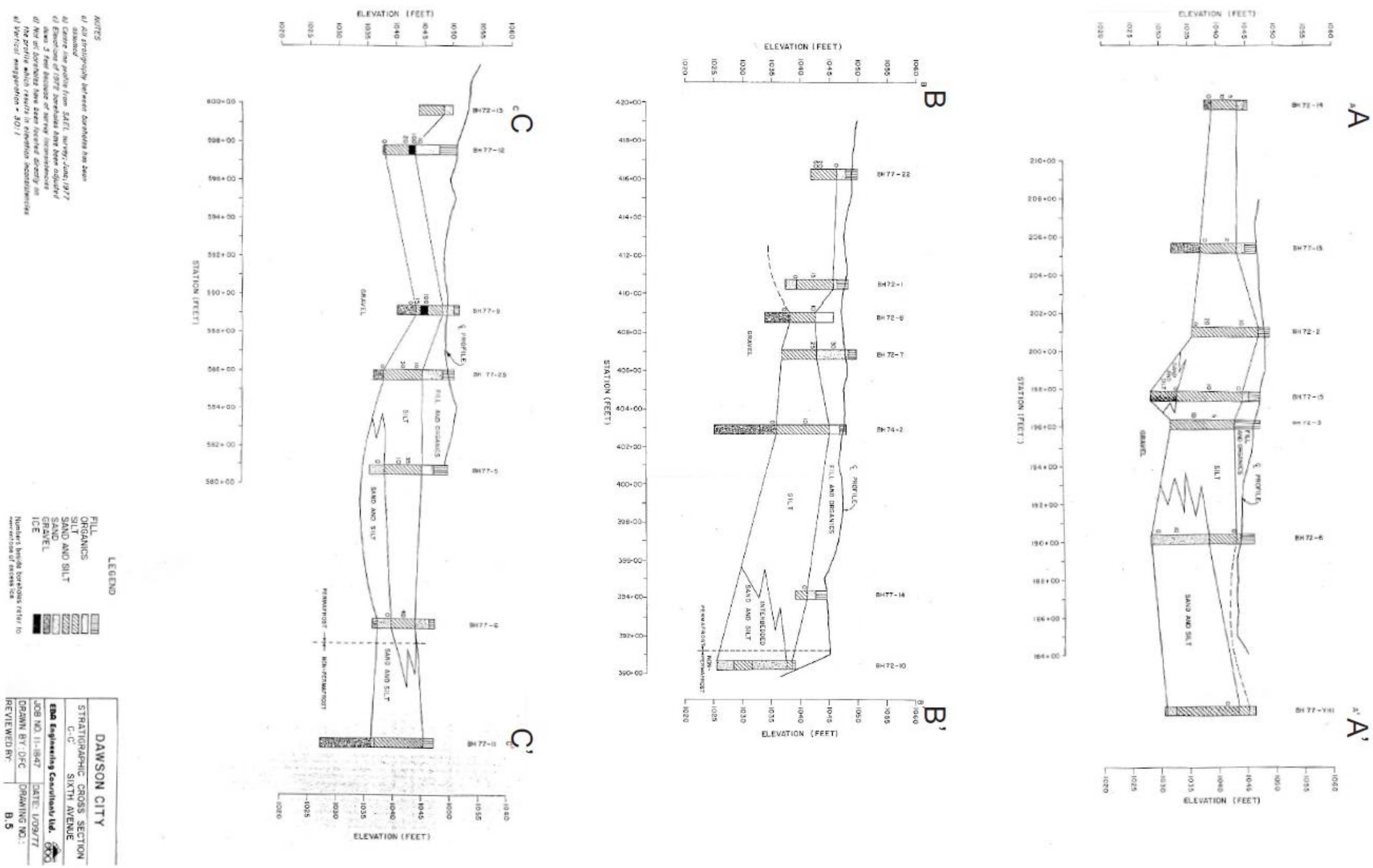
Spring Breakup

Yukon River spring breakup date at Dawson has shifted by about 7 days earlier over the last century.

A tripod is set up on the ice, and connected by cable to the Dänojà Zho Cultural Centre. When the ice starts to move, it takes the tripod with it and stops the clock, recording official break up time.
http://www.yukonriverbreakup.com

Appendix 1. Dawson Site Plans

Scans provide by B. Horton, Yukon College


DAWSON CITY
STRATIGRAPHIC CROSS SECTION
C-C'
SIXTH AVENUE
EBA Engineering Consultants Ltd.
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DATE: 1/09/77
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LEGEND
FILL
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SAND AND SILT
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STATION (FEET)
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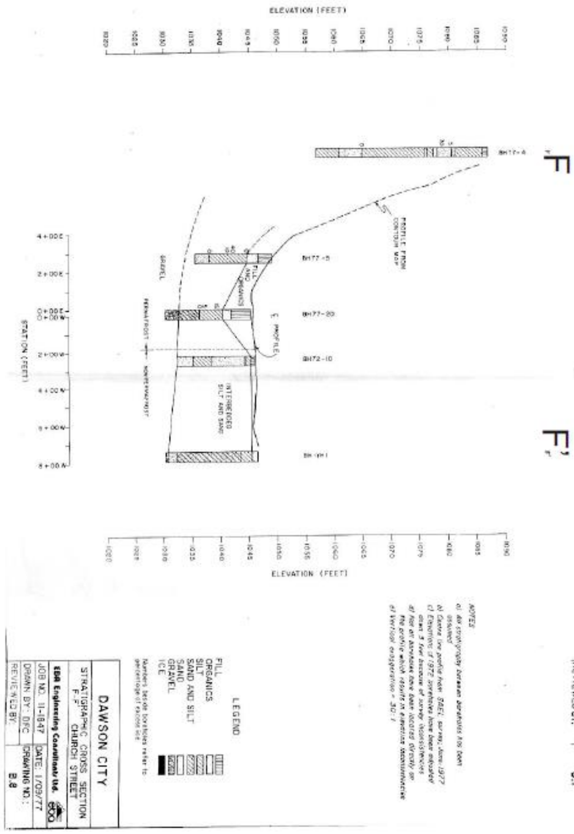
SILT
SAND AND SILT
FILL AND ORGANICS


DAWSON CITY
STRATIGRAPHIC CROSS SECTION F-F' CHURCH STREET
EBA Engineering Consultants Ltd.
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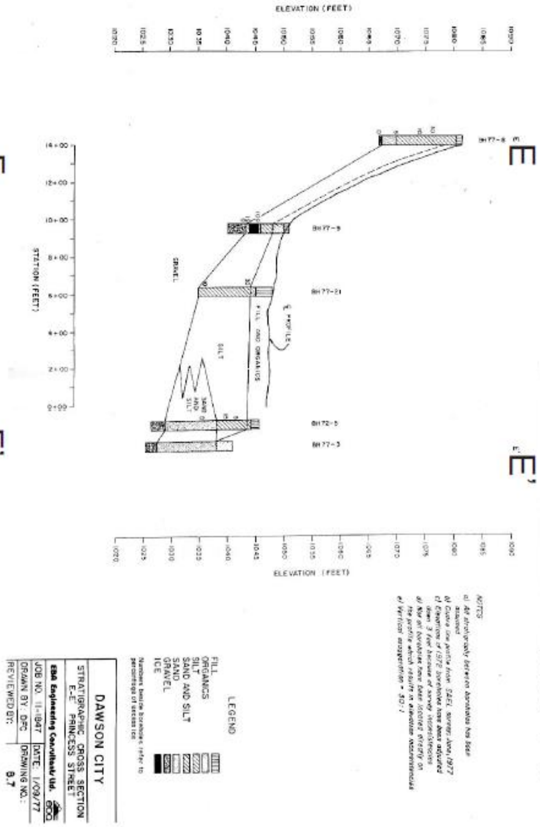
DAWSON CITY
STRATIGRAPHIC CROSS SECTION E-E' PRINCESS STREET
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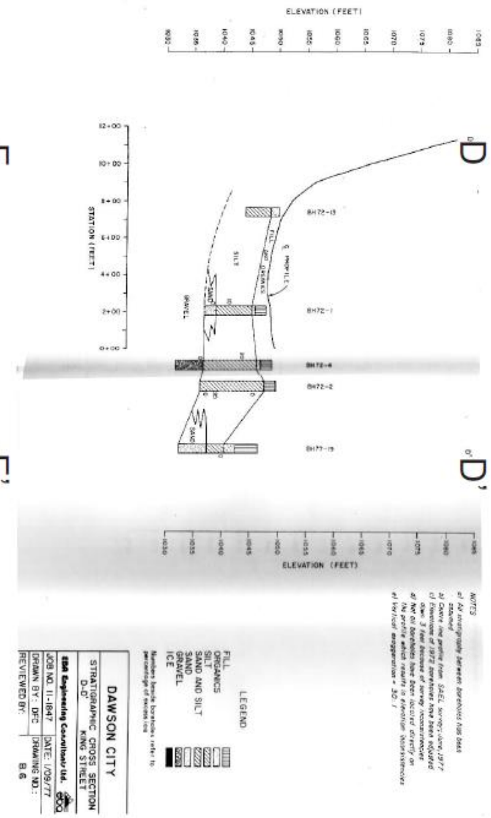
STATION (FEET)


NOTES
a) All stratigraphy between boreholes has been assumed
b) Centre line profile from SAEL survey, June, 1977
c) Elevations of 1972 boreholes have been adjusted down 3 feet because of survey inconsistencies
d) Not all boreholes have been located directly on the profile which results in elevation inconsistencies
e) Vertical exaggeration = 30:1
DAWSON CITY
STRATIGRAPHIC CROSS SECTION D-D' KING STREET
EBA Engineering Consultants Ltd.
JOB NO. 11-1847
DATE: 1/09/77
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SAND
GRAVEL
ICE
ELEVATION (FEET)
STATION (FEET)

Appendix 2. Northern Land Use Information Series (NLUIS) Maps

The maps present the major environmental and social features of land use in the region, including an ecological overview, wildlife, hunting and trapping, fish resources, recreation and tourism, archaeological sites, coastal classification, etc. Published by Agriculture Canada, Environment Canada, and Indian and Northern Affairs Canada between 1972 and 1986 at a 1:250,000 scale.

A. Dawson: http://sis.agr.gc.ca/cansis/publications/maps/nluis/250k/lu/nluis_250k_lu_116b_c.jpg

B. Stewart River: http://sis.agr.gc.ca/cansis/publications/maps/nluis/250k/lu/nluis_250k_lu_115o_n.jpg