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# Supplemental Climate Information: Gros Morne National Park


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# Preface

This is a supplement to the “Let’s Talks about Climate Change: Atlantic Region” report (Parker, 2017) and is intended to support climate change discussions and planning in Gros Morne National Park.

Future climate projections are modelled with several greenhouse gas concentration trajectories, called **Representative Concentration Pathways (RCP)** (Vuuren *et al.*, 2011). They describe possible climate futures and are named after respective radiative forcing values in the year 2100 relative to pre-industrial values (i.e., +2.6, +4.5 and +8.5 watts/$m^2$). **RCP 2.6** assumes we take action and greenhouse gas emissions peak in 2010-2020 and decline thereafter. **RCP 4.5** assumes emissions peak around 2040 and then decline. **RCP 8.5** assumes we take no action and emissions continue “status quo” to rise throughout the 21st century.

This is a site focussed document and to understand the larger climate change context please consult the Intergovernmental Panel on Climate Change assessment reports (e.g., IPCC, 2014) or Canada’s Changing Climate Assessments (http://www.nrcan.gc.ca/environment/impacts-adaptation/10029). With respect to adaptation and mitigation options, please review Gross *et al.* (2016) or Gray *et al.* (2017).

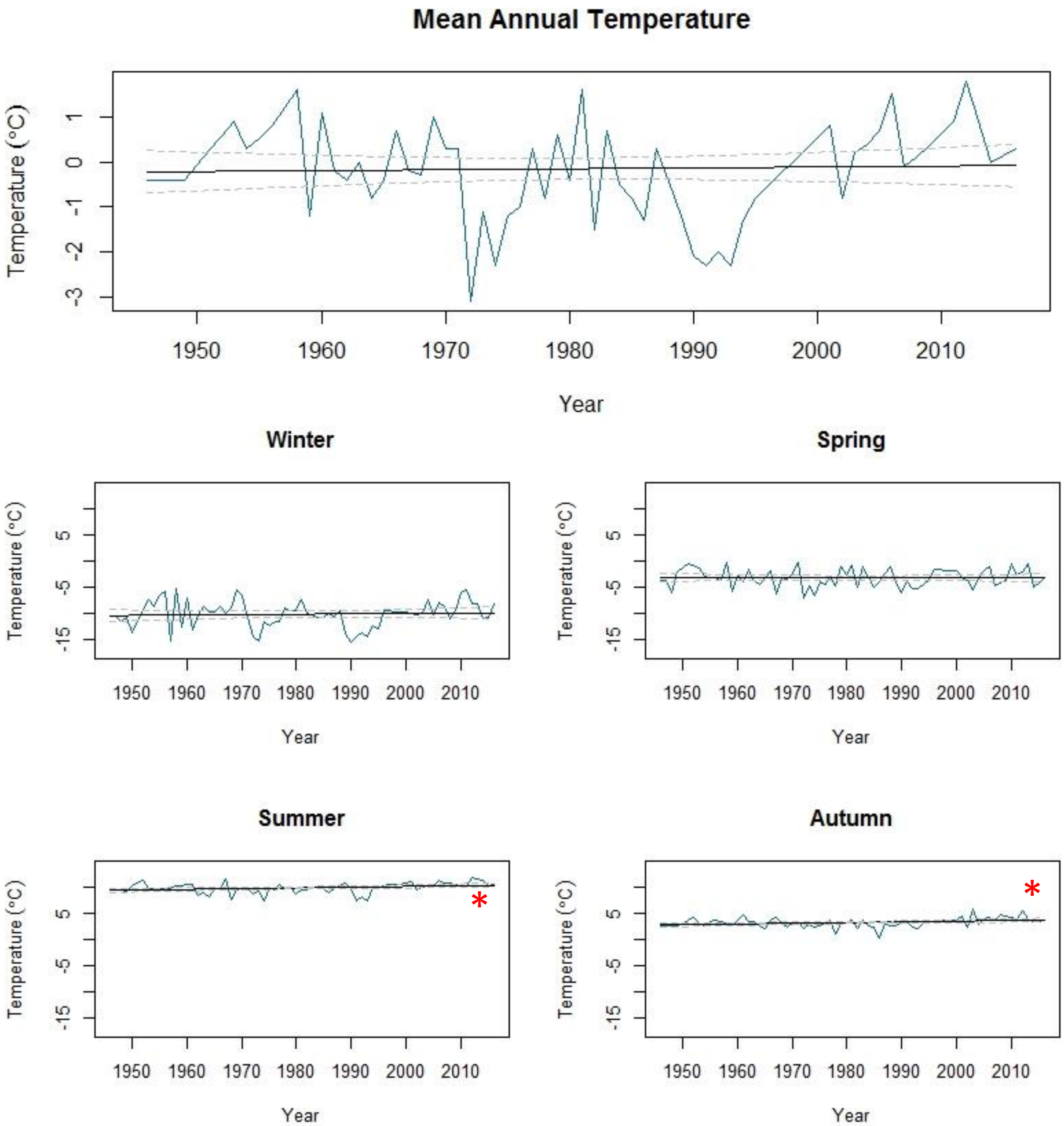
# Highlights

- Mean annual air temperatures for the Atlantic region have increased by 0.9 ±0.37˚C in last century (Lemmen *et al.*, 2016). Compared to other areas in Canada, this a relatively modest increase. At the Daniel's Harbour meteorological station (~32 km north of Gros Morne NP) summer and autumn temperatures have increased by ~1˚C since 1946. Seasonal differences are generally moderated by the ocean.
- The warming trend is projected to continue and model results indicate a further increase by 3 - 8˚C by 2100 depending on the location and RCP scenario.
- Total annual precipitation at Deer Lake has increased by ~445 mm (45%) since 1933. The relative increase in snow has been greater than that for rain.
- Today's "one in 100 year" rainfall event (i.e., 34.79 mm/hr) is projected to become a "one in 10-25 year" event and the future "one in 100 year" event is projected to increase to 47.43 mm/hr.
- A northward shift in storm track is expected to increase the storm frequency in the region (Loder *et al.*, 2013).
- Relative sea level has increased in the region and an estimated vertical allowance increase of 14 to 36 cm will be required by 2100.
- The growing season has already increased by 16 days since 1900 and will continue to increase as much 74 days under RCP 8.5 by 2100.
- AMEC (2012) provides a review of climate monitoring in Newfoundland.

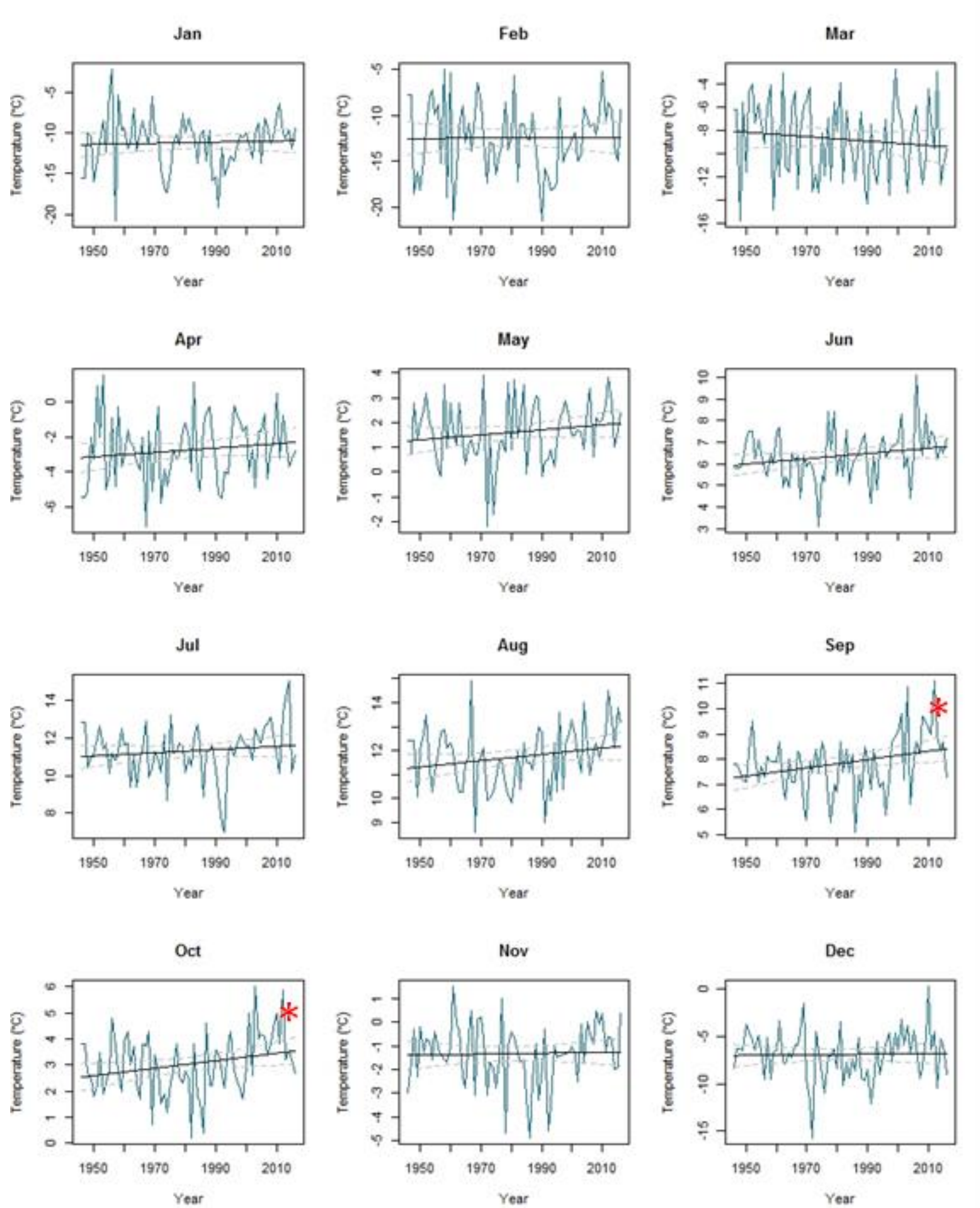
# 1. Observed Climate Trends

## 1.1 Temperature

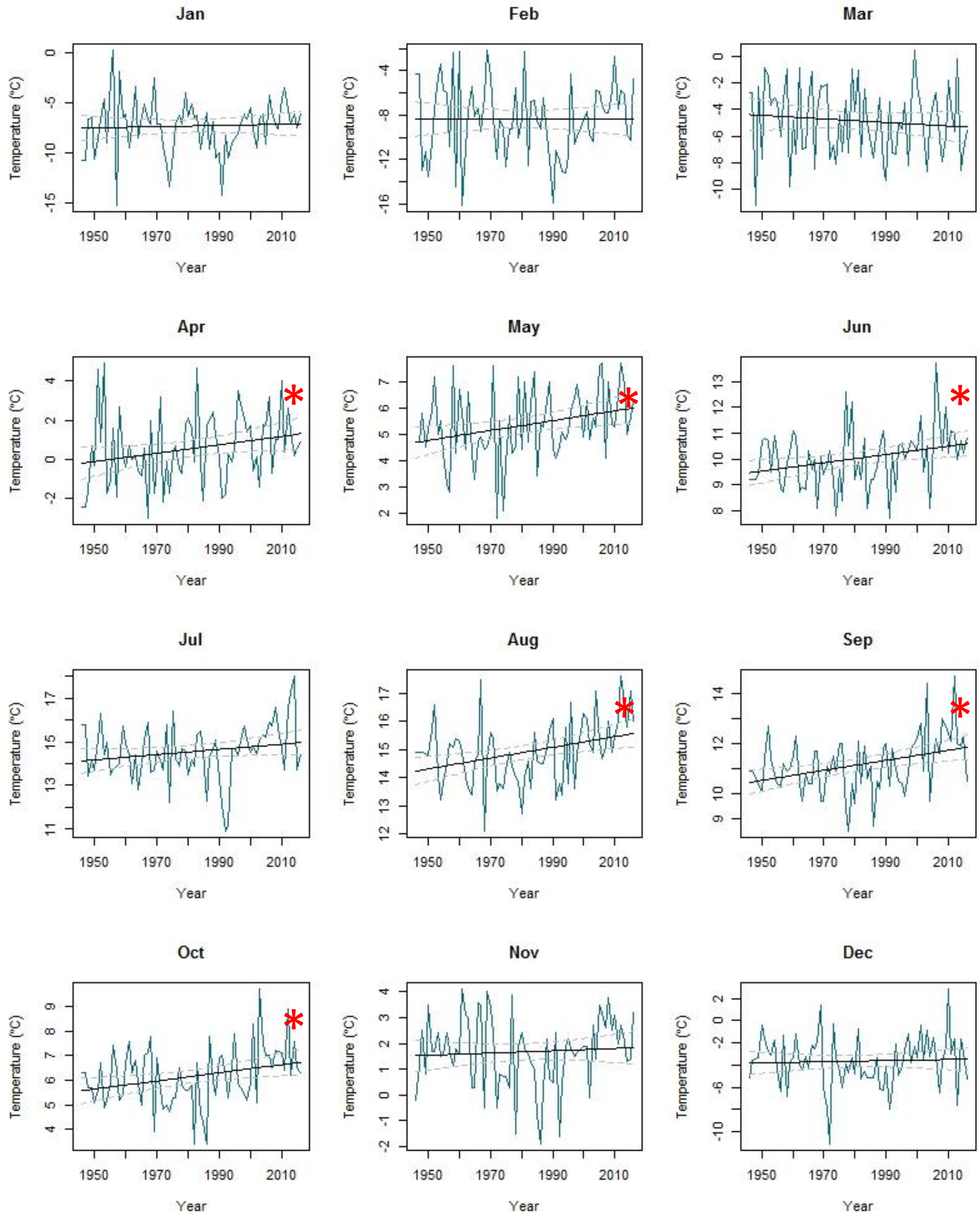
Mean annual, seasonal and monthly temperature at **Daniel's Harbour** climatological station (8401400) from 1946 to 2016 (ECCC, 2017). Trend determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).



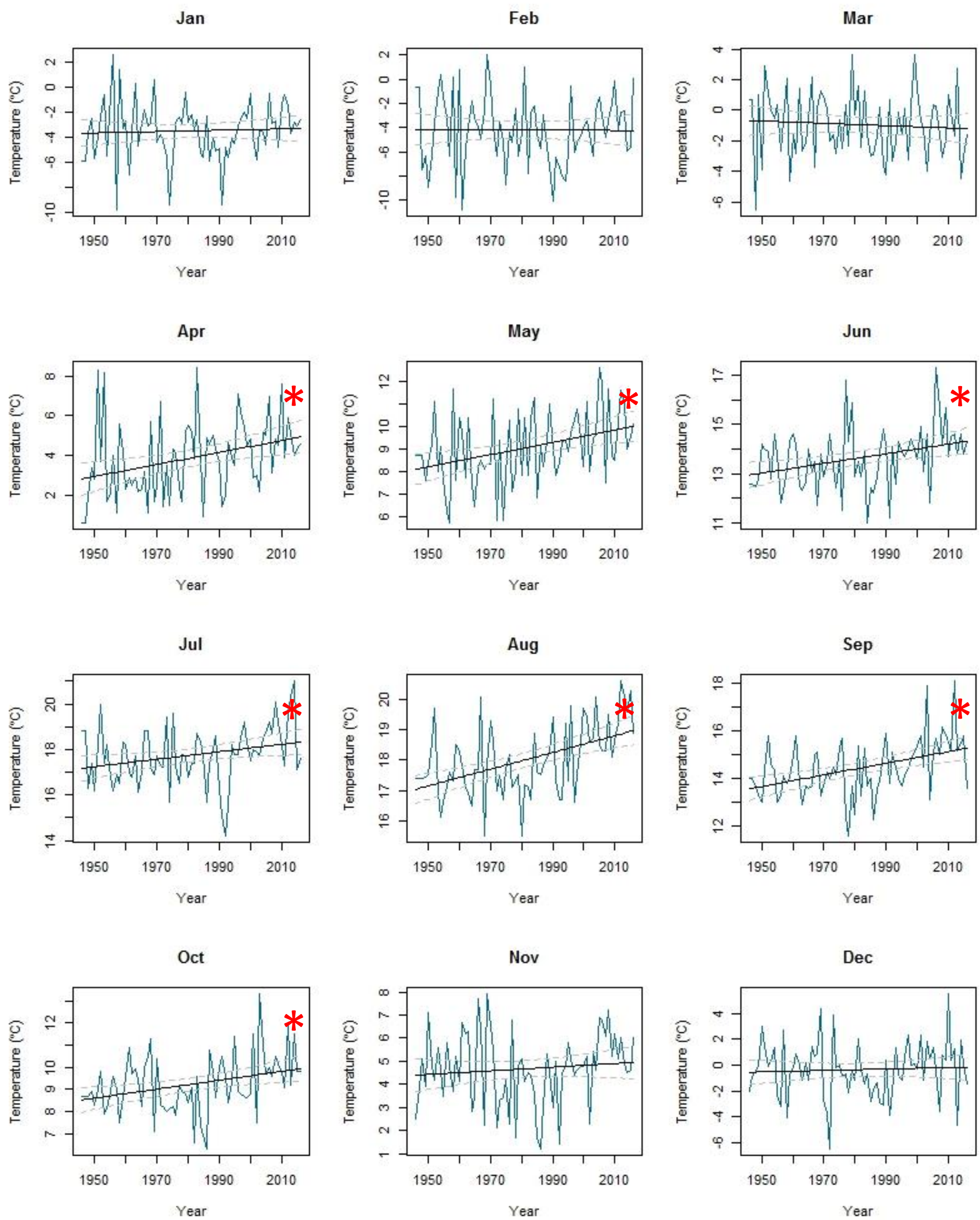

**Daniel's Harbour mean annual and seasonal temperature**. No statistically significant trend (P<0.05) observed in mean annual temperature. However, a statistically significant increase (P<0.05) observed for summer (Jun, Jul, Aug) and autumn (Sep, Oct, Nov). Both seasons have increased by ~1°C since 1946.




**Daniel's Harbour <u>mean</u> monthly temperature.** Only Sep and Oct demonstrated a statistically significant (P<0.05) increase in mean monthly temperature. The greatest increase since 1946 was observed for Sep, ~1.2°C.



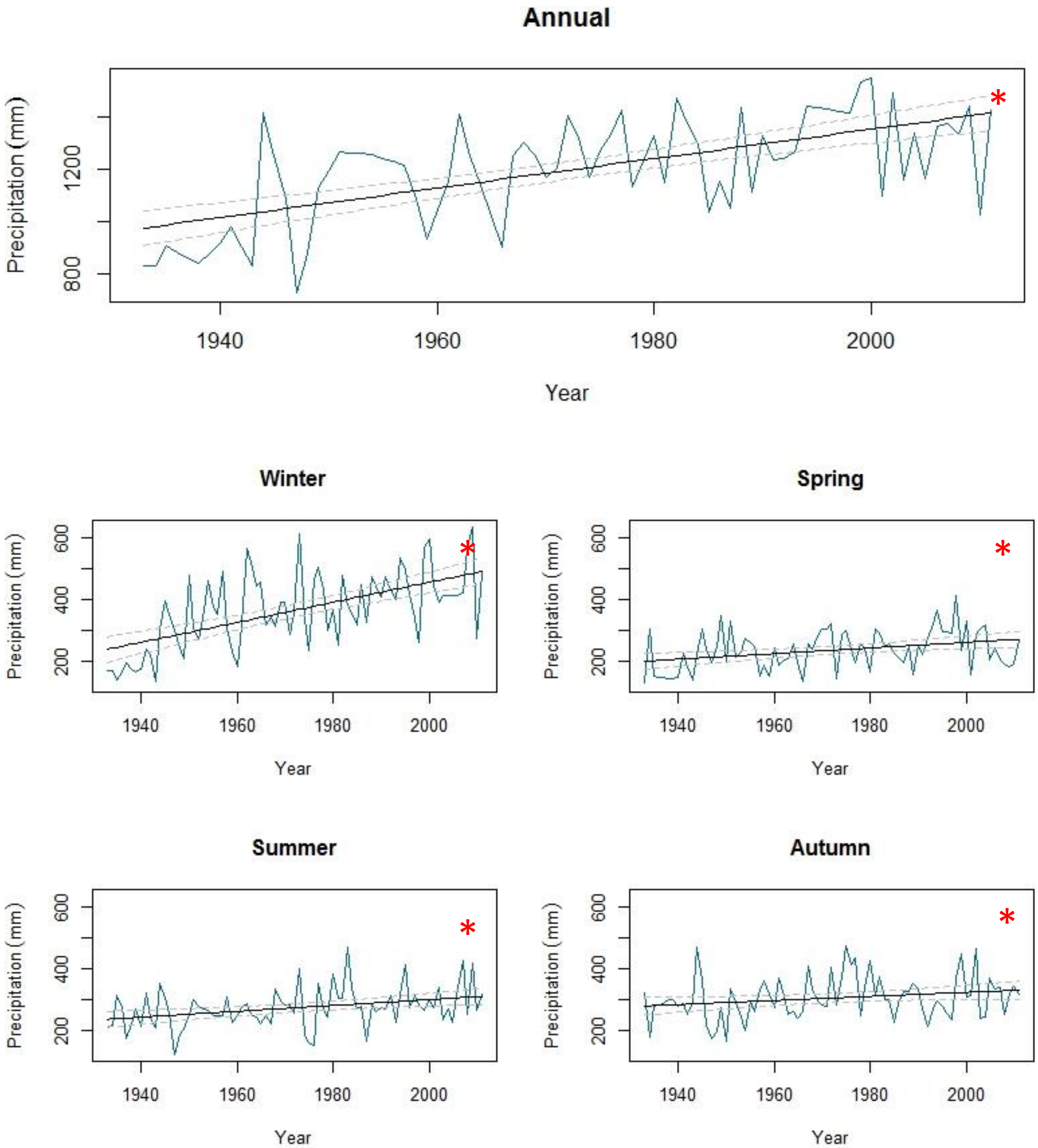

**Daniel’s Harbour mean monthly <u>minimum</u> temperature**. Apr, May, Jun, Aug, Sep, and Oct all demonstrated a statistically significant ($P<0.05$) increase in mean monthly minimum temperatures (i.e., nighttime). Both Apr and Sep demonstrated the greatest increase by ~1.4°C since 1946.



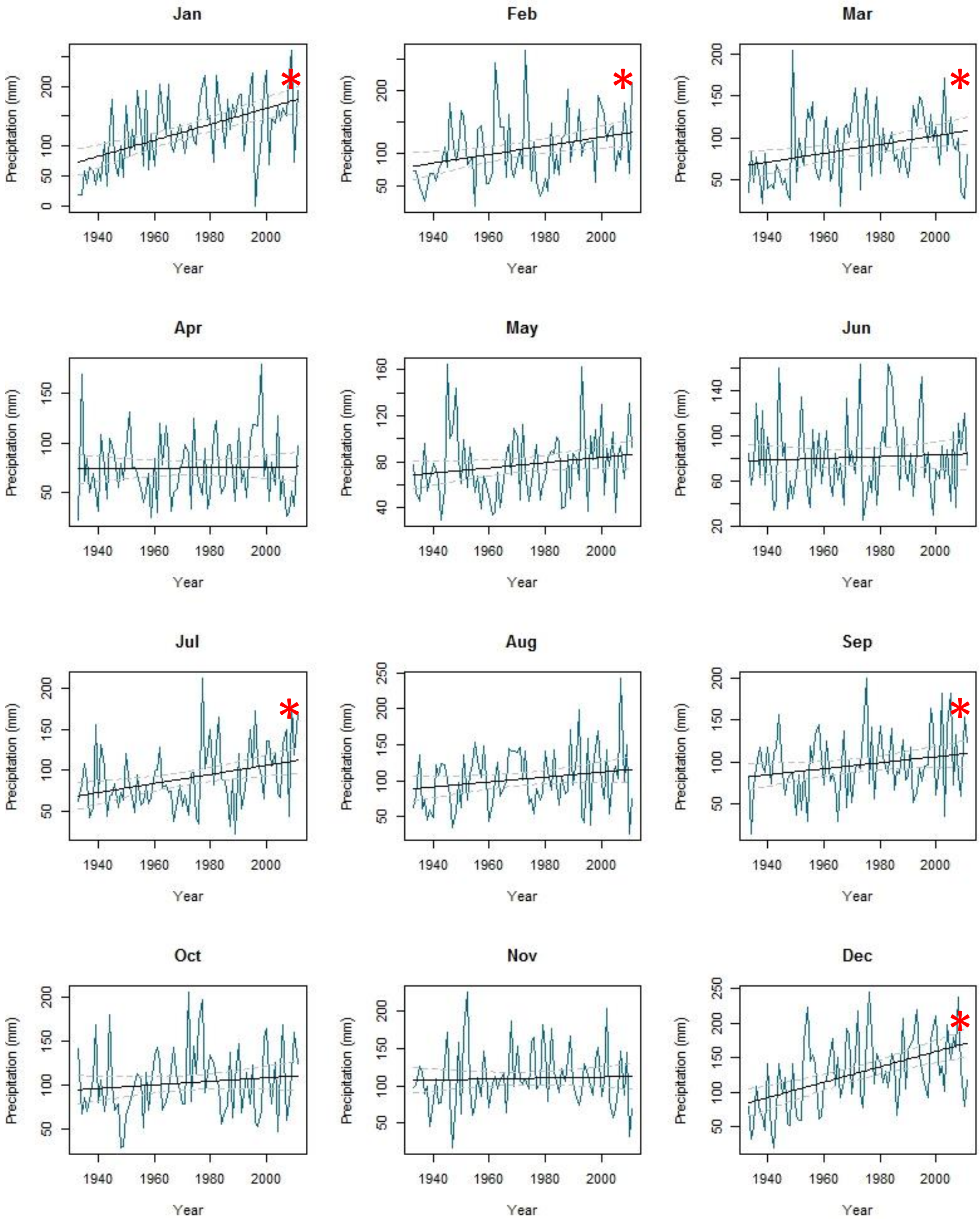

**Daniel's Harbour mean monthly <u>maximum</u> temperature.** Apr, May, Jun, Jul, Aug, Sep, and Oct all demonstrated a statistically significant (P<0.05) increase in mean monthly maximum temperatures (i.e., daytime). Apr demonstrated the greatest increase by ~2.1°C since 1946.

## 1.2 Precipitation

Total precipitation at **Deer Lake** climatological station (8401501) from 1933 to 2012 (ECCC, 2017). Trend determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).

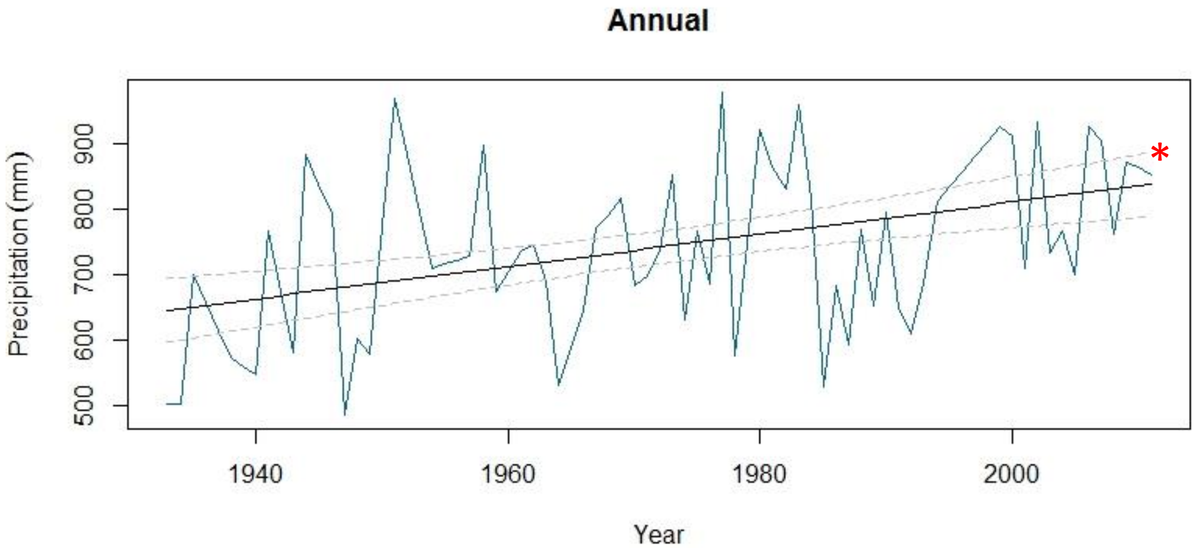



**Deer Lake total annual and seasonal precipitation.** Total annual precipitation has shown a statistically significant increase (P<0.05) by ~445 mm (45%) since 1933. All seasons have shown a statistically significant (P<0.05) increase, the greatest being observed for winter (Dec, Jan, Feb), ~254 mm (100%).



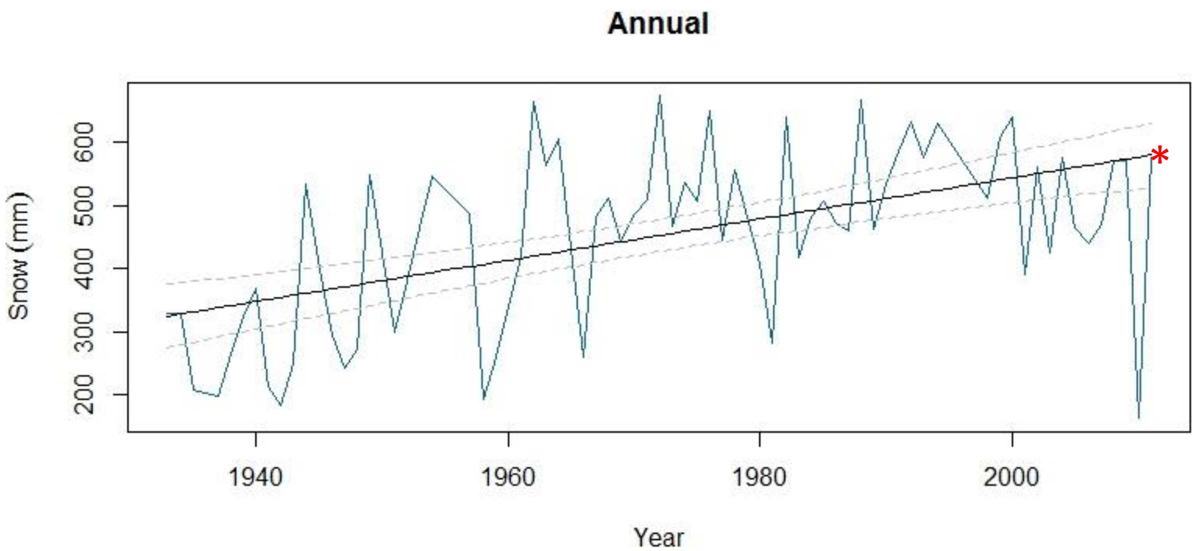

**Deer Lake total monthly precipitation.** Total monthly precipitation has shown a statistically significant increase (P<0.05) in Jan, Feb, Mar, Jul, Sep and Dec since 1933. The greatest increase being observed in Jan, ~105 mm (140%).

**Total Annual Rain**




Total annual rain has demonstrated a statistically significant (P<0.05) increase since 1933, ~194 mm (30%).

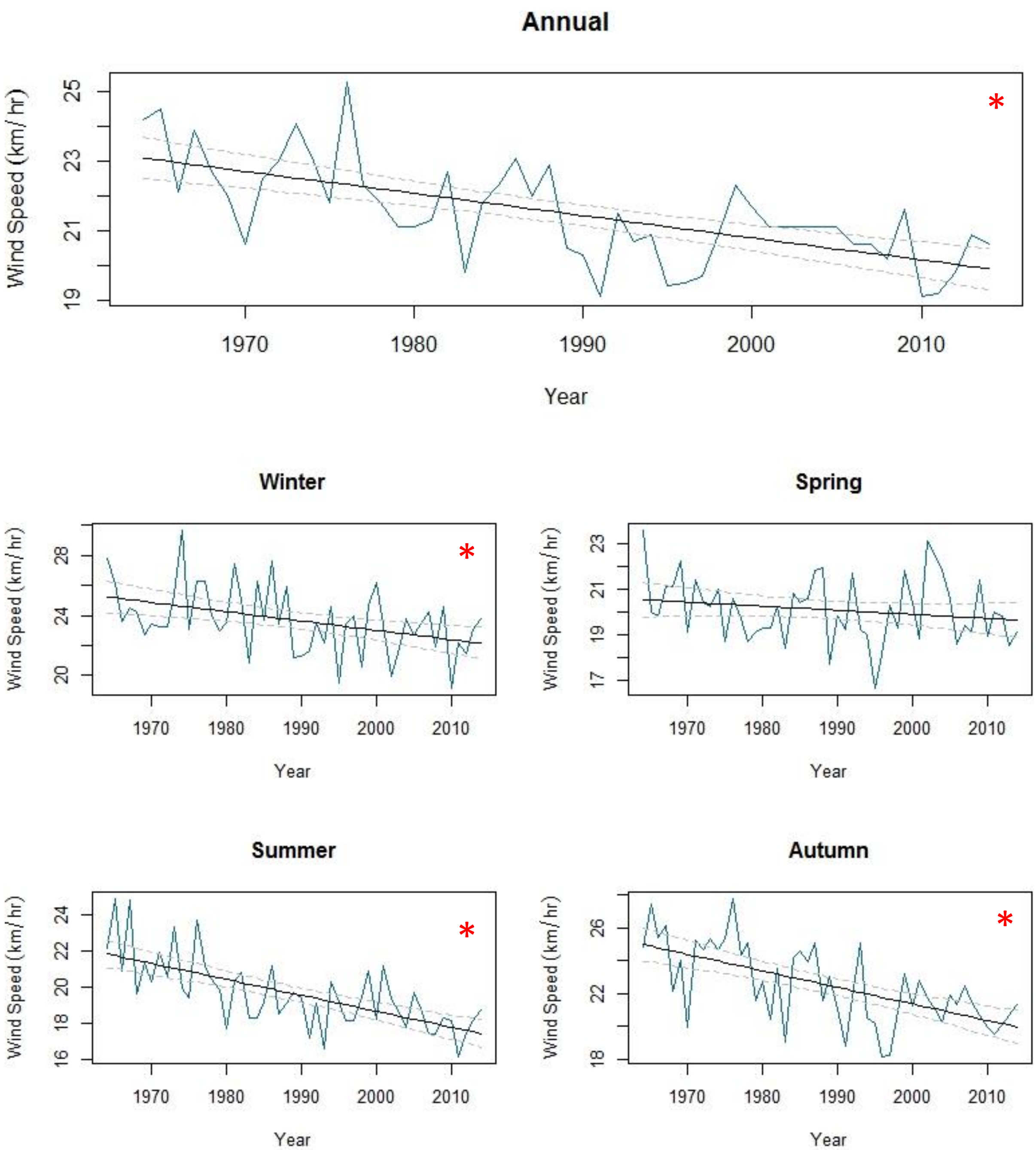
**Total Annual Snow**



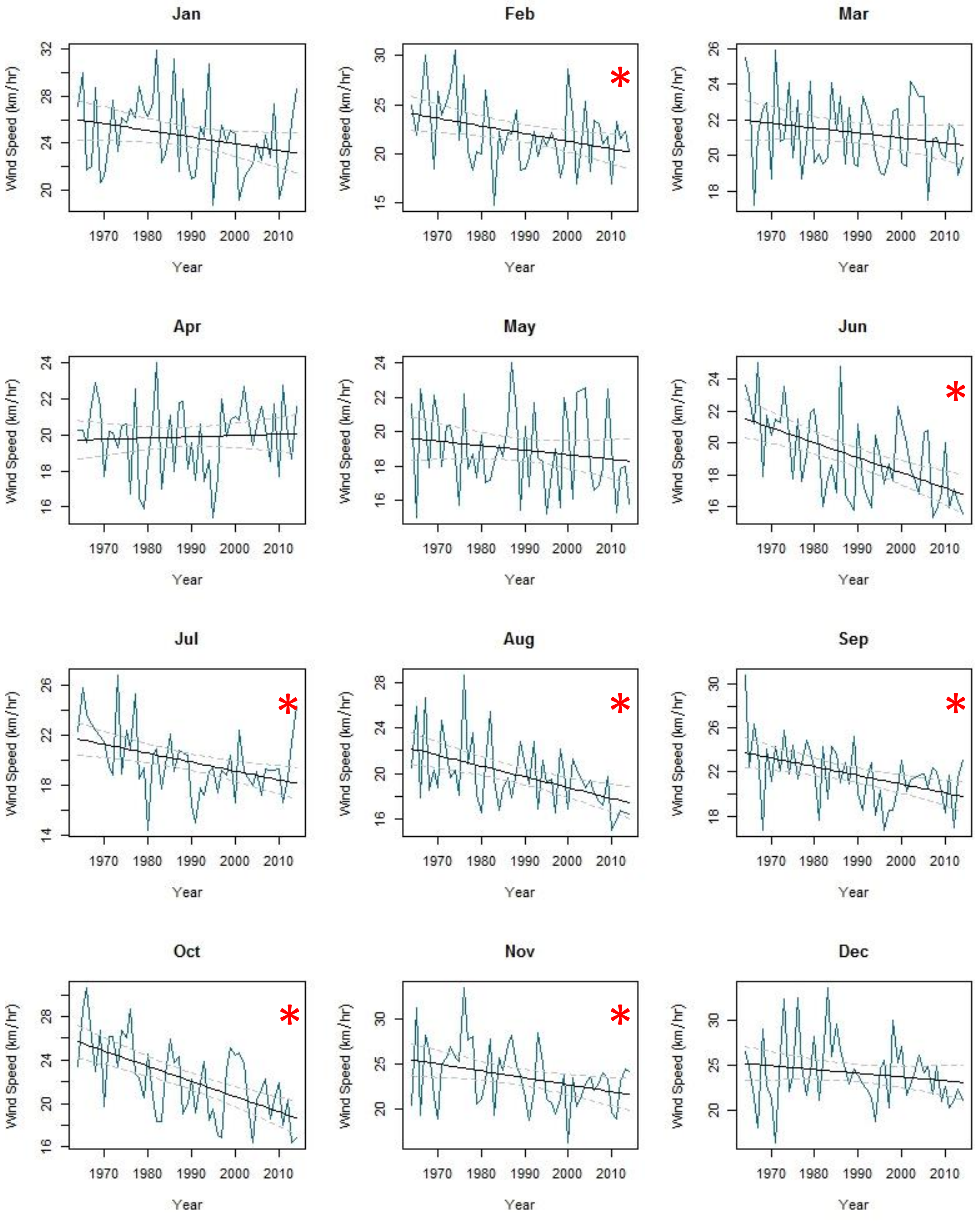

Total annual snow has demonstrated a statistically significant (P<0.05) increase since 1933, ~258 mm (80%).

## 1.3 Surface Wind Speed

Mean wind speeds at **Daniel's Harbour** climatological station (8401400) from 1964 to 2014 (ECCC, 2017). Trend determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).



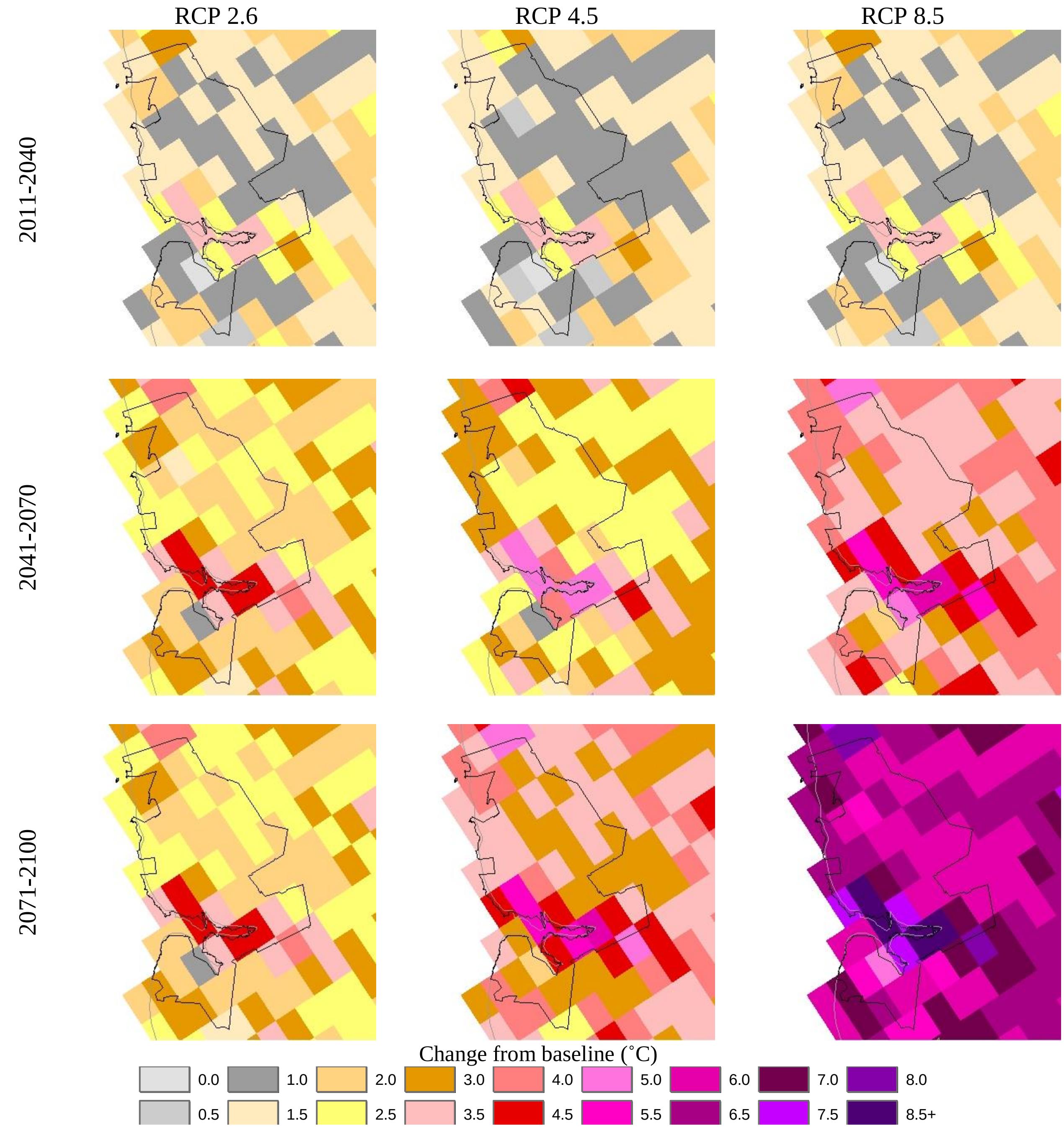

**Daniel's Harbour annual and seasonal mean wind speeds.** Mean annual wind speeds have demonstrated a statistically significant (P<0.05) decrease by ~5 km/hr (20%) since 1964. Seasonally, winter (Dec, Jan, Feb), summer (Jun, Jul, Aug) and autumn (Sep, Oct, Nov) have all demonstrated a statistically significant (P<0.05) decrease, the greatest being observed for autumn, ~8 km/hr (28%) since 1964.




**Daniel's Harbour monthly mean wind speeds**. Mean monthly wind speeds have demonstrated a statistically significant ($P<0.05$) decrease in Feb, Jun, Jul, Aug, Sep, Oct and Nov since 1964. The greatest decrease being observed for Oct, ~11 km/hr (37%) since 1964.

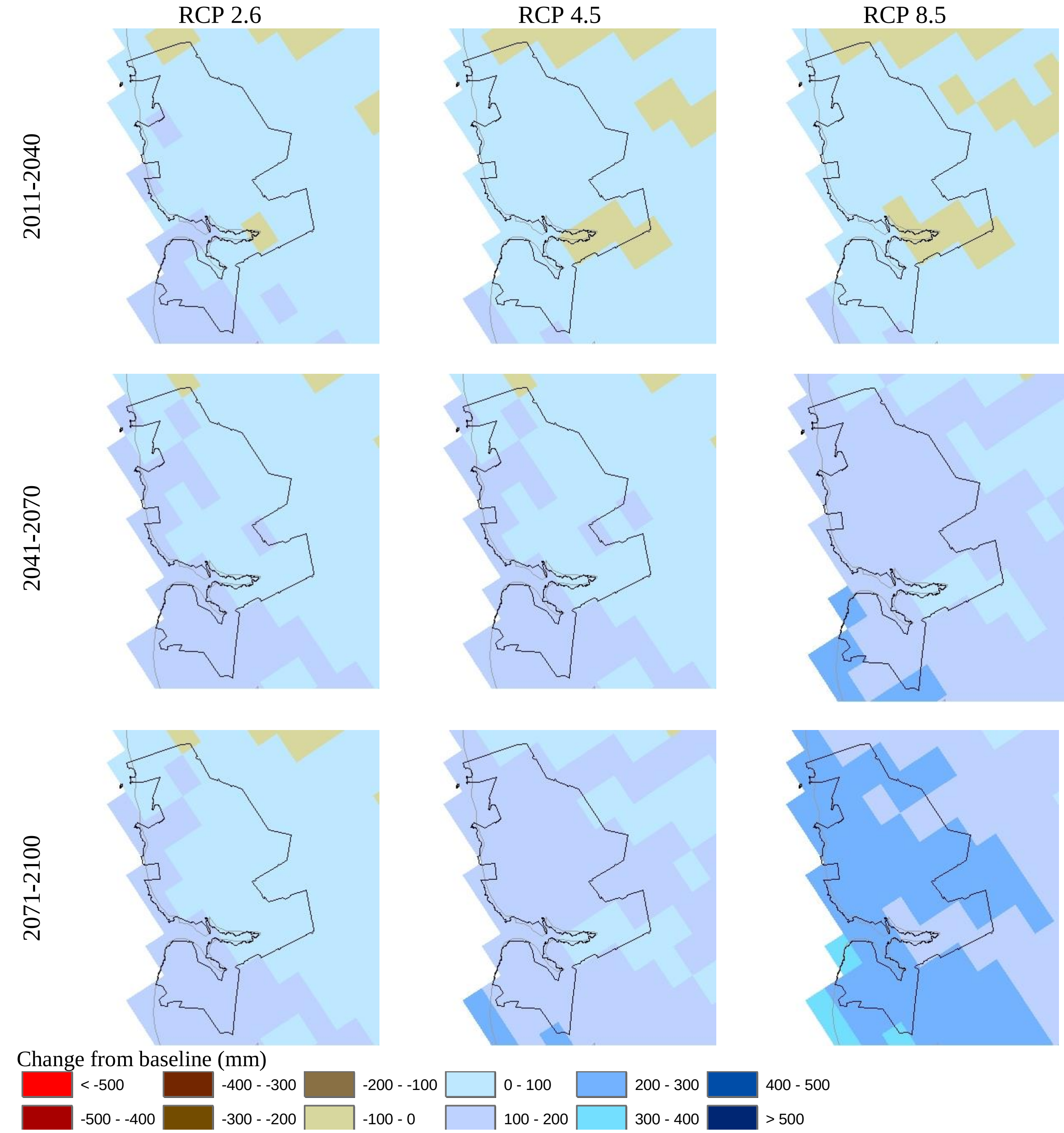
# 2. Projected Climate Trends

## 2.1 Temperature




**Projected mean annual temperature increase for Gros Morne National Park from a 1980-2010 baseline.** Composite projection of CanESM2, CESM1CAM5, HADGEM2ES and MIROCESM. Data source: Natural Resources Canada, Canadian Forest Service, http://cfs.nrcan.gc.ca/projects/3 (Price *et al.*, 2011).

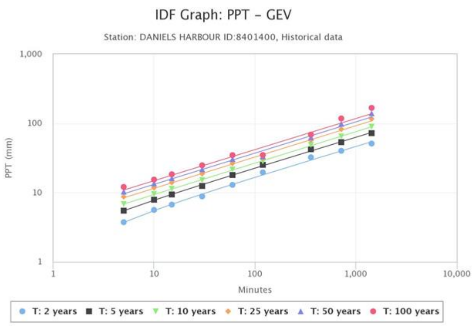
## 2.2 Precipitation




**Projected total annual precipitation change for Gros Morne National Park from a 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).

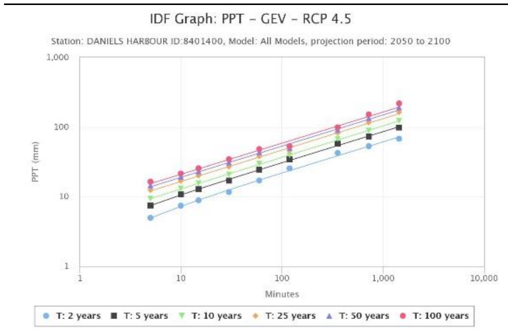
## 2.3 Rainfall Intensity, Duration and Frequency (IDF)

Extreme rainfalls calculated with Generalized Extreme Values (GEV) and an ensemble of climate models within IDF_CC Tool 3.0 (http://www.idf-cc-uwo.ca/; see Simonovic *et al.* (2017)). Engineering datasets are available at: http://climate.weather.gc.ca. Extreme precipitation for Atlantic Canada is also available at: http://atlantic-canada-precip.eas.cornell.edu.



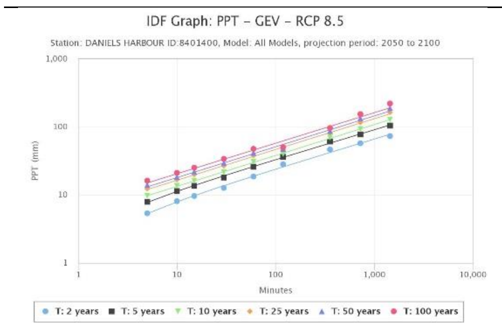

**Baseline** total precipitation amounts (mm) for Daniel's Harbour from 1969-1995.

| T (years) | 2 | 5 | 10 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|
| 5 min | 3.74 | 5.48 | 6.81 | 8.72 | 10.32 | 12.08 |
| 10 min | 5.62 | 7.89 | 9.53 | 11.76 | 13.54 | 15.43 |
| 15 min | 6.71 | 9.41 | 11.35 | 14.02 | 16.15 | 18.40 |
| 30 min | 8.82 | 12.49 | 15.14 | 18.79 | 21.72 | 24.83 |
| 1 h | 12.94 | 17.96 | 21.60 | 26.57 | 30.56 | 34.79 |
| 2 h | 19.60 | 25.21 | 28.22 | 31.37 | 33.32 | 34.97 |
| 6 h | 32.38 | 42.34 | 48.86 | 57.02 | 63.02 | 68.92 |
| 12 h | 40.16 | 53.59 | 64.86 | 82.56 | 98.74 | 117.93 |
| 24 h | 51.15 | 72.33 | 89.67 | 116.25 | 140.02 | 167.69 |




Projected (2050-2100) precipitation (mm) for Daniel's Harbour using an ensemble of models and **RCP 4.5**.

| T (years) | 2 | 5 | 10 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|
| 5 min | 4.96 | 7.47 | 9.33 | 12.41 | 14.52 | 16.43 |
| 10 min | 7.43 | 10.76 | 13.10 | 16.86 | 19.39 | 21.51 |
| 15 min | 8.87 | 12.83 | 15.60 | 20.09 | 23.10 | 25.62 |
| 30 min | 11.67 | 17.02 | 20.80 | 26.91 | 31.03 | 34.52 |
| 1 h | 17.10 | 24.50 | 29.69 | 38.08 | 43.70 | 48.38 |
| 2 h | 25.54 | 34.42 | 39.17 | 46.00 | 49.76 | 53.02 |
| 6 h | 42.55 | 57.61 | 67.48 | 82.52 | 92.07 | 99.31 |
| 12 h | 53.27 | 73.25 | 88.92 | 116.38 | 134.77 | 152.20 |
| 24 h | 68.05 | 98.68 | 122.65 | 163.90 | 192.15 | 219.18 |

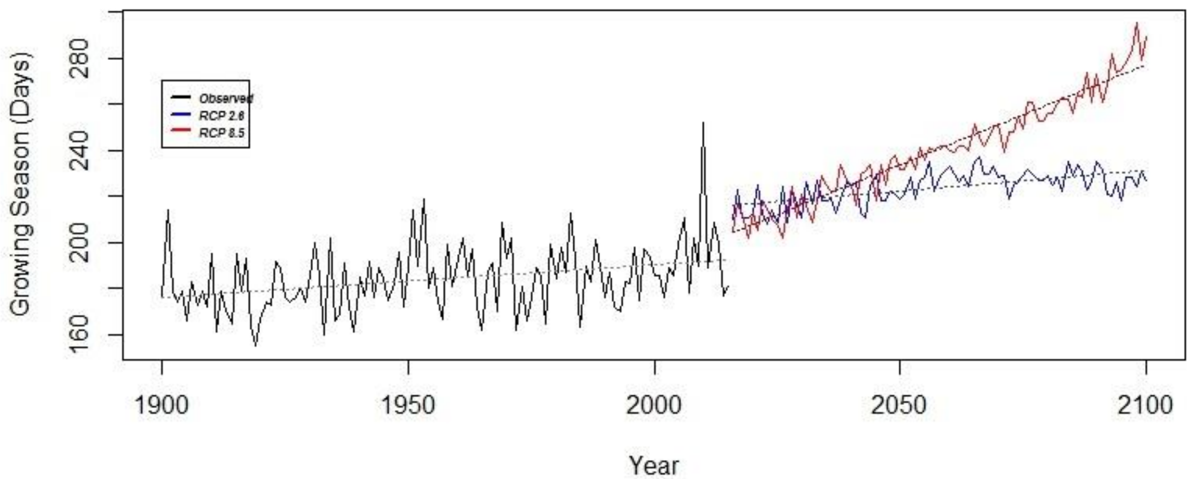


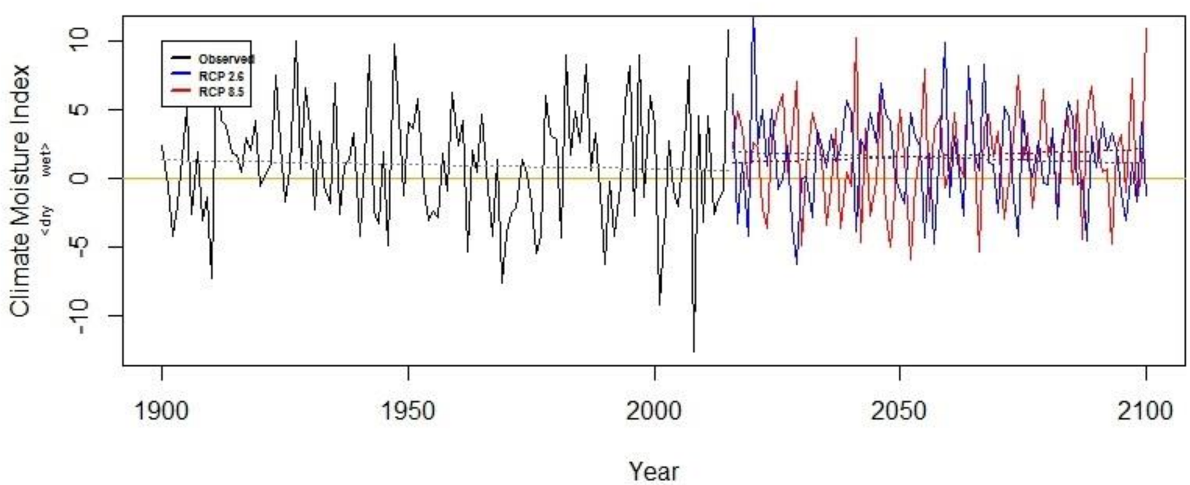

Projected (2050-2100) precipitation (mm) for Daniel's Harbour using an ensemble of models and **RCP 8.5**.

| T (years) | 2 | 5 | 10 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|
| 5 min | 5.36 | 7.90 | 9.69 | 12.34 | 14.01 | 16.20 |
| 10 min | 8.07 | 11.37 | 13.56 | 16.74 | 18.39 | 21.08 |
| 15 min | 9.63 | 13.55 | 16.15 | 19.94 | 21.92 | 25.12 |
| 30 min | 12.67 | 17.98 | 21.54 | 26.72 | 29.48 | 33.85 |
| 1 h | 18.57 | 25.88 | 30.74 | 37.81 | 41.47 | 47.43 |
| 2 h | 28.20 | 36.12 | 40.10 | 45.90 | 47.37 | 50.45 |
| 6 h | 46.51 | 60.95 | 69.47 | 81.91 | 86.69 | 96.26 |
| 12 h | 57.33 | 77.49 | 92.88 | 116.41 | 133.65 | 154.22 |
| 24 h | 73.16 | 104.36 | 127.97 | 163.72 | 189.76 | 220.59 |

## 2.4 Growing Season and Climate Moisture Index

**Growing Season** is calculated as the number of days between the last occurrence of 0°C in spring and the first occurrence of 0°C in autumn. The metric is a widely used indicator of plant photosynthetic activity (http://www.nrcan.gc.ca/forests/climate-change/forest-change/18470). The **Climate Moisture Index** (CMI) is calculated as the difference between annual precipitation and potential evapotranspiration. A positive CMI value indicates wet conditions and a negative value indicates dry conditions (http://www.nrcan.gc.ca/forests/climate-change/forest-change/17772). Data courtesy of Dan McKenney and John Pedlar, Canadian Forest Service. Generalized linear model and plots developed in R (R Core Team, 2017).



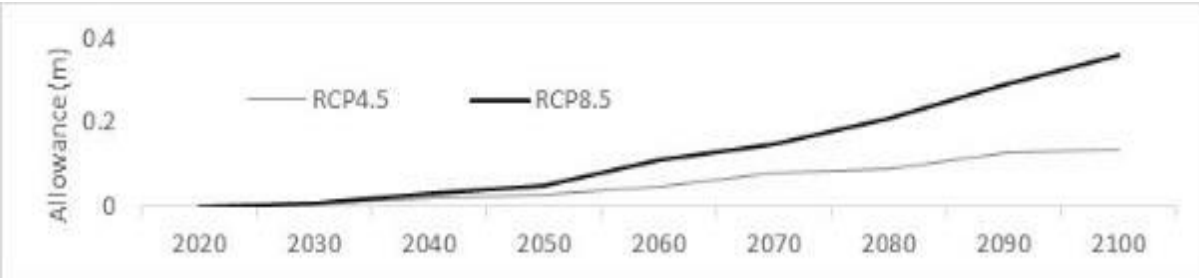




For Rocky Harbour, NL (49.59 N, 57.915 W). Trend in **growing season length** for the historic period and the RCP 2.6 and 8.5 future scenarios all demonstrate a statistically significant ($P<0.05$) increase, e.g., since 1900 growing season has increased by ~16 days and may increase by an additional 74 days under RCP 8.5. No statistically significant ($P<0.05$) trend observed for **CMI** values over the historic period or RCP scenarios. Future CMI values are generally positive, indicative of wet conditions. Although there is no statistically significant difference ($P<0.05$) between the historic and either RCP time periods, future projections are estimated to be positive (wet) 70% of time, an increase from 56% for the historic period. Finnis (2013) reports that frequent droughts is not currently or projected to be a concern.

# 3. Climate Change Impacts

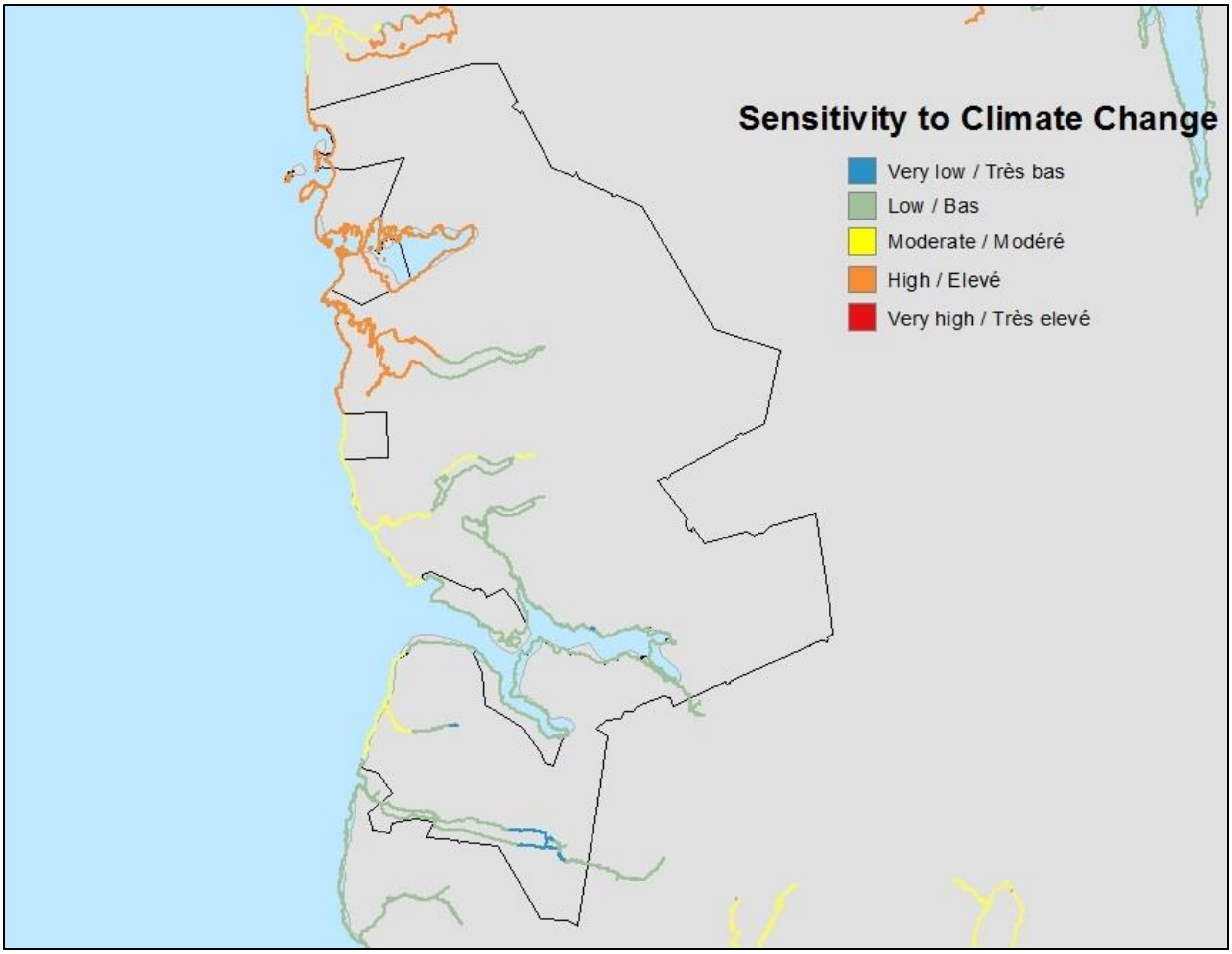
## 3.1 Sea Level Rise

Relative sea levels are rising in the region. For example, since 1960 Port Aux Basques has experienced an increase of 2.48 ± 0.4 mm/yr (~13.8 cm) (http://www.psmsl.org/products/trends/).



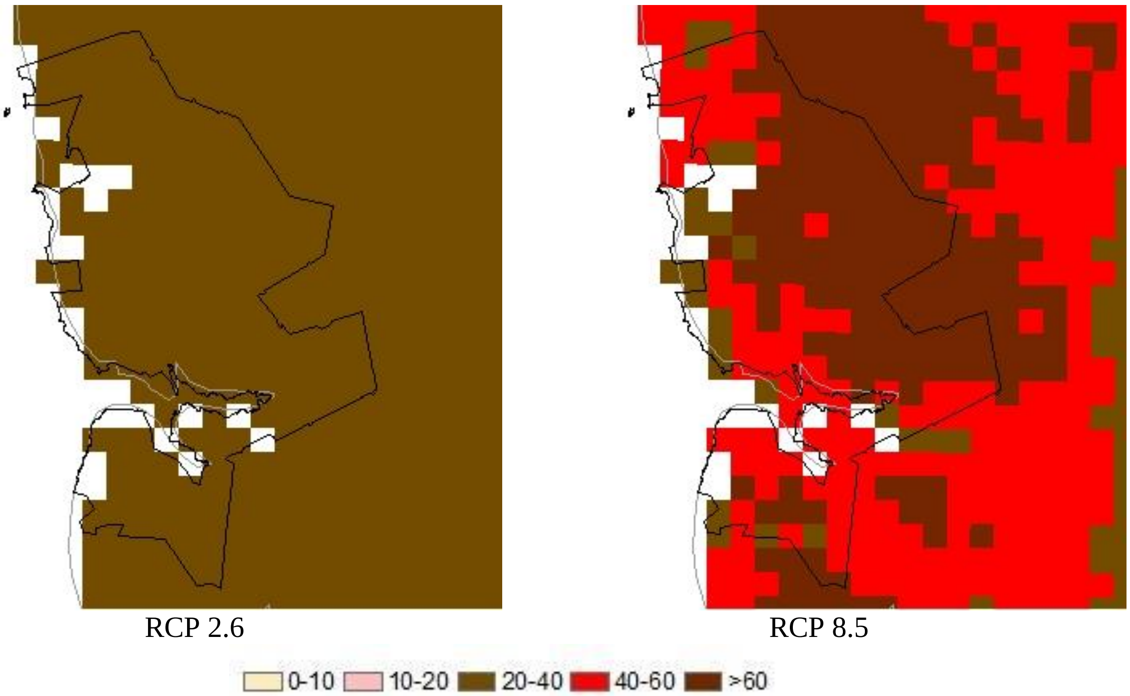

**Rocky Harbour, NL projected vertical allowance of 14 to 36 cm by 2100.** Vertical allowance for Rocky Harbour was acquired from the Canadian Extreme Water Level Adaptation Tool (CAN-EWLAT, http://www.bio.gc.ca/science/data-donnees/index-en.php). Vertical allowances are "recommended changes in the elevation of coastal infrastructure required to maintain the current level of flooding risk in a future scenario of sea level rise". These estimates are based on a future projection of regional sea level rise using the RCP 4.5 and RCP 8.5 scenarios and the historical water level records, including both tides and storm surge. The historical records do not incorporate predicted changes in storm tides.

**NOTE:**
Newfoundland and Labrador maintains an on-line "Geoscience Atlas" (http://geoatlas.gov.nl.ca/Default.htm) that includes data that may be relevant to characterizing the coast and understanding coastal sensitivity (e.g., coastal erosion index, coastal sensitivity index).




**Map of coastal sensitivity in Gros Morne National Park**. Sensitivity is based on coastal materials, landforms, relief, ground ice, wave height, tidal range, recent trends in sea ice concentration and projected sea level rise to 2050. Data provided by Natural Resources Canada (Couture and Manson, 2016).

## 3.2 Wildfire Regimes



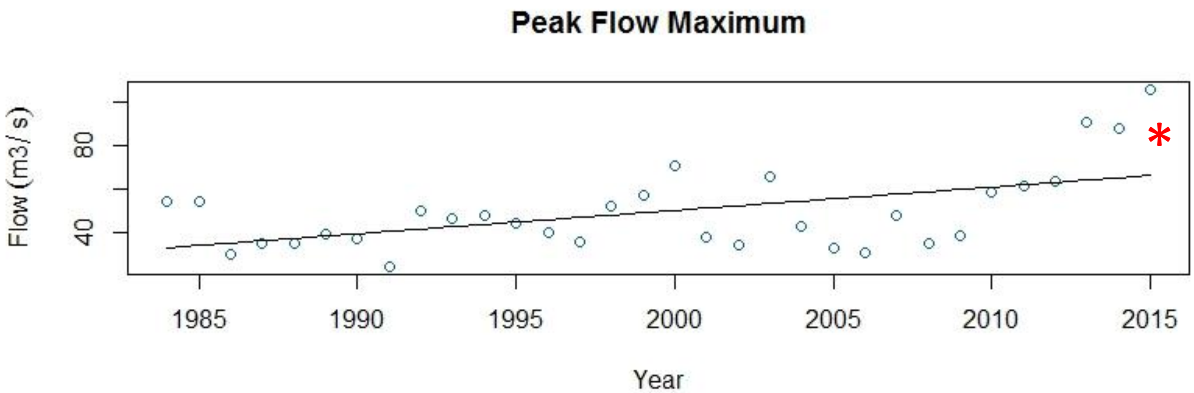

**Projected increase in wildfire season for Gros Morne National Park**. Length in days from baseline (1981-2010) by 2071-2100 under RCP 2.6 and RCP 8.5 scenarios. Data source Natural Resources Canada, http://cfs.nrcan.gc.ca/fc-data-catalogue.

**NOTE:**
Annual forest fire data (e.g., number of fires, area burned) for the province is available from the National Forestry Database (http://nfdp.ccfm.org/fires/jurisdictional_e.php). This database also includes forest insect defoliation (http://nfdp.ccfm.org/insects/jurisdictional_e.php). This may be used to assess provincial trends at least.

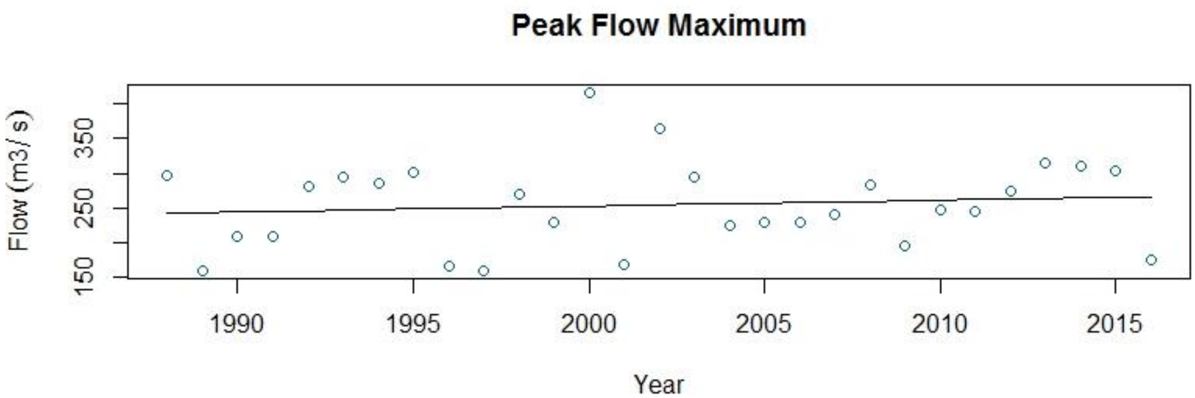
## 3.3 Hydrological Regimes

Changes to temperature (e.g., snowmelt) and precipitation (e.g., intensity, duration, frequency, rain vs snow) affects stream hydrology.

No long-term stream hydrological stations are currently maintained in Gros Morne NP, regional stations include Greavett Brook above Portland Creek Pond (02YE001) and Upper Humber River above Black Brook (02YL008), see Appendix 1 for data, and a discontinued station at Bottom Creek near Rock Harbour (02YH001).




**Greavett Brook Hydrological Station Annual Peak Flow ($m^3/s$)**. Preliminary analysis highlights a statistically significant ($P<0.05$) increasing trend in maximum peak flows from 1985 to 2015. Trend determined using a generalized linear model (R Core Team, 2017) and data from EC Data Explorer, HYDAT (Jan 17, 2018) (https://ec.gc.ca/rhc-wsc/). Additional analysis is recommended and could reveal patterns in minimum, maximum, and mean flows and levels, as well as timing and seasonal patterns.

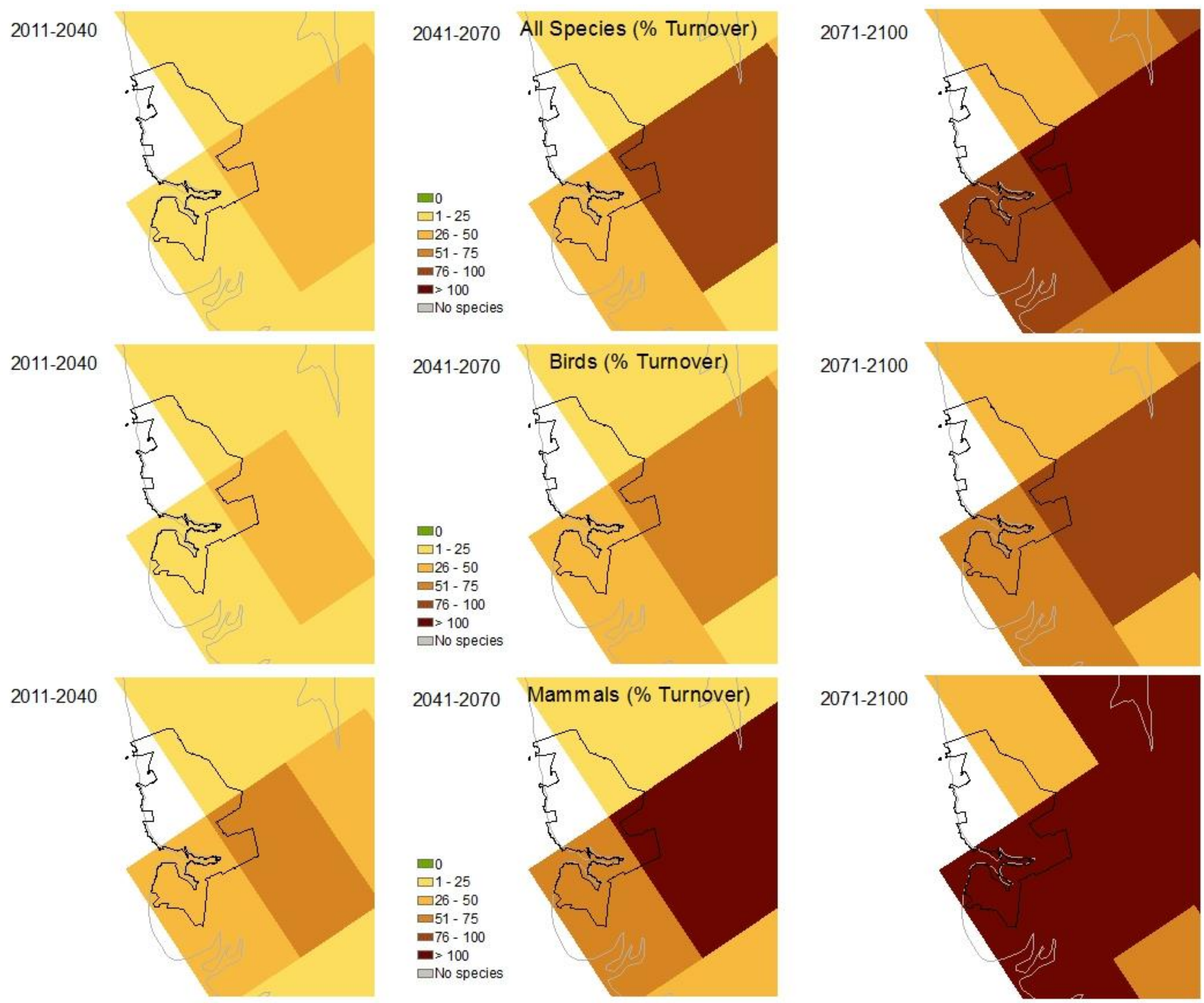



**Upper Humber River Hydrological Station Annual Peak Flow ($m^3/s$)**. Preliminary analysis highlights an increasing trend, but it is not statistically significant ($P<0.05$) from 1988 to 2016. Trend determined using a generalized linear model (R Core Team, 2017) and data from EC Data Explorer, HYDAT (Jan 17, 2018) (https://ec.gc.ca/rhc-wsc/)

**<u>NOTE:</u>**
Flood risk assessments are available for many communities in Newfoundland, including Trout River (Engineering Co. Ltd., 1990) and Parson's Pond (Martec Ltd, 1988).

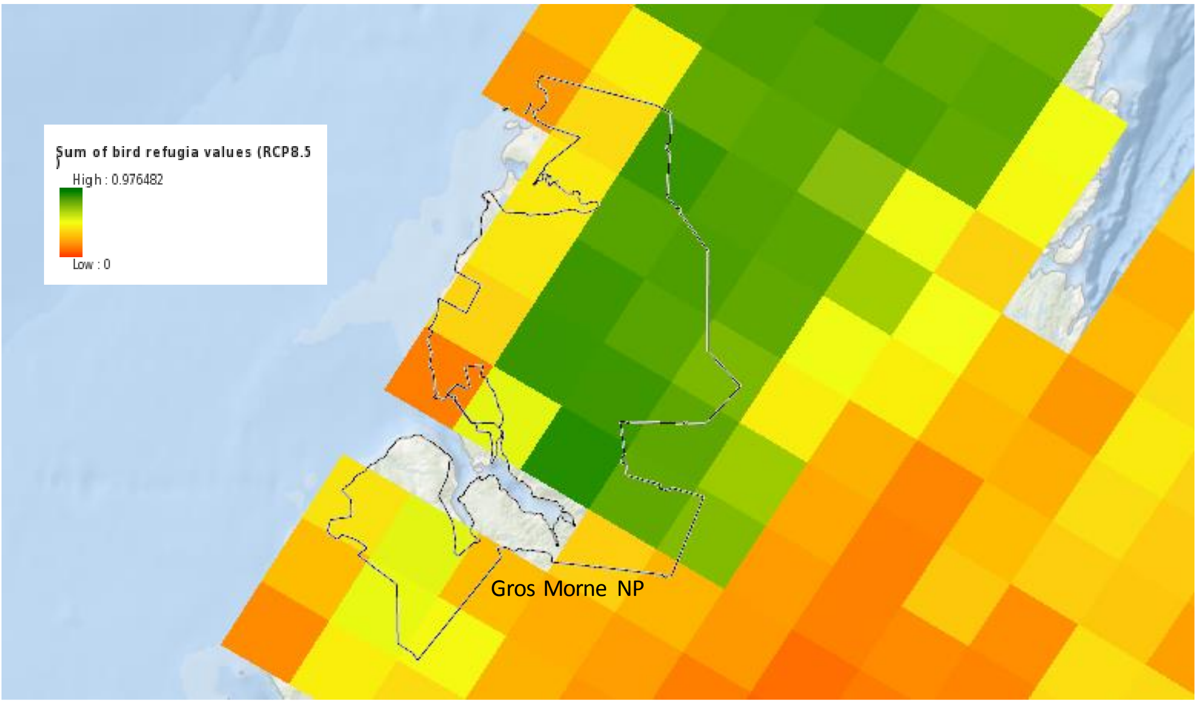
## 3.4 Biodiversity

Conditions, including milder winters and summer drought, may be more favourable for invasive species colonization (Langor *et al.*, 2014; Walther *et al.*, 2009) and for more extensive forest insect and disease outbreaks (e.g., spruce budworm, forest tent caterpillar, gypsy moth) (Warren and Lemmen, 2014; Warren *et al.*, 2013; Weed *et al.*, 2013). Furthermore, introduced animals that currently are restricted in distribution (e.g., Red Squirrel, Eastern Chipmunk, Red Backed Vole, American Toad, Wood Frog and Green Frog in Newfoundland) may increase in numbers and spread to new ecoregions or higher elevations. This may lead to impacts on native species, for example through increased depredation of songbird nests by squirrels and chipmunk (Whitaker *et al.*, 2015).



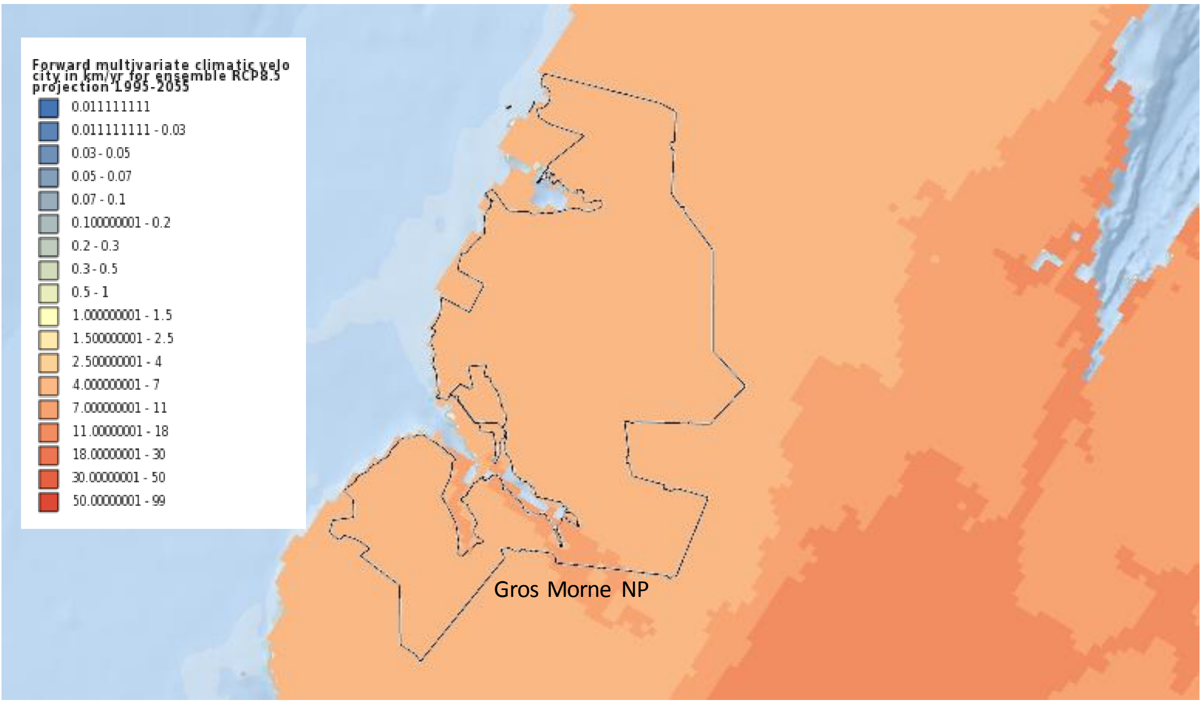

Percentage of projected species turnover (50 km x 50 km grid) relative to current species occurrence, assuming full dispersal (i.e., species can move into new areas) using ten coupled atmosphere-ocean general circulations models (AOGCMS) as in Lawler et al. (2009) and the A2 emission scenario. **Species turnover** is calculated as a composite measure of **species loss** (i.e., % of species currently in a cell whose projected future range does not include the cell) and **species gain** (i.e., % increase in species due to range expansion). Data and analysis discussed further in Lindsay et al. (2016).

**AdaptWest** ([https://adaptwest.databasin.org/](https://adaptwest.databasin.org/)) provides integrative tools that can inform conservation planning, including the following analysis and figure on climate velocity and species exposure to climate change (Stralberg *et al.*, 2018). North American coverage clipped for Gros Morne NP.

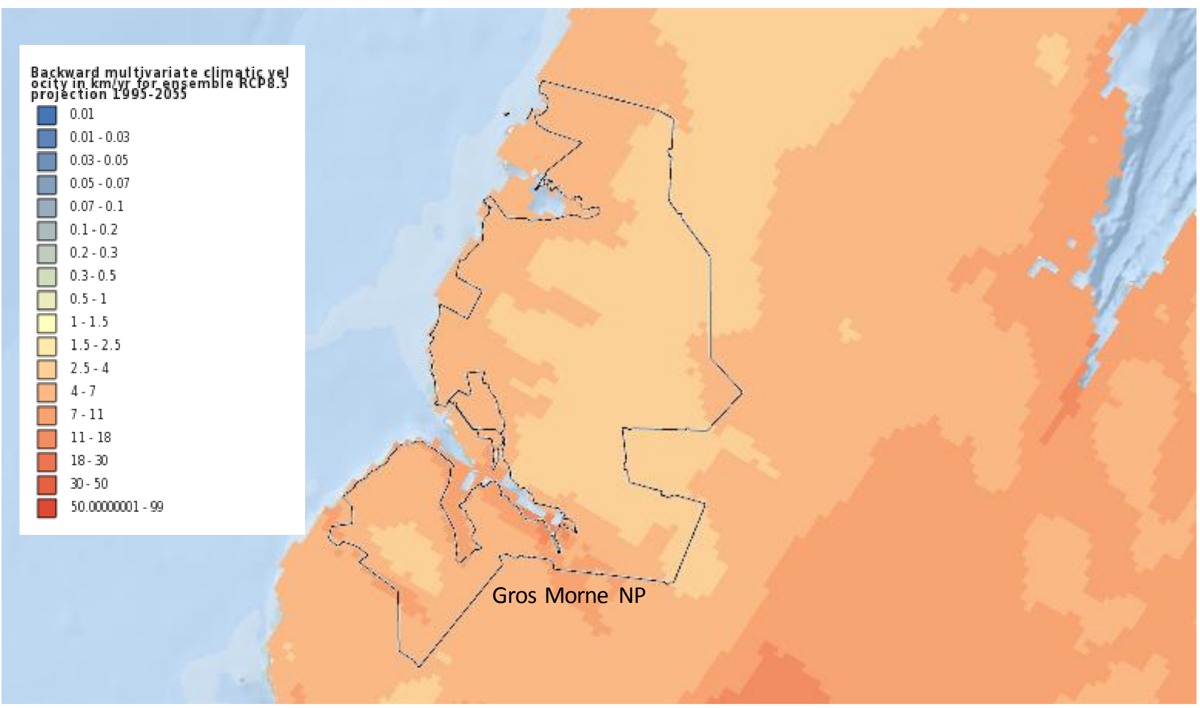



**Projected climate refugia areas for songbird species.** Refugia indices are based on niche-based velocities for individual species derived from Distler *et al.* (2015) for 268 songbirds. The Long Range Mountains appear to have high refugia value.


**Projected climate refugia areas for tree species.** Refugia indices are based on niche-based velocities for individual species derived from McKenney *et al*. (2011) for 324 tree species. Refugia potential for Gros Morne appears low.




**Forward climate velocity (km/yr).** The rate at which an organism in the current landscape has to migrate to maintain constant climate condition. Using RCP 8.5 projected velocities through 2041-2070 are 5-8 km/yr for Gros Morne NP.



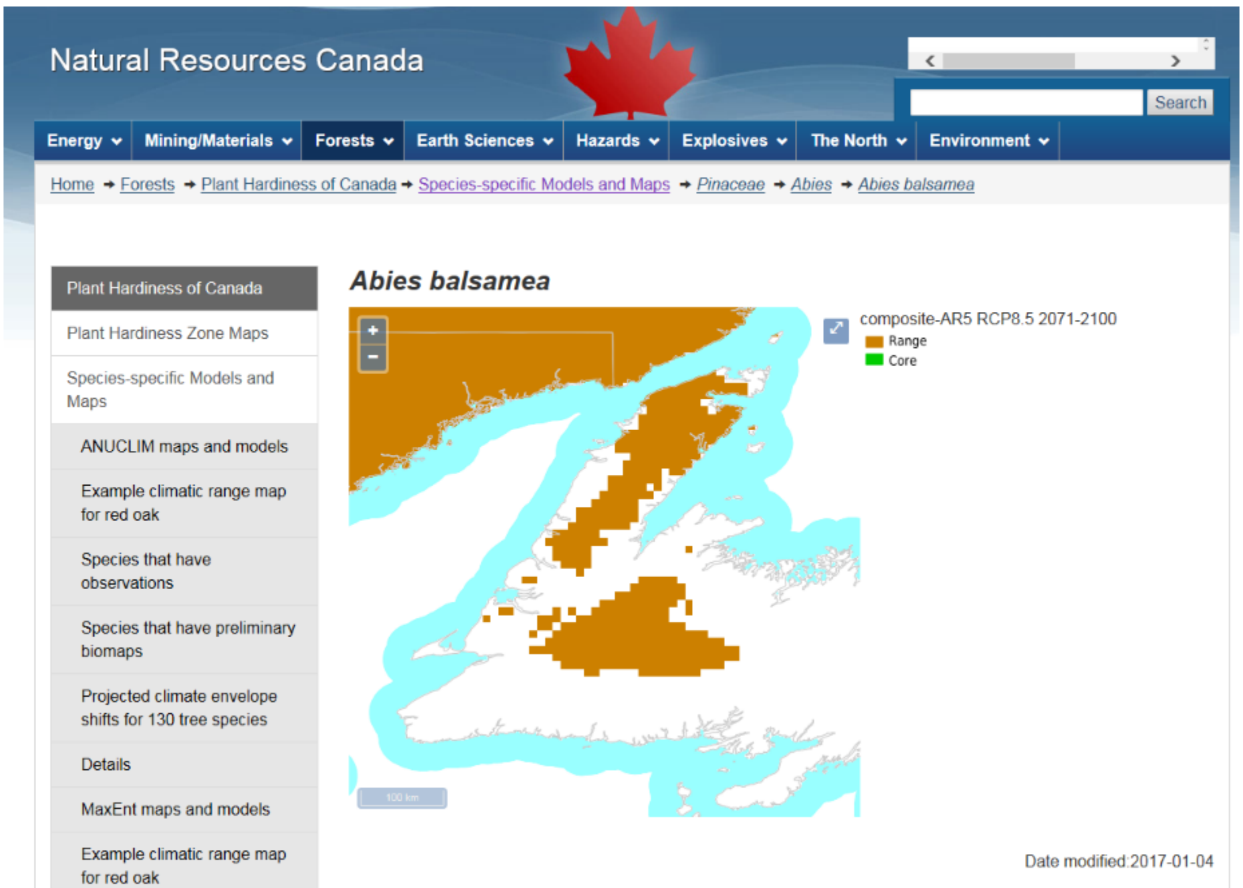

**Backward climate velocity (km/yr).** Given the projected future climate habitat of a grid cell, it is the minimum rate of migration for an organism from equivalent climate conditions to colonize this climate habitat. Using RCP 8.5 projected velocities through 2041-2070 are 3-12 km/yr for Gros Morne NP.

## Plant Hardiness

Plant hardiness is associated with probabilities of plant survival in relation to average, broad scale climatic conditions. As the climate changes, habitat suitability for plant species also changes. Natural Resources Canada maintains a plant hardiness database that includes future projections of plant hardiness (http://www.planthardiness.gc.ca/). A query of this database revealed a future decline in the number of species in the Rocky Harbour area (49.45N, 57.90W), see Table 1.

Table 1. Plant species richness for Rocky Harbour, NL based on plant hardiness projections.

| | 1971-2000 | 2011-2040 | 2041-2070 | 2071-2100 |
|---|---|---|---|---|
| **Full Range** | 813 | 818 | 534 | 392 |
| **Core Range** | 204 | 166 | 97 | 77 |




Balsam fir (*Abies balsamea*) is an example of a species whose core and full range is projected to change. Currently, Rocky Harbour is considered within the core range for this species, but depending on the future scenario it may no longer be within its core range. More models and information for this species are available: http://www.planthardiness.gc.ca/index.pl?m=9b&lang=en&speciesid=1000005.

**Additional Reading on Biodiversity**

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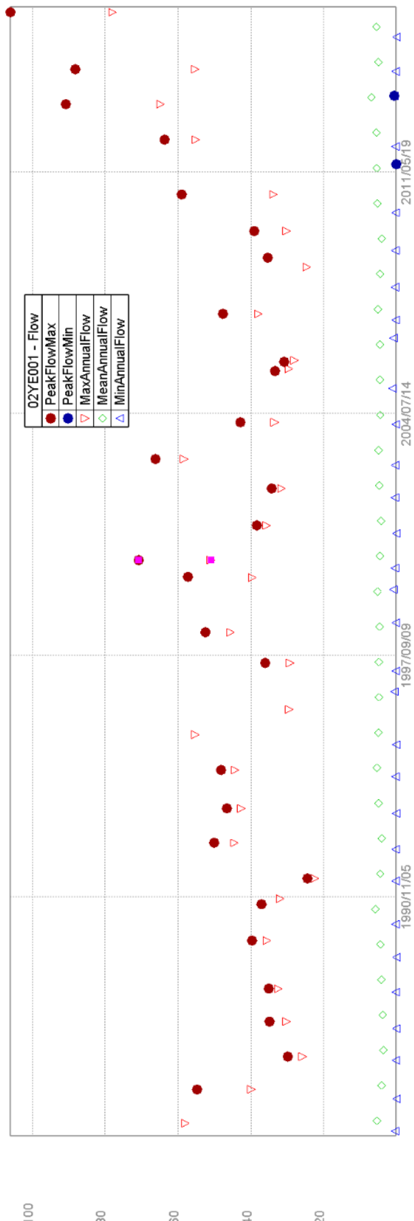
# Appendix 1. Stream Flow Data

Data from EC Data Explorer, HYDAT (Jan 17, 2018) (https://ec.gc.ca/rhc-wsc).

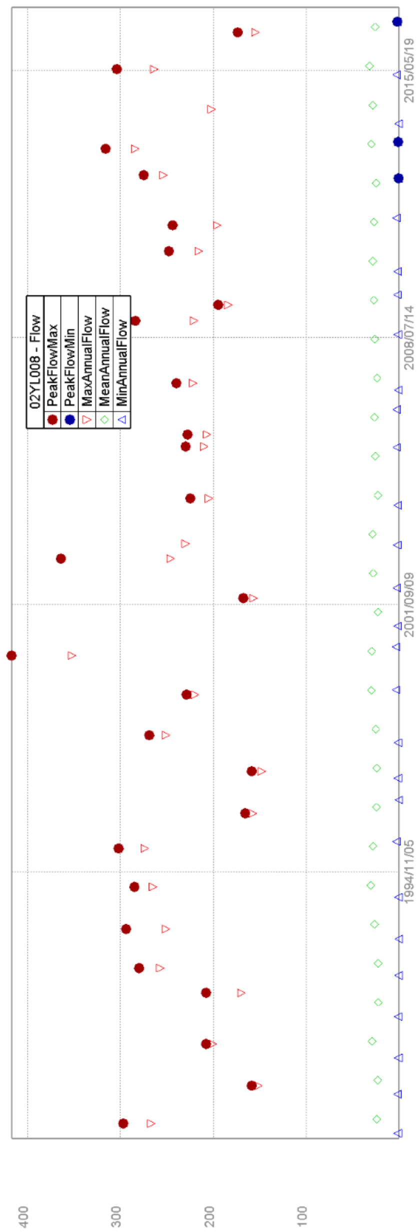
### A. Greavett Brook (02YE001) Annual Flow

| Year | Mean (m³/s) | Min. Month | Min. Day | Min. (m³/s) | Max. Month | Max. Day | Max. (m³/s) |
|---|---|---|---|---|---|---|---|
| 1984 | 5.37 | 3 | 15 | 0.4 | 6 | 3 | 58 |
| 1985 | 4.14 | 2 | 13 | 0.08 | 5 | 20 | 39.9 |
| 1986 | 3.68 | 3 | 19 | 0.279 | 4 | 24 | 25.8 |
| 1987 | 3.83 | 2 | 10 | 0.126 | 4 | 22 | 30.2 |
| 1988 | 4.16 | 2 | 22 | 0.229 | 3 | 28 | 32.5 |
| 1989 | 4.48 | 2 | 17 | 0.105 | 8 | 7 | 35.6 |
| 1990 | 5.82 | 1 | 25 | 0.34 | 10 | 15 | 32 |
| 1991 | 4.52 | 4 | 18 | 0.29 | 5 | 13 | 22.5 |
| 1992 | 4.13 | 3 | 9 | 0.334 | 5 | 15 | 44.5 |
| 1993 | 4.99 | 3 | 15 | 0.17 | 5 | 7 | 42.6 |
| 1994 | 5.43 | 4 | 2 | 0.355 | 6 | 8 | 44.4 |
| 1995 | 5 | 2 | 25 | 0.178 | 6 | 9 | 55.3 |
| 1996 | 4.84 | 8 | 29 | 0.616 | 2 | 26 | 29.5 |
| 1997 | 4.85 | 3 | 29 | 0.238 | 6 | 20 | 29.3 |
| 1998 | 4.68 | 8 | 9 | 0.241 | 5 | 4 | 45.6 |
| 1999 | 5.3 | 7 | 20 | 0.909 | 11 | 22 | 39.6 |
| 2000 | 4.62 | 2 | 27 | 0.558 | 5 | 19 | 51 |
| 2001 | 4.28 | 2 | 19 | 0.121 | 5 | 13 | 35.7 |
| 2002 | 4.77 | 2 | 26 | 0.552 | 5 | 31 | 31.6 |
| 2003 | 4.99 | 1 | 26 | 0.44 | 4 | 1 | 58.3 |
| 2004 | 4.53 | 3 | 25 | 0.253 | 4 | 15 | 33.5 |
| 2005 | 4.62 | 4 | 2 | 1.12 | 10 | 22 | 29.6 |
| 2006 | 4.65 | 9 | 4 | 0.927 | 1 | 17 | 28 |
| 2007 | 5.18 | 3 | 10 | 0.308 | 5 | 12 | 38 |
| 2008 | 4.59 | 2 | 13 | 0.44 | 9 | 7 | 24.7 |
| 2009 | 4.09 | 2 | 27 | 0.38 | 9 | 16 | 30.2 |
| 2010 | 5.3 | 3 | 26 | 0.33 | 9 | 30 | 33.8 |
| 2011 | 5.5 | 8 | 8 | 0.168 | | | |
| 2012 | 5.55 | 2 | 8 | 0.385 | 4 | 18 | 55.1 |
| 2013 | 6.95 | 7 | 17 | 0.726 | 4 | 21 | 64.8 |
| 2014 | 4.99 | 3 | 26 | 0.283 | 4 | 17 | 55.3 |
| 2015 | 5.57 | 3 | 16 | 0.07 | 11 | 28 | 78 |

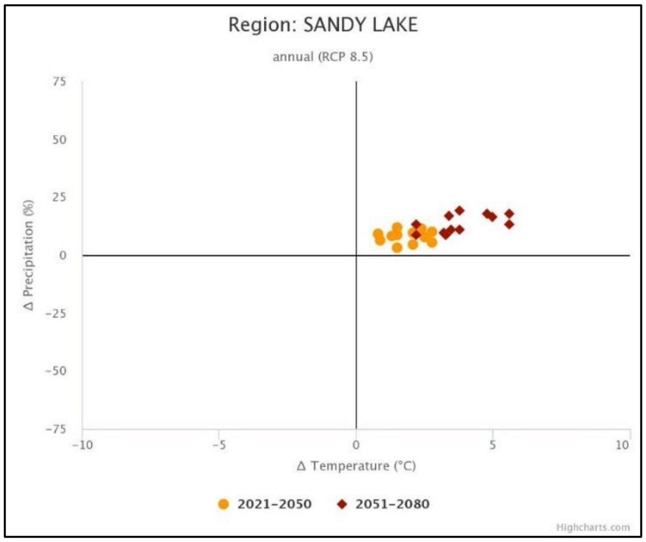


**B. Upper Humber River (02YL008) Annual Flow**

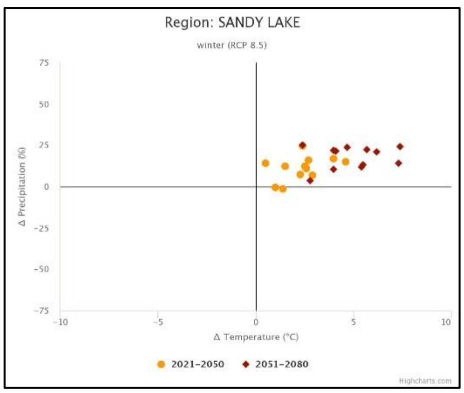
| Year | Mean (m³/s) | Min. Month | Min. Day | Min. (m³/s) | Max. Month | Max. Day | Max. (m³/s) |
|---|---|---|---|---|---|---|---|
| 1988 | 24.7 | 2 | 20 | 2.3 | 5 | 22 | 267 |
| 1989 | 23.7 | 2 | 21 | 2.4 | 5 | 10 | 152 |
| 1990 | 29.7 | 1 | 26 | 1.58 | 6 | 5 | 201 |
| 1991 | 23.1 | 2 | 16 | 1.63 | 9 | 27 | 170 |
| 1992 | 23.2 | 3 | 7 | 1.18 | 5 | 15 | 257 |
| 1993 | 27.1 | 2 | 12 | 1.21 | 5 | 17 | 251 |
| 1994 | 30.9 | 3 | 10 | 1.48 | 6 | 15 | 265 |
| 1995 | 28.8 | 8 | 13 | 3.67 | 6 | 9 | 274 |
| 1996 | 25 | 9 | 6 | 0.975 | 5 | 3 | 158 |
| 1997 | 24.5 | 3 | 27 | 2.11 | 6 | 2 | 148 |
| 1998 | 25.7 | 2 | 25 | 2.08 | 5 | 5 | 251 |
| 1999 | 30.6 | 7 | 4 | 4.11 | 5 | 20 | 220 |
| 2000 | 30 | 8 | 9 | 3.93 | 5 | 20 | 352 |
| 2001 | 23.5 | 2 | 20 | 2.32 | 11 | 8 | 157 |
| 2002 | 28.5 | 2 | 13 | 3.18 | 11 | 13 | 246 |
| 2003 | 29.2 | 3 | 20 | 2.88 | 4 | 2 | 230 |
| 2004 | 23.5 | 3 | 26 | 2.4 | 5 | 30 | 205 |
| 2005 | 26.2 | 9 | 20 | 3.42 | 9 | 28 | 210 |
| 2006 | 27.1 | 9 | 9 | 3.35 | 1 | 17 | 207 |
| 2007 | 24.3 | 3 | 10 | 1.92 | 5 | 13 | 222 |
| 2008 | 26.8 | 8 | 12 | 2.14 | 12 | 17 | 221 |
| 2009 | 27.7 | 8 | 18 | 2.69 | 5 | 16 | 184 |
| 2010 | 28.7 | 3 | 24 | 2.45 | 9 | 30 | 216 |
| 2011 | 27.5 | 8 | 8 | 3.56 | 5 | 31 | 196 |
| 2012 | 25.3 | 8 | 12 | 1.32 | 9 | 11 | 254 |
| 2013 | 30.5 | 7 | 19 | 1.77 | 5 | 15 | 284 |
| 2014 | 28.9 | 1 | 6 | 1.32 | 5 | 20 | 202 |
| 2015 | 32.6 | 4 | 9 | 3.33 | 6 | 1 | 264 |
| 2016 | 26.4 | 8 | 17 | 2.68 | 5 | 10 | 155 |



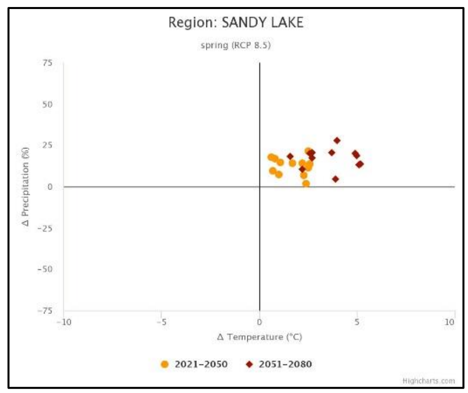
# Appendix 2. Model Scatterplots for Temperature and Precipitation



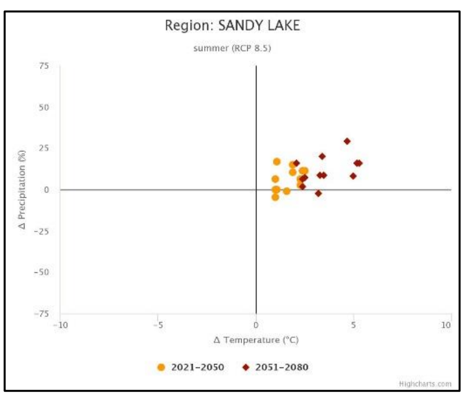

Annual



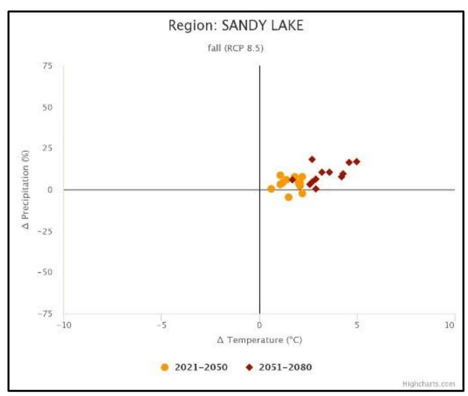

Winter




Spring




Summer




Autumn

**Climate models for Gros Morne area (10km x 10km grid).** Each point represents a single model-simulated temperature/precipitation response to the RCP 8.5 scenario. Statistically downscaled data (Bias Corrected Spatial Disaggregation; BCSD) derived from 12 CMIP5 global climate models: ACCESS1.0, CanESM2, CCSM4, CNRM-CM5, CSIRO-Mk3-6.0, GFDL-ESM2G, HadGEM2-CC, HadGEM2-LR, INM-CM4, MPI-ESM-LR, MRI-CGCM3, MIROC5 (PCIC, 2014). Figure source: Climate Atlas of Canada, https://climateatlas.ca/