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# DRAFT
# Supplemental Climate Information for Terra Nova National Park


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# Contents

# Preface

This is a supplement to the "Let's Talks about Climate Change: Atlantic Region" (Parker, 2017) report and is intended to support climate change discussions at Terra Nova National Park.

Future climate projections are modelled with several different 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 to rise "status quo" throughout the 21$^{st}$ century. We are currently tracking RCP 8.5.

This is a site focussed document and to understand the larger climate change context please review Canada's Changing Climate assessment reports (http://www.nrcan.gc.ca/environment/impacts-adaptation/10029) and the Intergovernmental Panel on Climate Change assessment reports (e.g., IPCC, 2014). With respect to adaptation options, review Gross *et al.* (2016), Parker *et al.* (2018), or Rockman *et al.* (2016).

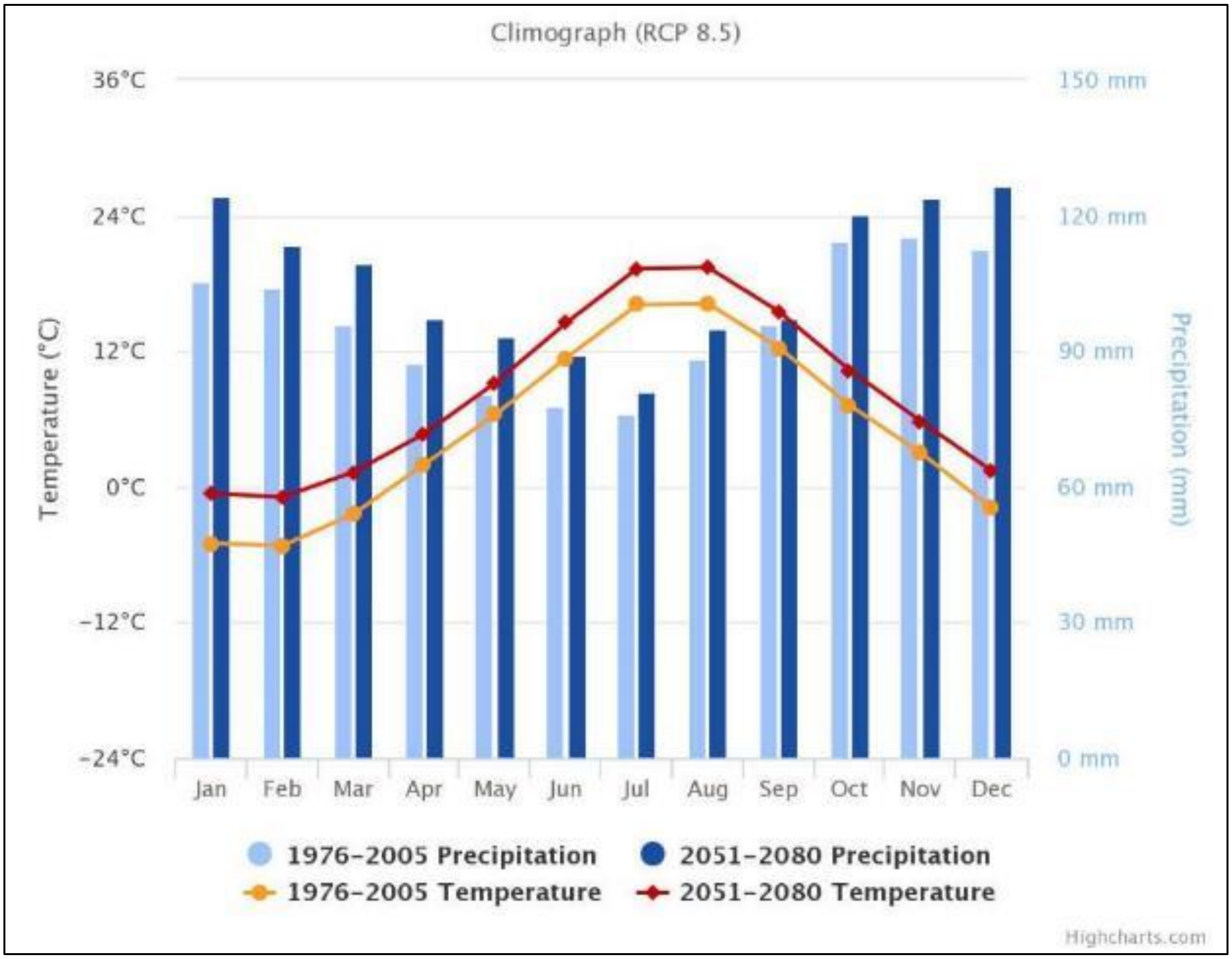

***Disclaimer***

Views, statements, findings and conclusions are solely those of the authors and do not necessarily reflect the views and policies of Parks Canada. Although the authors have made every effort to ensure that the information is accurate, complete and correct, neither Parks Canada nor the authors can guarantee its integrity. Readers are encouraged to verify with original sources.

# Highlights

Projected to become warmer, wetter and stormier (e.g., Finnis and Daraio, 2018).

- Mean annual air temperatures by 0.75˚C since 1937. Compared to other areas in Canada, this a relatively modest increase. Spring temperatures have increased the most.
- The warming trend is projected to continue by 2 - 6˚C by 2100.
- Total annual precipitation has increased by 37% since 1937. The relative increase in snow has been greater than that for rain.
- Today's "one in 100 year" rainfall event (i.e., 34 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 48 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 66 to 97 cm will be required by 2100.
- AMEC (2012) provides a review of climate monitoring in Newfoundland.

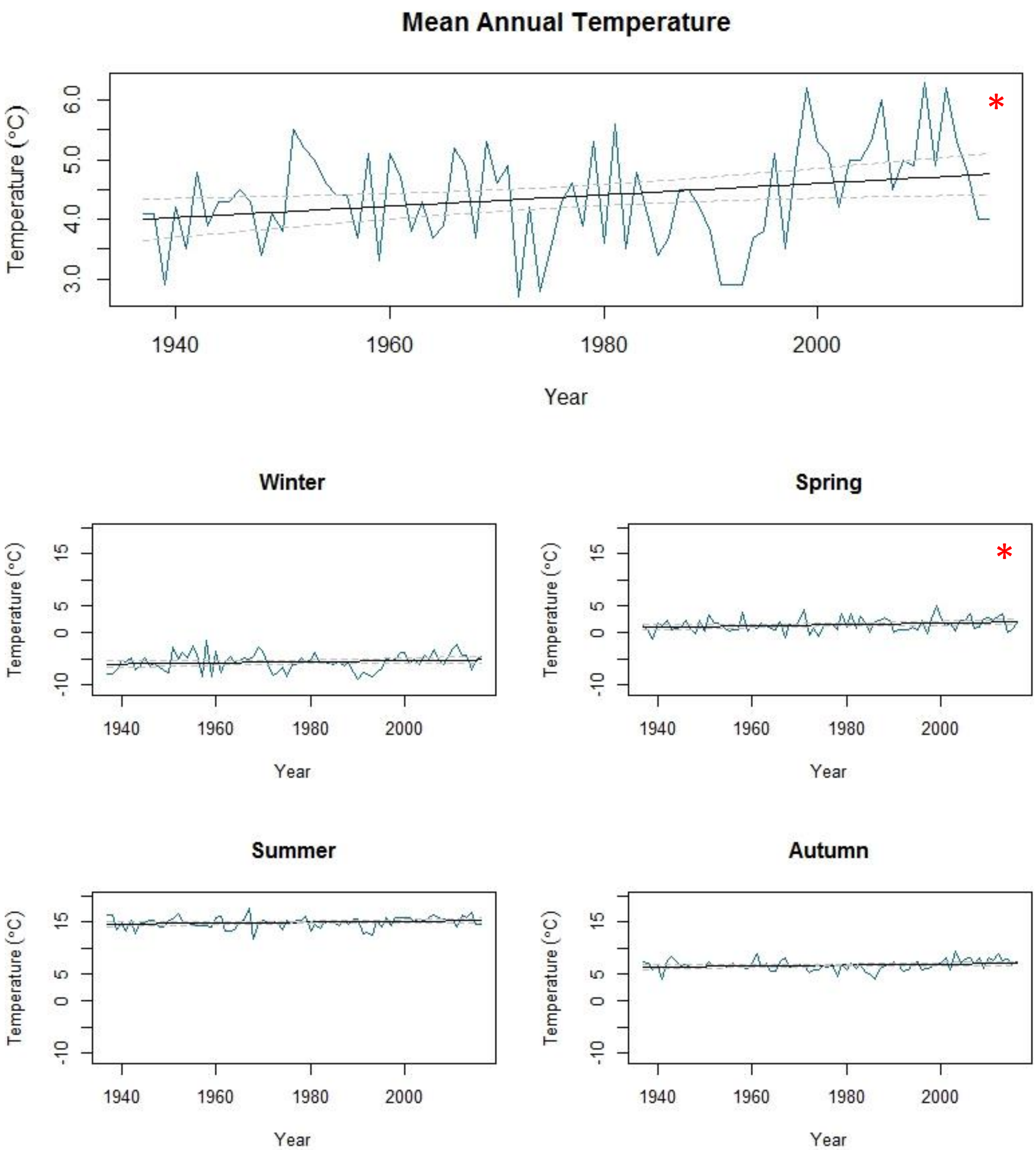



**Climograph for the Bonavista region**. Modelled monthly mean temperature and total precipitation for the 1976-2005 baseline and 2051-2080 future projection (RCP 8.5). Figure source: Climate Atlas of Canada (https://climateatlas.ca/).

# 1. Historic Climate

## 1.1 Temperature

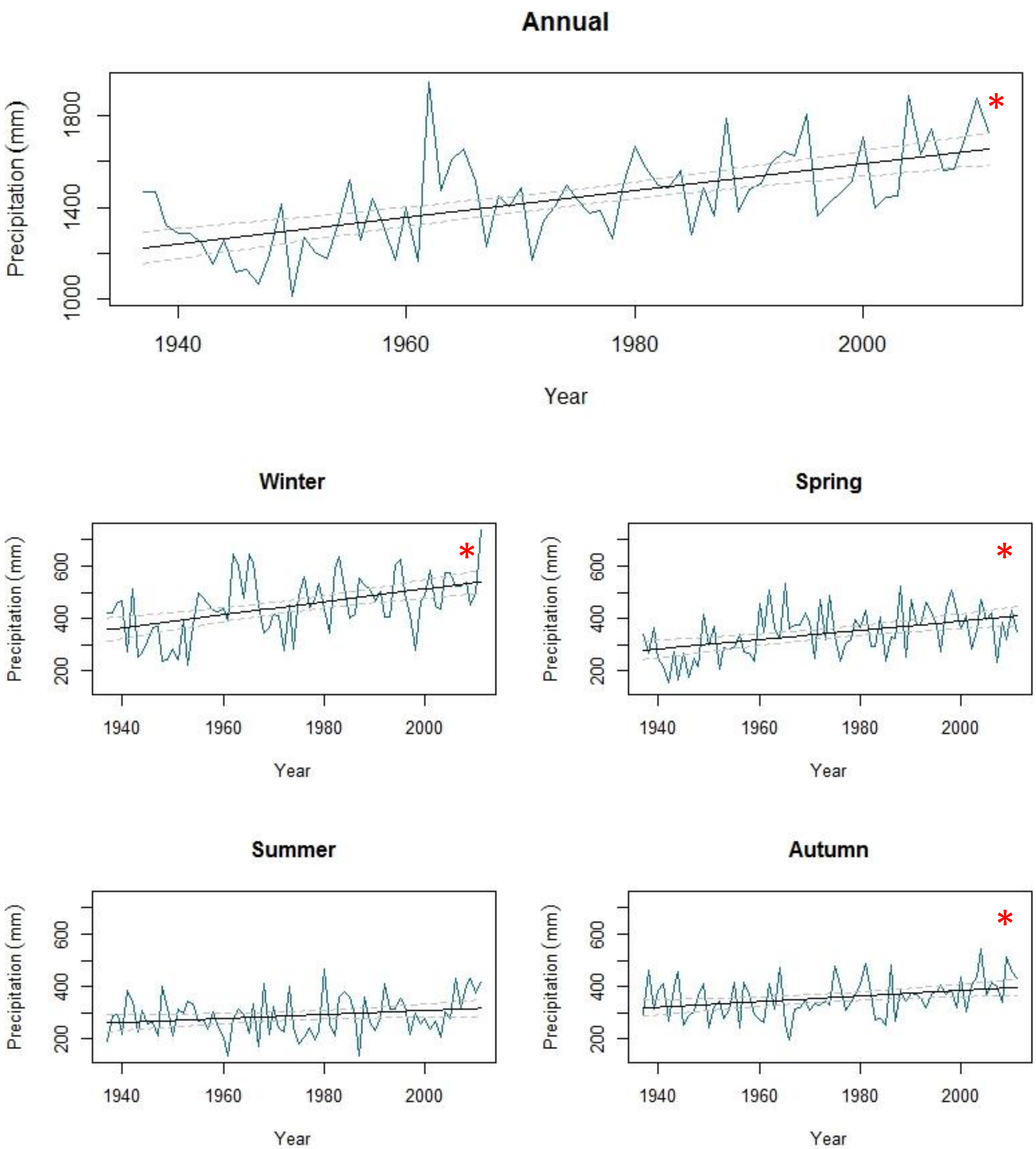
Gander (8401703) is the closest meteorological station with long term temperature data (ECCC, 2017). Trends from 1937 to 2016 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend ($P<0.05$).



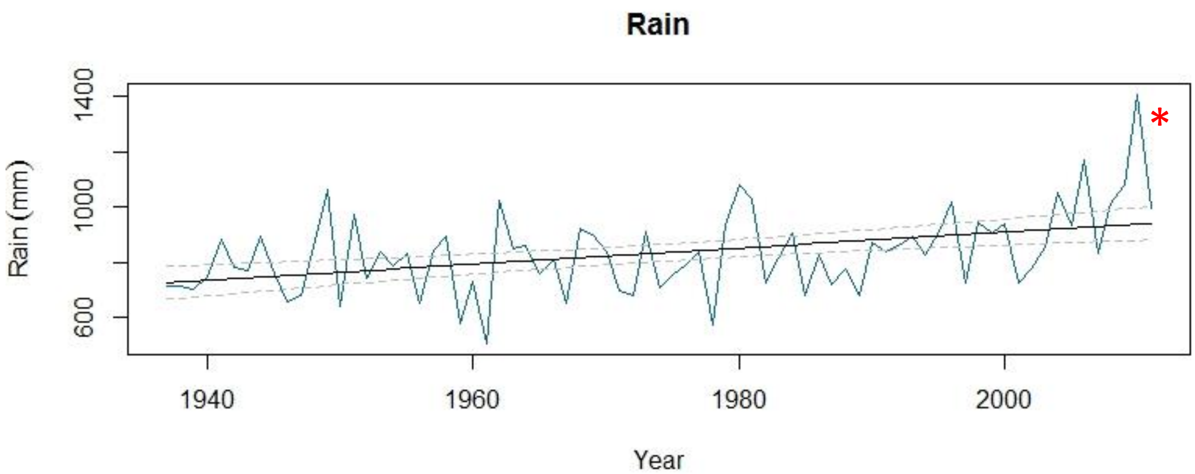

**Gander mean annual and seasonal temperature**. A statistically significant ($P<0.05$) increase observed in mean annual and spring (Mar, Apr, May) temperatures. Mean annual temperature has increased by ~0.75°C since 1937.

## 1.2 Precipitation

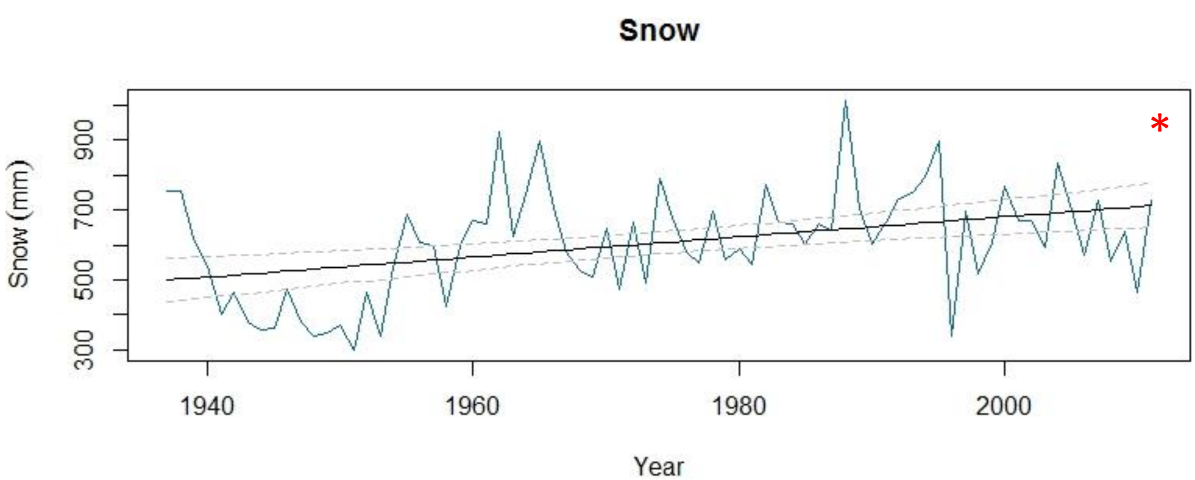
Gander (8401700 ) is the closest meteorological station with long term precipitation data (ECCC, 2017). Trends from 1937 to 2011 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend ($P<0.05$).




**Gander total annual and seasonal precipitation.** Total annual precipitation demonstrated a statistically significant increase ($P<0.05$), ~459 mm (37%) since 1937. All seasons except summer (Jun, Jul, Aug) demonstrated a statistically significant ($P<0.05$) increase, the greatest being observed for winter, ~194 mm (55%).



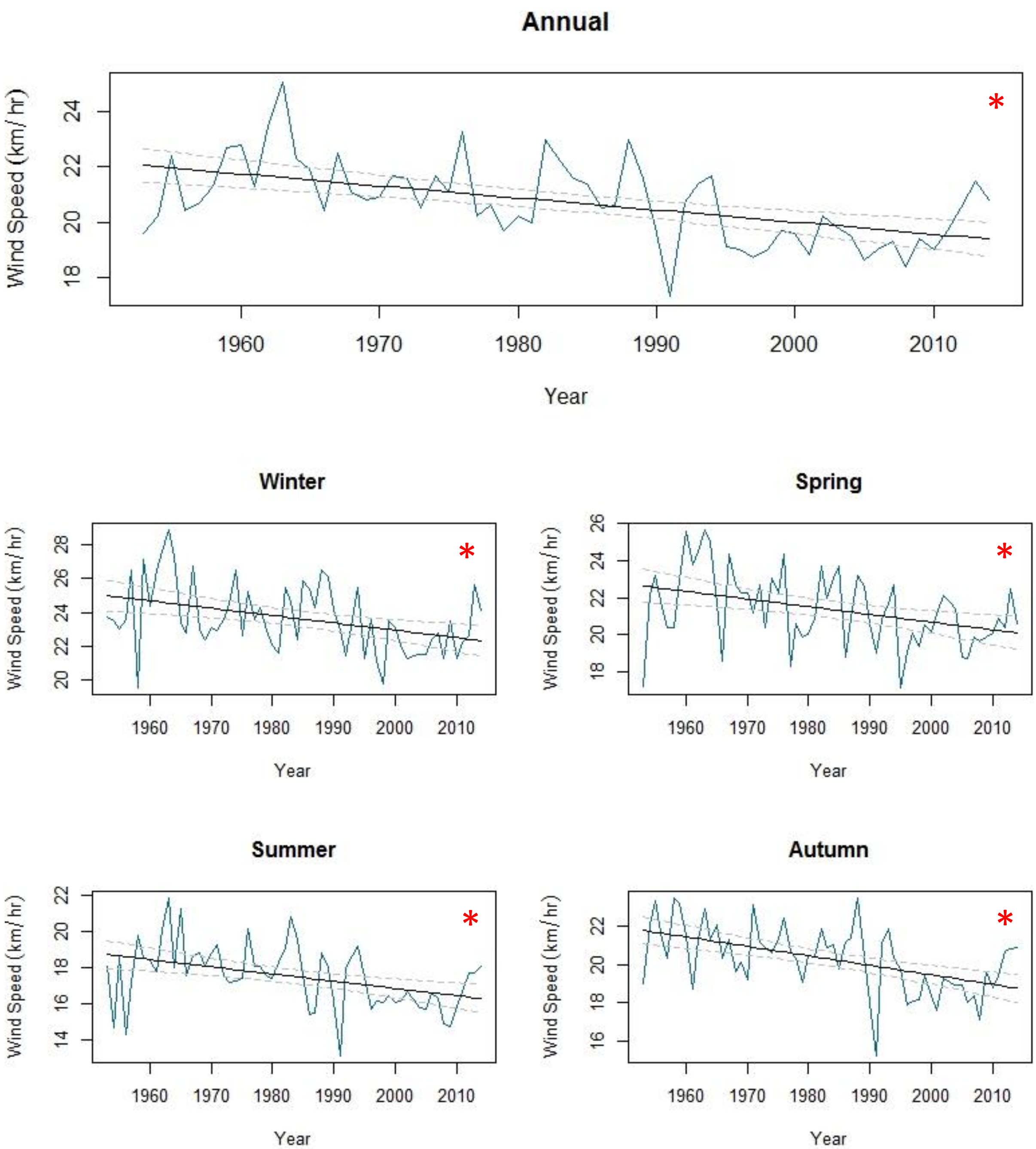

**Gander total annual rain** demonstrated a statistically significant (P<0.05) increase since 1937, ~230 mm (32%).




**Gander total annual snow** demonstrated a statistically significant (P<0.05) increase since 1937, ~227 mm (46%).

## 1.3 Surface Wind Speed

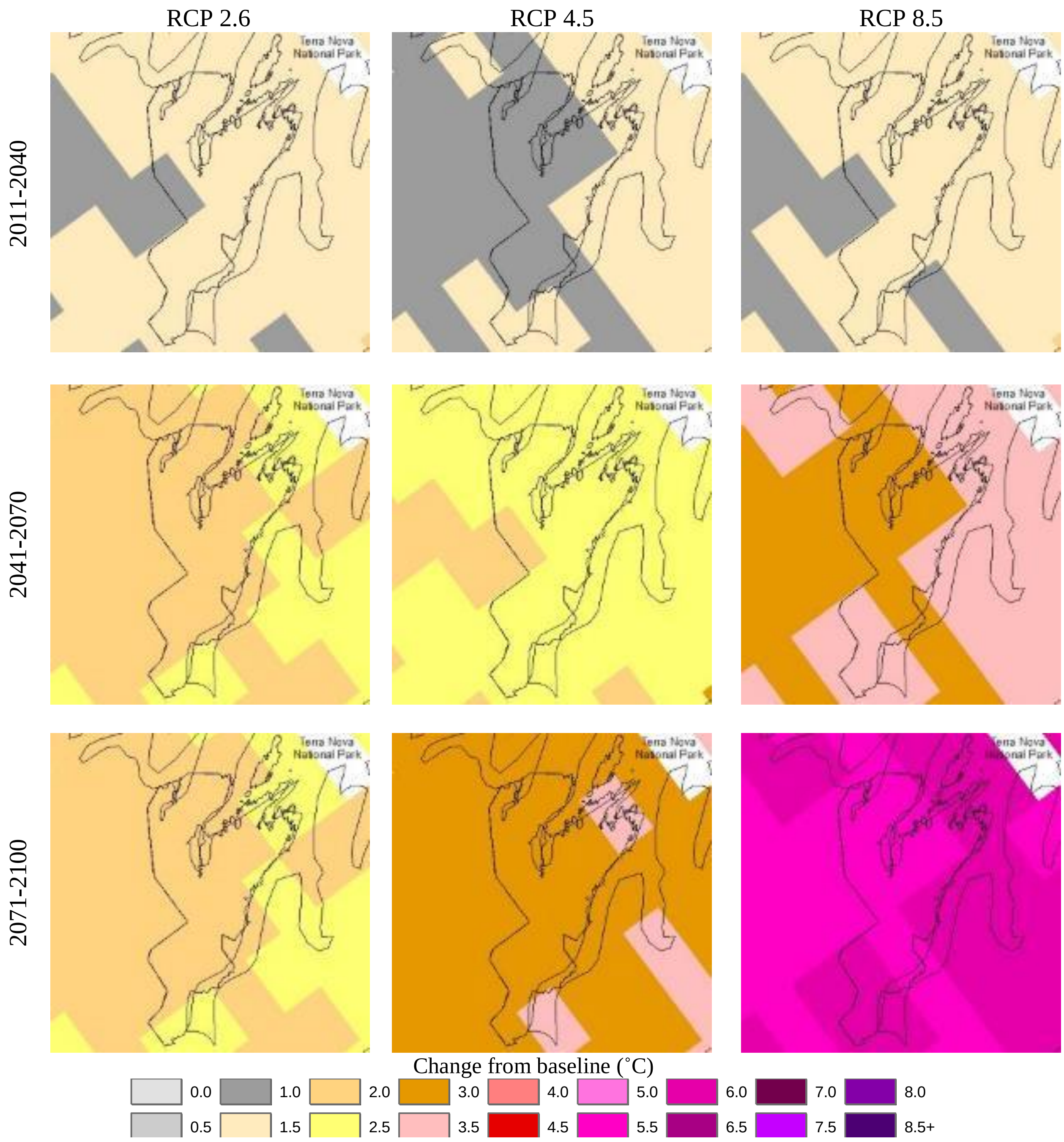
Gander (8401700) is the closest meteorological station with long term wind data (ECCC, 2017). Trends from 1953 to 2014 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).



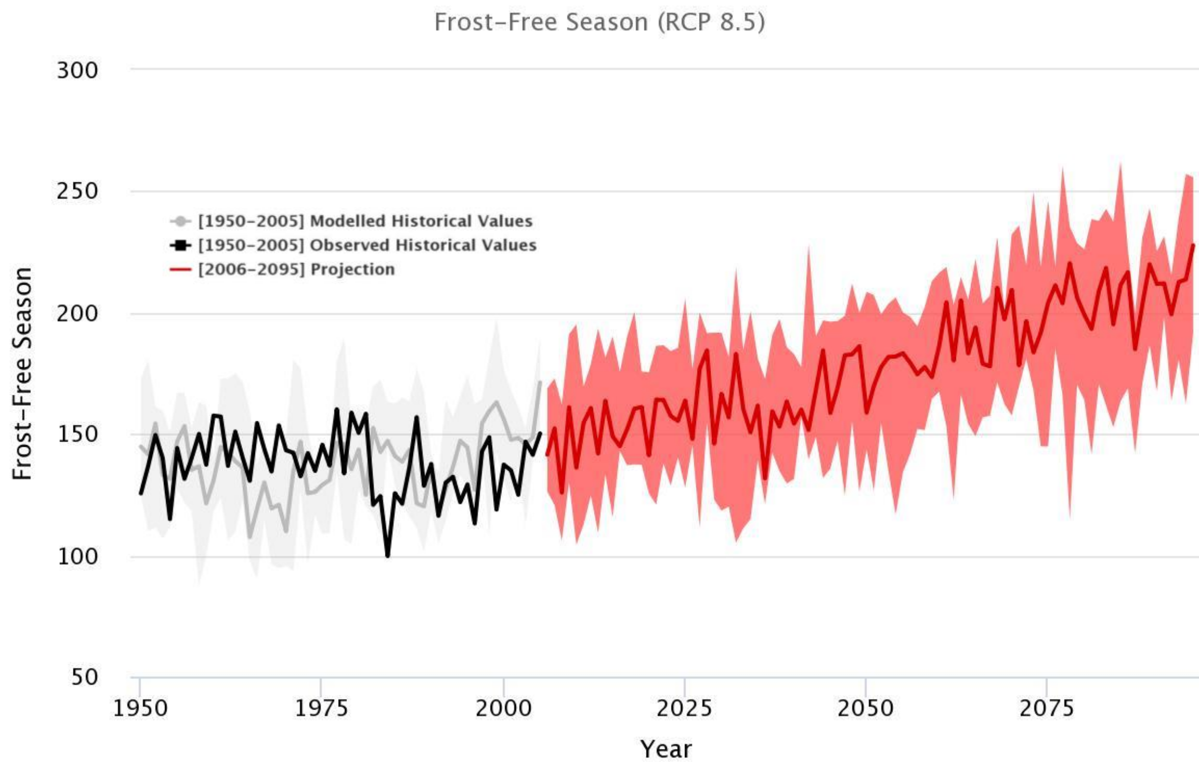

**Gander mean annual and seasonal wind speeds**. Mean annual wind speeds have demonstrated a statistically significant (P<0.05) decrease, -2.8 km/hr (-13%) since 1953. All seasons have demonstrated a statistically significant (P<0.05) decrease, the greatest being observed for autumn, -3.1 km/hr (-14%) since 1953.

# 2. Projected Climate Trends

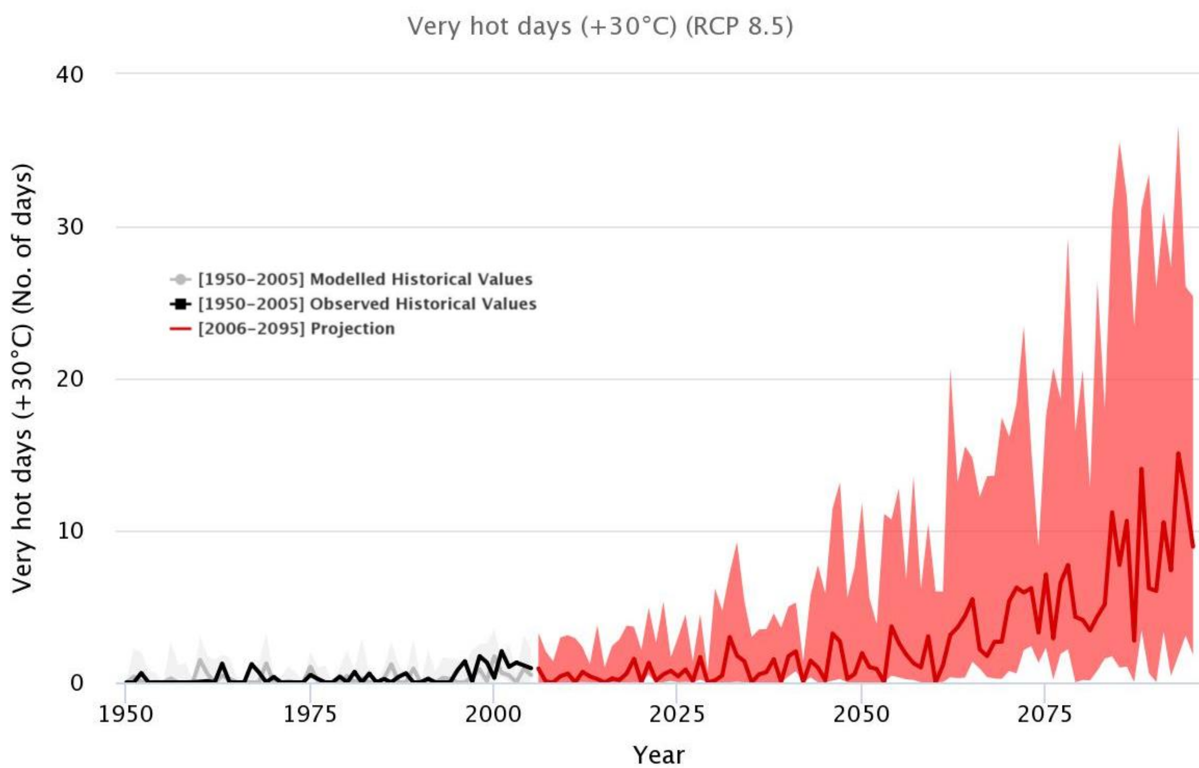
## 2.1 Temperature




**Projected mean annual temperature increase for Terra Nova 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). Depending on the RCP scenario and location, mean annual temperatures are projected to increase 2.0 to 6.0 °C by 2071-2100.

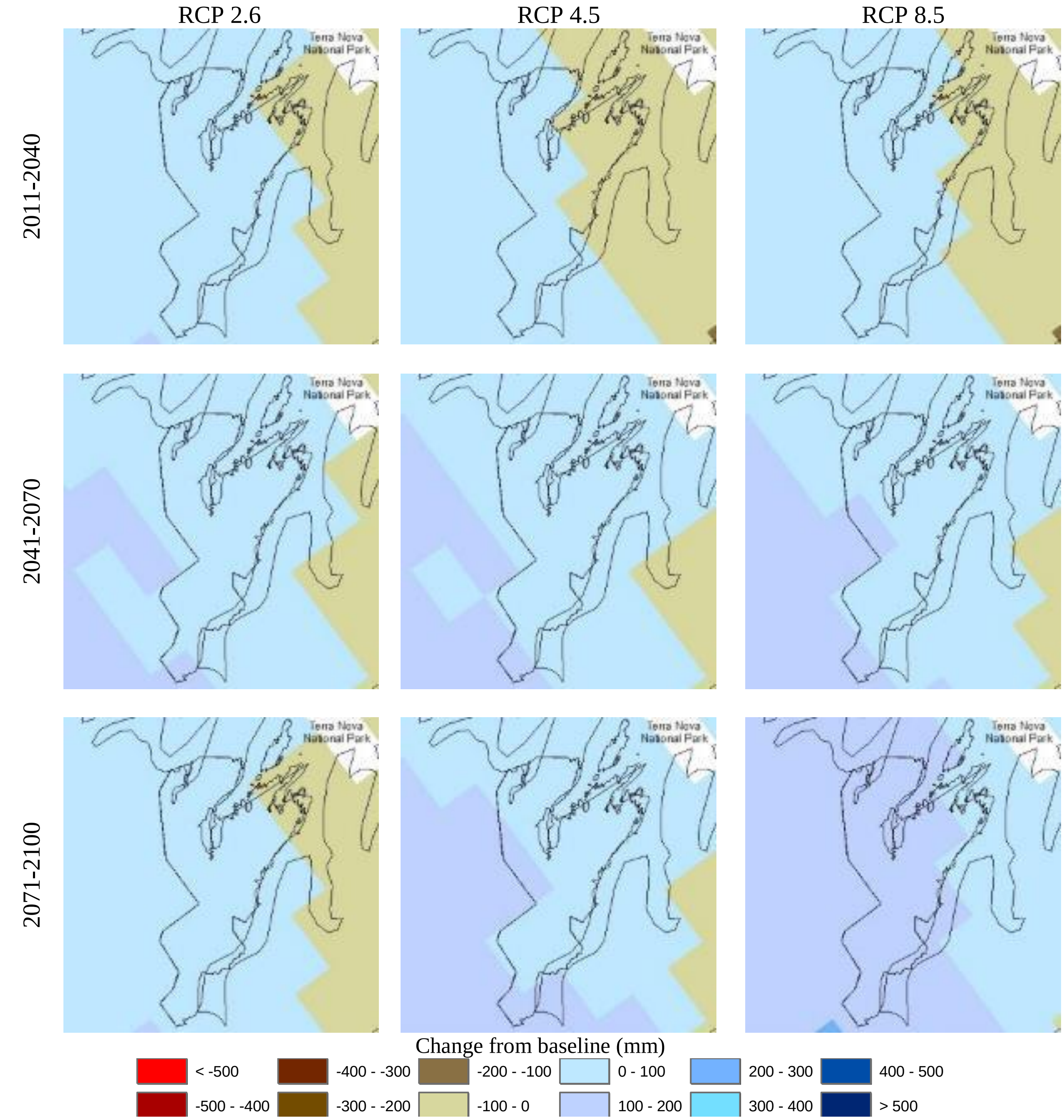



**The frost-free season (days) for the Bonavista region** is projected to increase by 48.6 days by 2051-2080. Figure source: Climate Atlas of Canada (https://climateatlas.ca/).




**Very hot days (+30˚C) for the Bonavista region** are projected to increase from 0.3 days/year for the 1976-2005 mean to 3.4 days/year by 2051-2080. Figure source: Climate Atlas of Canada (https://climateatlas.ca/).

## 2.2 Precipitation




**Projected total annual precipitation change for Terra Nova 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). Depending on the RCP scenario and location, total annual precipitation is projected to increase 0 to 150 mm by 2071-2100.

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

The rainfall IDF values in the following tables are calculated with IDF_CC Tool 3.0 (http://www.idf-cc-uwo.ca/) using Generalized Extreme Values (Simonovic *et al.*, 2017).

**Baseline** total precipitation amounts (mm) for Gander from 1939-2009.

| T (years) | 2 | 5 | 10 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|
| 5 min | 4.30 | 6.13 | 7.49 | 9.40 | 10.98 | 12.68 |
| 10 min | 6.27 | 8.84 | 10.72 | 13.32 | 15.44 | 17.69 |
| 15 min | 7.55 | 10.71 | 13.00 | 16.16 | 18.69 | 21.39 |
| 30 min | 9.87 | 14.03 | 17.31 | 22.15 | 26.33 | 31.06 |
| 1 h | 12.94 | 17.34 | 20.71 | 25.56 | 29.64 | 34.15 |
| 2 h | 17.83 | 23.16 | 27.17 | 32.84 | 37.54 | 42.67 |
| 6 h | 29.64 | 37.78 | 43.48 | 51.05 | 56.95 | 63.06 |
| 12 h | 38.36 | 48.39 | 55.09 | 63.64 | 70.04 | 76.43 |
| 24 h | 45.52 | 59.05 | 68.84 | 82.23 | 92.97 | 104.35 |

Projected (2050-2100) precipitation (mm) for Gander using an ensemble of models and **RCP 4.5**.

| T (years) | 2 | 5 | 10 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|
| 5 min | 5.33 | 7.56 | 9.12 | 11.57 | 13.66 | 15.52 |
| 10 min | 7.76 | 10.91 | 13.07 | 16.43 | 19.28 | 21.62 |
| 15 min | 9.33 | 13.21 | 15.85 | 19.95 | 23.37 | 26.11 |
| 30 min | 12.22 | 17.28 | 21.02 | 27.04 | 32.68 | 38.21 |
| 1 h | 16.00 | 21.40 | 25.23 | 31.35 | 36.77 | 41.94 |
| 2 h | 22.05 | 28.61 | 33.15 | 40.36 | 46.59 | 52.35 |
| 6 h | 36.62 | 46.72 | 53.17 | 63.22 | 70.86 | 76.91 |
| 12 h | 47.34 | 59.86 | 67.45 | 79.12 | 87.35 | 92.97 |
| 24 h | 56.28 | 72.98 | 84.09 | 101.51 | 115.59 | 127.56 |

Projected (2050-2100) precipitation (mm) for Gander using an ensemble of models and **RCP 8.5**.

| T (years) | 2 | 5 | 10 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|
| 5 min | 5.90 | 8.50 | 10.53 | 13.31 | 15.66 | 18.16 |
| 10 min | 8.60 | 12.26 | 15.09 | 18.93 | 22.01 | 25.46 |
| 15 min | 10.34 | 14.85 | 18.31 | 22.98 | 26.64 | 30.74 |
| 30 min | 13.51 | 19.46 | 24.27 | 31.04 | 37.06 | 43.54 |
| 1 h | 17.74 | 24.07 | 29.16 | 36.20 | 42.20 | 48.58 |
| 2 h | 24.47 | 32.17 | 38.33 | 46.76 | 53.71 | 60.83 |
| 6 h | 40.71 | 52.46 | 61.54 | 73.50 | 81.00 | 88.35 |
| 12 h | 52.70 | 67.19 | 78.13 | 91.19 | 99.26 | 106.40 |
| 24 h | 62.48 | 81.99 | 97.27 | 117.72 | 132.90 | 147.48 |

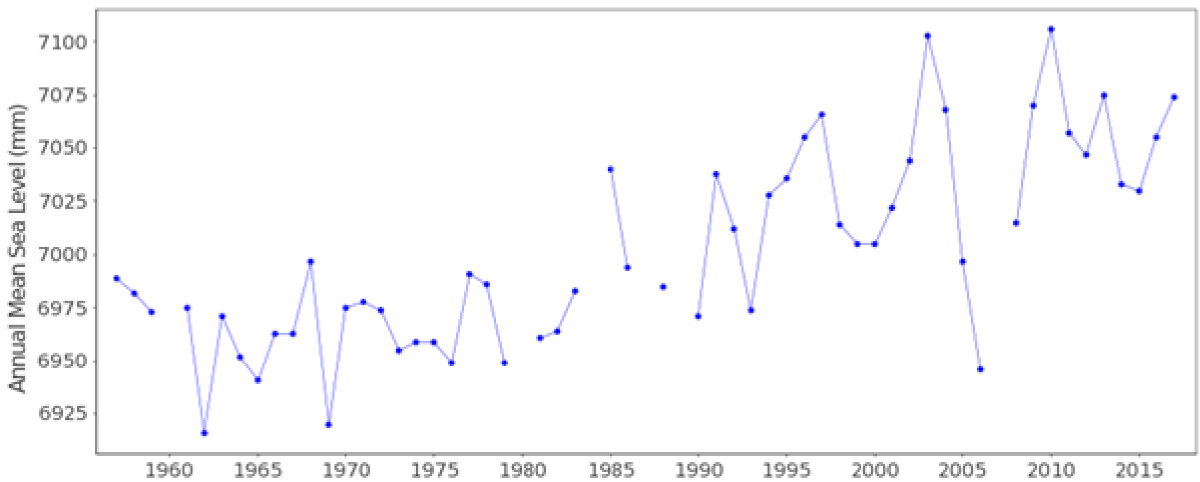
**Gander, NL IDF observations and projections.** Today's "one in 100 year" rainfall event (i.e., 34.15 mm/hr) is projected to be closer to a "one in 25 year" event by 2050-2100 for both RCP scenarios and the future "one in 100 year" rainfall event is projected to increase in intensity (i.e., between 41.94 – 48.58 mm/hr).

- IDF curves for stations around Newfoundland and Labrador were recently revised by Conestoga-Rovers & Associates (CRA, 2015). The station at Gander showed a positive increase in values.
- The Climate Atlas of Canada (https://climateatlas.ca/) projects that for Gander the number of heavy precipitation (>20mm) days/year will increase from the 1976-2005 baseline of 7.8 days to 10.1 days by 2051-2080. For the Bonavista region an increase of 9.1 to 11.5 days is projected.

- Glovertown is included in the Hurricane Season Flood Alert System (HSFAS). The Water Resources Management Division correlates the HSFAS Alerts from AMEC Environment & Infrastructure with water flow rates in the province's river systems. This information is sent to Fire and Emergency Services NL who then alert the affected communities and coordinate responses (e.g., 60 mm / 12 hrs is a 1 in 20 year event, 75 mm / 12 hrs is a 1 in 100 year event for the Terra Nova River). Flood risk mapping is available for Glovertown (ShawMont Newfoundland Limited, 1989).

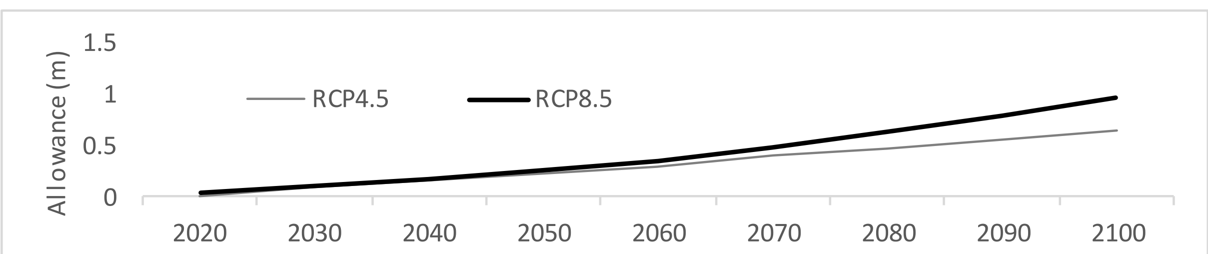
# 3. Climate Change Impacts

## 3.1 Relative Sea Level Rise



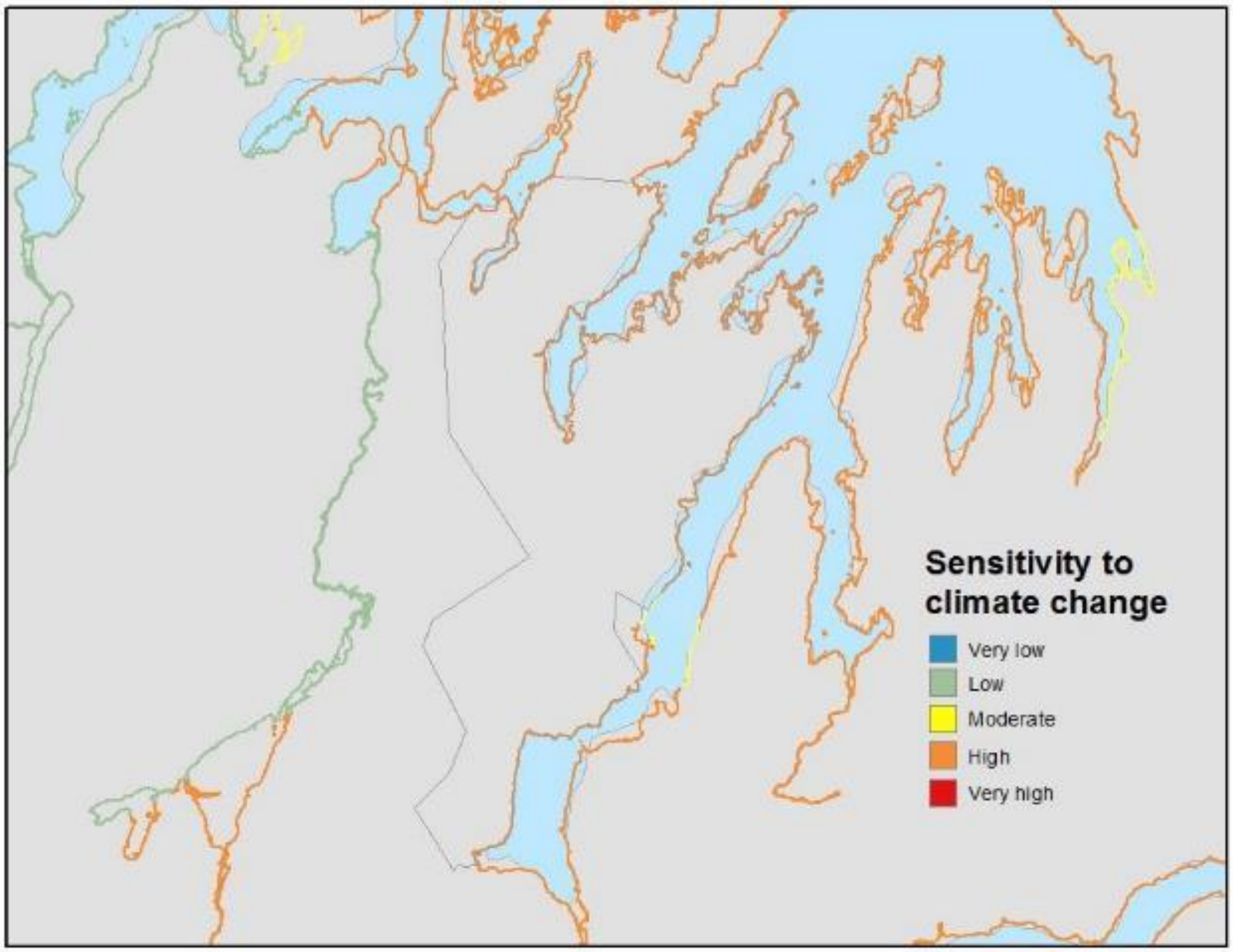

St. John's, NL annual mean sea level. Data source: PSMSL http://www.psmsl.org/data/obtaining/stations/393.php.

Vertical allowance for St. John's, NL acquired from the Canadian Extreme Water Level Adaptation Tool (CAN-EWLAT, http://www.bio.gc.ca/science/data-donnees/index-en.php). The 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.




St. John's, NL projected vertical allowance of 66 to 97 cm by 2100. Data source: CAN-EWLAT.

- At St. John's. NL between 1935 and 2008 three storm surge events above 60 cm, with the highest peak of 77 cm during Hurricane Irene in 1999, have been recorded (https://www.ec.gc.ca/hurricane).
- Projected sea level rise for St. John's, NL by 2100 using a high scenario (partially on IPCC AR5 RCP 8.5) is +1.84 m relative to 2010 (Han *et al.*, 2016).




Map of coastal sensitivity to climate change along Terra Nova's coast. 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. Most of the coast has "High" sensitivity. Data source: Natural Resources Canada (Couture and Manson, 2016).

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

## Additional Reading on Coastal Change

Catto, N. R. (2011). *Coastal Erosion in Newfoundland*. Prepared for Atlantic Climate Adaptation Solutions Association (ACASA). https://atlanticadaptation.ca/en/islandora/object/acasa%3A307.

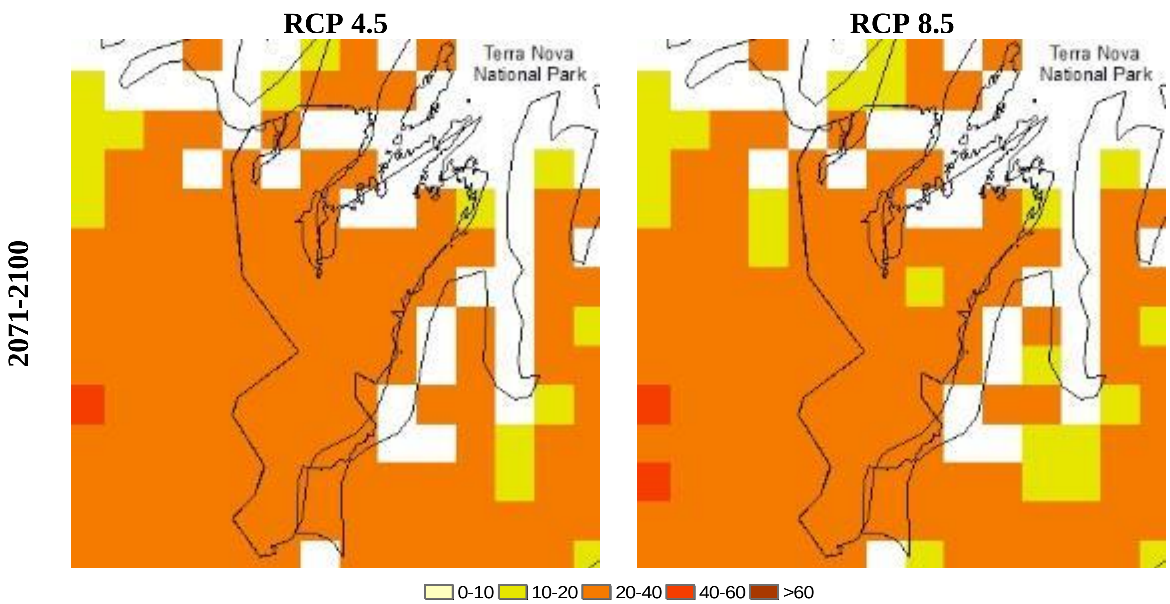
Irvine, M. L. (2015). *Monitoring Coastal Change in Newfoundland and Labrador: 2014 Update*. Newfoundland and Labrador Department of Natural Resources Geological Survey. https://www.nr.gov.nl.ca/nr/mines/geoscience/publications/currentresearch/2015/Irvine-2015.pdf.

Love, R., Milne, G. A., Tarasov, L., Engelhart, S. E., Hijma, M. P., Latychev, K., Horton, B. P., and Tornqvist, T. E. (2016). The contribution of glacial isostatic adjustment to projections of sea-level change along the Atlantic and Gulf coasts of North America. *Earths Future, 4*(10), 440-464. doi:10.1002/2016ef000363.

Zhai, L., Greenan, B. J. W., Hunter, J., James, T. S., Han, G., MacAulay, P., and Henton, J. A. (2015). Estimating Sea-Level Allowances for Atlantic Canada using the Fifth Assessment Report of the IPCC. *Atmosphere-Ocean, 53*(5), 476-490. doi:10.1080/07055900.2015.1106401.

## 3.2 Wildfire

- The frequency, seasonality, extent and severity of wildfires is closely tied to climatic conditions (e.g., Westerling *et al.*, 2006).
- Wildfire season length and frequency of extreme fire weather are expected to increase (Jain *et al.*, 2017).
- Wotton *et al.* (2017) project a future increase in the number of days where crown fires are likely to occur as well as an increase in the number of days when fire intensities (e.g., head fire intensity above 10,000 kW/m) could exceed the capabilities of suppression resources (doubling in some end of century scenarios).
- Wang *et al.* (2017) project an increase in the number of active burning days (i.e., spread days as related to daily fire weather).

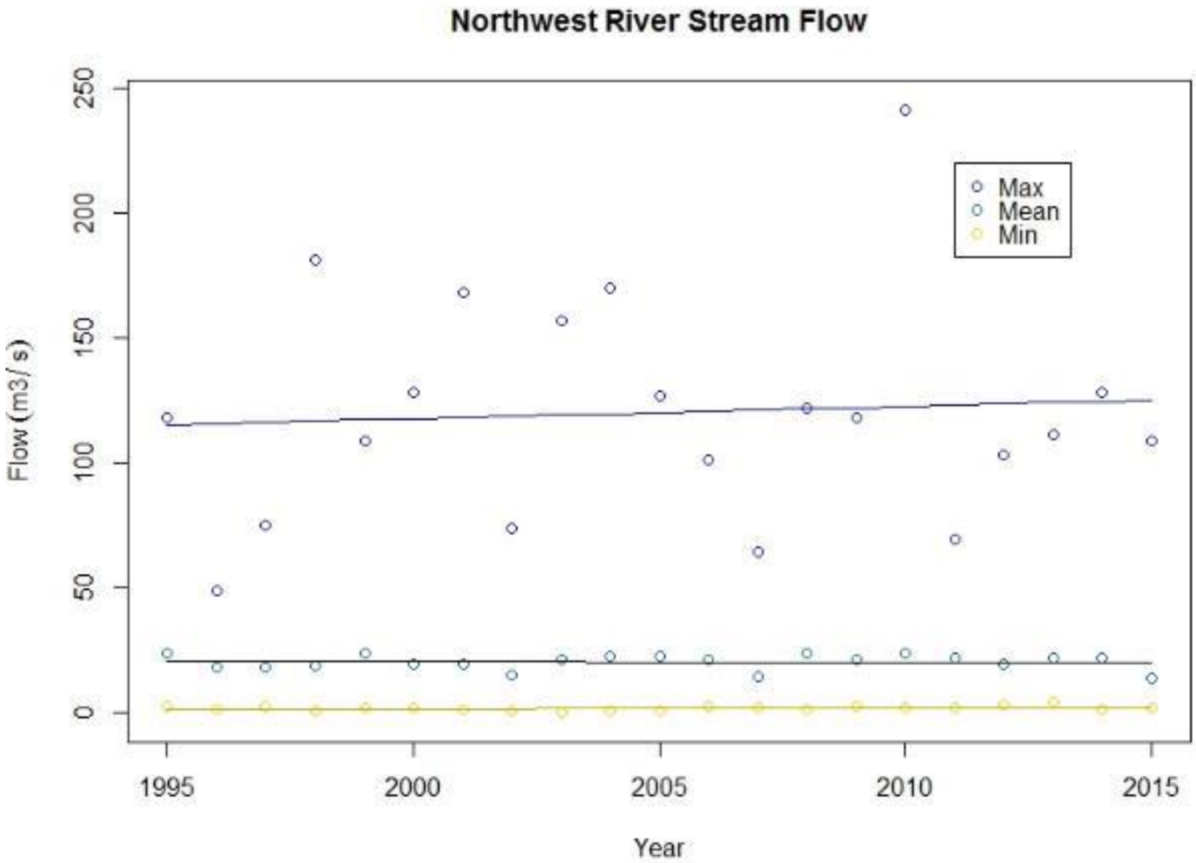



**Projected increase in wildfire season for Terra Nova National Park**. Increased length in days from baseline (1981-2010) under RCP 4.5 and RCP 8.5 scenarios. Depending on the RCP scenario and location, an increase of 18-39 days is projected by 2071-2100. Data source: Natural Resources Canada, http://cfs.nrcan.gc.ca/fc-data-catalogue.

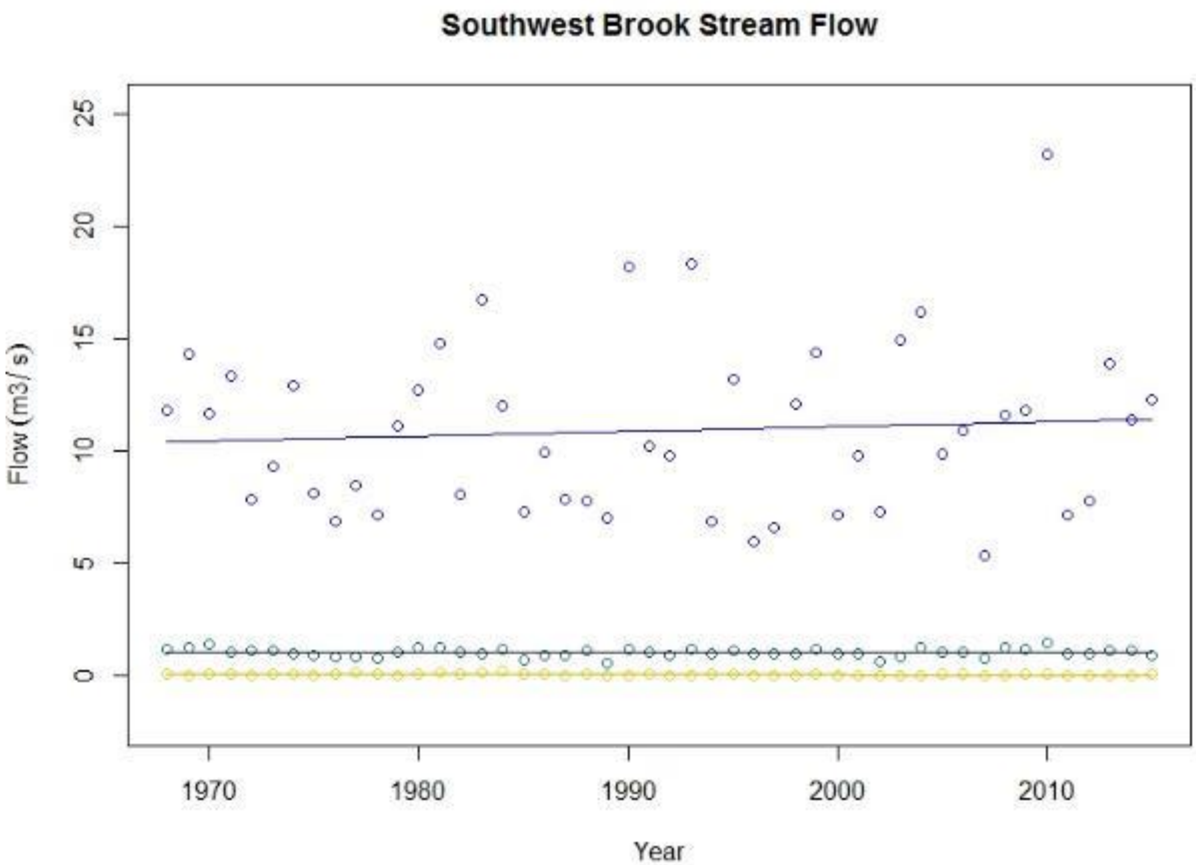
Annual forest fire data (e.g., number of fires, area burned) for the province is available from the National Forestry Database (http://nfdp.ccfm.org/fires/jurisdictional_e.php). This database also includes forest insect defoliation (http://nfdp.ccfm.org/insects/jurisdictional_e.php). This may be used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




**Northwest River at Terra Nova NP annual flow data for Station 02YS006.** Although a statistically significant ($P<0.05$) trend was not demonstrated for mean, max or min values, a slight increasing trend is noted for max and min annual flows. The majority of peak flows occur in April, however the largest flow was noted on September 23, 2010 (241 $m^3/s$), presumably associated with Hurricane Igor. Trend determined using a generalized linear model (R Core Team, 2017) and data from EC Data Explorer, HYDAT (July 16, 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.




**Southwest Brook at Terra Nova NP annual flow data for Station 02YS003 (HYDAT database, July 16, 2018 release).** A statistically significant ($P<0.05$) trend was not demonstrated for mean or max values, however a statistically significant ($P<0.05$) decrease was noted for min annual flows (-58%). The majority of peak flows occur in April, however the largest flow was noted on September 21, 2010 (23.2 $m^3/s$). Trend determined using a generalized linear model (R Core Team, 2017) and data from EC Data Explorer, HYDAT (July 16, 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.

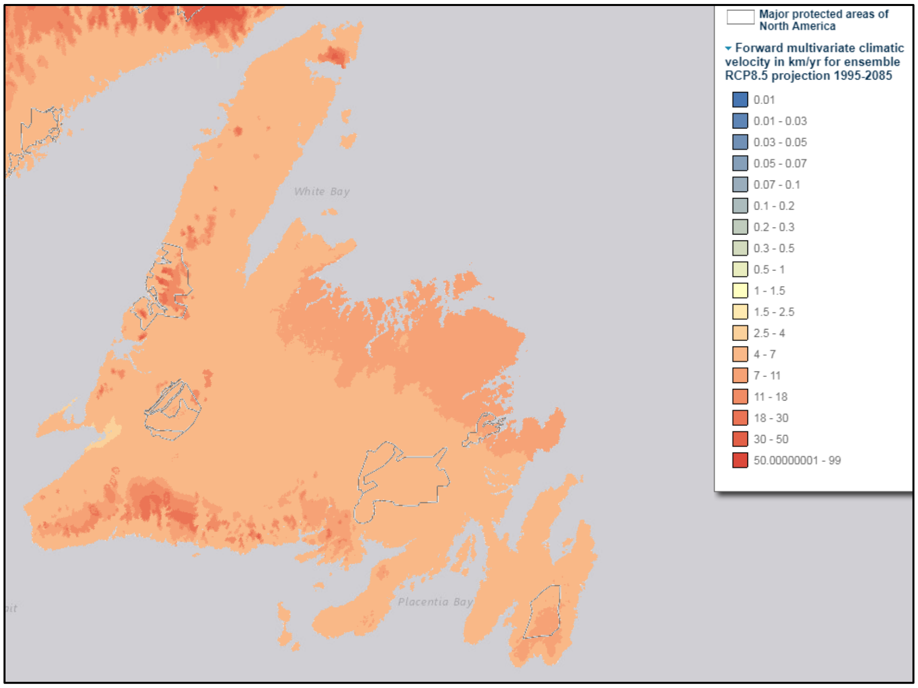
Historic hydrometric station data is also available on-line from the Government of Canada, https://wateroffice.ec.gc.ca/mainmenu/historical_data_index_e.html.

## 3.4 Biodiversity

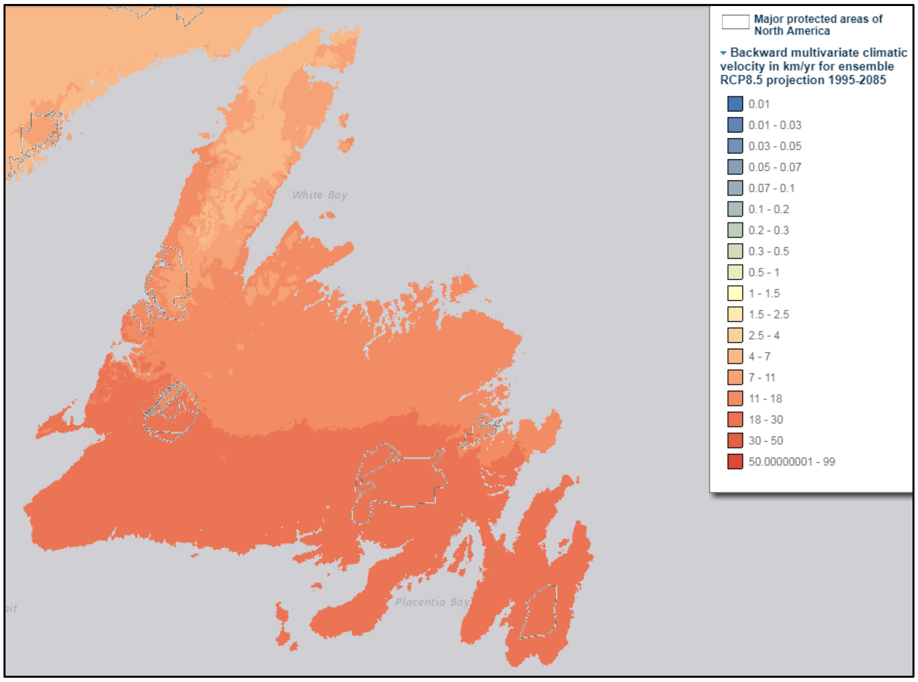
Conditions, including milder winters and summer drought, may be more favourable for invasive species colonization (Langor *et al.*, 2014; Walther *et al.*, 2009) and for more extensive forest insect and disease outbreaks (e.g., spruce budworm, forest tent caterpillar, gypsy moth) (Pureswaran *et al.*, 2018; 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).

## *Climate Velocity*

AdaptWest (https://adaptwest.databasin.org/) provides integrative tools that can inform conservation planning, including the following analysis on climate velocity.




**Forward climate velocity (km/yr).** The rate at which an organism in the current landscape has to migrate to maintain constant climate conditions. At TNNP the projected rate is **6-8 km/yr** for the 2071-2100 (RCP 8.5) period.




**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. At TNNP the projected rate is **16-18 km/yr** for the 2071-2100 (RCP 8.5) period.

**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 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 Terra Nova (48.53N, -53.97W), see following table.

Potential plant species richness for Terra Nova based on current and future plant hardiness projections.

| | 1971-2000 | 2011-2040 | 2041-2070 | 2071-2100 |
|---|---|---|---|---|
| **Full Range** | 1303 | 1384 | 1256 | 725 |
| **Core Range** | 647 | 653 | 445 | 306 |


Balsam fir (*Abies balsamea*) is an example of a species whose core and full range is projected to decline. Currently Terra Nova includes core range for this species, but by the end of century most RCP 8.5 based projections suggest that the park will be outside of its core and full range. More models and information for this species at: http://www.planthardiness.gc.ca/index.pl?m=9b&lang=en&speciesid=1000005

## *Other Observations and Trends*

- *Elaphostrongylus rangiferi*, a parasitic nematode, has become established in the Newfoundland caribou herd on the Avalon Peninsula as a result of the spread of diseases through climate change (Ball *et al.*, 2001; Bradley *et al.*, 2005).
- Demographic projections for caribou suggest long-term population limitation through indirect effects of climate change on calf predation by coyotes (Bastille-Rousseau *et al.*, 2018).
- Black bear predation of caribou calves is facilitated by time-lagged higher summer growing degrees, whereas coyote predation increases with current precipitation and winter temperature. Projections reveal that the impact of coyote predation could increase by as much as fivefold by 2085 (Bastille-Rousseau *et al.*, 2018).
- Favourable conditions during summer and winter prior to calving help female ungulates directly sustain pregnancy by enhancing access to forage and reducing energetic costs of movement (Bastille-Rousseau *et al.*, 2018; Couturier *et al.*, 2009).
- Climatic conditions during the ungulate calving period are more important for predator-driven neonate mortality during a population decline, when individuals are likely under nutritional stress (Bastille-Rousseau et al. 2016).
- Newfoundland caribou have exhibited the classic density-dependent responses—a rapid increase in abundance followed by a decline, mirrored by reduced body size. Density-dependent relationships are likely influenced by large-scale climate patterns, such as the North Atlantic Oscillation (NAO), that play a role in the forage growth patterns and availability. Positive and negative NAO phases are associated with specific weather patterns in Newfoundland that likely affect forage conditions. In general, the positive phase of the NAO is associated with below average winter temperatures and increased snowfall in Newfoundland, whereas the negative phase is associated with warmer, drier winters with reduced snow cover. Snowpack depth would

affect spring vegetation growth and accessibility, thereby affecting caribou nutrition and body growth (Mahoney *et al.*, 2011).

- Climate patterns may also affect caribou through increased insect harassment during the summer months, or icing of winter food resources (Mahoney *et al.*, 2011).
- Outbreaks of bitter crab disease in snow crabs off the Newfoundland coast have been associated with warmer temperatures (Marcogliese, 2008; Shields *et al.*, 2007).
- Off the coast of Newfoundland, ocean warming may be a contributing factor for the potential recovery of capelin and cod stocks (e.g., Rose and Rowe, 2015). However, acidification of the ocean may reduce the productivity of crustaceans and molluscs including lobster, crab, shrimp and oyster (e.g., Canadian Climate Forum, 2017).

## Additional Reading on Biodiversity


Bloom, R. G. and Mallik, A. U. (2004). Indirect effects of black spruce (*Picea mariana*) cover on community structure and function in sheep laurel (*Kalmia angustifolia*) dominated heath of eastern Canada. *Plant and Soil, 265*(1-2), 279-293. doi:10.1007/s11104-005-0508-4.

Bourne, C. M., Kehler, D. G., Wiersma, Y. F., and Cote, D. (2011). Barriers to fish passage and barriers to fish passage assessments: the impact of assessment methods and assumptions on barrier identification and quantification of watershed connectivity. *Aquatic Ecology, 45*(3), 389-403. doi:10.1007/s10452-011-9362-z.

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## 3.4 Cultural Resources

Assessing the impacts of relative sea level rise and increased storminess to cultural archaeological heritage has been undertaken at the Fortress of Louisbourg (FOL) (e.g., Duggan, 2014; Dunham, 2017; Johnston, 2011; Taylor, 1992; Taylor *et al.*, 2011; Taylor *et al.*, 2000), L'Anse aux Meadows and Bonavista Bay (Westley *et al.*, 2011). In fact, FOL has undertaken "rescue archaeology" as a proactive means to protect archaeological sites threatened by coastal erosion (e.g., Canadian Historic Sites, 1971; Dunham, 2017).


Defences erected to protect cultural resources at the Beaches site, Bonavista Bay, by the Burnside Heritage Foundation (http://digthequarry.com/Home.html). There are at least 41 recorded archaeological sites within the Bonavista Bay study area, 17% are considered to be at high vulnerability to coastal erosion (Westley *et al.*, 2011).

# 4. Additional Resources

- Newfoundland and Labrador citizen science mosquito and vector-borne disease surveillance project, contact: mosquitoNL@mun.ca.
- There are provincial long-term coastal erosion monitoring sites at Sandy Cove (beach and cliff) and Eastport (beach) (Irvine, 2015).
- Hurricane season flood information is available here: https://www.mae.gov.nl.ca/waterres/flooding/hurricane.html#system
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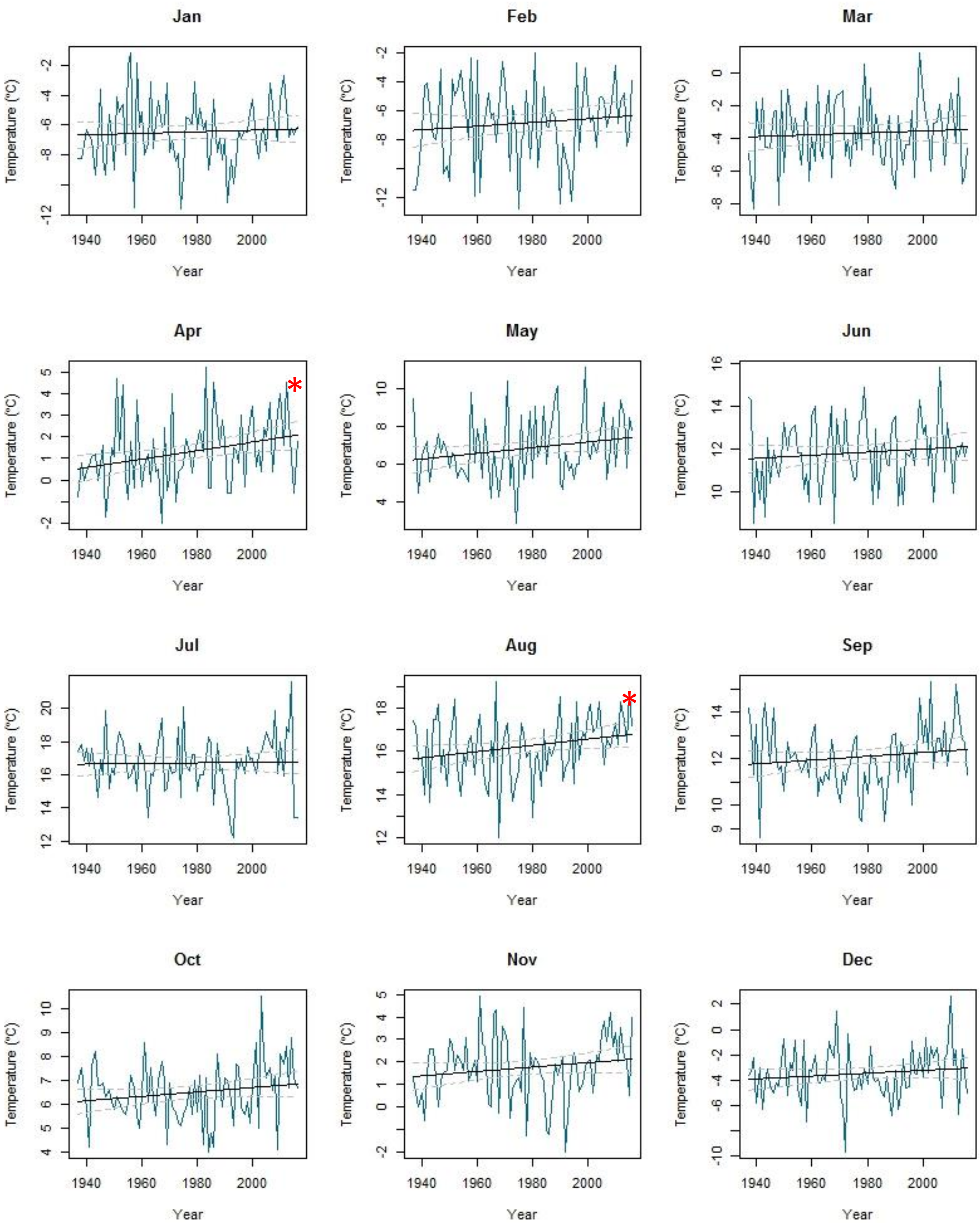
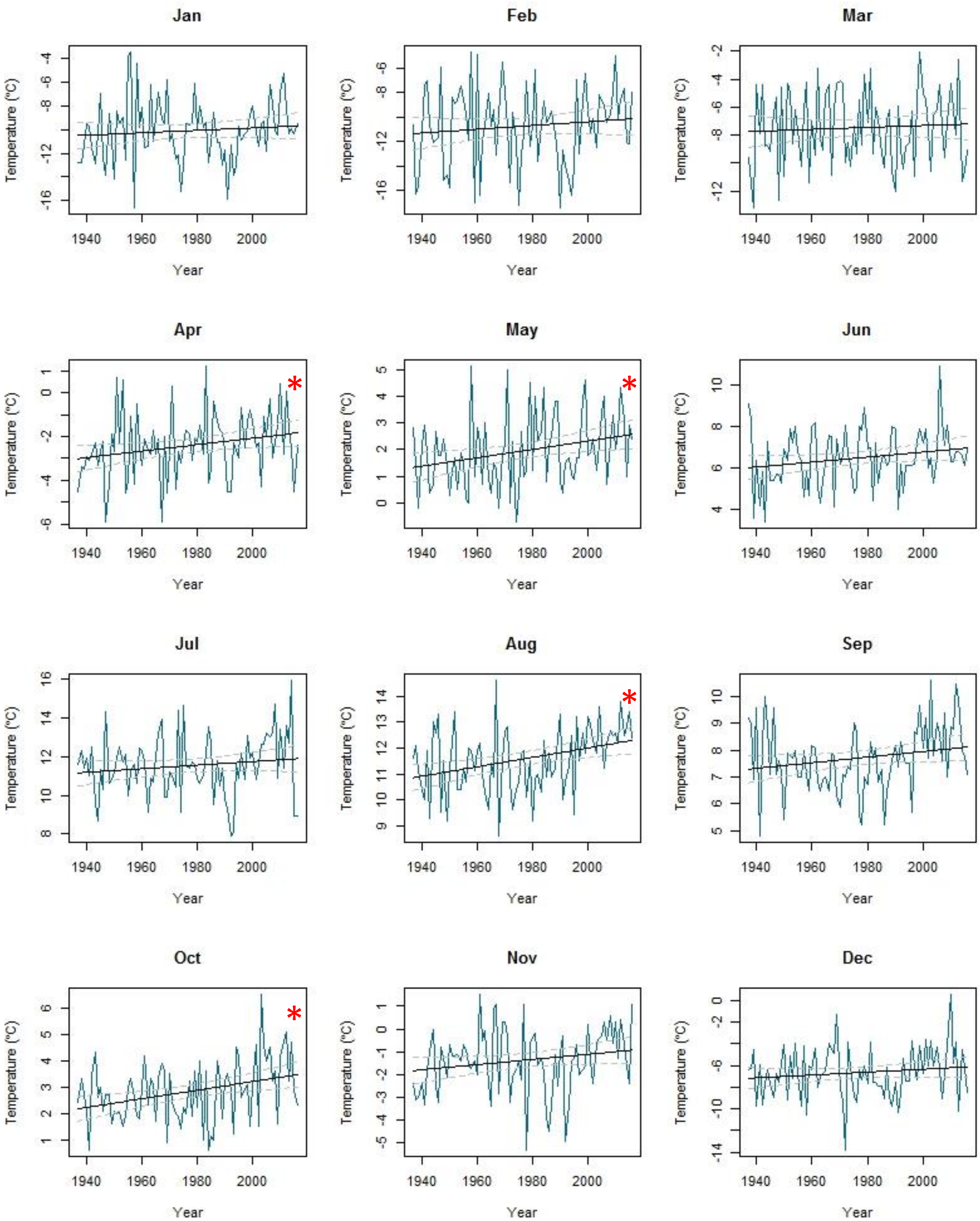
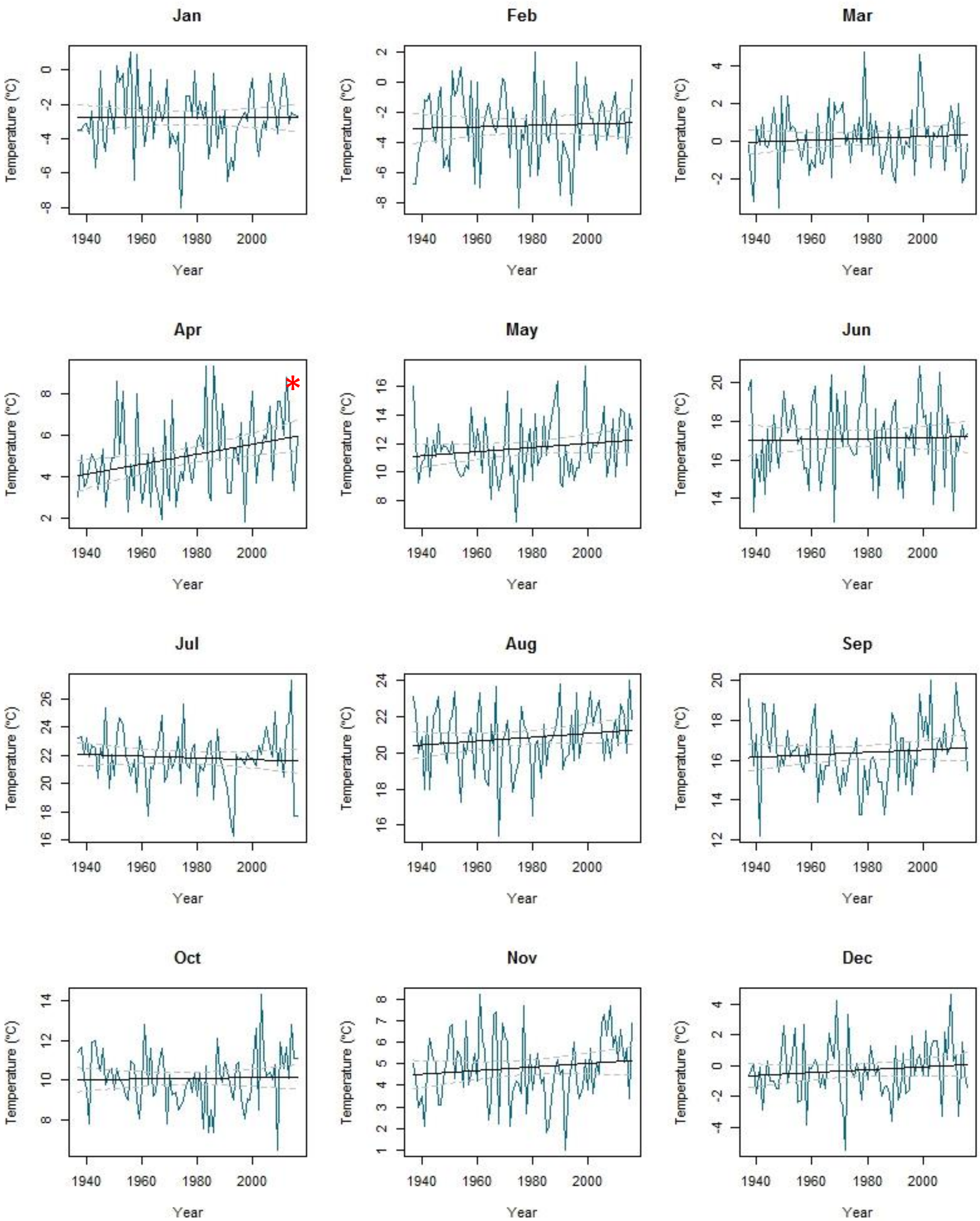
# Appendix 1. Additional Climate Trends



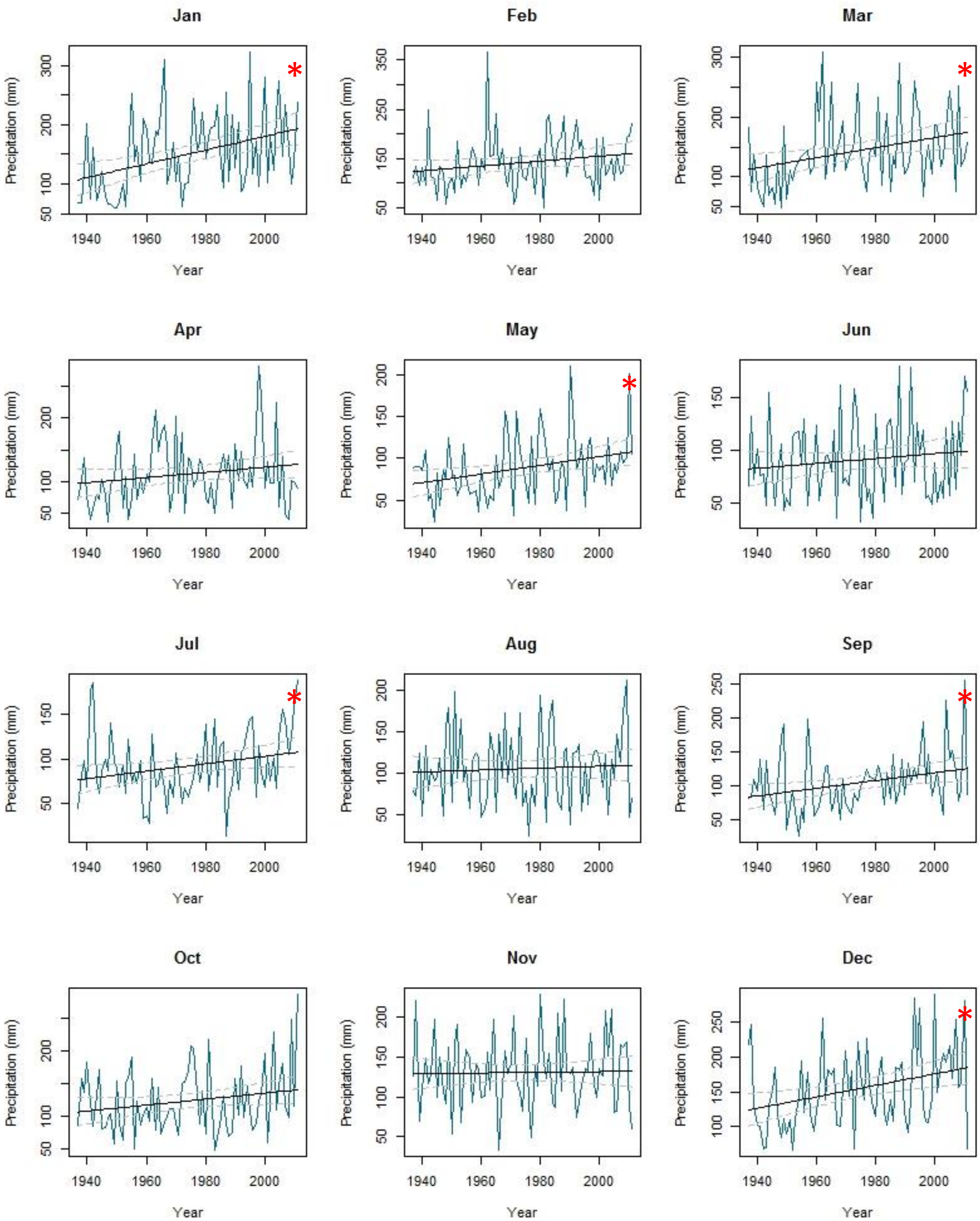

**Gander mean monthly temperature.** "*" = statistically significant trend (P<0.05).



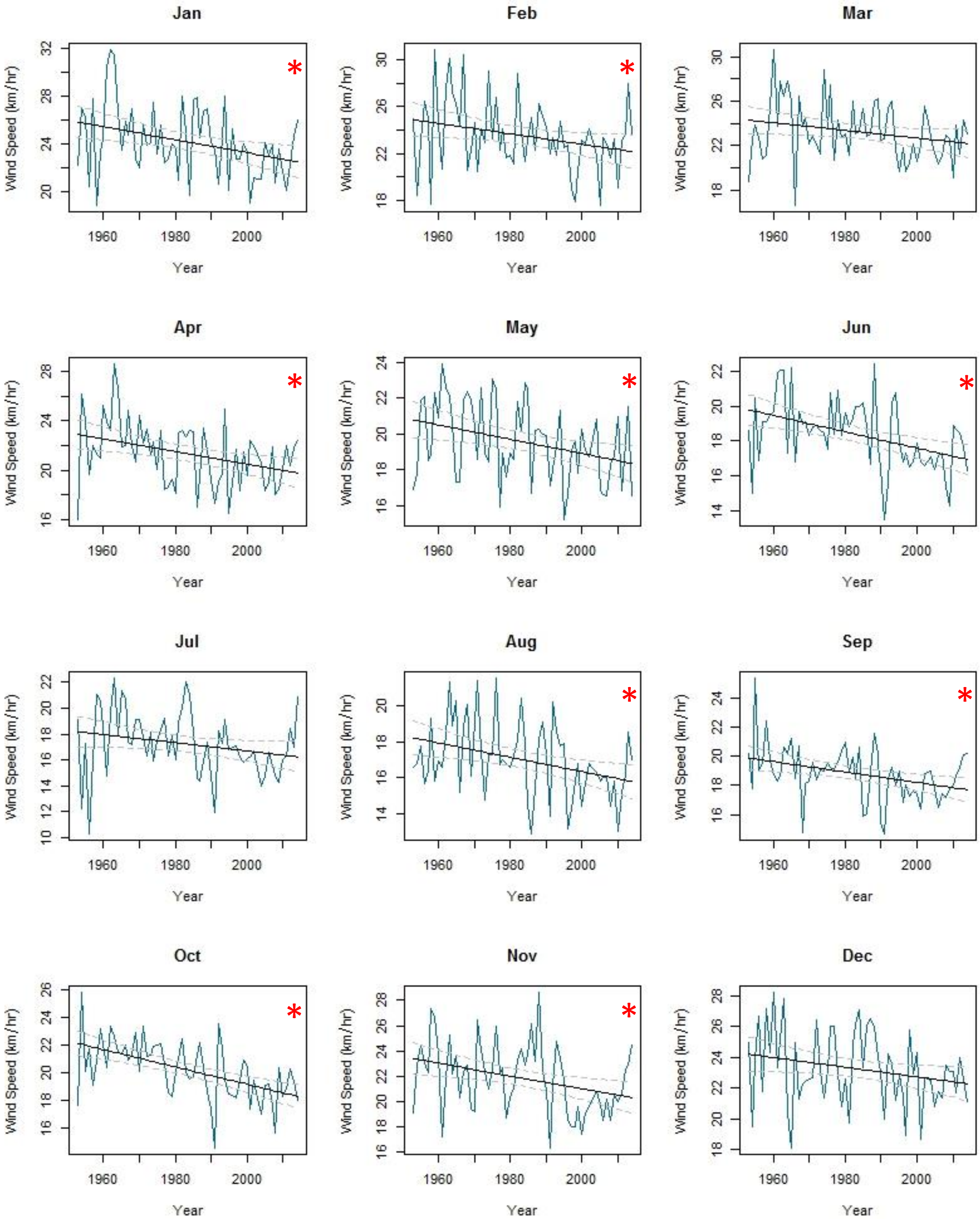

**Gander mean monthly <u>minimum</u> temperature** (i.e., nighttime). "*" = statistically significant trend (P<0.05).




**Gander mean monthly <u>maximum</u> temperature** (i.e., daytime). "*" = statistically significant trend ($P<0.05$).

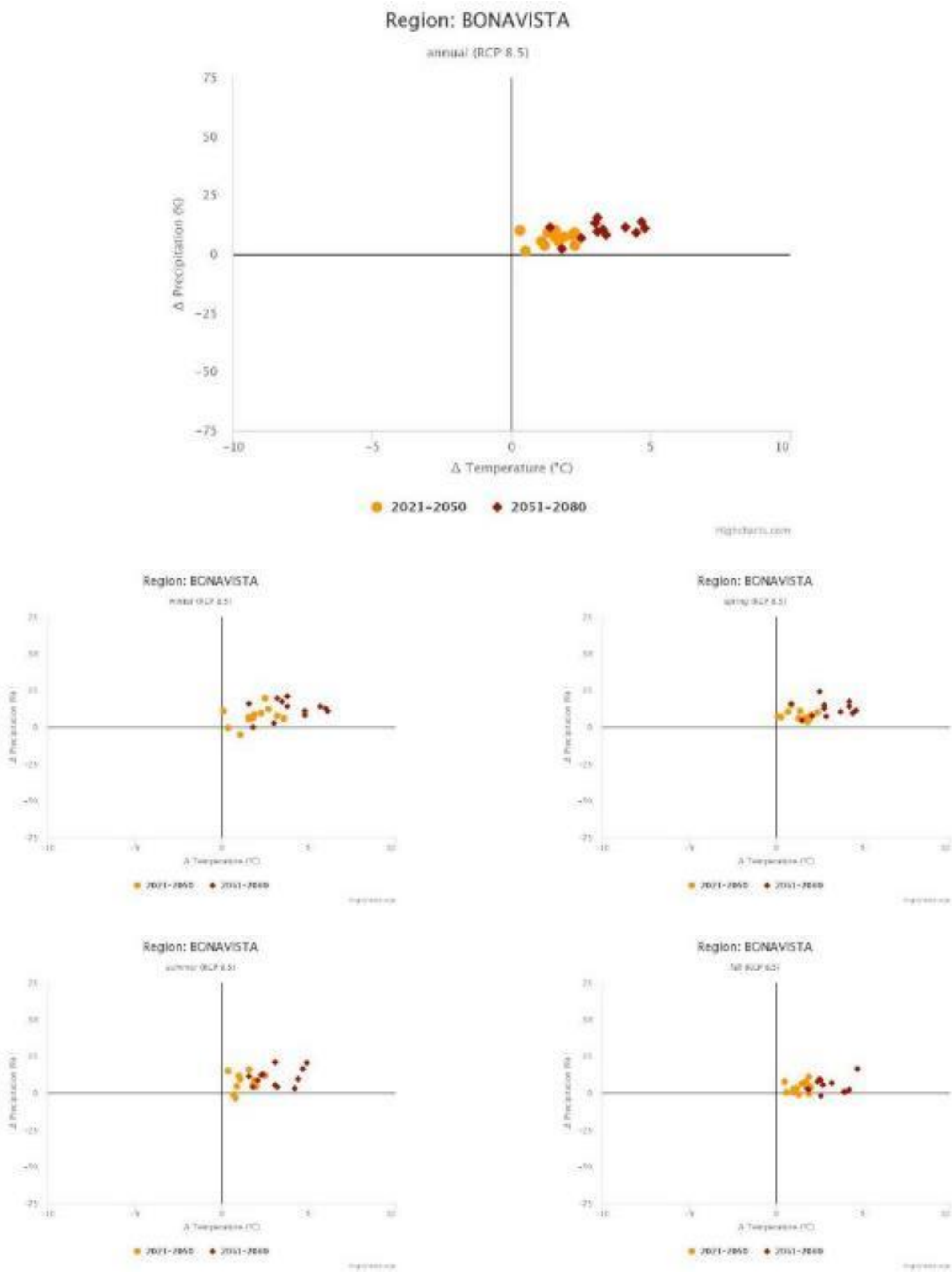



**Gander total monthly precipitation.** "*" = statistically significant trend (P<0.05).



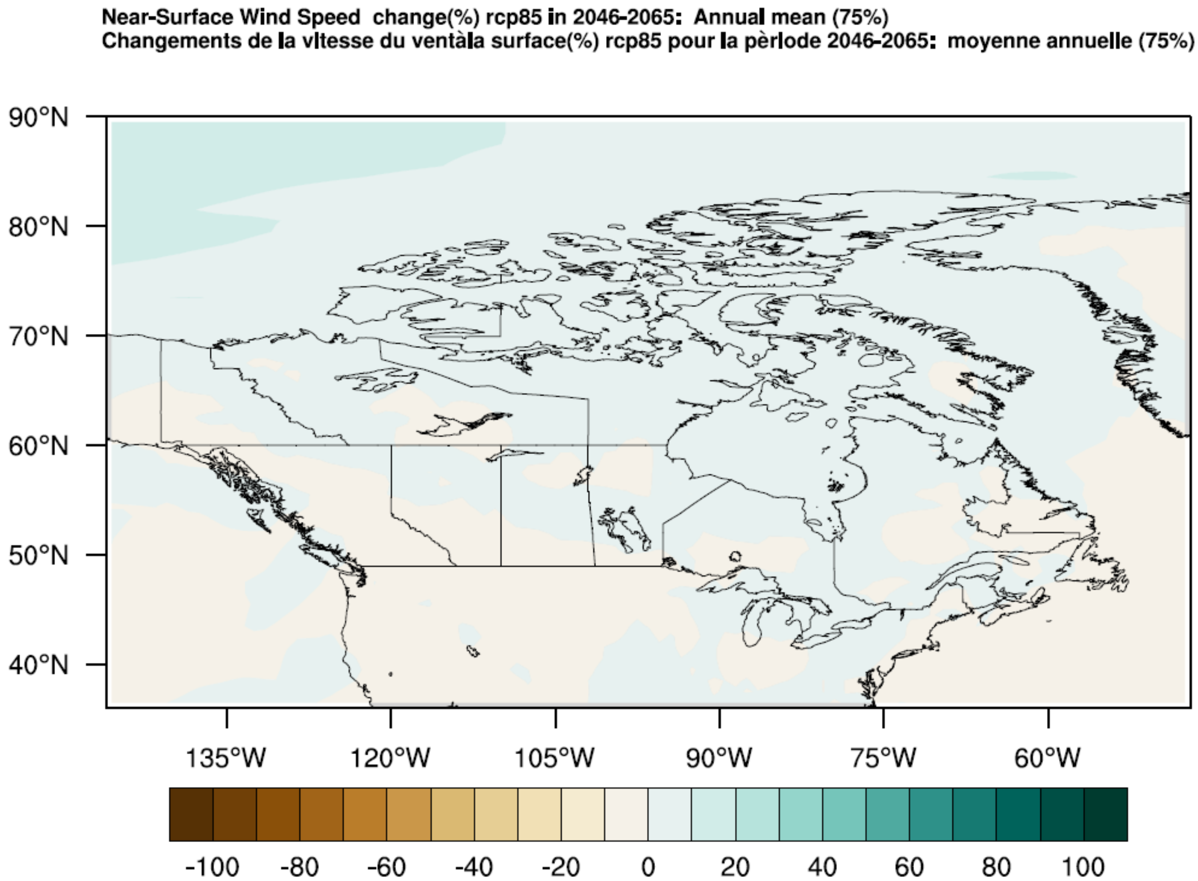

**Gander mean monthly wind speeds.** "*" = statistically significant trend (P<0.05).

# Appendix 2. Model Scatterplots for Temperature and Precipitation




**Climate models for the Bonavista Region.** 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). Most models project warmer and wetter conditions.

# Appendix 3. Near-Surface Wind Speed Projections




CMIP5 climate model (http://climate-scenarios.canada.ca/?page=download-cmip5) project decrease in wind speed in 2046-2065 from 1986-2005 reference period (RCP 8.5).