April 23, 2019

Supplemental Climate Information for Kejimkujik National Park and National Historic Site

Parks Canada Parcs Canada

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Preface

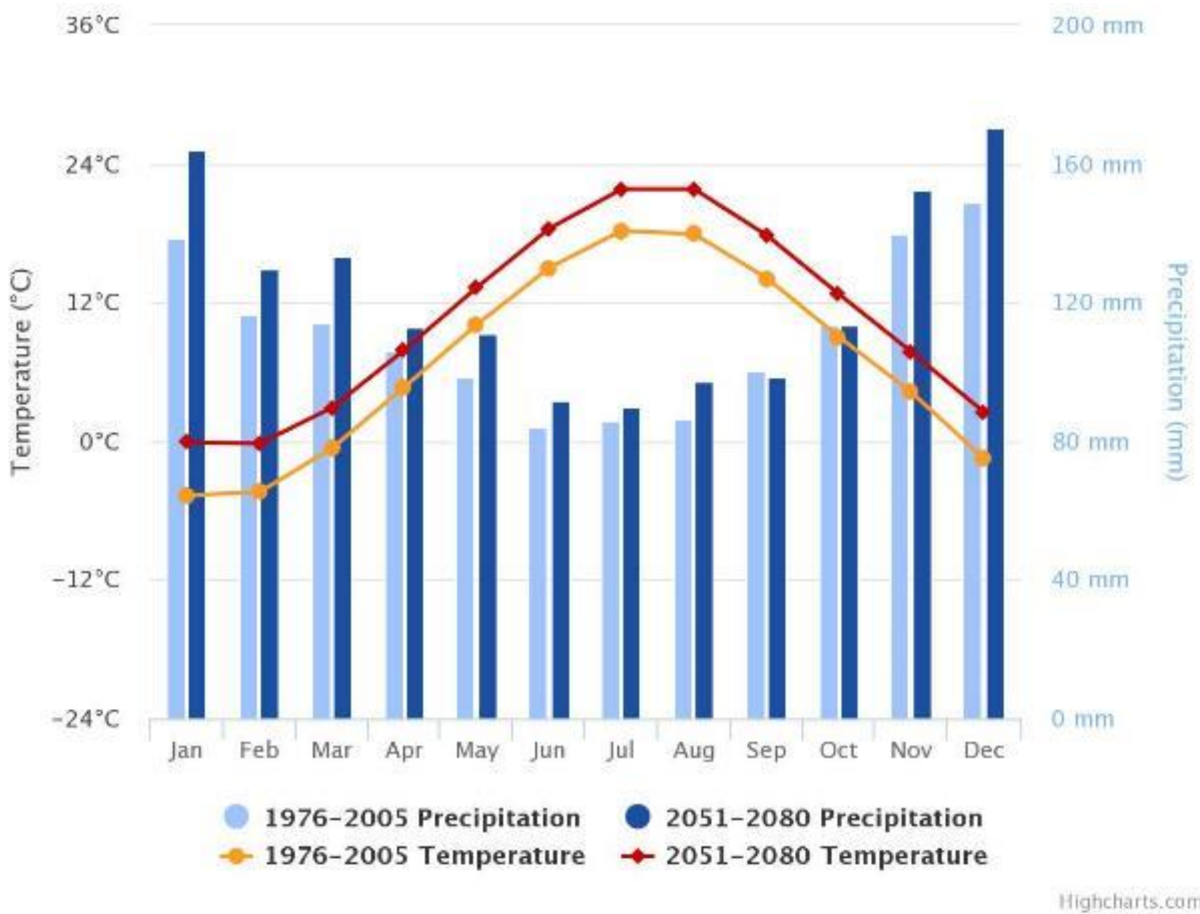
This is a supplement to the “Let’s Talks about Climate Change: Atlantic Region” (Parker, 2017) report and is intended to support climate change discussions at Kejimkujik National Park and National Historic Site.

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 21st 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.

Summary Climograph



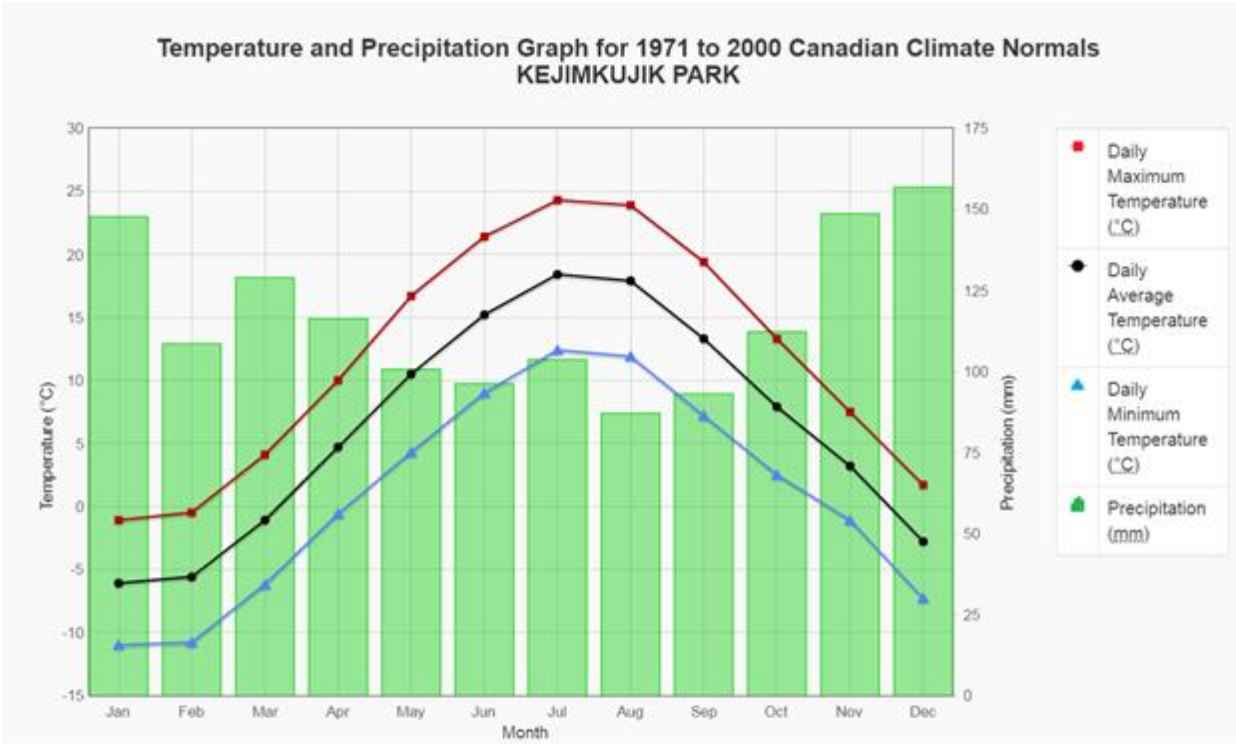
Climograph for Annapolis Royal region (RCP 8.5). Modelled monthly mean temperature and total precipitation for the 1976-2005 baseline and 2051-2080 future projection. Figure source: Climate Atlas of Canada (https://climateatlas.ca/).

1. Historic Climate

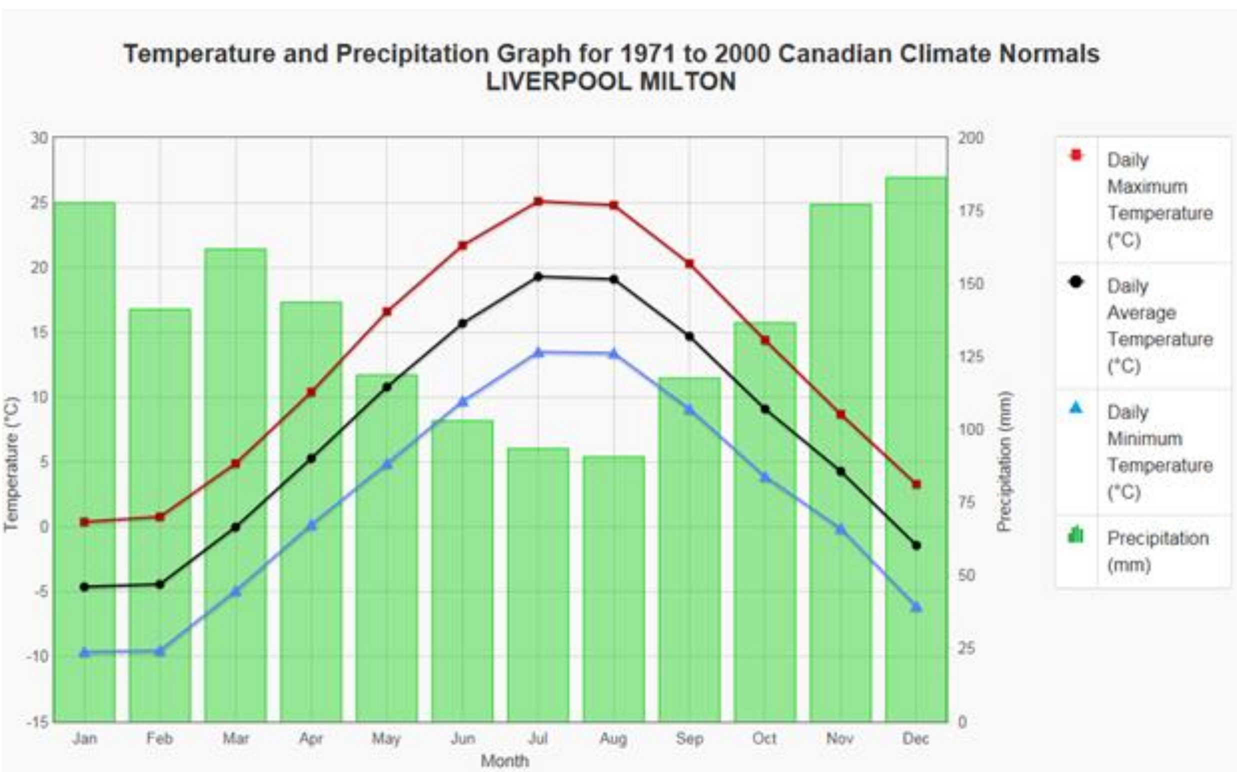
Kejimkujik National Park and National Historic Site (hereafter Kejimkujik) covers 403 km^2 in southwestern Nova Scotia. The park is composed of two sections, the larger is inland (381 km^2) approximately 65 km from the Atlantic coast and 55 km from the Bay of Fundy, and the smaller section (Kejimkujik Seaside, 22 km^2) is on the Atlantic coast (Parks Canada, 2010). Both Kejimkujik Seaside and Kejimkujik mainland are found within the Acadian Forest Ecozone (Rowe, 1972).

The inland portion of Kejimkujik contains an extensive wetland and lake system with a maximum elevation of 190 m, and lies within the Western Ecoregion of Nova Scotia (Neily *et al.*, 2017). For the 1971-2000 baseline, Kejimkujik Park Station (see plot below) recorded a mean annual temperature of 6.3°C, total annual precipitation of 1,399 mm (17% as snow; 13.9 days ≥ 25mm) and 1,741 growing degree days (i.e., the sum of the number of degrees Celsius that each day's mean temperature was above 5°C). The climate is marked by warm summers and mild, snowy winters. This mixedwood forest region is composed of spruce (*Picea rubens, P. mariana, P. gluaca*), Eastern Hemlock (*Tsuga canadensis*), White and Red Pine (*Pinus strobus, P. resinosa*), White Birch (*Betula papyrifera*), Red Maple (*Acer rubrum*), and Red Oak (*Quercus rubra*). The mainland portion of Kejimkujik is as far from the sea as is possible in Nova Scotia. This has created a distinct climatic zone within Atlantic Canada and accounts for a number of disjunct fauna and flora found in the area (e.g., Blanding's Turtle (*Emydoidea blandingii*), Eastern Ribbonsnake (*Thamnophis sauritus*), Water Pennywort (*Hydrocotyle umbellata*), and southern flying squirrel (*Glaucomys volans*).

Kejimkujik Seaside lies within the Atlantic Coastal Ecoregion of Nova Scotia (Neily *et al.*, 2017). For the 1971-2000 baseline, Milton-Liverpool station (closer to Kejimkujik Seaside, see plot below) recorded a mean annual temperature of 7.3°C, total annual precipitation of 1,647 mm (9.8% as snow; 20 days ≥ 25mm) and 1,926 growing degree days. This ecoregion covers a narrow coastal strip strongly influenced by the Atlantic Ocean. The region is exposed to high winds, high humidity, and fog during summer and fall and is slow to warm up in spring. It is marked by cool, wet summers and mild, wet winters with most precipitation falling as rain. Kejimkujik Seaside contains two lagoon ecosystems; St. Catherine's Estuary and Little Port Joli. Barrier beaches protect the saltmarshes, tidal mudflats and eel grass (*Zostera marina*) beds.



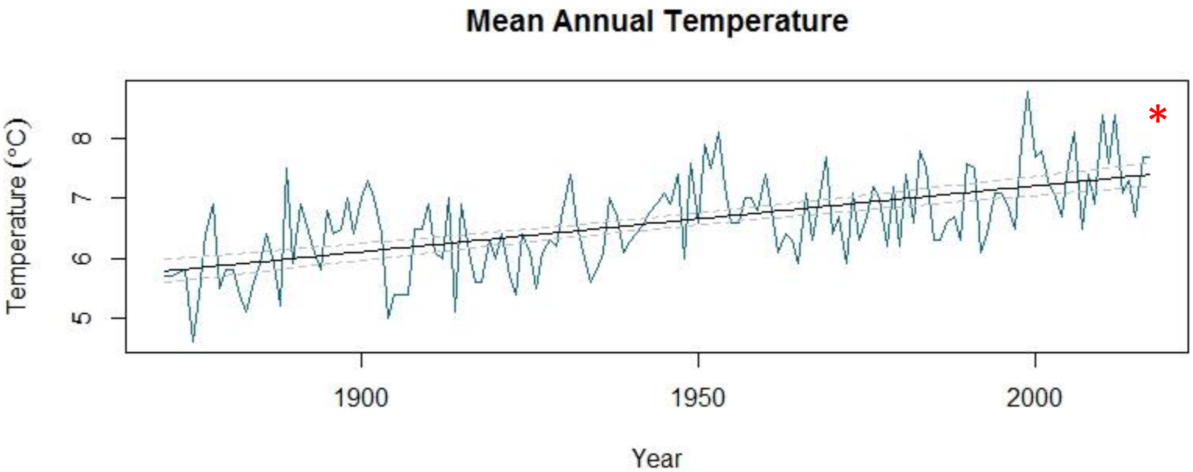
Climate “normals” (1971-2000) for Kejimkujik Park Station. Figure source: Environment and Climate Change Canada (http://climate.weather.gc.ca/climate_normals/).

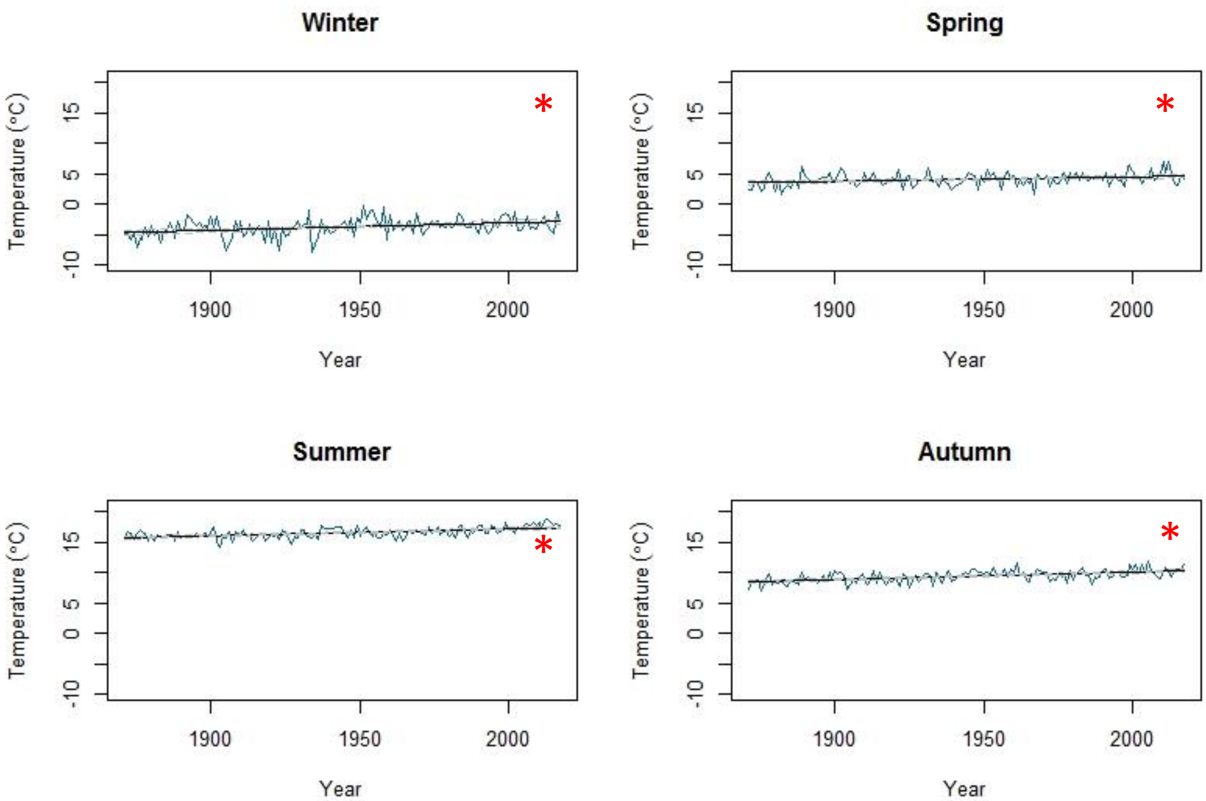


Climate “normals” (1971-2000) for Liverpool- Milton Station (close to Kejimkujik Seaside). Figure source: Environment and Climate Change Canada (http://climate.weather.gc.ca/climate_normals/).

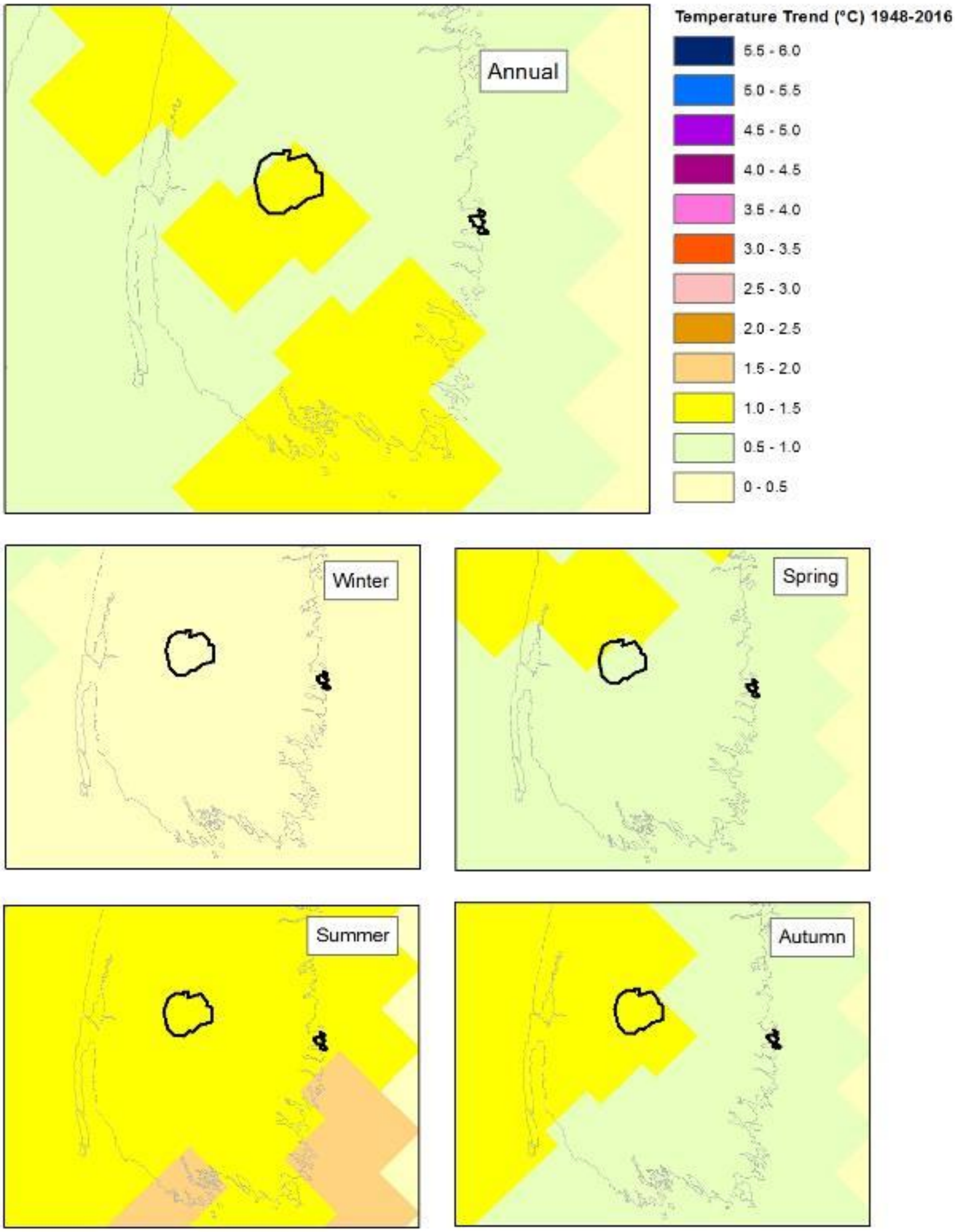
1.1 Temperature

Halifax (8202251) is the closest meteorological station with long-term temperature data (ECCC, 2017). Trends from 1872 to 2012 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).





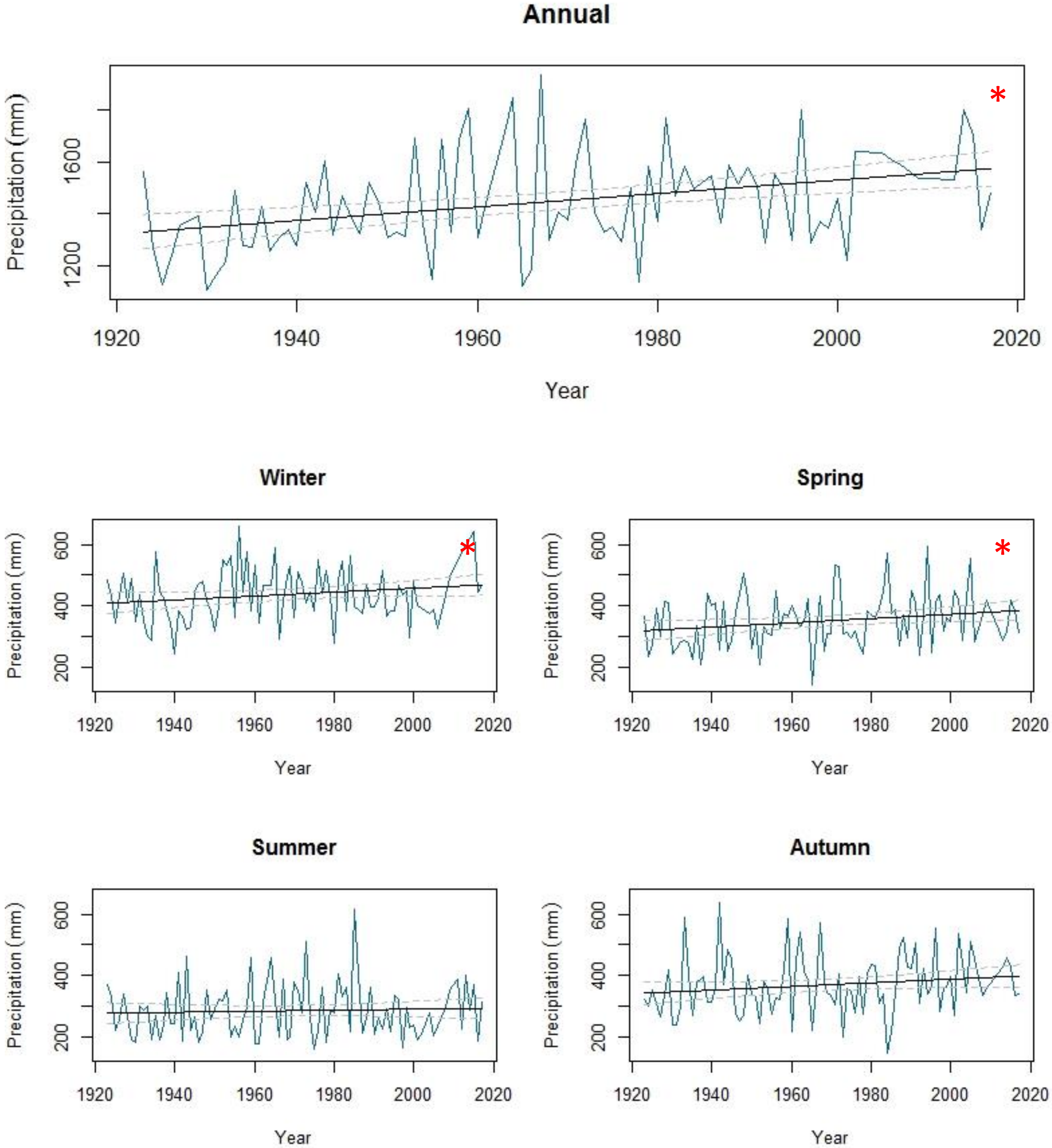
Liverpool mean annual and seasonal temperature. A statistically significant (P<0.05) increase observed in mean annual and seasonal temperatures. Mean annual temperature has increased by 1.6°C since 1872. Of all the seasons, autumn (Sep, Oct, Nov) temperature has increased the greatest, 2°C since 1872.



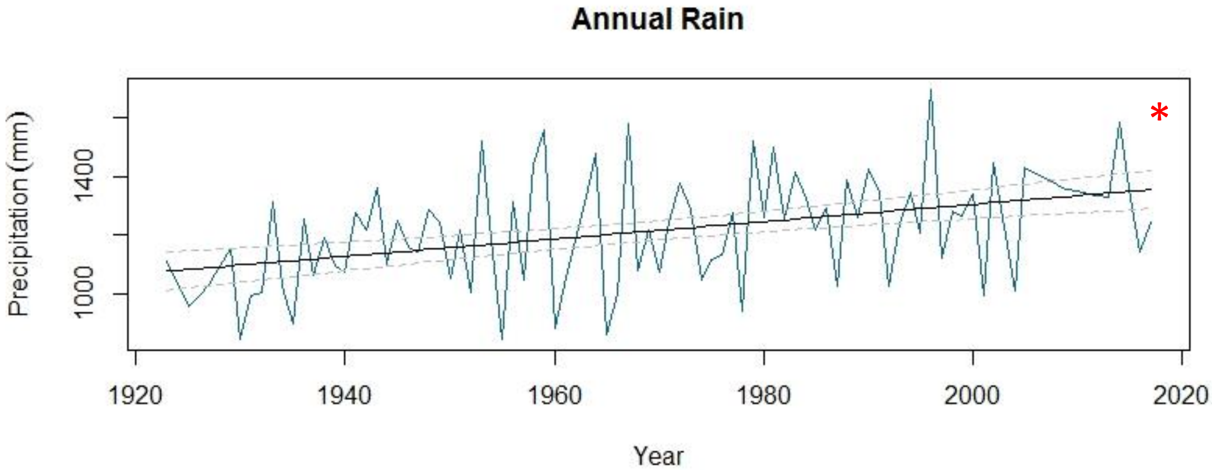
Mean annual and seasonal temperature trends (˚C) for Kejimkujik for 1948-2016. Based on Canadian gridded data (CANGRD) it represents the change in temperature over the period of record (1950-2016). Data source: https://climate-change.canada.ca/climate-data/#/historical-gridded-data.

1.2 Precipitation

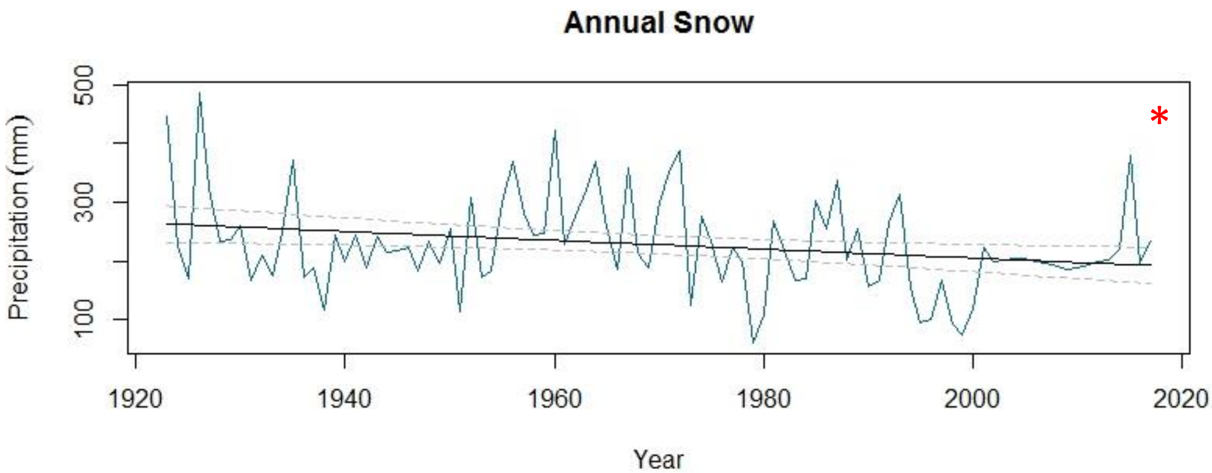
St. Margaret's Bay (8204800) is the closest meteorological station with long-term precipitation data (ECCC, 2017). Trends from 1923 to 2017 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).



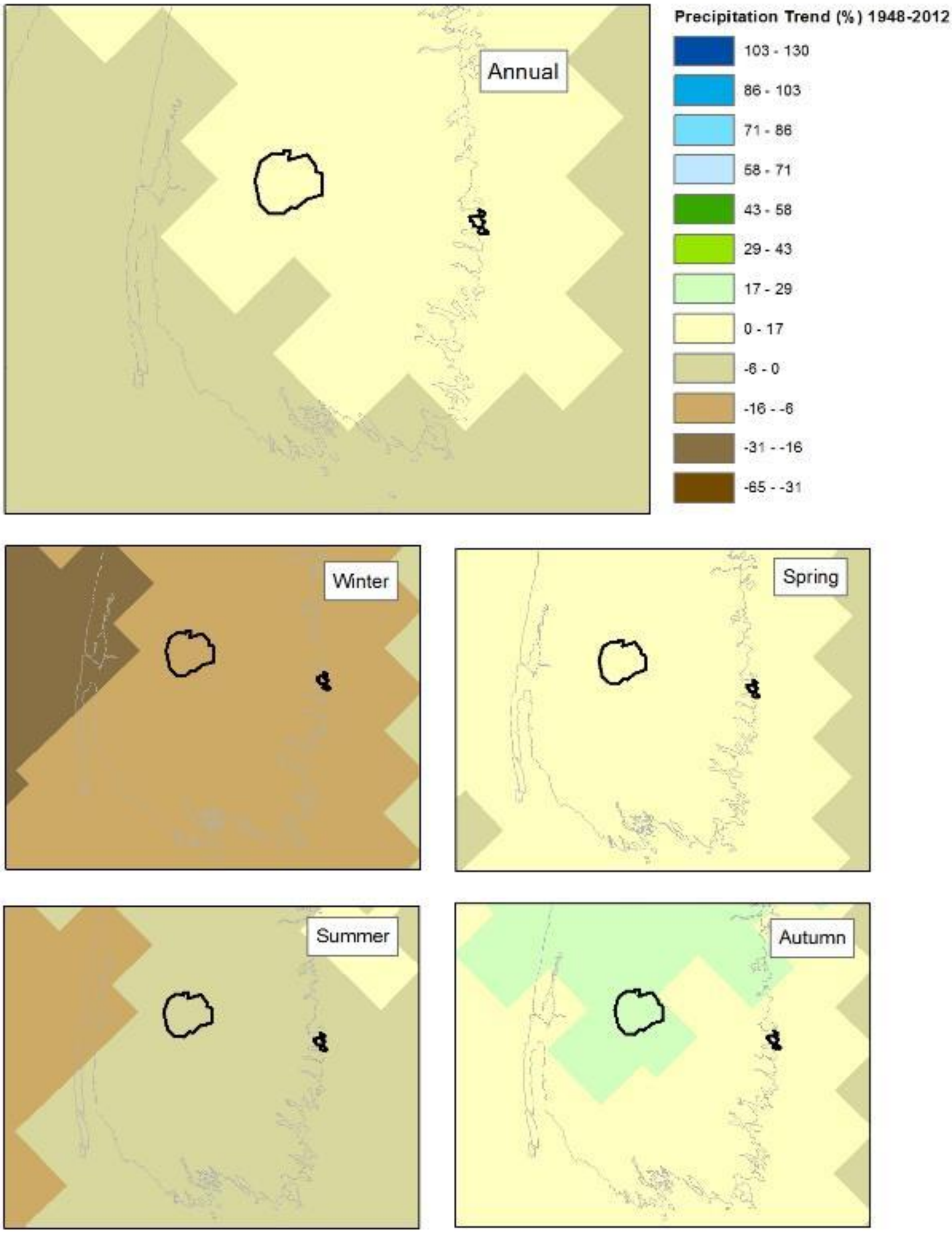
St. Margaret's Bay total annual and seasonal precipitation. Total annual precipitation demonstrated a statistically significant increase (P<0.05), +242 mm (18%) since 1923. Winter (Dec, Jan, Feb) and spring (Mar, Apr, May) demonstrated a statistically significant (P<0.05) increase, the greatest being observed for spring, +65 mm (20%).



St. Margaret's Bay total annual rain demonstrated a statistically significant (P<0.05) increase since 1923, +277 mm (+26%).



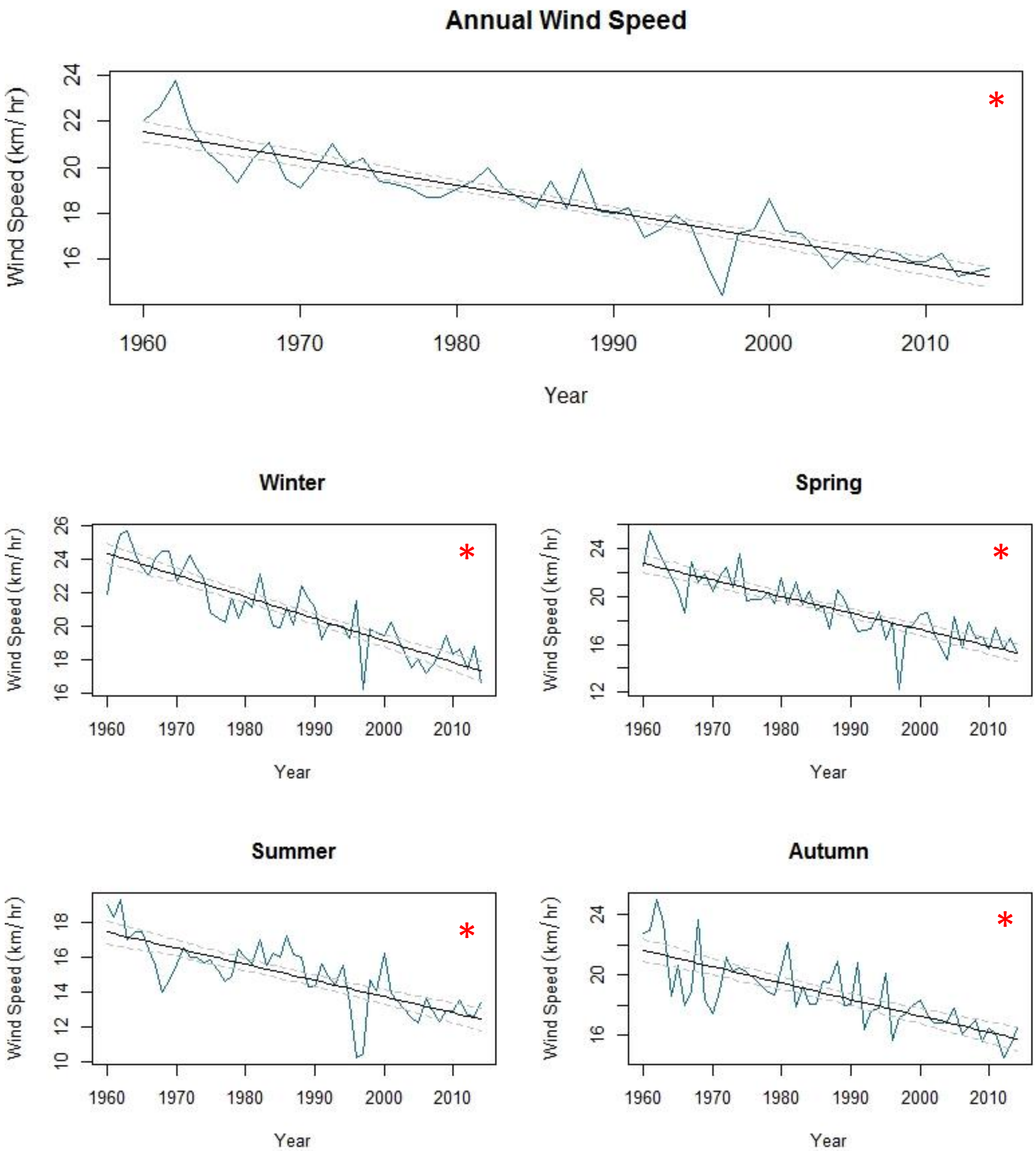
St. Margaret's Bay total annual snow demonstrated a statistically significant (P<0.05) decrease since 1923, -71 mm (-27%).



Total annual and seasonal precipitation trends (%) for Kejimkujik for 1948-2012. Based on Canadian gridded data (CANGRD) the relative trends reflect the percent change in total precipitation over the period of record (1948-2012). Data source: https://climate-change.canada.ca/climate-data/#/historical-gridded-data.

1.3 Surface Wind Speed

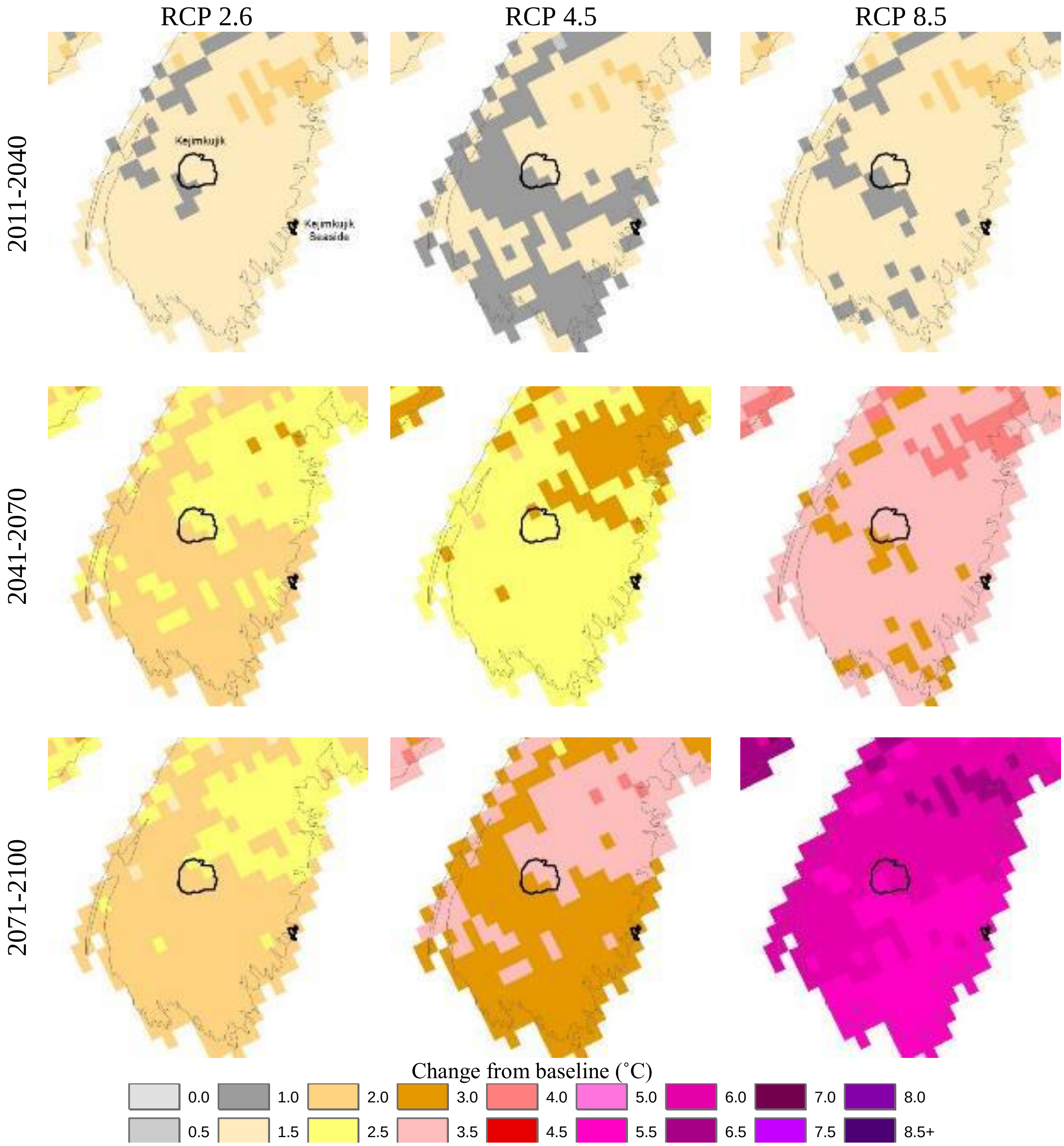
Western Head (8206240) is the closest meteorological station with long-term wind data (ECCC, 2017). Trends from 1960 to 2014 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend ($P<0.05$).



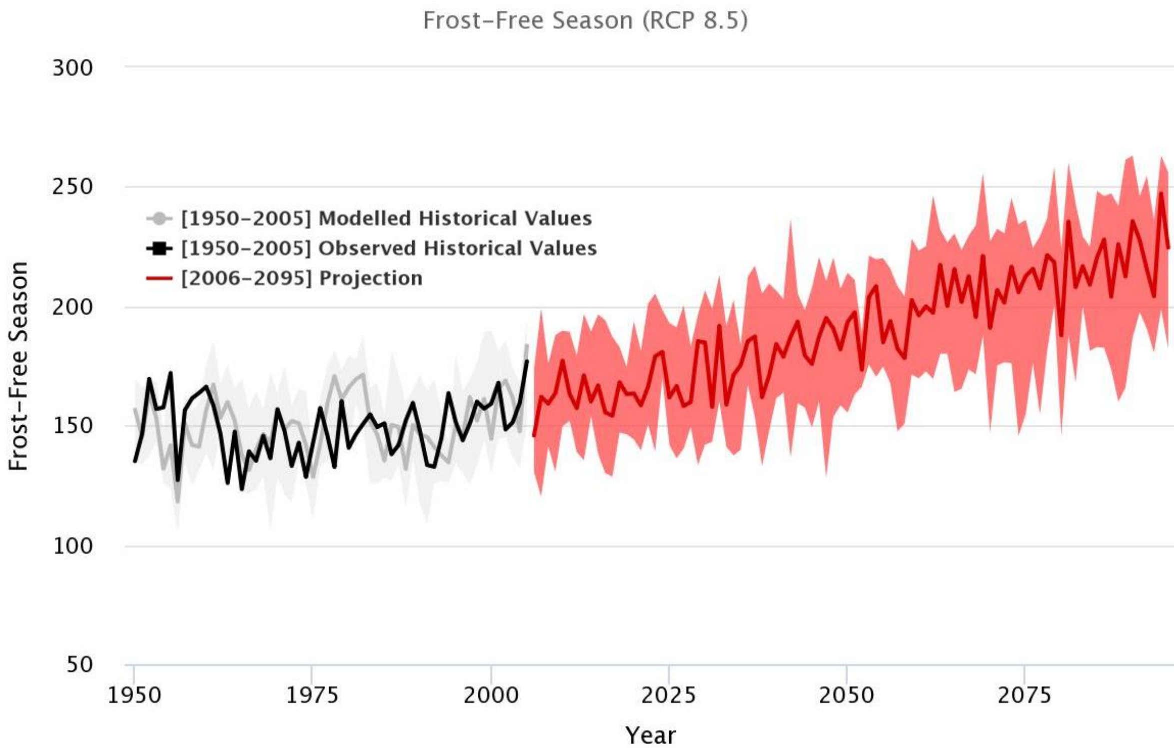
Western Head mean annual and seasonal wind speeds. Mean annual wind speeds have demonstrated a statistically significant ($P<0.05$) decrease, -6.3 km/hr (-29%) since 1960. All seasons demonstrated a statistically significant ($P<0.05$) decrease, the greatest being observed for spring, -7.5 km/hr (-32%) since 1960.

2. Projected Climate Trends

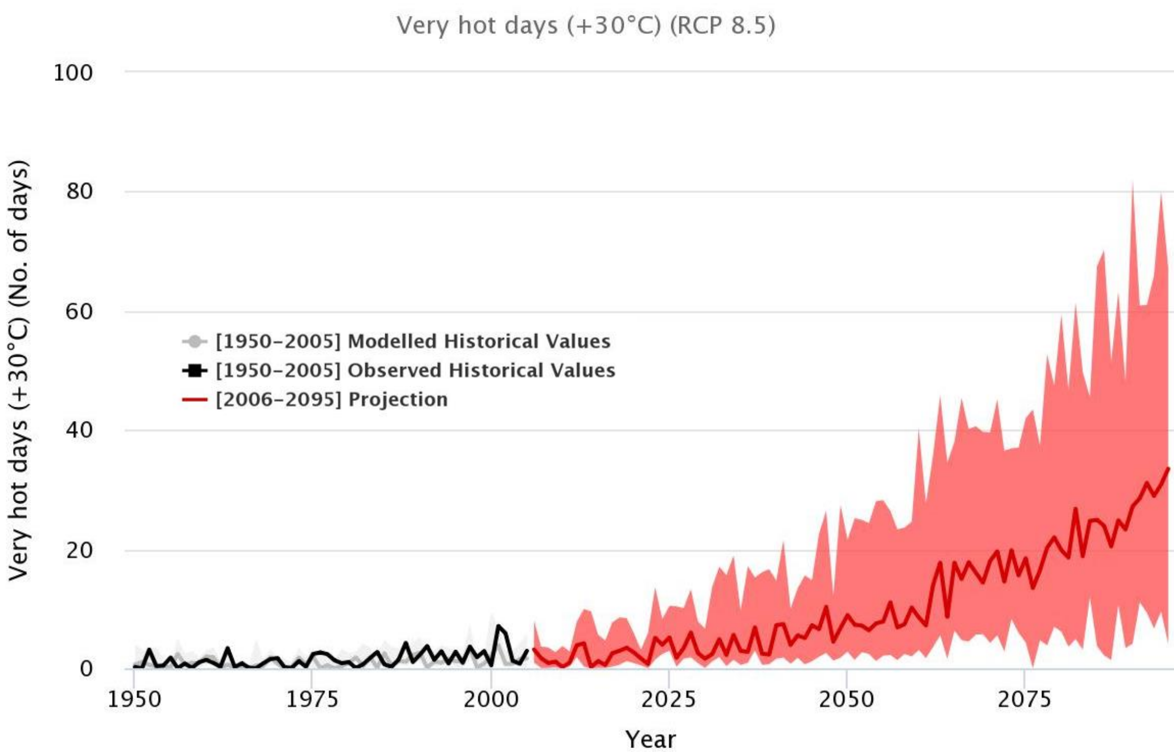
2.1 Temperature



Projected mean annual temperature increase for Kejimkujik 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, mean annual temperatures are projected to increase 2.5 to 6.0 °C by 2071-2100.

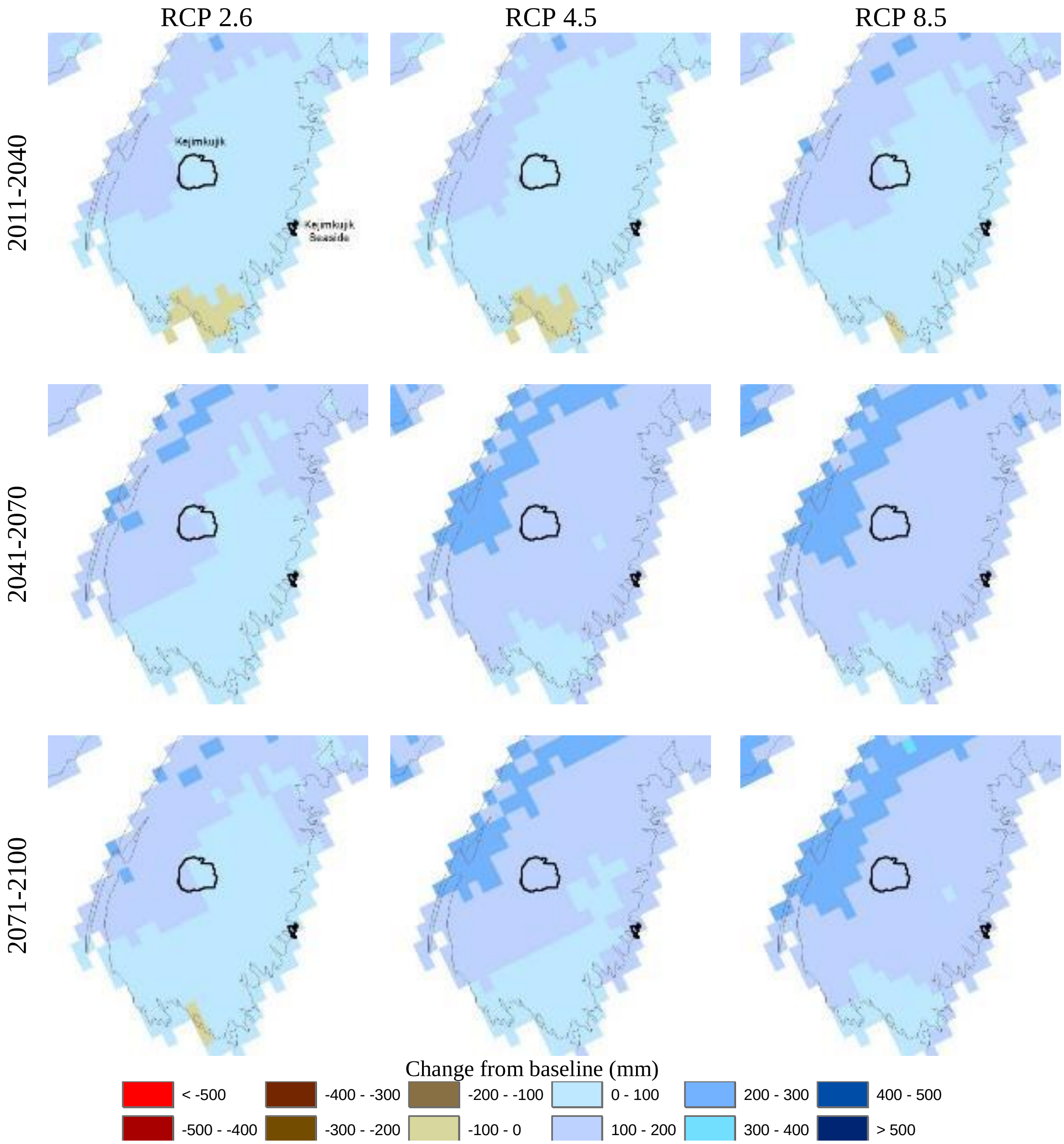


The frost-free season (days) for Annapolis Royal region is projected to increase by 48.9 days from the 1976-2005 baseline by 2051-2080 (https://climateatlas.ca/). Frost-free season approximates the length of growing season (i.e., no freezing temperatures to kill or damage plants).



Very hot days (+30˚C) for Annapolis Royal region are projected to increase from 1.2 days/year from the 1976-2005 baseline to 13.5 days/year by 2051-2080 (https://climateatlas.ca/).

2.2 Precipitation



Projected total annual precipitation change for Kejimkujik 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 (2.6, 4.5 or 8.5) scenario, total annual precipitation is projected to increase 100 to 175 mm by 2071-2100.

Rainfall Intensity, Duration and Frequency (IDF)

These rainfall IDF values 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 Western Head from 1973-2007.

T (years)	2	5	10	25	50	100
5 min	5.27	6.21	6.92	7.95	8.81	9.75
10 min	7.89	9.13	10.35	12.58	14.92	18.07
15 min	9.76	11.73	13.64	17.06	20.59	25.25
30 min	16.33	20.71	23.90	28.30	31.84	35.62
1 h	23.21	29.49	34.38	41.51	47.27	48.31
2 h	34.47	40.56	43.35	45.90	47.27	48.31
6 h	61.34	72.25	76.42	79.67	81.16	82.15
12 h	70.31	90.76	104.90	123.48	137.80	152.48
24 h	74.44	99.90	124.06	166.55	209.83	266.17

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

T (years)	2	5	10	25	50	100
5 min	6.71	8.14	9.29	10.85	12.08	13.45
10 min	9.95	11.83	13.76	16.81	19.73	23.30
15 min	12.32	15.23	18.09	22.69	27.08	32.48
30 min	20.80	27.11	32.00	38.64	43.81	49.68
1 h	29.55	38.63	45.95	56.37	64.83	67.43
2 h	44.15	53.59	58.31	63.61	66.75	67.43
6 h	78.59	94.96	102.47	109.86	113.79	115.05
12 h	89.61	118.93	140.56	169.51	190.44	215.60
24 h	96.02	134.87	168.66	221.28	269.03	325.31

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

T (years)	2	5	10	25	50	100
5 min	7.17	8.75	10.19	11.35	12.15	12.92
10 min	10.69	12.67	14.89	18.01	19.76	21.96
15 min	13.24	16.33	19.65	24.36	27.31	30.77
30 min	22.17	29.23	35.28	40.46	44.34	48.09
1 h	31.52	41.58	50.47	58.95	65.38	69.56
2 h	46.77	57.88	63.86	66.77	68.40	69.56
6 h	82.99	103.42	112.11	115.62	117.51	118.71
12 h	95.43	128.26	155.63	177.45	193.99	209.65
24 h	102.22	145.66	186.02	236.77	274.02	313.96

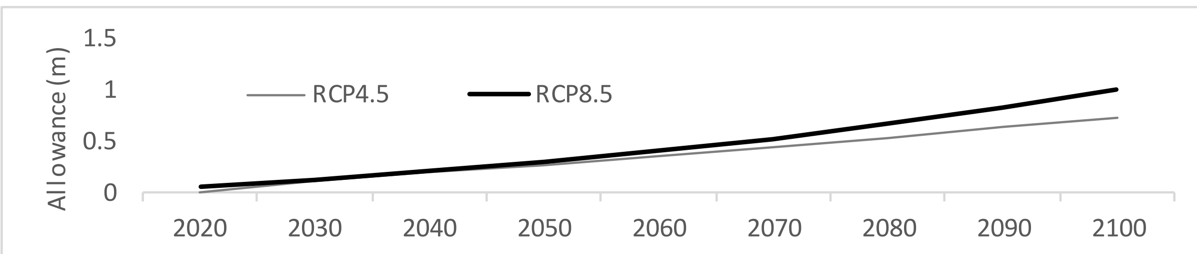
Western Head IDF observations and projections. Observe that today's "one in 100 year" rainfall event (i.e., 48.31 mm/hr) is projected to be closer to a "one in 10 year" event by 2050-2100 and the future "one in 100 year" rainfall event is projected to increase in intensity (i.e., 67.43 – 69.56 mm/hr). In addition, the Climate Atlas of Canada (https://climateatlas.ca/) projects that the number of heavy precipitation days (>20 mm) will increase from the 1976-2005 baseline of 16.5 days to 19.6 days (+3 days) by 2051-2080.

3. Climate Change Impacts

3.1 Relative Sea Level Rise

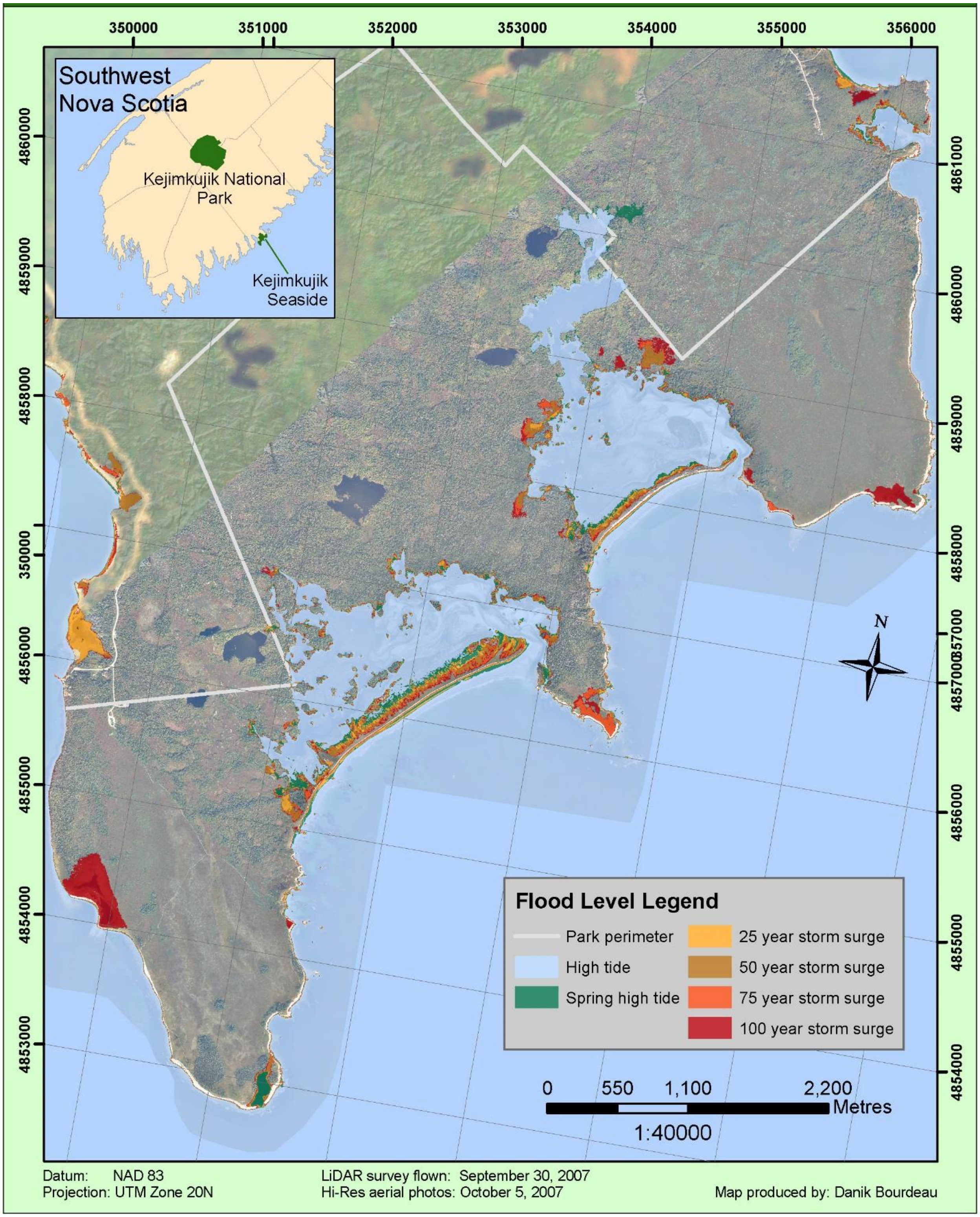
Relative sea level in the region is increasing due to the combined effect of sea level rise (~1.6 mm/yr) and land subsidence (~1.6 mm/yr). For example, between 1900 and 2016 sea level at Halifax increased by 3.28 ± 0.19 mm/yr (+38 cm) (http://www.psmsl.org/products/trends/).

Vertical allowance for Yarmouth were 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.

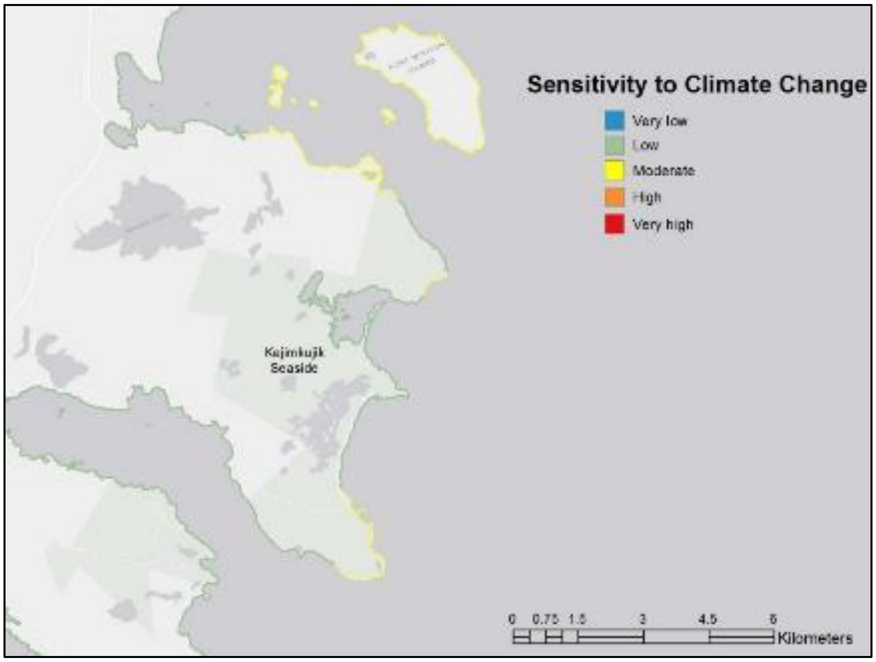


Yarmouth, NS projected vertical allowance of 73 to 101 cm by 2100 (CAN-EWLAT).

Comparing historic photos from 1927 until 2007, Bourdeau (2010) estimated that barrier beaches at Kejimkujik Seaside have moved landward. St Catherine’s River beach moved inland at a rate of 1.96 m/year and Little Port Joli moved at a rate of 0.2 m/year. The total lagoon area has also changed with the landward movement of the barrier beaches. St. Catherine’s River lagoon decreased by 22% and Little Port Joli lagoon decreased by 2.2%. Furthermore, Bourdeau (2009) modelled the impact of a 0.69 m increase in sea level by 2100 at the Kejimkujik Seaside. The exercise demonstrated a high risk of flooding for the lagoons in association with spring tides and storm surges and some uncertainty as to whether saltmarsh and eel grass beds will be able to migrate to the potential new locations.



Projected flood mapping for Kejimkujik Seaside for 2050. Prepared by Bourdeau (2009).



Coastal sensitivity to climate change 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 Species and Ecosystems

In general, the effects of climate change on biodiversity include: shifts in species distribution; changes in phenology; decoupling of interactions (plant-pollinator); reductions in population size; species extinction and extirpation; habitat loss; increased disease and spread of invasive species; competitive exclusion; and, change to ecosystem services (Nantel *et al.*, 2014; Nituch and Bowman, 2013). Some more specific regional effects include:

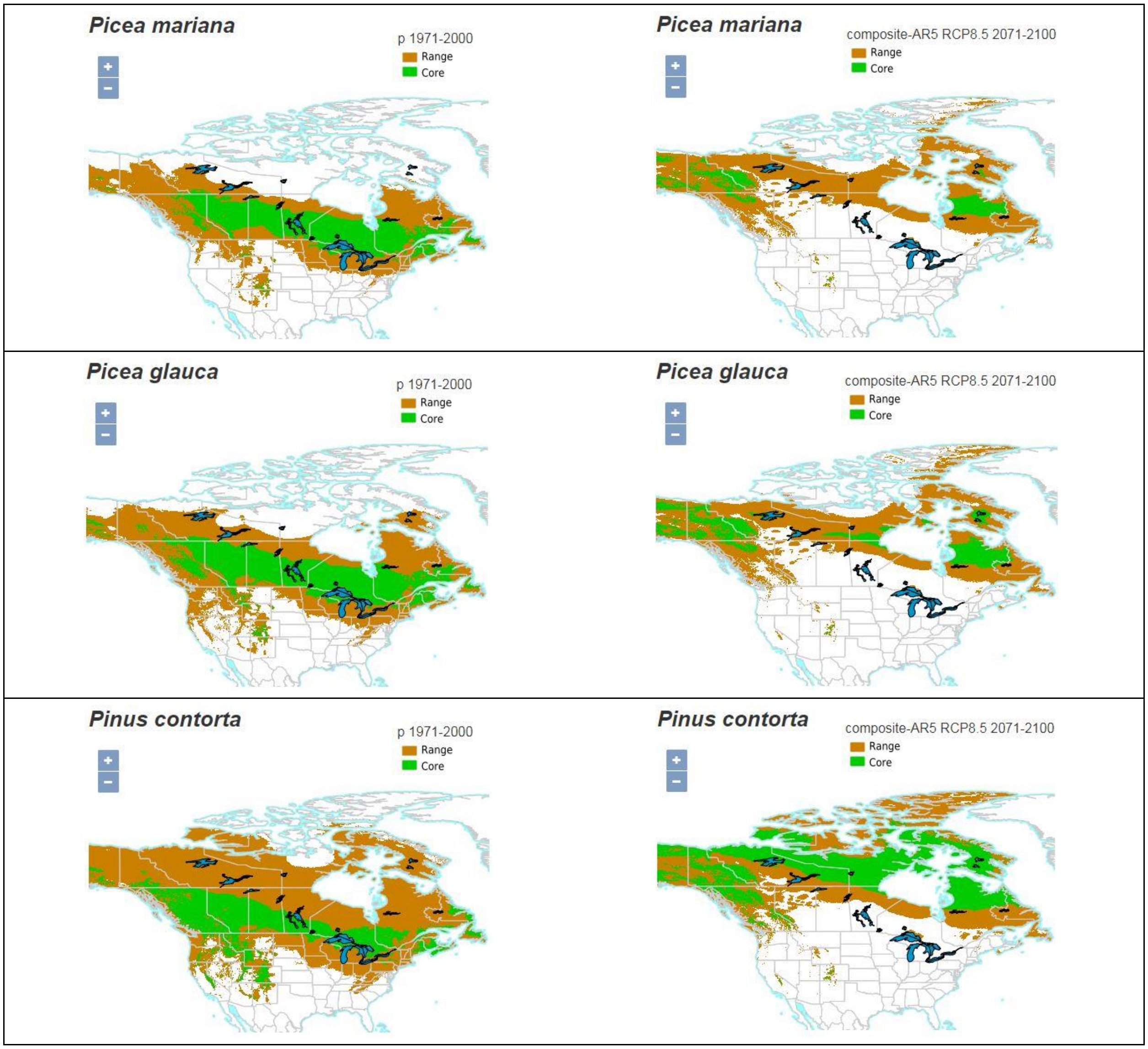
- Loss of boreal tree species, such as Balsam Fir, are projected due to climate change (Bourque and Hassan, 2008; Taylor *et al.*, 2017).
- Increasing incidences of Lyme disease (tick vector) have been linked to climate change (Eisen *et al.*, 2016; Nova Scotia, 2012). Climatic conditions may become more favourable for some mosquito vector diseases (e.g., West Nile Virus) in the future as well (Wudel and Shadabi, 2016).
- Earlier peaks in insect populations and plant biomass have been observed and may mismatch with migrant bird hatchling growth and development (e.g., asynchrony between wood warbler and eastern spruce budworm) (Knudsen *et al.*, 2011; Nituch and Bowman, 2013).
- Climate change will influence environmental chemistry and pollutants, including an exacerbation of the effects of acid deposition (lower pH due to higher CO2 levels), nutrient loading (precipitation events), and mercury toxicity (released under anoxic conditions, warmer waters increase the rate of methylation) (Michalak, 2016; Noyes *et*

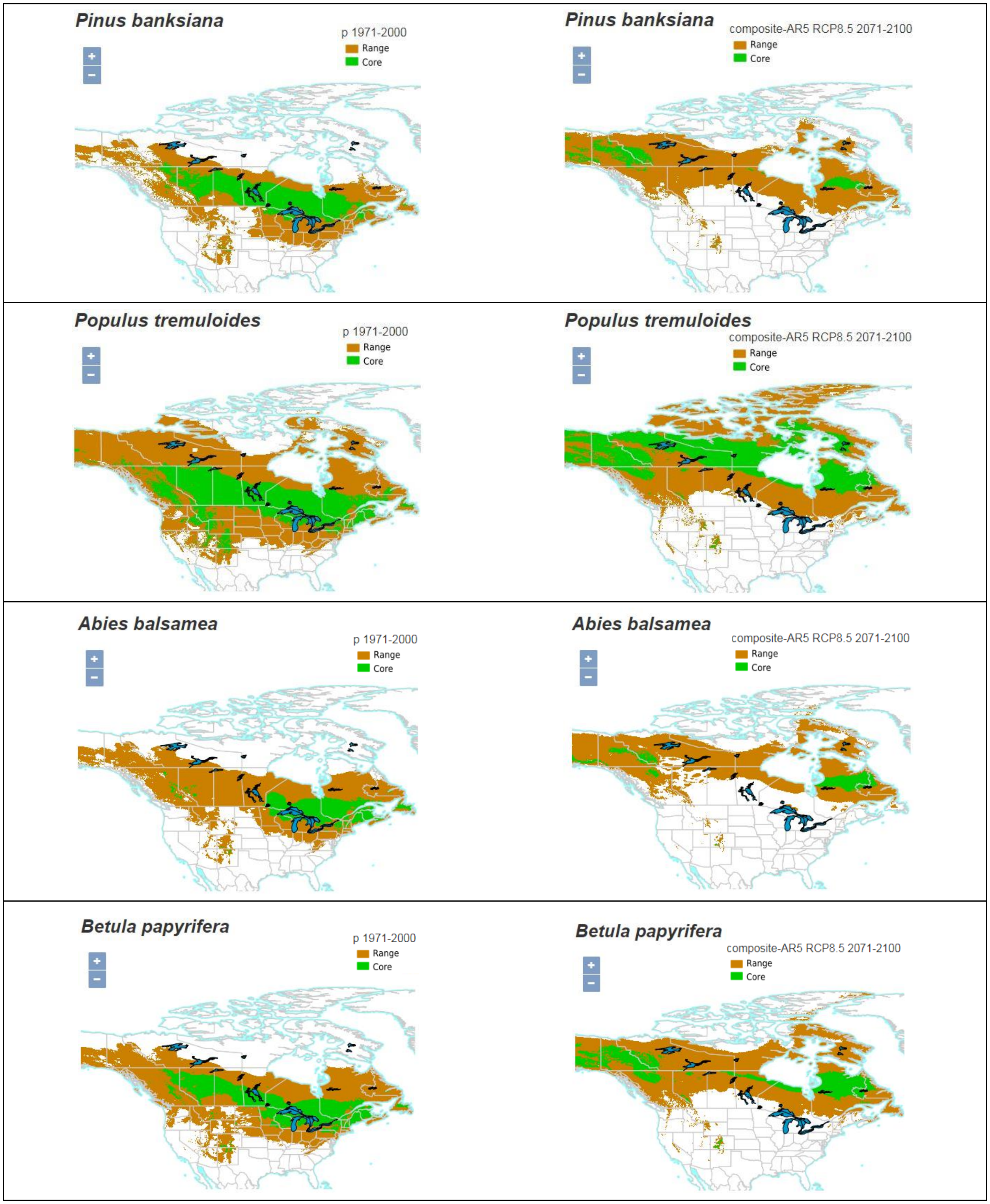
al., 2009). This may heighten environmental toxicity concerns at Kejimkujik (e.g., Clayden *et al.*, 2013; Korosi *et al.*, 2013; Little *et al.*, 2015; Scheuhammer *et al.*, 2016).

- A vulnerability assessment by Gomer (1999) identified several species threatened by climate change; Red Spruce (*Picea rubens*), Striped Maple (*Acer pensylvanicum*), Sugar Maple (*Acer saccharum*), Eastern Hemlock (*Tsuga canadensis*), American Beech (*Fagus grandifolia*), several disjunct coastal plain plants, and the American Marten (*Martes americana*).
- A total of 31 species were assessed for vulnerability by Osawa (2015) under a severe climate change scenario by 2080. Species highlighted as having a high vulnerability included, boreal tree species (i.e., Balsam Fir (*Abies balsamea*) and Black Spruce (*Picea mariana*)), Brook Trout, American Marten, and Mainland Moose (*Alces alces americana*). Species with high adaptability included Coyote (*Canis latrans*), White tailed Deer (*Odocoileus virginianus*), Fisher (*Martes pennanti*), Beaver (*Castor canadensis*) and hardwood species (e.g., Red Oak (*Quercus rubra*), Ironwood (*Ostrya virginiana*), and Red Maple (*Acer rubrum*)).
- Increased winter temperatures may make conditions favourable for the survival and impact of some forest insects (native and non-native). For instance, Emerald Ash Borer (*Agrilus planipennis*) was detected near Halifax in 2018 and Southern Pine Beetle (*Dendroctonus frontalis*) is moving northward (Williams and Liebhold, 2002).
- Eastern Hemlock are expected to decline as Hemlock Woolly Adelgid (HWA) spreads throughout southeastern Nova Scotia. It was discovered in Kejimkujik in 2018 and is expected to result in 80% mortality of Eastern Hemlock over the next 10 years. HWA is sensitive to cold winter temperatures, particularly fluctuations in late season (February and March). With warming winters HWA is projected to expand northward (Paradis *et al.*, 2008).
- Ice cover in the Northeast has decreased in the past 150 years (Magnuson *et al.*, 2000). Sapna *et al.* (2019) project that southern Nova Scotia will experience intermittent winter ice cover with an increase of + 2°C in air temperature. Less lake ice cover may result in lower lake levels due to increased evaporation rates. Lakes with less ice cover also tend to be warmer in the summer with high primary productivity and algae biomass (Weyhenmeyer *et al.*, 2008).
- An assessment of fishes in Nova Scotia reported cold-water species (e.g., Atlantic Whitefish (*Coregonus huntsman*), Brook Trout, Atlantic Salmon (*Salmo salar*)) are very susceptible to warming trends (Kanno and Beazley, 2004). Summer stream temperatures in Kejimkujik streams are often well above the temperature stress thresholds identified for Brook Trout (>20°C).
- Chain Pickerel (*Esox niger*) (discovered in 2018) and Smallmouth Bass (*Micropterus dolomieui*) are invasive fishes in Kejimkujik. Both are tolerant of warm waters and are expected to displace Brook Trout though direct predation and reduction of prey fishes (Davis *et al.*, 2017; Loppnow *et al.*, 2013).
- Eelgrass beds at Kejimkujik Seaside are expected to be negatively impacted by increases in summer temperatures (>30°C) resulting in lower dissolved oxygen concentrations and lower above ground shoot production (Bintz *et al.*, 2003). Warmer spring and fall temperatures are also expected to be favourable for invasive Green Crab and may negate the benefits of a longer growing period for Eelgrass and Soft-shelled Clams.

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 database that includes future projections of plant hardiness (http://www.planthardiness.gc.ca/).

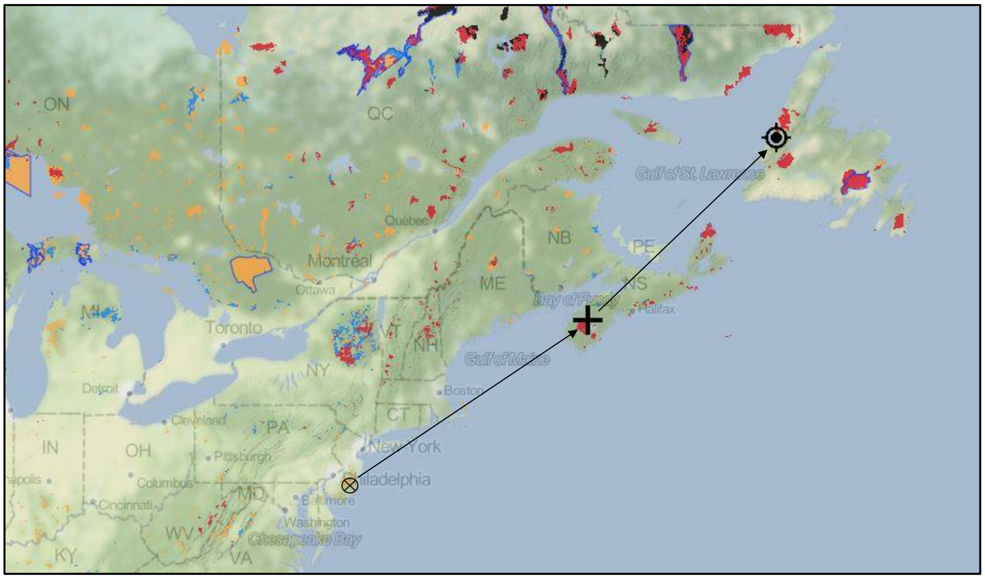




Change in core and full range for select tree species from a 1971-2000 baseline to 2071-2100 future projection (RCP 8.5) based on plant hardiness.

Climate Velocity

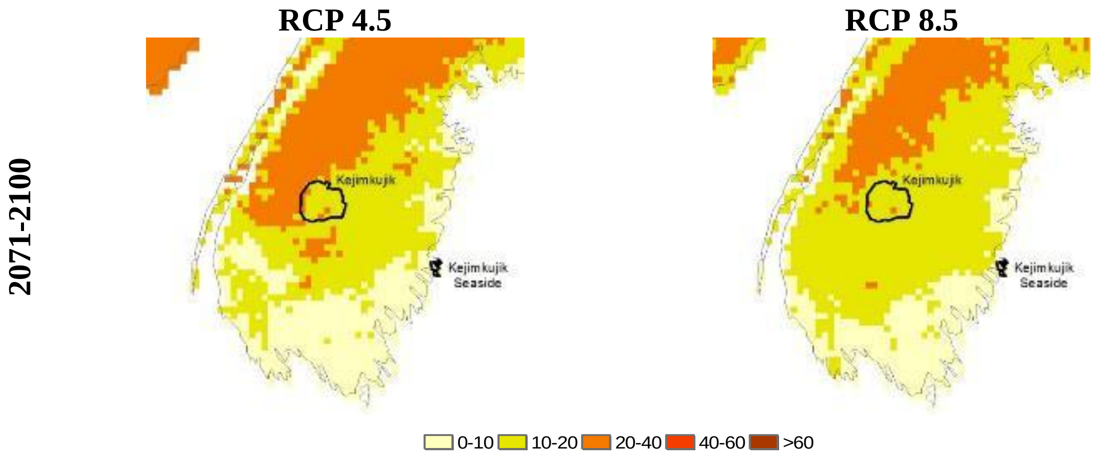
AdaptWest (https://adaptwest.databasin.org/) provides integrative tools that can inform conservation planning, including the following analysis on climate velocity.



Origin and destination of the future climate type for Kejimkujik (2080's, RCP 8.5) determined using the AdaptWest Climate Displacement Tool, https://adaptwest.databasin.org/pages/climate-displacement-protected-areas. Climate velocity data from AdaptWest further confirms that the climate type is outgoing (forward) at approximately 4 km/yr and incoming (backward) at approximately 14 km/yr (RCP 8.5). In other words, that is the rate an organism has to migrate to maintain constant climate conditions.

3.3 Wildfire

Due to positive trends in drying and escalation of potential fire severity and intensity, a moderate increase in wildfire risk is projected for this area (Whitman *et al.*, 2015).



Projected increase in wildfire season for Kejimkujik. Increased length in days from baseline (1981-2010) under RCP 4.5 and RCP 8.5 scenarios. An increase of approximately 14 days is projected by 2071-2100. Data source: Natural Resources Canada, http://cfs.nrcan.gc.ca/fc-data-catalogue.

- Lightening has a positive correlation with temperature, increasing risk of wildfire ignitions (e.g., Veraverbeke *et al.*, 2017; Woolford *et al.*, 2014).
- Flannigan *et al*. (2016) demonstrate that seasonal precipitation must increase 15% to offset every 1˚C rise in temperature.

3.4 Cultural Resources

Kejimkujik is one of the few National Parks where a large portion is also designated as a National Historic Site. This is in recognition of the strong connection the Mi'kmaq people have to Kejimkujik and have maintained since time immemorial. The cultural landscape includes waterways, encampments, burial grounds, lakes, wetlands and forests, all of which will be affected by climate change. The Mi'kmaq ways of thinking, including Etuaptmumk ("two-eyed seeing") and Netukulimk ("taking only what you need"), will be important for informing how Kejimkujik responds to the impacts of climate change.

Examples of climate change impacts to cultural resources in Kejimkujik include:

- Population decrease or loss of harvestable animals that are sensitive to warming temperatures (e.g., Mainland Moose, Brook Trout).
- Decrease or loss of culturally important plant species (e.g., White Birch, medicinal plants).
  Decrease or loss of culturally significant forest types, including Hemlock forests (Hemlock Woolly Adelgid impacts) and ash species (EAB and drying impacts on forested wetlands).
- Petroglyphs along Kejimkujik lake shores may be affected by changes in environmental conditions including water chemistry, wave action, and period of wetness (Marissa *et al.*, 2016; Parks Canada, 2017b).
- Increased frequency of storms and wind events could result in higher rates of erosion at known and unknown archeological sites inside streams (e.g., eel weirs) and beside stream banks.
- Sea level rise will result in an increased rate of erosion and exposure of known and unknown archeological sites along the coast (Melnick *et al.*, 2016).

3.5 Visitor Experience

It is expected that visitor patterns will change due to an earlier spring and warmer summer and autumn conditions.

- Maximum and minimum temperature were determined to be the most influential climate variable for predicting visitation in 15 national parks (these parks accounted for 86% of Parks Canada's visitation at the time) (Jones and Scott, 2006).
- The US National Park Service examined visitation response across their network and found that it generally increased as mean monthly temperatures increased, but decreased strongly as temperatures exceeded 25˚C. Future climate/visitation projections suggest that

there is a complex and cascading effect, and a consequent need to develop park and neighbouring community adaptation strategies (Fisichelli *et al.*, 2015).

- Hewer and Gough (2018) reviewed 30 years of climate change impacts on outdoor recreation in Canada, including increased risks to cold-weather activities and opportunities for warm weather activities.
- Decreased snowpack will negatively impact winter recreational activities such as snowshoeing, skiing, ice fishing, ice travel and snowmobiling.
- A longer and more intense fire season will affect visitor safety and experience (e.g., area closures, no campfires).
- Extreme weather events are the top risk globally in terms of likelihood and the second highest risk in terms of impact (after weapons of mass destruction) (World Economic Forum, 2018). Intense rainfall, lightning storms, hail, extreme winds and wildfire events are all potential hazards whose risks are projected to increase (e.g., Brimelow *et al.*, 2017; Cheng *et al.*, 2012; IPCC, 2012). Besides a potential role in emergency preparedness and response, protected areas are increasingly being recognized as a "natural solution" in terms of disaster risk reduction (e.g., flood control, protection from storm surge, etc.) (e.g., Dudley *et al.*, 2015; Lo, 2016; Murti and Buyck, 2014).
- More intense, frequent and longer heat waves during the summer could increase the pressure on Kejimkujik as people leave urban centres to cool off in lakes and oceans (Luber and McGeehin, 2004; 2008; Meehl and Tebaldi, 2004).
- Higher UV radiation under future ozone depletion (Bais *et al.*, 2015; Sitch *et al.*, 2007).

Climate change is a theme in Parks Canada's communication and interpretation programs (e.g., https://www.pc.gc.ca/en/nature/science/climat-climate). By engaging and inspiring the public, Parks Canada is able to build support for its mandate and adaptation actions. A place for "natural solutions" is a concept used to frame and present Parks Canada's response to climate change mitigation and adaptation, as it highlights the importance and effectiveness of ecosystem-based approaches (e.g., CPC, 2013; NAWPA, 2012)

"The changing climate surrounds us, compelling us to tell the story" (US NPS). Of related interest, is the US National Park Service climate change interpretation and education strategy (US NPS, 2016) and climate change interpreter training (http://idp.eppley.org/training/specialist/interpreting-climate-change). Parks Canada staff have found this training to be very helpful.

3.6 Assets and Infrastructure

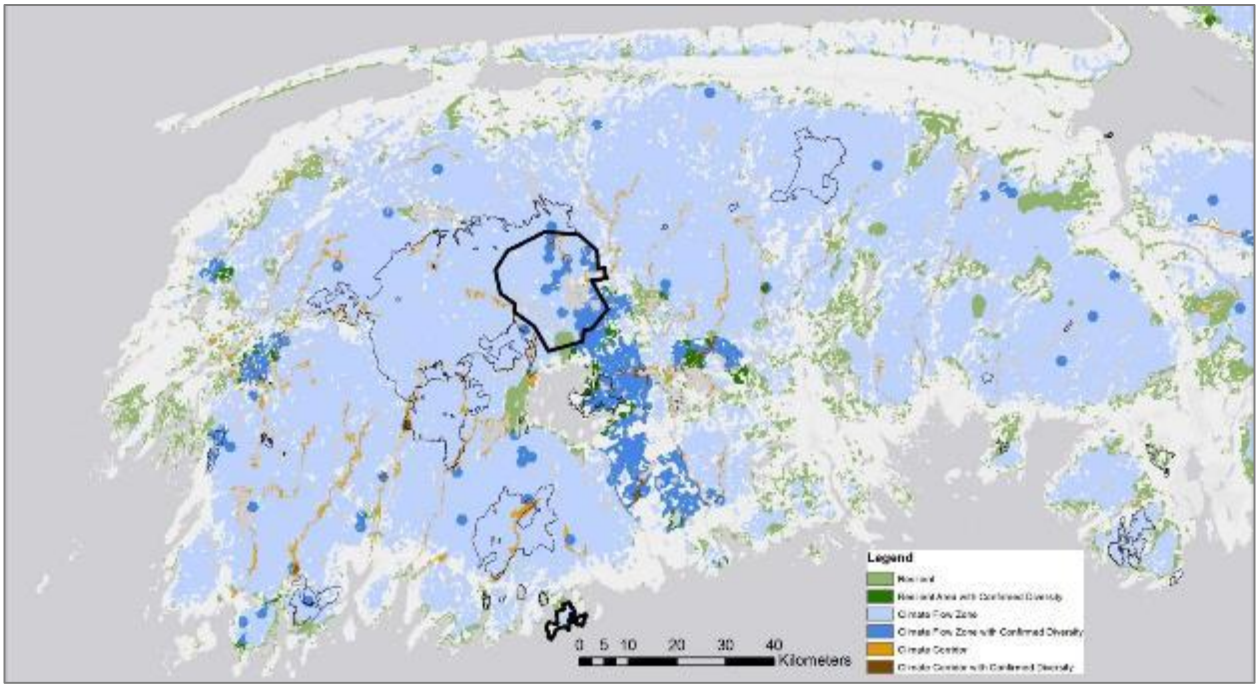
The impacts to Canada's assets and infrastructure from climate change are well documented (e.g., Boyle *et al.*, 2013; Canada, 2017; Palko and Lemmen, 2017; Warren and Lemmen, 2014) and are explicitly mentioned as a concern in Parks Canada's Departmental Plan (Parks Canada, 2017a). Although an assessment of vulnerabilities and risks to infrastructure has not been completed at Kejimkujik, in light of the information in this report, expected concerns could include:

- Flooding from intense rainfall and winter rain events, could overwhelming surface drainage capacity, septic beds, particularly undersized or debris filled culverts, bridges and damaging buildings facilities, boardwalks, bridges, and washing out roads, etc…
- Local flood modelling for the town of Bridgewater predicted an increase of 16% in discharge for the LaHave River for flood events occurring at 10 year intervals rather than at every 50 years (Webster *et al.*, 2014).
- Sea level rise and storm surge will result increased erosion and flooding to hiking trails at the Kejimkujik Seaside.
- Freezing rain or hail damage to buildings and power/communication lines.
- Longer wildfire season and more intense burns, especially given the high urban interface.
- Longer seasonal use of trails and roads by visitors. May be less frost damage to roads in milder winters.
- Increased temperatures could lead to premature weathering. Similarly, increased spring rains could lead to premature weathering and deterioration (e.g., building foundations, corrosion, and mold).
- Summer drought increases water demands and may exceed system capacity.
- The energy demands for cooling buildings will increase.

An assessment of greenhouse gas (GHG) emissions was not in the scope of this report. However, it is important to observe that throughout the document different RCP scenarios were presented and if we meet (and celebrate) RCP 2.6 or continue to track (and mourn) RCP 8.5, depends entirely on our actions to address and reduce GHG emissions today. Federally the government is committing to reducing GHG emissions by 80% below 2005 levels by 2050 (https://www.canada.ca/en/treasury-board-secretariat/services/innovation/greening-government/strategy.html). Also see Parks Canada's 2015 Master Plan to reduce GHG emissions (Parks Canada, 2015).

3.7 Related Information

Climate Resilient Landscape



The Nature Conservancy's Resilient Land Mapping Tool (Anderson *et al.*, 2016; http://maps.tnc.org/resilientland/). Kejimkujik and other protected areas mapped with black line. Resilient areas include areas of landscape diversity (micro-climates) and local connectedness. Climate corridors include narrow conduits, highly concentrated flow, e.g., riparian channels, linear ridge lines. Climate flow zones include high level plant and animal movement that is less concentrated than corridors, e.g., intact forests.

- **Two Countries, One Forest** is a Canada-U.S. collaborative of conservation organizations, researchers, foundations and conservation-minded individuals focused on the protection, conservation and restoration of the Northern Appalachian/Acadian ecoregion. The website includes publications, maps and data related to climate change and landscape management, https://programs.wcs.org/2c1forest/.

- **Southwest Nova Biosphere Reserve** is a UNESCO designation and promotes conservation and sustainable development within the 5 counties of Annapolis, Digby, Yarmouth, Shelburne and Queens. The association is currently working on a science atlas for the reserve, http://swnovabiosphere.ca/.

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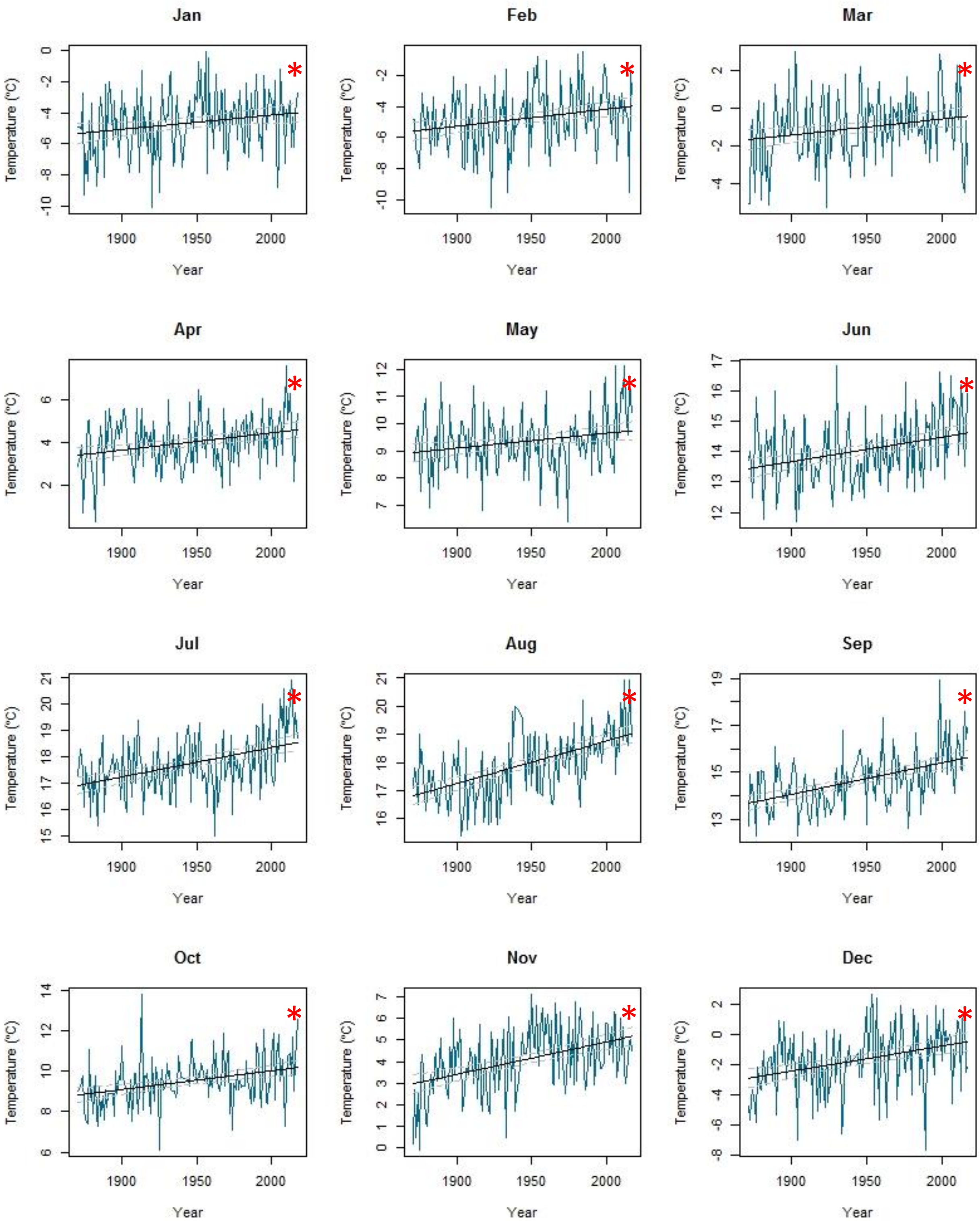
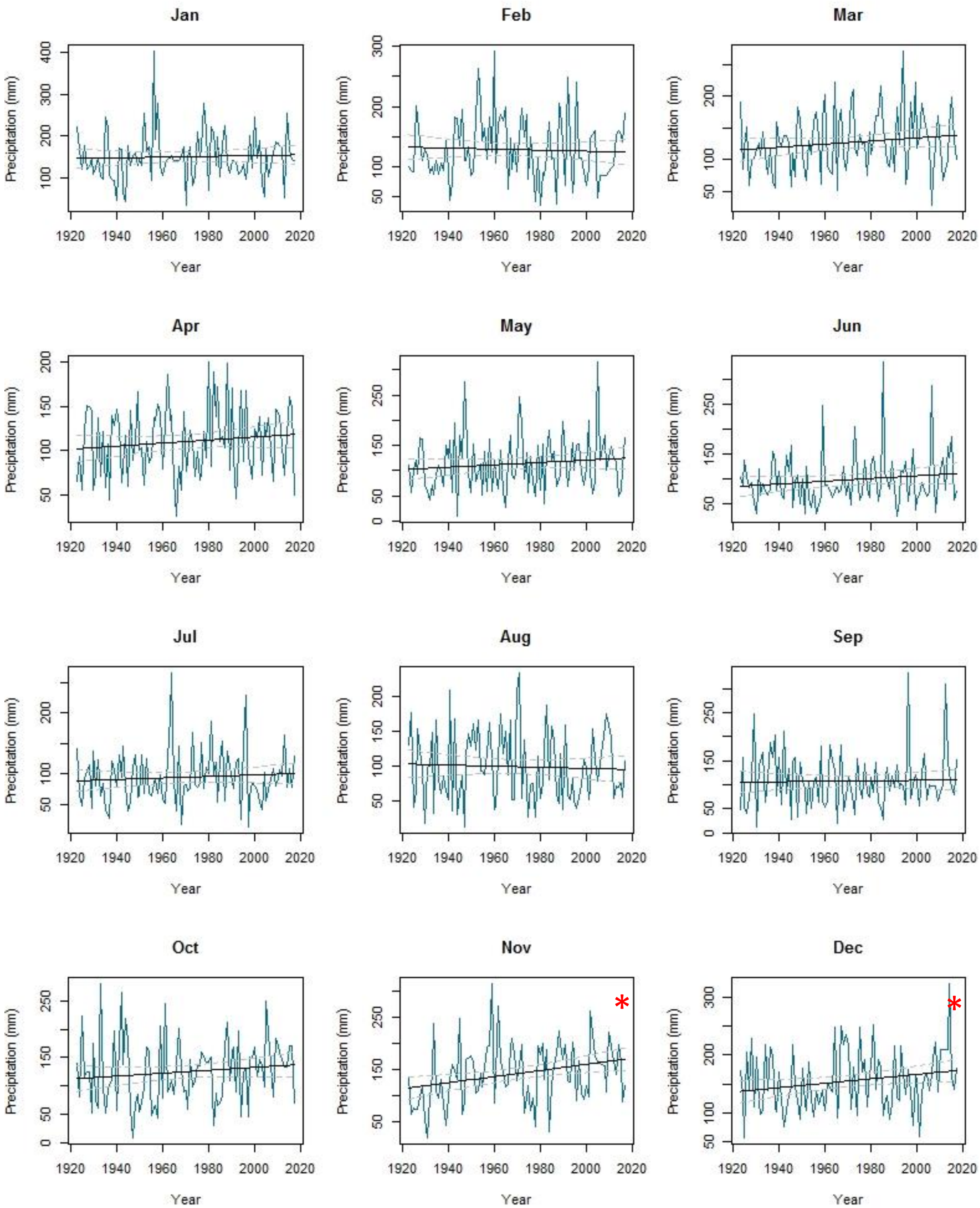
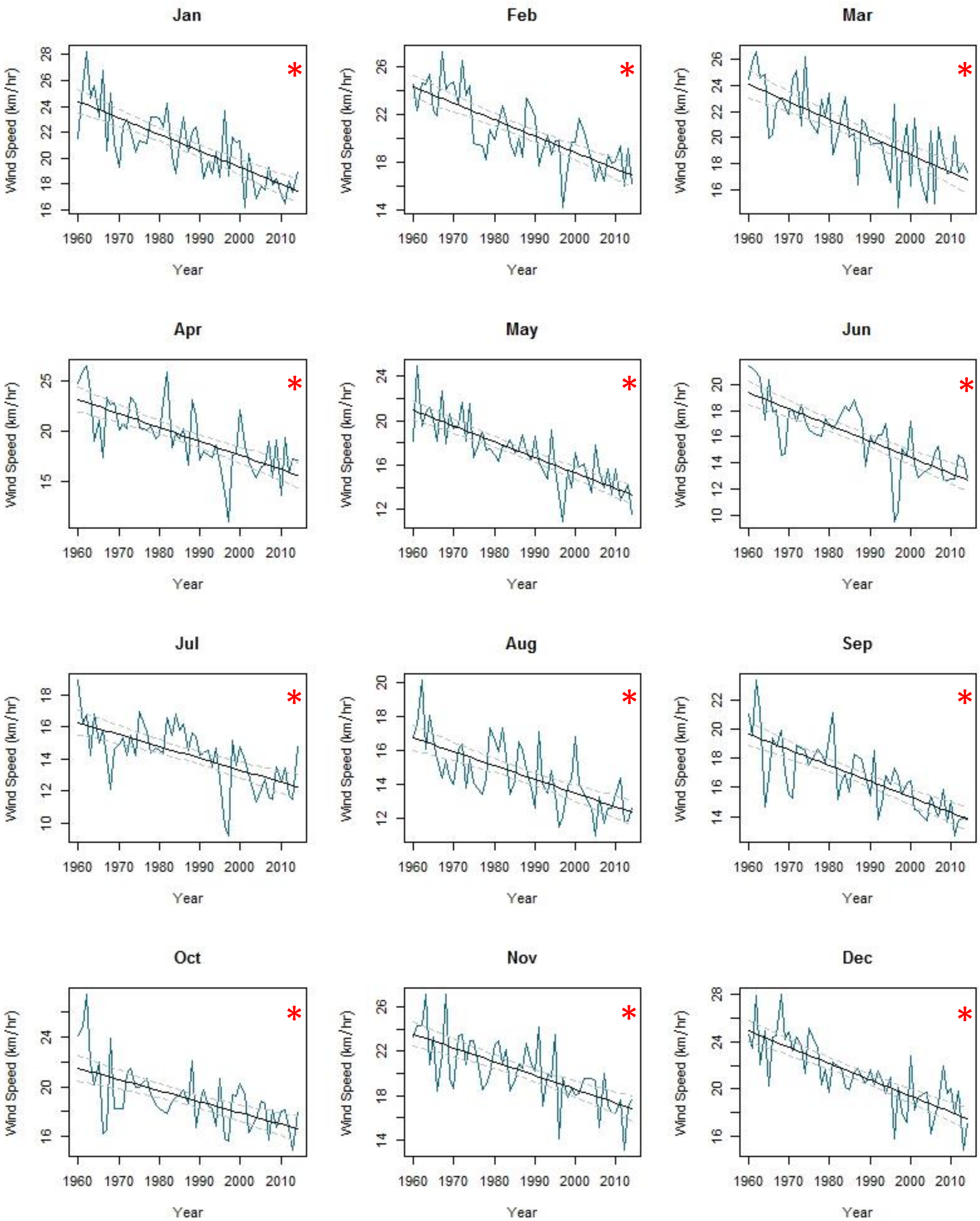
Appendix 1. Additional Climate Trends



Liverpool mean monthly temperature. All months demonstrated a statistically significant ($P<0.05$) increase. Dec demonstrated the greatest increase, 2.4°C since 1872.

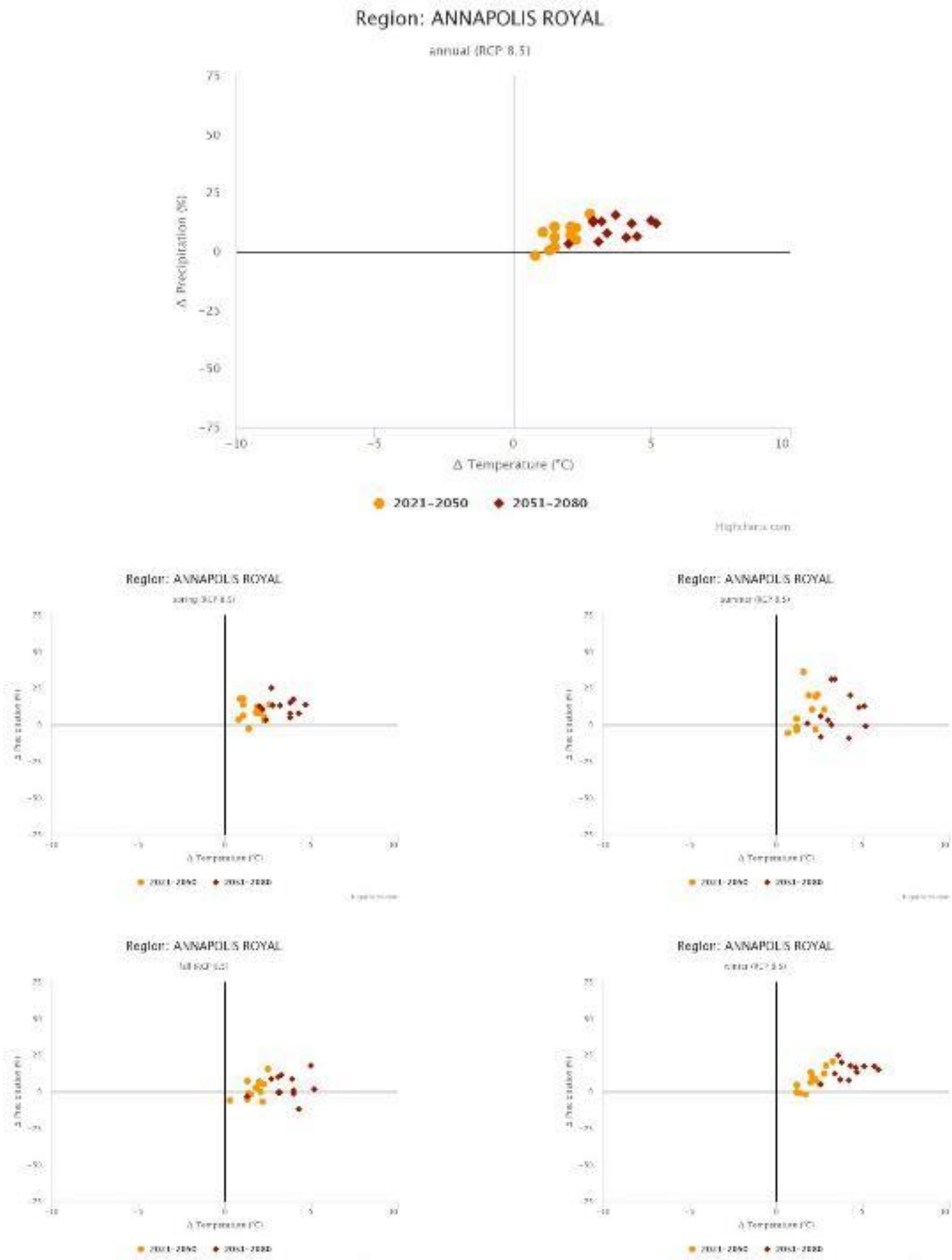


St. Margaret's Bay total monthly precipitation. All months except Feb and Aug demonstrated a slight increase in total monthly precipitation, Nov and Dec demonstrated a statistically significant increase (P<0.05) since 1923. The greatest increase being observed in Nov, +55 mm (+48%).



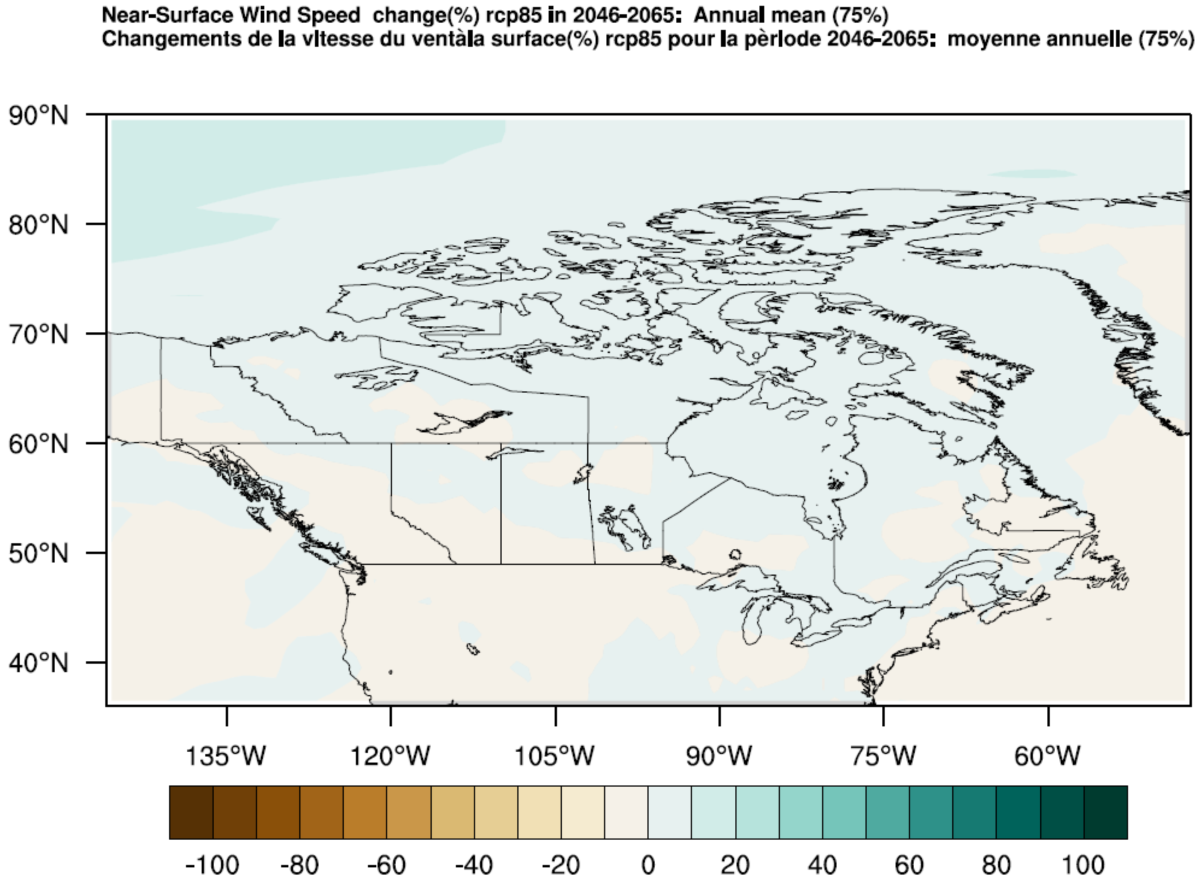
Western Head mean monthly wind speeds. All mean monthly wind speeds have demonstrated a statistically significant ($P<0.05$) decrease since 1960, the being observed for May, -7.6 km/hr (-36%).

Appendix 2. Model Scatterplots for Temperature and Precipitation



Climate models for Annapolis Royal 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). All the models project warmer conditions and most project 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).