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Supplemental Climate Information for Sable Island National Park Reserve

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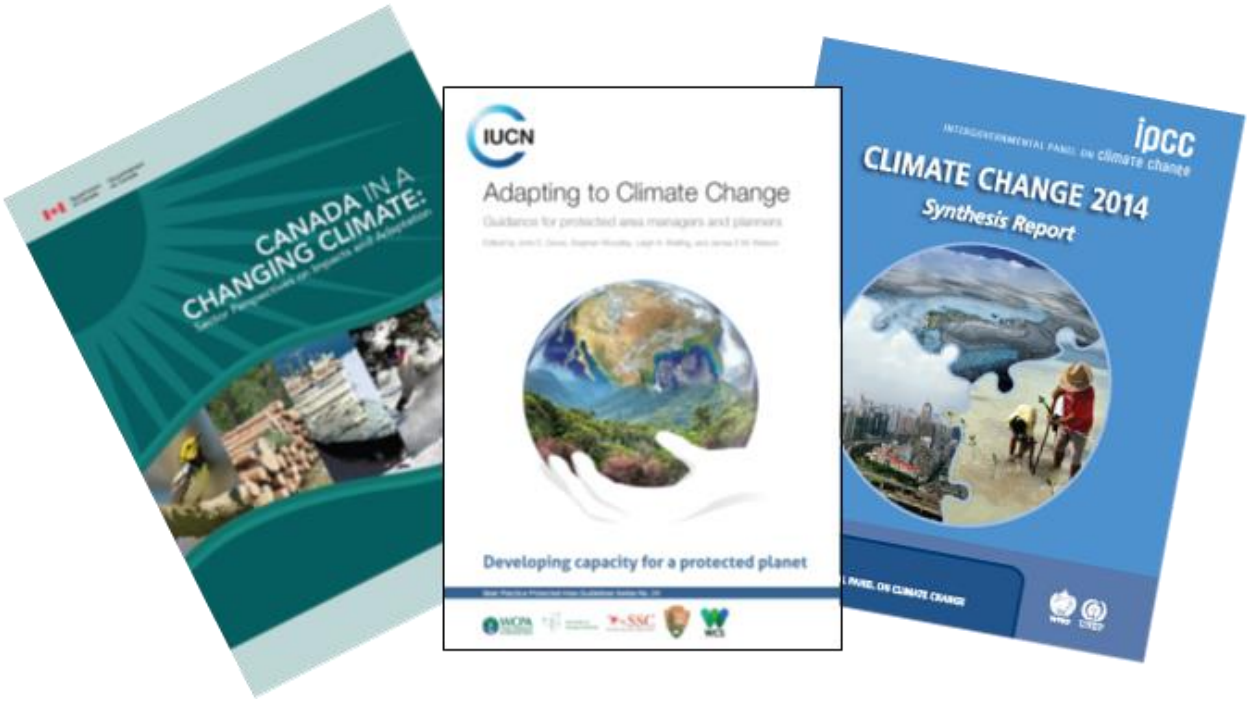
Contents

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 Sable Island National Park Reserve.

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 to rise "status quo" throughout the 21st century.

This is a site focussed document and to understand the larger climate change context please consult 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 and mitigation options, please review Gross *et al.* (2016).



Highlights

Sable Island is located in the North Atlantic Ocean approximately 156 km from the nearest landfall. It is a crescent-shaped "sandbar" approximately 49 km long and up to 1.3 km wide with a maximum elevation of just over 30 m above sea level (AGRG, 2015). It is subject to dynamic processes, including seasonal and long-term patterns in sand deposition and erosion. In addition to dune systems, the island features an extensive freshwater lens, a feral horse population, the world's largest grey seal breeding colony, and several rare and/or endemic species (Neily *et al.*, 2017).

- Mean annual air temperature has increased by ~1˚C since 1898 and is projected to continue to increase an additional 3 to 5˚C by 2071-2100. Winter is warming faster than the other seasons.
- Total annual precipitation has increased by ~15% from 1891–2001 and is projected to increase another 7-9% by 2071-2100. Total amount of precipitation in the form of rain has shown an increasing trend, while total amount in the form of snow appears stable. Precipitation in autumn is increasing more than the other seasons (winter is still the wettest season).
- Intensity of rainfall events (mm/hr) are projected to increase, e.g., todays' one in 100 year event is expected to become a one in 25 year event.
- Mean annual wind speed has decreased by 6% since 1953 and is projected to continue to decrease through to 2046-2065.
- Relative sea level is projected to continue to increase 3-4 cm/decade. The island remains very sensitive to climate change due to its relief, sand composition, wave exposure and projected sea level rise.
- The islands freshwater is supplied by precipitation. Information on the long-term influence of climate change is unavailable (e.g., precipitation, evaporation, sea level rise, salt water intrusions, etc…).
- Species at risk, including Sweat Bee and Savannah Sparrow may be affected by rising sea levels.

"...Sable Island, remarkable as regards its position, its shape, its structure, and still more as regards its history ... remains to this day shrouded in an obscurity no less remarkable" (Oxley, 1887).

Disclaimer

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

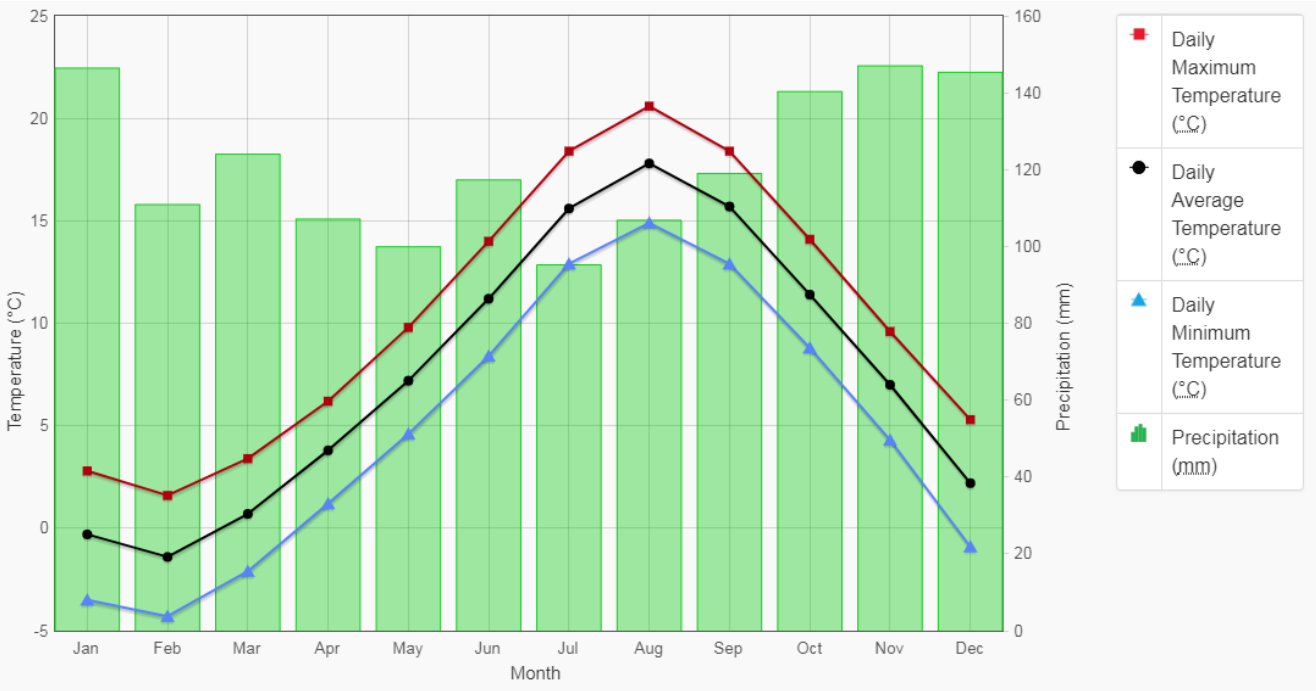
1. Historic Climate

Freedman (2014) provides a review of climate change on Sable Island, including information on the history of meteorological observations.

For long-term trend analysis, meteorological data from Environment and Climate Change Canada's (ECCC) Adjusted and Homogenized Canadian Climate Data (AHCCD) database was used in this report (ECCC, 2017). This data is summarized by month, season and year.

For additional analysis based on hourly values, please refer to ECCC's Historical Data (http://climate.weather.gc.ca/historical_data) for the stations listed in the following table.

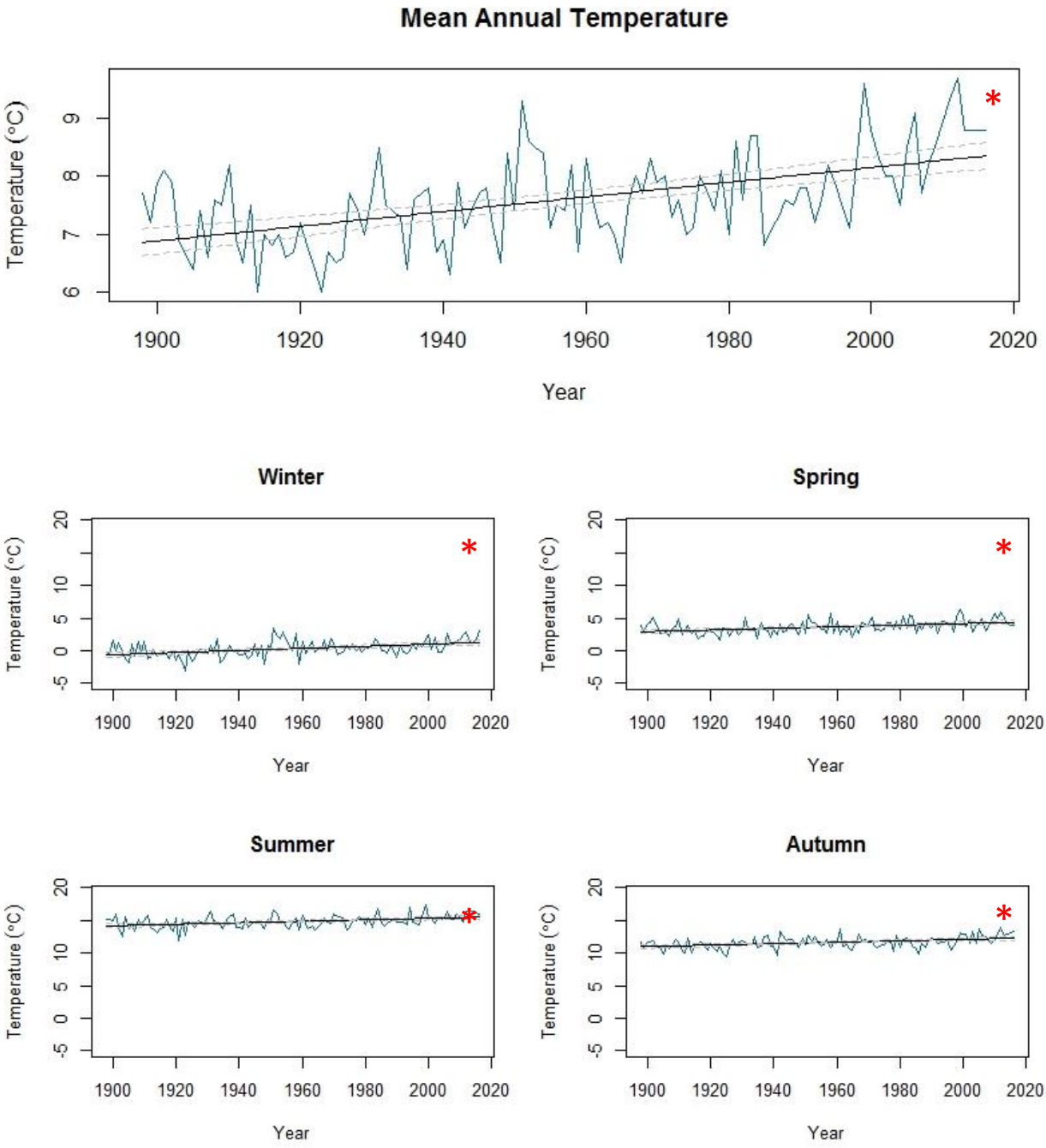
Name	Climate ID	Latitude	Longitude	Elevation (m)	First Year	Last Year	Hourly First Year	Hourly Last Year
Sable Island	8204700	435556000	-600034000	5	1891	2017	1953	2016
Sable Island	8204701	435600000	-600000000	4	1995	2006	1995	1998
Sable Island East	8204702	435800000	-594600000	7.6	1883	1930		
Sable Island A	8204703	435646000	-595735000	1.2	2014	2018	2014	2018
Sable Island 1	8204707	435600000	-600100000	4	1992	1996	1994	1994
Sable Island	8204708	435645000	-595735000	1.2	2017	2018	2017	2018



Temperature and precipitation climate "normals" (1971-2000) for Sable Island. Figure source: Environment and Climate Change Canada (http://climate.weather.gc.ca/climate_normals/).

1.1 Temperature

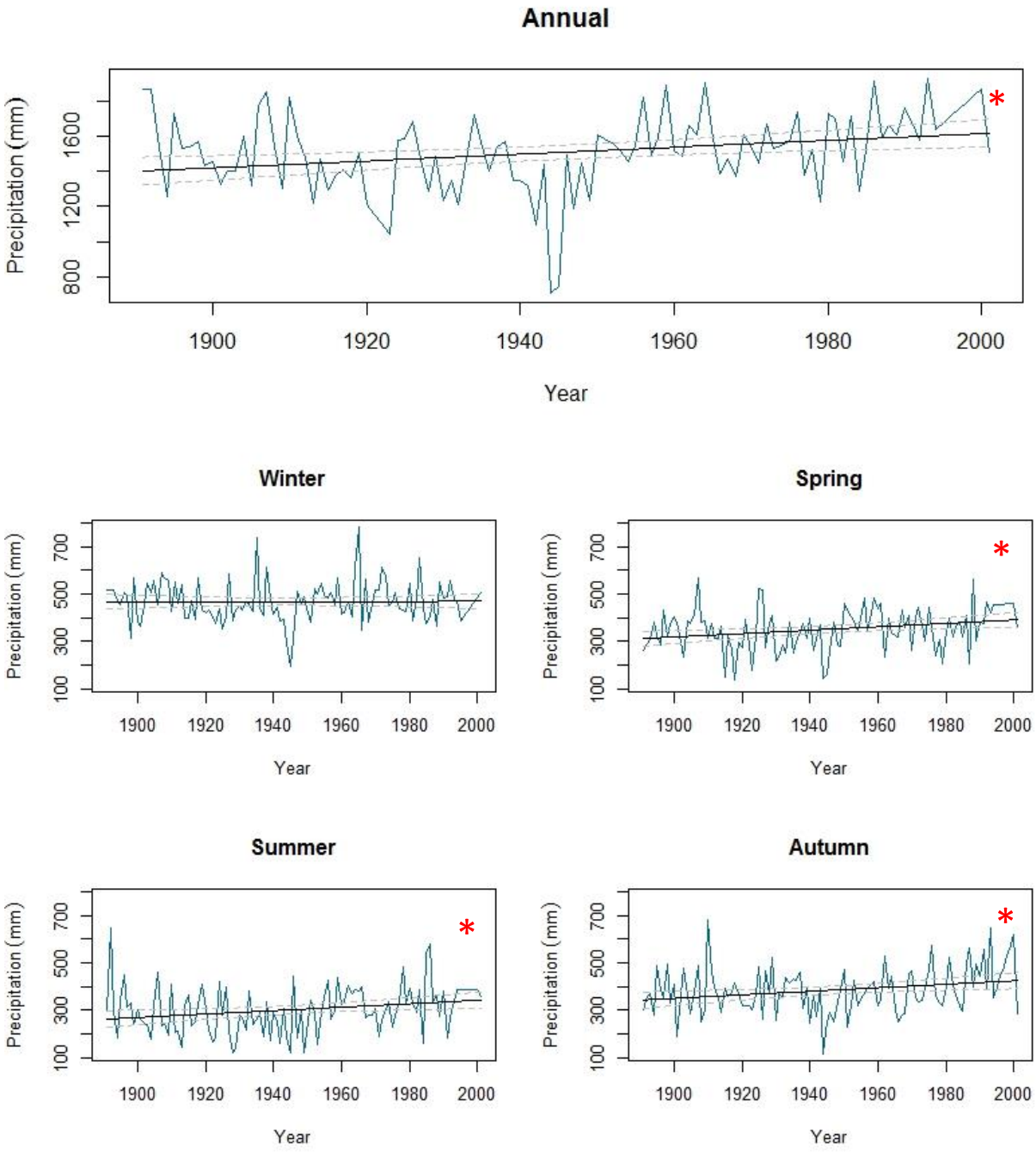
Sable Island (8204700) temperature data from AHCCD (ECCC, 2017). Trends from 1898 to 2016 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).



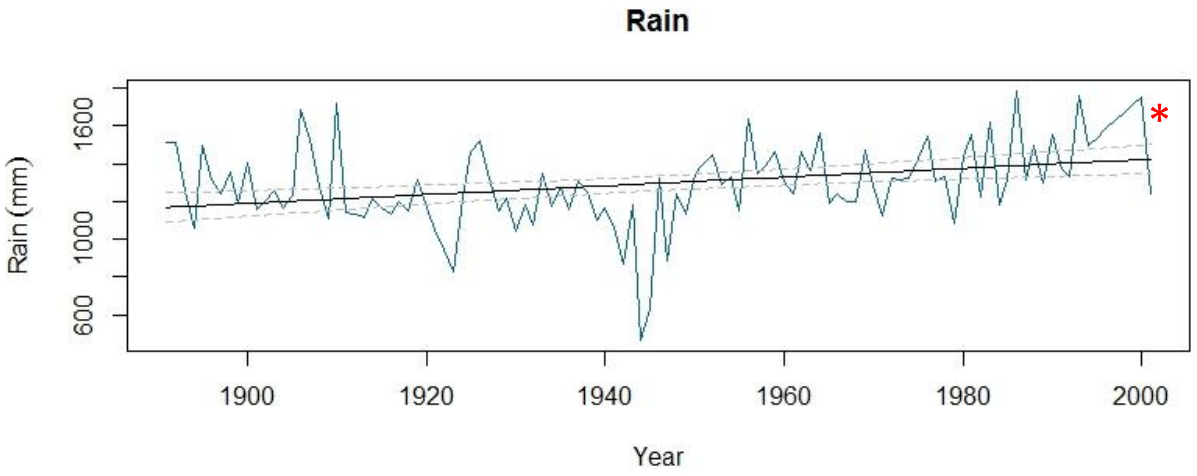
Sable Island mean annual and seasonal temperature. A statistically significant (P<0.05) increase observed in mean annual and seasonal temperatures. Mean annual temperature has increased by ~1°C since 1898. Of all the seasons, winter temperature has increased the greatest, ~1.3°C since 1898. Similarly, Freedman (2014) reports an increase of 0.11˚C / decade.

1.2 Precipitation

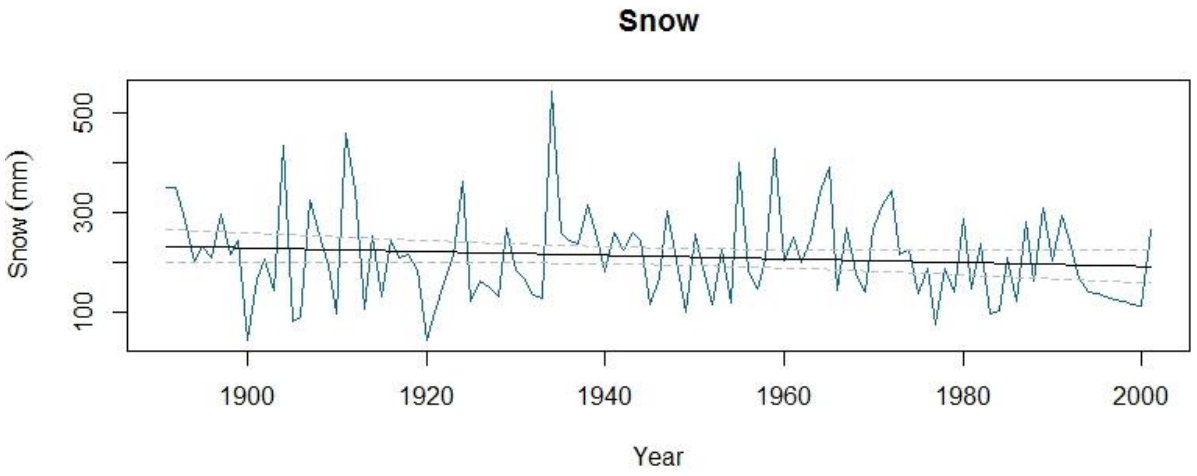
Sable Island (8204700) precipitation data from AHCCD (ECCC, 2017). Trends from 1891 to 2001 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).



Sable Island total annual and seasonal precipitation. Total annual precipitation demonstrated a statistically significant increase (P<0.05), ~251 mm (15%) between 1891-2001. All seasons except winter (Dec, Jan, Feb) demonstrated a statistically significant (P<0.05) increase, the greatest being observed for autumn, ~81 mm (23%).



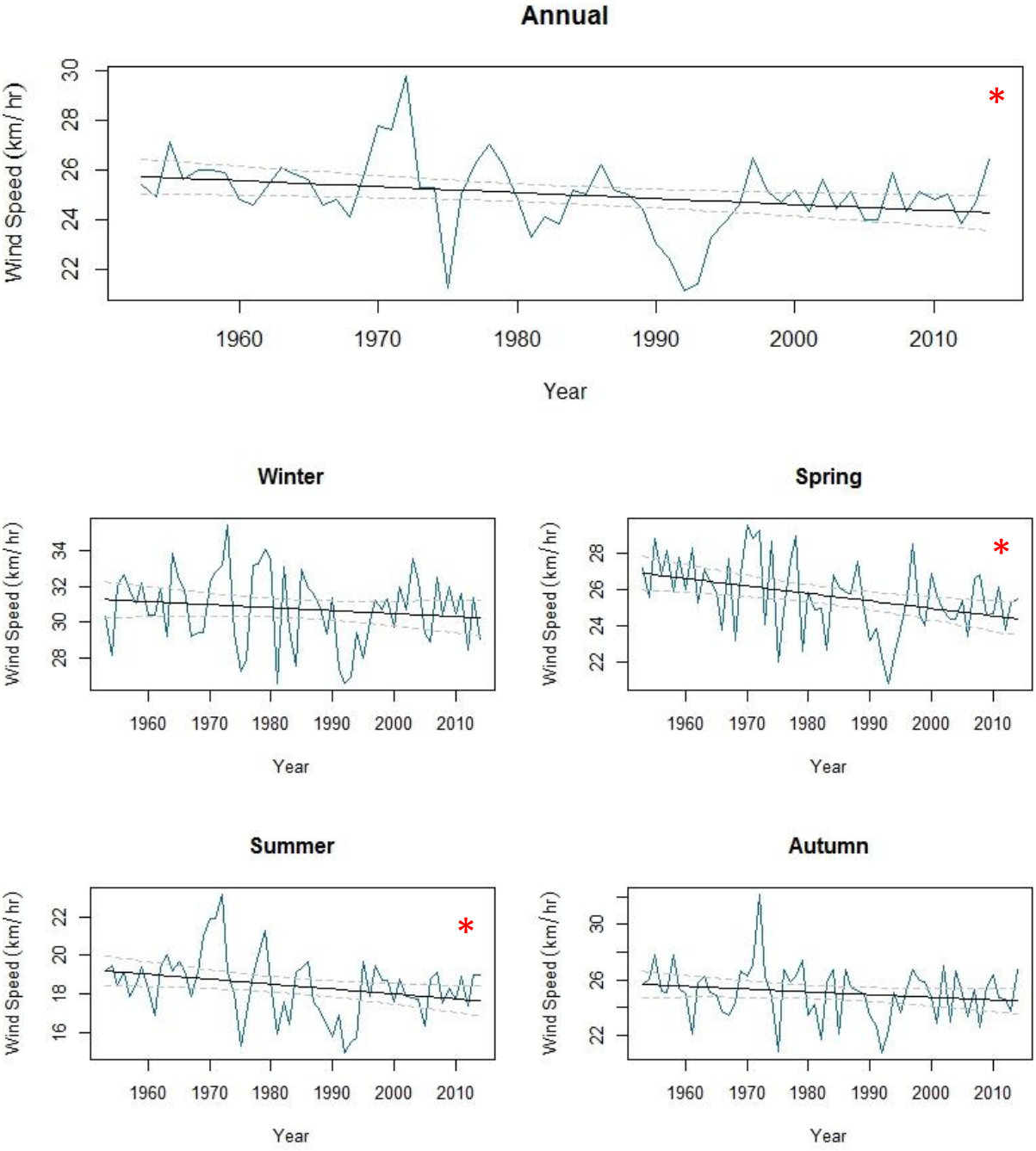
Sable Island total annual rain demonstrated a statistically significant (P<0.05) increase between 1891-2001, ~255 mm (21%).



Sable Island total annual snow did not demonstrate a statistically significant (P<0.05) trend between 1891-2001.

1.3 Surface Wind Speed

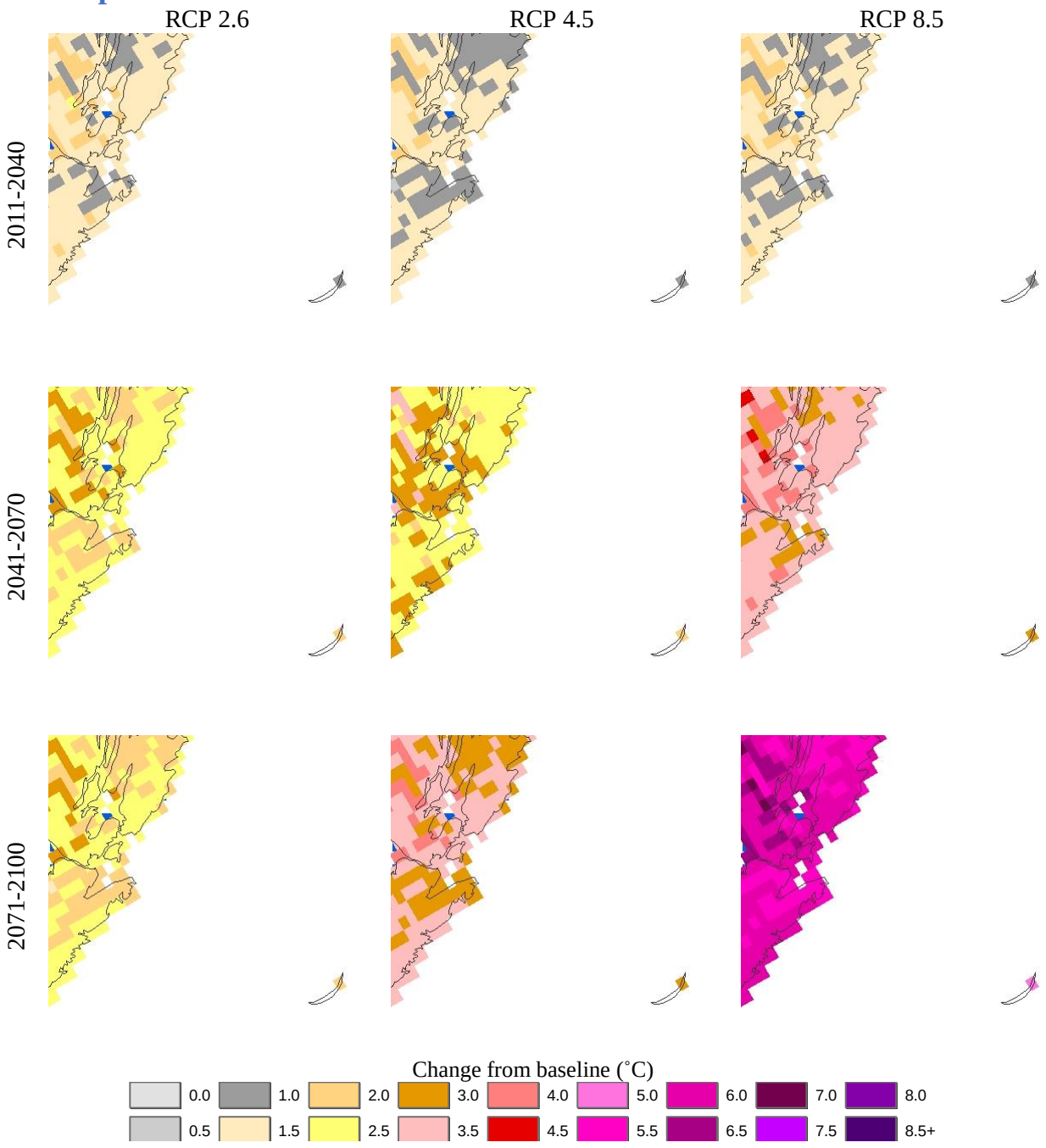
Sable Island (8204700) wind data from AHCCD (ECCC, 2017). Trends from 1953 to 2014 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).



Sable Island mean annual and seasonal wind speeds. Mean annual wind speeds demonstrated a statistically significant (P<0.05) decrease, ~1.4 km/hr (6%) since 1953. Spring (Mar, Apr, May) and summer (Jun, Jul, Aug) demonstrated a statistically significant (P<0.05) decrease, the greatest being observed for spring, ~2.5 km/hr (9%) since 1953. Similarly, Freedman (2014) reports a decrease in wind speeds, with fewer days with strong winds and more days with light winds.

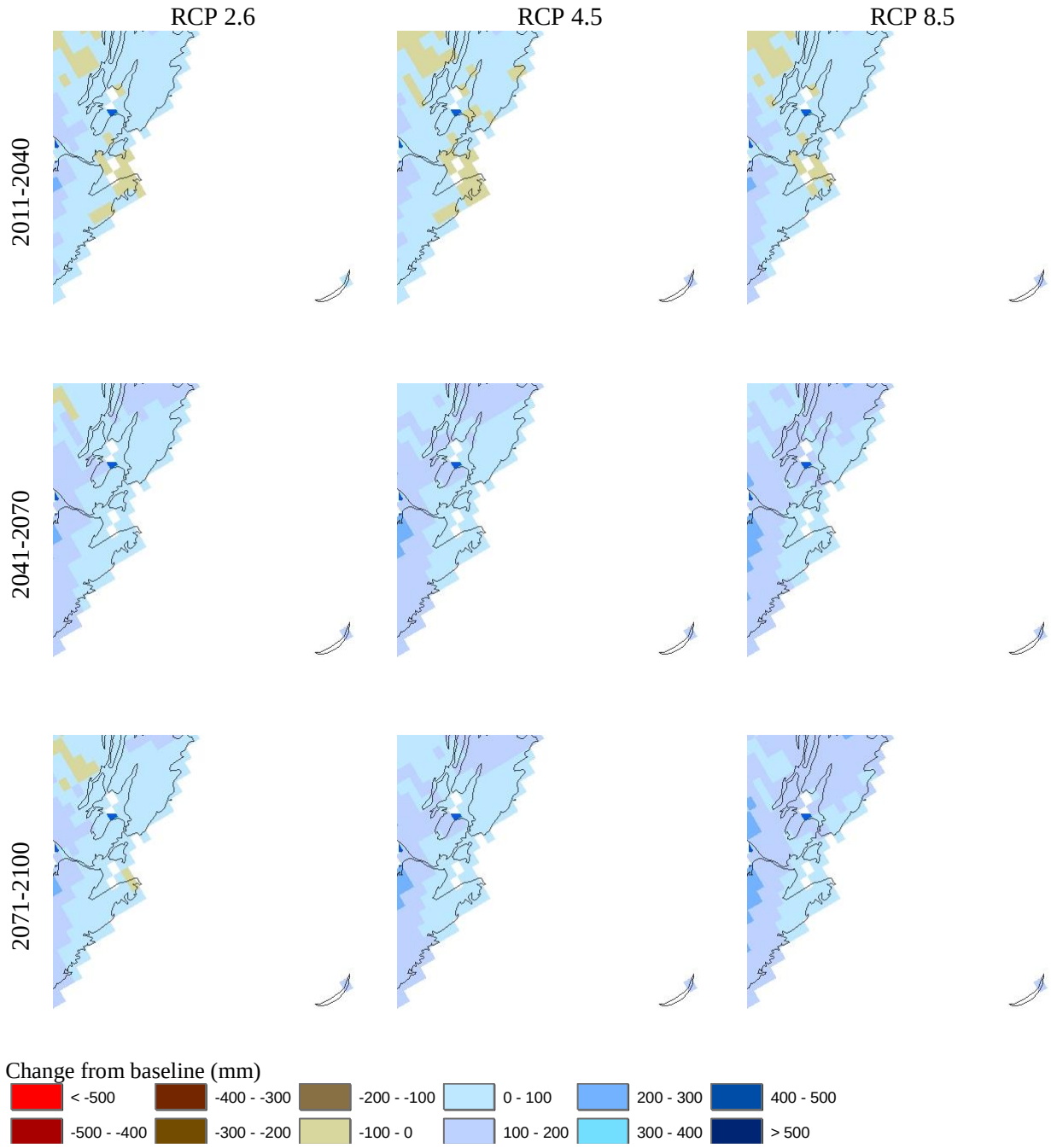
2. Projected Climate Trends

2.1 Temperature



Projected mean annual temperature increase for Sable Island from a 1980-2010 baseline. Composite projection of CanESM2, CESM1CAM5, HADGEM2ES and MIROCESM. Depending on scenario, mean annual temperature is **projected to increase by 2˚C (RCP 2.6), 3˚C (RCP 4.5) or 5˚C (RCP 8.5) by 2070-2100**. 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 Sable Island from a 1980-2010 baseline. Composite projection of four spatially interpolated downscaled Global Circulation Models: CanESM2, CESM1CAM5, HADGEM2ES and MIROCESM. Depending on scenario, total annual precipitation is **projected to increase by 117mm (RCP 2.6), 134mm (RCP 4.5) or 144mm (RCP 8.5) by 2070-2100**. Data source Natural Resources Canada, Canadian Forest Service, http://cfs.nrcan.gc.ca/projects/3 (Price *et al.*, 2011).

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 (1962-2012) total precipitation amounts (mm) for Sable Island. Column return intervals are years.

T (years)	2	5	10	25	50	100
5 min	6.76	8.89	10.25	11.93	13.13	14.31
10 min	9.51	12.38	14.32	16.83	18.74	20.66
15 min	11.95	15.39	17.71	20.67	22.91	25.15
30 min	17.10	21.92	24.98	28.70	31.36	33.92
1 h	22.75	29.28	34.07	40.70	46.07	51.83
2 h	30.05	39.23	46.24	56.35	64.85	74.26
6 h	50.15	63.07	71.54	82.14	89.94	97.62
12 h	62.04	80.22	92.27	107.52	118.84	130.10
24 h	68.98	88.95	102.40	119.64	132.63	145.67

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

T (years)	2	5	10	25	50	100
5 min	8.03	10.93	13.01	15.50	17.08	19.03
10 min	11.29	15.22	18.19	21.92	24.51	27.75
15 min	14.19	18.92	22.48	26.91	29.93	33.73
30 min	20.32	26.95	31.68	37.26	40.76	45.10
1 h	26.96	36.01	43.23	53.24	60.85	70.78
2 h	35.57	48.27	58.65	73.96	86.23	102.52
6 h	59.57	77.50	90.73	106.72	117.23	130.47
12 h	73.65	98.62	117.12	139.85	155.06	174.06
24 h	81.87	109.36	129.99	155.73	173.32	195.42

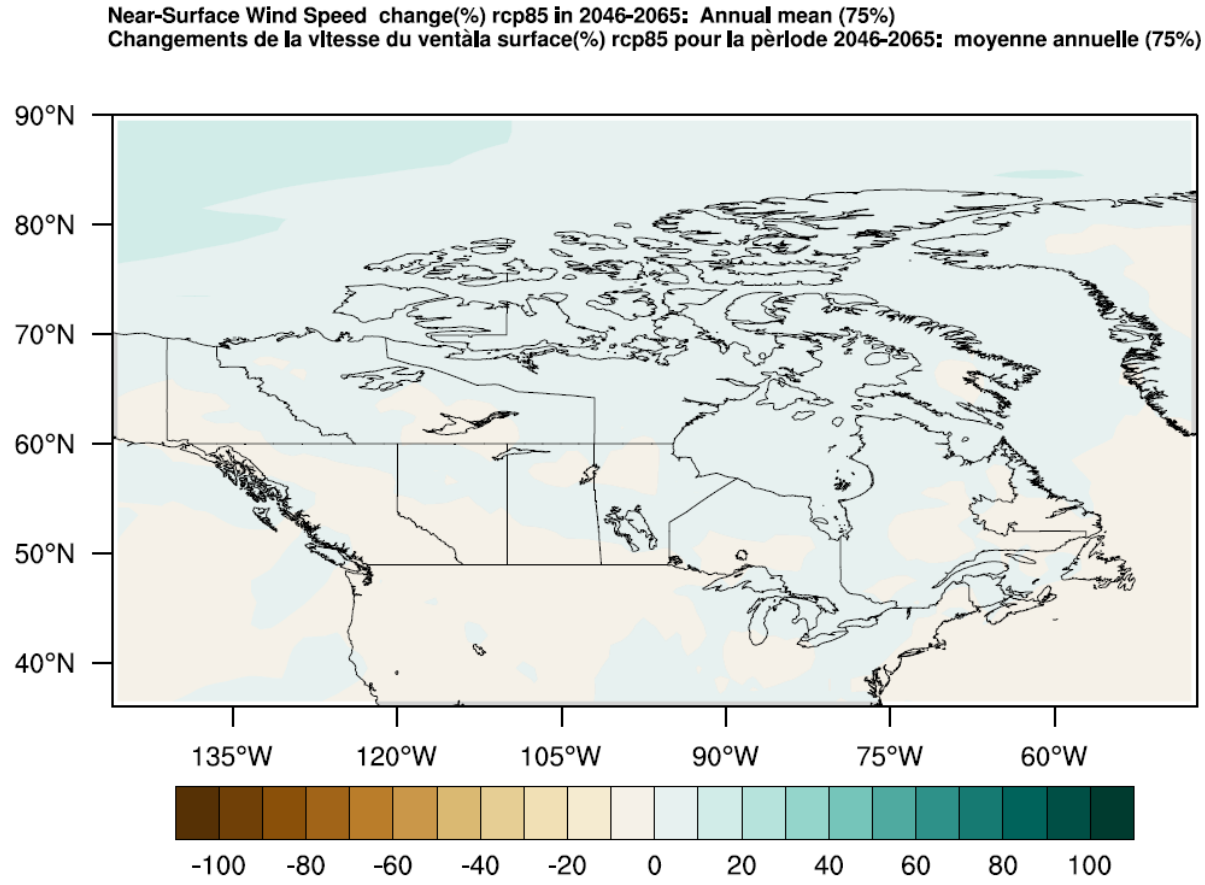
Projected (2050-2100) precipitation (mm) for Sable Island using an ensemble of models and **RCP 8.5**.

T (years)	2	5	10	25	50	100
5 min	9.55	12.22	13.76	15.46	16.62	17.88
10 min	13.42	17.05	19.25	22.00	24.40	26.85
15 min	16.87	21.20	23.80	26.90	29.64	32.40
30 min	24.17	30.18	33.53	37.17	39.50	42.09
1 h	32.02	40.35	46.02	55.12	63.15	68.40
2 h	42.18	53.97	62.71	78.52	88.11	96.62
6 h	70.84	86.94	96.15	106.37	114.52	123.10
12 h	87.57	110.46	123.98	139.38	152.59	165.85
24 h	97.33	122.53	137.65	155.73	171.70	187.84

Sable Island IDF observations and projections. Observe that today's "one in 100 year" rainfall event (i.e., 51.83 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., 68.40 – 70.78 mm/hr).

2.3 Wind

Mean wind speeds are generally projected to decrease (see figure below). With respect to hurricane intensity and frequency, there is some uncertainly, but most models support a general increase in the frequency of Category 4 and 5 hurricanes and a northward movement of activity (e.g., Knutson *et al.*, 2015; Kossin *et al.*, 2014; Thompson *et al.*, 2009)



The CMIP5 climate model (http://climate-scenarios.canada.ca/?page=download-cmip5) projects a decrease in wind speed in 2046-2065 from 1986-2005 reference period (RCP 8.5) for the Sable Island region.

Sable Island	**1985 – 2004**	**2045 – 2064**
Mean air temperature (°C)	8.7 ± 0.5	10.8 ± 0.5
Mean wind speed (m/s)	7.7 ± 0.3	7.5 ± 0.3
Mean wind direction (°)	274 ± 5	273 ± 5
Annual frequency of extreme wind	34.1 ± 6.1	30.9 ± 6.1

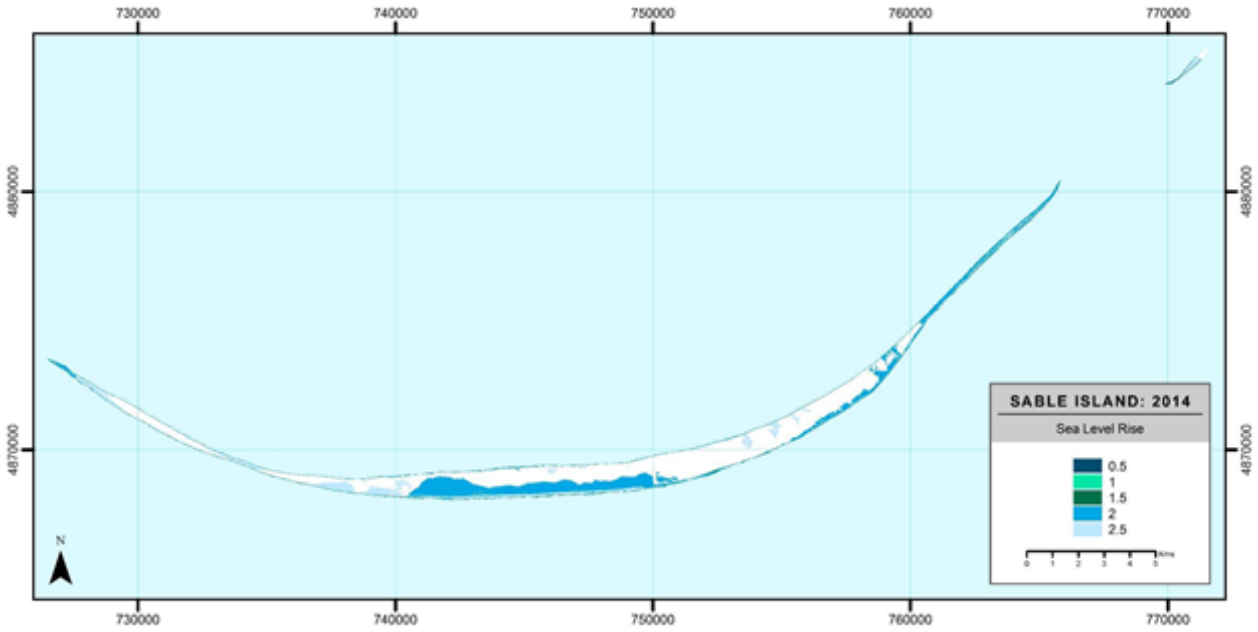
Bi-decadal ensemble of temperature and wind data, error indicates ± one STD. Data source: Loder *et al.* (2013)

3. Climate Change Impacts

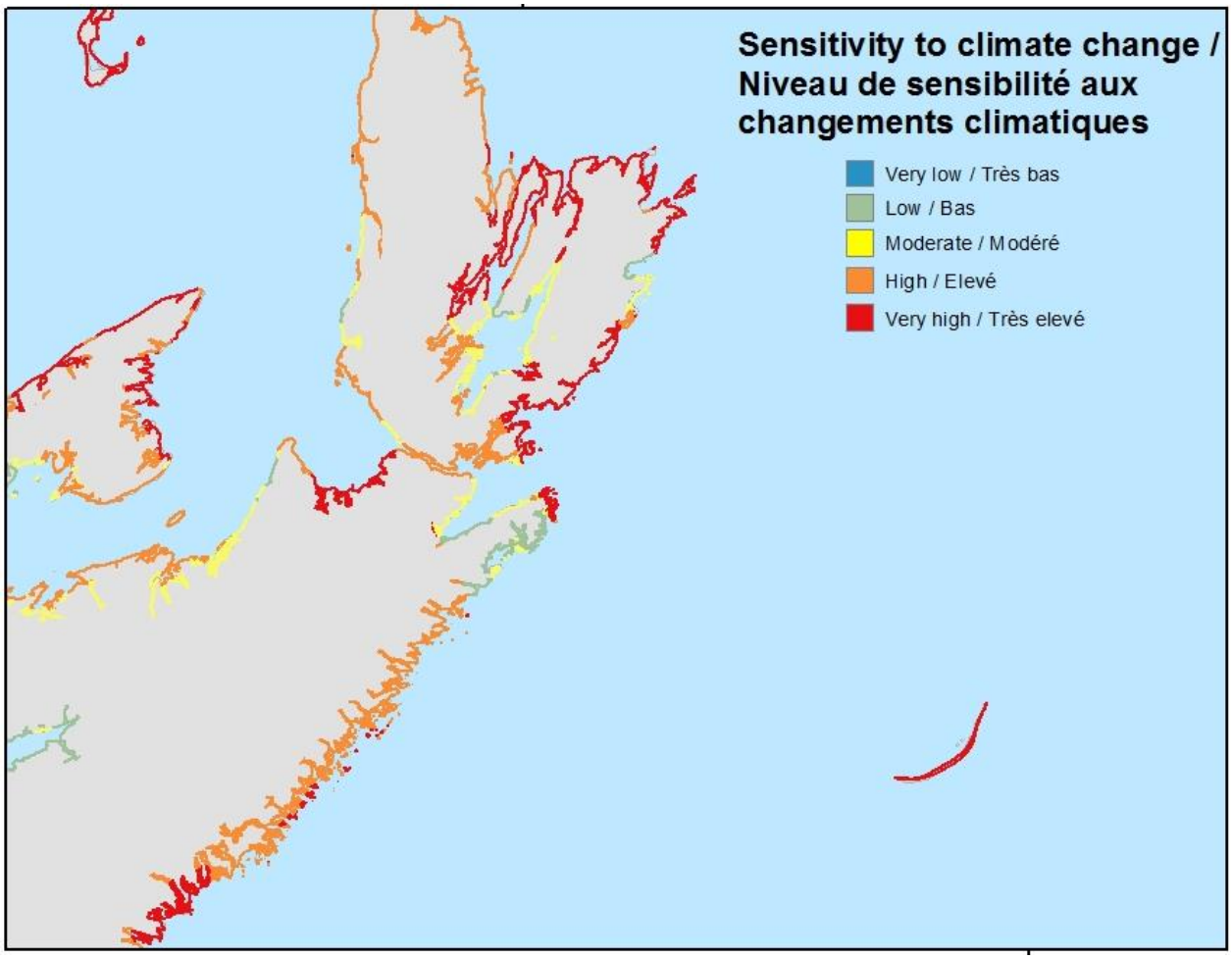
3.1 Sea Level Rise

Relative sea level rise appears to be a key long-term threat to the island (Beson, 1998). Sea level is influenced by ocean temperature (thermal expansion) and salinity, circulation patterns, glacier and ice-sheet melt water, and glacial isostatic adjustments (vertical land motion).

- Between 1900 and 2016 sea level at Halifax increased by 3.28 ± 0.19 mm/yr (total = ~38 cm) (PSMSL; http://www.psmsl.org/products/trends/). Storm surge frequency at Halifax does not appear to have changed in the past 90 years, however Hurricane Juan produced a remarkable 1.5m surge (Loder *et al.*, 2013).
- Thus far, on-going aggradation of the central part of Sable Island has kept pace with sea-level rise (Byrne and McCann, 1995), however the length and width of the island has decreased (e.g., see time series animation: https://mattga.ca/island_analysis/ (Griffin-Allwood, 2014)).
- Relative sea level rise for Sable Island from 1986-2005 to 2046-2065 is projected to be approximately 33-37 cm. On the decadal-scale it is a rise of 3-4 cm/decade (Loder *et al.*, 2013).



Impact of sea level rise from 0.5 to 2.5 m using a 2014 elevation model (AGRG, 2015).

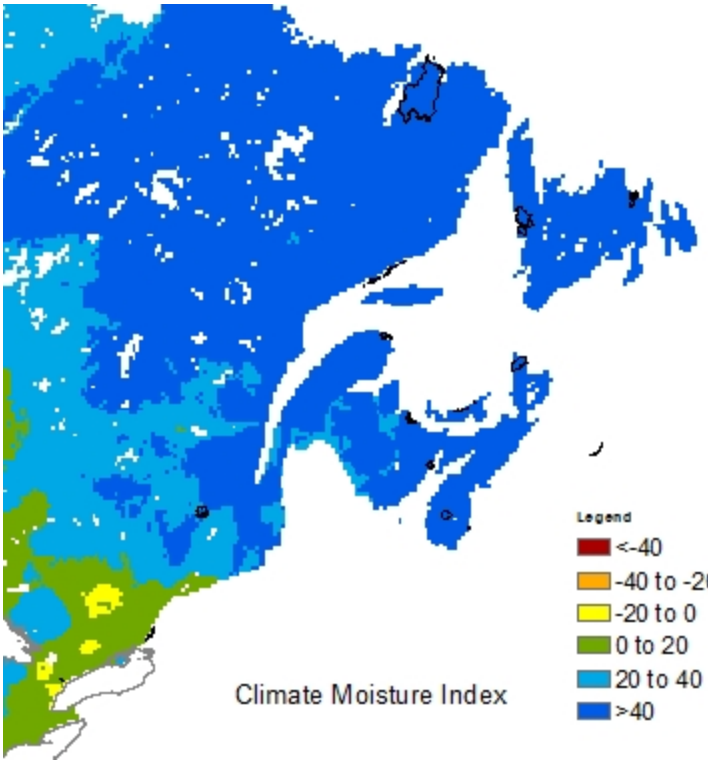


Map of coastal sensitivity to climate change in the Nova Scotia region. Sable Island is very sensitive. Sensitivity is based on coastal materials, landforms, relief, ground ice, wave height, tidal range, recent trends in sea ice concentration, and projected sea level rise to 2050. Data provided by Natural Resources Canada (Couture and Manson, 2016).

3.2 Species and Ecosystems

Freshwater

Precipitation provides the freshwater for all the ponds, wetlands and groundwater on the island and accumulates as a discontinuous lens overlying a saltwater table (Hennigar, 1976; Hennigar and Kennedy, 2016; Kennedy *et al.*, 2014). The ponds are a critical source of drinking water for the island's feral horses and provide important habitat for birds, fishes (e.g., killifish), plants and invertebrates (Neily *et al.*, 2017). Evapotranspiration has been estimated to be ~40% of precipitation, the remaining water infiltrates the sand and recharges the freshwater lens (no overland runoff) (Hennigar and Kennedy, 2016). Saltwater incursions and infilling by windblown sand continues to eliminate and reduce the extent of freshwater ponds and associated wetlands (Neily *et al.*, 2017). A review of future freshwater supplies was not discovered by this author.



The Climate Moisture Index (CMI) is calculated as the difference between annual precipitation and potential evapotranspiration. A positive CMI value indicates wetter conditions and a negative value indicates drier conditions. In general the projected CMI value for the Atlantic region is positive (wetter). The figure is for 2071-2100 (RCP 8.5). Data provided by Natural Resources Canada, http://www.nrcan.gc.ca/forests/climate-change/forest-change/17772

Other

- "Increased frequency and severity of storms, in addition to climate change and related sea level rise, are expected to drive change which will further decrease the quality and quantity of (Sweat) bee habitat on the island" (COSEWIC, 2014). The Sable Island **Sweat Bee** is listed as Threatened (http://www.registrelep-sararegistry.gc.ca).
- Adult sex ratios and polygyny thresholds (i.e., when females choose to mate with an already mated male over an unmated one to improve fitness) within the **feral horses** of Sable Island can be influenced by weather (e.g., precipitation) (Manning and McLoughlin, 2017; Manning *et al.*, 2015). Severe winters have affected horse survivorship (Welsh, 1975).
- The **Savannah Sparrow *princeps* subspecies** is particularly vulnerable to sea-level rise and any increase in the frequency and intensity of Atlantic storms (COSEWIC, 2009).
- Richardson *et al.* (2009) speculate that the **lichen** flora of the island will likely decrease due to climate change, sea level rise and substrate loss.
- There appears to be a progressive net loss of **vegetated dunes** over the past two centuries due to a mix of natural and human disturbance (Byrne and McCann, 1995; McCann and Byrne, 1994), however, Beson's (1998) review suggests no significant trend between the 1960s and 1980s.
- There are 13 restricted species of **plants** (Catling *et al.*, 1984), environmental threats include energy from wind and sea (Beson, 1998).

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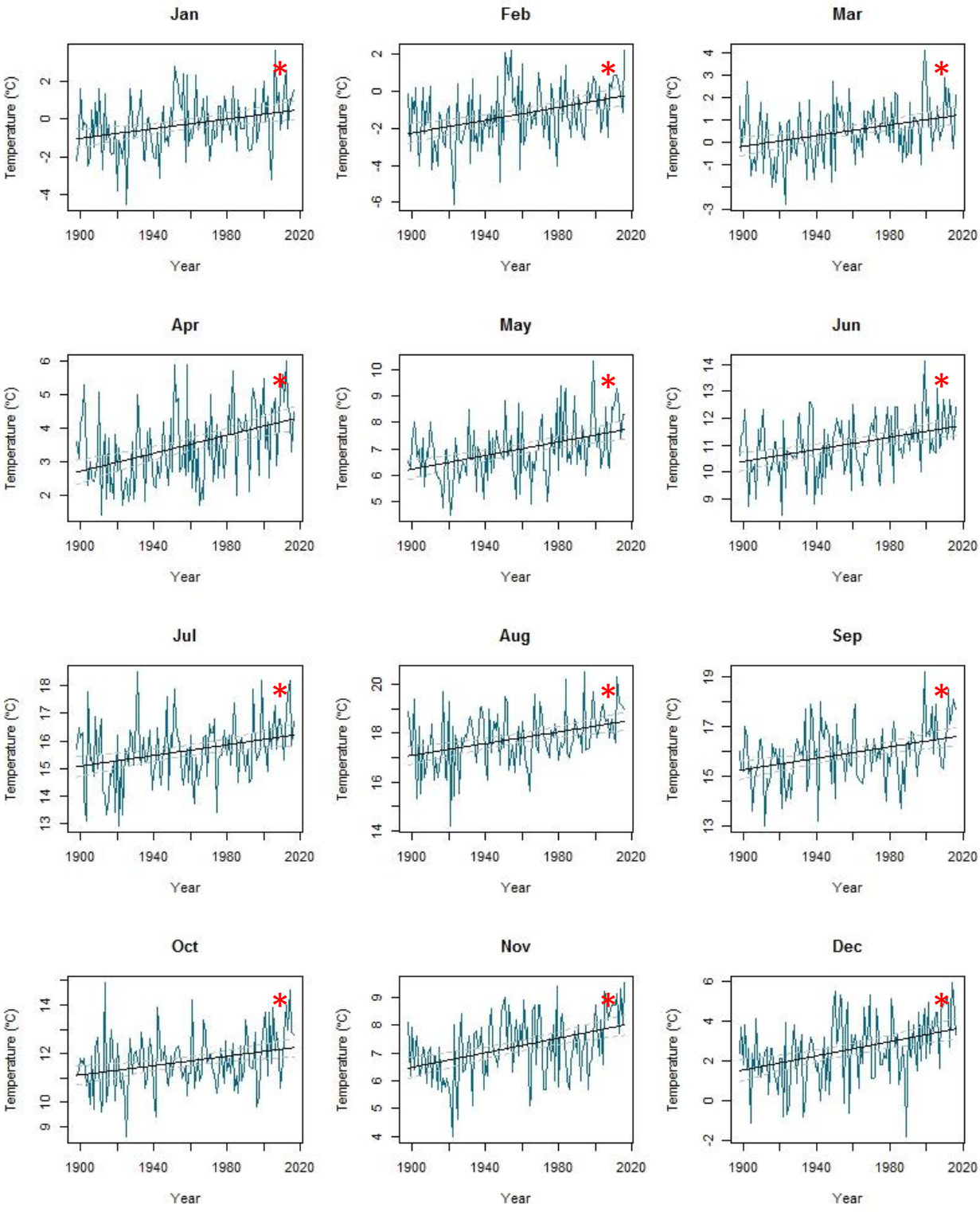
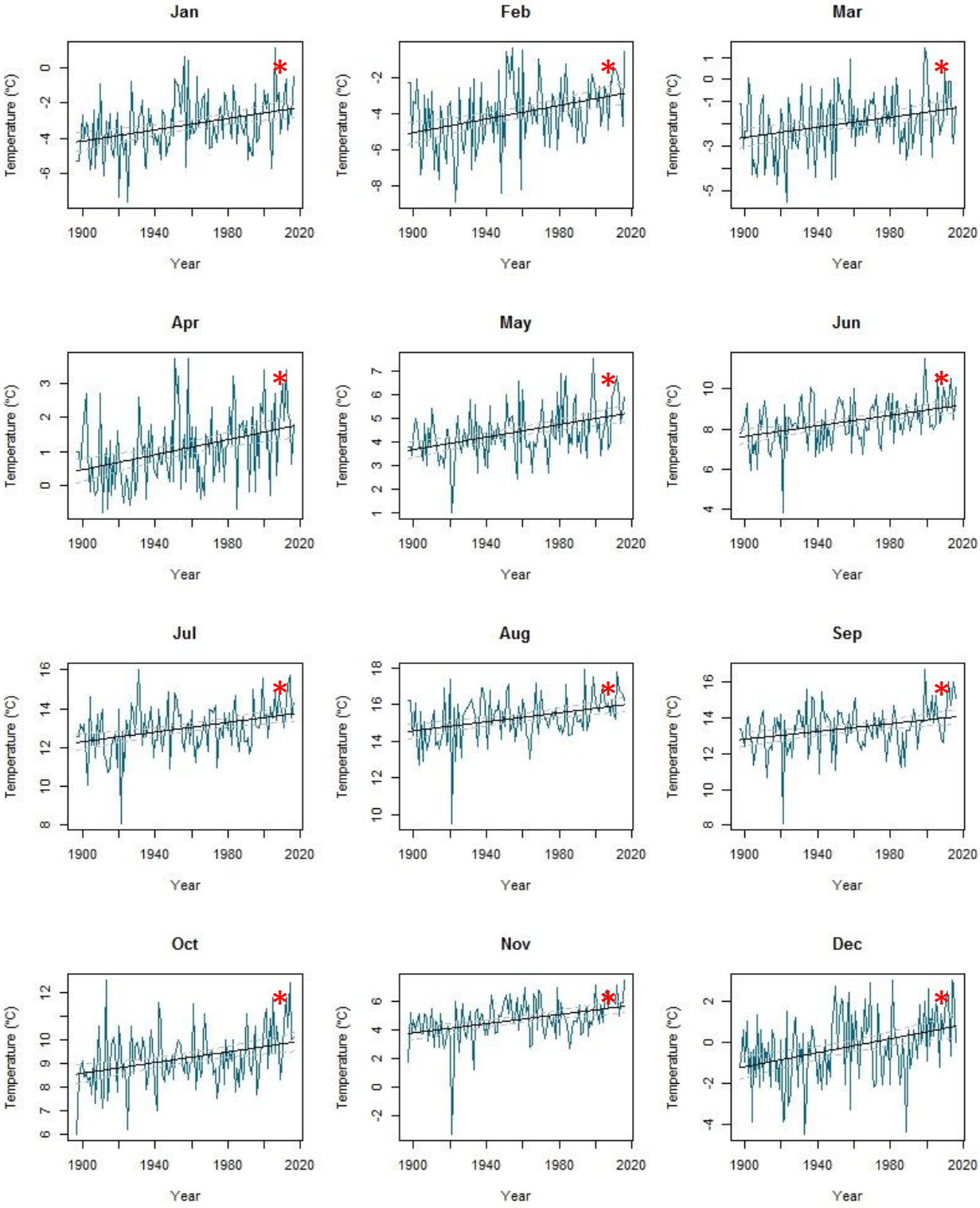
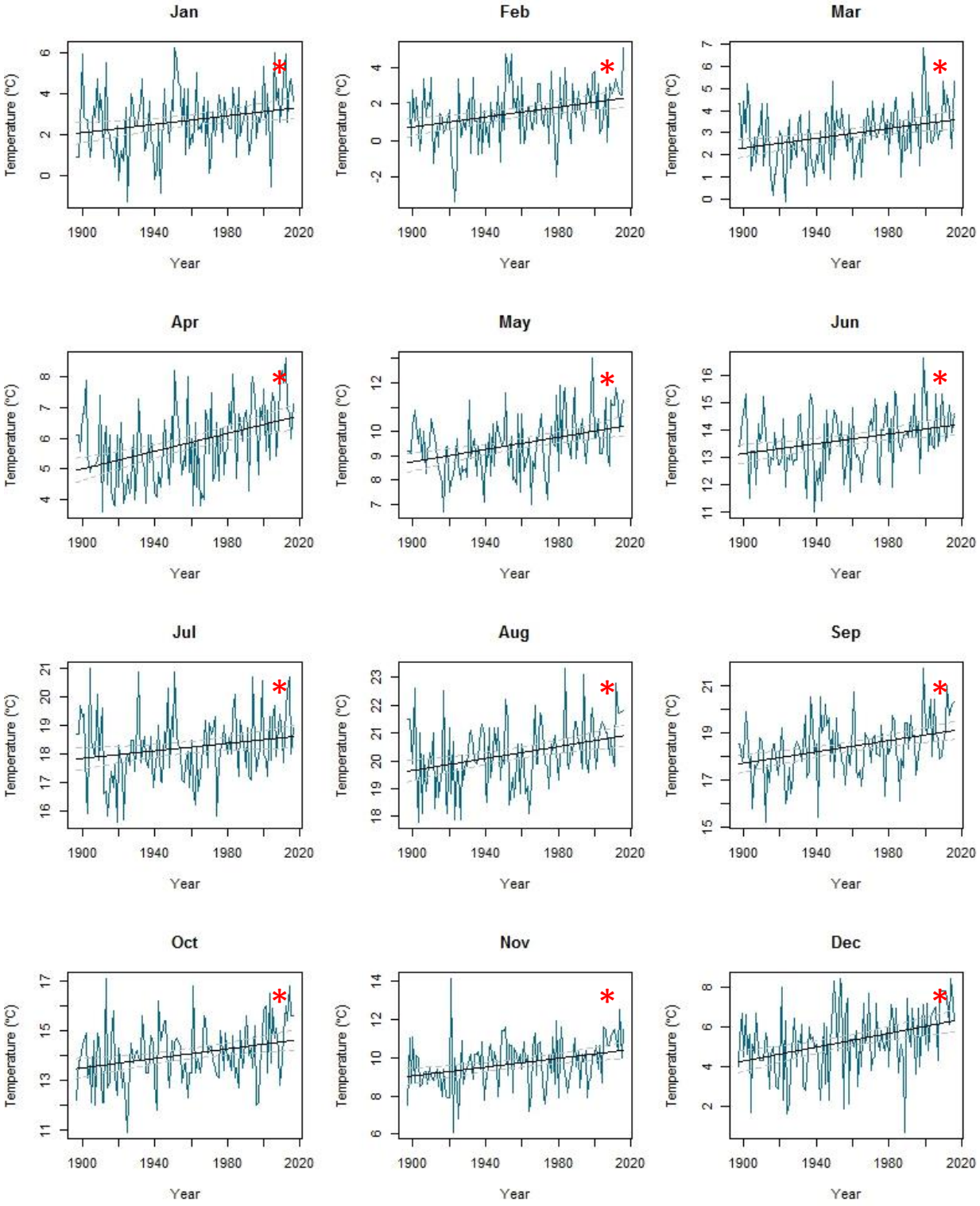
Appendix 1. Monthly Climate Trends



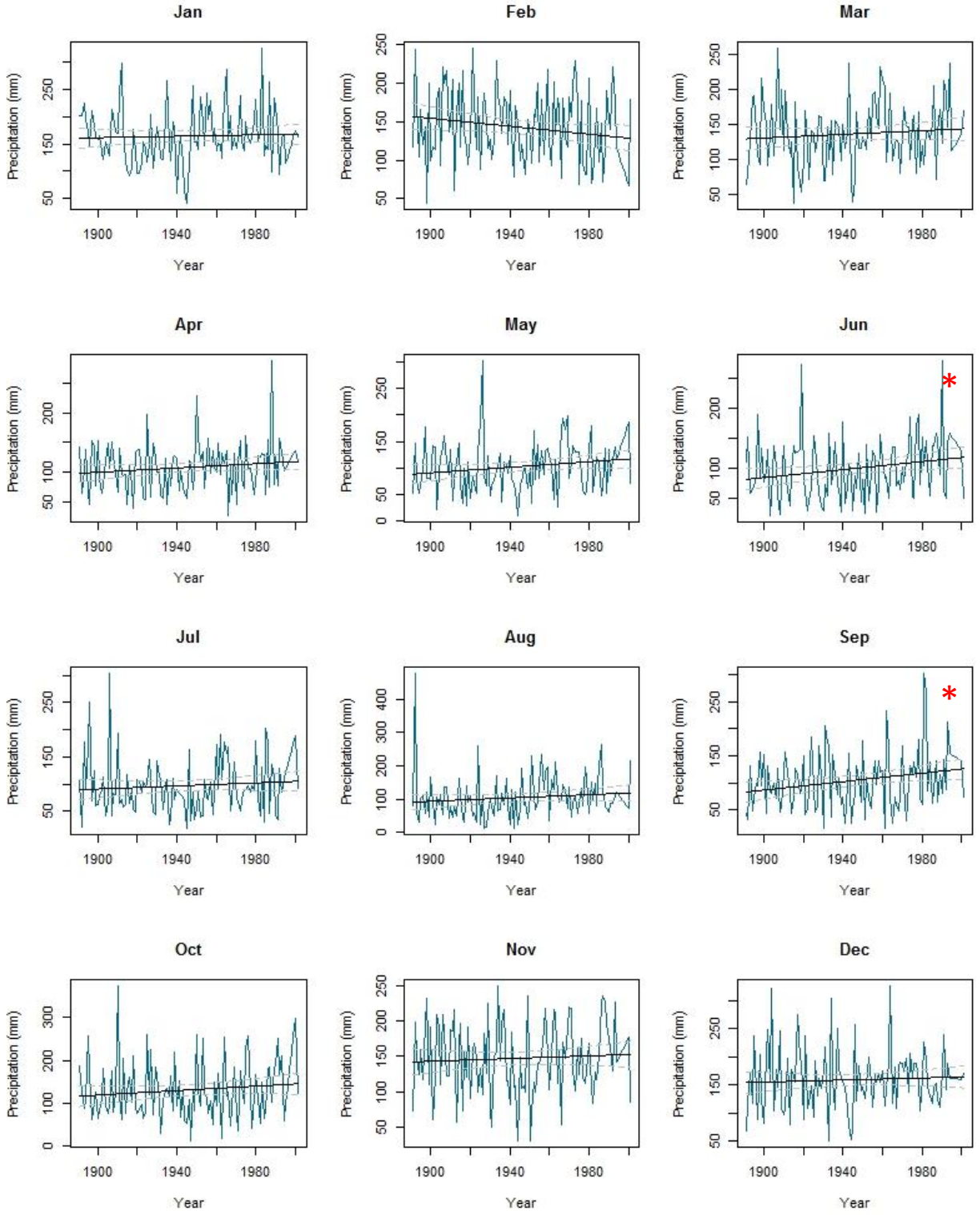
Sable Island mean monthly temperature. All months demonstrated a statistically significant (P<0.05) increase between 1898-2016. Dec demonstrated the greatest increase, +2°C.



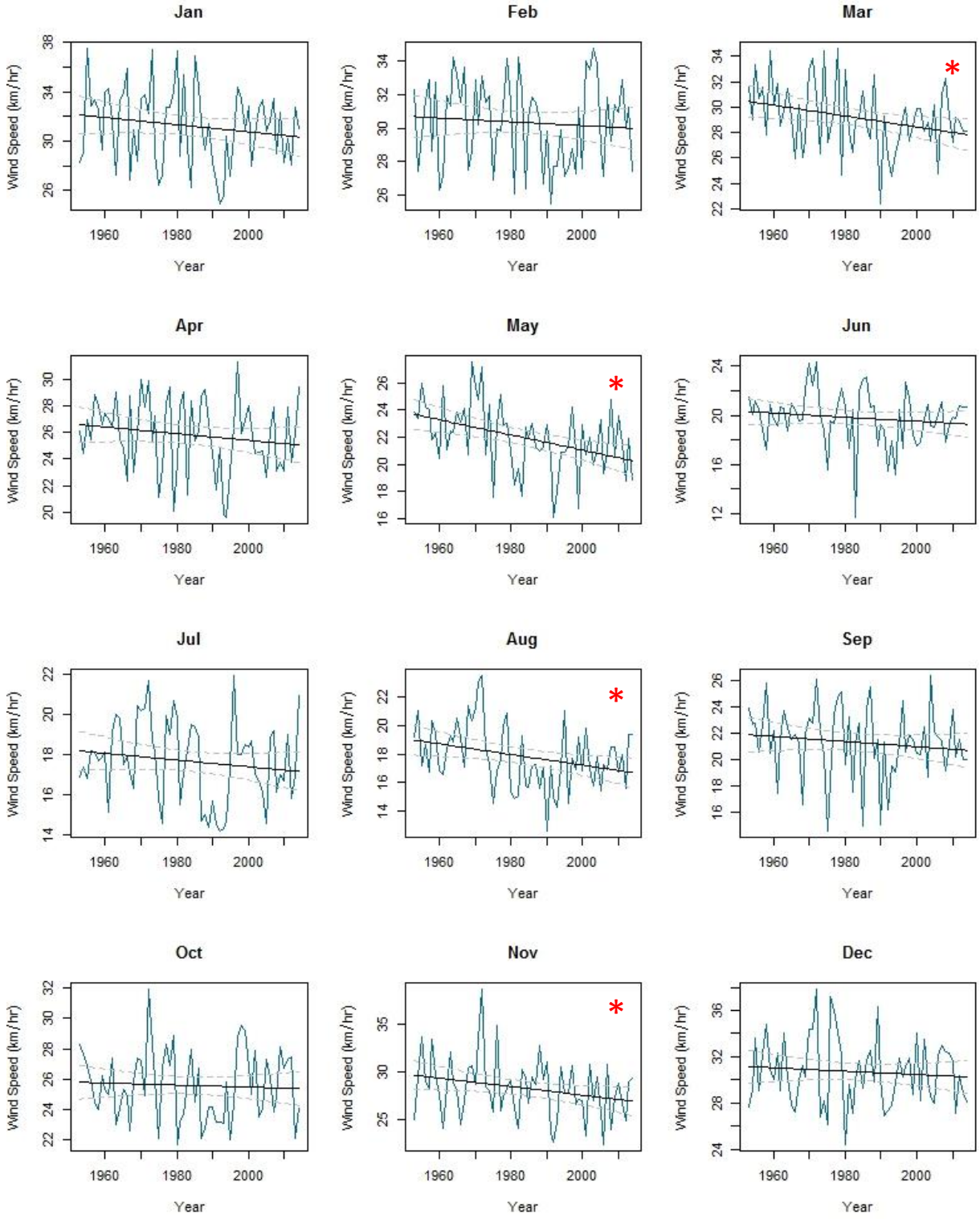
Sable Island mean monthly <u>minimum</u> temperature. All months demonstrated a statistically significant (P<0.05) increase in mean monthly minimum temperatures (i.e., nighttime) between 1898-2016. Dec demonstrated the greatest increase, +2°C.



Sable Island mean monthly <u>maximum</u> temperature. All months demonstrated a statistically significant (P<0.05) increase in mean monthly maximum temperatures (i.e., daytime) between 1898-2016. Dec demonstrated the greatest increase, +2°C.



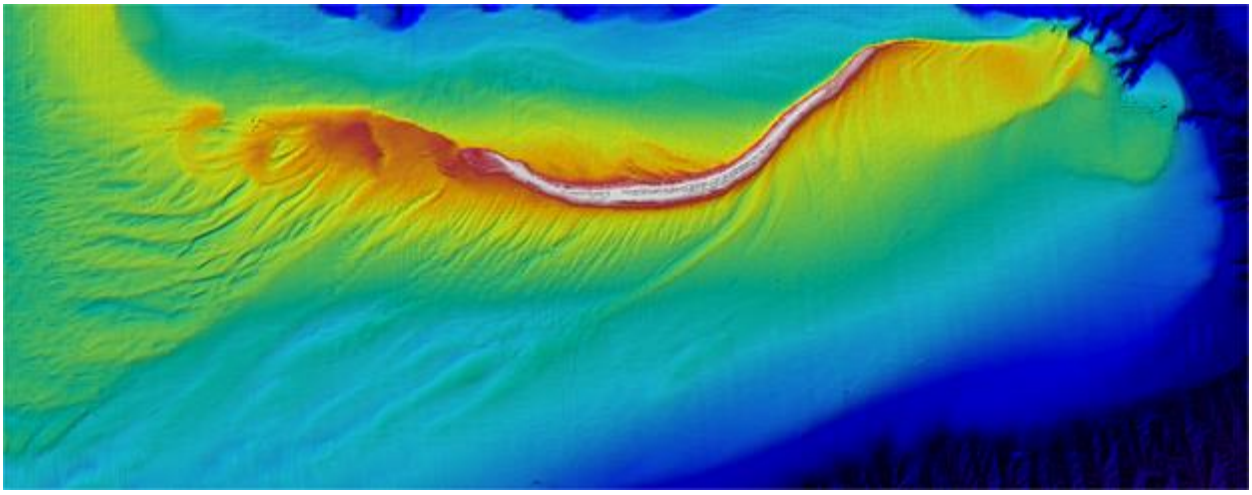
Sable Island total monthly precipitation. Total monthly precipitation demonstrated a statistically significant increase ($P<0.05$) in Jun and Sep between 1891-2001. The greatest increase being observed in Sep, +43 mm (52%).



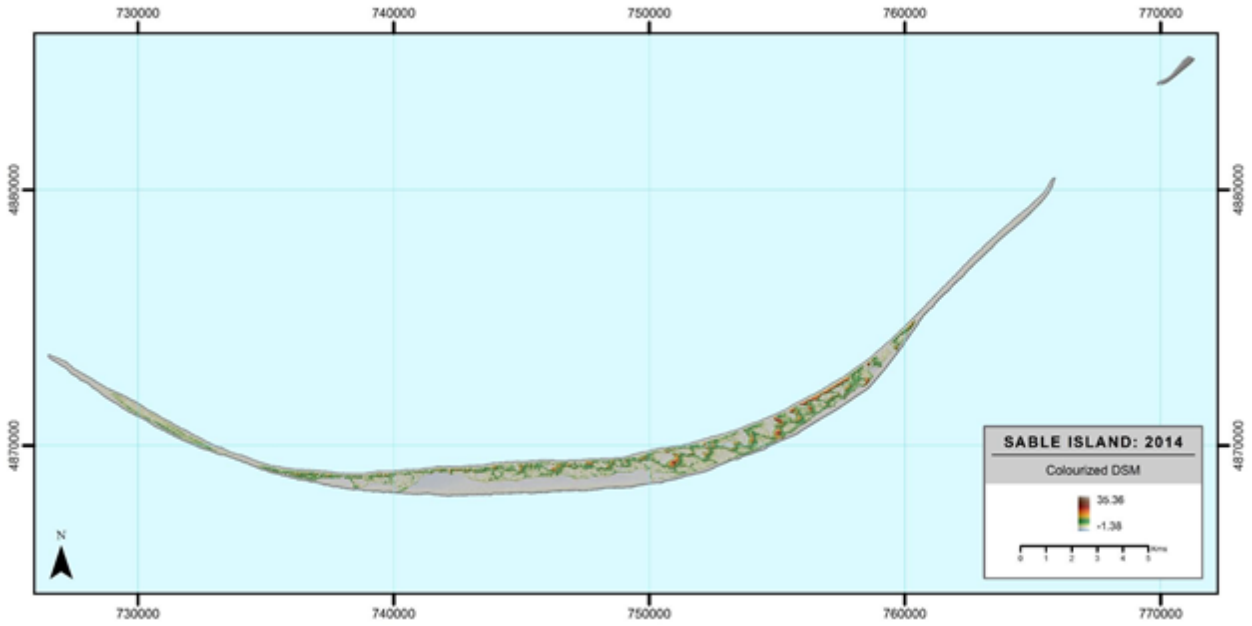
Sable Island mean monthly wind speeds. Mar, May, Aug and Nov demonstrated a statistically significant decrease ($P<0.05$) between 1953-2014. The greatest decrease being observed in Nov, - 2.7 km/hr (9%).

Appendix 2. Additional Information

Digital Elevation Model of Sable Island Bank (Webb and King, 2014)



Digital Surface Model of Sable Island (AGRG, 2015)



Greenhouse Gas Monitoring

Greenhouse gas (GHG) monitoring began on Sable Island in 1975 and currently includes hourly measurements of methane, carbon monoxide and carbon dioxide and weekly measurements of other GHGs (e.g., Waugh *et al.*, 2010; Worthy *et al.*, 2003). Data and quick plots are available from the World Data Centre for Greenhouse Gases (http://ds.data.jma.go.jp/gmd/wdcgg/wdcgg.html).