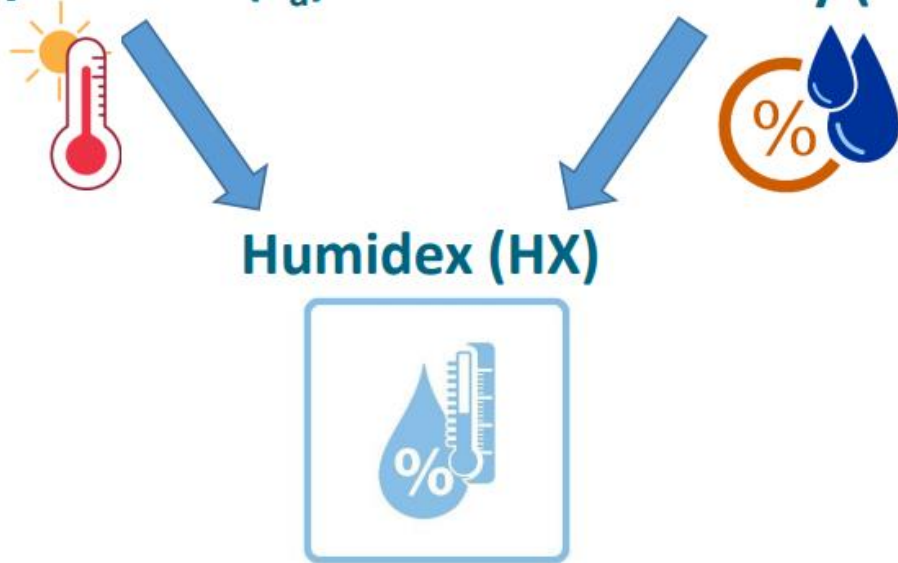# Humidex Climate Projections

Kenneth Chow, Housseyni Sankare, Emilia Diaconescu, Trevor Murdock, Alex Cannon

What is Humidex and how it is used

Humidex (HX) describes how hot the weather feels to a person, by taken into account the effect of heat and humidity.
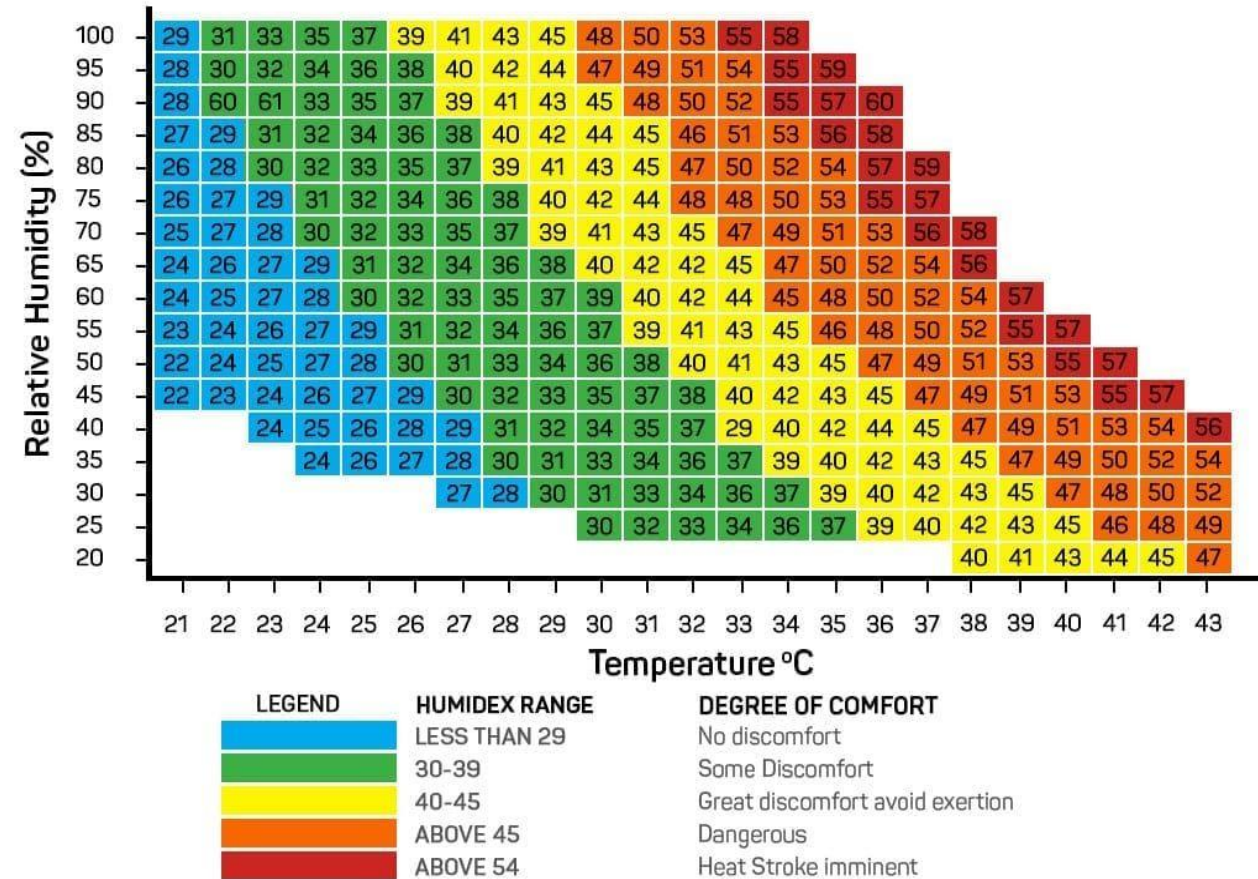

$$HX = T_a + \frac{5}{9}(\rho - 10)$$

$$\rho = 6.112 \times 10^{7.5 \times T_a/(237.7+T_a)} \times RH/100$$

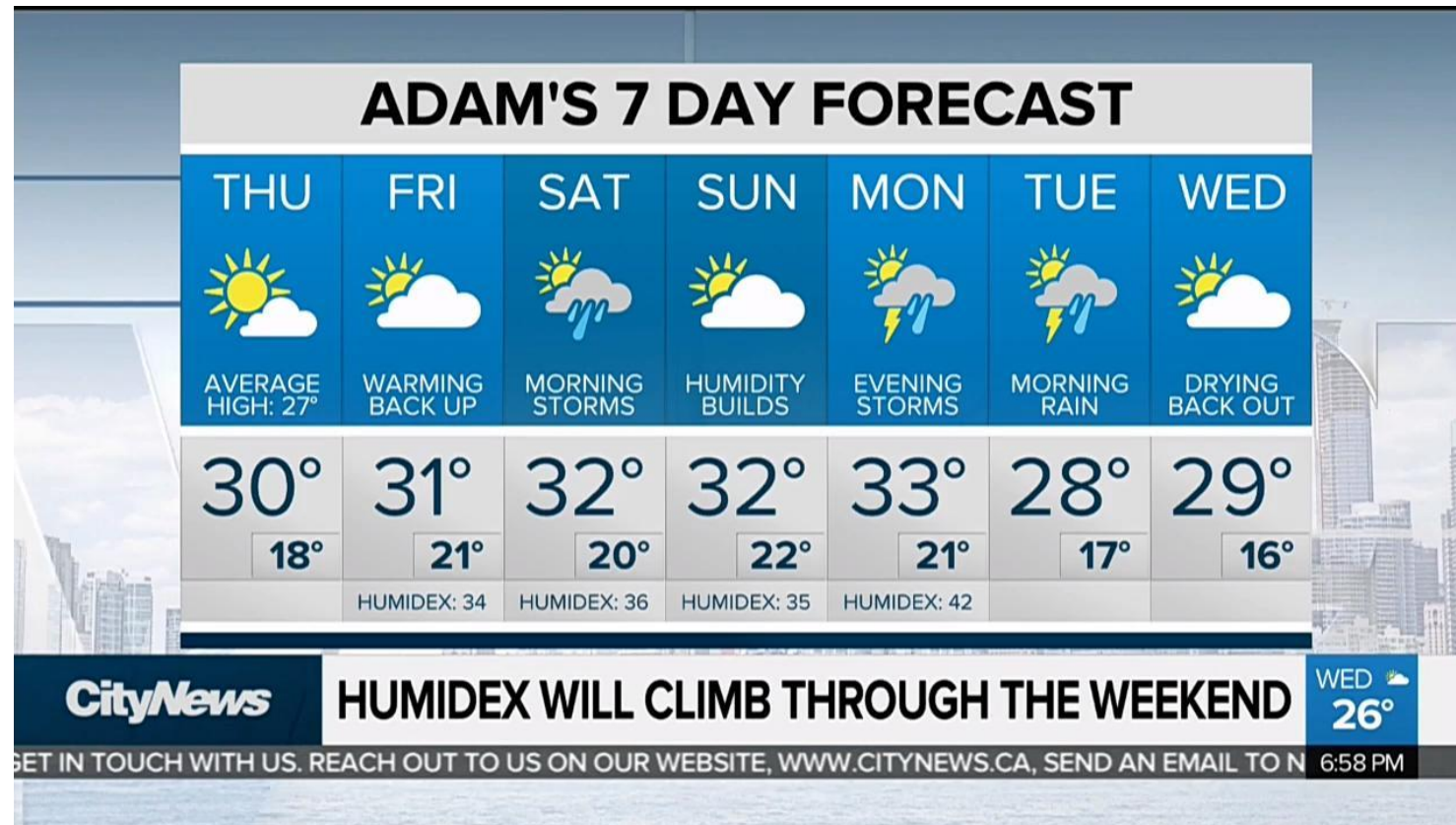HUMIDEX FROM TEMPERATURE AND RELATIVE HUMIDITY READINGS

LEGEND	HUMIDEX RANGE	DEGREE OF COMFORT
(blue)	LESS THAN 29	No discomfort
(green)	30-39	Some Discomfort
(yellow)	40-45	Great discomfort avoid exertion
(orange)	ABOVE 45	Dangerous
(red)	ABOVE 54	Heat Stroke imminent

Source: Environment Canada
https://www.canada.ca/en/environment-climate-change/services/seasonal-weather-hazards/spring-summer.html#humidex
Source: https://www.ccohs.ca/oshanswers/phys_agents/humidex.html
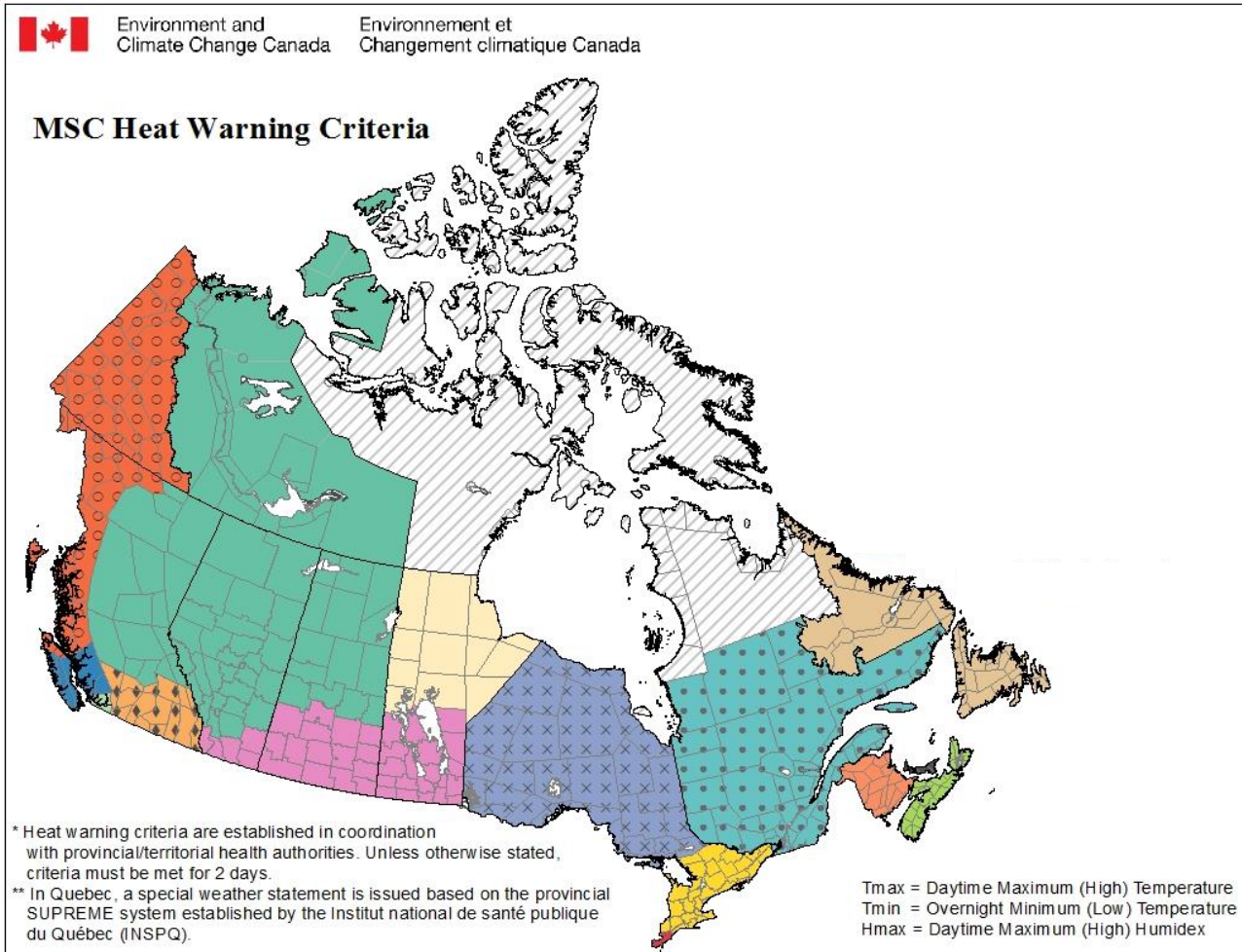
What is Humidex and how it is used

- **Computed as an hourly value and included in forecast**

What is Humidex and how it is used

- Computed as an hourly value and included in forecast
- **Included in MSC Heat warning system**

MSC Heat Warning Criteria

Environment and Climate Change Canada — Environnement et Changement climatique Canada

* Heat warning criteria are established in coordination with provincial/territorial health authorities. Unless otherwise stated, criteria must be met for 2 days.
** In Quebec, a special weather statement is issued based on the provincial SUPREME system established by the Institut national de santé publique du Québec (INSPQ).

Tmax = Daytime Maximum (High) Temperature
Tmin = Overnight Minimum (Low) Temperature
Hmax = Daytime Maximum (High) Humidex

Criteria*:

- (Tmax >= 26°C and Tmin >= 15°C) OR Hmax >= 34
- (Tmax >= 29°C and Tmin >= 16°C) OR Hmax >= 36
- (Tmax >= 27°C and Tmin >= 18°C) OR Hmax >= 35
- (Tmax >= 30°C and Tmin >= 18°C) OR Hmax >= 36
- (Tmax >= 30°C and Hmax >= 40 OR Tmax >= 40°C) for at least 1 hour
- (Tmax >= 31°C and Tmin >= 21°C) OR Hmax >= 42
- (Tmax >= 31°C and Tmin >= 20°C) OR Hmax >= 40
- (Tmax >= 29°C and Tmin >= 18°C) OR Hmax >= 36
- Tmax >= 32°C and Tmin >= 16°C (OR Hmax >= 38 in SK & MB)
- (Tmax >= 29°C and Tmin >= 16°C) OR Hmax >= 34
- Tmax >= 29°C and Tmin >= 14°C (OR Hmax >= 34 in SK only)
- Tmax >= 35°C and Tmin >= 18°C
- Tmax >= 33°C and Tmin >= 17°C
- Tmax >= 29°C and Tmin >= 16°C
- Tmax >= 28°C and Tmin >= 13°C

Heat Warning Program in development

What is Humidex and how it is used

- Computed as an hourly value and included in forecast
- Included in MSC Heat warning system
- **Included in Safety at Work Measures**:

  o Canadian Centre for Occupational Health and Safety
  o Sun Safety at Work Canada
  o Occupational Health Clinics for Ontario Workers Inc.
  o Eastern Ontario Health Unit
  o Work Safe Saskatchewan
  o Ministère de la Santé et des Services sociaux Québec
  o Nova Scotia's Department of Health and Wellness

Humidex 1 – Moderate physical work, unacclimatized worker, OR Heavy physical work, acclimatized worker	Response	Humidex 2 – Moderate physical work, acclimatized worker, OR Light physical work, unacclimatized worker
25 - 29	• supply water to workers on an "as needed" basis	32 - 35
30 - 33	• post Heat Stress Alert notice • encourage workers to drink extra water • start recording hourly temperature and relative humidity	36 - 39
34 - 37	• post Heat Stress Warning notice • notify workers that they need to drink extra water • ensure workers are trained to recognize symptoms	40 - 42
38 - 39	• work with 15 minutes relief per hour can continue • provide adequate cool (10 - 15°C) water • at least 1 cup (240 mL) of water every 20 minutes • workers with symptoms should seek medical attention	43 - 44
40 - 41	• work with 30 minutes relief per hour can continue in addition to the provisions listed previously	45 - 46*
42 - 44	• if feasible, work with 45 minutes relief per hour can continue in addition to the provisions listed above	47 - 49
45 or over	• only medically supervised work can continue	50* and over

Source: Occupational Health Clinics for Ontario Workers (OHCOW) – "Humidex Based Heat Response Plan"

Objectives

- Develop, across Canada, climate projections until the end of the century for daily maximum Humidex (HXmax) and HX threshold indices:
  - ➢ HX>30 (Discomfort days)
  - ➢ HX>35 (Caution days)
 - ➢ HX>40 (Extreme caution days)

Issues:

- Forecasts are using **hourly values** but climate projections are **daily or monthly**

- Model simulations have biases in estimating temperature and humidity historical values

- Climate simulations have coarse spatial resolutions

Project Steps

1. Find a method to estimate humidex indices from daily temperature and humidity

2. Find a high-resolution historical gridded dataset to use as target for bias correction

3. Identify the most appropriate bias correction methodology

4. Produce ensemble projections of HX and HX indices using results from 1, 2 and 3

Step 1: Daily HXmax approximation

Mean hourly temperature, relative humidity and humidex at Montreal for MJJAS (1980-2018)
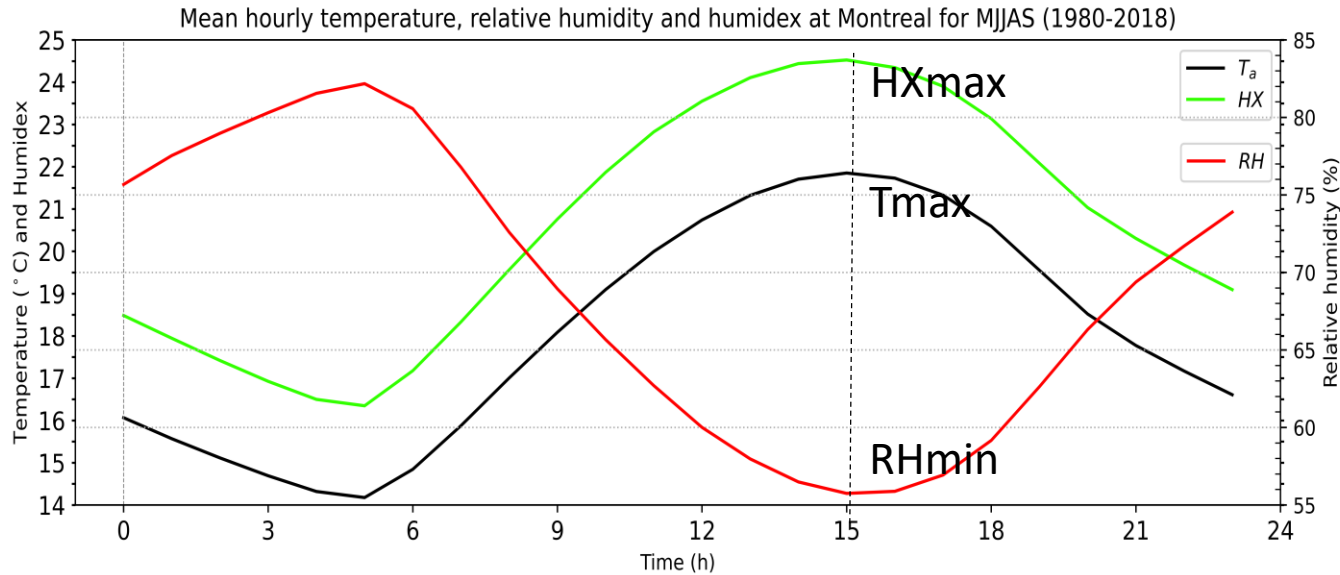
- Approximate daily HXmax by using daily Tmax and daily RHmin

- Evaluate approximation against hourly-based indices:

  o **Daily HXmax** HX>30, HX>35, HX>35

  o Metrics used: **mean bias** correlation coefficient, Perkins skill score

May–September (1980–2018)
Daily HXmax mean bias : between -1.3 and 0.0 units, with an average value of 0.5 units)
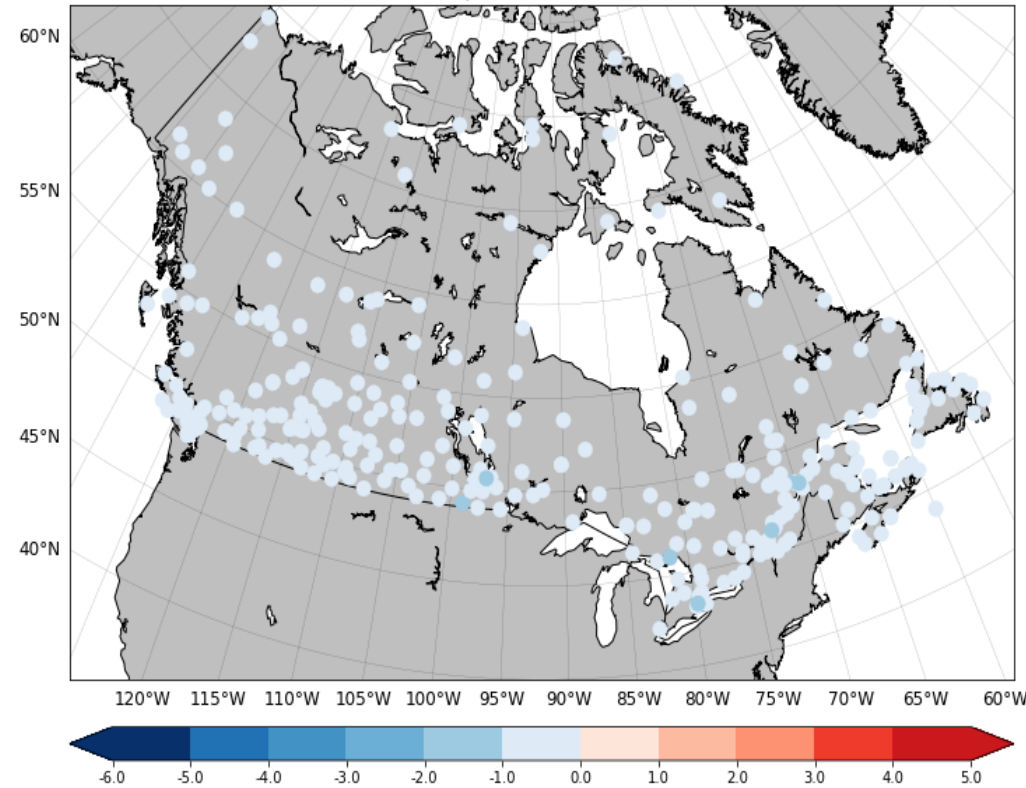
Diaconescu, E., Sankare, H., Chow, K., Murdock, T. Q., & Cannon, A. J. (2022). A short note on the use of daily climate data to calculate Humidex heat-stress indices. *International Journal of Climatology*, 1–13. https://doi.org/10.1002/joc.7833

Step 2: Identify target gridded dataset

Dataset	Description	Hourly variables	Spatial resolution, grid type	Time period
ERA5-Land / ECMWF (Muñoz-Sabater et al. 2021)	• Land-surface reanalysis driven by **ERA5** • ERA5 assimilates surface air temperature and dew point temperature	• surface air temperature • dew point temperature	9 km, octahedral reduced Gaussian grid transformed to regular lat-lon grid	1950 - 2018
Canadian Regional Deterministic Reforecast System (RDRSv2) / ECCC (Gasset et al. 2021)	• Historical reforecast driven by **ERA-Interim** • Direct assimilation of surface air temperature and dew point temperature	• surface air temperature • dew point temperature • relative humidity	~10 km, rotated grid transformed to regular lat-lon grid	1980 - 2018

Evaluation:

- Compared reanalysis data to stations
- May to September period (MJJAS) from 1980 to 2018
- Daily Tmax, RHmin **HXmax** and three HX indices (HX>30, **HX>35** HX>40)
- Metrics used: **mean bias** correlation coefficient, Perkins skill score

Evaluation of reanalysis against observations, 1980-2018

Mean Bias daily HXmax
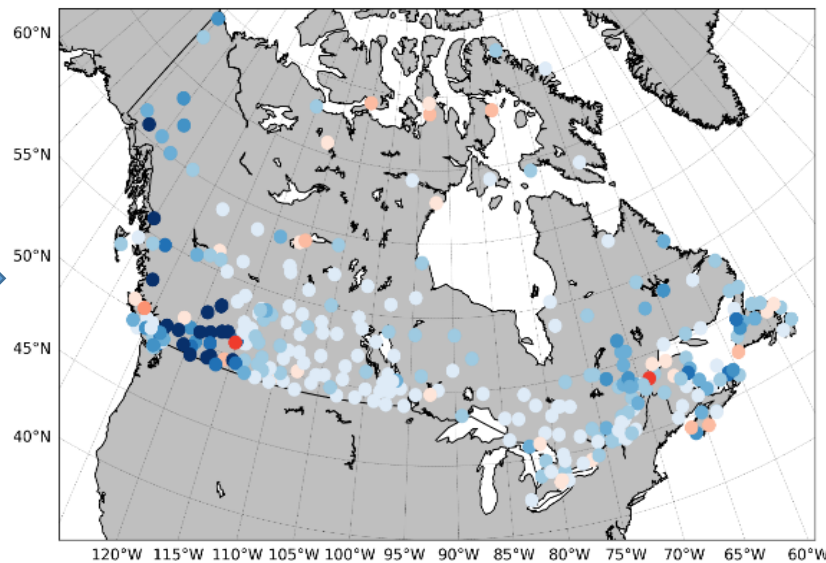
Mean Bias HX>35 (discomfort days)

ERA5-Land
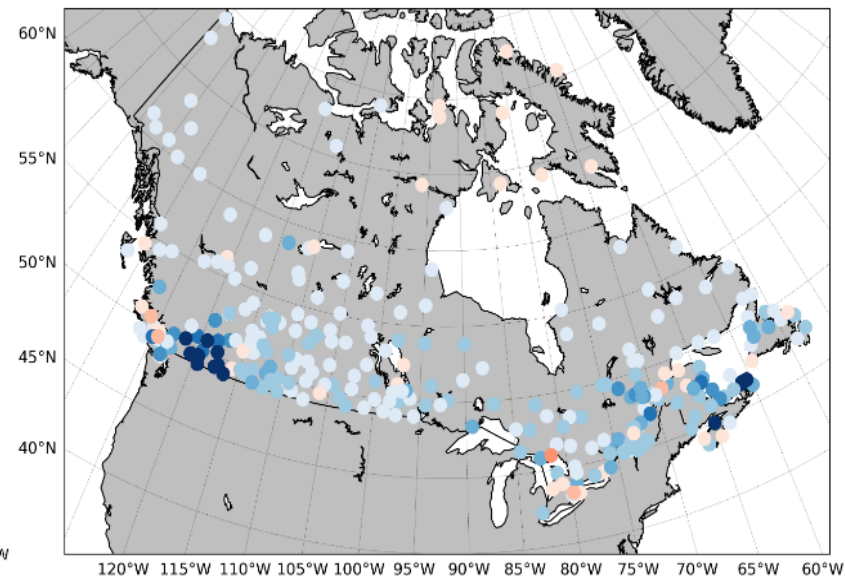
RDRSv2
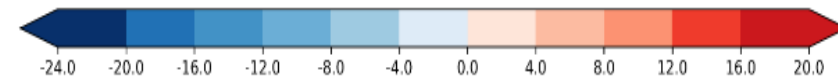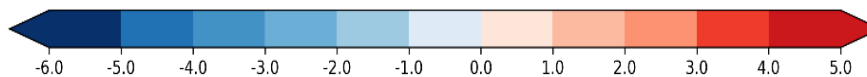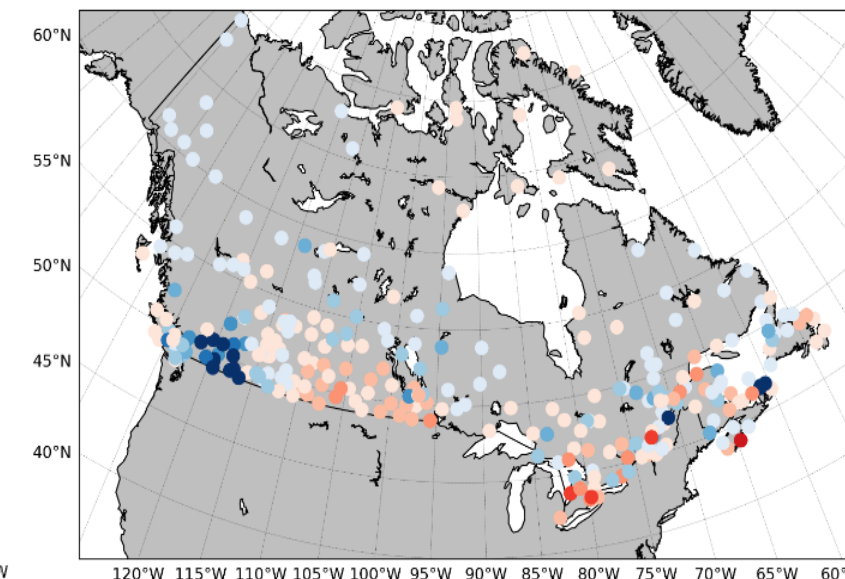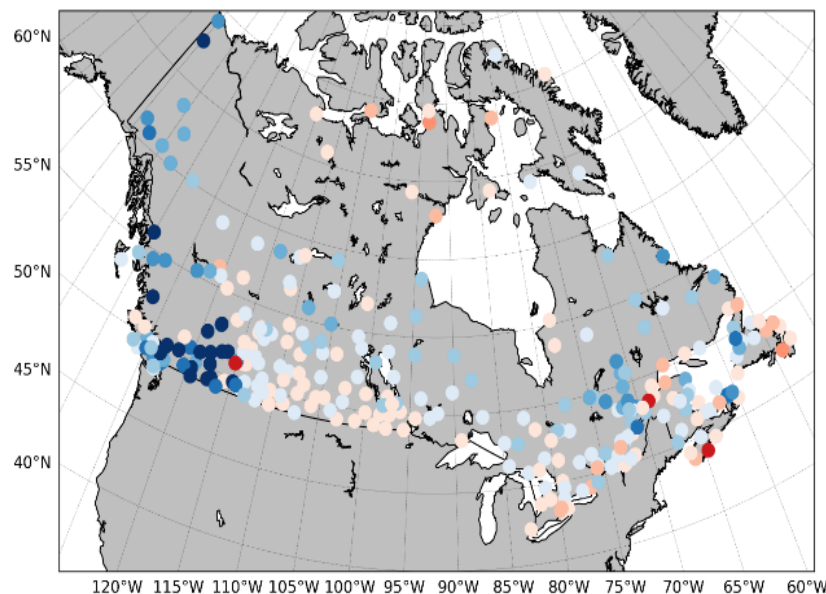
Step 3: Select Bias Correction Method

- 5 Bias correction techniques were tested:
  - **3 quantile mapping methods**
  - **BCCAQv2**
  - **MBCn**
- **Metrics**: mean bias, correlation coefficient
- **Variables**: Daily Tmax, RHmin, HXmax, HX>30, HX>35, HX>40

- Downscaled GCMs using a corresponding RCM historical period as the target
  - ➤ Outputs were compared against RCM data in the future period
  - ➤ BCCAQv2 and MBCn performed very well and were selected for final test

- Test of 2 GCMs bias corrected with BCCAQv2 and MBCn against reanalysis (ERA5-Land and RDRSv2)
  - ➤ Outputs were compared against stations

HX>30 (discomfort days): Bias Corrected GCM VS. Station Observations

Evaluation over 1980-2018 period

- Test the bias correction methods with the historical gridded data

- Methods performed similarly, but have better results when ERA5-Land is used as target.


BCCAQv2   MBCn

ERA5-Land
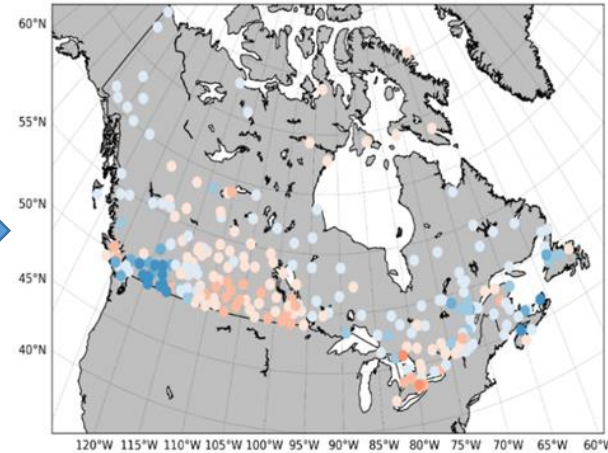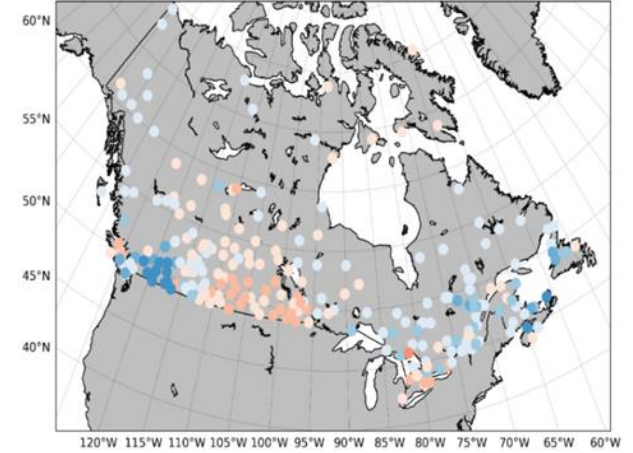
RDRSv2
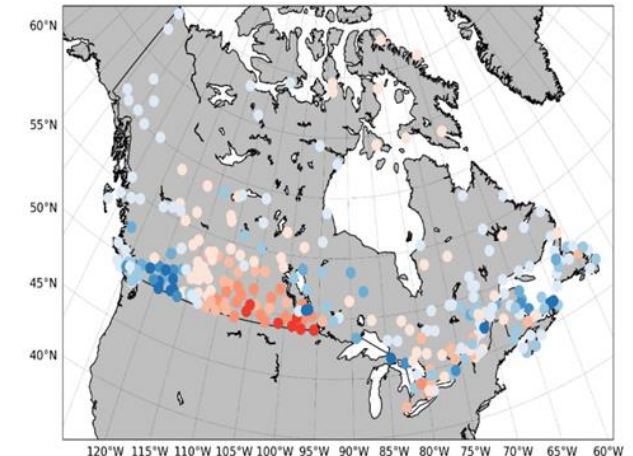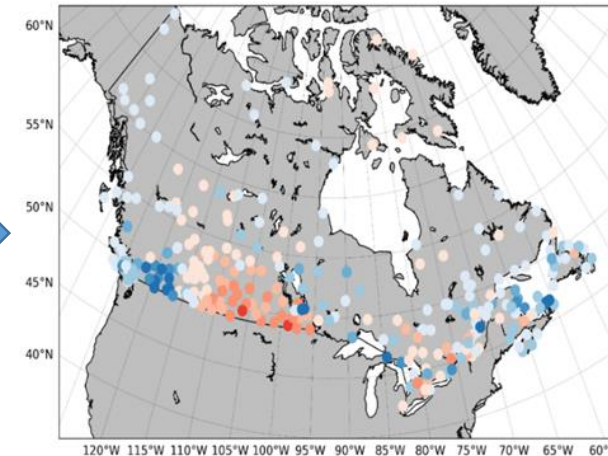
Difference in the # of days

Production: Dataset Details

- Download Tmax and RHmin output from 19 CMIP6 models
  - Period: 1950-2100
  - SSP126; SSP245 and SSP585

- Statistically downscaled and bias corrected ensemble
  - Downscaled and bias corrected method: **MBCn**
  - Target dataset: **ERA5-Land**

- Output preprocess:
  - Computation of daily HXmax
  - Computation of annual and 30y-averages of indices HX>30, HX>35, HX>40
  - Computation of the ensemble percentile for annual and 30y-averages of indices HX>30, HX>35, HX>40

Humidex Ensemble
ACCESS-CM2
ACCESS-ESM1-5
CMCC-ESM2
CNRM-CM6-1
CNRM-ESM2-1
CanESM5
EC-Earth3
EC-Earth3-Veg
EC-Earth3-Veg-LR
FGOALS-g3
GISS-E2-1-G
INM-CM4-8
INM-CM5-0
IPSL-CM6A-LR
MIROC-ES2L
MIROC6
MPI-ESM1-2-HR
MPI-ESM1-2-LR
MRI-ESM2-0

Annual Discomfort days (HX > 30), 1950-2100
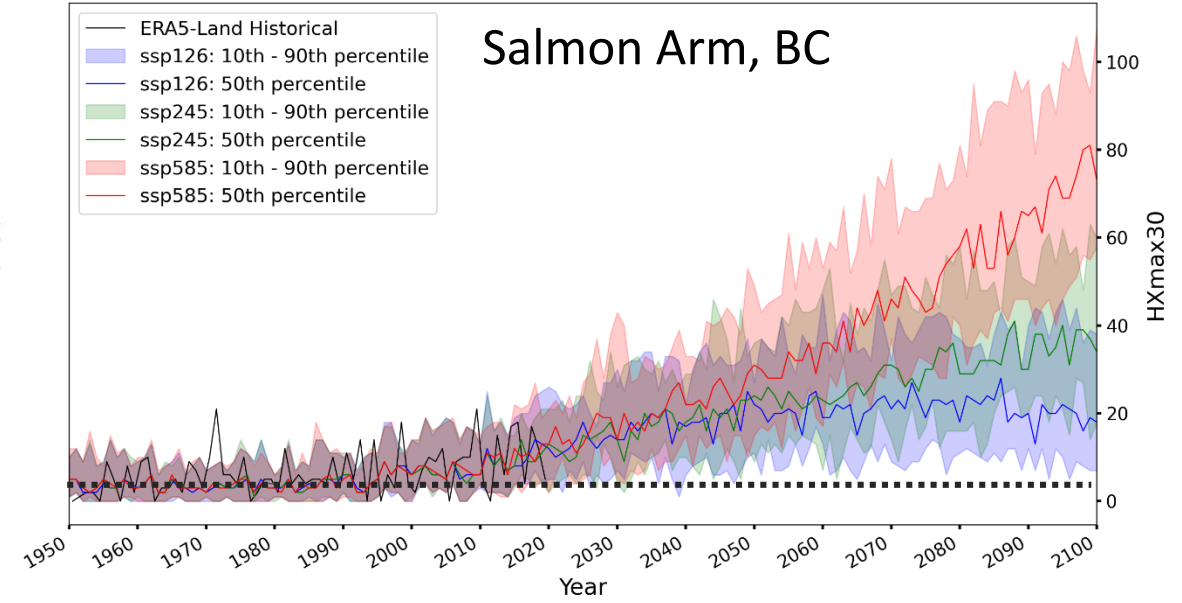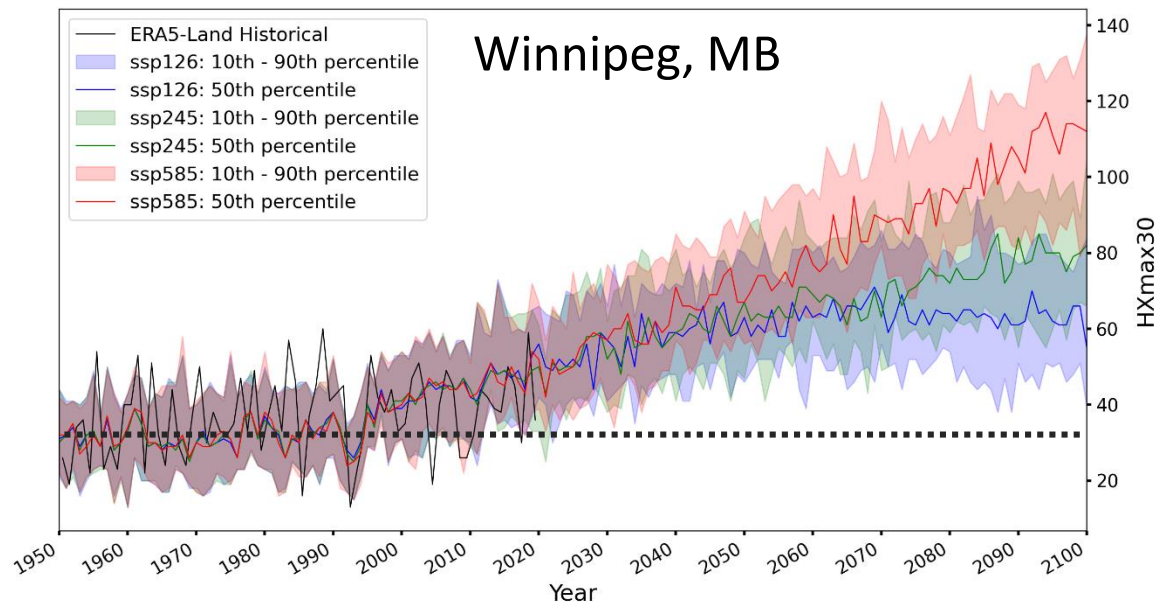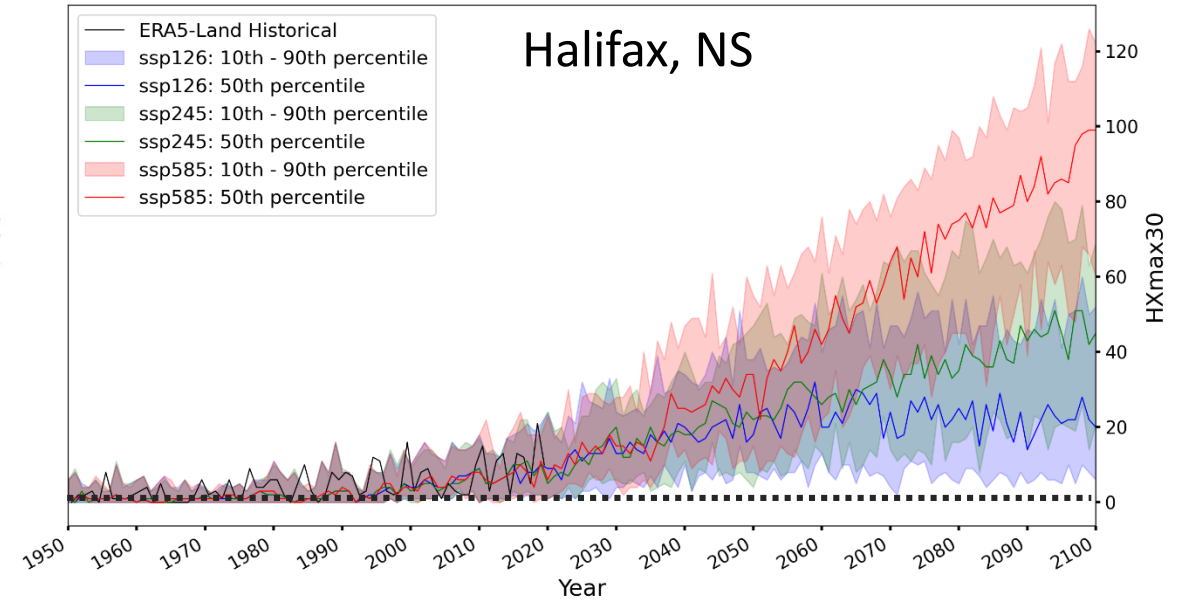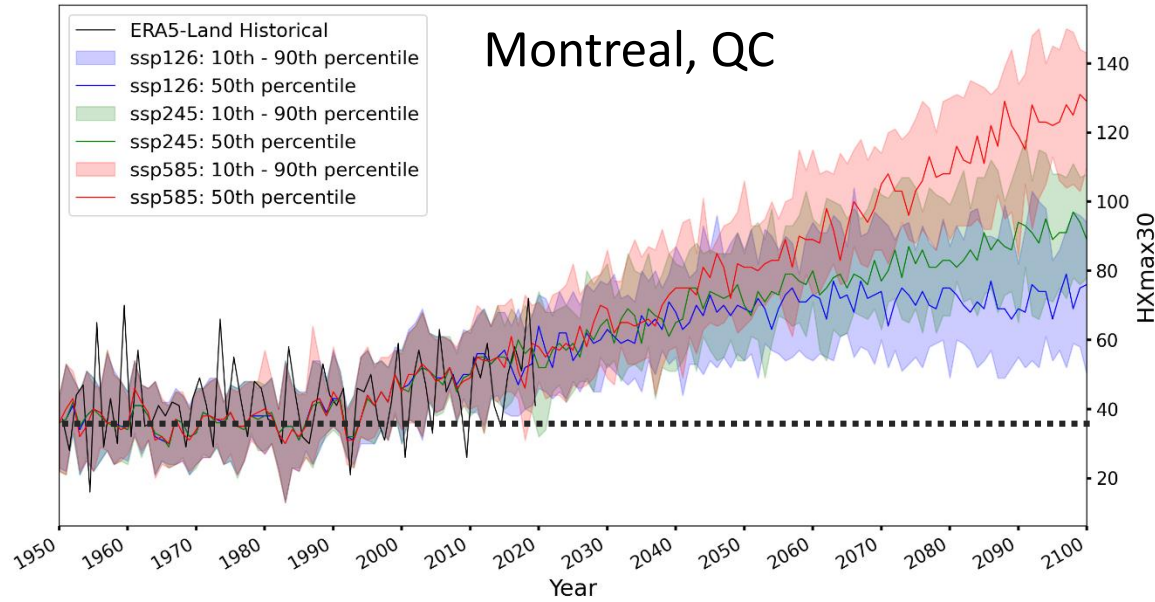
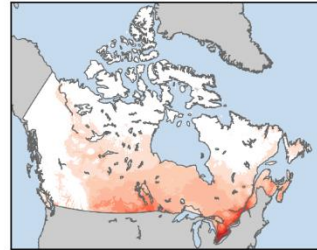# Annual Discomfort days (HX > 30)

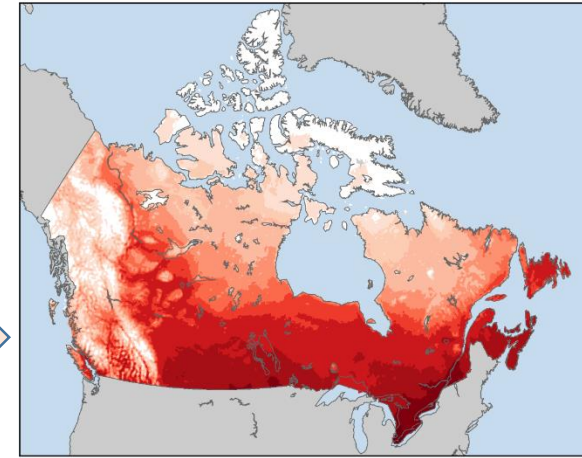Historical ensemble, 1981-2010
Median (50th Percentile)
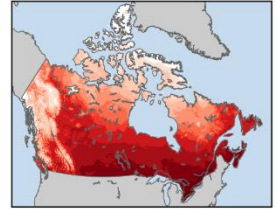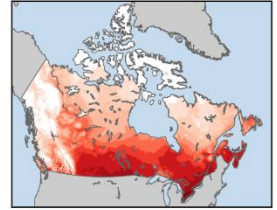Upper (90th Percentile)
Lower (10th Percentile)

ssp585 Ensemble, 2071-2100
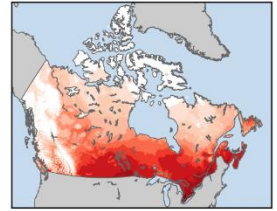Median (50th Percentile)
Upper (90th Percentile)
Lower (10th Percentile)
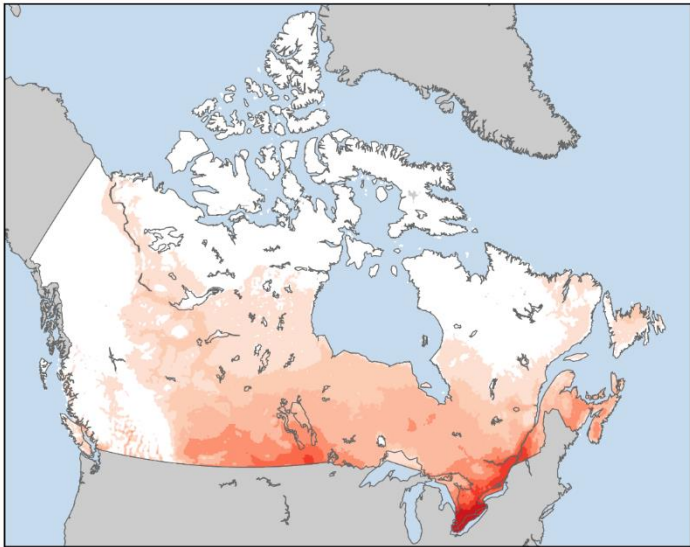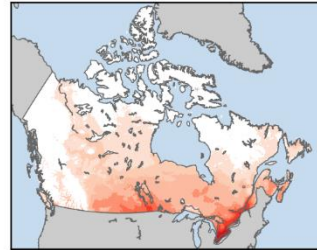
ssp126 Ensemble, 2071-2100
Median (50th Percentile)
Upper (90th Percentile)
Lower (10th Percentile)
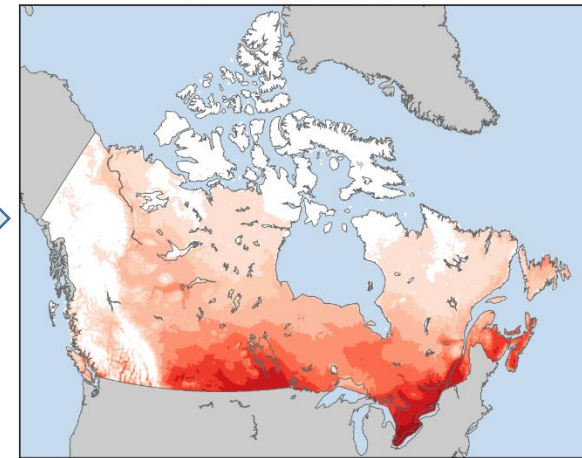
High emissions

Low emissions

HXmax30 (days)

0 1 5 10 20 30 40 50 75 100 125
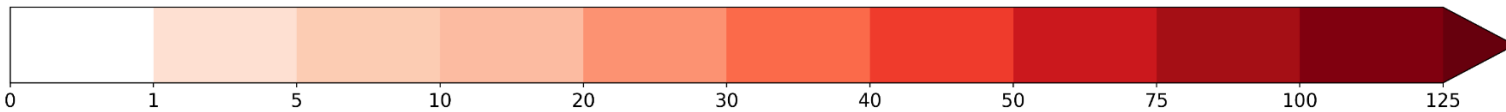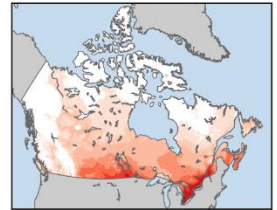
Areas with at least one Extreme Caution Day per year (HX > 40) during historical and future periods

High emission scenario (SSP 585)
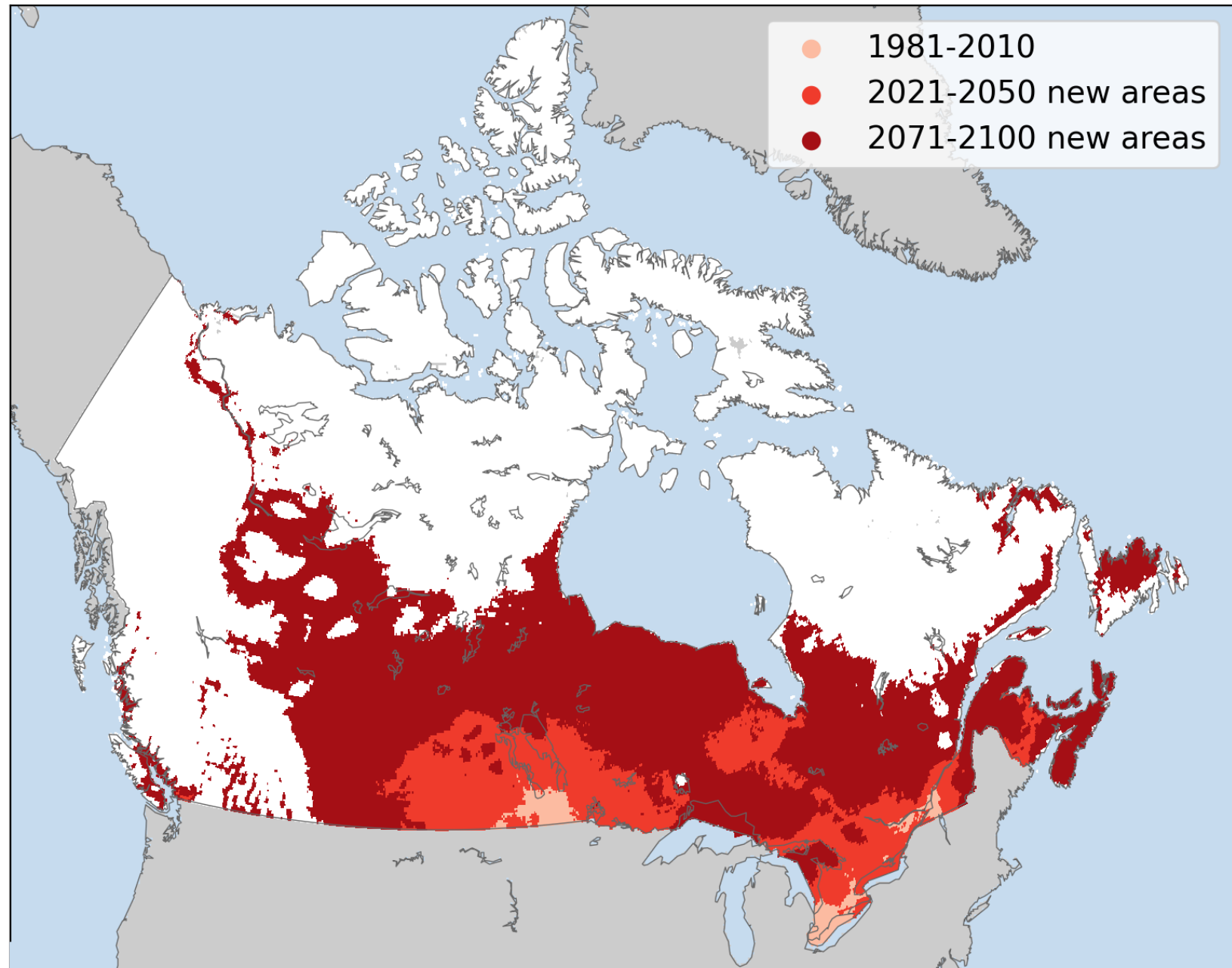
Legend:
- 1981-2010
- 2021-2050 new areas
- 2071-2100 new areas

Questions?

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FR: canada.ca/services-climatiques