Incorporating Climate Resilience for Municipal Infrastructure into the Updates of Existing Atlantic Canada Water and Wasterwater Design Guidelines

WORKSHOP # 1
INCORPORATING CLIMATE CHANGE

Halifax, Nova Scotia
Wednesday October 9th, 2019

CBCL

Agenda

Climate Change updates to ACWWA Guidelines

- Climate Change in Atlantic Canada
- ACWWA Climate Change Update Objectives
- Defining Climate Change and Climate Projections
- Sources of Climate Information
- Climate Change and Infrastructure
- Integrating Climate Change in Design - Example
- Climate Change in AWWCA Guidelines – how to proceed

Updates of Existing Atlantic Canada Water and Wasterwater Design Guidelines

Climate Change in Atlantic Canada

Climate Change in Atlantic Canada


Schools closed, travel disrupted as snow storm blasts parts of Atlantic Canada

Storm crews work in Fredericton on Feb. 25, 2019.


Storm surge was 'unreal,' resident of Newfoundland's south coast says

Charlie Wells says the breakwater behind his house was destroyed by Friday's waves

Meghan McCabe · CBC News · Posted: Dec 17, 2016 5:52 PM NT | Last Updated: December 17, 2016


Flooding in western P.E.I. causes damage, closes roads

Saturday's steady downpour led to some spectacular flooding

Sara Fraser · CBC News · Posted: Jan 15, 2018 8:32 PM AT | Last Updated: January 15, 2018


New Brunswick

Winter storm slams Eastern Canada, causing power outages, flash freeze warnings

Ontario, Quebec are under extreme cold warnings today

Elizabeth Fraser · CBC News · Posted: Jan 21, 2019 5:54 AM AT | Last Updated: January 21

Climate Trends in Atlantic Canada

Anticipated Changes

Known Changes

→ Increase in extreme temperature parameters
→ Increase in precipitation intensity and frequency
→ Melting of permafrost
→ Increases to extreme water levels

Likely Changes

→ Increase in freezing rain
→ Decrease in snow
→ Increase in wave energy

Highly Unknown

→ Increase in winds/gusts, or changes to dir.
→ Decrease in visibility

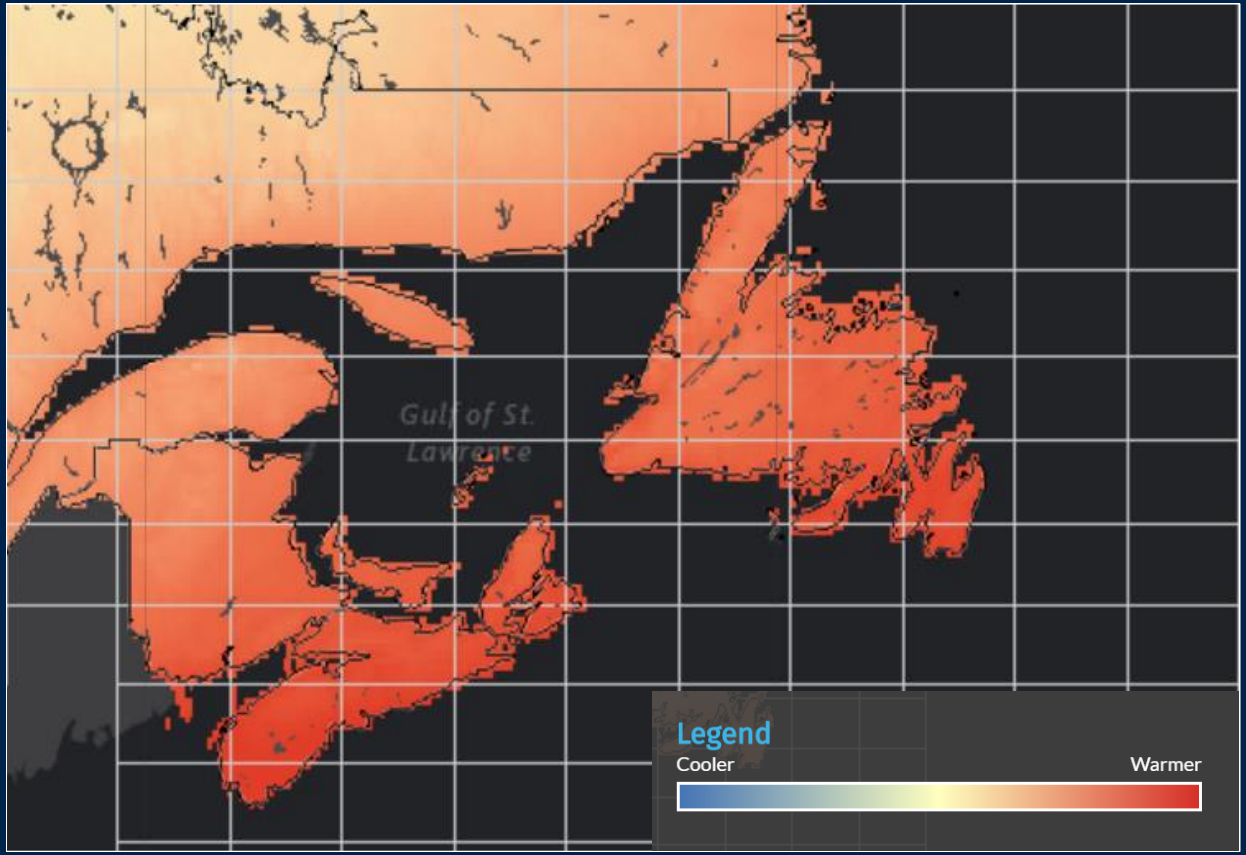


Figure: Minimum Projected Temperature for Time Period 2051-2080 at RCP8.5 (lowest temperature of the day)
Source: Climate Atlas of Canada

Climate Trends in Atlantic Canada

Cold Weather

→ Flash freezing

→ Frost days

→ Icing days

→ Heating Degree Days

→ Seasonal minimums

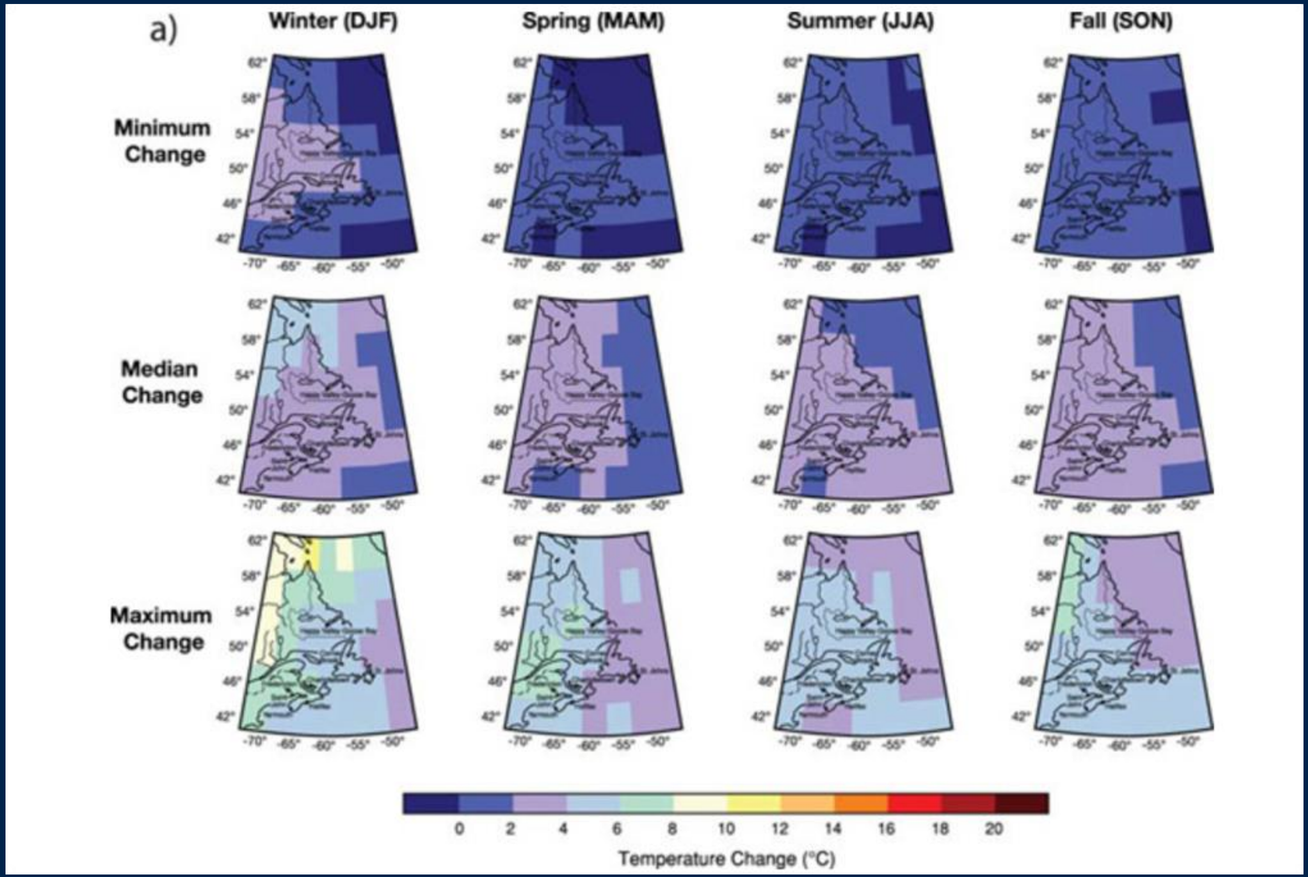


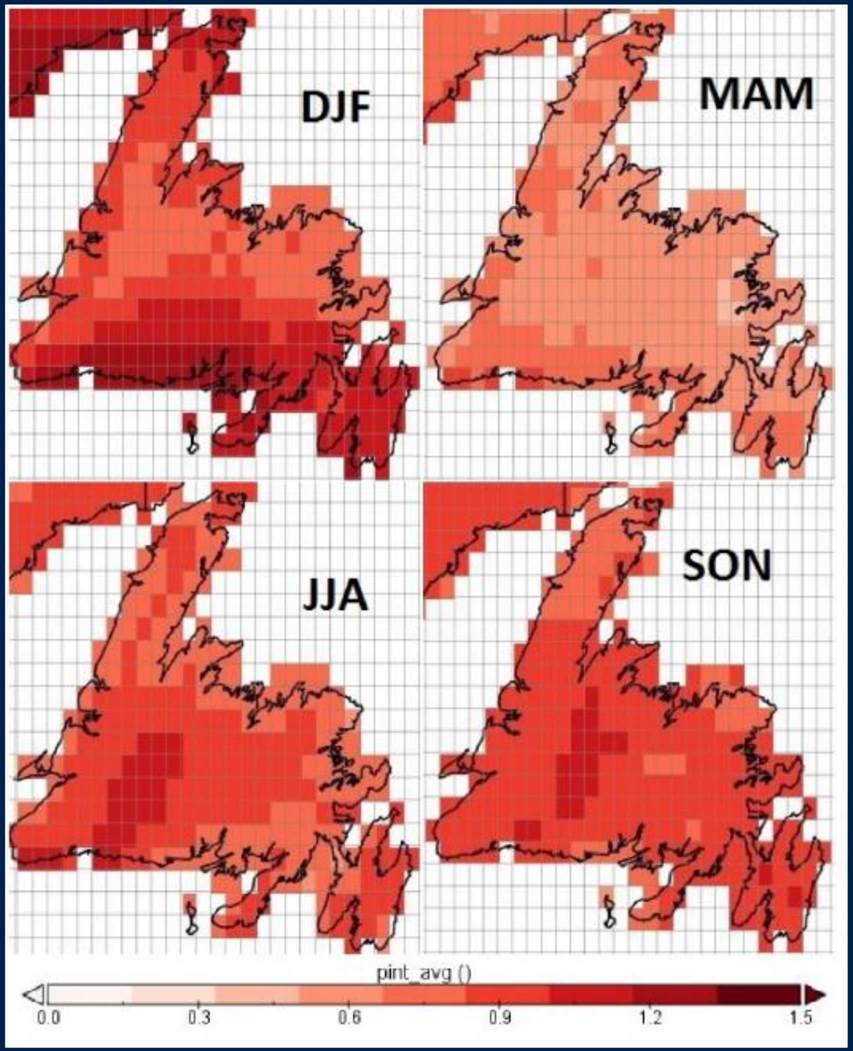
Figure: Climate scenario maps of seasonal temperature changes (months in brackets, 2050) Source: Natural Resources Canada, 2015

Climate Trends in Atlantic Canada

Changes in Precipitation

- → Extreme rainfall
- → Extreme snowfall
- → Freezing rain, sleet, and hail
- → Rain-on-snow
- → Flooding
- → Seasonal rainfall
- → Drought

Figure: Changes in mean intensity of precipitation events (mm/day) for 2041 -2070



(Source: Projected Impacts of Climate Change for the Province of Newfoundland & Labrador 2018 Update 2018)

Climate Trends in Atlantic Canada

Changes in Sea-level and Coastal Flooding

→ Sea-level rise

→ Storm surge

→ Wave run-up

→ Vertical land motion: subsidence and uplift

→ Coastal flooding and erosion

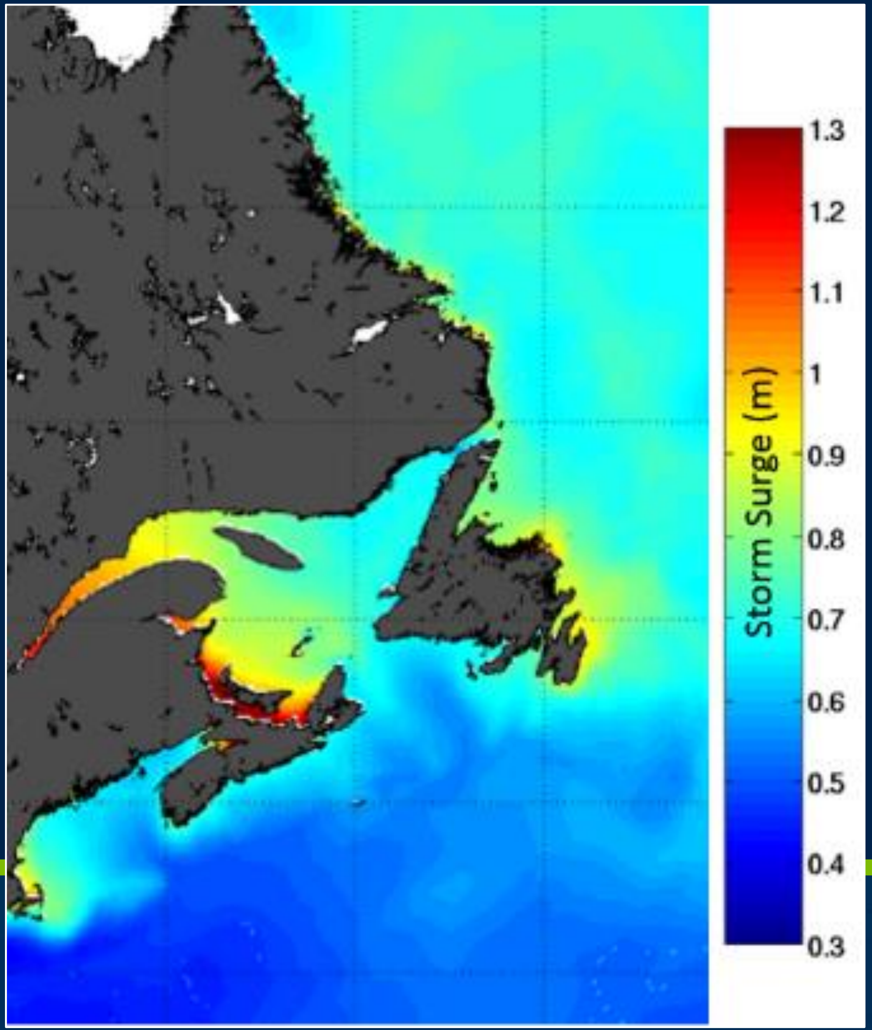


Figure: Modeled storm surge
(1 in 40-yr; Bernier & Thompson, Dalhousie)

Climate Trends in Atlantic Canada

Other considerations

- → Extreme Wind and Hurricanes
- → Sea Ice and River Ice
- → Acid rain
- → Fog
- → Lightning
- → Forest Fires
- → Extreme Weather
- → Flooding
- → Earthquake

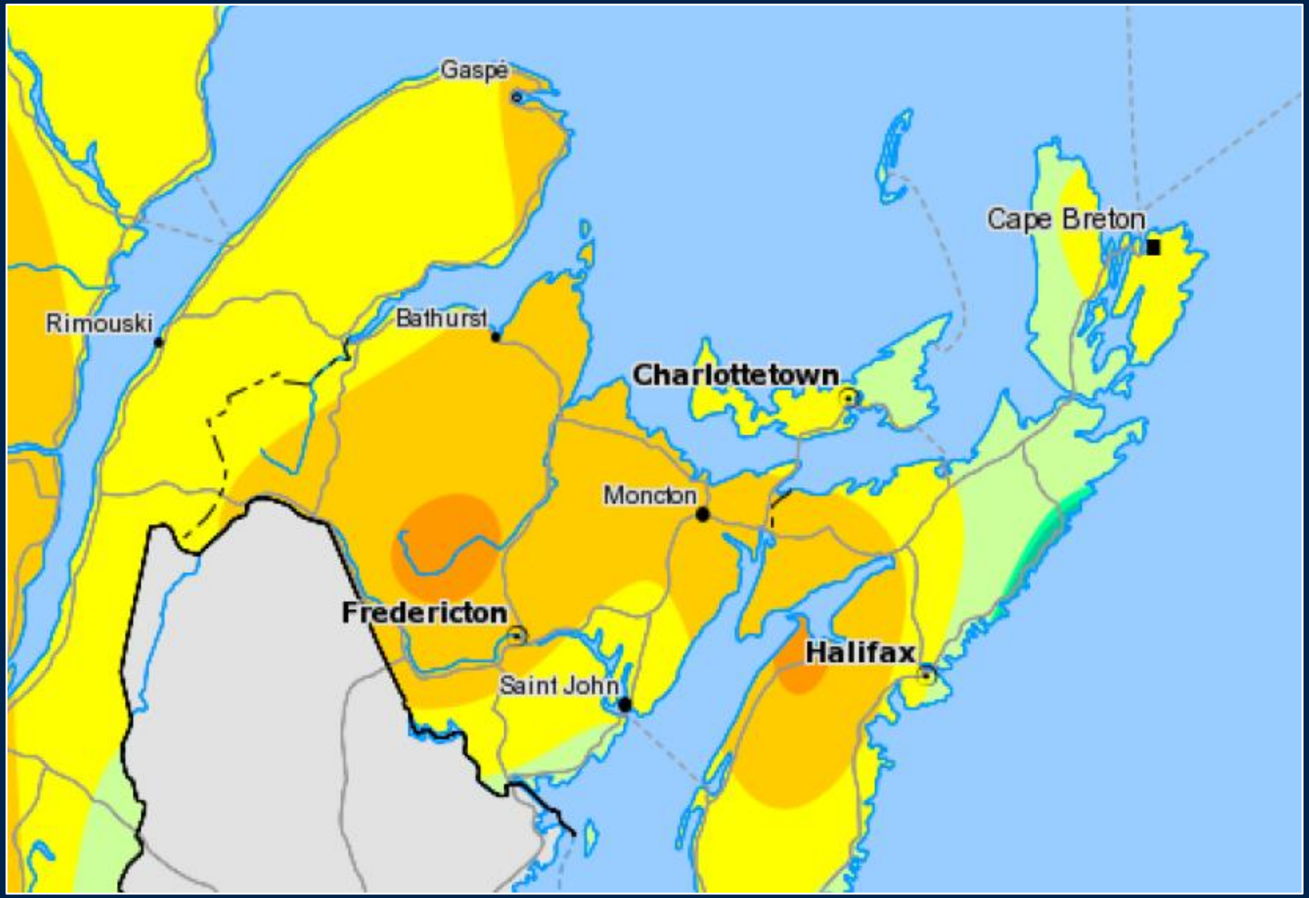


Figure: Forest Fire Severity Level for 2090-2100 (Natural Resources Canada, 2009)

Climate Change in Atlantic Canada

How to incorporate climate change parameters into infrastructure planning, design, operations, maintenance and….

ACWWA guidelines ?

Updates of Existing Atlantic Canada Water and Wasterwater Design Guidelines

ACWWA Program Objectives

Objectives

ACWWA Water & Wastewater Guidelines Update

→ Incorporate climate **resilience** when investigating, designing, approving, constructing, and operating municipal water and wastewater infrastructure in Atlantic Canada.

→ Inclusion of a new chapter on **Climate Resilience** into each of the Guidelines, and update of the existing sections to include climate **resilience requirements**

→ To build climate **adaptation** capacity through training workshops, webinars and dissemination of information.

Objectives

ACWWA Water & Wastewater Guidelines Update

- → **Climate Change science is constantly evolving:**
  - → New research, data, technology, programs, methods, etc.
  - → Understanding of global/regional climate trends
  - → Science and climate are both evolving simultaneously

- → **Therefore, ACWWA guidelines should be developed to:**
  - → Be a “living document”.
  - → Reference other “active” standards and climate data sources which are regularly updated, nationally recognized, and reliable.
  - → Focus on process, not specific data points.

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Updates of Existing Atlantic Canada Water and Wasterwater Design Guidelines

Defining Climate Change and Climate Projections

Weather vs. Climate

Short vs. Long-term

Weather

"the state of the atmosphere with respect to wind, temperature, cloudiness, moisture, pressure, etc." (NOAA 2013).

Weather generally refers to short-term variations on the order of minutes to about 15 days (NSIDC 2012).

Climate

"is usually defined as the average weather, or more rigorously, the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years" (IPCC 2014).

Climate and Engineering

Design Considerations

→ Changes that take place over periods < 30 years are generally referred to as climate variability. *

→ Changes that persist for > 30 years are generally referred to as climate change. *

→ Engineering design is primarily concerned about **extremes**.

  → The IPCC defines an extreme weather event as "an event that is rare at a particular place and time of year" (IPCC 2012).

* ASCE (2018)

Climate and Engineering

Design Considerations

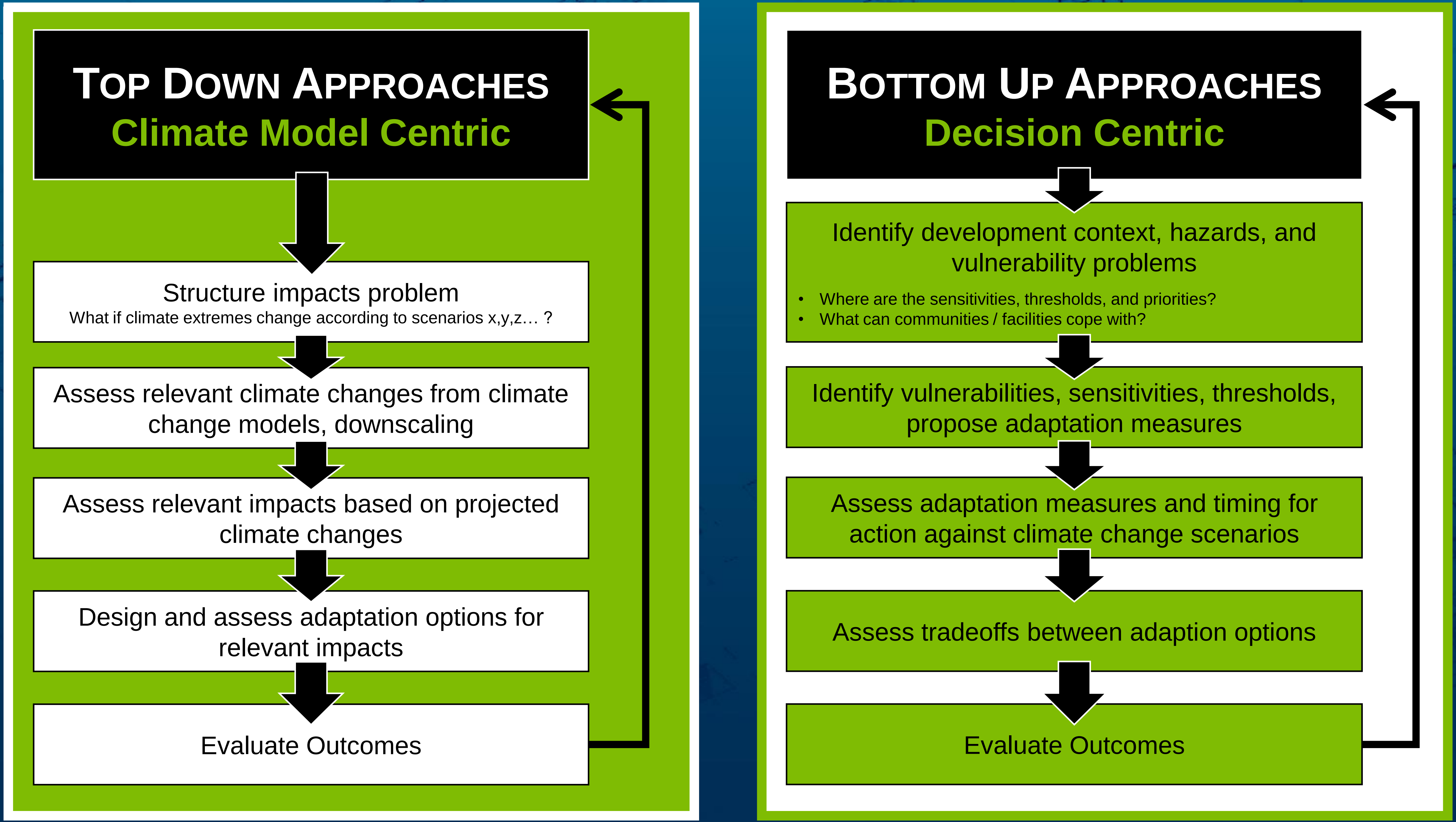
- Climate scientists and civil engineers have differing views on what statistically constitutes an extreme event.
- The IPCC states that an extreme weather event would "normally be as **rare** as or **rarer** than the 10th or 90th percentile of the observed probability density function."
- Civil engineering: **rare** is often defined in terms of an acceptable frequency of failure.
  - e.g. Large dams: MRIs of about 10,000 years (AEP of 0.0001).
  - e.g. Flood risk management: MRIs of 100 to 500 years (AEPs of 0.01 to 0.002).

Annual Probability of Exceedance (AEP)
Mean Recurrence Interval (MRI)

Top Down vs. Bottom Up

Decision Making Processes

How is Climate Change incorporated into infrastructure planning and decisions making processes?

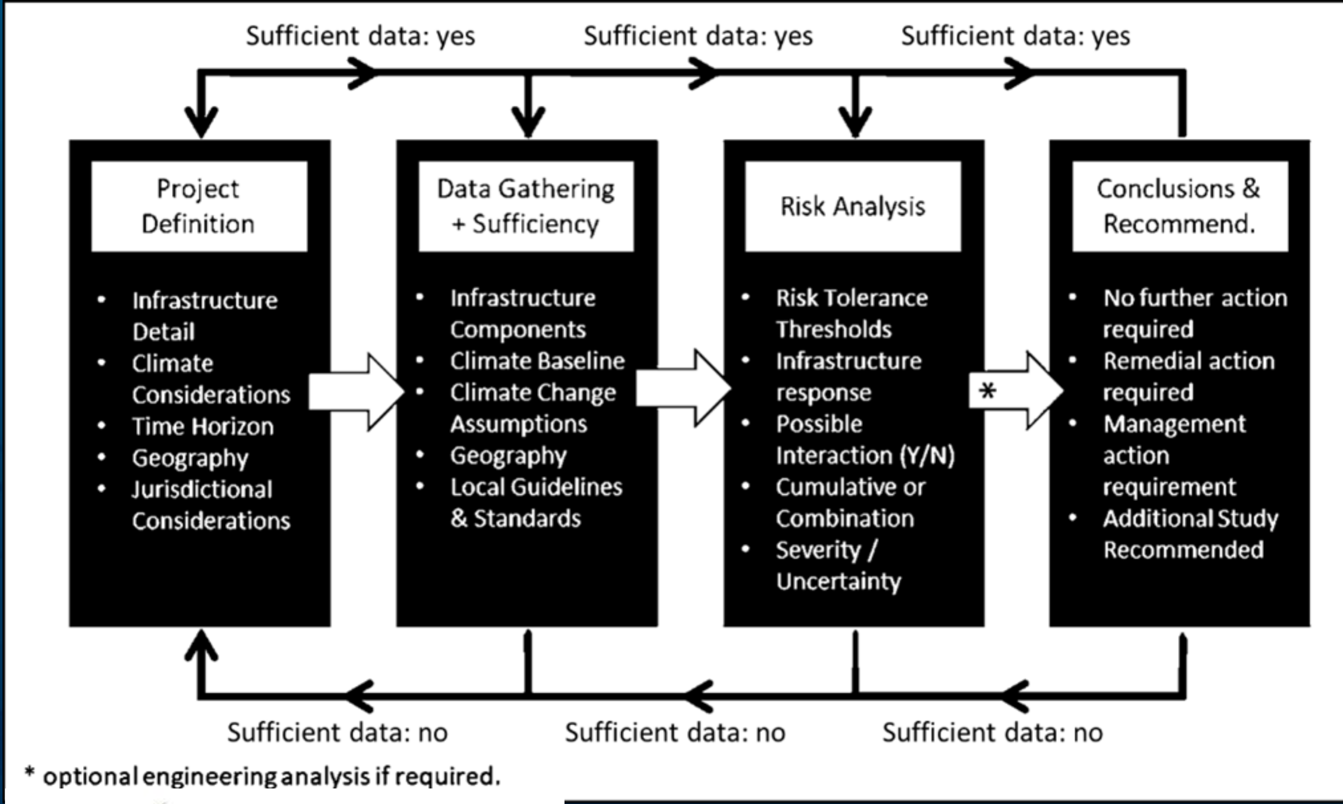


TOP DOWN APPROACHES
Climate Model Centric
Structure impacts problem
What if climate extremes change according to scenarios x,y,z… ?
Assess relevant climate changes from climate change models, downscaling
Assess relevant impacts based on projected climate changes
Design and assess adaptation options for relevant impacts
Evaluate Outcomes
BOTTOM UP APPROACHES
Decision Centric
Identify development context, hazards, and vulnerability problems
• Where are the sensitivities, thresholds, and priorities?
• What can communities / facilities cope with?
Identify vulnerabilities, sensitivities, thresholds, propose adaptation measures
Assess adaptation measures and timing for action against climate change scenarios
Assess tradeoffs between adaption options
Evaluate Outcomes

Infrastructure Climate Risk Assessment

PIEVC Engineering Protocol

- Engineers Canada PIEVC Engineering Protocol
- Protocol is a five step process to analyze the engineering vulnerability of an individual infrastructure to current and future climate parameters.
- Standardized transferable method
- It is not a spatial risk assessment tool to identify areas of high, medium or low risk.
- Can be used to make informed engineering judgments on what infrastructure requires adaptation, changes to operations or maintenance procedures.



Infrastructure Climate Risk Assessment

PIEVC Engineering Protocol

Purpose of assessment:
Prioritize risk of different infrastructure components
General trends, magnitudes, and level of confidence

Probabilities: assigned to climate parameters via scores from 0 to 7.

- Probability of occurrence of an event
- Probability of exceeding a threshold
- Probability of increase compared to existing

Severities: assigned independently of probabilities

- Prioritization of Risk

Probability	Score	Severity
Negligible –*Once in 100 years*	0	Negligible Not Applicable
Highly Unlikely - *Once in 10 years*	1	Very Low Some Measurable Change
Remotely Possible - *Once in 2-5 years*	2	Low Slight Loss of Serviceability
Possible Occasional - *Once a years*	3	Moderate Loss of Serviceability
Somewhat Likely - *A few times per year*	4	Major Loss of Serviceability Some Loss of Capacity
Likely - *Monthly*	5	Loss of Capacity Some Loss of Function
Probably - *Weekly*	6	Major Loss of Function
Near certain – *Daily*	7	Extreme Loss of Asset

Climate Resilient Infrastructure

In-short

→ Infrastructure that is planned, designed, built, and operated in a way that anticipates, prepares for, and adapts to, changing climate conditions.

→ It can withstand, respond to, and recover rapidly, from disruptions caused by changing climate conditions.

(OECD Environment Policy Paper No. 14, 2018).

Mitigation vs. Adaptation

What's the Difference?

MITIGATION

Reducing climate change.

Involves reducing the flow of heat-trapping greenhouse gases into the atmosphere.

ADAPTATION

Adapting to life in a changing climate.

Involves adjusting to actual or expected future climate.

Mitigation vs. Adaptation

Examples

Mitigation

Reducing energy demand by:

- Increasing energy efficiency.
- Phasing out fossil fuels by switching to low-carbon energy sources.
- Removing carbon dioxide from Earth's atmosphere.

Adaptation

- Rainwater storage
- Reducing paved areas
- Air conditioning in public schools
- Raising pumps at WWTP
- Public awareness campaigns
- Climate change planning tools
- Seawalls / managed retreat,
- etc.

Adaptation & Resilience

ACWWA Guidelines

Focus on Adaptation in guidelines.

Putting Adaptation & Resilience Together

The decision-making process and the set of actions (i.e. following ACWWA guidelines) [adaptation], to maintain the capacity of the system to deal with current or future predicted change, while maintaining options to develop [resilience].

Climate Change in Design

Past, Present, Future

Designers need to now account for both observed historical trends and climatic projections when undertaking water and wastewater projects.

Design Philosophy

Climate Projections

- Historical observations can no longer be relied on.
- Uncertainty and limitations associated with Climate Model projections at the project scale must be understood.

Recommended that:

- Engineers communicate and collaborate with climate scientists.
- Work closely with climate scientists to identify needs of the engineering community.
- Make limitations of climate science more transparent to engineers.

Practicing engineers, project stakeholders, and policy and decision makers should be informed about the uncertainty of the projections of future climate and the reasons for the uncertainty.

Updates of Existing Atlantic Canada Water and Wasterwater Design Guidelines

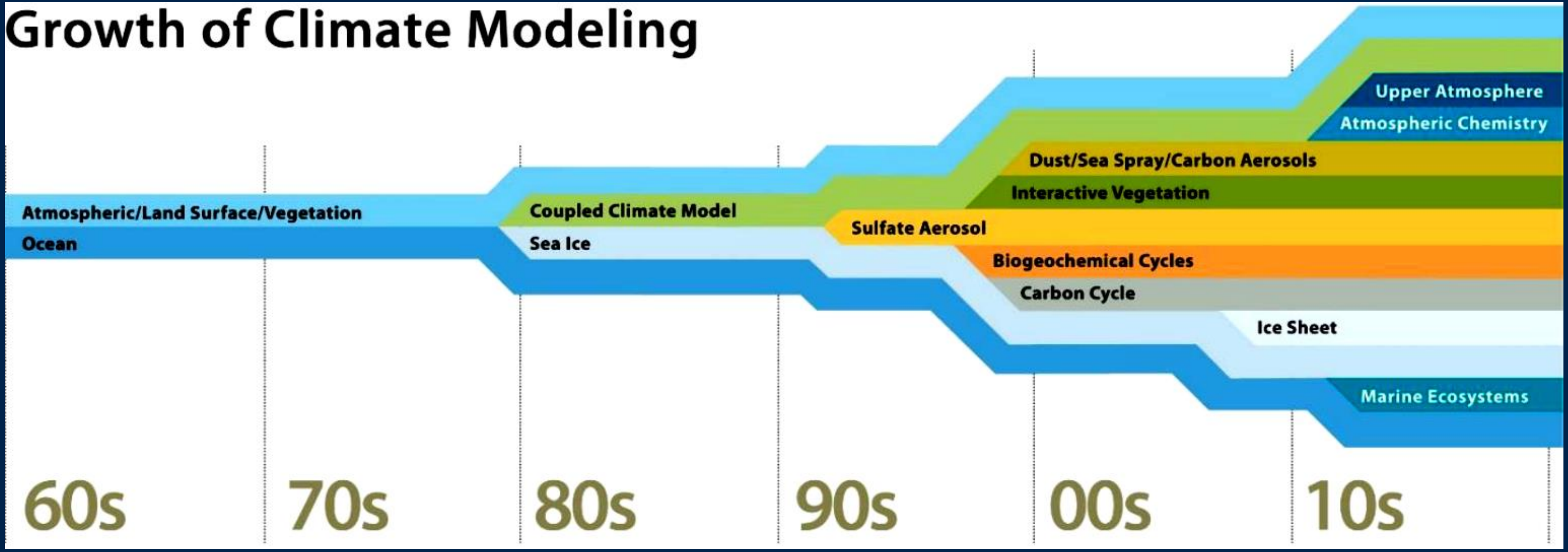
Sources of Climate Information

Climate Change Projections

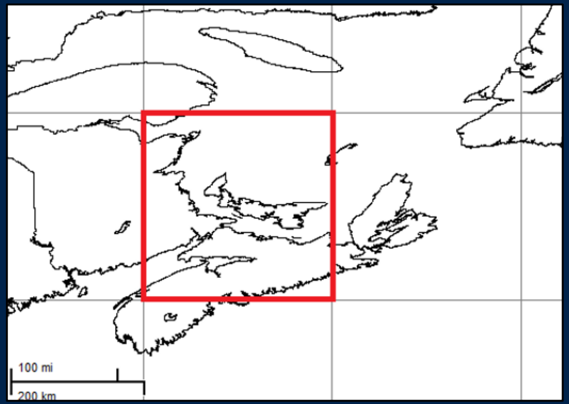
What is a Climate Model?

- **Global Climate Models (GCMs)** are complex numerical models which simulate and describe atmospheric, oceanic, and other processes which describe climate.
  - Divide the earth into cells (100-300 km spatial resolution within each cell).

- There are over **30 Global Climate Models (GCMs)** which are owned by institutions around the world and require significant computational power to run.



Global Climate Model
CGCM (100s km)



http://projects.upei.ca/climate/files/2012/07/Comer

Climate Change Projections

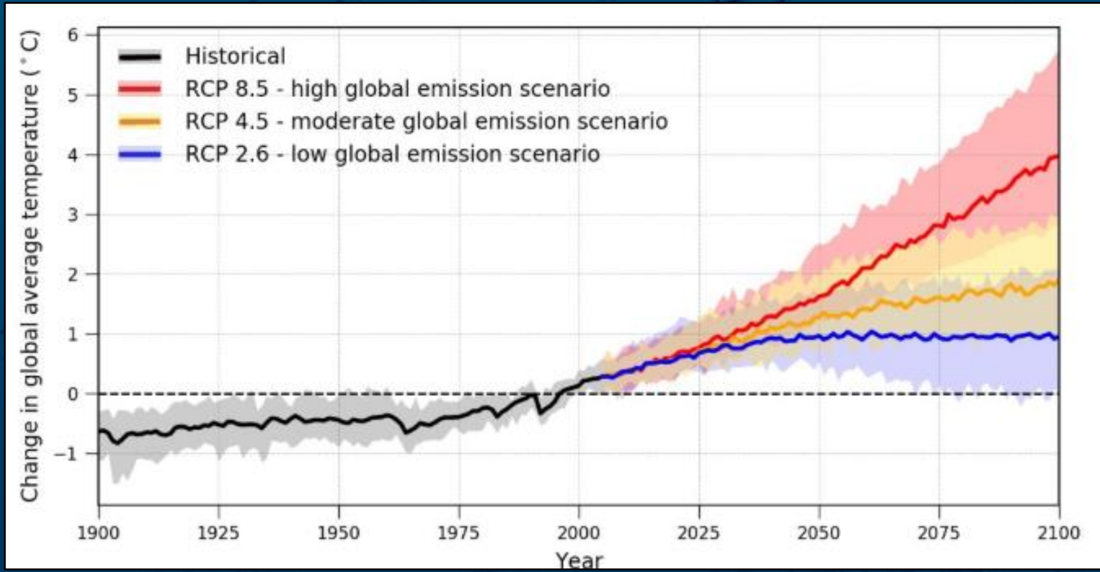
Common Representative Pathways

Three industry standard scenarios, called Representative Concentration Pathways (RCP), established by the IPCC

RCP 8.5 – A future with no implementation of policy changes to reduce emissions, and thus increasing GHG emissions in to the future.

RCP 4.5 – A future with relatively ambitious emissions reductions where CO2 emissions increase only slightly before a decline commences around 2040.

RCP 2.6 – A future where GHG emissions stay consistent until 2020 when they begin to decline until 2100.



Change in Global Average Temperature Relative to the 1986-2005 Reference Period for RCP 2.6, RCP 4.5, and RCP 8.5 (Canadian Centre for Climate Services)

Climate Change Projections

Common Representative Pathways

RCP	Temperature	Emission Trend
1.9	~1.5 °C	Very Strongly Declining Emissions
2.6	~2.0 °C	Strongly Declining Emissions
4.5	~2.4 °C	Slowly Declining Emissions
6.0	~2.8 °C	Stabilising Emissions
8.5	~4.3 °C	Rising Emissions

The relevant levels for the Paris Agreement (2016) lead to warming of well below 2 °C and to pursue 1.5 °C or below. This is captured by RCP 2.6 and RCP 1.9

Climate Change Projections

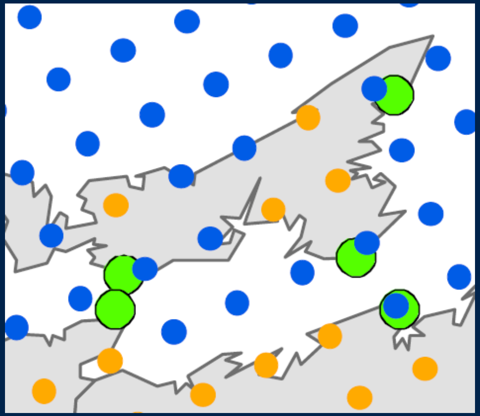
Regional Climate Models (RCMs)

Projections can be focused on smaller areas using a process referred to as “downscaling”.

REGIONAL CLIMATE MODELS (RCMS):

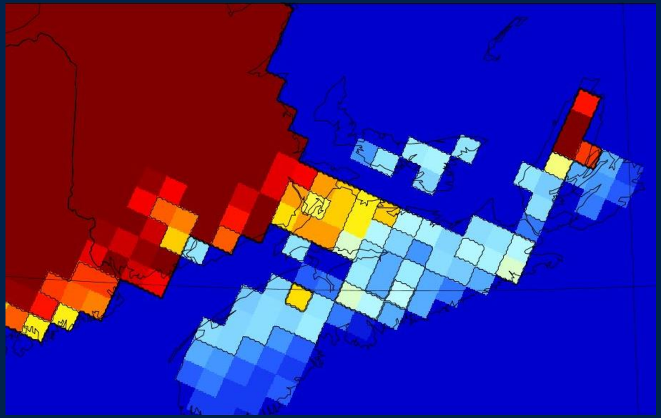
- Dynamically downscaled GCMs
- Smaller spatial area (e.g., one continent)
- Driven by a GCM
- Still very computationally expensive

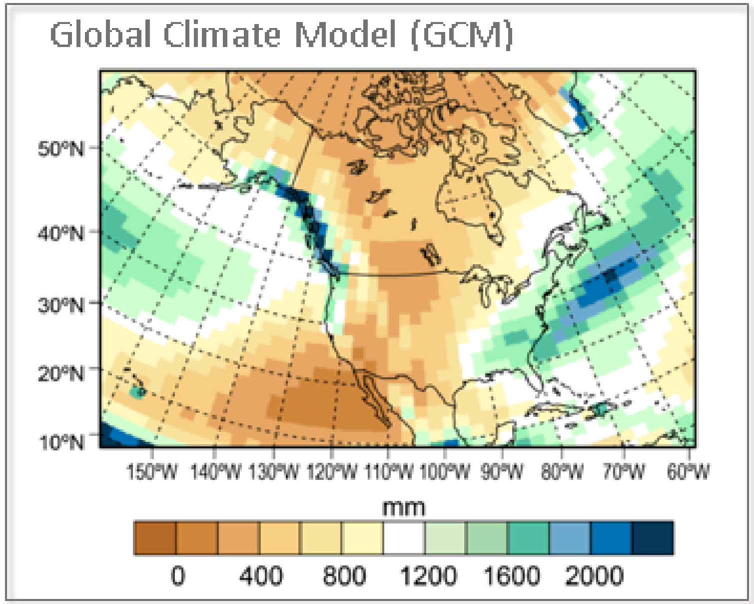
PRECIS
(25 km)

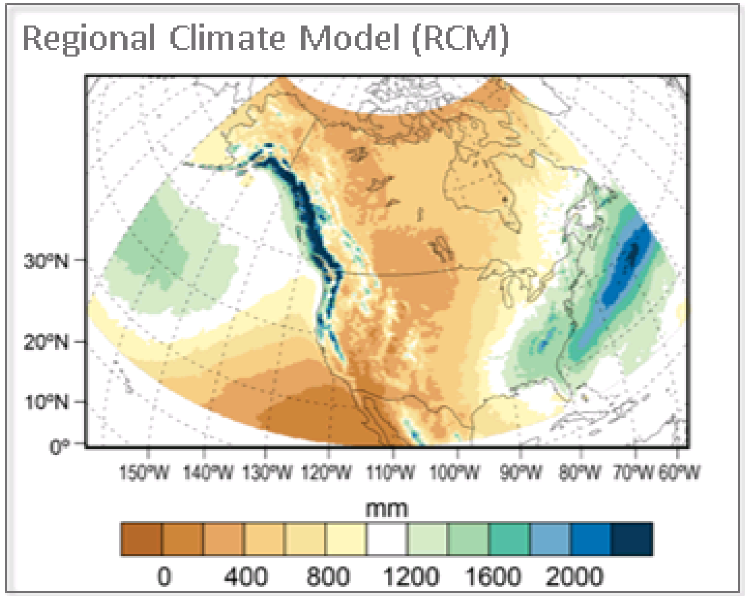


Blue = water
Orange = land
Green = project sites

CanRCM4
(25 km)







Climate Change Projections

Parameters vs. Indices

PARAMETERS are outputs of GCMs such as temperature, precipitation, snow, and wind, etc.

INDEX refers to calculations that are based on parameters, such as number of freeze-thaw cycles, duration, threshold-based, minimum, or extreme values.

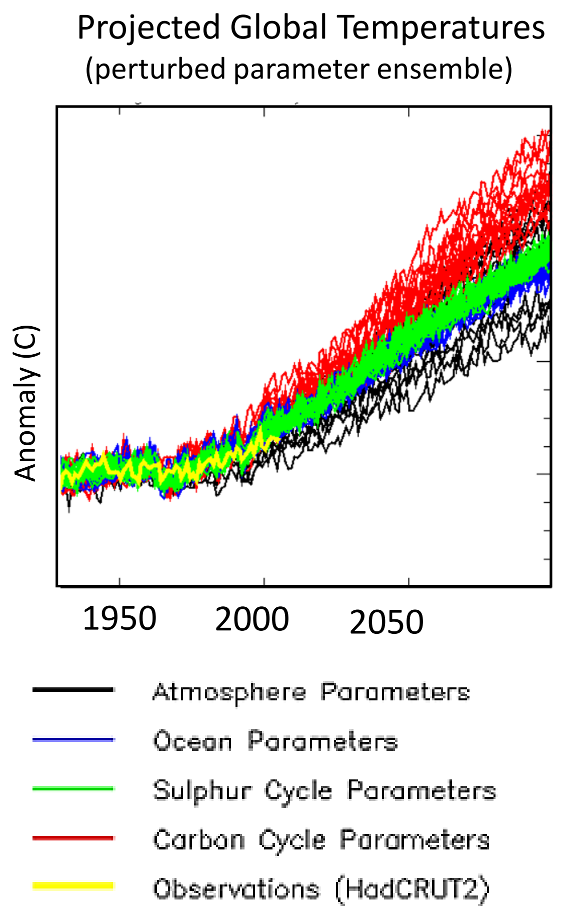
- Indices provide meaningful projections that can be used by decision-makers.
- Some indices require a combination of parameters, such as humidity which involves both precipitation and temperature.

Climate Change Projections

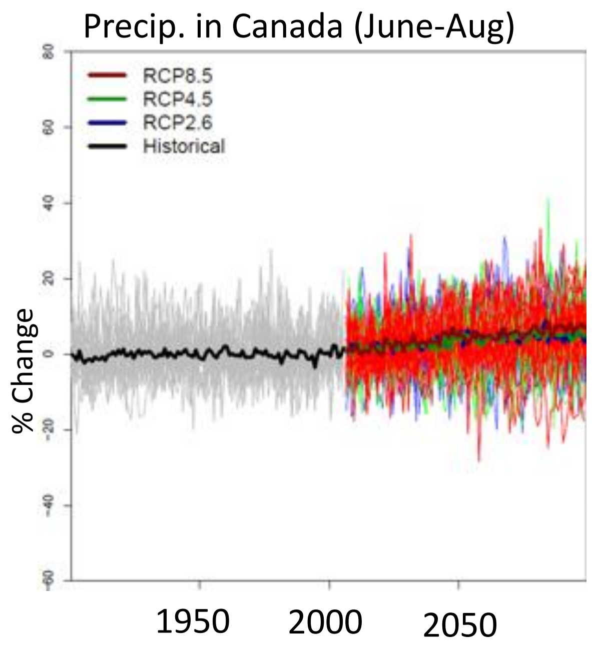
Model Variability and Uncertainty

- GCM and RCM data are subject to model **variability** and **uncertainty**.
- Can result in overestimates or underestimates of predicted values based on the numerical methods in the equations or the model.
- The use of a single model run can be considered as one possible future.
- The median of many model runs is considered to be a more unbiased representation of the future.
- This approach for managing model **uncertainty** and **variability** is called **ensemble modeling**.

Variability due to parameter selection



Variability between models



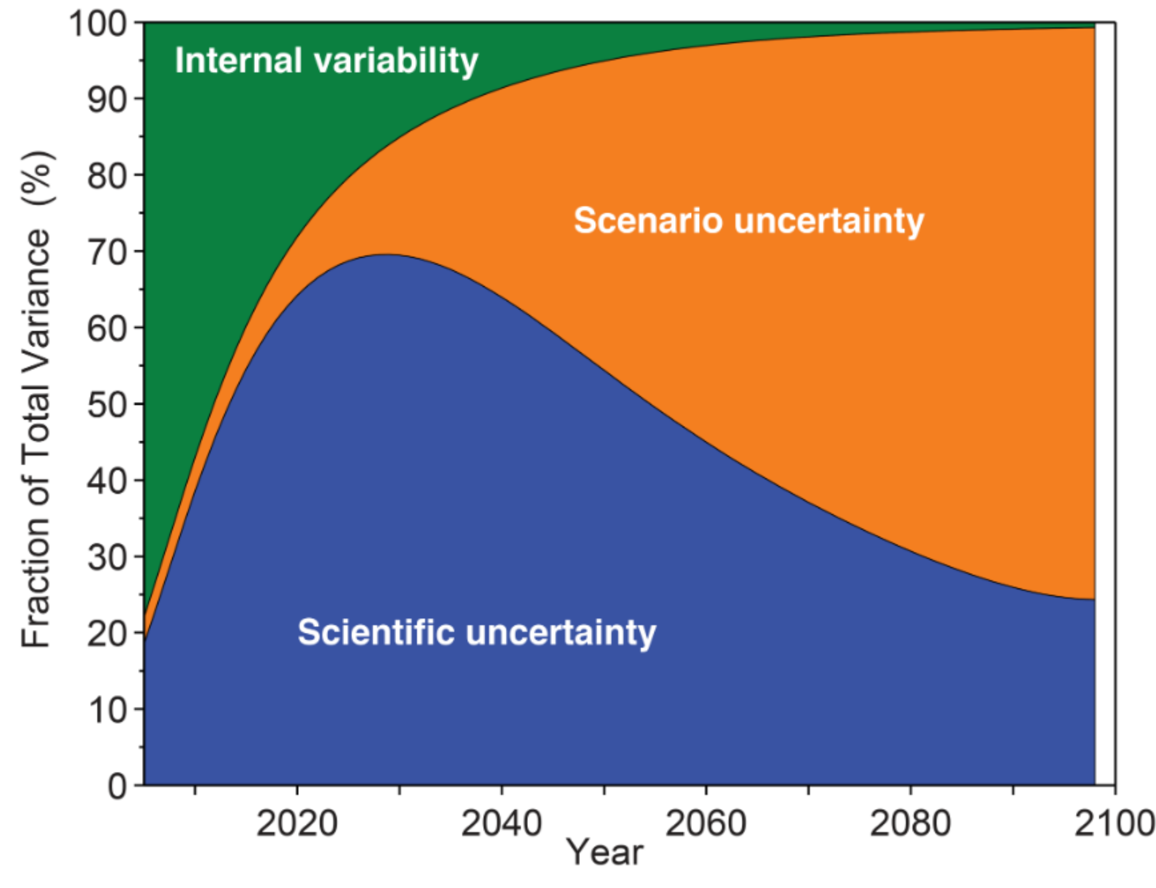
Climate Change Projections

Model Variability and Uncertainty

1. **Internal variability** – unpredictable natural fluctuations in the climate system that occur even without any changes in greenhouse gas concentrations.

2. **Scenario uncertainty** – The evolution of greenhouse gas emissions is highly uncertain.

3. **Scientific uncertainty** –Although climate models are the best tools available to study projections, there is inherent uncertainty in predictive models.



Expected Relative Contribution of Uncertainty Sources in Climate Modeling Over Time
(Adapted from Hawkins and Sutton 2009)

Climate Change Projections

Pros and Cons of Sources

Source	Pro	Con
GCM	• Ensemble of 36+ models	• Scale (100-300 km) • Ability of model to represent physical processes
RCM	• Scale (25 km)	• Fewer ensemble models • No feedback with GCM inputs
Statistical Downscaling	• Site-specific	• Sensitive to data quality • Ignores changes in processes
Extrapolate measured trends	• Site-specific	• Sensitive to data quality • Ignores changes in physical processes
Process understanding (literature)	• Project changes not captured in models	• Qualitative

Climate Change Projections

Data Sources

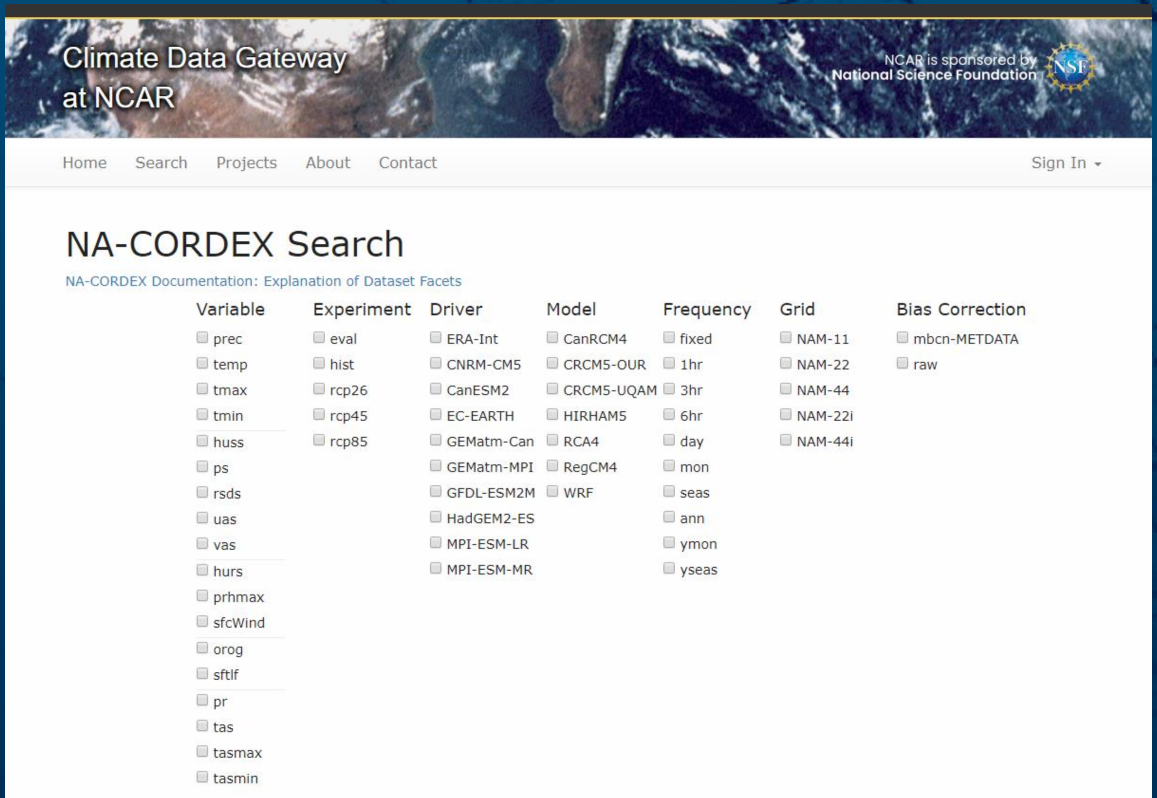
Examples of Data Sources
For use in Atlantic Canada

NA-CORDEX Data

US National Center for Atmospheric Research

- RCMs run over a domain covering most of North America using boundary conditions from global climate model (GCM) simulations in the CMIP5 archive.
- Run from 1950–2100 with a spatial resolution of 0.22°/25km or 0.44°/50km.
- Data is available for impacts-relevant variables at daily and longer frequencies in CF-compliant netCDF format.
- Requires expertise to access and interpret.

www.earthsystemgrid.org



Climate Data Extraction Tool

Government of Canada

https://climate-change.canada.ca/climate-data/#/

Français

Government of Canada | Gouvernement du Canada

Search Canada.ca

MENU

Home > Environment and natural resources > Weather, climate and hazards > Climate change > Adapting to Climate Change > Canadian Centre for Climate Services > Display and Download Climate Data

Climate data extraction tool

- Climate simulations
  - Global climate model scenarios
  - Statistically downscaled climate scenarios
  - Canadian Seasonal to Inter-annual Prediction

Climate data extraction tool

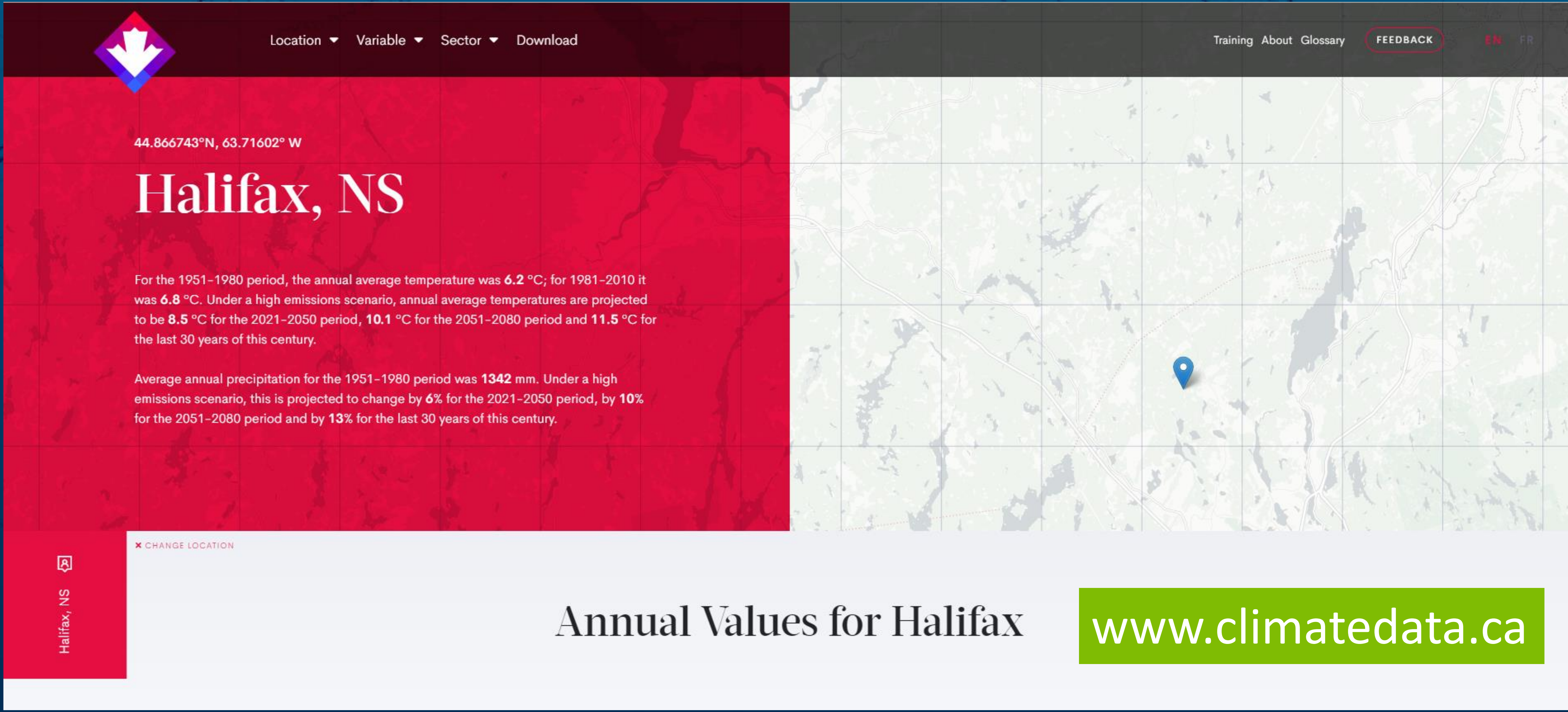
Use the climate data extraction tool to download climate data from the selected Environment and Climate Change Canada's datasets. You can specify the date ranges, variables, download format and other options.

Information

We value your feedback and are updating this tool continuously to ensure that it meets your needs. If you have any questions, comments or suggestions, contact the

Environment and Climate Change Canada

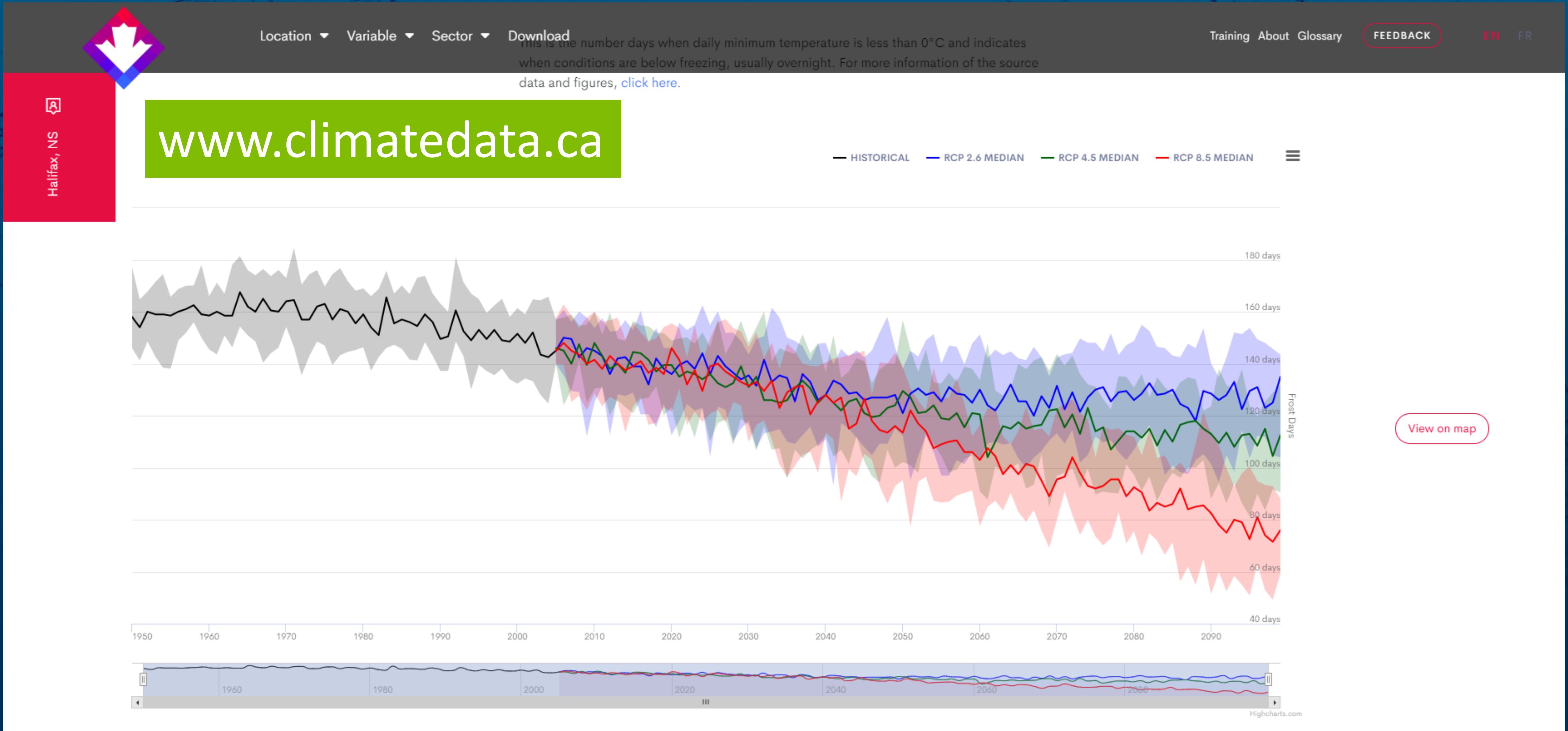
Canadian Centre for Climate Services (CCCS)



www.climatedata.ca

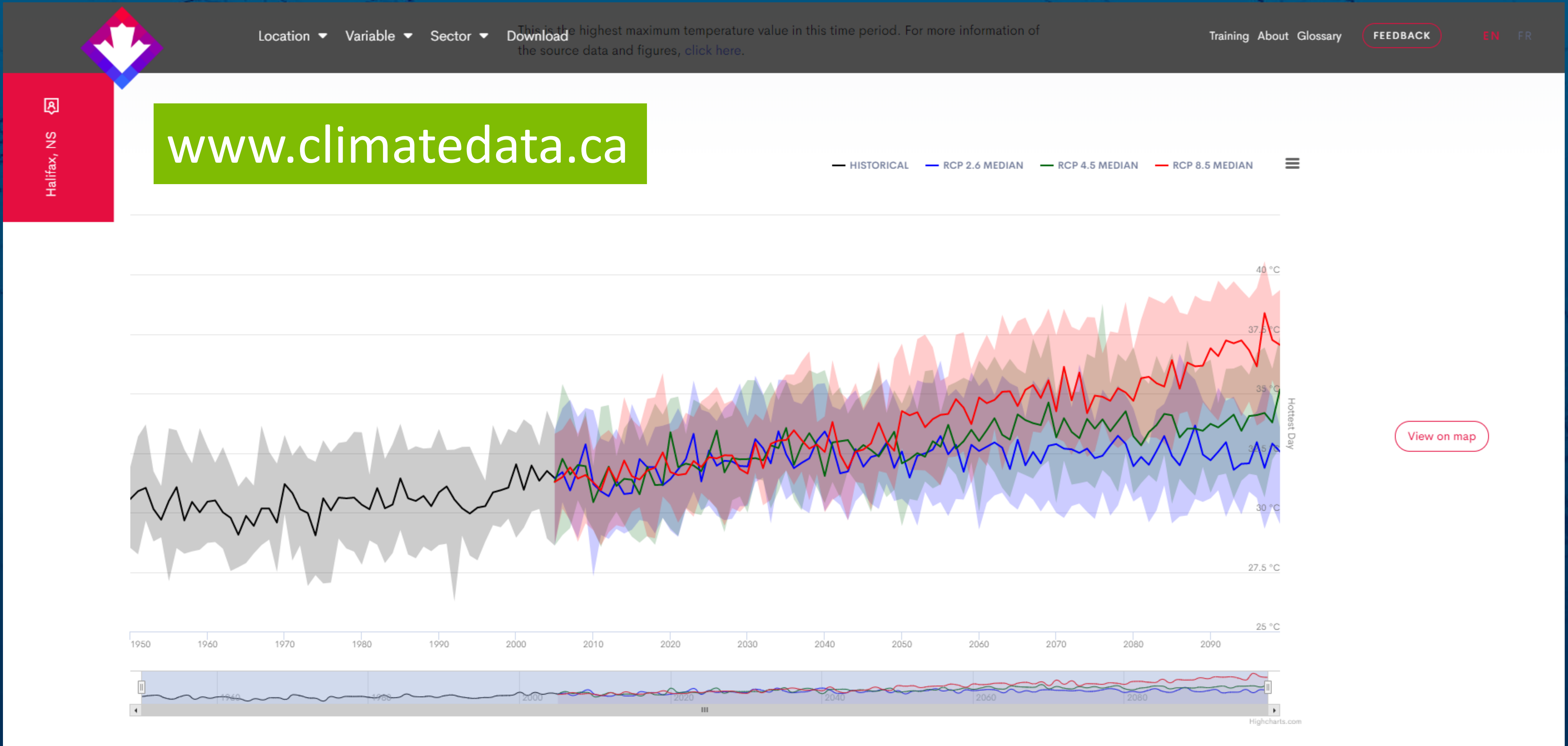
Climate Data Portal

Halifax – Frost Days



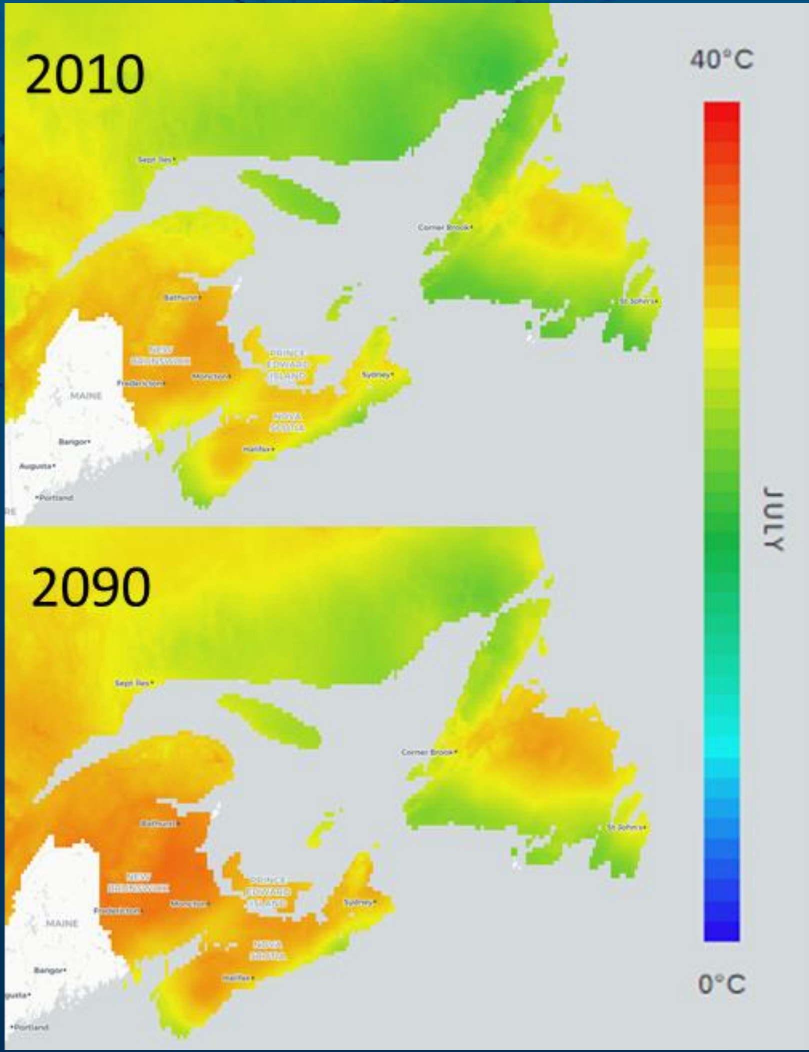
Climate Data Portal

Halifax – Hottest Days

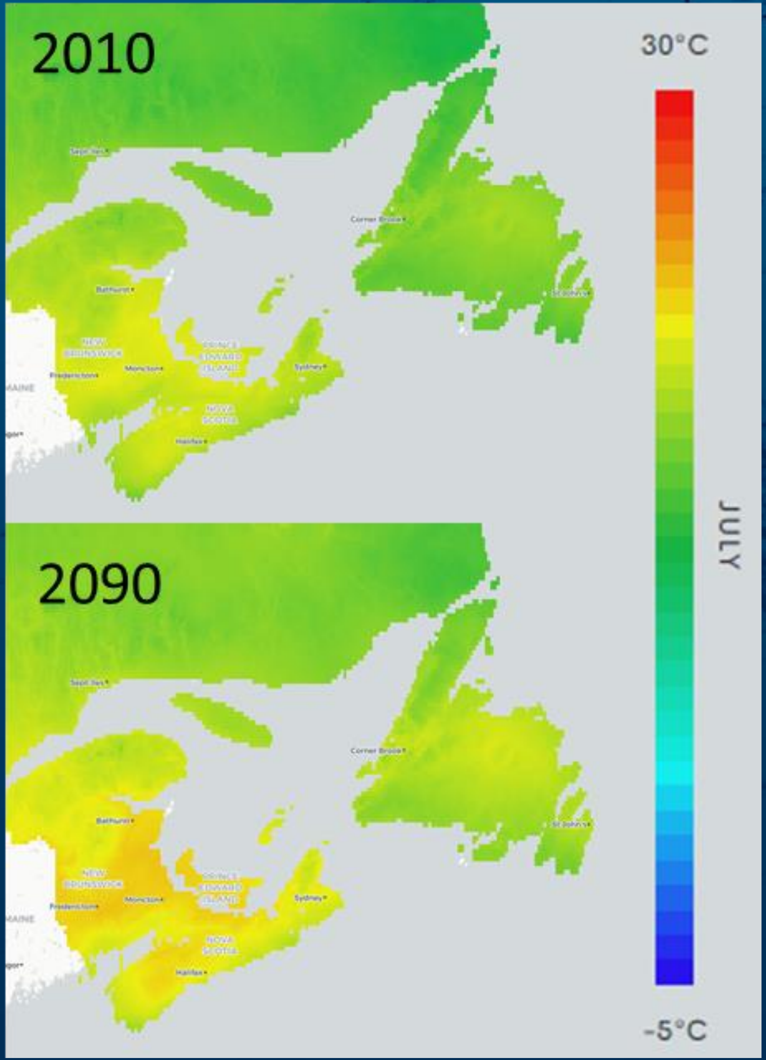


Climate Data Portal

Halifax – Hottest Days



Hottest Day
Month of July
RCP 4.5 Scenario



Mean Temperature
Month of July
RCP 4.5 Scenario

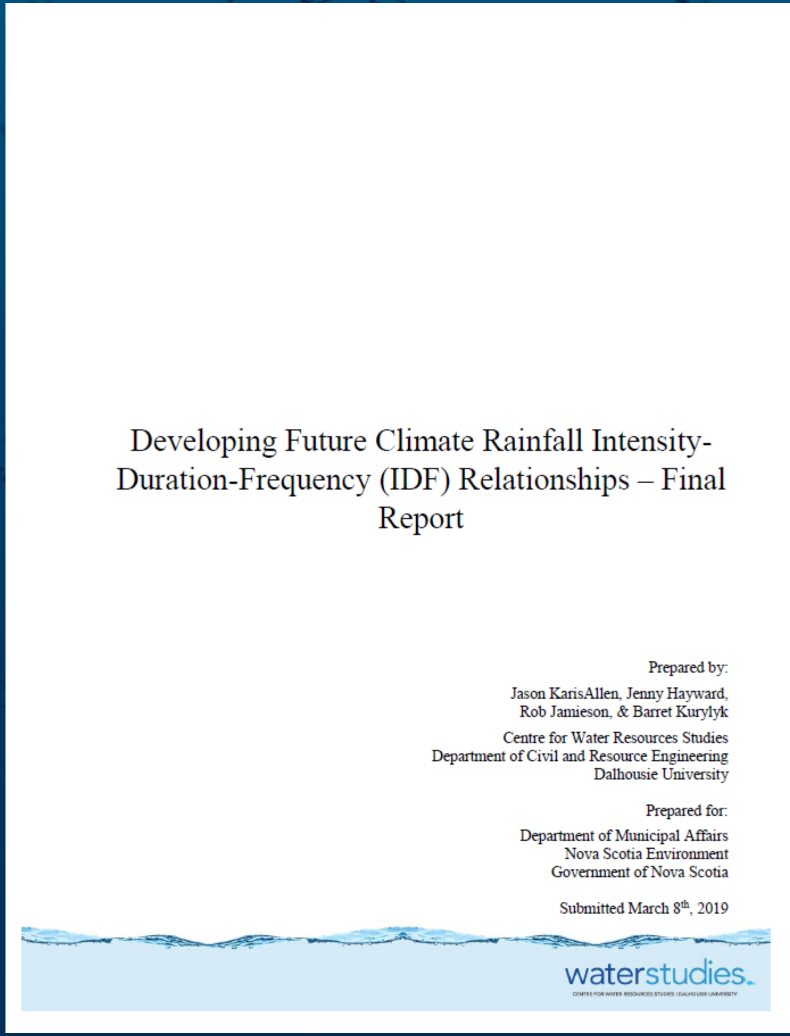
Updates of Existing Atlantic Canada Water and Wasterwater Design Guidelines

Developing IDF Curves which include Climate Change

Intensity-Duration-Frequency (IDF) Curves

Historic vs. Future Climate

- Intensity-Duration-Frequency (IDF) curves provide estimations of extreme rainfall probability, duration, and intensity.
- They are commonly applied by engineers, planners and hydrologists to inform design decisions (CSA, 2012).
- IDF relationships have historically been calculated using observed data.
- IDF relationships may be altered due to the impacts of climate change.
- Future patterns of rainfall can be estimated in several ways, including:
    - Statistical manipulations,
    - Climate models,
    - Climate indices, and
    - Analyses of physical properties that control climate.


Developing Future Climate Rainfall Intensity-Duration-Frequency (IDF) Relationships – Final Report

Prepared by:

Jason KarisAllen, Jenny Hayward, Rob Jamieson, & Barret Kurylyk

Centre for Water Resources Studies
Department of Civil and Resource Engineering
Dalhousie University

Prepared for:

Department of Municipal Affairs
Nova Scotia Environment
Government of Nova Scotia

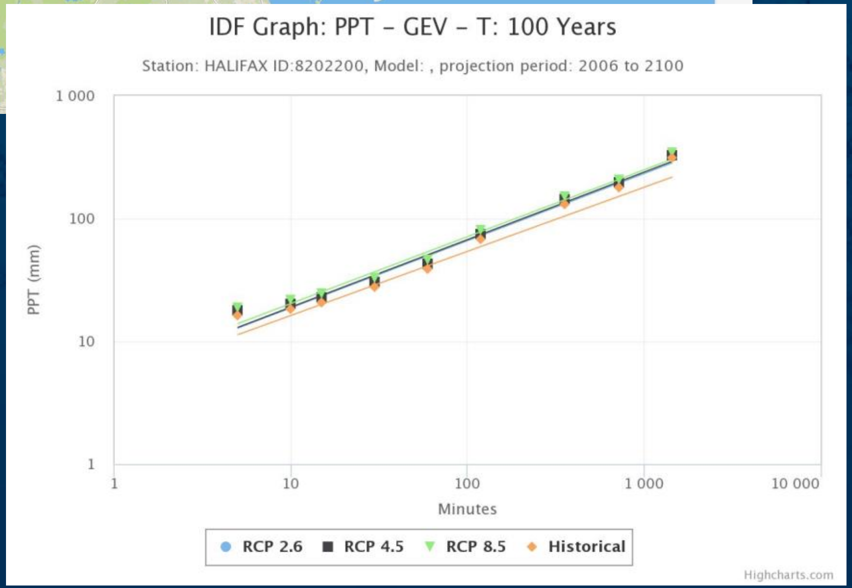
Submitted March 8th, 2019

waterstudies.

Rainfall Projections in a Changing Climate

IDF_CC web-tool

www.idf-cc-uwo.ca



- Online statistical downscaling tool developed by the Institute for Catastrophic Loss Reduction (ICLR) at Western University.
- Computerized web-based IDF tool integrates a user interface with a Geographic Information System (GIS).
- The user is able to:
  - Carry out statistical analysis on historical data,
  - Generate and verify possible future change using a combination of climate modeling outputs and locally observed weather data.

Intensity-Duration-Frequency (IDF) Curves

IDF_CC web-tool

Advantages	Disadvantages
Sub-daily rainfall projections achievable	Dependent on the accuracy of GCMs, statistical techniques and the quality/quantity of the historical record
Limited data handling, training or computation required	Inflexible interface options (i.e. projection period, GEV curve fit, GCM selection)
Data available for all of Canada	No measure of relative “skill” of GCMs
Accessible on all operating systems online	Does not utilize RCM data
Applicable graphical and tabular output	Assumes daily and sub-daily rainfall will scale at the same rate
Rapid and easy to use	Uncertainty regarding tool upkeep
	Climate model ensembles require updating

Resources

Climate Change Guidelines Development

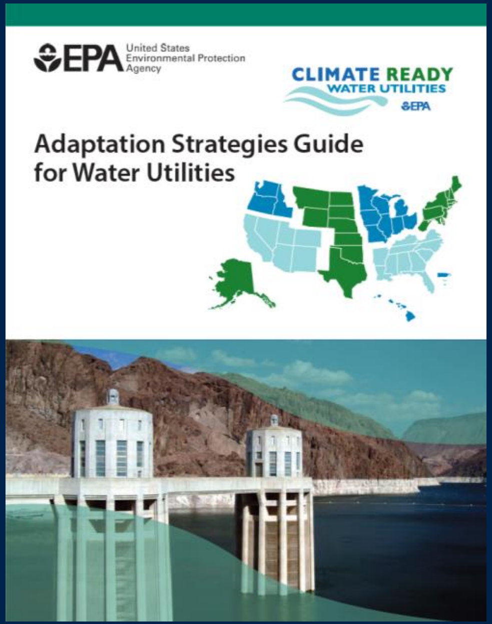
- Environment Canada Climate Data (Portal)
- Climate Atlas of Canada (CAC)
- Canadian Centre for Climate Services (CCCS)
- Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR)
- Pacific Climate Impacts Consortium, University of Victoria, (Jan. 2014). Statistically Downscaled Climate Scenarios.
- McKenney, D. W., et. al. (2011). Customized spatial climate models for North America
- Public Infrastructure Engineering Vulnerability Committee (PIEVC) Engineering Protocol.
- Intergovernmental Panel on Climate Change – Data Distribution Centre (DDC).
- Pacific Climate Impacts Consortium – Data Portals.
- University of Western Ontario – IDF-CC Tool.
- Environment and Climate Change Canada - Canadian Climate Data and Scenarios (CCDS).
- Climate Adaptation Knowledge Exchange (CAKE)
- University of Regina Climate Data Portal (CCDP)
- US sources (e.g., National Oceanic and Atmospheric Administration).
- Historical data from Environment and Climate Change Canada, Department of Fisheries and Oceans.

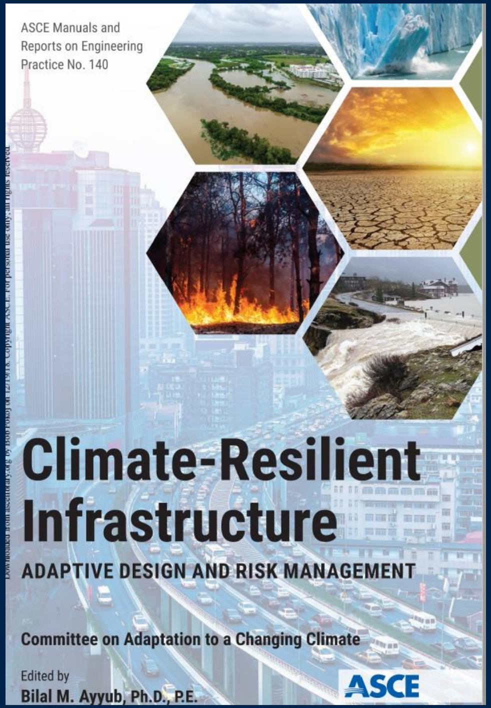
Updates of Existing Atlantic Canada Water and Wasterwater Design Guidelines

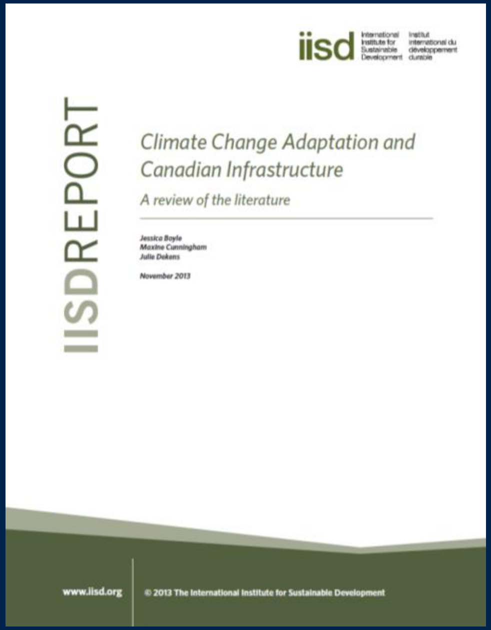
Climate Change and Infrastructure

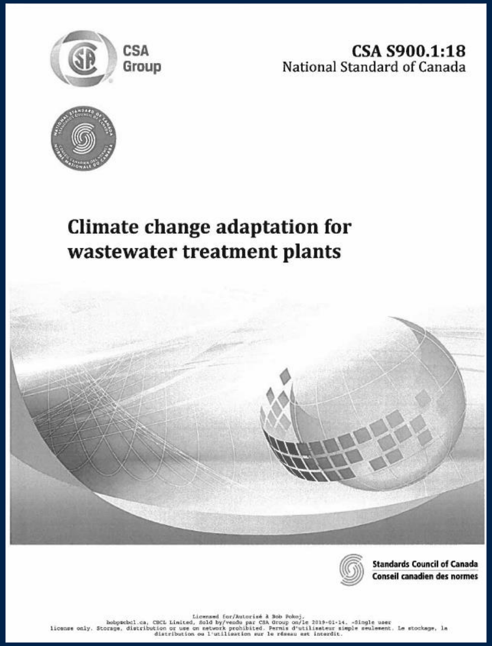
Climate Change and Infrastructure

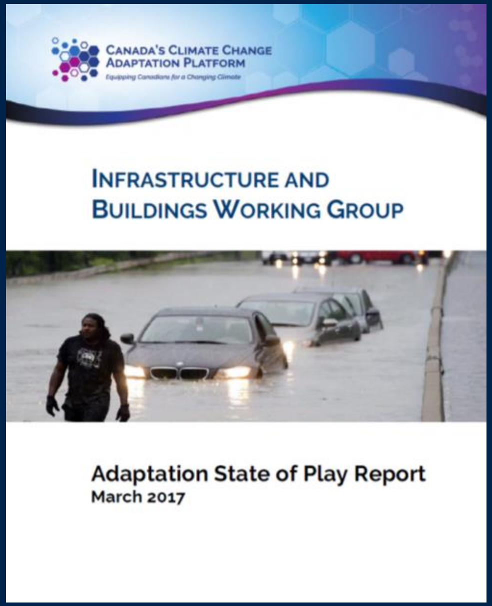
Many Available Resources











Drinking Water Infrastructure

Climate Parameter: Increasing Temperatures

Impact

Increased temperature is associated with early algae blooms, that can clog drinking water intakes and affects plant operations. Nutrient enriched urban and rural runoff.

Interaction with W

- Increased tem
- Cyanobacteria
- More beach cl

Suggested Adapt

- Predict toxic b
- Effective risk r ... ems.
- Continuous-im ... fy, and respond to early indica...

Drinking Water Infrastructure

Climate Parameter: Increasing Temperatures

Impact

Increased temperature is associated with early algae blooms, that can clog drinking water intakes and affects plant operations. Nutrient enriched urban and rural runoff

State of Adaptation "What is being done?"

- e.g. Lake Erie monitoring, open lake modeling, and tributary modeling.

Gaps/Barriers

- Access to, or limitations of, available algal bloom forecasting tools.

Existing Tools/Practices Addressing the Gaps / Barriers

- Water treatment technologies for nutrient removal i.e.: dissolved phosphorus removal implement on wider scale.
- Reduce urban heat island effect.

Recommendations/Opportunities to Address Remaining Gaps

- Opportunity to incorporate nutrient removal requirements in quality management standards through performance monitoring.
- Incentivize implementation of water treatment technologies for nutrient removal.

Updates of Existing Atlantic Canada Water and Wasterwater Design Guidelines

Example of Integrating Climate Change into Design

Climate Change in Design

Siting of Waste Water Treatment Plant Outfall

OBJECTIVE

Use Climate Change data to site a waste water treatment plant outfall in sensitive marine environment which is nutrient enriched.

PURPOSE: to identify which climate parameters may change in the future, and if possible, characterize the directions & rates of change (and uncertainty)

WHY: climate impacts on the lagoon ecosystem may affect its ability to assimilate WWTP discharge.

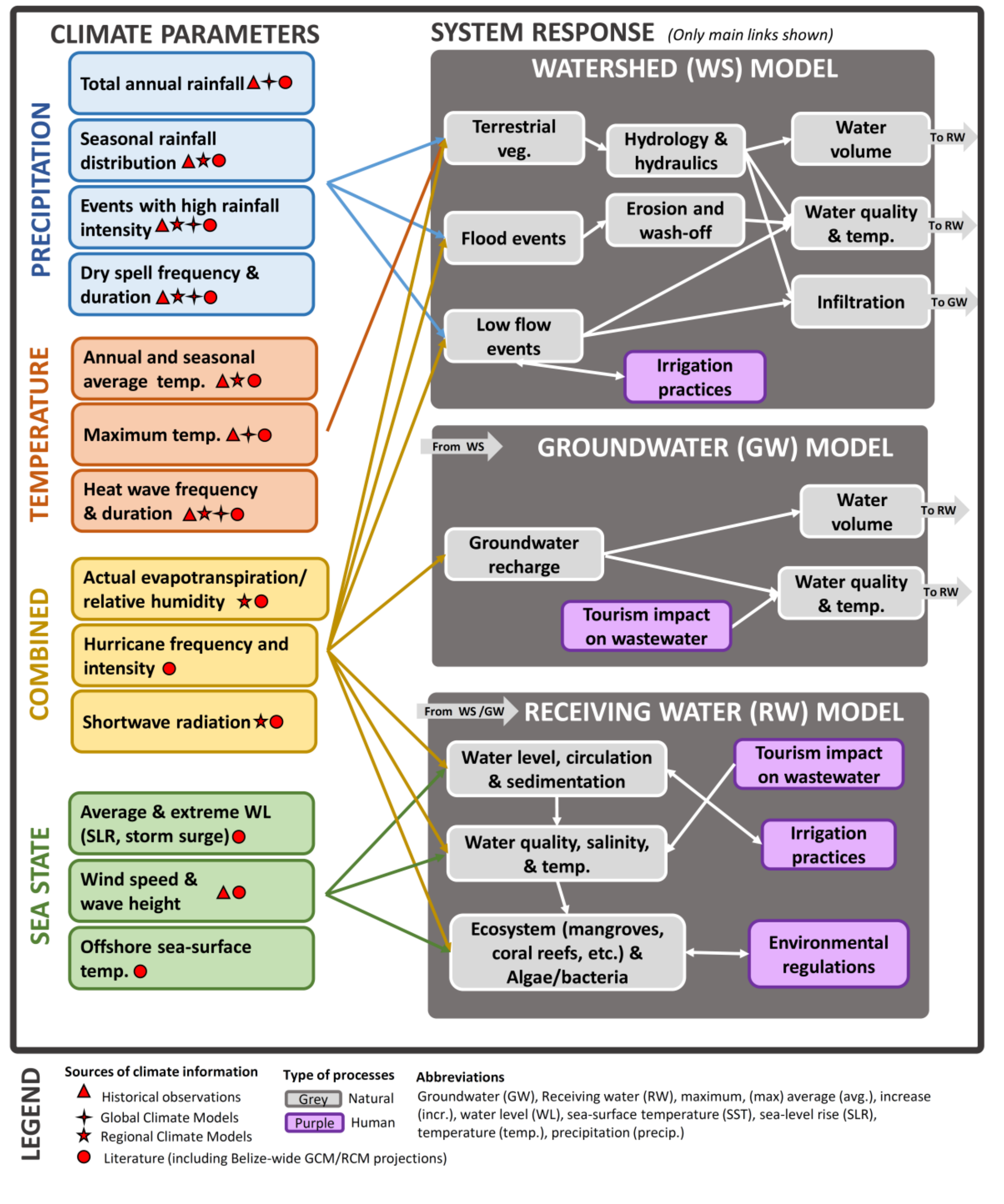
HOW:

1. Establish key climate parameters
2. Determine appropriate data sources
3. Conduct analyses, compare multiple sources, interpret results
4. Use findings to inform future model scenarios

Climate Change

Siting of WWTP Outfall

- Identify existing infrastructure / health / environmental risks.
- Assess existing / future climate scenarios.
- Scenario modelling of existing and future conditions.
- Generate solutions.



Updates of Existing Atlantic Canada Water and Wasterwater Design Guidelines

Next Steps

ACWWA Guidelines Approach

Inclusion of Climate Resilience

→ **Inclusion of a new chapter on Climate Resilience into each of the Guidelines**
  → i.e. CSA S900.1 – Climate Change Adaptation for Wastewater Treatment Plants
  → ISO 31000 - Risk management Standards
  → Engineers Canada PIEVC Assessments

→ **Update of the existing sections to include climate resilience requirements**
  → Flag and identify processes vulnerable to climate change impacts
  → Provide broad guidance / direction for adaptation

→ **Develop document based on user needs and feedback**
  → Series of workshops and iterations of document

ACWWA Guidelines Approach

Inclusion of Climate Resilience

ACWWA guidelines should be developed to:

→ Be a “living document”.

→ Reference other “active” standards and climate data sources which are regularly updated, nationally recognized, and reliable.

→ Focus on process, not specific data points.

Key Considerations

Incorporating Climate Change

- Climate information is NEVER perfect
  - Using it requires professional climate, engineering judgement
  - Climate thresholds or “breaking points” are **critical**

- Very precise information is not always required
  - Tailor climate requests to the specific needs of the assessment
  - Precise data may not be required if we only have a general sense of the specific infrastructure thresholds involved

- Engineers, asset owners, operators and climatologists need to work together
  - define terminology, define critical asset thresholds, analyze past failures

Climate Change

ACWWA Standards

Mike Chaulk and Mike Abbot will be discussing the individual guidelines in more detail….

Incorporating Climate Resilience for Municipal Infrastructure into the Updates of Existing Atlantic Canada Water and Wasterwater Design Guidelines

WORKSHOP # 1
INCORPORATING CLIMATE CHANGE

Halifax, Nova Scotia
Wednesday October 9th, 2019
dkolijn@cbcl.ca

The Final Word

Climate Change in Engineering

“ Engineers should develop a new paradigm for engineering practice in a world in which climate change may occur but cannot be projected with a high degree of certainty. ”
(ASCE 2015)