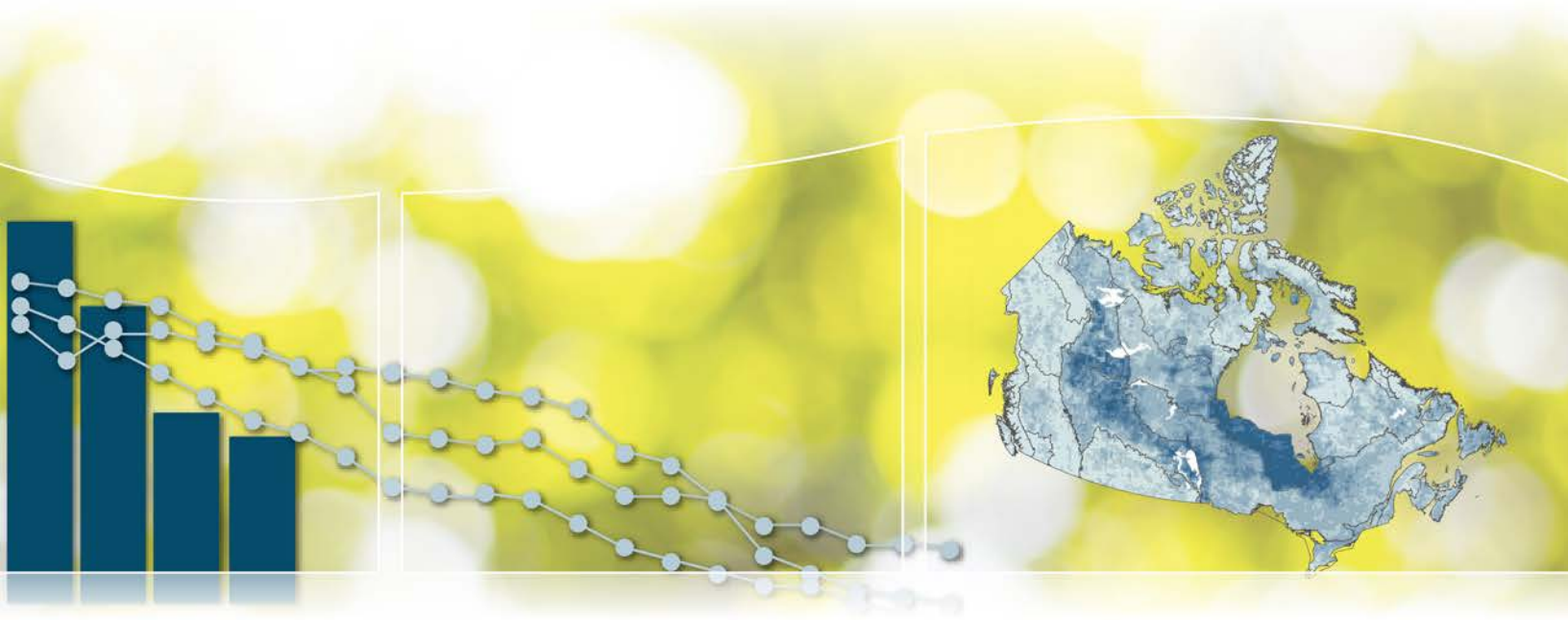
Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canadian Environmental Sustainability Indicators

Weather Warning Index



Canada

Suggested citation for this document: Environment and Climate Change Canada (2016) Canadian Environmental Sustainability Indicators: Weather Warning Index. Consulted on *Month day, year*.
Available at: www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=81552A43-1.

Cat. No.: En4-144/40-2016E-PDF
ISBN: 978-0-660-06014-9

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Canadian Environmental Sustainability Indicators

Weather Warning Index

September 2016

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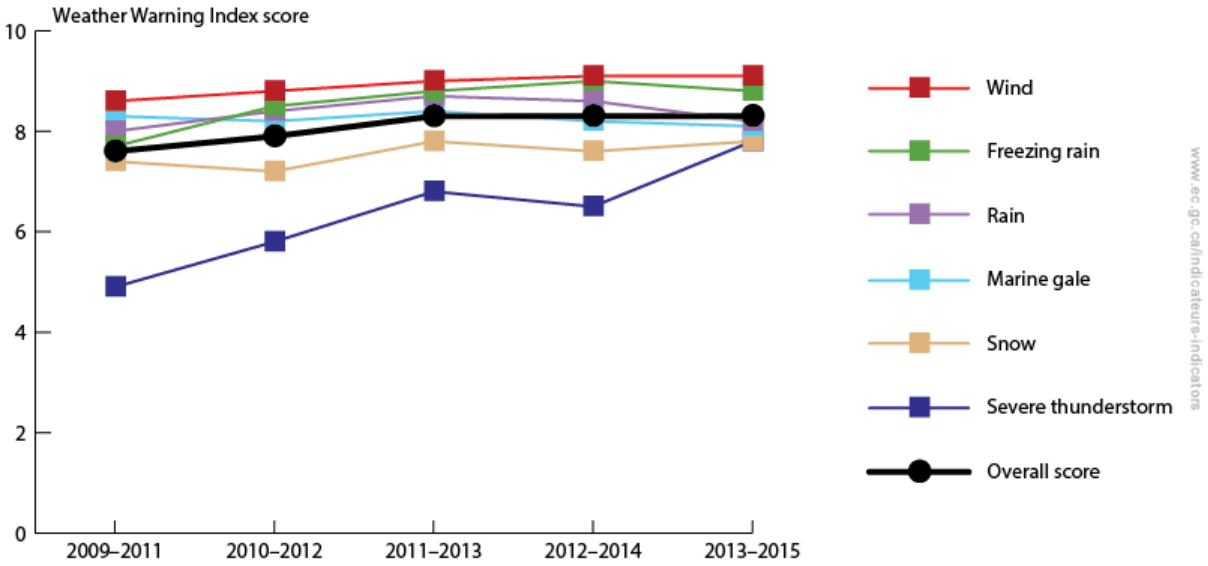
Part 1. Weather Warning Index Indicator

When severe weather threatens, Environment and Climate Change Canada issues public alert bulletins so that those in affected areas can take steps to protect themselves and their property from harm. Each year, the Meteorological Service of Canada issues, on average, 15 000 severe weather warnings. A weather warning is an urgent message that severe weather is either occurring or will occur. Warnings are usually issued 6 to 24 hours in advance, although some severe weather (such as thunderstorms) can occur rapidly, with less than a half-hour's notice.

The Weather Warning Index was created to track the performance of Environment and Climate Change Canada's severe weather warning system in providing Canadians with warnings with sufficient lead time. The overall score of the index increased from 7.6 to 8.3 between 2009–2011 and 2011–2013, and has remained at that level in the following periods.

Figure 1. Weather Warning Index and individual components for a three-year moving average, Canada, 2009–2011 to 2013–2015



Data for Figure 1

Note: The index reaches 10 if all extreme weather events in targeted areas were preceded by a warning with sufficient lead time, as per the weather warning performance targets. The overall index and its components are expected to exhibit modest fluctuations due to year to year changes in the predominant weather patterns.
Source: Environment and Climate Change Canada (2016) Meteorological Service of Canada – Integrated Planning and Performance Management Division.

The index is calculated based on information from six warning types that are representative of Canada's climate. These warning types are severe thunderstorm, rainfall, freezing rain, wind, snowfall and marine gale. For each warning type, a component score is determined based on the warning's accuracy in predicting an actual severe weather event and its timeliness in comparison to the lead times identified within Environment and Climate Change Canada's warning performance targets (see Table 5).

The index components are calculated using warning data from a set of selected geographical regions (see section Spatial coverage) considered representative of the Canadian climate and for which Environment and Climate Change Canada has sufficient warning event information.

The components are an indication of Environment and Climate Change Canada's performance in providing timely and accurate warnings for each warning type. For instance, the score for severe thunderstorm warnings highlights the challenge of forecasting severe thunderstorms in a timely and accurate manner when compared to other types of severe weather.

Environment and Climate Change Canada's national weather forecast and warning system relies on several observation networks to detect changes in the atmosphere and the development of threatening conditions. The monitoring infrastructure runs 24 hours a day, 7 days a week, 365 days a year. It includes 31 weather radar stations, over 80 lightning detection sensors, approximately 1580 surface weather and climate stations, 46 weather buoys, 54 ships equipped with automated observation systems, and 31 stations for launching balloon-borne observations of the upper atmosphere. Also extremely valuable to Environment and Climate Change Canada are hundreds of volunteer weather observers and severe weather watchers from coast to coast.

Weather warnings are invaluable for the protection of life and property. They are also critical to provincial and municipal emergency measures organizations (for managing flood control, sewer overflow and stormwater run-off) and for weather-sensitive users (such as snow removal operators and outdoor recreational enthusiasts).

Part 2. Data Sources and Methods for the Weather Warning Index Indicator

Introduction

The Weather Warning Index indicator is part of the Canadian Environmental Sustainability Indicators (CESI) program, which provides data and information to track Canada's performance on key environmental sustainability issues.

Description and rationale of the Weather Warning Index indicator

Description

The Weather Warning Index indicator provides Canadians with an overview of the state of Environment and Climate Change Canada's severe weather warning program. The index is calculated based on timeliness and accuracy information for six warning types that are representative of Canada's climate: rainfall, snowfall, freezing rain, wind, severe thunderstorm and marine gales.

Rationale

The index is intended to assess the performance of Environment and Climate Change Canada's severe weather warning program. Over time, Canadians will be equipped to track trends in performance of the severe weather warning program.

Recent changes to the indicator

Since the indicator was last published, there have been changes in the selection of public forecast regions used to calculate the index. Some regions were added or removed from the indicator while others were substituted. Historical values of the index have been re-calculated using the new regions to allow for comparisons among the different three-year periods included in this release of the indicator. New index values reflect the fact that data from the removed regions no longer contribute to the index, while values from the added regions are taken into account. For substituted regions, data from the original region are used in the index calculation up to the year of substitution to a new region.

Table 1 summarizes the removals, additions and substitution of forecast regions that have taken place since the last release.

Table 1. Changes to public forecast regions used to calculate the Weather Warning Index

	Removals	Additions	Substitutions
Public forecast regions for rainfall, snowfall, freezing rain and wind warnings	• Chibougamau (Quebec) • Fermont (Quebec)	• Eastern Townships (Quebec) • Lac-Saint-Jean (Quebec)	• From 2012 onwards, Goose Bay and vicinity was renamed Upper Lake Melville (Atlantic). • From 2012 onwards, replaced St. Georges with Channel – Port aux Basques and vicinity (only for Wreckhouse Wind warnings) (Atlantic). • From 2014 onwards, replaced Kapuskasing – Hearst with Timmins – Cochrane (Ontario).
Public forecast regions for severe thunderstorm warnings	n/a	n/a	• From 2012 onwards, Goose Bay and vicinity was renamed Upper Lake Melville (Atlantic). • From 2014 onwards, replaced Kapuskasing – Hearst – Smooth Rock Falls with Timmins – Cochrane – Iroquois Falls (Ontario).
Marine forecast regions for marine gale warnings	• Northern Lake Huron (Ontario) • Southern Lake Huron (Ontario)	n/a	• From 2013 onwards, replaced Donnacona to L'Isle-aux-Coudres with Beauport to L'Isle-aux-Coudres (Quebec). • From 2013 onwards, replaced Tadoussac to Pointe-des-Monts with Tadoussac to Pointe à Michel and Pointe à Michel to Pointe-des-Monts (Quebec). • From 2015 onwards, replaced Georges Bank with Browns Bank (Atlantic).

Note: n/a = not applicable. Historical values for the indicator were recalculated to remove data from removed regions and add data from added regions. Data from regions that were substituted are used in historical data up to the year of substitution.

Data

Data source

The data sources for the Weather Warning Index indicator include timeliness performance information for the identified six severe weather warning types. This information is compiled by comparing warnings issued by Environment and Climate Change Canada against severe weather reports submitted by the public and data collected by Environment and Climate Change Canada's observation network.

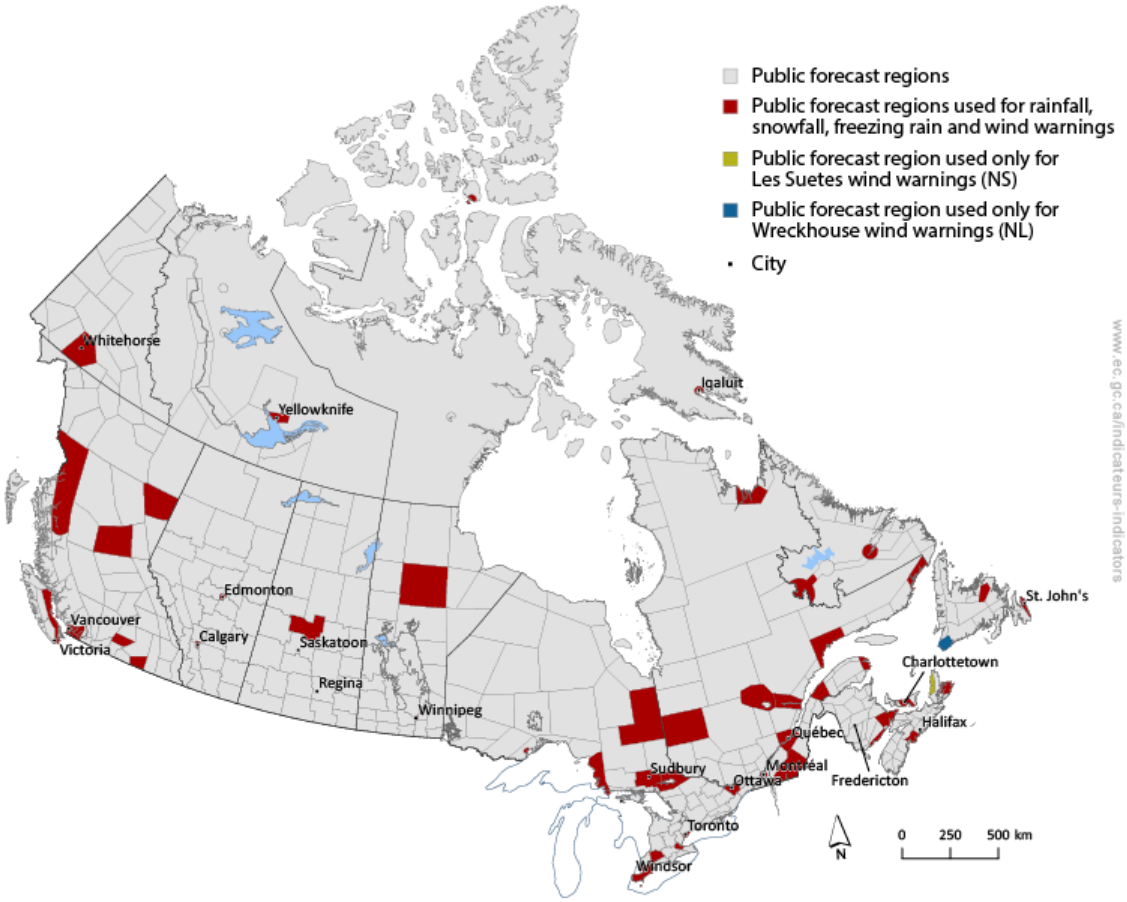
Timeliness statistics reflect the average lead time and target lead time for each of the six warning types, as determined by the warning performance targets (see Table 5). Accuracy statistics are expressed in terms of the extremal dependency index (EDI), which incorporates the number of hits, misses and false alarms for each of the six warning types.

These statistics are compiled by Environment and Climate Change Canada from available meteorological observations, archived warning bulletins and existing verification procedures.

Spatial coverage

Information reported in selected geographic regions for each warning group is used in calculating the index. These selected geographic regions are representative of Canada's climate and are areas that regularly have sufficient event data against which to compare severe weather warnings.

Figure 2. Public forecast regions with those used in the Weather Warning Index highlighted – rainfall, snowfall, freezing rain and wind warnings



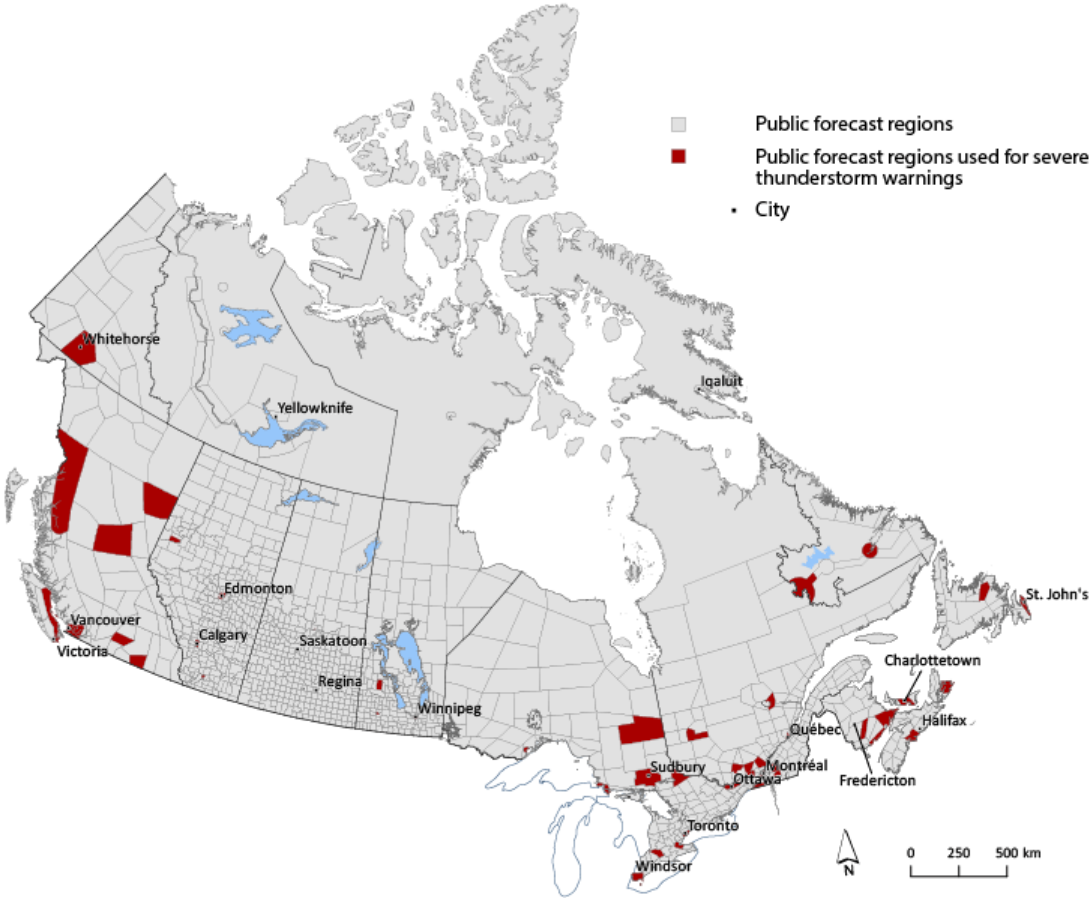
Note: Data from public forecast regions that were substituted is used in historical data up to the year of substitution. Some regions are not visible at the national scale. See Table 2 for the complete list.
Source: Environment and Climate Change Canada (2016) Forecast Regions of Canada. Meteorological Service of Canada – Integrated Planning and Performance Management Division.

Table 2. Public forecast regions used in the Weather Warning Index for rainfall, snowfall, freezing rain and wind warnings

Pacific and Yukon	Prairie and Northern	Ontario	Quebec	Atlantic
Metro Vancouver	City of Winnipeg	Windsor – Essex – Chatham-Kent	Metro Montréal – Laval	Saint John and County
Fraser Valley – West Including Abbotsford	Thompson – Nelson House – Split Lake	London – Middlesex	Eastern Townships	Moncton and Southeast New Brunswick
East Vancouver Island	City of Regina	City of Hamilton	Québec City	Halifax Metro and Halifax County West
Greater Victoria	City of Saskatoon	City of Toronto	Saguenay	Queens County PEI (Charlottetown)
North Coast – Inland Sections	Prince Albert – Shellbrook – Spiritwood – Duck Lake	City of Ottawa	Lac-Saint-Jean	Sydney Metro and Cape Breton County
Central Okanagan – Including Kelowna	City of Calgary	North Bay – West Nipissing	Rimouski – Mont Joli	Inverness County – Mabou and north (Les Suêtes, wind only)
West Kootenay	City of Edmonton – St. Albert – Sherwood Park	Greater Sudbury and Vicinity	Forillon National Park – Gaspé – Percé	2009 to 2011: St. Georges Since 2012: Channel-Port aux Basques and vicinity (Wreckhouse, wind only)
Prince George	Yellowknife Region	Sault Ste. Marie – Superior East	Abitibi	Gander and vicinity
BC North Peace River	Resolute	City of Thunder Bay	Sept-Iles – Port-Cartier	St. John's and vicinity

Pacific and Yukon	Prairie and Northern	Ontario	Quebec	Atlantic
Whitehorse	Iqaluit	2009 to 2013: Kapuskasing – Hearst Since 2014: Timmins – Cochrane	Blanc Sablon	Upper Lake Melville (known as Goose Bay and Vicinity before 2012)
–	–	–	Kuujjuaq	Labrador City and Wabush

Figure 3. Public forecast regions with those used in the Weather Warning Index highlighted – severe thunderstorm warnings



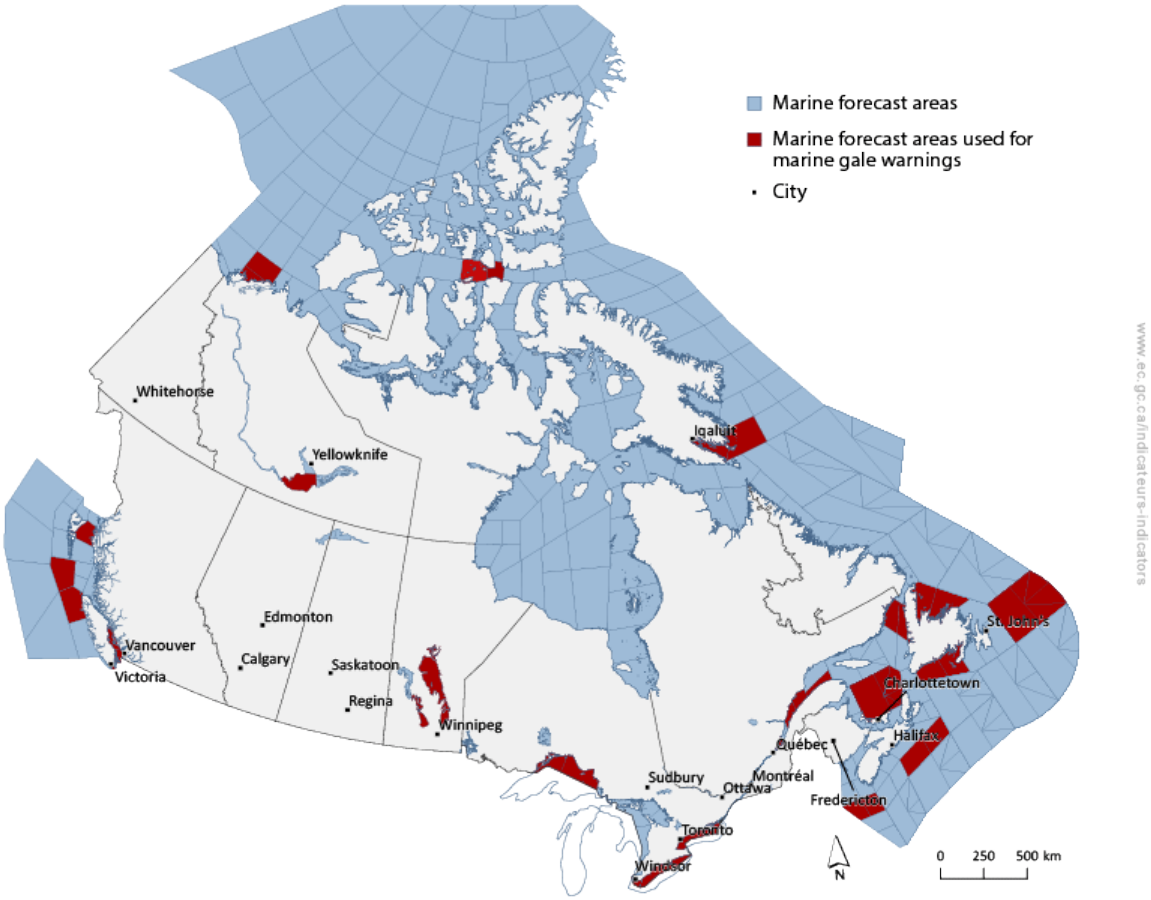
Note: Data from public forecast regions that were substituted is used in historical data up to the year of substitution. Some regions are not visible at the national scale. See Table 3 for the complete list.
Source: Environment and Climate Change Canada (2016) Forecast Regions of Canada. Meteorological Service of Canada – Integrated Planning and Performance Management Division.

Table 3. Public forecast regions used in the Weather Warning Index for severe thunderstorm warnings

Pacific and Yukon	Prairie and Northern	Ontario	Quebec	Atlantic
Metro Vancouver	City of Winnipeg	Windsor – Leamington – Essex County	Montréal Island area	Saint John and County
Fraser Valley-West including Abbotsford	City of Brandon	London – Parkhill – Eastern Middlesex County	Huntingdon area	Moncton and Southeast New Brunswick
East Vancouver Island	R.M. of Dauphin including Sifton and Valley River	City of Hamilton	Saint-Hyacinthe – Acton Vale area	Halifax Metro and Halifax County West
Greater Victoria	City of Regina	City of Toronto	Rawdon – Joliette area	Queens County PEI (Charlottetown)
North Coast – Inland Sections	City of Saskatoon	Ottawa North – Kanata – Orléans	Lachute area	Sydney Metro and Cape Breton County
Central Okanagan – Including Kelowna	City of Prince Albert	North Bay – Powassan – Mattawa	Mont-Tremblant – Sainte Agathe area	Oromocto and Sunbury County
West Kootenay	City of Calgary	Greater Sudbury and vicinity	Papineau-Labelle Reserve area	Gander and vicinity
Prince George	City of Edmonton – St. Albert – Sherwood Park	Sault Ste. Marie – St. Joseph Island	Val D'Or – Louvicourt area	St. John's and vicinity
BC North Peace River	City of Lethbridge	City of Thunder Bay	Granby – Waterloo area	Upper Lake Melville (known as Goose Bay and vicinity before 2012)

Pacific and Yukon	Prairie and Northern	Ontario	Quebec	Atlantic
Whitehorse	County of Grande Prairie near Grande Prairie and Wembley	2009 to 2013: Kapuskasing – Hearst – Smooth Rock Falls Since 2014: Timmins – Cochrane – Iroquois Falls	Quebec area	Labrador City and Wabush
–	–	–	Alma – Desbiens area	–

Figure 4. Marine forecast areas with those used in the Weather Warning Index highlighted – marine gale warnings



Note: Data from marine forecast areas that were substituted is used in historical data up to the year of substitution. Some areas are not visible at the national scale. See Table 4 for the complete list.
Source: Environment and Climate Change Canada (2016) Canadian Marine Warning Program. Meteorological Service of Canada – Integrated Planning and Performance Management Division.

Table 4. Marine forecast areas used in the Weather Warning Index for marine gale warnings

Pacific and Yukon	Prairie and Northern	Ontario	Quebec	Atlantic
Strait of Georgia – south of Nanaimo	Great Slave Lake Basin	Western Lake Superior	2009 to 2012: Donnacona to Isle-aux-Coudres Since 2013: Beauport to L'Isle-aux-Coudres	2009 to 2014: Georges Bank Since 2015: Browns Bank
Strait of Georgia – north of Nanaimo	Tuktoyaktuk	Eastern Lake Superior	Tadoussac to Pointe à Michel	Sable
Juan de Fuca Strait – East Entrance	Frobisher Bay	Western Lake Erie	Pointe à Michel to Pointe-des-Monts	Gulf – Magdalen
West Vancouver Island North	West Brevoort – southern half	Eastern Lake Erie	Pointe-des-Monts to Anticosti – southern half	Northeast Gulf
Queen Charlotte Sound – Western half	Barrow	Western Lake Ontario	–	Southwest Coast
Hecate Strait – Northern Half	Lake Manitoba	Eastern Lake Ontario	–	Northeast Coast
–	Lake Winnipeg – South Basin	–	–	Northern Grand Banks
–	Lake Winnipeg – North Basin	–	–	–

Temporal coverage

To reduce volatility from year to year, a three-year moving average is used for reporting purposes. The latest index uses data from calendar years 2013, 2014 and the most recent year, 2015. This is the fifth iteration of the index. The first iteration calculated a three-year moving average using 2009, 2010 and 2011 data, the second iteration used 2010, 2011 and 2012 data, the third iteration used 2011, 2012 and 2013 data and the fourth iteration used 2012, 2013 and 2014 data. The index is updated annually. Each spring, a value is calculated for the previous calendar year using available information.

Data completeness

Data for selected geographic regions for each warning type are used in calculating the index. These regions are representative of Canada's climate and are areas that regularly have sufficient event data against which to compare severe weather warnings.

Data timeliness

Data are available for each calendar year by the spring of the following year.

Methods

Definitions

There are several definitions of note with regard to the index, indicated below.

Accuracy definitions

An event is an individual instance of a weather or environmental hazard that meets hazard criteria thresholds.

A hit is defined as "a warning event was forecast and it occurred."

A miss is defined as "a warning event occurred but there was no advance warning provided or no alert was issued."

A false alarm is defined as "a warning event was forecast but conditions did not reach warning criteria."

A correct negative is defined as "no warning was issued and no event occurred."

Timeliness definitions

The event time is the time at which the criteria threshold is first met for an event. For alerts where the criteria thresholds are accumulated precipitation, the event time is the time at which the accumulated precipitation total first equals or exceeds the criteria amount.

The issue time is the time at which the alert was transmitted by the Environment and Climate Change Canada forecaster.

The lead time is the difference between the time that an alert is issued and the event time. For example, if an alert is issued at 09:00 and the event time is 09:30, the lead time is 30 minutes.

The target lead time is Environment and Climate Change Canada's performance goal for the timeliness of alerts. The target lead time is intended to provide adequate time for the public to take appropriate action when alerted of a predicted event. Other factors such as the predictability of an event and the ability of the public and media to receive notice of the message may influence the actual lead times provided.

Each of the six severe weather warnings that comprise the index has an associated performance target lead time, in terms of issuance of a warning. The target lead times for the six warning types are as indicated below in Table 5.

Table 5. Target lead time by severe warning type (Warning Performance Target)

Severe weather warning component type	Target lead time
Rainfall	greater than or equal to 12 hours
Freezing rain	greater than or equal to 6 hours
Wind	greater than or equal to 12 hours
Snowfall	greater than or equal to 18 hours
Severe thunderstorm	greater than or equal to 30 minutes
Marine gale	greater than or equal to 18 hours

Methodology

The index ranges from 0 to 10 and is constructed by taking a weighted mean of timeliness and accuracy statistics. To reduce volatility from year to year, a three-year moving average is used for reporting purposes.

Weighting

A 20% weight is assigned to the marine gale component of the index. The remaining severe weather warning types (severe thunderstorm, wind, rainfall, snowfall and freezing rain) are assigned a combined 80% weight in the index. Each of these land components is weighted based on its frequency of occurrence during the reporting periods.

Timeliness factors

To calculate the average lead time for each warning component, the warning issue time is subtracted from the time when the warning event occurred. Missed events are assigned zero lead time. The lead times so obtained are then averaged over the year to compute the "average lead time." This value is then compared to the target lead time for the specific warning type. The resultant value represents the "timeliness" aspect of the index.

Accuracy factors

The number of successfully detected events (hits), the number of missed events and the number of false alarms represent the "accuracy" aspect of the index. These values are used to calculate the extremal dependency index.

$$\text{extremal dependency index} = \frac{\log(\text{false alarm rate}) - \log(\text{hit rate})}{\log(\text{false alarm rate}) + \log(\text{hit rate})}$$

The hit rate is calculated using the number of hits and the number of misses. The false alarm rate is based on the number of false alarms and the number of correct negatives. The number of correct negatives is an estimate of the number of times during the reporting period that forecasters had to consider whether or not to issue a warning, and correctly decided against issuing one. Since the extremal dependency index is a ratio of logarithms, it does not matter which base is used.

$$\text{hit rate} = \frac{\text{hits}}{(\text{hits} + \text{misses})}$$

$$\text{false alarm rate} = \frac{\text{false alarms}}{(\text{false alarms} + \text{correct negatives})}$$

Weather Warning Index calculation

The index ranges between 0 and 10. It would attain a value of ten if all component warnings meet warning criteria and there are no missed events or false alarms.

The scoring formula for each warning component is as follows:

Case 1

If the average lead time is equal to or greater than the target lead time, the index component score becomes

$$\left[\text{extremal dependency index} + 0.5 \text{ x} \left(\frac{\text{average lead time}}{\text{target lead time}} - 1\right) \text{x}(1 - \text{extremal dependency index})\right] \text{ x } 10$$

Case 2

If the average lead time is less than the target lead time, the index component score becomes

$$\text{extremal dependency index } \text{x} \left(\frac{\text{average lead time}}{\text{target lead time}}\right) \text{x } 10$$

Assumptions

- All lead times are greater than or equal to zero.
- Individual lead times greater than twice the target lead time are assigned a value of twice the target lead time.

The Weather Warning Index calculation, timeliness and accuracy statistics and component scores for the three-year moving average 2013, 2014 and 2015 by warning type: rain, snow, freezing rain, wind, severe thunderstorms and marine gale are presented in Table 6.

Table 6. Weather Warning Index calculation, timeliness and accuracy statistics, 2013–2015

2013–2015	Rain	Snow	Freezing rain	Wind	Severe thunderstorm	Marine gale
Hits	239	236	178	286	91	2564
Misses	115	94	59	84	36	505
False alarms	144	135	69	167	544	978
Correct negatives	6702	9660	3744	19 713	27 679	3648
TOTAL	**7200**	**10 125**	**4050**	**20 250**	**28 350**	**7695**
Hit rate	0.68	0.72	0.75	0.77	0.72	0.84
False alarm rate	0.02	0.01	0.02	0.01	0.02	0.21
Extremal dependency index	0.815	0.855	0.867	0.898	0.844	0.793
Average lead time (in hours)	12.95	16.32	7.15	14.76	0.46	21.25
Target lead time (in hours)	12	18	6	12	0.5	18
Weight	20	19	13	21	7	20
Weather Warning Index component score	8.23	7.75	8.80	9.09	7.82	8.11
Individual weighted Weather Warning Index component score	**1.64**	**1.44**	**1.18**	**1.90**	**0.56**	**1.62**
Change with respect to 2012–2014 individual weighted Weather Warning Index	+0.25	-0.19	-0.16	+0.08	+0.08	-0.03

Weather Warning Index is the sum of the individual weighted Weather Warning Index component scores: 8.34

Note: False alarms are not available for severe thunderstorm alerts. A convective warning bias of five is used to estimate the number of false alarms, where:

False alarms = convective warning bias x (hits + misses) - hits

Caveats and limitations

Calculation of the index does not consider when weather warnings are received by Canadians, as this factor varies considerably depending upon how warnings are received (for example, via a media outlet or a website).

The index does not represent all forecast regions in Canada; instead, it represents areas that regularly have sufficient event data against which to compare severe weather warnings.

Part 3. Annexes

Annex A. Data tables for the figures presented in this document

Table A.1 Data for Figure 1. Weather Warning Index and individual components for a three-year moving average, Canada, 2009–2011 to 2013–2015

Warning type	2009–2011 score	2010–2012 score	2011–2013 score	2012–2014 score	2013–2015 score
Wind	8.6	8.8	9.0	9.1	9.1
Freezing rain	7.7	8.5	8.8	9.0	8.8
Rain	8.0	8.4	8.7	8.6	8.2
Marine gale	8.3	8.2	8.4	8.2	8.1
Snow	7.4	7.2	7.8	7.6	7.8
Severe thunderstorm	4.9	5.8	6.8	6.5	7.8
Overall score	**7.6**	**7.9**	**8.3**	**8.3**	**8.3**

Note: The index reaches 10 if all extreme weather events in targeted areas were preceded by a warning with sufficient lead time, as per the weather warning performance targets. The overall index and its components are expected to exhibit modest fluctuations due to year to year changes in the predominant weather patterns.
Source: Environment and Climate Change Canada (2016) Meteorological Service of Canada – Integrated Planning and Performance Management Division.

Annex B. References and additional information

References and further reading

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Ferro C *et al.* (2011) Extremal Dependence Indices: Improved Verification Measures for Deterministic Forecasts of Rare Binary Events. *Weather and Forecasting* 26(5): 699-713.

Wilson L and Giles A (2013) A new index for the verification of accuracy and timeliness of weather warnings. *Meteorological Applications* 20: 206-216.

Related information

Environment and Climate Change Canada – Hazardous Weather

www.ec.gc.ca

Additional information can be obtained at:

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