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Data Sources and Methods for the Weather Warning Index

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1 Introduction

The Weather Warning Index (www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=81552A43-1) is part of the Canadian Environmental Sustainability Indicators (CESI) program (www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=47F48106-1), which provides data and information to track Canada's performance on key environmental sustainability issues.

2 Description and rationale of the Weather Warning Index

2.1 Description

The Weather Warning Index provides Canadians with an overview of the state of Environment 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.

2.2 Rationale

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

2.3 Recent changes to the indicator

No methodological change has been made to the indicator since its inception in 2012.

3 Data

3.1 Data source

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

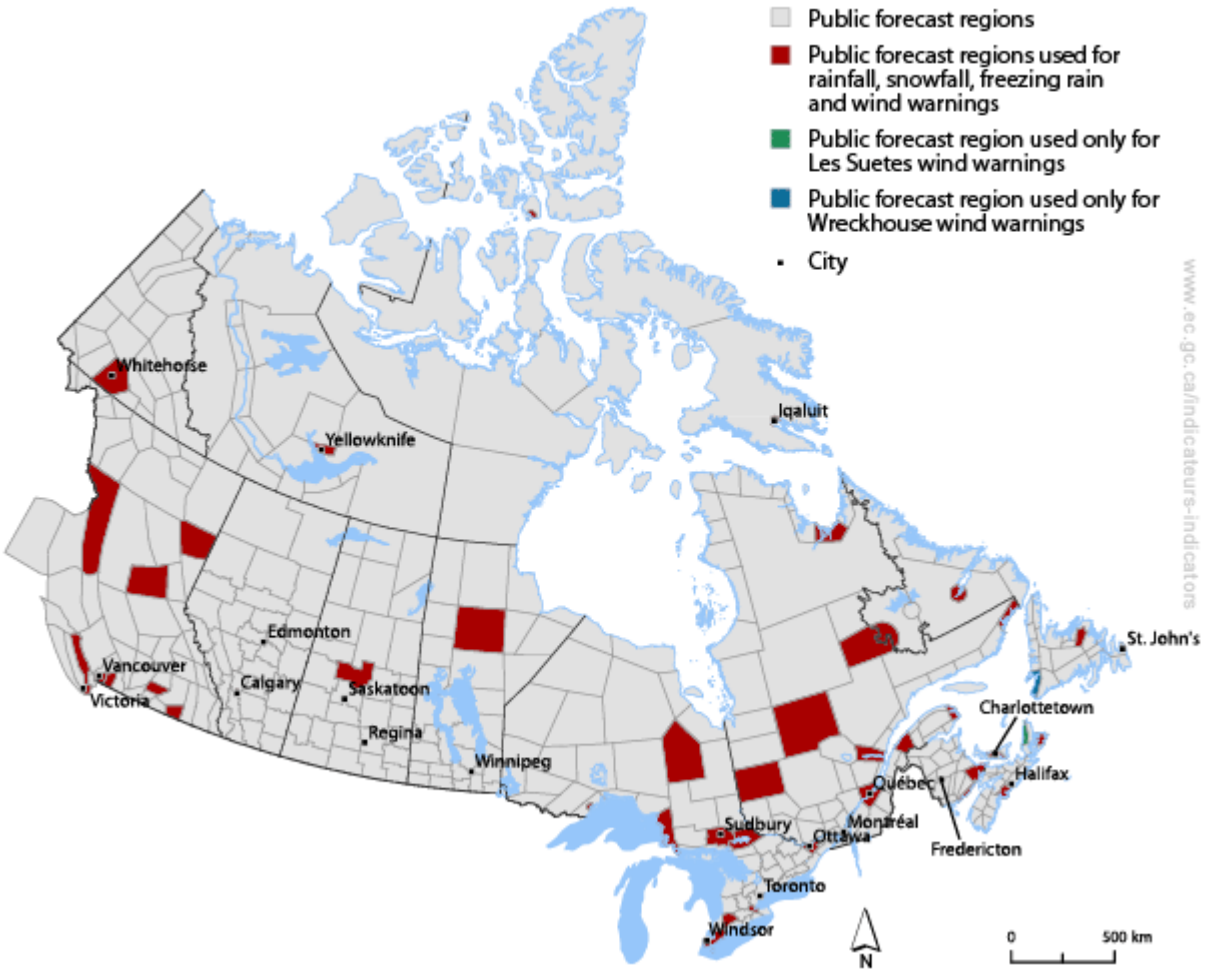
Timeliness statistics reflect the average lead time and target lead time for each of the six warning types, as determined by our warning performance targets. Accuracy statistics reflect the extremal dependency index (EDI), which incorporates the number of hits, misses and false alarms for each of the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

These statistics are compiled by Environment Canada from available meteorological observations, archived warning bulletins and existing verification procedures. This information is available in the quarterly and annual reports from the Meteorological Service of Canada (MSC) warning program prepared by the Integrated Planning and Performance Management Division of the Policy, Planning and Partnerships Directorate.

3.2 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.

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

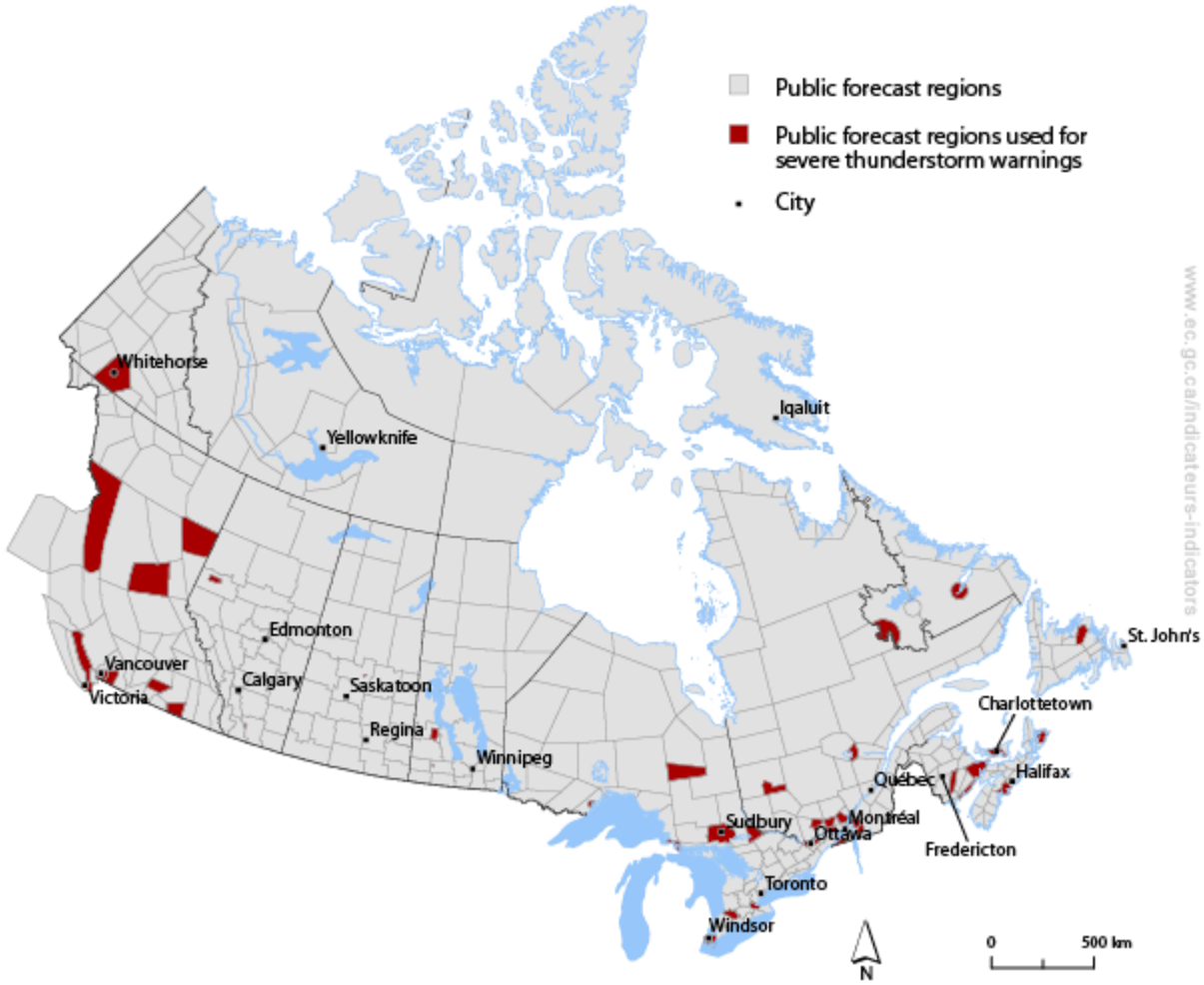


Note: Some public forecast regions are not visible at the national scale. See Table 1 for the complete list.
Source: Environment Canada (2014) Public Forecast Regions of Canada. Meteorological Service of Canada – Integrated Planning and Performance Management Division. Available from: www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=E5A4F19C-1

Table 1: 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	Montréal métropolitain - Laval	Saint John and County
Fraser Valley-West Including Abbotsford	Thompson – Nelson House – Split Lake	London - Middlesex	Québec City	Moncton and Southeast New Brunswick
East Vancouver Island	City of Regina	City of Hamilton	Saguenay	Halifax Metro and Halifax County West
Greater Victoria	City of Saskatoon	City of Toronto	Rimouski – Mont Joli	Charlottetown (Queens County P.E.I.)
North Coast – Inland Sections	Prince Albert – Shellbrook – Spiritwood – Duck Lake	City of Ottawa	Forillon National Park – Gaspé – Percé	Sydney Metro and Cape Breton County
Central Okanagan – Including Kelowna	City of Calgary	North Bay – West Nipissing	Abitibi	Inverness County (Les Suetes Wind only)
West Kootenay	City of Edmonton	Greater Sudbury and Vicinity	Chibougamau	St. Georges (Wreckhouse Wind only)
Prince George	Yellowknife Region	Sault Ste. Marie – St. Joseph Island	Sept-Iles – Port-Cartier	Gander and Vicinity
British Columbia, North Peace River	Resolute	City of Thunder Bay	Blanc Sablon	St. John's and Vicinity
Whitehorse	Iqaluit	Kapuskasing – Hearst	Fermont	Goose Bay and Vicinity
-	-	-	Kuujjuaq	Labrador City and Wabush

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



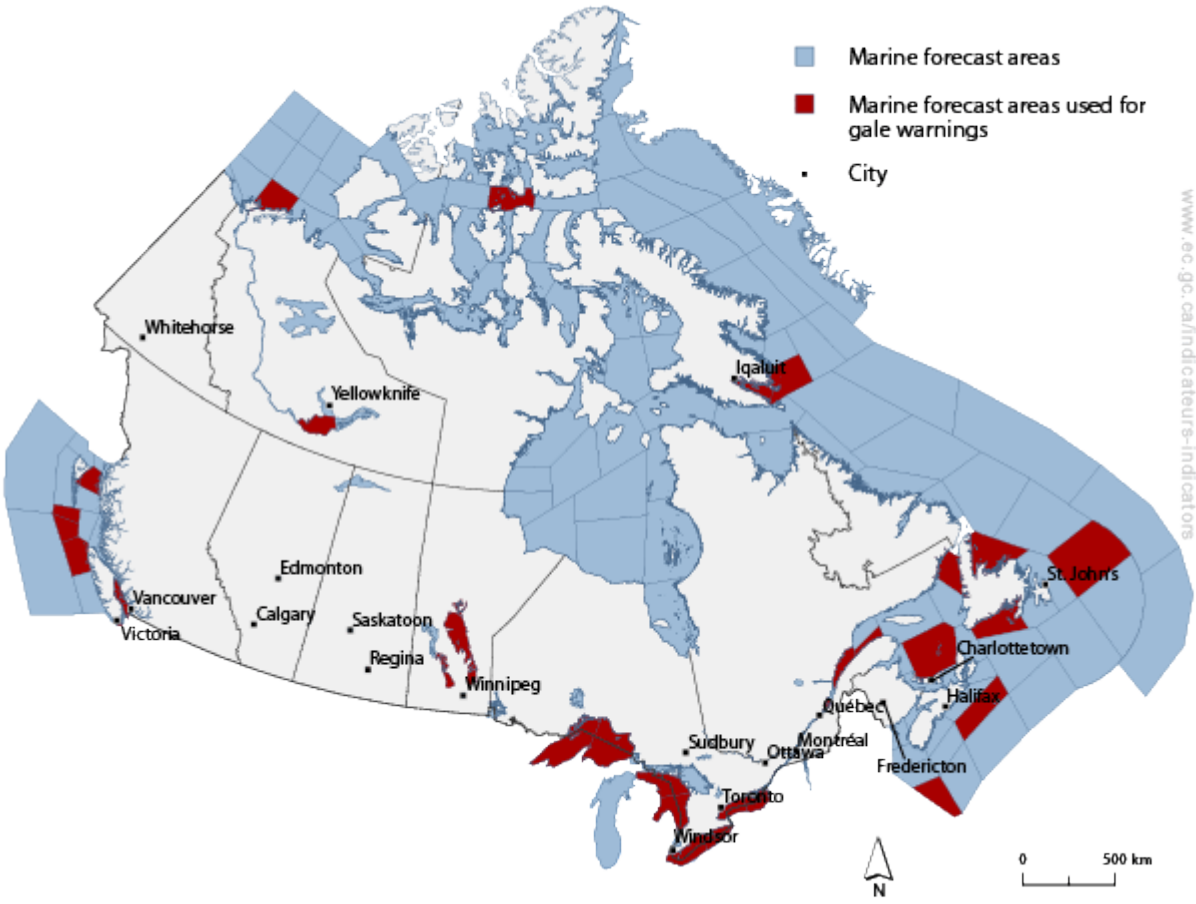
Note: Some public forecast regions are not visible at the national scale. See Table 2 for the complete list.
Source: Environment Canada (2014) Public Forecast Regions of Canada. Meteorological Service of Canada - Integrated Planning and Performance Management Division. Available from: www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=E5A4F19C-1

Table 2: 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 – Essex – Chatham-Kent (*Windsor - Leamington - Essex County*)	Montréal métropolitain – Laval (*l'ile de Montréal*)	Saint John and County
Fraser Valley-West Including Abbotsford	Brandon – Carberry – Treherne (*City of Brandon*)	London – Middlesex (*London - Parkhill - Eastern Middlesex County*)	Vaudreuil - Soulanges – Huntingdon (*Huntingdon*)	Moncton and Southeast New Brunswick
East Vancouver Island	Dauphin – Roblin – Winnipegosis (*R.M. of Dauphin including Sifton and Valley River*)	City of Hamilton	Vallée du Richelieu - Saint-Hyacinthe (*Saint-Hyacinthe – Acton Vale*)	Halifax Metro and Halifax County West
Greater Victoria	City of Regina	City of Toronto	Lanaudière (*Rawdon – Joliette*)	Charlottetown (Queens County P.E.I.)
North Coast – Inland Sections	City of Saskatoon	City of Ottawa (*Ottawa North - Kanata – Orléans*)	Lachute - Saint-Jérôme (*Lachute*)	Sydney Metro and Cape Breton County
Central Okanagan – Including Kelowna	Prince Albert – Shellbrook – Spiritwood – Duck Lake (*City of Prince Albert*)	North Bay – West Nipissing (*North Bay - Powassan – Mattawa*)	Laurentides (*Mont-Tremblant – Sainte Agathe*)	Oromocto and Sunbury County
West Kootenay	City of Calgary	Greater Sudbury and Vicinity	Haute-Gatineau - Lièvre – Papineau (*Reserve Papineau-Labelle*)	Gander and Vicinity
Prince George	City of Edmonton	Sault Ste. Marie – Superior East (*Sault Ste. Marie – St. Joseph Island*)	Abitibi (*Val D'Or – Louvicourt*)	St. John's and Vicinity
BC North Peace River	Lethbridge – Taber – Milk River (*City of*	City of Thunder Bay	Estrie (*Granby – Waterloo*)	Goose Bay and Vicinity

Pacific and Yukon	Prairie and Northern	Ontario	Quebec	Atlantic
	Lethbridge)			
Whitehorse	Grande Prairie – Beaverlodge – Valleyview (*Co. of Grande Prairie near Grande Prairie and Wembley*)	Kapuskasing – Hearst (*Kapuskasing - Hearst -Smooth Rock Falls*)	Québec	Labrador City and Wabush
-	-	-	Lac Saint-Jean (*Alma – Desbiens*)	-

Marine forecast areas with those used in the Weather Warning Index highlighted – gale warnings



Note: Some marine forecast areas are not visible at the national scale. See Table 3 for the complete list.
Source: Environment Canada (2014) Canadian Marine Warning Program. Meteorological Service of Canada - Integrated Planning and Performance Management Division. Available from: www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=B8834C38-1

Table 3: Marine forecast areas used in the Weather Warning Index for gale warnings

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

3.3 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 2011, 2012 and the most recent year 2013. This is the third iteration of the index. The first iteration calculated a three-year moving average using data from 2009, 2010 and 2011 and the second iteration used data from 2010, 2011 and 2012. The index is updated annually. Each spring, a value is calculated for the previous calendar year using available information.

3.4 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.

3.5 Data timeliness

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

4 Methods

4.1 Definitions

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

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

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 has been transmitted by the Environment 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 (TLT)** is Environment 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 4.

Table 4: 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

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 was reported."

4.2 Methodology

The index ranges from zero to ten 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.

4.2.1 Weighting

The index considers demographic and recreational statistics in its calculations. More specifically, given the statistic that 20% of Canadians engage in marine activities,[1] 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. In addition, each of these land components is weighted based on its frequency of occurrence during the reporting periods, which also reflects its impact on the overall population.

4.2.2 Timeliness factors

To calculate the average lead time (ALT) for each warning component, the warning issue time is subtracted from the time when the warning event occurred. The lead times so obtained are then averaged over the year to obtain the "average lead time". Missed events are assigned zero 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.

4.2.3 Accuracy factors

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

$$\text{EDI} = \frac{\log(\text{False Alarm Rate}) - \log(\text{Hit Rate})}{\log(\text{False Alarm Rate}) + \log(\text{Hit Rate})}$$

The hit rate is calculated using the number of hits and misses, and the false alarm rate is based on the number of false alarms and number of correct negatives (non-events). This requires an estimation of the number of periods of time during the year that no warning would be required (non-events). Since the EDI is a ratio of logarithms, it does not matter which base is used.

$$\text{Hit Rate} = \frac{\text{Hits}}{(\text{Hits} + \text{Misses})}$$

$$\text{False Alarm Rate} = \frac{\text{False Alarms}}{(\text{False Alarms} + \text{Non-Events})}$$

[1] Discover Boating Canada (2007) The economic impact of recreational boating in Canada: 2006 summary report. National Marine Manufacturers Association (NMMA) Canada.

4.2.4 Weather Warning Index calculation

The index ranges between zero and ten. 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 (ALT ≥ TLT), the index component score becomes

$$\left[EDI+0.5\,x\left(\frac{\text{Average Lead Time}}{\text{Target Lead Time}}-1\right)x(1-EDI)\right]x\ 10$$

Case 2

If the average lead time is less than the target lead time (ALT ‹ TLT), the index component score becomes

$$EDI\ x\left(\frac{\text{Average Lead Time}}{\text{Target Lead Time}}\right)x\ 10$$

4.2.5 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 2011, 2012 and 2013 by warning type: rain, snow, freezing rain, wind, severe thunderstorms and marine gale is presented in Table 5.

Table 5: Weather Warning Index calculation, timeliness and accuracy statistics, 2011-2013

2011-2013	Rain	Snow	Freezing rain	Wind	Severe* thunderstorm	Marine gale
Hits	196	323	161	263	126	2389
Misses	70	115	59	73	57	440
False alarms	137	187	67	168	789	802
Correct negatives	6797	9500	3763	19 746	27 378	4469
TOTAL	7200	10 125	4050	20 250	28 350	8100
Hit rate	0.74	0.74	0.73	0.78	0.69	0.84
False alarm rate	0.02	0.02	0.02	0.01	0.03	0.15
Extremal Dependency Index (EDI)	0.856	0.857	0.857	0.902	0.811	0.835
Average lead time (in hours)	14.32	16.26	6.31	14.13	0.42	20.09
Target lead time (in hours)	12	18	6	12	0.5	18

2011-2013	Rain	Snow	Freezing rain	Wind	Severe* thunderstorm	Marine gale
Weight	15	24	12	19	10	20
Weather Warning Index component score	*8.70*	*7.74*	*8.60*	*9.11*	*6.78*	*8.45*
Individual weighted Weather Warning Index component score	**1.28**	**1.88**	**1.05**	**1.70**	**0.69**	**1.69**
Change with respect to 2010-2012 individual weighted Weather Warning Index	-0.02	+0.36	+0.22	-0.20	0.00	+0.04

Weather Warning Index is the sum of the individual weighted Weather Warning Index component scores: 8.29

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

5 Caveats and limitations

This is only the third iteration of the Weather Warning Index, making trend analysis difficult to perform at this time. As more data become available over time it may be possible to track trends in the performance of Environment Canada's severe weather warning program.

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 via 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.

6 References and further reading

6.1 References

Discover Boating Canada (2007) The economic impact of recreational boating in Canada: 2006 summary report. National Marine Manufacturers Association (NMMA) Canada.

Environment Canada (2014) Marine warnings and watches. Retrieved on 26 May, 2014. Available from: www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=2EC4EC51-1&offset=10&toc=show

Environment Canada (2014) Public alerting criteria. Retrieved on 26 May, 2014. Available from: www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=D9553AB5-1

6.2 Further reading

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. Available from: www.onlinelibrary.wiley.com/doi/10.1002/met.1404/abstract

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