Cornell University

Northeast Regional Climate Center

Extreme Precipitation Analysis for Atlantic Canada

Technical Document

Christopher M. Castellano
Arthur T. DeGaetano

Northeast Regional Climate Center
Cornell University
Ithaca, NY

Environment and Climate Change Canada / Environnement et Changement climatique Canada

Gulf of Maine Council on the Marine Environment
Canada and the United States working together for a healthy environment

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Introduction

The frequency of extreme precipitation intensities over different durations is an important climatological tool used by the engineering community in planning and designing drainage structures. Such data are also crucial for estimating the extent and rarity of extreme precipitation events. Environment Canada currently provides official intensity–duration–frequency (IDF) information based on precipitation data from 565 stations across all 13 Canadian provinces. This project represents a collaborative effort between the Northeast Regional Climate Center (NRCC), Environment Canada, and the Gulf of Maine Council to establish a new website for sharing information about historical precipitation extremes in Maine and Atlantic Canada. The new website features interactive tools that allow users to visually display extreme precipitation data, as well as download extreme precipitation data for specific locations in various file formats. Products available on this website include:

1) Return period precipitation amounts and confidence intervals for a specific location (interpolated grid values or station values)
2) Annual maximum series (AMS) precipitation amounts for select stations
3) IDF curves for select stations
4) Precipitation frequency duration curves for a specific location (interpolated grid values or station values)
5) Gridded extreme precipitation data in ASCII and NetCDF formats (for spatial mapping applications)
6) Regional and provincial extreme precipitation maps

Precipitation Data

Sub-daily precipitation data for stations in Atlantic Canada with at least 10 years of valid data were provided directly by Environment Canada. These data consist of AMS precipitation amounts corresponding to 5-minuteute, 10-minuteute, 15-minuteute, 30-minuteute, 1-hour, 2-hour, 6-hour, 12-hour, and 24-hour durations. AMS values were only included for years in which no more than 10% of precipitation observations were missing at each station. The 53 sub-daily stations meeting this criterion are shown in Figure 1. For the gridded products, it was necessary to ensure that the final precipitation estimates accurately represented the present-day precipitation extremes. Therefore, any stations with less than 20 years of valid data and/or no valid AMS data from 1990 onward were excluded from the gridding procedure. Since a very limited number of stations in Maine and Atlantic Canada have long-term sub-daily precipitation data, supplemental daily precipitation data were used to increase the station density over the gridded domain. Daily AMS data were obtained from both Environment Canada and the Global Historical Climatology Network (GHCN). Overall, 38 sub-daily stations and 283 daily stations were used in the gridding analysis (Figure 2). Note that the gridding analysis excluded nearly all of Labrador due to extremely low station density.

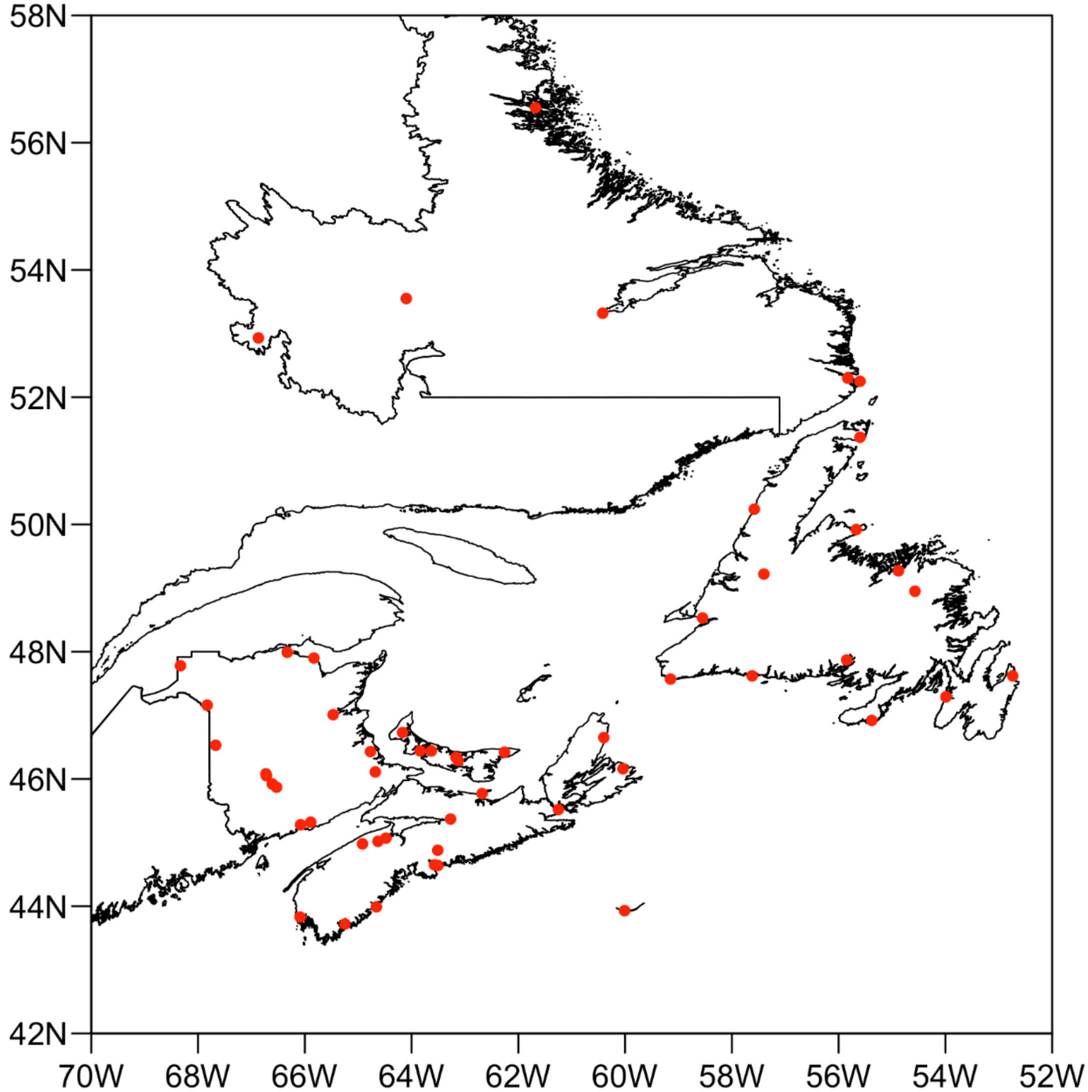

Figure 1: Map showing the locations of the 53 sub-daily stations in Atlantic Canada with at least 10 years of valid data.

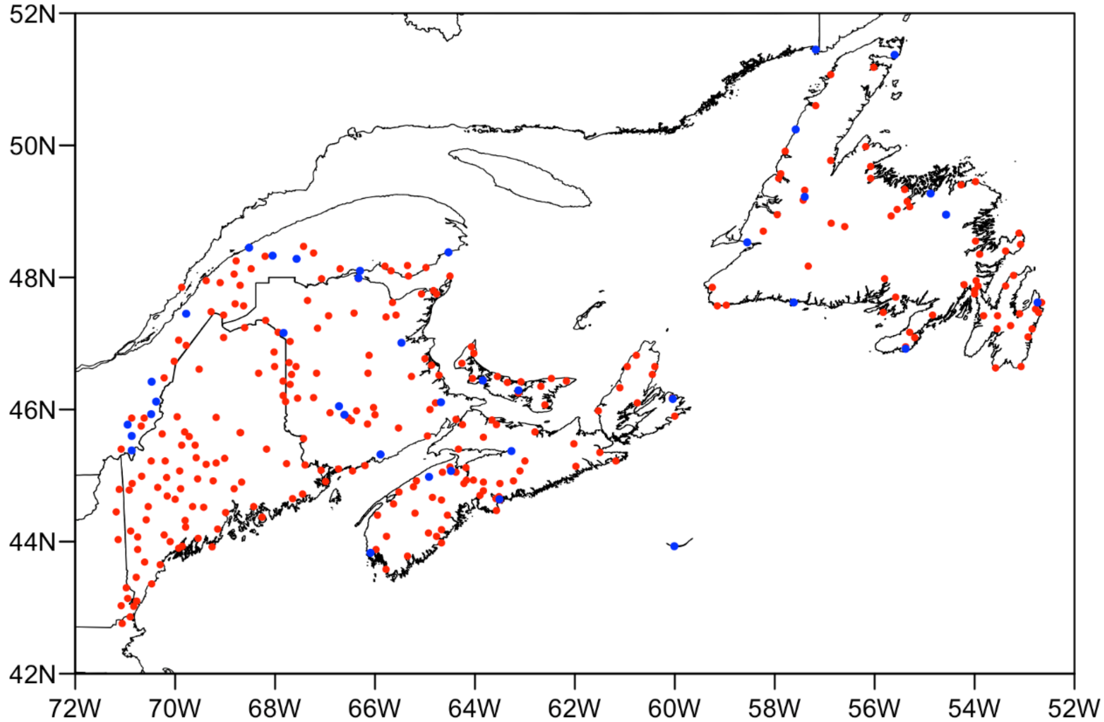

Figure 2: Map showing the locations of the 38 sub-daily stations (blue) and 283 daily stations (red) used to estimate the gridded precipitation extremes.

Precipitation Frequency Estimates

Extreme Value Fitting

After extracting sub-daily and daily AMS precipitation amounts from each station, the AMS values were used to estimate precipitation amounts corresponding to 2-, 5-, 10-, 25-, 50-, and 100-year return periods. Return period precipitation amounts were computed by fitting the Gumbel distribution (method of moments) to each station's AMS. For annual extreme data, the precipitation amount (X) for a specified return period (T), is given by:

$$X(T) = \mu + K(T)\sigma \quad (1)$$

where μ and σ are the AMS population mean and standard deviation, respectively, and:

$$K(T) = -\frac{\sqrt{6}}{\pi}\left(0.5772 + ln\, ln\frac{T}{T-1}\right) \quad (2)$$

Once the return period precipitation amounts were computed, it was possible to calculate precipitation intensities for each duration. For a given duration, the precipitation intensity simply represents the hourly rate of precipitation (expressed in mm/h). In order to estimate precipitation intensities for the daily stations, it was necessary to convert daily precipitation extremes to sub-daily (1-, 2-, 6-, 12-, and 24-hour) precipitation extremes. This was accomplished by identifying the daily stations that also report sub-daily precipitation data, and computing the ratios between the mean values of the daily AMS and sub-daily AMS distributions at each station. Only years during which valid AMS values exist for both the daily and sub-daily precipitation data were used in the comparison. Final conversion factors were obtained by calculating a weighted regional average of AMS ratios across all stations. Stations were weighted based on the number of years for which valid daily and sub-daily AMS values exist. These sub-daily conversion factors are provided in Table 1. The final IDF curves were smoothed by fitting a log-log regression to the intensity–duration relationship. This additional step allowed for the interpolation of return period precipitation intensities at intermediate durations.

Table 1: Table showing the regionally averaged conversion factors used to estimate sub-daily return period precipitation amounts from daily return period precipitation amounts.

Duration	Conversion Factor
1-hour	0.37
2-hour	0.49
6-hour	0.74
12-hour	0.92
24-hour	1.08

Confidence Intervals

One important caveat that must be considered when computing recurrence interval precipitation amounts is the discrepancy between the return period and the length of the data record. For example, this study estimates precipitation amounts corresponding to 100-year return periods at stations with data records as short as 10 years. Computation of the 100-year recurrence interval precipitation amounts requires extrapolation beyond the length of the data record, and thus introduces a large degree of uncertainty. One way to account for the uncertainty in return period precipitation amounts is to introduce confidence intervals, or bounds which represent the range of statistically likely values based on the sample distribution. For return period precipitation amounts calculated from the Gumbel distribution, confidence interval bounds can be estimated as:

$$CI = X(T) \pm t(\kappa)\sqrt{var\ X(T)} \tag{3}$$

where $t(\kappa)$ is the two-tailed z-score for a given confidence level (κ), based on a normal distribution [$t(\kappa)$ = 1.965 for κ = 95%], and $var\ X(T)$ is the variance of the estimate of $X(T)$, specific to the Gumbel distribution, given by:

$$var\ X(T) = \frac{\sigma^2}{n}[1 + 1.14K(T) + 1.10K(T)^2] \tag{4}$$

In Equation 4, σ is the AMS sample standard deviation, $K(T)$ is given by Equation 2, and n denotes the number of valid AMS values.

Gridded Estimates

Interpolation Routine

In addition to reproducing the station-based extreme precipitation statistics, the NRCC created high-resolution gridded products to allow users to obtain extreme precipitation estimates at any location in Maine and Atlantic Canada (excluding Labrador). The gridding process first required interpolation of station-based return period precipitation amounts to a uniform latitude–longitude grid (0.05° × 0.05° resolution). As noted above, 38 long-term sub-hourly stations and 281 long-term daily stations (Figure 2) were used in the interpolation routine. At any given grid cell, the precipitation amount corresponding to a specified duration and return period was estimated as the weighted average of precipitation amounts at all stations located within a 100-km radius of the grid cell center. The weighting factor (θ_k) for each qualifying station was determined by the station's distance from the grid cell and the station's period of record, and can be expressed as:

$$\theta_k = \alpha(\theta_d)_k + (1-\alpha)(\theta_n)_k \tag{5}$$

where $(\theta_d)_k$ is the distance component at station k, given by:

$$(\theta_d)_k = \frac{1}{d_k^2}\left(\sum_{i=1}^{N}\frac{1}{d_i^2}\right)^{-1} \tag{6}$$

and $(\theta_n)_k$ is the station record length component at station k, given by:

$$(\theta_n)_k = n_k\left(\sum_{i=1}^{N} n_i\right)^{-1} \tag{7}$$

For the purpose of this study, α = 0.60, and thus the distance component accounts for 60% of the total weighting, whereas the station record length component accounts for 40% of the total weighting. In Equations 6 and 7, d represents the horizontal distance between the grid cell and station k (in km), N denotes the number of stations within 100 km of the grid cell, and n denotes the period of record (number of valid AMS years) at station k. Equation 5 ensures that nearby stations with longer periods of record receive more weighting than stations with shorter data records located farther from a given grid cell. Because sub-hourly precipitation estimates were only calculated for the subset of stations with sub-hourly AMS data, the interpolation routine was initially executed for durations ranging from 1 hour to 24 hours. Gridded precipitation estimates corresponding to 5-, 10-, 15-, and 30-minute durations were obtained by computing ratios between the mean values of the 1-hour AMS and sub-daily AMS distributions at each station with sub-hourly data, and then multiplying the 1-hour precipitation estimates by a weighted regional average of AMS ratios. Stations were weighted based on the number of years for which valid hourly and sub-hourly AMS values exist. These sub-hourly conversion factors are provided in Table 2.

Table 2: Table showing the regionally averaged conversion factors used to estimate sub-hourly return period precipitation amounts from 1-hour return period precipitation amounts.

Duration	Conversion Factor
5-minute	0.31
10-minute	0.46
15-minute	0.56
30-minute	0.76

Smoothing Procedure

In order to reduce small-scale spatial irregularities in gridded precipitation extremes, the grid cell estimates were adjusted using a nearest neighbor smoothing procedure. For each grid cell with valid data, the final smoothed precipitation estimate was obtained by calculating the mean value across all grid cells with valid data located within a radius of three grid units from the grid cell of interest. This smoothing procedure helped reduce large discrepancies between nearby grid cells that may have been artificially inflated by differences in station period of record and limited station coverage.

Website Layout

Project Summary

The "About this Project" page provides summaries of the project background and motivation, the methodology Environment Canada uses to create its official extreme precipitation analyses, historical trends in extreme precipitation in Atlantic Canada, and website products and tools.

Data and Products

The "Data & Products" page allows users to access a variety of products, including extreme precipitation tables showing return period precipitation amounts and confidence intervals, AMS data, IDF graphs and tables showing precipitation intensities for different duration–frequency combinations, gridded extreme precipitation estimates, and regional and provincial extreme precipitation maps. The extreme precipitation tables and IDF data are available as HyperText Markup Language (HTML) products, and can be generated for select stations or point locations. The extreme precipitation tables are also available as text files in comma-separated values (CSV) format. The AMS data are available as HTML products only at select stations in Atlantic Canada. The gridded data are available in either in American Standard Code for Information Interchange (ASCII) or Network Common Data Form (NetCDF) format. The regional and provincial maps are available as Portable Network Graphics (PNG) image files.

Documentation

The "Documentation" page allows users to access this technical report, as well as official documentation explaining how Environment Canada estimates return period precipitation amounts and confidence intervals. This page also provides links to a separate IDF analysis for Newfoundland and Labrador and a web-based tool for computing IDF curves under future climate scenarios.

Acknowledgements

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