Package: STCCGEV (via r-universe)

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Title Conditional Copula Model for Crop Yield Forecasting

Version 1.0.0

Description Provides functions to model and forecast crop yields using a spatial temporal conditional copula approach. The package incorporates extreme weather covariates and Bayesian Structural Time Series models to analyze crop yield dependencies across multiple regions. Includes tools for fitting, simulating, and visualizing results. This method build upon established R packages, including 'Hofert' 'et' 'al'. (2025) <doi:10.32614/CRAN.package.copula>, 'Scott' (2024) <doi:10.32614/CRAN.package.bsts>, and 'Stephenson' 'et' 'al'. (2024) <doi:10.32614/CRAN.package.evd>.

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Encoding UTF-8

RoxygenNote 7.3.2

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LazyData true

LazyDataCompression xz

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NeedsCompilation no

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Contents

clayton.theta *Compute Clayton Copula Parameter from Kendall's Tau*

Description

Computes the Clayton copula dependence parameter based on Kendall's tau.

Usage

```
clayton.theta(tau)
```

Arguments

tau	Numeric, Kendall's tau correlation coefficient.

Value

Numeric, estimated Clayton copula parameter.

copula_list *Supported copula types*

Description

A list containing supported copula types.

Usage

```
copula_list
```

Format

A list of copula types.

copulas "Gaussian" "Clayton" "Frank" "Gumbel" "Joe"

`cropyields_covariates` *Data of the article "Probabilistic Crop Yields Forecasts With Spatio-Temporal Conditional Copula Using Extreme Weather Covariates"*

Description

Contains crop yields and climate indices data of 24 CD regions in Ontario from 1950 to 2022

Usage

```
cropyields_covariates
```

Format

A data frame with 1752 rows and 38 variables:

time chr: year from 1950-2022

CAR_CODE num: 1-4

CAR chr: Southern, Western, Central, Eastern Ontario

CD_CODE num

CD chr: 24 subregions

ID chr

lat num: latitude

lon num: longitude

yield num: wheat crop yield per census division, in bushel/acre

cdd num: Annual maximum number of consecutive days with daily precipitation below 1mm (unit = days)

cddcold_18 num: Annual cooling degree days above 18C (unit = degree_days)

dlyfrzthw_tx0_tn num: Annual number of days with a diurnal freeze-thaw cycle : tmax > 0 degc and tmin <= -1 degc

first_fall_frost num: First day of year with temperature below 0 degc for at least 1 days

frost_days num: Annual number of days with minimum daily temperature below 0C

ice_days num: Annual number of days with maximum daily temperature below 0 degC

nr_cdd num: The annual number of dry periods of 6 days and more, during which the maximal precipitation on a window of 6 days is under 1.0 mm

prcptot num: Annual total precipitation (unit = mm)

r1mm num: Annual number of days with daily precipitation over 1.0 mm/day

r10mm num: Annual number of days with daily precipitation over 10.0 mm/day

r20mm num: Annual number of days with daily precipitation over 20.0 mm/day

rx1day num: Annual maximum 1-day total precipitation (unit = mm)

rx5day num: Annual maximum 5-day total precipitation (unit = mm)

tg_mean num: Annual mean of daily mean temperatures (unit = C degrees)

tn_mean num: Annual mean of daily minimum temperatures (unit = C degrees)

tn_min num: Annual minimum of daily minimum temperatures (unit = C degrees)

tnlt_-15 num: Annual number of days where daily minimum temperature is below -15 degC

tnlt_-25 num: Annual number of days where daily minimum temperature is below -25 degC

tr_18 num: Annual number of tropical nights : defined as days with minimum daily temperature above 18 degc

tr_20 num: Annual number of tropical nights : defined as days with minimum daily temperature above 20 degc

tr_22 num: Annual number of tropical nights : defined as days with minimum daily temperature above 22 degc

tx_max num: Annual minimum of daily maximum temperature (unit = C degrees)

tx_mean num: Annual mean of daily maximum temperature (unit = C degrees)

txgt_25 num: Annual number of days where daily maximum temperature exceeds 25 degC

txgt_27 num: Annual number of days where daily maximum temperature exceeds 27 degC

txgt_29 num: Annual number of days where daily maximum temperature exceeds 29 degC

txgt_30 num: Annual number of days where daily maximum temperature exceeds 30 degC

txgt_32 num: Annual number of days where daily maximum temperature exceeds 32 degC

Source

ClimateData.ca

`dynamic.rho` *Compute Dynamic Gaussian Copula Correlation Parameter (rho)*

Description

Computes the time-varying correlation parameter (rho) for a Gaussian copula.

Usage

```
dynamic.rho(params, lagged_rho, X_t)
```

Arguments

`params`	Numeric vector of parameters: omega, alpha, and gamma coefficients.
`lagged_rho`	Numeric, the previous rho value.
`X_t`	Numeric vector or matrix of covariates at time t.

Value

Numeric, estimated dynamic Gaussian copula correlation.

dynamic.theta.clayton *Compute Dynamic Clayton Copula Parameter*

Description

Computes the Clayton copula parameter dynamically based on lagged values and covariates.

Usage

```
dynamic.theta.clayton(params, lagged_theta, X_t)
```

Arguments

params	Numeric vector of parameters: omega, alpha, and gamma coefficients.
lagged_theta	Numeric, the previous theta value.
X_t	Numeric vector or matrix of covariates at time t.

Value

Numeric, estimated dynamic Clayton copula parameter.

dynamic.theta.frank *Compute Dynamic Frank Copula Parameter*

Description

Computes the Frank copula parameter dynamically based on lagged values and covariates.

Usage

```
dynamic.theta.frank(params, lagged_theta, X_t)
```

Arguments

params	Numeric vector of parameters: omega, alpha, and gamma coefficients.
lagged_theta	Numeric, the previous theta value.
X_t	Numeric vector or matrix of covariates at time t.

Value

Numeric, estimated dynamic Frank copula parameter.

dynamic.theta.gumbel *Compute Dynamic Gumbel Copula Parameter*

Description

Computes the Gumbel copula parameter dynamically based on lagged values and covariates.

Usage

```
dynamic.theta.gumbel(params, lagged_theta, X_t)
```

Arguments

params	Numeric vector of parameters: omega, alpha, and gamma coefficients.
lagged_theta	Numeric, the previous theta value.
X_t	Numeric vector or matrix of covariates at time t.

Value

Numeric, estimated dynamic Gumbel copula parameter.

dynamic.theta.joe *Compute Dynamic Joe Copula Parameter*

Description

Computes the Joe copula parameter dynamically based on lagged values and covariates.

Usage

```
dynamic.theta.joe(params, lagged_theta, X_t)
```

Arguments

params	Numeric vector of parameters: omega, alpha, and gamma coefficients.
lagged_theta	Numeric, the previous theta value.
X_t	Numeric vector or matrix of covariates at time t.

Value

Numeric, estimated dynamic Joe copula parameter.

fit_bsts *Fit a Bayesian Structural Time Series (BSTS) Model*

Description

Fits a BSTS model for a time series y, given a vector or matrix of covariates z.

Usage

```
fit_bsts(y, z, lags = 0, MCMC.iter = 5000)
```

Arguments

y	A numeric vector (time series response variable).
z	A numeric vector or matrix (covariates).
lags	Integer, number of lags for the autoregressive component.
MCMC.iter	Integer, number of MCMC iterations.

Value

A fitted BSTS model.

frank.theta *Compute Frank Copula Parameter from Kendall's Tau*

Description

Computes the Frank copula dependence parameter based on Kendall's tau.

Usage

```
frank.theta(tau)
```

Arguments

tau	Numeric, Kendall's tau correlation coefficient.

Value

Numeric, estimated Frank copula parameter.

GH.theta *Compute Gumbel Copula Parameter from Kendall's Tau*

Description

Computes the Gumbel-Hougaard copula dependence parameter based on Kendall's tau.

Usage

```
GH.theta(tau)
```

Arguments

tau	Numeric, Kendall's tau correlation coefficient.

Value

Numeric, estimated Gumbel copula parameter.

init_params_full *Initial Parameters for 2D Pseudo-Loglikelihood Estimation*

Description

Initial Parameters for 2D Pseudo-Loglikelihood Estimation

Usage

```
init_params_full
```

Format

A numeric vector of length $(2 + M + 4 * D * M)$ where:

omega Baseline autoregressive coefficient.

alpha Parameter controlling variance.

gamma1, gamma2, gamma3 Coefficients related to external factors.

phi_gev AR(1) coefficient for GEV.

sigma_mu Std dev of innovations for AR(1) process for GEV.

sigma_gev GEV scale parameter for GEV.

xi_gev GEV shape parameter for GEV.

init_params_full_G — *Initial Parameters for 2D Pseudo-Loglikelihood-Generalized Estimation*

Description

Initial Parameters for 2D Pseudo-Loglikelihood-Generalized Estimation

Usage

```
init_params_full_G
```

Format

A numeric vector of length $(2 + M + 4 * D * M)$, structured as follows:

omega Baseline autoregressive coefficient.

alpha Parameter controlling variance.

gamma1, gamma2, gamma3 Coefficients related to external factors.

Climate variable parameters For each climate variable in each region, the following parameters are included:

- `mean(z)`, `sd(z)`, `sd(z)`, `xi_gev` for each region and variable.

init_params_noGEV — *Initial Parameters for 2D Pseudo-Loglikelihood Estimation without GEV models for covariates*

Description

Initial Parameters for 2D Pseudo-Loglikelihood Estimation without GEV models for covariates

Usage

```
init_params_noGEV
```

Format

A numeric vector of length $(2 + M)$ where:

omega Baseline autoregressive coefficient.

alpha Parameter controlling variance.

gamma1, gamma2, gamma3 Coefficients related to external factors.

joe.theta *Compute Joe Copula Parameter from Kendall's Tau*

Description

Computes the Joe copula dependence parameter based on Kendall's tau.

Usage

```
joe.theta(tau)
```

Arguments

tau	Numeric, Kendall's tau correlation coefficient.

Value

Numeric, estimated Joe copula parameter.

log_likelihood_Generalized *Compute Log-Likelihood for a Generalized Dynamic Copula-GEV Model*

Description

Computes the log-likelihood for a time-varying copula model combined with Generalized Extreme Value (GEV) margins.

Usage

```
log_likelihood_Generalized(params, U, Z, X, copula)
```

Arguments

params	Numeric vector of model parameters, including copula parameters (omega, alpha, gamma) and GEV distribution parameters.
U	Numeric matrix (n_train x D), pseudo-observations for the copula.
Z	Numeric array (n_train x D x M), observed data for each margin and sub-feature.
X	Numeric matrix (n_train x M), risk factors for the dynamic copula parameter.
copula	Character, specifying the copula type: "Clayton", "Frank", "Gumbel", "Joe", or "Gaussian".

Value

Numeric, negative log-likelihood value.

Examples

```
test_ll <- log_likelihood_Generalized(init_params_full_G,uu,
                      zz_train,xx_train,"Gaussian")
```

`log_likelihood_generalized_2d` *Generalized Log-Likelihood Function for 2D Copula-GEV Model*

Description

Computes the negative log-likelihood of a 2-dimensional copula-GEV model, incorporating dynamic Generalized Extreme Value (GEV) parameters and a time-varying copula structure.

Usage

```
log_likelihood_generalized_2d(params, u1, u2, X_t, z1, z2, copula)
```

Arguments

`params`	Numeric vector, model parameters including copula and GEV parameters.
`u1`	Numeric vector (length `n_train`), pseudo-observations for margin 1.
`u2`	Numeric vector (length `n_train`), pseudo-observations for margin 2.
`X_t`	Numeric matrix (`n_train x M`), risk factors affecting copula parameters.
`z1`	Numeric matrix (`n_train x M`), observed data for margin 1.
`z2`	Numeric matrix (`n_train x M`), observed data for margin 2.
`copula`	Character, specifying the copula type: "Clayton", "Frank", "Gumbel", "Joe", or "Gaussian".

Value

The negative log-likelihood value for optimization.

Examples

```
test_ll_2d <-log_likelihood_generalized_2d(init_params_full,
                                    uu[,1],
                                    uu[,2],
                                    xx_train,
                                    zz_train[,1,],
                                    zz_train[,2,],
                                    "Gaussian")
```

log_likelihood_noGEV *Compute Log-Likelihood for a Generalized Dynamic Copula Model without GEV covariates*

Description

Computes the log-likelihood for a time-varying copula model.

Usage

```
log_likelihood_noGEV(params, U, Z, X, copula)
```

Arguments

params	Numeric vector of model parameters, including copula parameters (omega, alpha, gamma).
U	Numeric matrix (n_train x D), pseudo-observations for the copula.
Z	Numeric array (n_train x D x M), observed data for each margin and sub-feature.
X	Numeric matrix (n_train x M), risk factors for the dynamic copula parameter.
copula	Character, specifying the copula type: "Clayton", "Frank", "Gumbel", "Joe", or "Gaussian".

Value

Numeric, negative log-likelihood value.

Examples

```
test_ll_noGEV <- log_likelihood_noGEV(init_params_noGEV,uu,
                     zz_train,x_train,"Gaussian")
```

medoid_names *list containing Dufferin and Wellington*

Description

list containing Dufferin and Wellington

Usage

```
medoid_names
```

Format

An object of class `list` of length 2.

n_test *19*

Description

19

Usage

```
n_test
```

Format

An object of class `integer` of length 1.

n_train *54*

Description

54

Usage

```
n_train
```

Format

An object of class `integer` of length 1.

plot_forecast *Plot Observed Data and BSTS Forecast*

Description

Creates a plot of observed data, forecasted values, and confidence intervals.

Usage

```
plot_forecast(
  forecast,
  data_train,
  data_test,
  time,
  quant_high,
  quant_low,
  observed_col,
  forecast_col,
  title
)
```

Arguments

forecast	A matrix of BSTS forecast samples.
data_train	Numeric vector, training data.
data_test	Numeric vector, test data.
time	Numeric vector, representing time indices.
quant_high	Numeric, upper quantile for confidence interval.
quant_low	Numeric, lower quantile for confidence interval.
observed_col	Character, color for observed data.
forecast_col	Character, color for forecasted data.
title	Character, title of the plot.

Value

A ggplot2 object.

---

plot_forecast_compare *Compare Forecasts from Two Models*

Description

Generates a time series plot comparing the forecasts from two models along with observed data.

Usage

```
plot_forecast_compare(
  forecast1,
  forecast2,
  data_train,
  data_test,
  time,
```

```
  quant_high,
  quant_low,
  col1,
  title
)
```

Arguments

forecast1	Numeric matrix, forecasted values from the first model (columns: time points).
forecast2	Numeric matrix, forecasted values from the second model (columns: time points).
data_train	Numeric vector, training data used for modeling.
data_test	Numeric vector, actual test data for evaluation.
time	Numeric vector, representing the time points corresponding to the data.
quant_high	Numeric, upper quantile (e.g., 0.9) for confidence interval.
quant_low	Numeric, lower quantile (e.g., 0.1) for confidence interval.
col1	Character, color for observed data lines.
title	Character, title for the plot.

Value

A ggplot2 object showing the forecast comparison.

---

simul.fun.noGEV *Simulate Multivariate Crop Yield Data Using a Generalized Copula-BSTS Model Without GEV Covariates*

Description

This function simulates multivariate crop yield data using a time-varying copula combined with Bayesian Structural Time Series (BSTS) models without GEV covariates for comparision.

Usage

```
simul.fun.noGEV(
  nsim = 100,
  n_train,
  n_test,
  copula,
  init_params,
  fn,
  U_train,
  Z_train,
  Z_test,
  X_train,
  X_test,
  Y_test,
  BSTS_list
)
```

Arguments

nsim	Integer, number of simulation replications.
n_train	Integer, number of training observations.
n_test	Integer, number of test observations.
copula	Character, specifying the copula type: "Clayton", "Frank", "Gumbel", "Joe", or "Gaussian".
init_params	Numeric vector, initial parameter values for optimization.
fn	Function, log-likelihood function for parameter estimation.
U_train	Numeric matrix (n_train x D), pseudo-observations for the copula.
Z_train	Numeric array (n_train x D x M), observed data for each margin and sub-feature.
Z_test	Numeric array (n_test x D x M), observed data for each margin and sub-feature.
X_train	Numeric matrix (n_train x M), risk factors for the dynamic copula parameter.
X_test	Numeric matrix (n_test x M), risk factors for the dynamic copula parameter.
Y_test	Numeric matrix (n_test x D), true future values for MSE calculation.
BSTS_list	List of length D, each element is a BSTS model for a different margin.

Value

A list containing:

optim_results	Results from the optimization process.
theta_sim	Simulated copula parameters across replications.
Y_sim	Simulated final BSTS-based forecasts.
MSE	Mean squared error for each simulation run.

---

simul_fun_generalized_2d

A Special Case of simulation_generalized in 2 Dimensions

Description

A Special Case of simulation_generalized in 2 Dimensions

Usage

```
simul_fun_generalized_2d(
  nsim,
  n_train,
  n_test,
  copula,
  init_params,
  fn,
```

```
  u1,
  u2,
  z1_train,
  z2_train,
  X_t,
  y1_test,
  y2_test,
  BSTS_1,
  BSTS_2
)
```

Arguments

nsim	Integer, number of simulation replications.
n_train	Integer, number of training observations.
n_test	Integer, number of test observations.
copula	Character, specifying the copula type: "Clayton", "Frank", "Gumbel", "Joe", or "Gaussian".
init_params	Numeric vector, initial parameter values for optimization.
fn	Function, log-likelihood function for parameter estimation.
u1	Numeric vector (n_train), first pseudo-observation for the copula.
u2	Numeric vector (n_train), second pseudo-observation for the copula.
z1_train	Numeric matrix (n_train x M), observed data for the first margin.
z2_train	Numeric matrix (n_train x M), observed data for the second margin.
X_t	Numeric matrix (n_train x M), risk factors for the dynamic copula parameter.
y1_test	Numeric vector (n_test), true future values for the first response variable.
y2_test	Numeric vector (n_test), true future values for the second response variable.
BSTS_1	Fitted BSTS model for the first response variable.
BSTS_2	Fitted BSTS model for the second response variable.

Value

A list containing:

theta_simulated	Simulated copula parameters across replications.
y1_simulated	Simulated values for the first response variable.
y2_simulated	Simulated values for the second response variable.
MSE	Mean squared error for each simulation run.
optim_results	Results from the optimization process.

simulation_generalized *Simulate Multivariate Crop Yield Data Using a Generalized Copula-GEV-BSTS Model*

Description

This function simulates multivariate crop yield data using a time-varying copula combined with Generalized Extreme Value (GEV) margins and Bayesian Structural Time Series (BSTS) models.

Usage

```
simulation_generalized(
  nsim = 100,
  n_train,
  n_test,
  copula,
  init_params,
  fn,
  U_train,
  Z_train,
  X,
  Y_test,
  BSTS_list
)
```

Arguments

nsim	Integer, number of simulation replications.
n_train	Integer, number of training observations.
n_test	Integer, number of test observations.
copula	Character, specifying the copula type: "Clayton", "Frank", "Gumbel", "Joe", or "Gaussian".
init_params	Numeric vector, initial parameter values for optimization.
fn	Function, log-likelihood function for parameter estimation.
U_train	Numeric matrix (n_train x D), pseudo-observations for the copula.
Z_train	Numeric array (n_train x D x M), observed data for each margin and sub-feature.
X	Numeric matrix (n_train x M), risk factors for the dynamic copula parameter.
Y_test	Numeric matrix (n_test x D), true future values for MSE calculation.
BSTS_list	List of length D, each element is a BSTS model for a different margin.

Value

A list containing:

optim_results	Results from the optimization process.
theta_sim	Simulated copula parameters across replications.
Y_sim	Simulated final BSTS-based forecasts.
MSE	Mean squared error for each simulation run.

---

time_all *1950-2022*

Description

1950-2022

Usage

```
time_all
```

Format

An object of class character of length 73.

---

time_test *2004-2022*

Description

2004-2022

Usage

```
time_test
```

Format

An object of class character of length 19.

time_train *1950-2003*

Description

1950-2003

Usage

```
time_train
```

Format

An object of class `character` of length 54.

uu *Pseudo-Observations of BSTS Residuals for Crop Yield Forecasting*

Description

Pseudo-Observations of BSTS Residuals for Crop Yield Forecasting

Usage

```
uu
```

Format

A matrix with dimensions (n_train, D):

n_train Number of time points used in the training set.

D Number of regions analyzed (`Dufferin`, `Wellington`).

Source

Derived from residuals of BSTS models fitted to crop yield data.

xx_all *Maximized Covariates Matrix for Crop Yield Forecasting*

Description

Maximized Covariates Matrix for Crop Yield Forecasting

Usage

```
xx_all
```

Format

A three-dimensional array with dimensions $(n_train + n_test, M)$:

n_train+n_test Number of time points used in the training set.

M Number of selected climate covariates used for modeling (cdd,frost_days,rx1day, tg_mean, txgt_25).

Source

Derived from historical climate data from ClimateData.ca.

xx_test *Maximized Covariates Matrix for Crop Yield Forecasting*

Description

Maximized Covariates Matrix for Crop Yield Forecasting

Usage

```
xx_test
```

Format

A three-dimensional array with dimensions (n_test, M):

n_test Number of time points used in the testing set.

M Number of selected climate covariates used for modeling (cdd,frost_days,rx1day, tg_mean, txgt_25).

Source

Derived from historical climate data from ClimateData.ca.

xx_train *Maximized Covariates Matrix for Crop Yield Forecasting*

Description

Maximized Covariates Matrix for Crop Yield Forecasting

Usage

```
xx_train
```

Format

A three-dimensional array with dimensions (n_train, M):

n_test Number of time points used in the training set.

M Number of selected climate covariates used for modeling (`cdd`,`frost_days`,`rx1day`, `tg_mean`, `txgt_25`).

Source

Derived from historical climate data from ClimateData.ca.

yy_all *Crop Yield Data*

Description

Crop Yield Data

Usage

```
yy_all
```

Format

A matrix with dimensions $(n_train + n_test, D)$:

n_train+n_test Number of time points used in the test set.

D Number of regions analyzed (`Dufferin`, `Wellington`).

Source

Historical crop yield records from ClimateData.ca.

yy_test *Crop Yield Data for Testing in BSTS Models*

Description

Crop Yield Data for Testing in BSTS Models

Usage

```
yy_test
```

Format

A matrix with dimensions (n_train, D):

n_train Number of time points used in the test set.

D Number of regions analyzed (`Dufferin`, `Wellington`).

Source

Historical crop yield records from ClimateData.ca.

yy_train *Crop Yield Data for Training in BSTS Models*

Description

Crop Yield Data for Training in BSTS Models

Usage

```
yy_train
```

Format

A matrix with dimensions (n_test, D):

n_test Number of time points used in the train set.

D Number of regions analyzed (`Dufferin`, `Wellington`).

Source

Historical crop yield records from ClimateData.ca.

zz_all *Standardized Covariates Array for Crop Yield Forecasting*

Description

Standardized Covariates Array for Crop Yield Forecasting

Usage

```
zz_all
```

Format

A three-dimensional array with dimensions $(n_train + n_test, D, M)$:

n_train+n_test Number of time points used in the training set.

D Number of regions analyzed (`Dufferin`, `Wellington`).

M Number of selected climate covariates used for modeling (`cdd`,`frost_days`,`rx1day`, `tg_mean`, `txgt_25`).

Source

Derived from historical climate data.

zz_test *Standardized Covariates Array for Crop Yield Forecasting*

Description

Standardized Covariates Array for Crop Yield Forecasting

Usage

```
zz_test
```

Format

A three-dimensional array with dimensions (n_test, D, M):

n_test Number of time points used in the testing set.

D Number of regions analyzed (`Dufferin`, `Wellington`).

M Number of selected climate covariates used for modeling (`cdd`,`frost_days`,`rx1day`, `tg_mean`, `txgt_25`).

Source

Derived from historical climate data.

zz_train *Standardized Covariates Array for Crop Yield Forecasting*

Description

Standardized Covariates Array for Crop Yield Forecasting

Usage

```
zz_train
```

Format

A three-dimensional array with dimensions (n_train, D, M):

n_test Number of time points used in the training set.

D Number of regions analyzed (`Dufferin`, `Wellington`).

M Number of selected climate covariates used for modeling (`cdd`,`frost_days`,`rx1day`, `tg_mean`, `txgt_25`).

Source

Derived from historical climate data from ClimateData.ca.

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