
ClimateNA v7.00

A program to generate climate normal, annual, seasonal and monthly data
for historical and future periods in North America

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March 12, 2021

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About this program

ClimateNA is a standalone MS Windows® software application (Wang et al. 2016) that extracts and downscales gridded (4 x 4 km) monthly climate data for the reference normal period (1961-1990) from PRISM (Daly et al. 2008) and WorldClim (Hijmans et al. 2005) to scale-free point locations. It also calculates many (>200) monthly, seasonal and annual climate variables. The downscaling is achieved through a combination of bilinear interpolation and dynamic local elevational adjustment. ClimateNA also uses the scale-free data as a baseline to downscale historical and future climate variables for individual years and periods between 1901 and 2100. A time-series function is available to generate climate variables for multiple locations and multiple years.

The program can read and output comma-delimited spreadsheet (CSV) files. The new version (since v6.00) can also directly read digital elevation model (DEM) raster (ASC) files and output climate variables in raster format for mapping. The spatial resolution of the raster files is up to user's preference. The coverage of the program is shown in Figure 1.

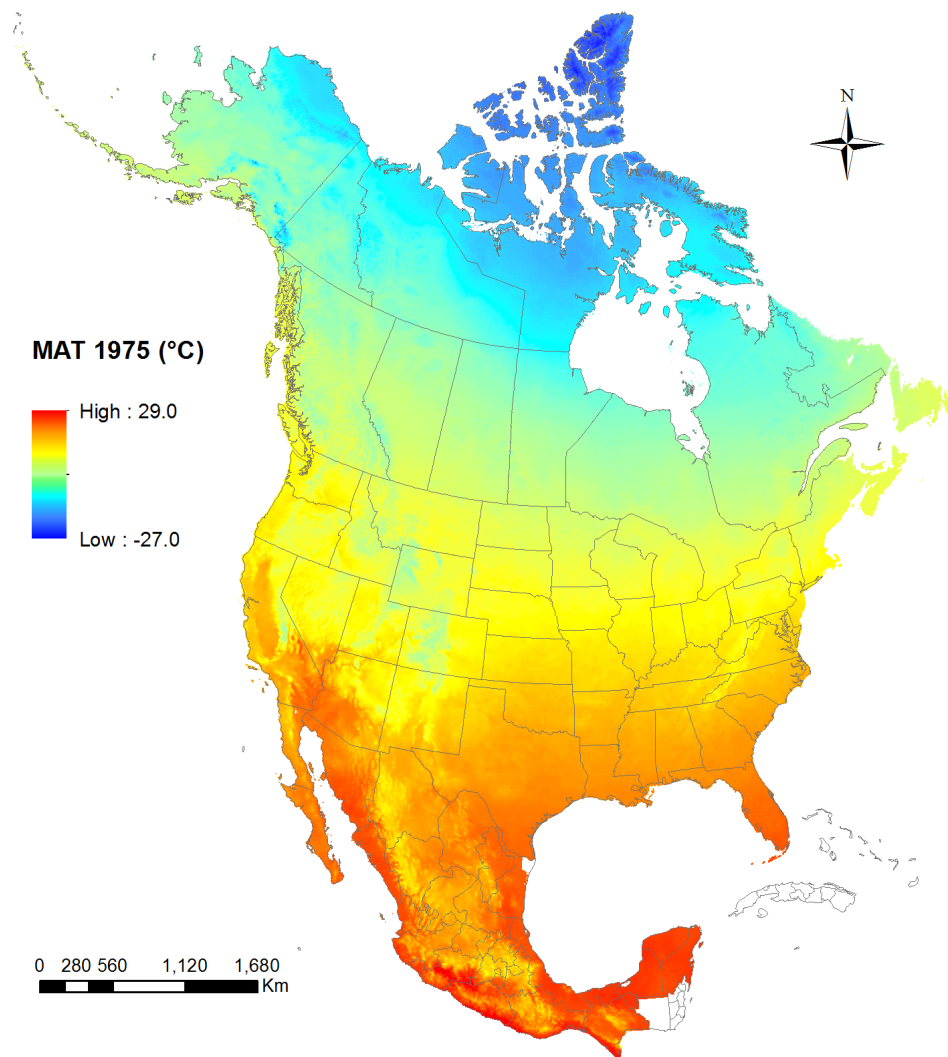


Figure 1. The coverage of ClimateNA. The extent of the coverage: longitude = -179.167 ~ -52.625°; latitude = 14.453 ~ 83.203°.

Data sources

Baseline data

The monthly baseline data for 1961-1990 normals were compiled from the following sources and unified at 4 x 4 km spatial resolution:

1. British Columbia: PRISM at 800 x 800 m from Pacific Climate Impact Consortium;
2. Parries provinces: PRISM at 4 x 4 km from the PRISM Climate Group (<http://www.prism.oregonstate.edu/>);
3. United States: PRISM at 800 x 800 m from the PRISM Climate Group (Daly *et al.* 2008);
4. The rest: WorldClim (Hijmans *et al.* 2005);
5. The monthly solar radiation data (1948-2010) were provided by Dr. Robbie Hember at University of British Columbia.

Historical data

Historical monthly data were developed by ourselves and replaced the data from Climate Research Unit (CRU ts4.01) (Harris *et al.* 2014), which were used in previous versions, for improved accuracies. The data are at the spatial resolution is 0.5 x 0.5°.

Future climate data

The future climate projections were from 13 General Circulation Models (GCMs) of the Coupled Model Intercomparison Project (CMIP6) to be included in IPCC sixth assessment report (AR6). The new set of emissions scenarios from CMIP6, called “Shared Socioeconomic Pathways” (SSPs), included SSP126, SSP245, SSP460, SSP370 and SSP585 for three normal periods (2011-2040, 2041-2070, and 2071-2100) and five 20-year periods (2001-2020, 2021-2040, 2041-2060, 2061-2080, and 2081-2100). When multiple runs are available for each GCM, an average was taken over the available (up to 10) runs. Ensembles among the 13 GCMs are also available. Time-series of monthly projections for individual years will be added later.

Paleoclimate data

Monthly paleoclimate data were not available yet from CMIP6.

How to add climate data from additional GCMs

The coordinate file “ClimateNA_GCM_coord_vID.csv” included in the “Reference” folder can be used as a template to add additional GCM data to the package by users. After the monthly climate data are added to the template, remove the first three columns and save it to the GCMdat folder with the extension name “.gcm”. This applies to GCM time series data as well.

Climate variables predicted

1) Annual variables:

Directly calculated annual variables:

MAT	mean annual temperature (°C),
MWMT	mean warmest month temperature (°C),
MCMT	mean coldest month temperature (°C),
TD	temperature difference between MWMT and MCMT, or continentality (°C),
MAP	mean annual precipitation (mm),

MSP	May to September precipitation (mm),
AHM	annual heat-moisture index $(MAT+10)/(MAP/1000)$
SHM	summer heat-moisture index $((MWMT)/(MSP/1000))$

Derived annual variables:

DD_0 (DD<0)	degree-days below 0°C, chilling degree-days
DD5 (DD>5)	degree-days above 5°C, growing degree-days
DD_18 (DD<18)	degree-days below 18°C, heating degree-days
DD18 (DD>18)	degree-days above 18°C, cooling degree-days
NFFD	the number of frost-free days
FFP	frost-free period
bFFP	the day of the year on which FFP begins
eFFP	the day of the year on which FFP ends
PAS	precipitation as snow (mm). For individual years, it covers the period between August in the previous year and July in the current year.
EMT	extreme minimum temperature over 30 years
EXT	extreme maximum temperature over 30 years
Eref	Hargreaves reference evaporation (mm)
CMD	Hargreaves climatic moisture deficit (mm)
MAR	mean annual solar radiation ($MJ\ m^{-2}\ d^{-1}$)
RH	mean annual relative humidity (%)
CMI	Hogg's climate moisture index (mm)
DD1040 (10<DD<40)	degree-days above 10°C and below 40°C

2) Seasonal variables:

Winter (_wt): Dec (prev. yr for an individual year) - Feb for annual, Jan, Feb, Dec for normals
 Spring (_sp): March, April and May
 Summer (_sm): June, July and August
 Autumn (_at): September, October and November

Directly calculated seasonal variables:

Tave_wt	winter mean temperature (°C)
Tave_sp	spring mean temperature (°C)
Tave_sm	summer mean temperature (°C)
Tave_at	autumn mean temperature (°C)
Tmax_wt	winter mean maximum temperature (°C)
Tmax_sp	spring mean maximum temperature (°C)
Tmax_sm	summer mean maximum temperature (°C)

Tmax_at	autumn mean maximum temperature (°C)
Tmin_wt	winter mean minimum temperature (°C)
Tmin_sp	spring mean minimum temperature (°C)
Tmin_sm	summer mean minimum temperature (°C)
Tmin_at	autumn mean minimum temperature (°C)
PPT_wt	winter precipitation (mm)
PPT_sp	spring precipitation (mm)
PPT_sm	summer precipitation (mm)
PPT_at	autumn precipitation (mm)
RAD_wt	winter solar radiation (MJ m ⁻² d ⁻¹)
RAD_sp	spring solar radiation (MJ m ⁻² d ⁻¹)
RAD_sm	summer solar radiation (MJ m ⁻² d ⁻¹)
RAD_at	autumn solar radiation (MJ m ⁻² d ⁻¹)

Derived seasonal variables:

DD_0_wt	winter degree-days below 0°C
DD_0_sp	spring degree-days below 0°C
DD_0_sm	summer degree-days below 0°C
DD_0_at	autumn degree-days below 0°C
DD5_wt	winter degree-days above 5°C
DD5_sp	spring degree-days above 5°C
DD5_sm	summer degree-days above 5°C
DD5_at	autumn degree-days above 5°C
DD_18_wt	winter degree-days below 18°C
DD_18_sp	spring degree-days below 18°C
DD_18_sm	summer degree-days below 18°C
DD_18_at	autumn degree-days below 18°C
DD18_wt	winter degree-days above 18°C
DD18_sp	spring degree-days above 18°C
DD18_sm	summer degree-days above 18°C
DD18_at	autumn degree-days above 18°C

NFFD_wt	winter number of frost-free days
NFFD_sp	spring number of frost-free days
NFFD_sm	summer number of frost-free days
NFFD_at	autumn number of frost-free days
PAS_wt	winter precipitation as snow (mm)
PAS_sp	spring precipitation as snow (mm)
PAS_sm	summer precipitation as snow (mm)
PAS_at	autumn precipitation as snow (mm)
Eref_wt	winter Hargreaves reference evaporation (mm)
Eref_sp	spring Hargreaves reference evaporation (mm)
Eref_sm	summer Hargreaves reference evaporation (mm)
Eref_at	autumn Hargreaves reference evaporation (mm)
CMD_wt	winter Hargreaves climatic moisture deficit (mm)
CMD_sp	spring Hargreaves climatic moisture deficit (mm)
CMD_sm	summer Hargreaves climatic moisture deficit (mm)
CMD_at	autumn Hargreaves climatic moisture deficit (mm)
RH_wt	winter relative humidity (%)
RH_sp	spring relative humidity (%)
RH_sm	summer relative humidity (%)
RH_at	autumn relative humidity (%)
CMI_wt	winter Hogg's climate moisture index (mm)
CMI_sp	spring Hogg's climate moisture index (mm)
CMI_sm	summer Hogg's climate moisture index (mm)
CMI_at	autumn Hogg's climate moisture index (mm)

3) Monthly variables

Primary monthly variables:

Tave01 – Tave12	January - December mean temperatures (°C)
TMX01 – TMX12	January - December maximum mean temperatures (°C)
TMN01 – TMN12	January - December minimum mean temperatures (°C)
PPT01 – PPT12	January - December precipitation (mm)
RAD01 – RAD12	January - December solar radiation (MJ m ⁻² d ⁻¹)

Derived monthly variables:

DD_0_01 – DD_0_12	January - December degree-days below 0°C
DD5_01 – DD5_12	January - December degree-days above 5°C
DD_18_01 – DD_18_12	January - December degree-days below 18°C
DD18_01 – DD18_12	January - December degree-days above 18°C
NFFD01 – NFFD12	January - December number of frost-free days
PAS01 – PAS12	January – December precipitation as snow (mm)
Eref01 – Eref12	January – December Hargreaves reference evaporation (mm)
CMD01 – CMD12	January – December Hargreaves climatic moisture deficit (mm)
RH01 – RH12	January – December relative humidity (%)
CMI01 – CMI12	January – December Hogg’s climate moisture index (mm)

How to install

No installation is required. Simply unzip all the files and subfolders into a folder on your hard disk and double-click the file `ClimateNA_v6.**.exe`. The program does not on network drives.

How to use

1) Use the program interactively

Latitude and longitude can be entered in either decimal degrees (e.g. Lat: 51.542, Long: 129.333) or degree, minute and second (e.g., 51°30’15”N, 129°15’30’W). Longitude information is accepted either in positive or negative values. Elevation has to be entered in meters, or empty if no elevation data are available. If "Monthly variables", "Seasonal variables" or "All variables" output variables was selected, an additional output sheet appears and annual climate variables are still calculated.

Output data can be saved as a text file and imported to spreadsheet file using space-delimited option.

2) For multi-location process

- Most users will have their sample data information in an Excel spreadsheet or in a text file. To make it possible for the program to read this data it must first be modified to a standard format.
- Create a spreadsheet with the headers “ID1, ID2, lat, long, el” as shown in the example below. ID1 and ID2 can be “Location”, “Region” or whatever, but they cannot contain “;”. The file must have the title row and all variables in the same order as shown. If you don’t have elevation information or a second ID, you have to put in “.” in the columns. If you have more information columns in your original file, you have to remove them.
- If you use a GPS or GIS software to obtain your location information for many samples latitude values in the western hemisphere will be negative. For convenience, you can use either positive or negative values, and the program will automatically convert the data.

	A	B	C	D	E	F
1	ID1	ID2	lat	long	el	
2	site1	regon1	46.98	-113.02	1000	
3	site1	regon2	51.25	-115.55	550	
4						

- After the spreadsheet is prepared as shown, save it as “comma delimited text file” by choosing “Save as ...” from the file menu, and then specifying (*.csv) from the “Save as type ...” drop-down menu.
- You can also directly create a comma delimited text file in any text editor such as Notepad. If there is a missing value, you need to enter a “.” between two commas.

```

ID1, ID2, lat, long, el
site1, regon1, 46.98, -113.02, 1000
site1, regon2, 51.25, -115.55, 550

```

- Save this text file with a .csv extension by writing out the full file name with extension in parenthesis when saving, e. g. “test.csv” instead of test.csv or test.
- Now you are ready for processing: Click on **Select input file** to read your spreadsheet and on **Specify output file** to specify your output file folder and file. Then, click the **Start** button. Climate variable information will be appended as additional columns to your input file. If elevation information is provided the climate variables will be elevation adjusted.

3) For Time Series

Time Series function works only for the multi-location process. Here are the steps to follow:

1. Select “Time Series” (for historical years) or a future time series in the period section drop box;
2. Select a variable category (monthly, seasonal, annual or all variables);
3. Input the starting and ending years in the pop-up boxes;
4. Specify input and output files, and click the “Calculate TS” button.

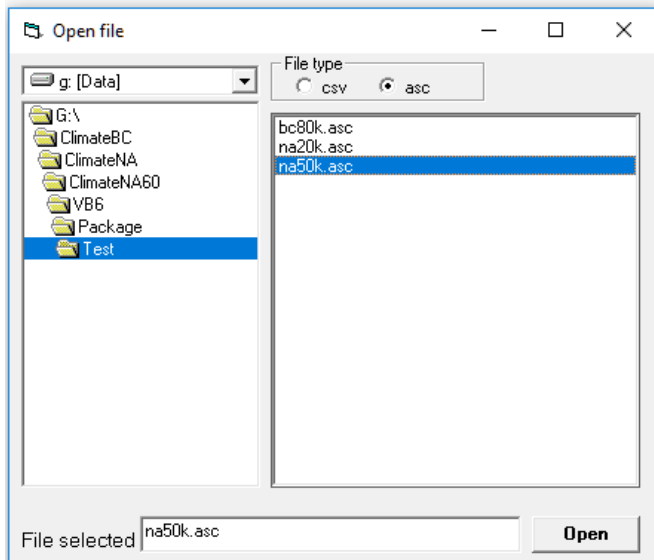
4) Read and output raster map files

1. Have a DEM raster file (*.asc) for the area of interest at the resolution you want. The

raster file is required to be in a latitude-longitude projection, prepared in ArcGIS or in R (QGIS format is not supported). Here is the R code to convert a raster in TIF to ASC:

```
Library(raster)
tif <- raster('C:/data/dem.tif')
NAvalue(tif) <- -9999
writeRaster(tif, 'C:/data/dem.asc', overwrite=True)
```

2. Click the “Select input file” button and a file open box will show up.
3. Navigate to the folder containing the raster file.
4. Select the File type: “asc” as shown in the following screenshot and only asc raster files will show up:



5. Select an asc input file and click “Open” button.
6. Click the “Specify output file” button, and a default folder will show up.
7. Click the “Save” button.
8. Click the “Start” button, and climate variables in ASCII raster format will be generated.
9. Projection: geographic coordinate system, GCS_WGS_1984
10. Data format: the following variables were multiplied by 10
 - Annual: MAT, MWMT, MCMT, TD, AHM, SHM, EMT, EXT and MAR;
 - Seasonal: Tmax, Tmin, Tave and Rad;
 - Monthly: Tmax, Tmin, Tave and Rad.

5) Process the raster output files

The output asc raster files can be directly imported (drag/drop) to ArcGIS or other GIS programs to generate maps. They can also be directly used in R to plot maps using the following code as an example:

```
Library(raster)
mat <- raster('C:/data/mat.asc')
plot(mat)
```

6) Tutorial videos

https://www.youtube.com/channel/UC6v_vfKWSZ_o05Ud-yscj7Q/video

How to refer

Wang T, Hamann A, Spittlehouse D, Carroll C (2016) Locally Downscaled and Spatially Customizable Climate Data for Historical and Future Periods for North America. PLoS ONE 11(6): e0156720. doi:10.1371/journal.pone.0156720

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