ClimateSA v1.99

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

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About this program

ClimateSA is a standalone MS Windows® application written in Visual Basic 6.0. It extracts and downscales climate data from built-in climate grids to estimate 75 climate variables for historical time periods (months, years, decades, and 30-year normal periods from 1901 to 2020), and for the future periods 2020s (2011-2040), 2050s (2041-2070) and 2080s (2071-2100), based on CMIP6 multi-model projections.

Climate variables generated by the software include monthly base variables (mean minimum, maximum and average temperature as well as precipitation). In addition, economically or biologically relevant variables such as growing and chilling degree days, heating and cooling degree days, precipitation as snow, number of frost free days, Hargrave's climate moisture deficit and reference evaporation, as well as seasonal variables.

The climate grids were developed with a deep neural network that uses geographic and atmospheric information to model local weather patterns at medium resolution. Subsequently, the ClimateSA software employs lapse-rate based dynamic downscaling to generate gridded data at high resolution, or to provide scale-free point estimates of climate variables for user-provided latitude, longitude and elevation coordinates.

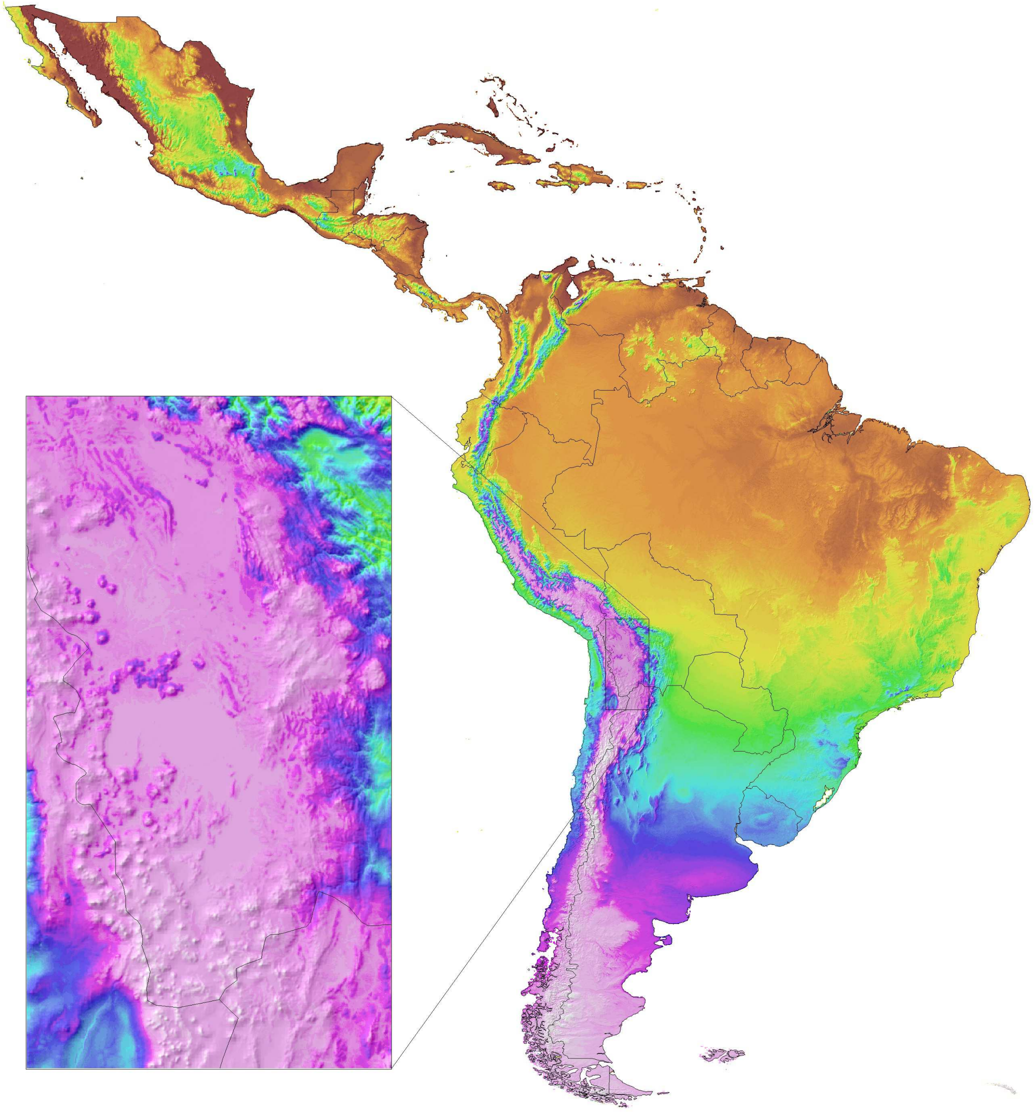


Figure 1. Extent of the ClimateSA data coverage. The example for mean coldest month temperature shows temperature inversions on the high plateaus of the Andes. Along elevation gradients of mountains centered on the plateau, temperature first rises (purple and blue shades on the base of the mountians) before lapse rates reverse towards colder conditions at the peak.

Climate variables predicted

1) **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),
DD<0 (DD_0)	degree-days below 0°C, chilling degree-days
DD>5 (DD5)	degree-days above 5°C, growing degree-days
DD<18 (DD_18)	degree-days below 18°C, heating degree-days
DD>18 (DD18)	degree-days above 18°C, cooling degree-days
NFFD	the number of frost-free days
PAS	precipitation as snow (mm) between January and December
EMT	extreme minimum temperature over 30 years
Eref	Hargreaves reference evaporation
CMD	Hargreaves climatic moisture deficit

2) Seasonal variables*

Three-month Seasons:

DJF	December-January-February
MAM	March-April-May
JJA	June-July-August
SON	September-October-November

Seasonally calculated variables:

Tmin	Average monthly minimum temperature (°C)
Tmax	Average monthly maximum temperature (°C)
Tave	Average monthly mean temperature (°C)
PPT / Prec	Total precipitation (mm)

3) Monthly variables*

Tmin01 ...12	Average monthly minimum temperature (°C)
Tmax01 …12	Average monthly maximum temperature (°C)
Tave01 …12	Average monthly mean temperature (°C)
PPT / Prec01 …12	Total precipitation (mm)

*) All monthly and seasonal variables are calculated as defined by the World Meteorological Organization (WMO). Temperature values are measured by minimum-maximum thermometers, and Tmin and Tmax for a month are the average of daily values for each month. Tave is the average of Tmin and Tmax for each month, and PPT is the total precipitation recorded in each month. Seasonal variables are calculated as the average of monthly variables for temperature and as the sum of monthly variables for precipitation.

Using the ClimateSA program

No installation is required for the software. Simply extract the downloaded zip file into a new folder. This folder should contain two files (“ClimateSA_v1.99.exe” and “Help.rtf”) and the three subfolders (“Baselinedat”, “Perioddat”, GCMdat”).   Start the program by double clicking the ClimateSA_v1.99.exe file.

1) Use the program interactively

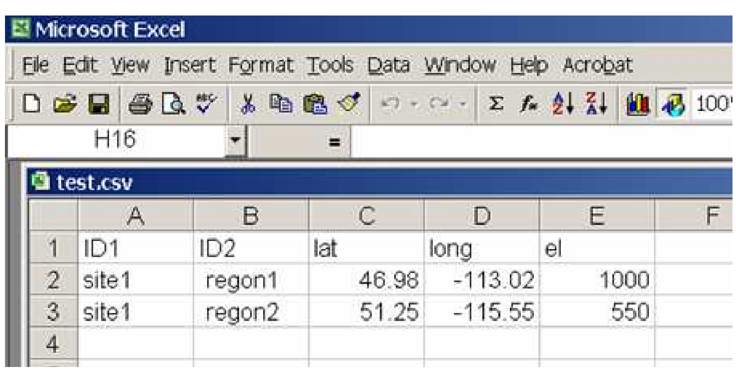
- Latitude and longitude can be entered in either decimal degrees (e.g. Lat: 51.542, Long: 129.333) or degree, minute and second (e.g., 51°30’15”N, 129°15’30’W). Longitude information is accepted either in positive or negative values. Elevation has to be entered in meters, or empty if no elevation data 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 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 be prepared in Comma Separated Values (CSV) format, and decimal point must be a period (.) not a comma.

- 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. It does not matter what variable names you choose, but the file **must** have the header row, and the variables **must** be in exactly the same order as shown below. If you don’t have elevation information or a second ID, you still need a variable header, you should put a period “.” in these columns. If you have more columns in your original file, you **must** remove them. Merge them back based on your IDs after the software is done with the data processing.

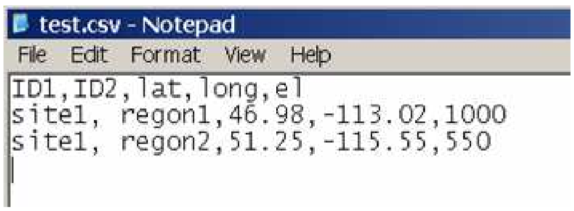


	A	B	C	D	E	F
1	ID1	ID2	lat	long	el	
2	site1	regon1	46.98	-113.02	1000	
3	site1	regon2	51.25	-115.55	550	
4						

- Also note that longitude values are read in decimal degrees, and western hemisphere longitudes and southern hemisphere latitude values must be negative. If you have your coordinates in degees, minutes (and seconds), you can apply the formual: DD+MM/60 (+SS/3600) to convert to decimal degrees in Excel.

- After the spreadsheet is prepared as shown, save it as “comma delimited text file” by choosing “Save as …” form 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.



- 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 [Calculate] 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.

R code to generate custom climate grids

- You can also generate your own custom climate grids with this handy R code. Find a digital elevation model in the projection and resolution that you prefer, and then clip it to your area of interest. From there, you create an input file and ID grid for later use:

```
library(terra)
dem <- rast("my_dem.tif")
aoi <- vect("my_area_of_interest.shp")

# harmonize projections as desired
aoi <- project(aoi, crs(dem))    # project aoi to dem crd system
# dem <- project(dem, crs(aoi))  # or other way around if desired
dem <- clip(dem, aoi)            # clip dem extent to aoi
dem <- mask(dem, aoi)            # mask dem by aoi

# write an ID raster in original coordinate system for later use
id_r <- dem; values(id_r) <- 1:ncell(dem);
names(id_r) <- "id"
writeRaster(id_r, "my_id.tif", overwrite=TRUE)
```

```
# create the columns required for the ClimateSA input file
land <- which(!is.na(values(dem)))
xy   <- crds(dem, df=TRUE)
elev <- values(dem)
pts  <- vect(xy[land,], geom=c("x","y"), crs=crs(dem))
xyll <- crds(project(pts, "EPSG:4326"), df=TRUE)

# write out the input file for the ClimateSA software
out <- data.frame(ID1=values(id_r)[land], ID2=0,
                  LAT=xyll$y, LONG=xyll$x, ELEV=elev[land])
write.csv(out, "my_input.csv", row.names=FALSE, na="")
```

- Now, run the input file through ClimateSA and then process the output file back into gridded climate data if you wish:

```
library(terra)
dt <- read.csv("my_output.csv")
dt[dt == -9999] <- NA
dt <- dt[complete.cases(dt), ]

id_r <- rast("my_id.tif")
vars <- setdiff(names(dt),
c("ID1","ID2","Latitude","Longitude","LAT","LONG"))
row_by_id <- match(values(id_r), dt$ID1)

dir.create("tiff_output", showWarnings=FALSE)

for (v in vars) {
  r <- setValues(id_r, dt[[v]][row_by_id])
  names(r) <- v
  writeRaster(r, file.path("tiff_output", paste0(v, ".tif")),
              overwrite=TRUE,
              gdal=c("COMPRESS=DEFLATE","ZLEVEL=9"))
}
```

References

Note that the ClimateSA package has not undergone peer-review in a journal yet. In the interim, reference like this: "*Climate data has been generated with the ClimateSA v1.99 software package, available at http://tinyurl.com/ClimateSA, based on methodology described by Namiiro et al. (2025) and Mahoney et al. (2022).*"

Namiiro, S., Hamann, A., Wang, T., Castellanos-Acuña, D. and Mahony, C.R., C. 2025. A high-resolution database of historical and future climate for Africa developed with deep neural networks. *Scientific Data* **11**: 1278, doi: 10.1038/s41597-025-05575-8.

Mahoney, C.R., Wang, T., Hamann, A., Cannon, A.J. 2022. A CMIP6 ensemble for downscaled monthly climate normals over North America. *International Journal of Climatology* **42**: 5871-5891.