CHELSA

Climatologies at High resolution for the Earth Land Surface Areas

CHELSA V2.1: Technical specification

Release Date: 24. 05. 2021

Document version: 1.3

Dirk Nikolaus Karger, Philipp Brun & Niklaus E. Zimmermann

Swiss Federal Research Institute WSL
Zürcherstrasse 111
CH-8903 Birmendorf
Switzerland

CHELSA: File Specification

Document maintained by Dirk Nikolaus Karger (WSL, dirk.karger@wsl.ch)

<u>CHELSA V.2.x</u> data should be cited as:

Scientific publication:

Karger, D.N., Conrad, O., Böhner, J., Kawohl, T., Kreft, H., Soria-Auza, R.W., Zimmermann, N.E., Linder, H.P. & Kessler, M. (2017) Climatologies at high resolution for the earth's land surface areas. *Scientific Data* 4, 170122. https://doi.org/10.1038/sdata.2017.122

Data citation:

Karger, D.N., Conrad, O., Böhner, J., Kawohl, T., Kreft, H., Soria-Auza, R.W., Zimmermann, N.E., Linder, H.P. & Kessler, M. (2021) Climatologies at high resolution for the earth's land surface areas. *EnviDat*. https://doi.org/ 10.16904/envidat.228.v2.1

Revision history

Version	Date	Changes
1.0	21.05.2021	Initial document
1.1	02.06.2021	Updated: Variable names
1.2	10.09.2021	Updated: Scale and offset
1.3	11.02.2022	Updated: New bioclim variables

Table of Contents

1. Introduction

High-resolution information on climatic conditions is essential to many applications in environmental and ecological sciences. The CHELSA (Climatologies at high resolution for the earth’s land surface areas) data (Karger et al. 2017) consists of downscaled model output temperature and precipitation estimates at a horizontal resolution of 30 arc sec. The temperature algorithm is mainly based on statistical downscaling of atmospheric temperatures. The precipitation algorithm incorporates orographic predictors including wind fields, valley exposition, and boundary layer height, with a subsequent bias correction. The resulting data consist of a monthly temperature and precipitation layers, and various derived variables.

As the CHELSA project is continuously expanded, certain new parameters, time scales etc. that are available now were not included in the original publication (Karger et al. 2017). We therefore provide this document as a guideline for the current climatic parameters available and will expand it as new parameters or time periods will become available. Please refer to the version history for changes made in the document.

Some of the parameter descriptions are different from those of the original publication (Karger et al. 2017), as we tried to keep as much of them consistent with CF naming conventions. Not all parameters, however, have a respective CF name.

2. CMIP6 ISIMIP3b

2.1 ISIMIP3b BA

CHELSA V2 is currently only available for a selected number of CMIP6 scenarios. Since the number of models and rcps has increased a lot from CMIP5 to CMIP6, we do not provide a full list of all possible GCM and SSP combinations at 1km resolution anymore. We rather opted for an approach of preselecting GCMs and SSP. The selection follows the models given for the Intersectoral Impact Model Intercomparion Project (ISIMIP). Before downscaling to 1km the models have been bias corrected using a trend-preserving bias correction following (Lange 2019). GCM selection follow that of ISIMIP3b documented here: https://www.isimip.org/documents/413/ISIMIP3b_bias_adjustment_fact_sheet_gWHNhgH.pdf

The priority of the model is given following ISIMIP3b. If less than five models are used, GCMs selection should follow the priority with priority=1 equals highest priority, and priority=5 equals lowest priority.

Some of the models show spatial interpolation artefacts from the statistical downscaling employed in ISIMIP3b_BA. These artefacts are an effect of the statistical downscaling in ISIMIP3b_BA, not from CHELSA, and therefore we cannot remove them.

For a total selection of all possible GCM and scenario combinations for various timeperiods, we provide the chelsa_cmip6 python package available here: https://gitlabext.wsl.ch/karger/chelsa_cmip6

Table 3.1 Climate Scenario Specifiers

Scenario specifier	Description
ssp126	SSP1-RCP2.6 climate as simulated by the GCMs.
ssp370	SSP3-RCP7 climate as simulated by the GCMs.
ssp585	SSP5-RCP8.5 climate as simulated by the GCMs.

Table 3.2. Climate forcing data and source for the CHELSA CMIP6 ISIMIP3 data. The priority of models follows the suggestions of the ISIMIP3b protocol.

title	model	institution	native resolution	ensemble member	priority
GFDL-ESM4	gfdl-esm4	National Oceanic and Atmospheric Administration, Geophysical Fluid Dynamics Laboratory, Princeton, NJ 08540, USA	288x180	r1i1p1f1	1
UKESM1-0-LL	ukesm1-0-ll	Met Office Hadley Centre, Fitzroy Road, Exeter, Devon, EX1 3PB, UK	192x144	r1i1p1f2	2
MPI-ESM1-2-HR	mpi-esm1-2-hr	Max Planck Institute for Meteorology, Hamburg 20146, Germany	384x192	r1i1p1f1	3
IPSL-CM6A-LR	ipsl-cm6a-lr	Institut Pierre Simon Laplace, Paris 75252, France	144x143	r1i1p1f1	4
MRI-ESM2-0	mri-esm2-0	Meteorological Research Institute, Tsukuba, Ibaraki 305-0052, Japan	320x160	r1i1p1f1	5

3. Format and File Organization

All files are provided as georeferenced tiff files (GeoTIFF). GeoTIFF is a public domain metadata standard which allows georeferencing information to be embedded within a TIFF file. Additional information included in the file are: map projection, coordinate systems, ellipsoids, datums, and fill values.

All GeoTIFF files are saved as integer with a compression = deflate, predictor = 2, and an internal scale and offset in case of continuous variables. Scale and offset are internally stored in the GeoTIFF files and are supported by GDAL Version 2.3 or higher. In some cases, problems have been reported using older versions of GDAL or ArcGIS. In this case the scale and offset has to be set manually for the variables.

GeoTIFF can be viewed using standard GIS software such as:

SAGA GIS – (free) http://www.saga-gis.org/

ArcGIS - https://www.arcgis.com/

QGIS - (free) www.qgis.org

DIVA – GIS - (free) http://www.diva-gis.org/

GRASS – GIS - (free) https://grass.osgeo.org/

3.1 Dimensions

All CHELSA files contain a variable that define the dimensions of longitude and latitude. The time variable is usually encoded in the filename.

Table 3.1. Dimension Variables

Name	Description	type	Attribute
longitude	Longitude	double	degrees_east
latitude	Latitude	double	degrees_north
variable	variable	int	variable

3.2 Variables

All variables of CHELSA are time-averaged and contain either daily, monthly, or annual means, but not mixtures of these. Instantaneous parameters are not provided. Monthly time-averaged are files usually based on means of synoptic hours. Monthly files represent averages for the calendar months, accounting for leap years. For monthly means, each file contains a single month. For annual means or accumulations, files contain a single year. For climatological values, a file contains the means of a given period (e.g. 1981-2010).

4. Grid Structure

All global CHELSA products are in a geographic coordinate system referenced to the WGS 84 horizontal datum, with the horizontal coordinates expressed in decimal degrees. The CHELSA layer extents (minimum and maximum latitude and longitude) are a result of the coordinate system inherited from the 1-arc-second GMTED2010 data which itself inherited the grid extent from the 1-arc-second SRTM data.

Grid extent:

Attribute		value
Resolution		0.0083333333
West extent (minimum X-coordinate, longitude):		−180.0001388888
South extent (minimum Y-coordinate, latitude)		−90.0001388888
East extent (maximum X-coordinate, longitude)		179.9998611111
North extent (maximum Y-coordinate, latitude)		83.9998611111
Rows		20,800
Columns		43,200

Note that because of the pixel center referencing of the input GMTED2010 data the full extent of each CHELSA grid as defined by the outside edges of the pixels differs from an integer value of latitude or longitude by 0.000138888888 degree (or 1/2 arc-second). Users of products based on the legacy GTOPO30 product should note that the coordinate referencing of CHELSA (and GMTED2010) and GTOPO30 are not the same. In GTOPO30, the integer lines of latitude and longitude fall directly on the edges of a 30-arc-second pixel. Thus, when overlaying CHELSA with products based on GTOPO30 a slight shift of 1/2 arc-second will be observed between the edges of corresponding 30-arc-second pixels.

5. File Naming Conventions

The filename of each CHELSA data product follows a similar structure including the respective model used, the variable short name, the respective time variables, and the accumulation (or mean) period in the following basic format:

CHELSA_[short_name]_[timeperiod]_[Version].tif

For CMIP6 data:

CHELSA_[short_name]_[timeperiod]_[model] _[ssp] _[Version].tif

6. Changes between version 1 and 2

- Shift from ERA-Interim to ERA5 as forcing data.
- Version 2 uses a temperature lapse rate based on the 950 and 850 hPa pressure level from the ERA5 reanalysis atmospheric temperature instead of estimating the temperature lapse rate through the entire atmosphere.
- Version 2 uses an improved bias correction for precipitation that wraps around the dateline. Precipitation is also bias corrected for systematic gauge undercatch using (Beck et al. 2020).
- All variables are saved as integers with a given offset and scale embedded in the geotiff file to arrive at e.g. Celsius or kg m^-2 (mm) (only for climatologies).

7. Variable Names

Table 7.1 gives the variable short names, longnames, units, scale, offsets, and explanations. Scale and offset are internally stored in the GeoTIFF files and are supported by GDAL Version 2.3 or higher. In some cases, problems have been reported using older versions of GDAL or ArcGIS. In this case the scale and offset has to be set manually for the variables. This can be done by first multiplying the raster values with the 'scale' value and then adding the 'offset' value.

7.1. Climatologies

shortname	longname	unit	scale	offset	explanation
bio1	mean annual air temperature	°C	0.1	-273.15	mean annual daily mean air temperatures averaged over 1 year
bio2	mean diurnal air temperature range	°C	0.1	0	mean diurnal range of temperatures averaged over 1 year
bio3	isothermality	°C	0.1	0	ratio of diurnal variation to annual variation in temperatures
bio4	temperature seasonality	°C/100	0.1	0	standard deviation of the monthly mean temperatures
bio5	mean daily maximum air temperature of the warmest month	°C	0.1	-273.15	The highest temperature of any monthly daily mean maximum temperature
bio6	mean daily minimum air temperature of the coldest month	°C	0.1	-273.15	The lowest temperature of any monthly daily mean maximum temperature
bio7	annual range of air temperature	°C	0.1	0	The difference between the Maximum Temperature of Warmest month and the Minimum Temperature of Coldest month

bio8	mean daily mean air temperatures of the wettest quarter	°C	0.1	-273.15	The wettest quarter of the year is determined (to the nearest month)
bio9	mean daily mean air temperatures of the driest quarter	°C	0.1	-273.15	The driest quarter of the year is determined (to the nearest month)
bio10	mean daily mean air temperatures of the warmest quarter	°C	0.1	-273.15	The warmest quarter of the year is determined (to the nearest month)
bio11	mean daily mean air temperatures of the coldest quarter	°C	0.1	-273.15	The coldest quarter of the year is determined (to the nearest month)
bio12	annual precipitation amount	kg m^{-2} $year^{-1}$	0.1	0	Accumulated precipitation amount over 1 year
bio13	precipitation amount of the wettest month	kg m^{-2} $month^{-1}$	0.1	0	The precipitation of the wettest month.
bio14	precipitation amount of the driest month	kg m^{-2} $month^{-1}$	0.1	0	The precipitation of the driest month.
bio15	precipitation seasonality	kg m^{-2}	0.1	0	The Coefficient of Variation is the standard deviation of the monthly precipitation estimates expressed as a percentage of the mean of those estimates (i.e. the annual mean)
bio16	mean monthly precipitation amount of the wettest quarter	kg m^{-2} $month^{-1}$	0.1	0	The wettest quarter of the year is determined (to the nearest month)
bio17	mean monthly precipitation amount of the driest quarter	kg m^{-2} $month^{-1}$	0.1	0	The driest quarter of the year is determined (to the nearest month)
bio18	mean monthly precipitation amount of the warmest quarter	kg m^{-2} $month^{-1}$	0.1	0	The warmest quarter of the year is determined (to the nearest month)
bio19	mean monthly precipitation amount of the coldest quarter	kg m^{-2} $month^{-1}$	0.1	0	The coldest quarter of the year is determined (to the nearest month)
cmi_max	Maximum monthly climate moisture index	kg m^{-2} $month^{-1}$	0.1	0	The climate moisture index of the month with the highest precipitation surplus

cmi_mean	Mean monthly climate moisture index	kg m^{-2} $month^{-1}$	0.1	0	Average monthly climate moisture index over 1 year
cmi_min	Minimum monthly climate moisture index	kg m^{-2} $month^{-1}$	0.1	0	The climate moisture index of the month with the highest precipitation deficit
cmi_range	Annual range of monthly climate moisture index	kg m^{-2} $month^{-1}$	0.1	0	Difference between maximum and minimum monthly climate moisture index
cmi_01, …, cmi_12	Monthly climate moisture indicies	kg m^{-2} $month^{-1}$	0.1	0	Climate moisture indices for each month
fcf	Frost change frequency	count	-	-	Number of events in which tmin or tmax go above, or below 0°C
fgd	first day of the growing season TREELIM	julian day	-	-	first day of the growing season according to TREELIM (https://doi.org/10.1007/s00035-014-0124-0)
gdd0	Growing degree days heat sum above 0°C	°C	0.1	0	heat sum of all days above the 0°C temperature accumulated over 1 year.
gdd5	Growing degree days heat sum above 5°C	°C	0.1	0	heat sum of all days above the 5°C temperature accumulated over 1 year.
gdd10	Growing degree days heat sum above 10°C	°C	0.1	0	heat sum of all days above the 10°C temperature accumulated over 1 year.
gddlgd0	Last growing degree day above 0°C	julian day	-	-	Last day of the year above 0°C
gddlgd5	Last growing degree day above 5°C	julian day	-	-	Last day of the year above 5°C
gddlgd10	Last growing degree day above 10°C	julian day	-	-	Last day of the year above 10°C
gdgfgd0	First growing degree day above 0°C	julian day	-	-	First day of the year above 0°C
gdgfgd5	First growing degree day above 5°C	julian day	-	-	First day of the year above 5°C
gdgfgd10	First growing degree day above 10°C	julian day	-	-	First day of the year above 10°C
gsl	growing season length TREELIM	number of days	-	-	Length of the growing season
gsp	Accumulated precipitation amount on	kg m^{-2} gsl^{-1}	0.1	0	precipitation sum accumulated on all days during the growing season based on TREELIM

	growing season days TREELIM				(https://doi.org/10.1007/s00035-014-0124-0)
gst	Mean temperature of the growing season TREELIM	°C	0.1	-273.15	Mean temperature of all growing season days based on TREELIM (https://doi.org/10.1007/s00035-014-0124-0)
hurs_max	Maximum monthly near-surface relative humidity	%	0.01	0	The highest monthly near-surface relative humidity
hurs_mean	Mean monthly near-surface relative humidity	%	0.01	0	Average monthly near-surface relative humidity over 1 year
hurs_min	Minimum monthly near-surface relative humidity	%	0.01	0	The lowest monthly near-surface relative humidity
hurs_range	Annual range of monthly near-surface relative humidity	%	0.01	0	Difference between maximum and minimum near-surface relative humidity
hurs_01, …, hurs_12	Monthly near-surface relative humidity	%	0.01	0	Near-surface relative humidity for each month
kg0	Köppen-Geiger climate classification	category	-	-	Köppen Geiger Koeppen, W., Geiger, R. (1936): Handbuch der Klimatologie. Gebrüder Borntraeger, Berlin. Wikimedia.
kg1	Köppen-Geiger climate classification	category	-	-	Köppen Geiger without As/Aw differentiation Koeppen, W., Geiger, R. (1936): Handbuch der Klimatologie. Gebrüder Borntraeger, Berlin. Wikimedia.
kg2	Köppen-Geiger climate classification	category	-	-	Köppen Geiger after Peel et al. 2007 Peel, M. C., Finlayson, B. L., McMahon, T. A. (2007): Updated world map of the Koeppen-Geiger climate classification. Hydrology and earth system sciences discussions, 4(2), 439-473. Free Access.
kg3	Köppen-Geiger climate classification	category	-	-	Wissmann 1939 Wissmann, H. (1939): Die Klima- und Vegetationsgebiete Eurasiens:

					Begleitworte zu einer Karte der Klimagebiete Eurasiens. Z. Ges. Erdk. Berlin, p.81-92.
kg4	Köppen-Geiger climate classification	category	-	-	Thornthwaite 1931 Thornthwaite, C. W. (1931): The climates of North America: according to a new classification. Geographical review, 21(4), 633-655. JSTOR.
kg5	Köppen-Geiger climate classification	category	-	-	Troll-Pfaffen Troll, C. & Paffen, K.H. (1964): Karte der Jahreszeitenklimate der Erde. Erdkunde 18, p5-28 Free Access.
lgd	last day of the growing season TREELIM	julian day	-	-	Last day of the growing season according to TREELIM (https://doi.org/10.1007/s00035-014-0124-0)
ngd0	Number of growing degree days	number of days	-	-	Number of days at which tas > 0°C
ngd5	Number of growing degree days	number of days	-	-	Number of days at which tas > 5°C
ngd10	Number of growing degree days	number of days	-	-	Number of days at which tas > 10°C
npp	Net primary productivity	g C m^{-2} yr^{-1}	0.1	0	Calculated based on the ‘Miami model’, Lieth, H., 1972. "Modelling the primary productivity of the earth. Nature and resources", UNESCO, VIII, 2:5-10.
pet_penman_max	Maximum monthly potential evapotranspiration	kg m^{-2} $month^{-1}$	0.01	0	The highest monthly potential evaporation; calculated with the Penman-Monteith equation.
pet_penman_mean	Mean monthly potential evapotranspiration	kg m^{-2} $month^{-1}$	0.01	0	Average monthly potential evaporation over 1 year; calculated with the Penman-Monteith equation.
pet_penman_min	Minimum monthly potential evapotranspiration	kg m^{-2} $month^{-1}$	0.01	0	The lowest monthly potential evaporation; calculated with the Penman-Monteith equation.
pet_penman_range	Annual range of monthly potential evapotranspiration	kg m^{-2}	0.01	0	Difference between maximum and minimum monthly potential evapotranspiration; calculated with the Penman-Monteith equation

pet_penman_01, …, pet_penman_12	Monthly potential evapotranspiration	kg m^{-2} $month^{-1}$	0.01	0	Potential evapotranspiration for each month; calculated with the Penman-Monteith equation
pr_01, …, pr_12	Monthly precipitation amount	kg m^{-2} $month^{-1}$	0.1	0	Precipitation amount for each month; "Amount" means mass per unit area. "Precipitation" in the Earth's atmosphere means precipitation of water in all phases.
rsds_max	Maximum monthly surface downwelling shortwave flux in air	MJ m^{-2} d^{-1}	0.001	0	The highest monthly surface downwelling shortwave flux in air
rsds_mean	Mean monthly surface downwelling shortwave flux in air	MJ m^{-2} d^{-1}	0.001	0	Average monthly surface downwelling shortwave flux in air over 1 year
rsds_min	Minimum monthly surface downwelling shortwave flux in air	MJ m^{-2} d^{-1}	0.001	0	The lowest monthly surface downwelling shortwave flux in air
rsds_range	Annual range of monthly surface downwelling shortwave flux in air	MJ m^{-2} d^{-1}	0.001	0	Difference between maximum and minimum monthly surface downwelling shortwave flux in air
rsds_01, …, rsds_12	Monthly potential evapotranspiration	MJ m^{-2} d^{-1}	0.001	0	Potential evapotranspiration for each month; calculated with the Penman-Monteith equation
scd	Snow cover days	count	-	-	Number of days with snowcover calculated using the snowpack model implementation in from TREELIM (https://doi.org/10.1007/s00035-014-0124-0)
sfcWind_max	Maximum monthly near-surface wind speed	m s^{-1}	0.001	0	The highest monthly near-surface wind speed; near surface represents 10 m above ground.
sfcWind_mean	Mean monthly near-surface wind speed	m s^{-1}	0.001	0	Average monthly near-surface wind speed over 1 year; near surface represents 10 m above ground.
sfcWind_min	Minimum monthly near-surface wind speed	m s^{-1}	0.001	0	The lowest monthly near-surface wind speed; near surface represents 10 m above ground.
sfcWind_range	Annual range of monthly near-	m s^{-1}	0.001	0	Difference between maximum and minimum monthly near-surface wind

	surface wind speed				speed; near surface represents 10 m above ground.
sfcWind_01, …, sfcWind_12	Monthly near-surface wind speed	m s^{-1}	0.001	0	Near-surface wind speed for each month; near surface represents 10 m above ground.
swe	Snow water equivalent	kg m^{-2} $year^{-1}$	0.1	0	Amount of luquid water if snow is melted
tasmax_01, …, tasmax_12	Mean daily maximum 2m air temperature	°C	0.1	-273.15	Daily maximum air temperature at 2 metres from hourly ERA5 data for each month
tas_01, …, tas_12	Mean daily air temperature	°C	0.1	-273.15	Daily mean air temperature at 2 metres from hourly ERA5 data for each month
tasmin_01, …, tasmin_12	Mean daily minimum air temperature	°C	0.1	-273.15	daily minimum air temperature at 2 metres from hourly ERA5 data for each month
tcc_max	Maximum monthly total cloud cover	%	0.01	0	The highest percentage of monthly total cloud cover
tcc_mean	Mean monthly total cloud cover	%	0.01	0	Average monthly total cloud cover over 1 year
tcc_min	Minimum monthly total cloud cover	%	0.01	0	The lowest percentage of monthly total cloud cover
tcc_range	Annual range of monthly total cloud cover	%	0.01	0	Difference between maximum and minimum monthly total cloud cover
tcc_01, …, tcc_12	Monthly total cloud cover	%	0.01	0	Total cloud cover for each month
vpd_max	Maximum monthly vapor pressure deficit	Pa	0.1	0	The highest monthly vapor pressure deficit
vpd_mean	Mean monthly vapor pressure deficit	Pa	0.1	0	Average monthly vapor pressure deficit over 1 year
vpd_min	Minimum monthly vapor pressure deficit	Pa	0.1	0	The lowest monthly vapor pressure deficit
vpd_range	Annual range of monthly vapor pressure deficit	Pa	0.1	0	Difference between maximum and minimum monthly vapor pressure deficit
vpd_01, …, vpd_12	Monthly vapor pressure deficit	Pa	0.1	0	Vapor pressure deficit for each month

7.2. Monthly

shortname	longname	unit	scale	offset	explanation
cmi	Climate moisture index	kg m^{-2} $month^{-1}$	0.1	0	Climate moisture index is the difference between precipitation

					amount and potential evapotranspiration
hurs	Near-surface relative humidity	%	0.01	0	
pet_penman	Potential evapotranspiration	kg m^{-2} $month^{-1}$	0.01	0	Calculated with the Penman-Monteith equation.
pr	Precipitation amount	kg m^{-2} $month^{-1}$/100	-	-	"Amount" means mass per unit area. "Precipitation" in the earth's atmosphere means precipitation of water in all phases.
rsds	Surface downwelling shortwave flux in air	MJ m^{-2} d^{-1}	0.001	0	Attenuating effects of clouds are accounted for
sfcWind	Near-surface wind speed	m s^{-1}	0.001	0	Near surface represents 10 m above ground.
tasmax	Mean daily maximum 2m air temperature	K/10	-	-	Daily maximum air temperatures at 2 metres from hourly ERA5 data
tas	Mean daily air temperature	K/10	-	-	Daily mean air temperatures at 2 metres from hourly ERA5 data
tasmin	Mean daily minimum air temperature	K/10	-	-	Daily minimum air temperatures at 2 metres from hourly ERA5 data
tcc	Total cloud cover	%	0.01	0	Considers clouds across the entire atmospheric column
vpd	Vapor pressure deficit	Pa	0.1	0	