CHELSA V1.2: Technical specification

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Climatologies at High resolution for the Earth Land Surface Areas

CHELSA V1.2: Technical specification

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CHELSA: File Specification

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CHELSAcmip5_timeseries

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Revision history

Version	Date	Changes
1.0	15.04.2019	Initial document
1.1	15.04.2019	Added solar radiation calculation

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 data and various derived parameters.

As the CHELSA project is continuously expanded, certain new parameters, time scales etc. are not included anymore in the original publication (Karger et al. 2017). We are therefore provide this document as a guideline of 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. Methods

2.1. Mean daily air temperature

For our downscaling approach of mean monthly temperatures, we used the monthly means of daily mean temperature derived from six-hourly synoptic data from ERA-Interim. Temperature lapse rates were calculated from the ERA-Interim for pressure levels from 1000 hPa to 300 hPa, using linear regression for each ERA-Interim grid cell. We then interpolated temperature to sea level using the derived lapse rates. Sea level temperatures were then interpolated between grid cells using B-spline interpolation, and then projected back on the elevational surface of the digital elevation model using the equation:

$$t = \Gamma_d * elev + t_0$$

where t equals the temperature at a given elevation, Γ_d equals the lapse rate, *elev* equals elevation at 30 arc sec. from the Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010)(Danielson and Gesch 2011) of the United States Geological Survey (USGS) and the National Geospatial-Intelligence Agency (NGA), and t_0 equals the interpolated temperature at sea level.

2.2 Mean daily maximum and minimum temperatures

Maximum (t_{max}) and minimum (t_{min}) temperatures were calculated using climatological aided interpolation. For that we used the mean monthly temperature values (t) and added, or subtracted the maximum or minimum daily temperature derived from the three-hourly data of minimum or maximum temperature since previous post processing data fields in ERA-Interim (Dee 2011):

$$t_{max} = t + \Delta t_{era\_max}$$

$$t_{min} = t - \Delta t_{era\_min}$$

where Δt_{era_max} and Δt_{era_min} are the respective differences between maximum and minimum temperatures interpolated to 30 arc sec resolution using B-spline interpolation from the mean monthly temperatures (t).

2.3. Surface temperatures

Land surface temperatures (lst) are calculated based on the SRAD model (Wilson and Gallant 2000) using:

$$lst = t - \Gamma_d(z_h - z_c) + C(S\frac{1}{S})(1\frac{0.1}{8})$$

where z_h is the elevation of high resolution grid, z_c is the elevation of the coarse grid, t is the temperature grid (monthly mean daily minimum -, monthly mean daily maximum -, or monthly mean daily mean air temperature), Γ_d is the monthly mean daily temperature lapse rate, C is a constant (currently set to 1.0), S is the short wave radiation ratio (short-wave irradiance on horizontal and sloping surfaces).

2.4 Precipitation amount

We used u-wind and v-wind components at the 10-m level of ERA-Interim as underlying wind components. These two wind components were interpolated to the CHELSA grid resolution using a B-spline interpolation. As the calculation of a windward leeward index (hereafter: wind effect) requires a projected coordinate system, both wind components were projected to a world Mercator projection and then combined to a directional grid. The wind effect H with windward component H_W and the leeward component H_L were then calculated using:

$$H_{\mathrm{W}} = \frac{\sum_{i=1}^{n} \frac{1}{d_{\mathrm{WH}i}} tan^{-1}\left(\frac{d_{\mathrm{WZ}i}}{d_{\mathrm{WH}i}}\right)}{\sum_{i=1}^{n} \frac{1}{d_{\mathrm{LH}i}}} + \frac{\sum_{i=1}^{n} \frac{1}{d_{\mathrm{LH}i}} tan^{-1}\left(\frac{d_{\mathrm{LZ}i}}{d_{\mathrm{LH}i}}\right)}{\sum_{i=1}^{n} \frac{1}{d_{\mathrm{LH}i}}}$$

$$H_{\mathrm{L}} = \frac{\sum_{i=1}^{n} \frac{1}{d_{\mathrm{WH}i}} tan^{-1}\left(\frac{d_{\mathrm{LZ}i}}{d_{\mathrm{WH}i}}\right)}{\sum_{i=1}^{n} \frac{1}{d_{\mathrm{LH}i}}}$$

where $d_{\mathrm{WH}i}$ and $d_{\mathrm{LH}i}$ refer to the horizontal distances in windward and leeward direction and $d_{\mathrm{WZ}i}$ and $d_{\mathrm{LZ}i}$ are the corresponding vertical distances compared with the considered raster cell. The second summand in the equation for H_W accounts for the leeward impact of previously traversed mountain chains. The horizontal distances in the equation for H_L lead to a longer-distance impact of leeward rain shadow. The final wind-effect parameter, which is assumed to be related to the interaction of the large-scale wind field and the local-scale precipitation characteristics, is calculated as $H = H_{\mathrm{L}} \times H_{\mathrm{W}}$ and generally takes values between 0.7 for leeward and 1.3 for windward positions. Both equations were applied to each grid cell at the CHELSA resolution in a World Mercator projection.

Although the wind effect algorithm can distinguish between the windward and leeward sites of an orographic barrier, it cannot distinguish extremely isolated valleys in high mountain areas. Such dry valleys are situated in areas where the wet air masses flow over an orographic barrier and are prevented from flowing into deep valleys. To account for these effects, we used a variant of the windward leeward equations with a linear search distance of 300 km in steps of 5° from 0° to 355° circular for each grid cell. The calculated leeward index was then scaled towards higher elevations using:

$$E = H_L^{\frac{elev}{c}}$$

which rescales the strength of the exposition index relative to elevation (*elev*) from GMTED2010, and gives valleys at high elevations larger wind isolations (*E*) than valleys located at low elevations. The correction constant *c* was set to 9000 m to include all possible elevations of the DEM. The constant has been set to 9000 m as values of $elev > c$ could lead to a reverse relationship between *elev* and H_L.

We used the boundary layer height *B* from ERA-Interim as indicator of the pressure level that has the highest contribution to the wind effect. The boundary layer height has been interpolated to the CHELSA resolution using a B-spline interpolation. The wind effect grid *H* containing the windward (H_W) and leeward (H_L) index values was then proportionally distributed to all grid cells falling within a respective 0.75° grid cell using:

$$H_{WB} = \frac{H_W}{1 - \left(\frac{|d| - d_{max}}{c}\right)}$$

$$H_{LB} = \frac{H_L}{1 - \left(\frac{|d| - d_{max}}{c}\right)}$$

with:

$$d = elev - B$$

With *d* being the distance between a grid cell and the boundary layer height *B*, d_{max} being the maximum distance between the boundary layer height *B* and all grid cells at the CHELSA resolution falling within a respective 0.75° grid cell, *c* being a constant of 9000 m, and *elev* being the respective elevation from GMTED2010 with:

$$B = B_{ERA} + elev_{ERA} + f$$

B being the height of the monthly means of daily mean boundary layer from ERA-Interim, $elev_{ERA}$ being the elevation of the ERA-Interim grid cell, and *f* being a constant of 500 m which takes into account that the level of highest precipitation is not necessarily at the lower bound of the boundary layer, but slightly higher.

2.5. Monthly precipitation timeseries

For accumulated parameters (total monthly precipitation), we used the monthly means of daily forecast accumulations of total precipitation initialized at the synoptic hours 0:00 and 12:00. To calculate monthly precipitation sums, we added the synoptic monthly means at time 0:00, step 12 and time 12:00, step 12 and multiplied it by the number of days in the respective month.

Model-generated estimates of the surface precipitation are extracted from short range forecasts, which vary with forecast length. This drift in the short-range forecasts can be a problem for monthly and climatic means. One very common approach is to calculate the difference between baseline precipitation from the GCM and the observed precipitation and apply this ‘factor of change’ to historically observed time series to generate a synthetic time series. We therefore performed three steps of bias correction.

We applied the monthly bias correction before the downscaling of the precipitation data on the ERA-interim precipitation values p_{ERA} directly. To this end, we used the monthly values p_{GPCC} of the gridded GPCC dataset(Schneider et al. 2013) to calculate the monthly bias R_m caused by the ERA-Interim parametrization, and the excessive or insufficient precipitation of the forecast algorithm for each month from Jan. 1979 – Dec. 2013 using:

$$R_m = \frac{p_{GPCC}}{p_{ERA}}$$

We only used grid cells with meterological stations present for R_m. The forecast algorithm used to produce the precipitation amounts for ERA-Interim exhibits a considerable spin up – spin down effect (too much or too less precipitation), that has a coherent spatial structure, with a larger bias over high elevation terrain, or specific land forms such as tropical rainforests(Kållberg 2011). Based on this observation, we assumed that grid cells without stations share a similar bias as their neighboring stations. To achieve a gap-free grid surface, we interpolated the gaps in the R_m grid using a multilevel B-spline interpolation with 14 error levels to a 0.75° resolution. The gap-free bias correction surface R_m was then multiplied with the ERA-Interim precipitation p_{ERA} to get the bias corrected monthly precipitation sums p_m at 0.75° resolution:

$$p_m = p_{ERA} * R_m$$

To achieve the distribution of monthly precipitation sums p including orographic effects, we used a linear relationship between the monthly bias corrected precipitation grids at the ERA resolution p_m and the boundary layer corrected wind effect surface H:

$$p = \frac{H}{\overline{\overline{H}}} * p_m$$

where $\overline{H}$ is the mean wind effect at ERA resolution. By using a linear relationship we archive that the data are to scale, e.g. the precipitation at 0.75° resolution exactly matches the mean precipitation at all 30°sec cells within the range of a 0.75° cell.

We used precipitation from a set of meteorological stations from GHCN, MeteoSwiss, and DWD to correct the remaining error between p and p_{Station}. We calculated the bias ratio between p and $p_{Station}$ and interpolated the bias ratio using a multilevel B-spline interpolation with 14 error levels to a 0.1° grid which matches the spatial accuracy of many GHCN stations. The resulting bias surface was then multiplied with p to achieve the final monthly precipitation estimates.

2.6 Monthly precipitation climatologies

We calculated the climatologies as the mean monthly sum of precipitation in the years 1979-2013 for each month. As slight errors in the precipitation sums can, however, accumulate over time, we applied an additional bias correction step using the GPCC Climatology Version 2015(Meyer-Christoffer et al. in press). We used the cells at which stations are present, calculated the bias between the annual accumulations and the GPCC climatology, and used a multilevel B-spline interpolation of the biases to a 0.25 grid to create the bias surface. This bias surface was then multiplied with the mean annual precipitation sums to create the final climatologies.

2.7 Relative Humidity

Relative humidity has been downscaled using relative humidity at the .75 resolution $RH_{.75}$ data from ERA interim for all available pressure levels. Vertical downscaling has been archived by spline interpolation of RH with geopotential height $Z_{.75}$.

$$S(RH_{.75}\ ,Z_{\ .75}\ )$$

This function has then been logit transformed to account for the bounded distribution of *RH* using:

$$y = log\frac{S(RH,Z)}{1 - S(RH,Z)}$$

Cloud cover has then been included by using cloud cover at the high resolution $cf_{.0083}$ and the mean of cloud cover at the coarse resolution $cf_{.75}$:

$$rh = y * \frac{cf_{.0083} + (cf_{.75} - cf_{.0083}) * (1 - cf_{.75})}{cf_{.75}}$$

The resulting values have then back transformed to achieve RH at the .0083 resolution.

$$RH_{.0083} = \frac{exp(rh)}{1 + exp(rh)}$$

2.8 Bioclimatic parameters

From the monthly temperature and precipitation values, we additionally calculated a set of derived parameters often used in ecological applications. These bioclimatic variables are derived variables from the monthly mean, min, max, mean temperature, and mean precipitation values. These variables are specifically developed for species distribution modelling and related ecological applications. They represent annual averages (e.g., mean annual temperature, annual precipitation), seasonality (e.g., annual range in temperature and precipitation), and extreme or limiting environmental factors (e.g., temperature of the coldest and warmest month, and precipitation of the wet and dry quarters). A quarter is defined as the period of three months (1/4 of the year). The procedure strictly followed that of ANUCLIM(Xu and Hutchinson 2013). The equations used to calculate the bioclimatic variables (where applicable) are:

t = mean daily air temperature
t_{max} = mean daily maximum air temperature
t_{min} = mean daily minimum air temperature
p = monthly precipitation amount

$$\text{bio1} = (\textstyle\sum_{i=1}^{12} t_i)/12$$

$$\text{bio2} = (\textstyle\sum_{i=1}^{12}(t_{max} - t_{min}))/12$$

$$\text{bio3} = (t * (t_{max} - t_{min})/\ t_{max} - t_{min}) * 100$$

$$\text{bio4} = (\sqrt{\tfrac{1}{11}\textstyle\sum_{i=1}^{12}(t_i -}(\textstyle\sum_{i=1}^{12} t_i/12))^2)*100$$

$$\text{bio7} = t_{max} - t_{min}$$

$$\text{bio12} = \textstyle\sum_{i=1}^{12} t_i$$

$$\text{bio15} = (\sqrt{\tfrac{1}{11}\textstyle\sum_{i=1}^{12}(p_i -}(\textstyle\sum_{i=1}^{12} p_i/12))^2)/(\textstyle\sum_{i=1}^{12} p_i)/12)$$

Not listed here are the variables which are based on quarters (3 consecutive months) or specific (wettest, driest, warmest, coldest) months.

2.9 Aridity

Aridity can be expressed as function of precipitation, temperature, and potential evapotranspiration (*pet*). We used the Aridity Index (UNEP 1997) to quantify precipitation availability over atmospheric water demand. The Aridity Index (*ai*) is calculated as:

$$ai = \frac{prec}{pet}$$

Where: *p* = Mean Annual Precipitation

and *pet* = Mean Annual Potential Evapotranspiration.

2.10 Hydrothermic Coefficient

Selyaninov's Hydrothermic Coefficient (*shc*), describes moistening conditions. Unlike precipitation measurements, *shc* takes into account temperature-related vaporability. *shq* is calculated using the following formula: the amount of precipitation during the period in which air temperatures are above + 5°C is divided by the sum of average daily temperatures for the same period reduced to its tenth part (Selyaninov, 1937). On the whole, *shc* values over 1 are typical of normal or excessive moistening, while those less than 1 are typical of moistening insufficient for basic cultivated crops.

2.11 Potential Evapotranspiration

Potential evapotranspiration (PET) was calculated following Hargreaves and Samani (1985). Monthly *pet* amount according to the Hargreaves method requires 1) monthly mean daily temperature (*t*); 2) daily temperature range (*td*), and 3) top of atmosphere radiation (*r*). *pet* has then been calculated using:

$$pet = 0.0023 * r * (t + 17.8) * td^{0.5}$$

td is a proxy to describe the effect of cloud cover on the quantity of radiation reaching the surface. *td* is calculated as the difference between monthly mean daily maximum (t_{max}) and monthly mean daily minimum temperature (t_{min})

2.12 Growing season length

Growing season length has been calculated using the TREELIM model (Paulsen and Körner 2014). To calculate the length of the growing season and the mean temperature of the growing season we interpolated mean monthly temperatures to a daily resolution using a B-cubic spline interpolation. We used a temperature-related stepwise interpolation of mean daily rainfall from annual data with a monthly resolution. This approach allocates given amount of precipitation water per grid cell by the plausibility to precipitation events in the following way: The mean per day event was assumed to be 5 mm if the monthly mean T was <5°C, 10 mm for 5–10°C, 15 mm for 10–15°C, 20 mm for >15°C (Paulsen and Körner 2014). As reliable gridded dataset for soil water holding capacity do not exist at a 30 arc-sec resolution globally, we used a fixed global soil water capacity of 220mm for the lower layer of the soil bucket model and a 30 mm for the upper layer. A present snow layer can constrain tree growth substantially. To account for that we assumed that all precipitation falls at daily mean temperatures <0°C and accumulates on the ground as long as daily mean temperatures remain <0 °C, or melts at temperatures >0°C by 0.84 kg m^{-2} day^{-1} $°C^{-1}$ (Paulsen and Körner 2014). Whenever rain falls on an existing snow layer, this water cools to 0 °C and the thermal energy (4.186 kJ kg^{-1} K^{-1}) is used to melt snow (333.5 kJ kg^{-1} snow) (Körner et al. 2011). Daily Potential evapotranspiration was estimated using the Hargreaves equation (Hargreaves and Samani 1985). The water balance for a given day was then calculated with a two-layer bucket model. We assumed an upper soil layer that holds a maximum of 30 kg m^{-2} of water and a lower layer with a water holding capacity of 220 kg m^{-2}. As long as water was available in the upper layer, daily evapotranspiration was assumed to equal potential evapotranspiration. At saturation any additional rain or snow melt water flows into the lower soil layer until saturation, with exceeding amounts of water creating runoff. We used a square root correction for the estimation of the actual daily evapotranspiration from deeper layers as soon as the upper layer contains 0mm H_2O: Daily evapotranspiration = daily potential evapotranspiration * (actual soil water content/ soil water capacity)1/2 in kg m^{-2} day^{-1}, with soil water values in kg m^{-2} (van Kouwen et al. 2005). Growing season length has then be defined as the number of days at which temperatures are above a given threshold (e.g. 0.9°C; 5°C), no snow cover is present, and water is available in the soil.

2.13 Mean Growing Season Temperatures

Mean growing season temperature has be defined as the mean daily mean temperatures at days on which temperatures are above a given threshold, no snow cover is present, and water is available in the soil.

2.14 Mean Growing Season Precipitation

Mean growing season temperature has be defined as the mean monthly precipitation amount cumulated over days on which temperatures are above a given threshold, no snow cover is present, and water is available in the soil.

2.15 Growing degree days

Growing degree days have been calculated by using the annual cumulative sum of temperatures above a given threshold [0°C, 5°C, 10°C, 30°C]. We interpolated mean monthly temperatures (t) to a daily resolution using a B-cubic spline interpolation and used this as input data for the growing degree days.

2.16 Frost change frequency

Frost change frequency was calculated from B-cubic spline interpolated monthly maximum and minimum temperatures to gain a daily resolution. *fcf* was then given as the number of daily events in which the daily temperature range encompasses zero. E.g., $t_{max} = 1$, $t_{min} = -1$ equals an *fcf* event.

2.17 Glacier height

Glacier height has been calculated by using the high resolution glacier shapefile (Ehlers et al. 2011) and the ICE6G model (Peltier et al. 2015). The high resolution shapefile have been converted to point locations and elevations have been extracted for the point localities. These points defining the boarders of the glaciers have been combined with a random sample of the ICE6G glacier elevations. The point localities have then been interpolated to the high resolution grid by using a Multilevel-B-spline interpolation using 14 error levels. Paleo orography has then been calculated by adding glacier height to the paleoDEM.

2.18 Solar radiation

The solar radiation calculation follows that of Böhner and Antonic 2009. Net shortwave radiation S_n (covering wavelengths from 0.3 to 3.0 µm) can be expressed as:

$$S_n = S_s + S_h + S_t - S_r = (S_s + S_d + S_t) \cdot (1 - r)$$

With S_n at the given point is the sum of direct solar radiation received from sun disk (S_s), diffuse solar radiation received from the sky's hemisphere (S_h) and radiation received by reflection of surrounding land surface (S_t), decreased for radiation reflected off from the surface (S_r).

Sn relates to the ideal horizontal surface unobstructed by surrounding land surface (in which case St is zero), then net shortwave solar radiation S_n^* on the land surface can be expressed as:

$$S_n^* = (S_s^* + S_h^* + S_t) * (1 - r)$$

where S_s^* and S_h^* are direct and diffuse solar radiation modified by topography, respectively. Topographic effects are included using:

$$\sin\theta = \cos\lambda\cos\delta\cos\varpi + \sin\lambda\sin\delta$$

$$\cos\phi = \frac{\cos\delta\cos\varpi - \sin\theta\cos\lambda}{\sin\lambda\cos\theta}$$

$$\delta = 23.45 * \sin\left(\frac{360° * [284 + J]}{365}\right)$$

$$\varpi = 15° * (12 - t)$$

where θ is the sun elevation angle, φ is sun azimuth, λ is the latitude, δ is the solar declination angle, J is Julian day number, ϖ is the hour angle in degrees and the value $12 - t$ is equal to the distance of the given mid-hour from the true solar noon (0.5, 1.5, 2.5 h, etc.).

The angle between a plane orthogonal to sun's rays and terrain (solar illumination angle) has been determined for each particular hour from:

$$\cos\gamma = \cos\beta \cdot \sin\theta + \sin\beta \cdot \cos\theta \cdot \cos(\varphi - \alpha)$$

where β and α are surface slope and aspect calculated from DEM, respectively, γ is solar illumination angle for given surface (defined by β and α) and for a given sun position on the sky (defined by θ and φ). Shadowing from neighboring terrain has been included using the horizon angle ϕ for any given grid cell in a DEM (with the elevation *z*), and is defined as the maximum angle toward any other point in a given azimuth, within a selected search distance (set to 10,000 m), determined by:

$$\varphi = artan\left(\frac{\Delta z}{d}\right)_{max}$$

where *d* is the distance to the point with higher elevation $z + \Delta z$ ($d \leq 10{,}000$ m). Topographic direct radiation $S^*_{s(h)}$ is calculated using:

$$S^*_{S(h)} = \varsigma \frac{S_{s(h)}}{\sin\theta}\cos\gamma$$

Where *ς* denotes binary mask (shadow = 0, non-shadow = 1), and $S_{s(h)}$ denotes direct hourly radiation to the unobstructed horizontal surface. Division by sin θ represents a recalculation from a horizontal surface to a surface orthogonal to the sun ray's. To integrate this functions over time, to follow the earth position relative to the sun, we weighted the direct component (cos *γ*) during the daily integration by the amounts of direct radiation flux for respective daily integration unit using:

$$S^*_{S(d)} = \sum_{i=1}^{n} S^*_{S(h)i} = \sum_{i=1}^{n} \varsigma_i \frac{S_{s(h)i}}{\sin\theta_i}\cos\gamma_i$$

$$S^*_{S(d)} = S_{S(d)} K_{S(d)}$$

$$K_{S(d)} = \sum_{i=1}^{n} \varsigma_i k_i \frac{\cos\gamma_i}{\sin\theta_i}$$

$$k_i = \frac{S_{S(h)_i}}{S_{S(d)}}$$

where $S^*_{S(d)}$ represents daily topographic direct radiation to the real land surface defined by β and α, i denotes a particular hour and n denotes the number of hours during the day. $S_{S(d)}$ represents daily direct solar radiation to the ideal horizontal surface unobstructed by surrounding land surface, $K_{S(d)}$ can be understood as daily topographic correction for direct radiation (i.e. as cumulative topographic effect during the day), and k is the portion of $S_{S(h)}$ in $S_{S(d)}$ for each particular hour during the day. k has been parameterized based on Antonic et. al (2000) using:

$$k = b_0 + \frac{b_1\theta^3}{\theta_{max}} + \frac{(b_2\theta + b_3\theta^2 + b_4\theta^3)}{\theta_{max}^2} + \lambda\left[\frac{(b_5\theta + b_6\theta^2)}{\theta_{max}} + \frac{(b_7\theta^2 + b_8\theta^3)}{\theta_{max}^2}\right]$$

With:

b_0 = 0.321419, b_1 = 0.005221, b_2 = 53.902664,

b_3 = 45.420267, b_4 = −8.817633, b_5 = −0.077503,

b_6 = 0.001064, b_7 = −0.252135, b_8 = 0.002904

For modelling of topographic effects on diffuse radiation, we calculated the sky view factor (Ψ_s) per grid cell of the digital elevation model based on horizon angles (ϕ) in different azimuth directions (Φ) of the full circle, around each grid cell:

$$\Psi_S = \frac{1}{N}\sum_{i=i}^{N}[\cos\beta\cos^2\varphi_i + \sin\beta\cos(\Phi_i - \alpha) * (90 - \varphi_i - \sin\varphi_i\cos\varphi_i)]$$

where N is the number of directions used to represent the full unit circle (set to 8) and ϕ_i is horizon angle in ith direction. Diffuse radiation S^*_h can be then calculated as:

$$S^*_h = S_h\Psi_S$$

The surface radiation received by reflection from surrounding land surface S_t is calculated as:

$$S_t \approx \Psi_t\left(S^*_{s(avg)} + S^*_{h(avg)}\right)r_0$$

$$\Psi_t \approx \frac{1+\cos\beta}{2} - \Psi_S$$

where $S^*_{s(avg)}$ and $S^*_{h(avg)}$ are direct and diffuse radiation for the same time unit, respectively, spatially averaged over the surrounding land surface visible from a grid cell, and r_0 is the spatially averaged reflectance (albedo factor) of the surrounding land surface (here set to 1). Direcg short-wave radiation under lumped atmospheric conditions $S^*_{S(d)l}$ is the calculated using:

$$sdir = S^*_{S(d)}\tau^m$$

with τ being the transmission coefficient of radiation through the atmosphere (set to 80%, assuming clear sky conditions), and *m* being the ration of the path length in the direction of the sun at zenith angle *z* to the path length in the vertical direction. The quantity of m can be calculated using:

$$m = \sec z = \frac{1}{\cos z}$$

The local transmission coefficient is then derived using:

$$\tau = \tau_{sl} + t_{lapse} * elev$$

where τ_{sl} is the transmission coefficient at sea level, and t_{lapse} is the transmissivity lapse rate, and *elev* is the elevation of the grid cell. Diffuse radiation under lumped atmospheric conditions $sdif$ is then calculated using:

$$sdif = (0.271 - 0.294\,\tau^{m})S^{*}_{S(h)}$$

To include cloud cover fraction *cf*, modis cloud cover fraction has been used (Wilson and Jetz 2016). Total surface solar radiation downwards *srad* has been then calculated using:

$$srad = sdif + sdir(1 - 0.75cf^{3.4})$$

3. Sub-models

3.1 CHELSA

The CHELSA (Climatologies at high resolution for the earth's land surface areas) data consists of downscaled model output temperature and precipitation estimates at a horizontal resolution of 30 arc sec for a climatological period from 1979-2013. The resulting data consist of a monthly temperature and precipitation climatologies and various derived parameters. Methods are described mainly in 2.3.

3.2 CHELSA timeseries

The CHELSA timeseries data consists of monthly downscaled model output temperature and precipitation estimates at a horizontal resolution of 30 arc sec. from 1979-2013. The resulting data consist of a mean monthly temperature and precipitation amounts. Methods are described in 2.2.

3.3 CHELSAcruts

CHELSAcruts is a delta change monthly climate dataset for the years 1901-2016 for mean monthly maximum temperatures, mean monthly minimum temperatures, and monthly precipitation sum. Here we use the delta change method by B-spline interpolation of anomalies (deltas) of the CRU TS 4.01 dataset. Anomalies were interpolated between all CRU TS grid cells and are then added (for temperature variables) or multiplied (in case of precipitation) to high resolution climate data from CHELSA V1.2 (Karger et al. 2017, Scientific Data). This method has the assumption that climate only varies on the scale of the coarser (CRU TS) dataset, and the spatial pattern (from CHELSA) is consistent over time. This is certainly a rather crude assumption, and for time periods for which more accurate data is available CHELSAcruts should be avoided if possible (e.g. use CHELSA V1.2 for 1979-2015). Different to CHELSA V1.2, CHELSAcruts does not take changing wind patterns, or temperature lapse rates into account, but rather expects them to be constant over time, and similar to the long term averages. As CHELSAcruts uses the temporal signal from CRU, its quality is influenced by this dataset as well. Problems arise in years before 1950, when weather station density was low. In general, the accuracy of the data gets lower, the further we go back in time.

3.4 CHELSA_[CMIP5]

CHELSA-[CMIP5] is a delta change climatological dataset for the years 2041-2060 and 2061-2080 for mean monthly maximum temperatures, mean monthly minimum temperatures, monthly precipitation amounts, and several derived parameters. We use the delta change method by B-spline interpolation of anomalies (deltas) of the respective CMIP5 GCM dataset. Anomalies were interpolated between all CMIP5 grid cells and are then added (for temperature variables) or multiplied (in case of precipitation) to high resolution climate data from CHELSA V1.2. This method has the assumption that climate only varies on the scale of the coarser (CMIP5) dataset, and the spatial pattern (from CHELSA) is consistent over time. CHELSA-[CMIP5] does not take changing wind patterns, or temperature lapse rates into account, but rather expects them to be constant over time, and similar to the long term averages.

Tab 3.4-1. Global circulation models included and the respective concentration pathways included in the CHELSA-[CMIP5] data

Global circulation model (GCM)	rcp2.6	rcp4.5	rcp6.0	rcp8.5
ACCESS1-0		x		x
bcc-csm1-1	x	x	x	x
BNU-ESM	x	x		x
CanESM2	x	x		x
CCSM4	x	x	x	x
CESM1-BGC		x		x
CESM1-CAM5	x	x	x	x
CMCC-CESM		x		x
CMCC-CM		x		x
CMCC-CMS		x		x
CNRM-CM5	x	x		x
CSIRO-Mk3-6-0	x	x	x	x
CSIRO-Mk3L-1-2		x		
EC-EARTH	x	x		x
FGOALS-g2	x	x		x
FIO-ESM	x	x	x	x
GFDL-CM3	x	x	x	x
GFDL-ESM2G	x	x	x	x
GFDL-ESM2M		x	x	x
GISS-E2-H	x	x		x
GISS-E2-H-CC		x		x
GISS-E2-R	x	x		x
GISS-E2-R-CC		x		x
HadGEM2-AO	x	x	x	x
HadGEM2-CC		x		x

HadGEM2-ES	x	x	x	x
inmcm4		x		x
IPSL-CM5A-LR	x	x	x	x
IPSL-CM5A-MR	x	x	x	x
MIROC-ESM	x	x	x	x
MIROC-ESM-CHEM	x	x	x	x
MIROC5	x	x	x	x
MPI-ESM-LR	x	x		x
MPI-ESM-MR	x	x		x
MRI-CGCM3	x	x	x	x
MRI-ESM1		x		x
NorESM1-M	x	x	x	x
NorESM1-ME	x	x	x	x

3.5 CHELSA_[PMIP3]

CHELSA-[PMIP3] is a delta change climatological dataset for the years 21000BP (before 1950) for mean monthly maximum temperatures, mean monthly minimum temperatures, monthly precipitation amounts, and several derived parameters. We use the delta change method by B-spline interpolation of anomalies (deltas) of the respective PMIP3 GCM dataset. Anomalies were interpolated between all PMIP3 grid cells and are then- or multiplied (in case of precipitation) to high resolution climate data from CHELSA V1.2 at a 0.5 grid resolution. Orography has been created based on methods described in XX. Precipitation has been calculated based on the methods described in 2.3 and included wind effects and boundary layer height conditions. Temperatures are downscaled based on the methods described in 2.2. Both temperature and precipitation have been bias corrected at a 0.5 degree grid resolution using a delta change method from CHELSA as the baseline climate and then adjusted the baseline climate by the changes of the preindustrial control and PMIP3 precipitation and temperature anomalies. GCMs included are: CCSM4, CNRM-CM5, FGOALS-g2, IPSL-CM5A-LR, MIROC-ESM, MRI-CGCM3, MPI-ESM-P.

3.6 CHELSA_[CMIP5]_timeseries

The CHELSA_[CMIP5]_timeseries present four downscaled global circulation models (GCMs) from the Coupled Model Intercomparison Project phase 5 (CMIP5) gridded monthly timeseries for the years 2006-2100 with an spatial resolution of 0.049° resolution (approximately 5 km at the equator). The downscaling algorithm is based on the CHELSA algorithm1 which provides a more accurate representation of temperature and precipitation in highly heterogeneous terrain. Mean monthly maximum daily temperatures and mean monthly minimum daily temperatures have been downscaled using the delta change method based with the high spatial resolution data taken from CHELSA V.1.2. Monthly precipitation sums have been calculated by applying the CHELSA algorithm directly on bias corrected GCM data. The CHELSA algorithm allows for take changing wind patterns and boundary layer conditions into affect, and therefore allows a better estimation of the changes in precipitation patterns in the future. Projected future climate variables were taken from four global circulation models (GCMs) driven by two scenarios of representative concentration pathways (RCPs) in a factorial manner. The four selected models originate from the CMIP5 collection of model runs used in IPCC's 5th Assessment Report (IPCC 2013). GCMs, are however often based on similar code which consequently results in similar output(Sanderson et al. 2015). We therefore choose models which show a low amount of interdependence to allow for a good representation of uncertainty in climate projections. Model selection was based on model interdependence in ensambles. The four models from which data were taken are: CESM1-BGC run by National Center for Atmospheric Research (NCAR); CMCC-CM run by the Centro Euro-Mediterraneo per I Cambiamenti Climatici (CMCC); MIROC5 run by the university of Tokyo; and ESM-MR25 run by Max Planck Institute for Meteorology (MPI-M); and ACCESS1-3, by the Commonwealth Scientific and Industrial Research Organization (CSIRO) and Bureau of Meteorology (BOM), Australia.

4. 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.

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/

4.1 Dimensions

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

Table 3.1-1. Dimension Variables Contained in GMAO NetCDF Files

Name	Description	type	Attribute
longitude	Longitude	double	degrees_east
latitude	Latitude	double	degrees_north
month	Month	int	month
year	Year A.D	int	year
day	Day of the month	int	day

4.2 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 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 (usually 1979-2013).

5. 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:

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.

6. 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:

[*SUBMODEL*]_[*short_name*]_[*day*]_[*month*]_[*year*]_[*Version*].tif

CHELSA_[CMIP5] models follow a slightly different file naming convention:

For precipitation (pr), and temperature (tas, tas_max, tas_min):

[*SUBMODEL*]_[*short_name*]_[accumulation_period]_[GCM]_[rcp]_r[*run*]i[initial_conditions]p[physics]_[coarse_grid_resolution]_[month]_[*Version*].tif

For bioclim variables:

[*SUBMODEL*]_bio_[accumulation_period]_[GCM]_[rcp]_r[*run*]i[initial_conditions]p[physics]_[coarse_grid_resolution]_[bioclim_index]_[*Version*].tif

For CHELSA_[PMIP] year 1 indicates 21000BP

5. Variable Names

5.1 Submodel: CHELSA

shortname	longname	unit	explanation
1st	First growing degree day [treshold_temperature]	julian day	First day of the year above a given threshold temperature
bio1	mean annual air temperature	°C/10	mean annual daily mean air temperatures averaged over 1 year
bio2	mean diurnal air temperature range	°C/10	mean diurnal range of temperatures averaged over 1 year
bio3	isothermality	°C/10	ratio of diurnal variation to annual variation in temperatures
bio4	temperature seasonality	°C/10	standard deviation of the monthly mean temperatures
bio5	mean daily maximum air temperture of the warmest month	°C/10	The highest temperature of any monthly daily mean maximum temperature
bio6	mean daily minimum air temperature of the coldest month	°C/10	The lowest temperature of any monthly daily mean maximum temperature
bio7	annual range of air temperature	°C/10	The difference between the Maximum Temperature of Warmest month and the Minimum Temperature of Coldest month
bio8	mean daily mean air tempertures of the wettest quarter	°C/10	The wettest quarter of the year is determined (to the nearest month)
bio9	mean daily mean air tempertures of the driest quarter	°C/10	The driest quarter of the year is determined (to the nearest month)
bio10	mean daily mean air tempertures of the warmest quarter	°C/10	The warmest quarter of the year is determined (to the nearest month)
bio11	mean daily mean air tempertures of the coldest quarter	°C/10	The coldest quarter of the year is determined (to the nearest month)
bio12	annual precipitation amount	kg m^{-2}	Accumulated precipitation amount over 1 year
bio13	precipitation amount of the wettest month	kg m^{-2}	The precipitation of the wettest month.

bio14	precipitation amount of the driest month	kg m^{-2}	The precipitation of the driest month.
bio15	precipitation seasonality	kg m^{-2}	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}	The wettest quarter of the year is determined (to the nearest month)
bio17	mean monthly precipitation amount of the driest quarter	kg m^{-2}	The driest quarter of the year is determined (to the nearest month)
bio18	mean monthyl precipitation amount of the warmest quarter	kg m^{-2}	The warmest quarter of the year is determined (to the nearest month)
bio19	mean monthly precipitation amount of the warmest quarter	kg m^{-2}	The coldest quarter of the year is determined (to the nearest month)
end	Last growing degree day [treshold_temperature]	julian day	Last day of the year above a given threshold temperature
epot	Potential evapotranspiration	kg m^{-2}	Potential evapotranspiration
fcf	Frost change frequency	number of events	Number of events in which tmin or tmax go above, or below 0°C
fcf	Frost change frequency	number of events	Number of events in which tmin or tmax go above, or below 0°C
fcf_dt_max	Maximum daily temperature span of frost change days	°C	Maximum daily temperature span of frost change days within 1 year
fcf_dt_mean	Mean daily temperature span of frost change days	°C	Mean daily temperature span of frost change days within 1 year
fcf_dt_stdc	Standard deviation of daily temperature span of frost change days	°C	Standard deviation of daily temperature span of frost change days within 1 year
fcf_tmin_mean	Mean daily minimum temperature of frost change days	°C	Mean daily minimum temperature of frost change days within 1 year
fcf_tmin_min	Coldest daily minimum temperature of all frost change days	°C	Coldest daily minimum temperature of all frost change days within 1 year
fgd	first day of the growing season TREELIM	julian day	First day o the growing season accoriding to TREELIM

gdd	Growing degree days heat sum above [treshold_temperature]	°C	heat sum of all days above the treshold temperature accumulated over 1 year.
gdd	Number of days above [treshold_temperature]	number of days	number of days above a given threshold temperature
gsl	growing season length TREELIM	number of days	Length of the growing season
gsp	Accumulated precipiation amount on days above [threshold_temperature]	kg m^{-2}	precipitation sum accumulated on all days above the threshold temperature over 1 year
gst	Mean temperature of the growing season TREELIM	°C/10	Mean temperature of all growing season days
gts	Growing degree days heat sum above [treshold_temperature]	°C/10	heat sum of all days above the treshold temperature accumulated over 1 year.
lgd	last day of the growing season TREELIM	julian day	Last day of the growing season according to TREELIM
lstmax	mean daily maximum surface temperature where land	°C/10	daily maximum surface temperature where land at 2 metres since previous post-processing from ERA interim averaged over 1 month extended using the SRAD model (Wilson & Gallant 2000)
lstmean	mean daily land surface temperature where land	°C/10	daily mean surface temperature where land at 2 metres since previous post-processing from ERA interim averaged over 1 month extended using the SRAD model (Wilson & Gallant 2000)
lstmin	mean daily minimum surface temperature where land	°C/10	daily minimum surface temperature where land at 2 metres since previous post-processing from ERA interim averaged over 1 month extended using the SRAD model (Wilson & Gallant 2000)
nfd	Number of frost days	number of days	Number of days at which tmin < 0°C

prec	precipitation amount	kg m^{-2}	"Amount" means mass per unit area. "Precipitation" in the earth's atmosphere means precipitation of water in all phases.
rh	relative humidity	%	daily mean near surface relative humidity averaged over 1 month
sdif	Accumulated diffuse downward short-wave radiation flux, clear sky	kJ m^{-2}	Downward diffuse solar (short-wave) radiation at the surface under clear sky conditions accumulated over the month
sdir	Accumulated direct downward short-wave radiation flux, clear sky	kJ m^{-2}	Downward direct solar (short-wave) radiation at the surface under clear sky conditions accumulated over the month
shc	Selyaninov's Hydrothermic Coefficient,	(kg m^{-2}/10)/Celsius)	shc describes moistening conditions. Unlike precipitation measurements, shc takes into account temperature-related vaporability. shq is calculated using the following formula: the amount of precipitation during the period in which air temperatures are above + 5°C is divided by the sum of average daily temperatures for the same period reduced to its tenth part (Selyaninov, 1937). On the whole, shc values over 1 are typical of normal or excessive moistening, while those less than 1 are typical of moistening insufficient for basic cultivated crops.
srad	Surface solar radiation downwards	kJ m^{-2}	Downward total (direct + diffuse) solar (short-wave) radiation at the surface accumulated over the month
stot	Accumulated downward short-wave radiation flux, clear sky	kJ m^{-2}	Downward total (direct + diffuse) solar (short-wave) radiation at the surface under clear sky conditions accumulated over the month
sw1	soil water in the upper soil layer	kg m^{-2}	Soil water content of the upper soil bucket

sw2	soil water in the lower soil layer	kg m^{-2}	Soil water content of the lower soil bucket
swe	snow water equivalent	kg m^{-2}	Equivalient liquid water of snow when melted
tmax	mean daily maximum air temperature	°C/10	daily maximum air temperatures at 2 metres since previous post-processing from ERA interim averaged over 1 month
tmean	mean daily air temperature	°C/10	daily mean air temperatures at 2 metres averaged over 1 month
tmin	mean daily minimum air temperature	°C/10	daily minimum air temperatures at 2 metres since previous post-processing from ERA interim averaged over 1 month

5.2 Submodel: CHELSA timeseries

shortname	longname	unit	explanation
tmax	mean daily maximum air temperature	K/10	daily maximum air temperatures at 2 metres since previous post-processing from ERA interim averaged over 1 month
tmean	mean daily air temperature	K/10	daily mean air temperatures at 2 metres averaged over 1 month
tmin	mean daily minimum air temperature	K/10	daily minimum air temperatures at 2 metres since previous post-processing from ERA interim averaged over 1 month
prec	precipitation amount	kg m^{-2}	"Amount" means mass per unit area. "Precipitation" in the earth's atmosphere means precipitation of water in all phases.

5.3 Submodel: CHELSAcruts

shortname	longname	unit	explanation
tmax	mean daily maximum air temperature	°C/10	daily maximum air temperatures at 2 metres averaged over 1 month

tmin	mean daily minimum air temperature	°C/10	daily minimum air temperatures at 2 metres averaged over 1 month
prec	precipitation amount	kg m^{-2}	amount refeers to means mass per unit area. precipitation in the earth's atmosphere means precipitation of water in all phases.

5.3 Submodel: CHELSA_[CMIP5]

shortname	longname	unit	explanation
bio1	mean annual air temperature	°C/10	mean annual daily mean air temperatures averaged over 1 year
bio2	mean diurnal air temperature range	°C/10	mean diurnal range of temperatures averaged over 1 year
bio3	isothermality	°C/10	ratio of diurnal variation to annual variation in temperatures
bio4	temperature seasonality	°C/10	standard deviation of the monthly mean temperatures
bio5	mean daily maximum air temperture of the warmest month	°C/10	The highest temperature of any monthly daily mean maximum temperature
bio6	mean daily minimum air temperature of the coldest month	°C/10	The lowest temperature of any monthly daily mean maximum temperature
bio7	annual range of air temperature	°C/10	The difference between the Maximum Temperature of Warmest month and the Minimum Temperature of Coldest month
bio8	mean daily mean air tempertures of the wettest quarter	°C/10	The wettest quarter of the year is determined (to the nearest month)
bio9	mean daily mean air tempertures of the driest quarter	°C/10	The driest quarter of the year is determined (to the nearest month)
bio10	mean daily mean air tempertures of the warmest quarter	°C/10	The warmest quarter of the year is determined (to the nearest month)
bio11	mean daily mean air tempertures of the coldest quarter	°C/10	The coldest quarter of the year is determined (to the nearest month)
bio12	annual precipitation amount	kg m^{-2}	Accumulated precipitation amount over 1 year

bio13	precipitation amount of the wettest month	kg m^{-2}	The precipitation of the wettest month.
bio14	precipitation amount of the driest month	kg m^{-2}	The precipitation of the driest month.
bio15	precipitation seasonality	kg m^{-2}	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}	The wettest quarter of the year is determined (to the nearest month)
bio17	mean monthly precipitation amount of the driest quarter	kg m^{-2}	The driest quarter of the year is determined (to the nearest month)
bio18	mean monthyl precipitation amount of the warmest quarter	kg m^{-2}	The warmest quarter of the year is determined (to the nearest month)
bio19	mean monthly precipitation amount of the warmest quarter	kg m^{-2}	The coldest quarter of the year is determined (to the nearest month)
tas_max	mean daily maximum air temperature	°C/10	daily maximum air temperatures at 2 metres since previous post-processing from ERA interim averaged over 1 month
tas	mean daily air temperature	°C/10	daily mean air temperatures at 2 metres averaged over 1 month
tas_min	mean daily minimum air temperature	°C/10	daily minimum air temperatures at 2 metres since previous post-processing from ERA interim averaged over 1 month
ps	precipitation amount	kg m^{-2}	amount refeers to means mass per unit area. precipitation in the earth's atmosphere means precipitation of water in all phases.

5.3 Submodel: CHELSA_[PMIP3]

shortname	longname	unit	explanation
bio1	mean annual air temperature	°C/10	mean annual daily mean air temperatures averaged over 1 year
bio2	mean diurnal air temperature range	°C/10	mean diurnal range of temperatures averaged over 1 year
bio3	isothermality	°C/10	ratio of diurnal variation to annual variation in temperatures
bio4	temperature seasonality	°C/10	standard deviation of the monthly mean temperatures
bio5	mean daily maximum air temperture of the warmest month	°C/10	The highest temperature of any monthly daily mean maximum temperature
bio6	mean daily minimum air temperature of the coldest month	°C/10	The lowest temperature of any monthly daily mean maximum temperature
bio7	annual range of air temperature	°C/10	The difference between the Maximum Temperature of Warmest month and the Minimum Temperature of Coldest month
bio8	mean daily mean air tempertures of the wettest quarter	°C/10	The wettest quarter of the year is determined (to the nearest month)
bio9	mean daily mean air tempertures of the driest quarter	°C/10	The driest quarter of the year is determined (to the nearest month)
bio10	mean daily mean air tempertures of the warmest quarter	°C/10	The warmest quarter of the year is determined (to the nearest month)
bio11	mean daily mean air tempertures of the coldest quarter	°C/10	The coldest quarter of the year is determined (to the nearest month)
bio12	annual precipitation amount	kg m^{-2}	Accumulated precipitation amount over 1 year
bio13	precipitation amount of the wettest month	kg m^{-2}	The precipitation of the wettest month.
bio14	precipitation amount of the driest month	kg m^{-2}	The precipitation of the driest month.
bio15	precipitation seasonality	kg m^{-2}	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}	The wettest quarter of the year is determined (to the nearest month)
bio17	mean monthly precipitation amount of the driest quarter	kg m^{-2}	The driest quarter of the year is determined (to the nearest month)
bio18	mean monthyl precipitation amount of the warmest quarter	kg m^{-2}	The warmest quarter of the year is determined (to the nearest month)
bio19	mean monthly precipitation amount of the warmest quarter	kg m^{-2}	The coldest quarter of the year is determined (to the nearest month)
tas_max	mean daily maximum air temperature	°C/10	daily maximum air temperatures at 2 metres since previous post-processing from ERA interim averaged over 1 month
tas	mean daily air temperature	°C/10	daily mean air temperatures at 2 metres averaged over 1 month
tas_min	mean daily minimum air temperature	°C/10	daily minimum air temperatures at 2 metres since previous post-processing from ERA interim averaged over 1 month
ps	precipitation amount	kg m^{-2}	amount refeers to means mass per unit area. precipitation in the earth's atmosphere means precipitation of water in all phases.

5.3 Submodel: CHELSA_[CMIP5]_timeseries

shortname	**longname**	**unit**	**explanation**
tmax	mean daily maximum air temperature	K	daily maximum air temperatures at 2 metres averaged over 1 month
tmin	mean daily minimum air temperature	K	daily minimum air temperatures at 2 metres averaged over 1 month
ps	precipitation amount	kg m^{-2}	amount refeers to means mass per unit area. precipitation in the earth's atmosphere means precipitation of water in all phases.

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