WEATHER FOR ENERGY TRACKER

USERS GUIDE

International Energy Agency

INTERNATIONAL ENERGYAGENCY

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies thatwill enhance the reliability, affordability and sustainability of energy in its 31 member countries, 11 association countries and beyond.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy Japan
Korea
Lithuania
Luxembourg
Mexico
Netherlands
New Zealand
Norway Poland
Portugal
Slovak RepublicSpain
Sweden
Switzerland
Republic of Türkiye
United Kingdom
United States

The European Commission also participates in the work of the IEA

IEA association countries:

Argentina
Brazil
China
Egypt
India
Indonesia
Morocco
Singapore
South Africa
Thailand
Ukraine

This document provides information regarding the April 2024 edition of the **Weather for Energy Tracker** platform and its database (the **Tracker**), developed by the International Energy Agency (IEA) in collaboration with Fondazione Euro-Mediterraneo Sui Cambiamenti Climatici (CMCC).[1]

Selected data are displayed and available for download at: www.iea.org/data-and-statistics/data-tools/weather-for-energy-tracker.

Complete sets of data are available at: weatherforenergydata.iea.org/.

This document can be found online at: Weather for Energy Tracker: Users Guide.

Please address your comments and inquiries to emissions@iea.org**.** We are keen to receive user feedback in order to improve further editions of this database.

Released: April 2024.

Note: *The Tracker is the result of a collaborative effort between the International Energy Agency (IEA) and the Fondazione Euro-Mediterraneo Sui Cambiamenti Climatici (CMCC). The Tracker reflects the views of the IEA Secretariat and CMCC but does not necessarily reflect those of their respective individual member countries. The Tracker does not constitute professional advice on any specific issue or situation. CMCC and the IEA make no representation or warranty, express or implied, in respect of the Tracker (including its completeness or accuracy) and shall not be responsible for any use of, or reliance on, the Tracker. Furthermore, neither the European Commission nor the European Centre for Medium-Range Weather Forecasts ECMWF is responsible for any use that may be made of the Copernicus information or data contained in the Tracker.*

For further information*, please contact: emissions@iea.org*.

Contains modified Copernicus Climate Change Service information [2024]. N*either the European Commission nor ECMWF is responsible for any use that may be made of the Copernicus information or data it contains.*

Population data derive from*:*

Center for International Earth Science Information Network (*CIESIN*), *Columbia University* (*2018*), *Gridded Population of the World, Version 4 (GPWv4): Population Count, Revision 11*; NASA Socioeconomic Data and Applications Center (SEDAC), *Palisades, NY*; *doi.org/10.7927/H4JW8BX5* (*accessed 29/06/2020*)*.*

Schiavina, Marcello; Freire, Sergio; MacManus, Kytt (2019): GHS population grid multitemporal (1975, 1990, 2000, 2015) R2019A. European Commission, Joint Research Centre (JRC) DOI: 10.2905/42E8BE89-54FF-464E-BE7B-BF9E64DA5218 PID: http://data.europa.eu/89h/0c6b9751-a71f-4062-830b-43c9f432370fConcept & Methodology:
Freire, Sergio; MacManus, Kytt; Pesaresi, Martino; Doxsey-Whitfield, Erin; Mills, Jane (2016): Development of new open and free multi-temporal global population grids at 250 m resolution. Geospatial Data in a Changing World; Association of Geographic Information Laboratories in Europe (AGILE). AGILE 2016.

[1] We would like to acknowledge Dr Silvio Gualdi, Dr. Ritika Kapoor and Dr. Enrico Scoccimarro (Centro Euro-Mediterraneo sui cambiamenti climatici) for their valuable insights and contribution to the design of this database.

Table of contents

Overview

The IEA and CMCC Weather for Energy Tracker is a new, free platform, which showcases global data on weather-related variables that can be useful for understanding, analysing and modelling the energy sector, from generation to use across sectors. Data are available at grid, country and sub-national levels, with a daily and monthly resolution from the year 1979[2] to the latest available month,[3] and including monthly climatologies and anomalies.

Given the strong interlinkage between energy generation and demand with weather variables, reliable, consistent and easily accessible data on an expanded portfolio of weather variables, e.g. temperatures, degree days, solar radiation and precipitation, are becoming more and more important. We believe that this product will help statisticians, researchers, modellers and analysts around the world as well as a broader audience interested in the energy sector.

The Weather for Energy Tracker includes data for 51 variables at global gridded level and monthly resolution (including monthly climatologies and monthly anomalies); and data for 50 variables at nationally and sub-nationally averaged levels at daily and monthly resolution (including monthly climatologies and monthly anomalies). The complete database is expected to be updated on a quarterly basis, every January, April, July and October. The data are available through the different options below:

- Interactive map. Users can select and download *ad hoc* data, at grid level and nationally and sub-nationally averaged, through the selection box for a selection of variables.
- Data repository. Complete sets of grid-level, nationally and sub-nationally averaged data are available for download at weatherforenergydata.iea.org.
- Interactive Excel file, the *Weather for Energy Tracker: Highlights*. Condensed, selected information in a user-friendly format.

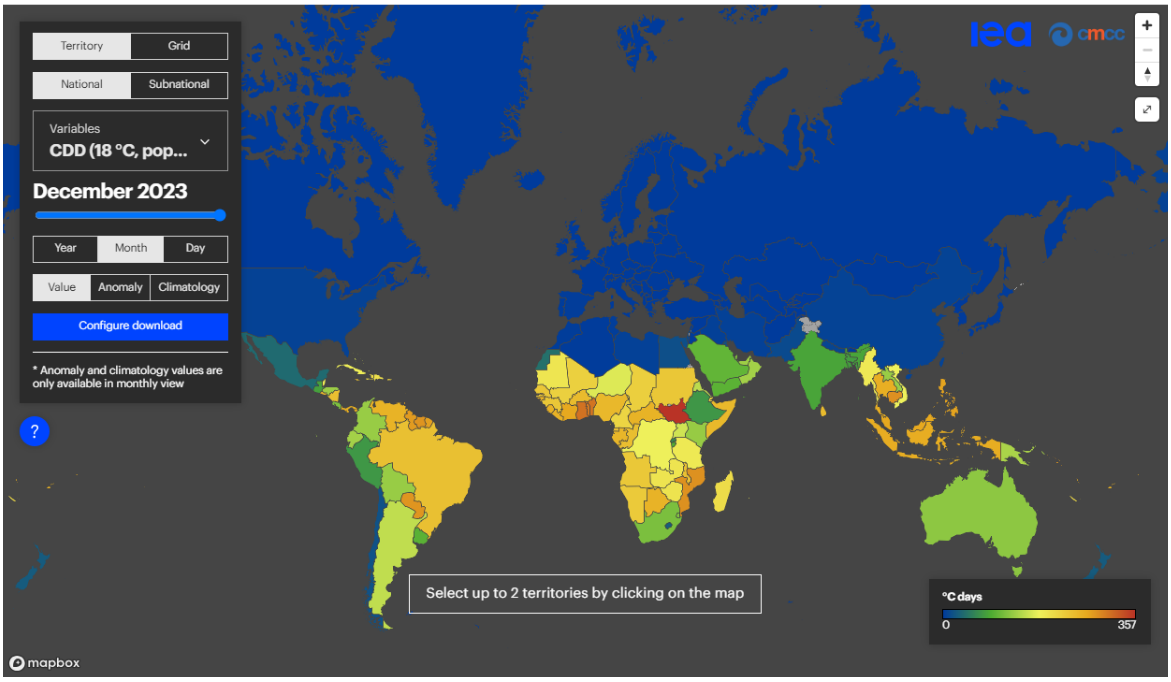
For more details on sources, variable definitions, and methodologies, please refer to the relevant sections of this document.

2 For now, data from 1979 to 1999 are only included in the data repository. It will be made available in the interactive map at a later date.
3 As of April 2024, the latest available month is March 2024.

Interactive map

The interactive global map is freely available online at www.iea.org/data-and-statistics/data-tools/weather-for-energy-tracker. It is expected to be updated every quarter.

Interactive map homepage



The full list of variables available through the map is shown in the menu. The map displays data in three views, which are accessible through the menu tabs *Territory*, which displays nationally averaged data for over 200 countries and sub-nationally averaged data for selected countries; and *Grid*, which displays gridded data for over 1 million geographical points around the world. The selection of variables is adapted to each of the two formats.

The data displayed in the interactive map spans from 1 January 2000 until the last day of the month prior to the release. Monthly anomalies and associated climatologies[4] are also available for monthly data.

Through the interactive map, selected data can be retrieved by clicking on the following button: Configure download

[4] *Climatologies* are averages of monthly values over a reference period (2000-2019 in this database). *Anomalies* are the differences between a given monthly value and its corresponding monthly climatology. For more details, please refer to the **Methodology** section.

More information on the dataset is available through the ? button.

Territory view

The territory view includes two maps: national map for displaying nationally-averaged indicators for over 200 countries in the world, and sub-national map that includes data for six countries (Australia, Brazil, Canada, People's Republic of China, Russian Federation and the United States).

In his view data are available for 19 selected variables, some of which are available using two averaging methods: *surface* (surface weighting) and *population* (population weighting).

The list of variables accessible for the territory map is presented in the table below. For more information on definitions of variables, please refer to the Definitions section.

Variables available in the territory map view

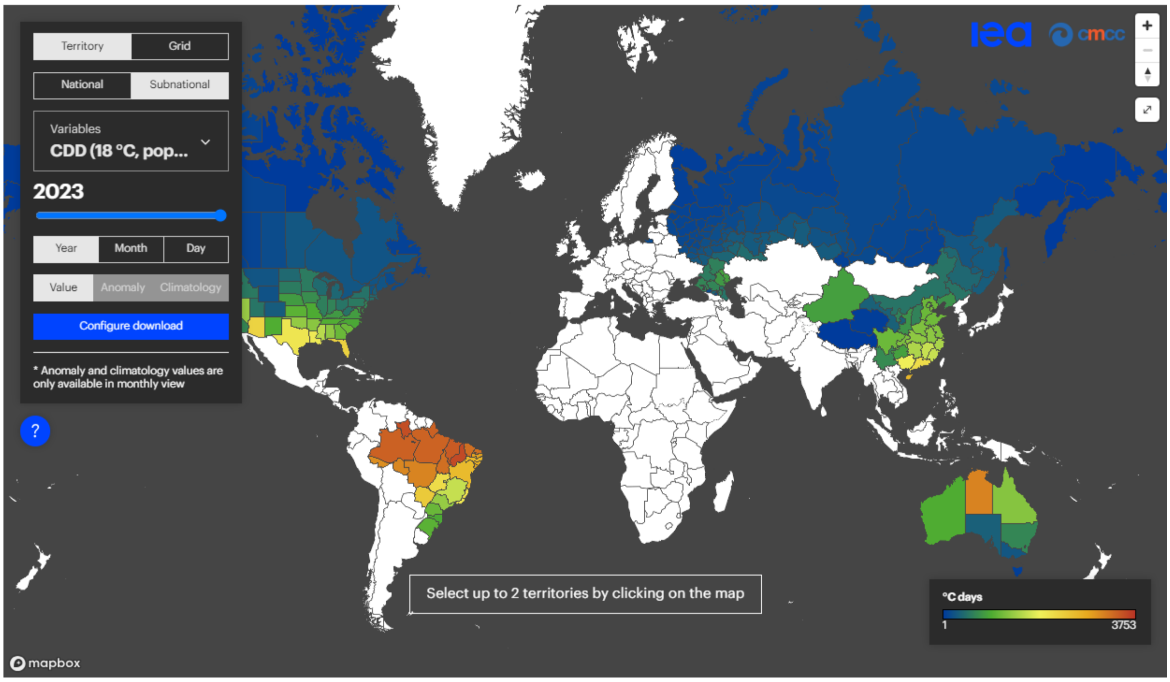
Variable	Averaging method
CDD (18 °C)	Population
CDD (21 °C)	Population
CDD (18 °C, humidity)	Population
HDD (16 °C)	Population
HDD (18 °C)	Population
Relative humidity	Surface
Total precipitation	Surface
Cloud coverage	Surface
Sunlight	Surface
Direct normal radiation	Surface
Global horizontal irradiance	Surface
Temperature (2 m)	Surface, population
Temperature max (2 m)	Surface, population
Temperature min (2 m)	Surface, population
Heat index (2 m)	Population

Humidex (2 m)	Population

Note: m = metre.

Please note that more variables are available on the grid map view than are on the territory map view.

Territory map, sub-national surface-weighted average of 2-metre temperature, year 2023



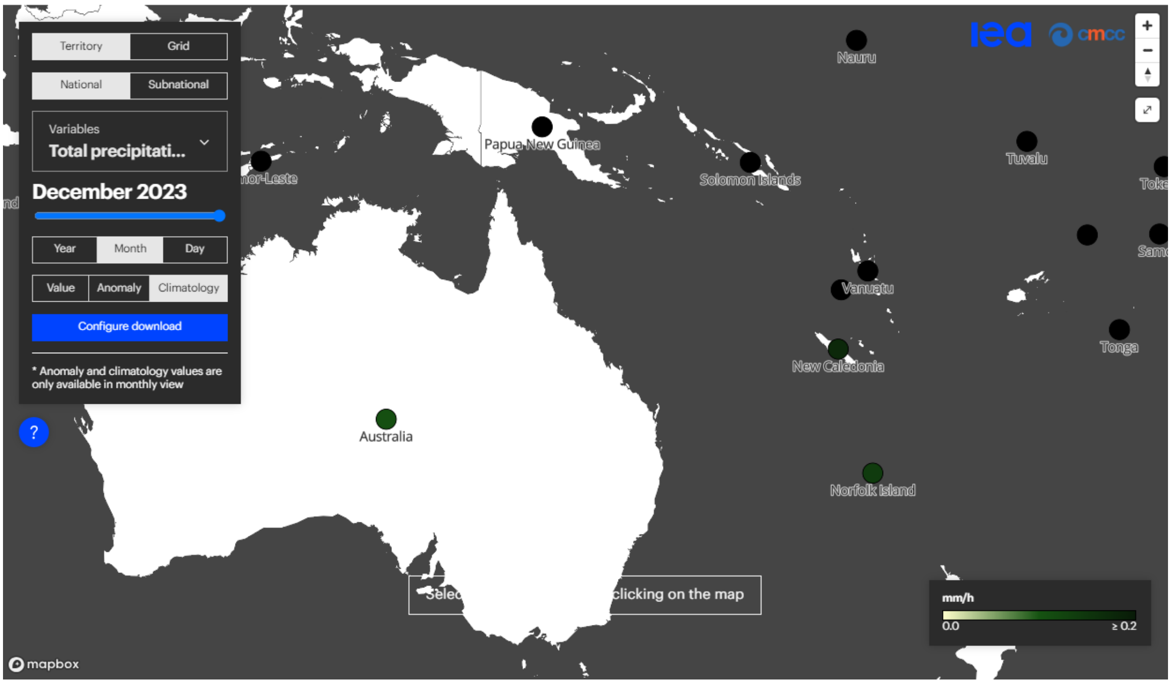
In the territory map, data are displayed at daily, monthly or annual resolution. At the monthly resolution, anomalies and climatologies are also available.

Territory map, surface-weighted average of national direct normal radiation anomalies for September 2023, global view

For example, the map above shows that in September 2023, direct normal radiation was above average in South America, while it was under in Eastern Africa.

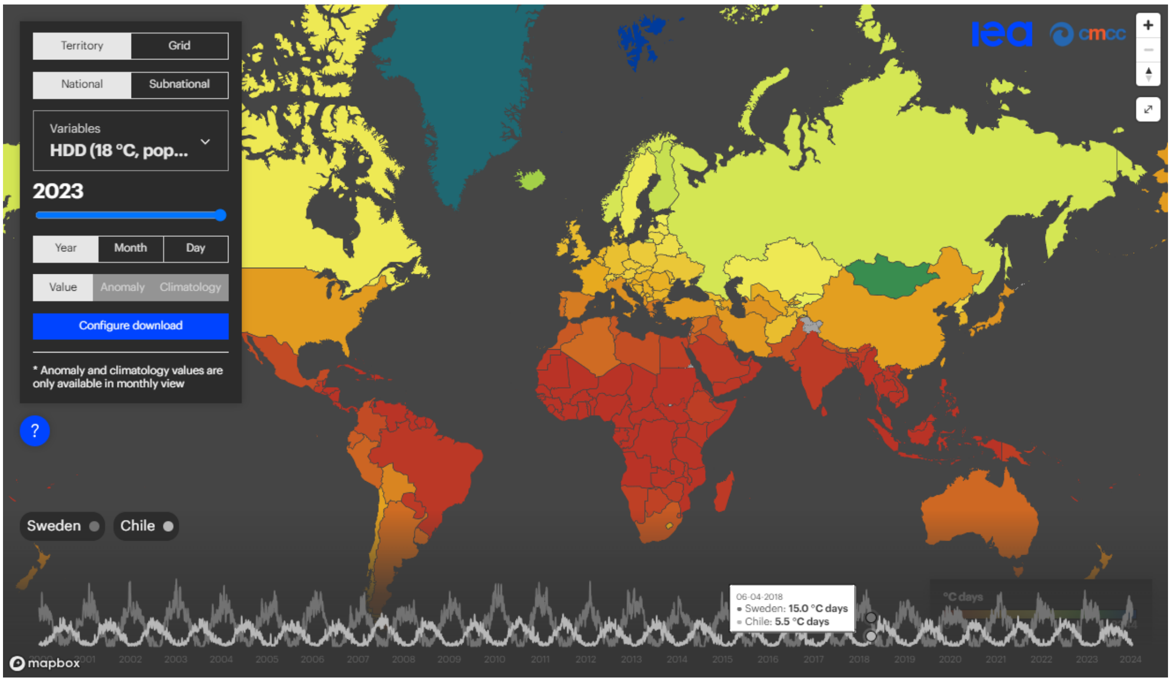
When zooming in, the map colour pattern changes so that the values for small territories are visible despite the relatively small area represented:

Territory map, national precipitation climatologies for December, regional zoom view



When selecting a territory, a graph at the bottom of the map displays the relevant time series. It is possible to plot two countries on the graph for quick comparisons.

Territory map, national HDD (18°C, population) for year 2023, graph-enabled



Data can be retrieved in CSV format by clicking the “Configure download” button:

The list of countries/regions can be customised, as well as the time range. For extracting the full time series of the dataset, it is advised not to select all countries/regions in a single file for size reasons, but instead to download it through the Data repository.

Grid map

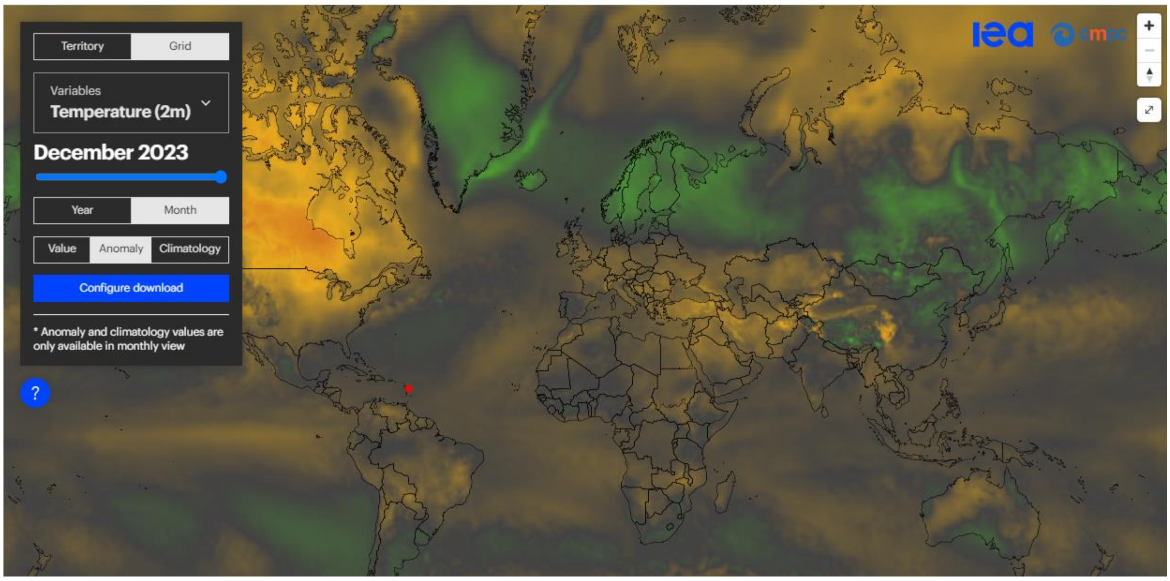
The grid map displays data for 20 variables on a gridded view. The map is composed of more than one million data points around the world: the resolution of the meshing is as fine as 0.25 degree by latitude and longitude. The list of variables accessible through the grid map is presented in the table below. For more information on variables definitions, please refer to the Definitions section.

Variables available in the grid map view

Variable
CDD (18 °C)
CDD (18 °C, humidity)
HDD (18 °C)
Relative humidity
Evaporation
Total precipitation
Runoff
Snowfall
Cloud coverage
Sunlight
Direct normal radiation
Global horizontal irradiance
Temperature (2 m)
Temperature max (2 m)
Temperature min (2 m)
Heat index (2 m)
Humidex (2 m)
Wind speed (100 m)
Wind speed (10 m)
Wind capacity factor (100 m)

Note: m = metre.

Grid map, 2-metre average anomaly of temperature, December 2023



Data are displayed as monthly or annual values. For monthly data, anomalies and climatologies are also available.

Data can be retrieved by clicking the "Configure download" button, pointing to the Data repository:

Due to the large amount of data embedded, the files for gridded data downloaded are in NetCDF format (Network Common Data Form – .nc). The NetCDF file includes data for the selected variable for all data points in the world, and at the selected time. For more information on the NetCDF format, please refer to unidata.ucar.edu/software/netcdf/.

Data repository

The data repository, freely available online at weatherforenergydata.iea.org/, includes the full set of monthly data, at grid level and at nationally and sub-nationally averaged level. Biannual updates are expected. The data repository spans from January 1979 to the month prior to the release (included).

The data repository contains:

- Monthly averages, anomalies and climatologies of gridded data for the entire time series for 51 variables. Each file corresponds to a variable and is composed of three dimensions: latitude, longitude and time. Data are available in NetCDF format.

- Daily and monthly nationally and sub-nationally averaged data for the entire time series for 50 variables. Each file corresponds to a variable and is composed of three dimensions: latitude, longitude and time. Data are available in CSV and NetCDF format.
- A name containing the wording *bysurf* (respectively, *bypop*), which implies that the means national values are computed using a surface (respectively, *population*) weighted averaging method.

Please note that size of gridded files can exceed 1 GB of size.

Whereas nationally and sub-nationally averaged files are available in CSV format, gridded data are only available in the data repository in NetCDF format, due to the large amount of data embedded. The NetCDF file for grid includes data for the selected variable for all data points in the world for the selected month. For more details on NetCDF format, please refer to unidata.ucar.edu/software/netcdf/.

Note that for territorial data, co-ordinates are given through codes (and not longitude and latitude). Please find the code descriptions in the Geographical Coverage section of this document or in the Excel file, "Country codes.xlsx" for national data and "Subnational codes.xlsx" for sub-national data, which are available in the data repository.

Users must not remove any sourcing and disclaimer notices within the files.

Interactive Excel file

The interactive Excel file, freely available at www.iea.org/data-and-statistics/data-tools/weather-for-energy-tracker, is expected to be updated every quarter.

This file offers users the possibility to easily access monthly data for selected variables, averaged at country level for over 200 countries. Selected variables are displayed here as of the April 2024 release, with a monthly resolution from January 2010 to the latest month available (March 2024 as of release).

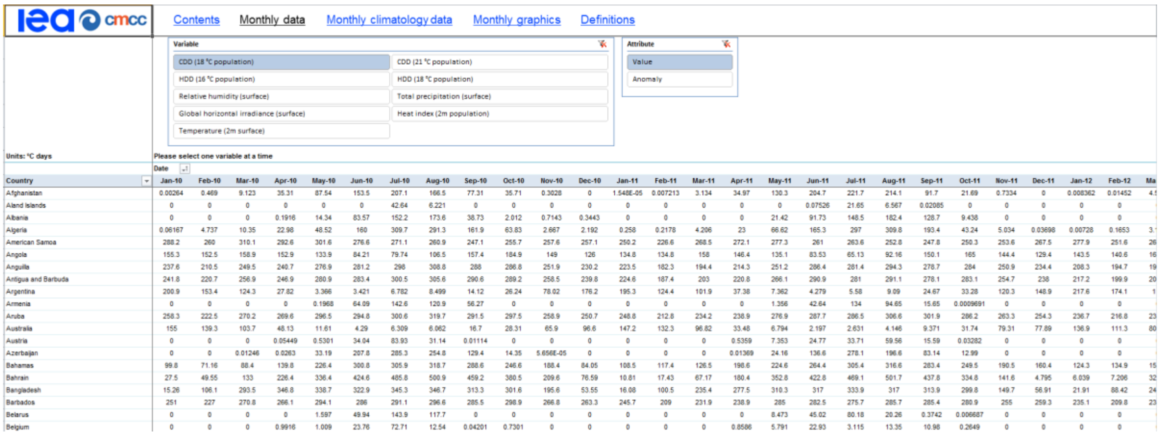
The list of variables accessible through the interactive Excel file is presented in the table below. For more information on variables definitions, please refer to the Definitions sections and, for more information, on the averaging methods, please refer to the Methodology section.

Variables available in the interactive Excel file

Variable	Averaging method
CDD (18 °C)	Population
CDD (21 °C)	Population
HDD (16 °C)	Population
HDD (18 °C)	Population
Relative humidity	Surface
Total precipitation	Surface
Global horizontal irradiance	Surface
Temperature (2 m)	Surface
Heat index (2 m)	Population

The file is composed of two main data tabs and a graphical one: "Monthly data", "Monthly climatology data" and "Monthly graphics". In the "Monthly data" tab, users can select a variable and an attribute (value or anomaly). In the "Monthly climatology data" tab, climatologies for the selected variable are displayed. In the "Monthly graphics" tab, users can display the values and anomalies for the selected variable in an interactive chart.

Excel file: sample view of the Data display tab, Anomalies for CDD (18ºC, population)



Country	Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10
Afghanistan	0.00264	0.469	9.123	35.31	87.54	153.5	207.1	166.5	77.31	35.71	0.3028	0
Aland Islands	0	0	0	0	0	0	42.64	6.221	0	0	0	0
Albania	0	0	0	0.1916	14.34	83.57	152.2	173.6	38.73	2.012	0.7143	0.3443
Algeria	0.06167	4.737	10.35	22.98	48.52	160	309.7	291.3	161.9	63.83	2.667	2.192
American Samoa	288.2	260	310.1	292.6	301.6	276.6	271.1	260.9	247.1	255.7	257.6	257.1
Angola	155.3	152.5	158.9	152.9	133.9	84.21	79.74	106.5	157.4	184.9	149	126
Anguilla	237.6	210.5	249.5	240.7	276.9	281.2	298	308.8	288	286.8	251.9	230.2
Antigua and Barbuda	241.8	220.7	256.9	246.9	280.9	283.4	300.5	305.6	290.6	289.2	258.5	239.8
Argentina	200.9	153.4	124.3	27.82	3.366	3.421	6.782	8.499	14.12	26.24	78.02	176.2
Armenia	0	0	0	0	0.1968	64.09	142.6	120.9	56.27	0	0	0
Aruba	258.3	222.5	270.2	269.6	296.5	294.8	300.6	319.7	291.5	297.5	258.9	250.7
Australia	155	139.3	103.7	48.13	11.61	4.29	6.309	6.062	16.7	28.31	65.9	96.6
Austria	0	0	0	0.05449	0.5301	34.04	83.93	31.14	0.01114	0	0	0
Azerbaijan	0	0	0.01246	0.0263	33.19	207.8	285.3	254.8	129.4	14.35	5.656E-05	0
Bahamas	99.8	71.16	88.4	139.8	226.4	300.8	305.9	318.7	288.6	246.6	188.4	84.05
Bahrain	27.5	49.55	133	226.4	336.4	424.6	485.8	500.9	459.2	380.5	209.6	76.59
Bangladesh	15.26	106.1	293.5	346.8	338.7	322.9	345.3	346.7	313.3	301.6	195.6	53.55
Barbados	251	227	270.8	266.1	294.1	286	291.1	296.6	285.5	298.9	266.8	263.3
Belarus	0	0	0	0	1.597	49.94	143.9	117.7	0	0	0	0
Belgium	0	0	0	0.9916	1.009	23.76	72.71	12.54	0.04201	0.7301	0	0

Country	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12
Afghanistan	1.548E-05	0.007213	3.134	34.97	130.3	204.7	221.7	214.1	91.7	21.69	0.7334	0	0.008362	0.01452
Aland Islands	0	0	0	0	0	0.07526	21.65	6.567	0.02085	0	0	0	0	0
Albania	0	0	0	0	21.42	91.73	148.5	182.4	128.7	9.438	0	0	0	0
Algeria	0.258	0.2178	4.206	23	66.62	165.3	297	309.8	193.4	43.24	5.034	0.03698	0.00728	0.1653
American Samoa	250.2	226.6	268.5	272.1	277.3	261	263.6	252.8	247.8	250.3	253.6	267.5	277.9	251.6
Angola	134.8	134.8	158	146.4	135.1	83.53	65.13	92.16	150.1	165	144.4	129.4	143.5	140.6
Anguilla	223.5	182.3	194.4	214.3	251.2	286.4	281.4	294.3	278.7	284	250.9	234.4	208.3	194.7
Antigua and Barbuda	224.6	187.4	203	220.8	266.1	290.9	281	291.1	278.1	283.1	254.7	238	217.2	199.9
Argentina	195.3	124.4	101.9	37.38	7.362	4.279	5.58	9.09	24.67	33.28	120.3	148.9	217.6	174.1
Armenia	0	0	0	0	1.356	42.64	134	94.65	15.65	0.0009691	0	0	0	0
Aruba	248.8	212.8	234.2	238.9	276.9	287.7	286.5	306.6	301.9	286.2	263.3	254.3	236.7	216.8
Australia	147.2	132.3	96.82	33.48	6.794	2.197	2.631	4.146	9.371	31.74	79.31	77.89	136.9	111.3
Austria	0	0	0	0.5359	7.353	24.77	33.71	59.56	15.59	0.03282	0	0	0	0
Azerbaijan	0	0	0	0.01369	24.16	136.6	278.1	196.6	83.14	12.99	0	0	0	0
Bahamas	108.5	117.4	126.5	198.6	224.6	264.4	305.4	316.6	283.4	249.5	190.5	160.4	124.3	134.9
Bahrain	10.81	17.43	67.17	180.4	352.8	422.8	469.1	501.7	437.8	334.8	141.6	4.795	6.039	7.206
Bangladesh	16.08	100.5	235.4	277.5	310.3	317	333.9	317	313.9	299.8	149.7	56.91	21.91	88.42
Barbados	245.7	209	231.9	238.9	285	282.5	275.7	285.7	285.4	280.9	255	259.3	235.1	209.8
Belarus	0	0	0	0	8.473	45.02	80.18	20.26	0.3742	0.006687	0	0	0	0
Belgium	0	0	0	0.8586	5.791	22.93	3.115	13.35	10.98	0.2649	0	0	0	0

Users must not remove any sourcing and disclaimer notices within the files.

Data sources

This database makes use of primary data for weather variable and population to derive various indicators.

Weather primary variables are extracted from ERA5 hourly dataset.[5] Fourteen variables are used as a source of 10 primary variables published as well as 42 derived indicators (more details can be found in Definitions section).

Data are retrieved using the Climate Data Store Application Program Interface (CDS API). Please find further documentation on the dedicated CDS API webpage.

The dataset is retrieved with the following parameters:

- Dataset short name: reanalysis-era5-single-levels
- Product type: reanalysis
- Space resolution: 0.25° x 0.25° longitude and latitude
- Format: netCDF files
- Time series: hourly data from 1 January 1979 to last hour of month prior to publication date

Population data are derived from the Center for International Earth Science Information Network (CIESIN), Columbia University, 2018, Gridded Population of the World, Version 4 (GPWv4)[6] and GHS population grid from (JRC)[7].

Data are interpolated to estimate yearly population values from 2000 to 2024. (more details in Methodology section). Those data are used to compute population weighted territorial averages for all indicators.

The mask embedded in the population dataset is also used to aggregate gridded data into national data.

[5] Hersbach, H. at al. (2018), ERA5 hourly data on single levels from 1959 to present. Copernicus Climate Change Service (C3S) Climate Data Store (CDS), (accessed: 9 November 2020), 10.24381/cds.adbb2d47

[6] Center for International Earth Science Information Network (CIESIN), Columbia University (2018), Gridded Population of the World, Version 4 (GPWv4): Population Count, Revision 11. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC), doi.org/10.7927/H4JW8BX5 (accessed: 29 May 2020).

[7] Schiavina, Marcello; Freire, Sergio; MacManus, Kytt (2019): GHS population grid multitemporal (1975, 1990, 2000, 2015) R2019A. European Commission, Joint Research Centre (JRC) DOI: 10.2905/42E8BE89-54FF-464E-BE7B-BF9E64DA5218 PID: http://data.europa.eu/89h/0c6b9751-a71f-4062-830b-43c9f432370fConcept & Methodology: Freire, Sergio; MacManus, Kytt; Pesaresi, Martino; Doxsey-Whitfield, Erin; Mills, Jane (2016): Development of new open and free multi-temporal global population grids at 250 m resolution. Geospatial Data in a Changing World; Association of Geographic Information Laboratories in Europe (AGILE). AGILE 2016.

The mask used to aggregate sub-national data is derived from files extracted from DIVA-GIS[8].

[8] Download data by country | DIVA-GIS

Definitions

Variables are separated in this section into two categories:

- Primary weather variable: Those variables are extracted from Copernicus Climate Change Service, 2024; ERA5 hourly data on single levels from 1970 to present (doi.org/10.24381/cds.adbb2d47), European Centre for Medium-Range Weather Forecasts. They are not manipulated further than resizing the units to more convenient units, and are used as input to derived indicators. The first table contains web and short names, definition and unit of each variable. The definition column contains a descriptive name of the variable, the corresponding ID to ERA5 dataset, and the unit conversion done if applicable. Link to ERA5 documentation
- Derived indicators: are relevant indicators derived from primary weather variables. The dedicated table contains web and short names, definitions and units of each variable. Methodologies used are more detailed under the methodological section of this document.

Primary weather variables

Web name: Temperature (2m)	**Short name:** Temperature	**Units:** °C
Definition	2 meters mean temperature. This parameter corresponds to item n°167 of ERA5 dataset, described as: *This parameter is the temperature of air at 2m above the surface of land, sea or inland waters. 2m temperature is calculated by interpolating between the lowest model level and the earth's surface, taking account of the atmospheric conditions.*	

Web name: Dew temperature (2m)	**Short name:** Temperaturedew	**Units:** °C
Definition	2 meters mean dew temperature. This parameter corresponds to item n°168 of ERA5 dataset, described as: *This parameter is the temperature to which the air, at 2 metres above the surface of the earth, would have to be cooled for saturation to occur. It is a measure of the humidity of the air. Combined with temperature and pressure, it can be used to calculate the relative humidity. 2m dew point temperature is calculated by interpolating between the lowest model level and the earth's surface, taking account of the atmospheric conditions.*	

Web name: Total precipitation	Short name: Precipitation	Units: mm/h
Definition	Total precipitation. This parameter corresponds to item n°228 of ERA5 dataset, described as: This parameter is the accumulated liquid and frozen water, comprising the rain and snow that falls to the earth's surface. It is the sum of large-scale precipitation and convective precipitation. Large-scale precipitation is generated by the cloud scheme in the ECMWF Integrated Forecasting System (IFS). The cloud scheme represents the formation and dissipation of clouds and large-scale precipitation due to changes in atmospheric quantities (such as pressure, temperature and moisture) predicted directly by the IFS at spatial scales of the grid box or larger. Convective precipitation is generated by the convection scheme in the IFS, which represents convection at spatial scales smaller than the grid box. This parameter does not include fog, dew or the precipitation that evaporates in the atmosphere before it lands at the surface of the earth. This parameter is the total amount of water accumulated over a particular time period which depends on the data extracted. The units of this parameter are depth in metres of water equivalent. It is the depth the water would have if it were spread evenly over the grid box. Care should be taken when comparing model parameters with observations, because observations are often local to a particular point in space and time, rather than representing averages over a model grid box. Unit is converted from m/h to mm/h.	

Web name: Snowfall	Short name: Snowfall	Units: mm/h
Definition	Snowfall. This parameter corresponds to item n°144 of ERA5 dataset, described as: This parameter is the accumulated snow that falls to the earth's surface. It is the sum of large-scale snowfall and convective snowfall. Large-scale snowfall is generated by the cloud scheme in the ECMWF Integrated Forecasting System (IFS). The cloud scheme represents the formation and dissipation of clouds and large-scale precipitation due to changes in atmospheric quantities (such as pressure, temperature and moisture) predicted directly by the IFS at spatial scales of the grid box or larger. Convective snowfall is generated by the convection scheme in the IFS, which represents convection at spatial scales smaller than the grid box. See further information. This parameter is the total amount of water accumulated over a particular time period which depends on the data extracted. The units of this parameter are depth in metres of water equivalent. It is the depth the water would have if it were spread evenly over the grid box. Care should be taken when comparing model parameters with observations, because observations are often local to a particular point in space and time, rather than representing averages over a model grid box. Unit is converted from m/h to mm/h.	

Web name: Runoff	**Short name:** Runoff	**Units:** mm/h
Definition	This parameter corresponds to item n°205 of ERA5 dataset, described as: Some water from rainfall, melting snow, or deep in the soil, stays stored in the soil. Otherwise, the water drains away, either over the surface (surface runoff), or under the ground (sub-surface runoff) and the sum of these two is simply called “runoff”. This parameter is the total amount of water accumulated over a particular time period which depends on the data extracted. The units of runoff are depth in metres. This is the depth the water would have if it were spread evenly over the grid box. Care should be taken when comparing model parameters with observations, because observations are often local to a particular point rather than averaged over a grid square area. Observations are also often taken in different units, such as mm/day, rather than the accumulated metres produced here. Runoff is a measure of the availability of water in the soil, and can, for example, be used as an indicator of drought or flood. Unit is converted from m/h to mm/h.	

Web name: Evaporation	**Short name:** Evaporation	**Units:** mm/h
Definition	Evaporation. This parameter corresponds to item n°182 of ERA5 dataset, described as: This parameter is the accumulated amount of water that has evaporated from the earth's surface, including a simplified representation of transpiration (from vegetation), into vapour in the air above. This parameter is accumulated over a particular time period which depends on the data extracted. The ECMWF Integrated Forecasting System convention is that downward fluxes are positive. Therefore, negative values indicate evaporation and positive values indicate condensation	

Web name: Cloud coverage	**Short name:** Cloud coverage	**Units:** %
Definition	Cloud coverage. This parameter corresponds to item n°164 of ERA5 dataset, described as: This parameter is the proportion of a grid box covered by cloud. Total cloud cover is a single level field calculated from the cloud occurring at different model levels through the at-mosphere. Assumptions are made about the degree of overlap/randomness between clouds at different heights	

Web name: Direct normal radiation	**Short name:** DNI	**Units:** $J/m^2/h$
Definition	Direct normal radiation. This parameter corresponds to item n° 228021 (Total sky direct solar radiation at surface) of ERA5 dataset, described as: *This parameter is the amount of direct solar radiation (also known as shortwave radiation) reaching the surface of the earth. It is the amount of radiation passing through a horizontal plane, not a plane perpendicular to the direction of the Sun. Solar radiation at the surface can be direct or diffuse. Solar radiation can be scattered in all directions by particles in the atmosphere, some of which reaches the surface (diffuse solar radiation). Some solar radiation reaches the surface without being scattered (direct solar radiation)*	

Web name: Global horizontal irradiance	**Short name:** GHI	**Units:** J/m²/h
Definition	Global horizontal irradiance. This parameter corresponds to item n° 169 (Surface solar radiation downwards) of ERA5 dataset, described as: *This parameter is the amount of solar radiation (also known as shortwave radiation) that reaches a horizontal plane at the surface of the earth. This parameter comprises both direct and diffuse solar radiation. Radiation from the Sun (solar, or shortwave, radiation) is partly reflected back to space by clouds and particles in the atmosphere (aerosols) and some of it is absorbed. The rest is incident on the earth's surface (represented by this parameter).* https://www.ecmwf.int/sites/default/files/elibrary/2015/18490-radiation-quantities-ecmwf-model-and-mars.pdf *To a reasonably good approximation, this parameter is the model equivalent of what would be measured by a pyranometer (an instrument used for measuring solar radiation) at the surface. However, care should be taken when comparing model parameters with observations, because observations are often local to a particular point in space and time, rather than representing averages over a* model grid box.	

Web name: Surface pressure	**Short name:** Surface pressure	**Units:** Pa
Definition	Surface pressure. This parameter corresponds to item n° 134 of ERA5 dataset, described as: *This parameter is the pressure (force per unit area) of the atmosphere on the surface of land, sea and in-land water. It is a measure of the weight of all the air in a column vertically above the area of the earth's surface represented at a fixed point. Surface pressure is often used in combination with temperature to calculate air density. The strong variation of pressure with altitude makes it difficult to see the low and high pressure systems over mountainous areas, so mean sea level pressure, rather than surface pressure, is normally used for this purpose.*	

Derived indicators

Variable: Temperature max (2m)	**Short name:** Temperature max	**Units:** °C
Definition	2-metre maximum temperature. It is calculated as the maximum of 2 metre hourly temperature over the period of time considered.	
Variable: Temperature min (2m)	**Short name:** Temperature min	**Units:** °C
Definition	2-metre minimum temperature. It is calculated as the minimum of 2 metre hourly temperature over the period of time considered.	
Variable: Heat index (2m)	**Short name:** HeatIndex	**Units:** °C
Definition	Humidity-corrected 2 meter temperature (heat index). More details on methodology here.	
Variable: Humidex (2 m)	**Short name:** Humidex	**Units:** °C
Definition	Humidity-corrected 2 metre temperature (humidex). More details on methodology here.	
Variable: CDD (65 °F)	**Short name:** CDD	**Units:** °C days

Definition	Cooling degree days (reference temperature 65 °F). More details on methodology here.	
Variable: CDD (10 °C)	**Short name:** CDD10	**Units:** C days
Definition	Cooling degree days (reference temperature 10 °C). More details on methodology here.	
Variable: CDD (16 °C	**Short name:** CDD16	**Units:** C days
Definition	Cooling degree days (reference temperature 16 °C). More details on methodology here.	
Definition	Cooling degree days (reference temperature 18 °C). More details on methodology here.	
Variable: CDD (21 °C)	**Short name:** CDD21	**Units:** C days
Definition	Cooling degree days (reference temperature 21 °C). More details on methodology here.	
Variable: CDD (23 °C)	**Short name:** CDD23	**Units:** C days
Definition	Cooling degree days (reference temperature 23 °C). More details on methodology here.	
Variable: CDD (26 °C)	**Short name:** CDD26	**Units:** °C days
Definition	Cooling degree days (reference temperature 26 °C). More details on methodology here.	
Variable: CDD (18 °C, 21 °C threshold)	**Short name:** CDDThold18	**Units:** °C days
Definition	Cooling degree days (reference temperature 18 °C and threshold temperature 21 °C. Examples: if the daily mean air temperature is 24°C, for that day the value of the CDD is 6 (24 °C-18 °C). If the daily mean air temperature is 20 °C, for that day the CDD is 0.). More details on methodology here.	
Variable: CDD (21 °C, 24 °C threshold)	**Short name:** CDDThold21	**Units:** °C days
Definition	Cooling degree days (reference temperature 21 °C and threshold temperature 24 °C. Examples: if the daily mean air temperature is 26°C, for that day the value of the CDD is 5 (26 °C-21 °C). If the daily mean air temperature is 22 °C, for that day the CDD is 0). More details on methodology here.	
Variable: CDD (23 °C, 26 °C threshold)	**Short name:** CDDThold23	**Units:** °C days
Definition	Cooling degree days (reference temperature 23 °C and threshold temperature 26 °C. Examples: if the daily mean air temperature is 30°C, for that day the value of the CDD is 7 (30 °C-26 °C). If the daily mean air temperature is 25 °C, for that day the CDD is 0). More details on methodology here.	
Variable: CDD (variable)	**Short name:** CDDVar	**Units:** °C days
Definition	Cooling degree days (reference temperature variable per region. Japan, India 21 °C; Rest of the World 18 °C). More details on methodology here.	
Variable: CDD (65 °F, humidity)	**Short name:** CDDhum	**Units:** °C days

Definition	Cooling degree days from temperature corrected by humidity (reference temperature 65 °F). Heat Index is used as input temperature. More details on methodology here.	
Variable: CDD (10 °C, humidity)	**Short name:** CDDhum10	**Units:** °C days
Definition	Cooling degree days from temperature corrected by humidity (reference temperature 10 °C). Heat Index is used as input temperature. More details on methodology here.	
Variable: CDD (16 °C, humidity)	**Short name:** CDDhum16	**Units:** °C days
Definition	Cooling degree days from temperature corrected by humidity (reference temperature 16 °C). Heat Index is used as input temperature. More details on methodology here.	
Variable: CDD (18 °C, humidity)	**Short name:** CDDhum18	**Units:** °C days
Definition	Cooling degree days from temperature corrected by humidity (reference temperature 18 °C). Heat Index is used as input temperature. More details on methodology here.	
Variable: CDD (21 °C, humidity)	**Short name:** CDDhum21	**Units:** C days
Definition	Cooling degree days from temperature corrected by humidity (reference temperature 21 °C). Heat Index is used as input temperature. More details on methodology here.	
Variable: CDD (23 °C, humidity)	**Short name:** CDDhum23	**Units:** C days
Definition	Cooling degree days from temperature corrected by humidity (reference temperature 23 °C). Heat Index is used as input temperature. More details on methodology here.	
Variable: CDD (26 °C, humidity)	**Short name:** CDDhum26	**Units:** C days
Definition	Cooling degree days from temperature corrected by humidity (reference temperature 26 °C). Heat Index is used as input temperature. More details on methodology here.	
Variable: CDD (18 °C, 21 °C threshold, humidity)	**Short name:** CDDhumThold18	**Units:** C days
Definition	Cooling degree days from temperature corrected by humidity (reference temperature 18 °C and threshold temperature 21 °C). Heat Index is used as input temperature. Examples: if the daily mean air temperature is 24 °C, for that day the value of the CDD is 6 (24 °C-18 °C). If the daily mean air temperature is 20 °C, for that day the CDD is 0). More details on methodology here.	
Variable: CDD (21 °C, 24 °C threshold, humidity)	**Short name:** CDDhumThold21	**Units:**
Definition	Cooling degree days from temperature corrected by humidity (reference temperature 21 °C and threshold temperature 24 °C). Heat Index is used as input temperature. Examples: if the daily mean air temperature is 26 °C, for that day the value of the CDD is 5 (26 °C-21 °C). If the daily mean air temperature is 22 °C, for that day the CDD is 0). More details on methodology here.	
Variable: CDD (23 °C, 26 °C threshold, humidity)	**Short name:** CDDhumThold23	**Units:** C days

Definition	Cooling degree days from temperature corrected by humidity (reference temperature 23 °C and threshold temperature 26 °C). Heat Index is used as input temperature. Examples: if the daily mean air temperature is 30 °C, for that day the value of the CDD is 4 (30 °C-26 °C). If the daily mean air temperature is 25 °C, for that day the CDD is 0). More details on methodology here.	
Variable: CDD (variable, humidity)	**Short name:** CDDhumVar	**Units:**
Definition	Cooling degree days from temperature corrected by humidity (reference temperature variable per region). Heat Index is used as input temperature. Japan, India 21 °C; Rest of the World 18 °C). More details on methodology here.	
Variable: CDD (65 °F, wet bulb)	**Short name:** CDDwet	**Units:** °C days
Definition	Cooling degree days from wet bulb temperature (reference temperature 65 °F). Wet bulb temperature is used as input temperature. More details on methodology here.	
Variable: HDD (65 °F)	**Short name:** HDD	**Units:** °C days
Definition	Heating degree days (reference temperature 65 °F). More details on methodology here.	
Variable: HDD (16 °C)	**Short name:** HDD16	**Units:** °C days
Definition	Heating degree days (reference temperature 16 °C). More details on methodology here.	
Variable: HDD (18 °C)	**Short name:** HDD18	**Units:** °C days
Definition	Heating degree days (reference temperature 18 °C). More details on methodology here.	
Variable: HDD (20 °C)	**Short name:** HDD20	**Units:** °C days
Definition	Heating degree days (reference temperature 20 °C). More details on methodology here.	
Variable: HDD (16 °C, 13 °C threshold)	**Short name:** HDDThold16	**Units:** °C days
Definition	Heating degree days (reference temperature 16 °C and threshold temperature 13 °C). Examples: if the daily mean air temperature is 12°C, for that day the value of the HDD is 4 (16 °C-12 °C). If the daily mean air temperature is 14 °C, for that day the HDD is 0). More details on methodology here.	
Variable: HDD (18 °C, 15 °C threshold)	**Short name:** HDDThold18	**Units:** °C days
Definition	Heating degree days (reference temperature 18 °C and threshold temperature 15 °C. Examples: if the daily mean air temperature is 12°C, for that day the value of the HDD is 6 (18 °C-12 °C). If the daily mean air temperature is 16 °C, for that day the HDD is 0.) More details on methodology here.	
Variable: HDD (20 °C, 17 °C threshold)	**Short name:** HDDThold20	**Units:** °C days
Definition	Heating degree days (reference temperature 20 °C and threshold temperature 17 °C. Examples: if the daily mean air temperature is 12°C, for that day the value of the HDD is 8 (20 °C-12 °C). If the daily mean air temperature is 19 °C, for that day the HDD is 0). More details on methodology here.	
Variable: HDD (variable)	**Short name:** HDDVar	**Units:** °C days

Definition	Heating degree days (reference temperature variable per region. Japan, Europe 16 °C; United States 11 °C; Rest of the World 18 °C). More details on methodology here.	
Variable: HDD (14 °C, wind)	**Short name:** HDDwind	**Units:** °C days
Definition	Heating degree days corrected by wind speed (reference temperature 14 °C). More details on methodology here.	
Variable: Relative humidity	**Short name:** RH	**Units:** %
Definition	Relative humidity based on 2 metres air and dew temperatures. More details on methodology here.	
Variable: Sun light	**Short name:** Daylight	**Units:** minute
Definition	Minutes of sunlight. More details on methodology here.	
Variable: Wind speed (100-m)	**Short name:** Wind100int	**Units:** m/s
Definition	100 metres wind speed is calculated using the eastward components (item 228246) and northward component (item 228247) of the 100 m wind. It is the horizontal speed of air, at a height of one hundred meters above the surface of the earth. Care should be taken when comparing this parameter with observations, because wind observations vary on small space and time scales and are affected by the local terrain, vegetation and buildings that are represented only on average in the ECMWF Integrated Forecasting System.	
Variable: Wind speed (10-m)	**Short name:** Wind10int	**Units:** m/s
Definition	10 metres wind speed is calculated using the eastward components (item 165) and northward component (item 166) of the 10 m wind. It is the horizontal speed of air, at a height of ten meters above the surface of the earth. Care should be taken when comparing this parameter with observations, because wind observations vary on small space and time scales and are affected by the local terrain, vegetation and buildings that are represented only on average in the ECMWF Integrated Forecasting System.	

Variable: Wind direction (100-m)	**Short name:** Wind100dir	**Units:** degree - anticlockwise, 0 is east
Definition	100 metres wind direction is calculated using the eastward components (item 228246) and northward component (item 228247) of the 100 m wind. This parameter is the direction from which the wind blows, in degrees anticlockwise from the east, at a height of a hundred meters above the surface of the earth.	
Variable: Wind direction (10-m)	**Short name:** Wind10dir	**Units:** degree - anticlockwise, 0 is east
Definition	10 metres wind direction is calculated using the eastward components (item 165) and northward component (item 166) of the 10 m wind. This parameter is the direction from which the wind blows, in degrees anticlockwise from the east, at a height of ten meters above the surface of the earth.	

Variable: Wind capacity factor (100-m)	**Short name:** Wind100power	**Units:** %
Definition	The wind capacity factor represents the percentage of power output over nominal power expected from a wind turbine on a specific point of the grid for a specific time. More details on methodology here.	

Geographical coverage

This document is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area. In this publication, 'country' refers to country or territory, as case may be.

Countries and territories

This table is available for download in excel format using this link.

Country/Territory	Short name	Code
Afghanistan	AFGHANIS	4
Aland Islands	ALANDISL	248
Albania	ALBANIA	8
Algeria	ALGERIA	12
American Samoa	AMSAMOA	16
Angola	ANGOLA	24
Anguilla	ANGUILLA	660
Antigua and Barbuda	ANTIGUA	28
Argentina	ARGENTINA	32
Armenia	ARMENIA	51
Aruba	ARUBA	533
Australia	AUSTRALI	36
Austria	AUSTRIA	40
Azerbaijan	AZERBAIJAN	31
Bahamas	BAHAMAS	44
Bahrain	BAHRAIN	48
Bangladesh	BANGLADESH	50
Barbados	BARBADOS	52
Belarus	BELARUS	112
Belgium	BELGIUM	56
Belize	BELIZE	84
Benin	BENIN	204
Bermuda	BERMUDA	60
Bonaire Saint Eustatius and Saba	BES	535
Bhutan	BHUTAN	64
British Indian Ocean Territory	BIOT	905

Country/Territory	Short name	Code
Plurinational State of Bolivia	BOLIVIA	68
Bosnia and Herzegovina	BOSNIAHERZ	70
Botswana	BOTSWANA	72
Bouvet Island	BOUVET	903
Brazil	BRAZIL	76
Brunei Darussalam	BRUNEI	96
Bulgaria	BULGARIA	100
Burkina Faso	BURKINA	854
Burundi	BURUNDI	108
British Virgin Islands	BVI	92
Cape Verde	CABOVERDE	132
Central African Republic	CAFRICREP	140
New Caledonia	CALEDONIA	540
Cambodia	CAMBODIA	116
Cameroon	CAMEROON	120
Canada	CANADA	124
Cayman Islands	CAYMAN	136
Chad	CHAD	148
Chile	CHILE	152
People's Republic of China	CHINA	156
Colombia	COLOMBIA	170
Comoros	COMOROS	174
Republic of the Congo	CONGO	178
Democratic Republic of the Congo	CONGOREP	180
Cook Islands	COOK	184
Costa Rica	COSTARICA	188
Cote d'Ivoire	COTEIVOIRE	384
Croatia	CROATIA	191
Cuba	CUBA	192
Curacao/Netherlands Antilles	CURACAO	531
Cyprus	CYPRUS	196
Czech Republic	CZECH	203
Denmark	DENMARK	208
Djibouti	DJIBOUTI	262
Dominica	DOMINICA	212
Dominican Republic	DOMINICANR	214
Ecuador	ECUADOR	218
Egypt	EGYPT	818
El Salvador	ELSALVADOR	222

Country/Territory	Short name	Code
Equatorial Guinea	EQGUINEA	226
Eritrea	ERITREA	232
Estonia	ESTONIA	233
Swaziland	ESWATINI	748
Ethiopia	ETHIOPIA	231
Faeroe Islands	FAROE	234
French Guiana	FGUYANA	254
Fiji	FIJI	242
Finland	FINLAND	246
French Polynesia	FPOLYNESIA	258
France	FRANCE	250
French Southern Territories	FSAT	902
Gabon	GABON	266
Gambia	GAMBIA	270
Georgia	GEORGIA	268
Germany	GERMANY	276
Ghana	GHANA	288
Greece	GREECE	300
Greenland	GREENLAND	304
Grenada	GRENADA	308
Guadeloupe	GUADELOUPE	312
Guam	GUAM	316
Guatemala	GUATEMALA	320
Guernsey	GUERNSEY	831
Guinea	GUINEA	324
Guinea-Bissau	GUINEABIS	624
Guyana	GUYANA	328
Haiti	HAITI	332
Heard Island and McDonald Islands	HIMI	904
Honduras	HONDURAS	340
Hong Kong (China)	HONGKONG	344
Hungary	HUNGARY	348
Iceland	ICELAND	352
India	INDIA	356
Indonesia	INDONESIA	360
Islamic Republic of Iran	IRAN	364
Iraq	IRAQ	368
Ireland	IRELAND	372
Israel	ISRAEL	376

Country/Territory	Short name	Code
Italy	ITALY	380
Jamaica	JAMAICA	388
Japan	JAPAN	392
Jersey	JERSEY	832
Jordan	JORDAN	400
Kazakhstan	KAZAKHSTAN	398
Kenya	KENYA	404
Kiribati	KIRIBATI	296
Korea	KOREA	410
Democratic People's Republic of Korea	KOREADPR	408
Kosovo	KOSOVO	999
Kuwait	KUWAIT	414
Kyrgyzstan	KYRGYZSTAN	417
Lao People's Democratic Republic	LAO	418
Latvia	LATVIA	428
Lebanon	LEBANON	422
Lesotho	LESOTHO	426
Liberia	LIBERIA	430
Libya	LIBYA	434
Lithuania	LITHUANIA	440
Luxembourg	LUXEMBOU	442
Madagascar	MADAGASCAR	450
Malawi	MALAWI	454
Malaysia	MALAYSIA	458
Maldives	MALDIVES	462
Mali	MALI	466
Malta	MALTA	470
Falkland Islands (Malvinas)	MALVINAS	238
Isle of Man	MANISLE	833
Marshall Islands	MARSHALL	584
Martinique	MARTINIQUE	474
Mauritania	MAURITANIA	478
Mauritius	MAURITIUS	480
Mayotte	MAYOTTE	175
Mexico	MEXICO	484
Micronesia (Federated States of)	MICRONESIA	583
Republic of Moldova	MOLDOVA	498
Mongolia	MONGOLIA	496

Country/Territory	Short name	Code
Montenegro	MONTENEGRO	499
Montserrat	MONTSERRAT	500
Morocco	MOROCCO	504
Mozambique	MOZAMBIQUE	508
Myanmar	MYANMAR	104
Namibia	NAMIBIA	516
Nauru	NAURU	520
Nepal	NEPAL	524
Netherlands	NETHLAND	528
Nicaragua	NICARAGUA	558
Niger	NIGER	562
Nigeria	NIGERIA	566
Niue	NIUE	570
Northern Mariana Islands	NMARIANA	580
Norfolk Island	NORFOLK	574
Republic of North Macedonia	NORTHMACED	807
Norway	NORWAY	578
New Zealand	NZ	554
Oman	OMAN	512
Pakistan	PAKISTAN	586
Palau	PALAU	585
State of Palestine	PALESTINE	275
Panama	PANAMA	591
Papua New Guinea	PAPUA	598
Paraguay	PARAGUAY	600
Peru	PERU	604
Philippines	PHILIPPINE	608
Pitcairn	PITCAIRN	612
Poland	POLAND	616
Portugal	PORTUGAL	620
Puerto Rico	PUERTORICO	630
Qatar	QATAR	634
Reunion	REUNION	638
Romania	ROMANIA	642
Russian Federation	RUSSIA	643
Rwanda	RWANDA	646
Western Samoa	SAMOA	882
Sao Tome and Principe	SAOTOME	678
Saudi Arabia	SAUDIARABI	682

Country/Territory	Short name	Code
Saint-Barthelemy	SBARTHEL	652
Senegal	SENEGAL	686
Serbia	SERBIA	688
Seychelles	SEYCHELLES	690
South Georgia and the South Sand-wich Islands	SGEORGIA	906
Saint Helena	SHELENA	654
Sierra Leone	SIERRALEO	694
Singapore	SINGAPORE	702
Saint Kitts and Nevis	SKITTS	659
Slovak Republic	SLOVAKIA	703
Slovenia	SLOVENIA	705
Saint Lucia	SLUCIA	662
Sint Maarten (Dutch part)	SMAARTEN	534
Solomon Islands	SOLOMON	90
Somalia	SOMALIA	706
South Africa	SOUTHAFRIC	710
Spain	SPAIN	724
Saint Pierre and Miquelon	SPIERRE	666
Spratly Islands	SPRATLY	907
Sri Lanka	SRILANKA	144
South Sudan	SSUDAN	728
Sudan	SUDAN	729
Suriname	SURINAME	740
Svalbard and Jan Mayen Islands	SVALBARD	744
Saint Vincent and the Grenadines	SVINCENT	670
Sweden	SWEDEN	752
Switzerland	SWITLAND	756
Syrian Arab Republic	SYRIA	760
Chinese Taipei	TAIPEI	158
Tajikistan	TAJIKISTAN	762
United Republic of Tanzania	TANZANIA	834
Thailand	THAILAND	764
Timor-Leste	TIMORLESTE	626
Togo	TOGO	768
Tokelau	TOKELAU	772
Tonga	TONGA	776
Trinidad and Tobago	TRINIDAD	780
Tunisia	TUNISIA	788

Country/Territory	Short name	Code
Turkey	TURKEY	792
Turkmenistan	TURKMENIST	795
Turks and Caicos Islands	TURKSCAIC	796
Tuvalu	TUVALU	798
United Arab Emirates	UAE	784
Uganda	UGANDA	800
United Kingdom	UK	826
Ukraine	UKRAINE	804
Uruguay	URUGUAY	858
United States	USA	840
United States Minor Outlying Islands	USMOS	908
United States Virgin Islands	USVI	850
Uzbekistan	UZBEKISTAN	860
Vanuatu	VANUATU	548
Bolivarian Republic of Venezuela	VENEZUELA	862
Viet Nam	VIETNAM	704
Wallis and Futuna Islands	WALLIS	876
Western Sahara	WESSAHARA	732
Yemen	YEMEN	887
Zambia	ZAMBIA	894
Zimbabwe	ZIMBABWE	716

Sub-national divisions

This table is available for download in excel format using this link.

Sub-national division	Short name	Country ISO code
Minnesota	US-MN	USA
Washington	US-WA	USA
Idaho	US-ID	USA
Montana	US-MT	USA
North Dakota	US-ND	USA
Michigan	US-MI	USA
Maine	US-ME	USA
Ohio	US-OH	USA
New Hampshire	US-NH	USA
New York	US-NY	USA
Vermont	US-VT	USA

Sub-national division	Short name	Country ISO code
Pennsylvania	US-PA	USA
Arizona	US-AZ	USA
California	US-CA	USA
New Mexico	US-NM	USA
Texas	US-TX	USA
Alaska	US-AK	USA
Louisiana	US-LA	USA
Mississippi	US-MS	USA
Alabama	US-AL	USA
Florida	US-FL	USA
Georgia	US-GA	USA
South Carolina	US-SC	USA
North Carolina	US-NC	USA
Virginia	US-VA	USA
Maryland	US-MD	USA
Delaware	US-DE	USA
New Jersey	US-NJ	USA
Connecticut	US-CT	USA
Rhode Island	US-RI	USA
Massachussets	US-MA	USA
Oregon	US-OR	USA
Hawaii	US-HI	USA
Utah	US-UT	USA
Wyoming	US-WY	USA
Nevada	US-NV	USA
Colorado	US-CO	USA
South Dakota	US-SD	USA
Nebraska	US-NE	USA
Kansas	US-KS	USA
Oklahoma	US-OK	USA
Iowa	US-IA	USA
Missouri	US-MO	USA
Wisconsin	US-WI	USA
Illinois	US-IL	USA
Kentucky	US-KY	USA
Arkansas	US-AR	USA
Tennessee	US-TN	USA
West Virginia	US-WV	USA

Sub-national division	Short name	Country ISO code
Indiana	US-IN	USA
Acre	BR-AC	BRA
Alagoas	BR-AL	BRA
Amapa	BR-AP	BRA
Amazonas	BR-AM	BRA
Bahia	BR-BA	BRA
Ceara	BR-CE	BRA
Distrito Federal	BR-DF	BRA
Espirito Santo	BR-ES	BRA
Goias	BR-GO	BRA
Maranhao	BR-MA	BRA
Mato Grosso do Sul	BR-MS	BRA
Mato Grosso	BR-MT	BRA
Minas Gerais	BR-MG	BRA
Para	BR-PA	BRA
Paraiba	BR-PB	BRA
Parana	BR-PR	BRA
Pernambuco	BR-PE	BRA
Piaui	BR-PI	BRA
Rio de Janeiro	BR-RJ	BRA
Rio Grande do Norte	BR-RN	BRA
Rio Grande do Sul	BR-RS	BRA
Rondonia	BR-RO	BRA
Roraima	BR-RR	BRA
Sao Paulo	BR-SP	BRA
Santa Catarina	BR-SC	BRA
Sergipe	BR-SE	BRA
Tocantins	BR-TO	BRA
Australian Capital Territory	AU-ACT	AUS
New South Wales	AU-NSW	AUS
Northern Territory	AU-NT	AUS
Queensland	AU-QLD	AUS
South Australia	AU-SA	AUS
Tasmania	AU-TAS	AUS
Victoria	AU-VIC	AUS
Western Australia	AU-WA	AUS
Alberta	CA-AB	CAN
British Columbia	CA-BC	CAN

Sub-national division	Short name	Country ISO code
Manitoba	CA-MB	CAN
New Brunswick	CA-NB	CAN
Newfoundland and Labrador	CA-NL	CAN
Northwest Territories	CA-NT	CAN
Nova Scotia	CA-NS	CAN
Nunavut	CA-NU	CAN
Ontario	CA-ON	CAN
Prince Edward Island	CA-PE	CAN
Quebec	CA-QC	CAN
Saskatchewan	CA-SK	CAN
Yukon	CA-YT	CAN
Anhui	CN-AH	CHN
Beijing	CN-BJ	CHN
Chongqing	CN-CQ	CHN
Fujian	CN-FJ	CHN
Gansu	CN-GS	CHN
Guangdong	CN-GD	CHN
Guangxi	CN-GX	CHN
Guizhou	CN-GZ	CHN
Hainan	CN-HI	CHN
Hebei	CN-HE	CHN
Heilongjiang	CN-HL	CHN
Henan	CN-HA	CHN
Hubei	CN-HB	CHN
Hunan	CN-HN	CHN
Jiangsu	CN-JS	CHN
Jiangxi	CN-JX	CHN
Jilin	CN-JL	CHN
Liaoning	CN-LN	CHN
Nei Mongol	CN-NM	CHN
Ningxia Hui	CN-NX	CHN
Qinghai	CN-QH	CHN
Shaanxi	CN-SN	CHN
Shandong	CN-SD	CHN
Shanghai	CN-SH	CHN
Shanxi	CN-SX	CHN
Sichuan	CN-SC	CHN
Tianjin	CN-TJ	CHN

Sub-national division	Short name	Country ISO code
Xinjiang Uygur	CN-XJ	CHN
Xizang	CN-XZ	CHN
Yunnan	CN-YN	CHN
Zhejiang	CN-ZJ	CHN
Andaman and Nicobar	IN-AN	IND
Andhra Pradesh	IN-AP	IND
Assam	IN-AS	IND
Bihar	IN-BR	IND
Chhattisgarh	IN-CT	IND
Dadra and Nagar Haveli	IN-DN	IND
Daman and Diu	IN-DD	IND
Delhi	IN-DL	IND
Goa	IN-GA	IND
Gujarat	IN-GJ	IND
Haryana	IN-HR	IND
Himachal Pradesh	IN-HP	IND
Jharkhand	IN-JH*	IND
Karnataka	IN-KA	IND
Kerala	IN-KL	IND
Madhya Pradesh	IN-MP	IND
Maharashtra	IN-MH	IND
Manipur	IN-MN	IND
Meghalaya	IN-ML	IND
Mizoram	IN-MZ	IND
Nagaland	IN-NL	IND
Orissa	IN-OR	IND
Puducherry	IN-PY	IND
Punjab	IN-PB	IND
Rajasthan	IN-RJ	IND
Sikkim	IN-SK	IND
Tamil Nadu	IN-TN	IND
Telangana	IN-TG	IND
Tripura	IN-TR	IND
Uttar Pradesh	IN-UP	IND
Uttaranchal	IN-UT	IND
West Bengal	IN-WB	IND
Adygey	RU-AD	RUS
Altay	RU-AL	RUS

Sub-national division	Short name	Country ISO code
Amur	RU-AMU	RUS
Arkhangel'sk	RU-ARK	RUS
Astrakhan'	RU-AST	RUS
Bashkortostan	RU-BA	RUS
Belgorod	RU-BEL	RUS
Bryansk	RU-BRY	RUS
Buryat	RU-BU	RUS
Chechnya	RU-CE	RUS
Chelyabinsk	RU-CHE	RUS
Chukot	RU-CHU	RUS
Chuvash	RU-CU	RUS
City of St. Petersburg	RU-SPE	RUS
Dagestan	RU-DA	RUS
Gorno-Altay	RU-GA	RUS
Ingush	RU-IN	RUS
Irkutsk	RU-IRK	RUS
Ivanovo	RU-IVA	RUS
Kabardin-Balkar	RU-KB	RUS
Kaliningrad	RU-KGD	RUS
Kalmyk	RU-KL	RUS
Kaluga	RU-KLU	RUS
Kamchatka	RU-KAM	RUS
Karachay-Cherkess	RU-KC	RUS
Karelia	RU-KR	RUS
Kemerovo	RU-KEM	RUS
Khabarovsk	RU-KHA	RUS
Khakass	RU-KK	RUS
Khanty-Mansiy	RU-KHM	RUS
Kirov	RU-KIR	RUS
Komi	RU-KO	RUS
Kostroma	RU-KOS	RUS
Krasnodar	RU-KDA	RUS
Krasnoyarsk	RU-KYA	RUS
Kurgan	RU-KGN	RUS
Kursk	RU-KRS	RUS
Leningrad	RU-LEN	RUS
Lipetsk	RU-LIP	RUS
Maga Buryatdan	RU-MAG	RUS

Sub-national division	Short name	Country ISO code
Mariy-El	RU-ME	RUS
Mordovia	RU-MO	RUS
Moscow City	RU-MOW	RUS
Moskva	RU-MOS	RUS
Murmansk	RU-MUR	RUS
Nenets	RU-NEN	RUS
Nizhegorod	RU-NIZ	RUS
North Ossetia	RU-SE	RUS
Novgorod	RU-NGR	RUS
Novosibirsk	RU-NVS	RUS
Omsk	RU-OMS	RUS
Orel	RU-ORL	RUS
Orenburg	RU-ORE	RUS
Penza	RU-PNZ	RUS
Perm'	RU-PER	RUS
Primor'ye	RU-PRI	RUS
Pskov	RU-PSK	RUS
Rostov	RU-ROS	RUS
Ryazan'	RU-RYA	RUS
Sakhalin	RU-SAK	RUS
Sakha	RU-SA	RUS
Samara	RU-SAM	RUS
Saratov	RU-SAR	RUS
Smolensk	RU-SMO	RUS
Stavropol'	RU-STA	RUS
Sverdlovsk	RU-SVE	RUS
Tambov	RU-TAM	RUS
Tatarstan	RU-TA	RUS
Tomsk	RU-TOM	RUS
Tula	RU-TUL	RUS
Tuva	RU-TY	RUS
Tver'	RU-TVE	RUS
Tyumen'	RU-TYU	RUS
Udmurt	RU-UD	RUS
Ul'yanovsk	RU-ULY	RUS
Vladimir	RU-VLA	RUS
Volgograd	RU-VGG	RUS
Vologda	RU-VLG	RUS

Sub-national division	Short name	Country ISO code
Voronezh	RU-VOR	RUS
Yamal-Nenets	RU-YAN	RUS
Yaroslavl'	RU-YAR	RUS
Yevrey	RU-YEV	RUS
Zabaykal'ye	RU-ZAB	RUS

Methodology

Methodology to derive population data

Population primary data are derived from SEDAC and JRC.[9] JRC is used for years 1979-1999 and SEDAC is used from 2000 onwards. It consists of estimates of human population (number of persons per pixel), consistent with national censuses and population registers, for the years 1975, 1990, 2000 (JRC) and 2000, 2005, 2010, 2015, 2020 (SEDAC). The 15 arc-minute resolution (equal to 0.25°) is selected, matching space resolution of weather data.

A linear interpolation is applied to estimate values for all years in between; such interpolation is done through the following equation:

$$P_{i,j,t} = P_{i,j,t=2000} + \frac{(\mathrm{t} - 2000)}{2005 - 2000} \cdot (P_{i,j,t=2005} - P_{i,j,t=2000})$$

Where:

$P_{i,j,t}$: population inside the grid cell defined by latitude i and longitude j in year t

i,j: latitude i and longitude j of the grid point

The same equation is applied similarly to the other periods of time.

Population for years after 2021 are extrapolated using 2015 and 2020 data.

Methodology to derive nationally-averaged values

The primary data are provided as gridded values: each datapoint represents data for a specific location on the globe, the meshing being as fine as 0.25° of latitude

[9] Center for International Earth Science Information Network - CIESIN - Columbia University. 2018. Gridded Population of the World, Version 4 (GPWv4): Population Count, Revision 11. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). doi.org/10.7927/H4JW8BX5. Accessed: 29/05/2020
Schiavina, Marcello; Freire, Sergio; MacManus, Kytt (2019): GHS population grid multitemporal (1975, 1990, 2000, 2015) R2019A. European Commission, Joint Research Centre (JRC) DOI: 10.2905/42E8BE89-54FF-464E-BE7B-BF9E64DA5218 PID: http://data.europa.eu/89h/0c6b9751-a71f-4062-830b-43c9f432370fConcept & Methodology: Freire, Sergio; MacManus, Kytt; Pesaresi, Martino; Doxsey-Whitfield, Erin; Mills, Jane (2016): Development of new open and free multi-temporal global population grids at 250 m resolution. Geospatial Data in a Changing World; Association of Geographic Information Laboratories in Europe (AGILE). AGILE 2016.

and longitude. Hence values are present at each node of a meshing of the world with 1440 values of longitude and 720 values of latitude.

Every land point of the meshing is associated with a country. For this, a mask is created in Python using the file provided together with the population dataset[10], with the same resolution as for weather variables, i.e. 0.25° by 0.25°.

The same procedure applies to sub-national aggregates, using a mask derived from data from DIVA-GIS[11].

National values are derived from gridded values – calculating from a weighted average of values from all datapoints within the land boundaries of each country. The average is presented with two weighing methods:

- Surface-weighted average
- Population-weighted average

Depending on the variable, national data are available for only one or for both of the above methods. When national data are calculated using surface weighted average, the name of variable contains “surface”, while it contains “population” if population weighted average method is used.

Surface-weighted average

This method is chosen when the implications on the energy sector of the variable do not depend on where the population is located.

The equation to compute national surface-weighted averages is:

$$V_k = \frac{\sum_{i,j}^{i,j \in k} A_{i,j} \cdot V_{i,j}}{\sum_{i,j}^{i,j \in k} A_{i,j}} \qquad (1)$$

Where:

V: weather variable to be average, e.g. temperature, wind speed, solar radiation, precipitation, etc.

[10] Center for International Earth Science Information Network - CIESIN - Columbia University. 2018. Gridded Population of the World, Version 4 (GPWv4); sedac.ciesin.columbia.edu/data/set/gpw-v4-population-count-rev11
Schiavina, Marcello; Freire, Sergio; MacManus, Kytt (2019): GHS population grid multitemporal (1975, 1990, 2000, 2015) R2019A. European Commission, Joint Research Centre (JRC) DOI: 10.2905/42E8BE89-54FF-464E-BE7B-BF9E64DA5218 PID: http://data.europa.eu/89h/0c6b9751-a71f-4062-830b-43c9f432370fConcept & Methodology: Freire, Sergio; MacManus, Kytt; Pesaresi, Martino; Doxsey-Whitfield, Erin; Mills, Jane (2016): Development of new open and free multi-temporal global population grids at 250 m resolution. Geospatial Data in a Changing World; Association of Geographic Information Laboratories in Europe (AGILE). AGILE 2016.

[11] Download data by country | DIVA-GIS

A: area of the grid box around the grid point i,j

k: country identifier

i,j: latitude and longitude of the grid points that fall inside the domain of k

As for homogeneous grids on a sphere the area of the grid box is proportional to the cosine of the latitude, equation (1) can be re-written as:

$$V_k = \frac{\sum_{i,j}^{i,j\in k} cos\,(lat_i)\cdot V_{i,j}}{\sum_{i,j}^{i,j\in k} cos\,(lat_i)} \qquad (2)$$

Where:

V: weather variable to be averaged, e.g. temperature, wind speed, solar radiation, precipitation, etc.

lat: latitude

Population-weighted average

This method is chosen when the implications on the energy sector of the weather variable or indicator depend on where the population is located.

The population dataset used is from the Center for International Earth Science Information Network for years 2000 to latest and from Joint Research Centre from 1979 to 1999[12].

The equation to compute population-weighted national averages is:

$$V_k = \frac{\sum_{i,j}^{i,j\in k} P_{i,j}\cdot V_{i,j}}{\sum_{i,j}^{i,j\in k} P_{i,j}} \qquad (3)$$

Where:

V: weather variable to be average, e.g. temperature, wind speed, solar radiation, precipitation, etc.

P: population inside the grid box defined by latitude *i* and longitude *j*

k: country identifier

i,j: latitude *i* and longitude *j* of the grid box that falls inside the domain of k

[12] Center for International Earth Science Information Network[12] - CIESIN - Columbia University. 2018. Gridded Population of the World, Version 4 (GPWv4); sedac.ciesin.columbia.edu/data/set/gpw-v4-population-count-rev11
Schiavina, Marcello; Freire, Sergio; MacManus, Kytt (2019): GHS population grid multitemporal (1975, 1990, 2000, 2015) R2019A. European Commission, Joint Research Centre (JRC) DOI: 10.2905/42E8BE89-54FF-464E-BE7B-BF9E64DA5218 PID: http://data.europa.eu/89h/0c6b9751-a71f-4062-830b-43c9f432370fConcept & Methodology: Freire, Sergio; MacManus, Kytt; Pesaresi, Martino; Doxsey-Whitfield, Erin; Mills, Jane (2016): Development of new open and free multi-temporal global population grids at 250 m resolution. Geospatial Data in a Changing World; Association of Geographic Information Laboratories in Europe (AGILE). AGILE 2016.

Methodology to derive indicators from primary data

Heating Degree Days (HDD) and Cooling Degree Days (CDD)

If $T \geq T_{ref}$ (standard methodology) or $T \geq T_{threshold}$ ('Thold' methodology13[13]):

$$HDD = 0 \qquad (4)$$

$$CDD = T - T_{ref} \qquad (5)$$

If $T \leq T_{ref}$ (standard methodology) or $T \leq T_{threshold}$ ('Thold' methodology[13]):

$$HDD = T_{ref} - T \qquad (6)$$

$$CDD = 0 \qquad (7)$$

Where

T: Air temperature for standard and 'Thold' methodology, Heat Index if corrected by humidity, wet bulb temperature if corrected using wet bulb temperature or wind corrected temperature as described below (°C)

T_{ref}: Reference temperature (°C)

$T_{threshold}$: Threshold temperature for 'Thold' methodology (°C)

Monthly HDD and CDD are sums of daily values.

To calculate HDD corrected by wind speed, the wind-corrected temperature is calculated as below, in accordance with the EuroDutch Gas Act methodology:

$$T_{correctedwind} = T - \frac{W_{10}}{1.5} \qquad (8)$$

[13] The 'Thold' methodology uses both T_{ref} and $T_{threshold}$ for the calculation of degree days as showed by the equations above. For example, if the reference temperature is set to 18°C and the threshold temperature to 21°C: when the daily mean air temperature is 24°C, the value of the CDD is 6 (24 °C-18 °C); when the daily mean air temperature is 20 °C, the CDD is 0. The same applies to HDD: if the daily mean air temperature is 12°C, for that day the value of the HDD is 6 (18 °C-12 °C); if the daily mean air temperature is 16 °C, for that day the HDD is 0. This methodology is aligned with the one used by Eurostat to calculate degree days at the national level; see ec.europa.eu/eurostat/cache/metadata/en/nrg_chdd_esms.html

Where

T: 2 meter air temperature (°C)

W_{10}: Wind speed at 10 meters (m/s)

Relative Humidity

The relative humidity was calculated using the Arden Buck equations (Buck)[14].

$$RH = \left(\frac{e^{C_1 * \frac{T_{dew}}{C_2 + T_{dew}}}}{e^{C_1 * \frac{T}{C_2 + T}}} \right) * 100 \qquad (9)$$

Where:

T: air temperature (K)

T_{dew}: dew temperature (K)

$C_1 = 17.052$

$C_2 = 240.97$

Heat Index

The Heat Index was developed by the U.S. National Oceanographic and Atmospheric Administration (NOAA) in 1978 and later adopted by the USA National Weather Service. It aims at combining the effects of air temperature and relative humidity into a single parameter that provides a measure of the perceived temperature. It was empirically derived by for specific conditions of temperature and relative humidity and later expanded by NOAA's Climate Prediction Center to be defined at all values. Higher values of Heat Index correspond to hotter perceived environmental conditions. The Heat Index is not defined when T<80 °F and RH<40%. The heat index can be used as index representative of severe weather conditions on its own or used to feed the calculation of heating degree days corrected suing heat indexes.

It can be calculated using equation (10) for all the grid points for which T>80 °F and RH>40%:

$$Heat\ Index\ (F) = C_0 + C_1 * T + C_2 * RH + C_3 * RH * T \mp C_4 * T^2 + C_5 * RH^2 + C_6 * T^2 * RH + C_7 * T * RH^2 + C_8 * T^2 * RH^2 \qquad (10)$$

[14] Buck. (s.d.). New Equations for Computing Vapor Pressure and Enhancement Factor

Where:

T: air temperature (°F)

RH: relative humidity (%)

$C_0 = -42.379$

$C_1 = 2.04901523$

$C_2 = 10.14333127$

$C_3 = -0.22475541$

$C_4 = -6.83783 * 10^{-3}$

$C_5 = -5.481717 * 10^{-2}$

$C_6 = 1.22874 * 10^{-3}$

$C_7 = 8.5282 * 10^{-4}$

$C_8 = -1.99 * 10^{-6}$

If T<80 °F or RH<40%, the Heat Index is equal to the air temperature.

Humidex

Humidex is calculated using the standard Humidex formula used by the Environment and Climate Change Canada[15]:

$$Humidex = T + C_1 * (C_2 * e^{C_3 * \left(\frac{1}{C_4} - \frac{1}{C_4 + T_{dew}}\right)} - 10) \quad (11)$$

Where

T: 2 meter air temperature (°C)

T_{dew}: 2 meter dew temperature (°C)

$C_1 = 0.555$

$C_2 = 6.11$

$C_3 = 5417.730$

$C_4 = 273.15$

Wet bulb temperature

Web bulb temperature is calculated using the following formula (Stull, 2011)[16]:

$$T_{wetbulb} = T * \arctan(C_1 * (RH + C_2)^{0.5} + \arctan(T + RH) - \arctan(RH + C_3) + C_4 * RH^{1.5} * \arctan(C_5 * RH) + C_6 \quad (12)$$

[15] Environment and Climate Change Canada[15] (climate.weather.gc.ca/glossary_e.html)

[16] Stull, R. (2011). Wet-Bulb Temperature from Relative Humidity and Air Temperature. *Wet-Bulb Temperature from Relative Humidity and Air Temperature*.

Where

T: air temperature (°C)

RH: relative humidity (%)

$C_1 = 0.151977$

$C_2 = 8.313659$

$C_3 = -1.676331$

$C_4 = 0.00391838$

$C_5 = 0.023101$

$C_6 = -4.686035$

Values are calculated for daily means.

Wind capacity factor

The wind capacity factor represents the percentage of power output over nominal power expected from a wind turbine on a specific point of the grid for a specific time. It is calculated using hourly wind speed as follow:

$$CF_{t,i,j} = \frac{1}{n} \sum_{t \in T} \frac{P_{output}^{t,i,j}\left(W_{100}^{t,i,j}\right)}{P_{nominal}} \qquad (13)$$

Where

$W_{100}^{t,i,j}$: wind speed at 100 meters above surface at time *t*, latitude *i* and longitude *j* (m/s)

$P_{output}^{t,i,j}$: net electrical power output at time *t*, latitude *i* and longitude *j* (MW)

$P_{nominal}$: nominal output of the wind turbine (MW)

T: time considered, e.g. day

t: hours in the interval *T*

n: number of hours in *T*

i,j: latitude *i* and longitude *j* of the grid point

The function $P_{output}^{t,i,j} = f(wind\ speed\ 100m_{t,i,j})$ is the power curve of the selected wind turbine, in our case the Vestas V110-2 MW.

Day light

The length of day light is calculated using the method used by NOAA[17].

As reported by the source:

[17] Based on the equations from Astronomical Algorithms by Jean Meeus, as presented in the file "NOAA_Sola_Calculations_day.xls". Further details are available at : www.esrl.noaa.gov/gmd/grad/solcalc/calcdetails.html

- The sunrise and sunset results are theoretically accurate to within a minute for locations between +/- 72° latitude, and within 10 minutes outside of those latitudes. However, due to variations in atmospheric composition, temperature, pressure and conditions, observed values may vary from calculations.
- The following spreadsheets can be used to calculate solar data for a day or a year at a specified site. They are available in Microsoft Excel and Open Office format. Please note that calculations in the spreadsheets are only valid for dates between 1901 and 2099, due to an approximation used in the Julian Day calculation.

Methodology to compute monthly climatologies and anomalies

Monthly climatologies are averaged values for a specific month over the reference period 2000 to 2019 here.

Monthly anomalies of each variable are calculated as the difference between a monthly value and the climatology of that variable for that specific month.

$$Climatology_{v,j} = \frac{\sum_{i \in R} V_{j,i}^{m}}{n} \qquad (14)$$

$$Anomaly_{v,j,i} = V_{j,i}^{m} - Climatology_{v,j} \qquad (15)$$

Where

V^m: monthly value of the weather variable for which the climatology and the anomaly are calculated

j: month

i: year

R: reference period, 2000 to 2019

n: number of years in the reference period

References

Copernicus Climate Change Service (2024), ERA5 hourly data on single levels from 1959 to present (doi.org/10.24381/cds.adbb2d47), European Centre for Medium-Range Weather Forecasts.

Atalla, G. L. (s.d.). A global degree days database for energy-related applications.

Buck. (s.d.). New Equations for Computing Vapor Pressure and Anhancement Factor.

DIVA-GIS (https://www.diva-gis.org/gdata). (s.d.).

G., S. R. (s.d.). The assessment of sultriness. Part I: a temperature humidity index based on human physiology and clothing science. J Appl Meteorol 1979;18(7):861e73.

Stull, R. (2011). Wet-Bulb Temperature from Relative Humidity and Air Temperature. *Wet-Bulb Temperature from Relative Humidity and Air Temperature*.

www.unidata.ucar.edu/software/netcdf/

regionmask.readthedocs.io/en/stable/

Natural Earth (www.naturalearthdata.com/)

Center for International Earth Science Information Network - CIESIN - Columbia University. 2018. Gridded Population of the World, Version 4 (GPWv4*): Population Count, Revision 11. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). doi.org/10.7927/H4JW8BX5. Accessed 29/06/2020.*

Schiavina, Marcello; Freire, Sergio; MacManus, Kytt (2019): GHS population grid multitemporal (1975, 1990, 2000, 2015) R2019A. European Commission, Joint Research Centre (JRC) DOI: 10.2905/42E8BE89-54FF-464E-BE7B-BF9E64DA5218 PID: http://data.europa.eu/89h/0c6b9751-a71f-4062-830b-43c9f432370fConcept & Methodology:
Freire, Sergio; MacManus, Kytt; Pesaresi, Martino; Doxsey-Whitfield, Erin; Mills, Jane (2016): Development of new open and free multi-temporal global population grids at 250 m resolution. Geospatial Data in a Changing World; Association of Geographic Information Laboratories in Europe (AGILE). AGILE 2016.

EuroDutch Gas Act

Environment and Climate Change Canada (climate.weather.gc.ca/glossary_e.html)

Jean Meeus, Astronomical Algorithms, www.esrl.noaa.gov/gmd/grad/solcalc/calcdetails.html