Visualization of changing climate hazards and underlying data sources – Background document

This background document describes the visualization of the indices presented in this report, the underlying data sources and calculation methods for the two fundamental underlying data sources: Copernicus Climate impacts indicators and ETC/CCA-derived climate indices.

The future projections for all climate indices presented in this report are based on bias-adjusted data. The bias adjustment was performed either by C3S contractors (for indices based on Copernicus climate impact indicators) or by ETC/CCA experts (for indices based on ETC/CCA data; see below for details).

Indices based on Copernicus climate impact indicators

Many indices in this report are based directly on data from the Copernicus Climate Change Service (C3S). C3S is a European Commission programme providing climate change services in support of European climate policies and actions. C3S contains the Climate Data Store (CDS), which provides European and global climate data covering the past as well as the future. All C3S CDS datasets are subjected to technical controls and quality evaluations to ensure high-quality data meeting the needs of the users. CDS datasets are freely available to all users and cover global, continental and regional scales. The CDS also offers a workspace, called CDS Toolbox, where users with sufficient technical knowledge can retrieve the data of interest, apply additional calculations, and display the results according to their specific needs.

The CDS contains several *general* climate datasets at different temporal and spatial resolution, such as climate observations at European level (e.g., the daily meteorological dataset E-OBS at 0.25° and 0.1° spatial resolution), reanalyses (e.g., the hourly ERA5 and ERA5-Land reanalyses at 0.25° and 0.1° spatial resolution, respectively), and projections for a large set of variables. Climate projections include CMIP5 and CMIP6 data with global coverage and the EURO-CORDEX dataset that covers Europe with a finer spatial resolution of 0.11°. CDS does not currently provide a comprehensive dataset of bias-adjusted projections for all climate variables, and the CDS Toolbox does not include bias-adjustment routines to be applied by users to the data of interest.

The CDS also includes *specific index* datasets (also known as ‘climate impact indicators’) containing processed data that respond to specific sectoral applications, such as agroclimatic indicators computed from bias-adjusted projections. The specific CDS datasets were developed independently for different sectoral user groups and as such are based on different input data, reference periods and bias-adjustment methods. Most of them are the outcomes of C3S contracts to build the C3S Sectoral Information System, which contains user-oriented products for several climate-sensitive sectors (e.g., energy, biodiversity, water management, human health and tourism). Several such contracts are currently ongoing and will provide continuous updates to the CDS resources.

An increasing number of the C3S climatic impact indicators can be explored interactively via the European Climate Data Explorer (ECDE) on Climate-ADAPT. The ECDE allows for the display of maps for different scenarios and time horizons, the display of time series for national and subnational regions, and the download of relevant images and data.

The ECDE is also the basis for the display of interactive maps for many of the hazard indices presented here. These maps show *either the absolute value or the projected changes* in an index for different selection options (e.g., time period, season, emissions scenario). Note that the temporal coverage of the indices and the specific selection options differ across indices. Some indices cover only the past (based on reanalysis data), others cover only the future (based on climate model projections), and still others cover both past and future (also based on climate model simulations). None of the indices currently included in the ECDE combines reanalysis data and climate model projections. The ECDE-based maps for projected changes show the *central value* of the model ensemble. The uncertainty in future climate projections for a given index in a specific region can be explored in regional time series graphs that can be produced in the ECDE.

Indices based on ETC/CCA data

About half of the indices in this report are based on a common dataset of ERA5 reanalysis data and bias-adjusted CMIP5 projections. The underlying datasets are included in the Copernicus Climate Data Store, but the bias adjustment of the CMIP5 projections was done offline (see Box 1 for details).

The past and projected changes for these indices are reported as annual time series for 1950–2020 based on reanalysis data and as smoothed time series over 1960–2091 for the three forcing scenarios RCP2.6, RCP4.5 and RCP8.5 (see Box 1). The time series represent the spatial average over the land area of all 38 EEA member and cooperating countries as of February 2020 (EEA38, hereafter referred to as 'Europe'). Furthermore, time series are also provided for three sub-continental regions: northern, central and southern Europe. These regions are very similar to three IPCC climate reference regions (NEU, WEU and MED in the IPCC AR5; NEU, WCE and MED in the IPCC AR6) (Iturbide et al., 2020: An update of IPCC climate reference regions for subcontinental analysis of climate model data: definition and aggregated datasets), but the extent of the IPCC regions was restricted to the EEA38 and slightly modified in order to include also Iceland and Turkey (see Figure 1).

Box 1 - Bias adjustment of the CMIP5 projections

The projection dataset covers a global latitude-longitude grid at a resolution of 0.5°x0.5° (~50 km). It is based on of daily bias-adjusted CMIP5 projections for the period 1950-2100 for three forcing scenarios (RCP2.6, RCP4.5 and RCP8.5). It was developed by the ETC-CCA partner VITO within the ongoing C3S Biodiversity contract. The raw CMIP5 climate model data were adjusted against ERA5 reanalysis by applying a quantile delta-mapping scheme (Switanek et al., 2017: Scaled distribution mapping: a bias correction method that preserves raw climate model projected changes) considering 1979–2018 as the overlapping period. This method allows to preserve the (absolute) climate-change signals of the original model data. The correction was performed at the native spatial resolution of the model data, and the results were then interpolated to a common 0.5°x0.5° grid. The choice of ERA5 reanalysis as reference dataset for the adjustment ensures that the results are independent from the local availability of climate observations. Consequently, these datasets provide global coverage of bias-adjusted data not only for temperature and precipitation, which are covered by observational datasets, but also for other climate variables, such as soil moisture levels, aridity, wind fields, cloudiness, surface radiation, heat exchange variables, sea surface temperature and sea-ice cover. The applied bias-adjustment procedure is univariate, so that each climate variable was corrected separately. The bias-adjusted data provide a wealth of climate-change information from a large ensemble of global climate models for the three forcing scenarios over the 21st century. However, the number of available models varies with RCP and variable ranging from 9 to 32.

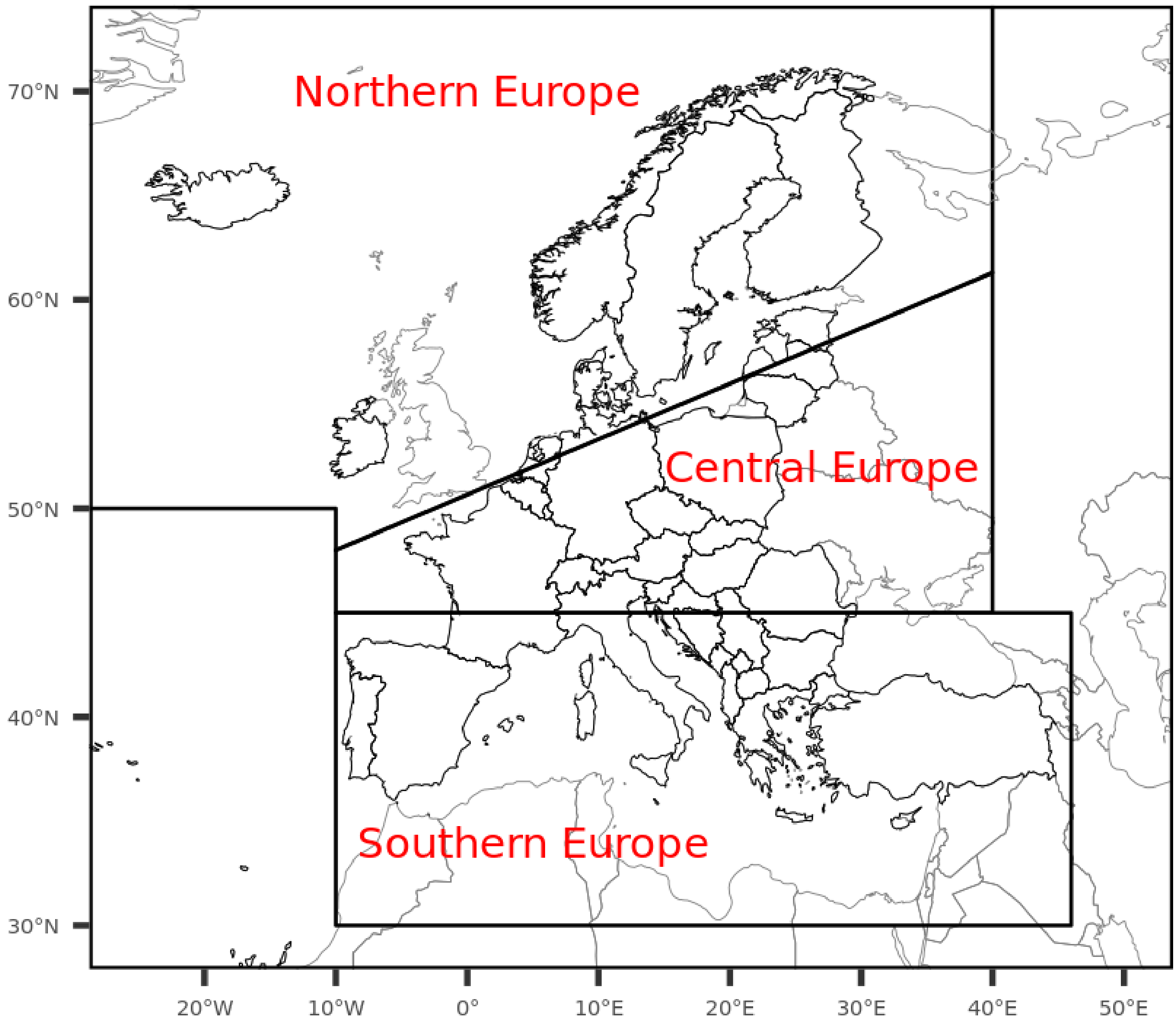
The index values over the past were computed on an annual basis from the ERA5 reanalysis for the period 1950–2020. The series of index values computed from the processed CMIP5 data for historical and future periods were filtered by averaging over a 20-year moving window so that the final CMIP5 index series cover the 1961–2091 period.

In addition to the bias-adjustment applied on the raw CMIP5 data, a further correction —the delta-change approach— was employed on the 20-year averaged indices, because the bias-adjusted CMIP5-based index values can still differ from the ERA5-based values during the reference period 1986–2005. These discrepancies are mainly due to differences in the dynamics of atmospheric variables between the two datasets (e.g. seasonality and day-to-day variation) that are not corrected in the first bias-adjustment step. The delta-change approach uses the mean value of the ERA5-based indices over the 1986–2005 reference period as baseline value. The projected changes in bias-adjusted CMIP5 indices were then superimposed on the ERA5 baseline values for the reference period rather than the CMIP5-based values:

$$Index_{CMIP5cor}(year) = Index_{CMIP5adj}(year) + (Index_{ERA5}(1986-2005) - Index_{CMIP5adj}(1986-2005))$$

The final set of CMIP5-based index projections presented here following bias adjustment and delta-change correction with respect to ERA5 ensures full consistency between the baseline reconstruction and the future data, while preserving the information on future climate change.

Figure 1 – European sub-continental regions based on the IPCC climate reference regions

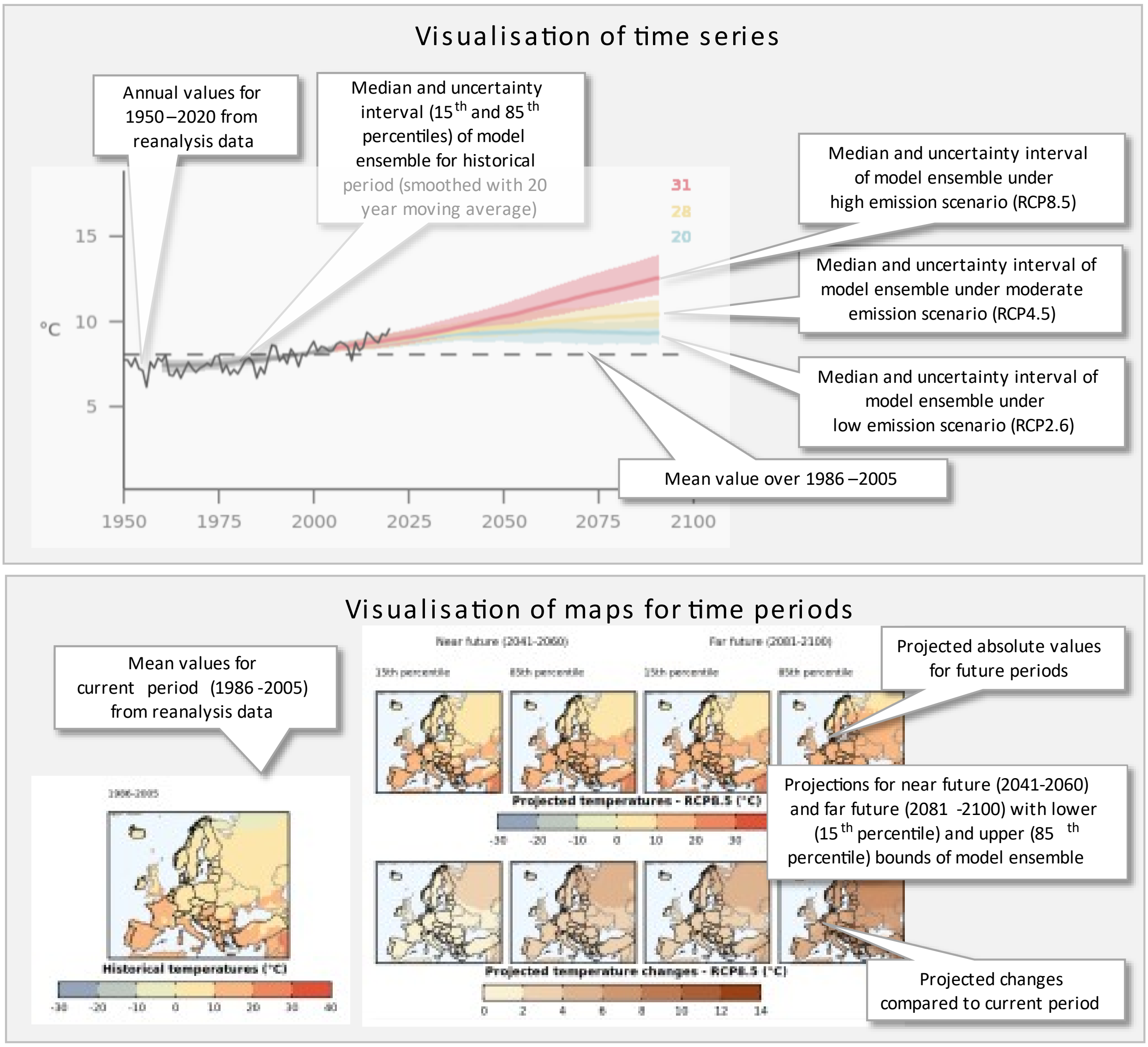


Note: The borders of the sub-regions were retrieved from the IPCC AR5 reference regions and modified to match with the EEA38 countries (marked by black borders). The northern Europe region was expanded westward to include Iceland, and the southern Europe region was extended eastward to include the whole Turkey.

Figure 2 shows the visualization of indices based on ETC/CCA data, which was inspired by the recent climate impact and risk assessment for Germany (UBA, 2021: Klimawirkungs-und Risikoanalyse 2021 für Deutschland (Teilbericht 1), Section 3.1.5). The *top panel* presents a time series graph that shows the annual values for 1950–2020 based on the ERA5 reanalysis dataset (black line). The graph also shows the values based on an ensemble of global climate models for the historical period (in grey) and for the three emissions scenarios RCP2.6 (low emissions, in blue), RCP4.5 (medium emissions, in yellow) and RCP8.5 (high emissions, in red), smoothed over 20 years. The model-based time series shows the median of the model ensemble (i.e., the central value) together with lower and upper bounds, which are represented by the 15th and 85th percentiles, respectively. This implies that the shaded ranges comprise the projections from 70 % of the models (i.e., approximately two thirds), but there is still a small chance (about one sixth each) that the future climate lies above or below that range. If an index represents a climate hazard in the narrow sense (i.e., where higher index values reflect a stronger hazard and thus a stronger risk), the 15th and 85th percentiles can be interpreted as 'optimistic' and 'pessimistic' scenarios, respectively. This interpretation does not apply to indices reflecting basic climate variables (such as mean temperature, precipitation or wind speed), which do not present climate hazards as such.

In addition to the time series, the indices based on ETC/CCA data also include maps that show spatial details of the current and projected climate hazard (bottom panel). These maps cover the recent period (1986–2005), near future (2041–2060) and far future (2081–2100). The maps for the near and far future can generally be selected for three emissions scenarios (RCP2.6, RCP4.5 and RCP8.5, respectively). They are presented both as absolute values and as changes compared to the baseline period (1986–2005). In an effort to show the range of plausible future conditions that societies need to consider in their adaptation efforts, maps are shown for the lower bound (15th percentile) and upper bound (85th percentile) of the model projections, but not for the median. Please see the comment above regarding the meaning and interpretation of these percentiles.

Figure 2 – Illustrative example for the visualisation of indices based on ETC/CCA data.



Final remarks

The past trends and projected changes for the indices presented here are consistent with the European summary in the IPCC AR6 (IPCC, 2021: Climate change information for regional impact and for risk assessment, Table 12.7). Note, however, that the climate projections presented here are based on a different set of forcing scenarios (RCP) and model ensembles (CMIP5 and EURO-CORDEX) than those in the IPCC AR6 (SSP-RCP and CMIP6, respectively). Therefore, differences in detailed projections can occur. The only climate hazard for which CMIP5 and CMIP6 give rise to a different qualitative summary assessment for Europe is 'Mean wind speed' (see Table 1 and the specific index for further information). A comprehensive overview of the differences in climate projections for Europe between CMIP5, CMIP6 and EURO-CORDEX for a large number of climate indices is available in a recent scientific article (Coppola et al., 2021: Assessment of the European climate projections as simulated by the large EURO-CORDEX regional and global climate model ensemble).

Climate datasets are associated with uncertainties due to imperfect or incomplete observations, model limitations and other factors. Therefore, expert knowledge or advice is necessary if climate data are being used for adaptation decisions at the subnational or local level. Particular care is needed when interpreting climate index projections for regions with complex topography (e.g., mountains) and for hazards influenced by local phenomena (e.g., urban heat island effect, local land subsidence), related to local-scale weather extremes (e.g., cloud bursts), and involving absolute thresholds (e.g., frost days).