CLIMATE CHANGE IMPACTS ON WATER MANAGEMENT IN CE AND TEACHER PILOT ACTIONS

Work package T1	Exploitation: concept of CE tools integration
Activity T1.1	Creation of common understanding and project conceptual framework
Deliverable T1.1.3	Documentation of Climate Change impacts on water management components based on existing studies and knowledge

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Table of contents

List of tables

List of figures

List of abbreviations

BC	Bias Correction
CC	Climate Change
CDD	Consecutive dry days
CE	Central Europe
CLMcom	Climate Limited-area Modelling Community
CNRM	National Meteorological Research Centre (France)
CORDEX	Coordinated Regional Downscaling Experiment project
CWB	Climate water balance
CWD	Consecutive wet days
DJF	Meteorological winter season (December, January, February)
DMI	Danish Meteorological Institute
ECA-D	European Climate Assessment & Dataset project
ETCCDI	Expert Team on Climate Change Detection and Indices
FD	Frost days
GCMs	General Circulation Models
GHGs	Greenhouse Gases
IAMs	Integrated Assessment Models
IPCC	Intergovernmental Panel on Climate Change
IPSL-INERIS	Institute Pierre-Simon Laplace
JJA	Meteorological summer season (June, July, August)
KNMI	Royal Netherlands Meteorological Institute
MAM	Meteorological spring season (March, April, May)
MPI-CSC	Helmholtz-Zentrum Geesthacht, Climate Service Center, Max Planck Institute for Meteorology
NMHSs	National Meteorological and Hydrological Services
NOAA	National Oceanic and Atmospheric Administration
NUTS	Nomenclature of Territorial Units for Statistics
P	Precipitation
PA	Pilot Actions
RCMs	Regional Climate Models
RCPs	Representative Concentration Pathways
RMIB-Ugent	Royal Meteorological Institute of Belgium and Ghent University
Rx1day	Indicator: (yearly) maximum 1-day precipitation averaged over the period of the interest
SMHI	Swedish Meteorological and Hydrological Institute
SON	Meteorological autumn season (September, October, November)

SU	Summer days
T	Temperature
WCRP	World Climate Research Program
WMO	World Meteorological Organization
WWTP	Waste water treatment plant

A. Introduction

The deliverable is formulated in the project concept (application) as follows:

D.T1.1.3: Climate change impacts on water management have been addressed in existing studies and projects. **A compilation of this knowledge in the participating countries** will add additional value to the understanding of stakeholder needs. The activity will examine the effects of climate change on water management and conflicts of interest with other sectors.

Part B of D.T1.1.3 is aimed at providing a general overview of expected climate change and its potential impacts over Central Europe (CE) domain, with a focus on the Pilot Actions (PAs). The definition of the current climate conditions, as well as the evaluation of the future variations of a number of weather/climate-related variables as a consequence of global warming, are supported by the availability of high-resolution climate models that allow obtaining assessment for both recent decades and future periods.

The deliverable is embedded in work package 1 that collects information from existing studies and projects that will be relevant for the TEACHER-CE tool development. Thus the purpose of **part C** is to evaluate and structure the main climate change impacts on water management activities and related adaptation options as entry point for the aimed tools or tool box. Those climate change-impacts are evaluated and documented that may play an important role in the context of the TEACHER-CE-project. Further direct and indirect impacts or interferences exist that are not documented here. Setting a focus and filtering the wide range of facts and findings is crucial for this paper to create a targeted basis for the conception of the TEACHER-CE tools.

For the concept development this document complements DT1.1. The overview of the most relevant CC-impacts and the resulting assessment shall be used to select the impact chains that will be tackled in the TEACHER-CE tools. The compilation of adaptation options and the assessment of potential synergetic or conflicting effects may serve as basis for the tool content to guide users towards adaptation strategies and measures. Furthermore, this compilation may inform the users of the TEACHER-CE tool and help them to make the best use out of the tool.

<u>The evaluation and compilation was guided by the following questions:</u>

- What are the main trends and aspects of climate change in Central Europe with a specific view to the water resources and pilot actions – cf. part B
- Which direct and indirect impacts of climate change have been assessed in the studies for the different fields of action of water management in Central Europe? – cf. part C
- Which adaptation needs, options, strategies and measures are described for the different fields of action of water management? – cf. part C
- What are potential synergies and conflicts between adaptation needs and measures of water management and/ or other sectors? – cf. part C

  Conclusion
- What are the main potential areas of synergies and conflicts? – cf. part C
- Which fields of action imply the highest potential of synergies and conflicts? cf. part D

B. Climate Change in Central Europe and the TEACHER-CE Pilot Actions

1. Aim and approach

In the following paragraphs, a general description of the datasets and models used is provided. Specifically, recent decades conditions are evaluated by elaborating data referred to the periods 1971-2000 and 1990-2019 while future variations are calculated as anomalies for two time periods (2021-2050 and 2071-2100) with reference to the period 1971-2000 and under two different IPCC scenarios of climalterant gasses (RCP4.5 and RCP8.5).

As already stated in D.T1.1.2, the analysis of the potential impacts of climate change on variables that are directly related to the water resources is carried out by considering a number of indicators that can be interpreted as proxies for climate-related hazards of higher interest for the topics covered by the project (such as floods, droughts, water availability). Specifically, the selected indicators are evaluated by exploiting daily temperature and precipitation data. They are:

- Seasonal Mean Temperature (x4): mean daily temperature for the four seasonal periods: winter (December-January-February, DJF), spring (March-April-May, MAM), summer (June-July-August, JJA), and autumn (September-October-November, SON);
- Seasonal Cumulative Precipitation (x4): mean value of the total cumulative precipitation evaluated for the four seasonal periods: winter (DJF), spring (MAM), summer (JJA), and autumn (SON).
- Consecutive Dry Days (CDD): maximum annual number of consecutive days with precipitation < 1mm averaged over the period of the interest.
- Consecutive Wet Days (CWD): maximum annual number of consecutive days with precipitation ≥ 1mm averaged over the period of the interest.
- Rx1day: (yearly) maximum 1-day precipitation averaged over the period of the interest.
- Summer Days (SU): annual count of days with daily maximum temperature > 25°C averaged over the period of the interest.
- Frost Days (FD): annual count of days with daily minimum temperature < 0°C averaged over the period of the interest.

Five of these indices (CDD, CWD, Rx1day, SU, FD) have been defined by the Expert Team on Climate Change Detection and Indices (ETCCDI). Nevertheless, further indicators could be added according to PPs' and stakeholders' requirements collected by the web-survey included in D.T1.1.2 (https://forms.gle/tDarSUcEtjreK8YB9).

The index-based approach is widely used in the literature for the assessment of both current climate conditions and expected variations in climate variables under different scenarios (Silliman et al., 2013a, b). Furthermore, it is used for supporting the qualitative evaluation of climate-related hazards (Christidis & Stott, 2016; Fioravanti et al., 2016; Dosio & Fischer, 2018; Hong &Ying, 2018; Reder et al., 2018). Climate indices are particularly useful for the assessment of the potential impacts of climate change on drinking water resources since they allow estimating expected variation in terms of frequency, intensity, and persistence of weather-induced extreme processes such as drought, heavy rain, and frost events, which are directly and indirectly related with the hydrological cycle and water availability.

The quantitative results and related statistical values are in general shown as comprehensive data tables while expected anomalies are in general provided in the form of easily interpretable maps.

Climate information evaluated in the frame of WP T1 activities will be provided by considering the Central Europe domain (Figure 1) at NUTS3 level for each country within the domain but not Germany where NUTS2 level will be used. Data will be shown as maps (suitable to be also included in the TEACHER-CE Toolbox). Furthermore, in order to have a deeper insight about PAs, a climate datasheet is provided for each of the nine PAs (in red in Figure 1). Datasheets could be used as support for discussions and interactions during the Stakeholders' workshops while, complemented by the other indicators arisen after users' requirements, to be downloaded from the TEACHER-CE Toolbox. In Table 1, the main PAs information is indicated.

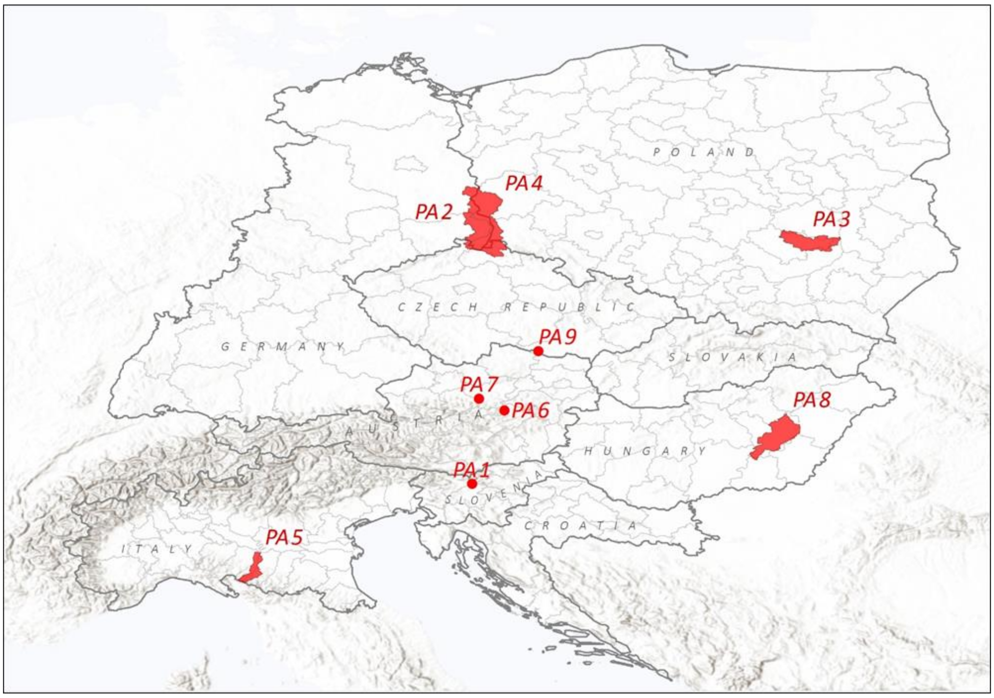

Figure 1: European countries included in the CE domain and TEACHER-CE Pilot Actions

Table 1: PA General information

PA Number	Country	PA Name	Surface in km²
PA 1	Slovenia	Part of Kamniška Bistrica basin	281.9
PA 2	Germany	Upper Lusatia county	2111.1
PA 3	Poland	Kamienna river basin	2022.8
PA 4	Poland	Lusatin Neisse basin	4395.9
PA 5	Italy	Enza basin	891.5
PA 6	Austria	Catchment area of the Vienna Water Supply	64.1
PA 7	Austria	Catchment area of Waidhofen/Ybbs	8.4
PA 8	Hungary	Nagykunsági river basin	2965.4
PA 9	Czech	National park Podyi	62.8

2. Evaluation of recent decades climate conditions

Recent decades climate conditions have been here analysed by considering the E-OBS dataset, which was developed within the “ENSEMBLES project” (van der Linden and Mitchell, 2009; Cornes et al., 2018) with the aim of supporting the validation of Regional Climate Models (RCMs) and improving the assessment and understanding of climate change impacts. The dataset contains gridded data on daily scale concerning mean temperature, daily minimum temperature, daily maximum temperature, daily precipitation sum, daily averaged sea level pressure, and global radiation. E-OBS data cover the entire European domain (25N-71.5N x 25W-45E.) with a regular grid resolution of 0.1°x 0.1° and 0.25°× 0.25°. They are provided, maintained and monthly uploaded in the frame of the European Climate Assessment & Dataset (ECA-D) project by the National Meteorological and Hydrological Services (NMHSs), individual researchers affiliated with a university, global data centres like the National Climatic Data Center (NOAA, Asheville, USA) or the synoptic messages from the Global Telecommunication System (van der Schrier et al., 2013). Figure 2 shows the distribution of the stations from which the gridded dataset is retrieved: it highlights how the density of the stations is highly variable across Europe; this aspect is worth to be noted since larger uncertainties in data have to be considered in areas less covered by observations (e.g. Southern Italy).For the analysis, the version 21.0e, released in May 2020, has been used. Further details about the features and the improvements associated to such version are retrievable at https://surfobs.climate.copernicus.eu/dataaccess/access_eobs.php#datafiles.

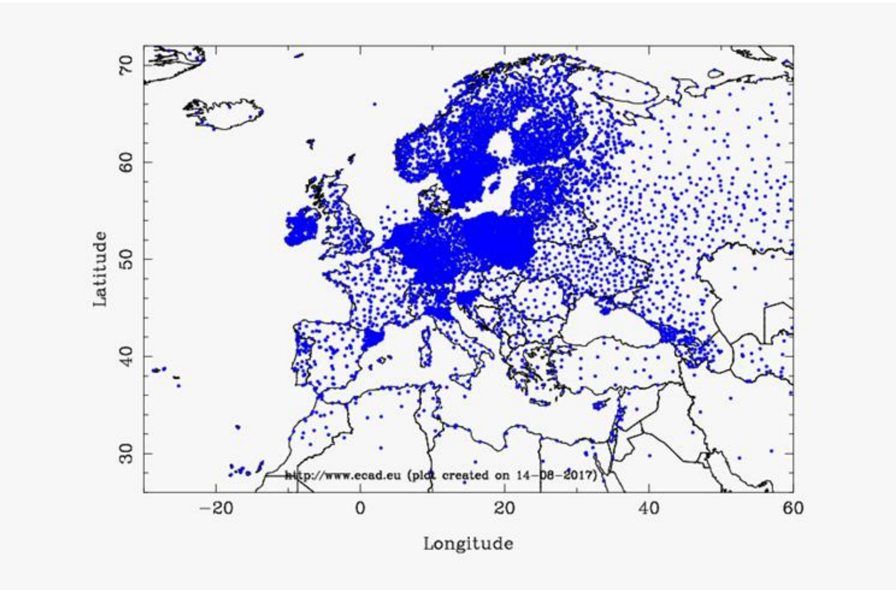

Figure 2: Distribution of European weather stations providing data for E-OBS gridded dataset

The dataset covers the period from 1-1-1950 up to 31-12-2019. Specifically, in order to analyse both the past and the present conditions and to highlight ongoing variations, two 30 years-long periods have been selected: 1971-2000 (used as a historical period) and 1990-2019 (used as a current period). The length of these periods has been chosen according to the World Meteorological Organization (WMO) indications, which suggest considering a time span long enough to properly take into account the interannual climate variability and limit the arising of a statistically significant trend in the weather pattern. Furthermore, the period 1971-2000 represents the same time span used as a reference for comparing local future climate projections with reference climate conditions.

Specifically, E-OBS data can be downloaded from the following links:

- https://surfobs.climate.copernicus.eu/dataaccess/access_eobs.php;
- https://www.ecad.eu/download/ensembles/download.php

In the following maps (from Figure 3 to Figure 7), each indicator evaluated from the E-OBS data (related to the period 1971-2000) over the CE domain is shown. In each map, the project's PAs are shown in grey. It worth stressing that the assessments provided by E-OBS are strongly influenced by the availability of the weather station data in the area of interest while statistical interpolation may permit returning data over the entire domain. Furthermore, it could be misleading to compare point weather observations with gridded datasets; the last ones should be able to retrieve information over an area, at least, comparable with the horizontal resolution of the datasets. Under such constraints, of course, extremes can appear highly smoothed in special way for very localized occurred events or over orographically complex areas.

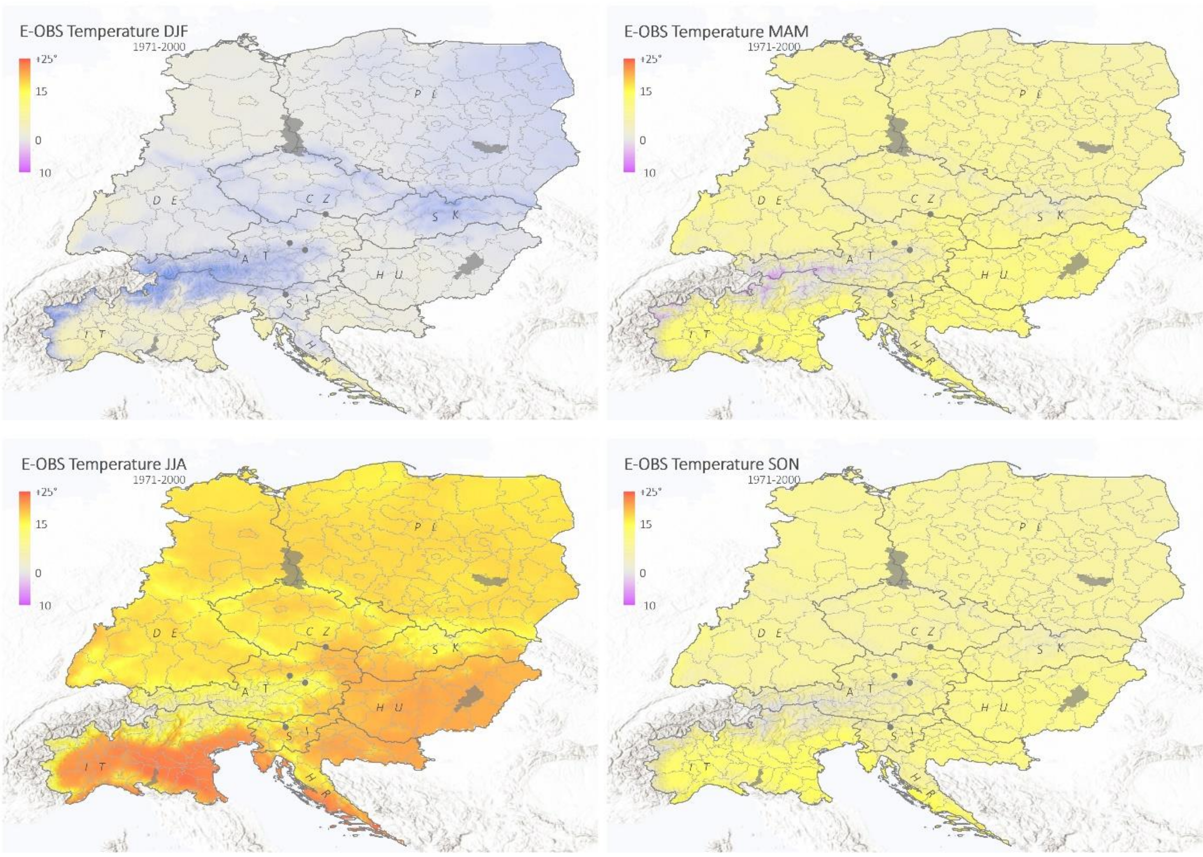

Figure 3: Seasonal temperature values over the CE domain as reported in E-OBS gridded dataset (1971-2000 period); data reported in Celsius degrees. TEACHER-CE Project's PAs are indicated in grey.

In Figure 3, the maps of the seasonal temperature over the CE domain are reported. In this case, a spatial pattern distribution across the domain is easily recognizable. In detail, during winter (DJF), the coldest conditions, which reach values lower than 0°C, are observed in the high altitude areas (over the Alps and Carpathians) while, on plain areas, the latitude plays a fundamental role in regulating the temperature values: the Italian territory included in the CE domain (including PA5), as well as the upper Adriatic area, are characterized by the absence of negative values while the North-eastern part of the domain (including PA4) shows lower temperature values. During summer (JJA), large parts of the domain, which include almost all the PAs, experience values ranging between 15-20°C;in the southernmost areas, where PA5 and PA8 are located, the temperature values reach and slightly exceed the 20°C while, with the highest values are retrieved over the Italian plain areas. In the Alpine domain, the values remain lower but higher than 0°C. During the intermediate seasons (MAM and SON), the lowest values characterize the Alpine territory which maintains values lower than 0°C. Furthermore, North-South growth gradients are detectable with the northernmost areas characterized by values lower than 10°C and the southernmost with higher values (up to 14-15°C). Accounting for the PAs, they are characterized by a substantial spatial homogeneity in the temperature patterns: no critical variations can be recognized over the territory of each single PA. This aspect is probably due to their limited extension and to the fairly homogeneous orography that characterises each PA.

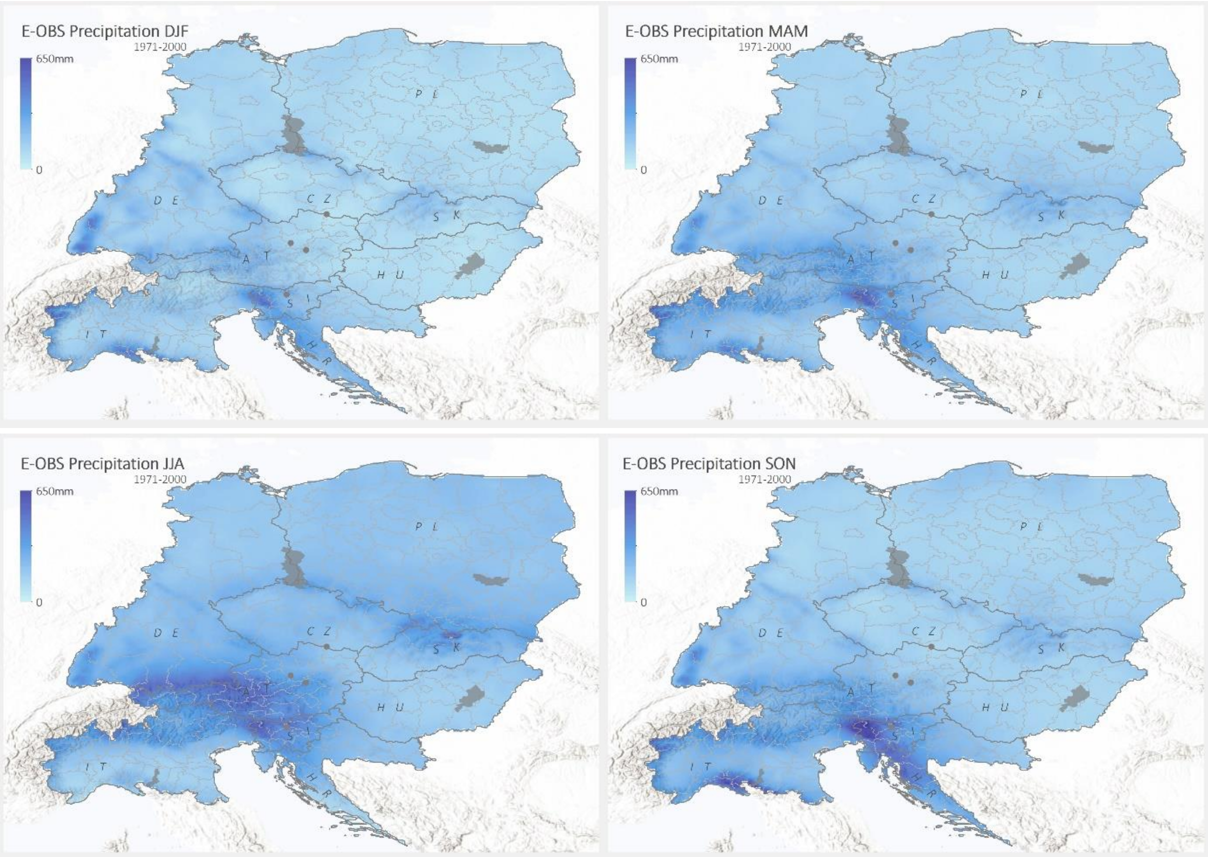

Figure 4: Seasonal cumulative precipitation values over the CE domain as reported in E-OBS gridded dataset (1971-2000 period); data reported in millimetres. TEACHER-CE Project's PAs are indicated in grey.

In Figure 4 data concerning seasonal cumulative precipitation are reported. In this case, variations among the seasons appear less pronounced compared to what observed for temperature. In winter (DJF), high values (up to 650 mm) characterize the Alpine, Apennine and high Adriatic areas while over a large part of the domain, precipitation does not exceed 200 mm. During the summer period (JJA), on a large part of the CE territory, high values are observed. In particular, in the North-eastern part of alpine Region, seasonal precipitation may arrive at about 650 mm. In this case, lower values are detected for Hungarian, Czech, and Polish areas while for Slovenian and Austrian areas significant values are retrievable (up to 500mm). The precipitation patterns are very similar for the intermediate seasons, with higher values (up to 650mm) observed in NE part of the Alpine Region and Liguria Apennines, especially during the autumn period (SON).

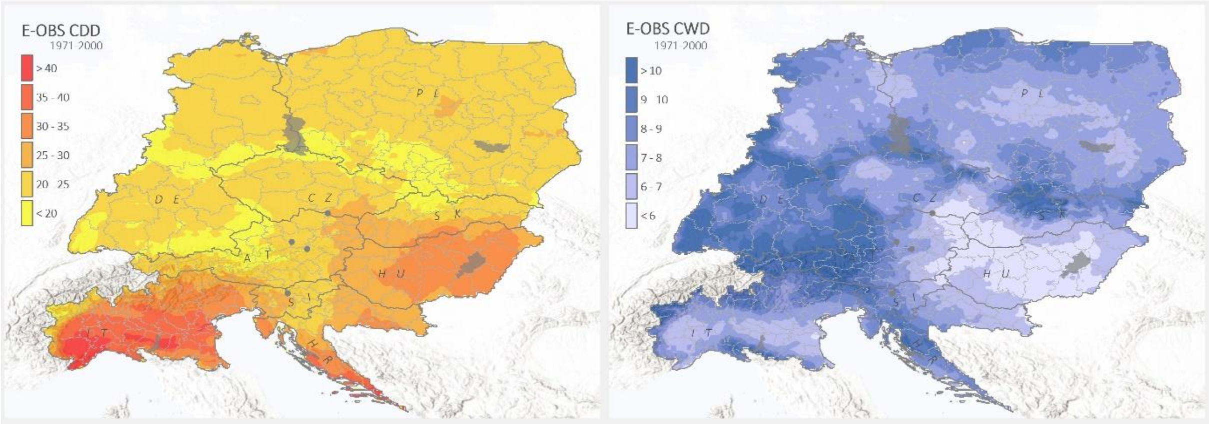

Figure 5: CDD and CWD values over the CE domain as computed through E-OBS gridded dataset (1971-2000 period); data reported in days. TEACHER-CE Project's Pas are indicated in grey.

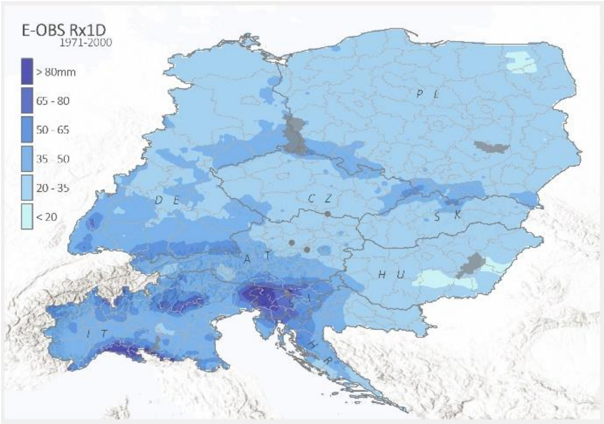

Figure 6: Rx1day values over the CE domain as computed through E-OBS gridded dataset (1971-2000 period); data reported in millimetres. TEACHER-CE Project's Pas are indicated in grey.

Then, in Figures 5 and 6, the spatial distribution of the three ETCCDI indicators related to the precipitation pattern (CDD, CWD, Rx1day) are displayed. The first two indicators provide a characterization of the precipitation temporal distribution while the third one can be assumed as a proxy for the occurrence of hydrological hazards since it takes into account the maximum daily amount of precipitation in the accounted period. In this context, it is worth recalling that ETCCDI indicators are designed to detect "moderately extreme weather events" (Wehner, 2013) then characterized by return time periods usually less than 10 years. For much rarer (more severe) phenomena, it is necessary to recur to extreme value statistical theories.

Concerning the CDD index, the highest values are observed in the southern part of CE domain including the Italian territory (PA5) and the Adriatic areas (including the Croatian territory), where more than 40 consecutive dry days are registered with the consecutive higher probability of issues related to the limited availability of the water resources. Very high values (up to 35 days) characterize most of the Hungarian territory (PA8). Medium values (20-25 days) are observed in a wide part of the territory in Germany, Poland, Czech Republic, Austria, and Slovenia. On the other hand, some areas, which include PA2 and PA4, result less affected, with CDD values that hardly exceeding 20 days.

Accounting for the CWD index, larger values characterize the high elevated areas (NE part of Alpine region) and the German southernmost part, where they may be higher than 10 days; on the other side, on plain areas, they are usually limited to 6-7 days. The lowest CWD values are observed over the Hungarian territory and the whole PA8.

Considering Rx1day, the lowest values are registered in some areas of the northernmost part Poland and Hungary. Over the main part of the CE domain, the Rx1day values do not exceed 50 mm. About the specific values, it is recommended to account for that the point weather stations provide much higher values while the information provided by E-OBS should be viewed as spatially averaged over areas, at least, comparable with the horizontal resolution of the dataset. Nevertheless, very high values characterize the mountain areas of the Alps, Apennines and South Germany. The highest values (> 80 mm) are observed in the eastern part of the Alpine region, over a large part of the Slovenian territory (including PA1), and in the Liguria region (IT). Furthermore, high values of Rx1day characterize also the southern part of Poland (e.g. Tatra Mts. areas). These regions are frequently affected by precipitation-induced hazards (pluvial/river floods).

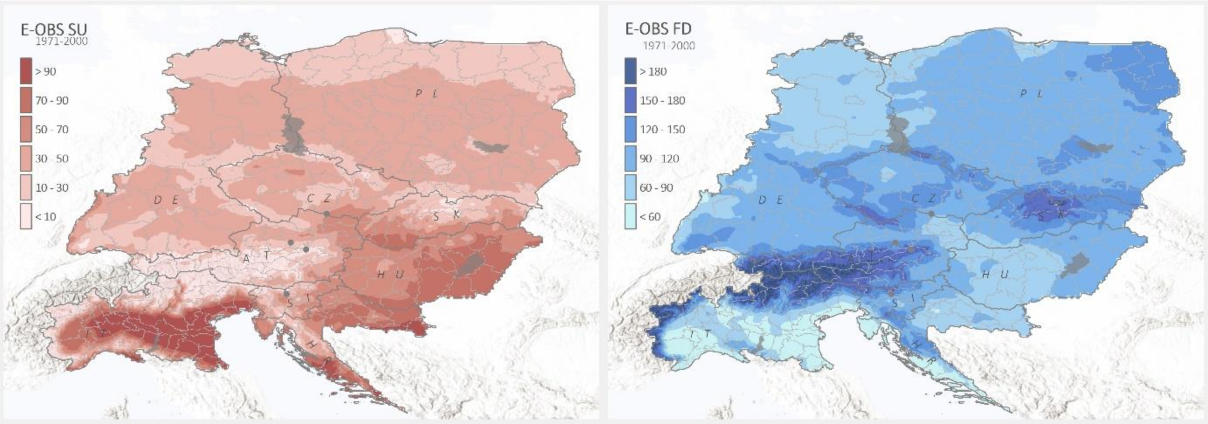

Figure 7: SU and FD values over the CE domain as computed through E-OBS gridded dataset (1971-2000 period); data reported in days. TEACHER-CE Projects Pas are indicated in grey.

Finally, the ETCCDI indicators related to the temperature patterns (SU and FD) evaluated over the CE domain are shown in Figure 7. Specifically, the highest values (>90) of the days with maximum temperature >25°C are observed over the Italian low-lying territory, which partly includes PA5. Very high (70-90 days) and high (50-70 days) SU values characterize almost all the Hungarian territory, including PA8, and a wide part of the Croatian zone, including both the inland areas and the coastal zone. Most of the central-northern CE territory is characterized by medium SU values ranging from 10 to 50 days. Finally, very low values (<10 days) characterize the Alpine region, including almost the whole Austrian territory (PA6 And PA7), the central part of Slovakia, and the Sudetes area in the southern Poland. As expected, the spatial pattern distribution of the FD index is almost opposite to the distribution of the SU indicator: the highest values (for which the mean annual value of days with minimum daily temperature <0°C is higher than 180) are observed over the Alpine region (including the North-eastern part of the Italian territory, Austria, part of Slovakia, and a limited area in Slovenia with the respective PAs) while the lowest values (less than 60 days) characterize the Italian flat territory, including partly PA5. The remaining part of the investigated territory is characterized by medium index values (from 90 to 150 days).

3. Future climate projections and expected anomalies

In the previous section, the main findings concerning the current climate conditions are displayed over the entire CE domain while detailed focuses for each PA are available in the dedicated factsheet reported in next paragraphs. In this section, the results of the assessment of future evolutions in weather forcing and associated hydrologic variables over the investigated domain are shown. This kind of analysis plays a crucial role in the definition and implementation of effective and adequate climate adaptation measurements.

3.1. Data basis and models

These assessments are in general carried out by means of numerical models which allow obtained future projections with high-spatial resolution and under different scenarios of economic development/growth and demographic changes at both the global and regional scale. To this aim, the evaluations of future concentrations of greenhouse gases (GHGs), aerosols, and chemically active gases (climalterant gases), as well as changes in land use expected for the next centuries, are provided by Integrated Assessment Models (IAMs). In this regard, the Intergovernmental Panel on Climate Change (IPCC) has selected four reference standard pathways (commonly known as RCP Representative Concentration Pathways). The four pathways proposed by the IPCC (RCP8.5, RCP6.0, RCP4.5, and RCP2.6) respectively estimate an increase in radiative forcing levels of 8.5, 6, 4.5 and 2.6 W/m2 by the end of the century compared to pre-industrial era (1750). Specifically, the first concentration pathways (RCP8.5 - business as usual) identifies the most pessimistic scenario for which very high emissions are expected to continue without the implementation of mitigation strategies. RCP4.5 and RCP6.0 represent the intermediate stabilization pathways for which substantial emission reductions are expected. Finally, RCP2.6 is a relatively optimistic scenario assuming high mitigation measurements and predicting that by the year 2100 the GHGs concentration will be only a little higher than today. It worth noting that the targets of the Paris Agreement (limiting the increase in global warming to 2°C and, hopefully, to 1,5°C) are only consistent with RCP2.6 scenarios while, under the other RCPs, higher increases can be expected. Of course, at regional scale, the global warming increase can be translated in higher or lower variations according the geomorphologic features of the areas. The response of the global climate system to the variation in concentration of the climalterant gases for both historical (reference) and future (projections) periods is in general simulated by means of General Circulation Models (GCMs). Nevertheless, due to their coarse horizontal resolution (70-80km), these models can simulate only large-scale atmospheric state (IPCC, 2014). In order to capture smaller-scale information, modelled climate data need to be downscaled in time and space. To this aim, several spatial downscaling techniques have been developed; they largely differ for computational costs, prerequisites and limitations. Downscaling techniques are classifiable as "statistical" and "dynamical" approaches. The first ones adopt frameworks based on empirical statistical relationships between "predictors" large-scale and “predictand” local climate variables, calibrated and validated on observed data and then applied to GCM variables. They require limited computational burden and also allow analysis at station scale but need long series of observed data for the definition of the statistical relationships. The latter ones involve the use of climate models over a limited area and with the highest resolution (RCMs - Regional Climate Models) nested for the area of interest on the global model from which they draw the boundary conditions. Currently adopted resolutions, in the order of approximately 10 km, allow both a better resolution of the orography and to solve a substantial fraction of the local atmospheric phenomena. Moreover, different experiments have proven their good capability in reproducing regional climate variability and changes (Feser, 2011). Even if this refinement makes it possible to accurately evaluate a remarkable fraction of weather patterns, dynamical approaches may misrepresent orography, land surface feedbacks and sub-grid processes, thus inducing biases preventing their direct use for impact analysis (Maraun, 2016; Maraun et al., 2015). To overcome this issue, different approaches, known as Bias Correction (BC) methods, have been proposed in recent years (Lafon et al., 2013; Teutschbein et al., 2012). They can be defined as statistical regression models calibrated for current periods in order to detect and correct biases, which are assumed to systematically affect the climate simulations. Although the advantages, limitations and warnings regarding their adoption are widely debated in recent literature (Ehret et al., 2012), they are currently recognized as a necessary stage in producing weather variables to use as inputs for impact-predictive tools. On the other side, in order to evaluate uncertainties associated with different realizations of climate experiments and favour the comparison among the simulations, in the last years, several consortiums have promoted “ensemble” initiatives. An ensemble represents a collection of model simulations characterizing a climate prediction or projection (IPCC, 2014). Differences in initial conditions and model formulation result in different evolutions of the modelled system. In the case of climate projections, the use of an ensemble of simulations can give information on uncertainty associated with model error and with internally generated climate variability. Among these initiatives, in more recent years, the World Climate Research Program (WCRP) has been established the Coordinated Regional Downscaling Experiment (CORDEX) project. This program aims at organizing an internationally coordinated framework in order to produce improved regional climate change projections for all land regions world-wide. Due to the higher spatial resolution, the results of RCMs are often used as input for climate change impact assessment studies and to support the definition of suitable adaptation strategies. In this study, anomalies in indicators have been calculated based on the data simulated by the regional models developed in the frame of the EURO-CORDEX program (Jacob et al., 2014), the European branch of the international CORDEX initiative (Giorgi et al., 2009). EURO-CORDEX climate simulations cover all the European territory with a spatial resolution of about 12 km and they are available for the period 1951-2100 (including therefore past and future time-spans) under three concentration scenarios (RCP2.6, RCP4.5, RCP8.5). Further specific information about the EURO-CORDEX climate models is provided in Hennemuth et al. (2017). Specifically, climate data used for the evaluation of future climate anomalies over the CE domain are based on the ensemble of the results of up to 19 models (reported in Table 2) run under the RCP4.5 and RCP8.5 scenarios.

Table 2: List of the EURO-CORDEX simulations available at ~12km resolution over Europe (EURO-CORDEX ensemble). Providing institution, driving model and adopted RCMs are also indicated.

Code	Institution	Driving model	RCM
1	CLMcom	CNRM-CM5_r1i1p1	CCLM4-8-17_v1
2	CNRM	CNRM-CM5_r1i1p1	Aladin53
3	RMIB-Ugent	CNRM-CM5_r1i1p1	Alaro
4	SMHI	CNRM-CM5_r1i1p1	RCA4_v1
5	KNMI	EC-EARTH	RACMO22E_v1
6	DMI	EC-EARTH	HIRHAM5_v1
7	CLMcom	EC-EARTH	CCLM4-8-17_v1
8	KNMI	EC-EARTH	RACMO22E_v1
9	SMHI	EC-EARTH	RCA4_v1
10	IPSL-INERIS	IPSL-CM5A-MR_r1i1p1	WRF331F_v1
11	SMHI	IPSL-CM5A-MR_r1i1p1	RCA4_v1
12	CLMcom	HadGEM2-ES	CCLM4-8-17_v1

Code	Institution	Driving model	RCM
13	KNMI	HadGEM2-ES	RACMO22E_v1
14	SMHI	HadGEM2-ES	RCA4_v1
15	CLMcom	MPI-ESM-LR_r1i1p1	CCLM4-8-17_v1
16	MPI-CSC	MPI-ESM-LR_r1i1p1	REMO2009
17	SMHI	MPI-ESM-LR_r1i1p1	RCA4_v1
18	MPI-CSC	MPI-ESM-LR_r1i1p1	REMO2009
19	DMI	NorESM1-M	HIRHAM5

In the following, the computed anomalies in indicators are provided as maps using the native grid resolution. Nevertheless, data are also computed at aggregated level (Country, NUTS1, NUTS2, NUTS3). They will be exploited for the development of the TEACHER-CE Toolbox. Furthermore, a focus for each PA is provided where information about recent decades (from E-OBS) and future time spans (from EURO-CORDEX) are used. In order to extract and elaborate a sufficient number of points from the gridded domain of the EURO-CORDEX models, a buffer of pertinence equal to the horizontal resolution of the respective dataset has been considered around each area of interest (at both NUTS and PAs level). Based on the climate projections obtained by means of the ensemble of the EURO-CORDEX simulations, the selected climate indicators have been evaluated for two future time periods: 2021-2050 for the short-term analysis and 2071-2100 for the long-term analysis. For each indicators (for the two periods and two RCPs), the expected future variations (with reference to 1971-2000 period) are calculated in terms of mean value. They will be reported in the following. Furthermore 25th, 50th and 75th distribution percentiles are also computed and made available for the TEACHER-CE Toolbox. Mean and quartile values are intended as computed using the 19 climate simulations reported in Table 2. In the following maps, the climate anomalies are displayed exploiting raw grid points while administrative level (NUTS2 for Germany and NUTS3 for all the other countries in the CE domain) are identified. In this case, they refer to the medium values. The full set of all the statistical values will be available online on the web-platform in form of table and maps in order to be downloaded by interested end-users.

3.2. Seasonal mean temperatures

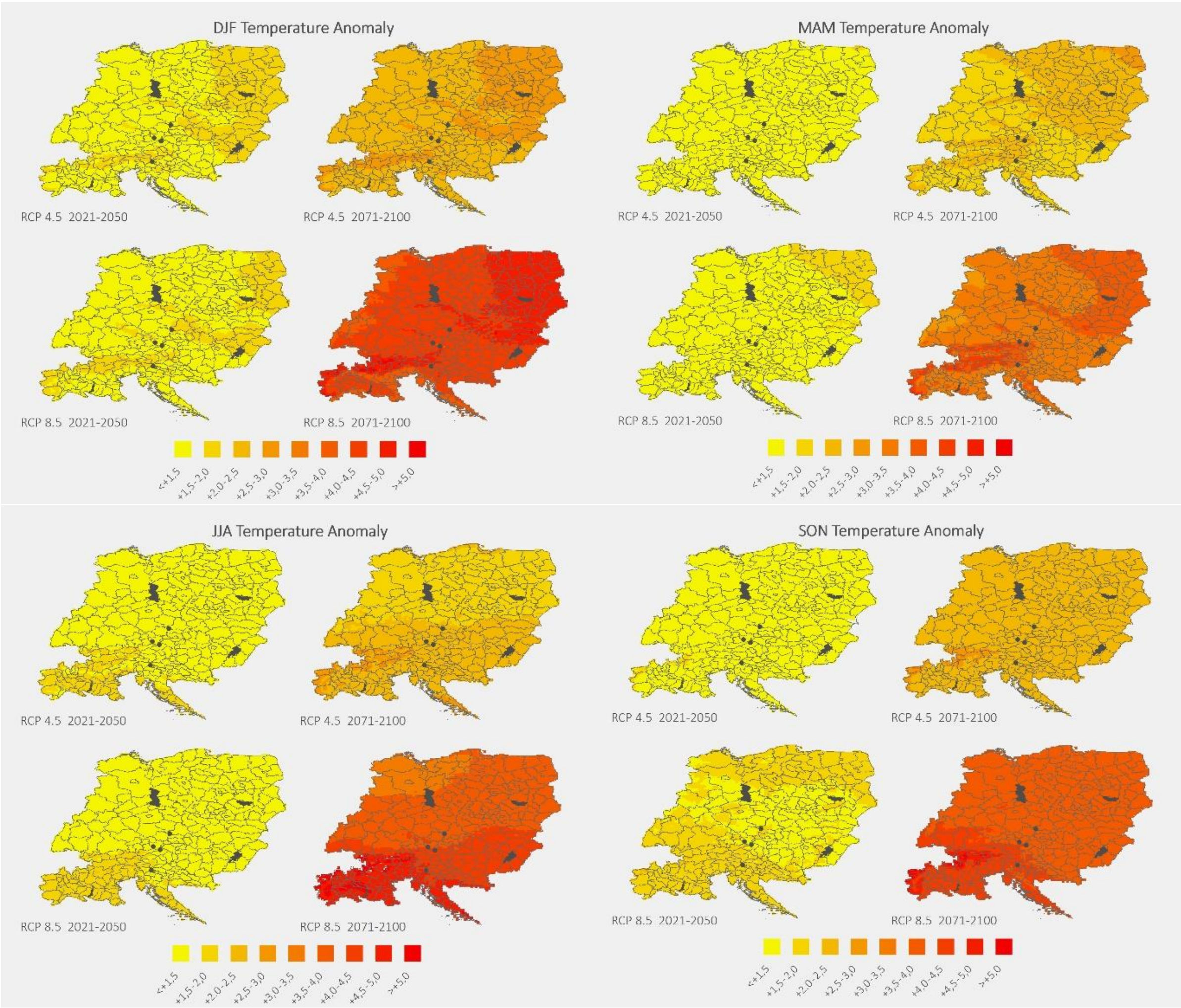

Figure 8: Expected variations (anomalies) in seasonal temperature over the CE domain for the period 2021-2050 and 2071-2100 (vs 1971-2000) under RCP4.5 and RCP8.5 scenarios; data are reported in Celsius degrees. TEACHER-CE Project's PAs are indicated in grey. NUTS3 boundaries (NUTS2 for Germany) are also included in the maps.

In Figure 8 the expected variations in seasonal temperature over the CE domain are shown for the period 2021-2050 and 2071-2100 (vs 1971-2000) under the two concentration scenarios taken into account in the study (RCP4.5 and RCP8.5). An increase (returned as mean value) in temperature is expected for all seasons under both RCPs and over the two time periods. Specifically, in the short time period, the winter increase (DJF) is lower than 1.5°C on the western part of the domain while on the eastern part it could arrive at about 2.5°C under both the RCPs scenarios. For the long time period, these values are expected to reach 3.5°C under the RCP4.5 scenario and up to (or even higher than) 5°C in the worst-case simulation (RCP8.5). Similar temperature anomalies are expected for the summer period (JJA), where a clear North-South growth gradient is evident. In this case, the Italian territory, the Alpine region, and the Adriatic zone show the highest anomalies (up to 2.5°C) in the short term period under both concentration scenarios while in the long-term period very high values (up to 3.5°C for RCP4.5 and to 5°C for RCP8.5) are obtained also for the eastern part of the CE domain, including Slovenia, Croatia, and Hungary. These data highlight the vulnerability of the high altitude areas that can be considered prone to be affected by changes in the temporal and spatial distribution of the snow cover.

During the intermediate seasons, a more homogenous distribution is observed. During MAM, on the short-term horizon, the expected increases should not exceed 1.5°C; only in the North-eastern part of the domain, higher increases are assessed under the scenario RCP8.5. Simulations for the long term period show values that do not exceed 3°C under RCP4.5 and 4.5°C under RCP8.5; in this case, only in the Alpine region and in some areas in Hungary larger variations are identified.

Finally, considering the autumn period (SON), large values are expected under RCP8.5 in the northern part of the CE domain, western Italy, and southern Germany: these values are in the range of 2-2.5°C for the short term period and up to 5°C in the long term period.

The spatial pattern distribution of the increasing temperature should be taken into account by policy-makers and administrators involved in the planning of local management and adaptation strategies, since the impacts of changing temperature conditions can lead to an increasing in the intensity and duration of periods with increased evapotranspiration atmospheric demand and larger water request (e.g. for civil purposes or irrigation), with consequent impacts on water resources availability.

3.3. Seasonal cumulative precipitation

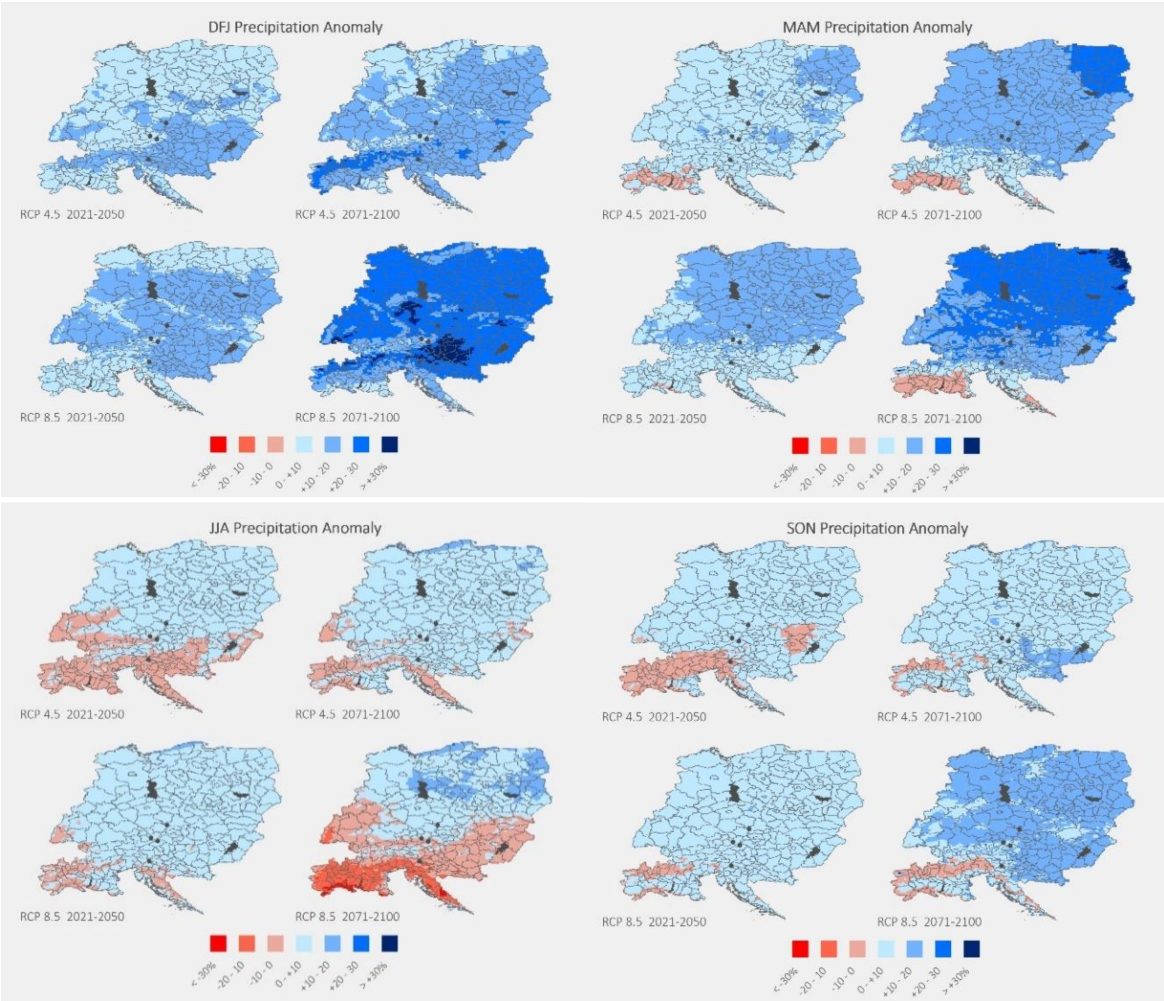

Figure 9: Expected variations (anomalies) in seasonal cumulative precipitation over the CE domain for the period 2021-2050 and 2071-2100 (vs 1971-2000) under RCP4.5 (upper maps) and RCP8.5 (lower maps) scenarios; data are reported in percentage. TEACHER-CE Project's PAs are indicated in grey. NUTS3 boundaries (NUTS2 for Germany) are also included in the maps.

Accounting for the precipitation anomalies (Figure 9), a spatial and temporal variability higher than the one evaluated for the temperature pattern is observed. In general, higher positive anomalies (up to 30% and even higher than 30% when accounting for the long time period under RCP8.5 scenario) are expected for the winter and spring periods, while, on the other hand, in the summer period negative variations (corresponding to a decreasing in the seasonal amount of cumulative precipitation) are observed (with values ranging from 20 to 30%), especially in the southern part of the domain, where negative anomalies higher than 30% are expected for the long term simulation (RCP8.5).

In detail, the winter spatial distribution, under the RCP4.5 scenario, shows values of the anomaly in the range of 10-20% over the Alpine region and the central part of the domain (short-term projections) while the anomalies are higher (20-30%) in the long term projections. Extreme winter variations are expected for the long term and worst-case scenario, in which some parts of the domain are expected to experience positive increases up to 30% respect to the reference period. Opposite conditions are observed for the summer period (JJA), when the southern regions of the CE domain result to be subject to a clear decrease of the amount of precipitation, with negative values of the anomalies that reach values higher than 30%. In this case, a very clear North-South gradient is observable, with very limited positive anomalies (less than 10%) in the central part of the domain, under both RCP4.5 and RCP8.5.

Considering the intermediate seasons, during SON, negative anomalies characterize the Alpine region under both the proposed scenarios (short and long term) while homogeneous values (ranging between 0 and +10%) are observed over the remaining part of the CE domain. In this case, an increase in the precipitation amount ranging from 20 to 30% is detected only for the long-term projections under the RCP8.5 scenario. Finally, in spring, the CE domain is characterized by positive values of precipitation anomalies under all the scenarios, with a particular focus on the North-eastern part of the domain (including almost the whole Polish territory), where the anomalies range from 10 to 30% but, in the long-term scenario, peaks can be higher than 30%. In this case, only the plain areas in Italy show low negative (up to -10%) anomalies values.

3.4. Consecutive dry and wet days

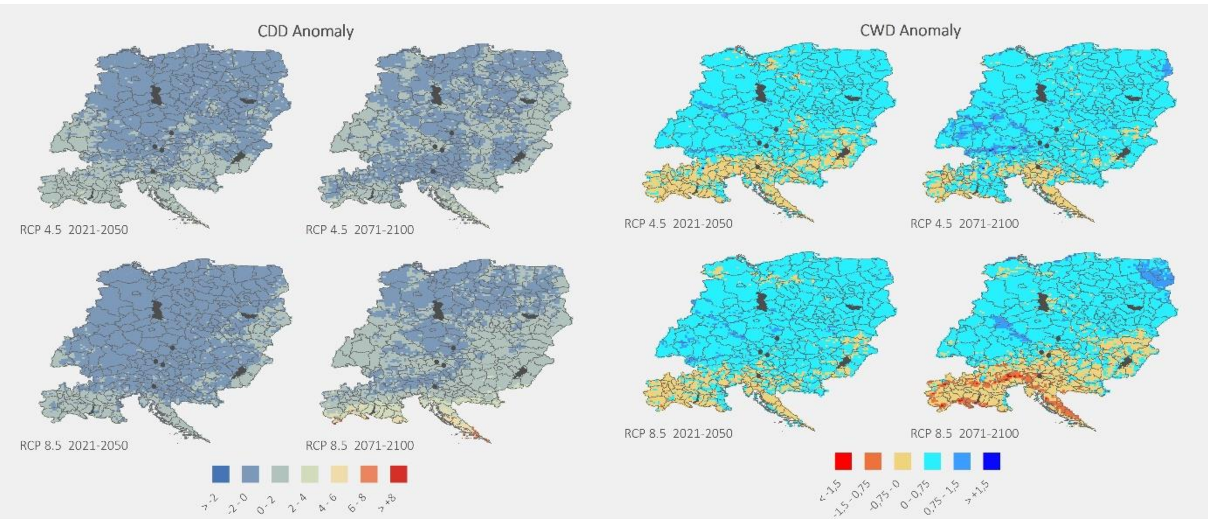

Figure 10: Expected variations (anomalies) in CDD and CWD over the CE domain for the period 2021-2050 and 2071-2100 (vs 1971-2000) under RCP4.5 (upper maps) and RCP8.5 (lower maps) scenarios; data are reported in days. TEACHER-CE Project's PAs are indicated in grey. NUTS3 boundaries (NUTS2 for Germany) are also included in the maps.

In Figure 10, the future expected variations in the maximum number of days with precipitation lower than 1mm (CDD) and equal or higher than 1mm (CWD) are shown. In the first case, on short term, limited spatial variations (ranging between -2 and + 2 days) over the entire domain are detected under both considered RCPs. Accounting for the long term scenarios, the spatial distribution of the CDD anomalies, which are confirmed to range between -2 and +2 days, become more variable, especially under RCP8.5: in this case, the plain areas of the Italian territory, as well as the Adriatic zones, are expected to be characterized by longer periods of consecutive dry days (up to 8 days).

For what concern CWD, the first element to stress is that expected variations stand in a range quite more limited than those considered for CDD (-1,5<CWD<1,5 vs -2<CDD<8). For the short term projections, very limited variations are expected to occur, with anomalies ranging from -0,75 days to 0,75 days. Reductions could primarily affect Alpine and Balkan regions. Considering the long term projections, stronger reductions are assessed over Italy, the Alps, and Balkan countries under RCP8.5. In this case, a decrease of 1 day in the length of wet periods is expected to occur. On the other hand, higher increases, up to 1,5 day, are assessed in the North-western part of the domain and the high-altitude areas bordering Austria, Germany and Czech.

3.5. Maximum 1-day precipitation (Rx1day)

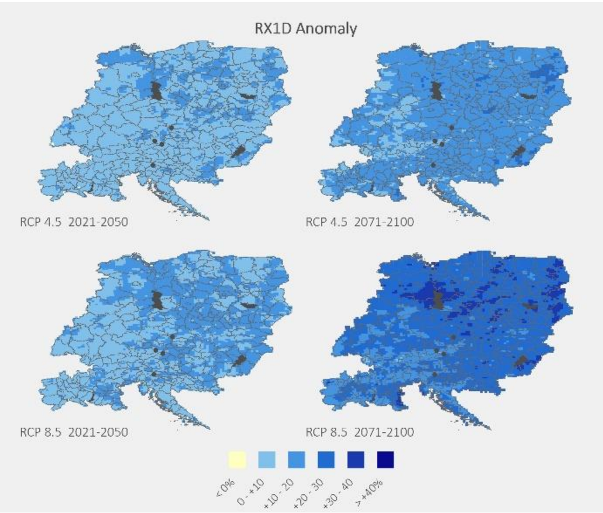

Figure 11: Expected variations (anomalies) in Rx1day over the CE domain for the period 2021-2050 and 2071-2100 (vs 1971-2000) under RCP4.5 (upper maps) and RCP8.5 (lower maps) scenarios; data are reported in percentage. TEACHER-CE Project's PAs are indicated in grey. NUTS3 boundaries (NUTS2 for Germany) are also included in the maps.

As for the seasonal precipitation pattern (cf. Figure 9), the variation in the maximum daily precipitation (Rx1day) is expressed in percentage (Figure 11). The expected anomalies of this indicator show a prevailing homogeneous distribution over the investigated territory. In detail, climate simulations for all the accounted scenarios provide a clear increasing signal (up to +40%) with no negative values observed meaning that a general increase in the magnitude of the rain events can be expected. Variations for the short term scenarios are expected to mostly range between 0 and 10 % under RCP4.5 scenario and between 0 and 20 % under the RCP8.5 scenario while, on long time horizon, the increase results highly exacerbated over all the domain. In particular, under the RCP8.5 scenario, a large part of Italian and Balkan territories could be affected by an increase of about 40 % while peaks in variation higher than 40 % are expected over the high altitude areas located in the North-eastern part of the domain, including PA3 and PA8.

In conclusion, in terms of rainfall distribution, an increase in CDD can be expected in the southern part of the CE domain while an increase in CWD is assessed in high altitude areas in the central part of the domain. Finally, the increase in Rx1day values is observed over a large part of the domain especially under the more pessimistic scenario.

3.6. Summer and frost days

Finally, the future expected variations in the number of summer and frost days (SU and FD) are reported in Figure 12. By comparing these two indicators it is clear that a general increase in temperature is detectable over the entire domain. Specifically, SU and FS anomalies result strictly linked to the time horizon (the farther, the higher the increase) and concentration scenario (the more severe, the higher the increase). Furthermore, in both cases, the North-South trend is charily observable: SU positive anomalies (which indicate an increase in the number of days with daily maximum temperature > 25°C) are higher in the southern part of the CE domain, with variation up to 30 days of increasing in the short term scenarios and up to 50 days (or even higher) in the long term scenarios. The most vulnerable areas are therefore located in Italy, Slovenia, Hungary, and Croatia (and related PAs included in the project – PA5, PA1, PA8). In the northern areas, the SU anomalies do not exceed the values of 10 days (for the short term scenarios) and 30-40 days (for the long term scenarios). Considering the FD anomalies, higher values are expected to occur in the northern areas of the CE domain, where the decrease in the number of days with a daily minimum temperature lower than 0°C is expected to range between 20 and 40 days in the short term scenarios and up to 80 days in the long term horizon (under the RCP8.5 scenario). Of course, such data are strictly linked to the current climate conditions. Areas in the north of the domain or in high-altitude areas currently experience a higher number of “Frost Days” that could be reduced by expected increases in temperatures.

In conclusion, the general increase in temperature over the CE domain reported in Figure 8 is confirmed by the overall variations in the distribution of the ETCCDI indicators strictly linked to the temperature patterns. As occurred for the seasonal temperature values, the number of summer days is expected to increase in all the scenarios (long and short term) and for both the accounted RCPs. At the same time, according to the model simulations, substantial decreases in the number of frost days are expected to occur over the entire domain.

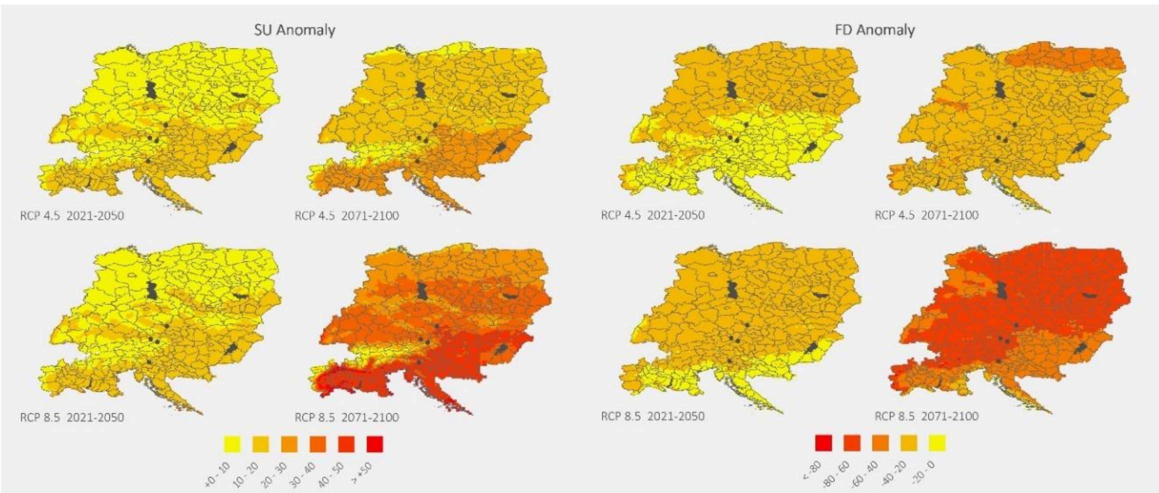

Figure 12: Expected variations (anomalies) in SU and FD over the CE domain for the period 2021-2050 and 2071-2100 (vs 1971-2000) under RCP4.5 (upper maps) and RCP8.5 (lower maps) scenarios; data are reported in days. TEACHER-CE Project’s PAs are indicated in grey. NUTS3 boundaries (NUTS2 for Germany) are also included in the maps.

3.7. Conclusion

In conclusion, in this chapter the following data have been shown:

1) climate conditions currently observed on Central Europe domain as returned by E-OBS gridded dataset. In this case, the evaluations are referred to the period 1970-2000;

2) future variations expected over the Central Europe domain on short (2021-2050) and long (2071-2100) time horizon under the effect of climate change by considering two IPCC concentration scenarios (RCP4.5 AND RCP8.5). In this case, the evaluations are based on the results provided by an ensemble of different climate models included in EURO-CORDEX initiative and characterized by very high horizontal resolution (0.11°, about 12 km over Europe).

To these aims, a number of weather indicators related to the temperature and precipitation patterns are taken into account: i) seasonal temperature and cumulative precipitation values; ii) consecutive dry and wet days and maximum daily precipitations (related to the precipitation pattern); iii) the number of summer and frost days (related to the temperature pattern). These indicators are in general assumed as a proxy for expeditious evaluations about future expected changes in quantity and quality of water resources and the occurrence and severity of local hydrological/hydraulic hazards. Specifically, expected variations evaluated for the investigated area could affect the availability of water resources and weather-induced hazards through different feedbacks mechanisms and with different magnitude according to the area, the time horizon and the selected scenario. In particular, strong increases in evaporative atmospheric demand as a consequence of increasing temperature could be expected over the entire hydrological year. Furthermore, the strong variations expected in high altitude areas could entail strong variations also in snow dynamics. These variations could strongly affect water balances and occurrences of hydrological hazards also in areas close to those directly interested by such variations.

4. The climate data sheets for the pilot actions

The climate datasheets contain information about recent decades and potential future changes of different climate variables and related indicators at the PAs scale. In addition, in order to provide a qualitative evaluation of the returned findings, the models' agreement level is indicated for each index in each scenario. In detail, the datasheets are organized as follows: in three data boxes (Figure 13). The first box includes information about seasonal mean temperature and cumulative precipitation; the second box included information about precipitation related indicators, expressed by means of three indices (CDD, CWD, Rx1day), and the third box shows information about temperature-related indicators, expressed by means of SU and FD indices. Specifically, the following data are provided:

- historical climate trends and current conditions evaluated from E-OBS dataset at a resolution of about 10 km for two periods (1971-2000 and 1990-2019); the first period is used for the evaluation of past climate conditions while the second one provides insights about ongoing changes;
- future climate anomalies evaluated from the ensemble of 19 EURO-CORDEX simulations at a resolution of about 12 km for two future periods (2021-2050 - Short Term (ST) and 2071-2100 - Long Term (LT)) under two different concentration scenarios (RCP4.5 and RCP8.5). The climate anomalies will be evaluated for a number of indicators that allow assessing the potential climate change impact on water-related variables and hazards;
- in the case of the EURO-CORDEX simulations, the evaluation of the models' agreement, as well as the assessment of the ensemble spread, is also provided in order to have a preliminary indication about the consistency/robustness of the results.

Figure 13: Example of data box included in each datasheet. Similar boxes are provided also for precipitation indices (CDD, CWD, Rx1day) and temperature indices (SU, FD).

In each box, the quantitative values of climate anomalies are represented by means of box and whisker plots (Figure 14). This kind of graphical method is commonly used to show statistical information (percentiles, maximum, and minimum values) related to ensembles of data series. Box and whisker plots are very useful when large numbers of observations are involved and when two or more data sets have to be compared. Specifically, the box spans the interquartile range since the ends of the box represent the upper and lower quartile and a line inside the box represents the median value while the whiskers, represented by the two lines outside the box, indicate the maximum and minimum values of the dataset.

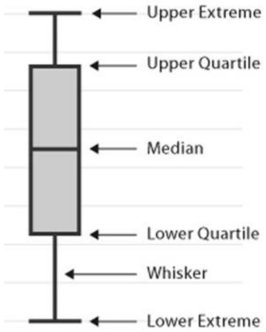

Figure 14: An example of a box and whisker plots.

For each indicator value evaluated for each scenario, details concerning the models' agreement and robustness of the results are provided. Specifically, the level of agreement among the climate models is assessed based on the number of models that confirm the evaluated sign of the anomaly (positive or negative) for each indicator (Table 3). To this aim, a simple graphical representation is added in a dedicated row in each box. Furthermore, in order to evaluate the reliability/robustness of the signal, the anomaly is compared with the natural variability computed by using E-OBS data (1971-2000) as reference. Specifically, if the anomaly is less than 1*SD (Standard Deviation), the robustness is indicated as weak, between 1 and 1.9 times it is considered moderate; larger anomalies (>=2*SD) are assumed as strong. This information is reported in each data box with a dedicated row where cells are coloured in yellow, orange and red, respectively.

Table 3: Assessment of the models' agreement

Models' agreement	Number of models	Symbol
Very low	<= 10	-
Low	11-13	*
Moderate	14-16	**
High	17-19	***

Synthesis of the results are attached as annexes to the Deliverable (following the scheme proposed in Table 4) but they are not included in datasheets.

For each indicator/time span/(concentration scenario), the values are computed as spatial mean over the PA domain including a buffer zone equal to the horizontal resolution of the investigated area. For evaluations about future time horizons, anomalies are computed as described in previous sections. Annex I.1 reports the instructions leaflet supporting not experts for a proper understanding of the provided data while Annex I.3 provides synthetic Tables about the data included in PAs datasheets.

Table 4: Synthesis of results for each PA

SHORT/LONG TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF								
	TMAM								
	TJJA								
	TSON								
Seasonal cumulative precipitation	PDJF								
	PMAM								
	PJJA								
	PSON								
CDD									
CWD									
Rx1day									
SU									
FD									

The datasheets for pilot action 1 - 9 are provided in annex I.2.

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C. Climate Change impacts on fields of action of water management and cross-sectoral consequences

1. Scope

1.1. Water management "components" in this compilation

Climate change imposes impacts on all aspects of "Water management". The term "water management" comprises many different fields of action on all administrative levels, regarding water quantity as well as water quality and concerning a wide variety of management tasks of freshwater and other waters (e.g. waste water) in different geographic circumstances (e.g. rivers, lakes, marine). In this compilation, this broad scope has been narrowed with a view to the main aims of the TEACHER-CE Tool to achieve a targeted input. The focus was set on the regional and local administrative level as these are the main target groups of the TEACHER-CE Tool. EU and national level were considered, as applicable. In some countries the national administrative level is responsible for regional or local tasks. EU and national level provide important regulative frameworks for water management. Furthermore, the tasks assigned to water management differ in the countries of CE[1]. Some fields of action are a joint responsibility of water management actors and other sectors or may even be fully in the responsibility of other sectors (e.g. water for irrigation in agriculture).

Fields of action mainly in the responsibility of water management as used in this compilation:

- Inland river flood management and protection
- Urban drainage and wastewater treatment
- Heavy rainfall and flash floods (management and protection)
- Groundwater protection and groundwater use
- Drinking water supply
- Navigability of water ways
- Dam and reservoir management
- Low water management
- Conservation of aquatic ecosystems

The fields of action regarding coastal flood defence, drainage of low-lying coastal areas and marine conservation encounter a wide variety of CC impacts and related adaptation options. However, very few areas of CE (Polish part of Baltic Sea and CE Italian part of the Mediterranean Sea) are concerned. Therefore, the TEACHER-CE partnership decided[2] to focus on the fields of action named above.

[1] The differentiation according to the regulations in each country is not subject of this study.

[2] Result of discussion at the partner web meeting on 15 July 2020.

Fields of action which often are in the joint responsibility of water management and other sectors or in the responsibility of other sectors/ actors:

- Agriculture/ forestry: Water for irrigation in agriculture (groundwater) etc.
- Energy/ industrial sector: Cooling water availability; Hydropower generation
- Urban areas: Urban planning and development

Further sectors are linked to the fields of action of water management mainly as users of water resources, e.g. tourism using surface waters for recreation or snow generation for skiing, with effects on water quantity and water quality. These are considered as far as potential conflicts with water management tasks in the light of a changing climate exist, but are not in the main focus of the TEACHER-CE Tool.

1.2. Cross-sectoral aspects regarding water resources relevant for CC adaptation

Changing climate parameters and their consequences for water availability and water quality lead to increasing adaptation needs in all sectors depending on water resources. Existing synergies and conflicts may be intensified or in some cases even may be balanced, while new conflicts (and synergies) will arise from increasing water resource pressures. The increasing competition on limited water resources and the adaptation needs, options and measures of the different sectors contain a high potential of conflicts. Figure 15 shows competition fields of several sectors where conflicts regarding climate change adaptation are expected to increase.

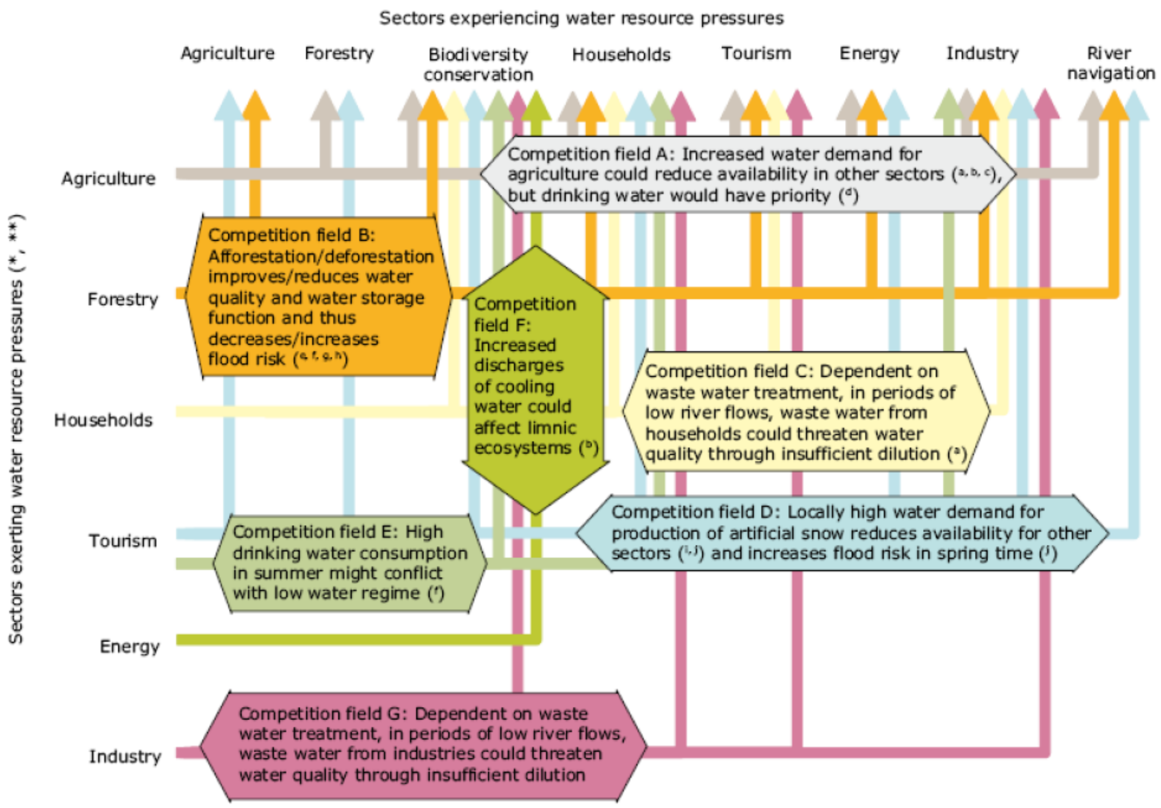

Figure 15: Fields of potential cross-sectoral water competition relevant for CC adaptation (source: EEA, 2009)

Examples for these competing fields and potential conflicts regarding water resources are (CESR, 2011; LAWA, 2019):

- Temporal, seasonal, or permanent decreases in river flow will cause a higher fraction of upstream water consumption that may endanger downstream water supply and navigation.
- Increasing irrigation water withdrawals due to rising temperatures may increase risks on environmental flows or water supply in the downstream neighbour country.
- Increasing water temperature in rivers and increasing thermal loadings due to cooling may lead to decreasing cooling potential and deterioration of water quality in downstream regions.
- During flood events upstream communities are interested in a fast transmission of the flood wave, whereas flood retention in the upper reaches of the river would help to reduce damages downstream. The projected increase in the magnitude of floods will intensify those conflicts."
- Conflicts can arise with increasing water scarcity between the concurring water users, e.g. drinking water supply, electricity production, agriculture (irrigation) or industry (e.g. for cooling processes). The place of origin does not necessarily have to coincide with the place of impact (e.g. water withdrawals in the upper reaches of a river, which can lead to a shortage in the lower reaches).
- Water management adaptation measures affect other sectors such as agriculture and the energy sector. Beside local and regional problems the aspects of the management of cross-border water resources have to be taken into account. Examples are the runoffs and the quality of the Danube River flowing through several countries of CE.
- Adaptation measures can also lead to synergies. Approaches to the decentralised concept of water sensitive urban designs can lead to a relief of the sewer system, an approximation to natural hydrological conditions and an improvement in the surface water quality by reducing the entry of untreated wastewater.

Additionally, potential conflicts caused or intensified by climate change between different sectors arise from intensified competition for land use. Adaptation needs in the water sector often call for restrictions regarding the land use for other sectors, e.g. retention areas restricting urban development or safeguarding groundwater quality restricting agricultural use.

In chapter 4 adaptation options and strategies in the different fields of action of water management and the relevant sectors for the TEACHER-CE tool include an assessment regarding potential conflicts and synergies.

2. Potential impacts of climate change on water-related processes

Expected changes in weather patterns and related spatial distribution estimated for the CE domain can lead to direct and indirect impacts on freshwater resources in terms of both quantity and quality. The extent of such impacts is complex and it is related to the occurrence of climate-related processes, such as droughts and heavy precipitations, which depend on the geographical areas as well as the size and other local geomorphological characteristics of the catchment area of interest (LAWA, 2017).

Potential climate impacts on water availability and quality could affect surface, ground and coastal waters. Table 5 provides an overview of general interrelation aspects and the categorisation of climate change trends and related impacts on water-related processes as proposed for the assessment. They are mostly related to the increase in temperature and change in annual and seasonal precipitation patterns (cf. chapter 3 and 4).

Table 5: Overview of changing climate parameters and impacts on variables of water management as used in this compilation

CC trend	CC impacts regarding water (often as consequence of a combination of several CC trends)
Higher temperatures	▪Higher water temperatures ▪Increased evapotranspiration ▪Prolonged vegetation periods ▪Increased dry periods, frequency and duration of droughts ▪Increase of incidents of low water ▪Higher water demand ▪Increase of transmission of invasive species
Changing precipitation patterns/ seasonal shift in precipitation amounts: **increased winter precipitation (rather rain than snow)**	▪Increase of frequency, height and duration of high-water events ▪Fluctuation of groundwater table ▪Rising water table
Changing precipitation patterns/ seasonal shift in precipitation amounts: **decreased precipitation in summer**	▪Increasing dry periods, frequency and duration of drought ▪Increase of incidents of low water ▪Higher water demand ▪Increase of nutrients input in groundwater
Heavy rainfall - increase in intensity and frequency (small scale)	▪Increase in flood runoff ▪Increase of erosion ▪Increase of nutrients input ▪Increase of frequency, height and duration of high-water event

Furthermore, for each CC trend, the indicators suitable for its characterization have been identified by CMCC (project partner 5) and selected among those calculated in previous sections. For each CC trend, relevant proxy indicators have been marked in red (high relevance) or in yellow (low relevance) while indicators that are not useful or relevant for characterizing such trend have been marked in white (no relevance). In addition to this, an analysis of the most prominent CC impacts across Pilots Actions has been performed based on the local climate data related to the trends of the indicators calculated at the PA scale, which have been summarized in dedicated datasheets and in the tables provided in Annex 2. In Table 6, relevant proxy indicators for each PA are marked with a dot in the corresponding cell.

Information reported in Table 6 is helpful for understanding which proxies should be used to assess different CC trends and for which PAs these variations are more significant. It provides a general overview of the potential impacts of climate change on water resources and can be considered useful for the definition of water management actions tailored according to the different potential issues characterizing each PA. In WP T2, further indicators will be identified permitting a more complete characterization of the expected impacts for the different areas.

For each of the accounted trend, the relevant indicators are highilighted in red (high relevance) and in yellow (low relevance). Furthermore, the dot inside the PAs cells states that the PA has to be considered potentially prone to be affected by the accounted impact.

Table 6: Climate change trends and related expected impacts and potential proneness of pilot actions

CC IMPACTS	PROXY INDICATORS													PILOT ACTIONS								
	T				P				CDD	CWD	tx1day	SU	FD	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON														
Higher water temperatures; Increased evapotranspiration; Prolonged vegetation periods; Increased dry periods, frequency and duration of droughts; Increase of incidents of low water; Higher water demand; Increase of transmission of invasive species	High	High	High	High								High	Low	•	•	•	•	•	•	•	•	•
Increase of frequency, height and duration of high-water events; Fluctuation of groundwater table; Rising water table	High			Low	High	High		High		Low			High	•	•	•	•		•	•	•	•
Increased dry periods, frequency and duration of droughts; Increase of incidents of low water; Higher water demand; Increase of transmission of invasive species						High	High		Low									•		•	•	
Increase in flood runoff Increase of erosion; Increase of nutrients input;										Low	High			•	•	•	•	•	•	•	•	•
Increased dry periods, frequency and duration of droughts; Increase of incidents of low water; Higher water demand	Low	Low	Low	Low	Low	Low	Low	Low	High			High					•	•	•	•		

Legend
- High Relevance
- Low Relevance
- No relevance

3. Impacts of climate change on fields of action of water management in Central Europe

Following, experienced and potential impacts as named in existing studies and research are summarised and categorised according to main tasks and fields of action of the water management sector related to water quantity and quality. Responsible actors may differ in the countries and are not necessarily "water management" actors, including many stakeholders from other sectors (see chapter 1). The order in the following sub-chapters does not reflect the severity or extent of impacts since these are subject for regional specifications.

The following overviews and compilations are based on

- the study LAWA 2017: Impacts of climate change on water management,
- the studies named in the literature references,
- with an adjusted structure and assessment regarding CE regions.

3.1. Inland river flood management and protection

The impact on inland river flood management and protection are categorised according to the catchment size. Along rivers of medium to large river catchments impacts related to flood protection levels and high (ground)water levels due to elevated river levels are important. In small and urban catchment areas as well as in Alpine catchment areas differing impact and climate change trends are prevailing and have to be considered.

Most impacts described in Table 7 have been experienced in at least one of the TEACHER-CE pilot regions. Main potentially affected pilot regions are the Kamniška Bistrica river basin (Slovenia, PA 1), the Piedmont Kamienna river basin (Poland, PA 3) and the Enza river basin (Italy, PA 5) as well as PA8. Although alpine areas are represented by the catchment areas of the drinking water sources of Vienna and Waidhofen/Ybbs (both Austria, PA 6 and PA 7), the impacts and related measures are addressed focussing on the carstic drinking water quality (cf. chapter 3.5).

Table 7: Overview of impacts on inland river flood management and protection

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Flood protection levels	▪Decline of flood protection level of existing structures ▪Need for adjusted design parameters of new protection structures and adjust existing ones to maintain desired level of protection ▪Increased risk of flooding of critical infrastructure (e.g. transportation, water and energy facilities) ▪Declined water quality from hazardous material set off by floods	Increase of frequency, height or duration of high-water events River catchments (medium to large scale) PA 1, 3, 4, 5, 8

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
High water levels due to elevated river levels	▪Increasing flow from surface water bodies into the aquifer leading to higher ground-water tables ▪Elevated groundwater persist longer than river floods, leading to a higher potential of damaging, especially for reservoir in flowing water ▪Increased risk of infiltration due to surface flooding	Increase of frequency, height or duration of high-water events CC impact on forest tree species, increased mortality, thus reduced forest retention capacity during high-water events PA 1, 3
Small and urban-dominated catchment areas	▪Increased incidents in small catchments with high proportion of sealed surfaces with direct response to small-scale convective precipitation events ▪Decrease of protection level along water bodies ▪Increased risk of floods in smaller water bodies ▪Increased hydraulic overloading with potential impact on morphology, e.g. increased bed erosion and endangering infrastructure (e.g. bridges)	Heavy rainfall - increase in intensity and frequency (small scale) Small and urban catchment areas (e.g. below 5 km^2) PA 1, 7
Alpine catchment areas	▪Increased flooding because of little or no retention areas (BMU in LAWA 2017 for DE) ▪Increase in flooding and mud flows in winter	Changing precipitation patterns, increased winter precipitation rather as rain than as snow Alpine region and similar mountainous regions PA 6

3.2. Urban drainage and wastewater treatment

The potential impacts on urban drainage and wastewater treatment can be differentiated regarding the parts of the drainage system which is concerned: the dimensioning of the drainage system, the waste water treatment itself and the impact on receiving waters. The impacts on urban drainage and wastewater treatment are less in the focus of the TEACHER-CE pilot actions, but they are considered as part of the integrated water management of the river basins.

Table 8: Overview of impacts on urban drainage and wastewater treatment

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Dimensioning drainage systems	▪Design level of existing drainage systems will be exceeded more often resulting in more frequent sewer overflow ▪Separate sewer systems: increased hydraulic stress in receiving waters ▪Combined rainwater and sewage systems: additionally increasing negative impact on the water quality of the receiving water streams ▪Impacts on other weak points in the sewer systems, e.g. storm-drain inlets ▪Increased design values plus 10% advisable (LAWA, 2017, for DE)resulting in higher costs, check backflow prevention according to technical standards ▪High sewage runoffs are often caused by flash floods in small catchment basins near residential areas. Drainage systems cannot manage those extremely heavy rainfall events. Water-sensitive urban planning, land-use and individual preparedness are necessary (e.g. adaptation measures of other sectors)	Heavy rainfall - increase in intensity and frequency Urbanised settlement areas in Central Europe, residential and industrial areas PAs 5, 9
Drainage and wastewater treatment	▪Combined sewer systems: Increased hydraulic load in winter on waste water treatment plants (WWTP) leads to more diluted substance concentration and can lead to a decline of the capacity of decomposition; in summer higher concentrations; affecting the oxygen consuming constituents within the sewer ▪Changed erosion dynamic in catchments can alter the particulate-matter load ▪Increased hydraulic and material pressures on water bodies with higher and more frequent discharges ▪In dry periods accumulation of sewer deposits, odours and corrosion in the sewer system ▪Contaminations accumulated during dry periods will be washed into the sewer system. Substances deposited can arrive as a surge at the WWTP which causes changes in the requirement of treatment equipment and increased operation costs	Seasonal shift of precipitation amounts: increase in winter, increasing dry periods with rising temperatures Urbanised settlement areas in Central Europe, residential and industrial areas PA 5

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Wastewater treatment	▪Increasing temperature of wastewater has a negative influence on the breakdown efficiency of the biological treatment processes ▪More rapid conversion of easily degradable substances within the sewer system, altering the composition of waste water ▪Effects on nitrification in the biological treatment process ▪Decrease of oxygen solubility could lead to higher electricity costs for oxygen input (total impact on energy consumption might be negligible) ▪Increased advance degradation could have a negative effect on the dosage of external carbon sources, if necessary	Increasing temperatures Urbanised settlement areas in Central Europe, residential and industrial areas
Water quality of streams	▪More frequent negative impact on the water quality of small receiving waters with less optimal dilution ▪Increasing role of WWTP outflows as proportion of the effluent of small receiving waters could lead to increased importance of high quality treatment and increased emission standards and process-related and operational adjustments needed	Increasing dry periods PA 3, 5

3.3. Heavy rainfall and flash floods management and protection

The impacts of climate change on heavy rainfall management concern both water quantity and water quality in rural and urban areas. Most TEACHER-CE pilot regions are affected by the impacts on agricultural land and soil (PAs 2, 3, 4, 8, 9).

Table 9: Overview of impacts on heavy rainfall and flash floods management and protection

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Heavy rainfall risk management	▪Direct damage from heavy rainfall ▪Indirect from heavy surface-water runoff and the resulting flooding (e.g. torrential flow, overflow of small urban rivers, of the drainage system) ▪Impacts depend on topography, hydrology, land use, vegetation, infiltration capacity and the damage potential (urban areas, critical infrastructure, population density) etc.	Heavy rainfall - increase in intensity and frequency PAs 1, 2, 4, 5
Alpine catchments	▪Immediate run-off will occur more often, coming along with debris, mud flows, slope movement	Heavy rainfall - increase in intensity and frequency PAs 1, 6, 7
Urban drainage	▪Short warning times, high flow velocities and debris transport, extreme and unpredictable changes in flow paths due to deposition / congested watercourses and erosion, sludge, etc. ▪Increasing importance of discharge routes for surface run-off	Heavy rainfall - increase in intensity and frequency PAs 2, 3

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Agricultural land and soil	▪Direct damage from erosion processes and the accumulation of eroded material, impacts on groundwater balance ▪Loss of soil, resulting reduction in soil fertility, crop losses, eroded structures e.g. channels, operational problems, crop losses from material deposit ▪Soil compaction decreases infiltration capacity and occurs often due to use of heavy farming equipment on (too) wet soil; wet conditions increase the risk; higher risk of soil compaction due to extended growing seasons inhibiting groundwater infiltration and structural stability ▪Higher temperatures (acceleration), wet and very dry conditions (slow-down) impact humus breakdown ▪Water erosion, soil erosion, nutrient and humus transfer - compliance with GAP good agricultural practice is needed	Heavy rainfall - increase in intensity and frequency - German areas in CE at risk from erosion include the Bavarian Tertiary Hills, Kraichgau, mountain and hill country of Lower Saxony and their loess plains - Marshes and clayey soils and regions with prolonged harvests with higher risk regarding soil compaction PAs 2, 3, 4, 8, 9
Infiltration capacity	▪Influenced by long dry periods, heavy rainfall on dry soil, depending on type of soil, (water quality: migration of pollutants) ▪Decrease of frost days: negative effect on frost mould, but more water may infiltrate	Heavy rainfall - increase in intensity and frequency PAs 2, 3, 4, 8, 9
Water quality	▪Influx of soil-borne substances into water bodies ▪Heavy rainfall after dry and warm periods: increased input of nutrients and sediments on top of increased algal bloom	Heavy rainfall - increase in intensity and frequency PAs 2, 3, 4, 8, 9 (and PA5)

3.4. Groundwater protection and groundwater use

The changes of climate parameters according to climate scenarios can have contradictory impacts on the recharge of groundwater and the water table: Increase of precipitation in winter can lead to (seasonal) increasing groundwater recharge and rising groundwater level whereas higher temperatures, prolonged drought, prolonged vegetation season and precipitation as heavy rainfall rather lead to a decrease of groundwater recharge with increasing demand and impacts on irrigation and drinking water supply (cf. chapter 3.5 and 3.6).

Examples of TEACHER-CE pilot regions affected by such impacts are PA 2, 3, 4, 5, 7, 8 and 9.

Table 10: Overview of impacts on groundwater protection and groundwater use

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE Pas
Groundwater recharge and water table	▪Increase in groundwater recharge ▪Rising groundwater levels: increasing risk of waterlogging for agricultural, forestry land and built structures (only one of many factors influencing waterlogging) ▪Increased load on drainage systems ▪Impair functioning of small-scale treatment systems and installation of infiltration systems (required minimum distance)	Increase of precipitation in winter Sandy soils are especially prone to nitrate leaching PA 3, 8
	▪Decrease of groundwater recharge	Higher temperatures, prolonged vegetation season PA 1, 2, 3, 4, 5, 8, 9
	▪Higher evaporation rates, greater demands on groundwater reserves (drinking water and irrigation) resulting in a drop of the water balance ▪Increased surface runoff, only limited groundwater recharge ▪Consider annual and seasonal recharge patterns and withdrawal amounts ▪Increasing fluctuation range expected and higher frequency of successive wet and dry years. ▪Increase in near-surface groundwater temperatures as well as changing groundwater levels leading to changes in chemical or biological processes ▪Increased entry of substances with increased infiltration and parallel weak uptake of plants during summer drought periods	Higher temperatures, prolonged drought and heat, decrease of climate water balance (CWB) in summer, increased intense rainfall - Higher impact envisaged in drier and low precipitation areas - Higher impact on smaller near-surface groundwater bodies with low yield and modest thickness, e.g. eastern Bavarian basement rock and central regions of eastern Germany PAs 1, 2, 3, 5, 8

3.5. Drinking water supply

The impacts on the supply of drinking water can be categorised according to the different sources of the raw water (groundwater and spring water, bank filtrate and water courses, dams and lakes) with specific impacts especially on the water quality. Higher temperatures and prolonged drought periods lead to increasing competition with other water uses such as increasing irrigation needs, use of cooling water and dam management (cf. chapter 3.6, 3.7 and 3.9).

Impacts on the drinking water supply are experienced and addressed in most TEACHER-CE pilot regions (PA 1, 2, 4, 5, 6, 7, 8, 9).

Table 11: Overview of impacts on drinking water supply

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Raw water availability/ quantity and quality	▪Increased scarcity of drinking water resources and overuse ▪Challenges in terms of security of public water supply ▪Increased competition with increased irrigation needs for agricultural land, parks, gardens, sports grounds etc. (groundwater abstraction) leading to declining ground water levels	Higher temperatures, prolonged drought and heat, decrease of precipitation in summer PAs 4, 5, 6, 7
Raw water from groundwater and spring water	▪Irrigation influencing groundwater quality: (salination, nutrients input) with indirect impact on drinking water supply by potentially rising nitrate levels in wells	Higher temperatures, prolonged drought and heat, decrease of precipitation in summer PAs 1, 2, 5, 6, 7
Raw water from bank filtrate and watercourses	▪Low water of watercourses have an effect on elevated concentrations of substances and may impact water quality. Withdrawal might be restricted during persisting low water ▪Increased probability of waterborne or water-transmitted pathogens entering water bodies and of other substances and pollutants posing risk to drinking water extraction and quality; high water: increased flooding of facilities with potential pollution and impact on water quality	Higher temperatures, prolonged drought and heat, decrease of precipitation in summer PAs 1, 5, 8
Raw water from drinking-water dams and lakes	▪Increased pressure to due falling water levels intensified by increasing droughts ▪Increasing technical problems with low inlet pressure ▪Increasing negative impact on water quality with low water tables ▪Changes of the ecosystem by shifts in circulation and stagnation periods due to elevated temperatures accelerated biological and chemical processes ▪Increasing demand on storage and buffering function with increasing variability of precipitation and temperatures;if priority is given to cope with flood prevention, storage volume for drinking water might be constrained ▪Increased impact on water quality by introduction of substances (e.g. micro-organisms) with surface run-off	Higher temperatures, prolonged drought and heat, decrease of precipitation in summer Heavy rainfall - increase in intensity and frequency and increase of frequency, height and duration of high-water events PA 9

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Distribution networks	▪Increasing impact, e.g. amplifying existing tendencies to bacterial aftergrowth	Higher temperatures, prolonged drought and heat, decrease of precipitation in summer No PA

3.6. Water for irrigation in agriculture

Main impact of higher temperatures, prolonged drought, decreased precipitation in summer and longer vegetation periods is the increasing need for irrigation while at the same time increasing restrictions on water abstractions allowances may occur. Almost all TEACHER-CE pilot regions are affected.

Table 12: Overview of impacts on water irrigation in agriculture

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Need for irrigation	▪Increased evaporation, decrease of water availability for infiltration, limited water availability in soils especially during growing season, increasing drought stress and decrease in agricultural output ▪In combination with heavy rainfall after drought periods increasing risk of surface run-off, exacerbating irrigation requirements ▪Changes in valid irrigation schemes dependant on types of cultivated crops	Higher temperatures, prolonged drought and heat, decrease of CWB in summer - Already dry regions in eastern Germany, e.g. Brandenburg, eastern part of Mecklenburg-Western Pomerania. PAs 2, 3, 4, 5, 8, 9
Available water for irrigation	▪Increasing restrictions on water abstraction allowance in extreme conditions	Higher temperatures, prolonged drought and heat, decrease of CWB in summer PAs 2, 3, 5, 8, 9

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Soil water conditions	▪With increasing drought during growing season the soil's water retention capacity becomes increasingly important, negative influences on soil impact irrigation necessities and negative effects on other materials cycles, lessen uptake of nitrate by plants and soil cracks during droughts with leaching of nitrate and translocation of substances with extreme precipitation ▪Increasing problems with cultivating heavy soils like clay, clay or loess becoming increasingly so hard that they are not suitable for cultivation. ▪Increased salinization on irrigated sites and soils of coastal regions ▪Gradual climatic changes can be accommodated, more frequent extreme weather events are problematic	Higher temperatures, prolonged drought and heat, decrease of CWB in summer PAs 2, 3, 5, 9

3.7. Cooling water availability

With increasing low discharge of river flows increasing restrictions on the use of cooling water for power plants and production processes may occur.

Table 13: Overview of impacts on cooling water availability

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Extent of cooling water shortage	▪Increasing low discharge and low water availability leading to restricted use at defined minimum discharge and consequently reduced or interrupted production ▪Increasing temperature: increased exceeding of allowed river warming by cooling water influence lead to more frequent restrictions on the use of cooling water ▪Concrete impact depending on cooling technology	Higher temperatures, prolonged drought and heat, decrease of precipitation in summer - Power plants and industrial sectors with need for cooling water for production processes - Higher impact on watercourses with high cooling water proportion compared to the discharge

3.8. Navigability of water ways

Increasing periods of high and low water flows affect the navigability of water ways and the task of water management to develop and maintain the water ways for transport. The negative impact on the navigability of water ways is experienced e.g. in TEACHER-CE pilot action 9, but is a side aspect in the pilot actions.

Table 14: Overview of impacts on navigability of water ways

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Development and maintenance for Inland water way transport	▪Increasing restriction of loads due to clearance height under bridges, river closures and suspension of shipping activities due to increasingly reaching the highest navigable water level ▪Permanent morphological changes, effects on sediment transport and deposition leading to bottlenecks during low water ▪Increasing fast stream velocities limit maneuverability ▪Increasing periods with low discharge lead to increasing limiting of shipping loads or even disrupture of transportations ▪Increasing impacts by water shortage on lock and sluice operation ▪Increasing economic losses and deals in supply chains ▪Increasing risk of accidents in narrowed navigation channels	Increase of frequency, height and duration of high-water events Increasing dry periods A detailed study on two Danube points indicates a negligible or even positive impact with a higher average discharge decreasing the number of days below the navigable level (JRC 2019) Less severe on regulated water ways PA 9

3.9. Dam and reservoir management

The impacts on dam and reservoir management concern both, increasing flooding and the role of dams in flood control as well as reduced inflow in summer with increasing water demand for many purposes. The increasing conflict potential is especially noticeable with multi-purpose dams.

Examples of affected regions in Central Europe are in the German regions of Thuringia and Saxony and the regions with reservoirs in Poland, Czech Republic or Slovakia (EEA 2016).

Table 15: Overview of impacts on dam and reservoir management

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Management	▪Changed inflow regime during summer: reduced inflow and increased demands ▪Increased incidents of heavy rain and flooding increased role in flood control, but also impact on hydraulic, static loads and effects downstream of the dam ▪In total wider variability of water levels over the course of the year	Seasonal shift of precipitation amounts: increase in winter, increasing dry periods with rising temperatures

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
	▪Increasing conflicts at multipurpose dams, monopurpose dams with pressure to develop into multipurpose dams	Regions with dams, e.g.in Germany Thuringia and Saxony PAs 3, 8, 9
Water quality	▪Changed physical, chemical and biological processes ▪Raised temperatures with impact on raw water quality ▪Increasing input of sediments due to erosion, nutrients etc.	Seasonal shift of precipitation amounts: increase in winter, increasing dry periods with rising temperatures In center of Poland, during the summer, large and small reservoirs struggle with cyanobacterial blooms. PAs 3, 8
Design and dimensioning	▪Altered conditions of design flood inflows ▪Altered loads on structures, e.g. due to fluctuating water levels ▪No increase of extremely rare flood design events (HQ100; HQ 10.000) expected ▪Changing wind conditions with effects regarding the safety board ▪Positive: use storage function as buffer	Seasonal shift of precipitation amounts: increase in winter, increasing dry periods with rising temperatures PA 8

3.10. Low water management

The task of low water management of rivers and streams encounters also an increasing conflict potential such as increasing withdrawal restrictions or restrictions on leisure use. Quantity and quality of inflows (e.g. from wastewater treatment plants) become more important.

The impacts are of importance for the TEACHER-CE pilot regions in combination with the impacts on agricultural and forestland as well as drinking water availability.

Table 16: Overview of impacts on low water management

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Water availability and quality of streams	▪Increasing conflicts, e.g. increasing (frequency and extension) withdrawal restrictions or restrictions on leisure use ▪Increasing negative impacts on aquatic fauna and aquatic ecology ▪Water quality: increase of material concentration, higher water temperatures leading e.g. to lower concentrations of dissolved oxygen ▪Quantity and quality of inflows become more important, e.g. increased requirements for WWTPs	Increasing dry periods with rising temperatures/ more frequent and/ or longer dry water bodies PAs 1, 2, 3, 4, 5, 8, 9

3.11. Hydropower generation

Both, increasing high and low flows can have a negative impact on the electricity production of hydroelectric plants. However, the impacts on hydroelectric plants concern mainly small run-of-river hydropower plants, which is a specific aspect not in the focus of the TEACHER-CE partnership.

The impacts on impoundment facilities are expected to cause increasing conflicts with other purposes of dam and reservoir management (chapter 3.9).

Table 17: Overview of impacts on hydropower generation

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Hydroelectric plants	▪Increasing demitral impact on year-round production: reduction or disruption of electricity output (low flows, less efficiency of turbine, cut off for maintaining minimum level in main channel), ▪Increasing flood conditions may limit electricity output also increasingly	Seasonal shift of precipitation amounts: increase in winter, increasing dry periods with rising temperatures constraints impact mainly small run-of-river hydropower plants PAs 1, 4, 9

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Impoundment facilities	▪Impoundment facilities can buffer extreme discharges. ▪Increasing conflicts with other purposes of damming, e.g. for the purpose of minimum flow, flood control or navigation. In these cases, electricity production is also negatively affected; cf. chapter 3.9 on dam and reservoir management	Seasonal shift of precipitation amounts: increase in winter, increasing dry periods with rising temperatures German CE regions of Bavaria and Baden-Württemberg with over 80% of Germany's hydroelectricity production No PA
Flood protection	▪Increasing safety requirements, necessary retrofits could exceed the limits of the economic viability of existing plants. ▪In the case of power plants with reservoirs in alpine regions, it must be taken into account that, for example, dumping and debris flows pose a major threat to the safety of the reservoirs. ▪Impoundment facilities in alpine regions: increasing danger from debris flow	Increase of frequency, height and duration of high-water events No PA

3.12. Conservation of aquatic ecosystems

The task of conserving aquatic ecosystems are concerned by the impacts of increasing dry periods with high temperatures with negative consequences especially for the cold Alpine waters and for slow-flowing water courses.

Potential impacts are of importance in TEACHER-CE pilot regions in combination with addressing the water quality of water courses (e.g. by adaption measures in the agricultural sector in the catchment area).

Table 18: Overview of impacts on conservation of aquatic ecosystems

Impact on	Impact (description)	CC trend Examples of affected regions in CE/ TEACHER-CE PAs
Reaching the objectives of WFD	▪Increased negative impact especially on endemic species, e.g. upper reaches of watercourses and cold Alpine waters ▪Increasing critical effects in slow-flowing water courses on the water's chemical and biological properties	Increasing dry periods with rising temperatures - Alpine regions PAs 5 - Slow-flowing watercourses PAs 2, 3, 5, 8, 9

4. Adaptation options of water management and potential synergies and conflicts

Adaptation options comprise a broad range of potential structural (e.g. implementing flood protection walls) and non-structural measures (e.g. adjusted land use planning, awareness raising or adjustment of management). They are well documented in many existing studies (cf. list of literature).

Below, potential adaptation options and measures are categorised according to the fields of action used for this compilation (based on LAWA, 2017). For each option exemplary measures are named. Details on further measures can be found in the annex.

Potential synergies and conflicts comprise:

- Synergies and conflicts between different adaptation measures of the water management sector
- Synergies and conflicts between adaptation measures of the water management sector with adaptation measures of other sectors.
- Synergies and conflicts between adaptation measures of the water management sector with goals and measures (not related to climate change adaptation) of other sectors.

The extent and intensity of potential synergies and conflicts were assessed based on the criteria described in Table 19. The actual extent and intensity of synergies and conflicts might differ and can only be assessed case-by-case with a view to the circumstances of the individual situation.

Table 19: General criteria used for the assessment of potential synergies and conflicts

Criteria	Assessment	Symbol
Synergies		
▪ **Synergies (ecological, economic, social) with adaptation measures of other sectors are widely expected (e.g. often described in literature and practice examples)**	High potential	● (green, filled)
▪ **Synergies (ecological, economic, social) with adaptation measures of other sectors can be expected, e.g. described in best-practice examples**	Medium potential	○ (green, open)
Conflicts		
▪ **Conflicts (of concurring land use, of management of uses like restrictions, of economic losses etc.) with several stakeholders from other sectors or within water management actors are usually expected and are very likely (e.g. already reported in literature and practice examples)**	High potential	● (red)
▪ **Conflicts (of concurring land use, of management uses) with stakeholders from other sectors or within water management actors are possible, manageable solutions exist (e.g. are often described in literature)**	Medium potential	● (yellow)
▪ **Conflicts are expected only in specific circumstances**	Low potential	● (green)

4.1. Inland river flood management and protection

Most adaption options for river flood management and protection dispose of a high conflict potential with other sectors. Often, land-uses such as agriculture, forestry, infrastructure and urban development are contradictory to the restoration of flood plains or the activation of additional retention areas. A close interaction with urban and regional spatial planning, land-use management and all sectors concerned is necessary. But also synergies can be created, for example restoring flood plains can have positive effects for the development of ecosystems.

Table 20: Overview of adaptation options and strategies regarding inland river flood management and protection

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Syner-gies	Con-flicts
Load case climate change	▪Assessing the augmentation of design parameters by a climate-change factor			● (low potential)
Technical flood protection	▪Evaluation, raising/strengthening of dikes, dams, terps, flood-protection walls ▪Mobile flood-control facilities	▪Conflicting land-use: agriculture, forestry, infrastructure	○ (medium potential)	● (medium potential)
Reclamation of flooding areas and restoration of flood plains	▪Reactivation of terrain structures with potential for retention ▪Dismantling of dikes and dams	▪Potential synergies for development of ecosystems, water quality ▪Conflicting land-use: agriculture, forestry, infrastructure	● (high potential)	● (high potential)
Activation of additional and optimisation of existing retention areas	▪Construction of flood-retention basins, polders ▪Restoration and reconnection of floodplains	▪Potential synergies for development of ecosystems, water quality (e.g. less nutrients) ▪Conflicts due to restrictions for other sectors, e.g. agriculture, with economic consequences	● (high potential)	● (high potential)
Land-use planning in flooding areas and flood-threatened areas (extreme events)	▪Flood-adapted planning, construction, renovation ▪No designation of crucial areas for building development ▪Modification/update of urban land-use plans	▪Synergies with nature conservation, ecosystems ▪Conflicting land-use ▪Land-use planning no original task of water management	● (high potential)	● (high potential)
Designation of priority and reserved areas (spatial planning)	Establishment of ▪Areas intended for dike relocation ▪Areas for existing or planned flood-retention basins	▪Synergies: insurance sector	○ (medium potential)	● (high potential)
Legend:	Level of synergy potential Level of conflict potential	● high potential ○ medium potential ● high potential ● medium potential ● low potential		

4.2. Urban drainage and wastewater treatment

Adaptation options for urban drainage and wastewater treatment comprise more or less conflict potential and several synergies. Conflicting land-use must be considered with retention measures in urban areas. Infiltrating rain water may lead to rising and too high groundwater levels. Little or no conflict potential exist when taking measures at the wastewater treatment plant.

Most options described below show synergies with the development of (urban) ecosystems, the re-use of rainwater, sustainable urban development and improving the micro-climatic situation.

Table 21: Overview of adaptation options and strategies regarding urban drainage and wastewater treatment

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Structural improvement and optimised operation of existing sewer networks	▪Lower flow rate ▪Minimisation of mixed-water discharge	▪Synergies: reduce/minimise impact on WWTP ▪Conflicts: economic - high costs	○	🟡
Adjustments in sewage plant operation	▪To cope with heavy rain, e.g. inflow management	▪Synergies: faster treatment with higher temperatures	○	🟢
Systems for rainwater treatment	▪Centralised or decentralised sedimentation shaft, pipe	▪Synergies with nature conservation, ecosystems	🟢	🟢
Centralised and decentralised retention measures in cities	▪Centralised: e.g. retention basins and cisterns for storage and use of rainwater ▪Decentralised, e.g.: multifunctional areas for water containment (roads, etc.)	▪Synergies: use of rainwater, improved micro climate depending on measure ▪Conflicting land-use	🟢	🔴
Utilising infiltration potential	▪Construction of infiltration systems and ponds ▪De-sealing of surfaces, use of water-permeable surfaces, avoiding soil compaction in green areas	▪Synergies: increased groundwater recharge, improved micro-climate ▪Conflicts: rising groundwater level/high groundwater	○	🟡
Incentives for decentralised rainwater management	▪Splitting of wastewater charges (separate charges for the disposal of wastewater and rainwater), ▪Promoting green roofs, specification for rain retention on building sites	▪Synergies: increased groundwater recharge, improved micro-climate ▪Conflicts: rising groundwater level/high groundwater	🟢	🟡
Protection of wastewater systems against flooding	▪Damming of the plants ▪Checking the elevation of structures ▪Flood-proof construction of the mechanical and electro-technical components of the plant			🟢

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Legend:	Level of synergy potential Level of conflict potential	● high potential ○ medium potential ● high potential ● medium potential ● low potential		

4.3. Heavy rainfall and flash floods management and protection

Adaptation options to cope with heavy rainfall include measures in urbanised and in rural areas. Structural measures often require changes in land-use implying land-use conflicts with other users. Measures such as water and sediment retention in outlying areas are mostly in the responsibility of other sectors (agriculture, forestry, road departments). Measures in urbanised areas such as emergency water routes impair accessibility. Little or no conflict potential exist when applying measures for raising awareness or behavioural preparedness.

Most options outside of urbanised areas show synergies with ecological aims, e.g. of soil conservation and nutrient retention.

Table 22: Overview of adaptation options and strategies regarding heavy rainfall and flash floods (management and protection)

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Water and sediment retention in outlying areas	▪Restore waterways to a more natural form ▪Small-scale rockfill in forest water bodies ▪Transverse channels on forest and field roads ▪Conversion of farmland to forest or grassland	▪Synergies: more groundwater recharge, nature preservation, soil conservation ▪Responsible: agriculture, forestry, road departments, local authorities	● (high potential)	● (high potential)
Retention through changes in silviculture	▪Reforestation ▪Conversion of forests to more deciduous trees (better infiltration conditions than conifers)	▪Synergies: erosion protection, soil conservation, climate change mitigation, improved microclimate through increased evaporation ▪Responsible: forestry authorities, forest industry, forest owners	● (high potential)	● (medium potential)
Barriers between urban and outlying areas	▪Longitudinal dikes, embankments ▪Containment trenches ▪Special design of rural roads	▪Responsible also: road departments, local authorities		● (medium potential)
Design of inlet fixtures on slopes	▪Use of efficient slope inlets, transverse gutters in the street ▪Facilitating water uptake by steeper transverse gradients of the roads	▪Synergies: nutrient, pollutant and sediment retention ▪Responsible: road departments, local authorities	○ (medium potential)	● (medium potential)

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Syner-gies	Con-flicts
Adapted slope management	▪Runoff and erosion control measures ▪Crop rows in the field parallel to slope ▪New hedge-planting parallel to slopes ▪Permanent vegetation ▪Planting of woodlands, cultivation and care of protective forests	▪Synergies: soil conservation, more water storage and infiltration into the ground, nutrient and sediment retention, facilitation of a natural runoff regime ▪Conflicts: restrictions on land-use ▪Responsible: municipalities, farmers, agricultural associations, forestry offices	● (green)	● (red)
Construction and securing of emergency water routes	▪Roads with raised kerbstones and overflow ditches	▪Synergies: simultaneous use as temporary water reservoirs ▪Conflicts: restricted accessibility, maintenance costs, compensation of private owners		● (red)
Property protection against the risk of flooding	▪Precautionary building measures, e.g. water barriers outside buildings (sills, walls) ▪Protective gates at property entrances ▪Backflow protection for building and property drainage ▪No storage of water-polluting substances in areas at risk of flooding (e.g. oil tanks)	▪Synergies: also protection against flooding caused by high river-water levels, protection against high groundwater levels ▪Responsible: property owners	○ (green)	● (yellow)
Organised measures in the event of an extreme situation	▪Alert and action plans for crisis management ▪Agreements and cooperation with nearby fire brigades ▪Mobile warning systems ▪Targeted communication/activation of recommended action directly before or during the event		○ (green)	● (green)
Behavioural preparedness and advanced training	▪Awareness raising and information measures ▪Cross-sector training ▪Behavioural preparedness e.g. through drills for evacuation	▪Synergies: raise acceptance for other measures	● (green)	● (green)
Regular maintenance and inspection of drainage systems	▪Use of three-dimensional grates ▪Conduct water inspections ▪Encourage the public to report blockages ▪Removal of sediment accumulation and plant growth			● (yellow)

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Performing hazard appraisals	▪Creation of local heavy-rain hazard and risk maps ▪Analyses of heavy-rain hazard and risk maps ▪More detailed analyses with site visits, local surveys and interviews in threatened areas ▪Review of the flood risk during the fire-prevention inspection of a building	▪Synergies with/ in addition to flood hazard and risk maps	○	●
Legend:	Level of synergy potential Level of conflict potential	● high potential ○ medium potential ● high potential ● medium potential ● low potential		

4.4. Groundwater protection and groundwater use

Most adaptation options in the field of action of groundwater protection and groundwater use dispose of a high conflict potential because of requiring changes in land-use not in the responsibility of water management (e.g. by agricultural actors) or restricting the extent of the uses of several other sectors (e.g. water abstractions by agriculture or other users). Again, the “soft” measure of monitoring implies the least conflicts.

Most options described below support achieving ecological aims such as nature preservation, soil protection, but also may contribute to coping with flooding.

Table 23: Overview of adaptation options and strategies regarding groundwater protection and groundwater use

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Climate-change-specific evaluations and adaptation of groundwater monitoring	▪Maintenance and expansion of networks of groundwater sampling points, groundwater monitoring, additional parameters ▪Observation of the impacts on groundwater of potential changes in vegetation and land use	▪Synergies: relevance for research, information on the risks associated with high groundwater levels/waterlogging		●

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Syner-gies	Con-flicts
Groundwater-protecting agricultural land use **(quality and quantity)**	▪Adjust/optimise fertilisation ▪Strengthening of agricultural advisory services ▪Support for organic farming ▪Precision farming with special consideration to soil condition and soil quality ▪Use of low-emission fertiliser application techniques ▪Use of fast-growing plants as catch crops/overwintering crops ▪Alterations of land uses ▪Groundwater management planning in agricultural areas	▪Synergies: possibly also reduction in greenhouse gas emissions; nature conservation ▪Conflicts: responsible actors, restrictions for agricultural development, economic losses/additional costs	●	●
Alteration of land uses	▪Organic farming ▪Conversion of arable land to grassland or forestry ▪Conversion of grassland from intensive to extensive management ▪Afforestation	▪Synergies: reduced risk of erosion, soil protection, climate mitigation ▪Conflicts: potential reduction in agricultural productivity	●	●
Protection of groundwater-dependent terrestrial ecosystems	▪Re-wetting of drained peatlands ▪Designation of peatlands as nature reserves ▪Alternative land uses on peatlands ▪Cessation of agricultural land use on peatlands	▪Synergies: climate change mitigation, nature conservation, soil protection, watercourse protection, flood protection, competing land-use ▪Conflicting land-use	●	●
Measures to promote groundwater recharge	▪Provision of water retention areas ▪Re-wetting of wetlands, restoration of near-natural aquatic structures ▪Forest conversion towards tree species diversity acc. to the natural forest type, in most case towards more deciduous trees ▪Reduction in the sealing of soil surfaces, increase of green spaces, infiltration potential	▪Synergies: reduction of surface runoff, flood protection, soil protection ▪Conflicts: responsible actors, restrictions/competing land-users	●	●
Measures to increase the available groundwater resources	▪Infiltration of treated surface water in infiltration basins	▪Conflicts: competing land-uses, competing demands on river water, only possible on well-drained soils		●

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Sustainable groundwater management	▪Management with regard to climate change impacts ▪Control of the quantities of abstracted groundwater based on groundwater levels ▪Establishment of minimum local groundwater levels ▪Depend allocation of water rights on groundwater monitoring	▪Synergies: nature conservation, protection of built structures susceptible to subsidence ▪Conflicts: allocated water rights, competing water abstraction, meet water demand in times of low water tables	● (green)	● (red)
Legend:	Level of synergy potential Level of conflict potential	● high potential ○ medium potential ● high potential ● medium potential ● low potential		

4.5. Drinking water supply

Adaptation options in this field of action comprise measures in the systems imposing mostly high costs and measures related to the water demand implying actions by private users or restricting other uses.

Table 24: Overview of adaptation options and strategies regarding drinking water supply

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Integrating climate change into public water supply planning	▪Determination of water resource and demands, and of the supply balances of individual water supply facilities ▪Assessment of the raw water quality of individual supply facilities	▪Synergies/basis for measures for groundwater protection	○	● (green)
Redundant water extraction systems	▪Tapping other, additional raw water sources ▪Development of regional and supra-regional network solutions (group suppliers, special-purpose associations, long-distance suppliers)	▪Synergies: safeguard against suddenly occurring water quality problems ▪Conflicts: high cost, utilisation of diverse and large resources		● (yellow)
Adaptation of public water supply infrastructure	▪Optimisation of existing water supply facilities (e.g. deeper wells) ▪Establishment of standby extraction systems and safeguarding further extraction options ▪Creation of greater storage capacities in waterworks and piping networks ▪Further drinking water treatment ▪Safeguarding infrastructure in the event of floods / natural hazards	▪Conflicts: high costs, competing land-use when safeguarding further extraction areas		● (yellow)

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Rainwater use	▪Collection and storage of rainwater in rain barrels, underground cisterns, ponds etc.	▪Synergies: reduced demand for potable water, rainwater suitability for crops, reduced loading of sewerage, lower sewage charges, effects on public water price/costs ▪Conflicts: private actors/owners, installation costs, land-use	🟢	🟡
Reduction of water demand	▪Optimised water-efficient production processes (industry, water utilities) ▪Restrictions upon water uses during dry periods ▪Rainwater harvesting ▪Multiple use of non-potable water ▪Incentives through drinking water pricing ▪Minimisation of pipe system losses ▪System inspections, maintenance and upgrading	▪Synergies: long-term cost savings ▪Conflicts with private actors / users		🔴
Improving water quality in the pipe system	▪Adjustment of system flushing ▪Supplementary disinfection in storage and distribution ▪Reduction of warming (e.g. unpaving surfaces, thermal insulation of pipes)	▪Conflicts: potentially high costs, resource-intense repairs		🟡
Further drinking water treatment	▪Nutrient reduction ▪Disinfection ▪Dilution with less polluted water ▪Particle removal	▪Conflicts: costs		🟡
Whole-area water yield management	▪Regional or state-wide water yield management, guided by the priority of public water supply ▪Priority for drinking water supply ▪Climate-resilient water supply planning ▪Adapted dam management ▪Detailed surveys of jeopardised water extraction facilities	▪Conflicts: competing water demands		🔴
Legend:	Level of synergy potential Level of conflict potential	🟢 high potential ○ medium potential 🔴 high potential 🟡 medium potential 🟢 low potential		

4.6. Agriculture and water

Most adaptation options require changes and restrictions on agricultural use of land and the applied techniques. Furthermore, they are completely under the responsibility of the agricultural sector and its actors. A wide variety of synergies can be noted contributing to ecological aims, improved water retention, groundwater protection or positive effects for agricultural production.

Table 25: Overview of adaptation options and strategies regarding agriculture and water

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Syner-gies	Con-flicts
Soil conservation/ protection of soils from erosion	▪Preventing soil compaction ▪Humus enrichment ▪Avoiding poaching and overgrazing, establishment of structural elements, e.g. hedgerows, establishment of vegetative strips in areas susceptible to runoff, grass-based farming on slopes at high risk of erosion	▪Synergies: nutrient supply, protection of watercourses achievement of WFD objectives, nature conservation, improved water retention, wind protection ▪Conflicts: requirements/ restrictions for agricultural use	🟢	🔴
Conservation tillage	▪Minimum tillage ▪Strip-tillage/soil loosening ▪Mulch seeding/direct seeding	▪Synergies: protection from erosion, protection of watercourses, achievement of WFD objectives, flood protection, nature conservation ▪Conflicts: potentially reduced yields, potentially increased requirements for pesticide use	🟢	🟡
Humus enrichment	▪Several measures, e.g. retention of harvest residues on the land ▪Retention of the natural water regime, foregoing drainage	▪Synergies: nutrient supply, protection from erosion ▪Conflicts: requirements/ restrictions for agricultural use	🟢	🟡
Adaptations in crop production	▪Measures, e.g. selection of drought-stress tolerant crops, production of winter crops, avoiding large-scale cultivation of crops susceptible to runoff and erosion	▪Synergies: protection from erosion efficient land-use, possibly greater yields due to longer growth periods ▪Conflicts: requirements/ restrictions on agricultural use	🟢	🟡
Irrigation efficiency	▪Drip irrigation ▪Demand-based irrigation ▪Precision irrigation	▪Synergies: optimum irrigation provides optimum conditions for plant nutrient supply, less nitrate leaching, less leaf wetting means that plants are less susceptible to fungal diseases ▪Synergies: costly investments into new methods	🟢	🟡
Groundwater substitution	▪Utilisation of water from surface waters ▪Rainwater utilisation	▪Conflicts: aquatic ecology and low water management, land consumption		🟡

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Syner-gies	Con-flicts
Organisational adaptations in agriculture	▪Cross-sectoral, complete recording of licenced abstractions in a single database and recording the actual quantities of water abstracted per annum ▪Cross-sectoral water resources management plans ▪Establishment of irrigation associations ▪Establishment of rules to mitigate the impact of crop failure	▪Conflicts: competing water demands from different sectors		● (yellow)
Forecasting/ information	▪Improved agri-meteorological forecasting ▪Good access to GIS-based climate parameters for demanding sectors	▪Synergies: optimisation of fertiliser and pesticide use, optimisation of labour use, yield increases	● (green)	● (green)
Legend:	Level of synergy potential Level of conflict potential	● (green) high potential ○ (green) medium potential ● (red) high potential ● (yellow) medium potential ● (green) low potential		

4.7. Cooling water availability

Most adaptation options imply a high conflict potential since they comprise high investment costs and are only a shared responsibility of water management together with mainly private or public owners of undertakings in need for cooling water.

Table 26: Overview of adaptation options and strategies regarding cooling water availability

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Syner-gies	Con-flicts
Installation of alternative cooling processes extensively independent of river flow	▪Dry cooling, hybrid cooling, recirculating cooling systems ▪Cooling tanks/compensating reservoirs ▪Use of rainwater	▪Synergies: prevention of steam plume formation ▪Conflicts: low thermodynamic efficiency, require extensive amount of space, complex instrumentation and control tasks, high operating and investment costs ▪Responsibility of private owners	○ (green)	● (red)
Erection of additional cooling towers	▪Dry cooling, recirculating wet cooling ▪Hybrid cooling towers	▪Conflicts: low efficiency of air cooling, complex instrumentation and control tasks, high operating and investment costs ▪Responsibility of private owners		● (red)

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Expanded recovery and use of discharged residual heat	▪Use of process heat via district heating networks ▪Mobile thermal energy storage systems ▪Development of local heating grids, expansion of integrated heating and cooling networks and groups	▪Synergies: climate change mitigation, nature conservation ▪Conflicts: high investment costs ▪Responsibility of private owners and municipalities	● (green)	● (yellow)
Emergency response plans	▪Regulation of prioritised water users and energy consumers ▪Agreements between water resources management authorities and energy producers on emergency response procedures ▪Formation of an emergency management team	▪Synergies: nature conservation, water resources conservation ▪Conflicts: competing river water users	● (green)	● (red)
Mitigating the impacts of power plant outages	▪Power plant networking system ▪Diverse distributed power generation sources, redundant power generation systems ▪Energy storage systems	▪Synergies: increased use of renewable resources ▪Conflicts: potentially more complex power line systems ▪Responsibility of private owners and policy making/regulations	○ (green)	● (red)
Legend:	Level of synergy potential Level of conflict potential	● high potential ○ medium potential ● high potential ● medium potential ● low potential		

4.8. Navigability of water ways

Potential adaptation measures comprise adaptations in the water ways as task of water management and adaptations taken by the private users (shipping). Adaptation measures in the water ways imply a high conflict potential especially with the sector of nature conservation.

Table 27: Overview of adaptation options and strategies regarding navigability of water ways

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Adaptation in an operational context	▪Small vessels ▪Lighter loads ▪Integrated logistics management (e.g. cooperation with other modes)	▪Conflicts: shift work for crews, reduced transport capacities, extension of routes, larger space requirement, high costs, less capacity ▪Responsibility of private owners / businesses		● (yellow)

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Water level forecasting	▪Early water level forecasting ▪Timely response to forecasting ▪Access to forecasts	▪Synergies: flood control, low water management	● (green)	● (green)
Adaptation in water resources management	▪Water level regulation ▪Diversion of water into/out of adjacent catchments ▪Canal system management	▪Synergies: flood control, low water management ▪Conflicts: nature conservation, user competition (mainly shipping, nature, tourism, energy)		● (red)
Adaptation of waterway infrastructure	▪Deepening of the navigation channel and ports ▪Installation of water-saving locks ▪Designation of low water navigation channels ▪Continuous sediment management	▪Conflicts: nature conservation, high level of effort, high costs ▪		● (red)
Construction and modification of ships	▪Smaller/lighter vessels ▪Improved manoeuvrability and navigability	▪Conflicts: lower transport capacities, higher investment / transport costs ▪Responsibility of private owners / businesses		● (yellow)
Legend:	Level of synergy potential Level of conflict potential	● high potential ○ medium potential ● high potential ● medium potential ● low potential		

4.9. Dam and reservoir management

Potential adaptation measures imply a medium to high conflict potential including handling of changing demands and competing usage requirements of different sectors and of other water management tasks, e.g. restrictions for water users of several sectors as well as restrictions on the way land is used and exploited. Furthermore, they may require additional land and can be costly.

Table 28: Overview of adaptation options and strategies regarding dam and reservoir management

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Review and structural optimisation of existing facilites	▪Redimensioning of storage zones ▪Increasing the flood relief capacity ▪Improving the controllability of the facility ▪Introduction of climate change design parameters	▪Sustainability of the measures, cost, relevance to safety, evaluation of design uncertainties (e.g. extreme flood events) and safety reserves	○	● (yellow)

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors – Description	Syner-gies	Con-flicts
Adaptive dam management	▪Regular upgrading and clearing of preimpoundment basins ▪Appropriate and large-scale management of solid matter ▪Measures to prevent erosion in the upstream catchment area	▪Conflicts: upstream catchment measures: land-use, requirements/ restrictions for agriculture etc.		🔴
	▪Revision of usage zones ▪Multi-criteria optimisation in the event of competing usage requirements ▪Ecological management: managing the water temperature in the downstream area ▪	▪Synergies: flood control, low water management, public water supply, hydropower generation ▪Conflicts: competing usage requirement of different sectors		🔴
Measures to safeguard water quality	▪Prevention of erosion in the upstream catchment area, technical measures, e.g. installation of variable/multiple raw water withdrawal points, aeration of the hypolimnetic water body, pre-cleaning	▪Synergies: potential deterioration of water quality downstream, high costs, space requirements ▪Conflicts: competing land-use and land-use requirements, e.g. in upstream catchment area		🟡
Systematic combined management of several dams	▪Coordinated management of several dams ▪Construction of collecting works ▪Construction of transfer systems (e.g. pipelines, ditches, tunnels)	▪Synergies: increased security of the public water supply and low water management in watercourses, ecologically required minimum flow, more stringent management of dams ▪Conflicts of objectives	🟢	🔴
Securing further locations for dams/building new dams	▪Geographic and hydrological investigations ▪Modelling and impact analyses ▪Land acquisition, land designation	▪Synergies: Water Framework Directive, acceptance is difficult if concrete need for use does not yet exist, land ownership situation (and competing land/water resource use)		🔴
Legend:	Level of synergy potential Level of conflict potential	● high potential ○ medium potential 🔴 high potential 🟡 medium potential 🟢 low potential		

4.10. Low water management

Most adaptation options imply a high conflict potential since they require restrictions of water use by different sectors and on land-use or consume land leading to conflicts with land owners.

Table 29: Overview of adaptation options and strategies regarding low water management

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Low water and temperature forecasting	▪Adjusting the measurement grid and gauges and increased monitoring during low water phases ▪Creation and extension of forecasting models ▪Inclusion of water temperature, other waterbody quality parameters in models ▪More accurate forecasts for smaller at-risk catchment areas, production of worst-case forecasts	▪Synergies: improved models also useful for assessing the impacts of climate change on low water and water temperatures	🟢	🟢
Planned measures to be applied if discharge falls below certain levels	▪Clarification of responsibilities ▪Definition of priority uses ▪Tightening rules governing discharges to water bodies when levels fall below threshold values ▪Emergency supply plan (for drinking water: e.g. use of tankers, public taps)	▪Conflicts: water demand by different sectors, e.g. navigability, agriculture, infiltration		🔴
Usage restrictions	▪Increased monitoring of uses and adaption of approvals under water law ▪Restrictions on the public use of surface waters ▪Restrictions on the withdrawal of non-potable water (e.g. for watering gardens) ▪Regulation of withdrawal for agricultural purposes ▪Restrictions on leisure use ▪Advance agreements on usage restrictions, definition of priorities ▪Targeted communication of restrictions	▪Conflicts: increasing pressure (and conflicts), complexity of existing water use approvals and established rights		🔴

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Syner-gies	Con-flicts
Measures to safeguard water quality	▪Reduction of inputs of nutrients and pollutants ▪Reduction of the withdrawal and input of cooling water ▪Providing shade by means of trees on the margins of water bodies ▪Aeration ▪Heat load plans and models ▪Removal of water-retaining works ▪Raising low water levels	▪Synergies: linear continuity of watercourses, dynamisation of discharge, conservation of aquatic ecosystems ▪Conflicts: falling leaves of trees introduce nutrients, requirements/ restrictions on land-use in catchment area	🟢	🔴
Oxygen management by aeration	▪Technical measures, e.g. turbine aeration, weir overflow, input of technical oxygen, wastewater aeration of sewage treatment plant discharge	▪Conflicts: high technical and energy costs		🟡
Raising low water levels	▪Construction/expansion of water storage systems/dams ▪Optimised management of existing multipurpose dams ▪Transfers from adjacent catchment areas	▪Synergies: navigability, hydropower generation, conservation of aquatic ecosystems ▪Conflicts: competition with flood protection, public water supply, considerable effort and expense	○	🔴
Creating storage capacity	▪Retention basins with long-term storage ▪Dams	▪Conflicts: Competing land-use, Water Framework Directive		🔴
Promoting natural water retention	▪Provision of flooding areas ▪Restoration of near-natural waters ▪Increasing the amount of green space/ reducing sealing	▪Synergies: Flood control, conservation of aquatic ecosystems, groundwater protection, soil protection ▪Conflicts: competing land-use	🟢	🔴
Legend:	Level of synergy potential Level of conflict potential	🟢 high potential ○ medium potential 🔴 high potential 🟡 medium potential 🟢 low potential		

4.11. Hydropower generation

Adaption measures require new infrastructure consuming land or impose negative ecological impacts implying a medium to high conflict potential.

Table 30: Overview of adaptation options and strategies regarding hydropower generation

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Increasing efficiency	▪Adjustment of turbines	▪Conflicts: limited potential, high costs		● (medium)
Flow-balancing measures	▪Expansion of storage capacity, retention measures ▪Storage control systems	▪Synergies: energy storage ▪Conflicts: aquatic ecology, Water Framework Directive, competing land uses, various storage requirements and uses	○ (medium)	● (high)
Ecological hydropower	▪Identify and maintain minimum flow, adequate leading flows for fish ▪Fish passage facilities, fish-friendly turbines and operations	▪Synergies: WFD ▪Conflicts: high costs, long technical lifespans of old turbines, production losses, "old rights"	● (high)	● (high)
Regionalisation of data	▪Regionalisation of data on mean and low water levels, with climatic and geographical conditions as explanatory variables in regression			● (low)
Adapted load management	▪Virtual power plants/smart grids ▪Integration of renewable energies	▪Conflicts: not in the responsibility of water management		● (medium)
Investing in energy storage technologies	▪Pumped-storage plants	▪Synergies: for renewable energies ▪Conflicts:(aquatic) ecology, landscape appearance, limited number of suitable sites, land-use	○ (medium)	● (high)
Legend:	Level of synergy potential Level of conflict potential	● high potential ○ medium potential ● high potential ● medium potential ● low potential		

4.12. Conservation of aquatic ecosystems

In this field of action, some adaption measures comprise requirements on land-use with restrictions for other sectors or are under the responsibility of other sectors implying a medium to high conflict potential. But also adaptation options exist with less conflict potential (e.g. evaluation and monitoring, warning services).

Table 31: Overview of adaptation options and strategies regarding conservation of aquatic ecosystems

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors		
		Description	Synergies	Conflicts
Improvement of longitudinal connectivity of watercourses	▪Construction of passable installations ▪Removal/conversion of lateral barriers ▪Optimised control of culverts ▪Creation of passable grown fields ▪Removal of obsolete artificial drainage systems"	▪Synergies: WFD objectives, EU Biodiversity Strategy, improved sediment budget, reduced streambed erosion	● (green)	● (green)
Alteration of hydromorphological structures	▪Removal of streambed and bank stabilisation ▪Installation of flow control structures ▪Widening of the stream channel, addition of rocks, etc. ▪Increasing the channel length ▪Re-wetting of floodplains, wetlands	▪Synergies: nature conservation, flood control, WFD objectives, EU Biodiversity Strategy, restoration of a near-natural soil water balance ▪Conflicts: large coherent networks of watercourse segments needed large-scale transfer processes may be triggered	● (green)	● (yellow)
Conservation and development of riparian zones	▪Planting and development of riparian woodland ▪Structuring of woodland margins ▪Planting of reeds ▪Establishment of riparian zones on arable land	▪Synergies: WFD objectives, MSFD and EU Biodiversity Strategy, soil protection, reducing water erosion of soils, restoration of a near-natural soil water balance, reducing water temperature ▪Conflicts: land-use conflicts with agriculture, forestry, infrastructure	● (green)	● (red)
Establishment of sedimentation barriers	▪Green cover in riparian zones ▪Berms in floodplains	▪Synergies: potentially improved nutrient supply for plants in riparian areas, WFD objectives, soil protection ▪Conflicts: land along watercourses, potential conflicts with conservation objectives in floodplains, potential accumulation of pollutants in the riparian area	● (green)	● (red)

Option	Example measure (further details see annex)	Synergies and conflicts with other adaptation measures/ other sectors: Description	Synergies	Conflicts
Environmentally friendly waterbody maintenance	▪E.g. preserve streambed sediments and structure to certain extent	▪Synergies: nature conservation, WFD objectives	● (green)	● (green)
Maintenance and expansion of protected areas	▪Establishment of Natura 2000 sites with a view to maintaining water-dependent habitat types ▪Source water protection areas	▪Synergies: landscape aesthetics, nature conservation, recreational function ▪Conflicts: conflicting land-uses and restricting other uses	● (green)	● (red)
Reducing non-point inputs of pollutants and nutrients	▪Support for organic farming ▪Conservation tillage reducing water erosion of soils, optimised fertiliser and pesticide applications ▪Establishment and development of wide riparian zones ▪WFD measures/near-natural watercourse design, water retention areas ▪Increased forest cover with natural tree species diversity	▪Synergies: nature conservation ▪Conflicts: responsibility of other sectors	● (green)	● (red)
Amendment of threshold values for abstraction and discharge (quantity, quality, water temperature)	▪Adjustment of water rights ▪Establishment of minimum water flows for power plant discharges ▪Development of thermal load plans for climate change ▪Monitoring of water temperatures and pollutants in watercourses	▪Synergies: nature conservation ▪Conflicts: restrictions on industry and wastewater treatment, ensuring security of supply, not all discharge regimes are flexible, costs incurred	○	● (red)
Water quality warning services	▪Introduction of a public warning system for water temperatures and other parameters ▪Intensified water quality measurements	▪Synergies: relevance of monitoring parameters for research	○	● (green)
Climate-change-specific evaluations and adaptation of watercourse monitoring	▪Monitoring at watercourses that are particularly strongly affected ▪Evaluation with respect to developments to date	▪Synergies: relevance for research ▪Conflicts: ongoing costs	○	● (green)
Legend:	Level of synergy potential Level of conflict potential	● (green) high potential ○ medium potential ● (red) high potential ● (yellow) medium potential ● (green) low potential		

5. Main potential areas for synergies and conflicts

The compilation and assessment in the preceding chapters has shown that almost all discussed adaption options in the examined fields of action of water management comprise distinctive potentials for synergies and/ or conflicts with tasks, targets or adaptation options of other fields of action of water management or other sectors (summary see Table 32). Low conflict potential is mostly associated with information, awareness raising or monitoring measures. Adaption measures concerning changes in regulation maintenance or concerning structural measures mostly dispose of a medium to high potential of creating conflicts.

Table 32: Potential of synergies and conflicts of water management adaptation measures with other sectors

Field of Action	Adaptation option	Synergies	Conflicts
Inland river flood management and protection	Load case climate change		🟢
	Technical flood protection	○	🟡
	Reclamation of flooding areas and restoration of flood plains	🟢	🔴
	Activation of additional and optimisation of existing retention areas	🟢	🔴
	Land-use planning in flooding areas and flood-threatened areas (extreme events)	🟢	🔴
	Designation of priority and reserved areas (spatial planning)	○	🔴
Urban drainage and wastewater treatment	Structural improvement and optimised operation of existing sewer networks	○	🟡
	Adjustments in sewage plant operation	○	🟢
	Systems for rainwater treatment	🟢	🟢
	Centralised and decentralised retention measures in cities	🟢	🔴
	Utilising infiltration potential	○	🟡
	Incentives for decentralised rainwater management	🟢	🟡
	Protection of wastewater systems against flooding		🟢
Heavy rainfall and flash floods management and protection	Water and sediment retention in outlying areas	🟢	🔴
	Retention through changes in silviculture	🟢	🟡
	Barriers between urban and outlying areas		🟡
	Design of inlet fixtures on slopes	○	🟡
	Adapted slope management	🟢	🔴
	Construction and securing of emergency water routes	○	🔴
	Property protection against the risk of flooding	○	🟡

Field of Action	Adaptation option	Synergies	Conflicts
	Organised measures in the event of an extreme situation	○ (green outline)	● (green)
	Behavioural preparedness and advanced training	● (green)	● (green)
	Regular maintenance and inspection of drainage systems		● (yellow)
	Performing hazard appraisals	○ (green outline)	● (green)
Groundwater protection and groundwater use	Climate-change-specific evaluations and adaptation of groundwater monitoring		● (green)
	Groundwater-protecting agricultural land use (quality and quantity)	● (green)	● (red)
	Alteration of land uses	● (green)	● (red)
	Protection of groundwater-dependent terrestrial ecosystems	● (green)	● (red)
	Measures to promote groundwater recharge	● (green)	● (red)
	Measures to increase the available groundwater resources		● (yellow)
	Sustainable groundwater management	● (green)	● (red)
Drinking water supply	Integrating climate change into public water supply planning	○ (green outline)	● (green)
	Redundant water extraction systems		● (yellow)
	Adaptation of public water supply infrastructure		● (yellow)
	Rainwater use	● (green)	● (yellow)
	Reduction of water demand		● (red)
	Improving water quality in the pipe system		● (yellow)
	Further drinking water treatment		● (yellow)
	Whole-area water yield management		● (red)
Agriculture and water	Soil conservation/ protection of soils from erosion	● (green)	● (red)
	Conservation tillage	● (green)	● (yellow)
	Humus enrichment	● (green)	● (yellow)
	Adaptations in crop production	● (green)	● (yellow)
	Irrigation efficiency	● (green)	● (yellow)
	Groundwater substitution		● (yellow)
	Organisational adaptations in agriculture		● (yellow)

Field of Action	Adaptation option	Synergies	Conflicts
	Forecasting/ information	● green	● green
Cooling water availability	Installation of alternative cooling processes extensively independent of river flow	○ green	● red
	Erection of additional cooling towers		● red
	Expanded recovery and use of discharged residual heat	● green	● yellow
	Emergency response plans	● green	● red
	Mitigating the impacts of power plant outage	○ green	● red
Navigability of water ways	Adaptation in an operational context		● yellow
	Water level forecasting	● green	● green
	Adaptation in water resources management		● red
	Adaptation of waterway infrastructure		● red
	Construction and modification of ships		● yellow
Dam and reservoir management	Review and structural optimisation of existing facilities	○ green	● yellow
	Adaptive dam management	○ green	● red
	Measures to safeguard water quality		● yellow
	Systematic combined management of several dams	● green	● red
	Securing further locations for dams/ building new dams		● red
Low water management	Low water and temperature forecasting	● green	● green
	Planned measures to be applied if discharge falls below certain levels		● red
	Usage restrictions		● red
	Measures to safeguard water quality	● green	● red
	Oxygen management by aeration		● yellow
	Raising low water levels	○ green	● red
	Creating storage capacity		● red
	Promoting natural water retention	● green	● red
Hydropower generation	Increasing efficiency		● yellow
	Flow-balancing measures	○ green	● red

Field of Action	Adaptation option	Synergies	Conflicts
	Ecological hydropower	🟢	🔴
	Regionalisation of data		🟢
	Adapted load management		🟡
	Investing in energy storage technologies	○	🔴
Conservation of aquatic ecosystems	Improvement of longitudinal connectivity of watercourses	🟢	🟢
	Alteration of hydromorphological structures	🟢	🟡
	Conservation and development of riparian zones	🟢	🔴
	Establishment of sedimentation barriers	🟢	🔴
	Environmentally friendly waterbody maintenance	🟢	🟡
	Maintenance and expansion of protected areas	🟢	🔴
	Reducing non-point inputs of pollutants and nutrients	🟢	🔴
	Amendment of threshold values for abstraction and discharge (quantity, quality, water temperature)	○	🔴
	Water quality warning services	○	🟢
	Climate-change-specific evaluations and adaptation of watercourse monitoring	○	🟢
Legend:	**Level of synergy potential** **Level of conflict potential**	**🟢 high potential ○ medium potential** **🔴 high potential 🟡 medium potential 🟢 low potential**	

The fields of action with the highest conflict potential and the sectors concerned are summarised in Table 35.

Main areas of potential conflicts concern

- Land-use conflicts outside of urban areas with the agricultural and foresting sector
- Land-use conflicts in urban areas with urban development (other urban uses) and private owners
- Potential restrictions on the use of the land with higher costs or economic losses for land-owners/users (agriculture, forestry, tourism, leisure use)
- Measures are partly or fully under the responsibility of other sectors or actors of other fields of water management imposing costs or changed procedures (agriculture, forestry, road departments, local authorities, private actors and owners of buildings, land or infrastructure)
- Competing demands on water uses of different fields of water management and other sectors (agriculture, energy, shipping, tourism, nature conservation).

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D. Conclusions for the Toolbox concept

The tables below summarise the results of the study. These findings provide input for the further toolbox development.

In Table 33 the climate change trends and the general impacts regarding water in Central Europe are summarised. According to the results of the study by CMCC the proneness of the TEACHER-CE pilot actions to the trends and impacts is shown. All pilot actions have to be considered potentially prone to higher air temperature and increasing frequency of heavy rainfall. Except for pilot action 5 (Enza basin, Italy) all pilot actions are expected to undergo changing precipitation patterns with an increase in winter season, whereas only three pilot actions to experience a seasonal shift of precipitation with a decrease in summer.

Table 33: Expected climate change trends and impacts regarding water in TEACHER-CE pilot actions

CC trend	CC impacts regarding water	Pilot actions potentially prone to impacts								
		1	2	3	4	5	6	7	8	9
Higher temperatures	▪Higher water temperatures ▪Increased evapotranspiration ▪Prolonged vegetation periods ▪Increased dry periods, frequency and duration of droughts ▪Increase of incidents of low water ▪Higher water demand ▪Increase of transmission of invasive species	●	●	●	●	●	●	●	●	●
Changing precipitation patterns/ seasonal shift in precipitation amounts: increased winter precipitation (rather rain than snow)	▪Increase of frequency, height and duration of high-water events ▪Fluctuation of groundwater table ▪Rising water table	●	●	●	●		●	●	●	●
Changing precipitation patterns/ seasonal shift in precipitation amounts: decreased precipitation in summer	▪Increasing dry periods, frequency and duration of drought ▪Increase of incidents of low water ▪Higher water demand ▪Increase of nutrients input in groundwater					●		●	●	
Heavy rainfall - increase in intensity and frequency (small scale)	▪Increase in flood runoff ▪Increase of erosion ▪Increase of nutrients input ▪Increase of frequency, height and duration of high-water event	●	●	●	●	●	●	●	●	●

The climate change impacts for each field of water management and their relevance (prevailing or considerable) for each pilot action are summarised in Table 34.

Most of the discussed impacts on water management have to be considered in at least one pilot action area. The TEACHER-CE project does not focus on hydropower generation, navigation and dam/ reservoir management. Nevertheless, adaption measures concerning these fields of water management dispose of a high potential of conflicts with relevant issues in some pilot action areas.

Table 34: Climate change impacts related to the fields of action and relevance for TEACHER-CE

Factsheet for TEACHER-CE Toolbox development										
Field of Action	Impact on	Relevance for TEACHER-CE pilot actions								
		1	2	3	4	5	6	7	8	9
Inland river flood management and protection	Flood protection levels	●		●	●	●			●	
	High water levels due to elevated river levels	●		●	●					
	Small and urban-dominated catchment areas	●						●		
	Alpine catchment areas						●			
Urban drainage and wastewater treatment	Dimensioning drainage systems					●				●
	Drainage and wastewater treatment					●				
	Wastewater treatment									
	Water quality of streams (receiving waters)			●		●				
Heavy rainfall and flash flood management and protection	Heavy rainfall risk management	●	●		●	●				
	Alpine catchments	●					●	●		
	Urban drainage			●						
	Agricultural land and soil		●	●	●				●	●
	Infiltration capacity		●	●	●				●	●
	Water quality		●	●	●	(●)			●	●
Groundwater protection and groundwater use	Groundwater recharge and water table - increase	●			●	●	●	●		
Drinking water supply	Raw water availability/ quantity and quality				●	●	●	●		
	Raw water from groundwater and spring water	●	●			●	●	●		
	Raw water from bank filtrate and watercourses	●				●			●	
	Raw water from drinking-water dams and lakes									●
	Distribution networks									

Factsheet for TEACHER-CE Toolbox development										
Field of Action	Impact on	Relevance for TEACHER-CE pilot actions								
		1	2	3	4	5	6	7	8	9
Water for irrigation in agriculture	Need for irrigation		●	●	●	●			●	●
	Available water for irrigation		●	●		●			●	●
	Soil water conditions		●	●		●				●
Cooling water availability	Extent of cooling water shortage									
Navigability of water ways	Development and maintenance for Inland water way transport									●
Dam and reservoir management	Management			●					●	●
	Water quality			●					●	
	Design and dimensioning								●	
Low water management	Water availability and quality of streams	●	●	●	●	●			●	●
Hydropower generation	Hydroelectric plants	●			●					●
	Impoundment facilities									
	Flood protection									
Conservation of aquatic ecosystems	Reaching the objectives of WFD		●	●		●			●	●

Twelve fields of actions of the water management sector were identified that are affected by climate change. For the further development of the TEACHER-CE Toolbox, the partnership agreed to focus on 7 of these fields of action, which are:

- Inland river flood management and protection
- Heavy rainfall and flash flood management and protection
- Groundwater protection and groundwater use
- Drinking water supply
- Water for irrigation in agriculture
- Low water management
- Conservation of aquatic ecosystems

In conclusion the following figure summarizes which fields of action will be addressed in the pilot region and which of these fields of actions are of special importance for the Toolbox (highlighted in blue).

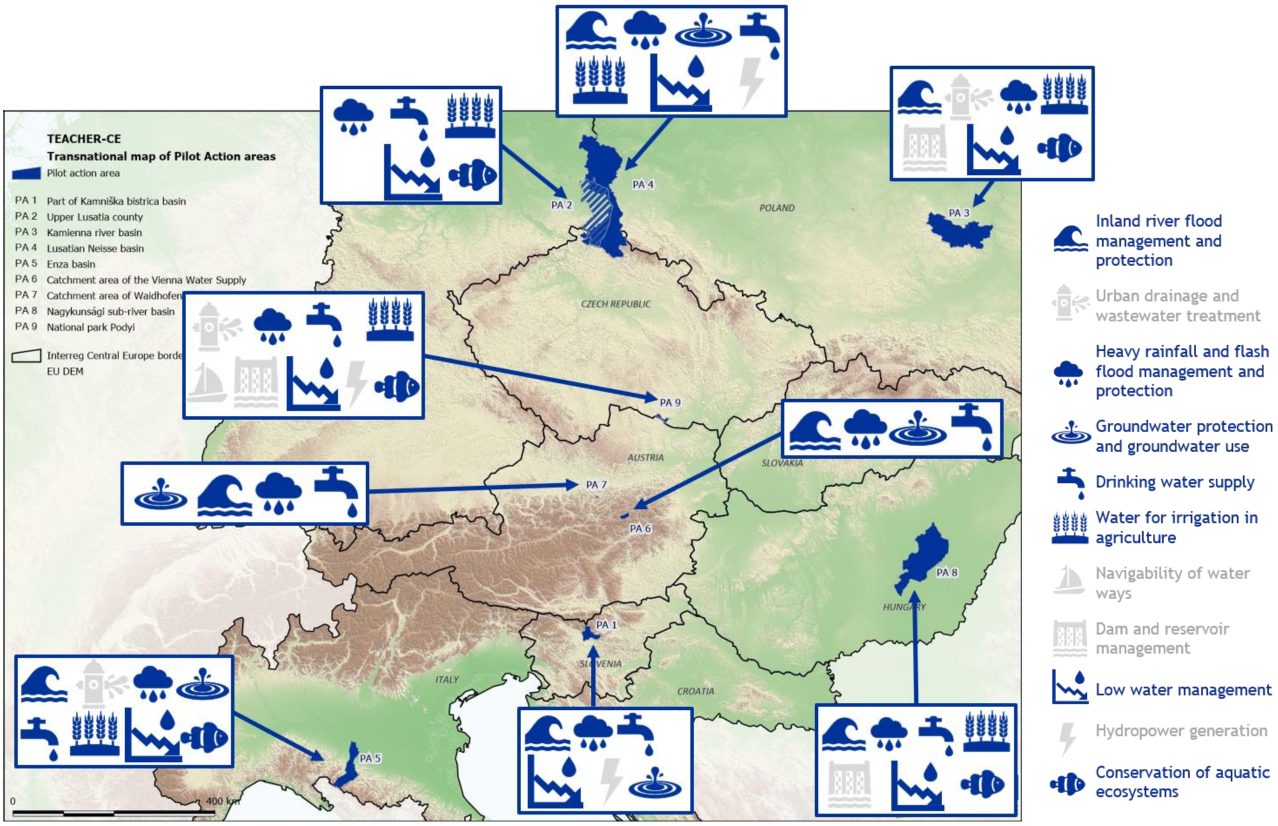


Figure 16: Fields of action that will be addressed in the pilot regions and focus for the TEACHER-CE toolbox (highlighted in blue)

Adaptation options with a high potential of conflicts with adaptation measures or needs of other sectors are summarised in Table 35.

Table 35: Fields of action and adaptation measures with highest conflict potential

Field of Action	Adaptation measure	High conflict potential with/ concerning
Inland river flood management and protection	Most adaption measures are land consuming or call for restrictions in land-use.	▪ Agriculture ▪ Forest ▪ Infrastructure ▪ Land-use planning (in rural and in urban areas)
Urban drainage and wastewater treatment	Centralised and decentralised retention measures in cities.	▪ Land-use in urban areas (land-use plans, private owners)
Heavy rainfall and flash floods management and protection	Structural measures in rural and urban areas often require changes or restrictions in land-se.	▪ Responsibility of other sectors: agriculture, forestry, road departments, local authorities ▪ Land-use planning in urban areas
Groundwater protection and groundwater use	Most adaptation measures call for restrictions for other sectors or competing land-uses.	▪ Agriculture ▪ Forestry ▪ Competing land-use ▪ Groundwater users

Field of Action	Adaptation measure	High conflict potential with/ concerning
Drinking water supply	Measures have to cope with competing land-uses, high costs and private responsible actors as well as competing water demand.	▪ Agriculture ▪ Private actors/ owners ▪ Competing land-use
Agriculture and water	Most adaptation options require changes and restrictions on agricultural use and proceedings.	▪ Agriculture (due to restrictions) ▪ Responsibility of other sectors
Cooling water availability	Adaptation options are not in the responsibility of water management, but of private owners and include high investment costs.	▪ Responsibility of private owners ▪ High costs
Navigability of water ways	Adaptation measures require actions by private ship owners with potential economic losses.	▪ Responsibility of private actors ▪ User competition: Shipping, nature conservation, tourism, energy production
Dam and reservoir management	Adaptation options require handling of changing demands and competing usage requirements of different sectors and of other water management tasks.	▪ User competition: different fields of water management, agriculture, tourism, energy ▪ Land owners upstream/catchment
Low water management	Measures include restriction of water use and on land-use, consume land and can be costly.	▪ User competition ▪ Land owners, e.g. agriculture
Hydropower generation	Some adaption measures, new infrastructure land consuming or impose negative ecological impacts.	▪ Competing land-use (agriculture, forestry) ▪ Ecology
Conservation of aquatic ecosystems	Adaption measures comprise requirements on land-use with restrictions for other sectors or are under the responsibility of other sectors.	▪ Agriculture ▪ Foresting ▪ Responsibility of other sectors

E. Annex

Annex I: Climate data sheets for the pilot actions (CMCC)

I.1 How to read the data set

Data about recent decades are provided by **E-OBS dataset** (Cornes et al., 2018; 10.1029/2017JD028200). The E-OBS dataset contains high spatial resolution daily gridded data that cover the European territory and is based on the observational data collated in the frame of the ECA&D initiative. The dataset spans the period from 1 January 1950 to present and it is updated frequently. E-OBS dataset includes daily temperature data (mean, maximum, and minimum values) as well as daily total precipitation and mean sea level pressure. Please, pay attention, the reliability of the returned information is strongly linked to the availability of weather observations used to build the datasets. They can change according the time span, the variable and the investigated area. Furthermore, the comparison between E-OBS dataset and point weather station data could result misleading. E-OBS is aimed at providing information at a scale comparable with the horizontal resolution of the dataset.

The mean value of each index is indicated in the table located on the left side of each data box for the two accounted periods (1971-2000 and 1990-2019).

Anomalies in weather indicators exploit climate simulations included in **EURO-CORDEX ensemble**. The EURO-CORDEX program represents the European branch of the international CORDEX initiative, which is a worldwide program sponsored by the World Climate Research Program (WRCP). It is aimed at organizing an internationally coordinated framework in order to produce improved regional climate projections for all land regions world-wide. Datasheets are based on the findings made available by 19 climate simulation chains where a Global Climate Model (GCM) is downscaled on a domain centered on Europe by using a Regional Climate Model (RCM). The 19 models, provided by different international research centers, differ for adopted GCM and/or RCM. Then, the joined use of such projections permit assessing uncertainties associated to climate models response (e.g. use of parametrizations, numerical schemes)

To account for the uncertainties associated to the future emissions and concentrations of the full suite of greenhouse gases (GHGs), aerosols, and chemically active gases, **Representative Concentration Pathways (RCPs)** are used. They are scenarios adopted by the IPCC in the Fifth Assessment Report (2014). Specifically, **scenario RCP4.5** represents an intermediate stabilization pathway for which substantial emission reductions are expected. It can be considered as a quite optimistic scenario. **Scenario RCP8.5** represents the worst-case for which very high emissions are expected to continue without the implementation of mitigation strategies; this scenario is also known as "business as usual".

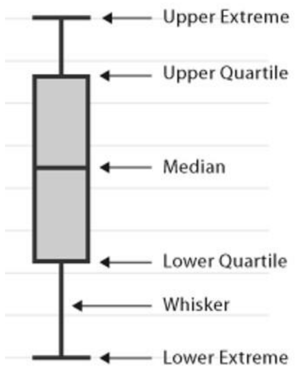
Two time horizons are considered: 2021-2050 - Short Term (ST) and 2071-2100 - Long Term (LT). They are expressed as anomalies with respect to the reference period 1971-2000 under the assumption that biases affecting climate simulation chains are comparable for current and future time spans.

The following indicators are taken into account:

- **Seasonal Mean Temperature** (x4): mean daily temperature for the four seasonal periods: winter (December-January-February, DJF), spring (March-April-May, MAM), summer (June-July-August, JJA), and autumn (September-October-November, SON);
- **Seasonal Cumulative Precipitation** (x4): mean value of the total cumulative precipitation evaluated for the four seasonal periods: winter (DJF), spring (MAM), summer (JJA), and autumn (SON).

- **Consecutive Dry Days (CDD):** maximum annual number of consecutive days with precipitation < 1mm averaged over the period of the interest.
- **Consecutive Wet Days (CWD):** maximum annual number of consecutive days with precipitation ≥ 1mm averaged over the period of the interest.
- **Rx1day:** (yearly) maximum 1-day precipitation averaged over the period of the interest.
- **Summer Days (SU)**: annual count of days with daily maximum temperature > 25°C averaged over the period of the interest.
- **Frost Days (FD):** annual count of days with daily minimum temperature < 0°C averaged over the period of the interest.

Future anomalies evaluated for each indicator are graphically illustrated by means of box and whisker plots (see an example in the following figure) in which the box expresses the lower and upper quartiles of the dataset (25^{th} and 75^{th} percentile, respectively) and the “whiskers” lines identify the upper and lower extremes (corresponding to maximum and the minimum values in the dataset). Finally, the median value (50^{th} percentile) is indicated by a horizontal line in the box.



The level of agreement among the climate models based on the number of models that confirm the evaluated sign of the anomaly (positive or negative) for each indicator:

Models’ agreement	Number of models	Symbol
Very low	<= 10	-
Low	11-13	*
Moderate	14-16	**
High	17-19	***

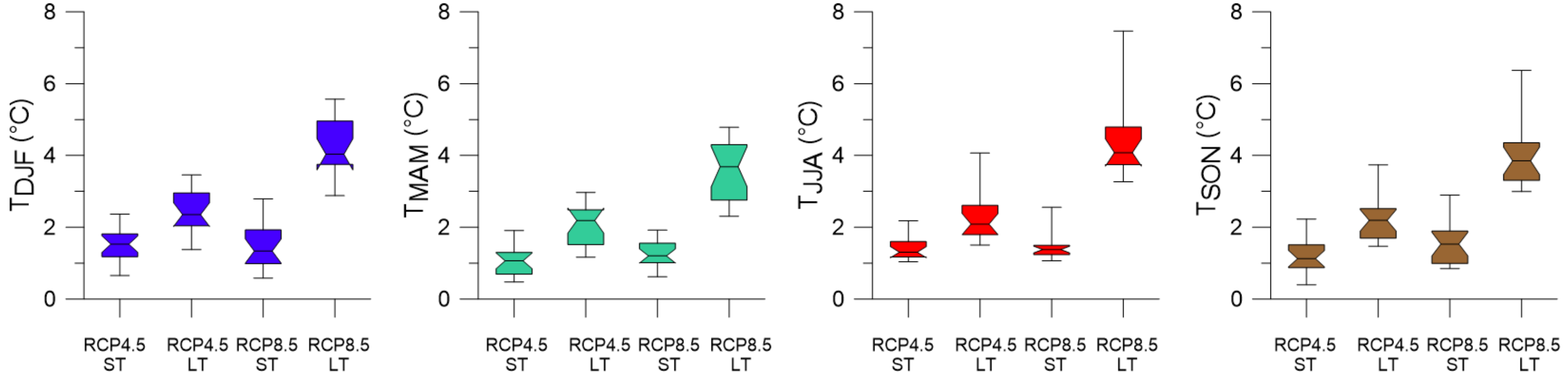
Finally, to test the reliability/robustness of the signal, the anomaly is compared with the natural variability, expressed by using Standard Deviation (SD) and computed by using E-OBS data (1971-2000) as reference:

Signal Robustness	Threshold
Weak	<1*SD
Moderate	1<=SD<2
High	>=2

I.2 Climate data sheets

Current period
[E-OBS v.21]

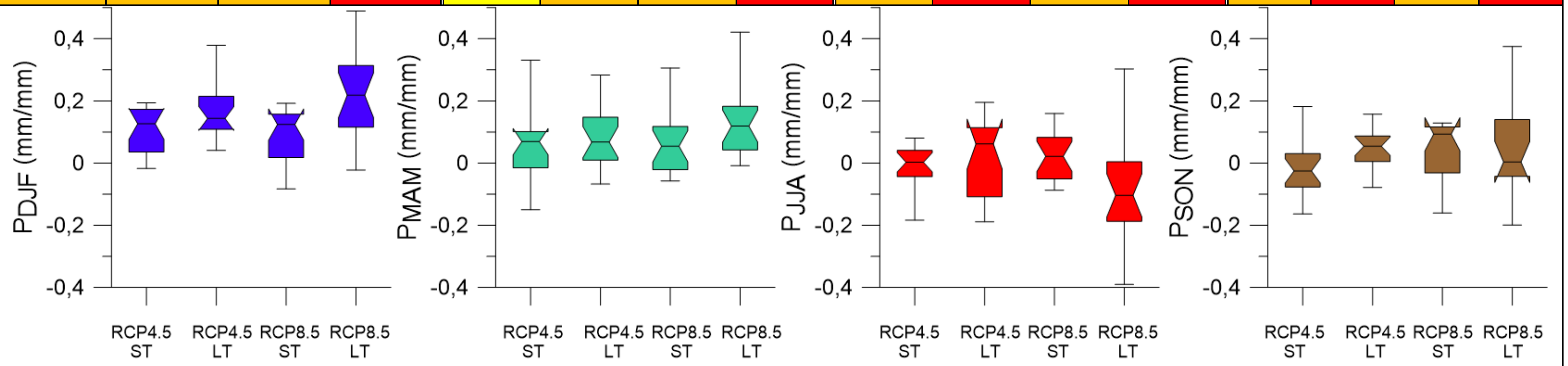
T(°C)	*1971 - 2000*	*1990 - 2019*
DJF	-1.3	-0.6
MAM	7.0	8.1
JJA	16.0	17.4
SON	7.6	8.6



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Robustness																

Current period
[E-OBS v.21]

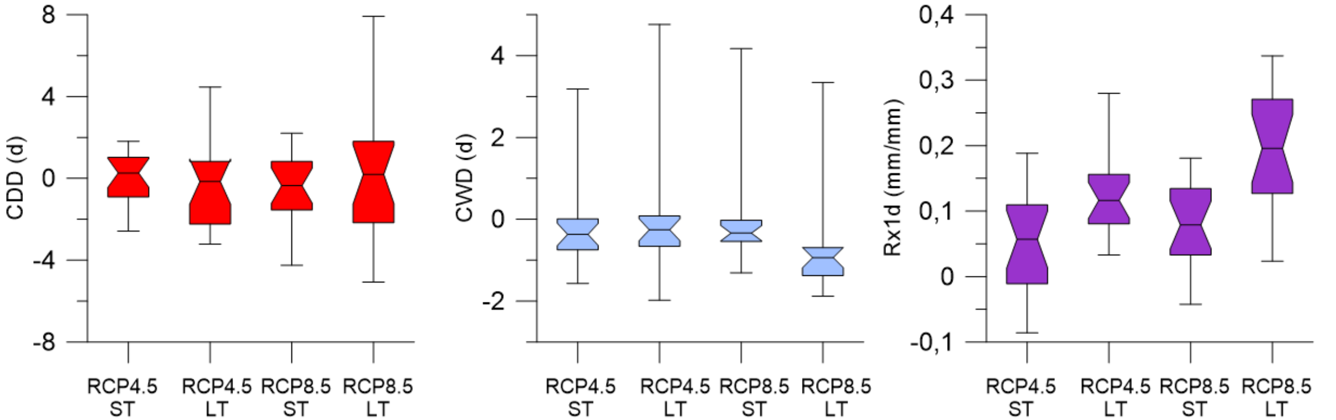
P	*1971 - 2000*	*1990 - 2019*
DJF	251.6	261.1
MAM	340.1	324.0
JJA	444.7	423.1
SON	451.2	492.3



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	**	***	*	**	*	***	-	*	*	**	*	**	*	-
Robustness																

Current period
[E-OBS v.21]

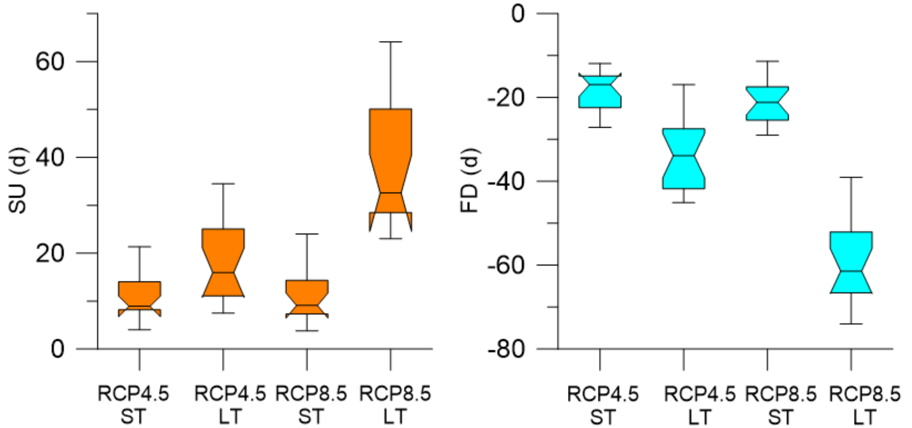
Index	*1971 - 2000*	*1990 - 2019*
CDD	24.3	23.1
CWD	8.3	8.3
Rx1d	74.5	78.0



Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	-	*	*	-	*	*	*	**	*	***	**	***
Robustness												

Current period
[E-OBS v.21]

Index	*1971 - 2000*	*1990 - 2019*
SU	28.4	41.6
FD	130.5	112.0

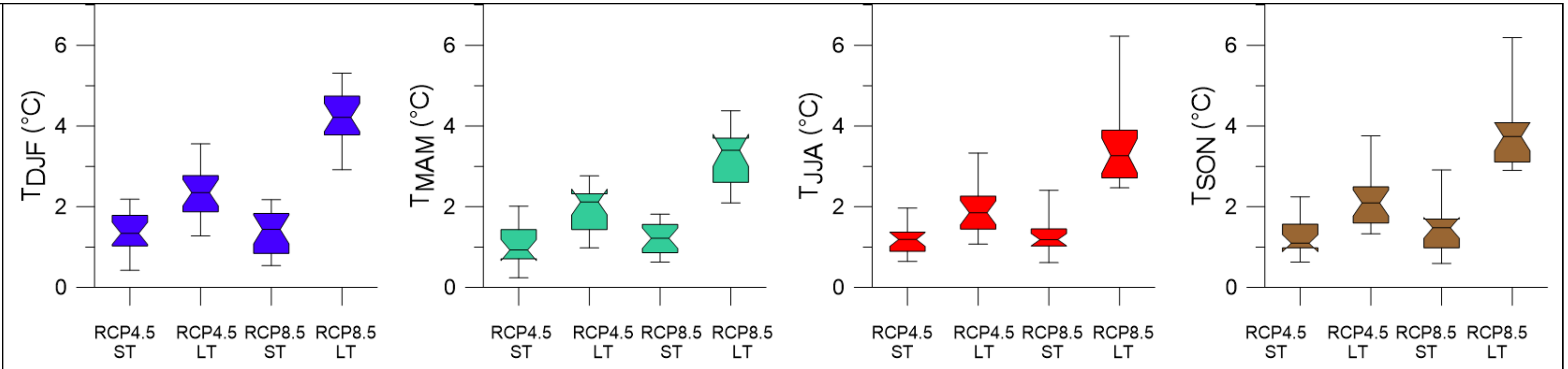


Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	***	***	***	***	***	***	***	***
Robustness								

Current period

[E-OBS v.21]

T(°C)	*1971 - 2000*	*1990 - 2019*
DJF	0.2	0.7
MAM	8.2	8.9
JJA	17.0	18.0
SON	8.6	9.1

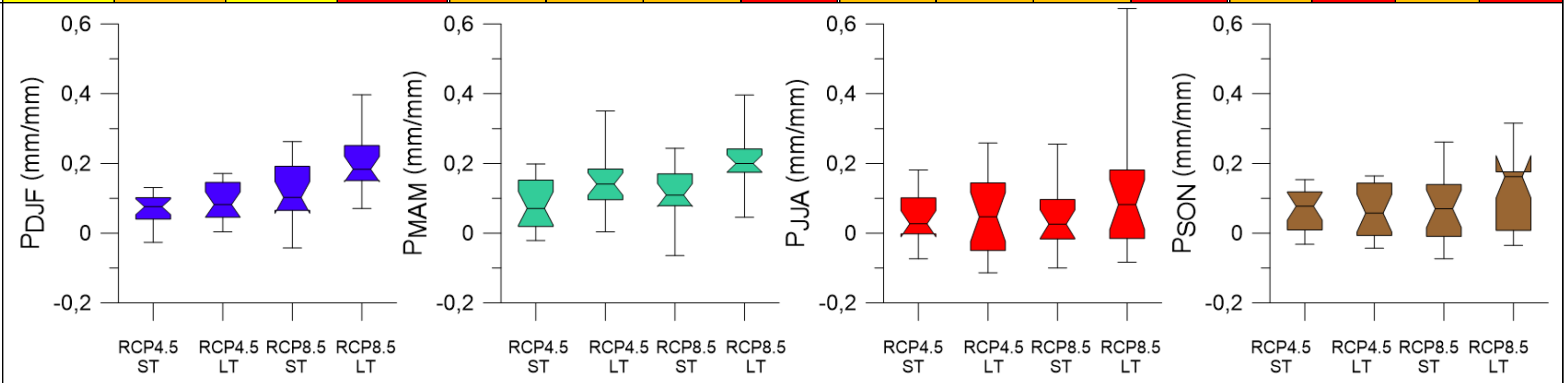


Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Robustness																

Current period

[E-OBS v.21]

P	*1971 - 2000*	*1990 - 2019*
DJF	145.5	141.7
MAM	156.7	148.3
JJA	224.5	235.9
SON	150.3	154.6

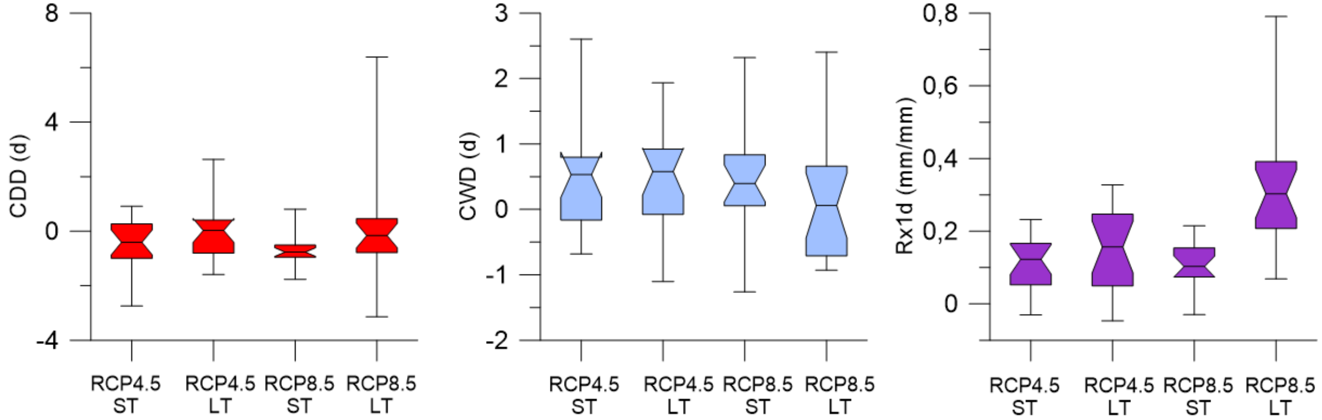


Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	***	***	**	***	***	***	*	*	*	*	**	**	**	**
Robustness																

Current period

[E-OBS v.21]

Index	*1971 - 2000*	*1990 - 2019*
CDD	20.2	20.7
CWD	8.9	8.0
Rx1d	37.2	37.3



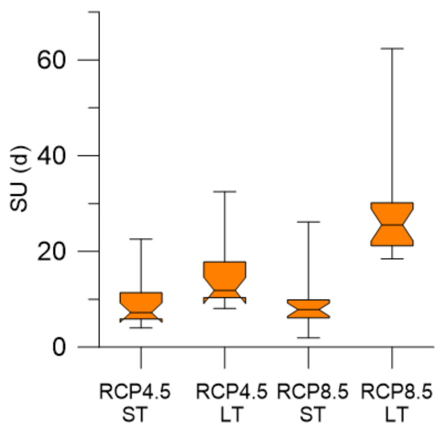
Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	*	-	**	*	*	*	**	-	**	***	**	***
Robustness												

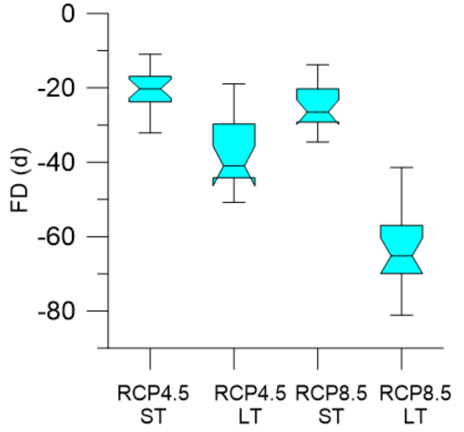
Pilot Action 2- Upper Lusatia county

Current period

[E-OBS v.21]

Index	*1971 - 2000*	*1990 - 2019*
SU	34.8	45.0
FD	92.9	92.2

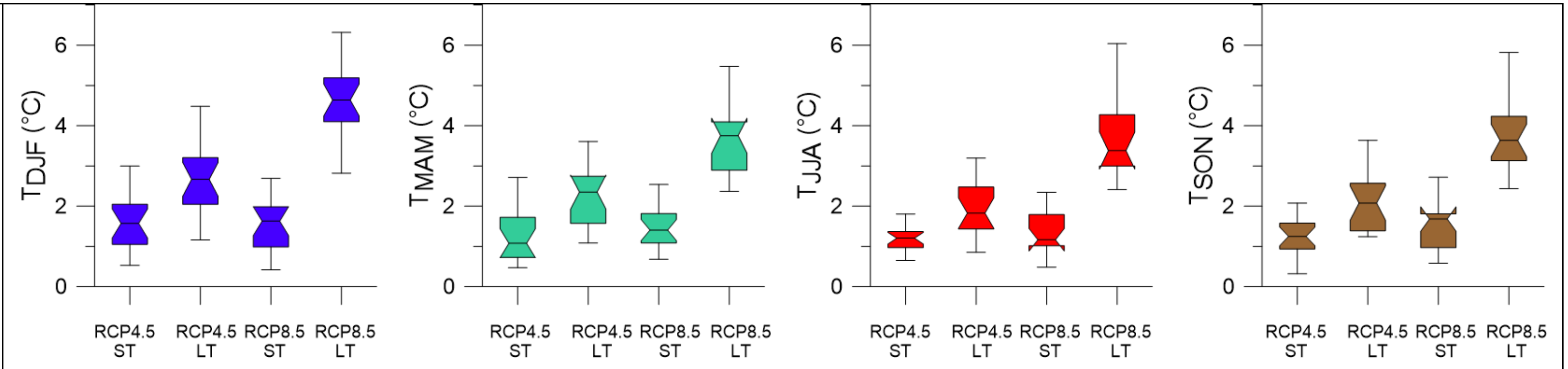




Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	***	***	***	***	***	***	***	***
Robustness								

Current period
[E-OBS v.21]

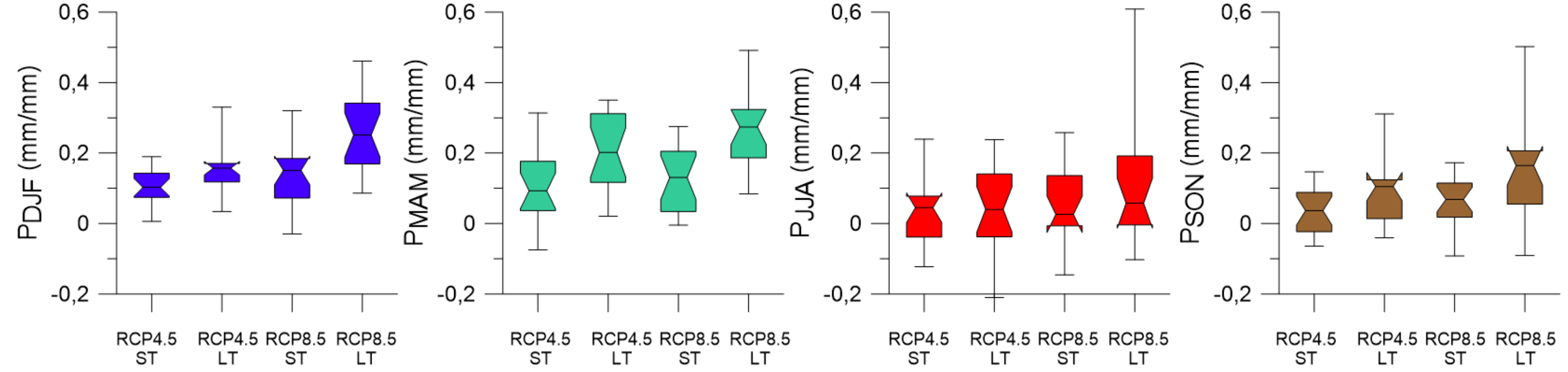
T(°C)	1971 - 2000	1990 - 2019
DJF	-1.7	-1.2
MAM	7.5	8.3
JJA	16.8	18.0
SON	7.5	8.3



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Robustness																

Current period
[E-OBS v.21]

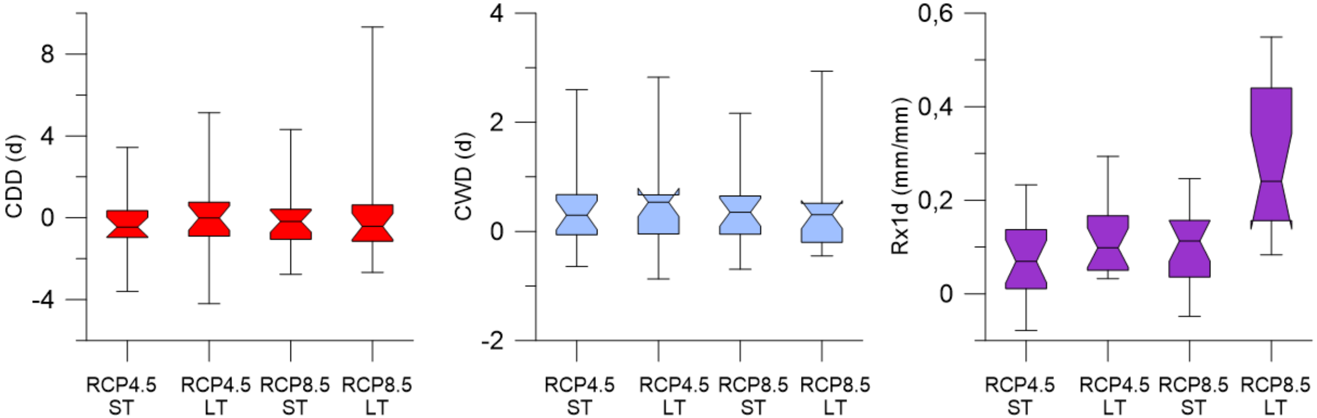
P	1971 - 2000	1990 - 2019
DJF	91.3	95.9
MAM	122.9	145.8
JJA	210.0	216.5
SON	131.6	138.2



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	***	***	**	***	***	***	*	*	*	**	*	**	**	***
Robustness																

Current period
[E-OBS v.21]

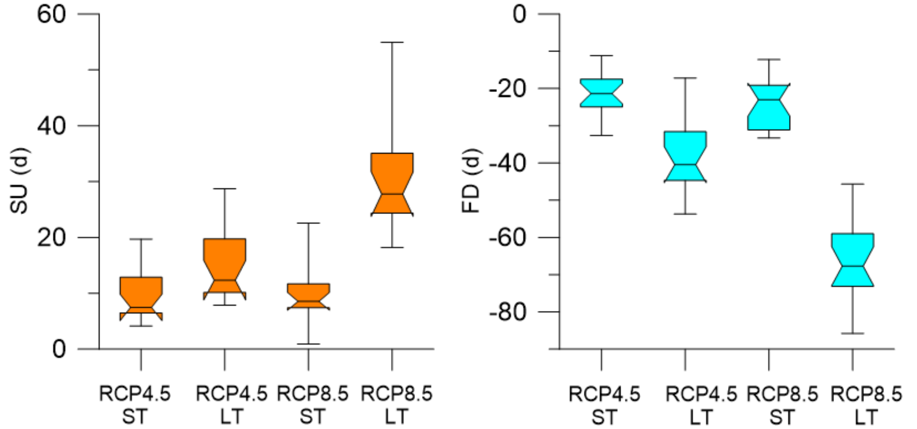
Index	*1971 - 2000*	*1990 - 2019*
CDD	22.4	20.8
CWD	7.2	7.1
Rx1d	25.6	27.6



Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	*	-	*	-	*	*	*	*	**	***	**	***
Robustness												

Current period
[E-OBS v.21]

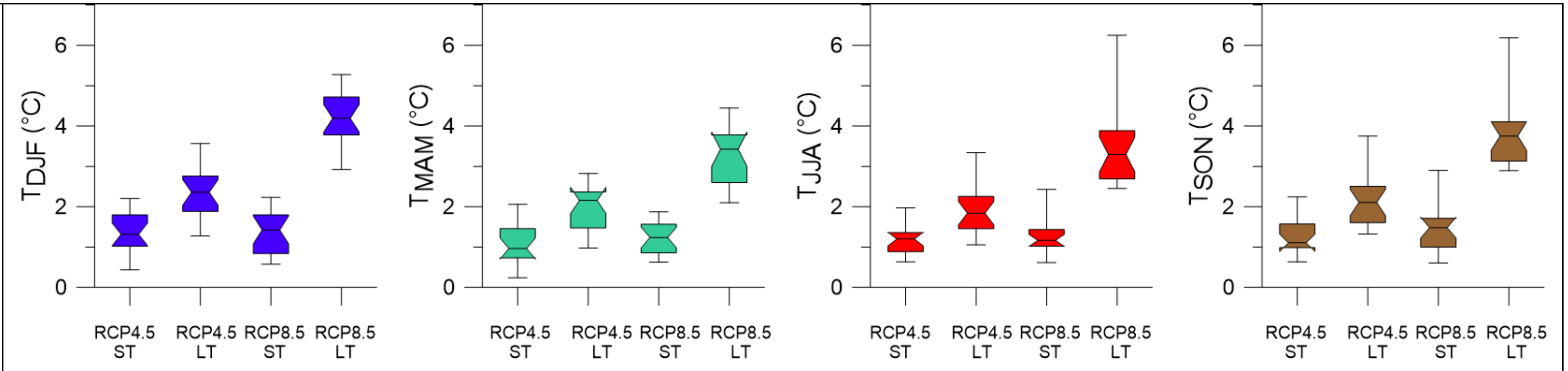
Index	*1971 - 2000*	*1990 - 2019*
SU	32.3	44.0
FD	121.5	111.1



Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	***	***	***	***	***	***	***	***
Robustness								

Current period
[E-OBS v.21]

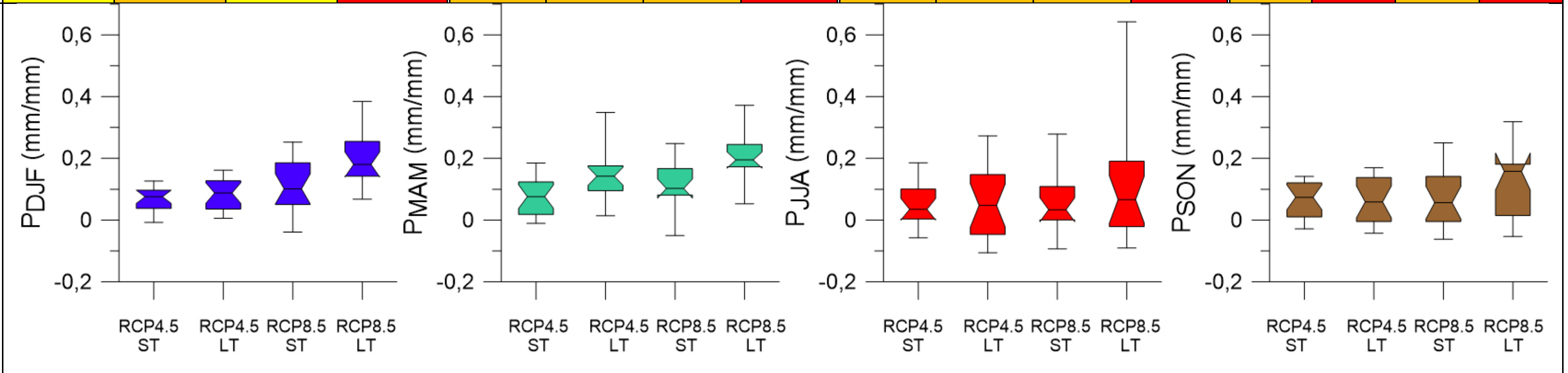
T(°C)	1971 - 2000	1990 - 2019
DJF	0.1	0.5
MAM	8.1	8.8
JJA	17.0	18.0
SON	8.5	9.0



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Robustness																

Current period
[E-OBS v.21]

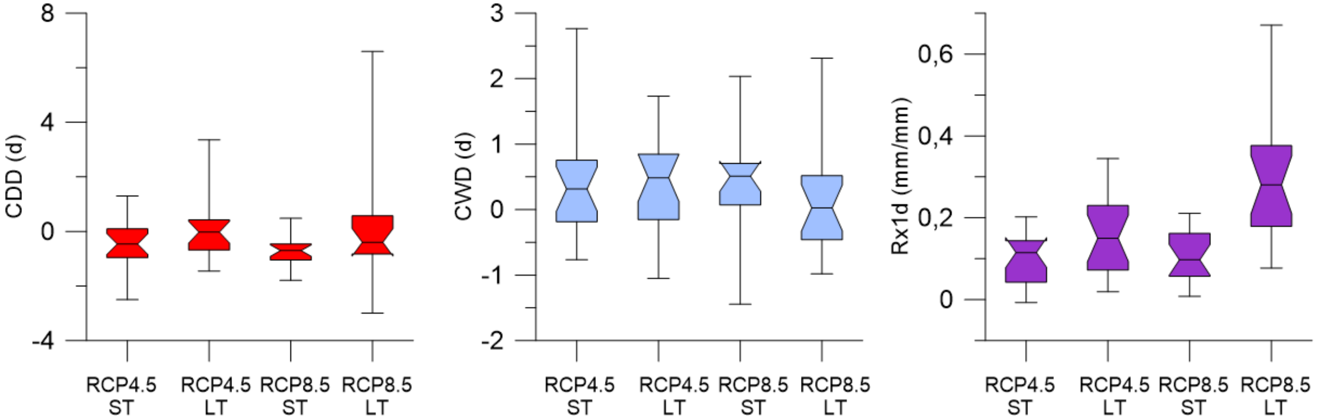
P	1971 - 2000	1990 - 2019
DJF	147.4	144.1
MAM	154.6	146.1
JJA	222.9	231.4
SON	149.2	153.8



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	***	***	**	***	***	***	*	*	*	*	**	**	**	**
Robustness																

Current period
[E-OBS v.21]

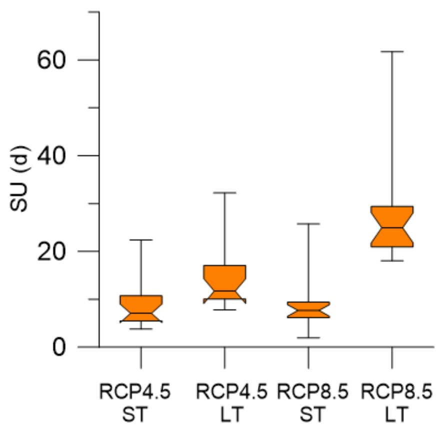
Index	*1971 - 2000*	*1990 - 2019*
CDD	20.6	20.7
CWD	8.7	8.0
Rx1d	37.0	36.9

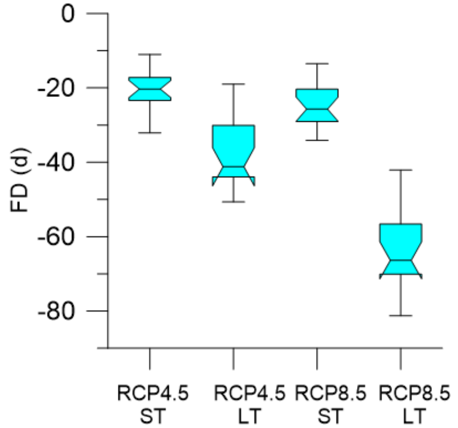


Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	*	-	**	*	*	*	**	-	**	***	**	***
Robustness												

Current period
[E-OBS v.21]

Index	*1971 - 2000*	*1990 - 2019*
SU	34.3	44.8
FD	96.5	95.8

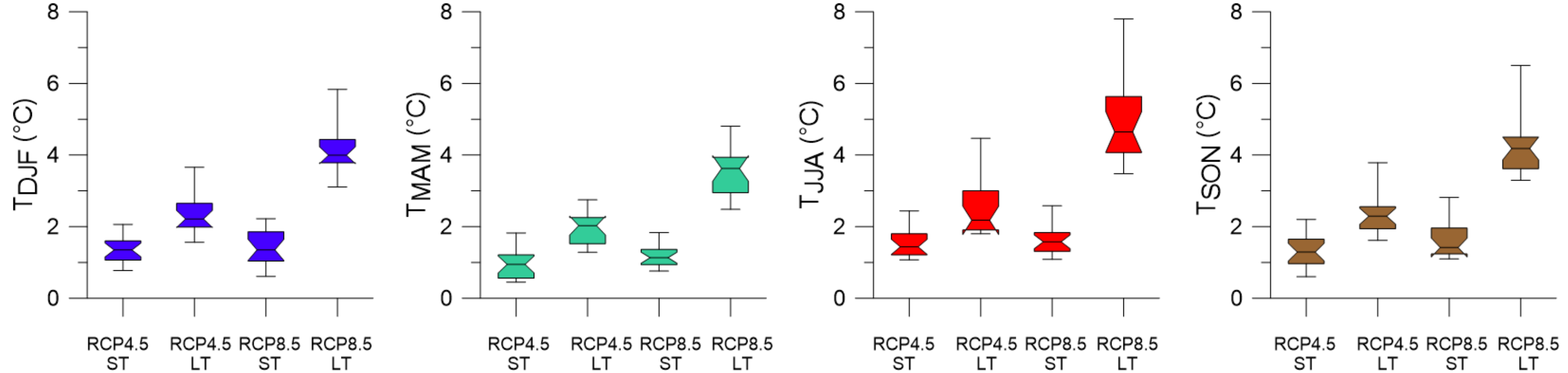




Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	***	***	***	***	***	***	***	***
Robustness								

Current period
[E-OBS v.21]

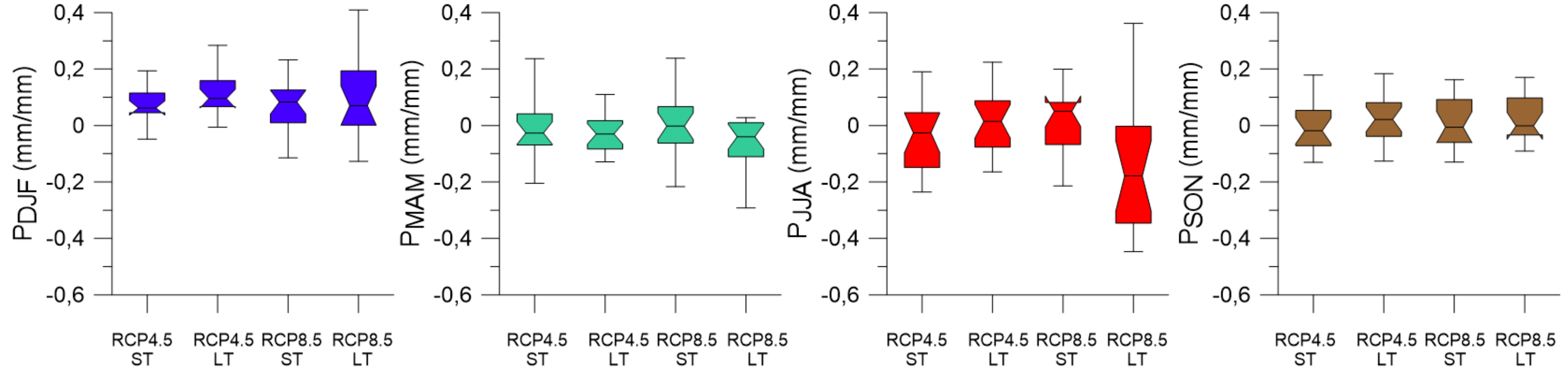
T(°C)	*1971 - 2000*	*1990 - 2019*
DJF	2.5	2.9
MAM	10.5	11.6
JJA	20.5	21.7
SON	11.7	12.3



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Robustness																

Current period
[E-OBS v.21]

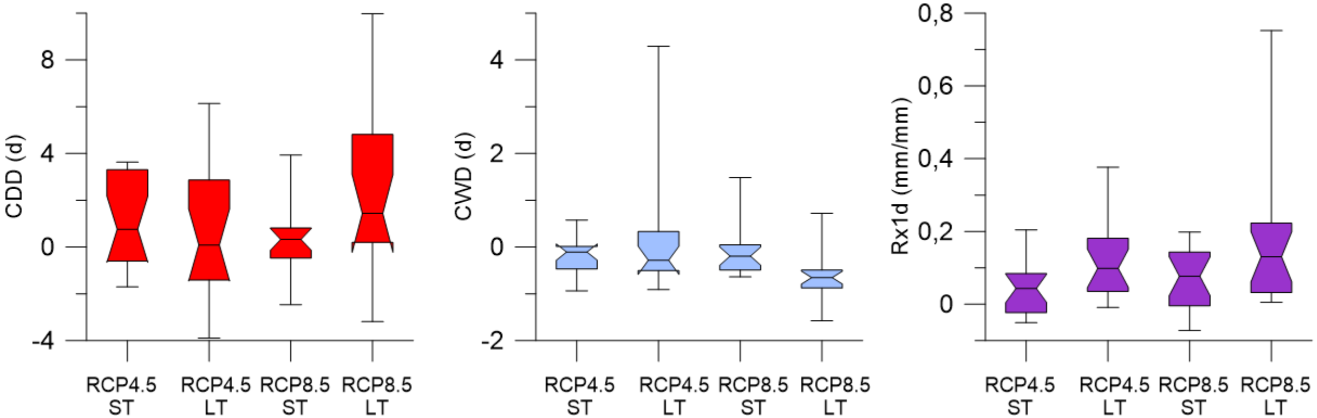
P	*1971 - 2000*	*1990 - 2019*
DJF	209.1	205.0
1MAM	242.0	243.8
JJA	173.3	136.0
SON	332.2	344.6



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	**	***	**	**	*	*	-	**	*	*	*	**	*	*	-	*
Robustness																

Current period
[E-OBS v.21]

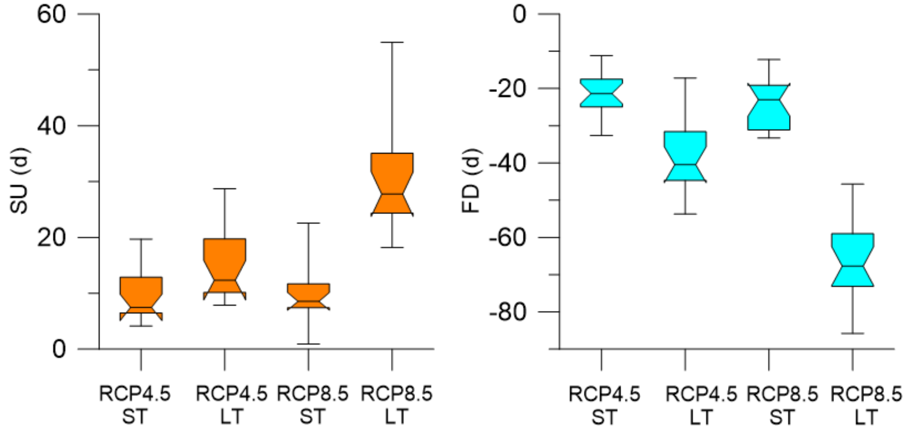
Index	*1971 - 2000*	*1990 - 2019*
CDD	37.1	35.5
CWD	8.0	8.2
Rx1d	57.0	59.3



Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	*	-	*	**	*	-	-	**	*	**	**	**
Robustness												

Current period
[E-OBS v.21]

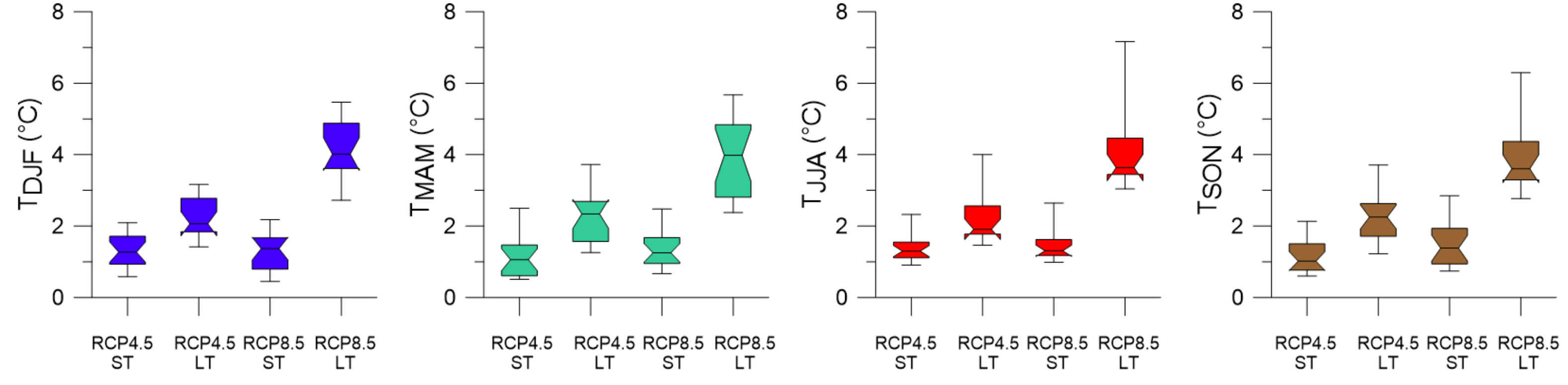
Index	*1971 - 2000*	*1990 - 2019*
SU	72.0	89.5
FD	65.5	58.8



Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	***	***	***	***	***	***	***	***
Robustness								

Current period
[E-OBS v.21]

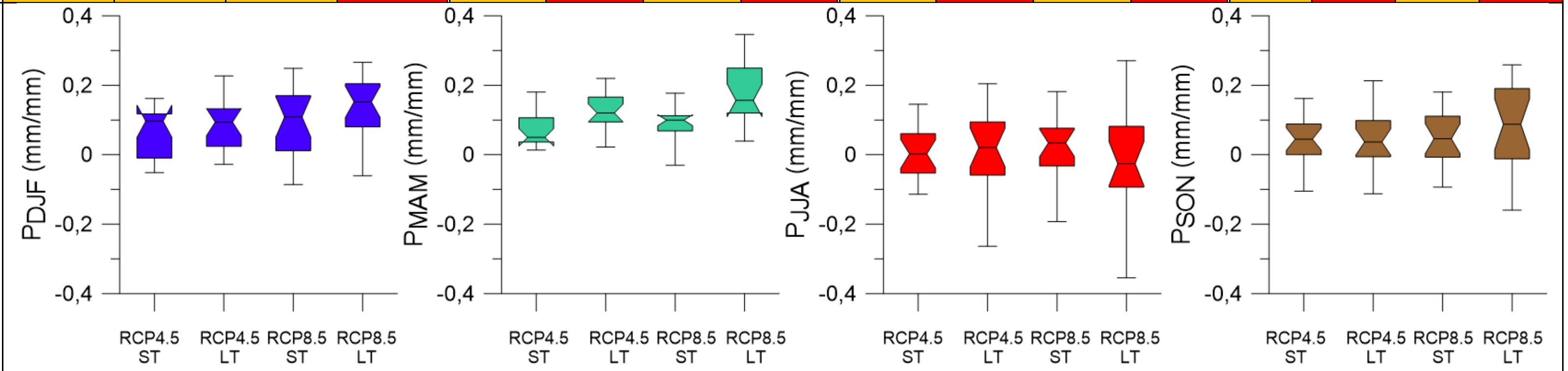
T(°C)	*1971 - 2000*	*1990 - 2019*
DJF	-2.5	-2.4
MAM	4.5	5.4
JJA	13.3	14.7
SON	6.1	6.4



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Robustness																

Current period
[E-OBS v.21]

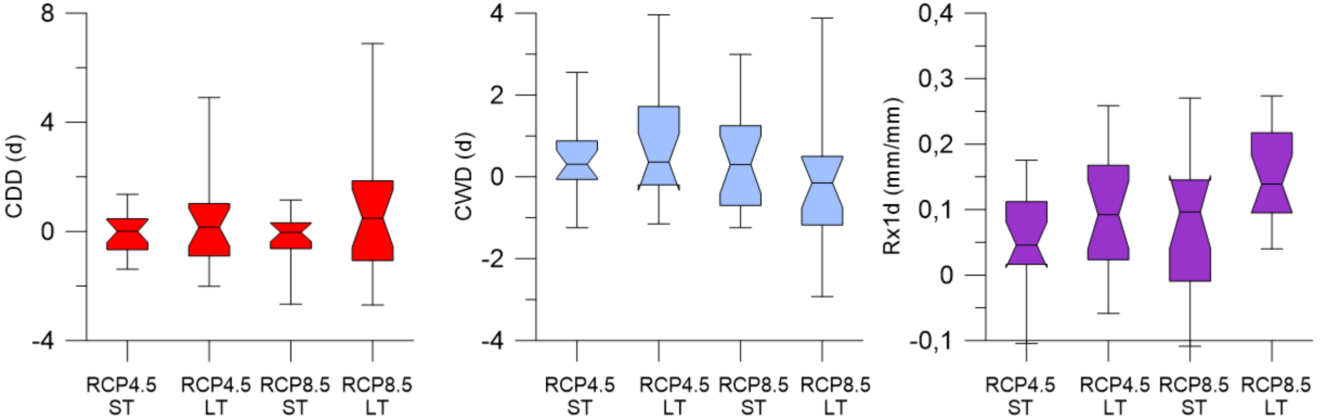
P	*1971 - 2000*	*1990 - 2019*
DJF	132.5	124.5
MAM	219.4	222.0
JJA	350.8	354.1
SON	208.2	231.9



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	*	**	**	***	***	***	***	***	-	*	*	*	**	*	**	**
Robustness																

Current period
[E-OBS v.21]

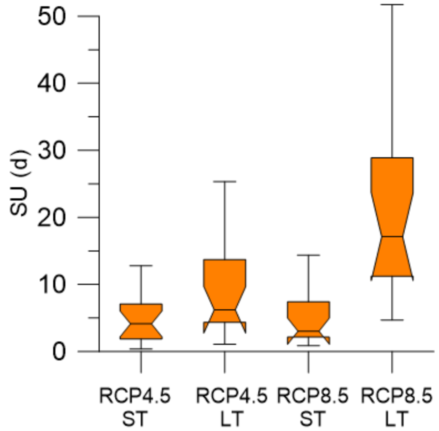
Index	*1971 - 2000*	*1990 - 2019*
CDD	21.2	20.8
CWD	7.8	7.4
Rx1d	33.3	37.4

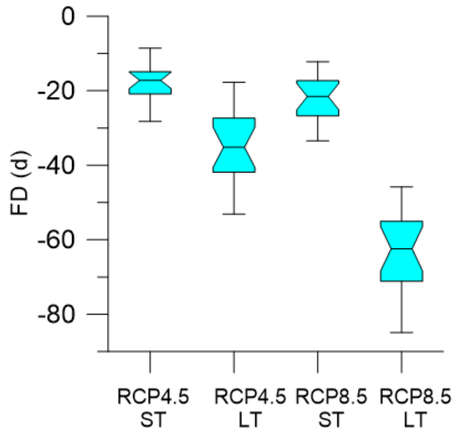


Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	-	*	-	*	*	*	*	*	**	**	**	***
Robustness												

Current period
[E-OBS v.21]

Index	*1971 - 2000*	*1990 - 2019*
SU	7.4	13
FD	159.6	143.8

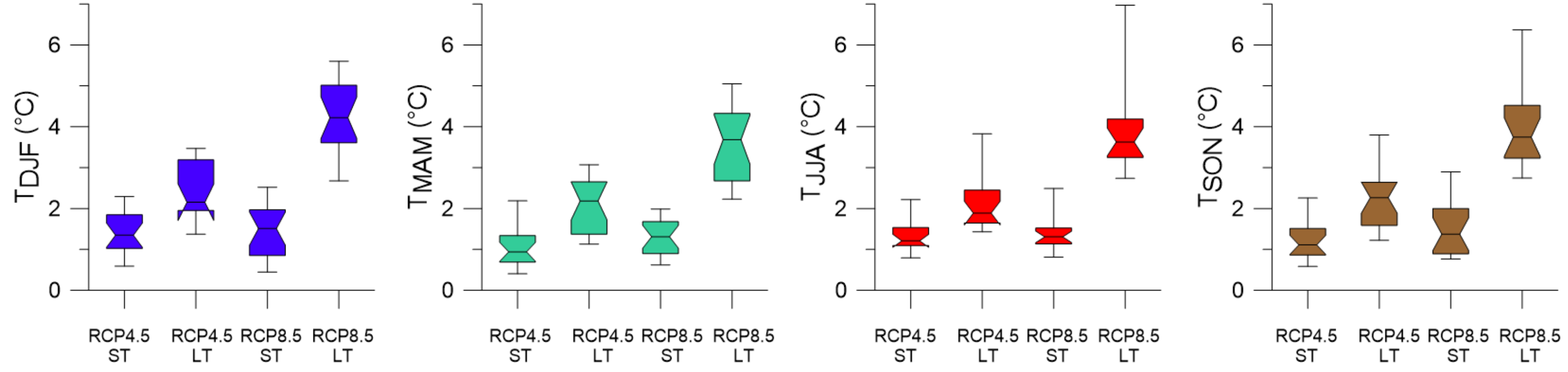




Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	***	***	***	***	***	***	***	***
Robustness								

Current period
[E-OBS v.21]

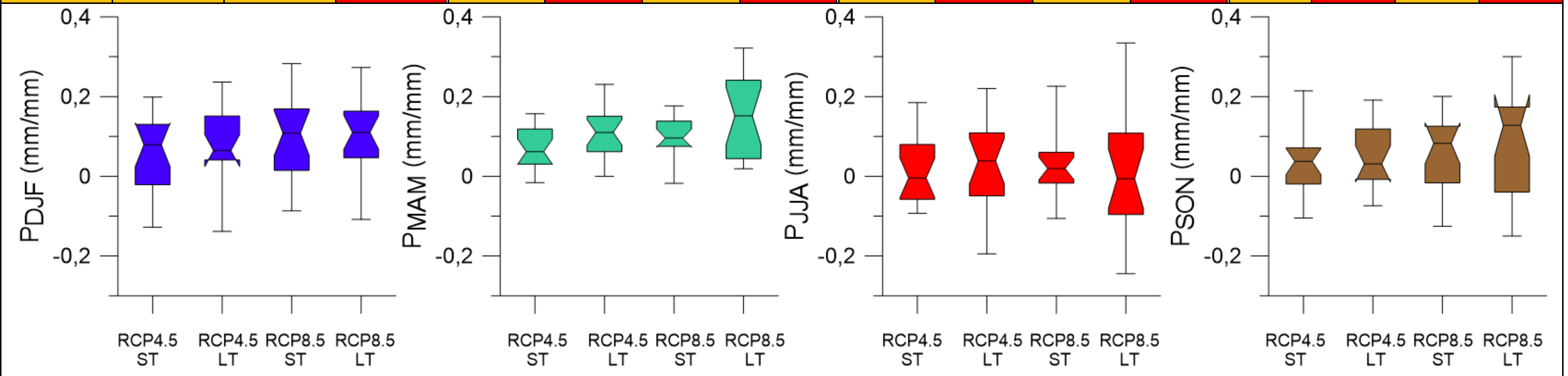
T(°C)	*1971 - 2000*	*1990 - 2019*
DJF	-1.2	-0.8
MAM	7.6	8.5
JJA	16.5	17.6
SON	8.1	8.6



Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Robustness																

Current period
[E-OBS v.21]

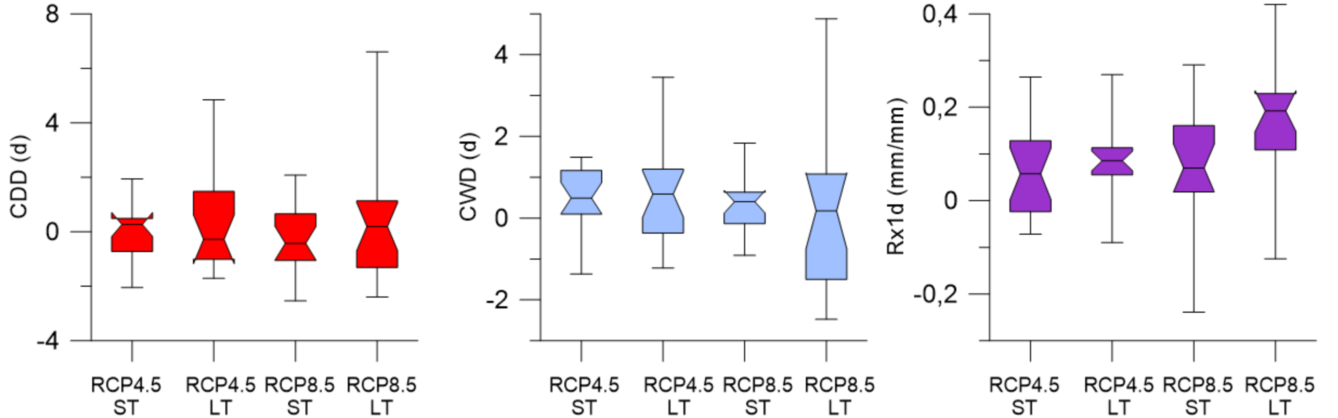
P	*1971 - 2000*	*1990 - 2019*
DJF	120.8	120.8
MAM	177.6	196.8
JJA	303.1	321.3
SON	168.1	192.6



Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	*	**	**	**	**	***	***	***	-	*	*	-	*	**	*	**
Robustness																

Current period
[E-OBS v.21]

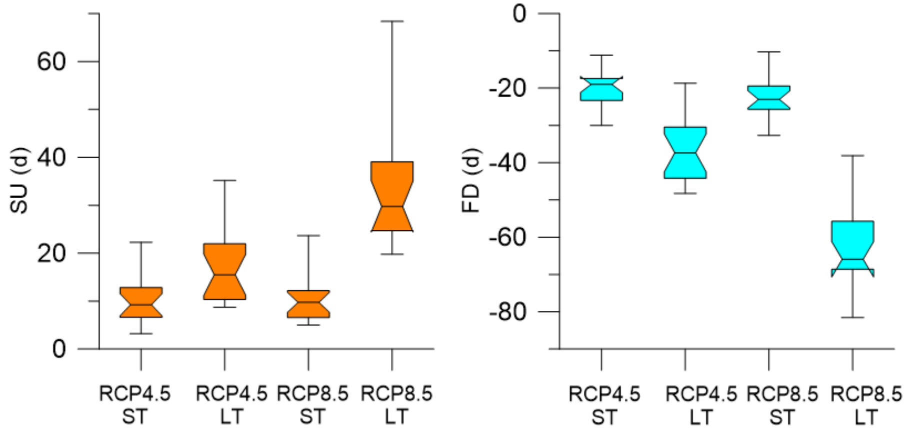
Index	*1971 - 2000*	*1990 - 2019*
CDD	21.9	20.2
CWD	8.3	8.1
Rx1d	27.9	32.5



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	-	-	*	-	*	*	*	-	*	**	**	***
Robustness												

Current period
[E-OBS v.21]

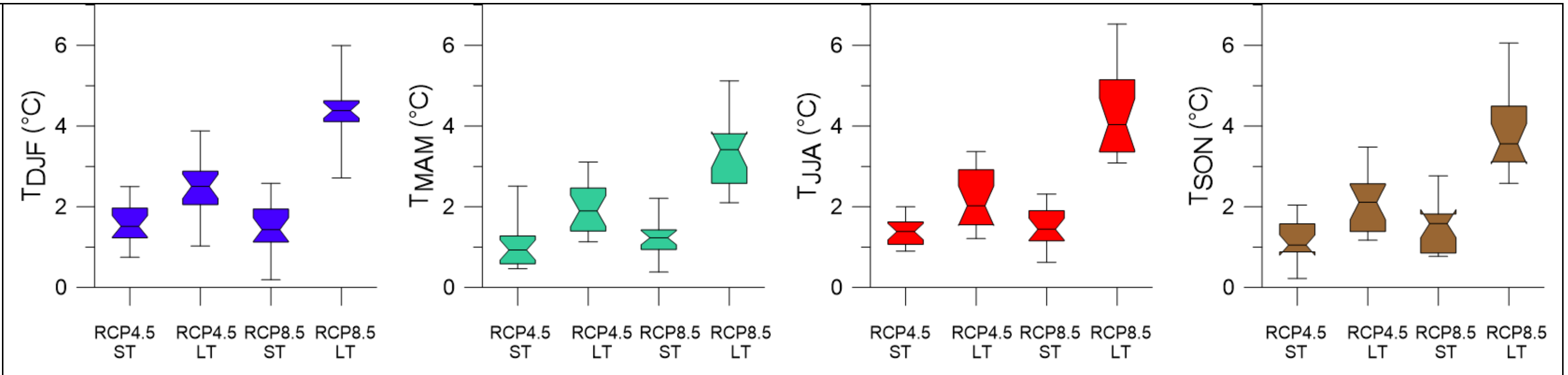
Index	*1971 - 2000*	*1990 - 2019*
SU	28.1	40.0
FD	126.0	113.1



Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	***	***	***	***	***	***	***	***
Robustness								

Current period
[E-OBS v.21]

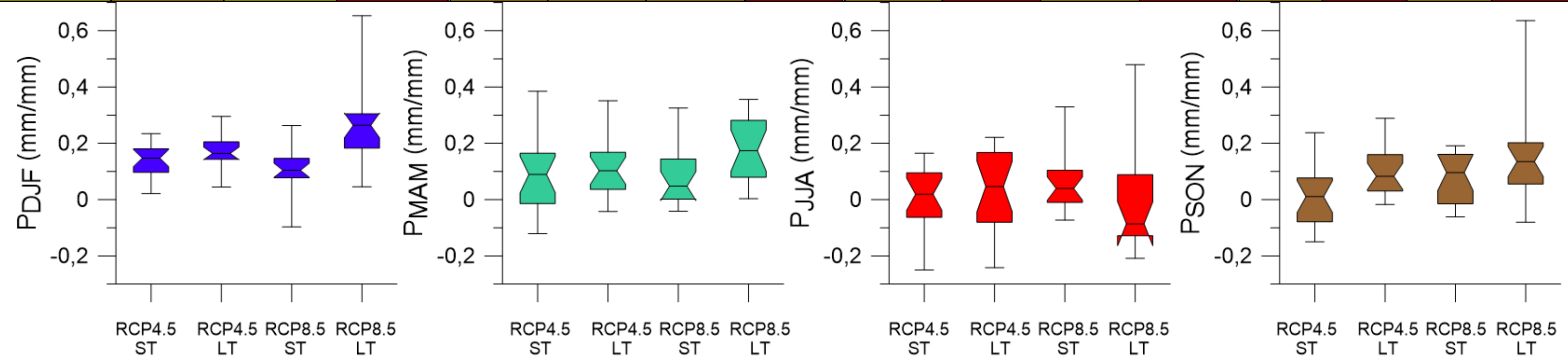
T(°C)	*1971 - 2000*	*1990 - 2019*
DJF	0.2	0.7
MAM	11.1	11.8
JJA	20.4	21.6
SON	10.6	11.4



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Robustness																

Current period
[E-OBS v.21]

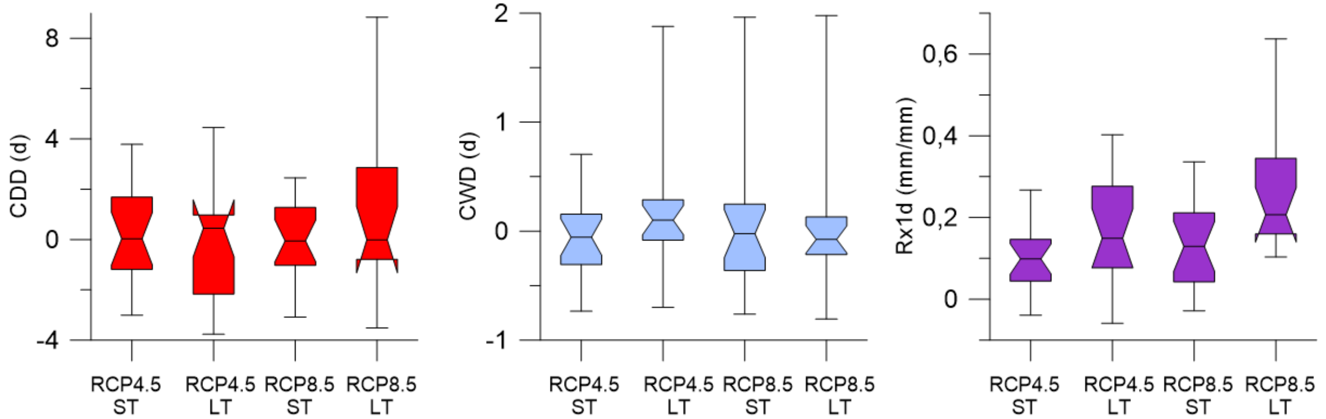
P	*1971 - 2000*	*1990 - 2019*
DJF	70.1	76.1
MAM	107.5	102.0
JJA	140.0	153.1
SON	106.7	121.7



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	**	***	**	***	**	***	-	*	*	-	-	***	**	**
Robustness																

Current period
[E-OBS v.21]

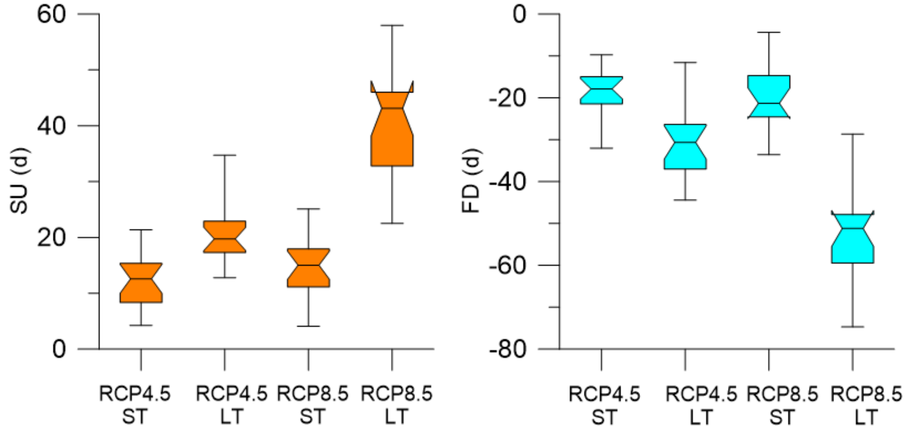
Index	*1971 - 2000*	*1990 - 2019*
CDD	33.3	30.3
CWD	5.8	5.8
Rx1d	21.6	22.3



Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	-	-	-	*	*	*	-	-	**	***	**	***
Robustness												

Current period
[E-OBS v.21]

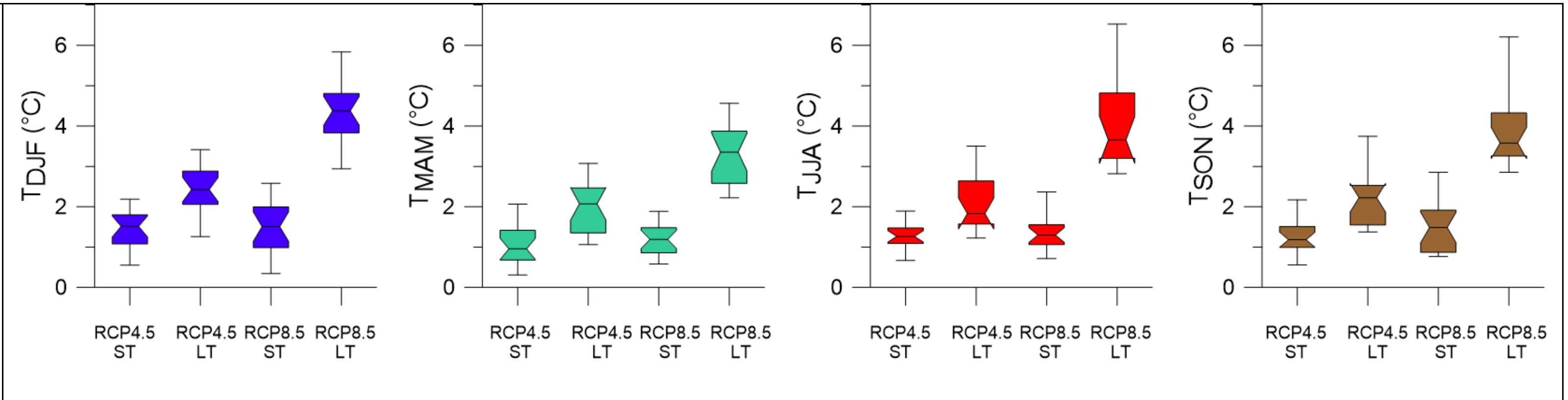
Index	*1971 - 2000*	*1990 - 2019*
SU	78.8	93.0
FD	92.0	83.2



Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	***	***	***	***	***	***	***	***
Robustness								

Current period
[E-OBS v.21]

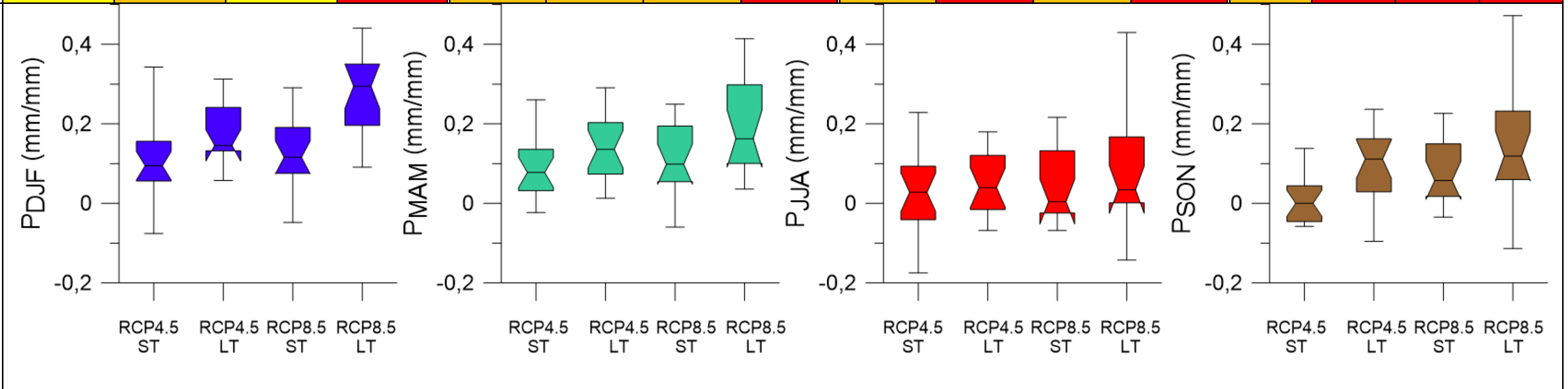
T(°C)	*1971 - 2000*	*1990 - 2019*
DJF	-0.5	-0.1
MAM	8.9	9.6
JJA	18.2	19.3
SON	8.8	9.3



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Robustness																

Current period
[E-OBS v.21]

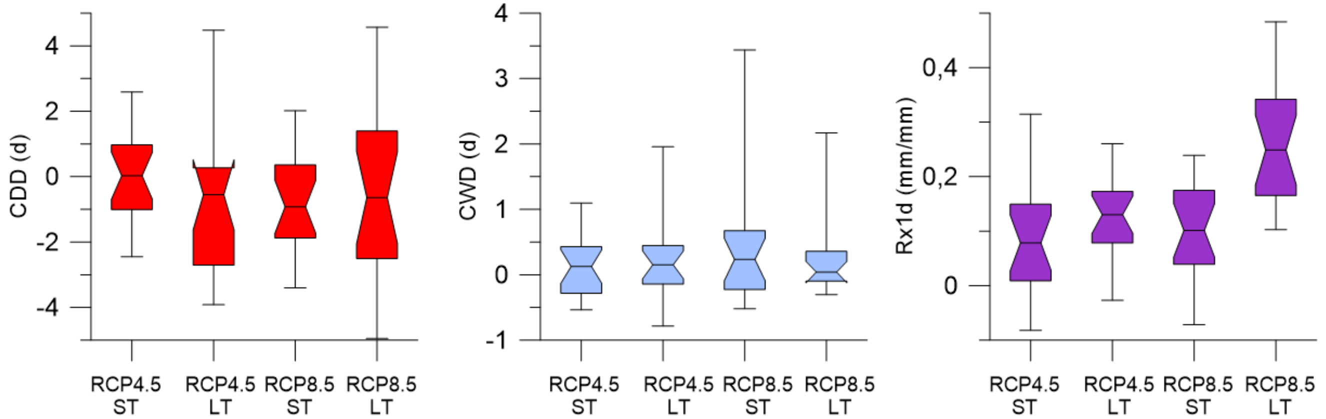
P	*1971 - 2000*	*1990 - 2019*
DJF	69.0	72.3
MAM	117.5	123.8
JJA	181.3	192.1
SON	103.6	117.7



Data information/Scenario	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT	RCP 4.5 ST	RCP 4.5 LT	RCP 8.5 ST	RCP 8.5 LT
Model agreement	***	***	***	***	***	***	***	***	*	*	*	*	-	**	**	***
Robustness																

Current period
[E-OBS v.21]

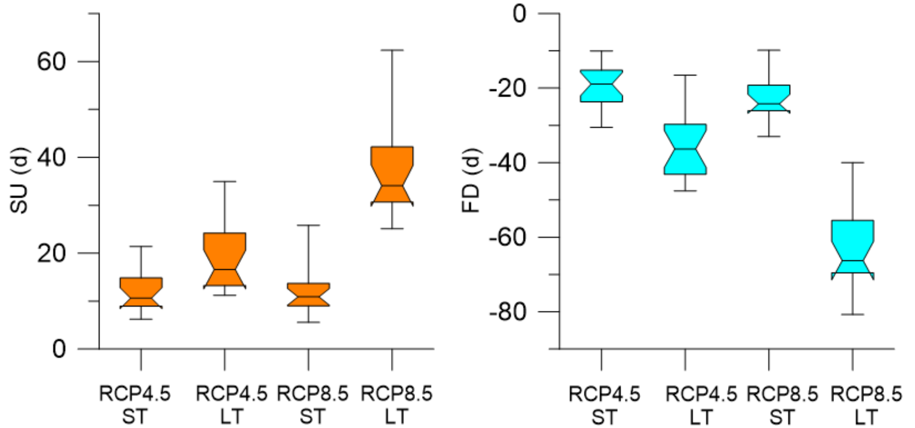
Index	*1971 - 2000*	*1990 - 2019*
CDD	24.3	23.5
CWD	6.3	5.9
Rx1d	27.7	29.7



Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	-	*	*	-	-	*	*	*	**	***	**	***
Robustness												

Current period
[E-OBS v.21]

Index	*1971 - 2000*	*1990 - 2019*
SU	48.0	58.7
FD	104.9	95.1



Data information/Scenario	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**	**RCP 4.5 ST**	**RCP 4.5 LT**	**RCP 8.5 ST**	**RCP 8.5 LT**
Model agreement	***	***	***	***	***	***	***	***
Robustness								

I.3 Synthesis of the PA results

PA1 - Part of Kamniška Bistrica basin (Slovenia)

PA1 - SHORT TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	1.49	1.19	1.53	1.81	1.47	1.03	1.34	1.90
	TMAM	1.06	0.73	1.06	1.30	1.26	1.02	1.20	1.55
	TJJA	1.41	1.19	1.31	1.57	1.47	1.25	1.38	1.50
	TSON	1.20	0.89	1.13	1.47	1.52	1.06	1.53	1.74
Seasonal cumulative precipitation	PDJF	0.11	0.04	0.13	0.17	0.09	0.02	0.12	0.15
	PMAM	0.06	-0.01	0.07	0.10	0.07	-0.01	0.05	0.11
	PJJA	-0.02	-0.04	0.00	0.04	0.02	-0.04	0.02	0.08
	PSON	-0.01	-0.07	-0.03	0.02	0.04	-0.02	0.09	0.11
CDD		-0.01	-0.80	0.26	0.96	-0.43	-1.28	-0.36	0.62
CWD		-0.27	-0.74	-0.37	-0.01	-0.13	-0.51	-0.34	-0.06
Rx1day		0.05	0.00	0.06	0.11	0.08	0.04	0.08	0.12
SU		10.94	8.21	8.92	13.92	11.01	7.38	9.09	13.83
FD		-18.29	-21.98	-16.97	-15.01	-20.93	-25.41	-21.18	-17.56

PA1 - LONG TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	2.44	2.07	2.35	2.95	4.35	3.84	4.03	4.86
	TMAM	2.06	1.53	2.19	2.47	3.59	2.84	3.69	4.20
	TJJA	2.26	1.81	2.09	2.48	4.45	3.75	4.08	4.77
	TSON	2.21	1.70	2.19	2.45	4.02	3.39	3.85	4.22
Seasonal cumulative precipitation	PDJF	0.16	0.11	0.14	0.20	0.23	0.12	0.22	0.31
	PMAM	0.09	0.01	0.07	0.15	0.13	0.04	0.12	0.18
	PJJA	0.02	-0.08	0.06	0.11	-0.09	-0.18	-0.10	0.00
	PSON	0.05	0.01	0.05	0.08	0.05	-0.04	0.00	0.12
CDD		-0.32	-1.92	-0.16	0.74	0.12	-1.80	0.19	1.62
CWD		-0.11	-0.54	-0.26	-0.02	-0.80	-1.32	-0.94	-0.69
Rx1day		0.12	0.08	0.12	0.15	0.19	0.14	0.20	0.26
SU		18.09	11.48	15.96	24.42	37.90	28.63	32.56	49.11
FD		-33.70	-41.59	-33.87	-27.63	-59.93	-66.52	-61.40	-52.10

PA2 - Upper Lusatia county (Germany)

PA2 - SHORT TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	1.35	1.03	1.34	1.70	1.35	0.87	1.44	1.79
	TMAM	1.05	0.72	0.93	1.41	1.24	0.99	1.22	1.52
	TJJA	1.17	0.93	1.19	1.36	1.25	1.04	1.18	1.36
	TSON	1.22	0.99	1.10	1.54	1.48	0.99	1.48	1.69
Seasonal cumulative precipitation	PDJF	0.07	0.04	0.08	0.10	0.12	0.07	0.10	0.17
	PMAM	0.08	0.02	0.07	0.14	0.12	0.08	0.11	0.16
	PJJA	0.04	0.01	0.03	0.09	0.05	-0.01	0.03	0.09
	PSON	0.07	0.02	0.08	0.11	0.07	0.00	0.07	0.13
CDD		-0.58	-0.99	-0.41	0.07	-0.71	-0.95	-0.77	-0.51
CWD		0.42	-0.13	0.53	0.76	0.40	0.07	0.40	0.83
Rx1day		0.11	0.06	0.12	0.17	0.11	0.08	0.10	0.15
SU		8.56	5.94	7.21	11.14	9.15	6.18	7.83	9.68
FD		-21.28	-23.64	-20.22	-17.38	-24.30	-28.70	-26.50	-20.32

PA2 - LONG TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	2.32	1.97	2.35	2.74	4.19	3.78	4.21	4.61
	TMAM	1.95	1.49	2.12	2.31	3.20	2.70	3.40	3.65
	TJJA	1.86	1.46	1.85	2.13	3.54	2.94	3.27	3.79
	TSON	2.16	1.61	2.09	2.45	3.83	3.14	3.74	4.06
Seasonal cumulative precipitation	PDJF	0.09	0.05	0.08	0.13	0.21	0.15	0.18	0.25
	PMAM	0.15	0.10	0.14	0.18	0.21	0.17	0.20	0.23
	PJJA	0.06	-0.05	0.05	0.12	0.10	-0.01	0.08	0.15
	PSON	0.07	0.01	0.06	0.14	0.12	0.03	0.16	0.18
CDD		-0.02	-0.75	0.03	0.40	-0.05	-0.78	-0.16	0.46
CWD		0.42	-0.03	0.58	0.85	0.12	-0.50	0.06	0.63
Rx1day		0.16	0.07	0.16	0.24	0.33	0.21	0.30	0.36
SU		14.18	10.41	11.83	17.56	29.14	21.23	25.54	29.97
FD		-37.74	-44.05	-40.98	-31.33	-63.12	-69.78	-65.15	-57.02

PA3 - Kamienna river basin (Poland)

PA3 - SHORT TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	1.58	1.11	1.57	2.01	1.49	1.00	1.63	1.96
	TMAM	1.23	0.73	1.08	1.71	1.47	1.17	1.41	1.75
	TJJA	1.18	1.00	1.20	1.35	1.31	1.07	1.16	1.62
	TSON	1.21	0.95	1.25	1.55	1.49	0.98	1.68	1.79
Seasonal cumulative precipitation	PDJF	0.11	0.08	0.10	0.14	0.13	0.07	0.15	0.18
	PMAM	0.10	0.04	0.09	0.17	0.12	0.05	0.13	0.20
	PJJA	0.04	-0.03	0.04	0.08	0.05	0.00	0.03	0.13
	PSON	0.03	-0.02	0.04	0.08	0.06	0.02	0.07	0.11
CDD		-0.47	-0.95	-0.46	0.15	-0.17	-0.90	-0.17	0.25
CWD		0.34	-0.02	0.30	0.59	0.36	-0.05	0.35	0.65
Rx1day		0.08	0.02	0.07	0.13	0.10	0.05	0.11	0.14
SU		9.14	6.50	7.47	12.12	9.93	7.39	8.56	11.57
FD		-21.68	-24.70	-21.35	-17.62	-24.07	-30.14	-23.01	-19.59

PA3 - LONG TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	2.62	2.09	2.67	3.14	4.66	4.12	4.64	5.08
	TMAM	2.25	1.61	2.35	2.73	3.57	2.93	3.75	4.08
	TJJA	1.94	1.47	1.83	2.44	3.69	3.00	3.38	4.26
	TSON	2.10	1.41	2.08	2.45	3.76	3.15	3.63	4.16
Seasonal cumulative precipitation	PDJF	0.15	0.12	0.16	0.17	0.26	0.17	0.25	0.33
	PMAM	0.19	0.12	0.20	0.29	0.26	0.20	0.27	0.32
	PJJA	0.04	-0.02	0.04	0.14	0.10	0.00	0.06	0.15
	PSON	0.09	0.02	0.11	0.12	0.14	0.06	0.16	0.20
CDD		0.05	-0.74	-0.01	0.70	0.06	-1.02	-0.42	0.62
CWD		0.42	-0.03	0.53	0.65	0.34	-0.14	0.31	0.49
Rx1day		0.13	0.06	0.10	0.17	0.29	0.17	0.24	0.38
SU		15.1	10.2	12.3	19.7	31.1	24.7	27.8	34.5
FD		-37.9	-44.2	-40.5	-32.0	-66.4	-72.9	-67.7	-59.5

PA4 - Lusatin Neisse basin (Poland)

PA4 - SHORT TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	1.36	1.03	1.32	1.73	1.35	0.87	1.43	1.80
	TMAM	1.07	0.74	0.96	1.41	1.26	1.00	1.24	1.53
	TJJA	1.16	0.94	1.20	1.34	1.25	1.03	1.17	1.35
	TSON	1.23	1.00	1.11	1.54	1.48	1.00	1.48	1.70
Seasonal cumulative precipitation	PDJF	0.06	0.04	0.08	0.09	0.11	0.06	0.10	0.16
	PMAM	0.08	0.02	0.08	0.12	0.12	0.08	0.10	0.15
	PJJA	0.05	0.01	0.04	0.09	0.06	0.00	0.03	0.10
	PSON	0.07	0.02	0.07	0.11	0.07	0.00	0.06	0.13
CDD		-0.47	-0.86	-0.46	0.01	-0.72	-1.00	-0.70	-0.46
CWD		0.38	-0.18	0.31	0.72	0.39	0.08	0.51	0.69
Rx1day		0.11	0.06	0.12	0.14	0.10	0.06	0.10	0.15
SU		8.27	5.60	7.06	10.50	8.91	6.13	7.66	9.18
FD		-21.25	-23.40	-20.30	-17.65	-24.29	-28.64	-25.72	-20.46

PA4 - LONG TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	2.33	1.96	2.36	2.76	4.21	3.80	4.19	4.61
	TMAM	1.98	1.52	2.16	2.36	3.24	2.71	3.43	3.73
	TJJA	1.86	1.46	1.84	2.14	3.55	2.95	3.30	3.79
	TSON	2.17	1.61	2.11	2.45	3.84	3.15	3.75	4.06
Seasonal cumulative precipitation	PDJF	0.08	0.04	0.09	0.12	0.20	0.15	0.18	0.25
	PMAM	0.15	0.10	0.14	0.18	0.22	0.18	0.19	0.23
	PJJA	0.06	-0.04	0.05	0.13	0.10	-0.02	0.07	0.16
	PSON	0.07	0.01	0.06	0.13	0.12	0.02	0.16	0.18
CDD		0.02	-0.66	-0.03	0.35	-0.06	-0.80	-0.40	0.51
CWD		0.38	-0.04	0.49	0.79	0.07	-0.41	0.03	0.46
Rx1day		0.16	0.09	0.15	0.22	0.31	0.20	0.28	0.35
SU		13.83	10.06	11.72	16.86	28.54	20.99	24.93	29.04
FD		-37.79	-43.93	-41.21	-31.45	-63.54	-69.98	-66.37	-56.87

PA5 - Enza basin (Italy)

PA5 - SHORT TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	1.36	1.08	1.35	1.59	1.38	1.13	1.35	1.59
	TMAM	0.99	0.67	0.94	1.20	1.18	0.95	1.13	1.35
	TJJA	1.56	1.28	1.43	1.74	1.62	1.31	1.58	1.82
	TSON	1.31	0.98	1.29	1.59	1.63	1.26	1.42	1.84
Seasonal cumulative precipitation	PDJF	0.07	0.05	0.06	0.11	0.06	0.01	0.08	0.11
	PMAM	-0.01	-0.07	-0.03	0.04	0.01	-0.06	0.00	0.07
	PJJA	-0.04	-0.13	-0.03	0.04	0.01	-0.06	0.05	0.08
	PSON	0.00	-0.07	0.01	0.08	-0.16	-0.34	-0.18	-0.03
CDD		1.08	-0.41	0.76	2.77	0.33	-0.33	0.33	0.73
CWD		-0.15	-0.42	-0.11	0.00	-0.10	-0.43	-0.19	-0.02
Rx1day		0.04	-0.02	0.04	0.08	0.04	-0.02	0.04	0.08
SU		14.66	12.00	14.54	16.30	15.37	11.66	15.46	18.03
FD		-16.62	-20.13	-16.44	-13.99	-18.80	-23.59	-20.29	-14.47

PA5 - LONG TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	2.31	2.01	2.21	2.58	2.28	2.01	2.21	2.58
	TMAM	1.94	1.54	2.03	2.24	3.50	2.96	3.62	3.93
	TJJA	2.46	1.94	2.18	2.78	4.94	4.13	4.65	5.61
	TSON	2.38	1.94	2.29	2.55	4.31	3.70	4.18	4.45
Seasonal cumulative precipitation	PDJF	0.11	0.07	0.10	0.16	0.09	0.01	0.07	0.19
	PMAM	-0.03	-0.08	-0.03	0.02	-0.06	-0.09	-0.04	0.00
	PJJA	0.00	-0.07	0.01	0.08	-0.16	-0.34	-0.18	-0.03
	PSON	-0.01	-0.06	-0.02	0.03	0.03	-0.03	0.00	0.10
CDD		0.53	-1.28	0.09	2.46	2.74	0.44	1.44	4.58
CWD		0.09	-0.50	-0.28	0.29	-0.62	-0.87	-0.65	-0.52
Rx1day		0.12	0.04	0.10	0.16	0.12	0.04	0.10	0.16
SU		23.7	20.0	22.3	25.7	45.5	40.3	45.0	50.0
FD		-29.0	-35.4	-29.0	-22.3	-46.0	-52.9	-42.4	-38.6

PA6 - Catchment area of the Vienna Water Supply (Austria)

PA6 - SHORT TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	1.3	1.0	1.3	1.6	1.3	0.8	1.4	1.7
	TMAM	1.1	0.7	1.1	1.4	1.3	1.0	1.3	1.6
	TJJA	1.4	1.1	1.3	1.5	1.4	1.2	1.3	1.5
	TSON	1.2	0.8	1.0	1.5	1.5	1.0	1.4	1.8
Seasonal cumulative precipitation	PDJF	0.06	-0.01	0.10	0.12	0.10	0.03	0.11	0.17
	PMAM	0.07	0.04	0.05	0.09	0.10	0.08	0.10	0.11
	PJJA	0.00	-0.04	0.00	0.05	0.02	-0.03	0.03	0.08
	PSON	0.05	0.01	0.05	0.09	0.06	0.00	0.05	0.11
CDD		-0.1	-0.7	0.0	0.4	-0.2	-0.5	0.0	0.3
CWD		0.4	0.0	0.3	0.8	0.4	-0.7	0.3	1.1
Rx1day		0.06	0.02	0.05	0.11	0.08	0.02	0.10	0.14
SU		4.9	2.1	4.1	6.9	5.2	2.2	3.0	7.4
FD		-17.5	-20.7	-17.2	-15.1	-21.8	-26.4	-21.6	-17.4

PA6 - LONG TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	2.2	1.9	2.1	2.7	4.1	3.6	4.0	4.9
	TMAM	2.2	1.6	2.3	2.7	3.9	3.0	4.0	4.7
	TJJA	2.2	1.8	1.9	2.4	4.1	3.5	3.6	4.4
	TSON	2.2	1.7	2.3	2.5	4.0	3.4	3.6	4.2
Seasonal cumulative precipitation	PDJF	0.09	0.03	0.09	0.13	0.13	0.09	0.15	0.19
	PMAM	0.13	0.10	0.12	0.16	0.17	0.12	0.16	0.22
	PJJA	0.01	-0.06	0.02	0.09	-0.02	-0.07	-0.03	0.07
	PSON	0.05	0.00	0.04	0.09	0.08	0.02	0.09	0.17
CDD		0.3	-0.7	0.2	0.9	0.7	-0.6	0.5	1.6
CWD		0.7	-0.1	0.4	1.4	-0.2	-1.2	-0.1	0.5
Rx1day		0.10	0.04	0.09	0.14	0.16	0.10	0.14	0.21
SU		9.2	4.5	6.2	13.3	21.4	11.5	17.1	28.8
FD		-34.9	-41.7	-35.2	-27.5	-63.9	-70.4	-62.4	-55.7

PA7 - Catchment area of Waidhofen/Ybbs (Austria)

PA7 - SHORT TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	1.4	1.0	1.3	1.8	1.4	0.9	1.5	1.9
	TMAM	1.1	0.7	0.9	1.3	1.3	0.9	1.3	1.6
	TJJA	1.3	1.1	1.2	1.5	1.4	1.2	1.3	1.5
	TSON	1.2	0.9	1.1	1.5	1.5	0.9	1.4	1.9
Seasonal cumulative precipitation	PDJF	0.06	-0.02	0.08	0.13	0.10	0.02	0.11	0.16
	PMAM	0.07	0.03	0.06	0.12	0.09	0.08	0.10	0.13
	PJJA	0.01	-0.06	0.00	0.07	0.03	-0.02	0.02	0.05
	PSON	0.04	-0.02	0.04	0.07	0.06	-0.01	0.08	0.12
CDD		-0.1	-0.6	0.3	0.5	-0.3	-1.0	-0.4	0.6
CWD		0.5	0.1	0.5	1.1	0.3	0.0	0.4	0.6
Rx1day		0.06	-0.02	0.06	0.13	0.08	0.03	0.07	0.14
SU		10.2	6.7	9.2	12.8	10.5	6.6	9.7	12.2
FD		-19.8	-22.9	-19.0	-17.5	-22.7	-25.6	-23.0	-19.6

PA7 - LONG TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	2.4	2.0	2.2	2.9	4.3	3.7	4.2	5.0
	TMAM	2.1	1.4	2.2	2.6	3.6	2.8	3.7	4.3
	TJJA	2.1	1.7	1.9	2.4	4.0	3.3	3.6	4.2
	TSON	2.2	1.6	2.3	2.6	3.9	3.3	3.7	4.4
Seasonal cumulative precipitation	PDJF	0.07	0.04	0.06	0.14	0.10	0.07	0.11	0.16
	PMAM	0.11	0.07	0.11	0.15	0.15	0.06	0.15	0.23
	PJJA	0.03	-0.05	0.04	0.11	0.01	-0.09	-0.01	0.09
	PSON	0.04	-0.01	0.03	0.10	0.09	0.00	0.13	0.17
CDD		0.2	-1.0	-0.3	1.4	0.2	-1.2	0.2	1.1
CWD		0.5	-0.3	0.6	1.0	0.0	-1.3	0.2	1.0
Rx1day		0.08	0.06	0.09	0.11	0.17	0.13	0.19	0.23
SU		16.7	10.5	15.5	21.3	33.8	24.7	29.7	38.4
FD		-36.2	-43.9	-37.4	-30.6	-62.9	-68.6	-65.9	-55.8

PA8 - Nagykunsági river basin (Hungary)

PA8 - SHORT TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	1.6	1.2	1.5	1.9	1.5	1.1	1.4	1.9
	TMAM	1.0	0.6	0.9	1.2	1.2	1.0	1.2	1.4
	TJJA	1.4	1.1	1.4	1.6	1.4	1.2	1.4	1.8
	TSON	1.1	0.9	1.1	1.5	1.5	0.9	1.6	1.8
Seasonal cumulative precipitation	PDJF	0.14	0.10	0.15	0.18	0.10	0.08	0.10	0.15
	PMAM	0.08	-0.01	0.09	0.14	0.08	0.00	0.05	0.11
	PJJA	0.01	-0.05	0.02	0.09	0.05	0.00	0.04	0.09
	PSON	0.01	-0.07	0.01	0.06	0.07	-0.01	0.10	0.15
CDD		0.1	-1.2	0.0	1.3	-0.1	-0.8	-0.1	1.2
CWD		-0.1	-0.3	-0.1	0.1	0.0	-0.3	0.0	0.2
Rx1day		0.10	0.05	0.10	0.14	0.13	0.05	0.13	0.20
SU		12.5	8.5	12.6	15.3	14.3	11.2	15.0	17.9
FD		-18.7	-21.3	-17.9	-15.3	-20.0	-24.4	-21.3	-14.8

PA8 - LONG TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	2.4	2.1	2.5	2.9	4.3	4.1	4.4	4.6
	TMAM	1.9	1.4	1.9	2.5	3.3	2.6	3.4	3.7
	TJJA	2.2	1.7	2.0	2.9	4.3	3.5	4.0	4.9
	TSON	2.1	1.4	2.1	2.5	3.8	3.2	3.6	4.3
Seasonal cumulative precipitation	PDJF	0.18	0.15	0.16	0.20	0.26	0.19	0.26	0.30
	PMAM	0.11	0.05	0.10	0.15	0.17	0.08	0.17	0.25
	PJJA	0.04	-0.07	0.05	0.15	-0.01	-0.12	-0.09	0.07
	PSON	0.10	0.04	0.08	0.15	0.16	0.06	0.14	0.19
CDD		0.0	-1.6	0.4	1.0	1.1	-0.6	0.0	2.3
CWD		0.1	-0.1	0.1	0.3	0.0	-0.2	-0.1	0.1
Rx1day		0.16	0.09	0.15	0.24	0.28	0.17	0.21	0.34
SU		21.0	17.3	19.7	22.8	39.5	33.1	43.1	45.9
FD		-30.9	-36.9	-30.7	-26.5	-52.6	-58.8	-51.2	-47.9

PA9 - National park Podyi (Czech)

PA9 - SHORT TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	1.5	1.1	1.5	1.8	1.5	1.0	1.5	2.0
	TMAM	1.0	0.7	1.0	1.4	1.2	0.9	1.2	1.5
	TJJA	1.3	1.1	1.3	1.4	1.3	1.1	1.3	1.5
	TSON	1.2	1.0	1.2	1.5	1.5	0.9	1.5	1.8
Seasonal cumulative precipitation	PDJF	0.13	0.06	0.09	0.15	0.14	0.08	0.12	0.19
	PMAM	0.09	0.05	0.08	0.12	0.11	0.06	0.10	0.19
	PJJA	0.03	-0.04	0.03	0.09	0.05	-0.02	0.00	0.12
	PSON	0.01	-0.04	0.00	0.04	0.08	0.02	0.06	0.14
CDD		-0.1	-0.8	0.0	0.7	-0.7	-1.6	-0.9	0.3
CWD		0.1	-0.3	0.1	0.4	0.4	-0.2	0.2	0.5
Rx1day		0.09	0.01	0.08	0.15	0.10	0.04	0.10	0.16
SU		11.7	9.1	10.6	14.5	12.1	9.1	10.9	13.4
FD		-19.5	-23.0	-18.9	-15.4	-22.7	-26.0	-24.2	-19.3

PA9 - LONG TERM SCENARIOS									
INDEX		Ensemble EURO-CORDEX RCP4.5				Ensemble EURO-CORDEX RCP8.5			
		mean	25th	50th	75th	mean	25th	50th	75th
Seasonal mean temperature	TDJF	2.4	2.1	2.4	2.9	4.4	3.9	4.4	4.8
	TMAM	1.9	1.4	2.1	2.4	3.3	2.6	3.4	3.8
	TJJA	2.0	1.6	1.8	2.5	3.9	3.2	3.7	4.5
	TSON	2.2	1.6	2.2	2.5	3.9	3.3	3.6	4.2
Seasonal cumulative precipitation	PDJF	0.18	0.13	0.15	0.24	0.27	0.21	0.29	0.34
	PMAM	0.14	0.08	0.14	0.20	0.20	0.12	0.16	0.29
	PJJA	0.05	-0.01	0.04	0.11	0.06	0.00	0.03	0.17
	PSON	0.09	0.03	0.11	0.16	0.16	0.07	0.12	0.22
CDD		-0.7	-2.2	-0.6	0.2	-0.6	-2.4	-0.6	1.4
CWD		0.2	-0.1	0.2	0.4	0.2	-0.1	0.0	0.3
Rx1day		0.13	0.08	0.13	0.17	0.26	0.17	0.25	0.32
SU		19.0	13.7	16.6	23.8	38.2	30.9	34.1	42.0
FD		-35.4	-42.9	-36.3	-30.1	-63.0	-69.3	-66.3	-55.8

Annex II: Analysis sheets – Potential adaptation options, measures and synergies and conflicts (IU)

II.1 How to read the table

- Field of action:
- Adaptation option:
- Responsible WM/other: blue: mainly in the responsibility of water management; brown: mainly in the responsibility of other sector(s); both: shared responsibility
- Level: main level of implementation
- Synergies:/conflicts: General assessment according to the following criteria:

General criteria used for the assessment of potential synergies and conflicts

Criteria	Assessment	Symbol
Synergies		
▪Synergies (ecological, economic, social) with adaptation measures of other sectors are widely expected (e.g. often described in literature and practice examples)	High potential	🟢
▪Synergies (ecological, economic, social) with adaptation measures of other sectors can be expected, e.g. described in best-practice examples	Medium potential	○
Conflicts		
▪Conflicts (of concurring land use, of management of uses like restrictions, of economic losses etc.) with several stakeholders from other sectors or within water management actors are usually expected and are very likely (e.g. already reported in literature and practice examples)	High potential	🔴
▪Conflicts (of concurring land use, of management uses) with stakeholders from other sectors or within water management actors are possible, manageable solutions exist (e.g. are often described in literature)	Medium potential	🟡
▪Conflicts are expected only in specific circumstances	Low potential	🟢

- In response to climate change impacts: as categorised in chapter C.2 and referring to general effects

II.2 Analysis sheets for the investigated fields of water management

Analysis sheets for the investigated fields of water management

- Inland river flood management and protection
- Urban drainage and wastewater treatment
- Heavy rainfall and flash floods management and protection
- Groundwater protection and groundwater use
- Drinking water supply
- Water for irrigation in agriculture
- Cooling water availability
- Navigability of water ways
- Dam and reservoir management
- Low water management
- Hydropower generation
- Conservation of aquatic ecosystems

N°	Adaptation Option / measure	Short description	Responsible: Watermanagement (WM) / Other (Oth)	Synergies/ conflicts Level of: Synergy potential: ● high ○ medium Conflict potential: ● low ● medium ● high	Level of Synergies	Level of conflicts	Increased high water	increase winter precip	Fluctuation groundw.	rising water table winter	Increased Erosion	Freq/ intens heavy rain	Increase in flood runoff	Freq.+duration droughts	increased incid.low water	higher demand on water	rising water temp	Nutrient inputs	CC resilience of n ecosys	Increase invasive species	CC in general	Sea-level rise	increase in storm floods	Increased storm surges
Field of action: Inland river flood management and protection																								
001	Load case climate change	· Assessing the augmentation of design parameters by a climate-change factor · Assessing the sensitivity of the structure to changes in basic data/design parameters	WM			● (low)																		
002	Technical flood protection	· Evaluation, raising/strengthening of dikes, dams, terps, flood-protection walls · Mobile flood-control facilities · Adaptation/new construction of retaining structures · Physical protection of buildings · Intensified maintenance, e.g. control and cleaning of screens,	WM/Oth	· responsibility of water management and local authorities/ local owners - conflicts with land-use/ existing uses	○ (medium)	● (medium)																		
003	Reclamation of flooding areas and restoration of flood-plains	· Reactivation of terrain structures with potential for retention (e.g. oxbow cutoffs) · Dismantling of dikes and dams · Removal of bank stabilisation structures · Raising river-bed levels	WM	· conflicting land-use: agriculture, forestry, infrastructure - potential synergies for development of ecosystems, water quality (e.g. less nutrients)	● (high)	● (high)																		
004	Activation of additional and optimisation of existing reten-tion areas	· Construction of flood-retention basins, polders · Restoration and reconnection of floodplains · Integration of control systems in existing flood polders · Emptying existing reservoirs prior to the onset of a flood event	WM	· conflicting land-use: agriculture, forestry, infrastructure - potential synergies for development of ecosystems, water quality (e.g. less nutrients)	● (high)	● (high)																		
005	Land-use planning in flooding areas and flood-threatened areas (extreme events)	· Flood-adapted planning, construction, renovation · No designation of crucial areas for development · Modification/update of urban land-use plans · Removal/dismantling of flood-sensitive usages · Adapted agricultural use (e.g. grassland) · Conversion from oil to gas heating or to renewable energies	Oth	· land-use planning no original task of water management · restricted use by other sectors, e.g. agriculture, with · economic consequences · potential synergies for development of ecosystems, water quality (e.g. less nutrients)	● (high)	● (high)																		
006	Designation of priority and reserved areas (spatial planning)	Establishment of · Areas intended for dike relocation · Areas for existing or planned flood-retention basins	WM/Oth	· conflicting land-use · synergies with nature conservation, ecosystems	○ (medium)	● (high)																		

N°	Adaptation Option / measure	Short description	Responsible: Watermanagement (WM) / Other (Oth)	Synergies/ conflicts Level of: Synergy potential: high, medium Conflict potential: low, medium, high	Level of Synergies	Level of conflicts	Increased high water	increase winter precip	Fluctuation groundw.	rising water table winter	Increased Erosion	Freq/ intens heavy rain	Increase in flood runoff	Freq.+duration droughts	increased incid.low water	higher demand on water	rising water temp	Nutrient inputs	CC resilience of n ecosys	Increase invasive species	CC in general	Sea-level rise	increase in storm floods	Increased storm surges
007	Flood-hazard and risk maps	· Spatial extent of flood events, heights, extreme historical events, etc. · Sufficient level of detail for local assessment and planning · Installations and objects with high damage potential (e.g. transformer stations) · EU Floods Directive	WM	· synergies: insurance sector	medium	medium																		
008	Identification /mapping of areas endangered by saturation (groundwat.)	· Providing basic data and maps · Information platform on current groundwater conditions and high groundwater levels · Information and advice on saturation problems and solutions	WM	· synergies wih flood risk maps	medium	medium																		
009	Property protection in the event of dangerously high groundwater levels	Building construction measures, e.g. · Sealing house walls through: "white or black tank", no oil tanks in cellars, new buildings without cellars	Oth	· synergies wih new developments	medium	medium																		
010	Flood partnerships	· Participation of interested parties in the planning of measures · Joint plausibility assessment of flood-hazard maps	Oth	· improved disaster-response coordination · conflicts between municipalities (e.g. up-/downstream)	high	medium																		
011	Organised response measures in the case of an extreme event	· Emergency strategies for transportation and supply infrastructure · Flood alert and action planning · Coordination and cooperation with neighbouring fire brigades · Improved early warning in affected areas · Mobile warning systems inform the population via media and WarnApps	WM/Oth	· (parallel systems exist)	high	low																		
012	Behavioural preparedness and continuing education	Awareness raising and information measures, e.g. · Inclusion of topics specific to climate change in school and vocational training curricula · flood-level marks reminiscent of past flooding events	Oth	· raise acceptance for other measures	high	low																		

N°	Adaptation Option / measure	Short description	Responsible: Watermanagement (WM) / Other (Oth)	Synergies/ conflicts Level of: Synergy potential: high, medium Conflict potential: low, medium, high	Level of Synergies	Level of conflicts	Increased high water	increase winter precip	Fluctuation groundw.	rising water table winter	Increased Erosion	Freq/ intens heavy rain	Increase in flood runoff	Freq.+duration droughts	increased incid.low water	higher demand on water	rising water temp	Nutrient inputs	CC resilience of n ecosys	Increase invasive species	CC in general	Sea-level rise	increase in storm floods	Increased storm surges
Field of action: Urban drainage and wastewater treatment																								
013	Structural improvement and optimised operation of existing sewer networks	Lower flow rate: · Lower flow rate, e.g. flushing as required, hydraulically more effective pipe profiles · Minimisation of mixed-water discharge, e.g. by sewer system control, measures for centralised and decentralised rainwater management	WM	· reduce/minimise impact on WWTP · conflicts: economic - high costs	medium	medium						x		x			x							
014	Adjustments in sewage plant operation	· to cope with heavy rain, e.g. inflow management (minimise polluted overflow)	WM/Oth	· faster treatment with higher temperatures	medium	low						x		x			x							
015	Systems for rainwater treatment	Centralised (e.g. retention soil-filter basin) or decentralised sedimentation shaft, pipe (e.g. sack)	WM/Oth	· synergies with nature conservation, ecosystems	high	low						x		x			x							
016	Centralised and decentralised retention measures in cities	Centralised, e.g.: · Rain overflow basin for storage of mixed water · Retention basins and cisterns for storage and use of rainwater Decentralised, e.g.: · Multifunctional areas for water containment (roads, car parks, playgrounds, etc.), green roofs, green areas (e.g. unpaved tramway lines as lawn strips, lawns, trees, parks, etc.)	WM/Oth	· use of rainwater (· improved micro climate (dep. on measure)) (Conflict: land use)	high	high						x												
017	Utilising infiltration potential	· Construction of infiltration systems and ponds · de-sealing of surfaces, use of water-permeable surfaces, avoiding soil compaction in green areas	Oth	· increased groundwater recharge · improved micro-climate · rising groundwater level/high groundwater	medium	medium						x												
018	Incentives for decentralised rainwater management	e.g. by · splitting of wastewater charges (separate charges for the disposal of wastewater and rainwater), · promoting green roofs, specification for rain retention on building sites	Oth	· increased groundwater recharge · improved micro-climate · rising groundwater level/high groundwater	high	medium						x												
019	Protection of wastewater systems against flooding	· Damming of the plants · Checking the elevation of structures · Flood-proof construction of the mechanical and electro-technical components of the plant	WM/Oth			low						x	x											

N°	Adaptation Option / measure	Short description	Responsible: Watermanagement (WM) / Other (Oth)	Synergies/ conflicts Level of: Synergy potential: high, medium Conflict potential: low, medium, high	Level of Synergies	Level of conflicts	Increased high water	increase winter precip	Fluctuation groundw.	rising water table winter	Increased Erosion	Freq/ intens heavy rain	Increase in flood runoff	Freq.+duration droughts	increased incid.low water	higher demand on water	rising water temp	Nutrient inputs	CC resilience of n ecosys	Increase invasive species	CC in general	Sea-level rise	increase in storm floods	Increased storm surges
Field of action: Heavy rainfall and flash floods management and protection																								
020	Water and sediment retention in outlying areas	e.g. · Restore waterways to a more natural form · Small-scale rockfill in forest water bodies · Transverse channels on forest and field roads · Conversion of farmland to forest or grassland	WM	· more groundwater recharge · nature preservation · soil conservation · responsible: agriculture, forestry, road departments, local authorities																				
021	Retention through changes in silviculture	· Reforestation · Conversion of forests to more deciduous trees (better infiltration conditions than conifers)	Oth	**responsible:** forestry authorities, forest industry, forest owners **synergies:** · erosion protection · soil conservation · climate change mitigation · improved microclimate through increased evaporation																				
022	Barriers between urban and outlying areas	· Longitudinal dikes, embankments · Containment trenches · Special design of rural roads	Oth																					
023	Design of inlet fixtures on slopes	e.g. · Use of efficient slope inlets · Transverse gutters in the street · Facilitating water uptake by steeper transverse gradients of the roads	Oth	· nutrient, pollutant and sediment retention · contributions to achieving the WFD, MSFD and EU biodiversity strategy objectives																				

N°	Adaptation Option / measure	Short description	Responsible: Watermanagement (WM) / Other (Oth)	Synergies/ conflicts Level of: Synergy potential: ● high ○ medium Conflict potential: ● low ● medium ● high	Level of Synergies	Level of conflicts	Increased high water	increase winter precip	Fluctuation groundw.	rising water table winter	Increased Erosion	Freq/ intens heavy rain	Increase in flood runoff	Freq.+duration droughts	increased incid.low water	higher demand on water	rising water temp	Nutrient inputs	CC resilience of n ecosys	Increase invasive species	CC in general	Sea-level rise	increase in storm floods	Increased storm surges
024	Adapted slope management	Runoff and erosion control measures, e.g. · Ground-working and row-planting parallel to the slope · Crop rows in the field parallel to slope · New hedge-planting parallel to slopes · Permanent vegetation · Planting of woodlands, cultivation and care of protective forests	Oth	**responsible:** municipalities, farmers, agricultural associations, forestry offices **conflicts:** · restrictions on land-use **synergies:** · soil conservation · more water storage and infiltration into the ground · nutrient and sediment retention · facilitation of a natural runoff regime thus supporting the objectives of the WFD, Natura 2000 network, MSFD and EU biodiversity strategy	●	●																		
025	Construction and securing of emergency water routes	e.g. · roads with raised kerbstones and overflow ditches	Oth	· restricted accessibility, maintenance costs, compensation of private owners · simultaneous use as temporary water reservoirs		●																		
026	Property protection against the risk of flooding	Precautionary building measures, e.g. · water barriers outside buildings (sills, walls), · protective gates at property entrances, · backflow protection for building and property drainage · No storage of water-polluting substances in areas at risk of flooding (e.g. oil tanks)	Oth	**responsible:** poperty owners synergies: · also protection against flooding caused by high river-water levels · protection against high groundwater levels	○	●																		
027	Organised measures in the event of an extreme situation	Alert and action plans for crisis management, e.g. · Emergency strategies for transportation infrastructures · Flood alerts and action plans · Agreements and cooperation with nearby fire brigades · Mobile warning systems · Targetted communication/activation of recommended action ("not in the cellar") directly before or during the event	WM/Oth		○	●																		

N°	Adaptation Option / measure	Short description	Responsible: Watermanagement (WM) / Other (Oth)	Synergies/ conflicts Level of: Synergy potential: high medium Conflict potential: low medium high	Level of Synergies	Level of conflicts	Increased high water	increase winter precip	Fluctuation groundw.	rising water table winter	Increased Erosion	Freq/ intens heavy rain	Increase in flood runoff	Freq.+duration droughts	increased incid.low water	higher demand on water	rising water temp	Nutrient inputs	CC resilience of n ecosys	Increase invasive species	CC in general	Sea-level rise	increase in storm floods	Increased storm surges
028	Behavioural preparedness and advanced training	Awareness raising and information measures, e.g. Inclusion of topics specifically related to climate change in training curricula · Cross-sector training · Raise awareness, especially in areas with water bodies that have not previously experienced flash floods · Behavioural preparedness, e.g. through drills for evacuation in particularly dangerous situations	Oth	· raise acceptance for other measures	●	●																		
029	Regular maintenance and inspection of drainage systems	· Use of three-dimensional grates · Conduct water inspections · Encourage the public to report blockages. · Removal of sediment accumulation and plant growth	Oth			●																		
030	Performing hazard appraisals	· Creation of local heavy-rain hazard and risk maps · Analyses of heavy-rain hazard and risk maps · More detailed analyses with site visits, local surveys and interviews in threatened areas · Review of the flood risk during the fire-prevention inspection of a building	WM	· synergies with/ in addition to flood hazard and risk maps	○	●																		
Field of action: Groundwater protection and groundwater use																								
031	Climate-change-specific evaluations and adaptation of groundwater monitoring	· Maintenance and expansion of networks of groundwater sampling points, groundwater monitoring, additional parameters (e.g. groundwater fauna) · Observation of the impacts on groundwater of potential changes in vegetation and land use	WM/Oth	· relevance for research · information on the risks associated with high groundwater levels/waterlogging		●																		

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032	Groundwater-protecting agricultural land use (quality and quantity)	Adjust/optimise fertilisation, e.g. · Compliance with the provisions of the Fertiliser Ordinance · Strengthening of agricultural advisory services · Support for organic farming · Precision farming with special consideration to soil condition and soil quality · Use of low-emission fertiliser application techniques · Use of fast-growing plants as catch crops/overwintering crops · Alterations of land uses · Groundwater management planning in agricultural areas	Oth	**conflicts:** · responsible actors, restrictions for agricultural development, economic losses/additional costs · nature conservation · possibly also reduction in greenhouse gas emissions																				
033	Alteration of land uses	· Organic farming · Conversion of arable land to grassland or forestry · Conversion of grassland from intensive to extensive management · Afforestation	Oth	· significance of species-rich grassland as an important conservation asset · reduced risk of erosion · soil protection · climate mitigation · potential reduction in agricultural productivity																				
034	Protection of groundwater-dependent terrestrial ecosystems	· Re-wetting of drained peatlands · Designation of peatlands as nature reserves · Alternative land uses on peatlands · Cessation of agricultural land use on peatlands	Oth	- conflicting land-use -Synergies · climate change mitigation · nature conservation · soil protection · watercourse protection · flood protection · competing land-use																				
035	Measures to promote groundwater recharge	· Provision of water retention areas · Re-wetting of wetlands, restoration of near-natural aquatic structures · Forest conversion towards more deciduous trees · Reduction in the sealing of soil surfaces, increase of green spaces, infiltration potential	Oth	**conflicts:** · responsible actors, restrictions/competing land-users · reduction of surface runoff · flood protection · soil protection																				
036	Measures to increase the available groundwater resources	· Infiltration of treated surface water in infiltration basins	WM/Oth	**(conflicts:** ·competing land-uses, competing demands on river water) · only possible on well-drained soils																				

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037	Sustainable groundwater management	· Management with regard to climate change impacts · Control of the quantities of abstracted groundwater based on groundwater levels · Establishment of minimum local groundwater levels · Depend allocation of water rights on groundwater monitoring	WM/Oth	**conflicts:** allocated water rights, competing water abstraction · meet water demand in times of low water tables Synergies: · nature conservation · protection of built structures susceptible to subsidence	●	●																		
Field of action: Drinking water supply																								
038	Integrating climate change into public water supply planning	· Determination of water resource and demands, and of the supply balances of individual water supply facilities · Asessment of the raw water quality of individual supply facilities	WM/Oth	synergies/basis for measures for groundwater protection	○	●																		
039	Redundant water extraction systems	· Tapping other, additional raw water sources · Development of regional and supra-regional network solutions (group suppliers, special-purpose associations, long-distance suppliers)	WM/Oth	· safeguard against suddenly occurring water quality problems · high cost · utilisation of diverse and large resources		●																		
040	Adaptation of public water supply infrastructure	· Optimisation of existing water supply facilities (e.g. deeper wells) · Establishment of standby extraction systems and safeguarding further extraction options · Creation of greater storage capacities in waterworks and piping networks · Further drinking water treatment · Safeguarding infrastructure in the event of floods / natural hazards	WM/Oth	High costs (**conflicts:** competing land-use when safeguarding further extraction areas)		●																		
041	Rainwater use	· Collection and storage of rainwater in rain barrels, underground cisterns, ponds etc.	WM/Oth	· reduced demand for potable water · rainwater suitability for crops · reduced loading of sewerage, lower sewage charges · Effects on public water price/costs (**conflicts:** private actors/owners, installation costs, land-use)	●	●																		

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042	Reduction of water demand	· optimised water-efficient production processes (industry, water utilities) · Restrictions upon water uses during dry periods · Rainwater harvesting · Multiple use of non-potable water · Incentives through drinking water pricing · Minimisation of pipe system losses · System inspections, maintenance and upgrading	Oth	**(conflicts:** · private actors / users) · long-term cost savings		● red (high)								■										
043	Improving water quality in the pipe system	· Adjustment of system flushing · Supplementary disinfection in storage and distribution · Reduction of warming (e.g. backfilling pipe trenches with material of low thermal conductivity, unpaving surfaces, thermal insulation of pipes	WM/Oth	· · potentially high costs · resource-intense repairs		● orange (medium)								■			■							
044	Further drinking water treatment	· Nutrient reduction · Disinfection · Dilution with less polluted water · Particle removal	WM/Oth			● orange (medium)						■												
045	Whole-area water yield management	· Regional or state-wide water yield management, guided by the priority of public water supply · priority for drinking water supply · Climate-resilient water supply planning · Adapted dam management · Detailed surveys of jeopardised water extraction facilities	WM/Oth	(**conflicts:** competing water demands)		● red (high)			■					■		■								
Field of action: Agriculture and water																								
046	Soil conservation /protection of soils from erosion	Several measures, e.g. · Preventing soil compaction · Humus enrichment · avoiding poaching and overgrazing, establishment of structural elements, e.g. hedgerows, establishment of vegetative strips in areas susceptible to runoff, grass-based farming on slopes at high risk of erosion	Oth	· nutrient supply · protection of watercourses · achievement of WFD objectives · nature conservation · flood protection as a result of improved water retention · wind protection (reduced evaporation and wind erosion) **conflicts:** requirements/restrictions for agricultural use	● green (high)	● red (high)					■	■		■										

N°	Adaptation Option / measure	Short description	Responsible: Watermanagement (WM) / Other (Oth)	**Synergies/ conflicts** **Level of:** Synergy potential: high medium Conflict potential: low medium high	Level of Synergies	Level of conflicts	Increased high water	increase winter precip	Fluctuation groundw.	rising water table winter	Increased Erosion	Freq/ intens heavy rain	Increase in flood runoff	Freq.+duration droughts	increased incid.low water	higher demand on water	rising water temp	Nutrient inputs	CC resilience of n ecosys	Increase invasive species	CC in general	Sea-level rise	increase in storm floods	Increased storm surges
047	Conservation tillage	· Minimum tillage · Strip-tillage/soil loosening · Mulch seeding/direct seeding	Oth	· protection from erosion · protection of watercourses · achievement of WFD objectives · flood protection · nature conservation **conflicts:** · potentially reduced yields · potentially increased requirements for pesticide use	●	●																		
048	Humus enrichment	Several measures, e.g. · Retention of harvest residues on the land · Retention of the natural water regime, foregoing drainage	Oth	· nutrient supply · protection from erosion (**conflicts:** requirements/restrictions for agricultural use)	●	●																		
049	Adaptations in crop production	Measures, e.g. selection of drought-stress tolerant crops, production of winter crops, avoiding large-scale cultivation of crops susceptible to runoff and erosion	Oth	· protection from erosion · efficient land-use · possibly greater yields due to longer growth periods (**conflicts:** requirements/restrictions on agricultural use)	●	●																		
050	Irrigation efficiency	· Drip irrigation · Demand-based irrigation · Precision irrigation	Oth	· optimum irrigation provides optimum conditions for plant nutrient supply · less nitrate leaching compared to over-irrigation · less leaf wetting means that plants are less susceptible to fungal diseases · costly investments into new methods	●	●																		
051	Groundwater substitution	· Utilisation of water from surface waters · Rainwater utilisation	Oth	**conflicts:** aquatic ecology and low water management, land consumption		●																		

N°	Adaptation Option / measure	Short description	Responsible: Watermanagement (WM) / Other (Oth)	Synergies/ conflicts Level of: Synergy potential: ● high ○ medium Conflict potential: ● low ● medium ● high	Level of Synergies	Level of conflicts	Increased high water	increase winter precip	Fluctuation groundw.	rising water table winter	Increased Erosion	Freq/ intens heavy rain	Increase in flood runoff	Freq.+duration droughts	increased incid. low water	higher demand on water	rising water temp	Nutrient inputs	CC resilience of n ecosys	Increase invasive species	CC in general	Sea-level rise	increase in storm floods	Increased storm surges
052	Organisational adaptations in agriculture	· Cross-sectoral, complete recording of licenced abstractions in a single database and recording the actual quantities of water abstracted per annum · Cross-sectoral water resources management plans · Establishment of irrigation associations · Establishment of rules to mitigate the impact of crop failure	Oth	(**conflicts:** competing water demands from different sectors)		● medium						x		x										
053	Forecasting/information	· Improved agri-meteorological forecasting · Good access to GIS-based climate parameters for demanding sectors	Oth	· optimisation of fertiliser and pesticide use · optimisation of labour use · yield increases	● high	● low															x			
Field of action: Cooling water availability																								
054	Installation of alternative cooling processes extensively independent of river flow	· Dry cooling, hybrid cooling, recirculating cooling systems · Cooling tanks/compensating reservoirs · Use of rainwater	Oth	· prevention of steam plume formation · low thermodynamic efficiency · require extensive amount of space · complex instrumentation and control tasks · high operating and investment costs · responsibility of private owners	○ medium	● high									x		x							
055	Erection of additional cooling towers	· Dry cooling, recirculating wet cooling · Hybrid cooling towers	Oth	· low efficiency of air cooling · complex instrumentation and control tasks · high operating and investment costs · responsibility of private owners		● high									x		x							
056	Expanded recovery and use of discharged residual heat	· Use of process heat via district heating networks · Mobile thermal energy storage systems · Development of local heating grids, expansion of integrated heating and cooling networks and groups	Oth	· climate change mitigation · nature conservation · high investment costs · responsibility of private owners and municipalities	● high	● medium									x		x							

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057	Emergency response plans	· Regulation of prioritised water users and energy consumers · Agreements between water resources management authorities and energy producers on emergency response procedures · Formation of an emergency management team	WM/Oth	· nature conservation · water resources conservation · competing river water users	● (high)	● (high)									■		■							
058	Mitigating the impacts of power plant outages	· Power plant networking system · Diverse distributed power generation sources, redundant power generation systems · energy storage systems	Oth	· increased use of renewable resources · potentially more complex power line systems · responsibility of private owners and policy making/regulations	○ (medium)	● (high)									■		■							
Field of action: Navigability of water ways																								
059	Adaptation in an operational context	· small vessels · lighter loads · integrated logistics management (e.g. cooperation with other modes)	Oth	· shift work for crews · reduced transport capacities · extension of routes · larger space requirement · high costs · less capacity · responsibility of private owners / businesses		● (medium)									■									
060	Water level forecasting	· early water level forecasting · timely response to forecasting · access to forecasts	WM/Oth	· flood control · low water management	● (high)	● (low)									■									
061	Adaptation in water resources management	· Water level regulation · Diversion of water into/out of adjacent catchments · Canal system management	WM	· flood control · low water management **conflicts:** · nature conservation · user competition (mainly shipping, nature, tourism, energy)		● (high)									■									
062	Adaptation of waterway infrastructure	· Deepening of the navigation channel and ports · Installation of water-saving locks · Designation of low water navigation channels · Continuous sediment management	WM	**conflicts:** · nature conservation · high level of effort · high costs		● (high)									■							■		■
063	Construction and modification of ships	· e.g. smaller/lighter vessels · Improved manoeuvrability and navigability	Oth	· lower transport capacities · higher investment / transport costs · responsibility of private owners / businesses		● (medium)	■								■									

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Field of action: Dam and reservoir management																								
064	Review and structural optimisation of existing facilities	· Redimensioning of storage zones · Increasing the flood relief capacity · Improving the controllability of the facility · Introduction of climate change design parameters	WM	· sustainability of the measures · cost · relevance to safety evaluation of design uncertainties (e.g. extreme flood events) and safety reserves																				
065	Adaptive dam management	· Regular upgrading and clearing of preimpoundment basins · Appropriate and large-scale management of solid matter · Measures to prevent erosion in the upstream catchment area	WM/Oth	(**conflicts**: upstream catchment measures: land-use, requirements/restrictions for agriculture etc.)																				
066	Adaptive dam management	· Redivision of usage zones · Multi-criteria optimisation in the event of competing usage require-ments · Ecological management: managing the water temperature in the downstream area	WM	· flood control · low water management · public water supply · hydropower generation (**conflicts:** competing sector usage requirements)																				
067	Measures to safeguard water quality	· Prevention of erosion in the upstream catchment area, technical measures, e.g. installation of variable/multiple raw water withdrawal points, aeration of the hypolimnetic water body, pre-cleaning	WM/Oth	· potential deterioration of water quality downstream · high costs · space requirements (**conflicts:** competing land-use and land-use requirements, e.g. in upstream catchment area)																				
068	Systematic combined management of several dams	· Coordinated management of several dams · Construction of collecting works · Construction of transfer systems (e.g. pipelines, ditches, tunnels)	WM	· increased security of the public water supply and low water management in watercourses · ecologically required minimum flow · more stringent management of dams · conflicts of objectives																				
069	Securing further locations for dams/building new dams	· Geographic and hydrological investigations · Modelling and impact analyses · Land acquisition, land designation	WM	· Water Framework Directive acceptance is difficult if concrete need for use does not yet exist · land ownership situation (and competing land/water resource use)																				

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Field of action: Low water management																								
070	Low water and temperature forecasting	· Adjusting the measurement grid and gauges and increased monitoring during low water phases · Creation and extension of forecasting models · Inclusion of water temperature, other waterbody quality parameters in models · More accurate forecasts for smaller at-risk catchment areas, production of worst-case forecasts	WM	· improved models also useful for assessing the impacts of climate change on low water and water temperatures	● green	● green																		
071	Planned measures to be applied if discharge falls below certain levels	· Clarification of responsibilities · Definition of priority uses · Tightening rules governing discharges to water bodies when levels fall below threshold values · Emergency supply plan (for drinking water: e.g. use of tankers, public taps)	WM/Oth	(conflicts: water demand by different sectors, e.g. navigability, agriculture, infiltration)		● red																		
072	Usage restrictions	· Increased monitoring of uses and adaption of approvals under water law · Restrictions on the public use of surface waters · Restrictions on the withdrawal of non-potable water (e.g. for watering gardens) · Regulation of withdrawal for agricultural purposes · Restrictions on leisure use · Advance agreements on usage restrictions, definition of priorities · Targeted communication of restrictions	WM/Oth	· increasing pressure (and conflicts) · complexity of existing water use approvals and established rights		● red																		
073	Measures to safeguard water quality	· Reduction of inputs of nutrients and pollutants · Reduction of the withdrawal and input of cooling water · Providing shade by means of trees on the margins of water bodies · Aeration · Heat load plans and models · Removal of water-retaining works · Raising low water levels	Oth	· liear continuity of watercourses · dynamisation of discharge · conservation of aquatic ecosystems (**conflicts:** falling leaves of trees introduce nutrients, requirements/restrictions on land-use in catchment area)	● green	● red																		

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074	Oxygen management by aeration	Technical measures, e.g. turbine aeration, weir overflow, input of technical oxygen, wastewater aeration of sewage treatment plant discharge	WM/Oth	· high technical and energy costs		medium									■		■							
075	Raising low water levels	· Construction/expansion of water storage systems/dams · Optimised management of existing multipurpose dams · Transfers from adjacent catchment areas	WM	· navigability · hydropower generation · conservation of aquatic ecosystems · competition with flood protection · public water supply · considerable effort and expense	medium	high									■		■							
076	Creating storage capacity	· Retention basins with long-term storage · Dams	WM	· competing land-use · Water Framework Directive		high									■									
077	Promoting natural water retention	e.g. · Provision of flooding areas · Restoration of near-natural waters · Increasing the amount of green space / reducing sealing	WM	· flood control · conservation of aquatic ecosystems · groundwater protection · soil protection (**conflicts**: competing land-use)	high	high									■									
	Field of action: Hydropower generation																							
078	Increasing efficiency	· adjustment of turbines	Oth	· limited potential · high costs		medium	■								■									
079	Flow-balancing measures	· Expansion of storage capacity, retention measures · storage control systems	Oth	synergies: energy storage **conflicts:** · aquatic ecology · Water Framework Directive · competing land uses · various storage requirements and uses	medium	high	■								■									
080	Ecological hydropower	· Identify and maintain minimum flow, adequate leading flows for fish · fish passage facilities, fish-friendly turbines and operations	WM/Oth	synergies: WFD **conflicts:** · high costs · long technical lifespans of old turbines · production losses · "old rights"	high	high								■			■		■		■			
081	Regionalisation of data	· Regionalisation of data on mean and low water levels, with climatic and geographical conditions as explanatory variables in regression	WM			low	■								■									

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082	Adapted load management	· Virtual power plants/smart grids · Integration of renewable energies	Oth	· not in the responsibility of water management		●																		
083	Investing in energy storage technologies	· Pumped-storage plants (· Batteries, "Power to gas" technology	Oth	synergies: for renewable energies **conflicts:** · (aquatic) ecology · landscape appearance · limited number of suitable sites	○	●																		
Field of action: Conservation of aquatic ecosystems																								
084	Improvement of longitudinal connectivity of watercourses	· Construction of passable installations · Removal/conversion of lateral barriers · Optimised control of culverts · Creation of passable groyne fields · Removal of obsolete artificial drainage systems	WM	synergies: · WFD objectives · EU Biodiversity Strategy · improved sediment budget · reduced streambed erosion	●	●																		
085	Alteration of hydromorphological structures	· Removal of streambed and bank stabilisation · Installation of flow control structures · Widening of the stream channel, addition of rocks, etc. · Increasing the channel length · Re-wetting of floodplains, wetlands	WM	synergies: · nature conservation · flood control · WFD objectives · EU Biodiversity Strategy · restoration of a near-natural soil water balance **conflicts:** · balanced sediment balance, sufficiently large coherent networks of watercourse segments needed large-scale and long-term sediment transfer processes may be triggered	●	●																		

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086	Conservation and development of riparian zones	· Planting and development of riparian woodland · Structuring of woodland margins · Planting of reeds · Establishment of riparian zones on arable land	WM/Oth	synergies: · promotion of habitat connectivity · aesthetic landscape design · WFD objectives · MSFD and EU Biodiversity Strategy · soil protection, reducing water erosion of soils, restoration of a near-natural soil water balance **conflicts:** · land-use conflicts with agriculture, forestry, infrastructure · retention effects in the case of flood events on vulnerable sites · planting of species that are as site-appropriate as possible	🟢	🔴																		
087	Establishment of sedimentation barriers	· Green cover in riparian zones · Berms in floodplains	WM	synergies: · potentially improved nutrient supply for plants in riparian areas · WFD objectives · soil protection **conflicts:** · land along watercourses · potential conflicts with conservation objectives in floodplains · potential accumulation of pollutants in the riparian area	🟢	🔴																		
088	Environmentally friendly waterbody maintenance	e.g. · Removal of washed in, deposited material · Preserve streambed sediments and structure to certain extent · Mowing of vegetation and banks to a height of approximately 10 cm · Restricting watercourse clearance to the time outside the periods of spawning, bird breeding, and vegetation and insect development	WM/Oth	synergies: · nature conservation · WFD objectives **conflicts:** · (more costly?)	🟢	🟢																		

N°	Adaptation Option / measure	Short description	Responsible: Watermanagement (WM) / Other (Oth)	Synergies/ conflicts Level of: Synergy potential: high / medium; Conflict potential: low / medium / high	Level of Synergies	Level of conflicts	Increased high water	increase winter precip	Fluctuation groundw.	rising water table winter	Increased Erosion	Freq/ intens heavy rain	Increase in flood runoff	Freq.+duration droughts	increased incid.low water	higher demand on water	rising water temp	Nutrient inputs	CC resilience of n ecosys	Increase invasive species	CC in general	Sea-level rise	increase in storm floods	Increased storm surges
089	Maintenance and expansion of protected areas	· Natura 2000 sites established with a view to maintaining water-dependent habitat types (including bans on watercraft, visitor management, regulation of recreational uses, ...) · Source water protection areas	Oth	synergies: · landscape aesthetics · nature conservation · recreational function **conflicts:** · conflicting land-uses	high	high													x		x			
090	Reducing non-point inputs of pollutants and nutrients	· Support for organic farming · Conservation tillage · Reducing water erosion of soils, optimised fertiliser and pesticide applications · Establishment and development of wide riparian zones · WFD measures/near-natural watercourse design, water retention areas · Increased forest cover · Peatland conservation	Oth	synergies: · nature conservation **conflicts:** · responsibility of other sectors	high	high					x	x												
091	Amendment of threshold values for abstraction and discharge (quantity, quality, water temperature)	· Adjustment of water rights (legal assessment/framework) · Establishment of minimum water flows for power plant discharges · Development of thermal load plans for climate change · Monitoring of water temperatures and pollutants in watercourses	WM/Oth	synergies: · nature conservation **conflicts:** · restrictions on industry and wastewater treatment · ensuring security of supply · not all discharge regimes are flexible · costs incurred	medium	high								x	x		x		x					
092	Water quality warning services	· Introduction of a public warning system for water temperatures and other parameters: pre-warning stage (critical temperatures to be expected shortly), warning and emergency stage · Intensified water quality measurements	Oth	synergies: · relevance of monitoring parameters for research	medium	low								x	x		x							
093	Climate-change-specific evaluations and adaptation of watercourse monitoring	· Monitoring at watercourses that are particularly strongly affected · Evaluation with respect to developments to date	WM/Oth	synergies: · relevance for research **conflicts:** · ongoing costs	medium	low						x	x	x	x		x							