



Common climate scenario baseline

Deliverable 3.6: Climate projections for multi-hazard and multi-sectoral risk assessment (common baseline across cases – final update)

WP3: Dynamic Multi-Sectoral Resilience Modelling and Assessment Framework

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List of abbreviations

AR5/AR6: Assessment Report 'no.' (from IPCC)

CMIP5/6: Coupled model intercomparison project 'no.'

CORDEX: Coordinated Regional Downscaling Experiment

CRCM: Canadian Regional Climate Model

CS: Case study (in the context of Deliverable 3.5; "cs" is sometimes used for "climate services")

ESD: Empirical statistical downscaling

ESGF: Earth System Grid Federation

ESM: Earth system model

GCM: Global climate model

GHG: Greenhouse gas emissions

GRIB: Gridded Binary or General Regularly-distributed Information in Binary form

IPCC: Intergovernmental Panel on Climate Change

LULCC: Land use and land cover changes

ML: Machine Learning

MSDMF: Multi-System Dynamic Resilience Modelling Framework

NetCDF: Network Common Data Form

RCM: Regional climate model

RCP: Representative concentration pathway

SSP: Shared socio-economic pathway

EXECUTIVE SUMMARY

This is the third edition of three deliverables aimed at guiding the implementation of systematic and state-of-the-art climate risk assessments across the nine ARSINOE case studies and the project as a whole.

The document extends deliverable D3.5 (September 2024) and unfolds the common climate scenario baselines used by the ARSINOE case studies.

The report contains three main parts: (i) an overview of how the common ARSINOE climate scenario baseline is used for the implementation of the ARSINOE Multi-System Dynamic Modelling Framework (D6.7), (ii) a summary of the resilience indicators and the corresponding requirements for climate data fulfilled by WP3, and (iii) a preliminary set of climate data analyses carried out at the European and regional scales to support upscaling and cross-evaluation of the case study results including beyond the project's lifetime. The latter will serve as the foundation for publication of ARSINOE's results in an international peer-reviewed journal.

1.0 Introduction

1.1 Scope of the deliverable

This report is the third version of three linked deliverables that underpins the implementation of the ARSINOE Multi-System Dynamic Resilience Modelling Framework (MSDMF) framework (D3.8) across nine case studies. The deliverables present the results of ARSINOE Task 3.3.

The first of the three deliverables (D3.4) was published in Month 12 (September 2022). It contains a description of the SSP/RCP framework (Riahi et al. 2017) used in the 6th Cycle of the Coupled Model Intercomparison Project (CMIP6) (O'Neill et al. 2016). It also provides a summary of available sources of climate projections for use in ARSINOE, including optional recommendations on model and scenario combinations to be used in the initial phase of the project. Finally, it contains

- A set of general guidelines for climate change impact assessments.
- An overview of the different hazard and impact models used within ARSINOE including relevant information on the individual climate baselines and climate data that will be used initially.
- A description and rationale for the “reference scenarios” (climate scenario baseline) to be implemented by all case studies, that is, SSP1-2.6 and SSP3-7.0.

The second deliverable (D3.5) was published in M36 (September 2024). This report provides an update to the climate scenario baseline introduced by D3.4. The updated baseline is based on regional climate projections from the ClimEx-II ensemble of simulations (Asselin et al. 2024) since CORDEX-CMIP6 data was not available for use in the project. In this context, D3.5 comprises the final set of guidelines for implementing the common climate scenario baseline in the case studies (D6.7). This includes:

- A description of the regional climate projections to be implemented by all case studies (ClimEx-II, SSP1-2.6 and SSP3-7.0), including the available time slices (1981-2010, 2071-2100).
- A list of ClimEx-II variables that can be accessed.
- An overview of the data requirements by case study.

Box. Where is the time slice corresponding to the near future (+30 years)?

As indicated in deliverable D3.4 and again in deliverable D3.10, the original ambition of Task 3.3 was to provide climate projections for two different time slices as part of the ARSINOE climate scenario baseline: one that would represent the near future, +30 years from now (mid of century), and one representing the end of century (2071-2100). This was assuming that updated CORDEX-CMIP6 data downscaling the latest generation of global climate simulations, also considered by the Intergovernmental Panel on Climate Change (IPCC) in its latest assessment report, would become available to replace the currently available CORDEX-CMIP5 data.

As reported in deliverable D3.5, such data were never made available, and hence the decision was made to use CORDEX-like climate simulations from the ClimEx-II experiment instead. Unfortunately, this ensemble of climate projections only covers the future period of 2064-2100.

To accommodate this problem and fulfil the needs of the stakeholders (and the urgency of the adaptation and mitigation challenges), case studies should continue to use their original set of climate projections for the near-term period, typical RCP4.5 and RCP8.5 (CMIP5), as discussed already in deliverable D3.4. Thus, due to the short time horizon, scenario uncertainty is likely to play a smaller role, and all the modelling teams have scenarios based on CMIP5 models readily available. For the longer time horizon, the ClimEx-II data will be used.

The aim of this deliverable (D3.6) is to provide contextual information on climate risks in Europe to facilitate comparative analysis across case studies. In the following we therefore investigate the ARSINOE climate scenario baseline from a European perspective, considering different indicators of temperature, precipitation and wind extremes.

1.2 Overview

This deliverable comprises the following material:

- A description of the resilience indicators and data requirements by case study associated with the implementation of the climate scenario baseline (Chapter 2).
- Indicators linked to precipitation extremes based on ClimEx-II climate projections (Section 3.1).
- Indicators linked to temperature extremes based on ClimEx-II climate projections (Section 3.2).
- Indicators linked to wind extremes based on ClimEx-II climate projections (Section 3.3).
- A discussion of extreme event clusters in the climate scenario baseline (Section 3.4).

A list of references is provided as an Annex.

2.0 Climate data requirements for the ARSINOE Wheel

Climate projections from the ClimEx-II ensemble of simulations were used to force all environmental models at the case study level except for CS5 (Canary Islands). Since the Canary Islands are not covered by the EURO-CORDEX domain, statistically downscaled CMIP6 data representing SSP1-2.6 and SSP3-7.0 were used in this case study.

ClimEx-II simulations were made available to all the case studies by LMU (Dr. Andrea Böhnisch). In some cases, the modelling teams pursued postprocessing on their own, while in most cases the climate data was subject to different levels and complexity of preprocessing.

To facilitate the data transfer process, a questionnaire was set up by the WP3 team for collecting the specifications of the climate data needed by each case study (see Annex). The questionnaire was sent to all case study modelers per mail, filled out and sent back to the WP3 team for preparing the data. Using this questionnaire, the case study modelers defined spatial coverage and aggregation, temporal resolution, and variables of interest for their modelling experiments. Also, some case studies asked for more specialized input. The level of preprocessing requested by the different case studies is given in Table 1.

Data was transferred using LMU's globus system, starting in November 2024. In some cases, multiple rounds of exchange and refinement were needed.

Table 2.1 Overview of data needs. The level of pre-processing refers to the climate data that was requested by the different case studies

Case Study	Required climate information	Comments
CS1	Raw data of temperature, wind, precipitation, humidity	No pre-processing (raw model data provided)
CS3	Spatially distributed temperature, precipitation, wind, relative humidity, short-wave radiation	Low level of pre-processing (data extracted/cut to domain and/or temporally/spatially aggregated)
CS4	Monthly precipitation and temperature time series	Low level of pre-processing
CS6 (Aliakmon River)	Precipitation, temperature, humidity, radiation, soil moisture, evaporation data; climate indicators	Medium level of pre-processing (more complex pre-processing steps needed e.g., simple indicator computation)
CS6 (Black Sea)	Wind, radiation, specific humidity, temperature, precipitation, evaporation; data checks	High level of pre-processing (highly complex pre-processing, e.g., extreme value analysis, additional data analysis)
CS6 (Bulgaria)	Monthly precipitation, temperature, evaporation, humidity; climate indicators	Medium level of pre-processing
CS7	Return levels for precipitation across all members	High-level of pre-processing
CS8	Change factors of return levels for precipitation across all members	High level of pre-processing
CS9	Daily minimum, maximum mean, temperatures, precipitation, evaporation, radiation, wind speed; constant fields	Low level of pre-processing

2.1 Model bias

Like most climate model simulations, results from the ClimEx-II ensemble of simulations have a bias. For temperature the ClimEx-II simulations are found to suffer a moderate warm bias (results not shown) when compared to observations or reanalysis. For wind (results not shown), the bias is generally small, although in some locations like along the Black Sea coastline the horizontal resolution (~12 km) of the regional climate model is too coarse to resolve local wind fields realistically, introducing inconsistencies.

For precipitation, the ClimEx-II simulations are found to be significantly biased in some locations. To exemplify, Figure 2.1 shows the annual precipitation in larger (hydrological) Bavaria as simulated by ClimEx-II with or without bias correction.

No general bias correction of the data was carried out. Instead, bias correction of the ClimEx-II data was performed at the case study level, by the local modelling teams, to ensure optimal results.

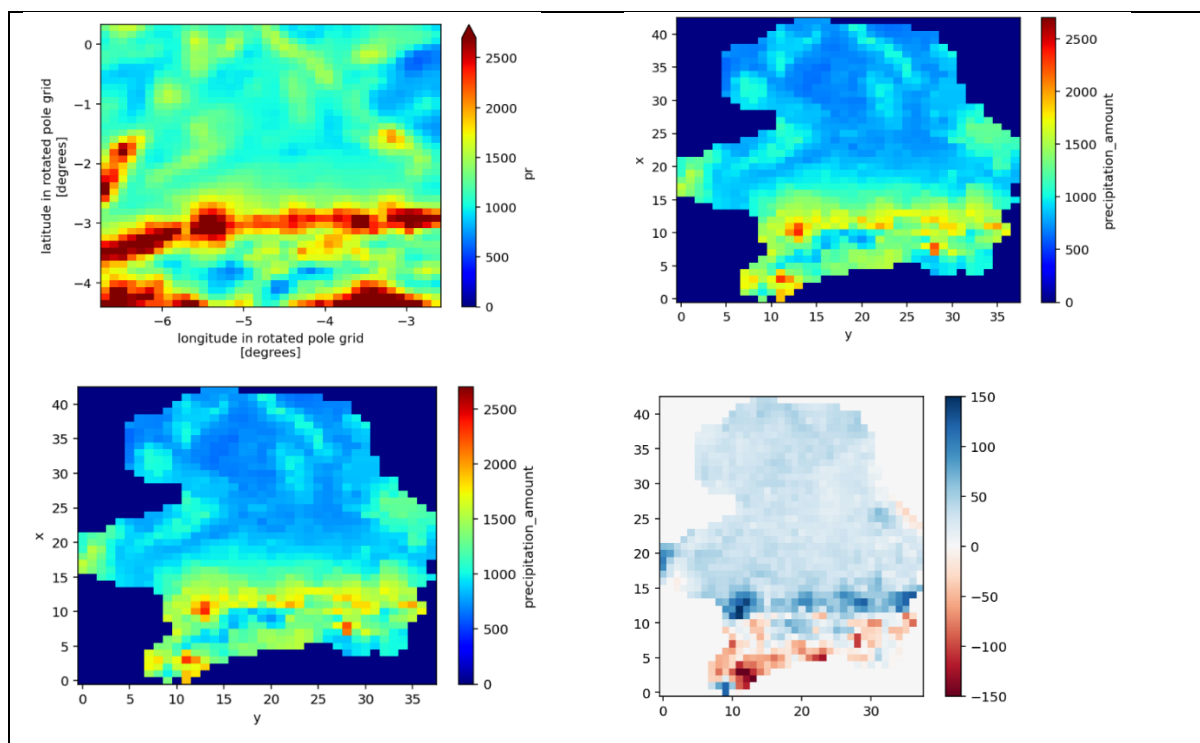


Figure 2.1 Annual precipitation in larger Bavaria (mm/year, 1981-2010). The upper left panel: one of the ClimEx-II ensemble members (epp); upper right panel: a reference data set based on interpolated station data; lower left panel: the climate data (epp) after bias correction; lower right panel: the climate data (epp, before bias correction) minus the reference data set

2.2 Resilience indicators

Tables 2.2-2.10 compile the climate resilience indicators defined in D6.7. They are reproduced here for the benefit of the reader. Between 4 and 13 indicators are defined within each of the ARSINOE case studies (including sub-case studies). While each indicator set is unique for a particular (sub-)case study, all the individual resilience indicators represent one of the following common dimensions: Social (Soc), Environmental (Env) or Economic (Eco). The indicators are described qualitatively below. They are calculated at the case study level using local- or regional-scale models from the base climate variables listed in Table 2.1. For more detailed information about the indicators, and how they are modelled from the climate data shown in Table 2.1, we kindly refer to D6.7.

Table 2.2 CS1 (Athens Metropolitan Area)

KPI	Description
1.1 Env	Mean air temperature
1.2 Soc	Vulnerable population (population living at postcodes with a socio-economic vulnerability index at or above the 75th percentile of the socio-economic vulnerability index) exposed to category 2 heatwave and above (see D6.7 for further information)
1.3 Soc	Vulnerable population (population living at postcodes with a socio-economic vulnerability index at or above the 75th percentile of the socio-economic vulnerability index) exposed to category 3 heatwave and above (see D6.7 for further information)

1.4 Soc	Population exposed to category 2 heatwave and above (see D6.7 for further information)
1.5 Eco	Economic vulnerability as a function of cooling degree days. Cooling Degree Day (CDD) is a climatological index describing the amount of energy required for indoor cooling (air-conditioning)

Table 2.3 CS2 (Mediterranean Ports)

KPI	Description
2.1 Soc	Weighted Health Risk Score (see D6.7 for further information)
2.2 Env	Change in offshore significant wave height – 1-year return period
2.3 Env	Change in offshore significant wave height – 100-year return period
2.4 Env	Change in mean wave agitation inside the port basin
1.5 Eco	Change in mean annual downtime at critical berths
1.6 Eco	Weighted Operational Downtime Risk Score (this is calculated by multiplying the sensitivity and likelihood of each hazard that affects economic activity and summing the results)

Table 2.4 CS3 (Main River Basin)

KPI	Description
3.1 Soc	Heat exposure: number of hot days per year in the region
3.2 Soc	Flood exposure: number of days per year above the current high flow with 20-year return period (HF20) at gauge Kleinheubach
3.3 Env	Hydrological drought conditions: number of days with baseline mean flow that are required to compensate for discharge deficit at gauging station Kleinheubach
3.4 Env	Plant available water: ratio of real evapotranspiration (ETR)/potential evapotranspiration (ETP) during hydrological summer period
3.5 Eco	Hydropower potential: mean flow at gauging station Kleinheubach/Main in m ³ /s

Table 2.5 CS4 (Ohrid and Prespa Lakes)

KPI	Description
4.1 Soc	Reduced availability of water for supply of households in the Prespa region, presented in [m ³ /annually], in relation to the reference period.
4.2 Env	Natural area affected - Reduced area covered with flora and fauna [m ²], dried out as a consequence of lowered water level of the Prespa Lake
4.3 Eco	Reduced availability of water for supply of dominant economy sector in the Prespa region (agriculture), presented in [m ³ / annually]; resulting in suppressed growth of sector's GDP
4.4 Eco	Reduced availability of water for electricity generation in HPPs cascade on the Drin River (outflowing from the Ohrid Lake), presented as a reduced generation of clean energy [GWh / annually]

Table 2.6 CS5 (Canary Islands)

KPI	Description
5.1 Soc	Total Groundwater Extraction: Measure of annual groundwater use
5.2 Env	Groundwater Extraction: Tracks usage relative to recharge rates
5.3 Env	Average Annual Precipitation: Regional variability in water input
5.4 Eco	Net Water Budget: Tracks the balance between water resources and demand over time

Table 2.7 CS6 (Black Sea)

KPI	Description
6.1 Soc	(Bulgaria) The percentage of local and seasonal population impacted by degraded water quality (based on bathing water classifications and proximity of settlements to key monitoring sites).
6.2 Env	(Bulgaria) Ecological capacity of the river measured through its ability to self-purify and restore good ecological status before reaching the Black Sea (assessed via sensor and lab data).
6.3 Eco	Estimated loss in economic activity linked to tourism due to poor water quality (referencing regional tourism statistics and potential service disruptions)
6.4 Soc	(Greece) Population Exposure: Percentage of the population affected by shifts in water quantity due to climate variability and flood-related risks
6.5 Eco	(Greece) Ecological Capacity: Water body's capacity to retain good ecological status compared to the quantity of water it receives
6.6 Eco	(Greece) Economic Impact: Estimated financial losses in economic sectors (e.g. agriculture, hydropower, tourism) due to deteriorating water availability
6.7	(Romania) Water Quality Index (on site measured data for Turbidity, Dissolved Oxygen and Chlorophyll)
6.8	(Romania) Water Quality Index (satellite data)
6.9	(Türkiye) Seasonal and interannual variability of algal blooms - Chlorophyll-a concentrations reach up to 20 mg/m ³ over the northwestern shelf, influenced by nutrient-rich inputs from major rivers (e.g., Danube, Dniepr). In the southwestern nearshore areas, values are typically between 1–2 mg/m ³ depending on local runoff and seasonal stratification (see D6.7 for further information)
6.10	(Türkiye) Oxygen concentration - Below the pycnocline (~80m) oxygen rapidly declines. Suboxic conditions (<20µM) typically develop between 80-120 m and anoxic transition (<2µM) is reached below 120m. These layers are expanding in both thickness and duration under future scenarios, especially in stratified shelf region (see D6.7 for further information)
6.11	(Türkiye) Hypoxic area extent - The hypoxic zone (Dissolved Oxygen < 63 µM) develops seasonally in intermediate layers of the Black Sea
6.12	(Türkiye) Projected changes in Net Primary Production (NPP) - NPP peaks at 140–240 mmol C/m ² /day in spring. POC flux to deeper layers increases under future scenarios
6.13	(Türkiye) Sea Surface Temperature (SST) anomaly. The SST in the southwestern Black Sea is expected to increase by +1.8 to +2.4 °C by 2080–2100 under SSP3–7.0 relative to the 2000–2020 baseline (see D6.7 for further information)

Table 2.8 CS7 (Southern Denmark)

KPI	Description
7.1 Soc	The number of buildings affected by flooding: the total number of homes, businesses, or other buildings in Esbjerg municipality statistically impacted by flooding
7.2 Soc	The number of people affected by flooding: the total number of people in Esbjerg city statistically impacted by flooding
7.3 Soc	The number of vulnerable people affected by flooding: the total number of vulnerable people in Esbjerg city, measured by the average yearly disposable income in a “neighborhood” in 2020 relative to the average yearly disposable income in Esbjerg municipality as a whole. This may be considered a measure of equity.
7.4 Soc	The number of people living in areas characterized by a high Social flood Vulnerability Index (SVI): a national index developed by the Danish Coastal Authority, which aims to capture both direct wellbeing loss due to flooding as well as indirect wellbeing loss due to flood-related critical service disruptions
7.5 Env	The susceptibility of vulnerable urban and rural nature to flooding: the total geographical area representing vulnerable urban and rural nature that is affected by flooding within the geographical domain of interest

7.6 Eco	Damage costs of flooding: the total economic damage costs of flooding across different building categories. While other socio-economic sectors like transport, health, tourism, recreational areas and agriculture may also contribute to the total costs, losses associated with flooded properties are generally the most significant. Calculated at the municipal level.
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Table 2.9 CS8 (Torbay)

KPI	Description
8.1 Soc	Number of properties flooded: the total count of homes, businesses, or other buildings that have been affected by flooding
8.2 Soc	Population and vulnerable communities are affected: the total number of people impacted by a specific event. This can include people who have suffered injuries or loss of access to basic services, loss of livelihoods etc. Specific groups will be at higher risk due to social, economic, or health related factors
8.3 Env	Flood extent areas beyond a specific threshold: the total geographical area covered by floodwater during a flooding event
8.4 Eco	Critical infrastructure assets and critical service affected: physical and digital systems that are crucial for national security, economic stability, and public safety

Table 2.10 CS9 (Sardinia)

KPI	Description
9.1 Soc	Average variation in yield: changes in future food production capacity
9.2 Soc	Year-to-year yield variability: risks for food stability and safety
9.3 Env	Irrigation demand: water pressure could affect the sustainability of high-quality food production
9.4 Eco	Yield stabilization: stable production of at least 2 t/ha as a global challenge for food supply

2.3 Extreme value analysis

Extreme precipitation statistics for CS6, CS7 and CS8 were calculated from the ClimEx-II data using extreme value analysis (Coles 2001).

Climate change factors to scale present day precipitation extremes were derived for the following return levels: 5, 10, 20, 50, 100, 200, 500 and 1000 years. We used a peak-over-threshold (POT) technique with a threshold = 35 mm/day. Single events were considered as being independent if they were separated by at least 120 hours. To increase the sample size, we pooled all members and the three locations per period/scenario. We fitted a Generalized Pareto distribution with L-moments using the R software package: extRemes v2.2 (Extreme Value Analysis by E. Gilleland, 2024).

The climate change factors (CFs) for SSP1-2.6 and SSP3-7.0 are defined as the ratio between the future and current return level (values):

$$CF(\text{scenario vs. reference}) = \text{return level}(\text{scenario, value}) / \text{return level}(\text{reference, value})$$

3.0 The ARSINOE climate scenario baseline

The following sections / figures yield insight into the shared ARSINOE climate scenario baseline at European level by means of multiple climate indicators (Table 3.1). The indicators depict different properties of the climate scenario and are intended as references spanning all nine case studies while allowing for “upscaling” ARSINOE results beyond the project as well.

To compensate for the fact that no bias correction is performed, most of the indicators listed below are presented as climate anomalies, that is, as the *difference between future and present model values*

rather than as absolute values. This at least partially compensates for model biases. For temperature anomalies, differences are expressed in absolute terms (degrees); for precipitation and wind anomalies, differences are expressed in percentages.

In this report, indicators are generally provided for summers (JJA) and winters (DJF) during a reference period (1981-2010) and two projected climate futures: SSP1-2.6 and SSP3-7.0 (2071-2100). While the projections do not cover a near-future period on the time axis, SSP1-2.6 can be interpreted as a low-warming future that is closer to current warming levels than SSP3-7.0, i.e., a near-future horizon on a “global warming axis” (see Gampe et al. 2024 for comparing time axis and global warming axis). Any change signals are a consequence of global warming that complies with SSP1-2.6 or SSP3-7.0 (greenhouse gas only, no land use/land cover changes implemented, cf. D3.5). In all instances, results derived from the four different ensemble members were averaged to obtain the indicators/figures shown below. The dots indicated in the maps represent the location of an ARSINOE case study. Note that CS5 (Canary Islands) is located outside the (European) domain of the regional climate model CRCM5 (Leduc et al. 2019).

Table 3.1 Climate indicators / scenario baseline. The reference period is (1981-2010); the future scenario periods: SSP1-2.6 and SSP3-7.0 (2071-2100)

Base variable	Indicator	Short name
Precipitation	Very heavy precipitation days > 20 mm/day (Figure 3.1.1-3.1.4)	R20
Precipitation	Water balance (Figure 3.1.5-3.1.8)	TH48
Precipitation	Wettest Day (Figure 3.1.9-3.1.12)	Rx1day
Precipitation	Maximum Consecutive Wet Days (Figure 3.1.13-3.1.14)	CWD
Precipitation	Maximum Consecutive Dry Day (Figure 3.1.15-3.1.16)	CDD
Temperature	Hot days (JJA) (Figure 3.2.1-3.2.2)	
Temperature	Hot nights (JJA) (Figure 3.2.3-3.2.4)	
Temperature	Cold days (DJF) (Figure 3.2.5-3.2.6)	
Wind	Winter (DJF) days when the daily surface maximum wind speed exceeds the historical 99th percentile (q99) threshold (Figure 3.3.1-3.3.2)	Q99

3.1 Precipitation extremes

3.1.1 Very heavy precipitation days (R20)

We define days with very heavy precipitation as calendar days with more than 20 mm/day (R20). We analyze the ensemble mean of the 30-year mean of seasonal sums per period (1981-2010, 2071-2100 for SSP1 and SSP3; greenhouse gas-only simulations). For climate change signals, we compute the relative change between SSP1/SSP3 and the reference period.

During summers, R20 occurs only rarely in the nine case study regions, and neither in large parts of the European continent (< 3 days/season) as shown in Figure 3.1. Higher sums (3-7 days/season) are related to mountainous regions and mountainous forelands, but not exclusively. Extreme precipitation during summers is often tied to (thermal) convective processes which are not directly linked to orography.

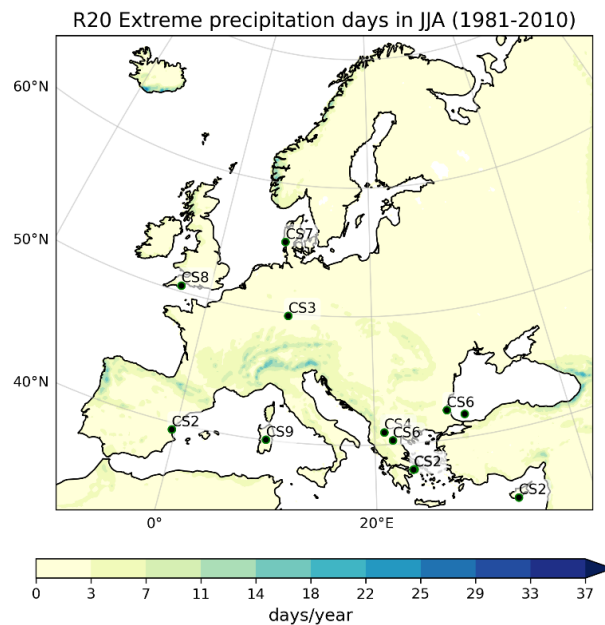


Figure 3.1.1. Very heavy precipitation days during summer (JJA) under current conditions (ensemble average).

Figure 3.1 Very heavy precipitation days during summer (JJA) under current conditions (ensemble average)

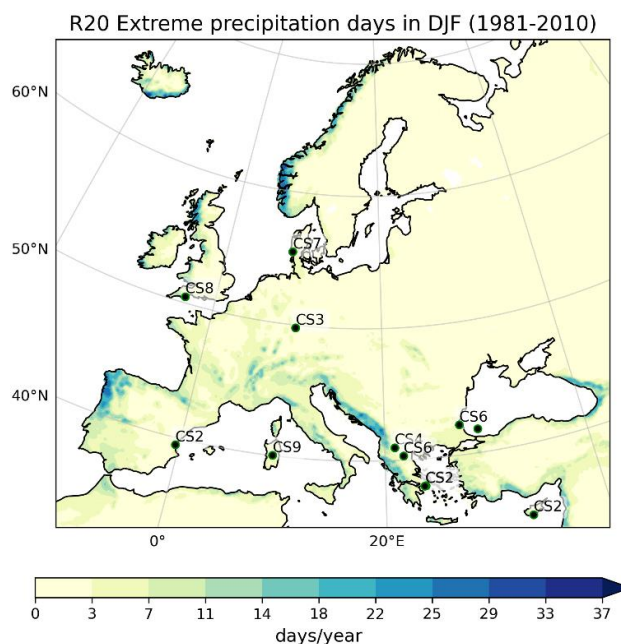


Figure 3.2 Very heavy precipitation days during winter (DJF) under current conditions (ensemble average).

During winters, R20 days are most frequent in the windward (western) parts of coastal and mountainous regions as shown in Figure 3.2. This points towards orographic lifting processes of moist airmasses that are advected from the Atlantic as the major causes for intense precipitation, resulting in up to 37 days per winter. In the case study regions, R20 occurs 3-7 times per season.

Trends:

During summers, the frequency of R20 increases across large parts of Europe in both SSPs in agreement with the higher water holding capacity of warmer air masses (Clausius Clapeyron relationship) (see Figure 3.3). The spatial pattern of changes is similar in both scenarios (a decrease in the Atlantic and Mediterranean regions, increase in western/central and eastern Europe), but more pronounced under SSP3, with particularly strong increases in Northern Europe (80-100 % increase). CS3, CS4, CS6, and CS7 are projected to experience up to 30 % (SSP1) or 60 % (SSP3) more R20 days, whereas R20 days occur less frequently in CS2, CS1, CS8 and CS9 by up to 30 % (SSP1) or 60 % (SSP3). The reductions could be attributed to less available water during JJA.

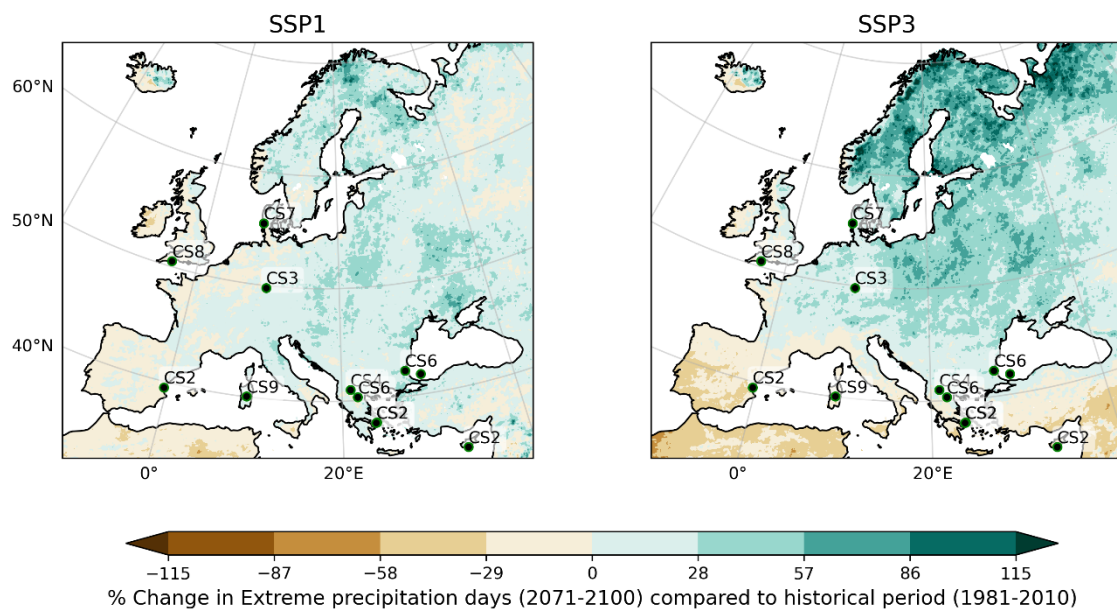


Figure 3.3 Ensemble average percentage change of very heavy precipitation days per summer (JJA)

Winters are characterized by a widespread increase in R20 days across Europe, mainly on the western sides/regions of the mountains (Figure 3.4). These are regions in which R20 is relatively frequent even under current conditions. The frequency increases are seen to be more pronounced than during summer, as is the present frequency. R20 frequency more than doubles in some Northern European regions in SSP1 and in nearly all of Northern Europe in SSP3. Central and Eastern Europe experiences frequency increases by up to 60 % under SSP1 and up to 90 % under SSP3. Western and Mediterranean regions are subject to reductions by up to 30 % under both scenarios. This means that in particular CS3, CS4, CS6, and CS7 will experience up to 30 % (SSP1) and 60 % (SSP3) more R20 days, whereas CS1, CS2, CS8 and CS9 are located in regions with frequency decreases by up to 30 % in both SSPs, or very close to transitional regions in which the signal may not be significant.

For both summer and winter, we caution that the weak trend classes should be treated carefully because of potentially considerable internal climate variability.

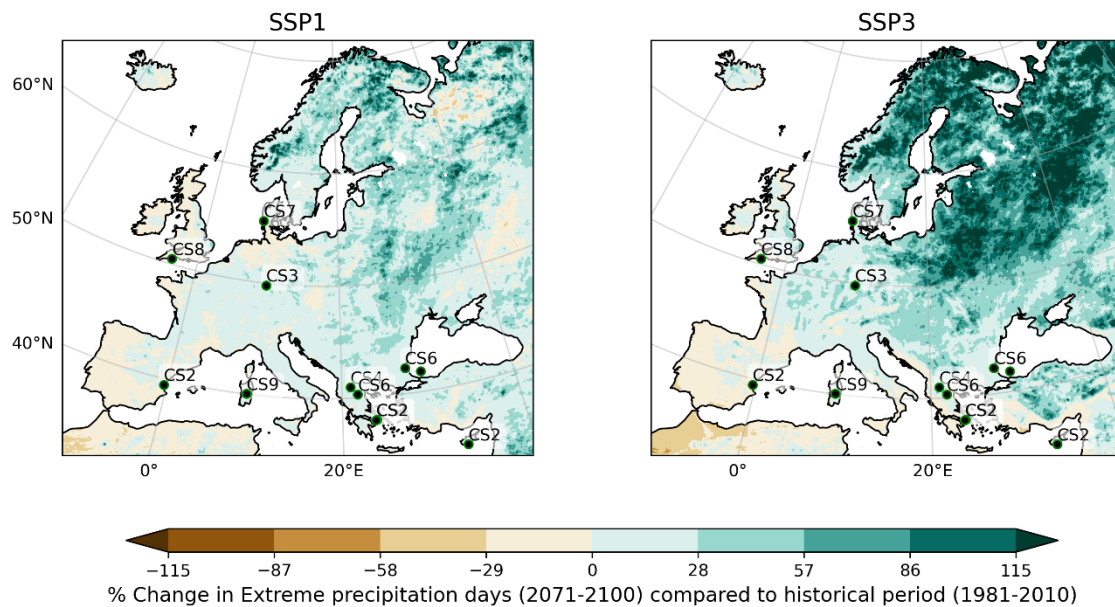


Figure 3.4 Ensemble average percentage change of very heavy precipitation days per winter (DJF)

3.1.2 Water balance

The climatological water balance (the difference between precipitation and potential evapotranspiration) is used as an indicator to describe the seasonal water availability across Europe. The computation of potential evapotranspiration is based on Thornthwaite (1948). It accounts for climate change signals in both precipitation and temperature. Here we show the ensemble mean of the 30-year mean of seasonal sums per period (1981-2010, 2071-2100 for SSP1 and SSP3; greenhouse gas-only simulations). For climate change signals, we compute the relative change between SSP1/SSP3 and the reference period.

Under current conditions, the summer water balance is positive in the western part of Europe (Atlantic region to central Europe), but negative towards the continental regions and the Mediterranean (Figure 3.5). The highest values are found in mountainous regions. A negative water balance (i.e. $PET > PR$) indicates moisture limited conditions. The case studies are mostly located in regions with negative water balances (CS1, CS2, CS9) or close to areas with sign changes (CS3, CS4, CS6, CS7, CS8) which indicates caution when reporting the sign (e.g., due to signal being partially masked by climate variability).

During the winter months, the water balance is positive across Europe, with the highest values found on the western sides of mountain ranges and with a general decreasing gradient towards the east (Figure 3.1.6). Thus, all case study regions are in principle located in areas with positive climatological water availability. Under these conditions, $PR > PET$ is because of more moisture availability and/or less energy availability to drive potential evapotranspiration.

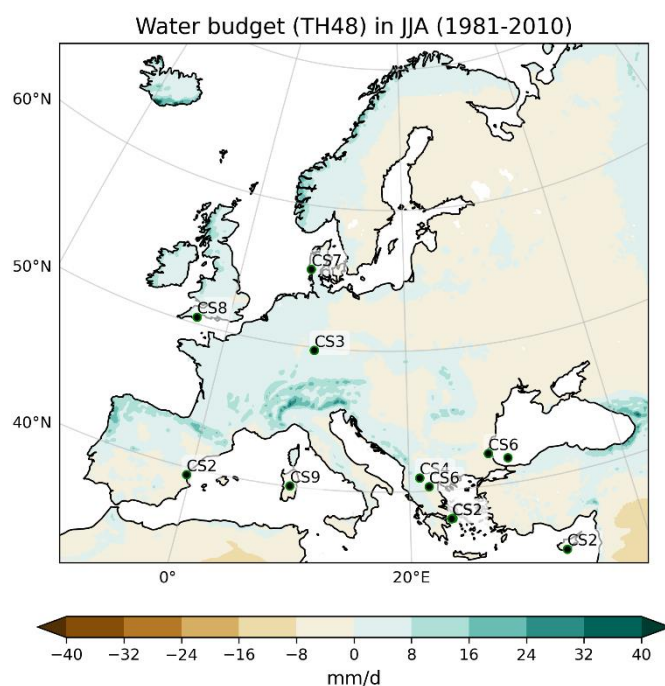


Figure 3.5 Water budget during summer months (JJA) under current conditions (ensemble average)

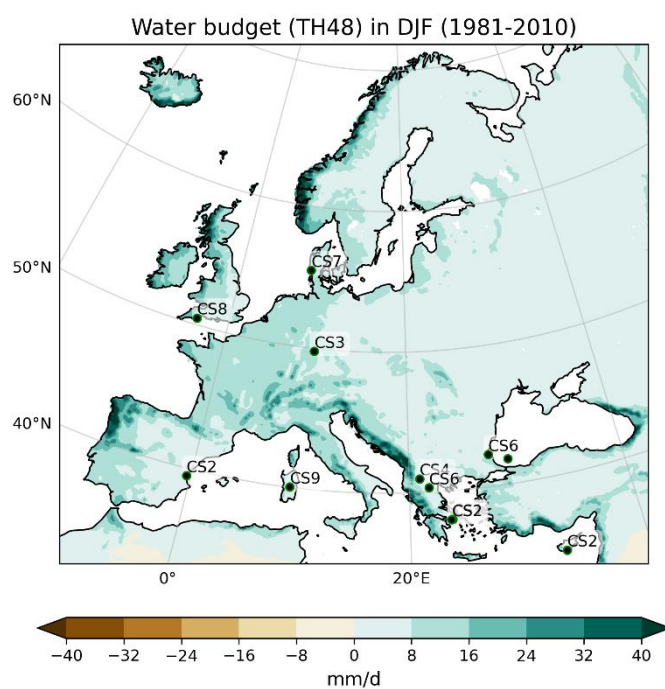


Figure 3.6 Water budget during winter months (DJF) under current conditions (ensemble average)

Trends:

The trends of the water balance during JJA show similar patterns for both SSP1 and SSP3 (Figure 3.7), with more pronounced signals in SSP3, particularly in the northeastern part of the domain and on the Iberian Peninsula. Regionally, relative changes of large magnitude and different signs occur in proximity, corresponding to areas with low absolute water budget values, often with the opposing sign in the reference period. Also, regionally, trends intensify current conditions, e.g. in western and central-eastern Europe. Positive trends can be found in areas with a currently negative water balance such as southern Spain, Sweden, Finland and western Russia. Negative trends can be found in areas where currently the water balance is positive such as Northern Spain, Great Britain and Ireland, Iceland and western Scandinavia. Under SSP1, two subcases of CS6, CS7 and CS8 experience decreasing water availability (up to -60%), whereas CS1, CS2, CS3 and CS9 can experience increases by up to $+60\%$. CS4 and one subcase of CS6 are located too close to areas of signal change to infer trends. Under SSP3, the distribution is similar except for CS4 showing up to -60% and two subcases of CS6 showing positive trends.

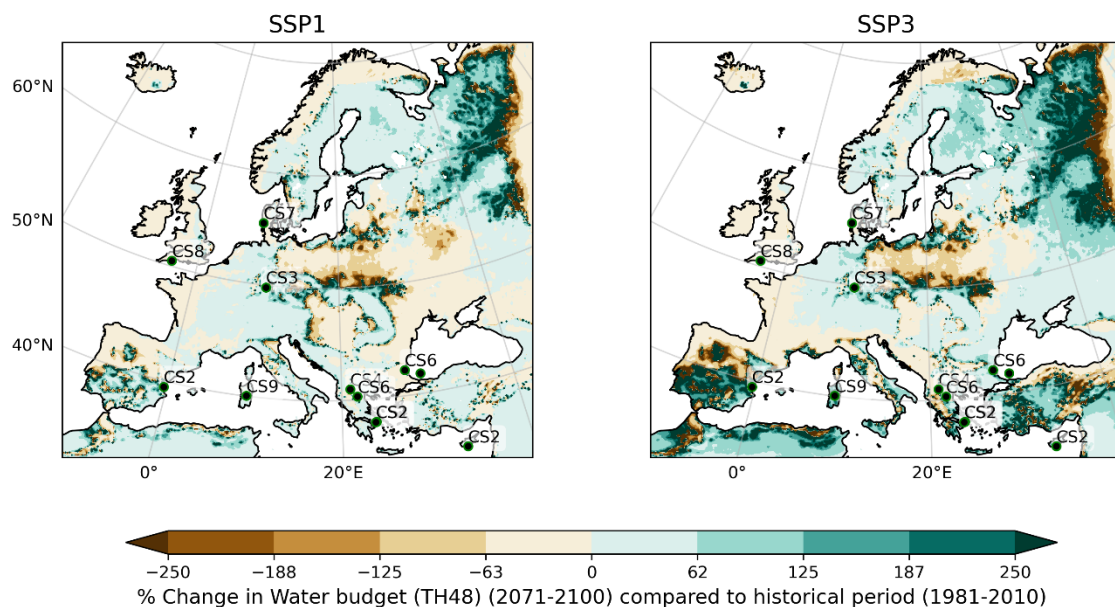


Figure 3.7 Ensemble average percentage change of water budget during summer (JJA)

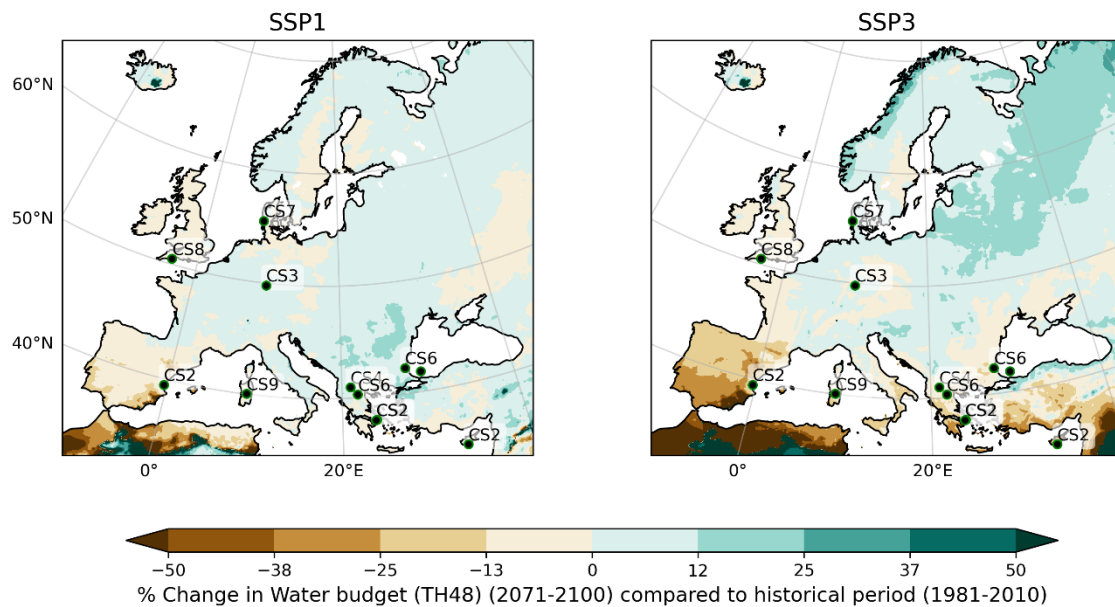


Figure 3.8 Ensemble average percentage change of water budget during winter (DJF)

During winter months, the range of trends is smaller than for summer months. Under SSP1, most of Europe is subject to water balance increases of up to +12 %, except for the Atlantic and parts of the Mediterranean regions, and some areas in central Europe and Scandinavia. Among the case studies, CS3, CS4, and CS6 experience positive changes, whereas CS1, CS2, CS7, CS8, and CS9 are subject to negative changes under SSP1. Under SSP3, we see changes that are more pronounced, particularly in western Scandinavia, Northeastern Europe and western Russia and the Iberian Peninsula and Turkey. Here, CS1, CS2, CS4, CS6, CS8 and CS9 experience a decreasing water balance; only CS3 experiences (partly) an increase of the water balance.

Given that the water balance is positive across the entire domain under current conditions and changes are not exceeding 100 %, the absolute water balance is projected to be still positive but reduced compared to present conditions.

3.1.3 Wettest Day (Rx1day)

The relative change in Wettest Day (Rx1day) precipitation was calculated separately for the summer months (JJA) and the winter months (DJF). For each year in the historical period (1981–2010), the seasonal maximum daily precipitation was identified, and a mean value was computed across years and model realizations to obtain the historical Rx1day ensemble average. Using this historical ensemble average for Rx1day, the number of days exceeding the historical threshold was computed for each season individually. This process was repeated for the future period (2071–2100), using the same historical thresholds to determine the number of exceedance days. An ensemble average of the number of exceedances was then calculated for the historical and future periods separately to obtain a mean value across the separate realizations. Finally, the mean historical and future exceedances were compared to determine the relative change in Rx1day.

The number of days exceeding Rx1day in the historical period is calculated as the days exceeding the ensemble average Rx1day over the period 1981-2010 for winter and summer (Figures 3.9 and 3.10). There is, to a large degree, no discernible spatial pattern in the number of exceedances during the historical period. However, we can see a greater number of exceedances over the Alps and the

mountainous regions of Norway during winter, and we see a greater number of exceedances over Southern Europe, particularly Spain and the Mediterranean region, during summer.

The percent change in days exceeding Rx1day in the SSP1 and SSP3 scenarios (2071 – 2100) is shown in Figures 3.1.11 and 3.1.12.

During winter, large increases (>75%) are found across many portions of Europe for the SSP3 scenario, particularly over Northern Europe, Eastern Europe, Spain, and the Mediterranean region. The smallest increase is concentrated over Central Europe. For the SSP1 scenario, the largest increases in the number of days exceeding Rx1day follow a similar pattern as the high-end emission scenarios, particularly over Northern and Eastern Europe.

During summer, an increase in the number of days exceeding Rx1day in the SSP3 scenario is concentrated over Central, Northern, and Eastern Europe. Conversely, in the southern portion of the domain across Spain and the Mediterranean, a large decrease in the number of days exceeding Rx1day is projected. In the SSP1 scenario, there are large parts of Europe that witness an increase in the number of days exceeding Rx1day with notable exceptions over areas of Spain and Portugal.

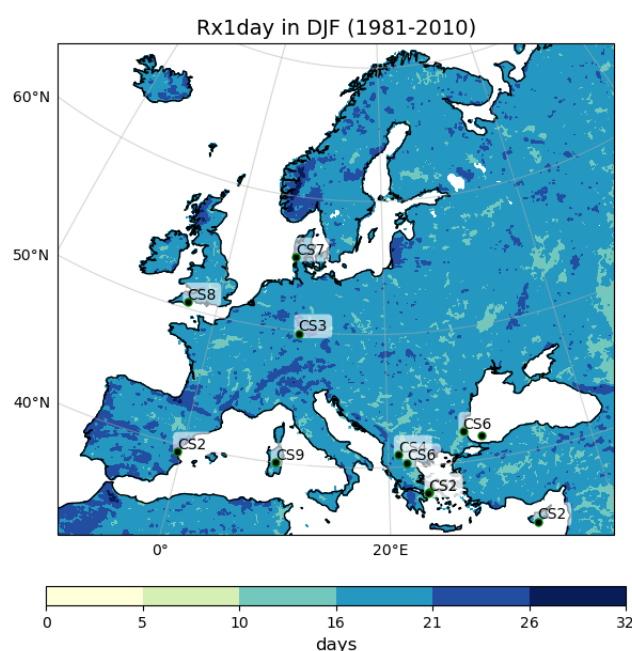


Figure 3.9 Total number of days exceeding Rx1day (ensemble average) during winter (DJF) under historical conditions (1981-2010)

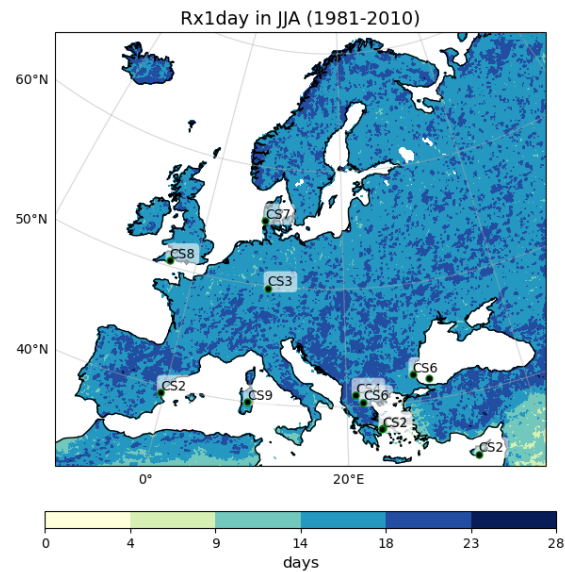


Figure 3.10 Total number of days exceeding Rx1day (ensemble average) during summer (JJA) under historical conditions (1981-2010)

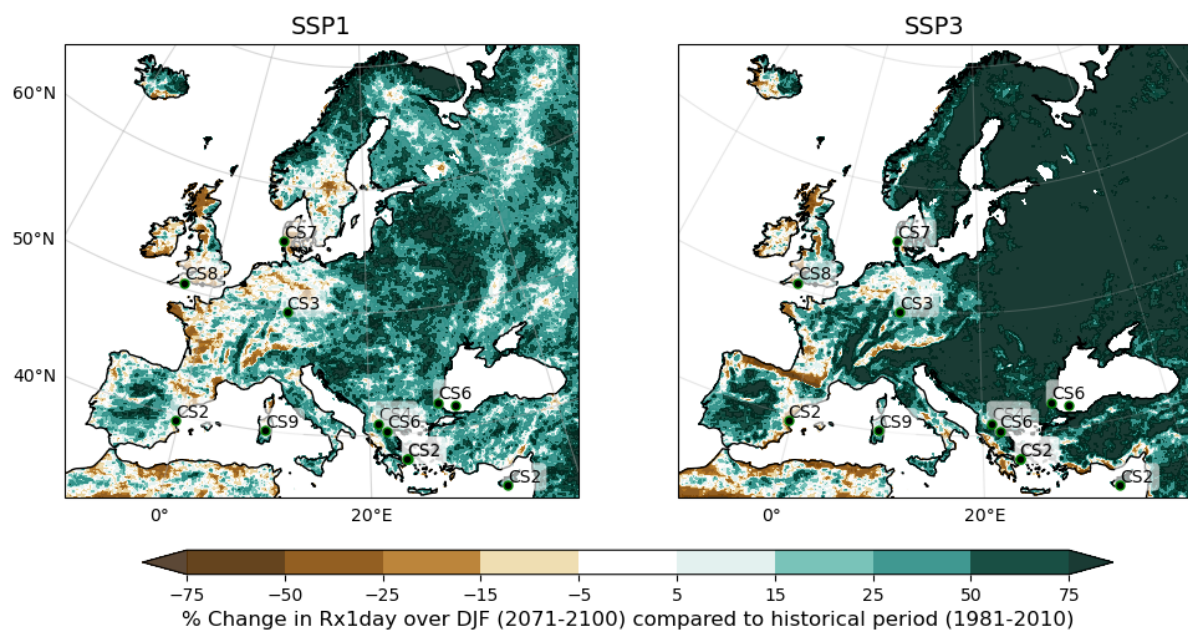


Figure 3.11 Percent change in the number of days exceeding Rx1day during winter (DJF) in the SSP1 and SSP3 scenarios (2071 – 2100)

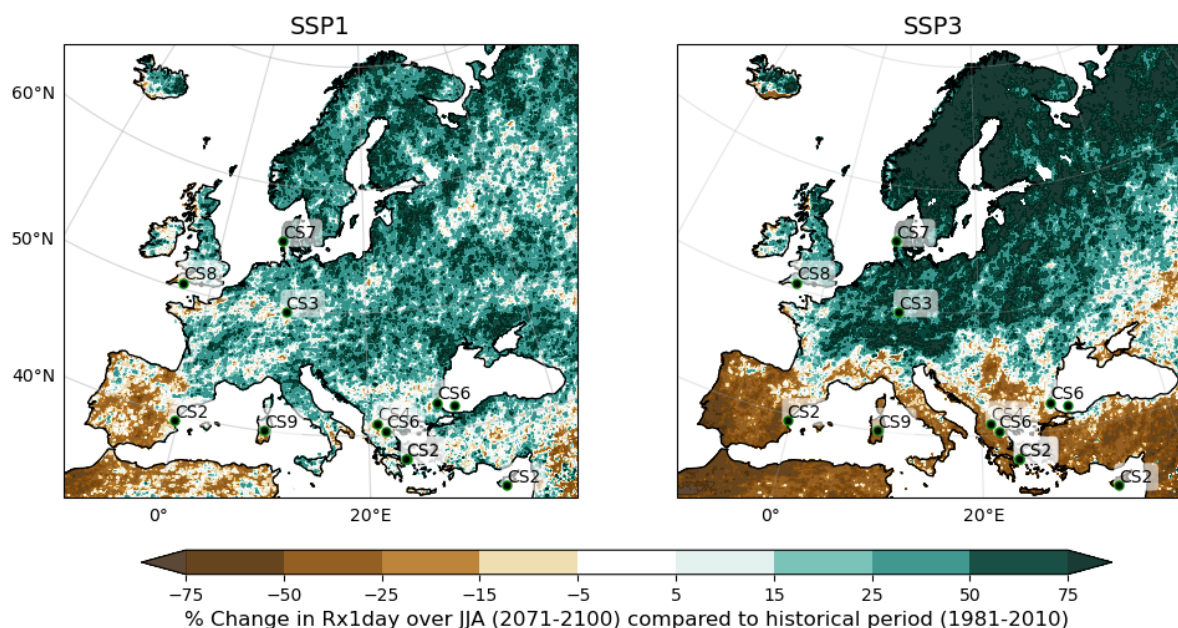


Figure 3.12 Percent change in the number of days exceeding Rx1day during summer (JJA) in the SSP1 and SSP3 scenarios (2071 – 2100)

3.1.4 Maximum Consecutive Wet Days (CWD)

The relative change in the maximum consecutive number of wet days (CWD) was calculated for the winter months (DJF). For each year in the historical period (1981–2010), the maximum CWD for DJF was calculated using the function *maximum_consecutive_wet_days* from the python package *xclim*. A wet day is defined as any day with a daily precipitation value above 1 mm of precipitation. Afterwards, a mean value was computed across years and model realizations to obtain the historical ensemble average. This process was repeated for the future period (2071–2100), resulting in a mean value representing the future CWD ensemble average. Finally, the ensemble average maximum CWD for the historical and future periods were compared to determine the relative change in the maximum consecutive wet days.

The maximum number of consecutive wet days in the historical period is calculated over the period 1981–2010 for winter (Figure 3.1.13). Regions showing the largest number of consecutive wet days during winter are concentrated over areas located close to the Atlantic ocean, specifically the Iberian Peninsula, Western Europe, Ireland, the United Kingdom, and the mountainous regions of Northern Europe.

The percent change in maximum consecutive wet days in the SSP1 and SSP3 scenarios (2071 – 2100) is shown in Figures 3.14.

During winter, in the SSP3 scenario, the largest increase in the maximum number of consecutive wet days is concentrated over Eastern Europe, with increases projected over Northern Europe and the Iberian Peninsula as well. A decrease in the maximum number of consecutive wet days is noted across the coastal regions of the Mediterranean. Similarly, for the SSP1 scenario, the largest increases are projected over Eastern Europe, with areas of Central Europe also exhibiting an increase.

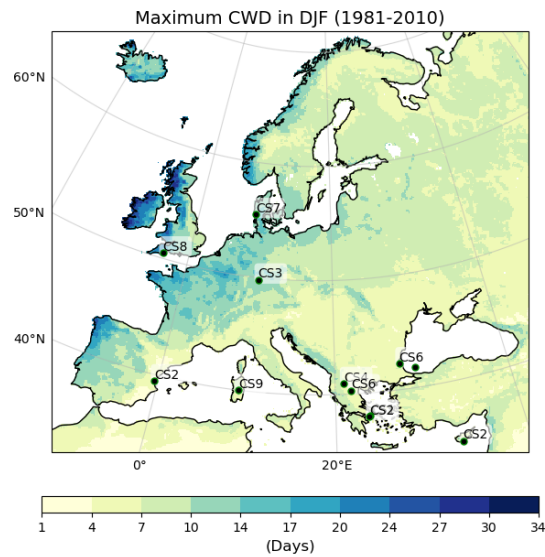


Figure 3.13 Maximum consecutive wet days (ensemble average) during winter (DJF) under historical conditions (1981-2010)

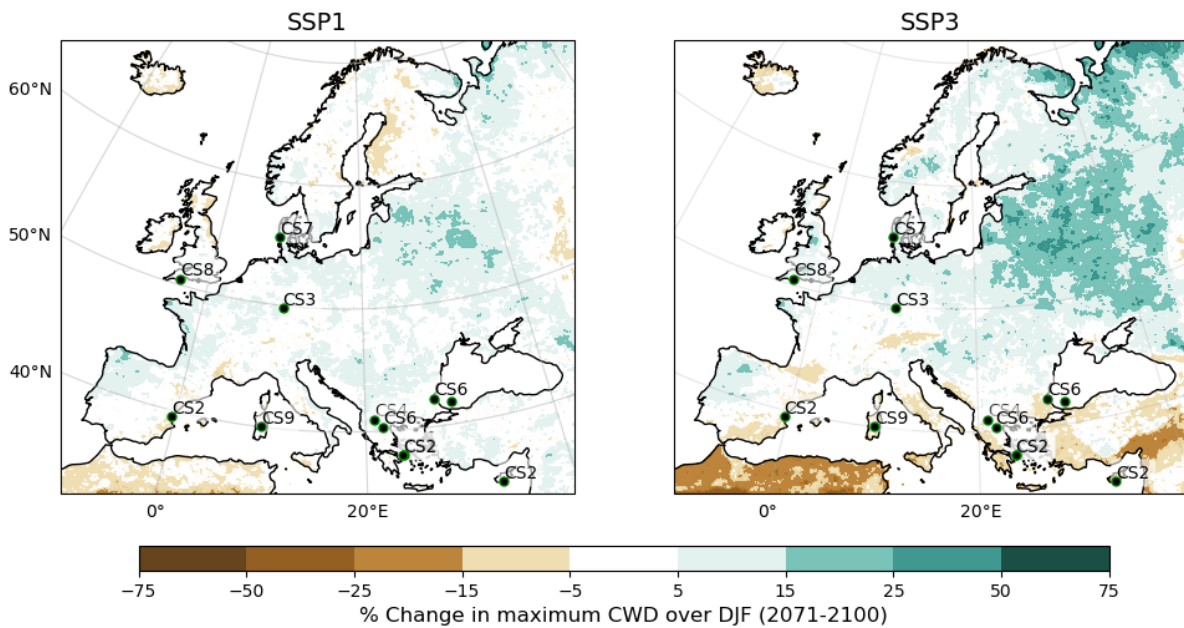


Figure 3.14 Percent change in maximum consecutive wet days during winter (DJF) in the SSP1 and SSP3 scenarios (2071 – 2100)

3.1.5 Maximum Consecutive Dry Days (CDD)

The relative change in the maximum consecutive dry days (CDD) was calculated for the summer months (JJA). For each year during the historical period (1981–2010), the maximum CDD for JJA was calculated using the function *maximum_consecutive_dry_days* from the python package *xclim*. A dry day is defined as any day with a daily precipitation value below 1 mm of precipitation. Afterwards, a mean value was computed across years and model realizations to obtain the historical ensemble average. This process was repeated for the future period (2071–2100), resulting in a mean value representing the future CDD ensemble average. Finally, the ensemble average maximum CDD for the historical and future periods were compared to determine the relative change in the maximum consecutive dry days.

The maximum number of consecutive dry days in the historical period is calculated over the period 1981–2010 for summer (Figure 3.1.15). Regions showing the largest number of consecutive dry days during summer are concentrated over southern Europe, particularly the Iberian Peninsula and the Mediterranean region.

The percent change in maximum consecutive dry days in the SSP1 and SSP3 scenarios (2071 – 2100) is shown in Figures 3.16.

During summer, in the SSP3 scenario, an increase in the maximum number of consecutive dry days is widespread over the continent, but the largest increase is projected over Southern Europe, particularly the Iberian Peninsula and the Mediterranean region. A decrease in the maximum number of consecutive dry days is noted across the coastal and mountains areas of Norway. Similarly, in the SSP1 scenario, large areas of Europe exhibit an increase in the number of consecutive dry days. Central Europe sticks out as a region exhibiting a slight decrease in the number of consecutive dry days.

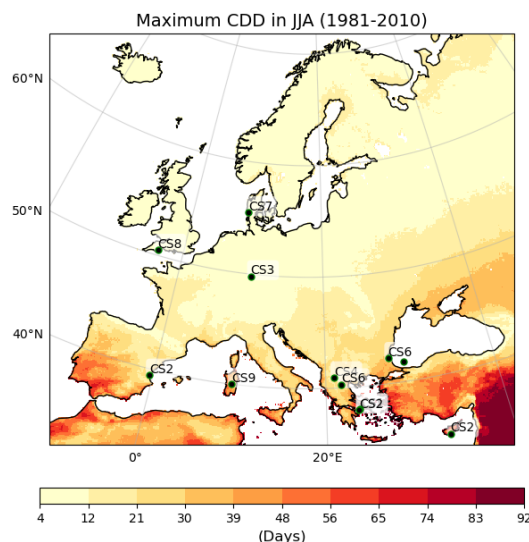


Figure 3.15 Maximum consecutive dry days (ensemble average) during summer (JJA) under historical conditions (1981–2010)

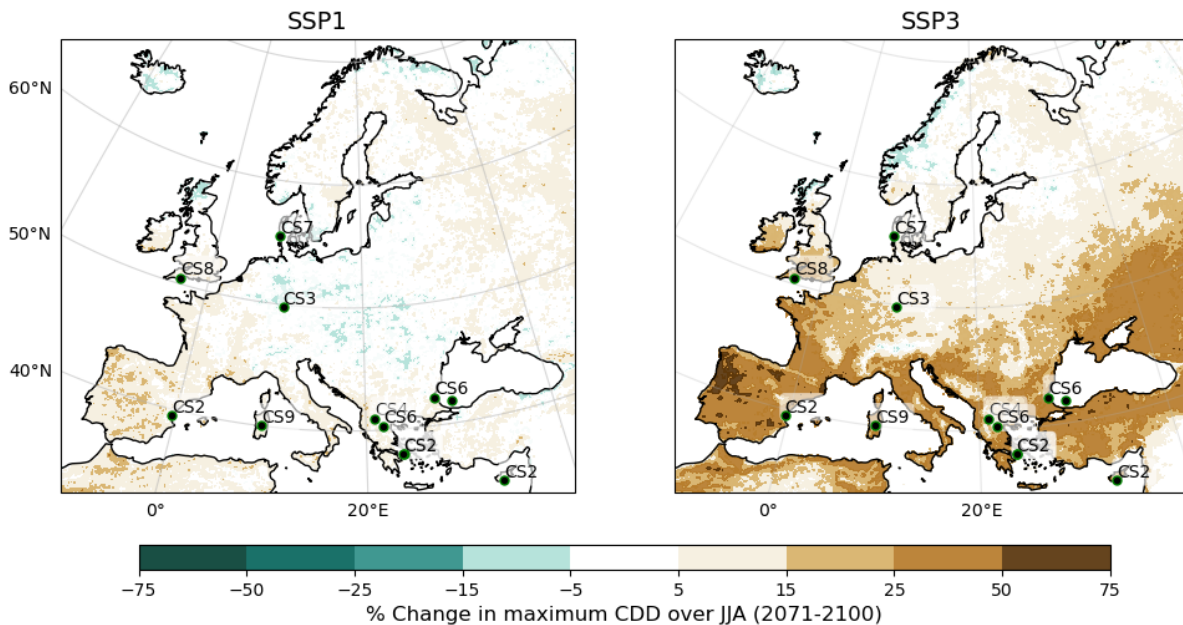


Figure 3.16 Percent change in maximum consecutive dry days during summer (JJA) in the SSP1 and SSP3 scenarios (2071 – 2100)

3.2 Temperature extremes

Three types of temperature extremes are assessed: hot days, hot nights and cold days. The hot days and hot nights are calculated over the summer months (JJA) whereas cold days are calculated over the winter months (DJF).

3.2.1 Hot days (JJA)

The number of hot days is calculated as the number of days where the maximum daily temperature exceeds a threshold during JJA. The threshold is calculated from the historical simulation (1981 – 2010) as the 0.95 quantile (q95) of maximum daily temperature in JJA (Figure 3.17). q95 is highest in the south of Europe with values between 33°C - 38°C. Mountainous regions have the lowest q95 with values between 9°C - 14°C. In central Europe, q95 varies between 28°C - 33°C.

The percent change in number of hot days in the SSP1 and SSP3 scenarios (2071 – 2100) is shown in Figure 3.18. In the SSP3 scenario, an increase of 500% in the number of hot days is found in large parts of southern Europe. The increase is lowest (100-150%) in Central Europe. In the SSP1 scenario, the increase in number of hot days is more moderate than in SSP3, with the highest increase (100-150%) found in South and North Europe and lowest increase (5-25%) found in Central Europe.

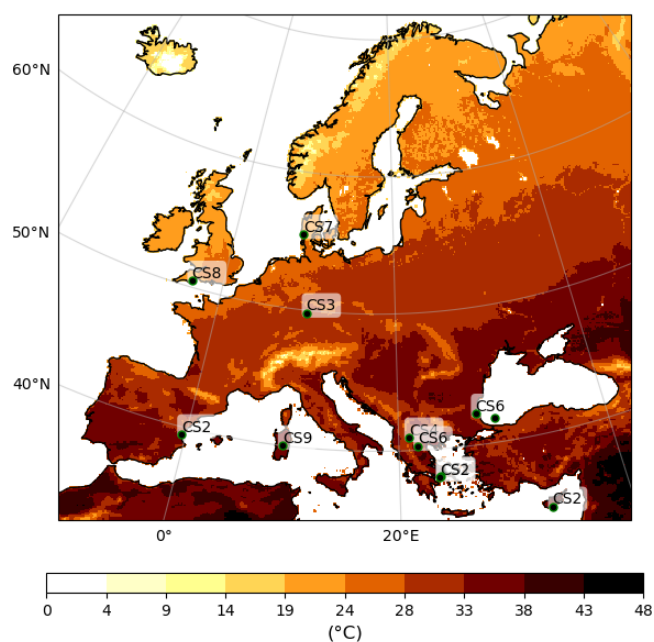


Figure 3.17 0.95 quantile (q95) of maximum daily temperature in JJA (1981 – 2010)

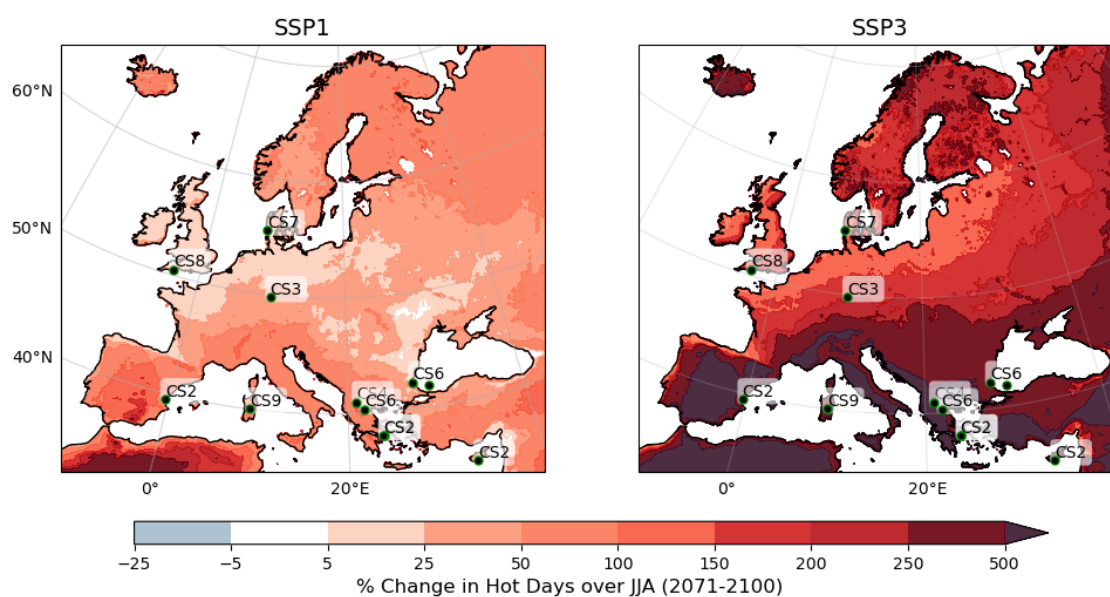


Figure 3.18 Percent change in number of hot days in the SSP1 and SSP3 scenarios (2071 – 2100)

3.2.2 Hot nights (JJA)

The number of hot nights is calculated as the number of days where the minimum daily temperature exceeds a threshold during JJA. The threshold is calculated from the historical simulation (1981 – 2010) as the 0.95 quantile (q95) of minimum daily temperature in JJA (Figure 3.19). Similarly to the q95 values of daily maximum temperature, the q95 of daily minimum temperature is highest in the south of Europe (between 17°C - 23°C) and lowest in mountainous regions (5°C - 8°C). In central Europe, q95 varies between 14°C - 17°C.

The percent change in number of hot nights in the SSP1 and SSP3 scenarios (2071 – 2100) is shown in Figure 3.20. In both the SSP1 and SSP3 scenarios, there is a greater increase in the number of hot nights compared to the increase in the number of hot days. In the SSP3 scenario, the increase in number of hot nights is greater than 250% in all of Europe and in the SSP1 scenario, the increase in number of hot nights is greater than 100% in all of Europe.

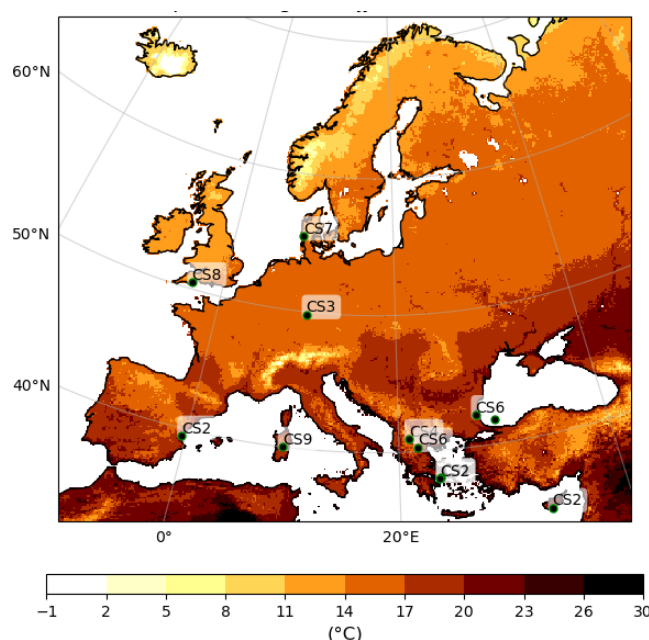


Figure 3.19 0.95 quantile (q95) of minimum daily temperature in JJA (1981 – 2010)

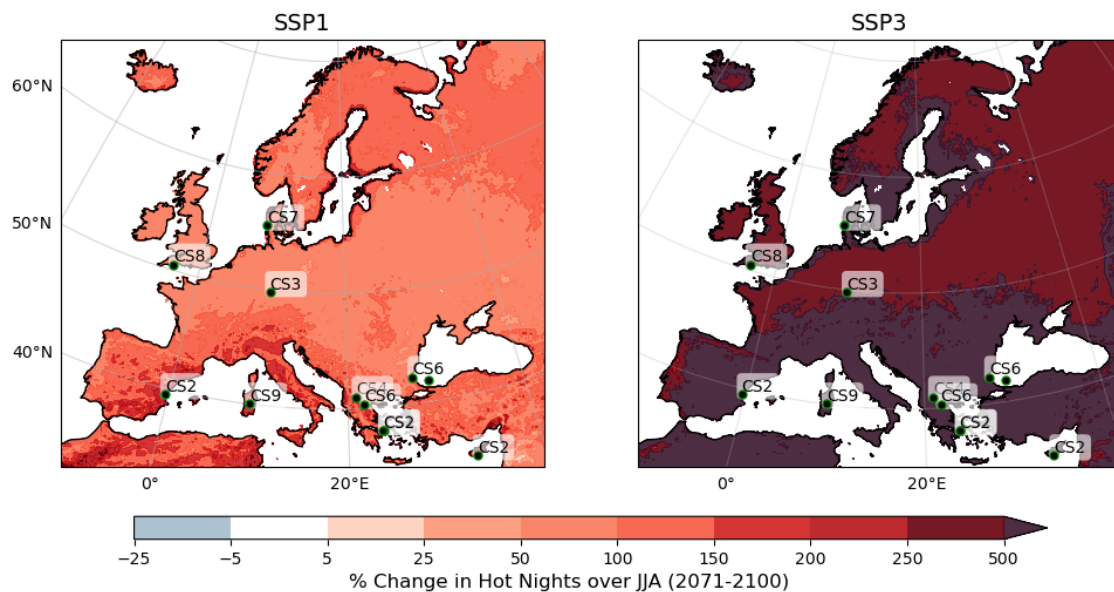


Figure 3.20 Percent change in number of hot days in the SSP1 and SSP3 scenarios (2071 – 2100)

3.2.3 Cold days (DJF)

The number of cold days is calculated as the number of days where the minimum daily temperature is below a threshold during DJF. The threshold is calculated from the historical simulation (1981 – 2010) as the 0.05 quantile (q5) of minimum daily temperature in DJF (Figure 3.21). An east to west pattern can be identified, with a gradient in the q5 of minimum daily temperature from between -3°C and 3°C in the southwest of Europe to between -33°C and -44°C in northeast Europe.

The percent change in number of cold days in the SSP1 and SSP3 scenarios (2071 – 2100) is shown in Figure 3.22. In the SSP3 scenario, the decrease in the number of cold days of greater than 75% is found in all parts of Europe compared to between 25% and 75% in most of Europe in the SSP1 scenario.

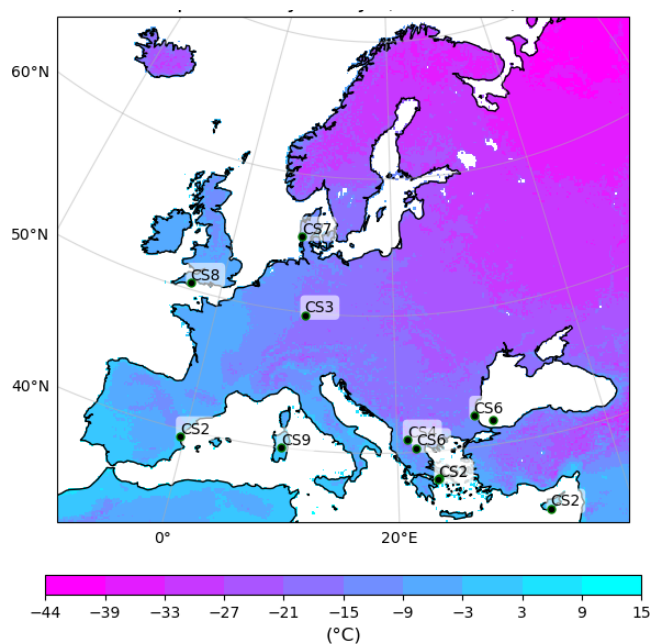


Figure 3.21 0.05 quantile (q5) of minimum daily temperature in DJF (1981 – 2010)

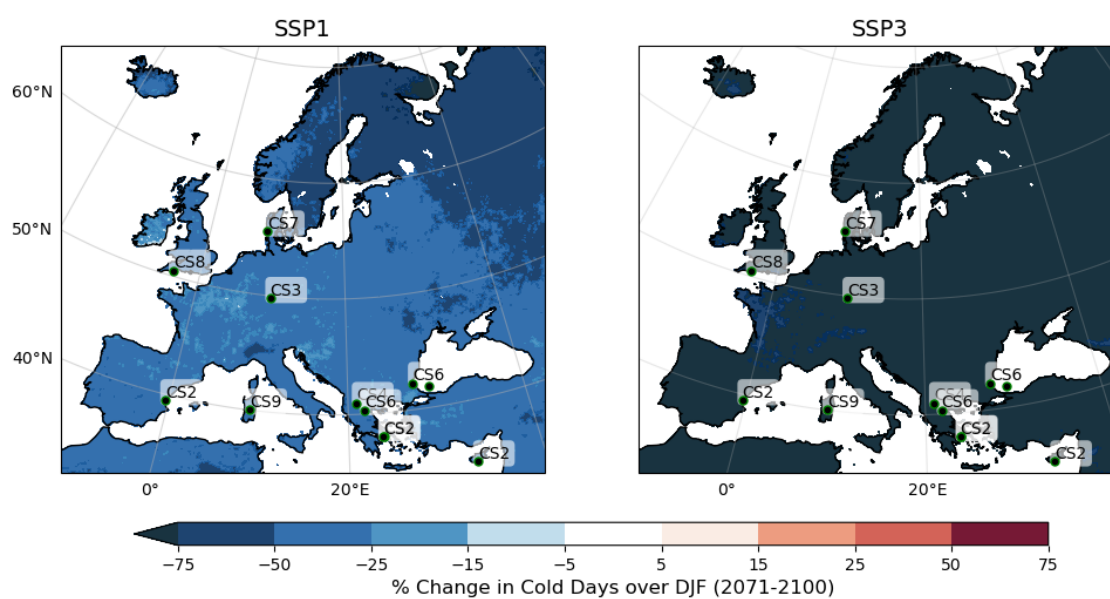


Figure 3.22 Percent change in number of cold days in the SSP1 and SSP3 scenarios (2071 – 2100)

3.3 Wind extremes

In this analysis, wind extremes (windy days) are defined as winter (DJF) days when the daily surface maximum wind speed exceeds the historical 99th percentile (q99) threshold, calculated over the 1981–2010 reference period. Figure 3.23 shows the ensemble average of these q99 wind speed thresholds for Europe. The highest values are found in the northwestern coast of Europe, particularly along the British Isles, the Atlantic coast of France and Norway, and the Netherlands, where q99 wind speeds range between 20–33 m/s. These regions are frequently impacted by extratropical cyclones, making them particularly vulnerable to extreme wind events. The influence of these storms extends into central and northern Europe, with q99 values around 15–20 m/s in Germany, Poland, and the Baltic countries. Lower q99 wind speeds are observed over mountainous regions such as the Alps, as well as across southern and interior parts of Europe, except for some river valleys in the Italian and Iberian Peninsulas, where q99 values can be locally large.

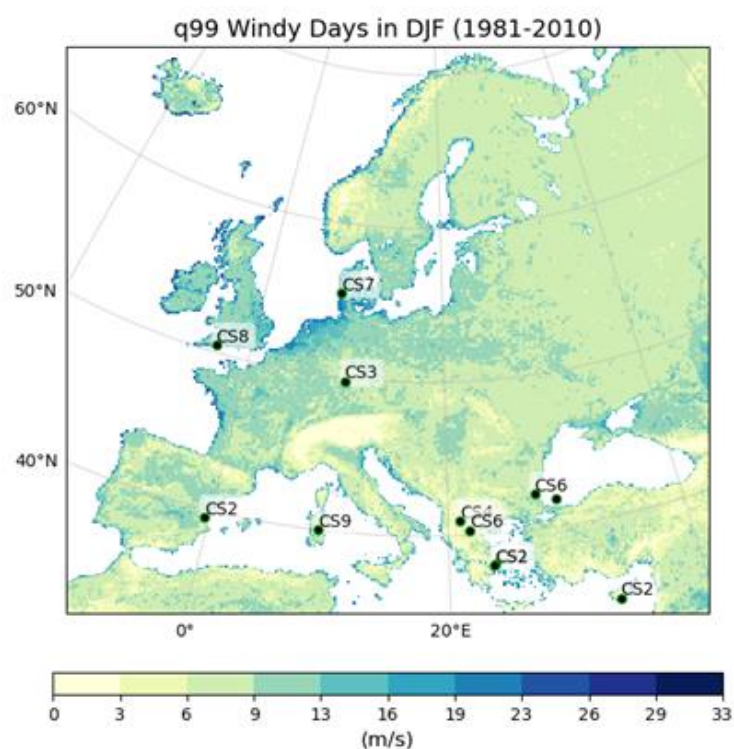


Figure 3.23 0.99 quantile (q99) of maximum daily wind speed in DJF (1981 – 2010)

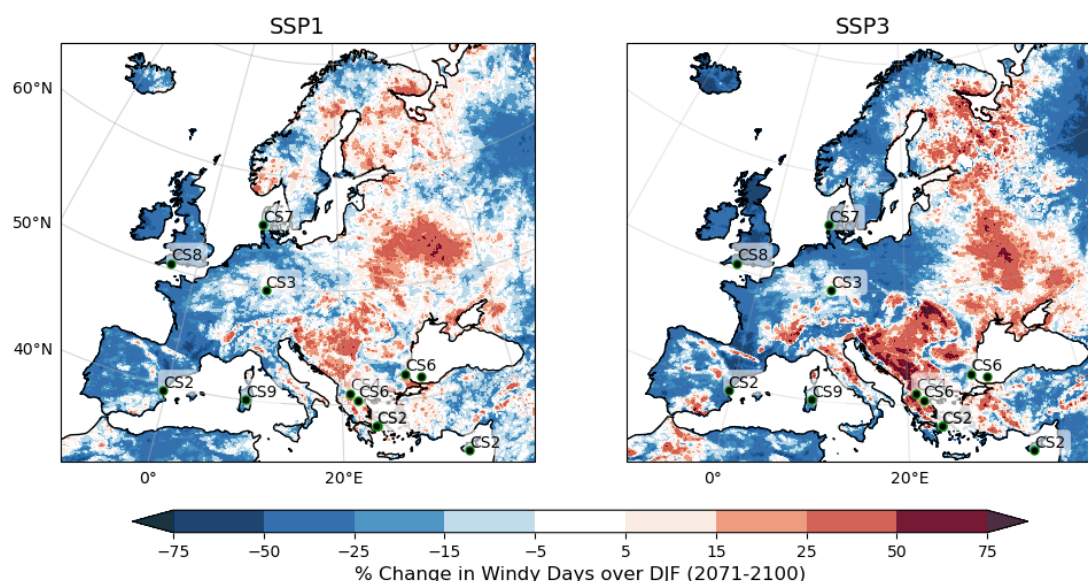


Figure 3.24 Percent change in number of windy days in the SSP1 and SSP3 scenarios (2071 – 2100)

Figure 3.24 shows the projected percentage change in the number of winter (DJF) windy days over the period 2071–2100 under the SSP1-2.6 (left) and SSP3-7.0 (right) scenarios. Both scenarios exhibit a pronounced west-to-east contrast in changes, with the larger differences observed under SSP3. Under SSP1 the Atlantic-facing coasts of France, the Netherlands, Iberia, and the British Isles see declines in windy days of roughly 25–50 %. These reductions are similar under SSP3, except in Scotland where windy days drop by about 75 %. In contrast, the Balkans, Ukraine, and the Adriatic region experience increases in windy days. Under SSP3, these rises reach up to +75 % along the Adriatic coast and around +50% in eastern Europe.

The western decrease on windy days likely reflects a shift in the winter storm track, that might potentially reduce the wind energy resource in this part of Europe, while the increased frequency of windy days in the east could present a greater risk to infrastructure not designed for such conditions.

3.4 Clusters of extreme events across Europe

In the preceding sections, we depict the results of nine different extreme indicators related to precipitation (section 3.1), temperature (section 3.2) and wind (section 3.3).

A highly qualitative analysis of the maps shown above is presented in Table 11. They confirm some geographical clusters that are largely in agreement with previous studies.

Temperature extremes increase all over Europe, particularly in southern Europe with the Iberian peninsular standing particularly out. At the same time, we see a generally decreasing trend in wet extremes for large parts of southern Europe except for RX1day (winter). Four of the ARSINOE case studies lie in this region. CS2 (Mediterranean Ports), CS4 (Ohrid-Prespa Lakes) and CS6 (Black Sea) have the widest geographical coverage of all ARSINOE case studies spanning multiple areas from the Port of Valencia to the Black Sea.

There are mixed signals along the Atlantic region and in part of central Europe with a combination of wet and dry conditions, suggesting that more detailed local analyses are needed to uncover the impacts, e.g. including geographically compound effects. Case study 3 (Main River) and 8 (Torbay) are located in this region.

In northern and eastern Europe, there are clear trends towards wetter extremes, but also of hotter extremes although not everywhere so pronounced as in south. The combination of increasing wet and dry extremes is likely to lead to unprecedented conditions locally with potentially compounding effects on human and natural systems in some places. Case study 7 (Southern Denmark) is located in this area.

While it is evident from the above that more detailed geographical analyses reveal clusters of increasing extreme event exposure tied to e.g. local conditions all over Europe, these are beyond the scope of the current deliverable. This will be included in the upcoming deliverable D6.4 (M48).

Table 3.1 Trends

Indicator	Increasing trend	Decreasing trend
Extreme precipitation days	N, E Europe	Iberian Peninsula
Water balance	N, E Europe (except for some areas)	Iberian Peninsula, south Mediterranean
RX1day (winter)	N, E Europe (except for some areas)	Part of Atlantic region, Iberian Peninsula
RX1day (summer)	N, E Europe (except for some areas)	Iberian Peninsula, south Mediterranean
Maximum Consecutive Wet Days	Most of Europe (weak signal for SSP1-2.6)	South Mediterranean
Maximum Consecutive Dry Days	S, E Europe (strong signal)	Norwegian mountains
Hot days	Everywhere, strongest signal in the south	Everywhere, strongest signal in the south
Hot nights	Everywhere, strongest signal in the south	Everywhere, strongest signal in the south
Cold days	East to west pattern, everywhere	Everywhere
Windy days	E Europe	W Europe

4.0 Conclusions

This report is the third and final deliverable from Task 3.3 (M45).

As a supplement to D6.7 (Implementation of the ARSINOE Multi-System Dynamic Modelling Framework Wheel and Resilience Assessment for Case Studies) it documents the climate data requirements by case study and by resilience indicator (“KPI”) associated with the implementation of the common climate scenario baseline across the nine different ARSINOE case studies.

It also provides a contextual setting for the horizontal analysis of the case studies to appear in D6.4. Hence, chapter 3 maps the results for nine extremes indicators at the European level drawn from the climate scenario baseline (present day; SSP1-2.6 and SSP3-7.0, 2081-2100), that is:

- Extreme precipitation days
- Water balance
- RX1day (winter)
- RX1day (summer)
- Maximum Consecutive Wet Days
- Maximum Consecutive Dry Days
- Hot days
- Hot nights
- Cold days
- Windy days

The location of the ARSINOE case studies (except for CS5-Canary Islands) are indicated on each of the abovementioned maps (Chapter 3) to ease subsequent analysis and for comparison with results found in other studies.

In addition to this report, it is planned that the content of D3.6 – and more generally Task 3.3 – are to be disseminated in at least two peer-reviewed scientific papers, submitted shortly after the end of the ARSINOE project (M48).

References

Asselin, O., Leduc, M., Paquin, D., Noblet-Ducoudré, N., Rechid, D., Ludwig, R.: Blue in Green: Forestation Turns Blue Water Green, Mitigating Heat at the Expense of Water Availability, accepted for publication in *Environmental Research Letters*, 2024.

Coles, S. (2001) *An Introduction to Statistical Modeling of Extreme Values*. Springer Series in Statistics, Springer-Verlag, London. - References - Scientific Research Publishing Coles, S. (2001) *An Introduction to Statistical Modeling of Extreme Values*

Gampe, D., Schwingshackl, C., Böhnisch, A., Mittermeier, M., Sandstad, M., and Wood, R. R. (2024): Applying global warming levels of emergence to highlight the increasing population exposure to temperature and precipitation extremes, *Earth Syst. Dynam.*, 15, 589–605, <https://doi.org/10.5194/esd-15-589-2024>.

Leduc, M. and Coauthors, 2019: The ClimEx Project: A 50-member Ensemble of Climate Change Projections At 12-km Resolution Over Europe and Northeastern North America With the Canadian Regional Climate Model (CRCM5). *Journal of Applied Meteorology and Climatology*, 58, 663–693, doi:10.1175/JAMC-D-18-0021.1.

O'Neill, B. C., Tebaldi, C., van Vuuren, D. P., Eyring, V., Friedlingstein, P., Hurtt, G., Knutti, R., Kriegler, E., Lamarque, J.-F., Lowe, J., Meehl, G. A., Moss, R., Riahi, K., and Sanderson, B. M.: The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6, *Geosci. Model Dev.*, 9, 3461–3482, <https://doi.org/10.5194/gmd-9-3461-2016>, 2016.

Riahi, K., van Vuuren, D. P., Kriegler, E., Edmonds, J., O'Neill, B. C., Fujimori, S., . . . Tavoni, M. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global Environmental Change*, 42, 153-168. <https://doi.org/10.1016/j.gloenvcha.2016.05.009>.

Annex

Questionnaire for collecting data requests to WP3 – Implementation of climate scenario baseline

#####

CS#:

Please nominate a contact person for questions and organizing data exchange.

Contact:

e-mail:

Please tick off the boxes and provide further information where applicable.

Raw or processed data?

☐ Our team just needs the raw (netCDF) data files from the ClimEx-II experiment and will extract the necessary information ourselves (please contact: **Andrea Boehnisch** <a.boehnisch@iggf.geo.uni-muenchen.de>).

Extent / domain:

Please note latitudes/longitudes or provide shape(s) of your area(s) of interest.

☐ latitude / longitude box

Latitudes:

Longitudes:

☐ specific shape /extent provided by case study (please send to: **Andrea Boehnisch** <a.boehnisch@iggf.geo.uni-muenchen.de>)

Experiments:

☐ ERA5 driven LUC (historical)

☐ GHG (greenhouse gas) only

☐ GHG and LUC (land use change combinations) *[optional]*

Variables:

Please indicate the climate model output variables you need (raw data, like precipitation, temperature etc.)

Variables:

Indicators:

Please indicate the climatological/hydrological indicators you request (processed, like SPI, climate change factors, return periods)

Indicators:

Spatial aggregation:

- ☐ Gridded data
- ☐ Aggregated time series. Please indicate the spatial aggregation measure (e.g., mean, median, sum, extract at specific grid cell for coordinates XY, etc.)

Extraction measure:

- ☐ Point data (e.g. for return period estimates)

Temporal resolution:

- ☐ 3-hourly
- ☐ Daily*
- ☐ Monthly*
- ☐ Annual*
- ☐ Other (e.g., seasons). Please specify:

Temporal resolution*:

* Please specify aggregation (sums, means, standard deviation, return periods, etc.):

Spin-up periods: (e.g. if this applies to your hydrological model)

- ☐ No
- ☐ Yes. Please indicate the optimal number of spin-up years before the modelling periods (1979-2015, 2081-2100 [2080-2099]).

Data format:

- ☐ netCDF (climate model output)
- ☐ csv (time series only) / txt (time series only)
- ☐ other. Please specify the data format. We may come back to you if we cannot comply with your requested data format.

Data format:

Other requests:

Please indicate further comments / requests not met with the above queries – and show up at our Wednesday meetings from 11-12.

Other requests:

Systems Innovation Approach (SIA) addresses the growing complexity, interdependencies and interconnectedness of modern societies and economies, focusing on the functions of the cross-sectoral system? as a whole? and on the variety of actors. The Climate Innovation Window (CIW) is the EU reference innovations marketplace for climate adaptation technologies. ARSINOE shapes the pathways to resilience by bringing together SIA and CIW, to build an ecosystem for climate change adaptation solutions. Within the ARSINOE ecosystem, pathways to solutions are co-created and co-designed by stakeholders, who can then select either existing CIW technologies, or technologies by new providers (or a combination) to form an innovation package. This package may be designed for implementation to a specific region, but its building blocks are transferable and re-usable; they can be re-adapted and updated. In this way, the user (region) gets an innovation package consisting of validated technologies (expanding the market for CIW); new technologies implemented in the specific local innovation package get the opportunity to be validated and become CIW members, while the society (citizens, stakeholders) benefits as a whole. ARSINOE applies a three-tier, approach: (a) using SIA it integrates multi-faceted technological, digital, business, governance and environmental aspects with social innovation for the development of adaptation pathways to climate change for specific regions; (b) it links with CIW to form innovation packages by matching innovators with end-users/regions; (c) it fosters the ecosystem sustainability and growth with cross-fertilization and replication across regions and scales, at European level and beyond, using specific business models, exploitation and outreach actions. The ARSINOE approach is show-cased in nine widely varied demonstrators, as a proof-of-concept with regards to its applicability, replicability, potential and efficacy.

