DELIVERABLE D.T1.2.3

Elaboration of maps with hot-spots of extreme potencial impacts on cultural heritage

Version 1

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CONTENTS

1. INTRODUCTION

Deliverable D.T1.2.3 “Elaboration of maps with hot-spots of extreme potential impacts on cultural heritage” illustrates the methodology followed and implemented for the realization of local maps intended to show Municipalities in Central Europe where the combination of threats and cultural heritage targets leads to a high risks. This deliverable has been realized within the Activity A.T1.2 “Mapping the exposure of cultural heritage to extreme events (floods, heavy rain) in changing climate”. Sections 2 and 3 of the present deliverable summarize the climate models, downscaling approaches tools of data analysis, climate indices and variables utilized. Section 4 includes representative examples of the different typologies of maps elaborated which are fully available in the WebGIS tool of ProteCHt2save. The description of the tool is given in Deliverable D.T1.2.2.

As explained in Deliverable D.T1.1.2 for the elaboration of maps in ProteCHt2save, we applied the Euro-CORDEX simulations at 0.11 degrees resolution and analysed RCM historical and projection simulations, to calculate anomalies and changes of future climatologies with respect to past conditions. The historical period we accounted for, is the time slice 1987-2016, while for the future we referred to long-term climatologies around mid-21st century (e.g., 2021-2050) band end of century (e.g. 2071-2100).

We have considered two future emission scenarios among those employed in the latest IPCC assessment report (AR5), namely RCP4.5 (stabilization) and RCP8.5 (pathway), whose characteristics are summarized here below:

The detailed description of climate model data, downscaling and analysis tools is given in Deliverable D.T1.1.2.

2. CLIMATE EXTREME INDICES AND CLIMATE VARIABLE

The analysis of changes in climate extremes, such as dry spells or intense precipitation, exploited software tools developed by ISAC-CNR providing indices to evaluate statistics of extreme events for temperature and precipitation and to compare them with observed extremes. They implemented standard indices defined by the Expert Team on Climate Change Detection Indices (ETCCDI), whose definition can be found at the Climdex Project web site (www.climdex.org) and other indices measuring hydro climatic intensity.

The 27 standardised indices recommended by the CCI/WCRP/COMM Expert Team on Climate Change Detection and Indices (ETCCDI) allowing to compare results across time periods, regions and source datasets and all of them derived from daily temperature and precipitation data.

For ProteCh2save mapping, 5 extreme climate indices selected were chosen among the 27 indices mentioned above and described in the Deliverable D.T1.1.2. As showed in Figure 1, they refer to the following extreme events: heavy rain, flooding, drought and extreme heating. These indices were selected to evaluate statistics of extreme events for temperature and precipitation and to compare them with observed extremes.

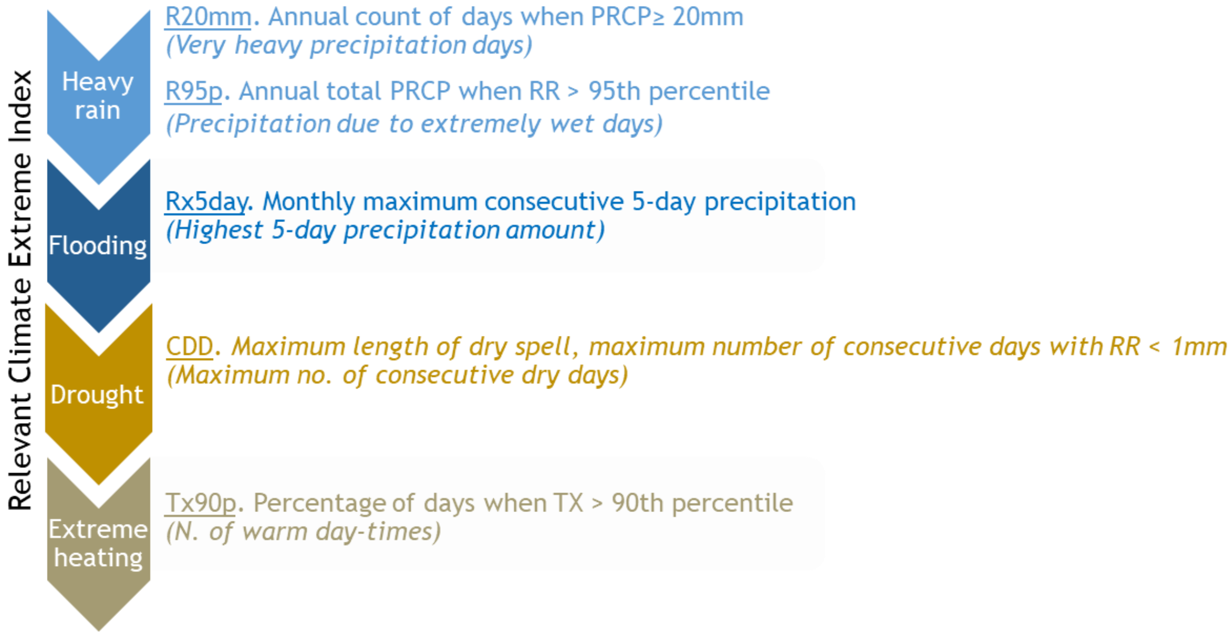
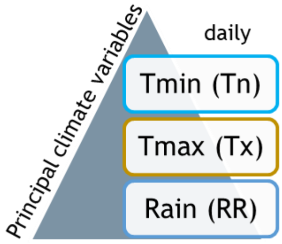


Figure 1 Relevant Climate Extreme Indices selected for evaluating extreme events

For example:

- events of heavy rain per year are estimated calculating the annual count of days when precipitation is higher than 20 mm (R20mm index),
- how much rain fell during the rainiest 5-day stretch of the year is estimated calculating the Monthly maximum consecutive 5-day precipitation (Rx5day).

In Figure 2 are summarized the principal climate variables take in to consideration for the elaboration of the 5 climate extreme indices described before and also mapped.



Climate variables	Code	Description
Tmin	Tn	daily minimum temperature
Tmax	Tx	daily maximum temperature
Precipitation	RR	daily precipitation sum

Figure 2. Principal climate variables selected for calculating Climate extreme indices.

3. ELABORATION OF MAPS

Data from models has been used for the production of:

- maps of changes of principal climate variables
- maps of changes related to climate extreme indices

For each of the 5 climate risk indices and of the 3 climate variables chosen, maps related to historical and future projections have been produced.

Specifically, the maps produced refer to differences between:
-[1987 -2016] and [1951 – 1980] for historical observations
-[2021 – 2050] and [1976 – 2005] for near future projection
-[2071 – 2100] and [1976 – 2005] for far future projections

The values reported for each variable and climate extreme index are relative and relate to changes with respect to a period of reference.

3.1. Historical observations

Maps with spatial resolution of 25X25 Km for historical observation have been elaborated for both climate extreme indices and variables, considering the time slice 1987-2016 (Figs. 3 and 4).

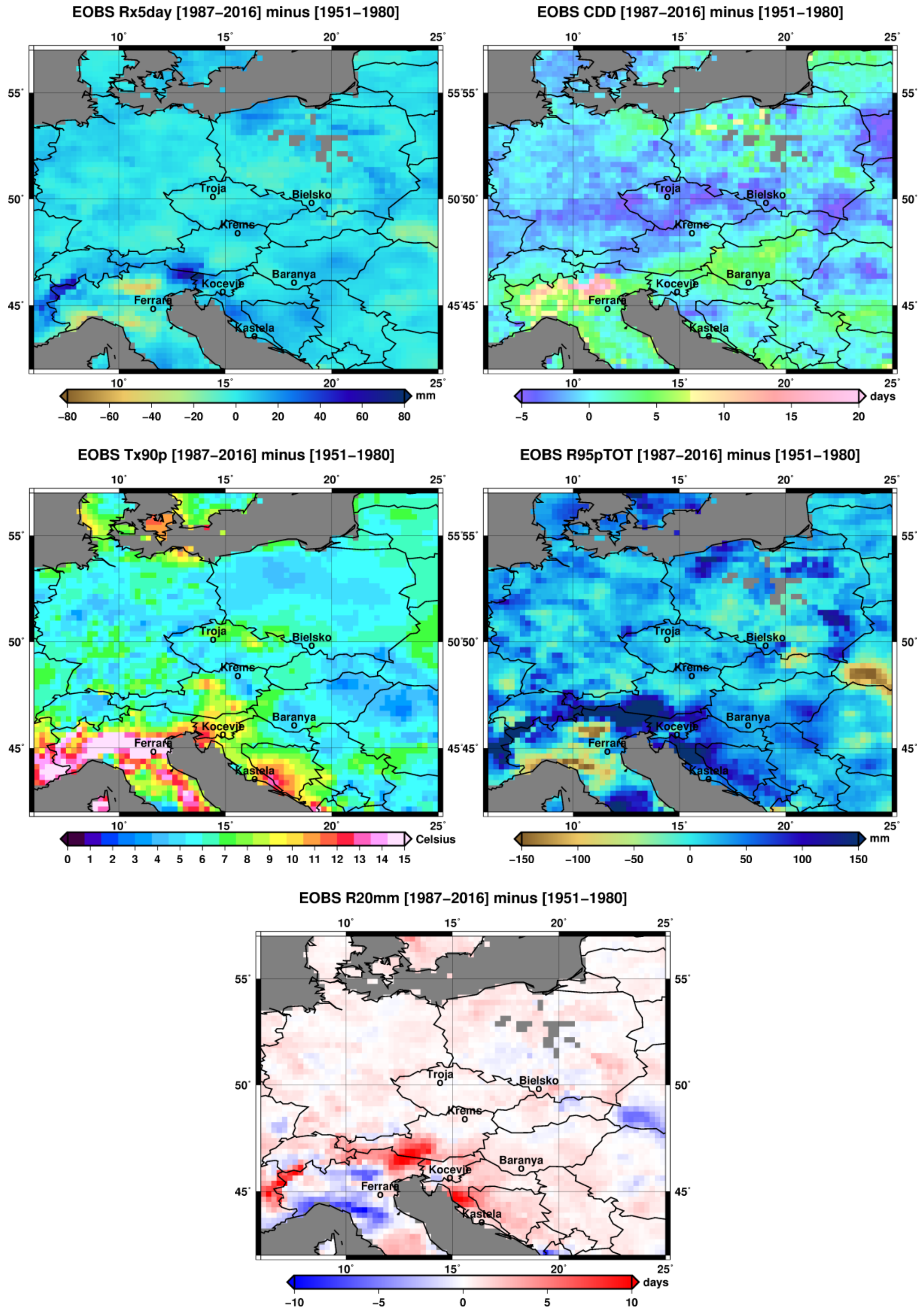


Figure 3. Maps elaborated for historical observations relating to the 5 climate extreme indices selected.

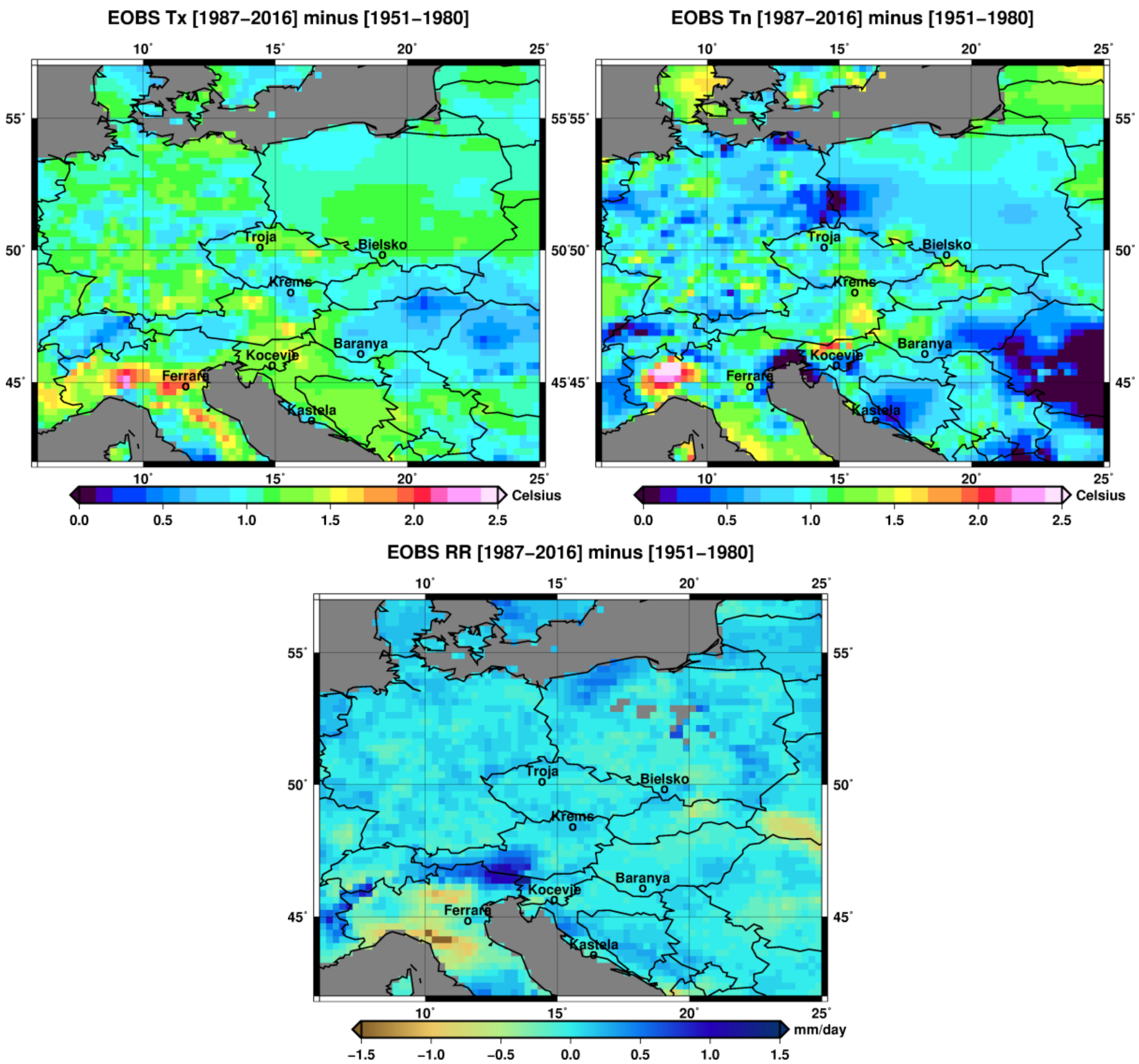


Figure 4. Maps elaborated for historical observations relating to the 3 climate variables selected (RR, Tx and Tn).

3.2. Future Projections

In this section, risk maps with spatial resolution of 12X12 Km referring to heavy rain, flooding, drought and extreme heat are provided. Specifically changes of temperature and precipitation and of climate extreme indices are available for 2 future 30-year periods (2021-2050 & 2071-2100) with respect to the reference historical one (1976-2005) and under Representative Concentration Pathway scenarios RCP4.5 (stabilization) and RCP8.5 (pathway)

3.2.1. Individual model projections

12 different combination of models have been taken into account for the elaboration of the maps related to the future projection. Table 1 shows the different combination of models used which identification code include acronyms for: the Entity which developed the Global Simulation (EGS); the Global Model applied (GS); the Entity which developed the Regional Simulation (ERS); the Regional Model utilized (RM).

Table 1.

	EGS	GS	ERS	RM
1	CNRM-CERFACS	CNRM-CM5	CLMcom	CCLM4-8-17
2	CNRM-CERFACS	CNRM-CM5	SMHI	RCA4
3	ICHEC	EC-EARTH	CLMcom	CCLM4-8-17
4	ICHEC	EC-EARTH	DMI	HIRHAM5
5	ICHEC	EC-EARTH	KNMI	RACMO22E
6	ICHEC	EC-EARTH	SMHI	RCA4
7	MOHC	HadGEM2-ES	KNMI	RACMO22E
8	MOHC	HadGEM2-ES	SMHI	RCA4
9	IPSL	CM5A-MR	SMHI	RCA4
10	MPI-M	MPI-ESM-LR	CLMcom	CCLM4-8-17
11	MPI-M	MPI-ESM-LR	MPI-CSC	REMO2009
12	NCC	NorESM1-M	DMI	HIRHAM5

As previously described, each of these models has been run for each climate extreme index and climate variable chosen. In addition, the projections cover near (2021-2050) and far (2071-2100) future both under RCP 4.5 and RCP 8.5 scenario.

In view of this, 4 maps have been produced for each model leading to have 36 maps for each climate extreme index and variables and a total of 384 maps related to individual model projections.

In Figures 5-8 maps produced by running one combination of models (ICHEC-EC-EARTH-DMI-HIRAM5) for each climate extreme index and climate variable are reported as an example of a complete series of maps that we can obtain using one model for the projection.

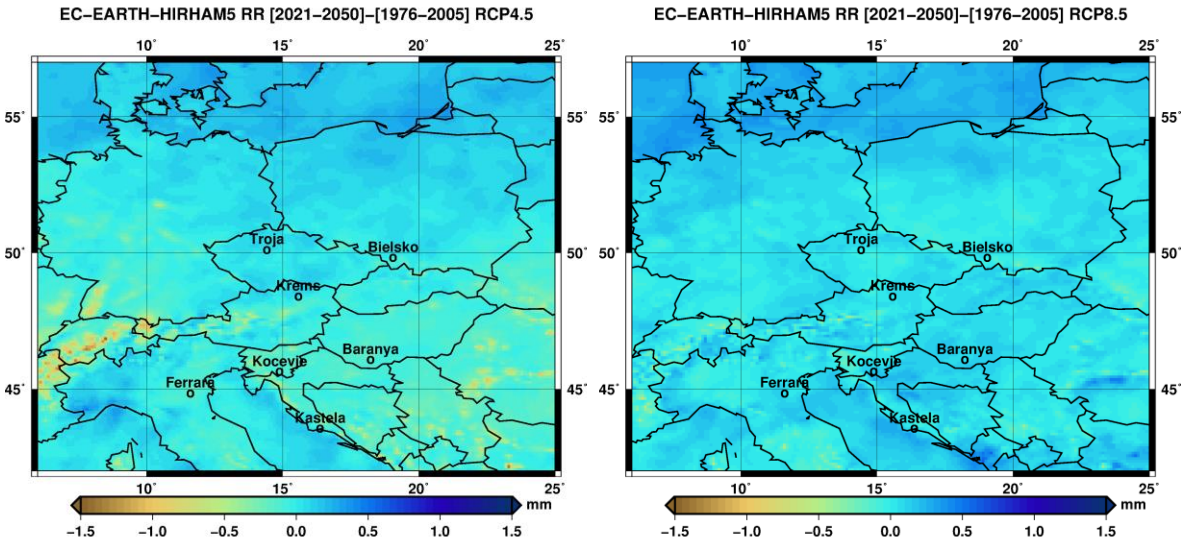


Figure 5. Maps related to the RR climate variable variation in near future (2021-2050) under RCPs 4.5 and 8.5. Projection elaborated with Model EC-EARTH-HIRAM5.

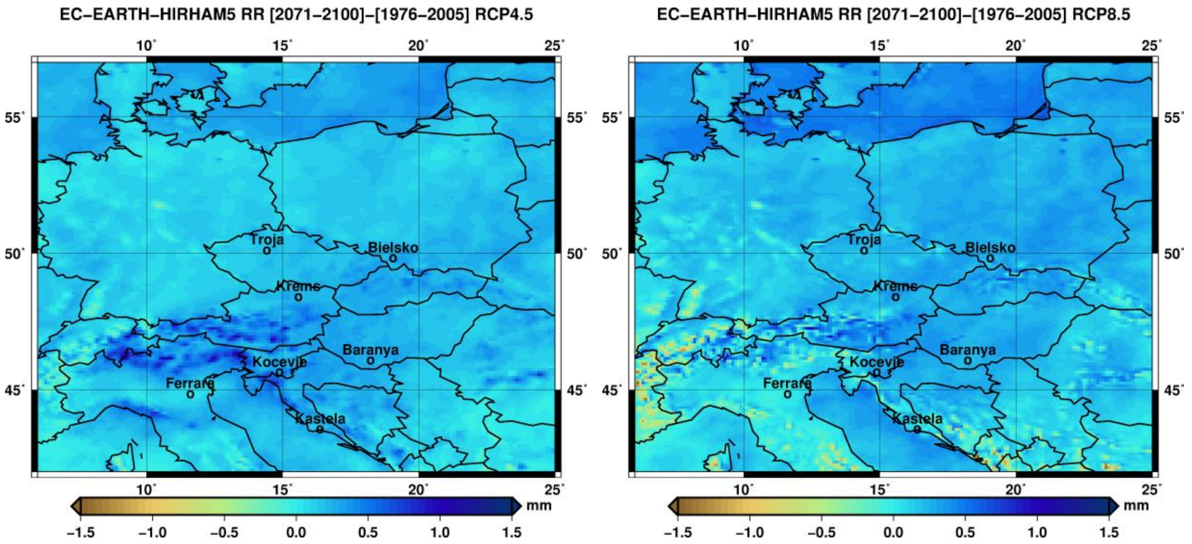


Figure 6. Maps related to the RR climate variable variation in the far future (2071-2100) under RCPs 4.5 and 8.5. Projection elaborated with Model EC-EARTH-HIRAM5.

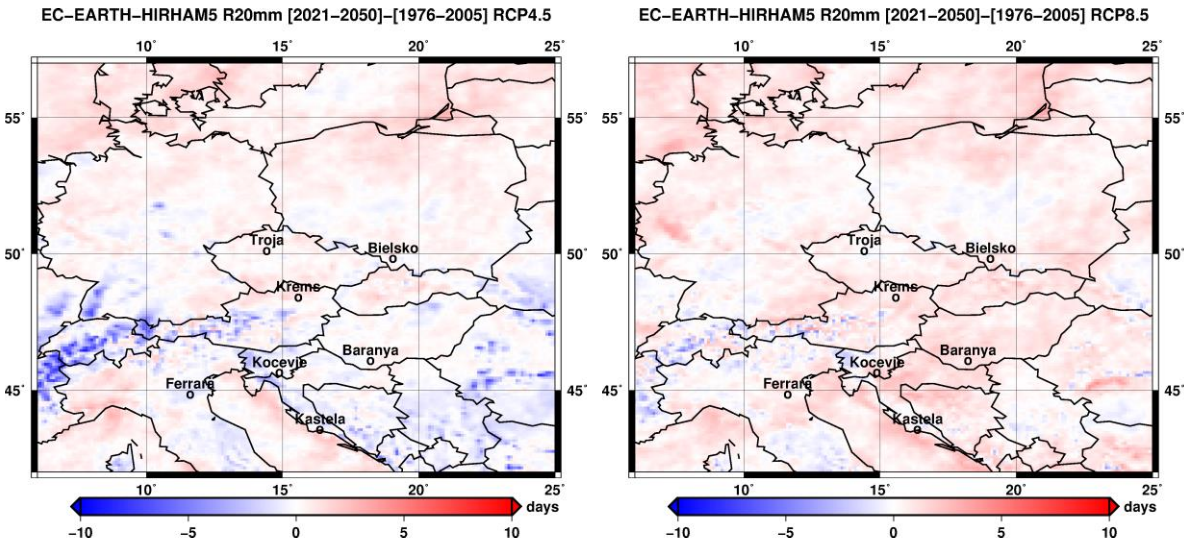


Figure 7. Maps related to the R20mm climate risk index variation in near future (2021-2050) under RCPs 4.5 and 8.5. Projection elaborated with Model EC-EARTH-HIRAM5.

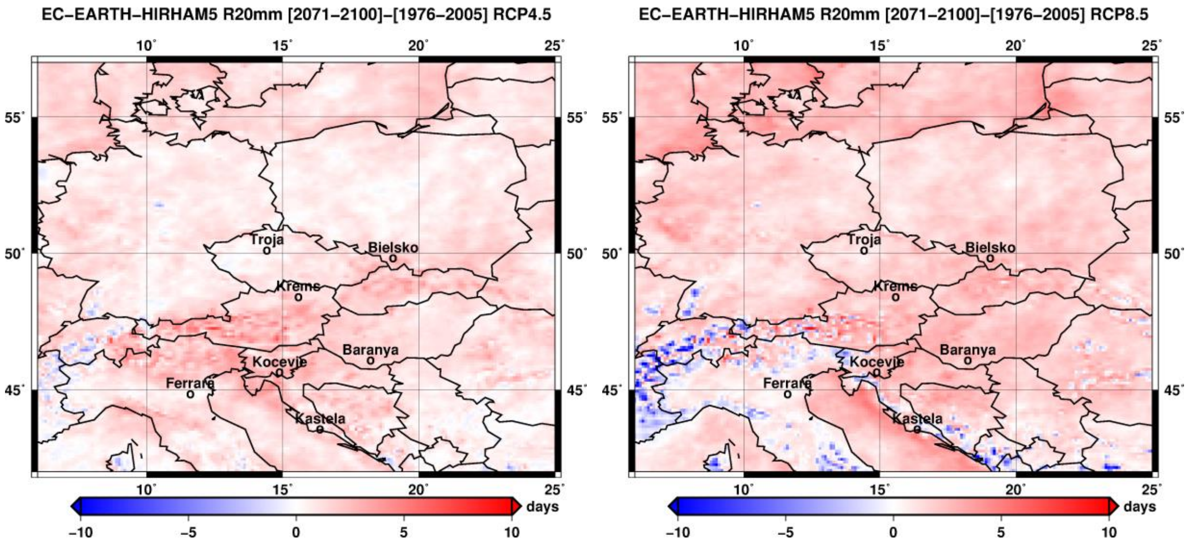
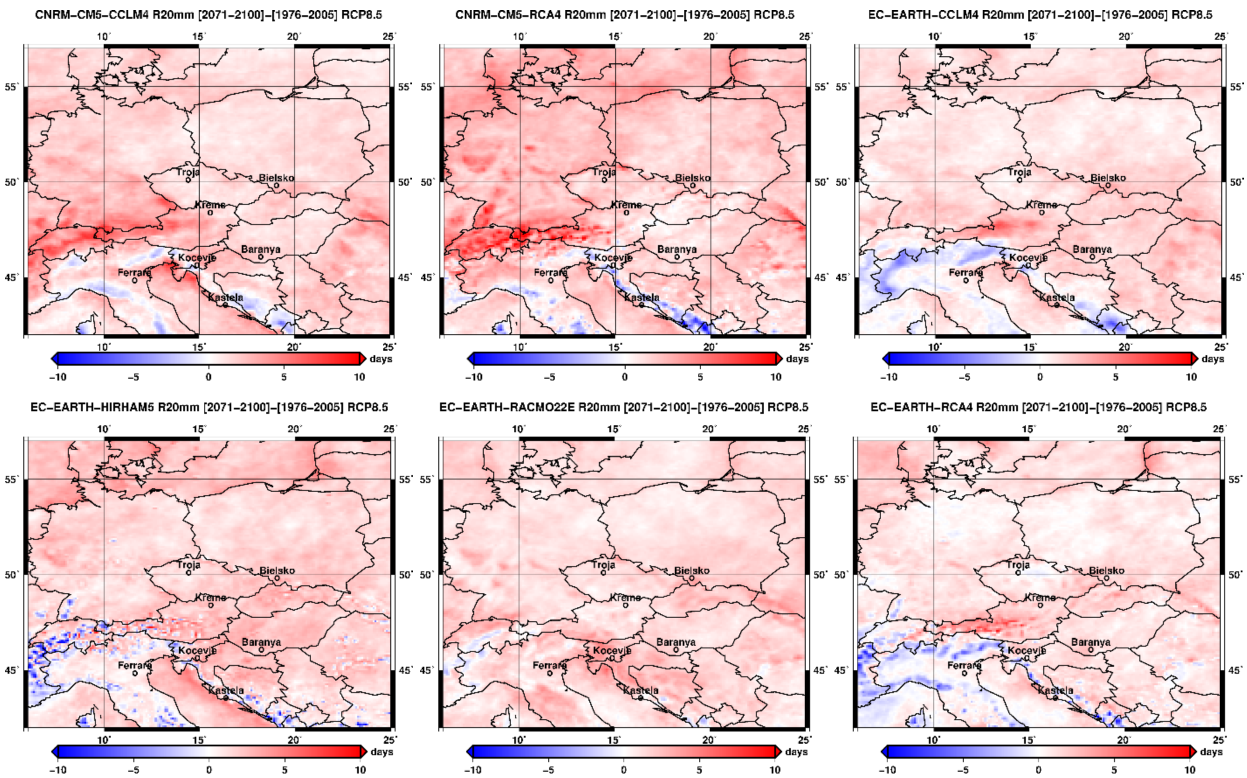


Figure 8. Maps related to the R20mm climate risk index variation in far future (2071-2100) under RCPs 4.5 and 8.5. Projection elaborated with Model EC-EARTH-HIRAM5.

Figure 9 shows the maps obtained for one climate extreme index using all 12 combination of models for the same time coverage (far future) and RCP scenario (RCP 8.5) as an example of the complete series of maps that we can obtain using all models and appreciate the variation among.



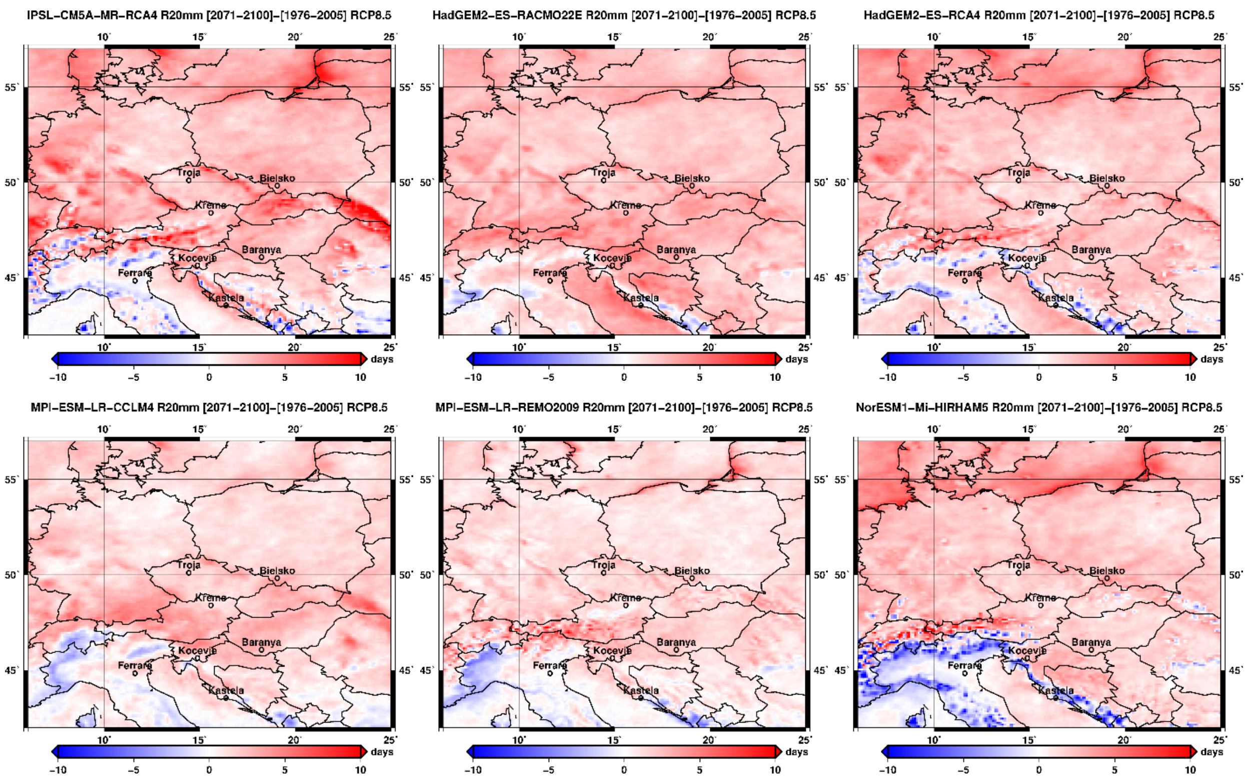


Figure 9. Maps related to the R20mm climate extreme index variation in far future (2071-2100) under RCP 8.5 among the 12 different models used.

3.2.2. Models ensemble statistics

Projections need to explore key uncertainties that are consistent with current knowledge, and that affect future climate. For this, projections are based on ensembles of climate simulations.

In order to summarize in a more easily understandable way the results obtained by mapping the extreme indices using different models a model ensemble statistic was carried out. In particular, were produced maps for minimum, mean and maximum realizing other 96 maps.

Here below maps from one of the models utilized related to a single climate extreme index (R20mm) are reported as an example of a complete series of maps that we can obtain using the models ensemble statistic (Figs. 10-15).

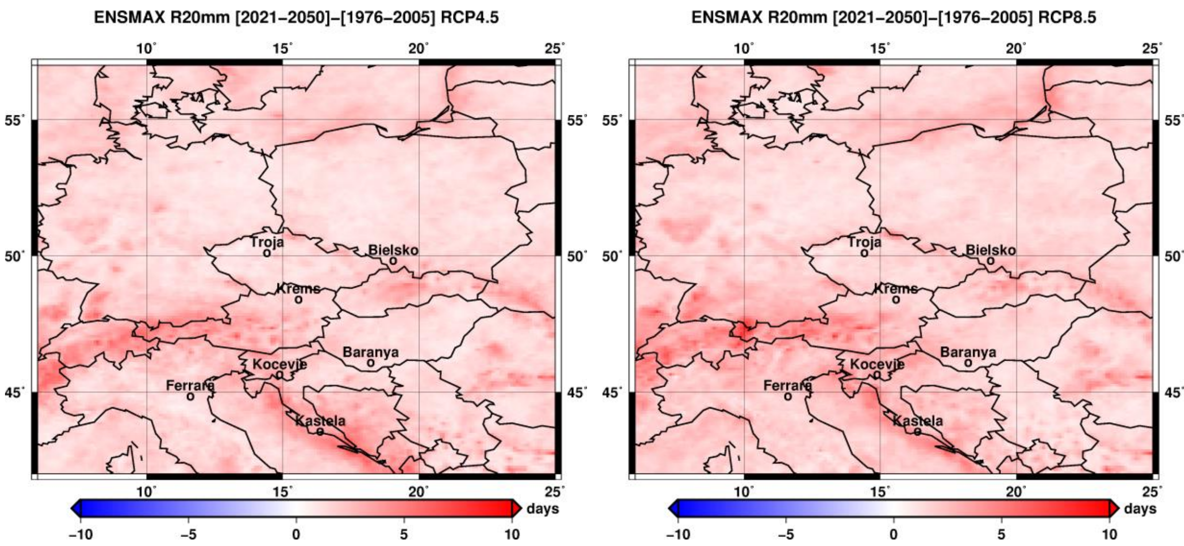


Figure 10. Climatic projection related to the model ensemble statistic of the R20mm climate extreme index (maximum variation) considering near future (2021-2050) under RCPs 4.5 and 8.5.

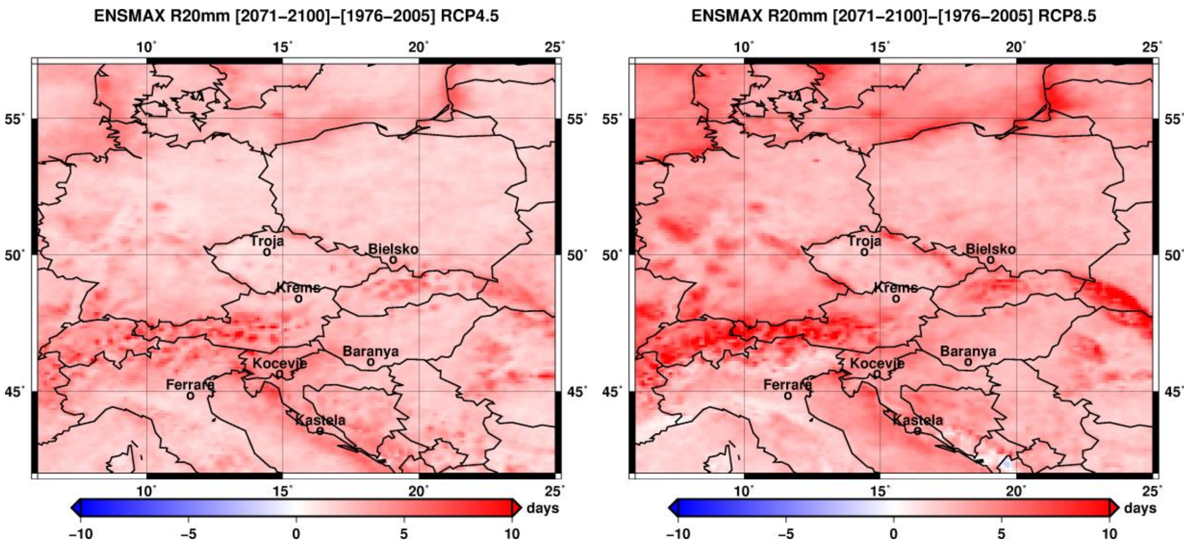


Figure 11. Climatic projection related to the model ensemble statistic of theR20mm climate extreme index (maximum variation) considering far future (2071-2100) under RCPs 4.5 and 8.5.

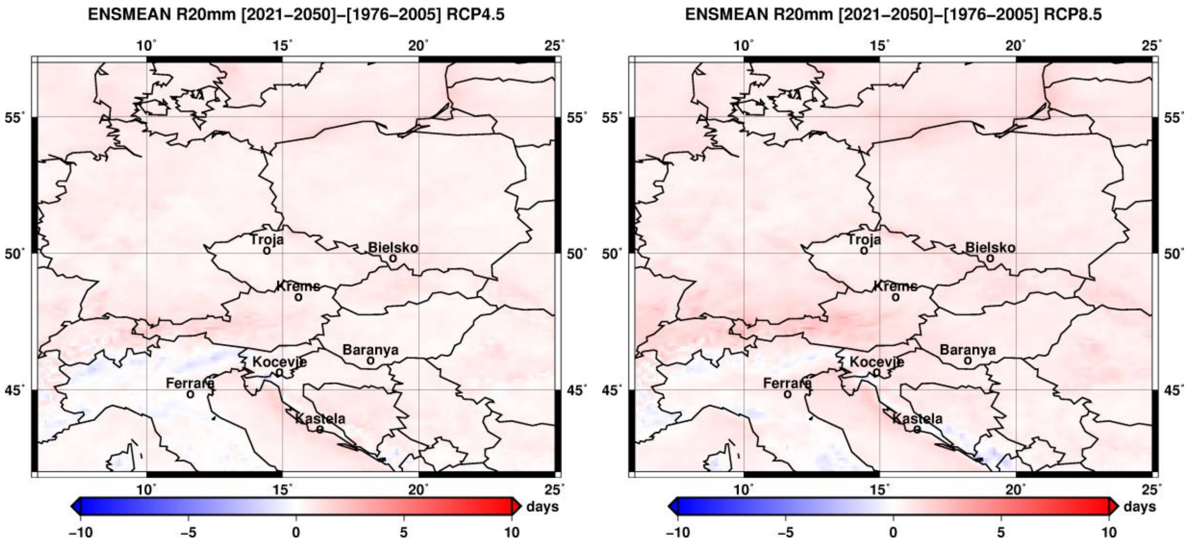


Figure 12. Climatic projection related to the model ensemble statistic of the R20mm climate extreme index (mean variation) considering near future (2021-2050) under RCPs 4.5 and 8.5.

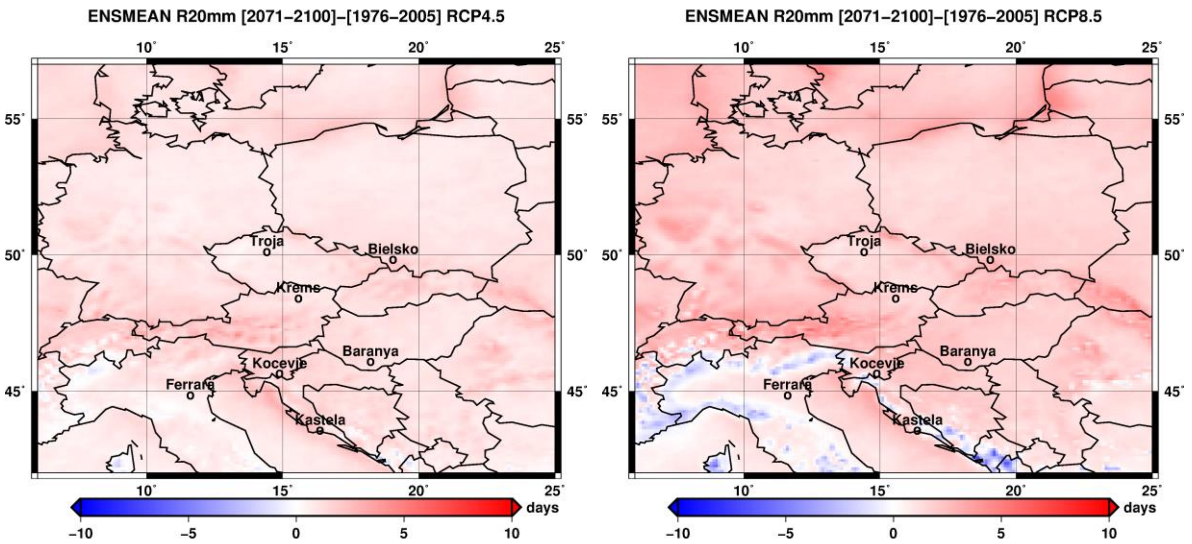


Figure 13. Climatic projection related to the model ensemble statistic of the R20mm climate extreme index (mean variation) considering near future (2071-2100) under RCPs 4.5 and 8.5.

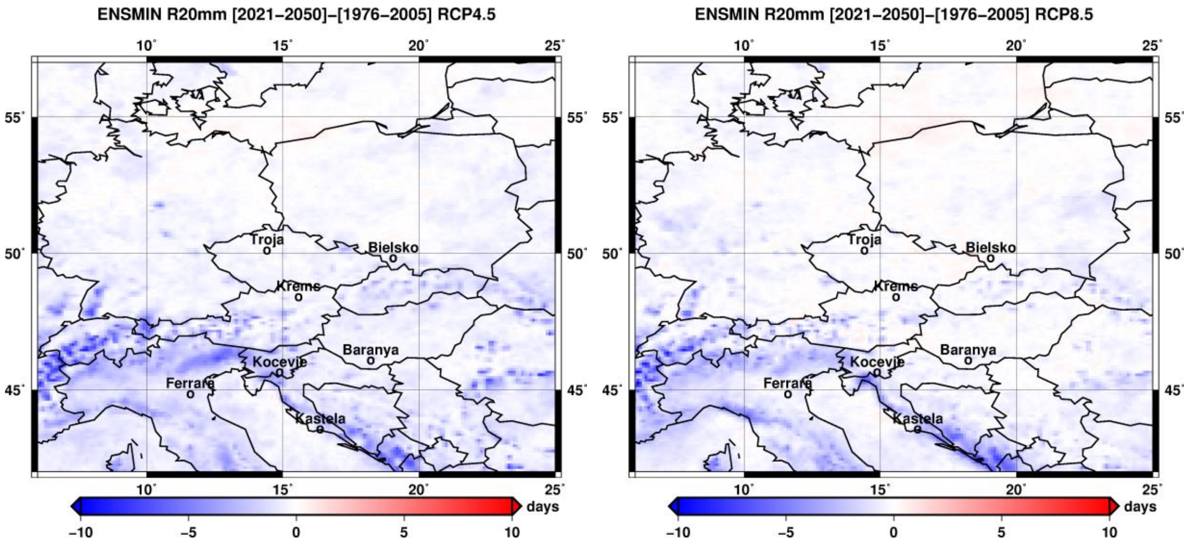


Figure 14. Climatic projection related to the model ensemble statistic of the R20mm climate extreme index (minimum variation) considering near future (2021-2050) under RCPs 4.5 and 8.5.

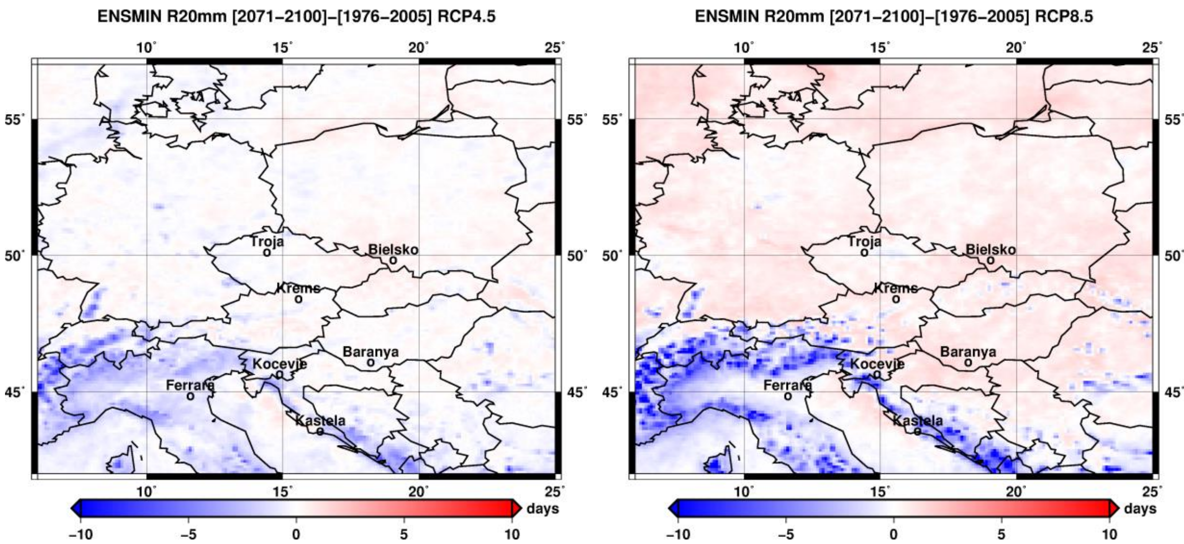


Figure 15. Climatic projection related to the model ensemble statistic of the R20mm climate extreme index (minimum variation) considering near future (2071-2100) under RCPs 4.5 and 8.5.

3.2.3. Confidence and uncertainties

Uncertainty in GCM and RCM simulations are mainly due to:

- Internal variability.
  Initial condition uncertainty. Variability that is unforced by natural or anthropogenic forcing, but generated internally in the climate system. Beyond a few years, this is unpredictable.
- Modelling uncertainty (sampled by multi-model ‘ensembles’, e.g. CMIP5)
  - Structural uncertainty, from different ways to approximate the climate system when building a model.
  - Parametric uncertainty, model parameters that control unresolved processes can take a range of plausible values.

- Scenario uncertainty.
  The uncertainty in global socio-economic development and associated greenhouse gas and aerosol emissions

Many factors affect confidence in observed and projected changes in extremes. Our confidence in observed changes in extremes depends on the quality and quantity of available data and the availability of studies analyzing these data. It consequently varies between regions and for different extremes. Our confidence in projected changes varies with the type of extreme, as well as the considered region and season, depending on the amount and quality of relevant observational data and model projections, the level of understanding of the underlying processes, and the reliability of their simulation in models (assessed from expert judgment, model validation, and model agreement).

4. ELABORATION OF TIME SERIES

Time series at local level of the pilot sites with downscaling of 1 Km and referring to the past period (1950 – 2016) were carried out for each climate variable and climate extreme (Fig. 16).

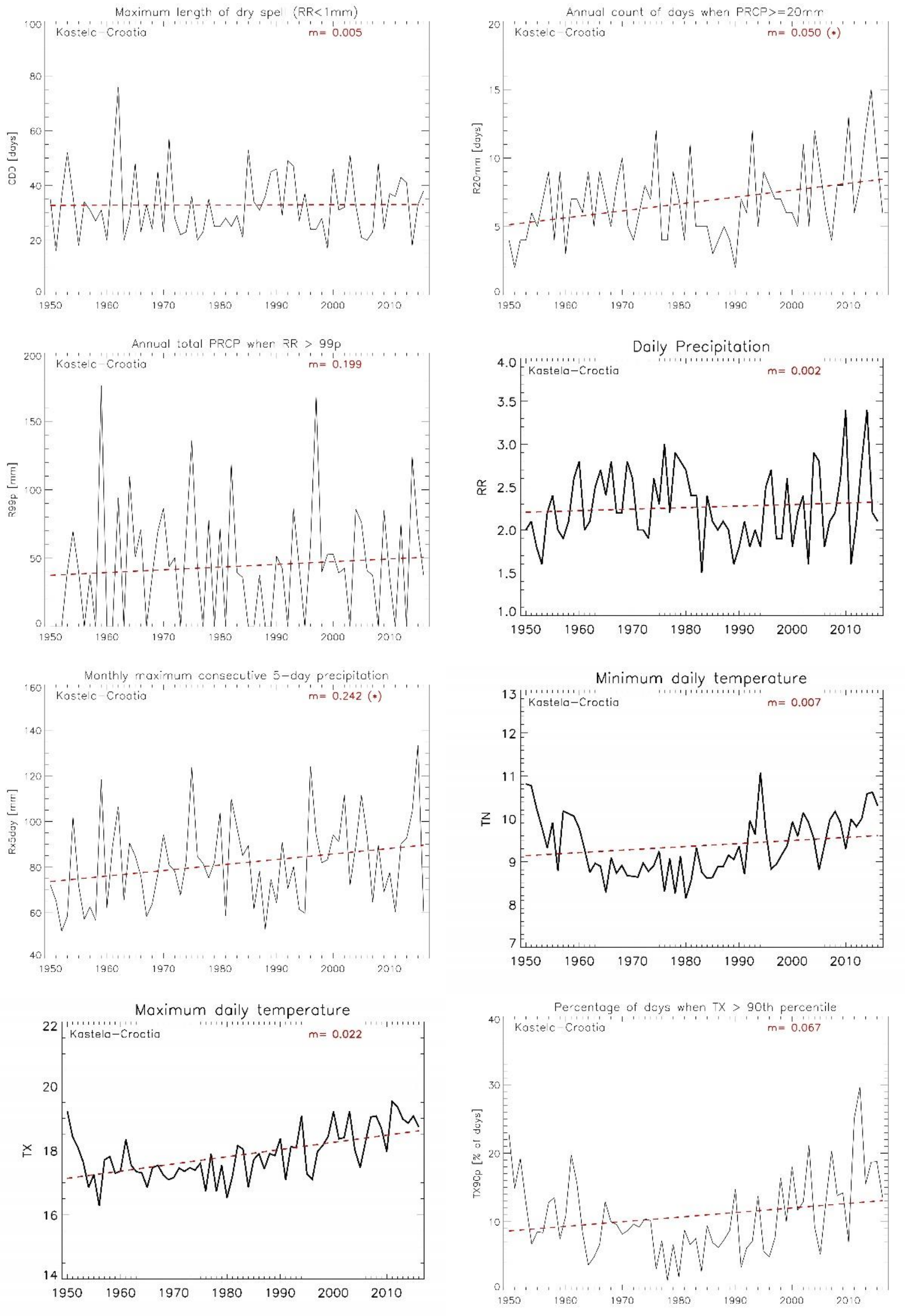


Figure 16. An example of a set of time series elaborated for the City of Kastela.

5. FINAL REMARKS

Figure 17 summarizes the total number of maps produced divided for different Time coverage and RCPs.

All these 488 maps have been inserted in the ProteCHt2save Web GIS Tools for Risk Mapping and it is avaiable in the dedicated “Maps” Page (Deliverable D.T1.2.2).

Maps Summary

8 maps	Historical (1987-2016) wrt (1951-1980)
120 maps	Near future (2021-2050) wrt (1975-2005) - RCP4.5 96 maps from individual models & 24 maps form model ensemble statistics
120 maps	Near future (2021-2050) wrt (1975-2005) – RCP8.5 96 maps from individual models & 24 maps form model ensemble statistics
120 maps	Far future (2071-2100) wrt (1975-2005) - RCP4.5 96 maps from single individual & 24 maps form model ensemble statistics
120 maps	Far future (2071-2100) wrt (1975-2005) - RCP8.5 96 maps from single individual & 24 maps form model ensemble statistics