Deliverable D3.1

CLIMATE DATA AND SCENARIO SELECTION

Version 1.1

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EXECUTIVE SUMMARY

This deliverable report, entitled “D3.1 – Climate data and scenario selection”, documents the performed climate related severity analysis for Rhodes, Granada, Venice and Tønsberg. The analysed climate data has been obtained from the EURO-CORDEX project, utilizing multiple Regional Climate Model simulations which have been forced by different Global Climate Models to cover the period from 1981 to 2100. The analyses have been performed under three alternative Representative Concentration Pathway (RCP) scenarios, RCP2.6, RCP4.5 and RCP8.5, representing low, medium and high greenhouse-gas emissions. The variables considered in the analysis include temperature, precipitation and wind. The identified episodic events as well as return levels for heavy precipitation and high wind speeds are stored hierarchically in the Dataset_D3.1.zip file.

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1. INTRODUCTION

1.1. DOCUMENT ORGANISATION

This specific document “D3.1 – Climate data and scenario selection” is organized in separate Sections in order to facilitate search, reference and further analysis as needed.

Next, Section 2 includes a description for materials and methods used in the analyses. The results are presented and discussed in Section 3. The results for each heritage site are presented in a separate subsection.

Finally, conclusions are drawn in Section 4.

1.2. GENERAL OBJECTIVE

This deliverable “D3.1 – Climate data and scenario selection” is focusing on the severity analysis of climate impacts performed for the cultural heritage sites in Rhodes, Granada, Venice and Tønsberg. The obtained information will be employed in determining site-specific severity criteria for climate stressors. Temperature, precipitation and wind were considered in the analysis.

Acronym	Abbreviations
RCM	Regional Climate Model
GCM	Global Climate Model
RCP	Representative Concentration Pathway
CORDEX	Coordinated Regional Climate Downscaling Experiment
WP	Work Package
ICHEC	Irish Center for High-End Computing
CLMcom	Climate Limited-area Modelling Community
KNMI	Koninklijk Nederlands Meteorologisch Instituut
SMHI	Swedish Meteorological and Hydrological Institute
RCA4	Rossby Centre regional atmospheric model 4
MOHC	Met Office Hadley Center
HadGEM2-ES	Hadley Centre Global Environmental Model 2 - Earth System
MPI-M	Max Planck Institute for Meteorology
MPI-ESM-LR	Max Planck Institute Earth System Model Low Resolution

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2. MATERIALS AND METHODS

The climate data used here were obtained from the EURO-CORDEX archive (Kotlarski et al., 2015). We used daily data with a 0.11° × 0.11° (approximately 12.5 km × 12.5 km) horizontal resolution. For each site (Rhodes, Granada, Venice and Tønsberg), the grid point closest to the site was selected to represent meteorological conditions in the site. In order to cover uncertainty related to future climatic conditions, we chose several RCM simulations driven with lateral boundary conditions from different GCM runs. In addition, we studied three alternative RCP scenarios, RCP2.6, RCP4.5 and RCP8.5, representing the low end, central and high end, respectively, of the scenarios in terms of emissions and radiative forcing (van Vuuren et al., 2011).

The RCP2.6 scenario ambitiously aims to limit the increase of global mean temperature to 2 °C. The radiative forcing in that scenario reaches 2.6 W m^{-2} relative to preindustrial conditions in the year 2100. The RCP4.5 scenario represents a world characterized by relatively well-succeeded mitigation of greenhouse gas emissions. In that scenario, the radiative forcing stabilizes at 4.5 W m^{-2} relative to preindustrial conditions in the year 2100 without ever exceeding that value. The higher end emission scenario RCP8.5 represents a world without any efficient mitigation activities applied leading to a radiative forcing of 8.5 W m^{-2} by 2100.

The analyzed climate model simulations covering the period from 1981 to 2100 are listed in Table 2.1. The simulations were chosen on the basis of data availability for the required variables under all the three RCP scenarios. We downloaded the following variables: daily maximum and minimum near-surface (2 m height) air temperatures, daily precipitation sum, daily maximum sustained wind speed (10 min average of wind speed at a 10 m height) and daily means of eastward and northward wind components at 10 m height. A total of seven model runs were analysed for each emission scenario, except for the RCP8.5 scenario, precipitation and wind direction data were not available for the SMHI-RCA4 model run driven by the MPI-M-MPI-ESM-LR model, and neither for the SMHI-RCA4 model runs driven by the MOHC-HadGEM2-ES model were the wind direction data available. Three of the model runs were driven by the ICHEC-EC-EARTH model (Hazeleger et al., 2012), two of them by the MOHC-HadGEM2-ES model (Martin et al., 2011) and also two model runs were driven by the MPI-M-MPI-ESM-LR model (Stevens et al., 2013). Three of the GCMs were downscaled by the SMHI-RCA4 model, two of them by the KNMI-RACMO22E model and one either by the CLMcom-CCLM4-8-17 model and by the MPI-CSC-REMO2009 model. In addition, we analysed a model run driven by the ERA-Interim reanalysis data (Dee et al., 2011) for each of the four RCMs used in downscaling the GCM data (Table 2.2).

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Table 2.1. Climate model runs analysed over the period 1981–2010. Data from model runs driven by the MOHC-HadGEM2-ES model extend only to 2099. The scenario model runs beginning from 2006 were merged with the historical model runs ending in 2005. Hence, the period 1981–2005 is identical in different RCP scenarios.

Driving GCM	Ensemble	RCM Model	Downscaling realisation	Type of calendar
ICHEC-EC-EARTH	r12	CLMcom-CCLM4-8-17	v1	gregorian
ICHEC-EC-EARTH	r12	KNMI-RACMO22E	v1	gregorian
ICHEC-EC-EARTH	r12	SMHI-RCA4	v1	gregorian
MOHC-HadGEM2-ES	r1	KNMI-RACMO22E	v2	360 days
MOHC-HadGEM2-ES	r1	SMHI-RCA4	v1	360 days
MPI-M-MPI-ESM-LR	r1	MPI-CSC-REMO2009	v1	gregorian
MPI-M-MPI-ESM-LR	r1	SMHI-RCA4	v1a	gregorian

Table 2.2. Analysed RCM model runs that were driven by the ERA-Interim reanalysis.

Ensemble	RCM Model	Downscaling realisation	Analysis period
r1	CLMcom-CCLM4-8-17	v1	1989–2008
r1	KNMI-RACMO22E	v1	1981–2010
r1	MPI-CSC-REMO2009	v1	1989–2008
r1	SMHI-RCA4	v1	1981–2010

Slightly different parameters were analysed for each site based on the site-specific meteorological risks. Alternating freeze and thaw cycles were recognised as a threat in every location, and thus the number of days with 2-m air temperature crossing the interval from -1 °C to +1 °C was analysed at each site. As Venice was additionally recognised to be very vulnerable to the extreme cold, during the most severe cold spells temperature dropping even below -5 °C, in Venice the number of days with minimum temperature below -5 °C were also counted. In addition to alternating freeze and thaw cycles, heavy precipitation leading to flash floods or longer periods with abundant rain pose a risk to every site. Thus, we detected the days with heavy precipitation and 5-day periods with highest precipitation amounts, similarly at each site. In Venice, heavy rain is particularly problematic if strong southeasterly winds blowing from the Adriatic Sea raise the sea level simultaneously. In Venice, we thus analysed also projected changes in strong southeasterly winds and detected the combined occurrences of heavy precipitation and strong southeasterly wind. Strong winds in general were

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recognized as a threat for Rhodes and Tønsberg, and projected changes in strong wind speeds were thus analysed in these locations.

For 1-day and 5-day precipitation amounts, as well as for strong wind speeds, return levels were first calculated from the four ERA-Interim driven model runs. These return levels were then used in determining thresholds for episodic events. For 1-day and 5-day precipitation sums, two thresholds were selected. The lower thresholds were set so low that they are surpassed on several days per year at each site, on average. Thus, we did not consider any site-specific thresholds as there are plenty of events for all sites with the lower thresholds anyway. Parameters analysed at each site are summarized in Table 2.3.

Table 2.3. Analysed parameters at each site. The dates with threshold values surpassed, along with the values of variables in question, for tas1, tminm5, r1d20, r1d50, t5d50, r5d100, ws15, ws20 and r1d50sewind are listed in .txt files in the Dataset_D3.1.zip having a hierarchical structure. Results from each model run for each site are stored in separate files. Return levels for heavy precipitation events and strong winds (rr_return_levels, ws_return_levels and se_wind_return_levels) are calculated for the 30-year periods 1981–2010, 2011–2040, 2041–2070 and 2071–2100. They are similarly stored in the Dataset_D3.1.zip, separately for each model run. For more details, see Appendix A.

Parameter	Explanation	Rhodes	Granada	Venice	Tønsberg
tas1	Daily minimum temperature at 2 m height is lower than -1 °C and daily maximum temperature is higher than +1 °C	x	x	x	x
tminm5	Daily minimum temperature at 2 m height is below -5 °C			x	
r1d20	Daily precipitation sum exceeds 20 mm	x	x	x	x
r1d50	Daily precipitation sum exceeds 50 mm				
r5d50	5-day precipitation sum exceeds 50 mm	x	x	x	x
r5d100	5-day precipitation sum exceeds 100 mm				
rr_return_levels	Return levels for 1-day and 5-day precipitation sums	x	x	x	x
wsmax15	Daily maximum 10-min average of wind speed at 10 m height exceeds 15 m/s	x			x
wsmax20	Daily maximum 10-min average of wind speed at 10 m height exceeds 20 m/s	x			

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wsmax_return_levels	Return levels for daily maximum 10-min average wind speeds	x			x
r1d50sewind6	Daily precipitation sum exceeds 50 mm and daily average southeasterly wind component exceeds 6 m/s			x	
sewind_return_levels	Return levels for daily average southeasterly wind components			x	

3. RESULTS

3.1. RHODES

Rhodes is the largest of the Dodecanese islands located in the Mediterranean Sea. Because of the proximity of the sea, freezing temperatures in Rhodes are rare. Table 3.1.1 shows that freeze-thaw cycles with temperature dropping below -1 °C occurred only in one of the four studied ERA-Interim driven model runs. As temperatures shift towards warmer conditions due to climate change, freeze-thaw cycles are projected to become even rarer but not non-existent in the future (Table 3.1.2). Nevertheless, in the high-emission RCP8.5 scenario, the scenario with most pronounced warming, no freeze-thaw cycles occur in any of the studied model runs after the mid-21st century.

Return levels for heavy precipitation show some variability between different model runs (Tables 3.1.3 and 3.1.4). Future scenarios do not indicate marked change in the occurrence of heavy precipitation in Rhodes (Tables 3.1.5, 3.1.6 and 3.1.7). In the most extreme climate change scenario RCP8.5, return levels for less extreme events seem to somewhat decrease and the lower threshold events (r1d20) become less frequent. However, according to the multi-model mean, daily precipitation sum surpasses 50 mm approximately every other year throughout the 21st century regardless of the emission scenario (Table 3.1.7). Similarly, return levels for 5-day precipitation sum achieved once in five years seem to remain virtually unchanged (Table 3.1.6).

Highest wind speeds in Rhodes are much higher according to the CLMcom-CCLM4-8-17 and KNMI-RACMO22E models relative to the MPI-CSC-REMO2009 and SMHI-RCA4 models (Table 3.1.8). In the future, return levels for high wind speeds are not projected to change much (Table 3.1.9). Like in heavy precipitation events, there is some tendency for weakening of the less extreme high wind speeds under the RCP8.5 scenario (Tables 3.1.9 and 3.1.10).

Table 3.1.1. Numbers of freeze-thaw cycles (daily minimum temperature is below -1 °C and daily maximum temperature is above +1 °C) in the ERA-Interim driven RCM runs in Rhodes.

ERA-Interim driven RCM run	Number of episodic events	Analysis period
CLMcom-CCLM4-8-17	3 cases / 20 years	1989–2008
KNMI-RACMO22E	0 cases / 30 years	1981–2010
MPI-CSC-REMO2009	0 cases / 20 years	1989–2008
SMHI-RCA4	0 cases / 30 years	1981–2010

Table 3.1.2. Multi-model mean annual numbers of freeze-thaw cycles (daily minimum temperature is below -1 °C and daily maximum temperature is above +1 °C) in GCM driven RCM runs in Rhodes. The numbers in parentheses show the intermodel spread in the numbers of events.

Period	Number of episodic events per year		
	RCP2.6	RCP4.5	RCP8.5
1981–2010	0.04 (0.00–0.17)	0.02 (0.00–0.10)	0.02 (0.00–0.10)
2011–2040	0.04 (0.00–0.17)	0.03 (0.00–0.13)	0.01 (0.00–0.07)
2041–2070	0.01 (0.00–0.07)	0.00 (0.00–0.00)	0.00 (0.00–0.00)
2071–2100	0.02 (0.00–0.13)	0.02 (0.00–0.10)	0.00 (0.00–0.00)

Table 3.1.3. Return levels of 1-day precipitation sums in mm in the ERA-Interim driven RCM runs in Rhodes. For example, 1/5 yr refers to a 1-day precipitation sum occuring once every five years, on average.

ERA-Interim driven RCM run	1/5 yr	1/3 yr	1/1 yr	3/1 yr	5/1 yr
CLMcom-CCLM4-8-17	69.0	62.0	40.9	22.6	16.9
KNMI-RACMO22E	67.3	50.5	36.9	25.1	20.1
MPI-CSC-REMO2009	70.5	57.5	35.8	22.0	19.0
SMHI-RCA4	58.9	47.5	32.5	23.0	18.3

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Table 3.1.4. As in Table 3.1.3 but for 5-day precipitation sums.

ERA-Interim driven RCM run	1/5 yr	1/3 yr	1/1 yr	3/1 yr	5/1 yr
CLMcom-CCLM4-8-17	132.5	132.5	105.6	66.5	52.5
KNMI-RACMO22E	113.0	108.4	88.1	69.6	62.0
MPI-CSC-REMO2009	113.5	101.6	84.5	67.9	56.5
SMHI-RCA4	105.7	97.5	70.3	56.1	49.4

Table 3.1.5. Multi-model mean return levels of 1-day precipitation sums in mm in GCM driven RCM runs in Rhodes.

Period	Multi-model mean return levels								
	RCP2.6			RCP4.5			RCP8.5		
	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr
1981–2010	69.5	42.1	22.5	70.6	42.0	22.7	73.8	42.2	22.6
2011–2040	65.8	40.9	22.0	66.9	41.8	22.2	72.1	41.7	22.7
2041–2070	74.0	42.4	22.1	73.5	40.8	21.9	73.9	42.3	21.4
2071–2100	70.0	41.5	22.9	74.5	40.8	21.0	72.6	39.7	19.6

Table 3.1.6. As in Table 3.1.5 but for 5-day precipitation sums.

Period	Multi-model mean return levels								
	RCP2.6			RCP4.5			RCP8.5		
	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr
1981–2010	151.7	104.4	67.4	139.3	104.7	67.9	156.4	105.5	67.1
2011–2040	149.5	101.1	65.7	153.1	101.2	65.5	161.8	107.1	67.4
2041–2070	155.1	109.9	66.0	143.2	102.5	65.1	158.6	110.1	65.4
2071–2100	151.2	103.4	66.9	148.2	105.3	63.9	160.1	103.4	59.5

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Table 3.1.7. Multi-model mean annual numbers of days with precipitation above 20 mm (r1d20) and above 50 mm (r1d50) in GCM driven RCM runs in Rhodes. The numbers in parentheses show the intermodel spread in the numbers of events.

Period	Number of episodic events per year					
	RCP2.6		RCP4.5		RCP8.5	
	r1d20	r1d50	r1d20	r1d50	r1d20	r1d50
1981–2010	7 (5–8)	0.6 (0.4–1.0)	7 (5–9)	0.6 (0.4–0.9)	7 (5–9)	0.6 (0.3–0.9)
2011–2040	6 (5–10)	0.6 (0.4–0.8)	6 (5–10)	0.5 (0.2–1.0)	7 (5–10)	0.5 (0.1–1.0)
2041–2070	6 (4–9)	0.6 (0.4–0.7)	6 (4–10)	0.5 (0.3–0.8)	6 (4–9)	0.6 (0.2–1.2)
2071–2100	7 (5–10)	0.5 (0.3–0.8)	6 (4–8)	0.5 (0.3–0.9)	5 (4–8)	0.6 (0.4–0.8)

Table 3.1.8. Return levels of daily maximum 10-minute average wind speeds at 10 m height in m/s in the ERA-Interim driven RCM runs in Rhodes. For example, 1/5 yr refers to a 10-minute average wind speed occuring once every five years, on average.

ERA-Interim driven RCM run	1/5 yr	1/3 yr	1/1 yr	3/1 yr	5/1 yr
CLMcom-CCLM4-8-17	24.7	23.2	21.1	18.8	17.7
KNMI-RACMO22E	23.0	22.1	20.7	18.2	17.1
MPI-CSC-REMO2009	18.3	16.9	16.0	14.8	14.2
SMHI-RCA4	16.7	15.4	13.9	12.8	12.3

Table 3.1.9. Multi-model mean return levels of daily maximum 10-minute average wind speeds in m/s in GCM driven RCM runs in Rhodes.

Period	Multi-model mean return levels								
	RCP2.6			RCP4.5			RCP8.5		
	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr
1981–2010	20.6	17.9	15.2	20.0	17.8	15.3	21.5	18.5	15.6
2011–2040	20.5	18.2	15.3	20.1	17.7	15.2	21.3	18.5	15.7
2041–2070	21.1	18.3	15.2	20.4	18.0	15.3	20.7	18.3	15.6
2071–2100	20.5	17.9	15.1	20.6	18.0	15.1	21.0	17.7	14.9

Table 3.1.10. Multi-model mean annual numbers of days with a maximum 10-minute average wind speed above 15 m/s in GCM driven RCM runs in Rhodes. The numbers in parentheses show the intermodel spread in the numbers of events.

Period	Number of episodic events per year		
	RCP2.6	RCP4.5	RCP8.5
1981–2010	9.0 (0.6–20.1)	9.1 (0.4–20.6)	10.1 (1.0–19.5)
2011–2040	9.6 (0.8–21.3)	8.6 (0.4–20.0)	10.2 (0.9–19.6)
2041–2070	8.8 (0.8–19.0)	8.7 (0.6–20.5)	9.8 (0.8–19.4)
2071–2100	8.6 (0.7–19.9)	8.2 (0.7–18.0)	7.6 (0.5–15.7)

3.2. GRANADA

Granada is located in southern Spain at an elevation over 700 m above sea level. Although Granada is still located relatively close to sea, freeze-thaw cycles are quite common in Granada due to the relatively high terrain elevation. However, different RCMs simulate very different number of freeze-thaw cycles (Table 3.2.1). On average, there are only one freeze-thaw cycle every third year based on the MPI-CSC-REMO2009 model but almost 40 freeze-thaw cycles every year according to the SMHI-RCA4 model. In the future, there is a clear decreasing tendency projected in the occurrence of freeze-thaw cycles in Granada, the decrease being the larger the higher are the greenhouse-gas emissions (Table 3.2.2).

Also in simulating heavy precipitation, different RCMs yield quite different results in Granada (Tables 3.2.3 and 3.2.4). 5-year return level of 5-day precipitation sum is twice as large in the ERA-Interim driven MPI-CSC-REMO2019 model run relative to the CLMcom-CCLM4-8-17 model run (Table 3.2.4). In general, precipitation

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levels in the Mediterranean region are projected to decrease due to global warming but similarly as in Rhodes, it is in Granada reflected mainly to lower thresholds and short return levels under the RCP8.5 scenario (Tables 3.2.5, 3.2.6 and 3.2.7).

Table 3.2.1. Numbers of freeze-thaw cycles (daily minimum temperature is below -1 °C and daily maximum temperature is above +1 °C) in the ERA-Interim driven model runs in Granada.

ERA-Interim driven RCM run	Number of episodic events	Analysis period
CLMcom-CCLM4-8-17	186 cases / 20 years	1989–2008
KNMI-RACMO22E	798 cases / 30 years	1981–2010
MPI-CSC-REMO2009	7 cases / 20 years	1989–2008
SMHI-RCA4	1125 cases / 30 years	1981–2010

Table 3.2.2. Multi-model mean annual numbers of freeze-thaw cycles (daily minimum temperature is below -1 °C and daily maximum temperature is above +1 °C) in GCM driven RCM runs in Granada. The numbers in parentheses show the intermodel spread in the numbers of events.

Period	Number of episodic events per year		
	RCP2.6	RCP4.5	RCP8.5
1981–2010	32.7 (0.23–54.5)	33.0 (0.17–55.5)	33.6 (0.20–55.0)
2011–2040	26.2 (0.10–47.9)	23.8 (0.03–43.2)	23.0 (0.07–43.2)
2041–2070	23.4 (0.03–44.8)	19.4 (0.03–38.3)	13.8 (0.10–25.3)
2071–2100	23.4 (0.03–41.5)	15.0 (0.00–29.6)	6.4 (0.00–13.0)

Table 3.2.3. Return levels of 1-day precipitation sums in mm in the ERA-Interim driven RCM runs in Granada. For example, 1/5 yr refers to a 1-day precipitation sum occuring once every five years, on average.

ERA-Interim driven RCM run	1/5 yr	1/3 yr	1/1 yr	3/1 yr	5/1 yr
CLMcom-CCLM4-8-17	54.5	48.1	41.6	28.1	23.0
KNMI-RACMO22E	62.6	57.8	42.5	30.0	24.4
MPI-CSC-REMO2009	92.1	78.6	59.0	38.5	30.3
SMHI-RCA4	75.4	66.0	46.1	29.1	22.7

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Table 3.2.4. As in Table 3.2.3 but for 5-day precipitation sums.

ERA-Interim driven RCM run	1/5 yr	1/3 yr	1/1 yr	3/1 yr	5/1 yr
CLMcom-CCLM4-8-17	107.7	105.1	90.6	72.0	63.5
KNMI-RACMO22E	164.5	156.2	117.3	89.6	77.1
MPI-CSC-REMO2009	214.3	206.2	155.5	102.2	88.5
SMHI-RCA4	193.4	159.7	128.8	90.2	73.4

Table 3.2.5. Multi-model mean return levels of 1-day precipitation sums in mm in GCM driven RCM runs in Granada.

Period	Multi-model mean return levels								
	RCP2.6			RCP4.5			RCP8.5		
	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr
1981–2010	86.3	55.0	29.1	84.1	55.2	29.8	82.8	54.5	29.1
2011–2040	77.6	52.4	28.2	85.4	55.2	29.2	81.3	53.0	28.1
2041–2070	91.7	57.1	30.9	78.2	52.5	27.0	83.3	53.3	26.6
2071–2100	86.7	55.7	29.7	88.1	51.3	27.3	89.2	50.9	24.3

Table 3.2.6. As in Table 3.2.5 but for 5-day precipitation sums.

Period	Multi-model mean return levels								
	RCP2.6			RCP4.5			RCP8.5		
	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr
1981–2010	221.0	155.5	99.5	205.3	157.2	100.2	214.0	154.3	98.0
2011–2040	195.2	147.8	93.3	205.4	149.1	96.1	220.2	148.4	94.6
2041–2070	251.3	170.3	102.2	194.8	146.7	90.7	209.1	151.9	89.8
2071–2100	264.5	150.3	98.0	222.9	150.3	92.0	201.4	142.8	79.4

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Table 3.2.7. Multi-model mean annual numbers of days with precipitation above 20 mm (r1d20) and above 50 mm (r1d50) in GCM driven RCM runs in Granada. The numbers in parentheses show the intermodel spread in the numbers of events.

Period	Number of episodic events per year					
	RCP2.6		RCP4.5		RCP8.5	
	r1d20	r1d50	r1d20	r1d50	r1d20	r1d50
1981–2010	10 (6–20)	1.6 (0.4–5.1)	10 (6–20)	1.5 (0.4–4.8)	10 (6–20)	1.5 (0.4–5.0)
2011–2040	10 (5–22)	1.4 (0.3–5.1)	10 (6–19)	1.4 (0.3–4.1)	9 (6–18)	1.3 (0.3–4.5)
2041–2070	11 (5–23)	1.7 (0.4–6.2)	9 (5–19)	1.3 (0.3–4.5)	9 (4–18)	1.2 (0.5–4.1)
2071–2100	10 (5–21)	1.6 (0.3–5.3)	9 (4–17)	1.3 (0.3–4.2)	7 (3–15)	1.1 (0.4–3.6)

3.3. VENICE

Venice, located in the northern shore of the Adriatic Sea, has a generally cooler climate than Granada and Rhodes because of the more northern location. Freeze-thaw cycles occur thus in Venice more commonly (Table 3.3.1). The differences in the frequency of freeze-thaw cycles among the RCM simulations are in Venice rather similar than in Granada: the freeze-thaw cycles occur much more commonly in the KNMI-RACMO22E and SMHI-RCA4 model runs compared to the CLMcom-CCLM4-8-17 and especially MPI-CSC-REMO2009 model runs. Same applies also for the occurrence of extreme cold days with minimum temperature below -5 °C (Table 3.3.3). While the minimum temperature in the KNMI-RACMO22E model drops below -5 °C in Venice on 27 days per year, on average, it never does it in the MPI-CSC-REMO2009 model. In the future, both freeze-thaw cycles and extreme cold temperatures are both projected to become less frequent (Tables 3.3.2 and 3.3.4). The projected decline is particularly steep in the occurrence of extreme cold temperatures (Table 3.3.4).

Model differences in the occurrence of heavy precipitation events in Venice are smaller than in Granada (Tables 3.3.5 and 3.3.6). Unlike in Rhodes and Granada, in Venice heavy precipitation is projected to become an increasing threat as climate turns warmer (Tables 3.3.7, 3.3.8 and 3.3.9). Under the high-emission RCP8.5 scenario, even an increase of 46% is projected in the 5-year return level of 5-day precipitation sum according to the multi-model mean (Table 3.3.8).

Venice is particularly vulnerable for flooding when heavy precipitation occurs accompanied by strong southeasterly winds blowing from the Adriatic Sea pushing the sea level to rise. With selected thresholds (daily precipitation sum above 50 mm and daily average southeasterly wind component above 6 m/s), these events are rather rare (Table 3.3.10). Model simulations still indicate

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increasing frequency of these events in the future (Table 3.3.11), similarly to the occurrence of heavy precipitation events themselves. Indeed, the change is assumably due to intensifying of heavy precipitation events, since the return levels for strong southeasterly winds shown in Table 3.3.12 are not projected to change much in the future (Table 3.3.13). Interestingly, only under the low-emission RCP2.6 scenario the 5-year return level of daily average southeasterly wind component is projected to increase by about 10%.

Table 3.3.1. Numbers of freeze-thaw cycles (daily minimum temperature is below -1 °C and daily maximum temperature is above +1 °C) in the ERA-Interim driven model runs in Venice.

ERA-Interim driven RCM run	Number of episodic events	Analysis period
CLMcom-CCLM4-8-17	57 cases / 20 years	1989–2008
KNMI-RACMO22E	2023 cases / 30 years	1981–2010
MPI-CSC-REMO2009	25 cases / 20 years	1989–2008
SMHI-RCA4	1006 cases / 30 years	1981–2010

Table 3.3.2. Multi-model mean annual numbers of freeze-thaw cycles (daily minimum temperature is below -1 °C and daily maximum temperature is above +1 °C) in GCM driven RCM runs in Venice. The numbers in parentheses show the intermodel spread in the numbers of events.

Period	Number of episodic events per year		
	RCP2.6	RCP4.5	RCP8.5
1981–2010	31.8 (0.6–75.5)	32.0 (0.7–75.3)	34.0 (0.8–76.1)
2011–2040	25.9 (0.4–72.8)	25.4 (0.6–66.7)	26.4 (0.6–64.6)
2041–2070	22.7 (0.1–64.9)	20.4 (0.5–58.0)	18.4 (0.3–49.1)
2071–2100	21.8 (0.5–64.6)	18.0 (0.1–52.6)	9.8 (0.0–32.2)

Table 3.3.3. Numbers of extreme cold days with minimum temperature below -5 °C in the ERA-Interim driven model runs in Venice.

ERA-Interim driven RCM run	Number of episodic events	Analysis period
CLMcom-CCLM4-8-17	3 cases / 20 years	1989–2008
KNMI-RACMO22E	802 cases / 30 years	1981–2010
MPI-CSC-REMO2009	0 cases / 20 years	1989–2008
SMHI-RCA4	42 cases / 30 years	1981–2010

Table 3.3.4. Multi-model mean annual numbers of extreme cold days with minimum temperature below -5 °C in GCM driven RCM runs in Venice. The numbers in parentheses show the intermodel spread in the numbers of events.

Period	Number of episodic events per year		
	RCP2.6	RCP4.5	RCP8.5
1981–2010	6.8 (0.1–23.7)	7.1 (0.1–25.3)	8.1 (0.2–23.6)
2011–2040	5.6 (0.0–23.2)	3.7 (0.0–14.4)	4.6 (0.0–15.3)
2041–2070	4.3 (0.0–16.6)	2.6 (0.0–11.7)	2.3 (0.0–8.5)
2071–2100	3.9 (0.0–18.2)	2.4 (0.0–10.5)	0.6 (0.0–2.4)

Table 3.3.5. Return levels of 1-day precipitation sums in mm in the ERA-Interim driven RCM runs in Venice. For example, 1/5 yr refers to a 1-day precipitation sum occuring once every five years, on average.

ERA-Interim driven RCM run	1/5 yr	1/3 yr	1/1 yr	3/1 yr	5/1 yr
CLMcom-CCLM4-8-17	70.5	68.9	48.0	30.7	24.8
KNMI-RACMO22E	69.1	66.4	53.4	35.2	28.2
MPI-CSC-REMO2009	101.5	68.6	52.6	31.6	22.8
SMHI-RCA4	61.4	59.3	41.9	31.1	23.9

Table 3.3.6. As in Table 3.3.5 but for 5-day precipitation sums.

ERA-Interim driven RCM run	1/5 yr	1/3 yr	1/1 yr	3/1 yr	5/1 yr
CLMcom-CCLM4-8-17	149.6	117.4	102.9	80.2	69.5
KNMI-RACMO22E	165.7	144.9	113.4	90.0	78.5
MPI-CSC-REMO2009	191.1	162.7	121.1	87.1	70.4
SMHI-RCA4	130.5	112.7	94.7	76.2	68.1

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Table 3.3.7. Multi-model mean return levels of 1-day precipitation sums in mm in GCM driven RCM runs in Venice.

Period	Multi-model mean return levels								
	RCP2.6			RCP4.5			RCP8.5		
	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr
1981–2010	78.4	47.9	26.0	80.3	47.2	25.9	74.6	47.2	25.9
2011–2040	88.7	51.0	27.7	74.2	48.3	27.1	75.4	49.0	27.4
2041–2070	90.1	53.4	29.2	83.7	51.0	27.5	93.2	54.9	29.3
2071–2100	82.3	52.5	29.1	93.7	53.6	28.4	90.1	55.5	29.7

Table 3.3.8. As in Table 3.3.7 but for 5-day precipitation sums.

Period	Multi-model mean return levels								
	RCP2.6			RCP4.5			RCP8.5		
	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr
1981–2010	152.3	109.7	71.7	161.9	108.3	70.8	145.3	105.2	70.9
2011–2040	172.0	127.4	78.2	148.6	108.9	74.4	159.0	113.6	73.3
2041–2070	186.8	122.6	80.0	181.5	116.1	75.2	197.3	131.0	81.0
2071–2100	166.0	122.1	80.3	195.8	122.9	77.0	212.1	136.6	80.8

Table 3.3.9. Multi-model mean annual numbers of days with precipitation above 20 mm (r1d20) and above 50 mm (r1d50) in GCM driven RCM runs in Venice. The numbers in parentheses show the intermodel spread in the numbers of events.

Period	Number of episodic events per year					
	RCP2.6		RCP4.5		RCP8.5	
	r1d20	r1d50	r1d20	r1d50	r1d20	r1d50
1981–2010	9 (6–11)	0.8 (0.3–1.1)	9 (6–11)	0.8 (0.4–1.2)	9 (6–11)	0.8 (0.3–1.2)
2011–2040	10 (6–13)	1.0 (0.5–1.6)	10 (8–13)	0.9 (0.5–1.7)	10 (7–14)	0.9 (0.5–1.5)
2041–2070	11 (8–14)	1.2 (0.7–1.9)	10 (7–12)	1.0 (0.7–1.6)	11 (8–13)	1.2 (0.7–1.5)
2071–2100	11 (8–13)	1.3 (0.6–2.2)	10 (7–13)	1.1 (0.6–1.9)	10 (7–13)	1.4 (0.7–1.9)

Table 3.3.10. Numbers of days when precipitation sum exceeds 50 mm and the southeasterly component of wind at 10 m height is higher than 6 m/s in the ERA-Interim driven RCM runs in Venice.

ERA-Interim driven RCM run	Number of episodic events	Analysis period
CLMcom-CCLM4-8-17	3 cases / 20 years	1989–2008
KNMI-RACMO22E	4 cases / 30 years	1981–2010
MPI-CSC-REMO2009	3 cases / 20 years	1989–2008
SMHI-RCA4	2 cases / 30 years	1981–2010

Table 3.3.11. Multi-model mean annual numbers of days when precipitation sum exceeds 50 mm and the southeasterly component of wind at 10 m height is higher than 6 m/s in GCM driven RCM runs in Venice. The numbers in parentheses show the intermodel spread in the numbers of events.

Period	Number of episodic events per year		
	RCP2.6	RCP4.5	RCP8.5
1981–2010	0.08 (0.00–0.24)	0.06 (0.00–0.17)	0.07 (0.00–0.24)
2011–2040	0.14 (0.03–0.45)	0.06 (0.00–0.17)	0.10 (0.03–0.17)
2041–2070	0.15 (0.13–0.20)	0.10 (0.03–0.14)	0.15 (0.03–0.34)
2071–2100	0.10 (0.03–0.21)	0.10 (0.00–0.20)	0.13 (0.03–0.21)

Table 3.3.12. Return levels of daily average southeasterly component of wind at 10 m height in m/s in the ERA-Interim driven RCM runs in Venice. For example, 1/5 yr refers to a 1daily average southeasterly component of wind occuring once every five years, on average.

ERA-Interim driven RCM run	1/5 yr	1/3 yr	1/1 yr	3/1 yr	5/1 yr
CLMcom-CCLM4-8-17	10.4	9.0	7.0	4.9	4.2
KNMI-RACMO22E	8.7	8.4	6.6	4.4	3.6
MPI-CSC-REMO2009	9.2	8.6	6.0	4.7	4.0
SMHI-RCA4	9.1	8.4	6.8	4.7	4.1

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Table 3.3.13. Multi-model mean return levels of daily average southeasterly component of wind at 10 m height in m/s in GCM driven RCM runs in Venice.

Period	Multi-model mean return levels								
	RCP2.6			RCP4.5			RCP8.5		
	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr
1981–2010	8.8	6.7	4.1	8.9	6.5	4.1	8.8	6.5	4.1
2011–2040	8.6	6.4	4.0	8.9	6.6	4.2	8.6	6.5	4.0
2041–2070	9.4	6.9	4.3	8.7	6.4	4.0	8.8	6.6	4.0
2071–2100	9.7	7.0	4.2	9.3	6.7	4.1	8.6	6.4	4.0

3.4. TØNSBERG

Tønsberg, located in southern Norway, has a quite different climate relative to other inspected sites in the Mediterranean Area. Freeze-thaw cycles occur in Tønsberg more frequently than in any other site (Table 3.4.1), however, their frequency varies among the model simulations similarly as in Venice. Also here global warming leads to a diminishing occurrence of freeze-thaw cycles. According to the multi-model mean, the frequency of freeze-thaw cycles decreases by 16% under the RCP2.6 scenario, 27% under the RCP4.5 scenario and 48% under the RCP8.5 scenario by the end of century, relative to the period of 1981–2010 (Table 3.4.2).

The MPI-CSC-REMO2009 model produces clearly the heaviest precipitation events in Tønsberg (Tables 3.4.3 and 3.4.4), like was the case also in Granada and Venice. In Tønsberg, heavy precipitation events are projected to slightly intensify in the future (Table 3.4.5, 3.4.6 and 3.4.7). Furthermore, the projected change is largest under the RCP8.5 scenario and smallest under the RCP2.6 scenario, although the differences in the rate of the change are not dramatic between the emission scenarios.

Highest wind speeds simulated by different RCMs do not diverge much in Tønsberg (Table 3.4.8). Compared to Rhodes were wind speeds were similarly studied, the models do not generally simulate as high wind speeds in Tønsberg. In the future, the return levels of high wind speeds are projected to remain nearly unaltered in Tønsberg (Table 3.4.9). Only minor increases are projected for the 1-year and 5-year return levels of sustained wind speed. Nevertheless, even this minor increase might result as a considerably increase in the occurrence of wind speeds higher than 15 m/s (Table 3.4.10).

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Table 3.4.1. Numbers of freeze-thaw cycles (daily minimum temperature is below -1 °C and daily maximum temperature is above +1 °C) in the ERA-Interim driven model runs in Tønsberg.

ERA-Interim driven RCM run	Number of episodic events	Analysis period
CLMcom-CCLM4-8-17	481 cases / 20 years	1989–2008
KNMI-RACMO22E	2203 cases / 30 years	1981–2010
MPI-CSC-REMO2009	165 cases / 20 years	1989–2008
SMHI-RCA4	1594 cases / 30 years	1981–2010

Table 3.4.2. Multi-model mean annual numbers of freeze-thaw cycles (daily minimum temperature is below -1 °C and daily maximum temperature is above +1 °C) in GCM driven RCM runs in Tønsberg. The numbers in parentheses show the intermodel spread in the numbers of events.

Period	Number of episodic events per year		
	RCP2.6	RCP4.5	RCP8.5
1981–2010	52.0 (8.5–85.4)	51.0 (8.0–83.3)	52.2 (8.4–84.9)
2011–2040	45.4 (8.6–81.5)	45.0 (7.8–77.3)	43.8 (5.9–77.7)
2041–2070	41.5 (6.3–73.9)	42.0 (6.9–77.4)	37.3 (5.4–67.3)
2071–2100	43.7 (7.8–78.7)	37.2 (7.0–67.0)	26.9 (2.6–55.6)

Table 3.4.3. Return levels of 1-day precipitation sums in mm in the ERA-Interim driven RCM runs in Tønsberg. For example, 1/5 yr refers to a 1-day precipitation sum occuring once every five years, on average.

ERA-Interim driven RCM run	1/5 yr	1/3 yr	1/1 yr	3/1 yr	5/1 yr
CLMcom-CCLM4-8-17	50.8	44.8	36.1	26.3	23.0
KNMI-RACMO22E	57.8	48.1	36.9	27.6	24.6
MPI-CSC-REMO2009	74.4	63.2	51.2	37.5	30.4
SMHI-RCA4	57.6	48.7	41.6	32.5	28.8

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Table 3.4.4. As in Table 3.4.3 but for 5-day precipitation sums.

ERA-Interim driven RCM run	1/5 yr	1/3 yr	1/1 yr	3/1 yr	5/1 yr
CLMcom-CCLM4-8-17	109.0	106.7	89.5	68.6	61.6
KNMI-RACMO22E	118.1	110.7	88.3	70.1	62.9
MPI-CSC-REMO2009	222.8	151.7	132.0	98.6	87.6
SMHI-RCA4	133.9	126.8	102.5	80.0	71.9

Table 3.4.5. Multi-model mean return levels of 1-day precipitation sums in mm in GCM driven RCM runs in Tønsberg.

Period	Multi-model mean return levels								
	RCP2.6			RCP4.5			RCP8.5		
	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr
1981–2010	57.8	39.4	25.2	56.8	39.4	25.2	56.9	39.0	25.3
2011–2040	55.8	39.9	26.4	55.9	40.8	26.4	59.1	41.3	26.8
2041–2070	56.9	41.1	26.5	57.5	42.1	27.0	58.3	42.8	27.4
2071–2100	55.3	41.0	26.5	61.4	42.5	27.4	60.5	44.1	29.6

Table 3.4.6. As in Table 3.2.5 but for 5-day precipitation sums.

Period	Multi-model mean return levels								
	RCP2.6			RCP4.5			RCP8.5		
	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr
1981–2010	122.8	93.0	68.4	124.4	91.8	69.0	124.3	94.0	68.8
2011–2040	139.6	100.4	70.9	121.3	95.9	71.9	128.1	97.7	72.9
2041–2070	120.1	96.1	71.8	129.2	98.9	73.0	125.0	99.3	73.7
2071–2100	123.4	98.4	72.0	128.0	100.3	74.3	148.0	108.8	79.3

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Table 3.4.7. Multi-model mean annual numbers of days with precipitation above 20 mm (r1d20) and above 50 mm (r1d50) in GCM driven RCM runs in Tønsberg. The numbers in parentheses show the intermodel spread in the numbers of events.

Period	Number of episodic events per year					
	RCP2.6		RCP4.5		RCP8.5	
	r1d20	r1d50	r1d20	r1d50	r1d20	r1d50
1981–2010	10 (5–16)	0.4 (0.1–0.9)	10 (6–15)	0.4 (0.1–0.8)	10 (6–15)	0.4 (0.1–0.8)
2011–2040	11 (6–15)	0.4 (0.0–1.0)	11 (6–15)	0.4 (0.1–1.2)	11 (6–16)	0.4 (0.2–1.1)
2041–2070	11 (7–16)	0.4 (0.1–0.7)	11 (7–17)	0.5 (0.3–1.1)	12 (8–16)	0.5 (0.1–1.0)
2071–2100	11 (7–16)	0.4 (0.1–1.1)	12 (7–14)	0.4 (0.2–0.6)	14 (9–18)	0.6 (0.1–1.2)

Table 3.4.8. Return levels of daily maximum 10-minute average wind speeds at 10 m height in m/s in the ERA-Interim driven RCM runs in Tønsberg. For example, 1/5 yr refers to a 10-minute average wind speed occuring once every five years, on average.

ERA-Interim driven RCM run	1/5 yr	1/3 yr	1/1 yr	3/1 yr	5/1 yr
CLMcom-CCLM4-8-17	15.6	14.6	13.2	12.0	11.5
KNMI-RACMO22E	15.9	15.5	14.1	13.0	12.3
MPI-CSC-REMO2009	15.3	14.9	13.5	12.0	11.4
SMHI-RCA4	14.9	14.7	13.5	12.2	11.7

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Table 3.4.9. Multi-model mean return levels of daily maximum 10-minute average wind speeds in m/s in GCM driven RCM runs in Tønsberg.

Period	Multi-model mean return levels								
	RCP2.6			RCP4.5			RCP8.5		
	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr	1/5 yr	1/1 yr	5/1 yr
1981–2010	15.3	13.6	11.8	15.2	13.6	11.8	15.2	13.6	12.0
2011–2040	15.0	13.4	11.7	15.3	13.6	11.8	15.4	13.7	11.8
2041–2070	15.0	13.5	11.8	15.3	13.6	11.7	15.3	13.7	11.7
2071–2100	15.1	13.3	11.6	15.5	13.8	11.8	15.9	14.1	12.0

Table 3.4.10. Multi-model mean annual numbers of days with a maximum 10-minute average wind speed above 15 m/s in GCM driven RCM runs in Tønsberg. The numbers in parentheses show the intermodel spread in the numbers of events.

Period	Number of episodic events per year		
	RCP2.6	RCP4.5	RCP8.5
1981–2010	0.25 (0.03–0.50)	0.22 (0.00–0.47)	0.23 (0.00–0.47)
2011–2040	0.23 (0.00–0.41)	0.30 (0.10–0.60)	0.33 (0.07–0.55)
2041–2070	0.23 (0.03–0.45)	0.32 (0.00–0.79)	0.36 (0.03–0.93)
2071–2100	0.25 (0.07–0.66)	0.37 (0.00–0.90)	0.43 (0.03–0.70)

4. CONCLUSIONS

The impact of climate change on extreme weather conditions affecting the cultural heritage sites in Rhodes, Granada, Venice and Tønsberg were studied in WP3.1 and the results of this inspection are summarized in this report. The study period covered the years from 1981 until 2100. The analyses were based on the dynamically downscaled CORDEX model data under three alternative climate change pathways. A total of seven different GCM–RCM combinations were studied in evaluating the future climatic changes. Four RCMs were used in dynamically downscaling the GCM data, and these RCMs were also forced by the ERA-Interim reanalysis data over the recent past. This showed large intermodel differences in simulating most of the extreme events. However, future projections were mainly uniform among the model simulations when considering whether the specific risks for the heritage sites were projected to increase or decrease.

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To conclude, freeze-thaw cycles were projected to become less common in all the studied locations. Even more pronounced seems to be the decrease in the frequency of extreme cold days in Venice. These changes were found to be largest under the high-emission RCP8.5 scenario and smallest under the low-emission RCP2.6 scenario. Risks related to heavy precipitation were projected to increase in Tønsberg and Venice. In Rhodes and Granada, on the other hand, heavy precipitation events were projected to become somewhat less frequent in the late 21st century under the high-emission scenarios, although the frequency of most intense precipitation events was not projected to change markedly even in that case. Strong winds were studied in Rhodes and Tønsberg. Wind-related risks were not found to be greatly affected by climate change. The results for Tønsberg indicated some tendency towards higher frequency of strong winds whereas in Rhodes a minor decrease in the risk could be possible. In Venice, virtually no change was projected for the occurrence of strong southeasterly winds posing risk for coastal flooding due to sea level rise. However, due to an increasing frequency of heavy precipitation in Venice, the episodes with strong southeasterly winds might be more often associated with heavy precipitation increasing the flood risk.

This document does not completely show the results of the climate risk analysis. Comprehensively the results are stored in the hierarchical Dataset_D3.1.zip file as described in detail in the Appendix A.

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Appendix A

Dataset containing a register of all the scenarios.

The dataset (Dataset_D3.1.zip) is organized into a directory structure, facilitating convenient access to results associated with different criteria.

The README of the dataset is presented below:

README

This folder / subdirectory contains the data of episodic periods (days) identified from the results from an ensemble of climate model systems applying specific selection criteria. The model systems, selection criteria and the data itself are described and summarized in the HYPERION report D3.1 "Climate Data and Scenario Selection" in which the content of this README file is also found in Appendix A.

The temporal resolution is one day (24 hours) and the data spans over the time period 1981–2100 or 1981–2099, except for the ERA-Interim-driven reanalysis results which span either from 1981 to 2010 or from 1989 to 2008.

Each data file contains the dates (one date per line) on which the severity criterion in question is met. The date is given in the format YYYY-MM-DD. The absolute value of a variable (or variables) in question is given after the date, separated by a semicolon. The unit is degC for temperatures, mm for precipitation and m/s for wind speed.

The data files are ordered into a three-level subdirectory tree as follows. The upper subdirectory level contains this README file and four subdirectories: Granada, Rhodes, Tonsberg and Venice referring to the sites. Each subdirectory contains four subdirectories: rcp26, rcp45, rcp85 and ERA-Interim. The first three of these, i.e., rcp26, rcp45 and rcp85, refer to the lower-end, central and higher-end pathway climate scenarios up to the year 2100, respectively. ERA-interim refers to reanalysis data produced using the CLMcom-CCLM4-8-17 (time period 1989–2008), KNMI-RACMO22E (time period 1981–2010), MPI-CSC-REMO2019 (time period 1989–2008) and SMHI-RCA4 (time period 1981–2010) models forced by the ERA-Interim data. Finally, all these three subdirectories contain two or three lowest-level subdirectories: Precipitation, Temperature and Wind. These subdirectories contain all data files produced using different model setups and different criteria.

The structure of the file names is as follows. The name begins with a character substring describing the quantity in question. Following this substring comes a number or a character string describing the criterion in question. These are as listed below.

- Tas
    - near-surface (2 m) air temperature, criteria:
        - 1 temperature crosses the interval [-1 degC, 1 degC] during the day
- tmin
    - near-surface (2 m) minimum air temperature, criteria:
        - m5 minimum temperature is below -5 degC during the day
- wsmax
    - maximum wind speed (10 min average) at 10 m height, criteria:
        - 15 maximum surface wind speed exceeds 15 m/s during the day
        - 20 maximum surface wind speed exceeds 20 m/s during the day
- r1d
    - daily precipitation sum, criteria:
        - 20 daily precipitation sum exceeds 20 mm 50 daily precipitation sum exceeds 50 mm
- r5d
    - precipitation sum of five consecutive days, criteria:
        - 50 total precipitation sum of five consecutive days exceeds 50 mm
        - 100 total precipitation sum of five consecutive days exceeds 100 mm
- r1d50sewind
    - combined occurrence of heavy precipitation and high southeasterly winds, criteria:
        - 6 daily average southeasterly component of wind at 10 m height exceeds 6 m/s while daily precipitation sum simultaneously exceeds 50 mm

Not all variables are made available for every location. Additionally, return levels have been calculated for wsmax, r1d and r5d, in Venice also for daily average southeasterly component of wind (sewind). These files contain the return levels for four different time periods: 1981–2010, 2011–2040, 2041–2070 and 2071–2100 (or 2071–2099). These files contain the following data for each time period:

max	The maximum value
1/5yr	The value occurring once every five years, on average
1/4yr	The value occurring once every four years, on average
1/3yr	The value occurring once every three years, on average
1/2yr	The value occurring once every two years, on average
1/1yr	The value occurring once every year, on average
2/1yr	The value occurring twice every year, on average
3/1yr	The value occurring three times a year, on average
4/1yr	The value occurring four times a year, on average
5/1yr	The value occurring five times a year, on average

The data originating from each climate model run is placed in a separate file but the return levels for r1d and r5d are placed in the same files named as "rr_return_levels...". Except the return level data from all the ERA-Interim driven reanalysis has been placed in the same files for each location. In these files, in addition to model-specific return levels, also the multi-model mean values of the return levels are provided.

The rest of file names have been constructed as follows. Separated with an underscore, is first placed "EUR-11" to imply that the data originates from the CORDEX model runs covering Europe in 0.11 x 0.11 degree horizontal resolution. Then, separated by an underscore, is given the acronym of the global climate model used for driving the CORDEX model simulations. These are ICHEC-EC-EARTH, MOHC-HadGEM2-ES and MPI-M-MPI-ESM-LR. The next character string, separated by an underscore, specifies the representative concentration pathway (RCP) scenario: rcp26, rcp45 or rcp85. Then, the next character string, separated by an underscore specifies the ensemble member of model run, which is r12i1p1 for the model runs driven by ICHEC-EC-EARTH model and r1i1p1 otherwise. After this, separated by an underscore is placed the acronym for the regional climate model. These are CLMcom-CCLM4-8-17, KNMI-RACMO22E, SMHI-RCA4 and MPI-CSC-REMO2009. Next, again after and underscore, is shown the downscaling realization, which is v1, v1a or v2. Then, followed by an underscore, is placed a word "day" implying that the data originates from CORDEX model runs containing daily data. Then, after an underscore, is specified the time period over which the file contains data. The time period is specified in a format YYYYMMDD-YYYYMMDD. As the last substring, again after underscore, the site is specified. Options are granada, rhodes, tonsberg and venice. As an example of a data file name can be e.g.,

r1d50_EUR-11_ICHEC-EC-EARTH_rcp26_r12i1p1_KNMI-RACMO22E_v1_day_19810101-21001231_venice.txt

The ERA-Interim driven reanalysis data files are named otherwise the same way but the substring for global climate model has been replaced by the string "ECMWF-ERAINT" and the RCP scenario is replaced by the string "evaluation". For instance as:

tas1_EUR-11_ECMWF-ERAINT_evaluation_r1i1p1_MPI-CSC-REMO2009_v1_day_19890101-20081231_rhodes.txt

Those files containing return levels from several different ERA-Interim driven climate models, have shorter file names. For instance as:

r1d_return_levels_EUR-11_ECMWF-ERAINT_evaluation_tonsberg.txt

All data files are ASCII-text files, hence the extension txt.