Ref. Ares(2019)3043991 - 07/05/2019

PANOPTIS

Development of a Decision Support System for increasing the Resilience of Road Infrastructure based on combined use of terrestrial and airborne sensors and advanced modelling tools-

Grant Agreement Number: 769129

D3.1: Climate Data and Scenario Selection

Work package	WP3: Atmospheric Forcing Modelling, Weather Now/Fore-Casting and Data Processing
Activity	Task3.1: Assessment of Climate Data and Selection Scenarios
Deliverable	D3.1 Report on Climate Data and Scenario Selection
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Status	Final (F)
Version	2.0
Dissemination Level	Public (PU)
Document date	07/05/2019
Delivery due date	31/03/2019
Actual delivery date	07/05/2019
Internal Reviewers	Fotios Barmpas
	This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement no769129.

Document Control Sheet

Version history table			
Version	**Date**	**Modification reason**	**Modifier**
1.0	07/05/2019		*FMI*
2.0	07/05/2019	*Internal review*	*FMI*

Legal Disclaimer

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Abbreviation	Definition
RCM	Regional Climate Model
GCM	Global Climate Model
RCP	Representative Concentration Pathway
RAIN	Risk Analysis of Infrastructure Networks for Extreme Weather Events (project)
LES	Large Eddy Simulation
CORDEX	Coordinated Regional Climate Downscaling Experiment

Executive Summary

This deliverable report, titled "**D3.1 Climate data and scenario selection**", communicates the performed climate related severity analysis on both pilot sites in Spain and Greece. The 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 both the past (1981-present) and the future (present-2100) climate pathways. The analysis identifies episodic periods when chosen severity criteria have been met, providing climate scenario information for subsequent weather impact downscaling analysis.

1 Introduction

1.1 Purpose of the Document

This document will describe the severity analysis of climate impacts performed for the PANOPTIS pilot sites in Spain and Greece. Wind, temperature and precipitation are considered in the analysis. The obtained results for the frequency of events surpassing the specified severity criteria are presented herein. The generated scenario dataset for wind is employed to establish appropriate boundary conditions for the subsequent high-resolution Large-eddy simulations which provide downscaled information for the considered wind-related climate impacts. In addition, the dataset for temperature and precipitation events is used directly in deriving location-specific impact factors for hazard assessment.

1.2 Intended audience

The deliverable is primarily targeted for PANOPTIS project partners and WP3 collaborators, but it is also accessible to general audience.

2 Severity criteria for meteorological variables

Severity analysis for adverse and extreme weather events entails identification and classification of events that are expected to affect the transportation network and infrastructure (Vajda et al., 2014). Such analysis has been carried out for two sites/roads: one in Spain (77.5 km long section of A2 highway in the province Guadalajara) and one in Greece (62.2 km long mountainous section of Egnatia Motorway in the prefecture of Epirus). We have analysed the regional climate model (RCM) data from three models (REMO, RCA and CLM) for the target areas. The data has been obtained from the Euro-CORDEX project and we have used the 0.11° resolution data (12.5 km).

The RCM simulations were driven with different lateral boundary conditions: ERA-Interim (Dee et al., 2011) and global climate model (GCM) data for the past and current climate (1981-2010), and GCM data for the future climate up to year 2100 available from the Euro-CORDEX project. Moreover, for each GCM-driven RCM simulation we have tried to find multiple different GCM-forcings. The future climate simulations were chosen to follow RCP2.6 and RCP4.5, which are the lower-end and central pathway (respectively) of the future's greenhouse-gas concentration pathway scenarios. The GCM's for the future lateral forcing were the same as for the historical period and included both future scenarios, if available.

All analysed variables stored on a geo-referenced grid were subjected to identical treatment: we use rectangular lat/lon boxes around the pilot sites and analyse all the values within these areas (see Figure 1). Moreover, threshold values were selected for all analysed variables for identifying the cases fitting into the severe condition class. In this work, we have used two approached for the threshold values. Primarily, we have used the same threshold for both sites allowing one-to-one comparison. Secondarily, we have used site-specific limits to identify the upper extreme of the severity distribution. Example visualizations from randomly chosen episodic periods from both pilot sites are shown in Figure 2 and Figure 3.

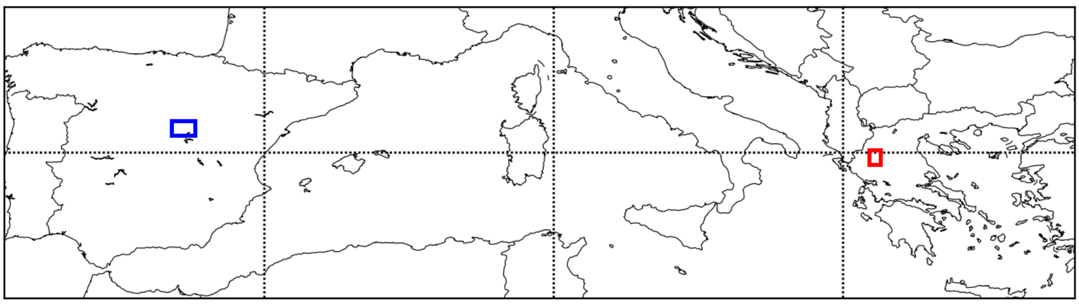

Figure 1: Study areas in Spain (blue box) and Greece (red box).

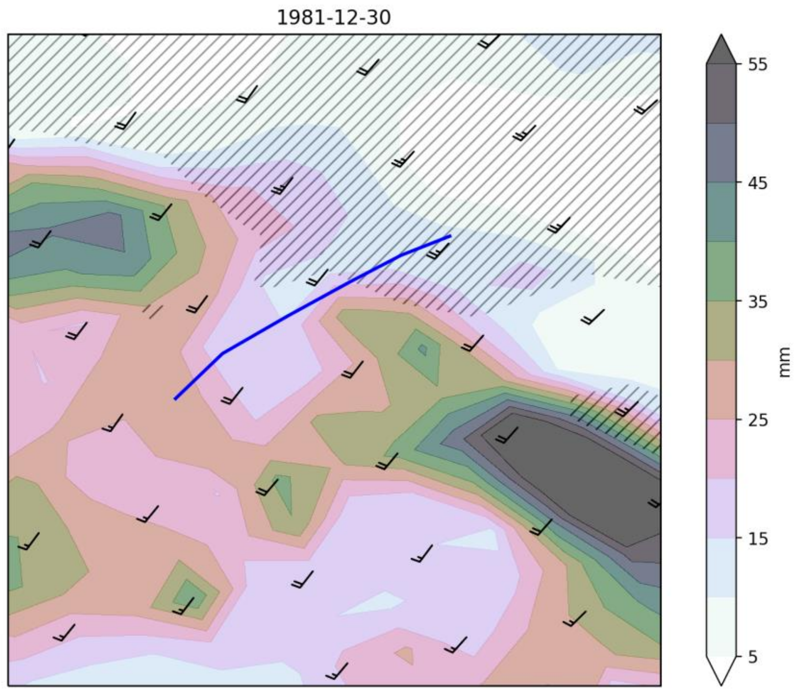

Figure 2: REMO using ERA-Interim in Spain: shading shows daily precipitation, hatching shows areas where wsmax is at least 15 m/s, barbs show mean wind (knots), and blue line shows the road.

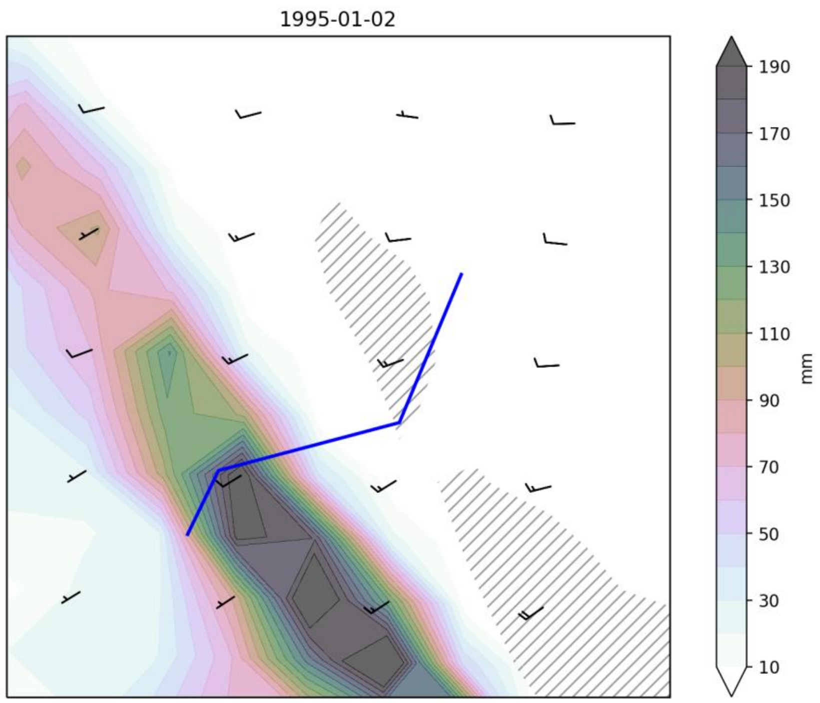

Figure 3: REMO using ERA-Interim in Greece: shading shows daily precipitation, hatching shows areas where wsmax is at least 15 m/s, barbs show mean wind (knots), and blue line shows the road.

2.1 Temperature

The temperature measure considered herein is the surface (2 m) air temperature. When the air temperature goes below zero degrees the probability for slippery road conditions increases. However, the sub-zero temperatures does not automatically mean slippery conditions as the wetness of the road surface is another important factor. To quantify the potential slippery conditions from the air temperature data we have used a common approach, where we check if the daily maximum temperature is over a certain threshold whilst the daily minimum is below the threshold with the same absolute value but negative sign (assuming Celsius degrees). During these so-called zero crossing days, the risk for slippery conditions is very high (Vajda et al., 2014).

The common threshold value used for both sites is 1 °C, i.e. the severity criterion is met if the daily maximum is over 1 °C and the daily minimum below -1 °C. The site specific thresholds were: 3 °C for Spain and 4 °C for Greece.

Table 1: The number of severe temperature events for Spain / Greece from different RCMs driven with different GCMs for RCP2.6. Values are calculated with the default threshold value of 1 °C. The last column shows the same analysis made using the Era-Interim data as the driver.

RCM	*RCA*		*RACMO*		*CCLM4*	*REMO*	*REMO*
GCM	*MPI*	*HadGEM*	*HadGEM*	*EC-EARTH*	*EC-EARTH*	*MPI*	*Era-Interim*
1981-2100	7202 / 11063	7593 / 11488	12709 / 15627	16543 / 19852	7543 / 10125	1538 / 7108	
1981-2010	2126 / 3038	2400 / 3443	3743 / 4438	4456 / 5342	2164 / 2661	501 / 1931	764 / 2130
2011-2040	1760 / 2614	1873 / 2945	3174 / 3899	4218 / 4953	1904 / 2654	411 / 1699	
2041-2070	1610 / 2609	1671 / 2585	2884 / 3577	3881 / 4802	1771 / 2466	350 / 1693	
2071-2100	1706 / 2801	1631 / 2492	2878 / 3686	3988 / 4755	1704 / 2344	276 / 1785	

Table 1 shows the number of temperature events for Spain and Greece from different RCMs driven with different GCMs for RCP2.6. Overall, there is a clear trend that the frequency of events will decrease. However, it seems that after 2011-2040 the decrease is settling and in some cases the number of events even increase slightly when reaching the end of the century.

2.2 Precipitation

For precipitation the severity criteria were derived based on the information gathered from the FP7 project RAIN (Risk Analysis of Infrastructure Networks for Extreme Weather Events). We have used two separate approaches for the daily precipitation to screen both short-term and long-term heavy precipitation events. First, if the daily precipitation exceeds a certain limit, we have classified the day to be in severe road safety class. Secondly, if the precipitation sum of 5-consecutive days exceeds a certain limit, we have done the same classification.

The common threshold values for precipitation were: 40 mm/d and 100 mm/5-d (total sum of 5-consecutive days). The daily precipitation sum threshold for Spain was 50 mm/d and for Greece 100 mm/d and the thresholds for 5-consecutive days were for Spain 120 mm/5-d and for Greece 250 mm/5-d.

Table 2: The number of severe precipitation events for Spain / Greece from different RCMs driven with different GCMs for RCP2.6. Values are calculated with the default threshold value of 100 mm/5-d. The last column shows the same analysis made using the Era-Interim data as the driver.

RCM	*RCA*		*RACMO*		*CCLM4*	*REMO*	*REMO*
GCM	*MPI*	*HadGEM*	*HadGEM*	*EC-EARTH*	*EC-EARTH*	*MPI*	*Era-Interim*
1981-2100	1018 / 5570	570 / 4848	358 / 3128	170 / 2122	238 / 1702	1303 / 3344	
1981-2010	257 / 1317	146 / 1107	101 / 718	23 / 456	50 / 384	299 / 785	162 / 457
2011-2040	249 / 1398	107 / 1232	69 / 856	48 / 632	73 / 420	347 / 802	
2041-2070	276 / 1332	163 / 1358	124 / 846	46 / 506	71 / 473	358 / 848	
2071-2100	236 / 1523	153 / 1135	64 / 703	53 / 528	44 / 425	299 / 909	

Table 2 shows the number of precipitation events for Spain and Greece from different RCMs driven with different GCMs for RCP2.6. In Spain, the number of events will overall decrease, while there are some fluctuations. For Greece, there is a clear increasing trend, which means more long-term precipitation episodes in the future.

2.3 Winds

The wind variable considered herein is the 10 min average of maximum surface (10 m) wind. The wind severity was obtained by analysing the surface maximum wind speeds. For the wind speeds, we used again two threshold approach, but there was no need to have more site specific values. Vajda et al. (2014) give three criteria: 17 m/s, 25 m/s and 32 m/s for wind gust speed defined as the maximum 3 s average. However, we cannot use any criteria based on wind gust speed since the RCMs cannot capture such short-term events. Therefore we have to use criteria based on the 10 min averaged wind speed which is a default output variable of all RCMs. We selected to use two thresholds: 12 m/s and 15 m/s for both sites. These threshold values were found meaningful for the analysed areas. These thresholds are also reasonably well in line with the first two criteria given by Vajda et al. (2014) assuming a gust factor (defined as the ratio between 3 s averaged to 10 min averaged wind speeds) value of about 1.6 recommended by WMO (Harper et al, 2010).

Table 3: The number of severe wind events for Spain / Greece from different RCMs driven with different GCMs for RCP2.6. Values are calculated with the default threshold value of 12 m/s. The last column shows the same analysis made using the Era-Interim data as the driver.

RCM	*RCA*		*RACMO*		*CCLM4*	*REMO*	*REMO*
GCM	*MPI*	*HadGEM*	*HadGEM*	*EC-EARTH*	*EC-EARTH*	*MPI*	*Era-Interim*
1981-2100	2101 / 4055	1180 / 3554	970 / 334	738 / 153	967 / 144	897 / 1023	
1981-2010	489 / 969	318 / 862	260 / 64	170 / 38	242 / 40	212 / 229	151 / 135
2011-2040	526 / 984	254 / 922	223 / 85	186 / 36	232 / 37	230 / 241	
2041-2070	558 / 1044	307 / 922	239 / 98	188 / 30	255 / 31	226 / 295	
2071-2100	529 / 1058	299 / 837	247 / 85	194 / 49	238 / 36	229 / 258	

Table 3 shows the number of wind events for Spain and Greece from different RCMs driven with different GCMs for RCP2.6. The signal from the wind analysis is not very strong and models show both increasing and decreasing possibilities. As in many wind-related analyses done before the outcome is very uncertain and no clear trend is present.

3 Conclusions

In this work package we have delivered regional climate model (RCM) data on severe weather events for the purpose of climate related risk assessment and micro- and meso-scale modellers. The analysis has been done for the two pilot site locations in Spain and Greece. Using different global climate model (GCM) driver RCMs and two future emission pathways, we identified the number of severe events for temperature, precipitation and wind. The selected future scenarios involved RCPs 2.6 and 4.5, where 2.6 represents the most optimistic greenhouse-gas concentration scenario for limiting anthropogenic climate change and 4.5 representing the second most optimistic scenario in which the greenhouse gas emissions are assumed to peak around 2040.

The results show that the number of zero-temperature crossing events, which indicate high risk of slippery road condition, will decrease especially during the first half of the century. Concerning heavy precipitation conditions, the results show that in the Spanish site, the number of events will likely decrease slightly, while for the greek site, there is a clear increasing trend. For the heavy wind conditions, the results show no clear future trend.

In this document, only the results from RCP2.6 scenario are presented whereas all the analysed results can be found from the dataset stored in the project's cloud storage system (Redmine).

The scenario dataset for wind is employed to establish appropriate boundary conditions for the subsequent high-resolution LES simulations (which generate downscaled information) whereas the dataset for temperature and precipitation events is used directly in climate related hazard assessment.

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Annexes

Dataset containing a register of all the scenarios (stored within Redmine project platform).

The dataset ("Dataset_D3.1.tgz" on Redmine) 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 PANOPTIS 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, except for the ERA-Interim-driven REMO
reanalysis results which span from 1981 to 2010.

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 followed by a dummy timestamp
"T12:00:00.000000000". The file format is ASCII text.

The data files are ordered into a three-level subdirectory tree as
follows. The upper subdirectory level contains this README file and
two subdirectories: Greece and SPAIN referring to the sites. Both
subdirectories GREECE and SPAIN contain three subdirectories rcp26,
rcp45 and ERA-Interim. The first two of these, rcp26 and rcp45, refer
to the lower-end and central pathway climate scenarios up to year
2100, respectively. ERA-interim refers to reanalysis data for the
years 1981-2010 produced using the REMO model forced by the ERA-
Interim data. Finally, all these three subdirectories contain
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: surface (2 m) air temperature, criteria:
      1: temperature crosses the interval [-1 C, 1 C] during the day
      3: temperature crosses the interval [-3 C, 3 C] during the day
      4: temperature crosses the interval [-4 C, 4 C] during the day

wsmax: maximum surface (10 m) wind speed (10 min average)
      12: maximum surface wind speed exceeds 12 m/s during the day
      15: maximum surface wind speed exceeds 15 m/s during the day

r:  precipitation (rain)
      1d40:  daily precipitation sum exceeds 40 mm
      1d50:  daily precipitation sum exceeds 50 mm
      1d100: daily precipitation sum exceeds 100 mm
      5d100: total sum of five consecutive days exceeds 100 mm
      5d120: total sum of five consecutive days exceeds 120 mm
```

5d250: total sum of five consecutive days exceeds 250 mm

Next, separated with an underscore, is placed the name or acronym of the regional climate model (RCM) used. These are RCA, RACMO, CCLM4 and REMO. The next character string, again separated by underscore specifies the name or acronym of the global climate model used for driving the RCMs: These are MPI, HadGEM and EC-EARTH. After this follows the acronym for the climate pathway scenario: rcp26 or rcp45. As the last substring, again after underscore, the site is specified as either Greece or SPAIN. As an example of a data file name can be e.g.

tas3_REMO_MPI_rcp26_SPAIN.txt

The ERA-Interim driven REMO reanalysis data files are named otherwise the same way but the combination of the substrings for global climate model and climate scenario is replaced by the string "ERA-Interim". For instance as

r5d100_REMO_ERA-INTERIM_SPAIN.txt

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