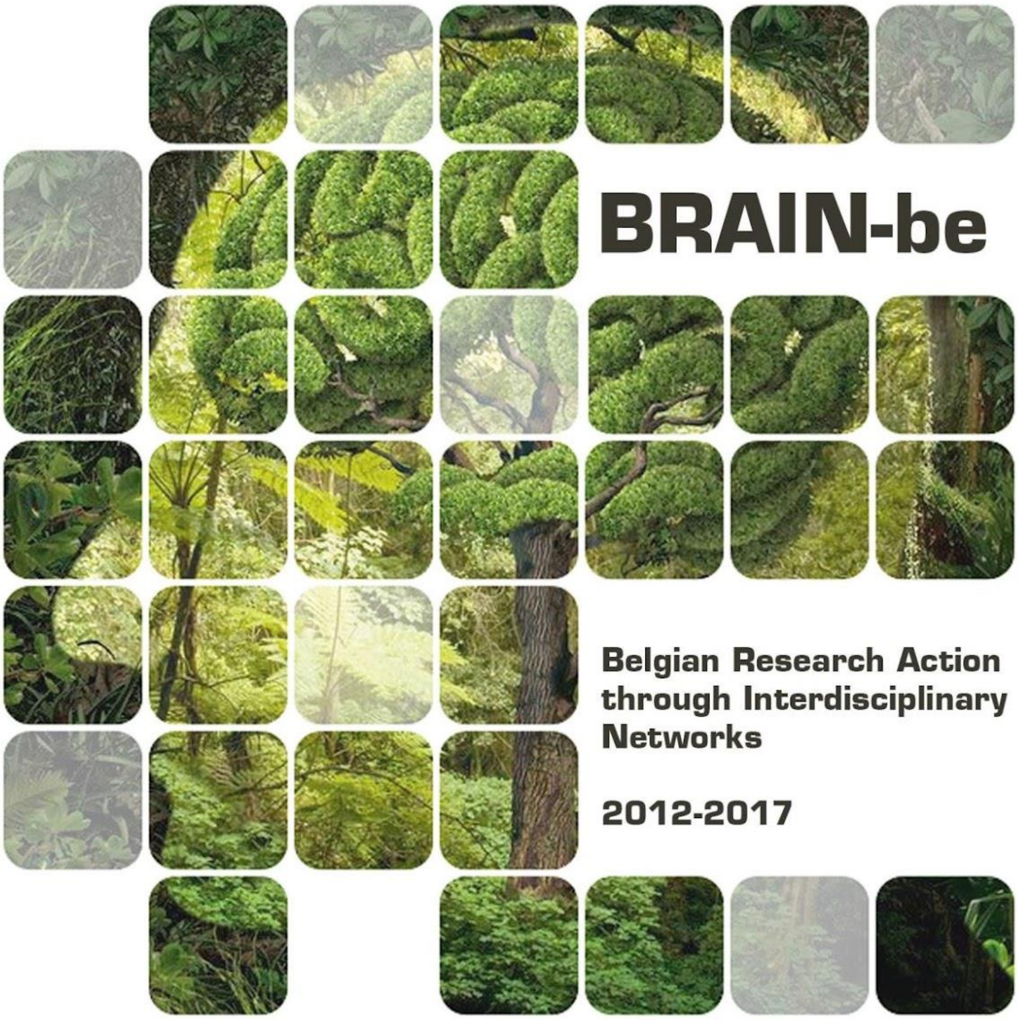

VALORISATION PROJECT

CICADA.be

Coherent Integration of climate projections into Climate ADaptation plAnning tools for BElgium

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Published in 2021 by the Belgian Science Policy Office
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VAN SCHAEYBROECK, B., MENDOZA PAZ, S., WILLEMS, P., CICADA.be: Coherent Integration of climate projections into Climate ADaptation plAnning tools for BElgium. Final Report. Brussels: Belgian Science Policy Office 2021 – 22 p. (BRAIN-be - (Belgian Research Action through Interdisciplinary Networks))

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1. SUMMARY

Within the CORDEX.be project the foundations for climate services for Belgium had been created through the gathering of a large network of climate experts and the creation of detailed climate projections for Belgium. Even though CORDEX.be led to a large amount of climate data, a more thorough harmonization of the enormous amount of produced data was still necessary in order to establish a coherent picture of the climate-change impacts on Belgium. A valorization of the CORDEX.be project results has been effectuated by 1) using the climate projections for further impact assessment in different fields, and, 2) establishing harmonized climate projections in line with specific stakeholders needs which are existing online tools for climate adaptation (FPS Health, VMM and AWAC).

Continued collaboration after the CORDEX.be project intensified the ties among the project partners and the establishment of a large set of climate data within CORDEX.be enabled a wide range of external collaborations.

2. INITIAL OBJECTIVES AND VALORISATION FOCUS

The initial objective of the CICADA.be project was to integrate the CORDEX.be climate model projections into existing online tools for climate adaptation. The steps to realize this were: 1) to collect the stakeholder's requests, needs, suggestions and practical limitations in the context of their climate-adaptation tools, 2) agree on an approach to combine the CORDEX.be climate data with existing climate projections into coherent harmonized climate projections in line with the stakeholder's needs. 3) Communicate these results and incorporate them in the existing climate adaptation tools.

During the stakeholders meeting of (6 June 2019) the stakeholders expressed their needs and interests. Apart from the initial stakeholders (FPS Health, VMM and AWAC), also Brussels Environment was present. After a first analysis a meeting was organized (10 January 2020) discussing a best approach to represent the CORDEX.be results for the different required variables in line with most stakeholder requirements. Based on this final methodology the data extraction and production of maps were then successfully performed by KU Leuven. Section 4 presents the projected climate change in Belgium by perturbed distributed climate maps that contain: potential evapotranspiration, rainfall, relative humidity, temperatures, solar radiation, and wind speed. Together with this information, the gridded maps were compared with Uccle series from the period 1901-2020 to estimate statistics for 100 years on precipitation and potential evapotranspiration. These maps and data can serve as direct input for the regional support tools for adaptation (adapt2climate.be, klimaat.vmm.be and leswallonssadaptent.be).

Apart from the initial objectives the CICADA.be project was taken as an opportunity to answer the societal need for detailed climate information for Belgium in the context of the ongoing climate crisis, both from the academic and the non-academic sectors (see Section 3).

3. OVERVIEW EXTERNAL COLLABORATION(S)

Since the end of the CORDEX.be there has been a large uptake of the project deliverables. More specifically, the high-resolution climate projections over Belgium have already been widely requested and used. Users range from scientists, public authorities to the private sector. More specifically:

- Urban impact study: In Cugnon et al. (2019) CORDEX.be projections have been used to investigate the impact of land-use scenarios on the summer climate in terms of heat waves and the urban heat island for the city of Brussels.

- Extreme rainfall: In Van de Vyver et al (2021), Helsen et al. (2021) and Vanden Broucke et al. (2019) the CORDEX.be climate simulations for rainfall extremes were investigated in detail.

- Impact study on urban mortality: Together with health experts De Troeyer et al. (2020) the relation between temperature and mortality was investigated over Brussels and Antwerp (using CORDEX.be data).

- Impact study on forestry: De Wergifosse et al. (2020) used CORDEX.be climate-change projections to investigate the impact on forestry.

- Together with other institutes the RMI contributed to an international study that related climate change to the July 2021 rainfall event over Belgium, Germany and the Netherlands that led to catastrophic flooding. The Belgian high-resolution CORDEX.be climate projections were important in this work since they were the only one providing high-resolution and long-term projections.

- The (RMI) CORDEX.be climate projections are currently being used within the BREGILAB and EPOC projects funded by the energy transition fund that combines the expertise of 14 Belgian academic partners to improve the current state-of-the-art energy models thereby providing a consistent calculation for the long-term energy future in Belgium.

- The RMI has received a wide range of data requests from its climate projections ranging from private companies (e.g. Colruyt, CSTC-WTCB-BBRI) to public authorities (e.g. Brussels Environment). The RMI has made its climate simulations available through its open data portal but also provided these users with expert information on how to handle.

- The climate scenarios are being used by KU Leuven and partners in a number of hydrological and hydraulic impact projects for authorities in Flanders, such as revising the Sigmaplan for De Vlaamse Waterweg, climate change impact analysis on water availability for the Vlaamse Milieumaatschappij and partner organisations, climate change impact analysis on water availability for drinking water production and the availability of rainwater as alternative water source for the water company Fluvius, the water availability and salt intrusion problem along the Albert Canal and the Harbour of Antwerp for Water-link and Port of Antwerp, the water availability and salt intrusion problem along the Canal of Gent-Terneuzen for North Sea Port and partners.

4. GENERATED PRODUCTS AND IMPLEMENTED APPROACHES

The main generated CICADA.be product is the harmonized climate projections following the stakeholders requirements. Here we outline the approach and give the main results as worked out by KU Leuven (Santiago Mendoza Paz and Patrick Willems).

4.1 Context

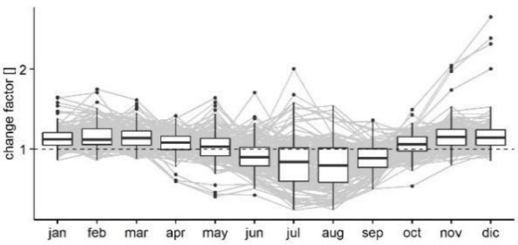
Climate change has become a major concern for many authorities due to the potential risk of affecting infrastructure and human lives. Information on the changes is crucial to develop correct policies to cope with these possible risks. One of the advantages of the information presented together with this report is that we can obtain from it the changes of the climate in the future and their distribution across the country; on the other hand, the use of simple monthly change factors might not be robust enough, hence, to have a more accurate description of complex processes, e.g., extreme events, more advanced methods are recommended.

4.2 Methodology

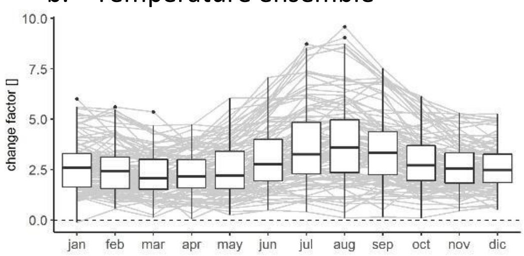
4.2.1 Obtaining changes for the future

Ensembles were obtained from the available CORDEX.be climate model simulations for Belgium, adjusting the spread of climate change signals based on the larger ensemble of all available CMIP5 GCM runs and EURO-CORDEX runs; after statistical downscaling based on the quantile perturbation method. From those ensembles, 5th, 50th, and 95th percentiles of changes were obtained for the different variables considered. Figure 1 shows the change factors for all the ensembles in the form of boxplots; the box plots are a good way to visualize large datasets as they allow to easily spot the median, the 25th and 75th percentiles (interquartile range) and the outliers.

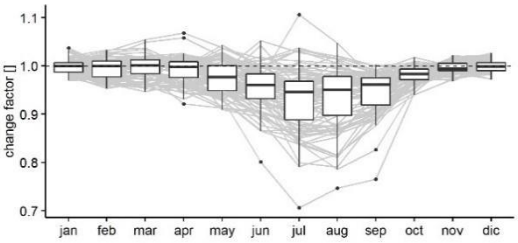
a. Precipitation ensemble



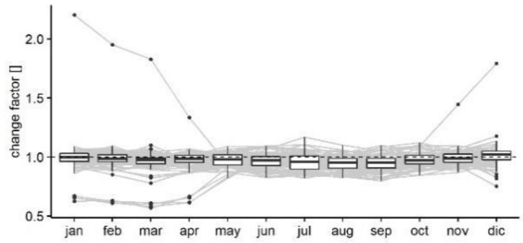
b. Temperature ensemble



c. Relative humidity ensemble



d. Wind velocity ensemble



e. Solar radiation ensemble

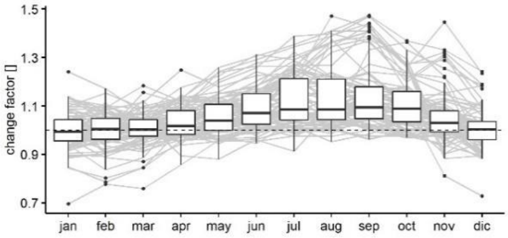


Figure 1 Change factors of the ensembles. The gray lines show all the different GCMs simulations, the boxplots show the summarized information of the simulations; note that the dots show the outliers.

Some comments can be done by looking at the overall picture of figure 1. In the case of precipitation, the months of winter (December, January, and February), show a tendency in the future to increase, while for the summer months (June, July, and August), the tendency is to decrease. On the other hand, the spring and autumn seasons do not show a marked behavior; at the begging of the spring, there is a tendency of increased rainfall in the future, but the last month shows that the amounts will more or less follow the same quantities as in the present period; in the autumn case, at the begging, the rainfall tends to decrease, while for the last months of the season, the tendency is to increase. The temperature shows a tendency to increase in all months; this tendency is slightly higher in the summer months. The relative humidity shows a marked decrease in the summer and autumn months, while for the rest of the year, the change seems irrelevant. Opposite to relative humidity, the solar radiation shows a marked increase in the summer and autumn months, and in the rest of the year, the change seems irrelevant. In the case of wind velocity, there is no clear tendency in most of the months except for the summer, where the wind velocities tend to decrease.

The presented changes in figure 1 are valid for a target year 2085 as the middle in the period 2071-2100. For different target years, the use of these change factors involves the assumption that the changes of the values between the middle of the current period (1975, from 1961-1990) and the middle of the future period (2085, from 2071-2100) have a linear behavior. Hence, a linear interpolation was used in obtaining the change factors for the different target years needed (2030, 2050, and 2100).

4.2.2 Perturbing present climate

After the procedure explained in 3.1, the next step involves the use of the obtained change factors to perturb the series on the present conditions. As the change factors were obtained at a monthly scale, the days from each of the months were perturbed with their correspondent change factor. Because we want to take into account the uncertainty in the future, the perturbation was performed for the different percentiles as well, this means that 3 different perturbations were done for each of the months, making it 36 perturbations for each of the target years.

This step is important because the 50th percentile is suitable for the analysis of the mean impacts, but for the high impacts, a combination of the 95th and 5th percentiles is needed depending on which type of situation we are dealing with, that is, wet situations or dry situations.

4.2.3 Statistics of the future climate and comparisons

After the perturbations were done, important statistics were calculated to make it easier to analyze the impacts in the future scenarios, both mean and high. Table 1 shows all the statistics involved in the project.

Table 1 Statistics calculated in the project for the present period and all the future period target years

Precipitation	Potential evapotranspiration	Temperature	Relative Humidity	Wind velocity	Solar radiation
Annual	Annual	Annual	Annual	Annual	Annual
Seasonal (4 seasons)	Winter season	Seasonal (4 seasons)	Winter season	Winter season	Winter season
Monthly (12 months)	Summer season	Monthly (12 months)	Summer season	Summer season	Summer season
Heavy rainfall (> 20 mm & >30 mm)	Monthly (12 months)	Total number of heatwaves for a 20-year period			
Seasonal wetdays (4 seasons)		Max length of the heatwaves for a 20-year return period			
Seasonal drydays (4 seasons)		Annual number of hot days			
Annual length of the dry spells		Annual number of tropical days			
Max length of the dry spells for a 30-year return period		Annual number of frost days			
Daily extreme rainfall for a 1-year return period					
Daily extreme rainfall for a 5-year return period					
Daily extreme rainfall for a 10-year return period					
Daily extreme rainfall for a 15-year return period					
Daily extreme rainfall for a 30-year return period					

4.3 Results

4.3.1 Average results of the perturbed series

The tables below show the average changes in all the statistics indicators according to their different percentiles and target years.

Table 2 Average changes in the precipitation amounts and the precipitation indices

	Variable	low (5th percentile)				Mean (50th percentile)				High (95th percentile)			
		2030	2050	2085	2100	2030	2050	2085	2100	2030	2050	2085	2100
Precipitation amounts	Annual	0.88	0.83	0.75	0.72	1.01	1.01	1.02	1.02	1.16	1.22	1.33	1.37
	Summer	0.72	0.62	0.44	0.36	0.92	0.89	0.84	0.82	1.14	1.19	1.28	1.31
	Winter	0.97	0.96	0.95	0.94	1.06	1.09	1.13	1.14	1.21	1.29	1.42	1.48
	Spring	0.93	0.90	0.86	0.84	1.04	1.06	1.08	1.09	1.18	1.24	1.35	1.40
	Autumn	0.89	0.85	0.79	0.76	1.02	1.02	1.03	1.04	1.13	1.18	1.27	1.30
	January	0.98	0.97	0.95	0.95	1.06	1.08	1.12	1.14	1.19	1.27	1.39	1.44
	February	0.98	0.97	0.95	0.94	1.06	1.08	1.11	1.13	1.24	1.32	1.47	1.53
	March	0.96	0.95	0.93	0.92	1.07	1.09	1.14	1.15	1.20	1.27	1.39	1.44
	April	0.93	0.90	0.85	0.84	1.04	1.06	1.08	1.09	1.15	1.20	1.30	1.34
	May	0.89	0.86	0.79	0.76	1.01	1.02	1.03	1.03	1.17	1.24	1.35	1.40
	June	0.81	0.74	0.62	0.56	0.95	0.93	0.90	0.89	1.13	1.17	1.25	1.29
	July	0.68	0.56	0.36	0.27	0.92	0.89	0.84	0.81	1.18	1.25	1.37	1.42
	August	0.67	0.55	0.34	0.25	0.89	0.86	0.79	0.76	1.11	1.14	1.21	1.24
	September	0.80	0.73	0.60	0.55	0.94	0.92	0.88	0.86	1.06	1.09	1.13	1.15
	October	0.91	0.88	0.82	0.79	1.03	1.04	1.05	1.06	1.13	1.18	1.26	1.30
	November	0.96	0.95	0.92	0.91	1.07	1.10	1.15	1.17	1.20	1.27	1.39	1.45
	December	0.97	0.96	0.94	0.93	1.07	1.10	1.14	1.16	1.20	1.28	1.41	1.46
Precipitation indices	rainfall > 20 mm	0.67	0.57	0.44	0.40	1.03	1.04	1.06	1.07	1.54	1.76	2.17	2.35
	rainfall > 30 mm	0.53	0.41	0.29	0.25	0.98	0.99	1.01	1.02	1.74	2.06	2.71	3.02
	Summer wetdays	0.96	0.93	0.85	0.79	1.00	1.00	0.99	0.98	1.03	1.03	1.06	1.06
	Winter wetdays	1.00	1.00	1.00	1.00	1.04	1.04	1.04	1.04	1.04	1.08	1.08	1.08
	Spring wetdays	1.00	1.00	0.99	0.99	1.03	1.03	1.03	1.03	1.03	1.05	1.07	1.07
	autumn wetdays	0.99	0.99	0.96	0.96	1.03	1.03	1.03	1.03	1.04	1.05	1.07	1.07
	Summer drydays	1.05	1.07	1.12	1.16	1.02	1.02	1.03	1.03	1.00	0.99	0.98	0.98
	Winter drydays	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00	0.96	0.96	0.96
	Spring drydays	1.03	1.03	1.03	1.03	1.00	1.00	1.00	1.00	1.00	0.99	0.97	0.97
	Autumn drydays	1.04	1.04	1.06	1.07	1.01	1.01	1.01	1.01	1.00	0.99	0.97	0.97
	Average length of the dry spells	1.01	1.02	1.08	1.14	0.98	0.98	0.98	0.99	0.96	0.97	0.95	0.95
	Max length of the dry spell	1.05	1.07	1.14	1.21	1.01	1.01	1.02	1.03	0.99	0.99	0.98	0.98

Table 3 Average changes in the precipitation extremes and the non-extreme temperatures

Variable		low (5th percentile)				Mean (50th percentile)				High (95th percentile)			
		2030	2050	2085	2100	2030	2050	2085	2100	2030	2050	2085	2100
Precipitation extremes	Summer t1	0.72	0.62	0.45	0.39	0.92	0.89	0.84	0.82	1.14	1.19	1.28	1.31
	Summer t5	0.71	0.61	0.45	0.39	0.91	0.88	0.83	0.81	1.13	1.18	1.26	1.30
	Summer t10	0.70	0.60	0.44	0.39	0.91	0.88	0.82	0.80	1.13	1.17	1.26	1.29
	Summer t15	0.70	0.60	0.45	0.40	0.91	0.88	0.82	0.80	1.13	1.17	1.25	1.29
	Summer t30	0.70	0.60	0.46	0.41	0.91	0.88	0.82	0.80	1.13	1.18	1.27	1.30
	Winter t1	0.97	0.96	0.94	0.94	1.06	1.09	1.13	1.15	1.21	1.28	1.42	1.47
	Winter t5	0.97	0.96	0.94	0.94	1.06	1.09	1.13	1.15	1.21	1.28	1.42	1.47
	Winter t10	0.97	0.96	0.94	0.94	1.06	1.09	1.13	1.15	1.21	1.28	1.42	1.47
	Winter t15	0.97	0.96	0.94	0.94	1.06	1.09	1.13	1.15	1.21	1.28	1.42	1.47
	Winter t30	0.97	0.96	0.95	0.94	1.06	1.09	1.13	1.14	1.21	1.28	1.42	1.48
Temperature	Annual	0.45 °C	0.61 °C	0.89 °C	1.02 °C	1.34 °C	1.83 °C	2.68 °C	3.04 °C	2.91 °C	3.96 °C	5.81 °C	6.61 °C
	Summer	0.55 °C	0.75 °C	1.09 °C	1.24 °C	1.64 °C	2.24 °C	3.29 °C	3.74 °C	3.97 °C	5.41 °C	7.94 °C	9.02 °C
	Winter	0.40 °C	0.54 °C	0.80 °C	0.91 °C	1.21 °C	1.65 °C	2.42 °C	2.75 °C	2.45 °C	3.35 °C	4.91 °C	5.58 °C
	Spring	0.35 °C	0.48 °C	0.70 °C	0.79 °C	1.07 °C	1.46 °C	2.14 °C	2.43 °C	2.26 °C	3.09 °C	4.53 °C	5.14 °C
	Autumn	0.49 °C	0.67 °C	0.98 °C	1.12 °C	1.43 °C	1.95 °C	2.86 °C	3.25 °C	2.93 °C	4.00 °C	5.86 °C	6.66 °C
	January	0.47 °C	0.64 °C	0.95 °C	1.08 °C	1.24 °C	1.69 °C	2.48 °C	2.82 °C	2.47 °C	3.36 °C	4.93 °C	5.60 °C
	February	0.38 °C	0.51 °C	0.75 °C	0.86 °C	1.17 °C	1.59 °C	2.33 °C	2.65 °C	2.46 °C	3.36 °C	4.92 °C	5.59 °C
	March	0.24 °C	0.32 °C	0.47 °C	0.53 °C	1.00 °C	1.37 °C	2.00 °C	2.28 °C	2.13 °C	2.90 °C	4.25 °C	4.83 °C
	April	0.42 °C	0.57 °C	0.83 °C	0.94 °C	1.10 °C	1.50 °C	2.21 °C	2.51 °C	2.01 °C	2.74 °C	4.01 °C	4.56 °C
	May	0.40 °C	0.54 °C	0.80 °C	0.91 °C	1.11 °C	1.51 °C	2.22 °C	2.52 °C	2.65 °C	3.61 °C	5.30 °C	6.02 °C
	June	0.57 °C	0.77 °C	1.14 °C	1.29 °C	1.43 °C	1.95 °C	2.86 °C	3.25 °C	3.23 °C	4.40 °C	6.46 °C	7.34 °C
	July	0.53 °C	0.72 °C	1.06 °C	1.21 °C	1.68 °C	2.30 °C	3.37 °C	3.82 °C	4.23 °C	5.77 °C	8.46 °C	9.62 °C
	August	0.54 °C	0.74 °C	1.08 °C	1.23 °C	1.81 °C	2.47 °C	3.63 °C	4.12 °C	4.43 °C	6.04 °C	8.85 °C	10.06 °C
	September	0.64 °C	0.87 °C	1.28 °C	1.45 °C	1.68 °C	2.30 °C	3.37 °C	3.83 °C	3.60 °C	4.91 °C	7.20 °C	8.18 °C
	October	0.52 °C	0.72 °C	1.05 °C	1.19 °C	1.33 °C	1.82 °C	2.66 °C	3.03 °C	2.72 °C	3.72 °C	5.45 °C	6.19 °C
	November	0.31 °C	0.42 °C	0.62 °C	0.70 °C	1.27 °C	1.73 °C	2.54 °C	2.89 °C	2.48 °C	3.38 °C	4.96 °C	5.64 °C
	December	0.35 °C	0.47 °C	0.69 °C	0.78 °C	1.22 °C	1.67 °C	2.44 °C	2.78 °C	2.44 °C	3.32 °C	4.87 °C	5.54 °C

Table 4 Average changes in the temperature extremes, the relative humidity, the wind velocities, the global radiation and the potential evapotranspiration amounts

Variable		low (5th percentile)				Mean (50th percentile)				High (95th percentile)			
		2030	2050	2085	2100	2030	2050	2085	2100	2030	2050	2085	2100
Temperature extremes	Total number of heatwaves for a 20-year period	0	1	2	2	5	8	15	19	24	52	102	118
	Max length of the heatwaves for a 20-year return period	1	1	1	2	3	4	6	7	8	15	29	35
	Annual number of hot days	3	5	7	8	14	20	33	39	44	64	96	106
	Annual number of tropical days	0	1	1	2	3	5	9	11	14	26	54	67
	Annual number of frost days	-5	-7	-10	-12	-16	-21	-29	-32	-29	-36	-44	-47
Relative Humidity	Annual	0.96	0.95	0.93	0.92	0.99	0.99	0.98	0.98	1.01	1.01	1.02	1.02
	Summer	0.92	0.89	0.84	0.82	0.98	0.97	0.95	0.95	1.01	1.01	1.02	1.02
	Winter	0.99	0.98	0.97	0.97	1.00	1.00	1.00	1.00	1.01	1.01	1.02	1.02
Wind velocities	Annual	0.93	0.90	0.86	0.84	0.99	0.99	0.98	0.98	1.03	1.04	1.07	1.07
	Summer	0.93	0.90	0.85	0.83	0.98	0.97	0.96	0.95	1.03	1.04	1.06	1.07
	Winter	0.93	0.91	0.86	0.84	1.00	1.00	1.00	1.00	1.04	1.05	1.08	1.09
Global radiation	Annual	0.98	0.97	0.96	0.96	1.03	1.04	1.06	1.06	1.13	1.17	1.26	1.29
	Summer	0.99	0.99	0.98	0.98	1.04	1.05	1.08	1.09	1.16	1.21	1.31	1.36
	Winter	0.94	0.92	0.89	0.87	1.00	1.00	1.00	1.00	1.06	1.09	1.13	1.14
Potential evapotranspiration	Annual	1.02	1.02	1.04	1.04	1.09	1.12	1.17	1.20	1.24	1.33	1.49	1.55
	Summer	1.02	1.03	1.05	1.05	1.10	1.13	1.19	1.22	1.27	1.37	1.54	1.61
	Winter	1.02	1.02	1.03	1.04	1.08	1.12	1.17	1.19	1.24	1.32	1.47	1.54
	January	1.01	1.01	1.02	1.02	1.09	1.12	1.17	1.19	1.27	1.36	1.53	1.61
	February	1.03	1.04	1.07	1.07	1.08	1.10	1.15	1.17	1.19	1.26	1.38	1.43
	March	0.99	0.99	0.99	0.99	1.04	1.05	1.07	1.08	1.17	1.23	1.33	1.38
	April	1.02	1.03	1.04	1.05	1.05	1.06	1.09	1.11	1.13	1.18	1.26	1.29
	May	0.99	0.99	0.98	0.98	1.08	1.10	1.15	1.17	1.17	1.23	1.34	1.39
	June	1.02	1.02	1.04	1.04	1.08	1.11	1.16	1.19	1.22	1.30	1.44	1.50
	July	1.02	1.03	1.05	1.05	1.09	1.13	1.18	1.21	1.28	1.39	1.56	1.64
	August	1.03	1.04	1.06	1.07	1.12	1.16	1.23	1.26	1.30	1.41	1.60	1.69
	September	1.04	1.05	1.08	1.09	1.11	1.16	1.23	1.26	1.36	1.49	1.71	1.81
	October	1.03	1.05	1.07	1.08	1.09	1.12	1.18	1.20	1.28	1.38	1.55	1.63
	November	1.01	1.01	1.01	1.01	1.11	1.15	1.22	1.25	1.29	1.40	1.58	1.66
	December	1.00	1.00	1.00	1.01	1.10	1.13	1.19	1.22	1.27	1.37	1.54	1.61

4.3.2 Analysis for mean impacts and high impacts in the future.

The mean impacts should be analyzed with the 50th percentile results as they represent the mean change in the future scenario. On the other hand, the high impacts in the future should be analyzed depending on the variable and the situation, e.g., if we are under a drought indicator, we should use the results coming from the 5th percentile in the case of precipitation and the 95th percentile results from the temperature and the potential evapotranspiration, or if the case is the extreme rainfall, the results coming from the 95th percentile of the daily extreme rainfall should be used. Hereafter, the description of the results is for the target year 2085 (2071-2100 period) but the same information for all the target years is available via the .csv files presented together with this report.

Following the previous, we present the mean impacts in the rainfall for the target year of 2085. According to figure 2, the seasonal rainfall will increase in the winter season, and it will decrease on the summer season, but in an overall average (at annual basis) the tendency for the rainfall is to increase; the latter is also supported by figure 3 that shows an increase in the wet days in the winter together with an increase of the dry days in the summer. Referring to the dry spells, the maximum duration of the highest dry spells in the present will slightly increase in the future.

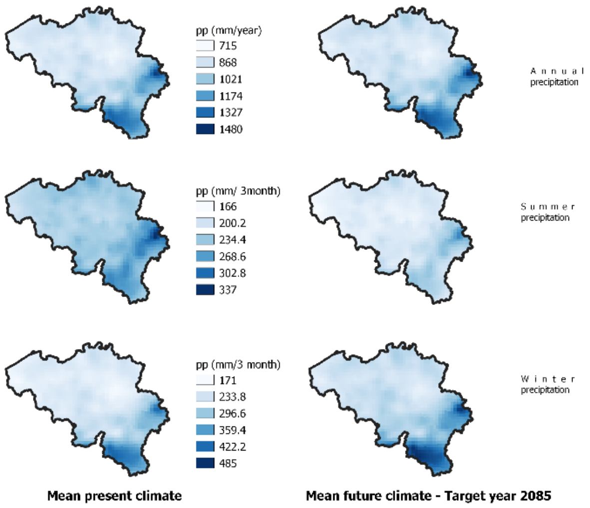


Figure 2 Mean impacts on the rainfall amounts for different aggregation levels; at the top the annual rainfall, in the middle the summer rainfall, and at the bottom, the winter rainfall. Present conditions are on the left and future conditions on the right.

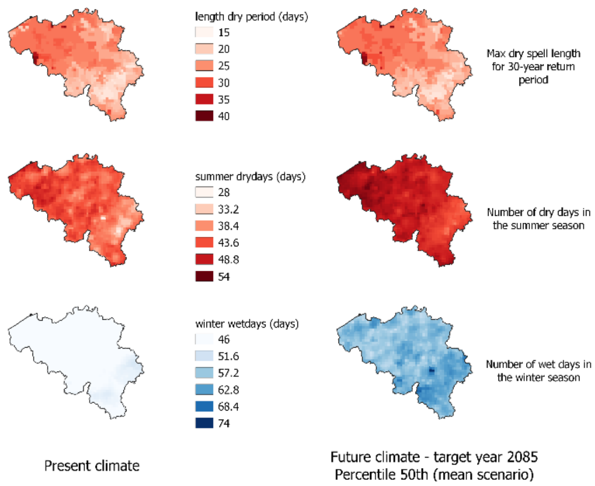


Figure 3 Mean impacts on the rainfall occurrence for the summer and the winter seasons. At the top the max length of the dry spells for a 30-year return period, in the middle the dry day frequency in the summer, and at the bottom the wet day frequency in the winter

Additionally, if we take a look at the heavy rainfall and the daily extreme rainfall for different return periods, we can notice a slight increase in the extreme rainfall for the year 2085. Figures 4 and 5 depict the mean changes in extreme rainfall for the mentioned future period.

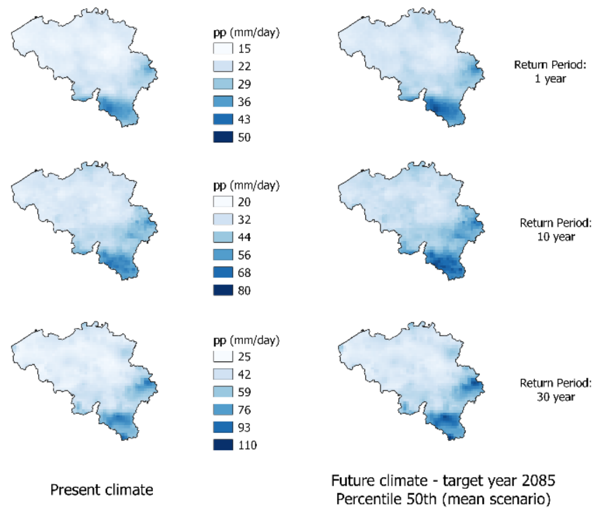


Figure 4 Mean impacts on the daily rainfall extreme intensities for different return periods. At the top 1 year of return period, in the middle 10 years of return period, and at the bottom 30 years of return period. On the left, the present conditions are presented and the future on the right.

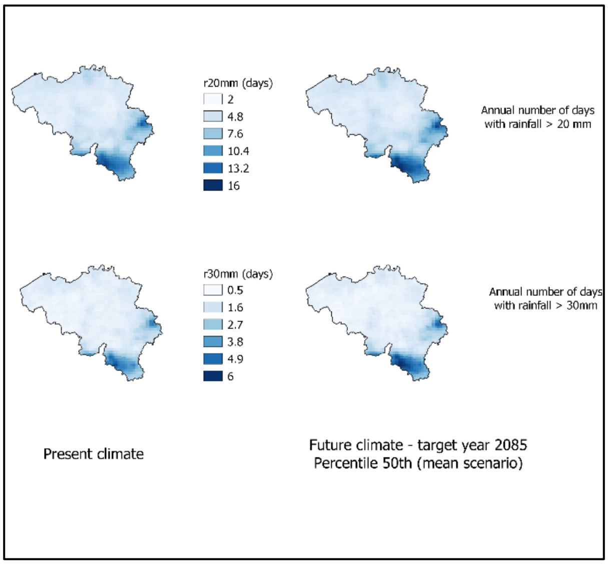


Figure 5 Mean impacts on the frequency of days with heavy precipitation. The annual number of days with more than 20 mm at the top, and at the bottom, the annual number of days with more than 30 mm. The present conditions are on the left, and the future conditions on the right.

Next, we present the high impacts on the rainfall for the target year 2085. According to figure 6, the annual and the winter rainfall present a noticeable increase, while the summer rainfall shows a marked decrease; this is also supported by figure 7 in which, the wet days and the dry days present a strong increase in the winter and the summer seasons respectively. Moreover, the maximum length of the dry spells for a 30-year return period will increase in the entire country.

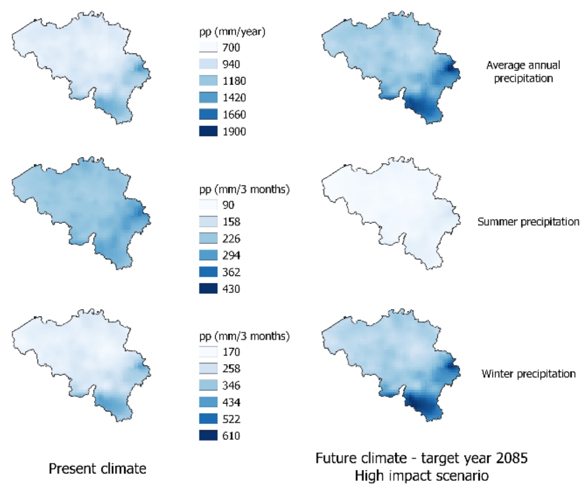


Figure 6 High impacts on the rainfall amounts for different aggregation levels; at the top the annual rainfall, in the middle the summer rainfall, and at the bottom, the winter rainfall. Present conditions are on the left and the future conditions on the right.

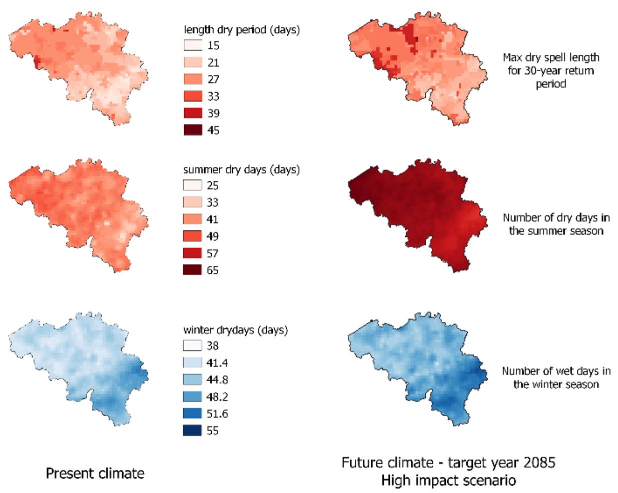


Figure 7 High impacts on the rainfall occurrence for the summer and the winter seasons. At the top the max length of the dry spells for a 30-year return period, in the middle the dry day frequency in the summer, and at the bottom the wet day frequency in the winter. Present conditions are on the left and the future conditions on the right.

On the daily extreme rainfall, the changes in the high impact scenario are strong. As figures 8 and 9 show, the rainfall extremes are strongly increasing in the frequency of heavy rainfall and the intensities of all the return periods. The hilly region of Belgium seems more affected by both the intensities and occurrences of the extremes.

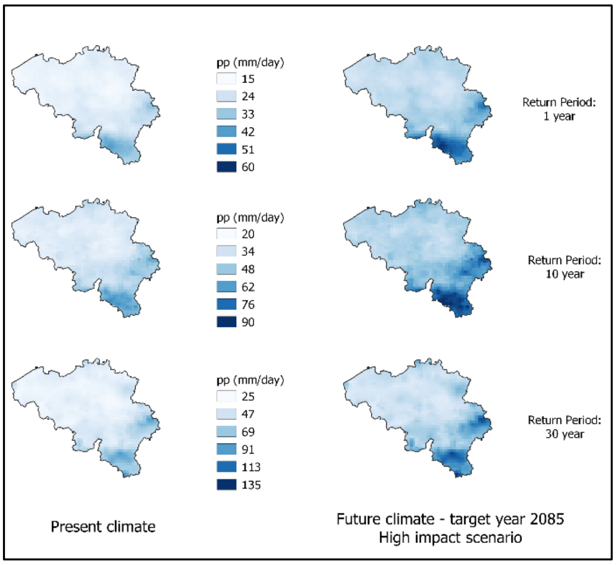


Figure 8 High impacts on the daily rainfall extreme intensities for different return periods. At the top 1 year of return period, in the middle 10 years of return period, and at the bottom 30 years of return period. On the left, the present conditions and the future conditions on the right.

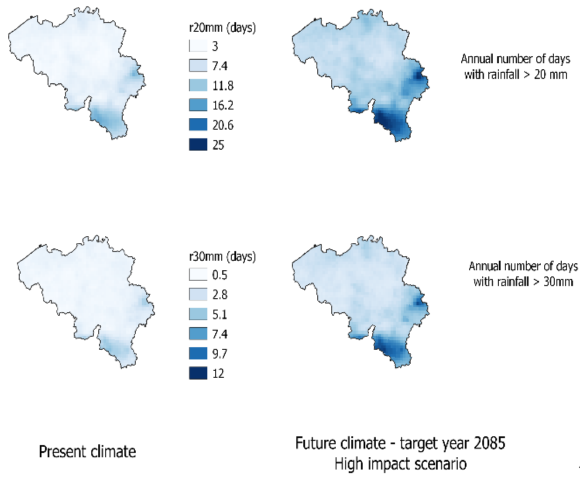


Figure 9 High impacts on the frequency of days with heavy precipitation. The number of days with more than 20 mm at the top, and at the bottom, the number of days with more than 30 mm. The present conditions are on the left, and the future conditions on the right.

Regarding the temperatures, there is a general tendency to increase in all the statistic indicators for both the mean and high impacts. Moreover, the summer season is more affected by the rise of temperatures in the future scenario; for instance, this season is already affected by heatwaves which are a risk for human health, and in the future scenario, the frequency of these heatwaves is going to increase together with their duration. Figures 10 and 12 illustrate well this point for both the mean and high impact scenarios. On the other hand, the frequency of days with frozen temperatures is going to greatly decrease in the winter season; figures 11 and 13 illustrate these impacts for both the mean and high scenarios. The overall impact is that warmer winters and very warm summers are expected for Belgium.

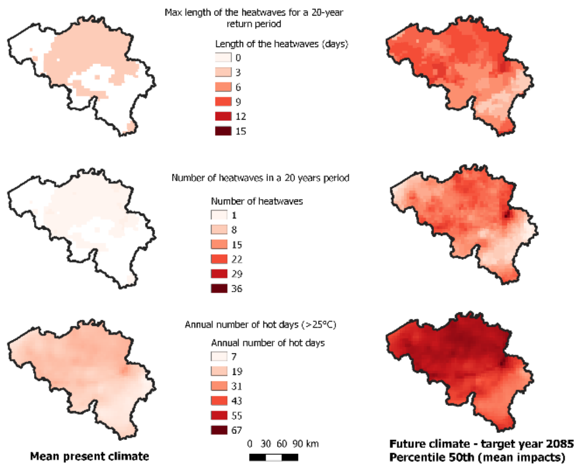


Figure 10 Mean impacts on the extreme temperature indices. At the top the maximum length of the heatwaves for a 20-years return period, in the middle the total number of heatwaves for a 20-year period, and at the bottom the total number of hot days (>25 °C) per year. The present conditions are on the left while the future conditions on the right.

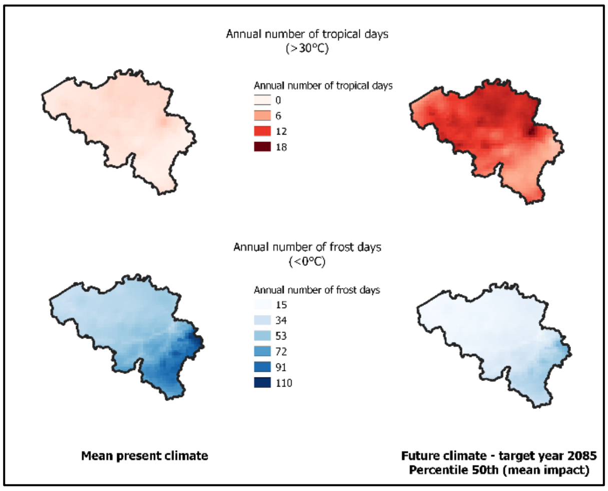


Figure 11 Mean impacts on the extreme temperature indices. At the top the total number of tropical days (>30 °C) per year, and at the bottom the total number of frost days (<0 °C) per year. The present conditions are on the left while the future conditions on the right.

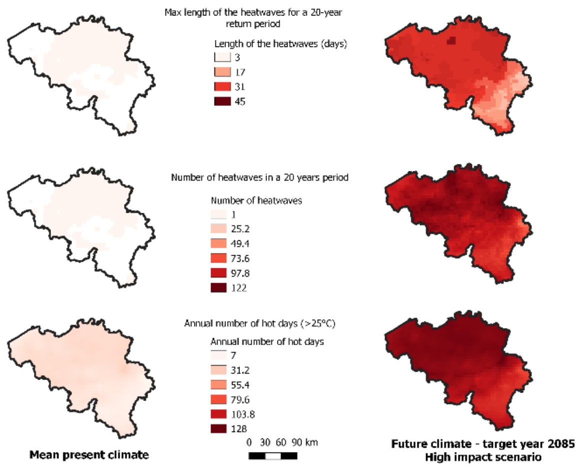


Figure 12 High impacts on the extreme temperature indices. At the top the maximum length of the heatwaves for a 20-years return period, in the middle the total number of heatwaves for a 20-year period, and at the bottom the total number of hot days (>25 °C) per year. The present conditions are on the left while the future conditions on the right.

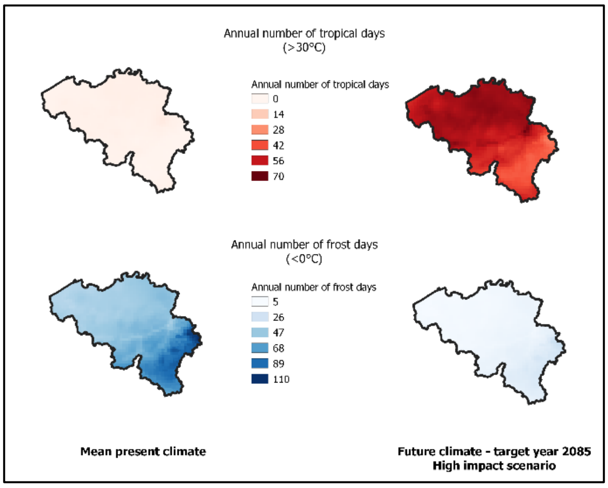


Figure 13 High impacts on the extreme temperature indices. At the top the total number of tropical days (>30 °C) per year, and at the bottom the total number of frost days (<0 °C) per year. The present conditions are on the left while the future conditions on the right.

Regarding the other climate variables (relative humidity, solar radiation, and wind velocities), the changes in the mean impact scenario seem stronger in the summer season, while in the winter, they are hardly noticeable. According to table 4 (also see figure 14), relative humidity and wind velocities show a decrease, while solar radiation shows an increase for the summer season. Accordingly, the tendency of these variables is similar in the high impact scenario, but the decrease/increase of relative humidity/solar radiation is more evident than the changes in the wind velocities.

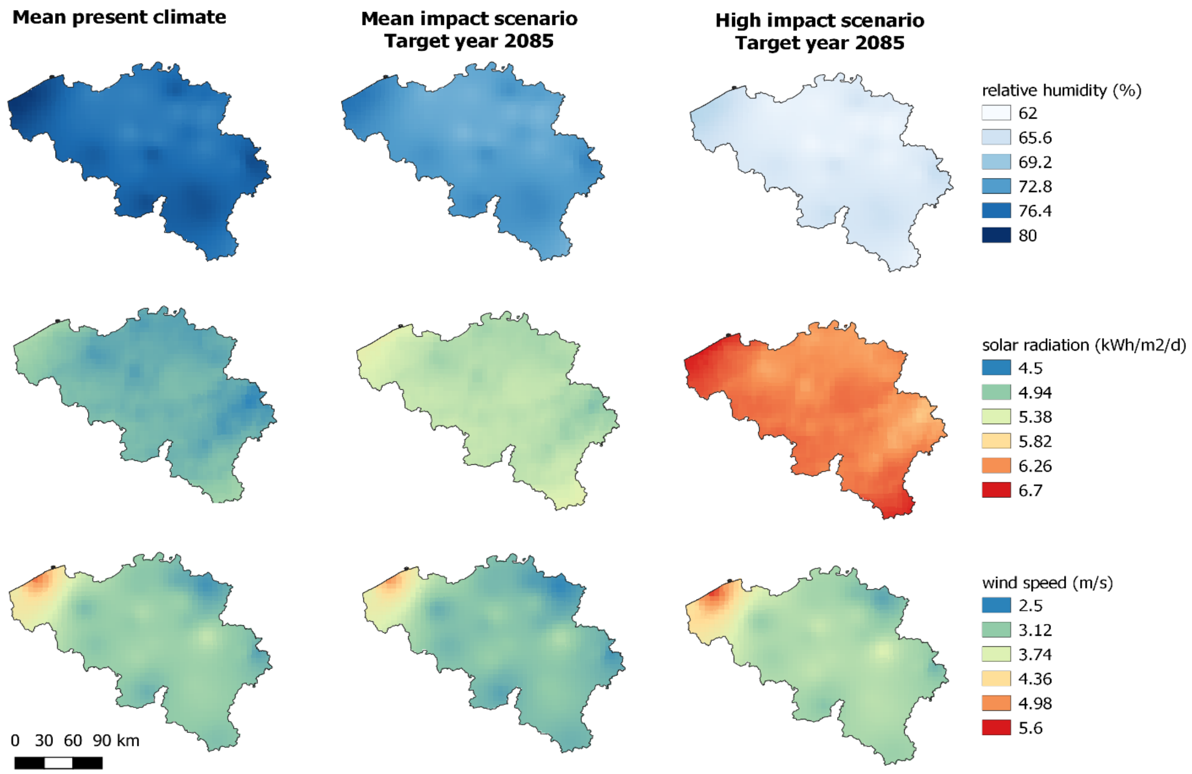


Figure 14 Projected changes for the summer season and the target year 2085. At the top the relative humidity, in the middle the solar radiation, and at the bottom the wind velocities. The changes are shown for the same target year but different future scenarios.

We stress that for additional information on different target years, refer to the tables 2, 3, and 4 and the data attached to this document. All the perturbed statistics are on .csv format.

4.4 Discussion

The projected changes show that Belgium will have to deal with the consequences of high temperatures, especially in the summer season. Also, the country might face water supply problems as the cumulated amount of rainfall is reducing and the potential evapotranspiration is increasing; at the same time, the extreme rainfall intensity and frequency are projected to increase. However, regarding low temperatures, as the climate is heating, Belgium will face less cold winters.

The importance of providing spatially distributed information rather than point information relies on the fact that some areas might be more affected than others depending on the analyzed variable and the specific local features. For example, for studies on wind velocities, the changes might be more important on the coast (figure 14), or the elevation of temperatures might be more important for big urban areas due to the heat-island effect.

Depending on specific features, the different impact scenarios might become more important than others, e.g., for long-time water supply projects, the mean impacts in the future might be more important, but for flooding protection, the high impacts are more important. Similarly, the information on different target years is important; depending on the project, long-term or short-term projections will make more sense than others, e.g., for the planning of optimal land-use changes until the late of this century, information about the future climate for the year 2100 might be more important for the extreme events during the last phase of the implementation.

5. IMPACT AND ADDED VALUE OF THE VALORISATION ACTION

The main added value of the CICADA.be valorization effort is the creation of harmonized climate projections for Belgium that are coherent for all users, and combine the CORDEX.be projections with existing internationally-available projections (as outlined in Section 4 and Termonia et al., 2018). The main impact constitutes the wide range of impact studies (see Section 3) and new collaborations that were based on the CORDEX.be climate projections.

The RMI has received a wide range of data requests from its climate projections ranging from private companies (e.g. Colruyt, CSTC-WTCB-BBRI) to public authorities (e.g. Brussels Environment). The RMI has made its climate simulations available through its open data portal but also provided these users with expert information on how to handle.

In the context of the July 2021 rainfall event that led to severe flooding over Belgium, Germany and the Netherlands, a tweet was sent (P. Willems) relating the CICADA.be results to the ongoing extreme rainfall event: "*Neerslagextremen voor België: aantal mm/dag gemiddeld eens om de 1, 10, 30 jaar, huidig en toekomstig klimaat >50mm zoals op meerdere plaatsen in Limburg de voorbije 24u, is uitzonderlijk, maar frequentie neemt toe".* Moreover, together with other institutes the RMI contributed to a study that related the (ongoing) climate change to the July 2021 event. The Belgian high-resolution CORDEX.be climate projections played a key role in this work. This received major national and international news coverage (e.g. CNN, NYTimes).

The CORDEX.be climate projections were used in the KMI Klimaatrapport 2020.

Given the strong attention to climate change and the impact on floods and droughts, it is expected that different types of impact studies will be carried out in the future by the different water authorities and partner organisations in Belgium, making use of the climate scenarios. KU Leuven and RMI have close contacts with these authorities and will continue disseminating and applying the latest climate-change information.

6. MEASURES TO MAINTAIN THE COLLABORATION(S)

The CORDEX.be project caught the attention of different researchers and gave rise to ideas for new collaborations. Strong collaborations exist among the CORDEX.be partners but also with external partners thanks to the CORDEX.be project. FED-tWIN projects have been approved for ULg and KU Leuven (Patrick Willems and Xavier Fettweiss) in collaboration with RMI. Further ongoing collaborations include those between RMI and Sciensano on heat-mortality relations and UCL concerning the impact of climate change on forestry (REGE+ Belspo NR B2/212/P1/REGE+) where CORDEX.be. The CORDEX.be data hub will still be maintained by the RMI.

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