VLAAMSE MILIEUMAATSCHAPPIJ

KU LEUVEN

Actualisatie en verfijning klimaatscenario's tot 2100 voor Vlaanderen

Appendix 3: Ruimtelijke patronen voor België op basis van Europese en Belgische fijnmazige klimaatmodellen

Studie uitgevoerd in opdracht van MIRA, Milieurapport Vlaanderen

Onderzoeksrapport

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Afdeling Aard- en Omgevingswetenschappen
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Documentbeschrijving

Titel
Actualisatie en verfijning klimaatscenario's tot 2100 voor Vlaanderen - Appendix 3: Ruimtelijke patronen voor België op basis van Europese en Belgische fijnmazige klimaatmodellen.

Dit rapport verschijnt in de reeks MIRA Ondersteunend Onderzoek van de Vlaamse Milieumaatschappij. Deze reeks bevat resultaten van onderzoek gericht op de wetenschappelijke onderbouwing van het Milieurapport Vlaanderen.

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Samenwerking
De hoge-resolutie klimaatmodelresultaten voor België werden ter beschikking gesteld door:
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Resultaten werden afgestemd op CMIP-5 analyse in discussie met:
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Inhoud
Dit is de 3^e technische Appendix (Engelstalig) bij het MIRA rapport 'Actualisatie en verfijning klimaatscenario's tot 2100 voor Vlaanderen'. Ze rapporteert de ruimtelijke patronen van de CORDEX-modellen, de MACCBET modellen en het ALARO model die bekomen werden voor België. De ruimtelijke patronen werden aangemaakt voor jaarlijkse temperatuur, zomerneerslag, winterneerslag en enkele extremen. Op deze manier is het mogelijk om na te gaan of er consistente ruimtelijke patronen aanwezig zijn in de klimaatprojecties voor België.

Wijze van refereren
Beullens J. & Van Lipzig N.P.M. (2015), Actualisatie en verfijning klimaatscenario's tot 2100 voor Vlaanderen - Appendix 3: Ruimtelijke patronen voor België op basis van Europese en Belgische fijnmazige klimaatmodellen. Studie uitgevoerd in opdracht van de Vlaamse Milieumaatschappij, MIRA, MIRA/2015/04, KU Leuven. Raadpleegbaar op www.milieurapport.be.

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1 Introduction

For the spatial patterns in Belgium and Flanders model runs of CORDEX, MACCBET and ALARO were used. The MACCBET model and ALARO model are two high resolution models, with a spatial resolution of 3 km and 4 km. These models can be used to gain insight in the spatial patterns of climate change within Belgium. Due to the high spatial resolution it is possible to model explicit convection, something which is not possible with the lower resolution models. For CORDEX, five 12 km runs were used. The 50 km runs were not used because the resolution of these runs is too low to analyze spatial patterns in Belgium and especially in Flanders.

Spatial patterns maps were made for the yearly temperature, the winter precipitation, the summer precipitation, the number of days with a maximum temperature above 25 °C, the number of days with a minimum temperature below 0 °C and the number of days with a total daily precipitation above 10 mm. This was one done for both, RCP4.5 and RCP8.5 scenarios. A normalization was carried out to study the spatial pattern within Belgium separately of the amplitude of the climate change signal. For temperature, this was done by expressing the temperature increase over a century in comparison with the increase in Uccle. For precipitation, this was done by normalizing the signal with the maximum absolute precipitation change found within Belgium. For precipitation, a comparison with Uccle was found to be inappropriate due to the more random spatial patterns of precipitation and the small change for Uccle in some of the model integrations.

2 Yearly temperature

The spatial patterns maps for the change in temperature show the difference in temperature increase per 100 years ($\mathbf{\Delta T_{diff}}$), between a grid cell i ($\mathbf{\Delta T_i}$) and the grid cell representing Uccle ($\mathbf{\Delta T_{Uccle}}$).

$$\mathbf{\Delta T_{diff} = \Delta T_i - \Delta T_{Uccle}}$$

For the CORDEX runs, the temperature increase per century at gridbox i was derived from the timeseries of the annual mean values for this gridbox from 2006 till 2100 using linear regression.

For the MACCBET runs and the ALARO run this ΔT_i was determined in a different way because these runs do not have continuous data from 2006 till 2100. The MACCBET runs have data for a period of ten years and the ALARO run has data for a period of 30 years. The temperature increase per 100 years was derived by the use of a rescaling factor (**f**):

$$\mathbf{\Delta T_i = (T_{i(FUT)} - T_{i(PRES)})*f,}$$

where $T_{i(FUT)}$ is the mean temperature for grid cell i for the whole period of the future run (see Table 1), $T_{i(PRES)}$ is mean temperature for the grid cell i for the whole period of the present run (see Table 1), and f is a rescaling factor:

$$\mathbf{f=100/(Year\_FUT-Year\_PRES),}$$

where Year_FUT is the middle of the time interval for the future model integrations (2030 for the run FUT2030, 2064 for the run FUT2064, and 2085 for the run FUT2085) and Year_PRES is the middle of the time interval for the present-day model integration (2005 for MACCBET and1974 for RMI).

Table 1: Belgian climate scenarios (MACCBET$_{(1)}$ and ALARO$_{(2)}$)

period	lateral boundary	scenario	acronym
1961-1990$_{(2)}$	ERA-40	/	HIST_ERA
2001-2010$_{(1)}$	ERA-Interim	/	PRES_ERA
2001-2010$_{(1)}$	EC-Earth	/	PRES_EC
2026-2035$_{(1)}$	EC-Earth	RCP4.5	FUT2030_RCP4.5
2060-2069$_{(1)}$	EC-Earth	RCP4.5	FUT2064_RCP4.5
2060-2069$_{(1)}$	EC-Earth	RCP8.5	FUT2064_RCP8.5
2071-2100$_{(2)}$	Arpège	SRES A1B	FUT2085_A1B

Table 2 shows for every model the expected temperature increase for the grid cell Uccle.

Table 2: Expected temperature increase per century for the grid cell Uccle (RCP4.5 and 8.5)

model	ΔT_{Uccle} (°C) RCP4.5	ΔT_{Uccle} (°C) RCP8.5
CCLM	1.43	4.12
RACMO22E	1.61	3.62
RCA_CNRM	1.45	4.04
RCA_ICHEC	1.85	4.25
RCA_MOHC	2.71	4.85
FUT2030	4.32	/
FUT2065	1.14	2.24
FUT2085_A1B	2.58	/

2.1 RCP4.5

All the runs show an expected temperature increase by the end of the century. The magnitude of the increase varies from run to run, with for example for the CCLM run an expected increase of 1.43 °C in Uccle and for the MOHC run an expected increase of 2.71 °C in Uccle. For the CCLM run (Figure 1) the spatial variability is modest. The expected temperature increase in most of the regions in Belgium is lower or equal to that one of Uccle (1.43 °C). At the coast and in the east of Belgium the temperature increase is expected to be around 0.05 and 0.1 °C lower than in Uccle. In the Northeast of France and some parts in the West of Belgium the increase is expected to be higher. The RACMO22E run (Figure 5) modeled a clearly spatial pattern of the temperature in Belgium, with less warming Northwest of Uccle and more warming Southeast of Uccle. The tempering effect of the sea is clearly visible in this run. The warming at the coast is projected to be 0.1 °C or 0.2 °C lower than the warming in Uccle (1.61 °C), while in the south the projected warming is 0.1 °C or 0.2 °C higher than in Uccle. The FUT2085_A1B run (Figure 8) from the RMI, the FUT2064_RCP4.5 run (Figure 7), the CNRM run (Figure 2) and the MOHC run (Figure 4) show the same spatial patterns. The FUT2030_RCP4.5 run (Figure 6) shows a change that is going from Northeast to Southwest. Within the Northeast an expected temperature increase up to 0.5 °C lower than in Uccle (4.32 °C) and in the Southwest a warming of 0.7 °C higher than in Uccle. Also the tempering effect of the sea at the coast is visible. The ICHEC run (Figure 3) shows the same spatial patterns as the FUT2030_RCP4.5 run of MACCBET.

All the model runs indicate to a temperature increase by the end of the century following the RCP4.5 scenario. The warming is expected to be lower in the Northwest of Belgium due to the tempering effect of the sea. The projected warming in the south and the southeast of Belgium is largest.

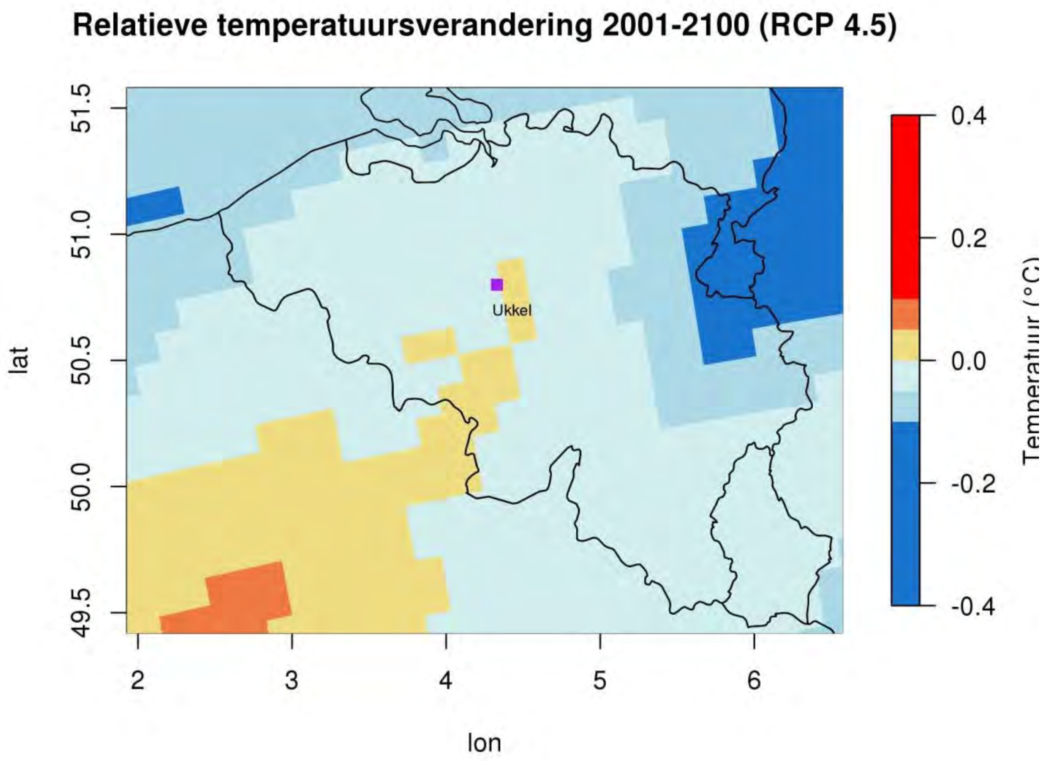


Figure 1: Temperature change CCLM by the end of the century, compared to Uccle (RCP4.5)

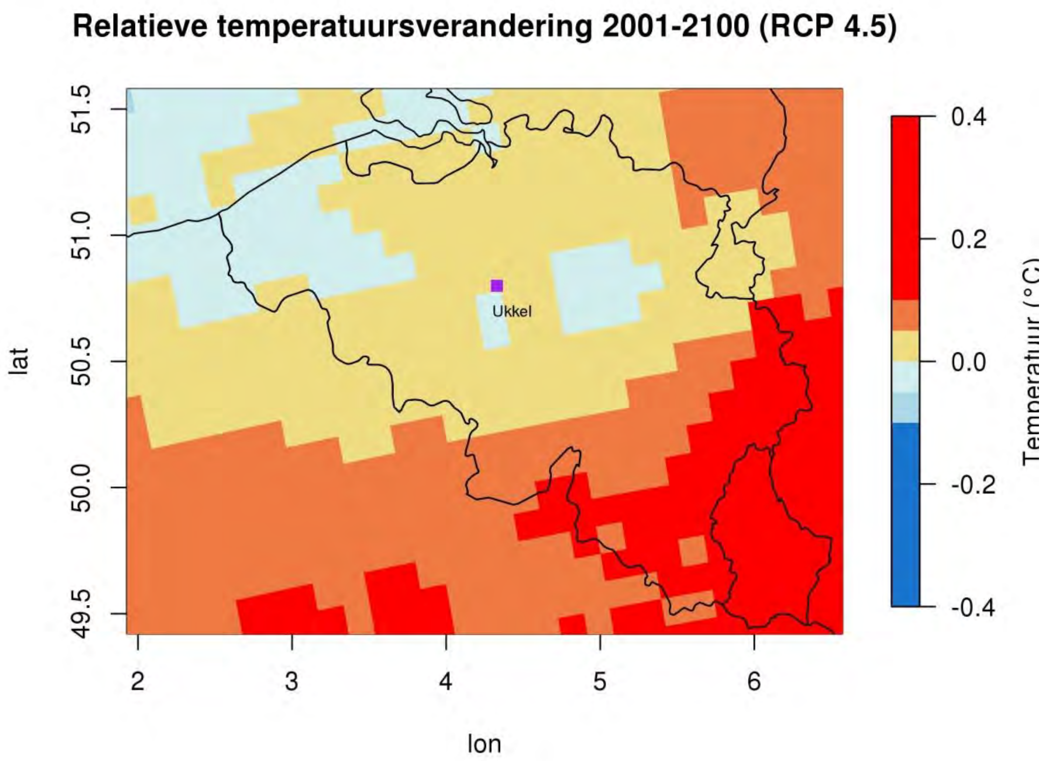


Figure 2: Temperature change CNRM by the end of the century, compared to Uccle (RCP4.5)

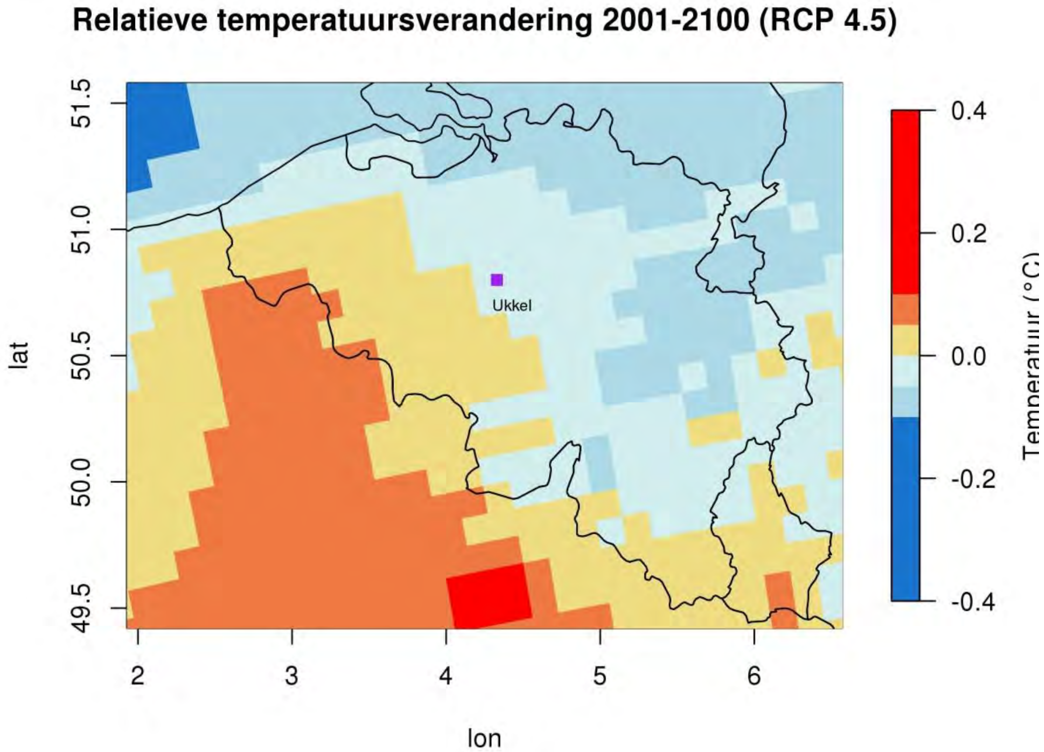


Figure 3: Temperature change ICHEC by the end of the century, compared to Uccle (RCP4.5)

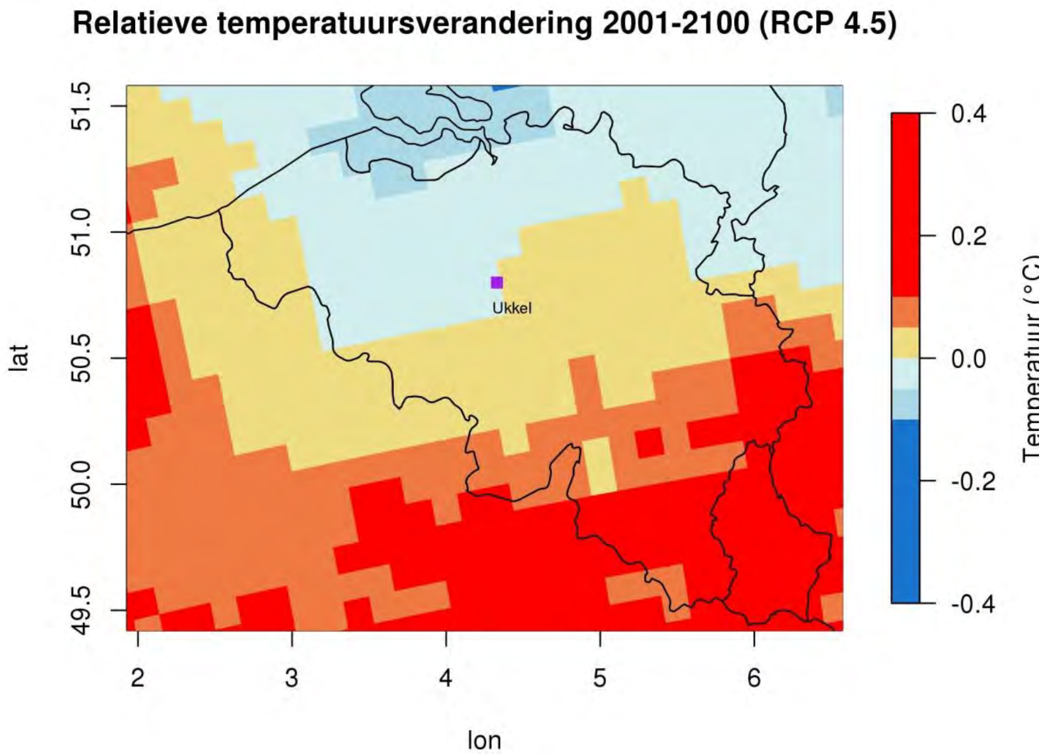


Figure 4: Temperature change MOHC by the end of the century, compared to Uccle (RCP4.5)

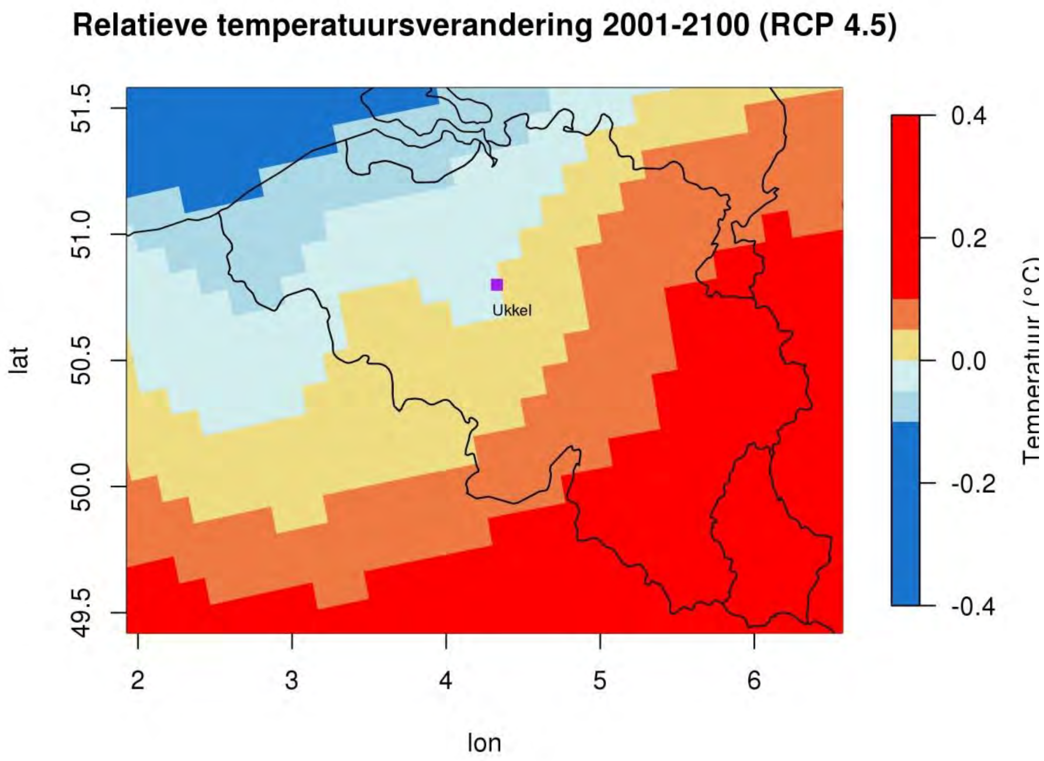


Figure 5: Temperature change RACMO22E by the end of the century, compared to Uccle (RCP4.5)

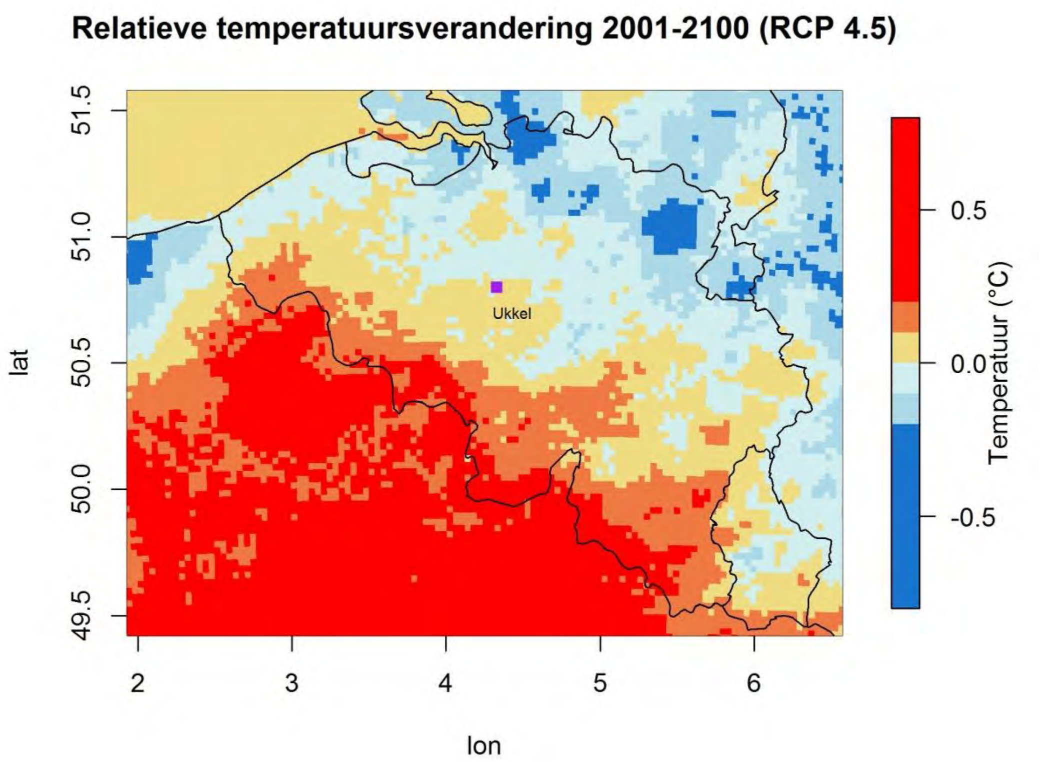


Figure 6: Temperature change FUT2030_RCP4.5 by the end of the century, compared to Uccle (RCP4.5)

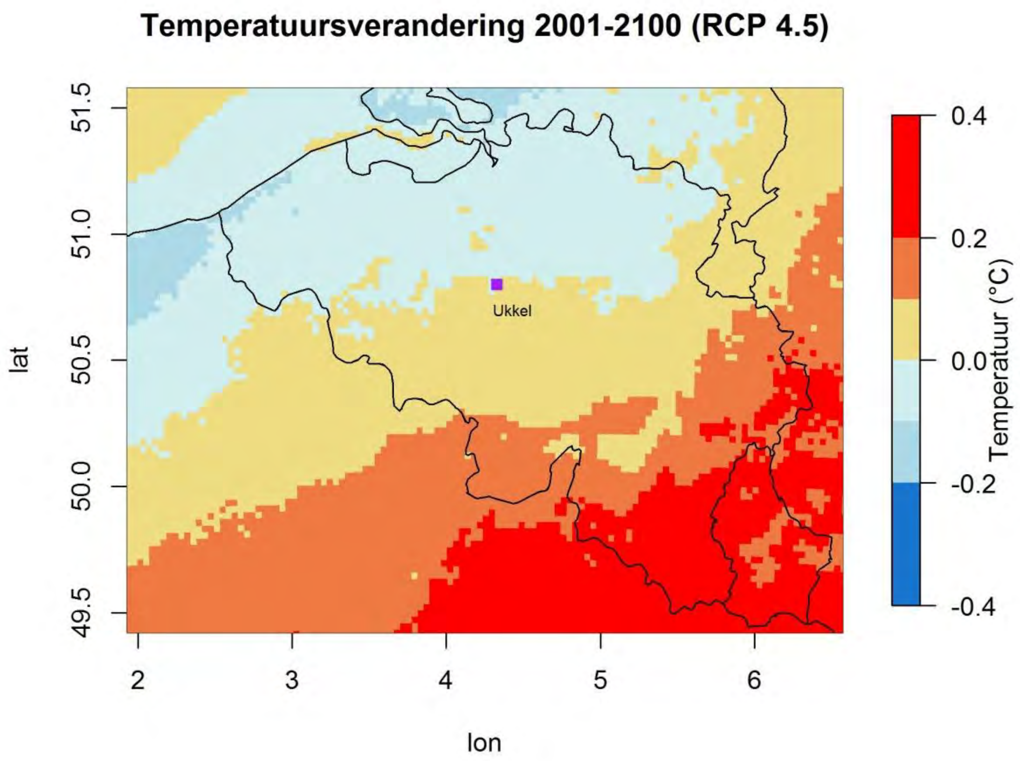


Figure 7: Temperature change FUT2064_RCP4.5 by the end of the century, compared to Uccle (RCP4.5)

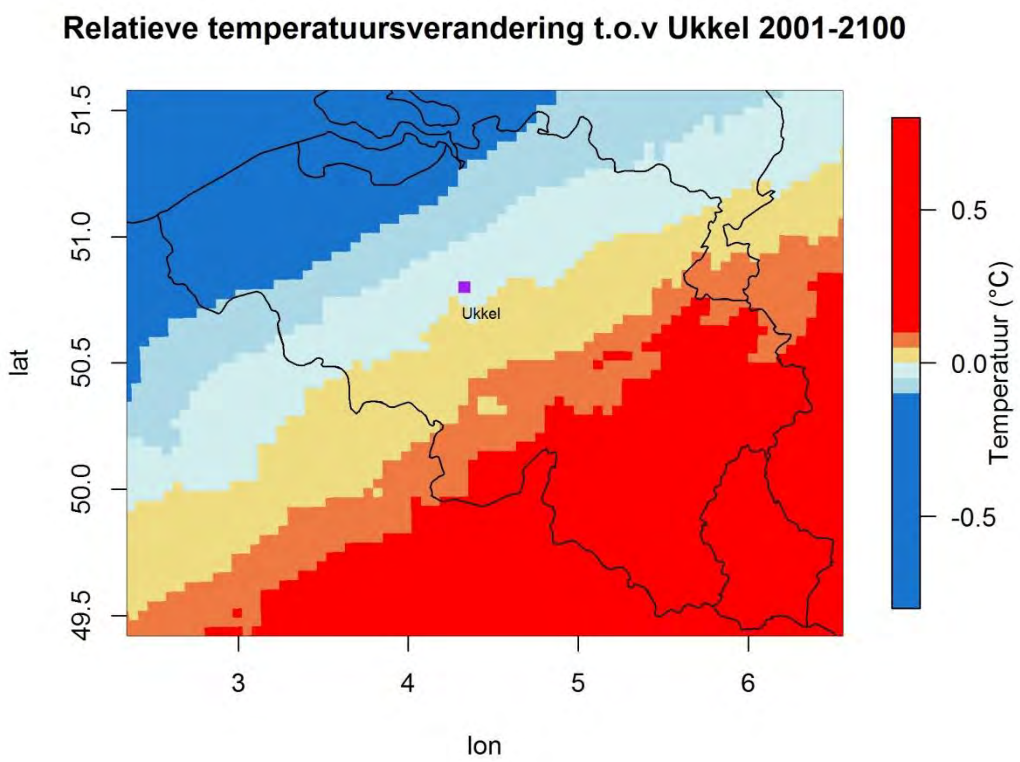


Figure 8: Temperature change FUT2085_A1B by the end of the century, compared to Uccle (RCP4.5)

2.2 RCP8.5

All the spatial patterns maps for the CORDEX models (Figure 9, 10, 11, 12 and 13) show strong similarities. A stronger temperature increase is expected in the South-East than the expected temperature in the North-West. All the five figures show a tempering effect of the sea near the coast. Note that the sea surface temperature that is determined by the driving GCM (General Circulation model) appears to be the dominant factor for the spatial patterns of the model projections for temperature.

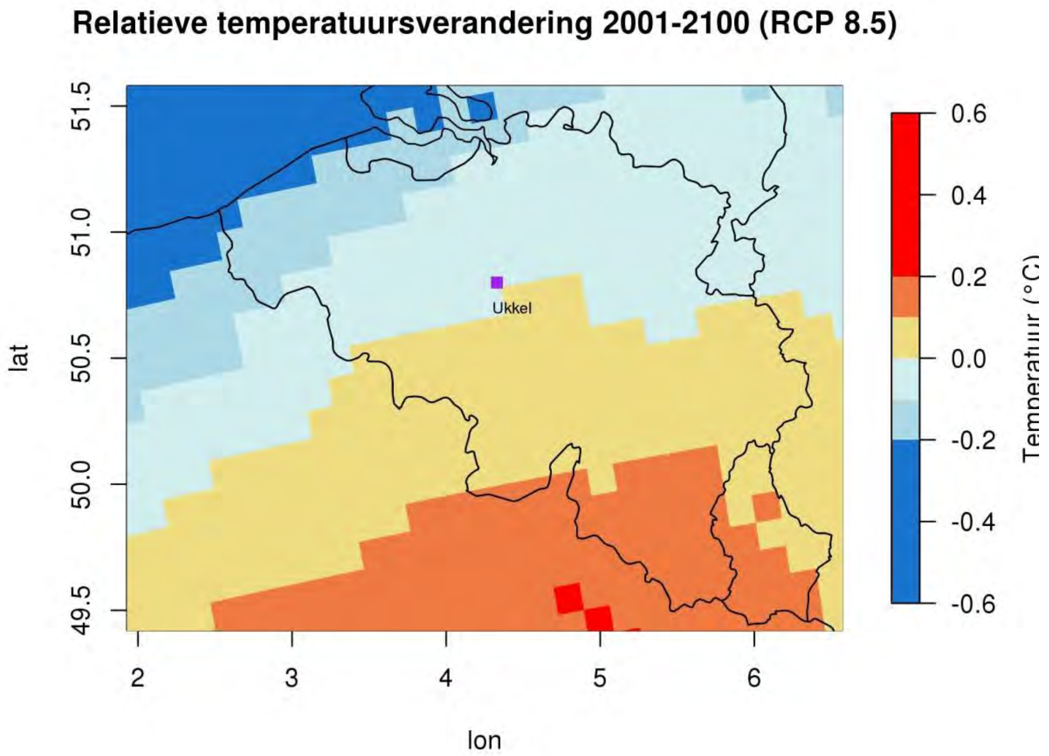


Figure 9: Temperature change CCLM by the end of the century, compared to Uccle (RCP8.5)

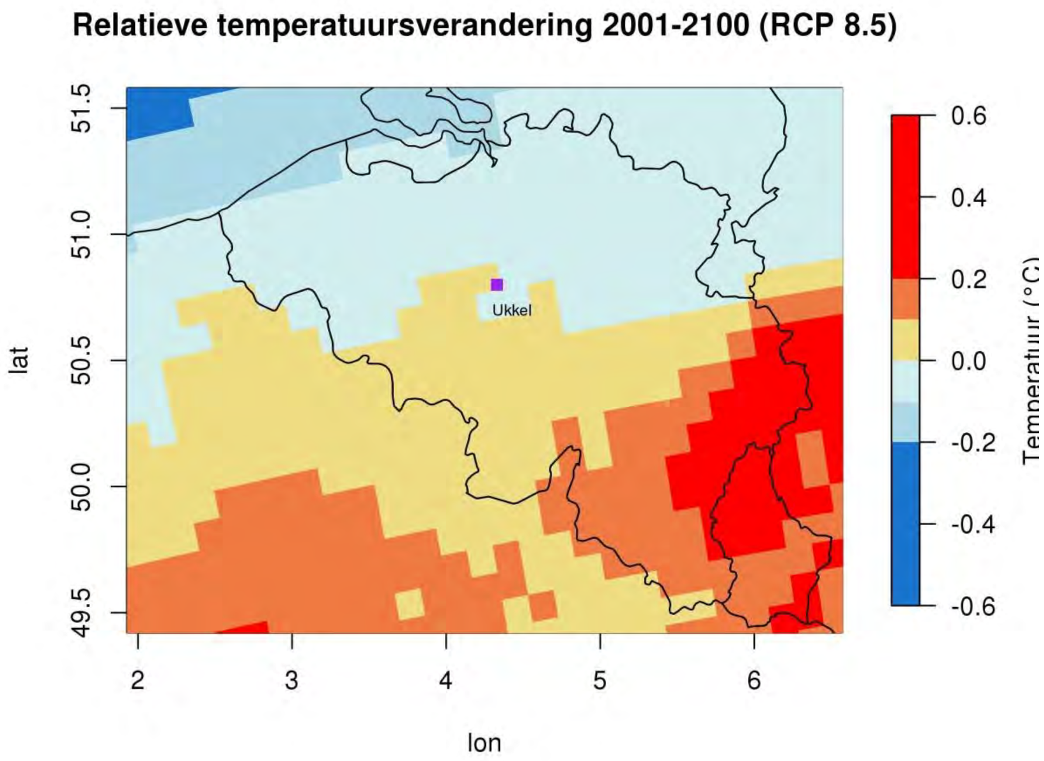


Figure 10: Temperature change CNRM by the end of the century, compared to Uccle (RCP8.5)

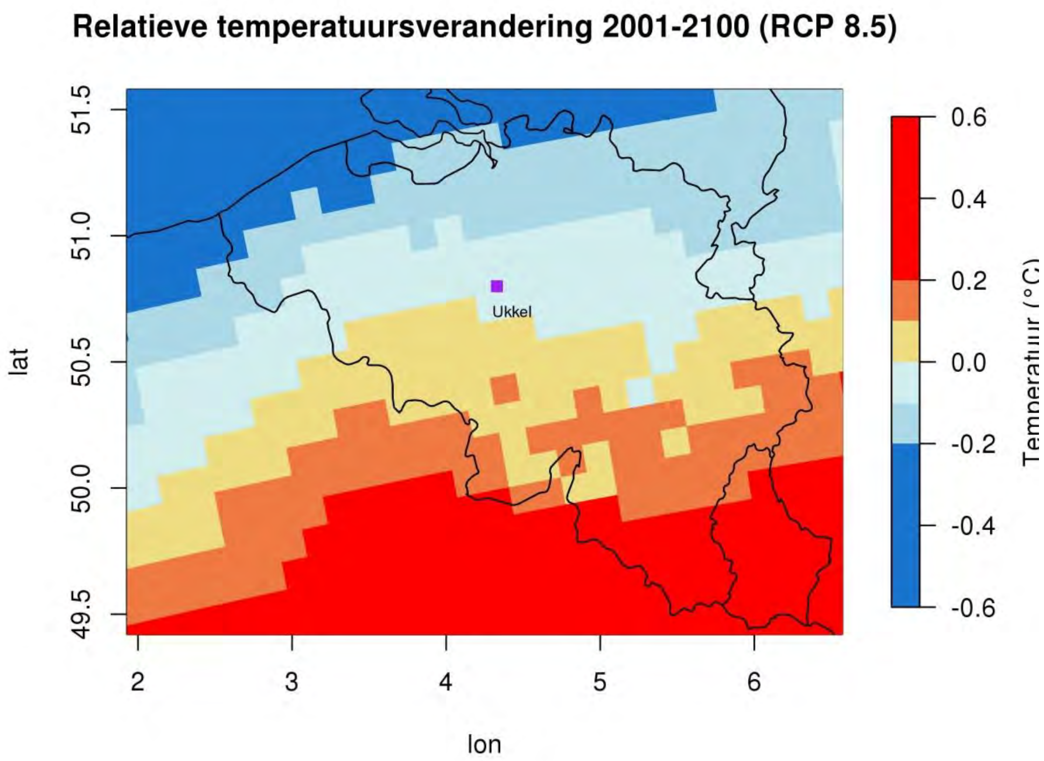


Figure 11: Temperature change ICHEC by the end of the century, compared to Uccle (RCP8.5)

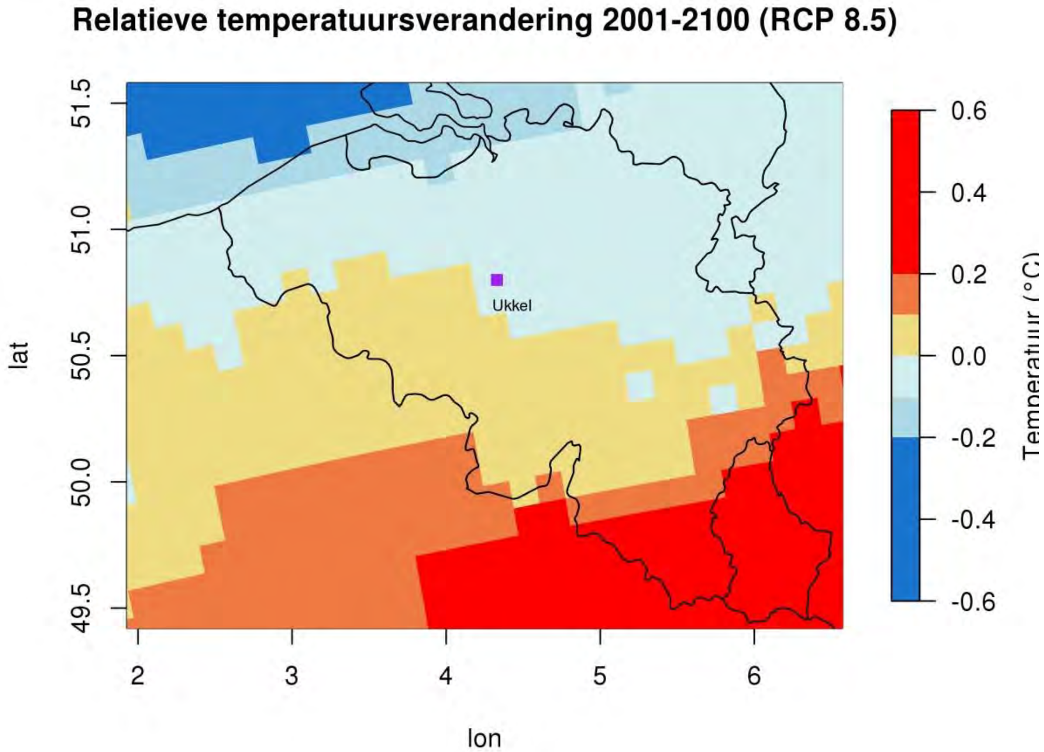


Figure 12: Temperature change MOHC by the end of the century, compared to Uccle (RCP8.5)

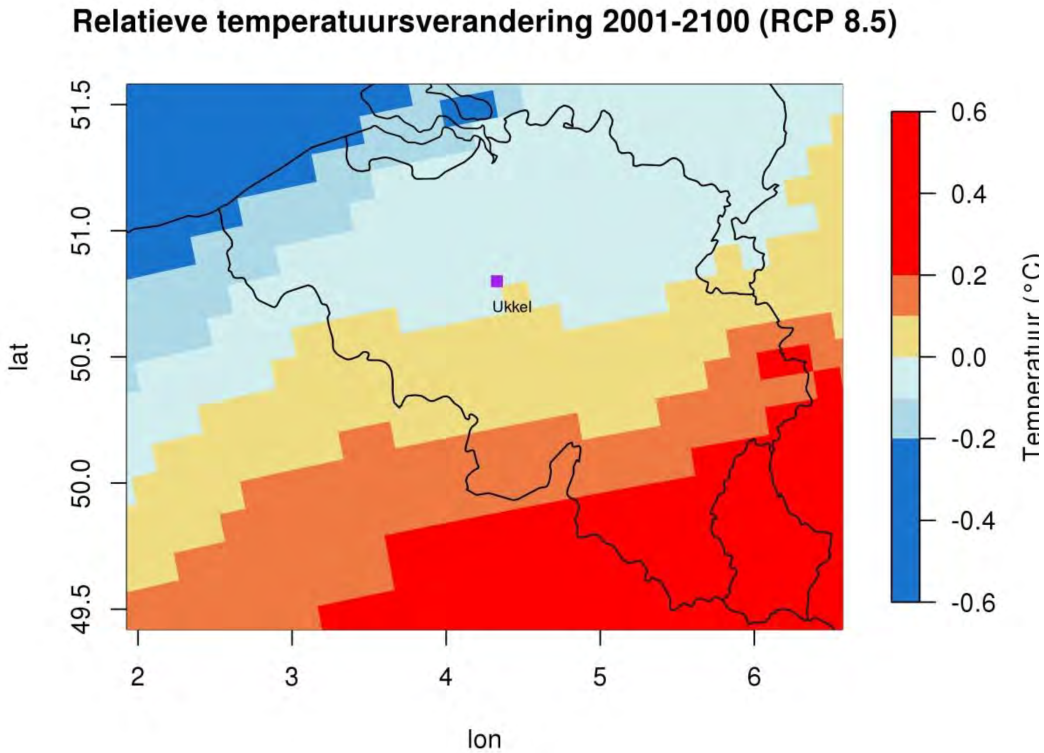


Figure 13: Temperature change RACMO22E by the end of the century, compared to Uccle (RCP8.5)

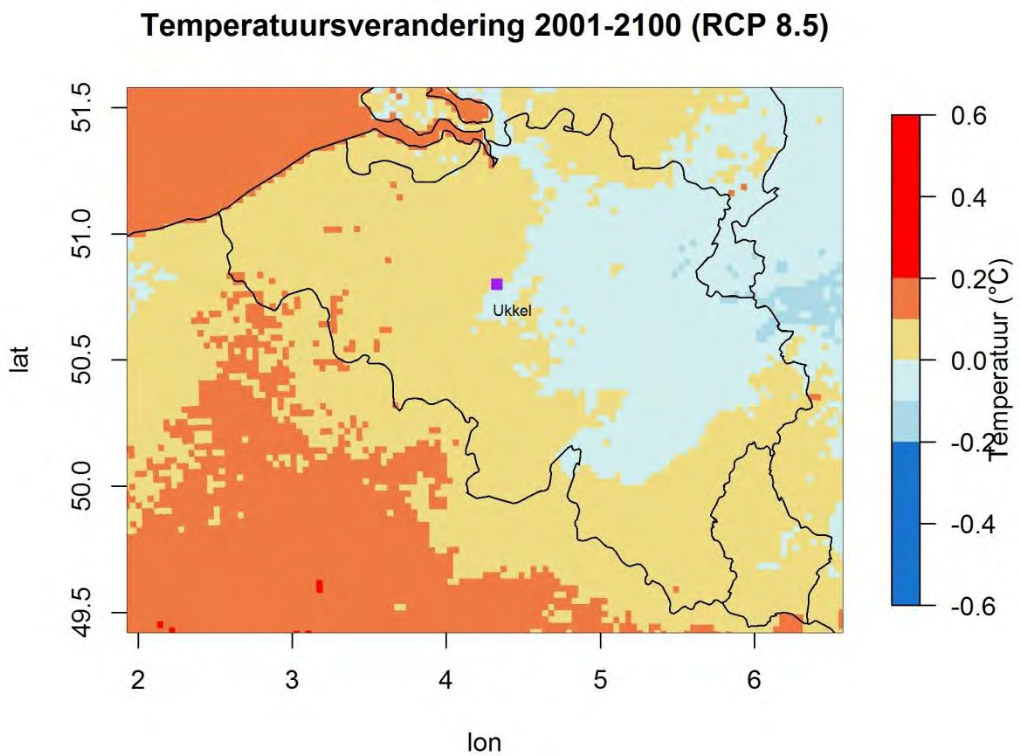


Figure 14: Temperature change FUT2064_RCP8.5 by the end of the century, compared to Uccle (RCP8.5)

3 Winter precipitation

The spatial patterns maps for the winter precipitation and summer precipitation show for every grid cell the fraction of the maximum predicted precipitation change in Belgium.

$$\Delta P_i = \Delta P_i \,/\, |\Delta P|_{max}$$

Where ΔP_i is the fraction of the maximum predicted precipitation change for grid cell i (1=maximum increase; 0=no change; -1=maximum decrease), ΔP_i is precipitation change per 100 years for grid cell i (measured in the same way as the increase in temperature, see section 2), $|\Delta P|_{max}$= absolute value of the maximum precipitation change per 100 years for all grid cells over the domain.

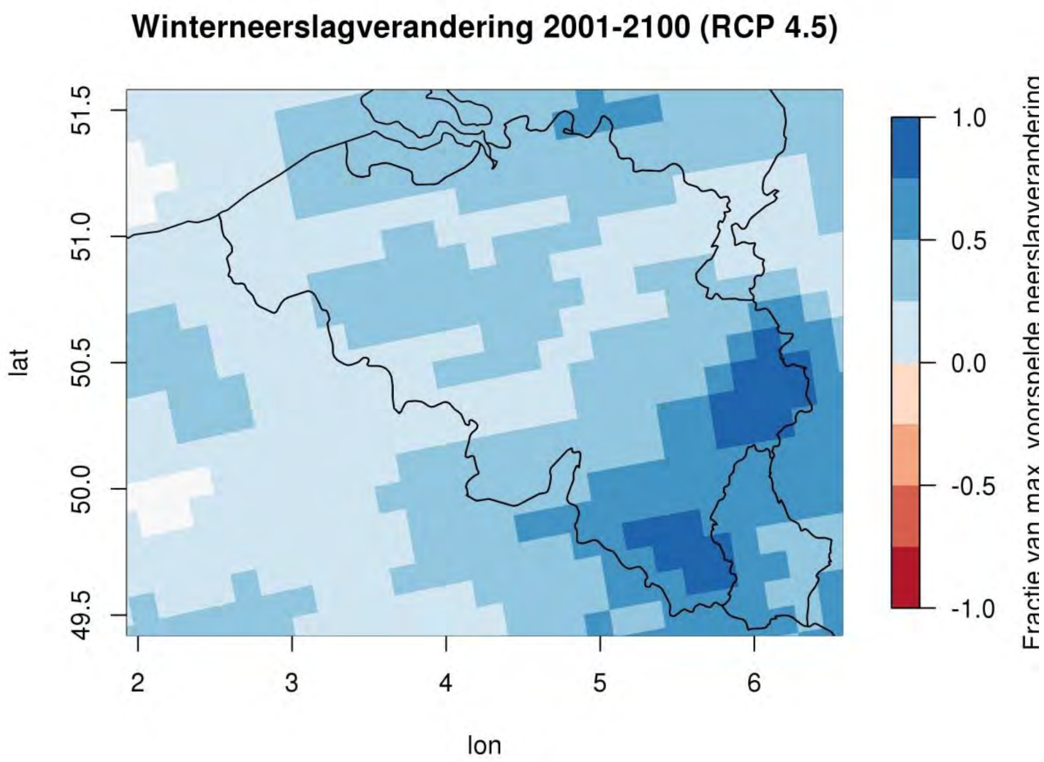
The maximum change in precipitation for each model is shown in Table 3.

Table 3: Maximum predicted change in winter precipitation

model	ΔP_{max} (mm) RCP4.5	ΔP_{max} (mm) RCP8.5
CCLM	62.66	75.10
RACMO22E	-48.22	146.33
RCA_CNRM	135.13	193.73
RCA_ICHEC	122.57	97.87
RCA_MOHC	34.16	130.02
FUT2030	125.39	/
FUT2065	77.33	78.1
FUT2085_A1B	90.22	/

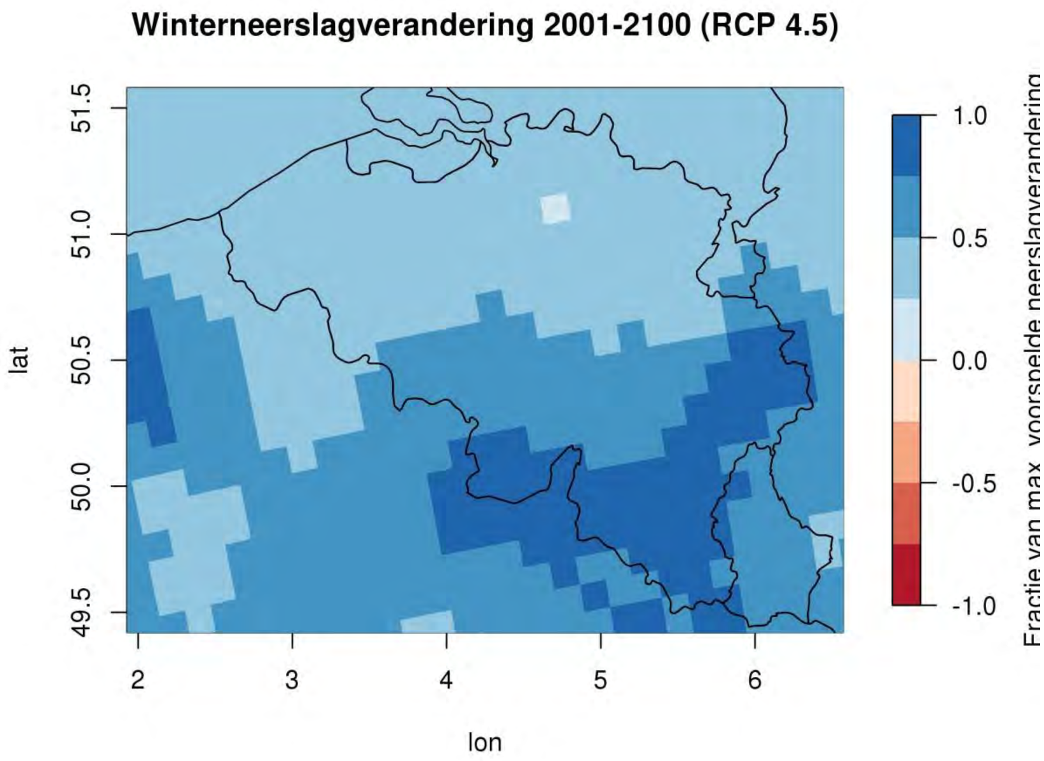
3.1 RCP4.5

For the winter precipitation there is a lot of variation between the different model runs. The model runs of CCLM, CNRM and ICHEC (Figures 15,16 and 17) show the same spatial patterns in Belgium. In every region there is an expected increase in winter precipitation and the biggest increase is situated in the south and the southeast of Belgium. This is probably the result of the topography in these regions. The high resolution model of the RMI (Figure 22) models also a big increase in the south of Belgium, but not in the Southeast. The FUT2030_RCP4.5 run (Figure 20) shows much variety, with in some regions an expected increase and in other regions an expected decrease in winter precipitation. The other run of MACCBET, FUT2064_RCP4.5 (Figure 21) models an increase in winter precipitation at the coast and a decrease in the center and the South of Belgium, in contrast with the CCLM, CNRM and ICHEC run. Also the MOHC and the RACMO run (Figure 18 and 19) are in contrast with these runs. They show an expected decrease in the amount of winter precipitation. For the MOHC run is this the fact in almost every region of Belgium, especially in the West. For the RACMO run this decrease is situated in the South and the Southeast of Belgium.



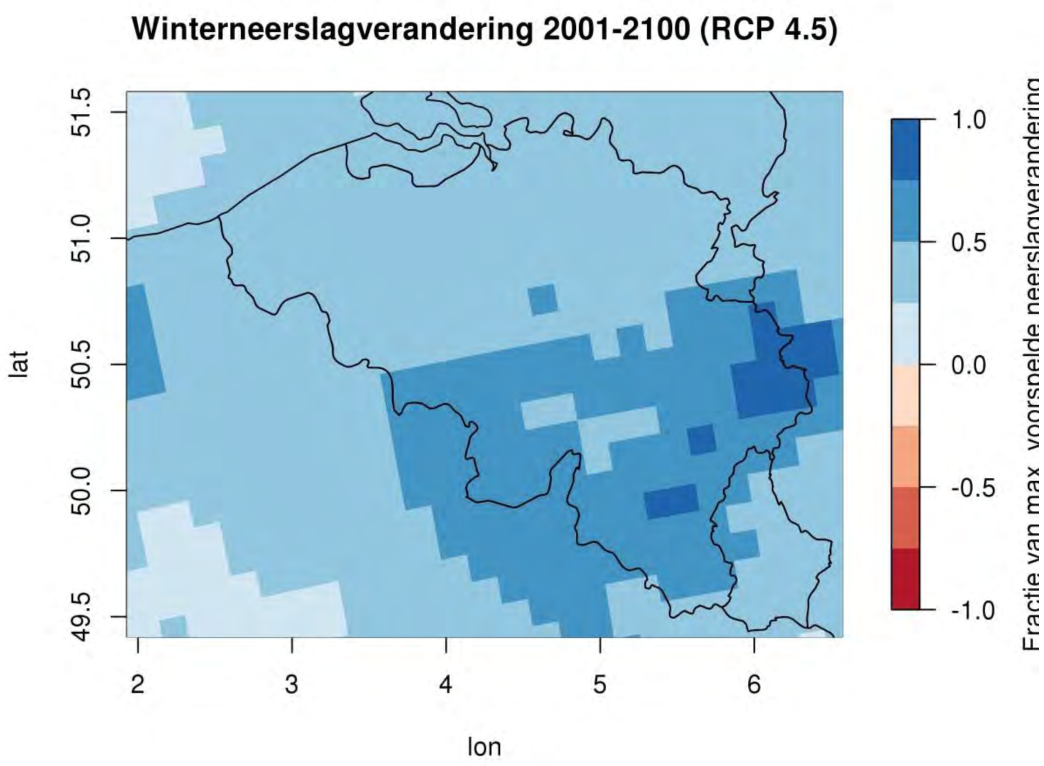
1=maximum increase; 0=no change; -1=maximum decrease

Figure 15: Predicted change in winter precipitation CCLM, RCP4.5



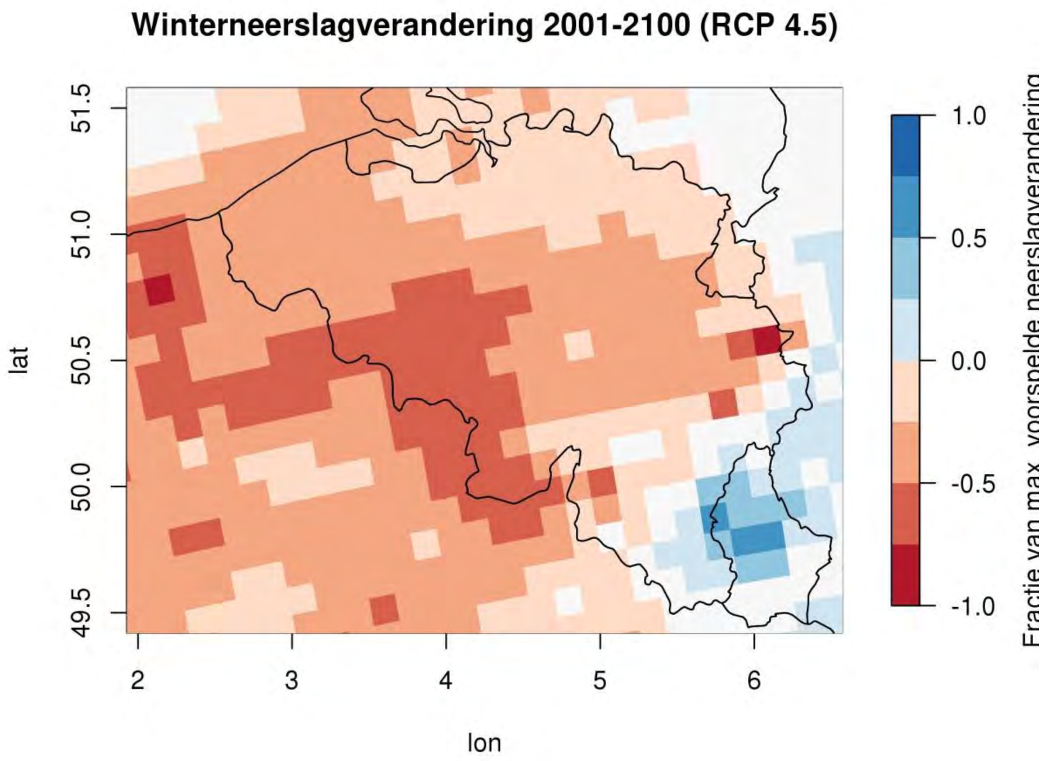
1=maximum increase; 0=no change; -1=maximum decrease

Figure 16: Predicted change in winter precipitation CNRM, RCP4.5



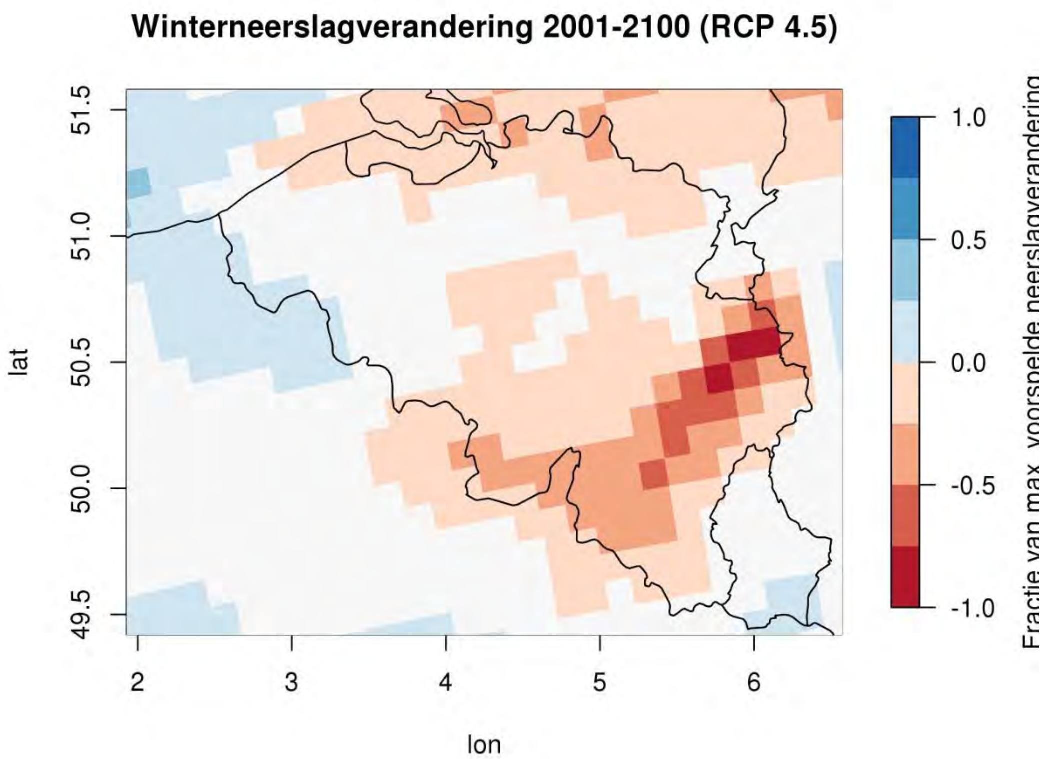
1=maximum increase; 0=no change; -1=maximum decrease

Figure 17: Predicted change in winter precipitation ICHEC, RCP4.5



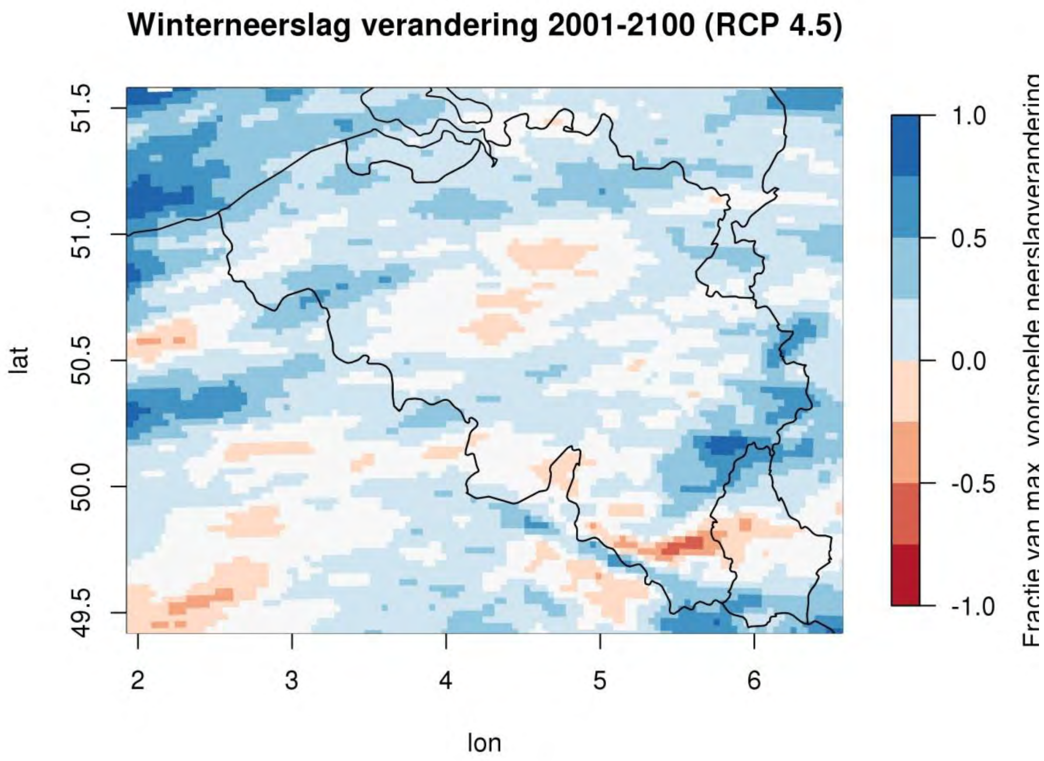
1=maximum increase; 0=no change; -1=maximum decrease

Figure 18: Predicted change in winter precipitation MOHC, RCP4.5



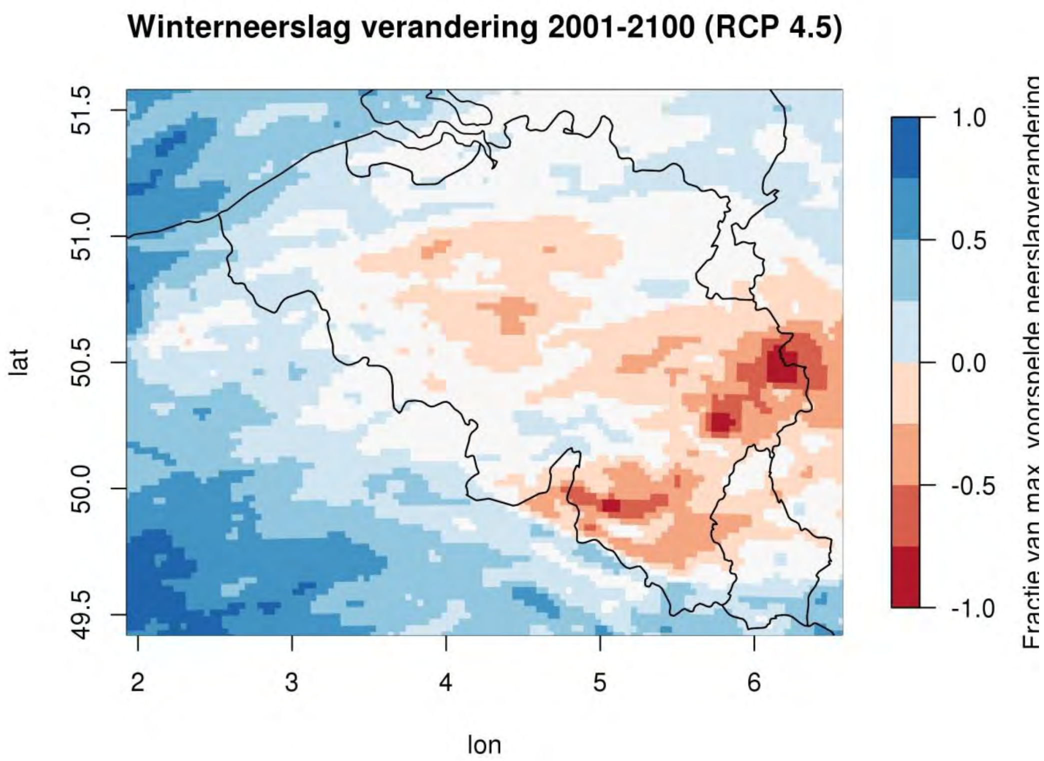
1=maximum increase; 0=no change; -1=maximum decrease

Figure 19: Predicted change in winter precipitation RACMO22E, RCP4.5



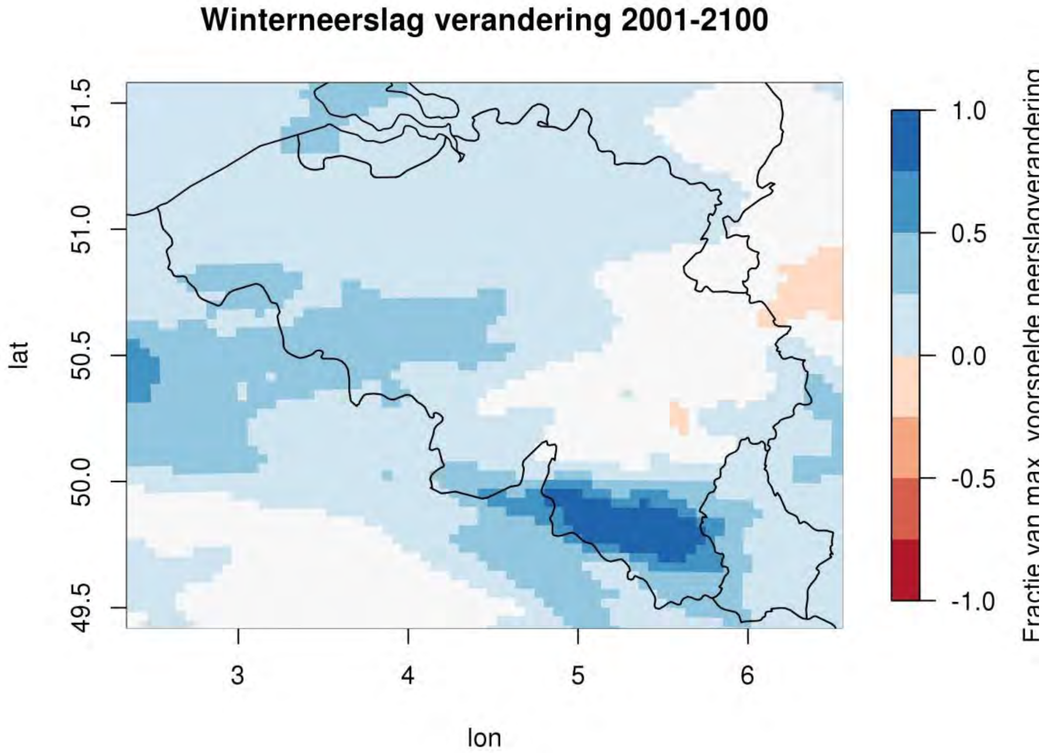
1=maximum increase; 0=no change; -1=maximum decrease

Figure 20: Predicted change in winter precipitation FUT2030_RCP4.5, RCP4.5



1=maximum increase; 0=no change; -1=maximum decrease

Figure 21: Predicted change in winter precipitation FUT2064_RCP4.5, RCP4.5



1=maximum increase; 0=no change; -1=maximum decrease

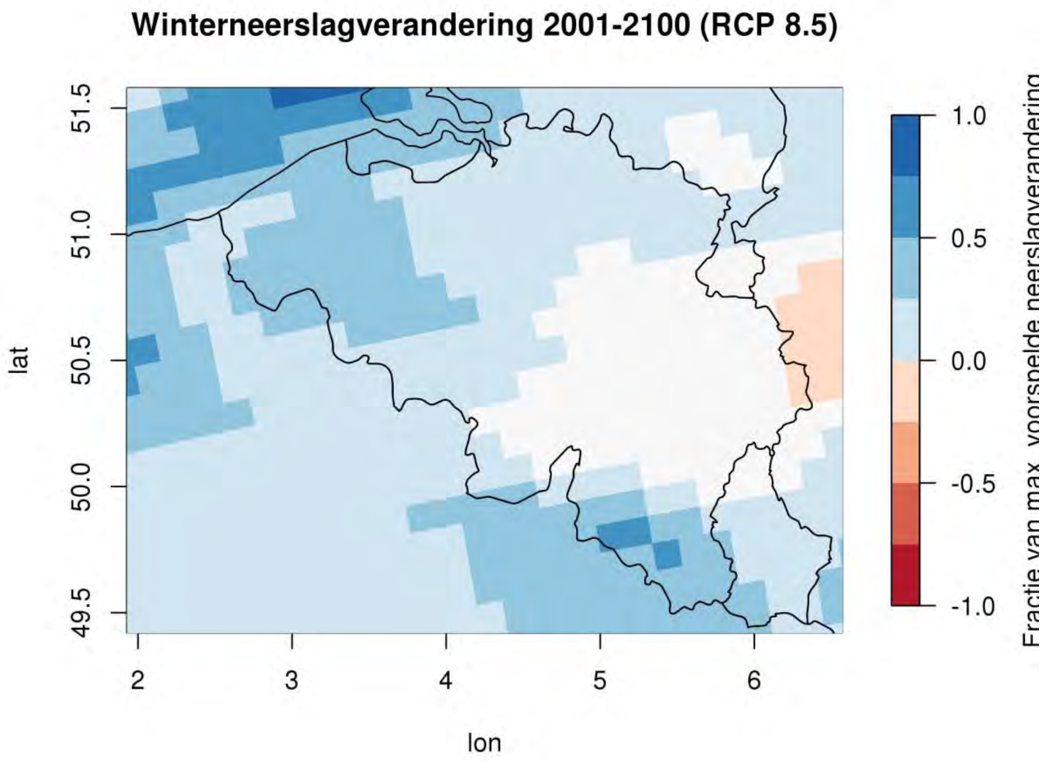
Figure 22: Predicted change in winter precipitation FUT2085_A1B

3.2 RCP8.5

For the RCP8.5 scenario only six runs were available. The maximum predicted change in winter precipitation for this scenario is also shown in Table 3.

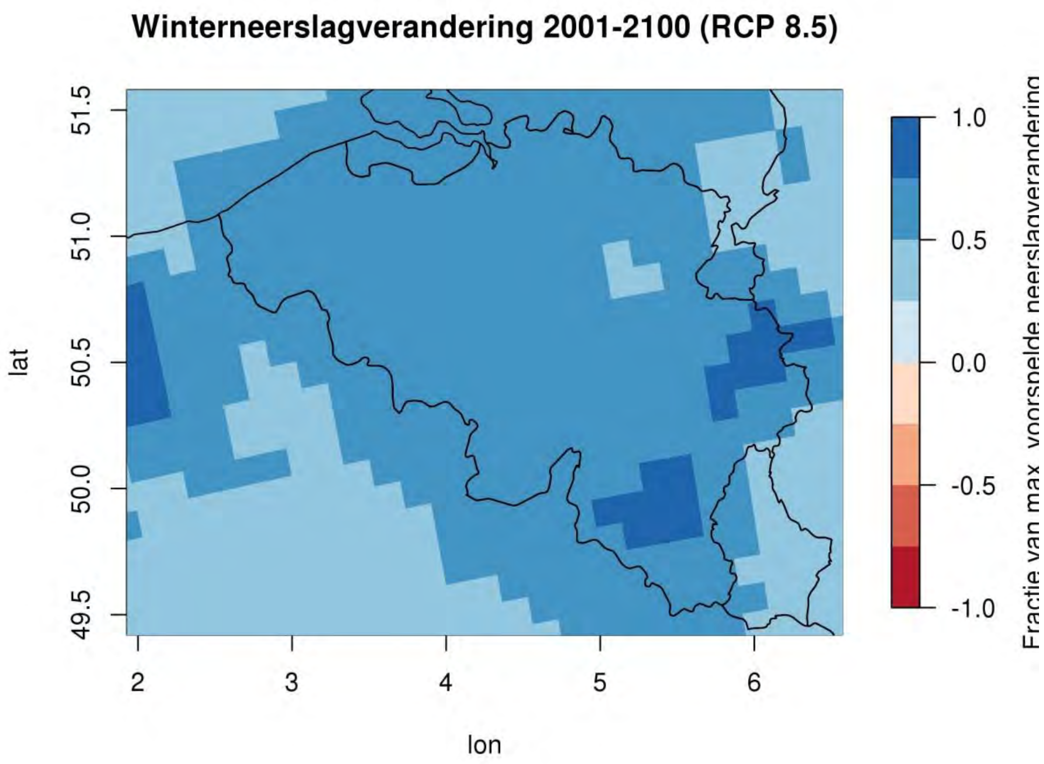
All the CORDEX models (Figure 23, 24, 25, 26 and 27) show an expected increase in winter precipitation by the end of the century. Depending on the model the expected increase is the biggest in the North or in the South of Belgium. The explanatory factor for the big increase in the North/Northwest would be the sea. Higher temperatures in the winter would lead to more evaporation of the seawater and more precipitation at the coast. In the south this would be a combination of higher temperatures and topography. The FUT2064_RCP8.5 run of MACCBET (Figure 28) is different from the CORDEX runs but it shows a clear spatial pattern, with an expected increase in winter precipitation in the North, a smaller increase in the center and in the extreme South a projected decrease in winter precipitation.

From these models there can be concluded that there is expected to be spatial differences between the North and the South of Belgium. The winter precipitation in the North is expected to increase because all models agree. The change in winter precipitation in the south of Belgium is still uncertain.



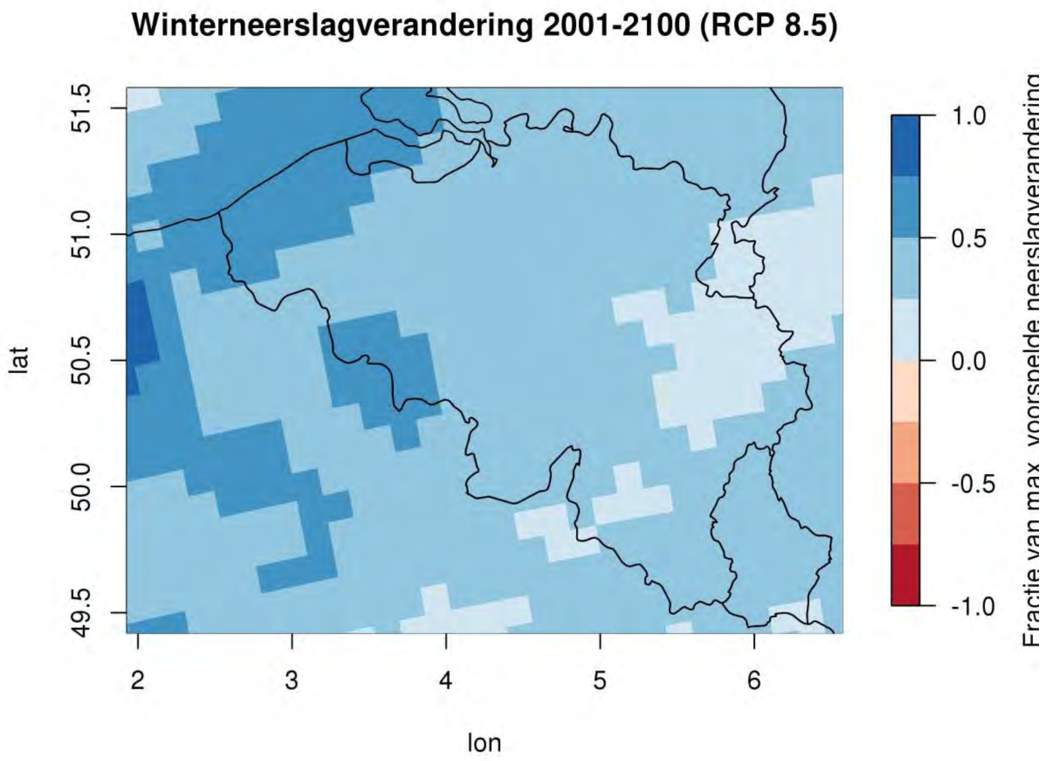
1=maximum increase; 0=no change; -1=maximum decrease

Figure 23: Predicted change in winter precipitation CCLM, RCP8.5



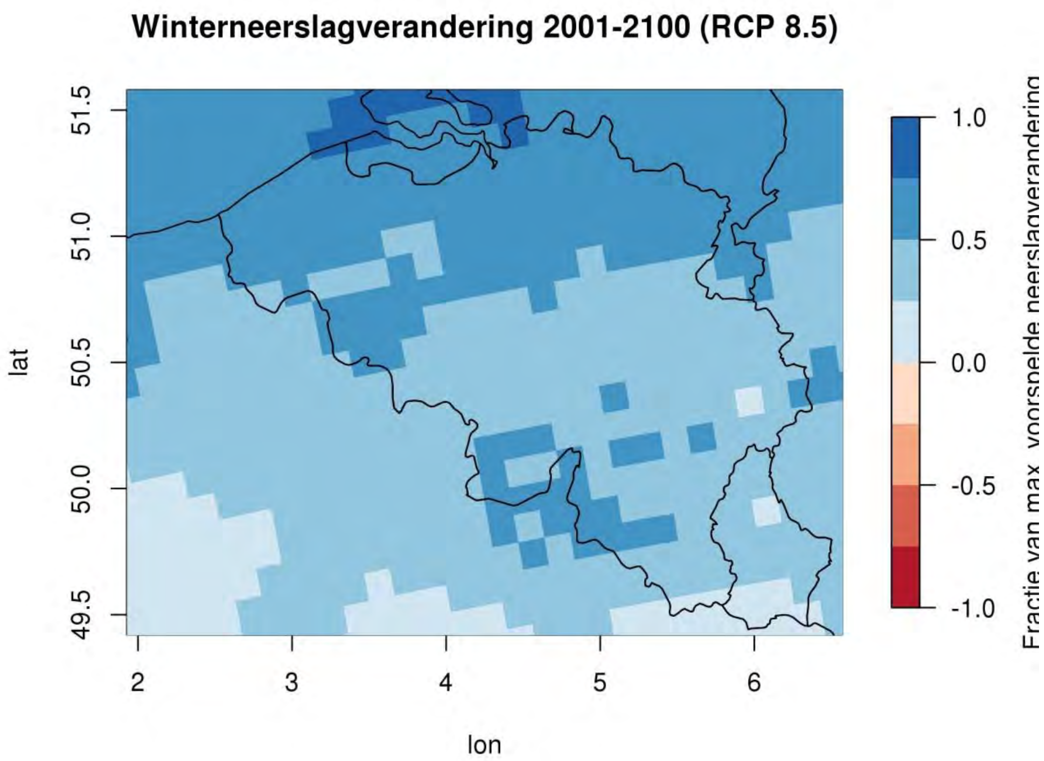
1=maximum increase; 0=no change; -1=maximum decrease

Figure 24: Predicted change in winter precipitation CNRM, RCP8.5



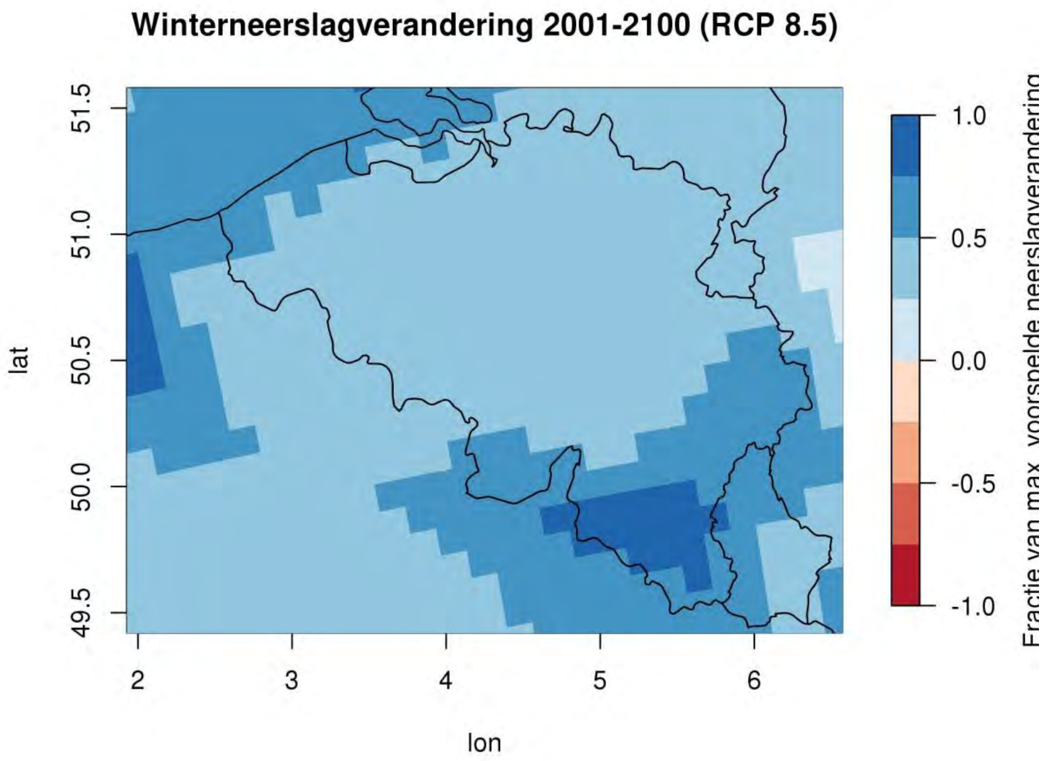
1=maximum increase; 0=no change; -1=maximum decrease

Figure 25: Predicted change in winter precipitation ICHEC, RCP8.5



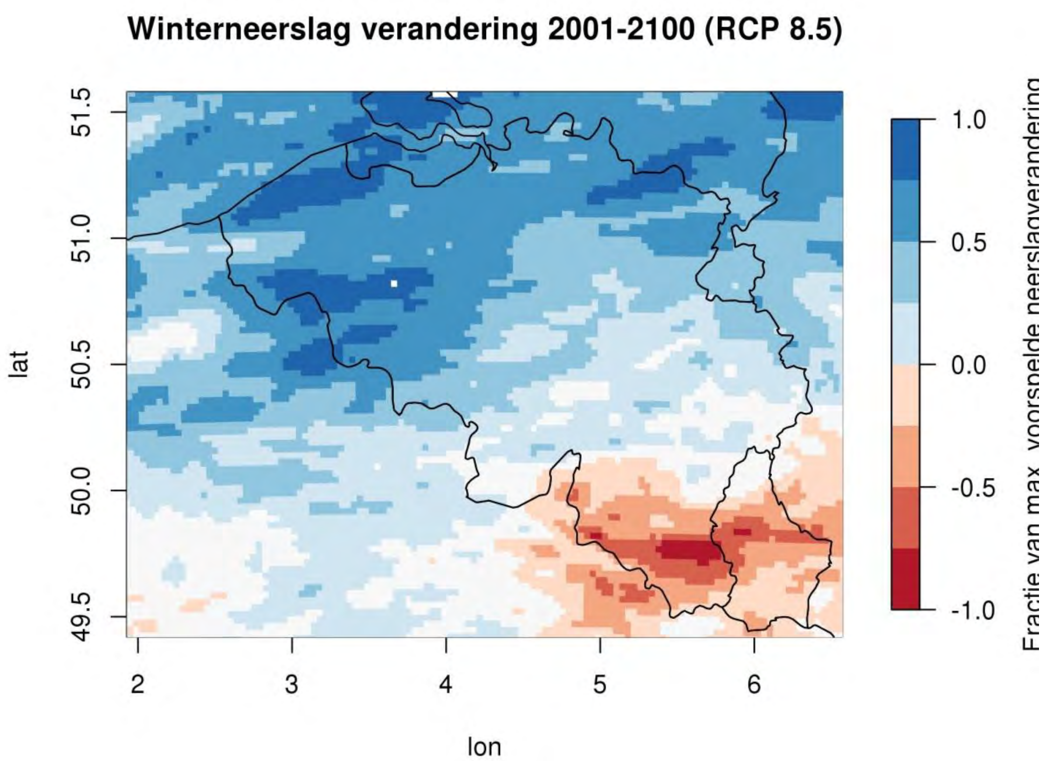
1=maximum increase; 0=no change; -1=maximum decrease

Figure 26: Predicted change in winter precipitation MOHC, RCP8.5



1=maximum increase; 0=no change; -1=maximum decrease

Figure 27: Predicted change in winter precipitation RACMO22E, RCP8.5



1=maximum increase; 0=no change; -1=maximum decrease

Figure 28: Predicted change in winter precipitation FUT2064_RCP8.5, RCP8.5

4 Summer precipitation

The spatial patterns for the change in summer precipitation were also modeled with the use of the maximum predicted precipitation change. The values for every model are listed below (Table 4).

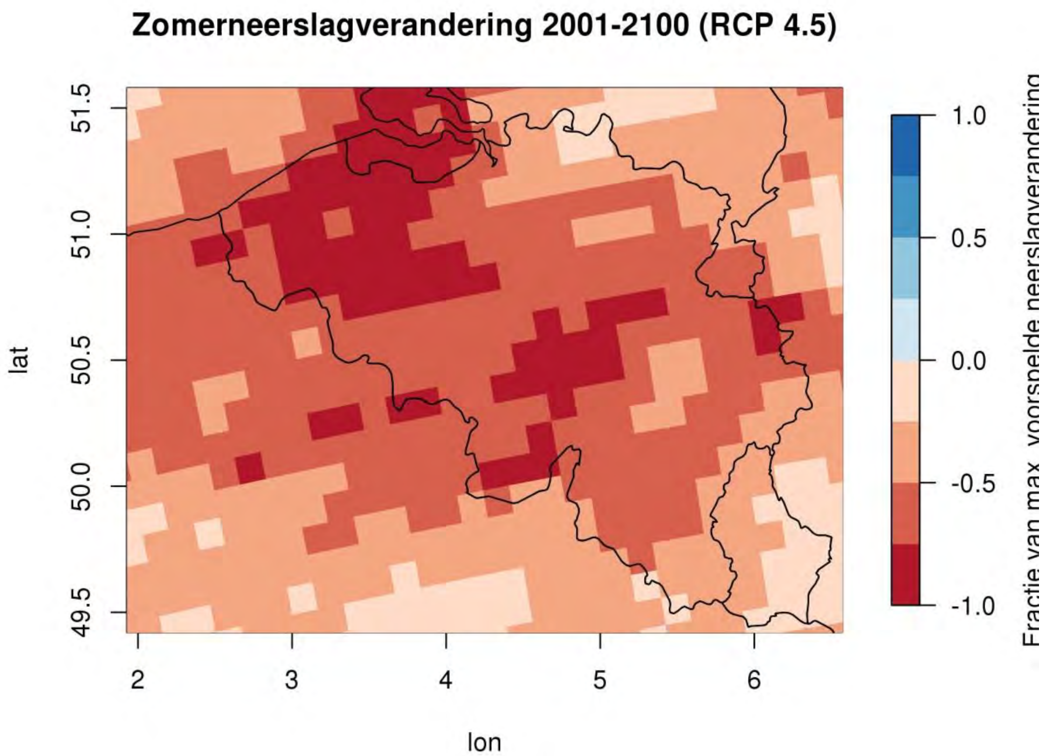
Table 4: Maximum predicted change in summer precipitation

model	ΔP_{max} (mm) RCP4.5	ΔP_{max} (mm) RCP8.5
CCLM	-78.49	-148.82
RACMO22E	37.94	-97.39
RCA_CNRM	123.52	-110.49
RCA_ICHEC	-102.23	-225.42
RCA_MOHC	-61.54	-117.96
FUT2030	-239.14	/
FUT2065	-139.37	-142.77
FUT2085_A1B	-70.15	/

4.1 RCP4.5

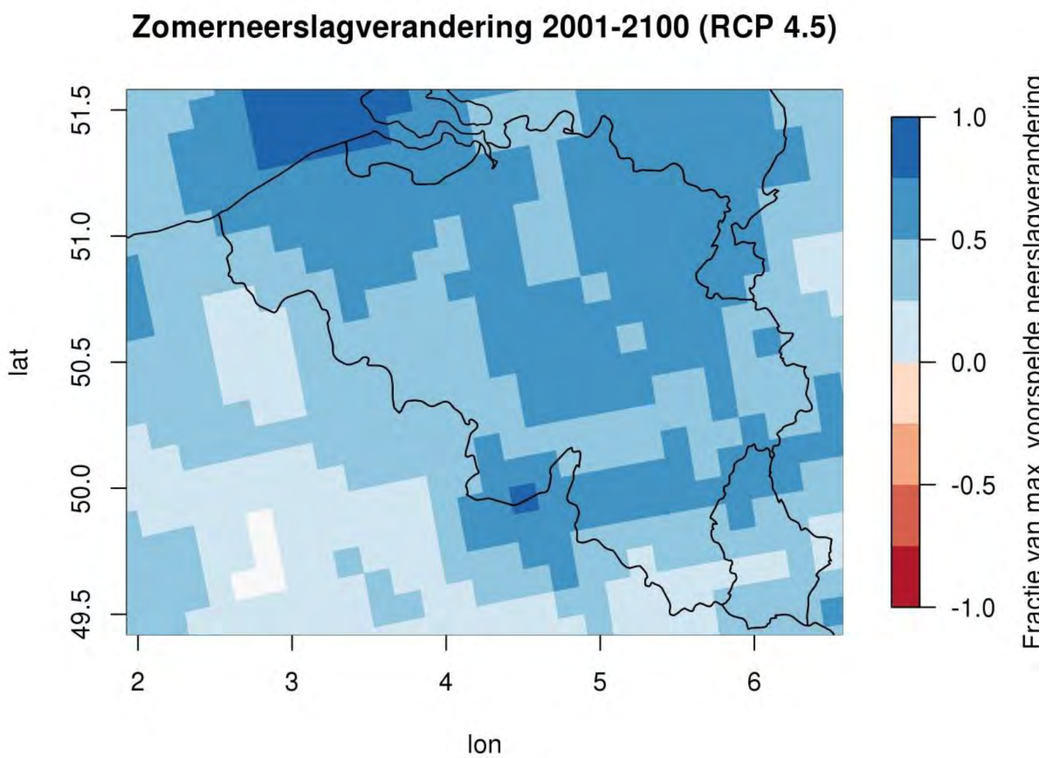
Just like for the change in winter precipitation, there is much variation between the different models for the change in summer precipitation for the RCP4.5 scenario. The CCLM model (Figure 29) models a expected decrease in summer precipitation for whole Belgium. The biggest decrease would be in the Northwest of Belgium, near the coast. The CNRM model (Figure 30) is in contrast with the CCLM model because it shows an expected increase in summer precipitation for every region in Belgium. The ICHEC run (Figure 31), the FUT2085_A1B run (Figure 34) and the FUT2064_RCP4.5 run (Figure 36) show also an expected decrease in summer precipitation for Belgium. The FUT2085_A1B from the RMI and the FUT2064_RCP4.5 from MACCBET are very similar, with the largest decrease in the South and the Southeast of Belgium. The ICHEC run has a different spatial pattern, with a Southwest-Northeast change. The RACMO22E run (Figure 33) and the FUT2030_RCP4.5 run (Figure 35) show also some similarities. Both runs model a decrease in summer precipitation at the coast and an increase in the center en the Northeast of the country. The last model, the MOHC run (Figure 32), shows a clearly visible spatial pattern, with an increase in summer precipitation in the North and a decrease in the South.

There is still a lot of uncertainty in the projected spatial patterns of change in summer precipitation. However, by the end of the century a decrease in summer precipitation in the South is expected because most of the models agree on this phenomenon.



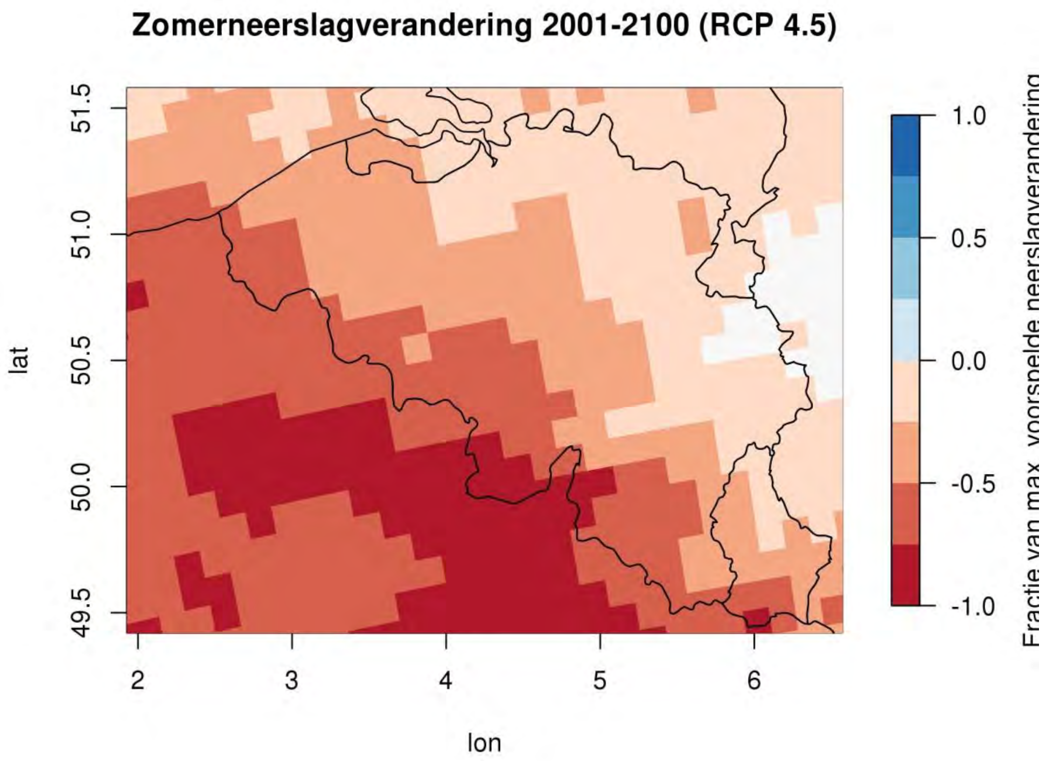
1=maximum increase; 0=no change; -1=maximum decrease

Figure 29: Predicted change in summer precipitation CCLM, RCP4.5



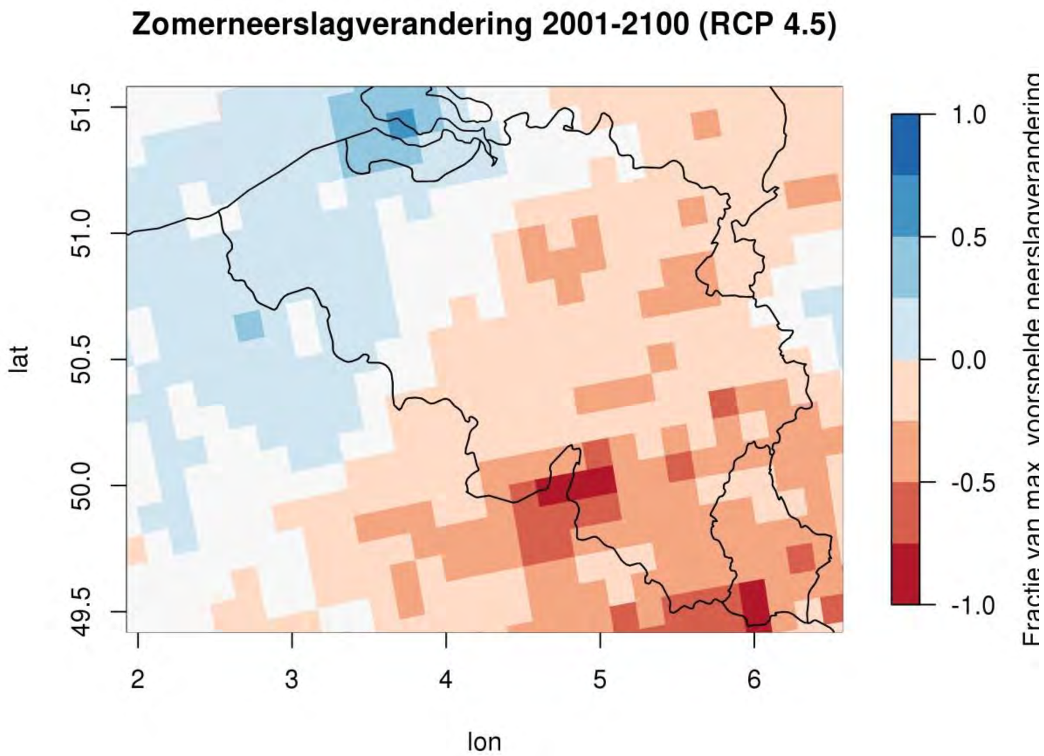
1=maximum increase; 0=no change; -1=maximum decrease

Figure 30: Predicted change in summer precipitation CNRM, RCP4.5



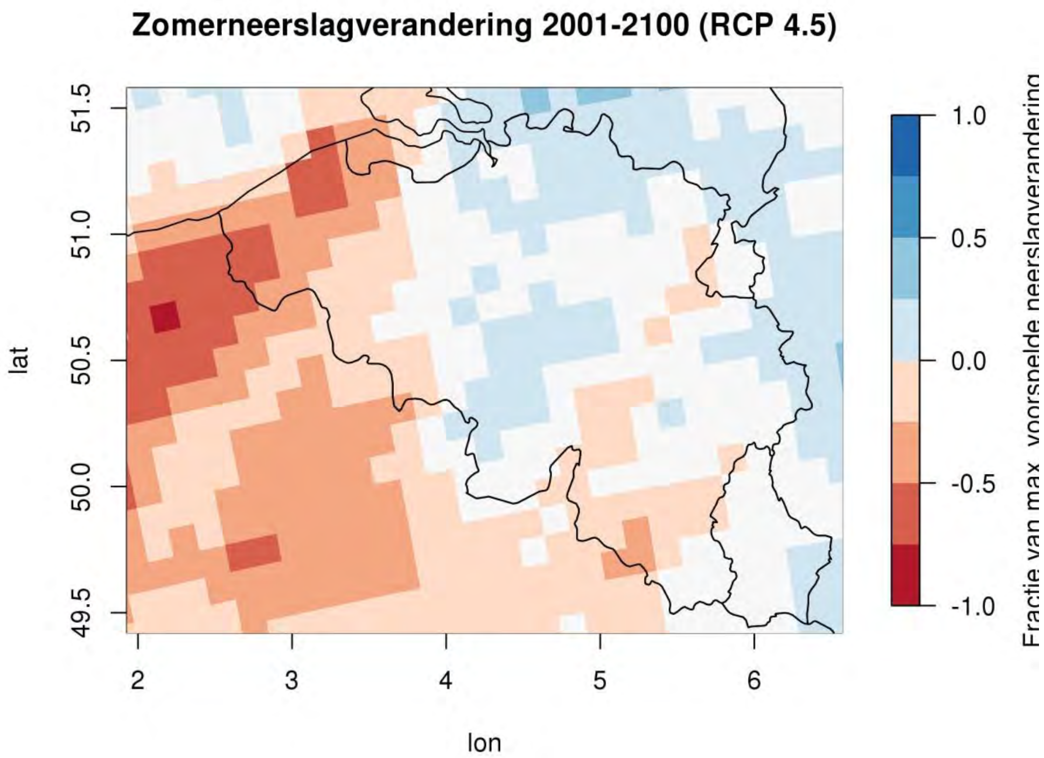
1=maximum increase; 0=no change; -1=maximum decrease

Figure 31: Predicted change in summer precipitation ICHEC, RCP4.5



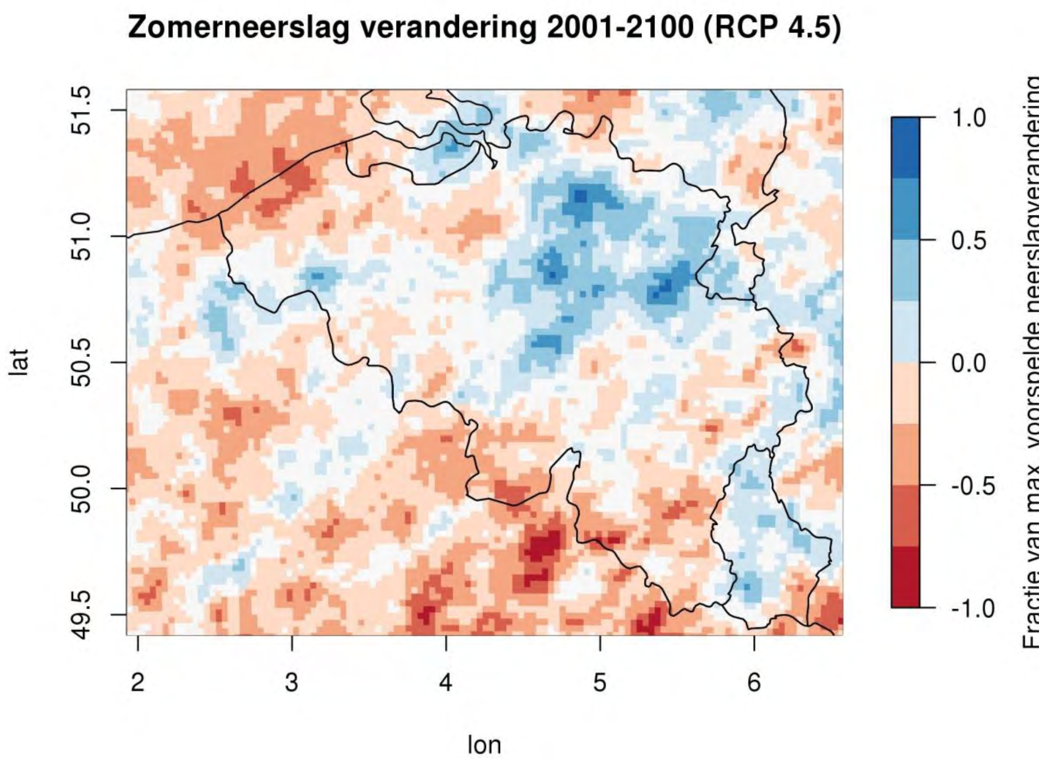
1=maximum increase; 0=no change; -1=maximum decrease

Figure 32: Predicted change in summer precipitation MOHC, RCP4.5



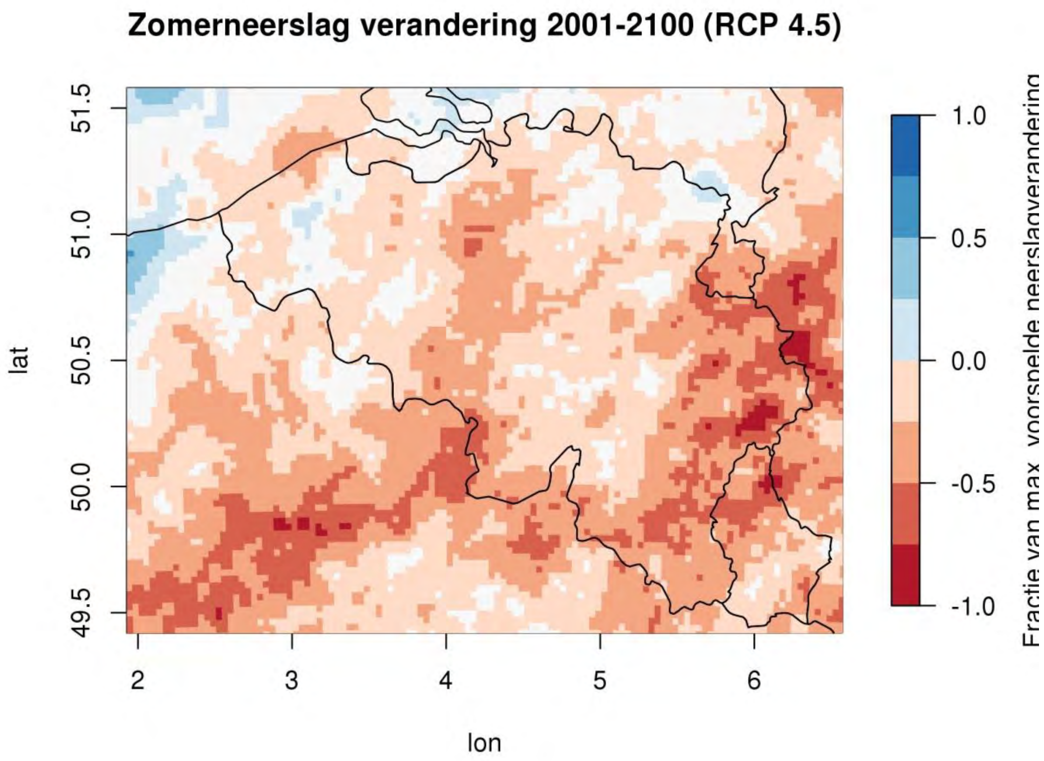
1=maximum increase; 0=no change; -1=maximum decrease

Figure 33: Predicted change in summer precipitation RACMO22E, RCP4.5



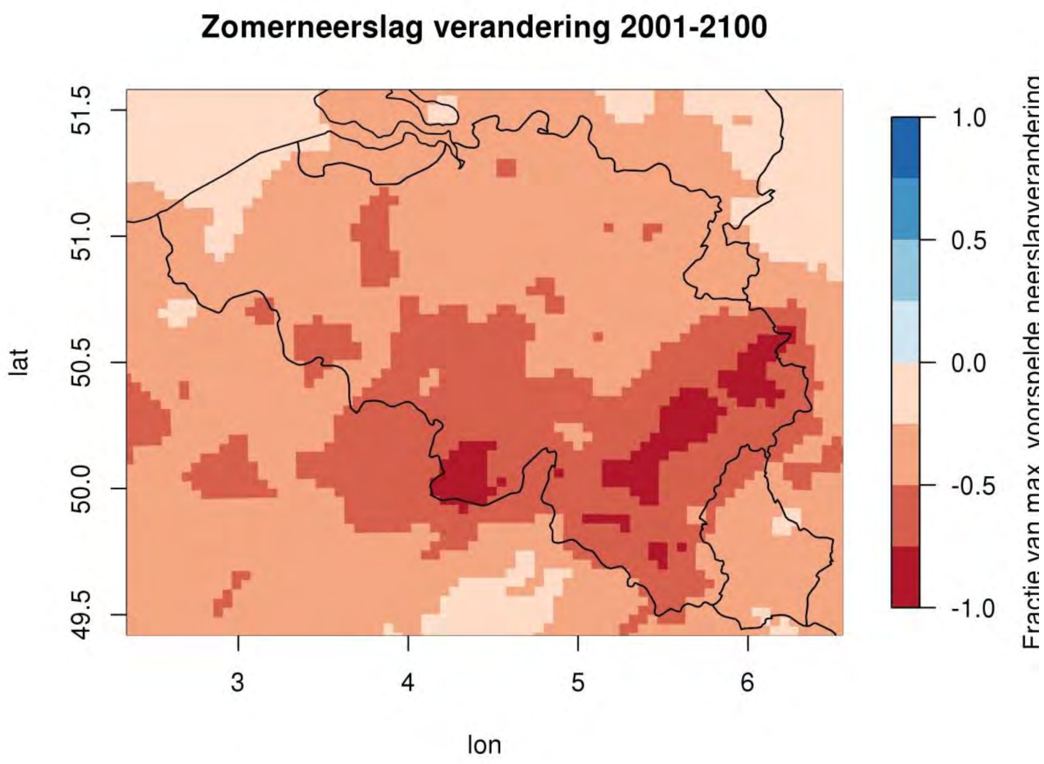
1=maximum increase; 0=no change; -1=maximum decrease

Figure 34: Predicted change in summer precipitation FUT2030_RCP4.5, RCP4.5



1=maximum increase; 0=no change; -1=maximum decrease

Figure 35: Predicted change in summer precipitation FUT2064_RCP4.5, RCP4.5



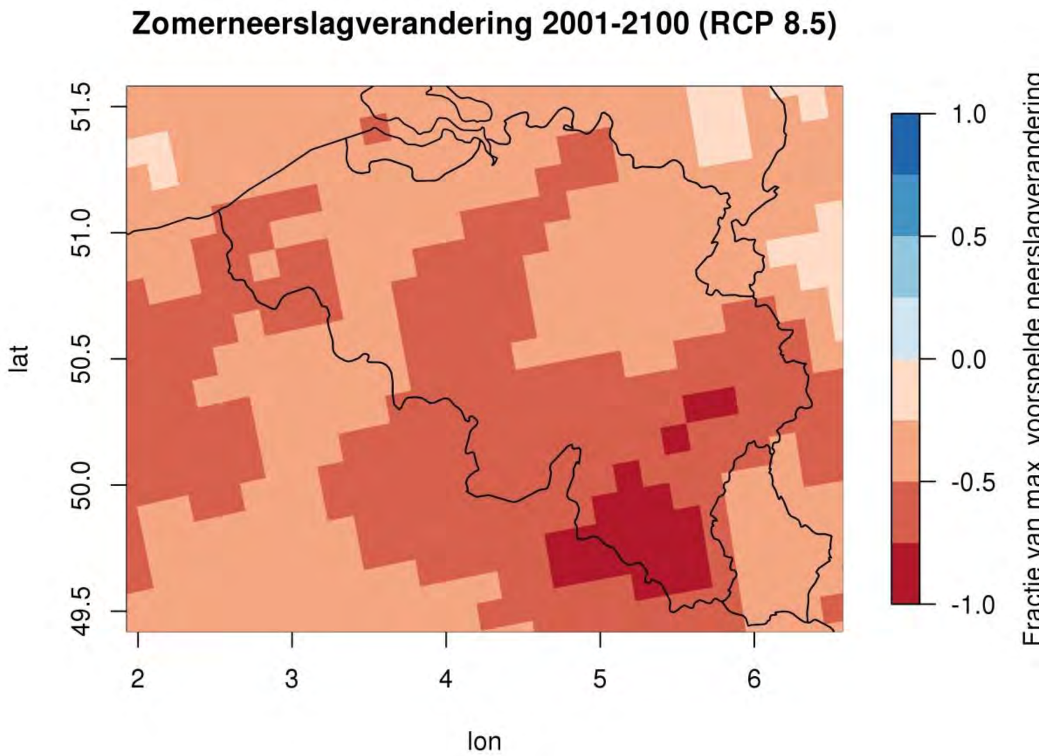
1=maximum increase; 0=no change; -1=maximum decrease

Figure 36: Predicted change in summer precipitation FUT2085_A1B

4.2 RCP8.5

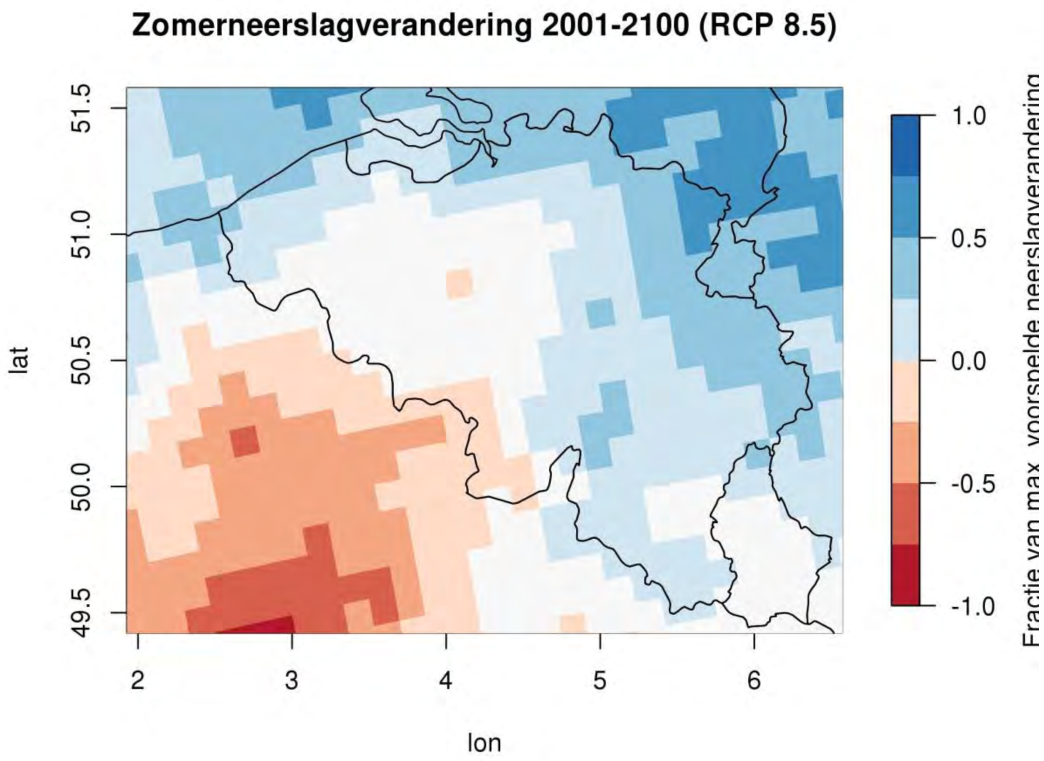
Looking at the RCP8.5 scenario for change in summer precipitation, five of the six model runs expect a decrease in summer precipitation for the whole of Belgium. This decrease will be the strongest in the South of Belgium. The FUT2064_RCP8.5 run (Figure 42) of MACCBET models also a strong decrease in summer precipitation at the coast and even a small increase in the east of Belgium. The CNRM run (Figure 38) is in contrast with the other runs and shows an expected increase in summer precipitation by the end of the century.

The model projections hint to a stronger decrease in the summer precipitation in the south compared to the north, as this pattern in modeled in two third of the runs.



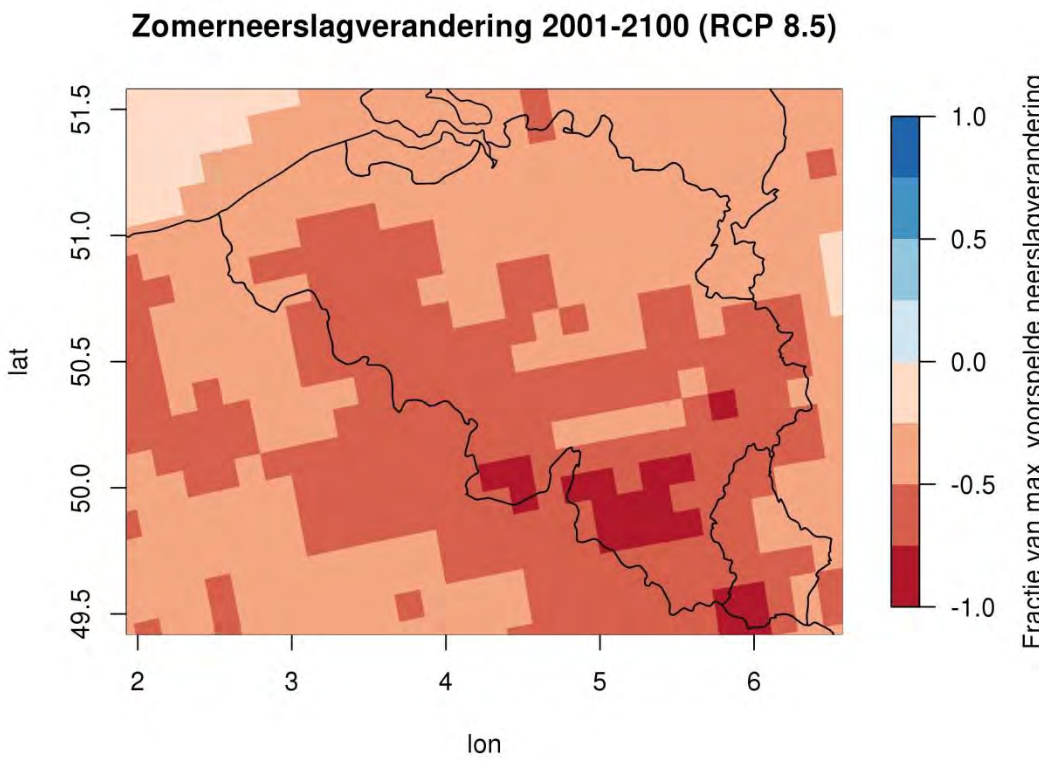
1=maximum increase; 0=no change; -1=maximum decrease

Figure 37: Predicted change in summer precipitation CCLM, RCP8.5



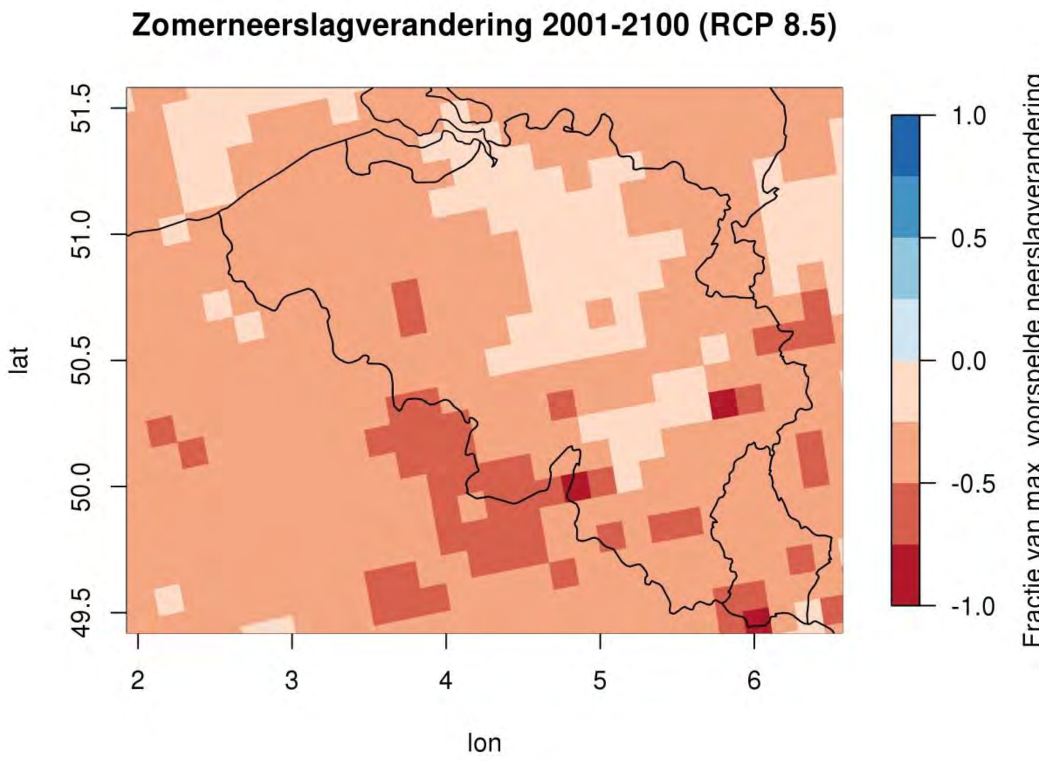
1=maximum increase; 0=no change; -1=maximum decrease

Figure 38: Predicted change in summer precipitation CNRM, RCP8.5



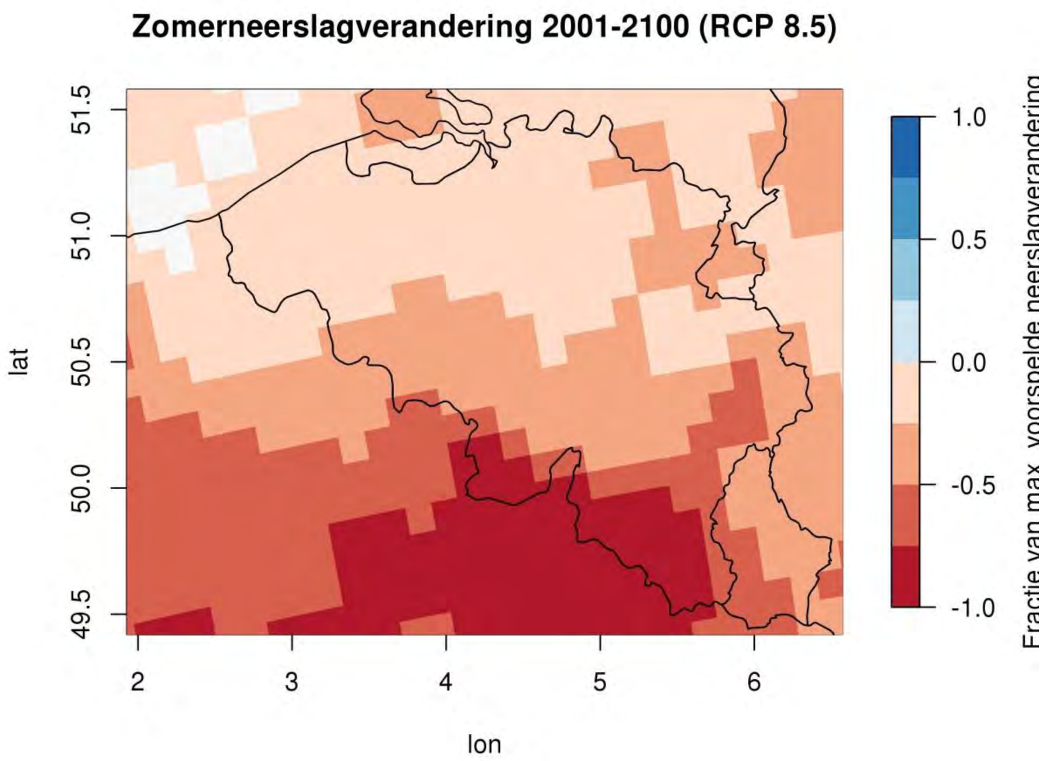
1=maximum increase; 0=no change; -1=maximum decrease

Figure 39: Predicted change in summer precipitation ICHEC, RCP8.5



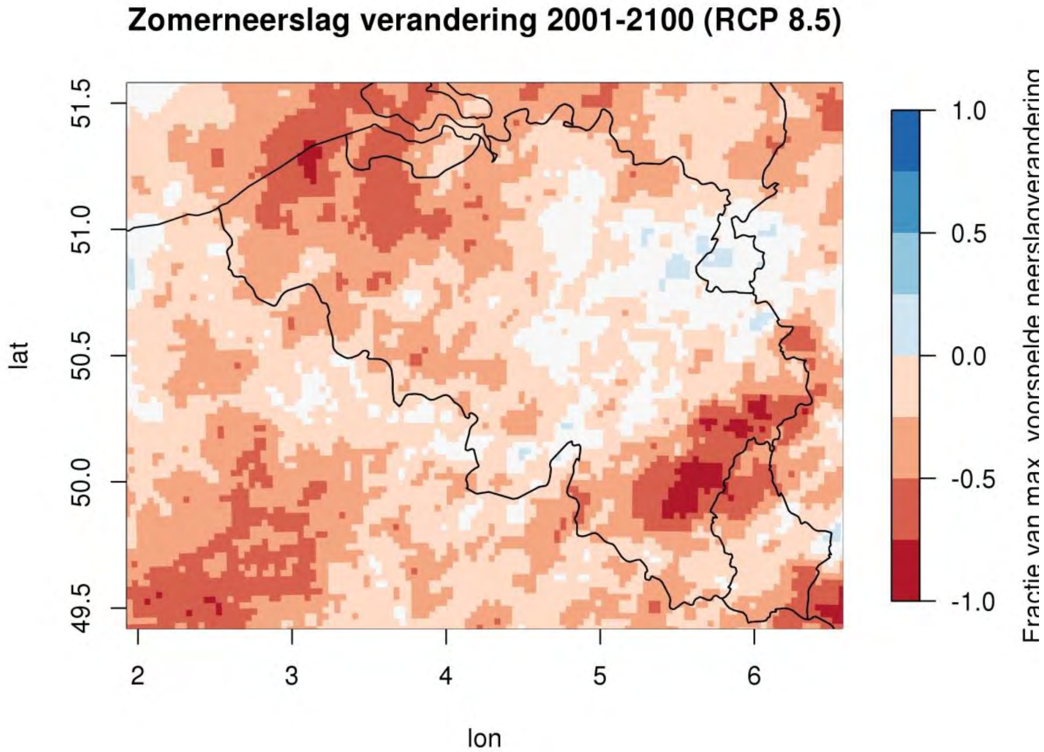
1=maximum increase; 0=no change; -1=maximum decrease

Figure 40: Predicted change in summer precipitation MOHC, RCP8.5



1=maximum increase; 0=no change; -1=maximum decrease

Figure 41: Predicted change in summer precipitation RACMO22E, RCP8.5



1=maximum increase; 0=no change; -1=maximum decrease

Figure 42: Predicted change in summer precipitation FUT2064_RCP8.5, RCP8.5

5 Number of days above 25 °C

5.1 RCP4.5

To look at the change in extreme events in Belgium, three parameters were modeled. For these parameters the absolute values are shown here. The first parameter is the number of days with a maximum temperature above 25 °C (ND25) and is a measure for the number of heat waves. All the models (except the CNRM model (Figure 44)) show the same pattern. An increase in ND25 is expected by the end of the century and this increase is projected to be the biggest in the center of Belgium. Near the coast and in the Ardennes the increase is expected to be smaller.

By the end of the century more heat waves are expected for Belgium. The expected increase in ND25 is the biggest in the center of the country. Near the coast and in the Ardennes the increase in ND25 is expected to be less than in the center.

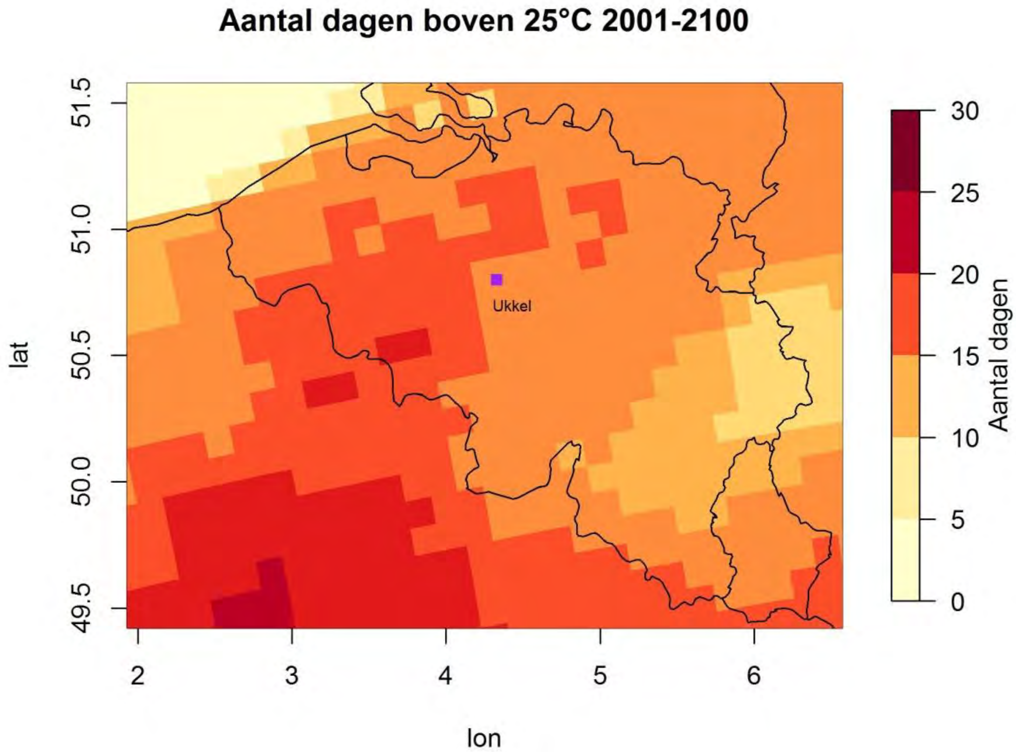


Figure 43: Predicted change in number of days with a maximum temperature >25 °C CCLM, RCP4.5

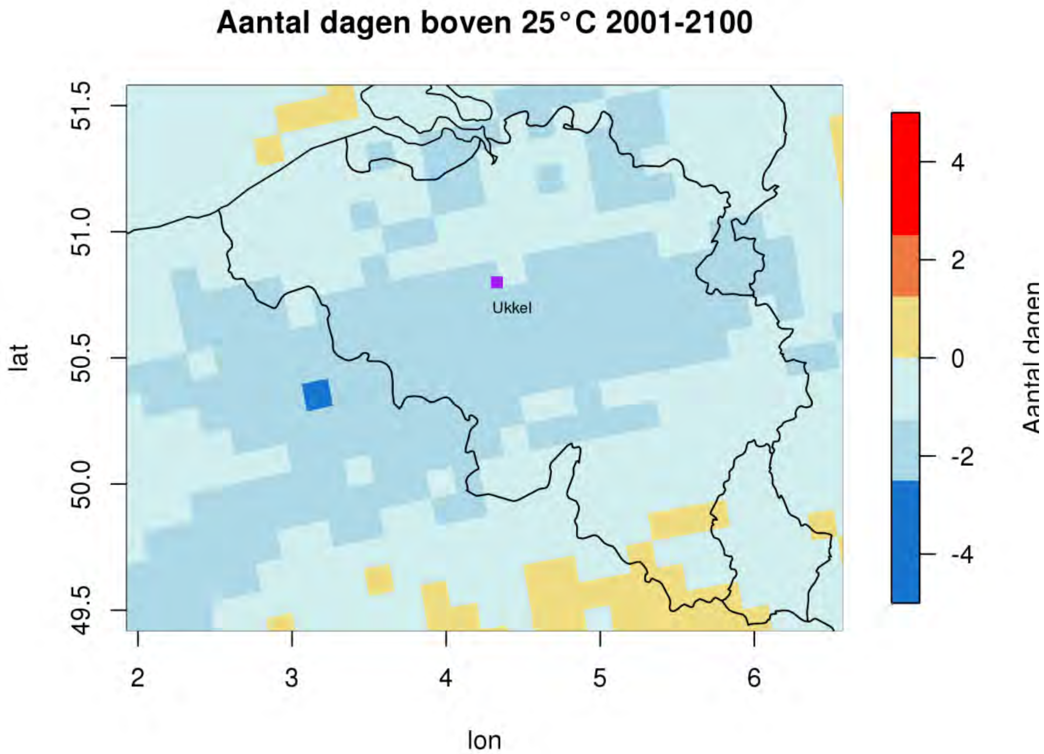


Figure 44: Predicted change in number of days with a maximum temperature >25 °C CNRM, RCP4.5

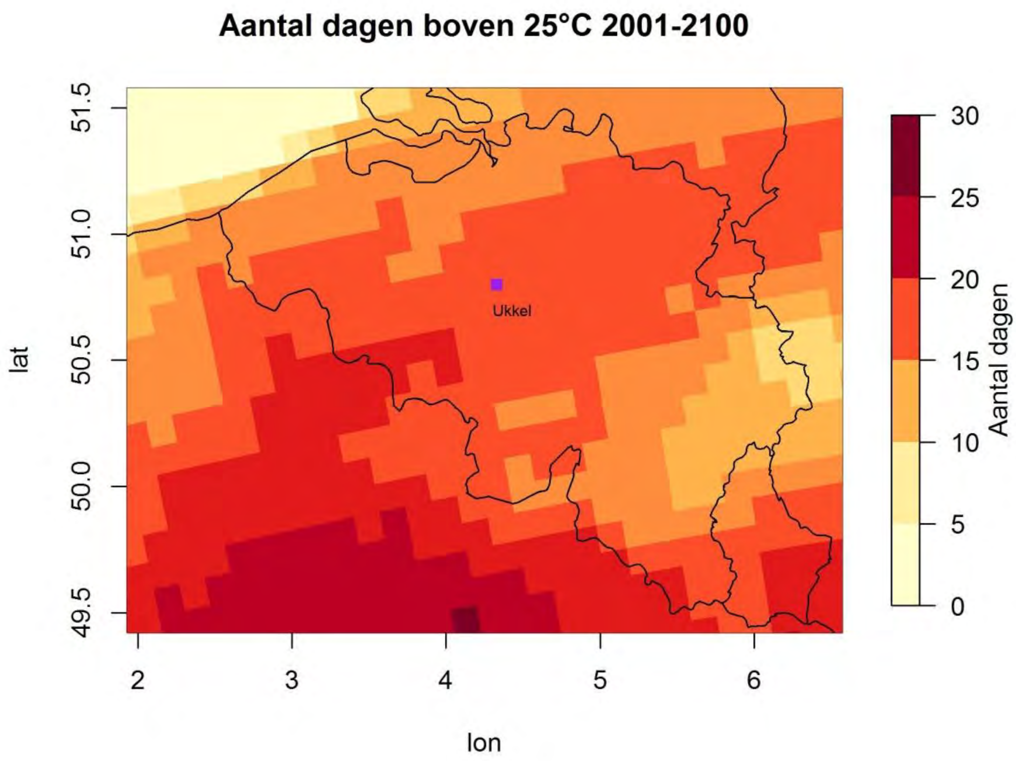


Figure 45: Predicted change in number of days with a maximum temperature >25 °C ICHEC, RCP4.5

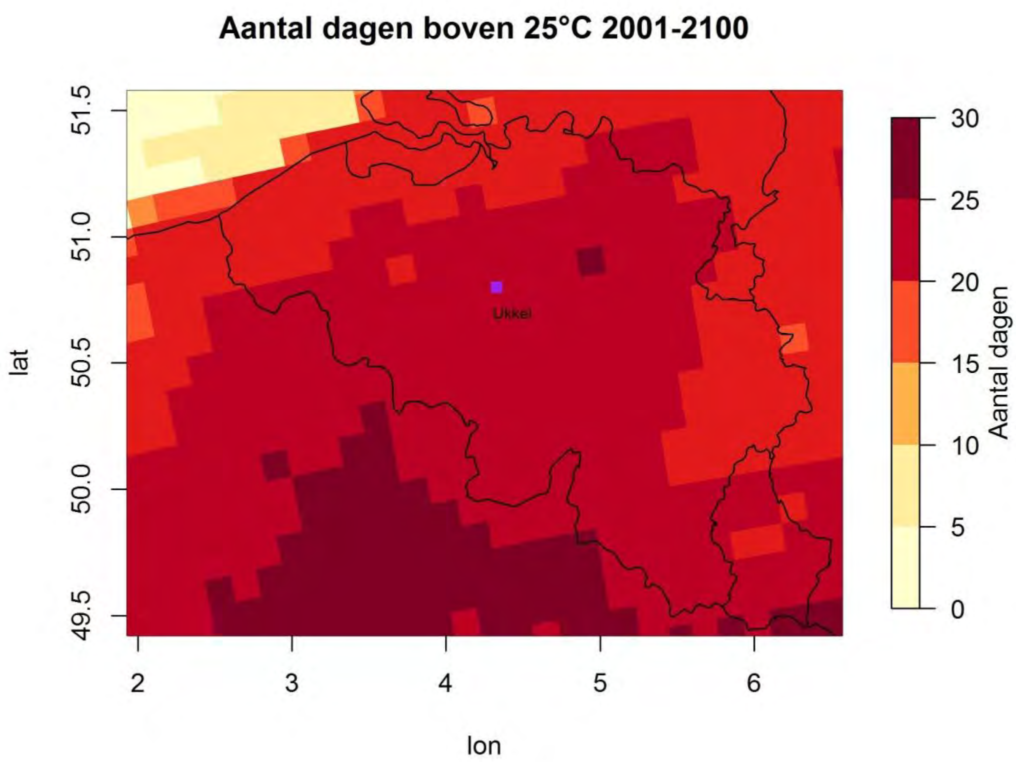


Figure 46: Predicted change in number of days with a maximum temperature >25 °C MOHC, RCP4.5

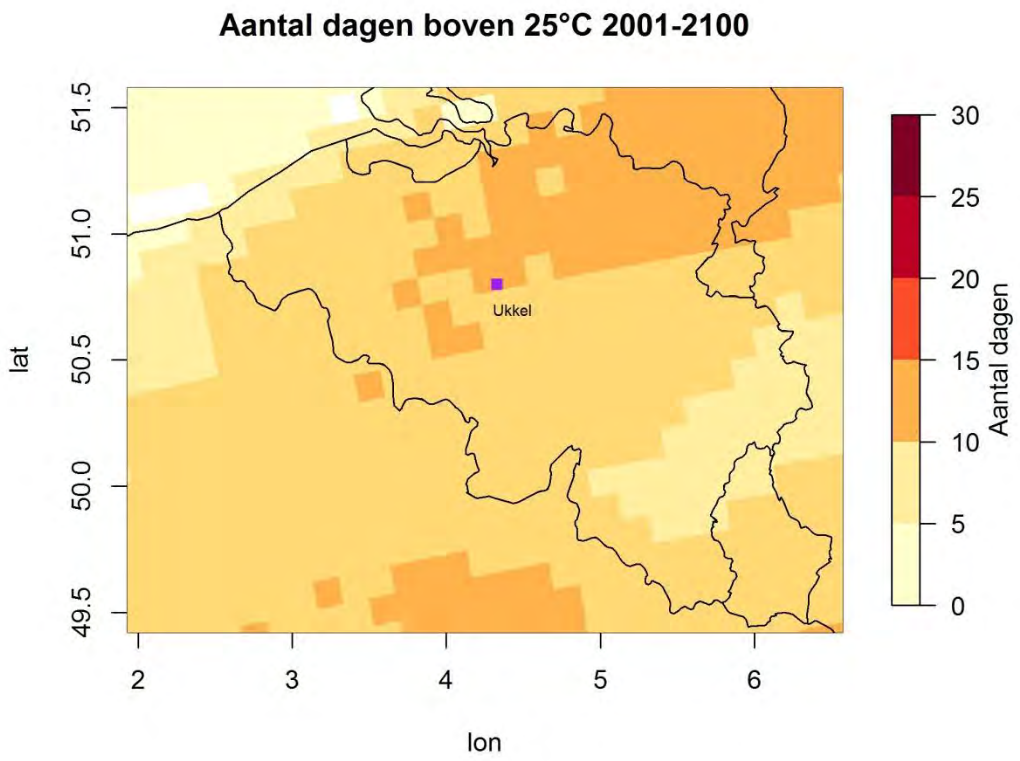


Figure 47: Predicted change in number of days with a maximum temperature >25 °C RACMO22E, RCP4.5

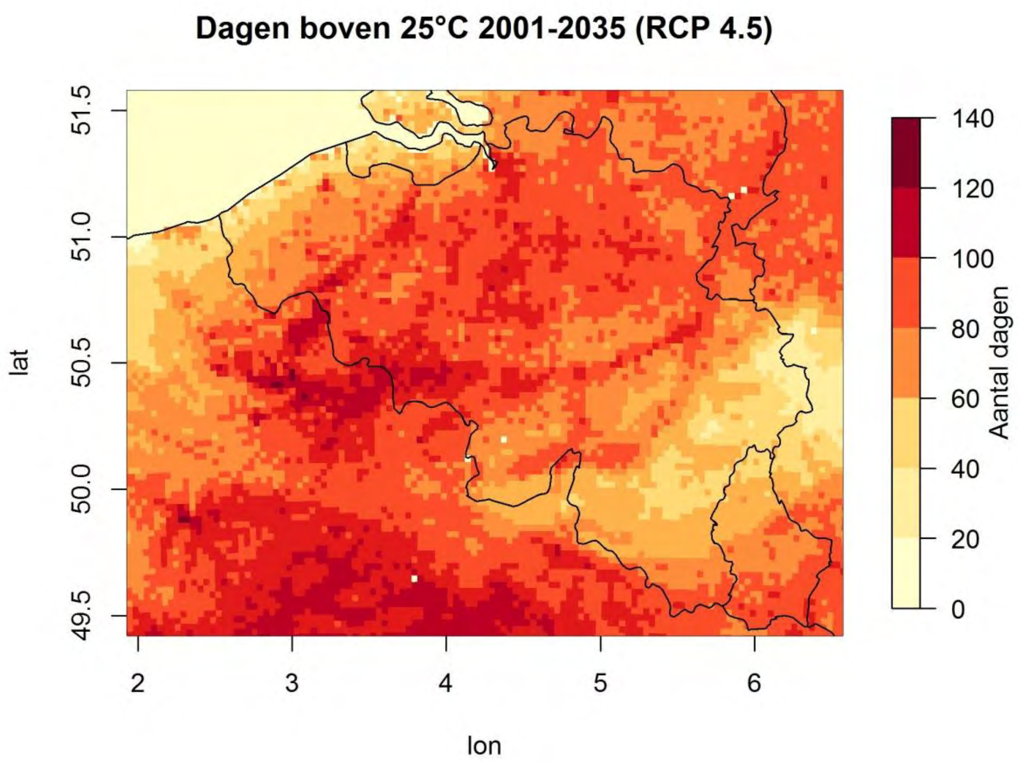


Figure 48: Predicted change in number of days with a maximum temperature >25 °C FUT2030_RCP4.5

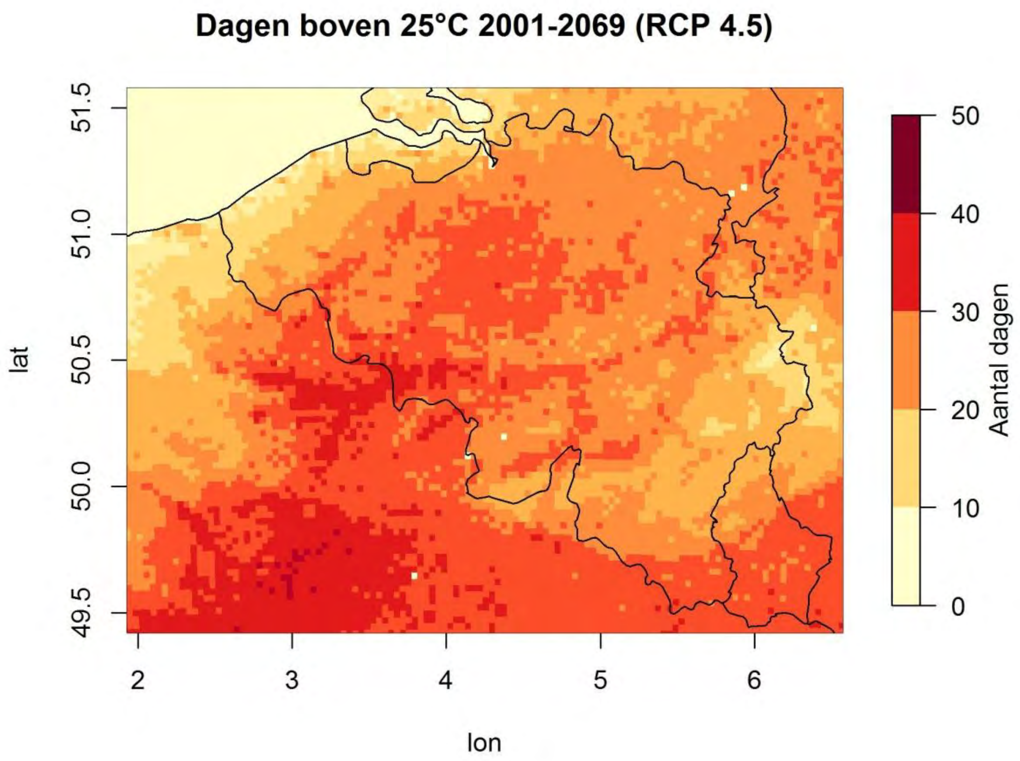


Figure 49: Predicted change in number of days with a maximum temperature >25 °C FUT2064_RCP4.5

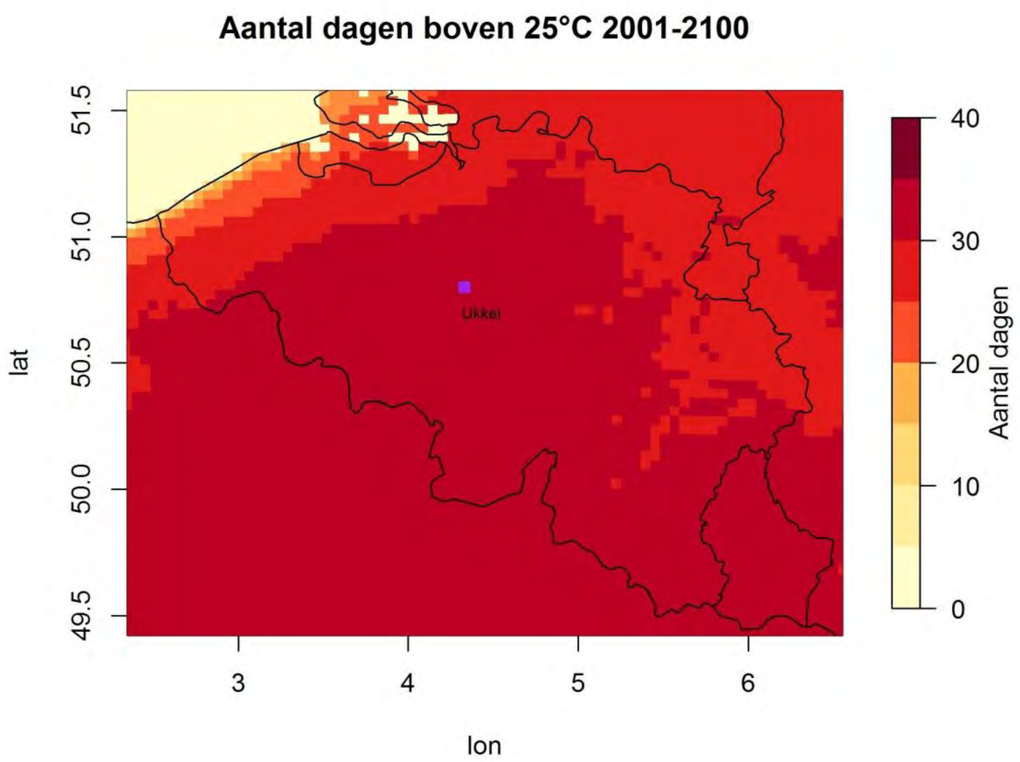


Figure 50: Predicted change in number of days with a maximum temperature >25 °C FUT2085_A1B

5.2 RCP8.5

For the RCP8.5 scenario the same conclusions can be drawn as for the RCP4.5 scenario. For the RCP8.5 scenario the increase in the ND25 in most of the models is expected to be bigger. In this scenario it is not the CNRM model that is inconsistent with the other models but the CCLM model (Figure 51).

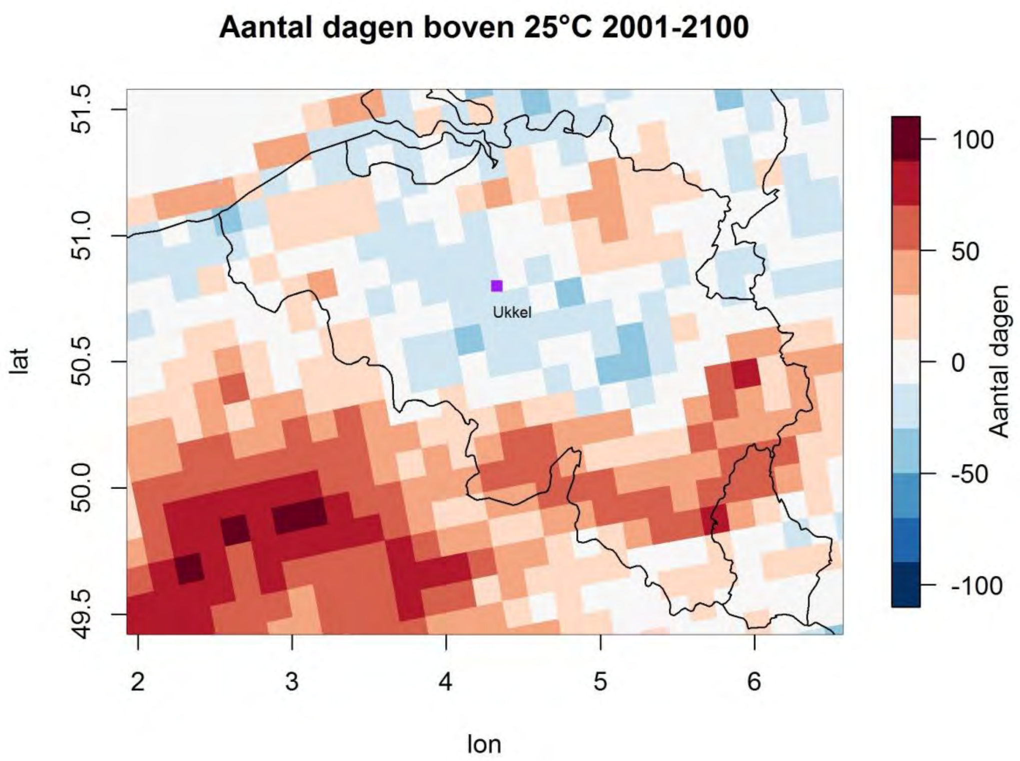


Figure 51: Predicted change in number of days with a maximum temperature >25 °C CCLM, RCP8.5

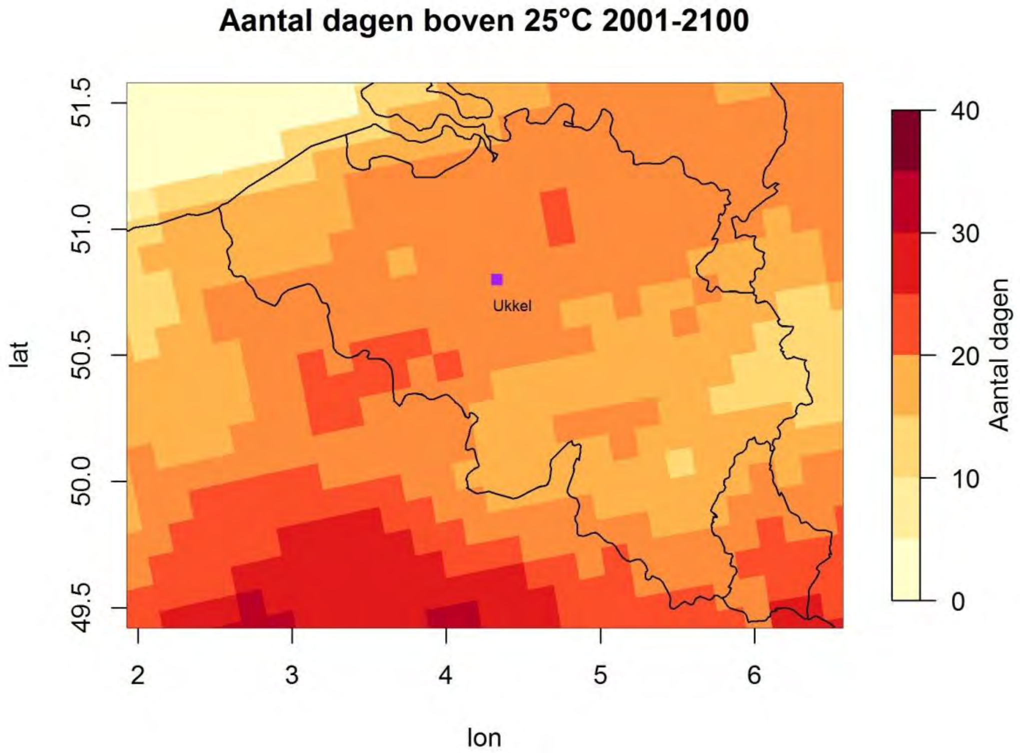


Figure 52: Predicted change in number of days with a maximum temperature >25 °C CNRM, RCP8.5

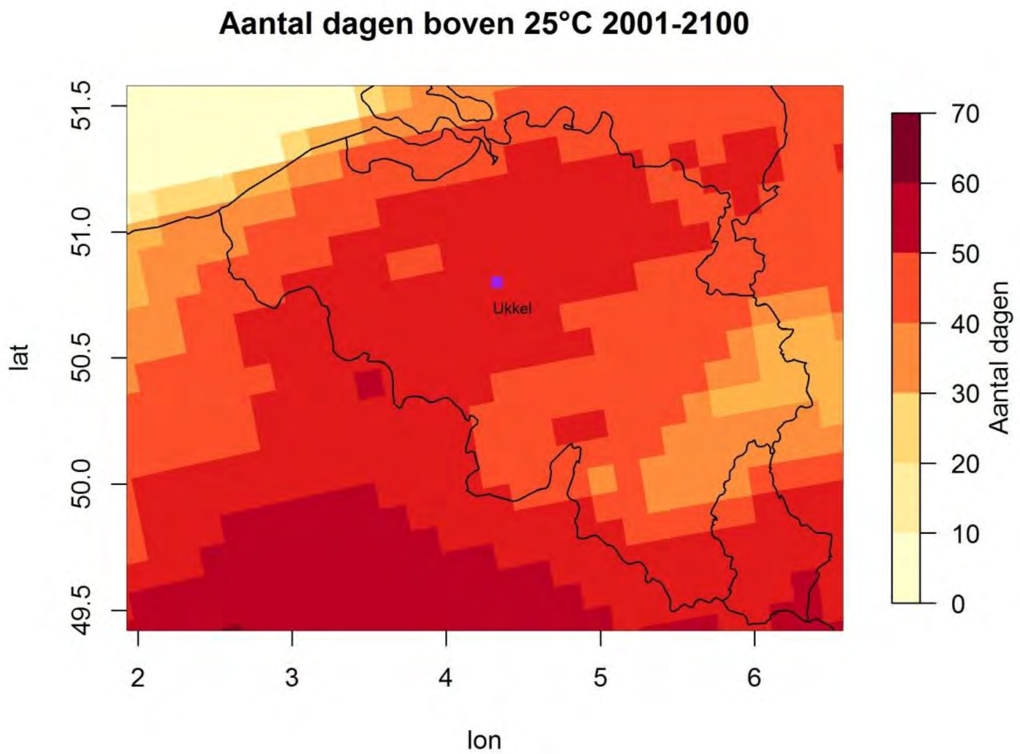


Figure 53: Predicted change in number of days with a maximum temperature >25 °C ICHEC, RCP8.5

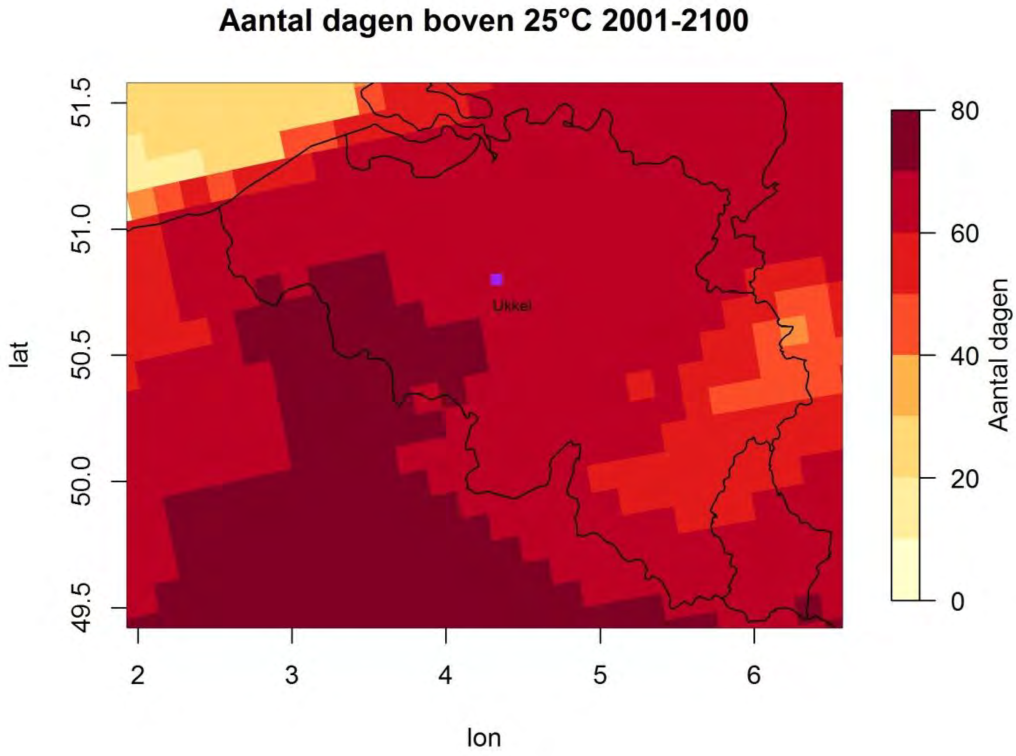


Figure 54: Predicted change in number of days with a maximum temperature >25 °C MOHC, RCP8.5

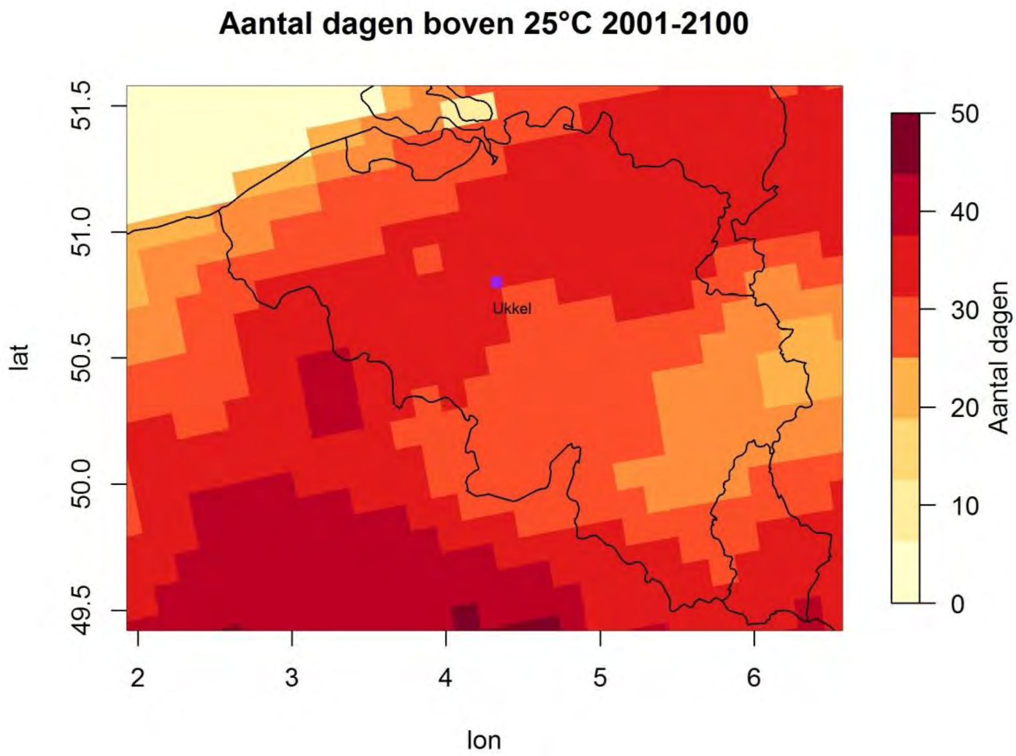


Figure 55: Predicted change in number of days with a maximum temperature >25 °C RACMO22E, RCP8.5

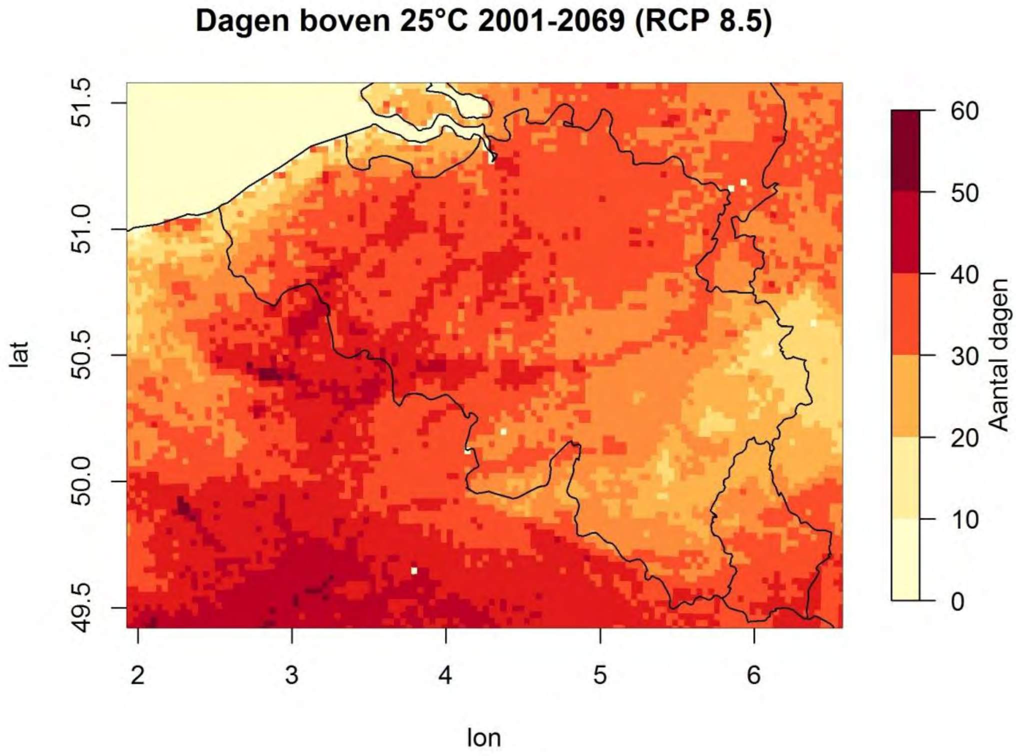


Figure 56: Predicted change in number of days with a maximum temperature >25 °C FUT2064_RCP8.5, RCP8.5

6 Number of days under 0 °C

6.1 RCP 4.5

The second parameter that was modeled, is the change in the number of days with a minimum temperature below 0 °C (=ND0) and it is a measure for the number of cold waves. For the RCP4.5 scenario all the models show the same spatial pattern. For every region in Belgium a decrease in ND0 is expected by the end of the century. This decrease is projected be the biggest in the Ardennes, the South and Southeast of Belgium. Near the coast the projected decrease is smaller. The FUT2064_RCP4.5 model of MACCBET (Figure 63) models a small increase of ND0 at the coast.

By the end of the century less cold waves are expected for Belgium. The expected decrease ND0 is the biggest in the Ardennes. Near the coast the decrease in ND0 is expected to be less.

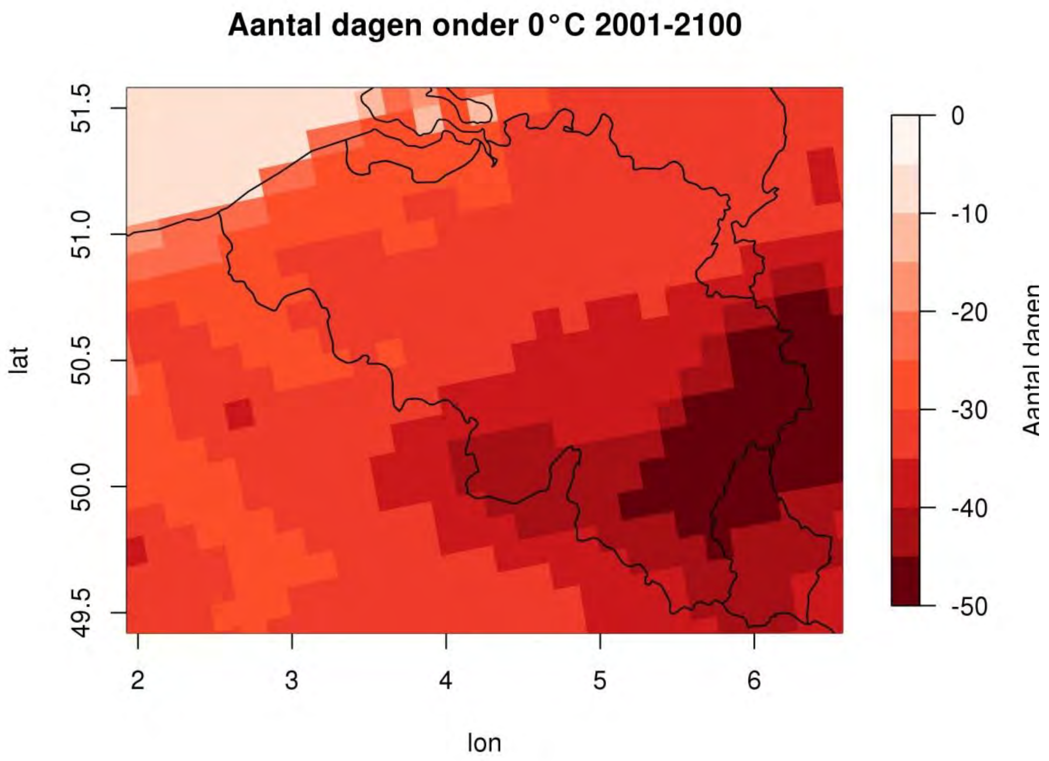


Figure 57: Predicted change in number of days with a minimum temperature <0 °C CCLM, RCP4.5

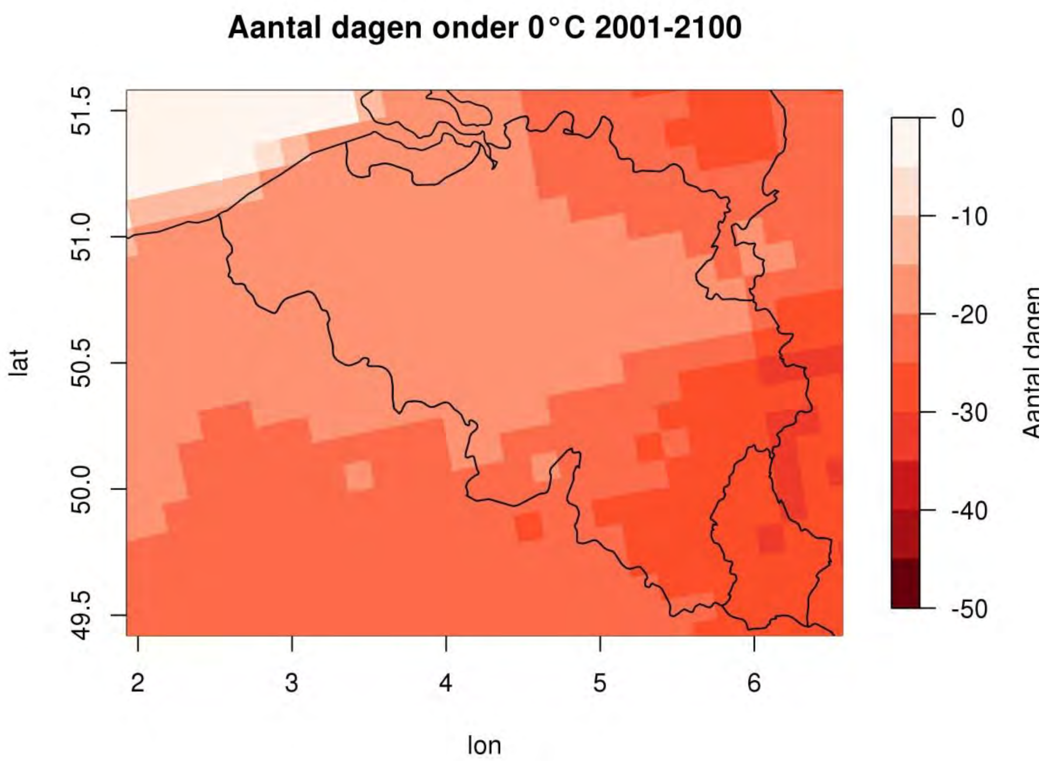


Figure 58: Predicted change in number of days with a minimum temperature <0 °C CNRM, RCP4.5

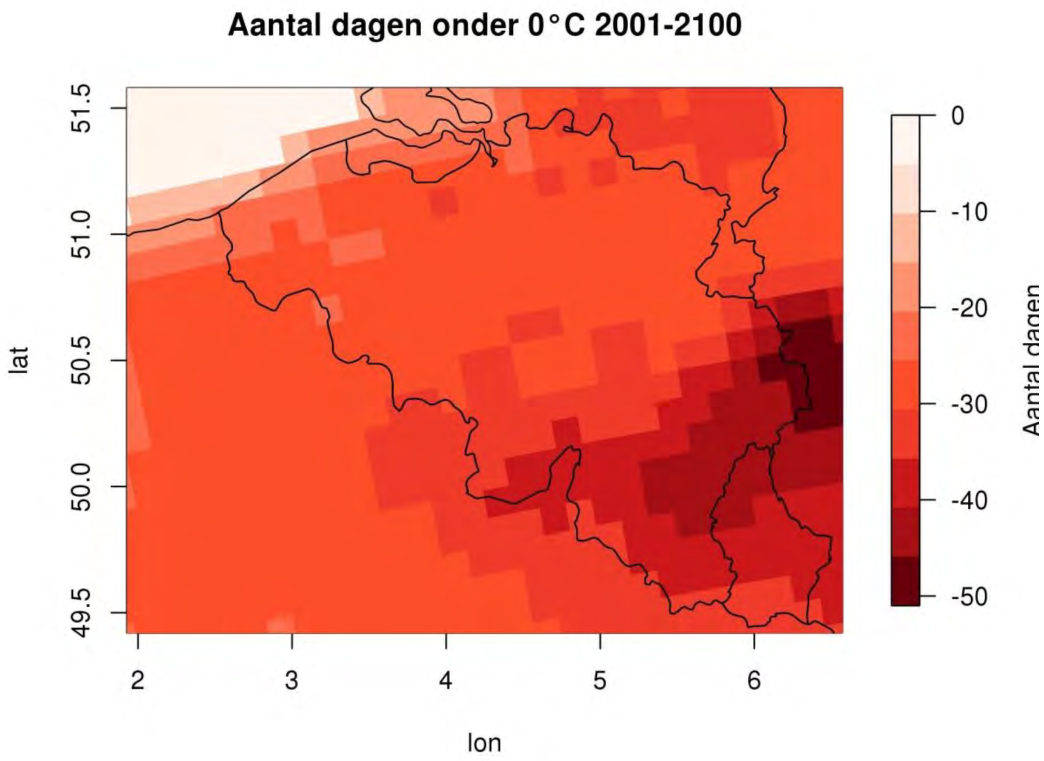


Figure 59: Predicted change in number of days with a minimum temperature <0 °C ICHEC, RCP4.5

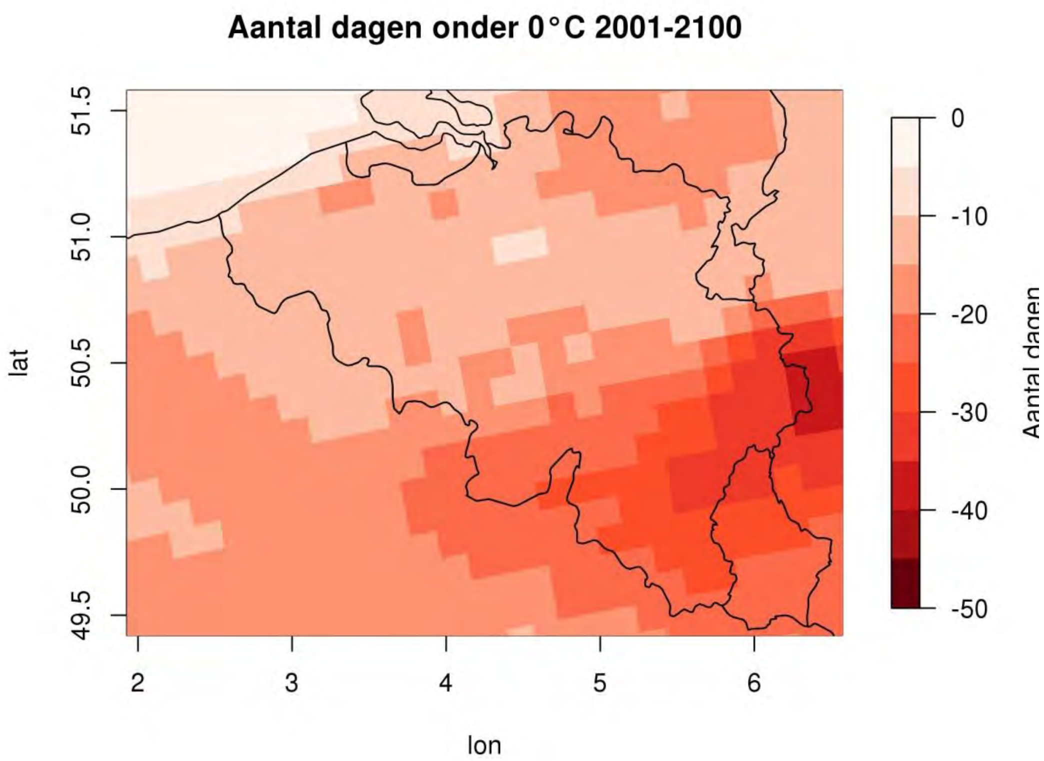


Figure 60: Predicted change in number of days with a minimum temperature <0 °C MOHC, RCP4.5

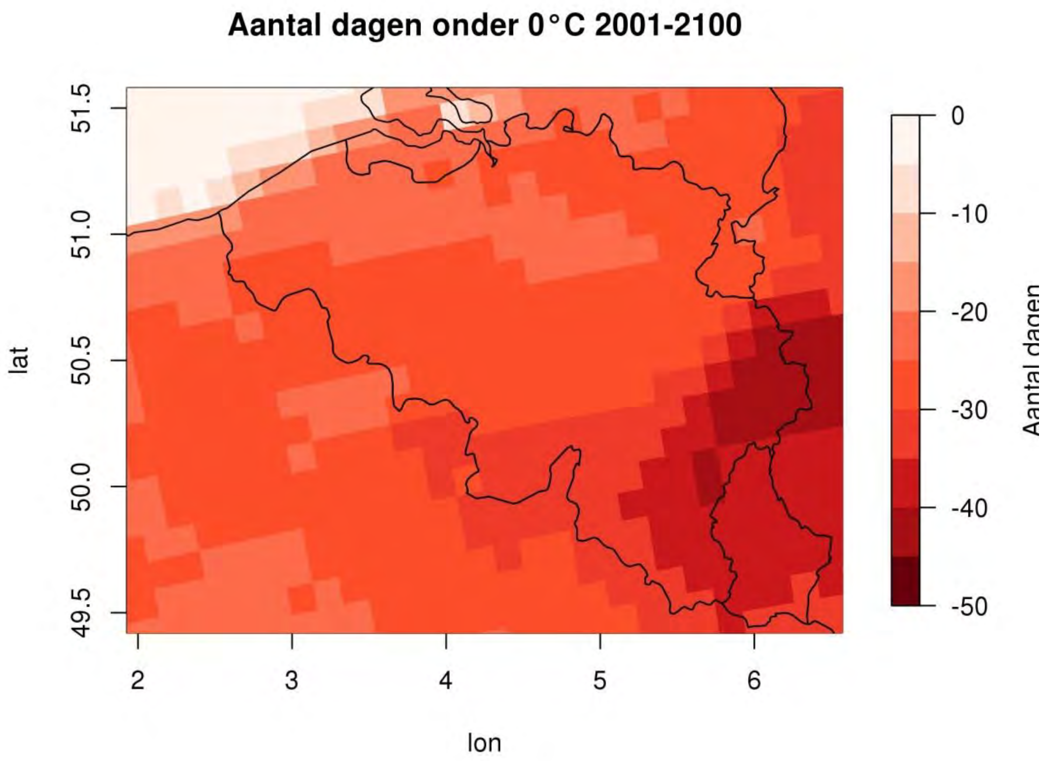


Figure 61: Predicted change in number of days with a minimum temperature <0 °C RACMO22E, RCP4.5

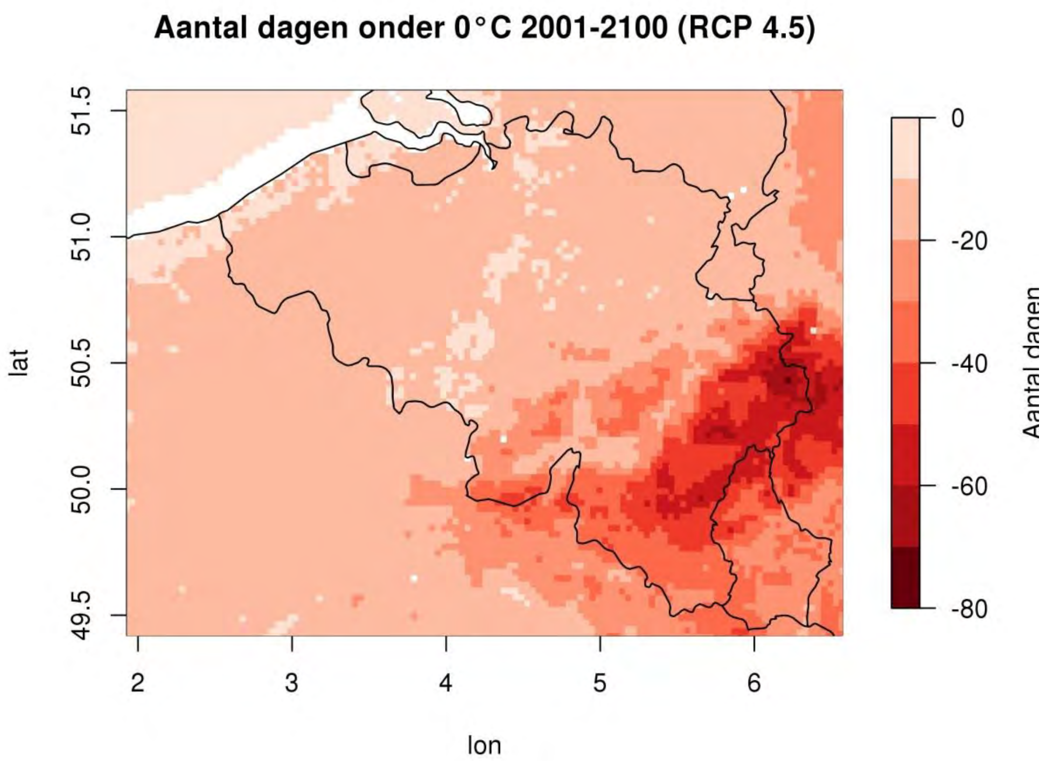


Figure 62: Predicted change in number of days with a minimum temperature <0 °C FUT2030_RCP4.5

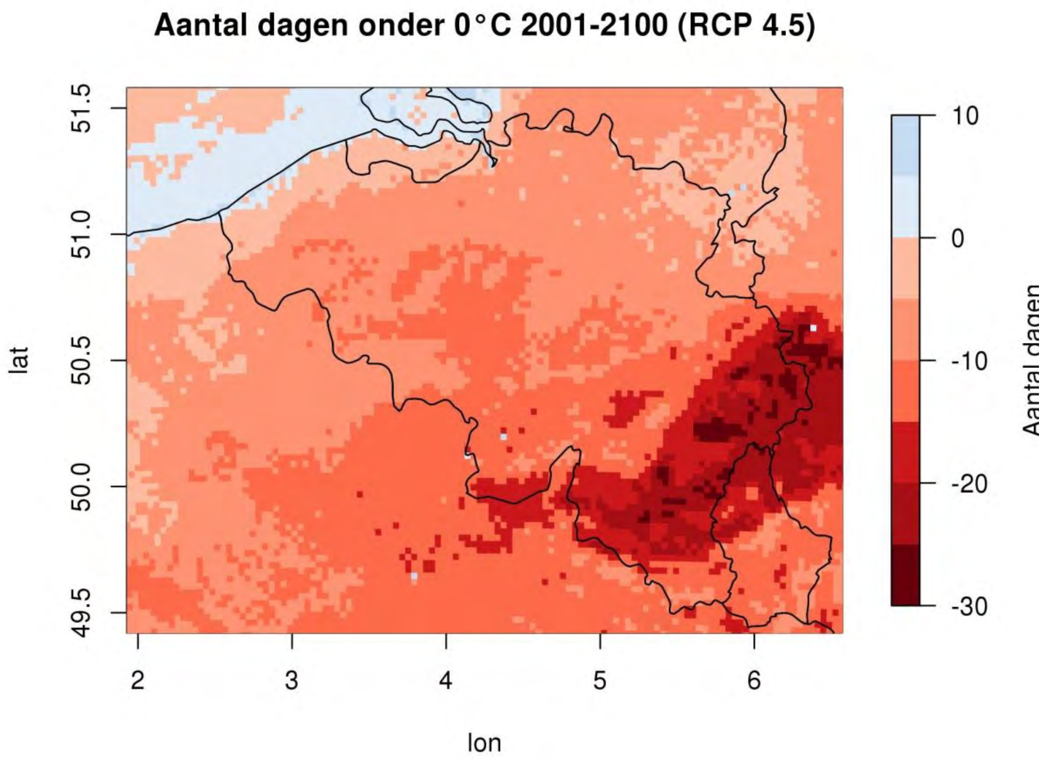


Figure 63: Predicted change in number of days with a minimum temperature <0 °C FUT2064_RCP4.5

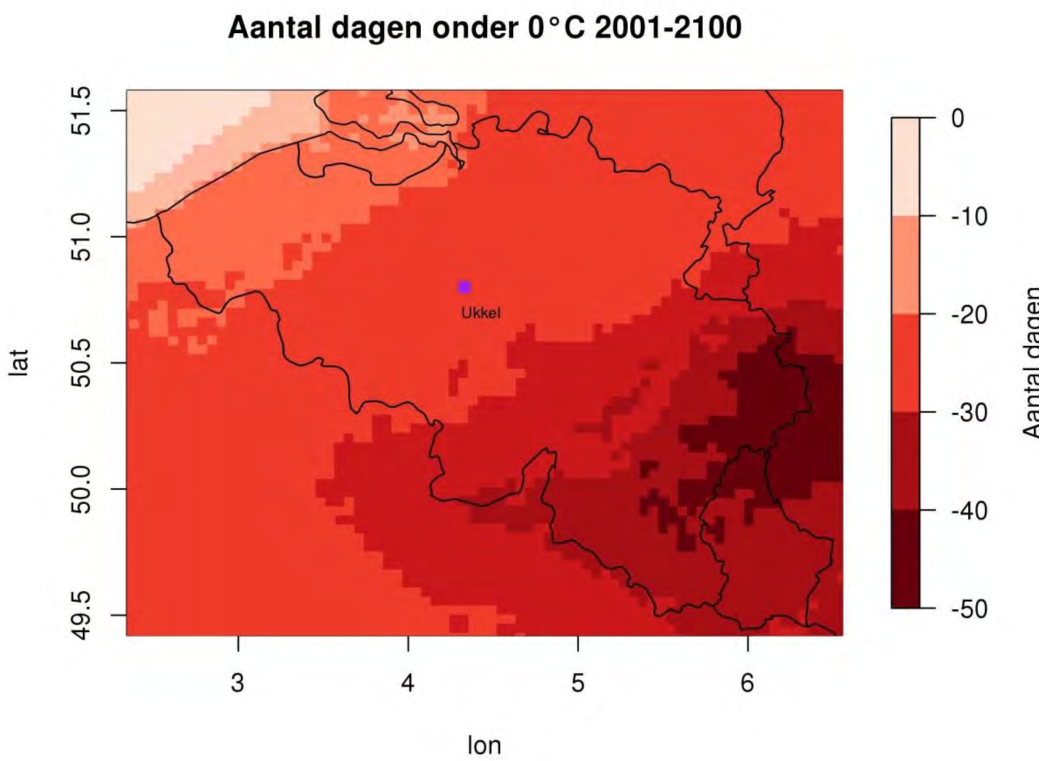


Figure 64: Predicted change in number of days with a minimum temperature <0 °C FUT2085_A1B

6.2 RCP8.5

For the RCP8.5 scenario the same conclusions can be drawn as for the RCP4.5 scenario. For the RCP8.5 scenario the decrease is expected to be bigger.

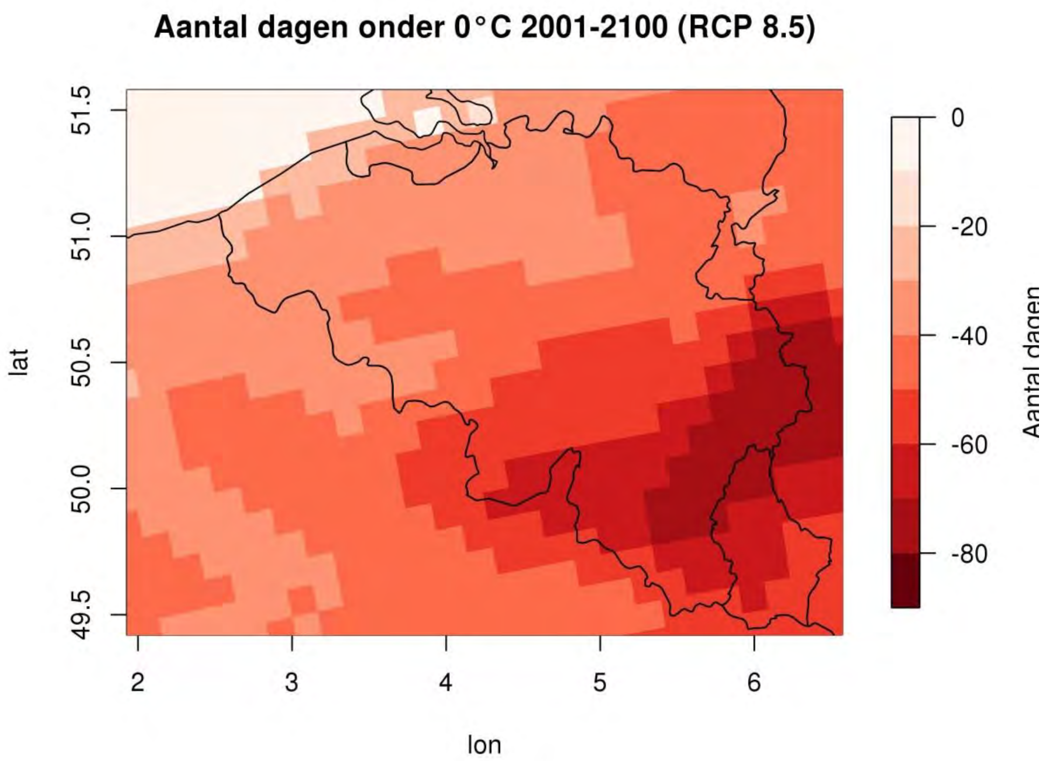


Figure 65: Predicted change in number of days with a minimum temperature <0 °C CCLM, RCP8.5

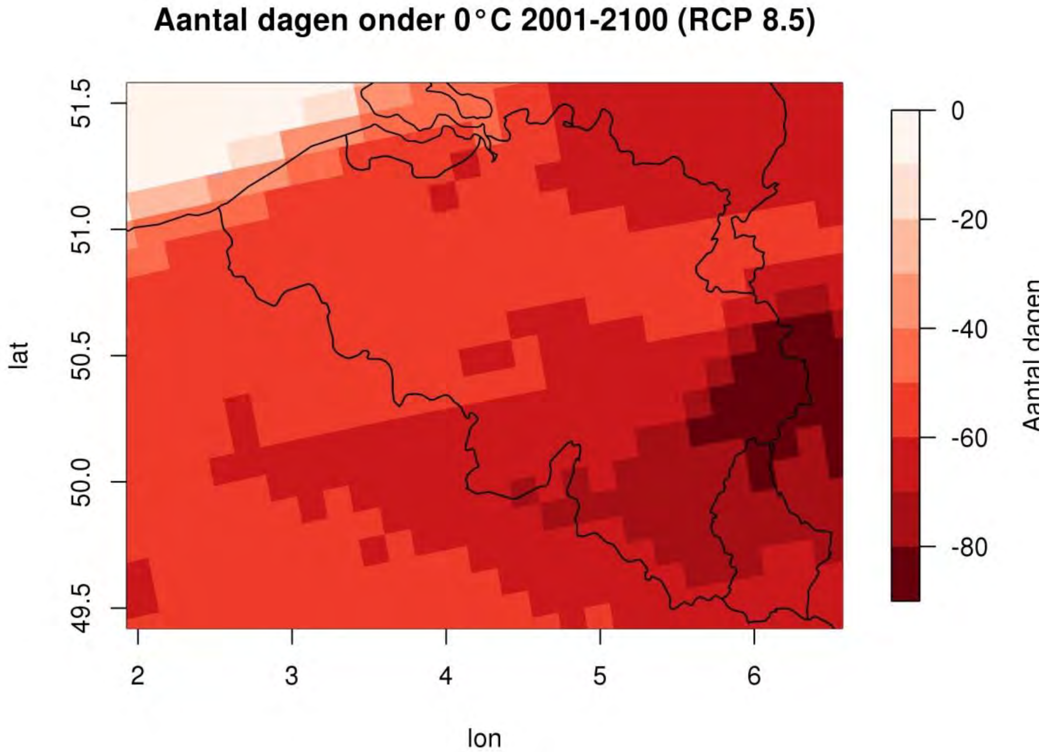


Figure 66: Predicted change in number of days with a minimum temperature <0 °C CNRM, RCP8.5

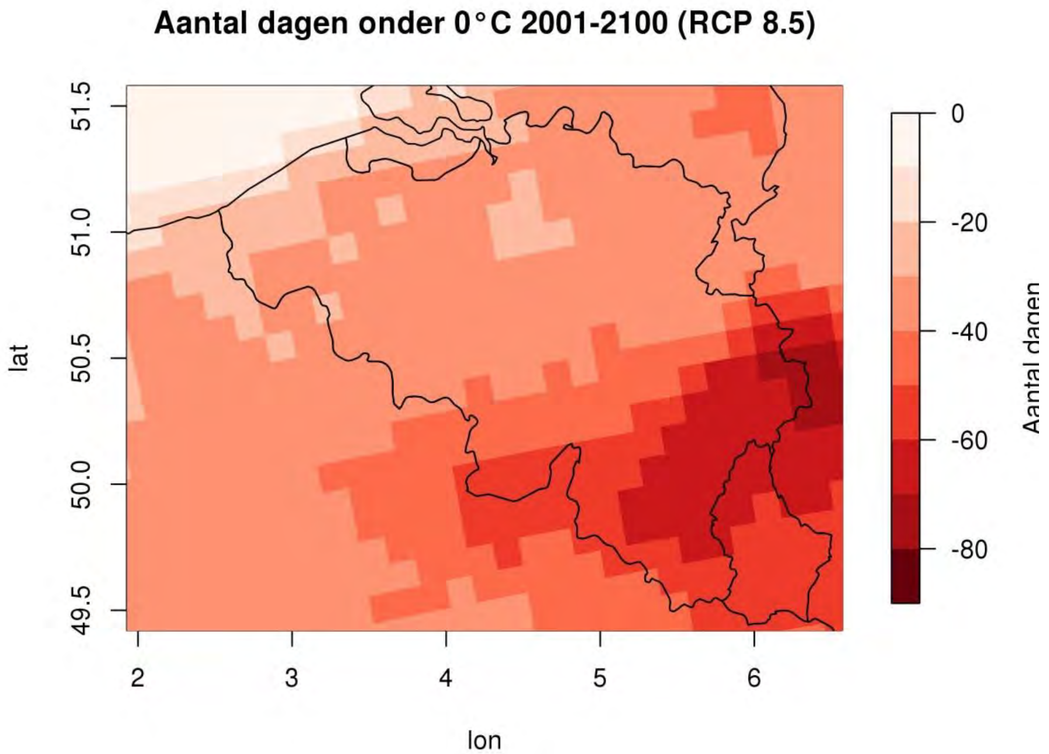


Figure 67: Predicted change in number of days with a minimum temperature <0 °C ICHEC, RCP8.5

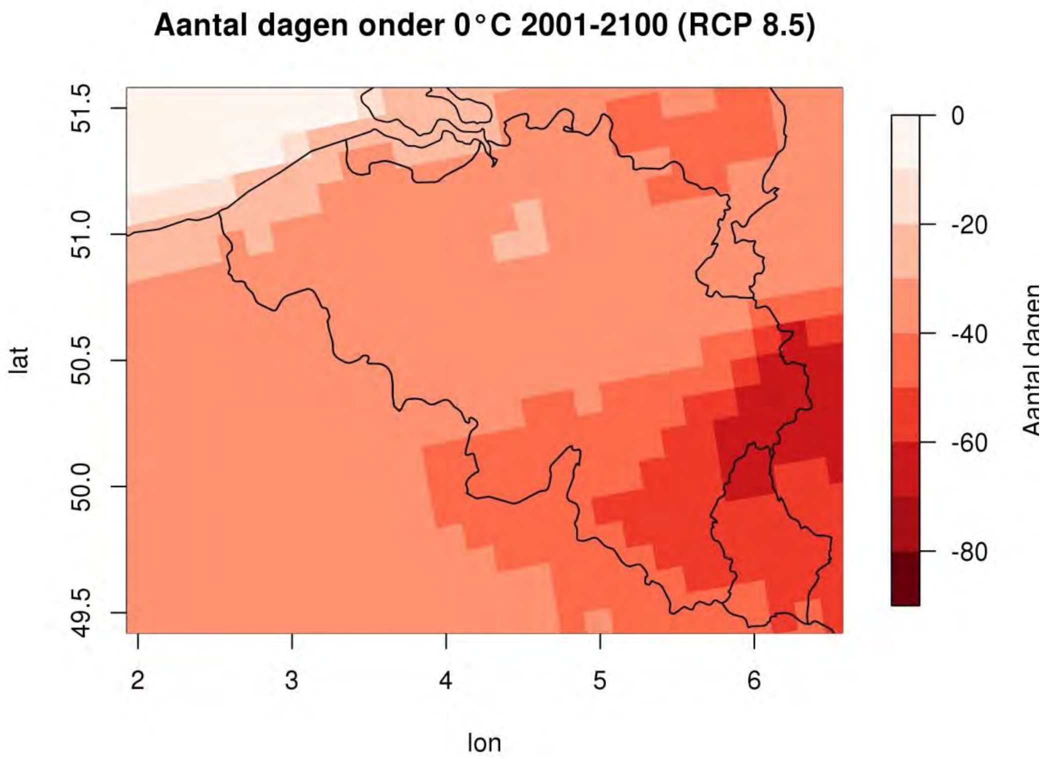


Figure 68: Predicted change in number of days with a minimum temperature <0 °C MOHC, RCP8.5

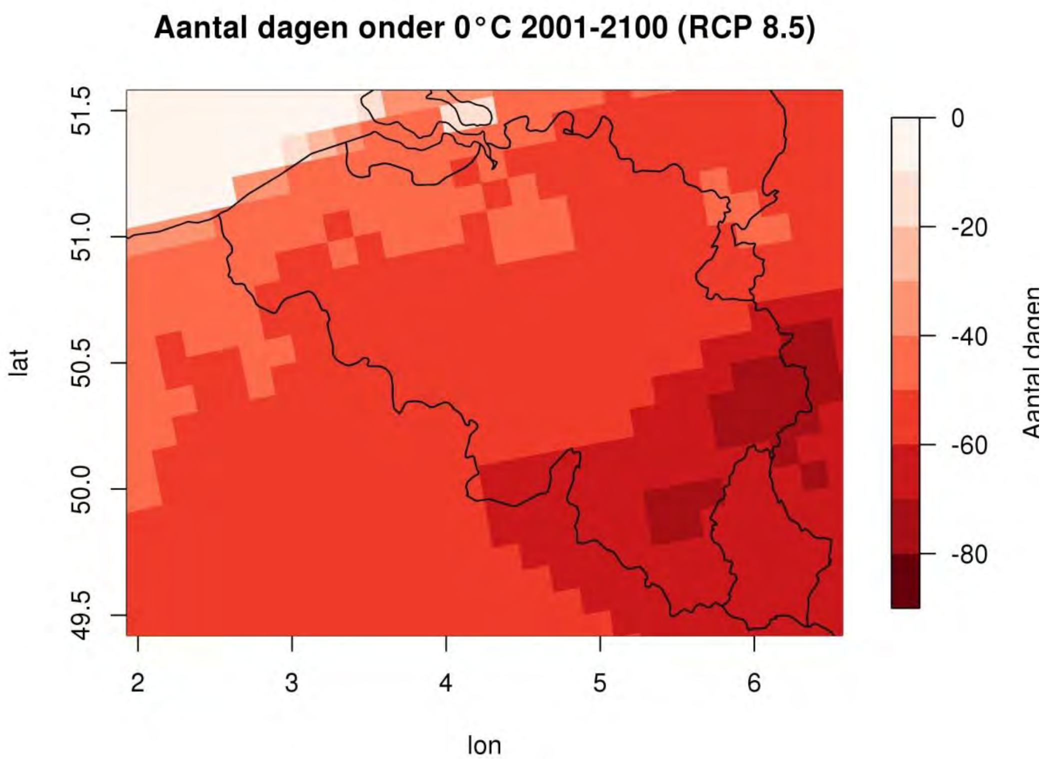


Figure 69: Predicted change in number of days with a minimum temperature <0 °C RACMO22E, RCP8.5

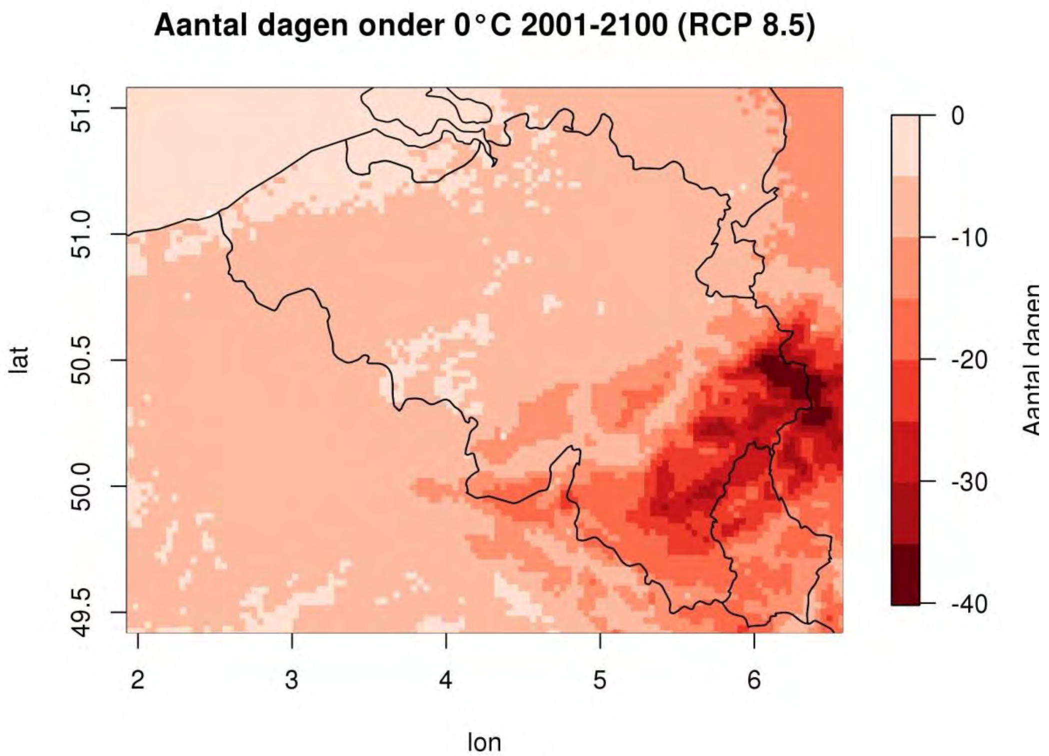


Figure 70: Predicted change in number of days with a minimum temperature <0 °C FUT2064_RCP8.5

7 Number of days above 10 mm

7.1 RCP4.5

The last extreme parameter modeled, was the number of days with a daily precipitation amount above 10 mm (ND10). If the amount in precipitation for one day is above 10 mm, there can be spoken of an extreme precipitation event. Three models (CCLM model, CNRM model and ICHEC model) expect the biggest increase in ND10 by the end of the century in the Ardennes. For the CNRM model (Figure 72) and the ICHEC model (Figure 73) an increase is also expected at the coast, just as for the RACMO22E model (Figure 75). This is not the case for the CCLM model (Figure 71), where a decrease is expected at the coast. The MOHC model (Figure 74) shows a decrease in ND10 in the Ardennes and a small increase at the coast. The high resolution models show a similar pattern. In most of the regions in Belgium a decrease is expected in ND10. The expected decrease is the biggest in the South of Belgium. The FUT2030_RCP4.5 and FUT2064_RCP4.5 (Figure 76 and 77) model also a strong decrease in the North of Belgium, where the FUT2085_A1B run (Figure 78) models almost no change by the end of the century.

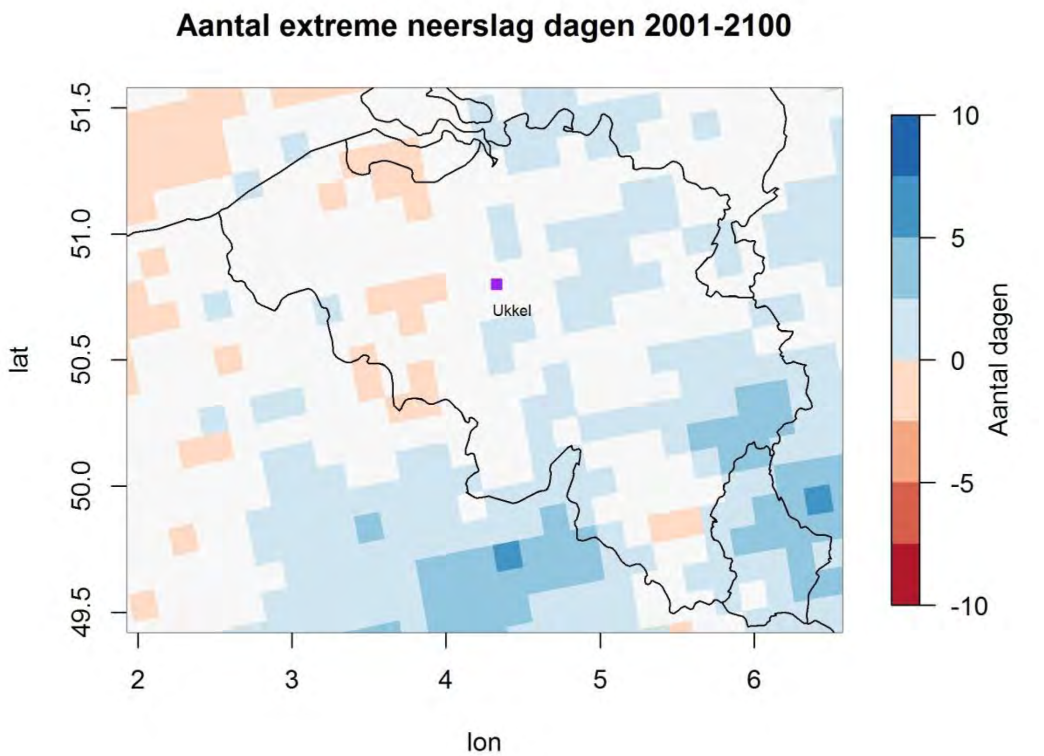


Figure 71: Predicted change in number of days with a daily precipitation amount >10 mm CCLM, RCP4.5

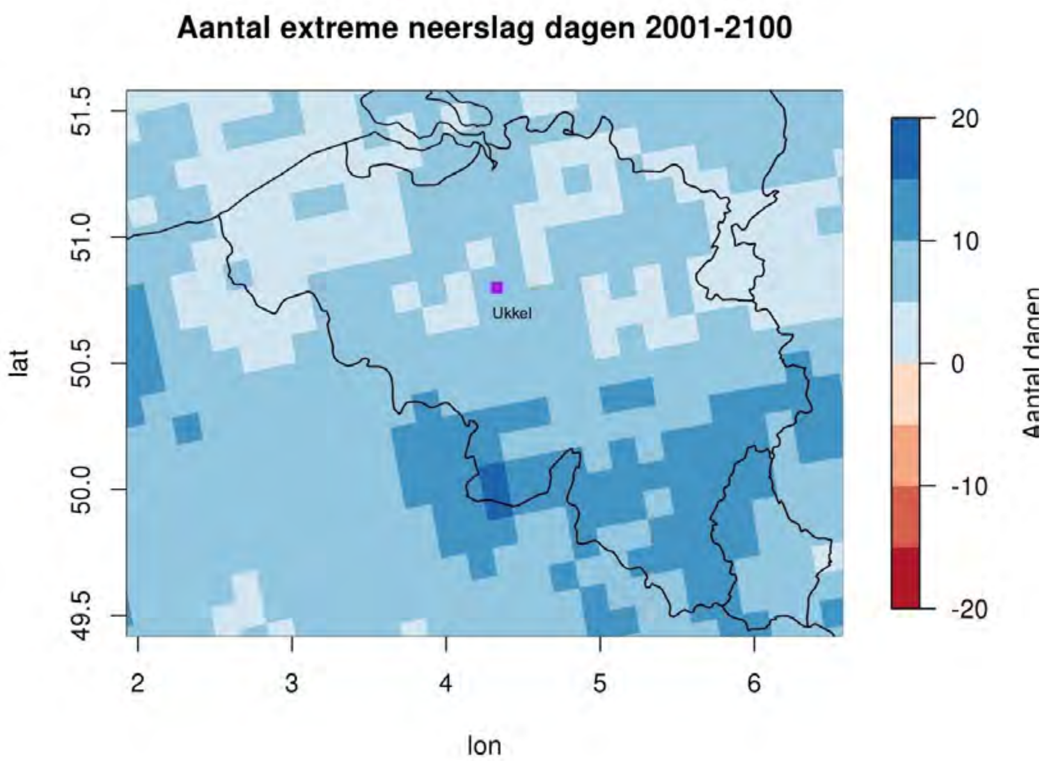


Figure 72: Predicted change in number of days with a daily precipitation amount >10 mm CNRM, RCP4.5

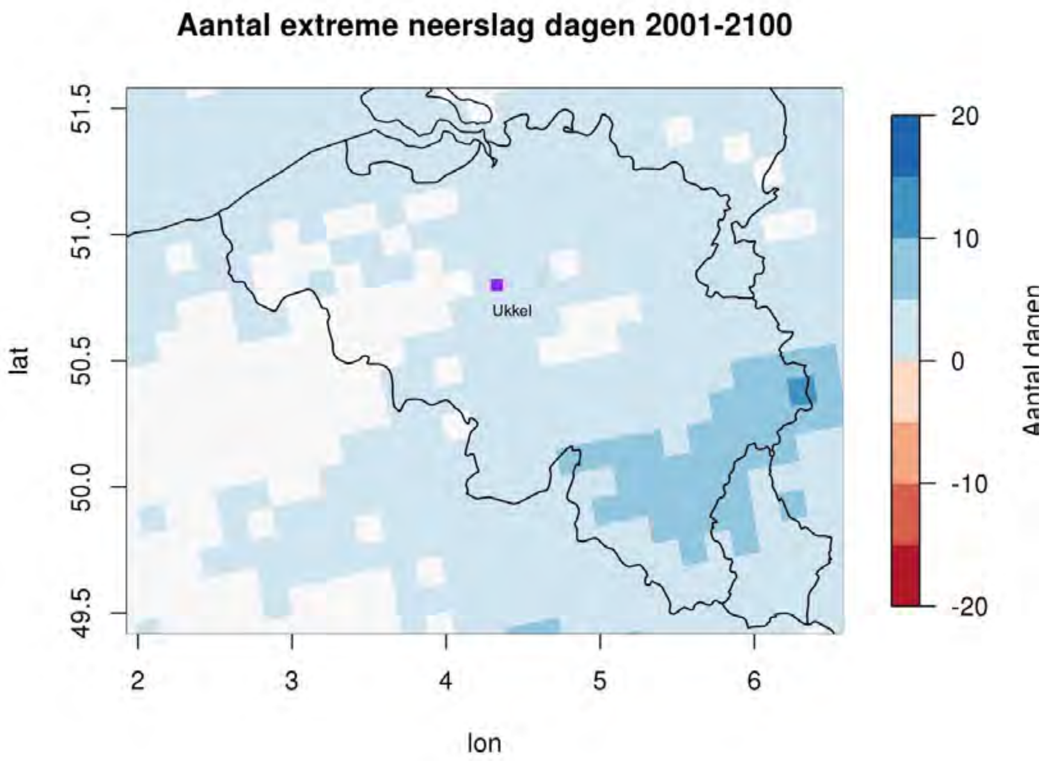


Figure 73: Predicted change in number of days with a daily precipitation amount >10 mm ICHEC, RCP4.5

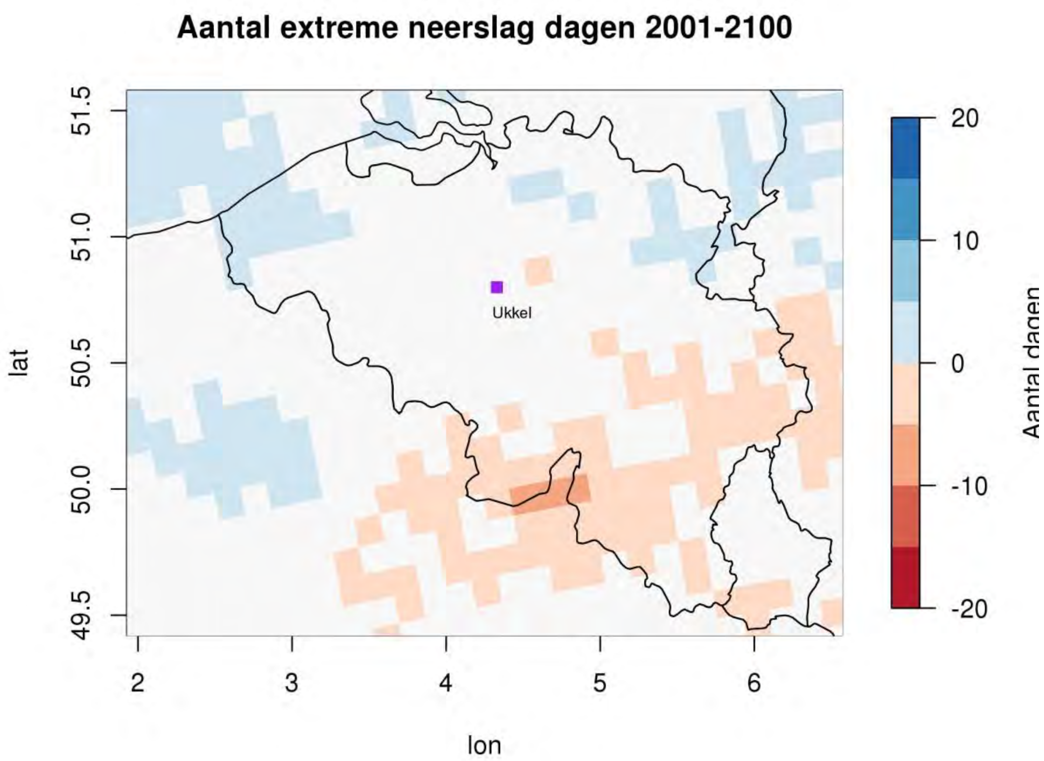


Figure 74: Predicted change in number of days with a daily precipitation amount >10 mm MOHC, RCP4.5

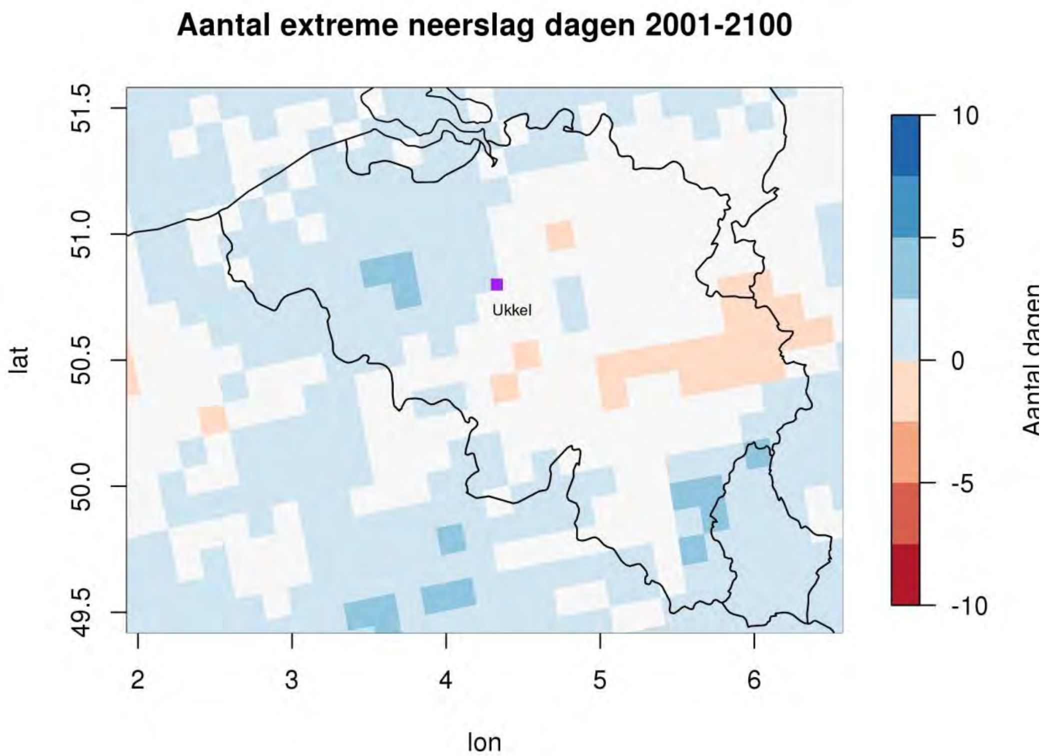


Figure 75: Predicted change in number of days with a daily precipitation amount >10 mm RACMO22E, RCP4.5

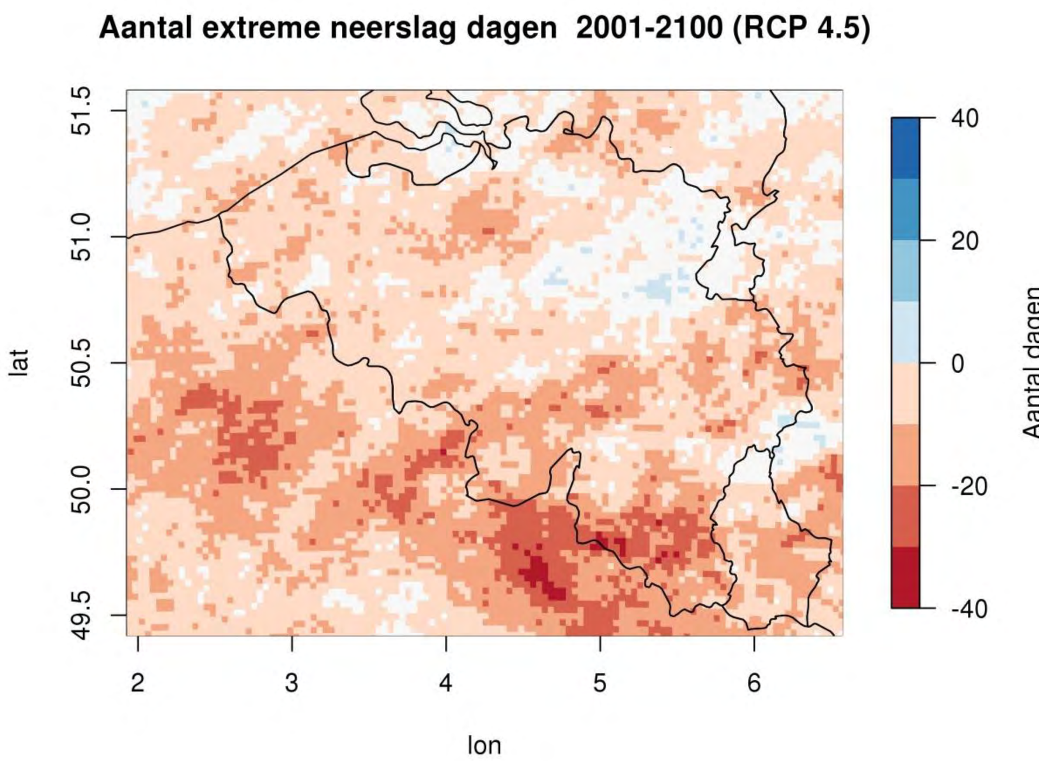


Figure 76: Predicted change in number of days with a daily precipitation amount >10 mm FUT2030_RCP4.5

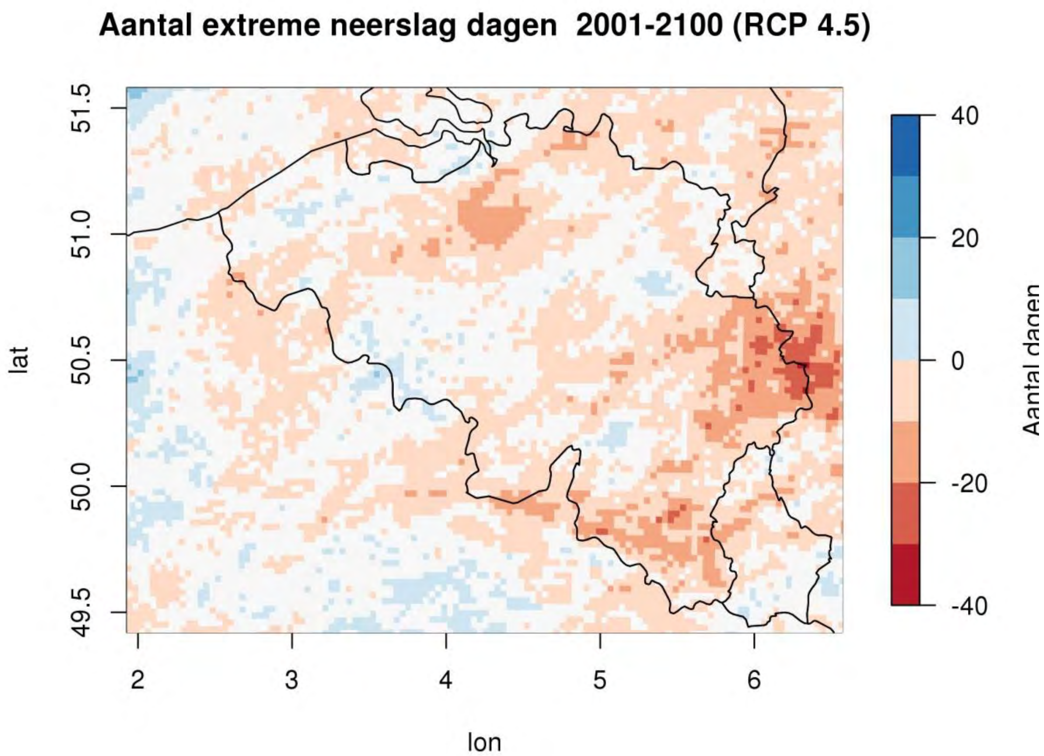


Figure 77: Predicted change in number of days with a daily precipitation amount >10 mm FUT2064_RCP4.5

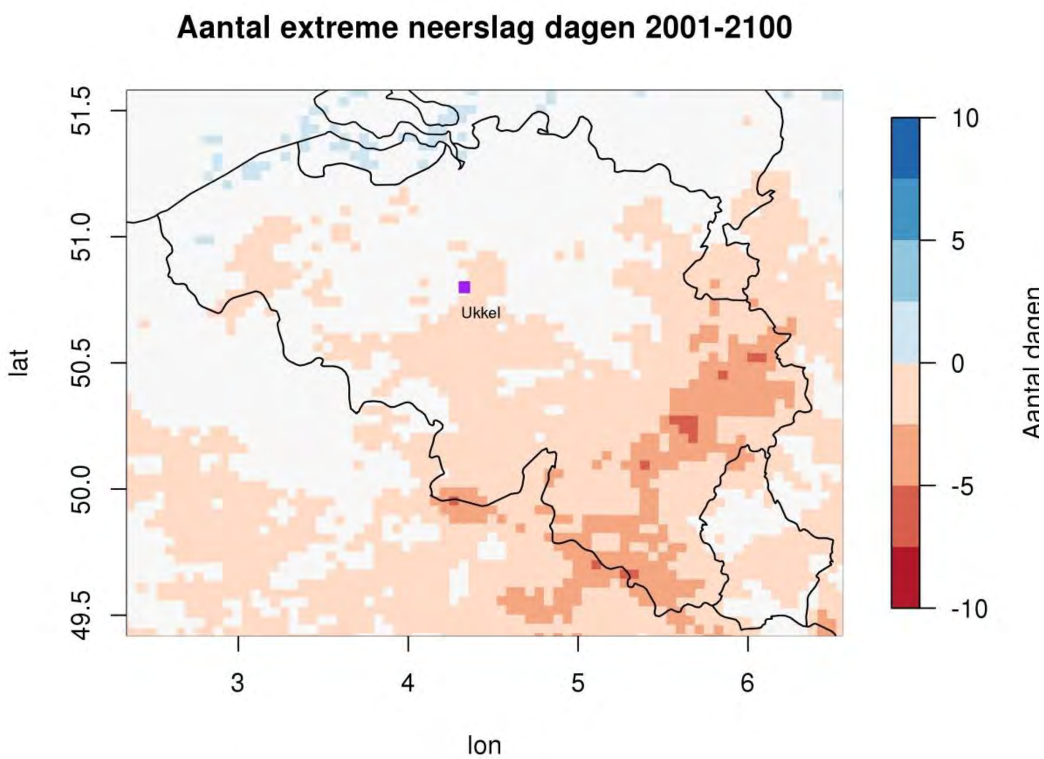


Figure 78: Predicted change in number of days with a daily precipitation amount >10 mm FUT2085_A1B

7.2 RCP8.5

For the RCP8.5 scenario the spatial patterns are more similar to each other. All the runs models an increase in ND10 in the Northern part of Belgium. The CNRM model (Figure 79), MOHC model (Figure 81) and RACMO22E model (Figure 82) also show an expected increase in ND10 in the South of Belgium. Also the FUT2064_RCP8.5 run (Figure 83) shows this pattern but in the extreme South a decrease is expected. The CCLM model (Figure 78) and ICHEC (Figure 80) expect a decrease in the South.

According to this scenario the ND10 are expected to increase in the North of Belgium. For the South there is no pronounced pattern because the models are inconsistent with each other.

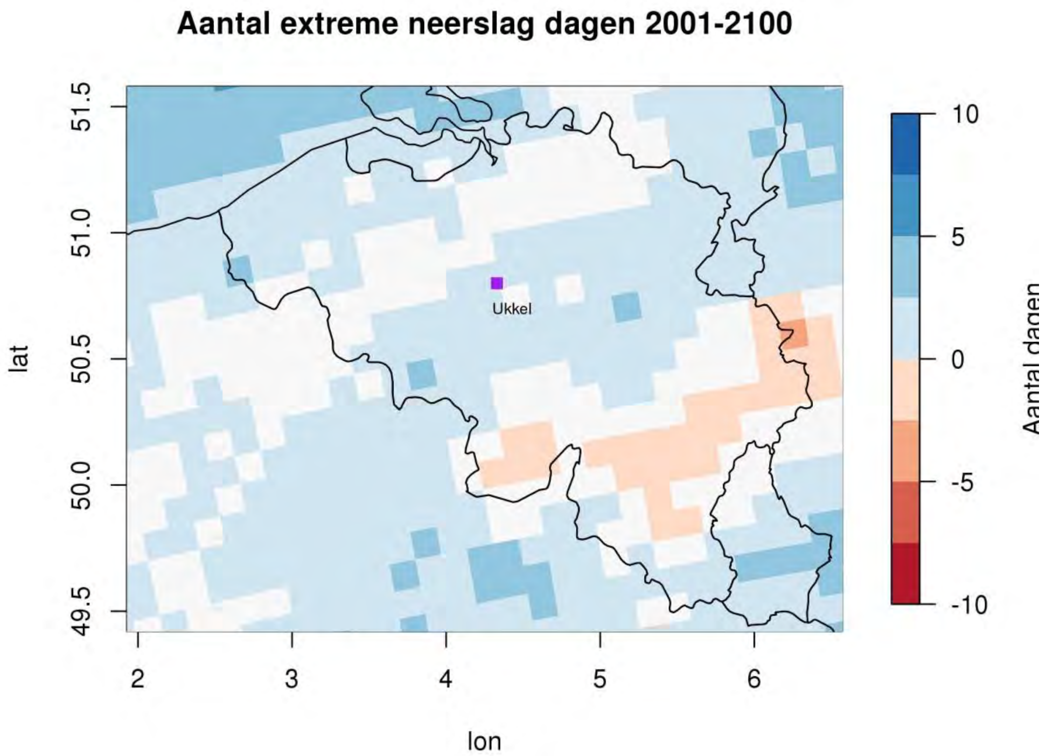


Figure 79: Predicted change in number of days with a daily precipitation amount >10 mm CCLM, RCP8.5

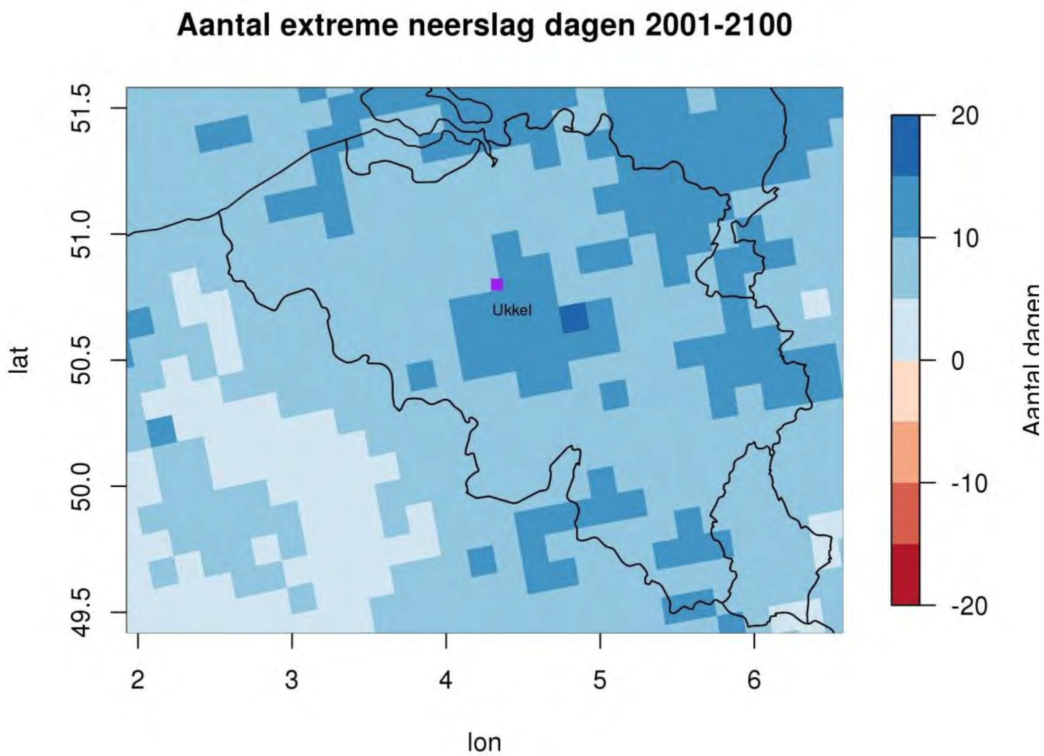


Figure 80: Predicted change in number of days with a daily precipitation amount >10 mm CNRM, RCP8.5

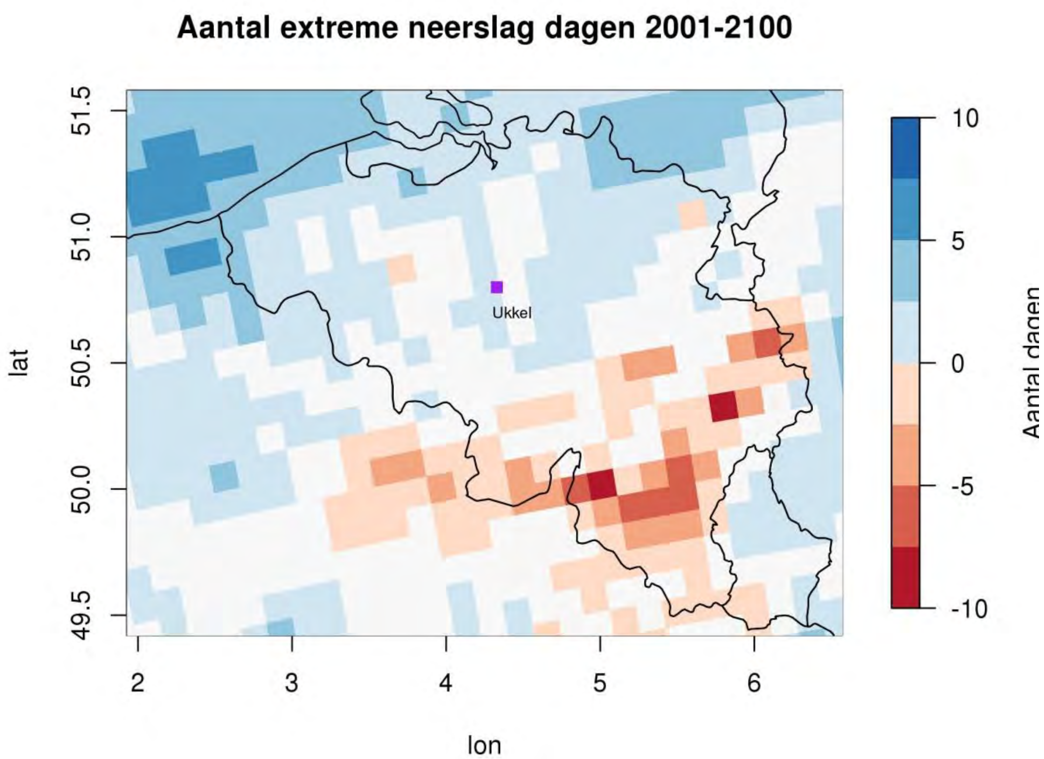


Figure 81: Predicted change in number of days with a daily precipitation amount >10 mm ICHEC, RCP8.5

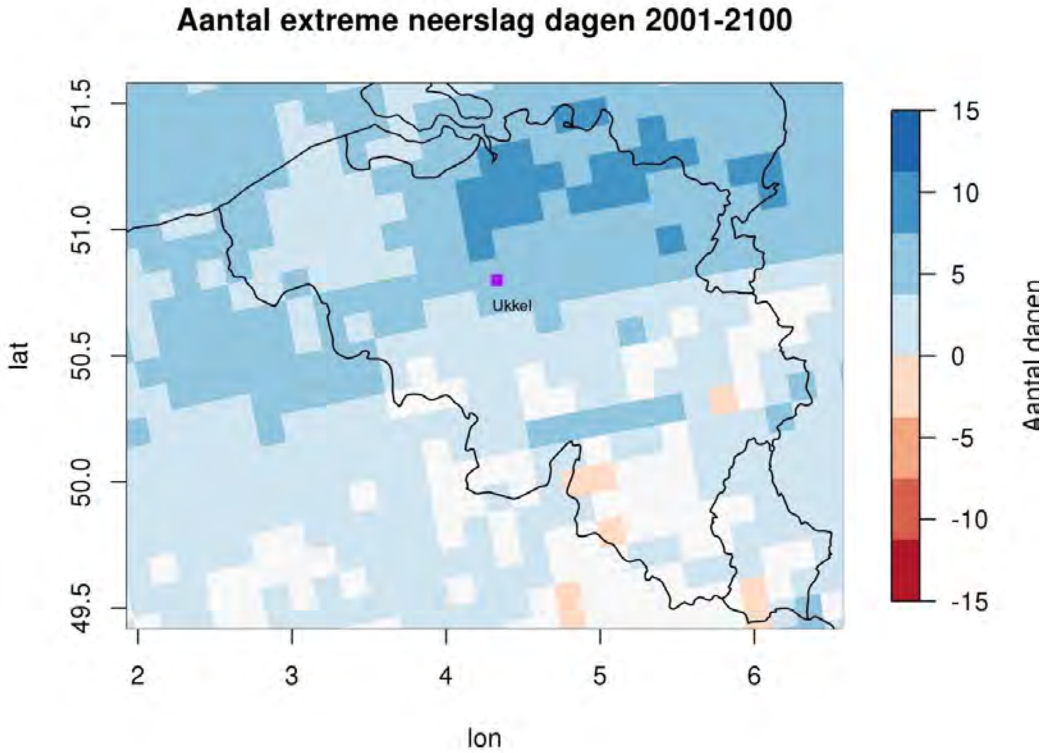


Figure 82: Predicted change in number of days with a daily precipitation amount >10 mm MOHC, RCP8.5

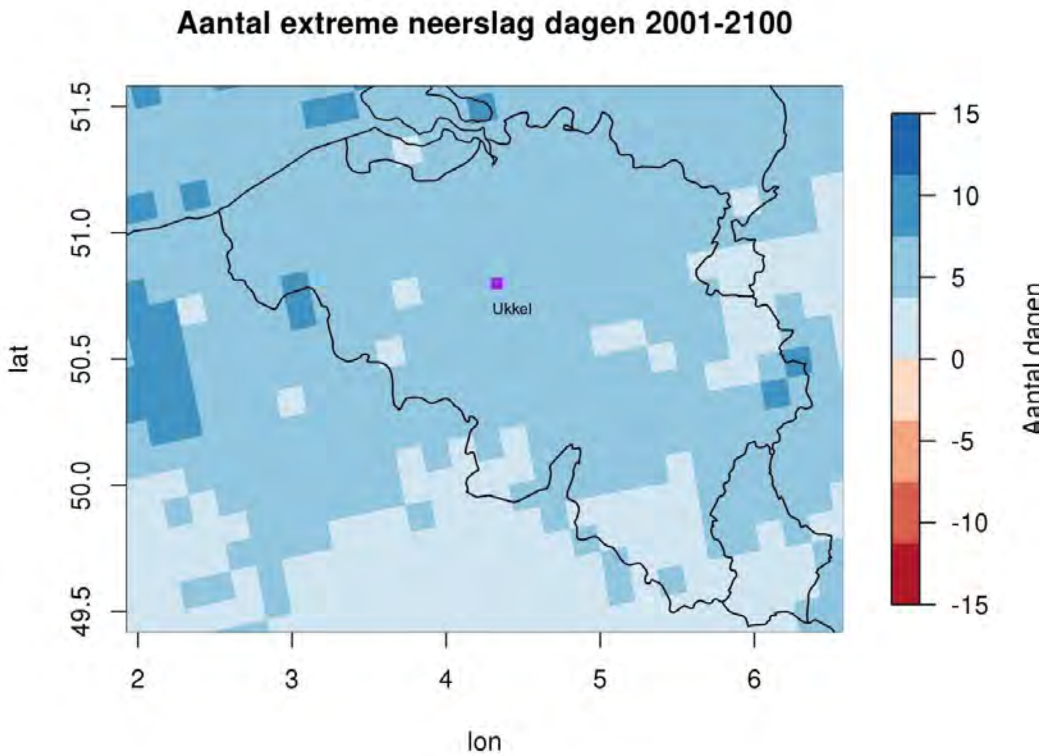


Figure 83: Predicted change in number of days with a daily precipitation amount >10 mm RACMO22E, RCP8.5

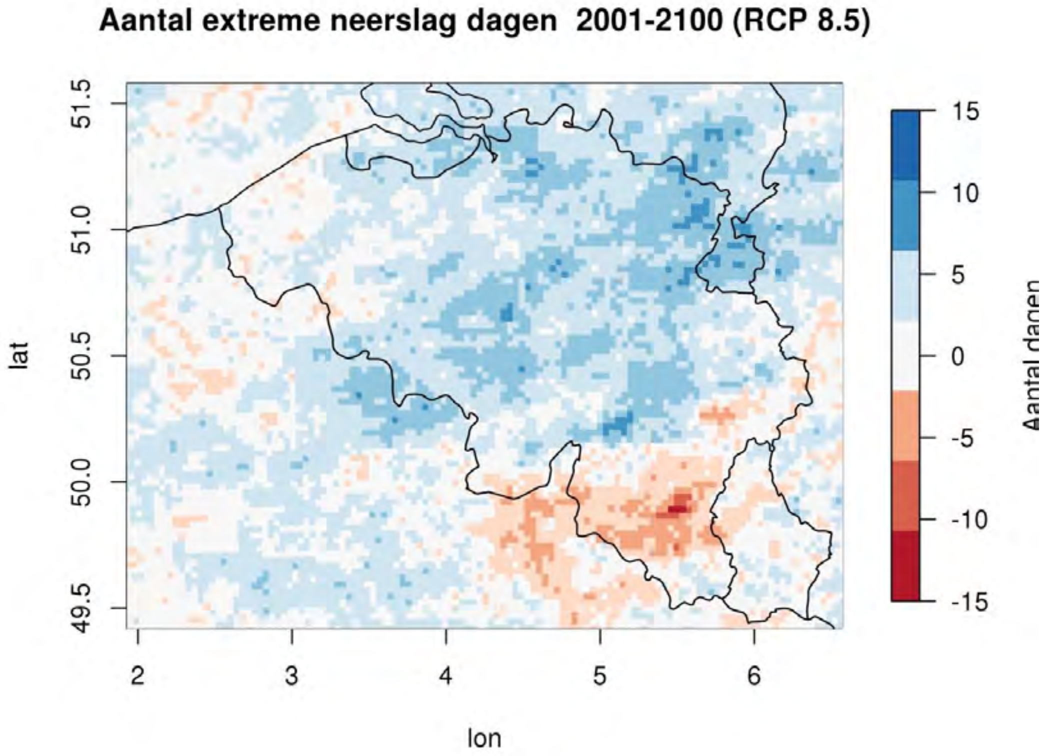


Figure 84: Predicted change in number of days with a daily precipitation amount >10 mm FUT2064_RCP8.5

8 General conclusions

There is a spatial pattern in the warming over Belgium: At the coast, the warming is 0.05 to 0.4 °C lower than in Uccle and in the Ardennes, the warming is 0.05 to 0.4 °C higher than in Uccle. This is due to the stronger temperature signal over land compared to the oceans.

In about half of the models, the increase in precipitation is largest over the Ardennes. This hints to the possibility of an orographic amplification of the precipitation signal, although care has to be taken as the other half of the models do not show this amplification so strongly.

In four out of six models for RCP8.5, there is an amplified signal in winter precipitation at the North-Sea in Belgium compared to the rest of the domain. This effect is strongest in the four models with the largest change in temperature gradient from the North Sea to Uccle.

In two third of the models, the decrease in summer precipitation is larger in the southern part of Belgium compared to the Northern part.

By the end of the century more heat waves are expected for Belgium. The expected increase in ND25 is the biggest in the center of Belgium. Near the coast and in the Ardennes the increase in ND25 is expected to be less. This spatial pattern is confirmed by 85 % of the models for both scenarios.

By the end of the century less cold waves are expected for Belgium. The expected decrease ND0 is the biggest in the Ardennes. Near the coast the decrease in ND0 is expected to be less. This spatial pattern is confirmed by all the models for both scenarios

In 75 % of the models the ND10 are expected to increase in the North of Belgium. For the South there is no pronounced pattern because in half of the models an increase in ND10 is expected and in the other half a decrease.

ANNEX

A Scheldt river basin

For the yearly temperature, winter precipitation and summer precipitation maps with a bigger range were made. On this maps it is for example possible to locate the Scheldt river basin and to look at changes for this basin in one of the parameters. On these maps the absolute values of the parameters are shown. It was only possible to generate maps for the CORDEX models because the ALARO model and MACCBET models don't have the range to model data far beyond Belgium. So for each parameter and each scenario five maps are available. For the temperature the MOHC model for both scenarios show a unexpected signal in the west above the sea. This is probably an error in the obtained data.

A.1 Temperature RCP4.5

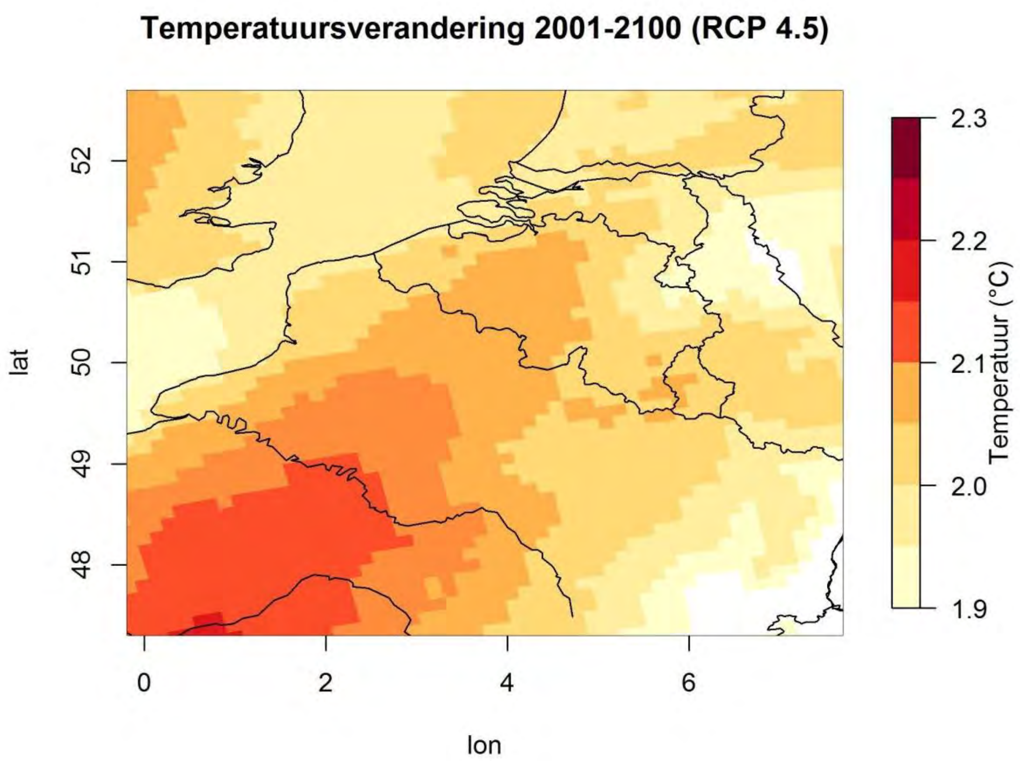


Figure 85: Temperature change CCLM by the end of the century, RCP4.5

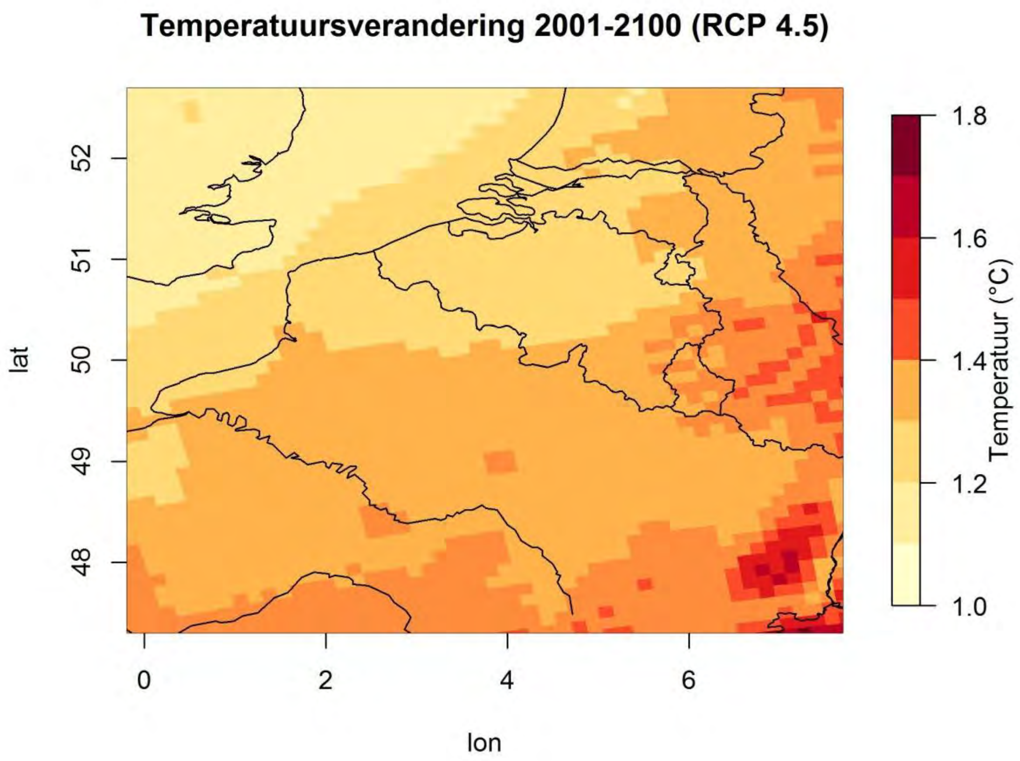


Figure 86: Temperature change CNRM by the end of the century, RCP4.5

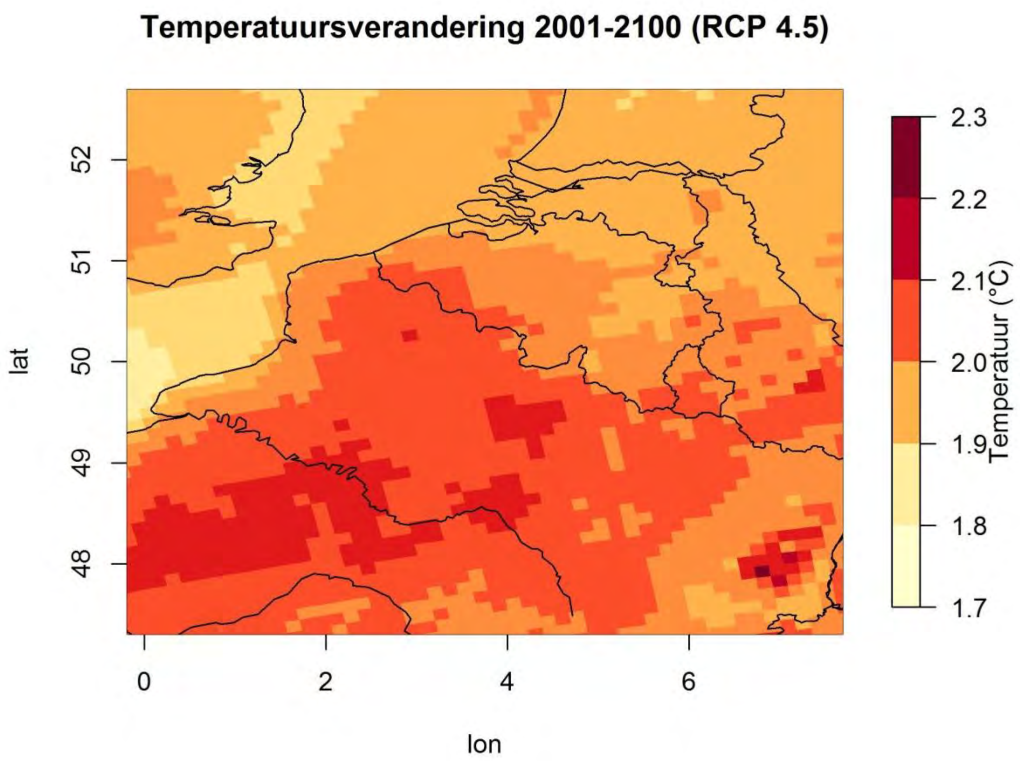


Figure 87: Temperature change ICHEC by the end of the century, RCP4.5

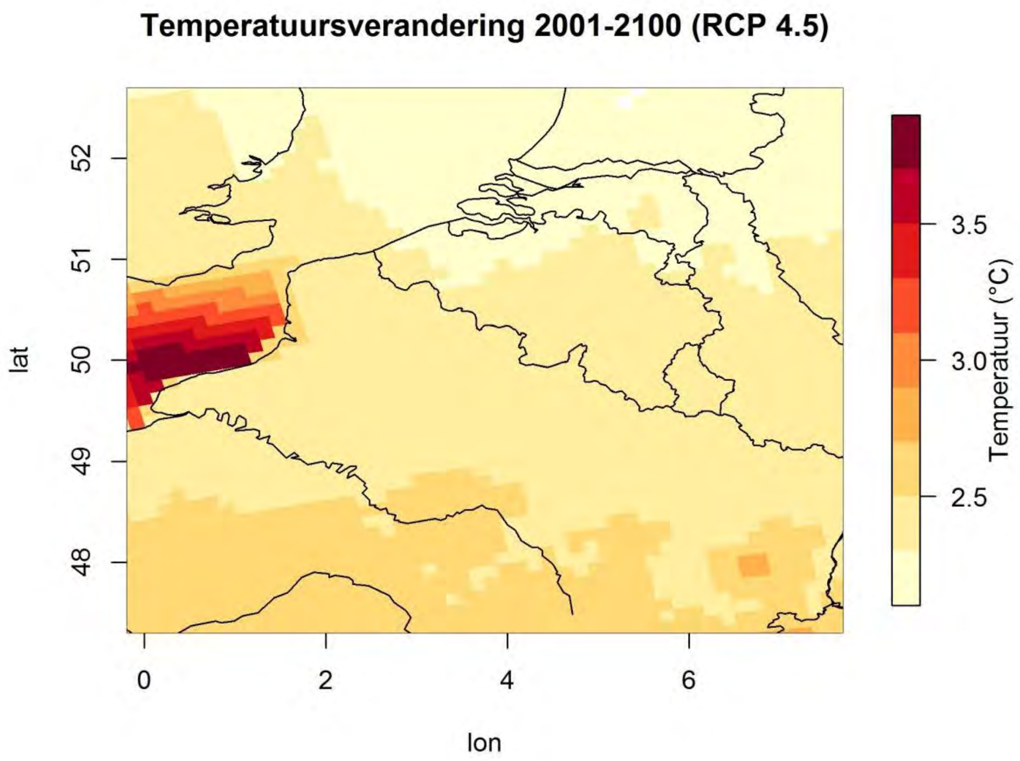


Figure 88: Temperature change MOHC by the end of the century, RCP4.5

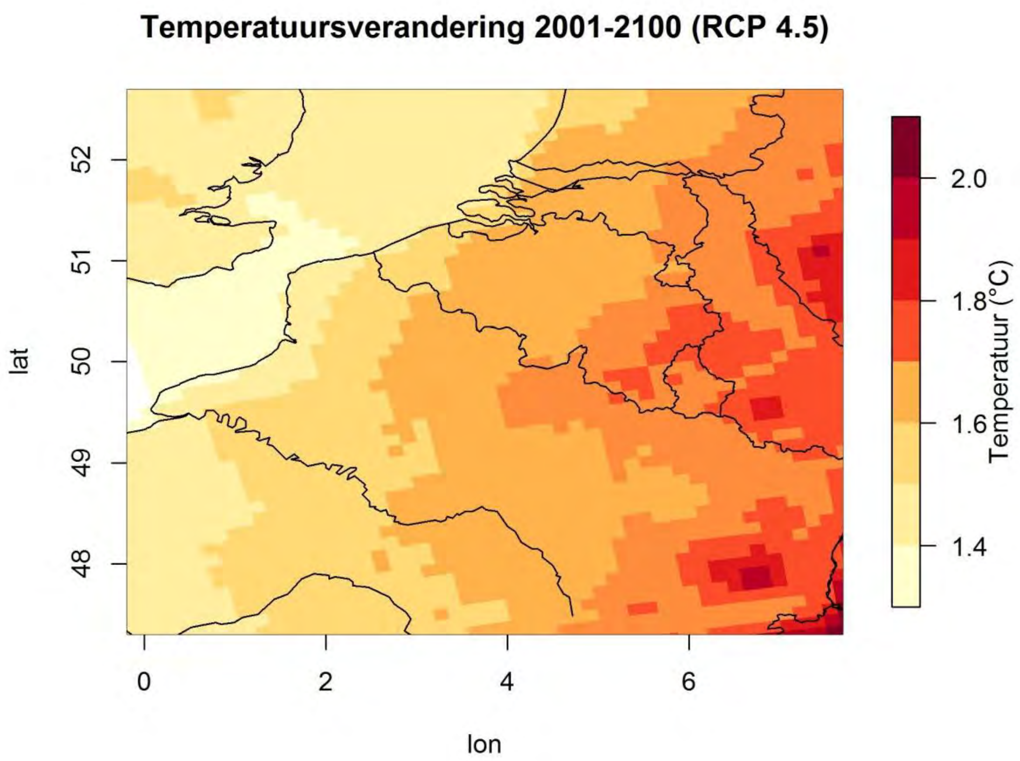


Figure 89: Temperature change RACMO22E by the end of the century, RCP4.5

A.2 Temperature RCP8.5

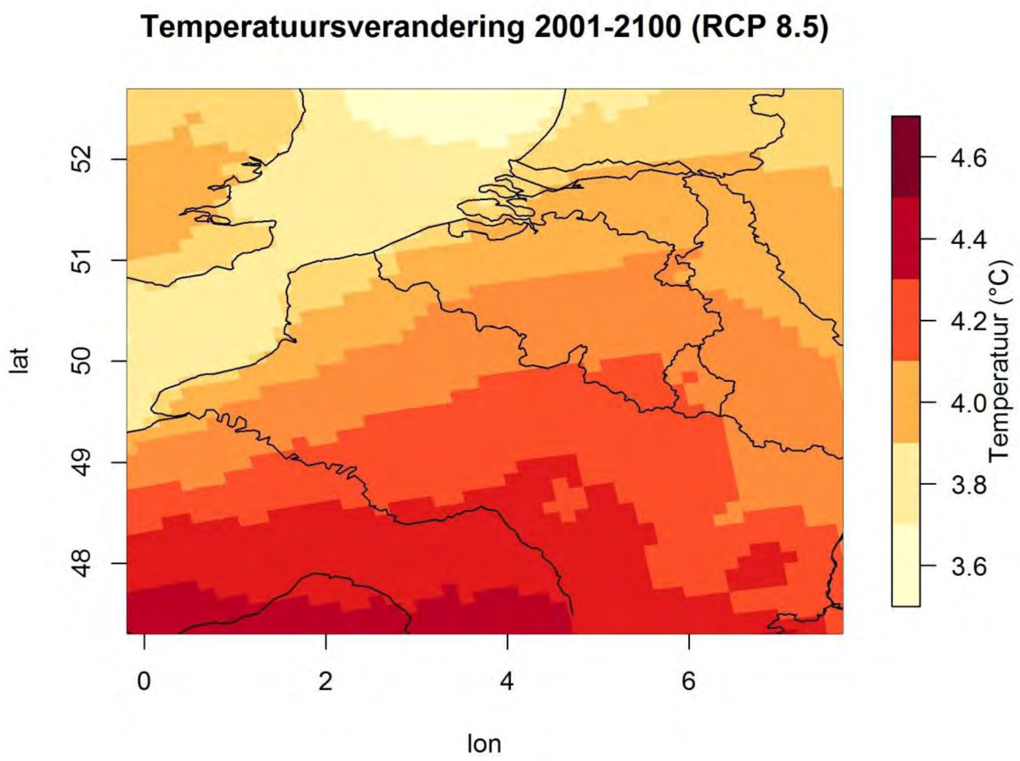


Figure 90: Temperature change CCLM by the end of the century, RCP8.5

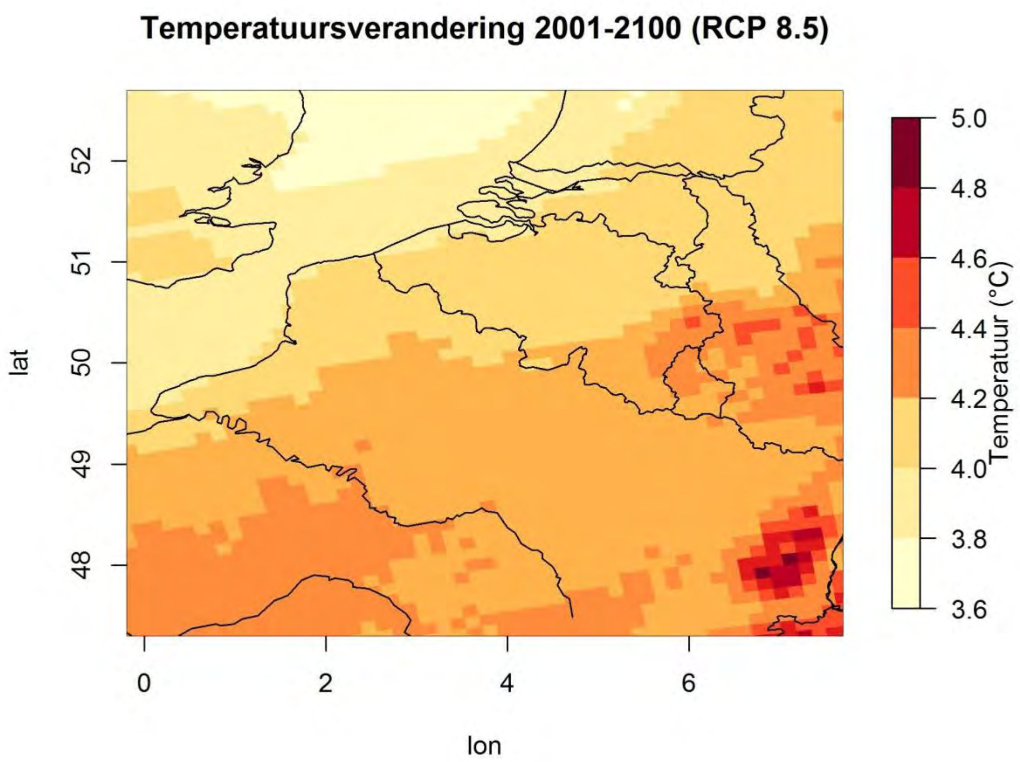


Figure 91: Temperature change CNRM by the end of the century, RCP8.5

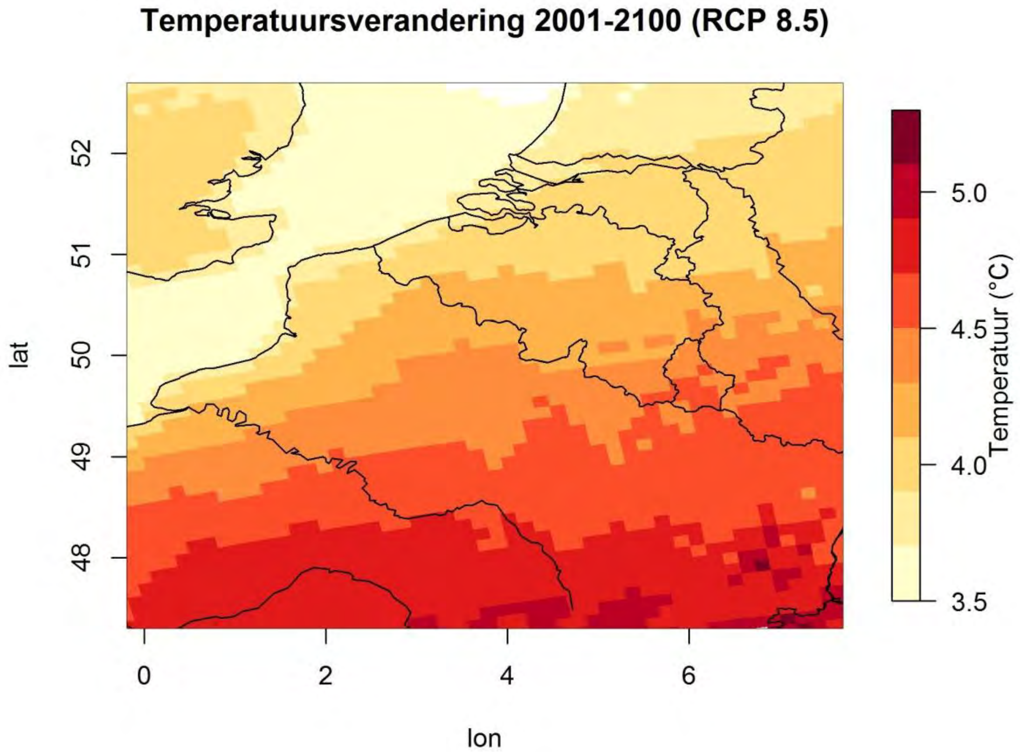


Figure 92: Temperature change ICHEC by the end of the century, RCP8.5

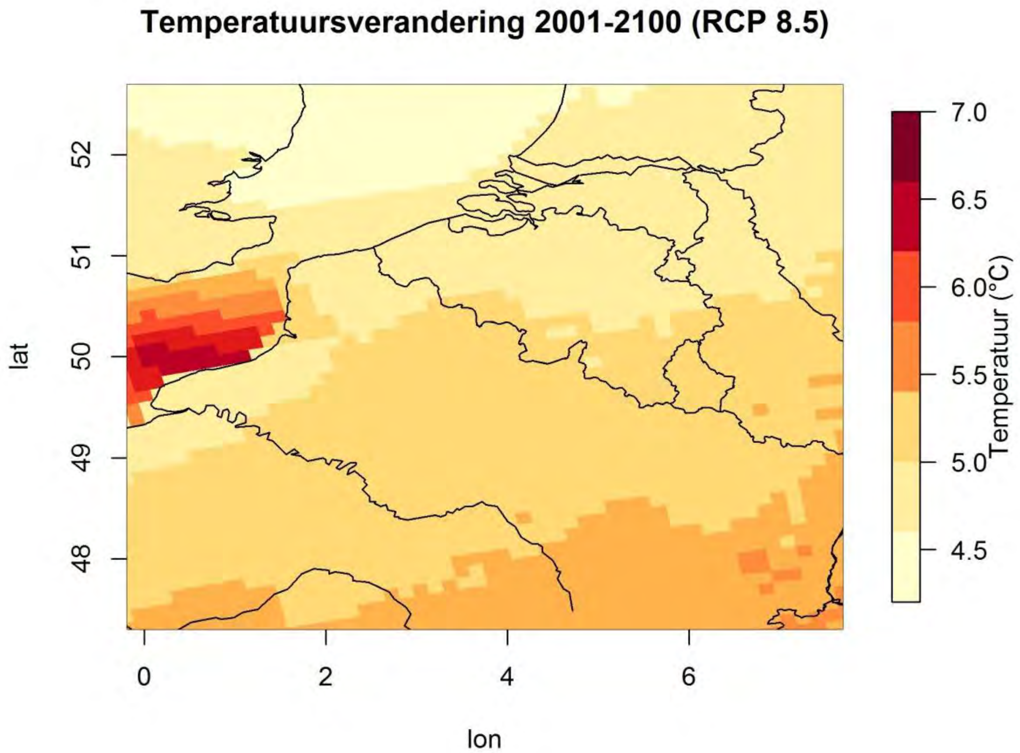


Figure 93: Temperature change MOHC by the end of the century, RCP8.5

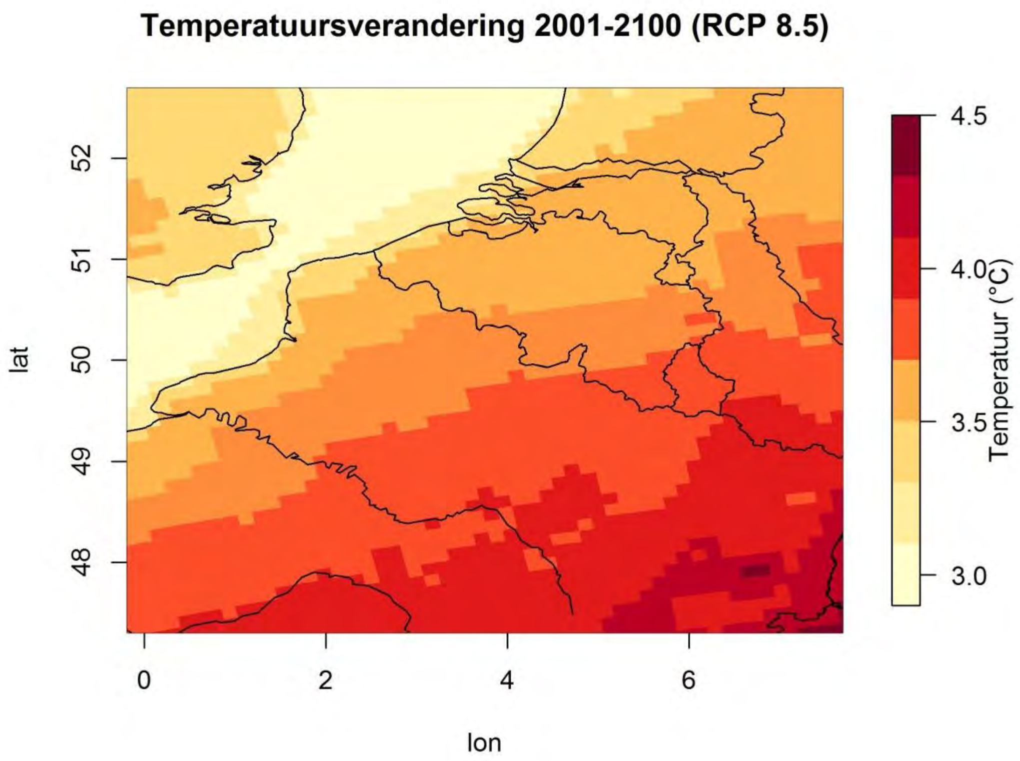


Figure 94: Temperature change RACMO22E by the end of the century, RCP8.5

A.3 Winter precipitation RCP4.5

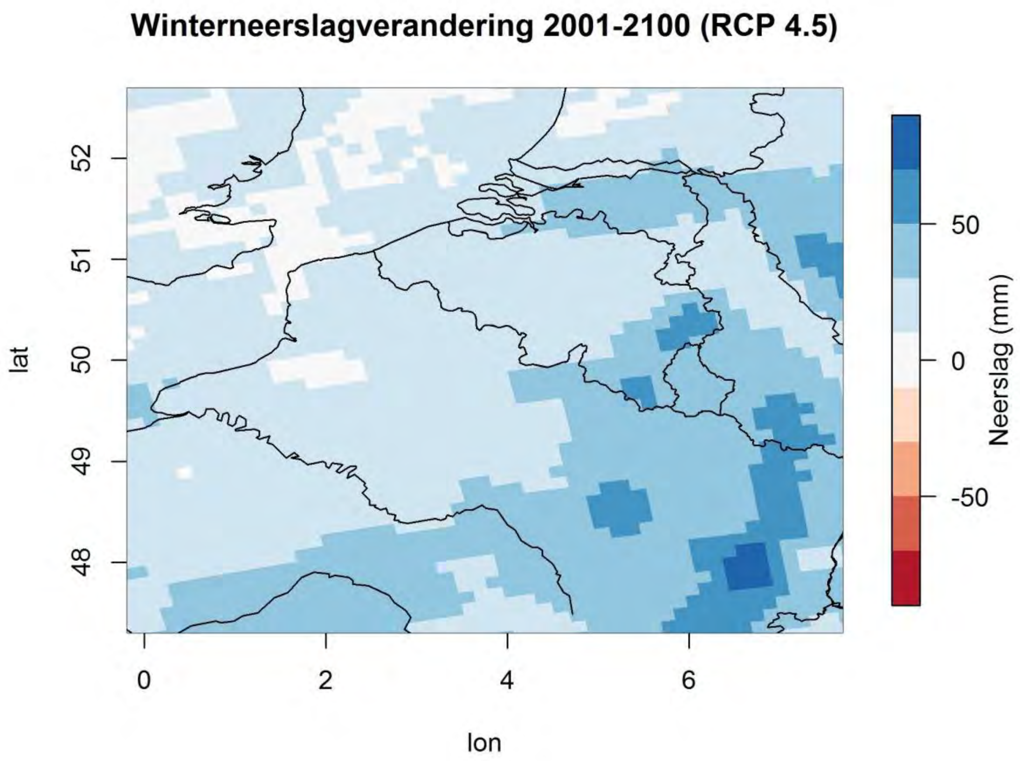


Figure 95: Predicted change in winter precipitation CCLM, RCP4.5

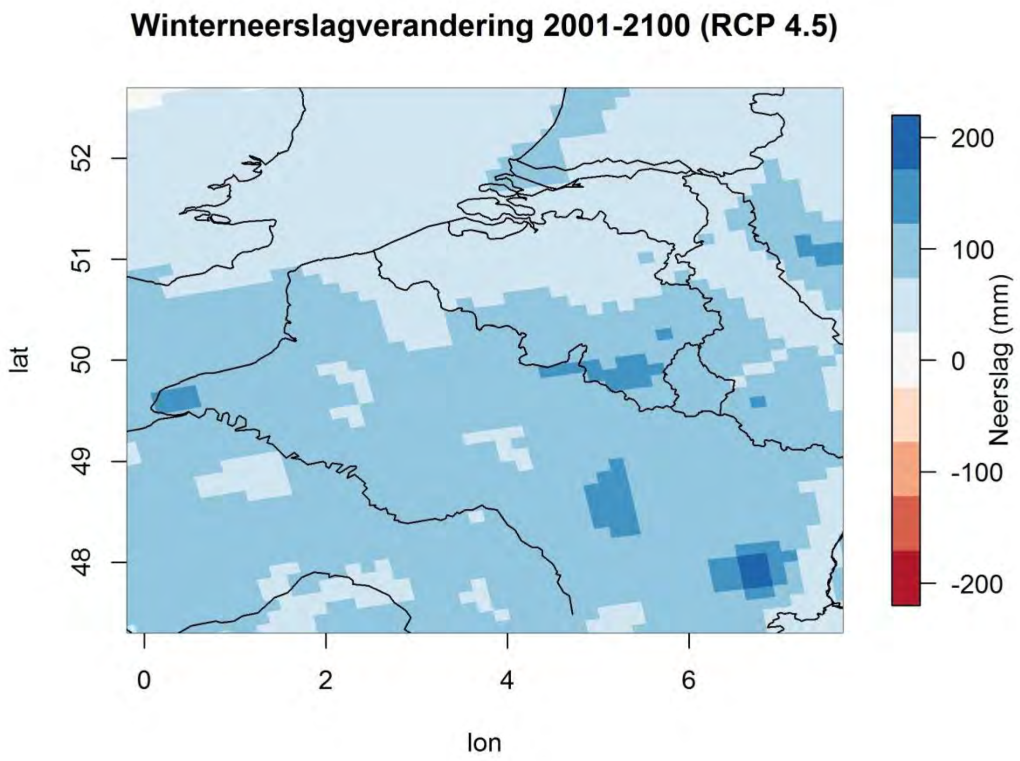


Figure 96: Predicted change in winter precipitation CNRM, RCP4.5

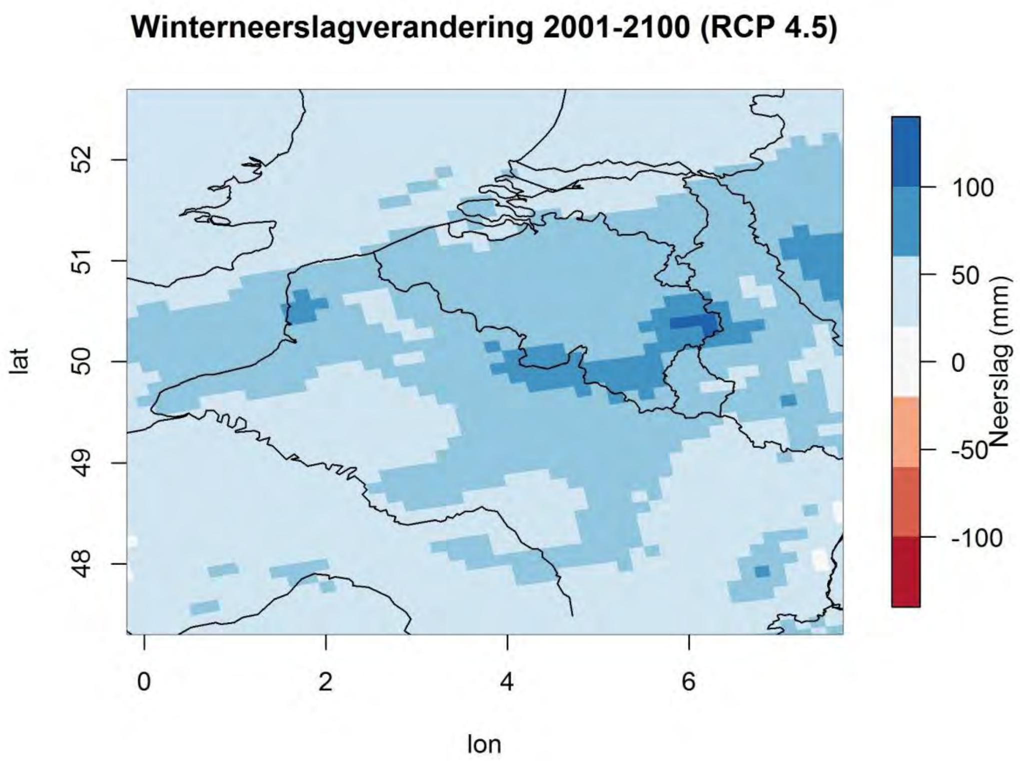


Figure 97: Predicted change in winter precipitation ICHEC, RCP4.5

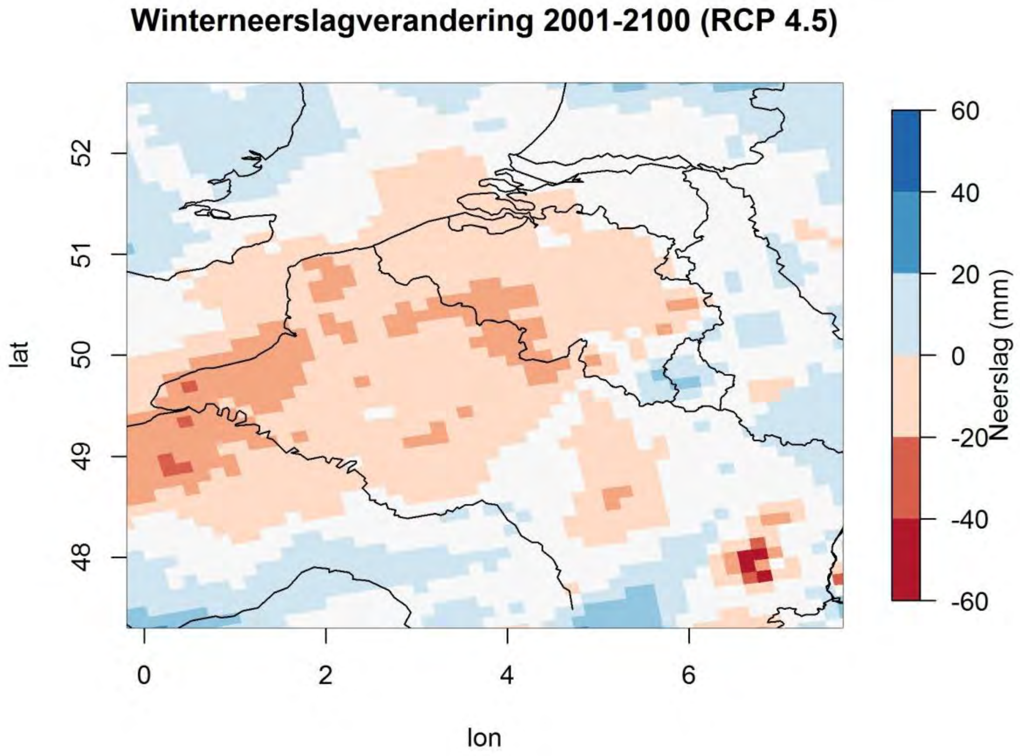


Figure 98: Predicted change in winter precipitation MOHC, RCP4.5

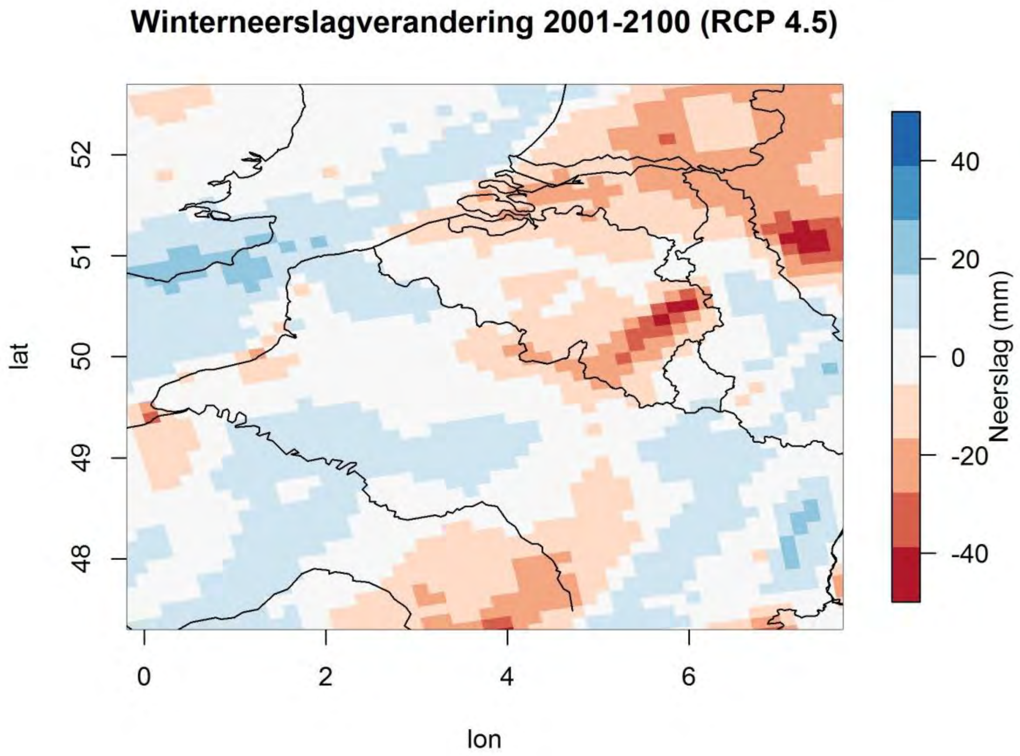


Figure 99: Predicted change in winter precipitation RACMO22E, RCP4.5

A.4 Winter precipitation RCP8.5

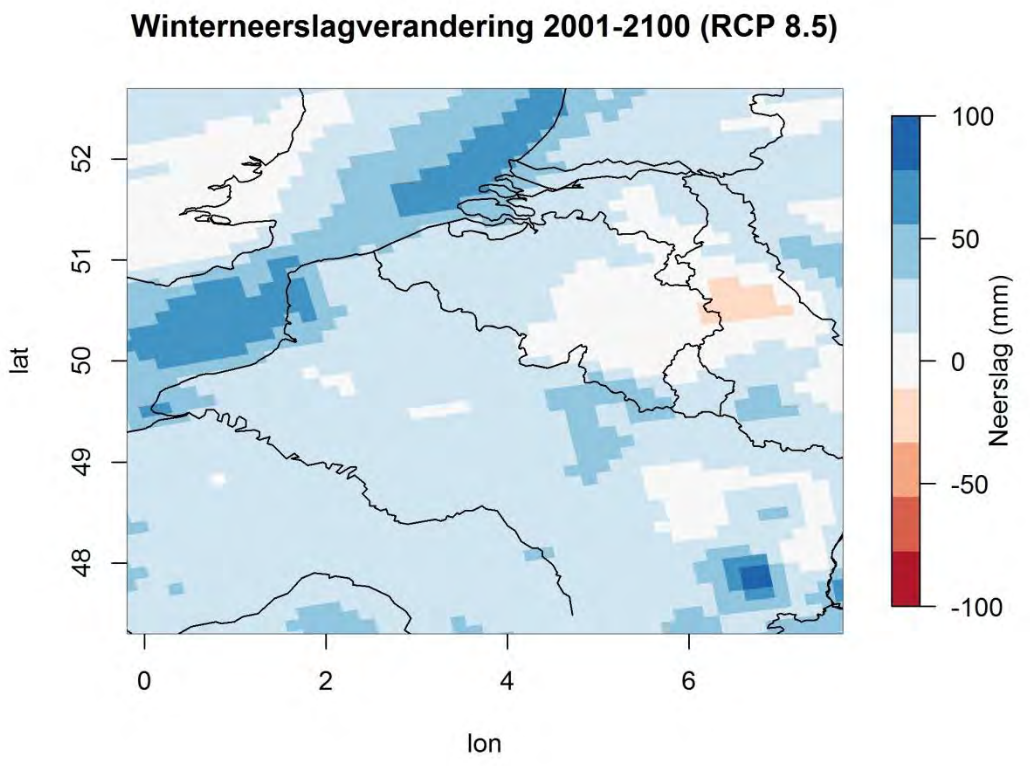


Figure 100: Predicted change in winter precipitation CCLM, RCP8.5

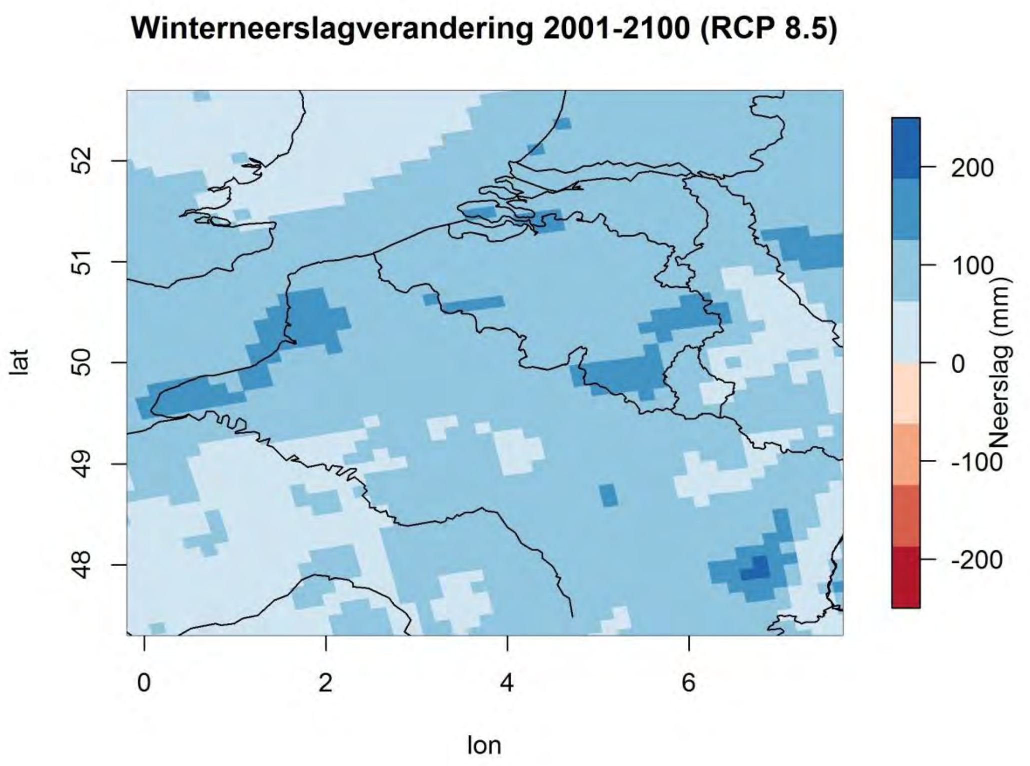


Figure 101: Predicted change in winter precipitation CNRM, RCP8.5

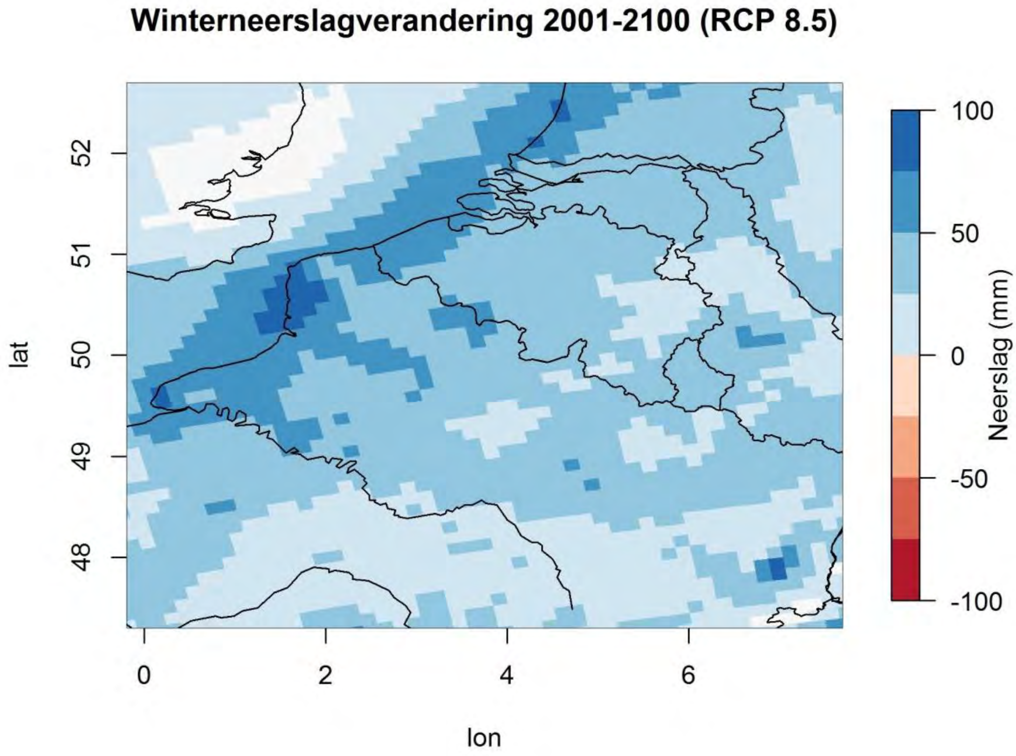


Figure 102: Predicted change in winter precipitation ICHEC, RCP8.5

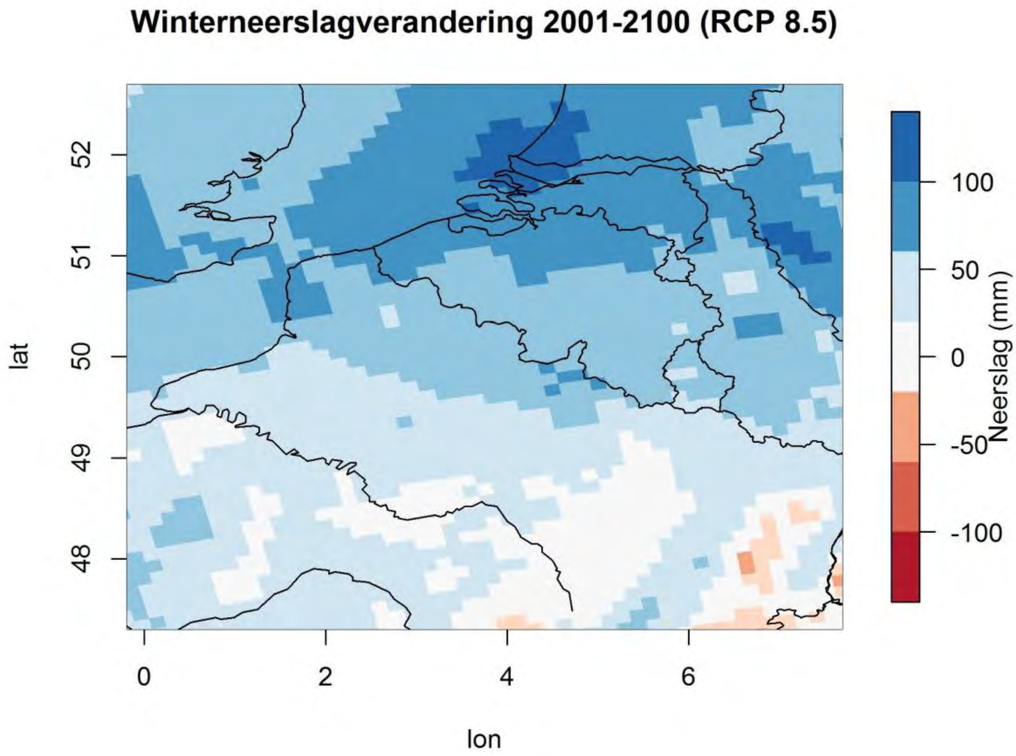


Figure 103: Predicted change in winter precipitation MOHC, RCP8.5

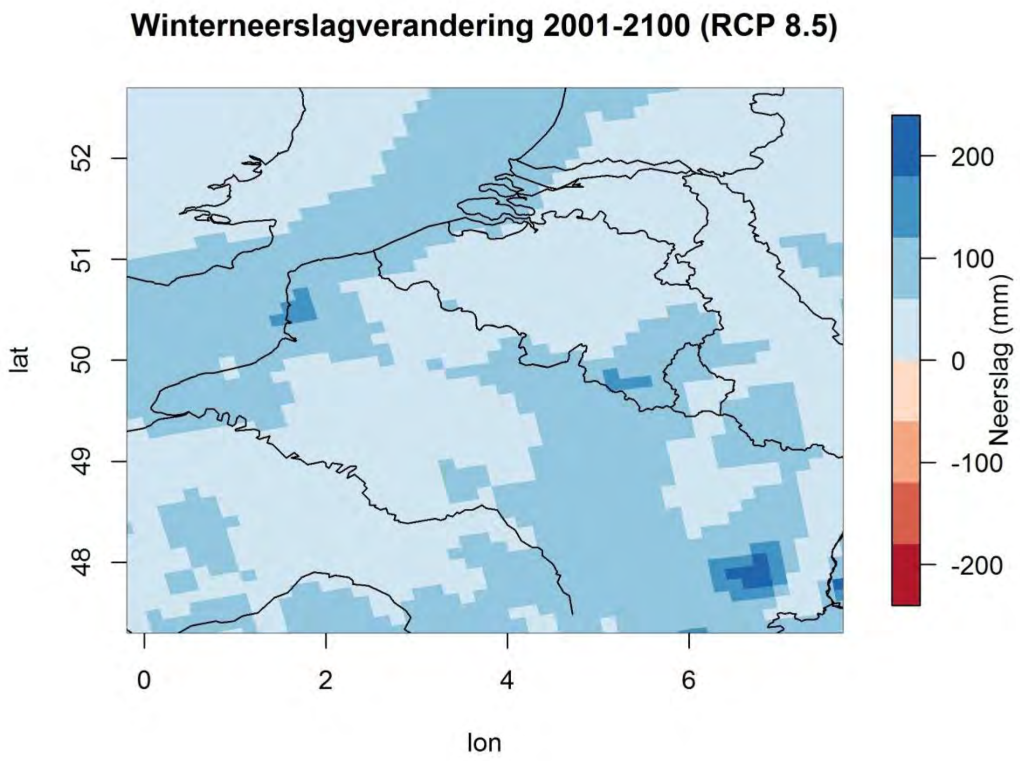


Figure 104: Predicted change in winter precipitation RACMO22E, RCP8.5

A.5 Summer precipitation RCP4.5

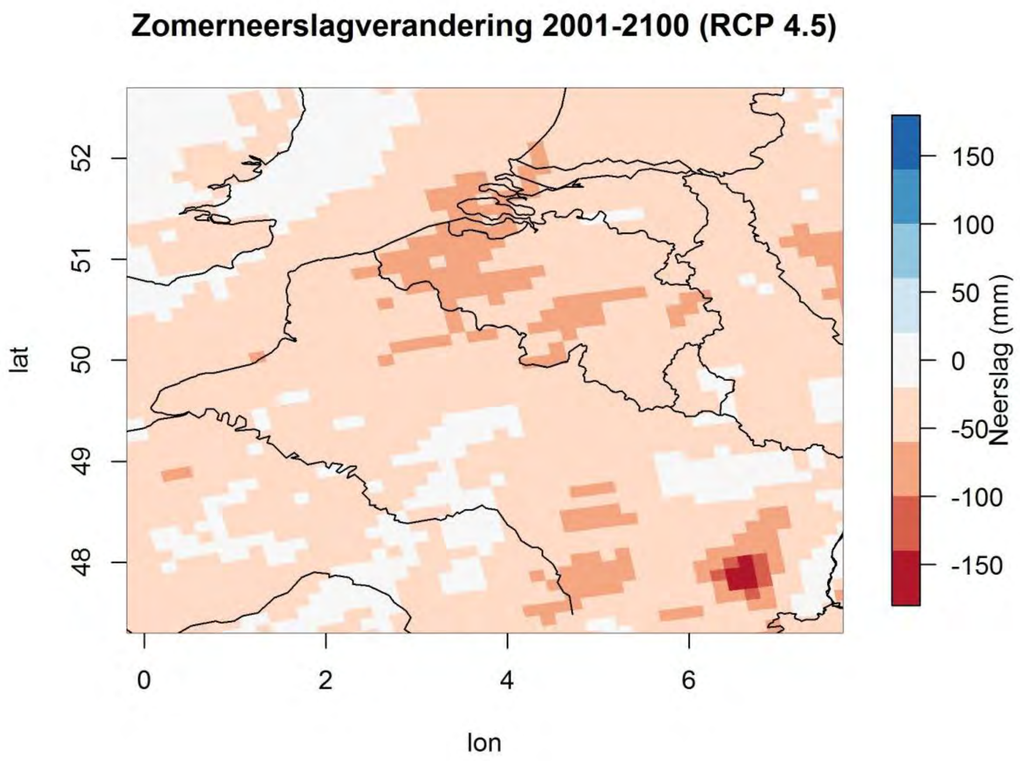


Figure 105: Predicted change in summer precipitation CCLM, RCP4.5

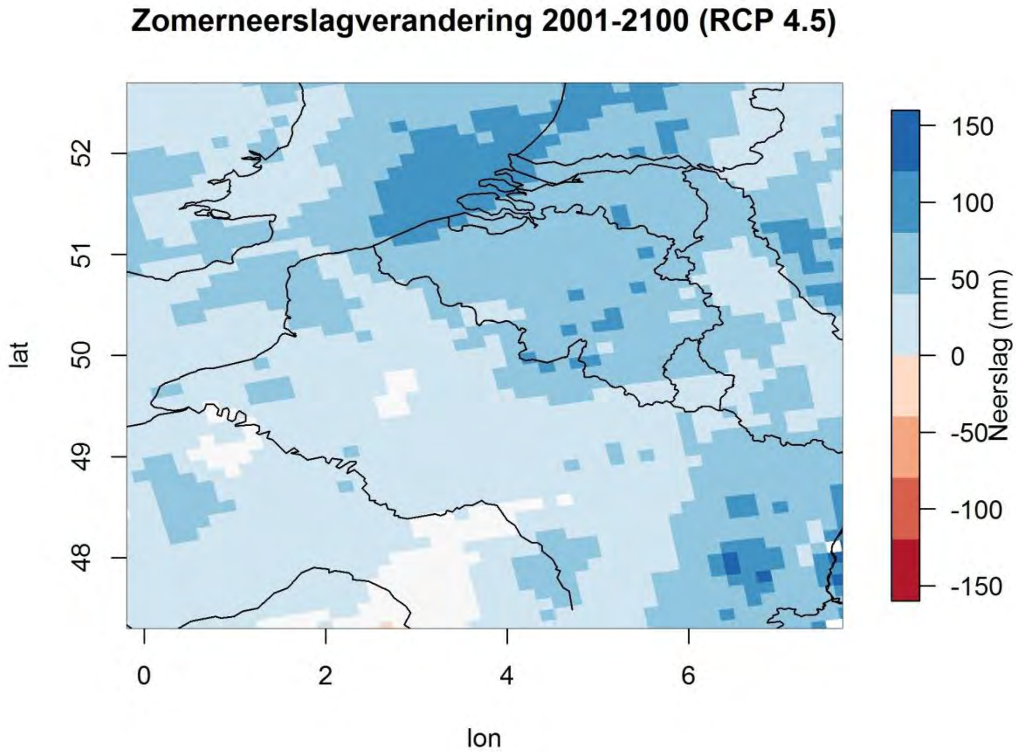


Figure 106: Predicted change in summer precipitation CNRM, RCP4.5

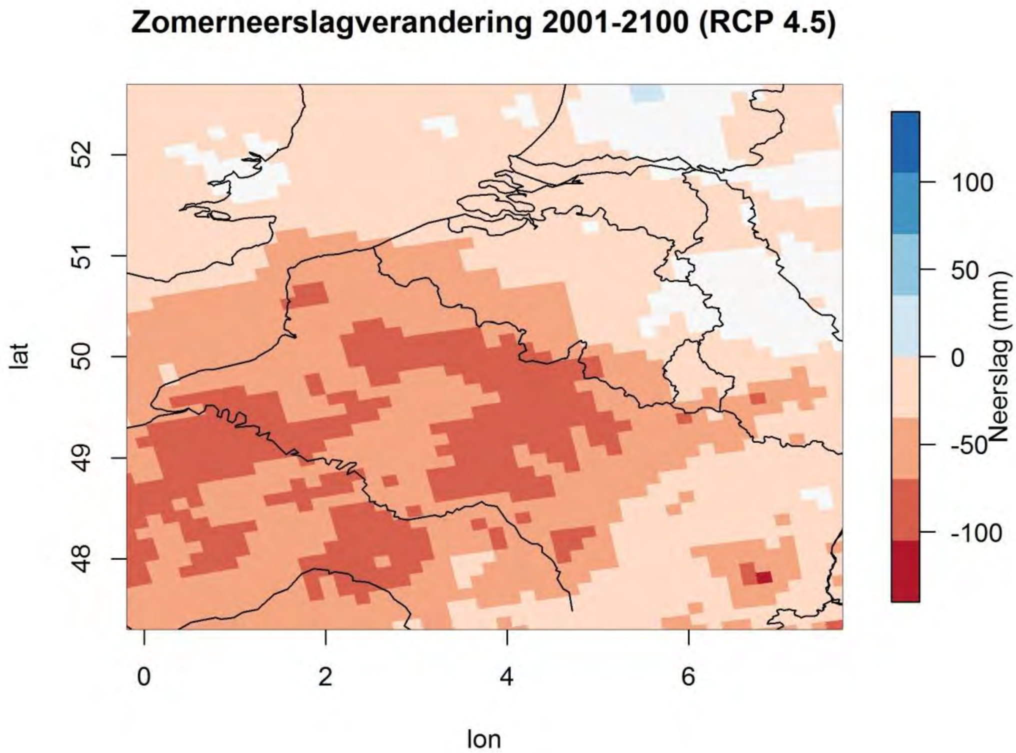


Figure 107: Predicted change in summer precipitation ICHEC, RCP4.5

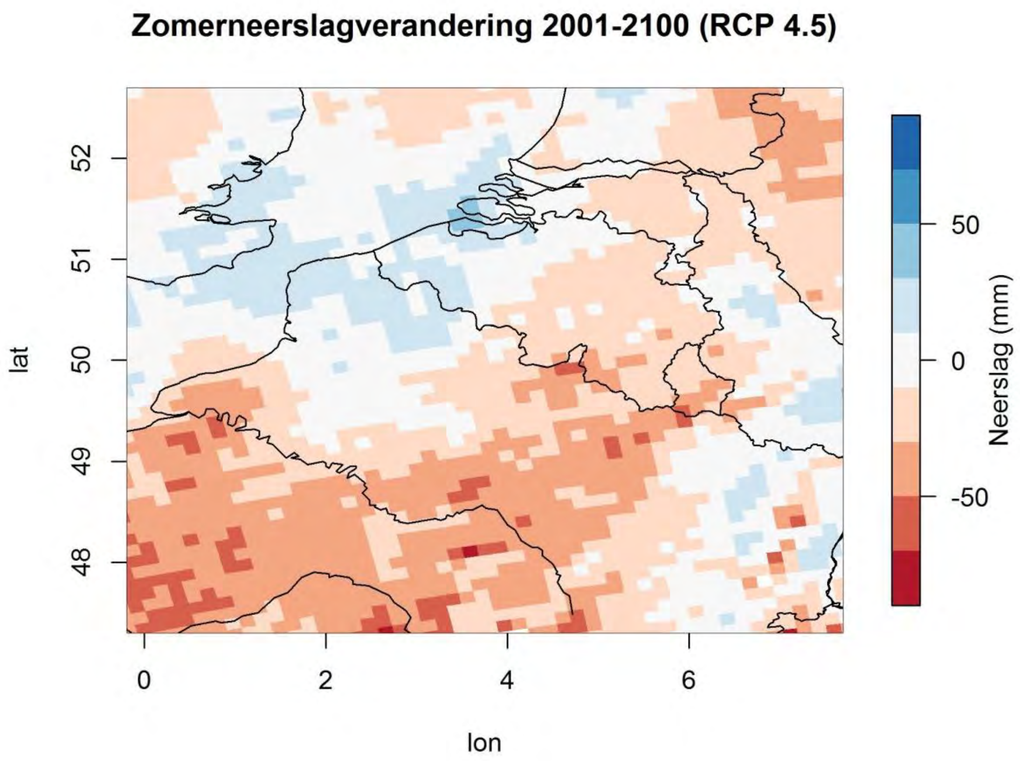


Figure 108: Predicted change in summer precipitation MOHC, RCP4.5

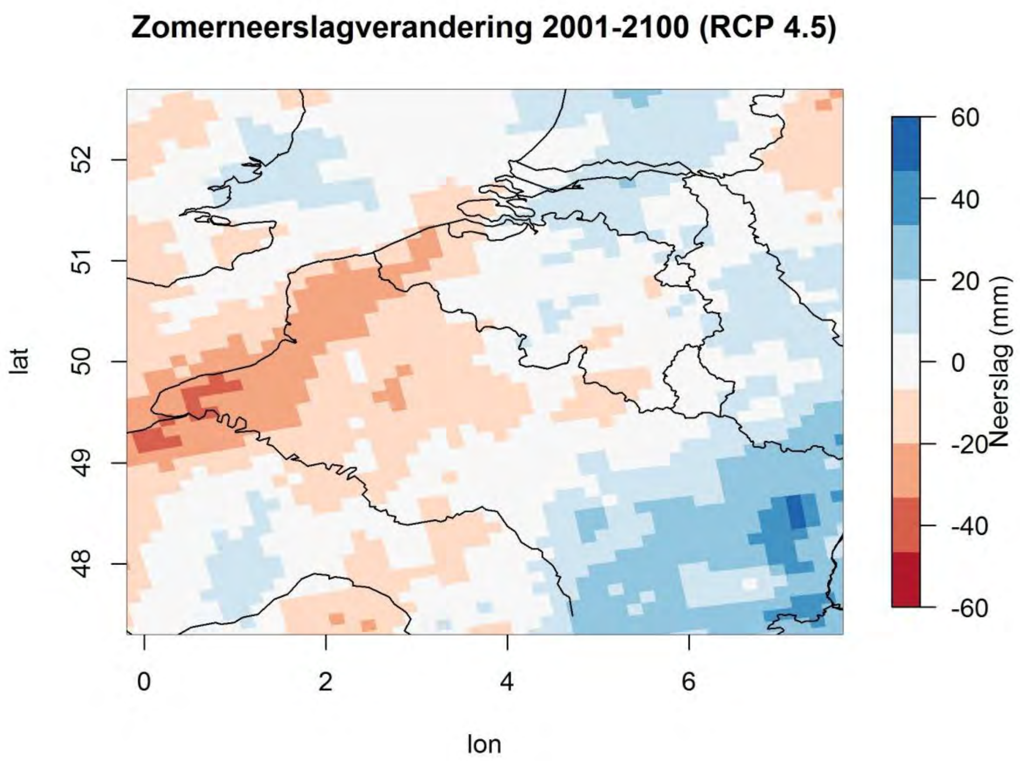


Figure 109: Predicted change in summer precipitation RACMO22E, RCP4.5

A.6 Summer precipitation RCP8.5

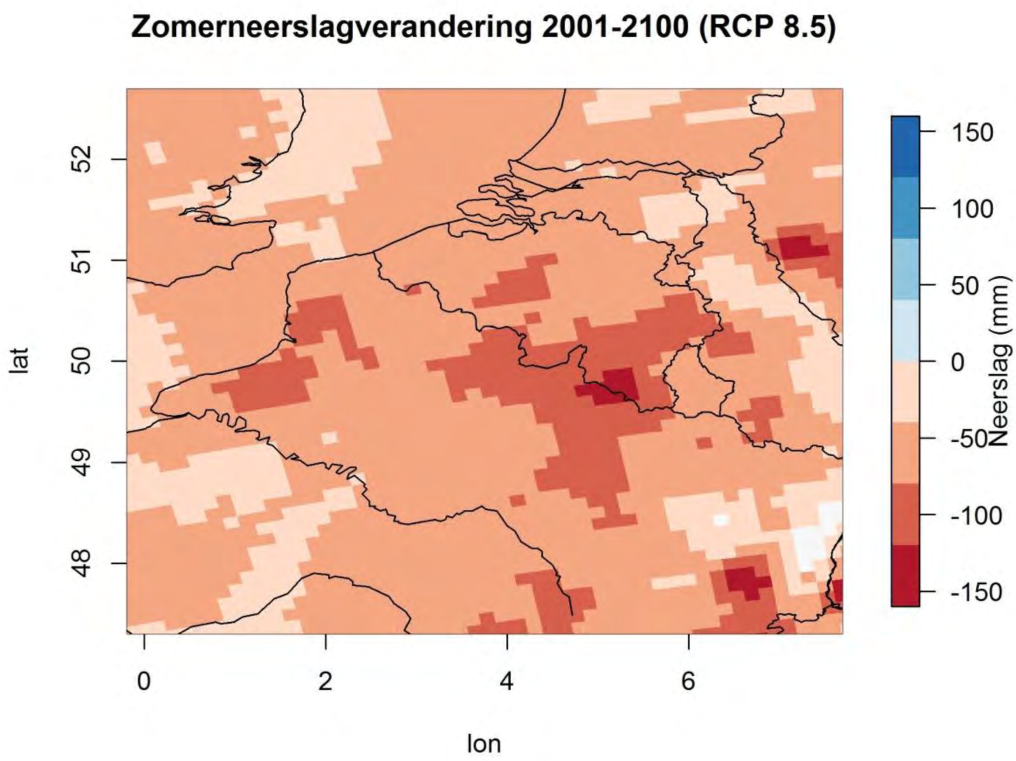


Figure 110: Predicted change in summer precipitation CCLM, RCP8.5

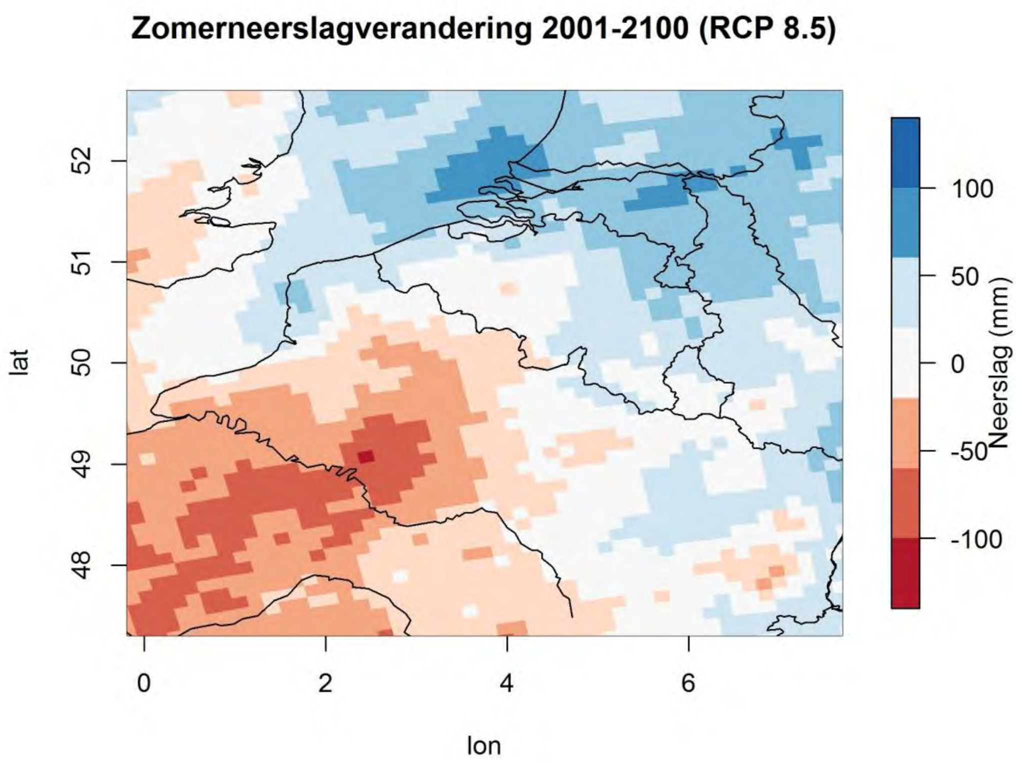


Figure 111: Predicted change in summer precipitation CNRM, RCP8.5

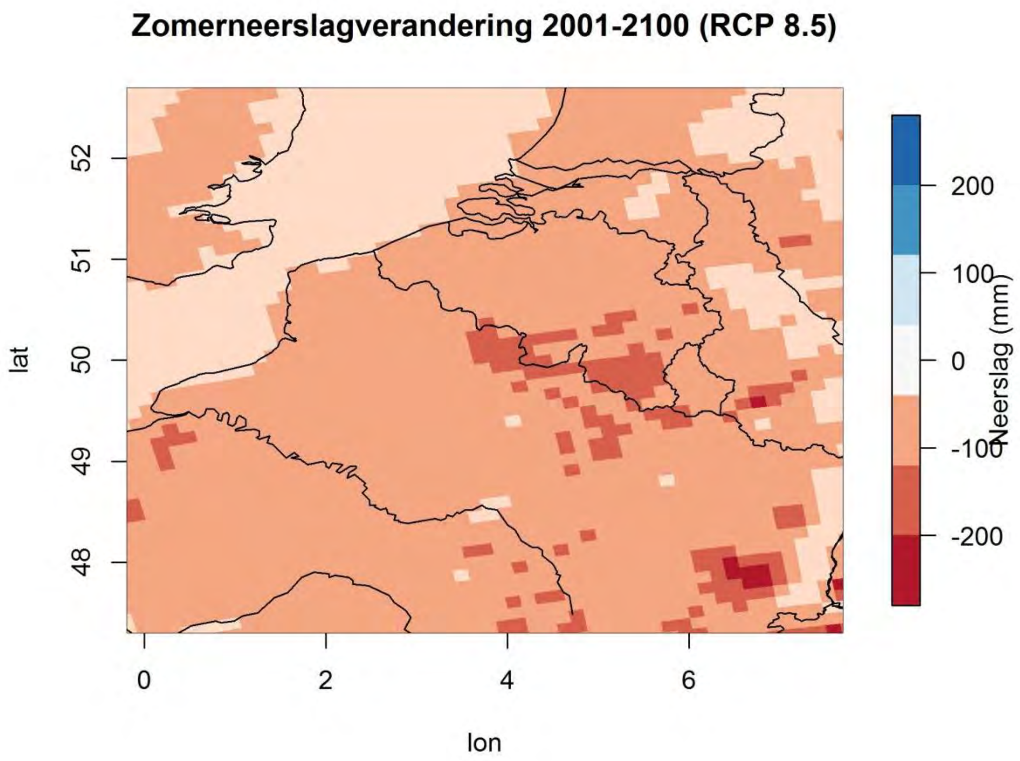


Figure 112: Predicted change in summer precipitation ICHEC, RCP8.5

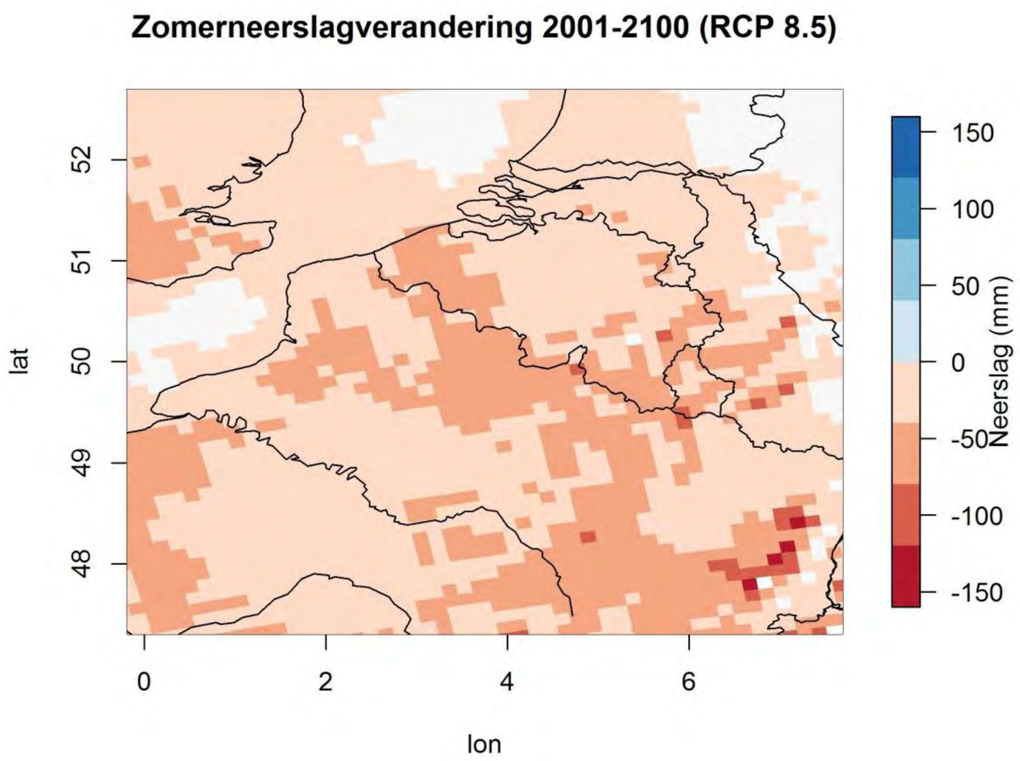


Figure 113: Predicted change in summer precipitation MOHC, RCP8.5

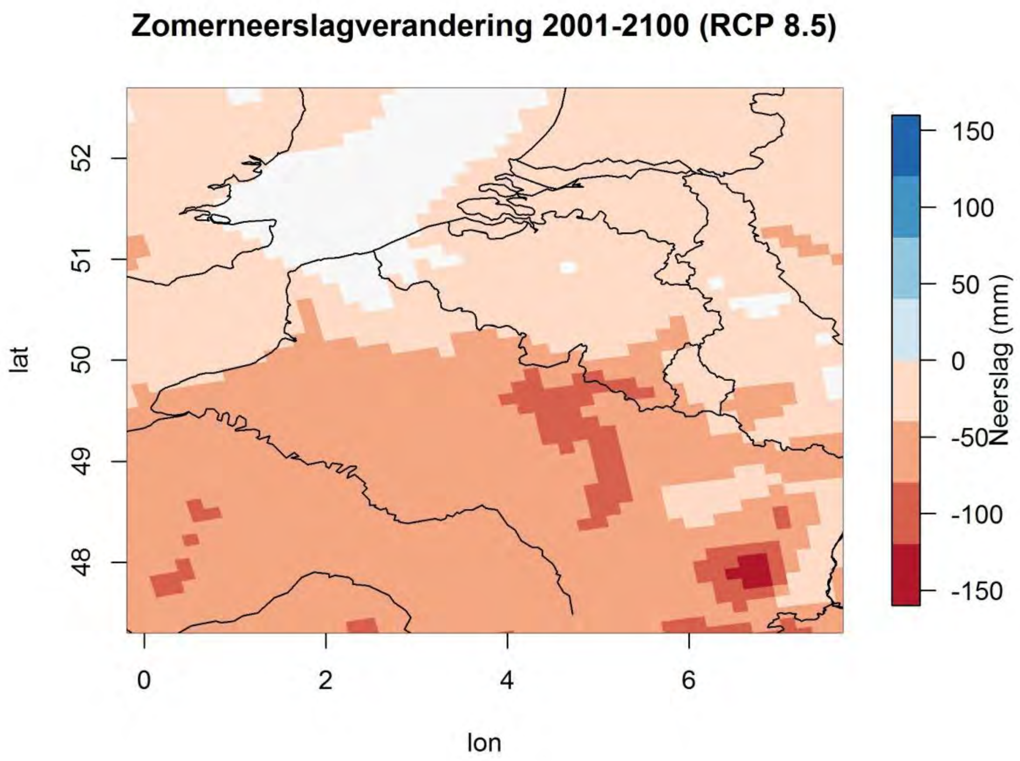


Figure 114: Predicted change in summer precipitation RACMO22E, RCP8.5