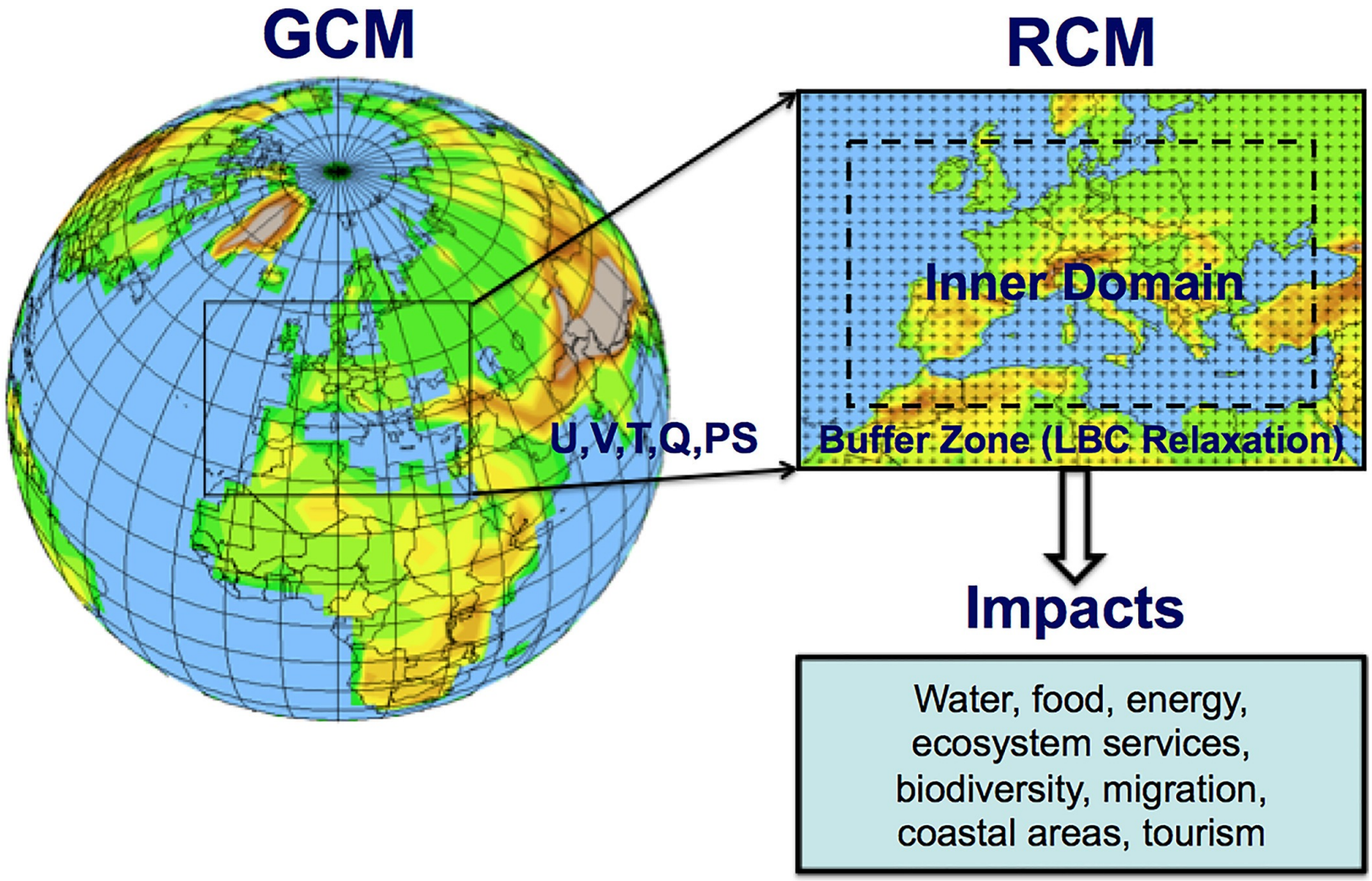
CLIM0026: Climate change in Belgium

Changements climatiques en français

1. Regional climate modelling



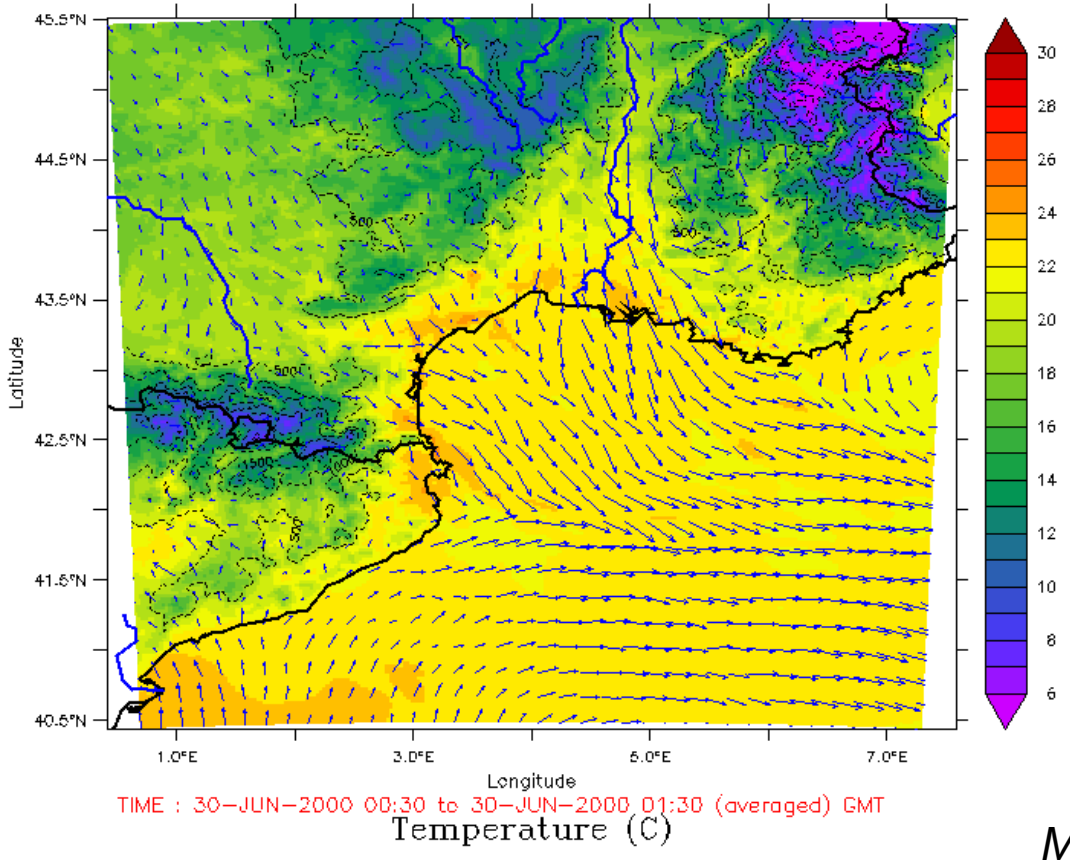
A RCM can be forced by

- "free" GCMs for performing **future projections** (IPCC),
- weather forecast global models (like GFS, ECMWF) for performing **forecast**,
- reanalysis (perfect GCM where observations are assimilated into) for performing **hindcast**

1. Regional climate modelling

Added values

1. The RCM physics and parameters can be tuned for a specific area/climate while the GCM physics needs to work well over each climate.
2. Higher spatial resolution for a reduced computer time allows to better take into account local circulations and processes.

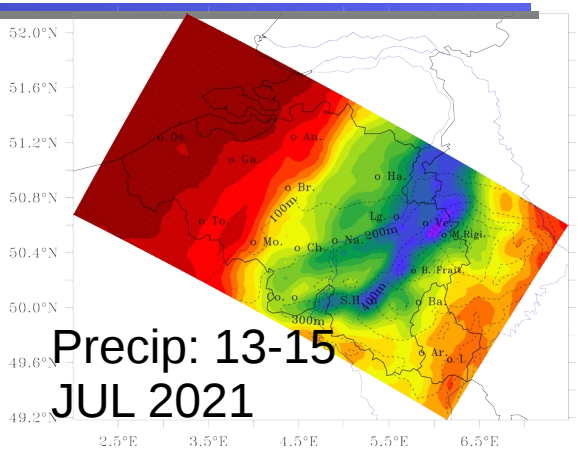


MAR forced by ERA5 and run at 2.5km

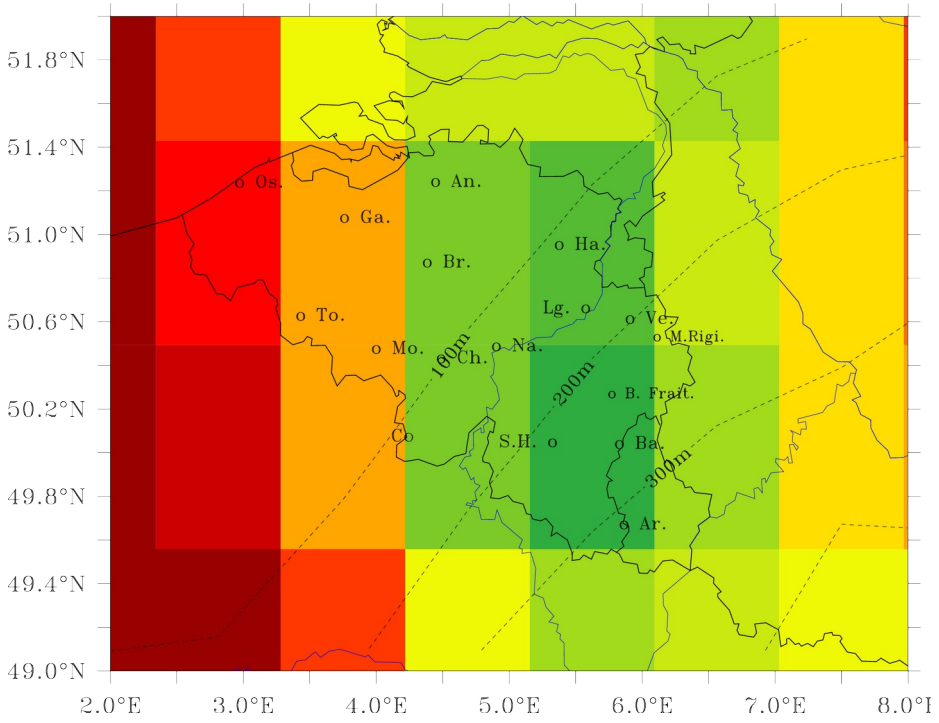
1. Regional climate modelling

Added values

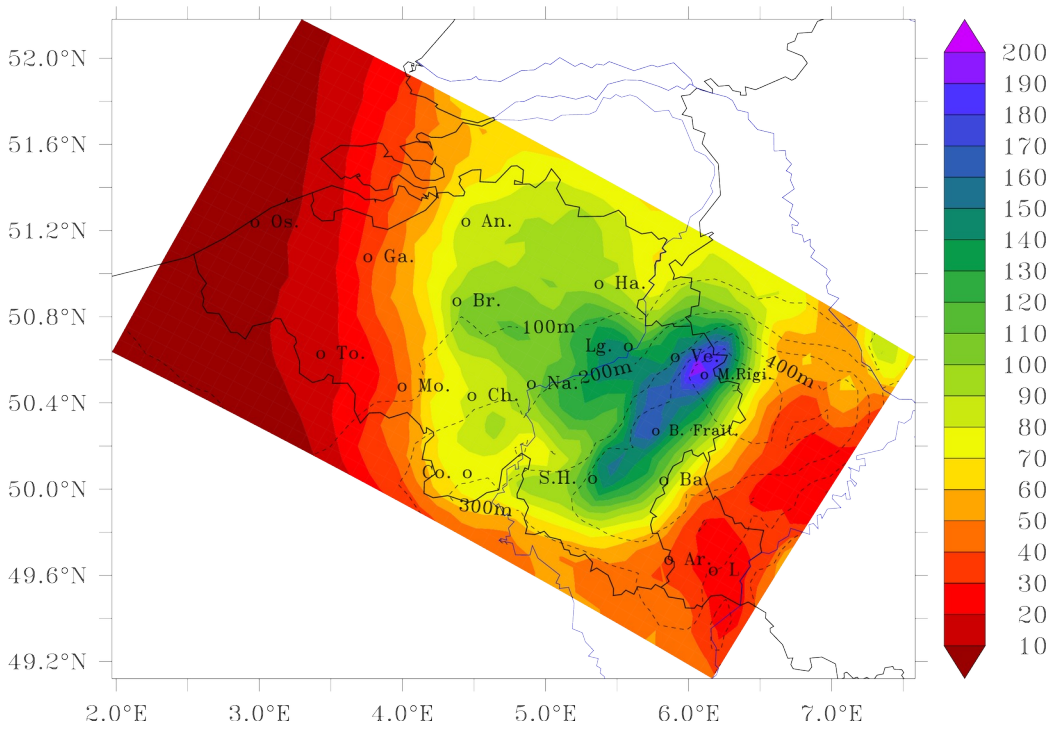
3. Simulation of (extreme) precipitation linked to local topography (barrier) or convective events.



Precip: 13-15 JUL 2021



Precipitation over 31 JUL – 02 AUG 2034 from MPI-ESM1-2-HR (ssp585)



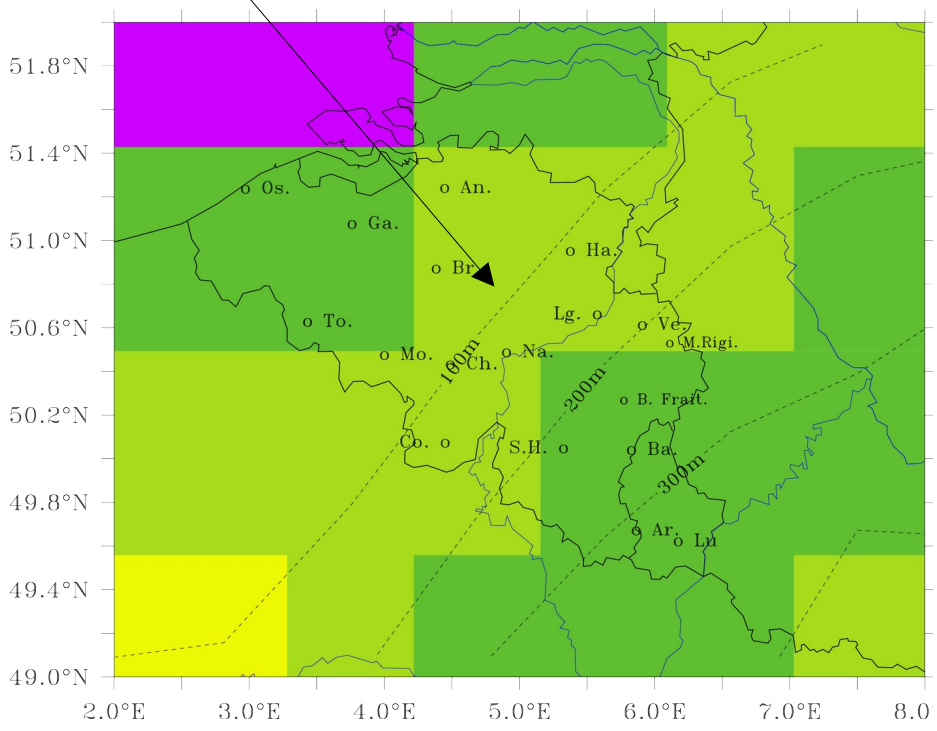
Precipitation over 31 JUL – 02 AUG 2034 from MAR forced by MPI-ESM1-2-HR (ssp585)

1. Regional climate modelling

Added values

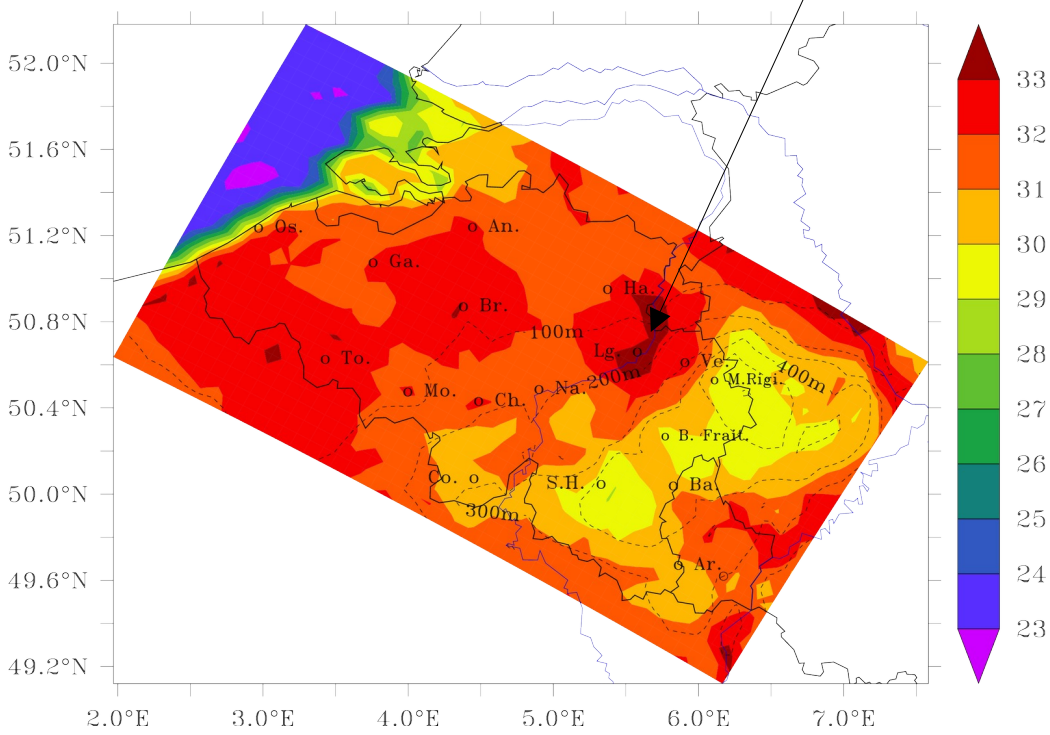
4. Heat waves, droughts, ... and links to complex land use + ability to correct GCM biases in the planetary boundary layer.

MPI-ESM1-2-HR is too cold



Tmax in Summer 2034
from MPI-ESM1-2-HR (ssp585)

urban heat island effect

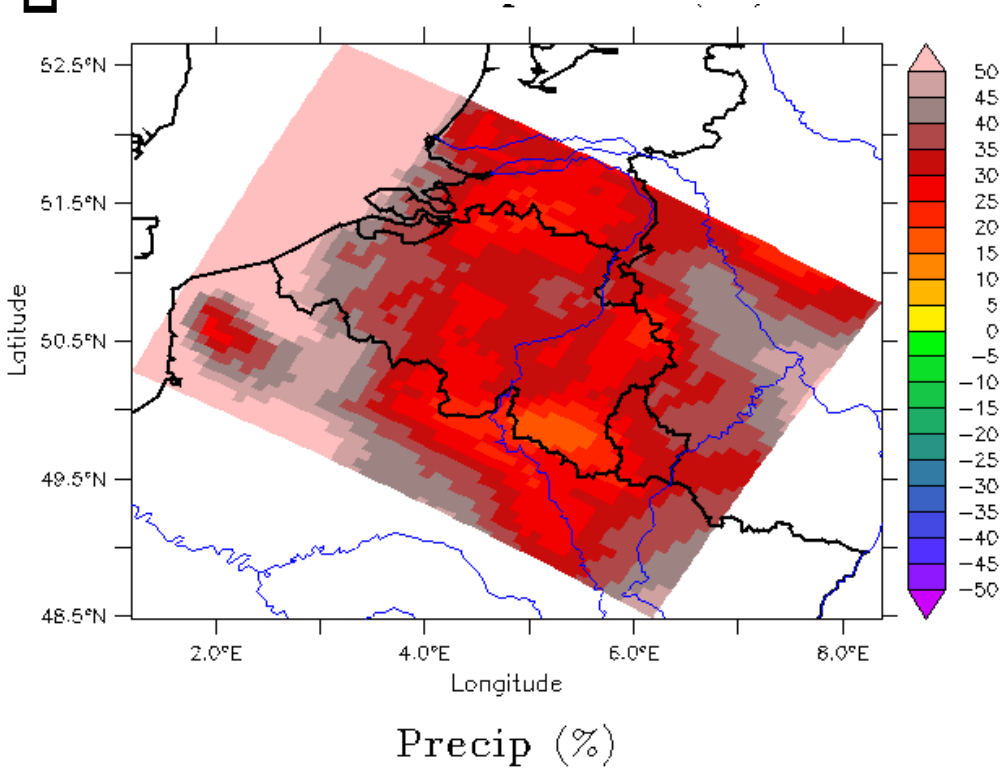


Tmax in Summer 2034
from MAR forced by MPI-ESM1-2-HR (ssp585)

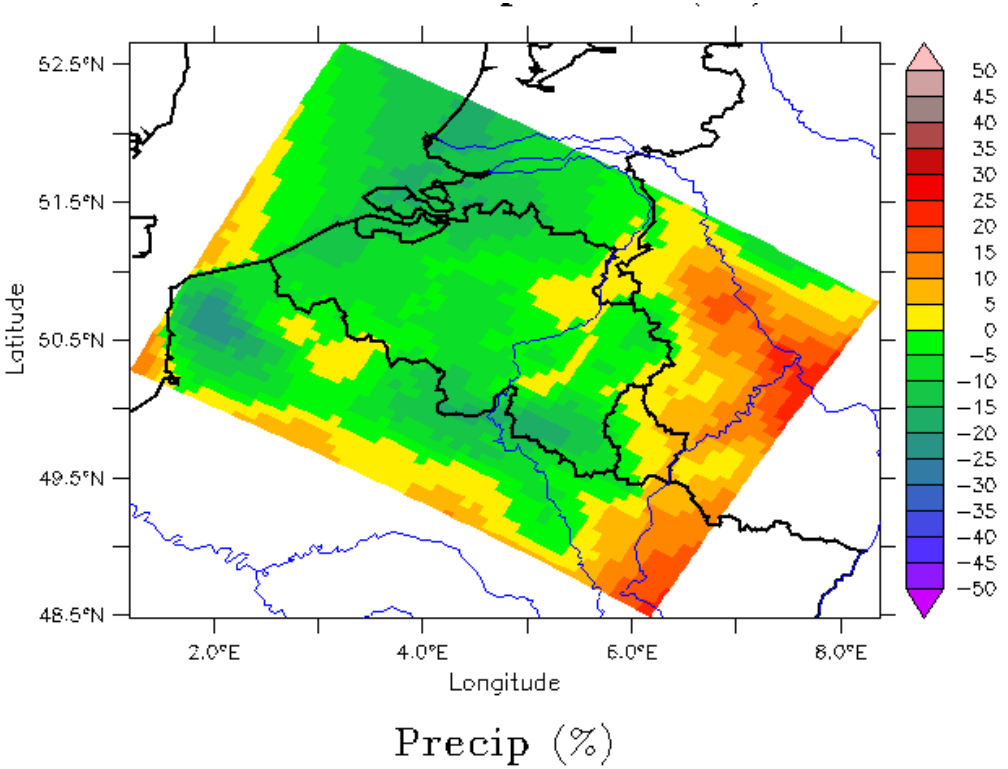
1. Regional climate modelling

Drawbacks

1. RCM is not able to correct large scale biases (general atmospheric circulation)



Amount of precipitation simulated
by MAR forced by MIROC6 (1981-2010)
vs
MAR forced by ERA5 (1981-2010)



Amount of precipitation simulated
by MAR forced by MIROC6 (1981-2010)
vs
MAR forced by ERA5 (1981-2010)

1. Regional climate modelling

4 Scénarios du GIEC

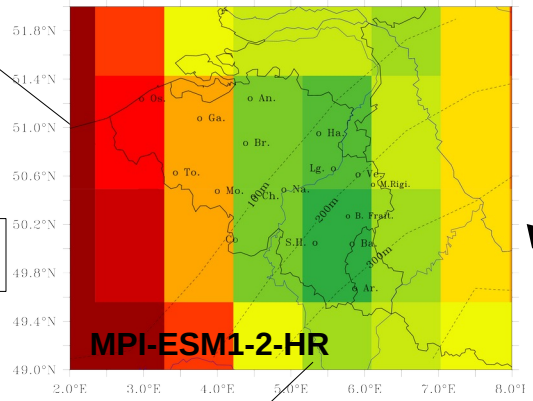
ssp126 | ssp245 | ssp370 | ssp585

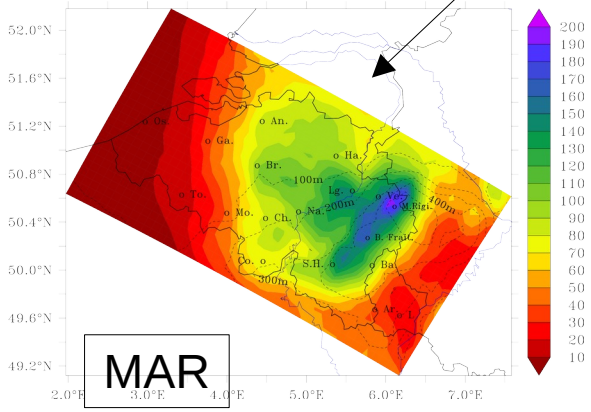
~30 GCMs

GCM1 | GCM2 | GCM3

MAR | MAR

Zoom over Belgium





<u>Selection</u> of GCM with respect to

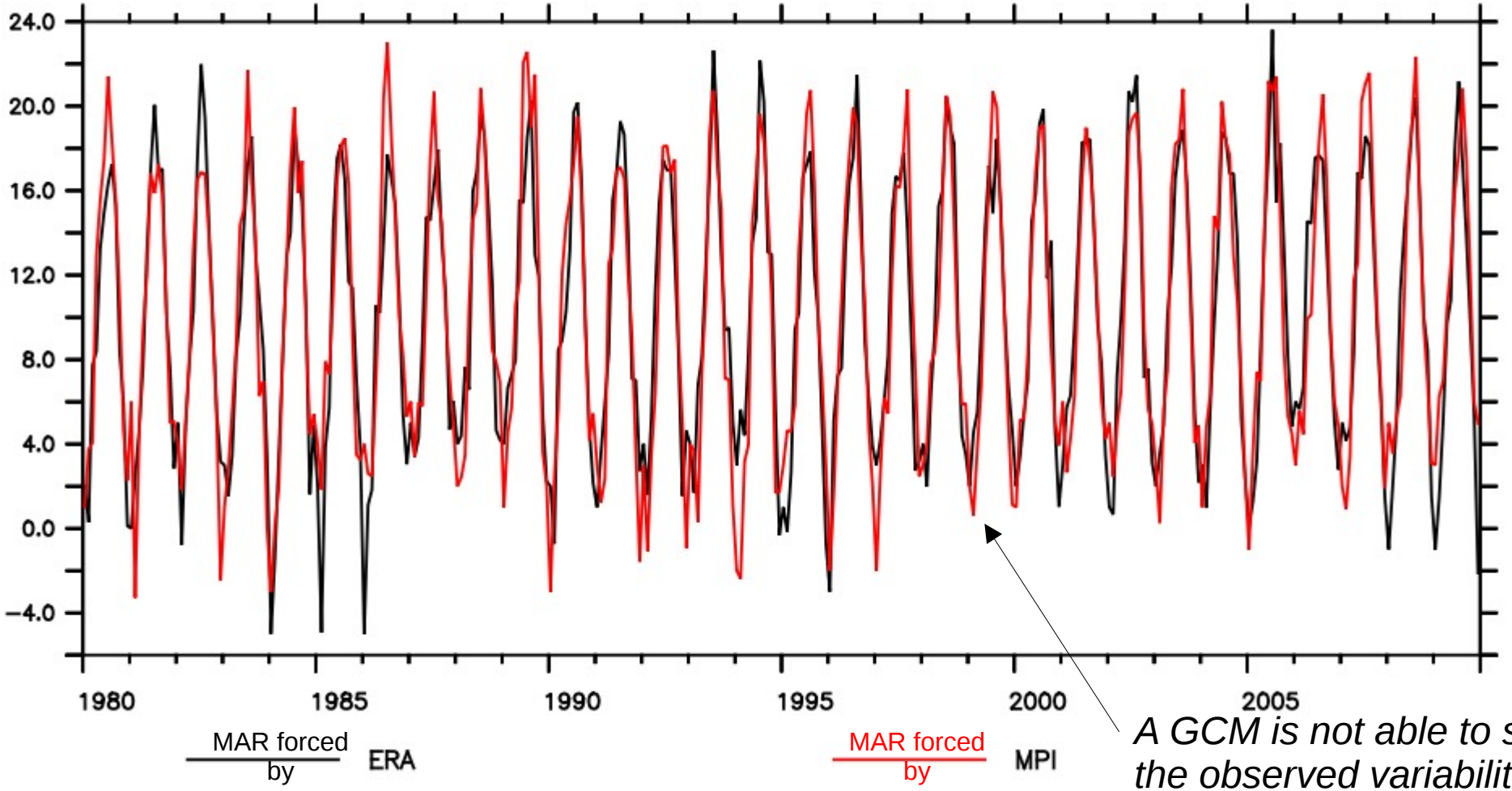
1. their ability to simulate current climate in the free atmosphere
2. their climate sensitivity
3. the availability of outputs

CORDEX Europe

GCM name	Run	Marks/Criteria	TCR Plausible range (1.2K-2.4K)
NorESM2-MM[15]	r1i1p1f1	1/17	1.33
MIROC6[16]	r1i1p1f1	1/20	1.55
MPI-ESM1-2-HR	r1i1p1f1	1/20	1.66
CNRM-ESM2-1	r1i1p1f2	1/19	1.86
CESM2[17]	r11i1p1f1	1/18	2.06
CMCC-CM2-SR5[18]	r1i1p1f1	1/15	2.09
IPSL-CM6A-LR[19]	r1i1p1f1	2/16	2.32
EC-Earth3-Veg[20]	r1i1p1f1	2/15	2.62
UKESM1-0-LL[21]	r1i1p1f2	2/19	2.79

2. Use of future projections: correction

You need 1st to (eventually) correct the model to have in **AVERAGE** over 1981-2010 for example the same climate than ERA5 (the observation).

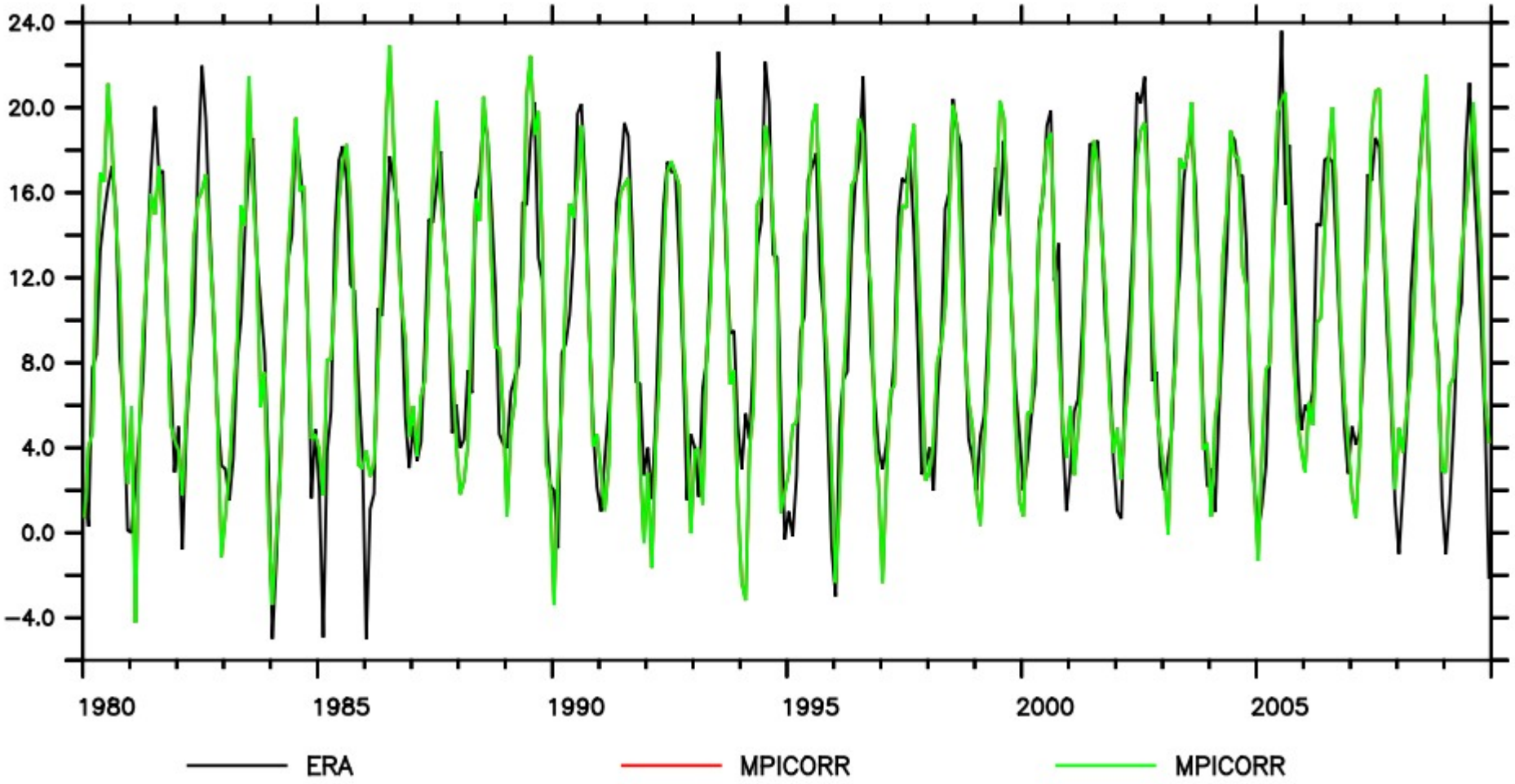


Raw monthly temperature for Gembloux.

A GCM is not able to simulate the observed variability but the average/std dev should be the same!

2. Use of future projections: correction

The same plot where ave(MPI)=ave(ERA) and std(MPI)=std(ERA) at the monthly time scale



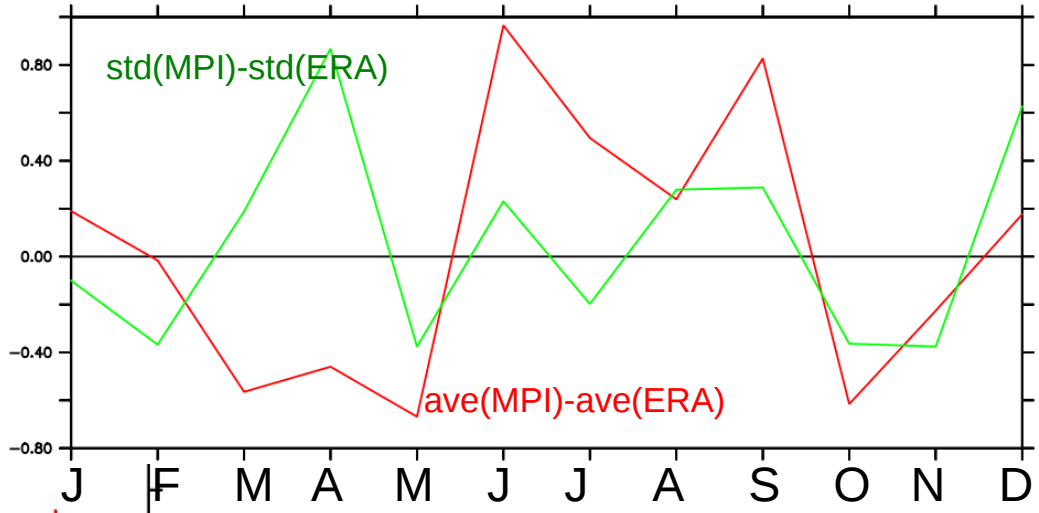
2. Use of future projections: correction

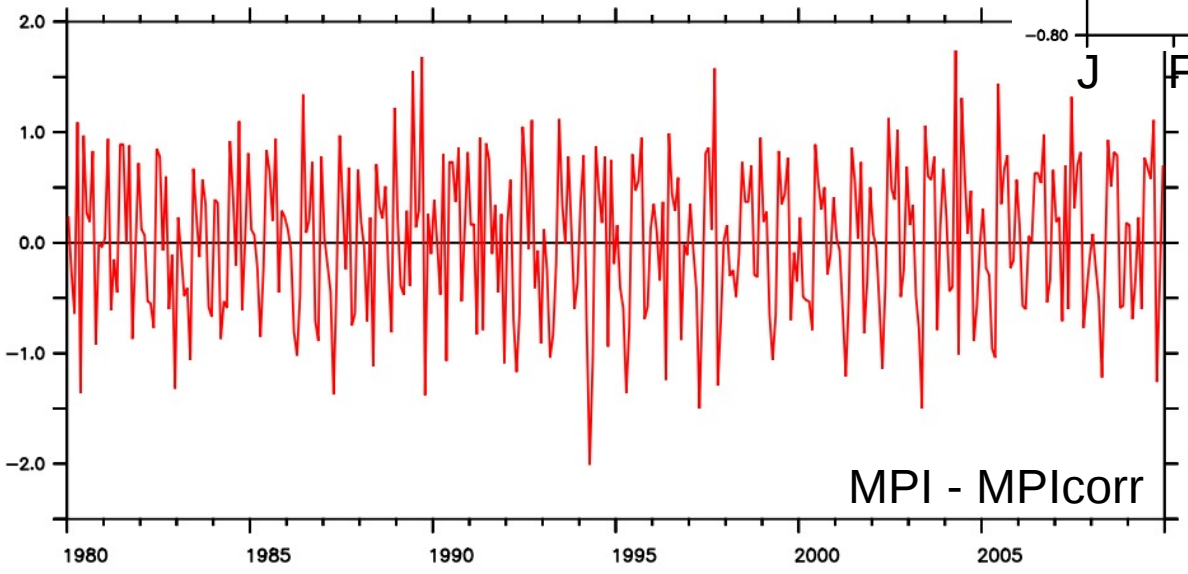
For each month:

MPIcorr = (MPI – ave(MPI))/std(MPI)*std(ERA)+ave(ERA)

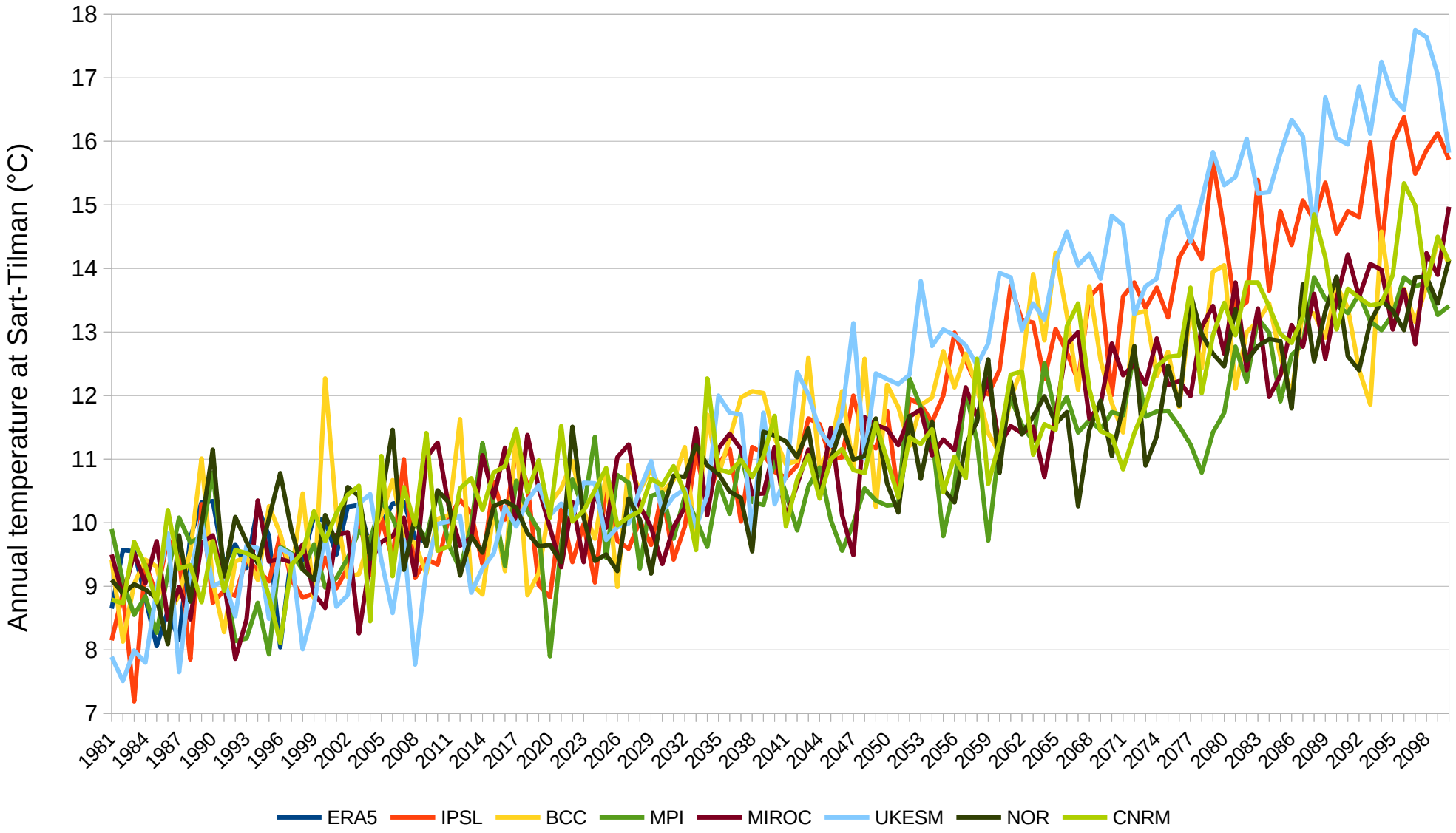
We assume that the biases remain constant in time!

Some times, the correction of STD could enhance the changes and it is not recommanded in this case





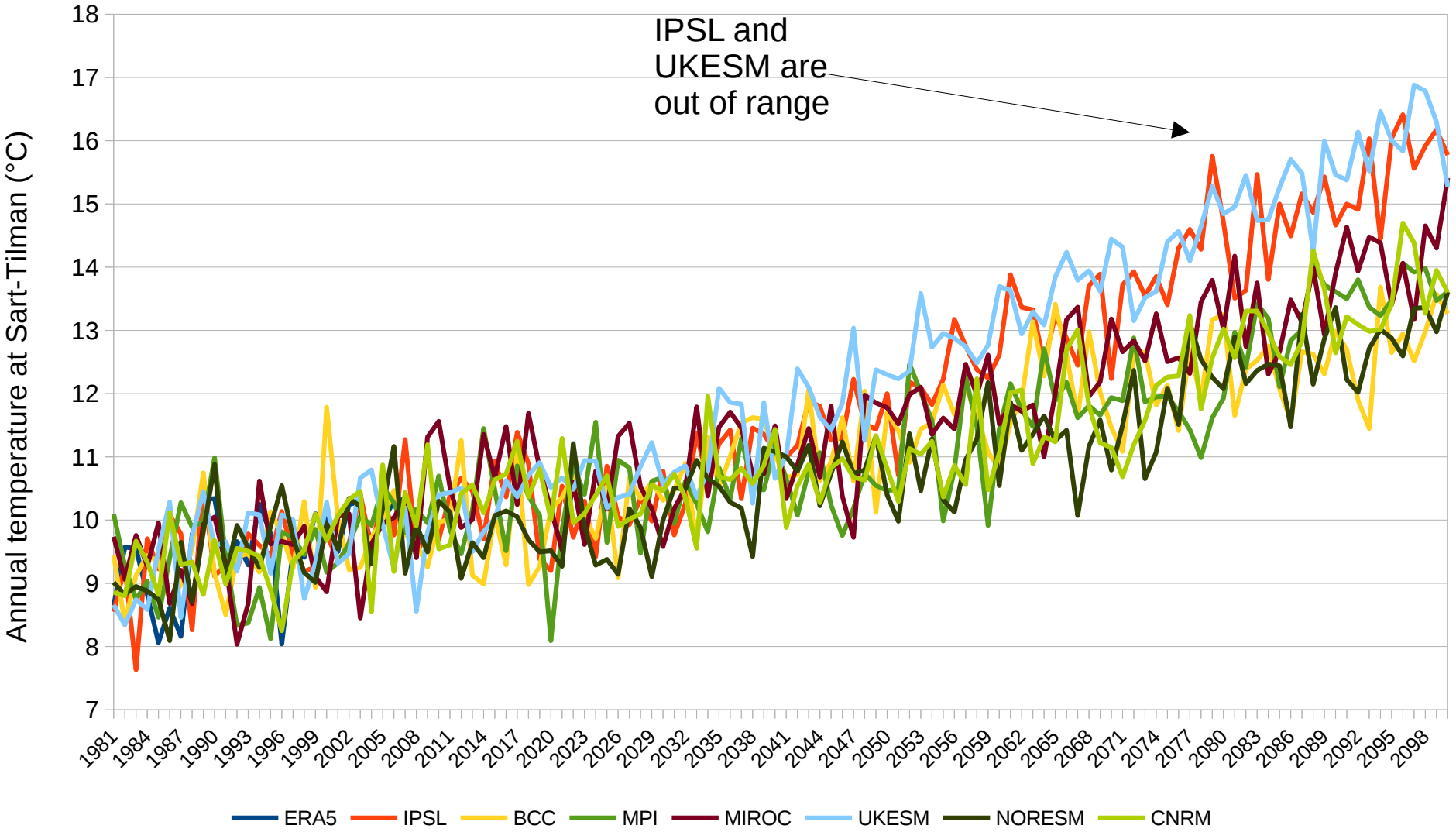
2. Use of future projections: ensemble



Raw outputs for the Sart-Tilman pixel

2. Use of future projections: ensemble

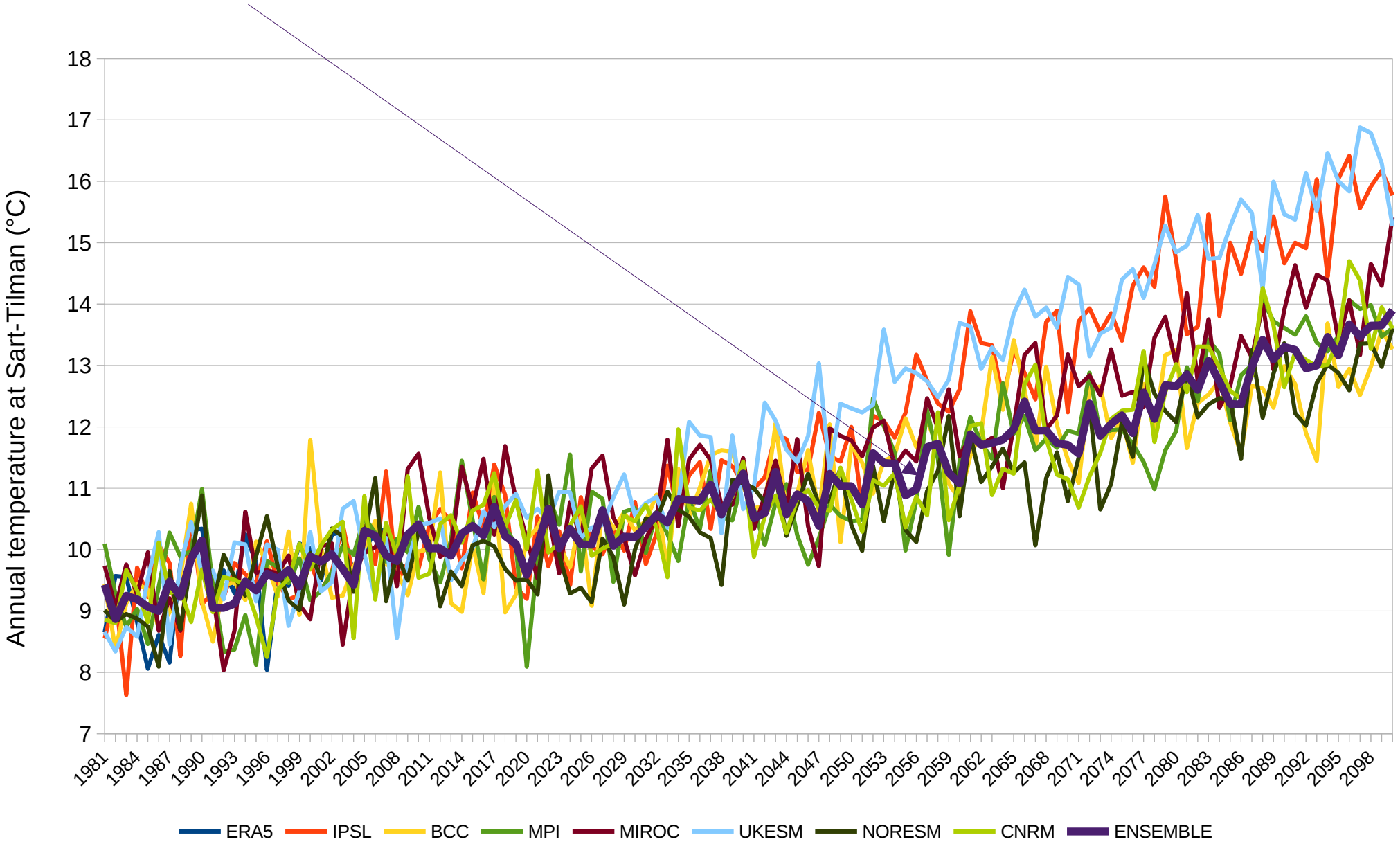
The ensemble mean should be computed over BCC, MPI, MIROC, NORESM and CNRM



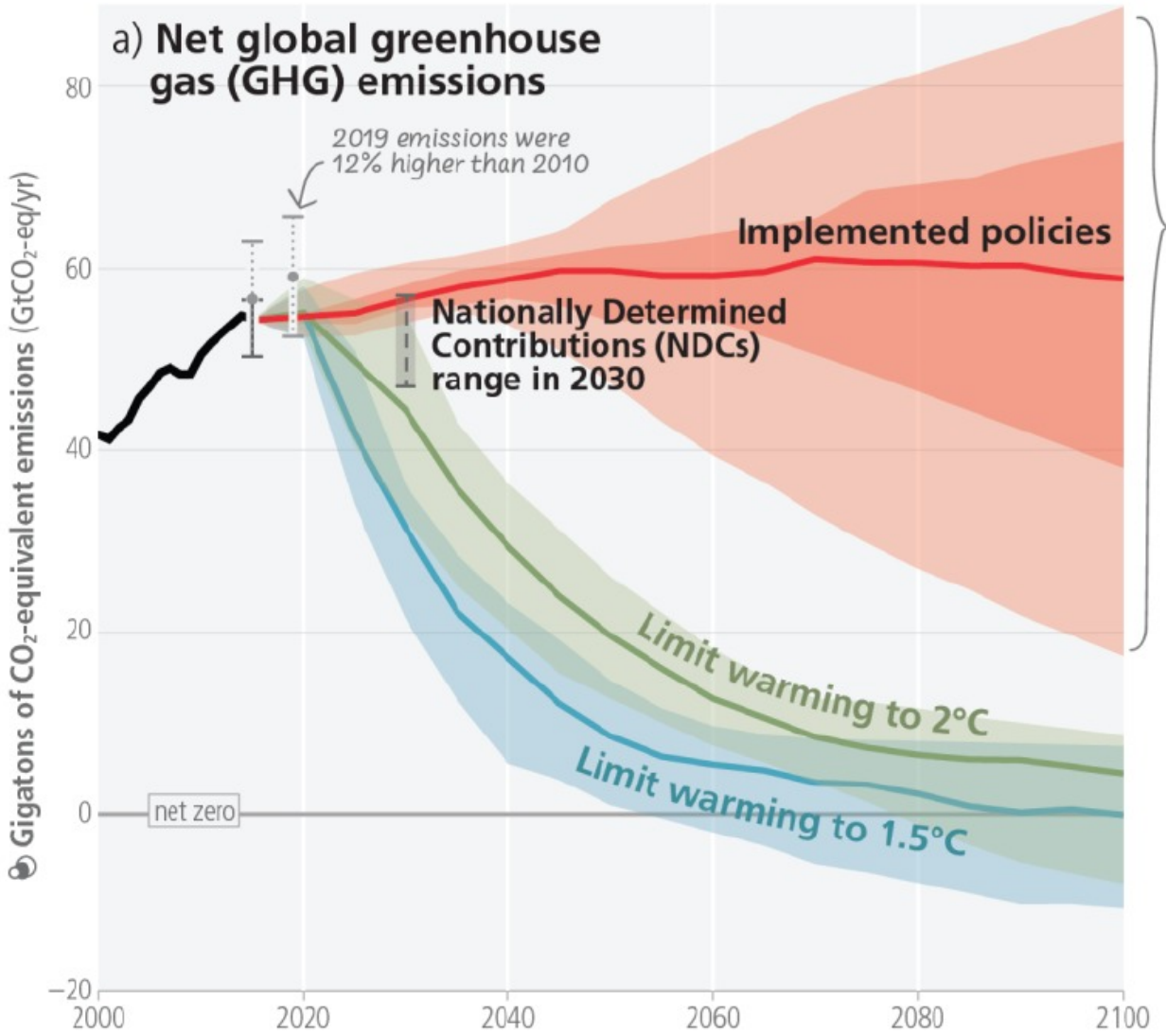
Same with ave/std = to ERA over 1981-2010

2. Use of future projections: ensemble

The **ensemble mean** should be computed over BCC, MPI, MIROC, NORESM and CNRM



3. Future change in Belgium



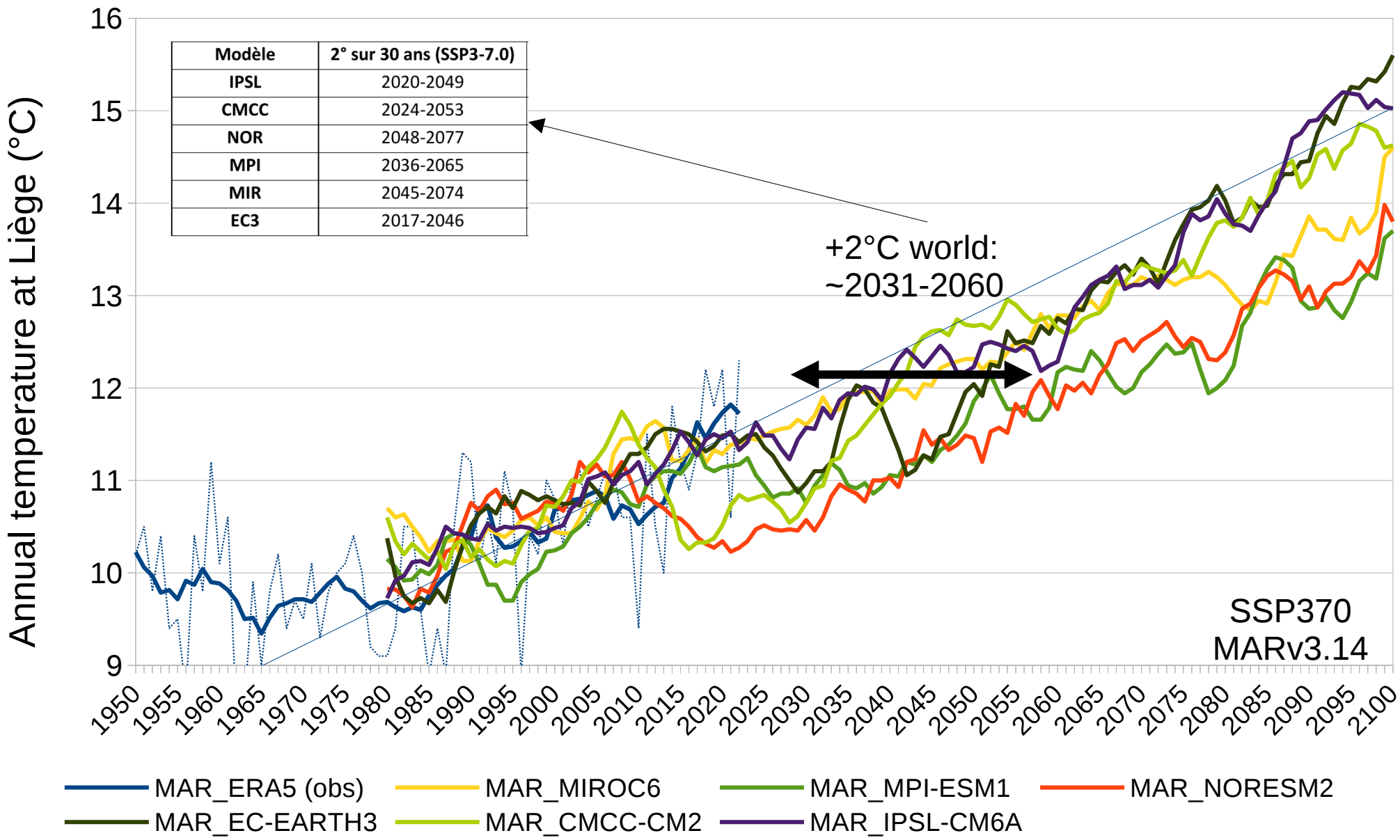
The current more likely scenario is between SSP245 and SSP**370**. Results of **SSP370** will be shown hereafter.

Implemented policies result in projected emissions that lead to warming of 3.2°C, with a range of 2.2°C to 3.5°C (medium confidence)

Key

- Implemented policies (median, with percentiles 25-75% and 5-95%)
- Limit warming to 2°C (>67%)
- Limit warming to 1.5°C (>50%) with no or limited overshoot
- Past emissions (2000–2015)
- Model range for 2015 emissions
- Past GHG emissions and uncertainty for 2015 and 2019 (dot indicates the median)

3. Future changes in Belgium (in a +2°C world)



Modèle	2° sur 30 ans (SSP3-7.0)
IPSL	2020-2049
CMCC	2024-2053
NOR	2048-2077
MPI	2036-2065
MIR	2045-2074
EC3	2017-2046

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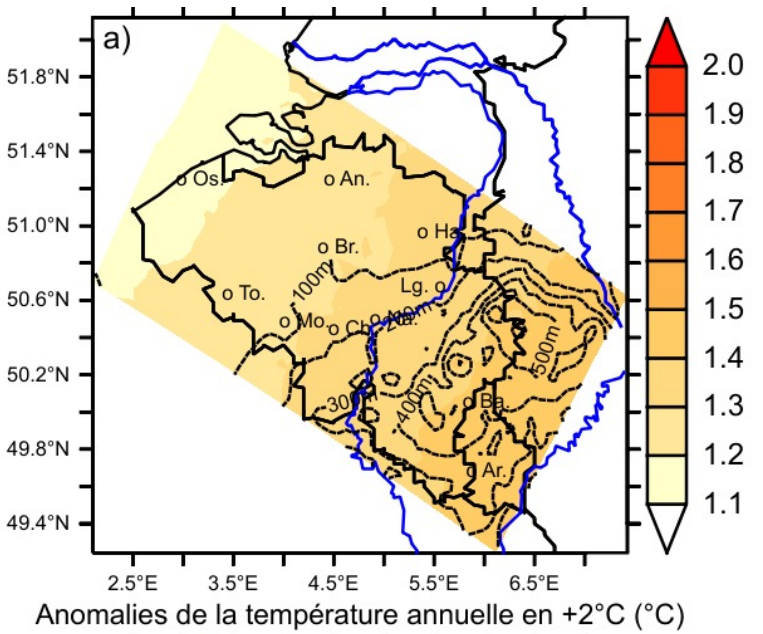
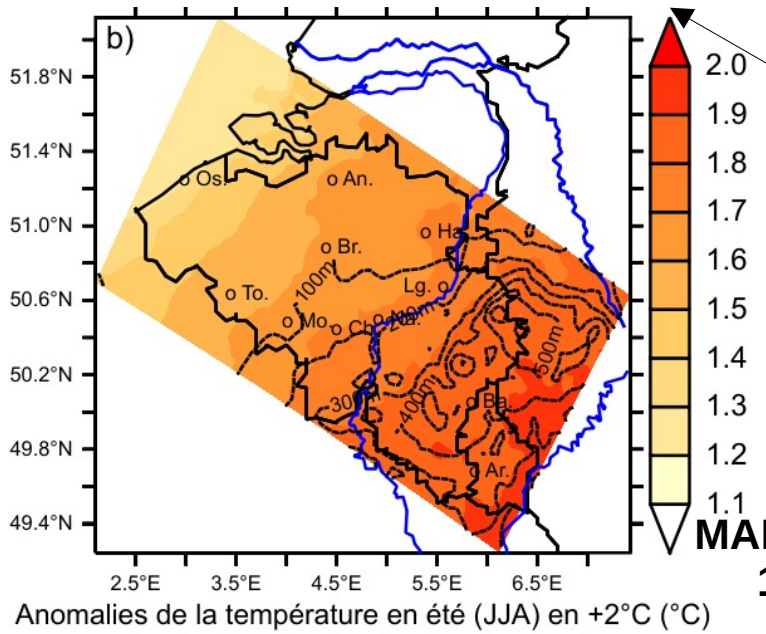


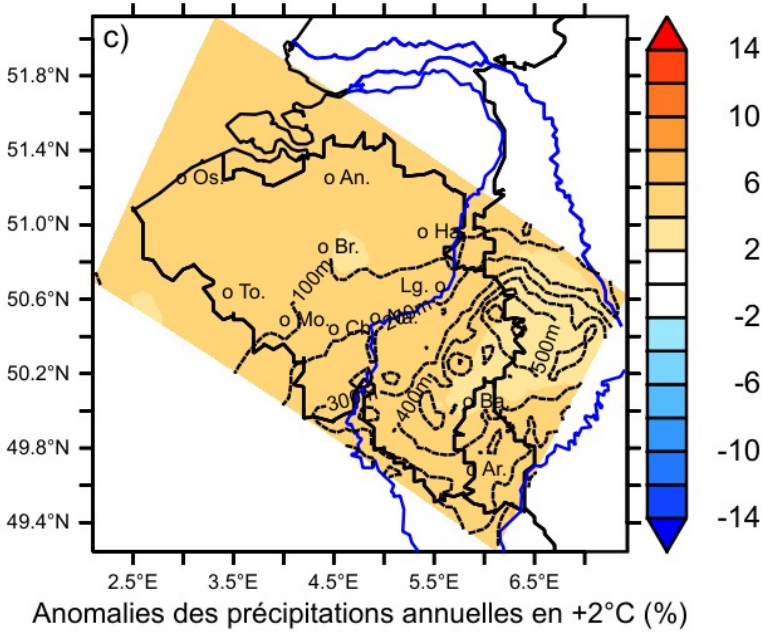
Anomalies de la température annuelle en +2°C (°C)



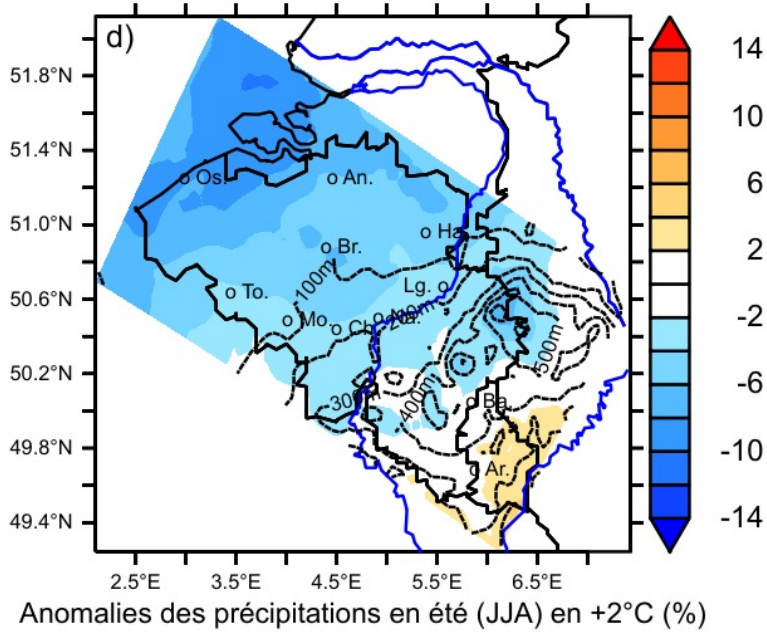
Anomalies de la température en été (JJA) en +2°C (°C)

+1.3°C vs 1850-1900

MAR Reference: 1981-2010



Anomalies des précipitations annuelles en +2°C (%)



Anomalies des précipitations en été (JJA) en +2°C (%)

Ensemble mean of 6 forcing ESMs

SSP370: ~2031-2060

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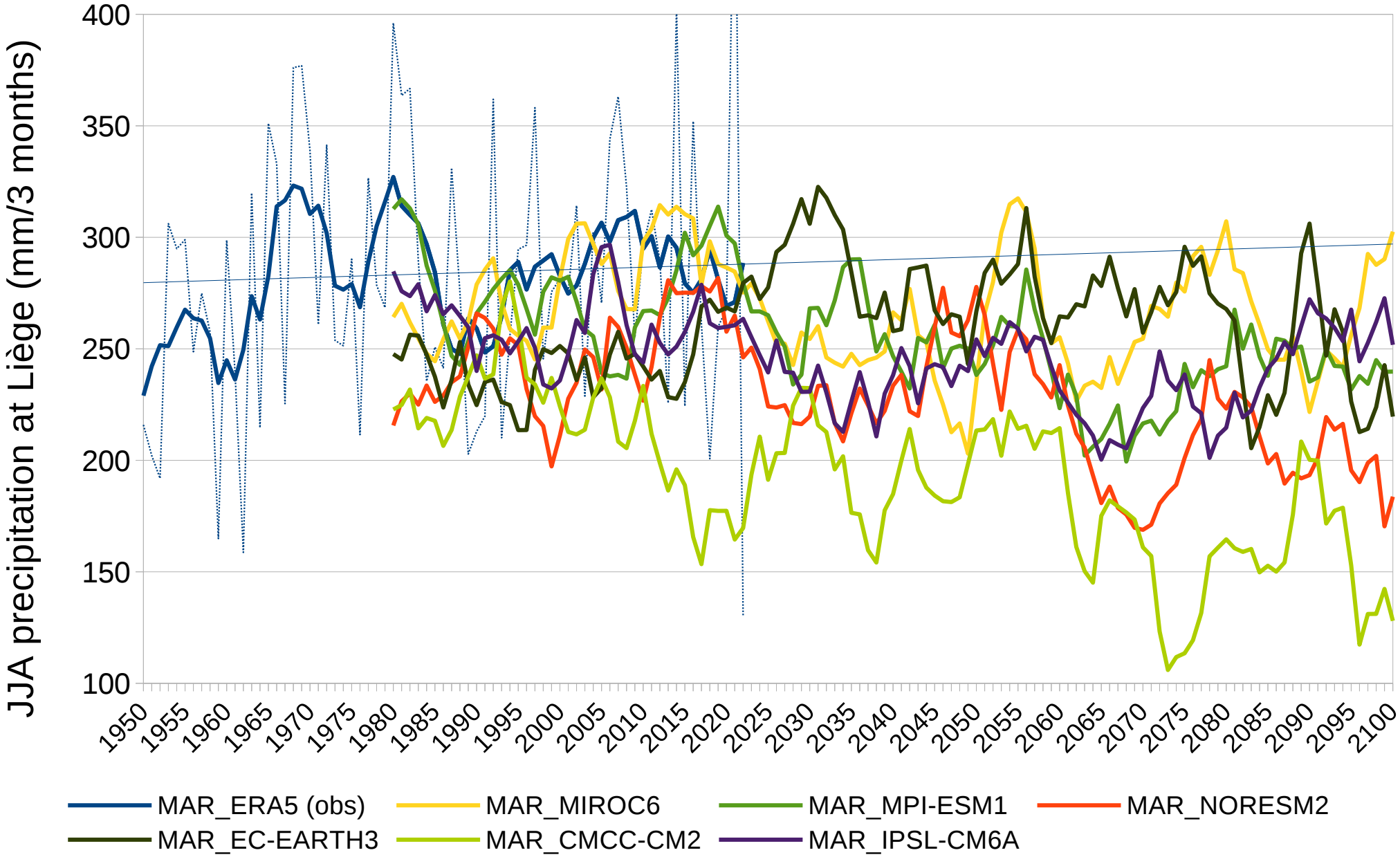

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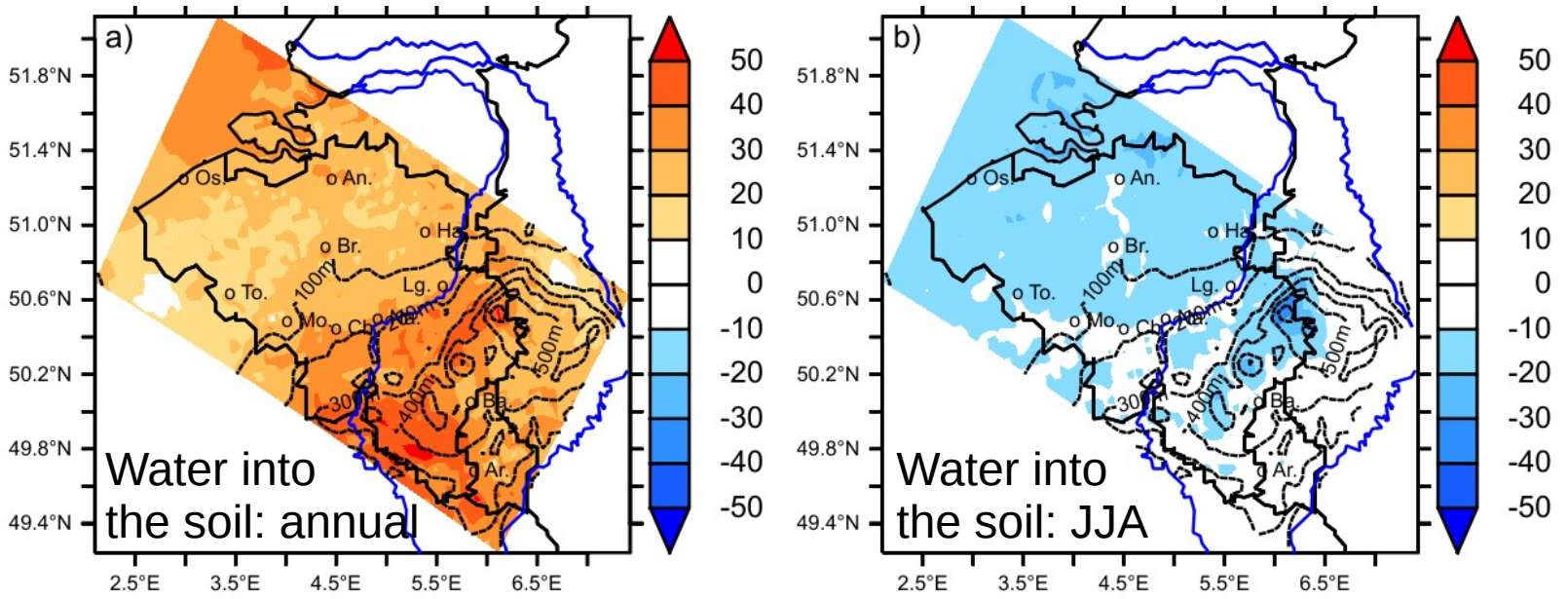

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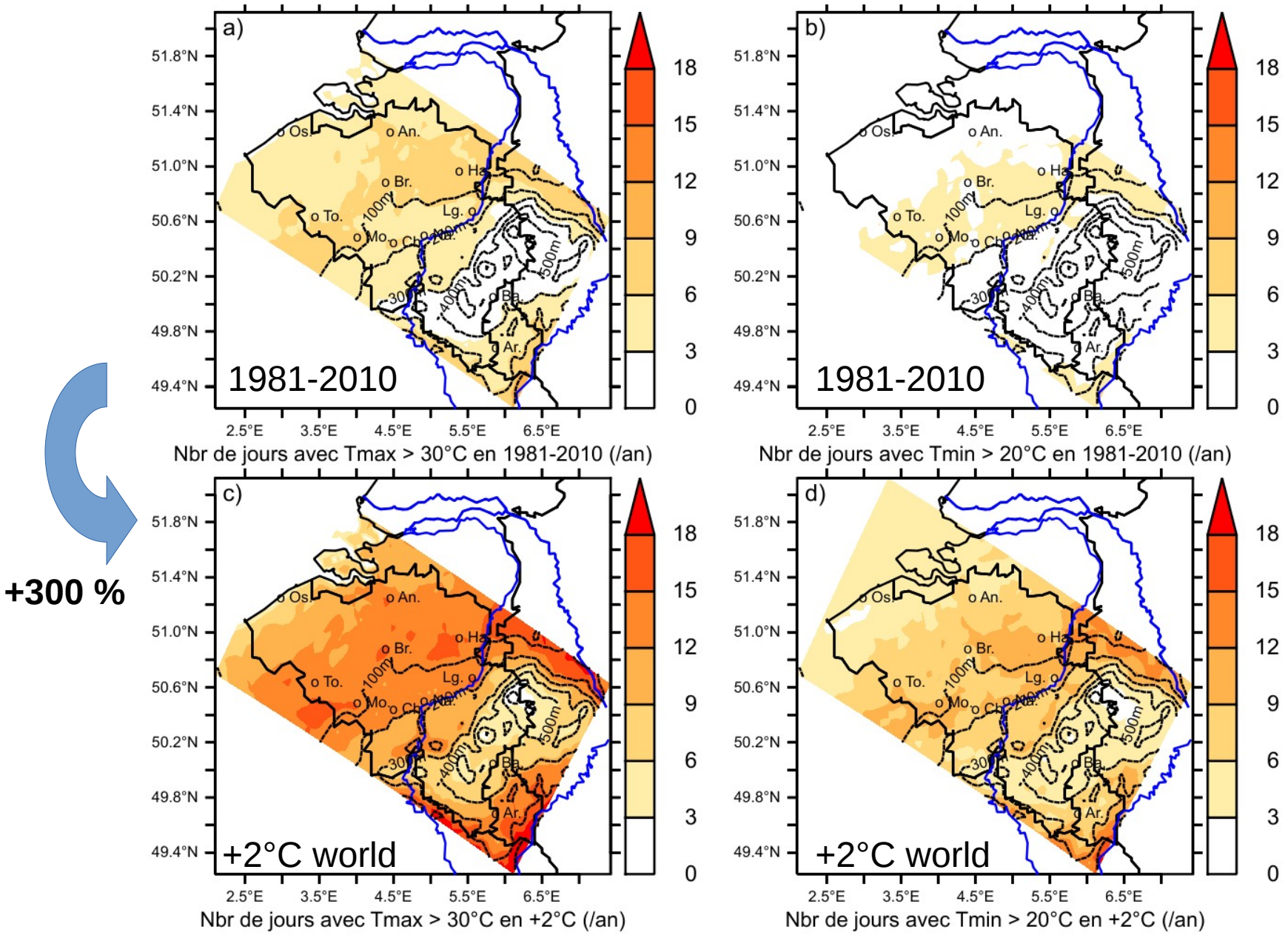
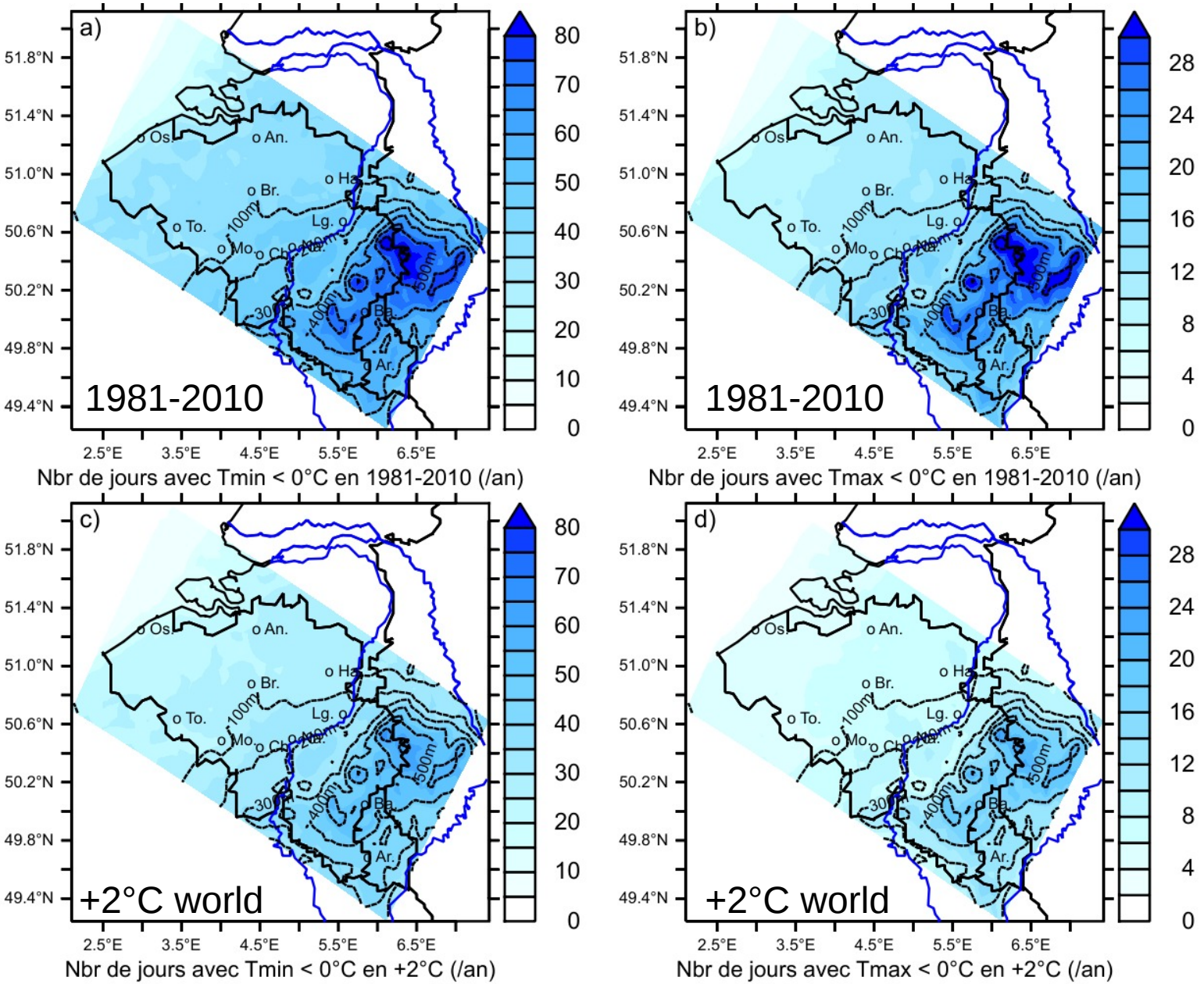
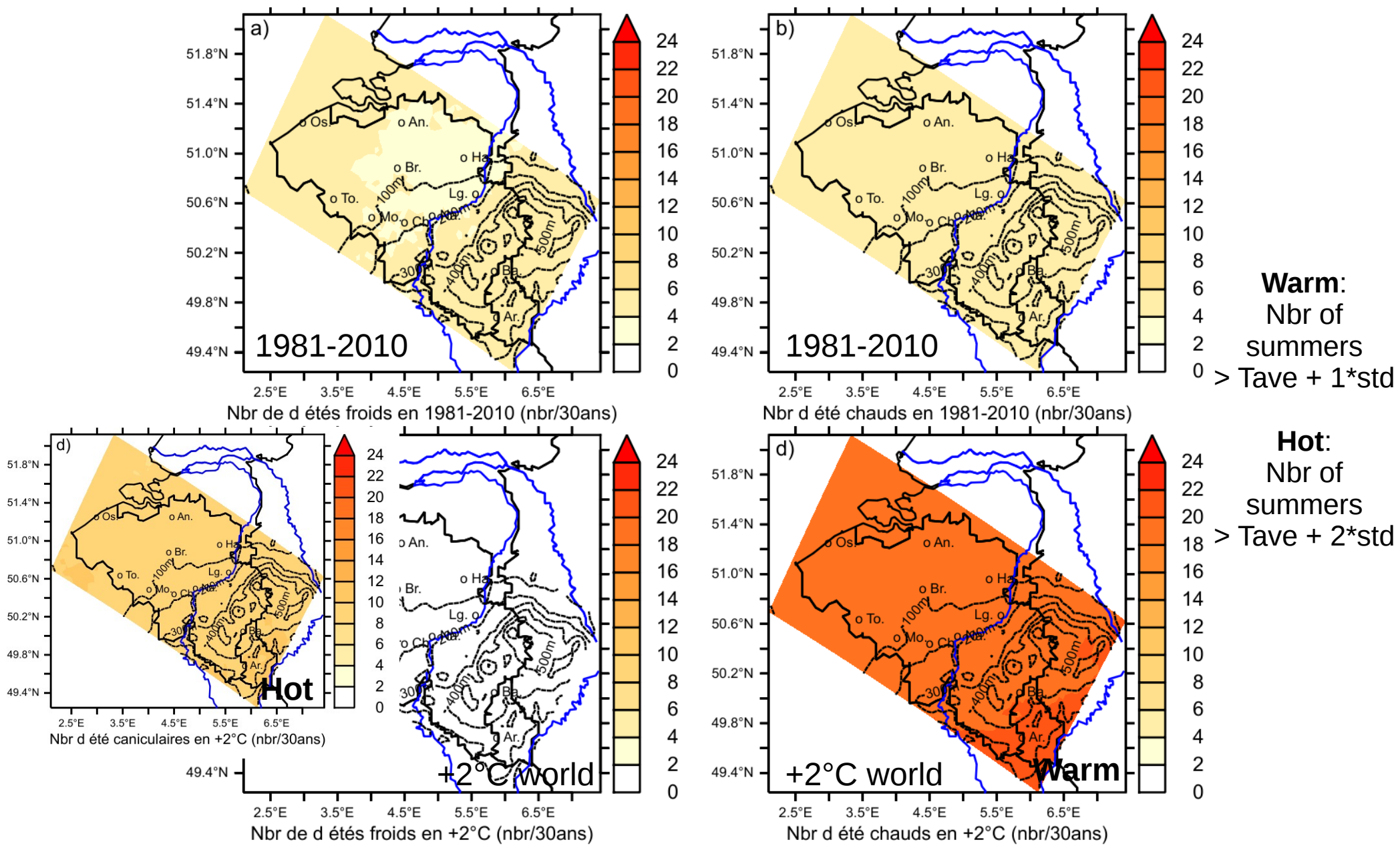


3. Future changes in Belgium (in a +2°C world)



-30-50 %

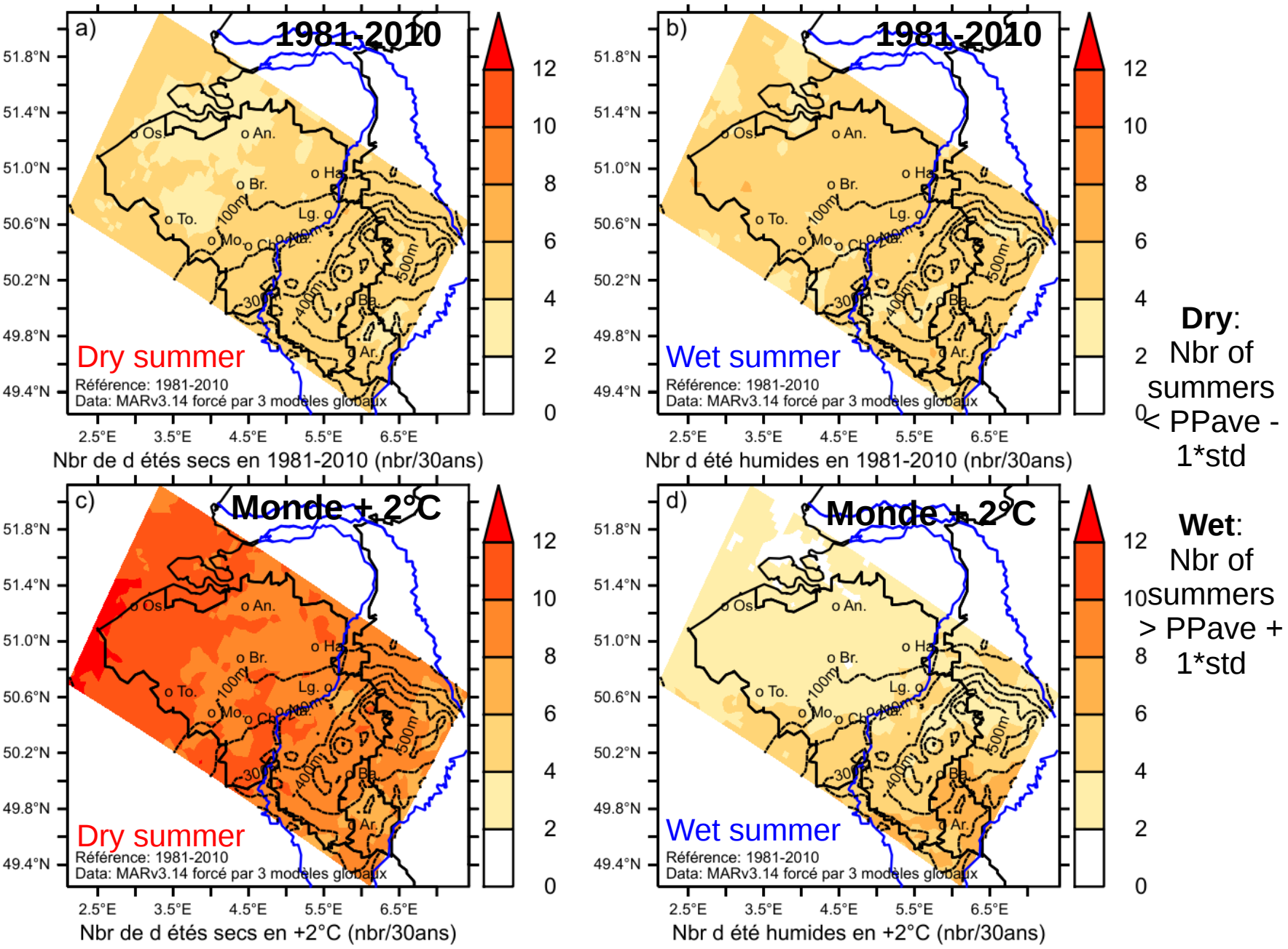
3. Future changes in Belgium (in a +2°C world)



Warm: Nbr of summers > Tave + 1*std

Hot: Nbr of summers > Tave + 2*std

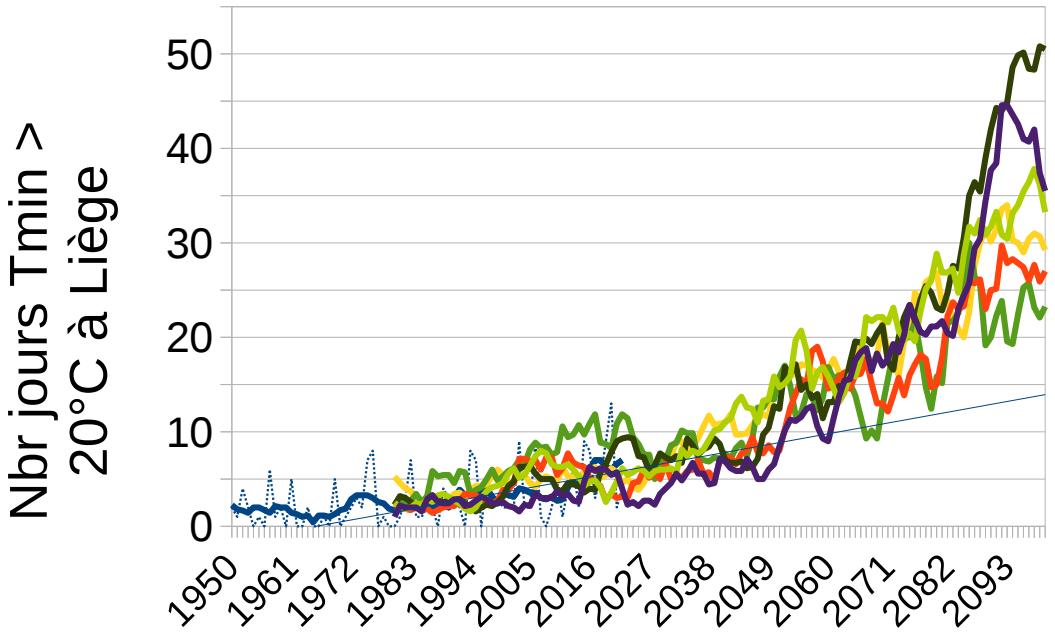
3. Future changes in Belgium

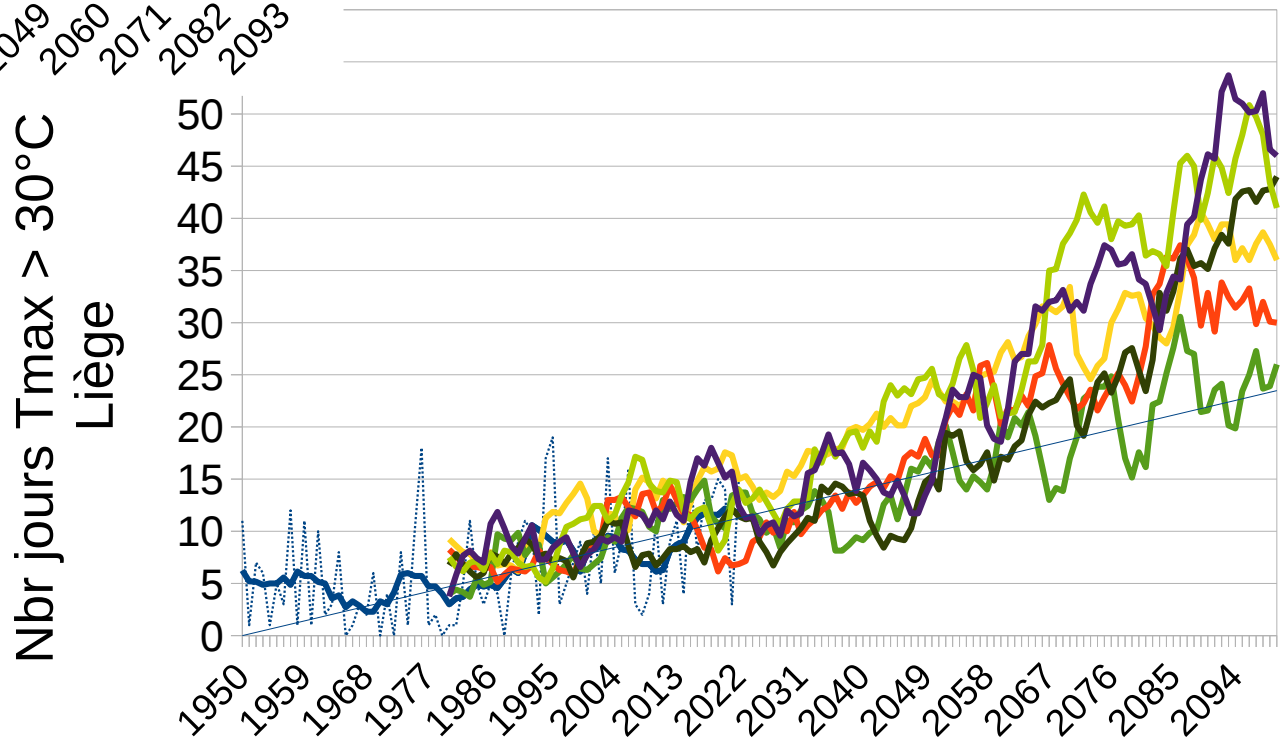


Dry: Nbr of summers < PPave - 1*std

Wet: Nbr of summers > PPave + 1*std

3. Future changes in Belgium





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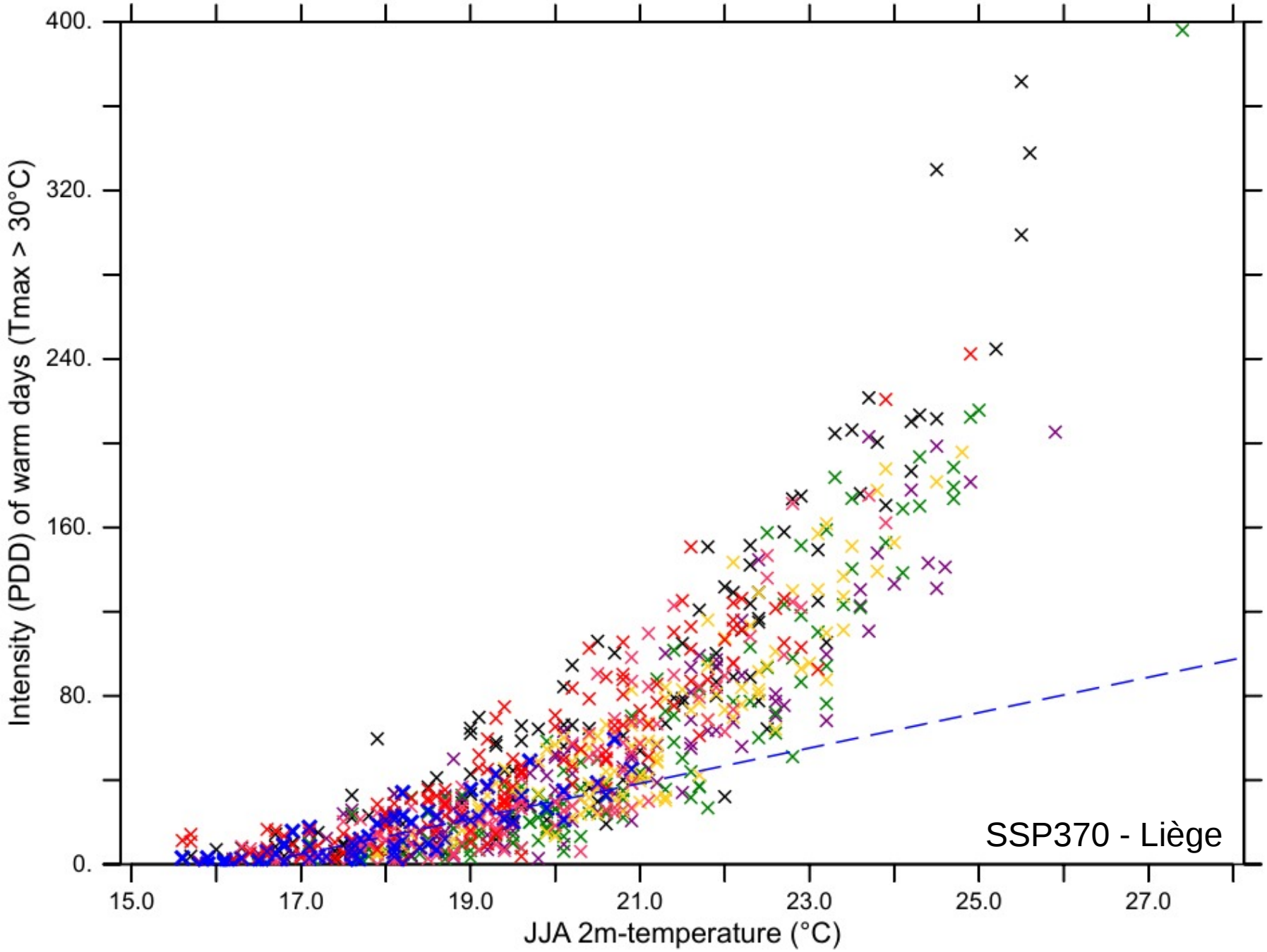

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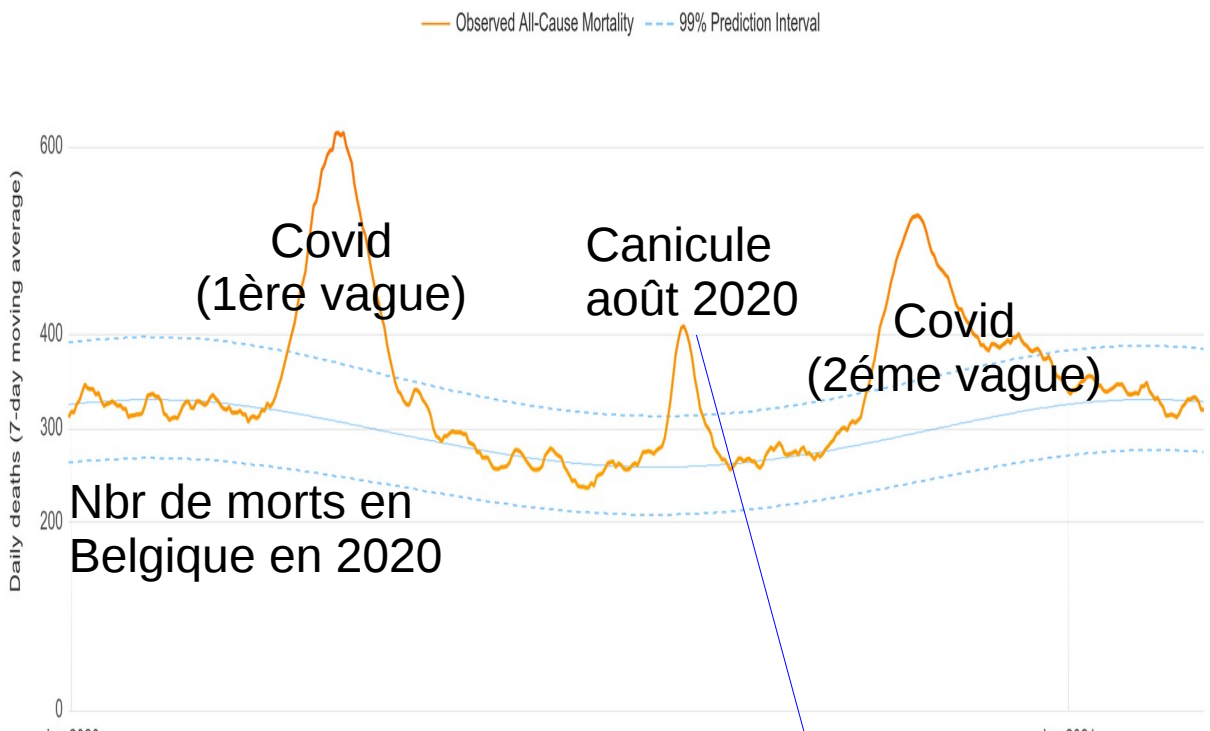
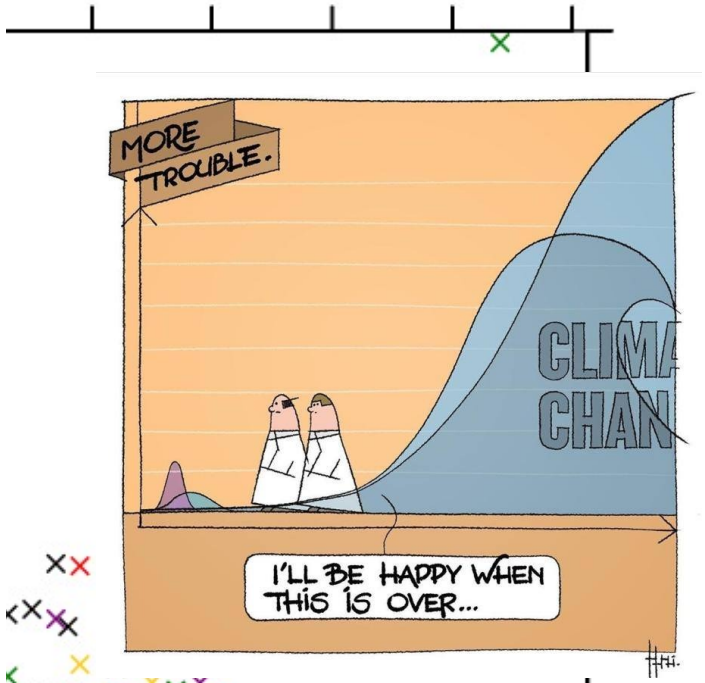
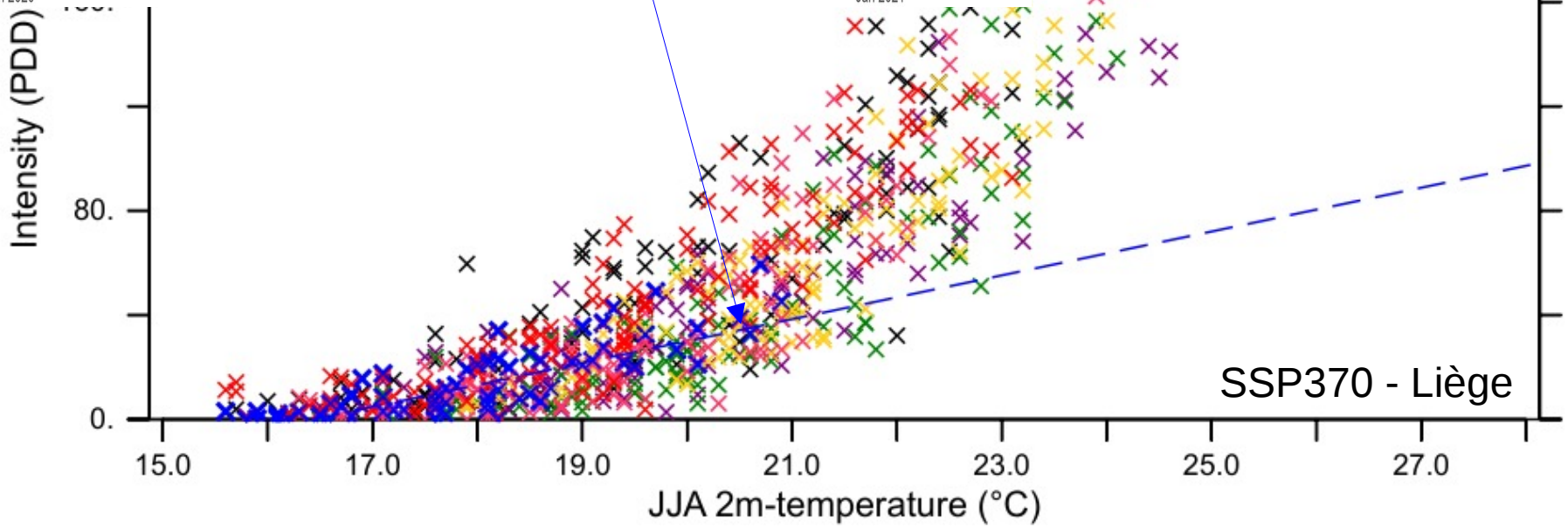
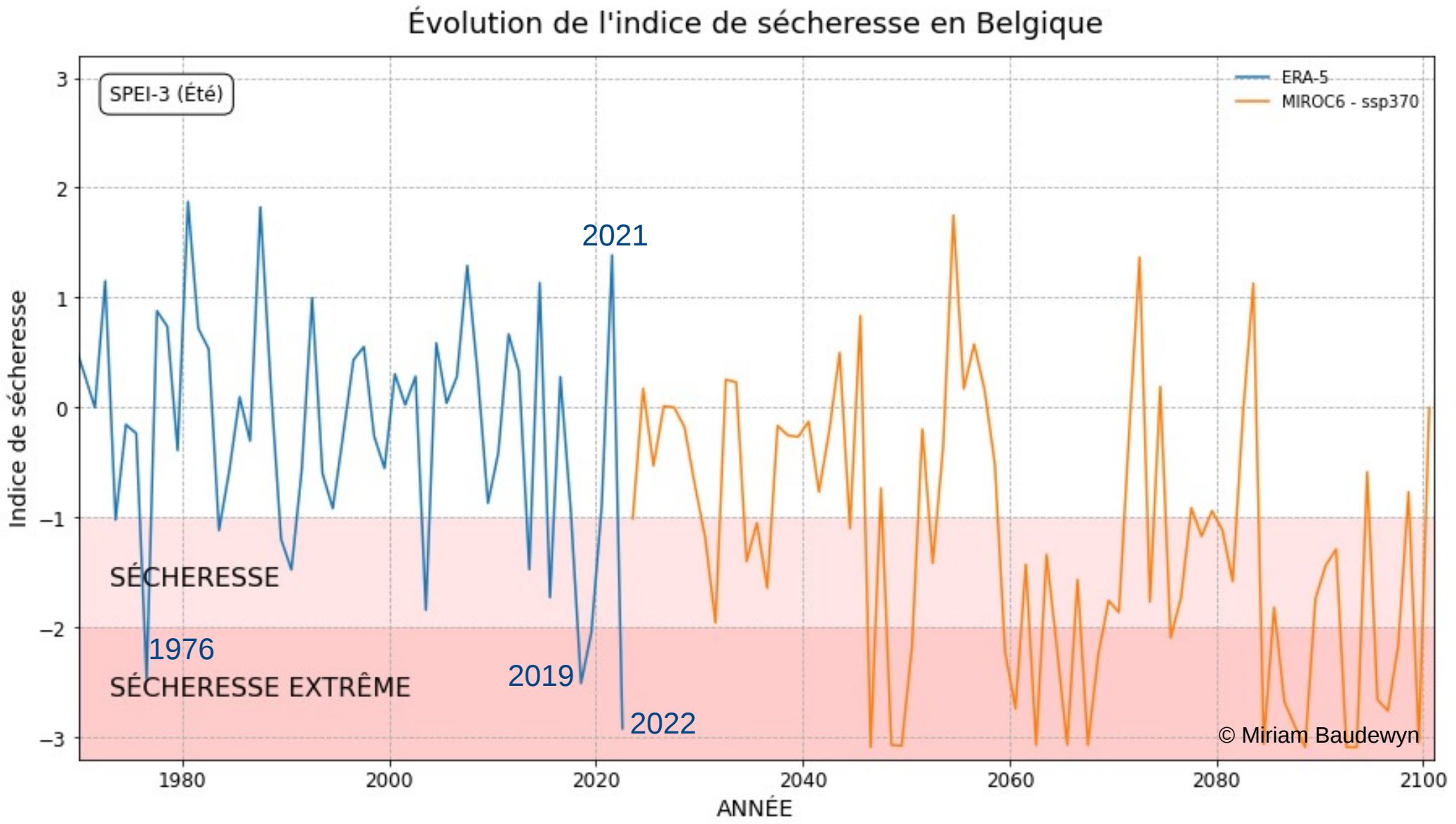






3. Future changes in Belgium



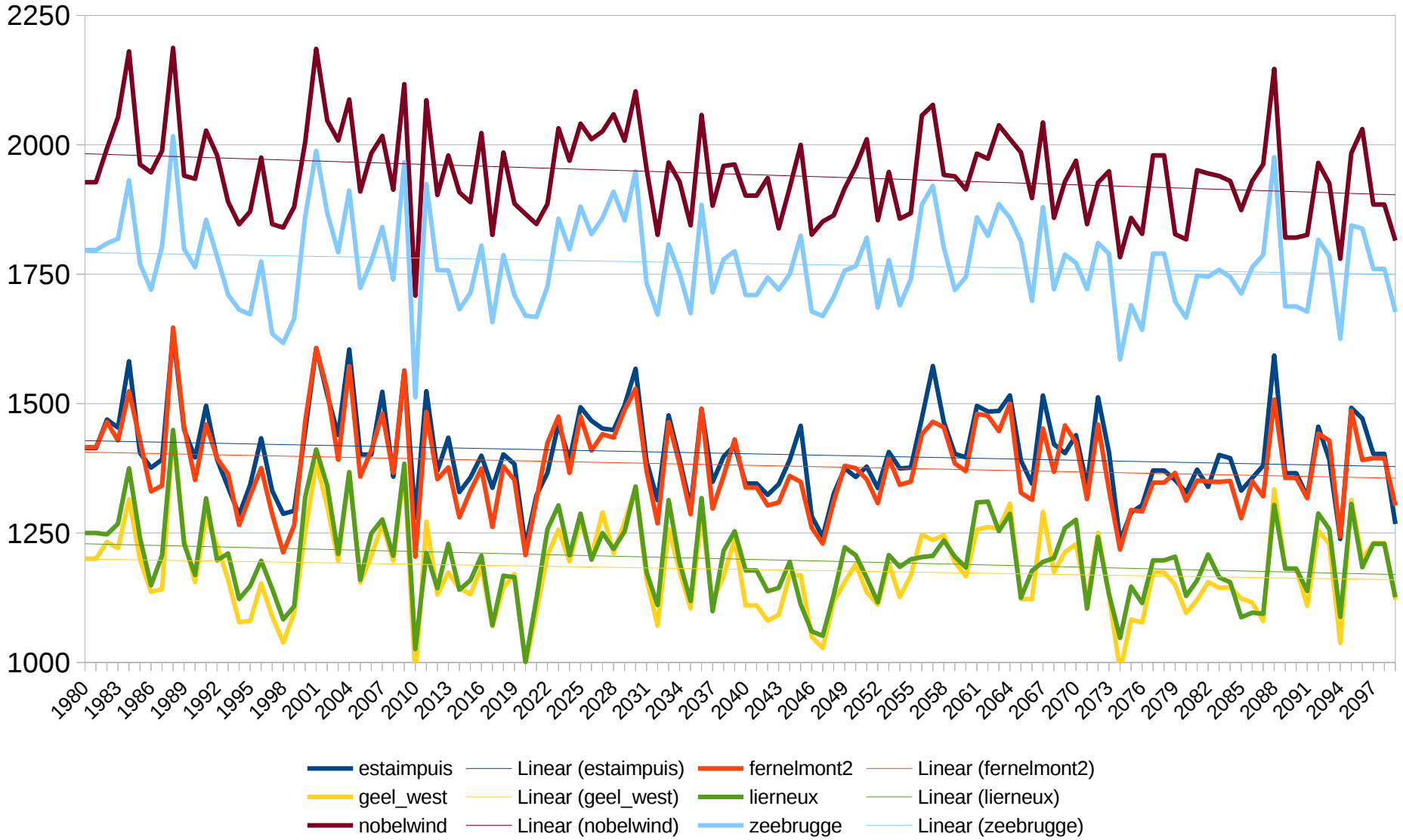
Evolution du SPEI (Standardised Precipitation-Evapotranspiration) index

3. Future changes in Belgium

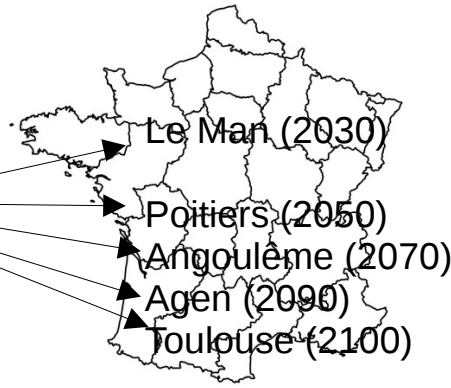
Production = ρ v^3

Air density ↓

Decrease in summer



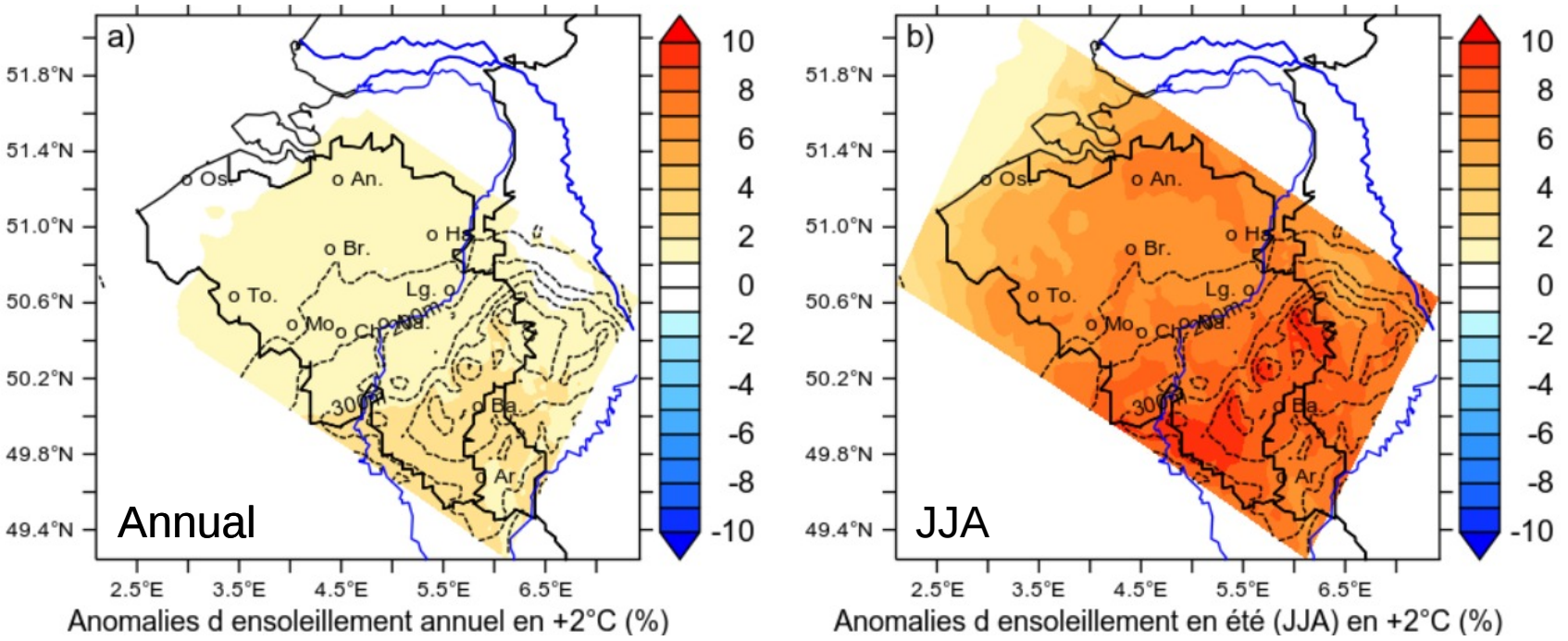
3. Future changes in Belgium (in a +2°C world)



Climate of Liège in 2100 ~ climate of Toulouse!

	Observé	Observé	Projeté	Projeté	Projeté	Projeté	Projeté
	1981-2010	2011-2022	2011-2030	2021-2040	2041-2060	2061-2080	2081-2100
Température moyenne (°C)	10.3	11.4	10.8	11.0	11.8	12.7	13.7
Température en été (°C)	18.0	19.0	18.7	18.9	20.0	21.2	22.2
Nbr de jours avec Tmax > 30°C	7	10	10	11	17	25	34
Nbr de jours avec Tmax > 35°C	0	1	1	1	2	6	8
Nbr de jours avec Tmax > 40°C	0	0	0	0	0	0	1
Nbr de jours avec Tmin > 20°C	3	6	5	6	11	17	29
Nbr de jours avec Tmin < 0°C	44	28	39	38	30	24	6
Nbr de jours avec Tmax < 0°C	13	7	10	9	7	15	4
Precipitation annuelle (mm)	834	777	862	854	883	865	870
Précipitation en été (mm)	288	285	290	281	286	256	264
Chute de neige (mm)	68	54	63	61	43	34	22
Nbr de jours avec 1cm de neige	5	3	3	3	1	1	1
Ensoleillement en été (%)	100	103	101	102	104	108	108

3. Future changes in Belgium



Anomalies d ensoleillement annuel en +2°C (%)

Anomalies d ensoleillement en été (JJA) en +2°C (%)

Anomaly of solar radiation (in %) with respect to 1981-2010

4. Extreme events

To have extreme events (like tornados, thunderstorm, …), we need:

1. **high temperatures** (which is enhanced by Global Warming)
   => Global Warming brings more energy to the system

2. **vertical instability** (which can be dampen by global warming)
   => the warming of high atmosphere will be larger than low atmosphere
      => more stable temperature profiles (at the large scale at least)

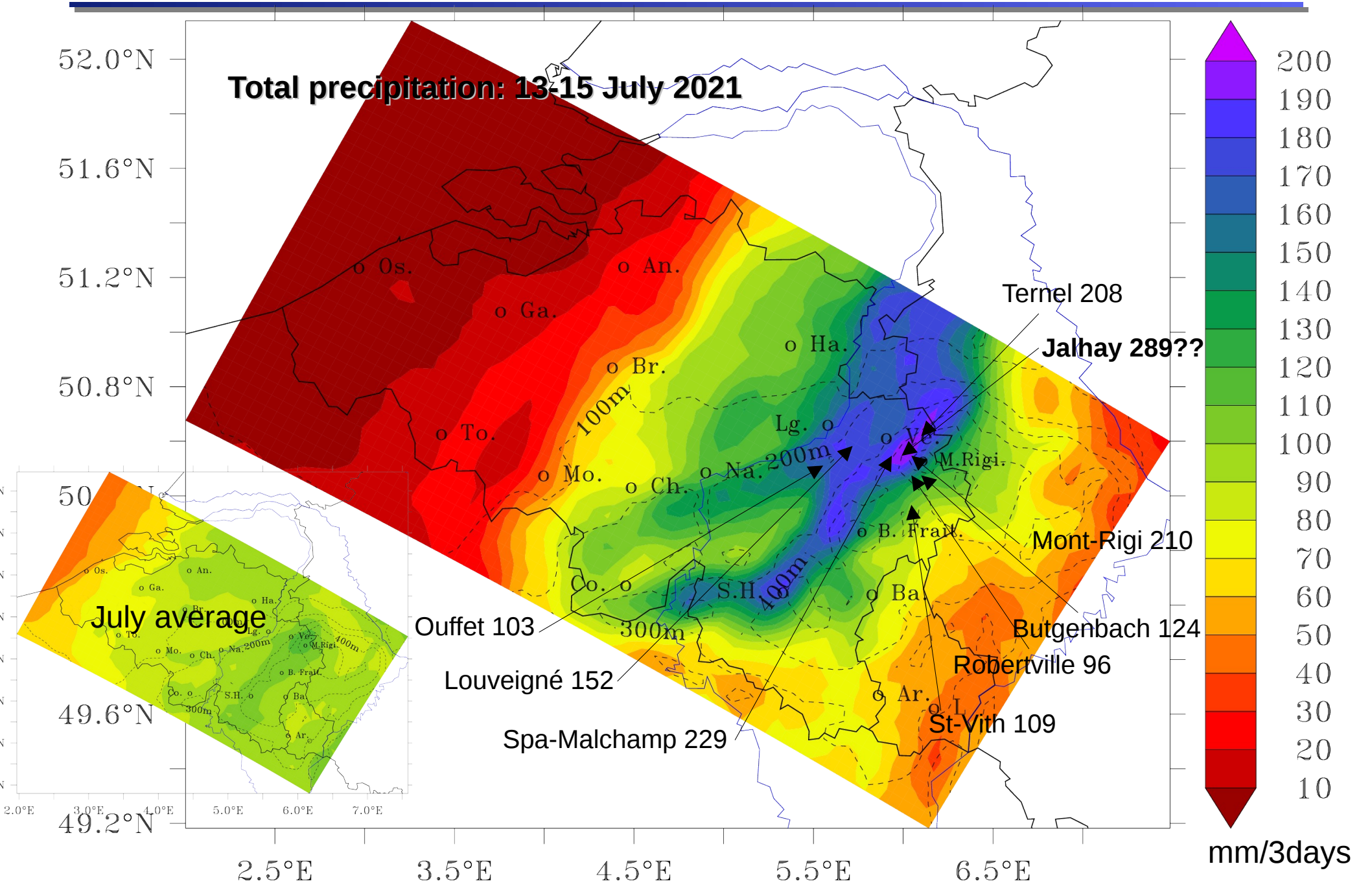
3. **thermic contrasts** (which can be dampen by global warming)
   => Warming of North Pole is larger than Equator
      => damping of the atmospheric dynamics

4. **weak atmospheric dynamics** (which is dampen by global warming)
   => Global Warming favours blocking at our latitude which enhances extreme events

+ the climate models are not able to generate them

It is very hard to predict their evolution BUT due to the expansion of human infrastructures, a same event will generate a lot of more destruction!!

4. Extreme events: July 2021 floods



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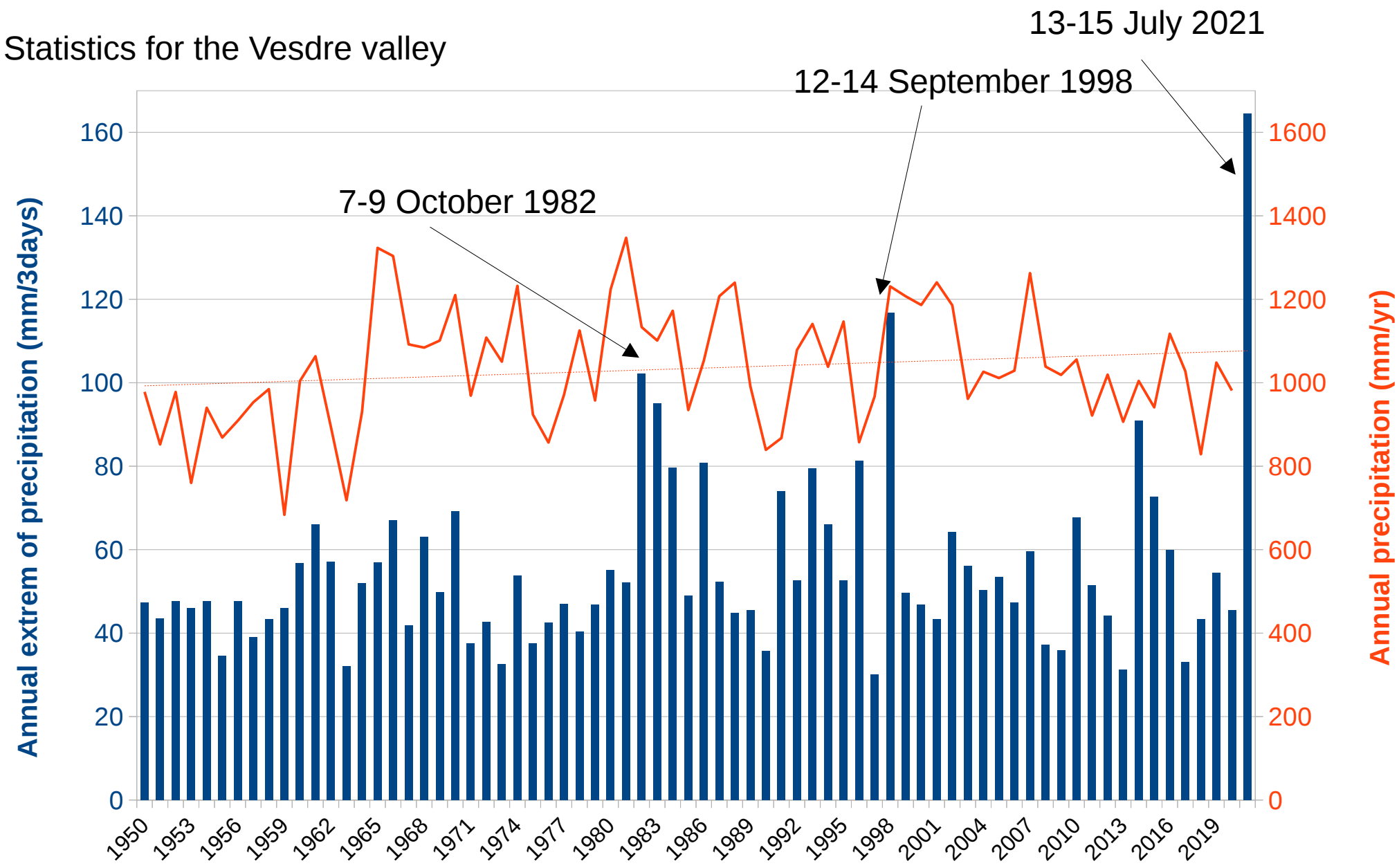
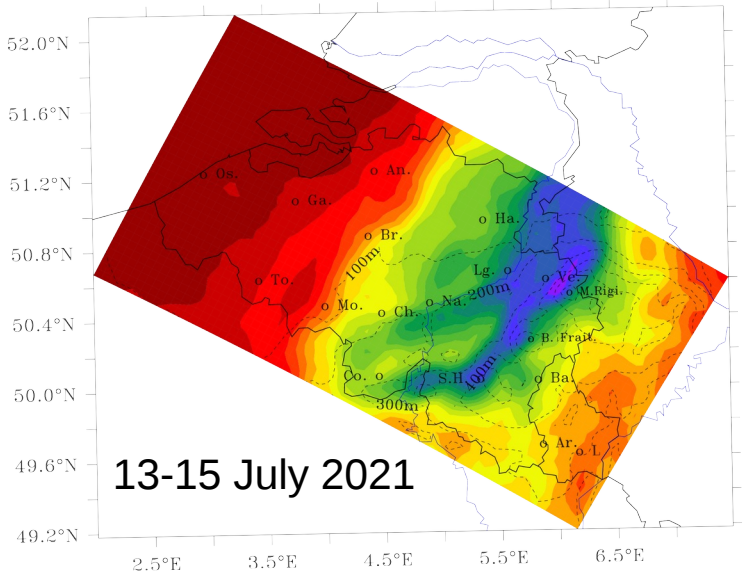
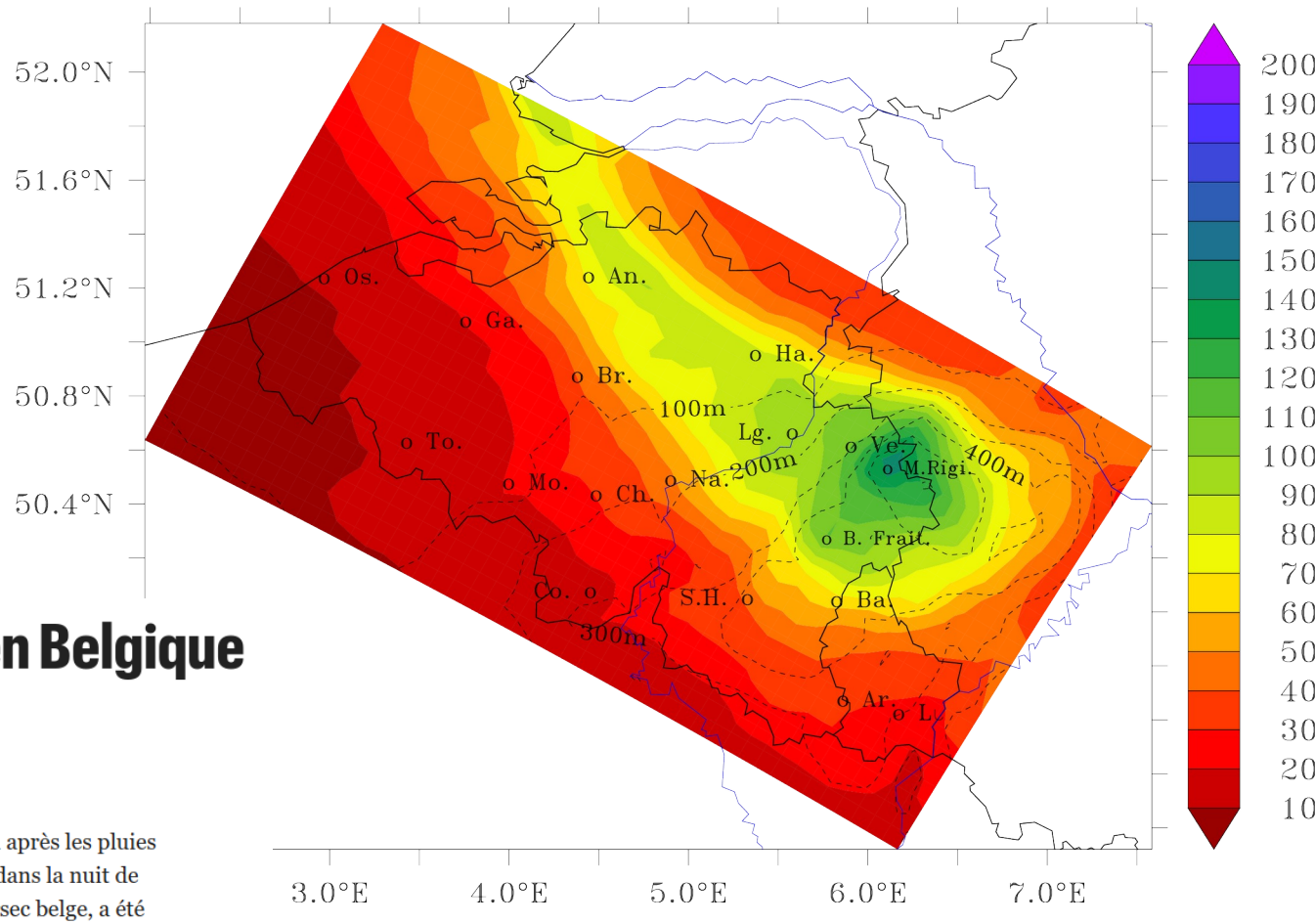


4. Extreme events: July 2021 floods





12-14 September 1998

Inondations catastrophiques en Belgique

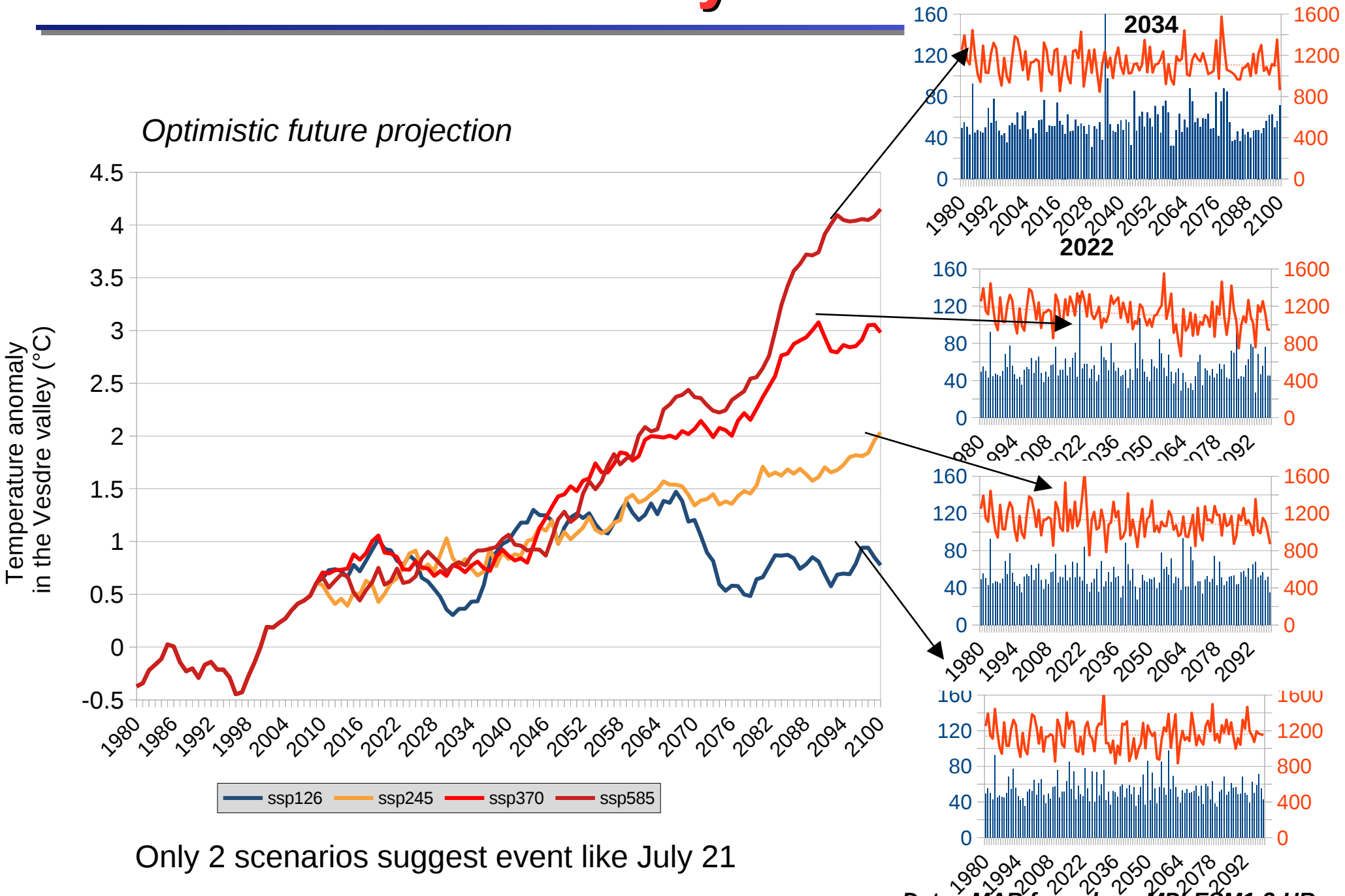
Le Parisien

Par

Le 15 septembre 1998 à 00h00

La Belgique et les Pays-Bas ont les pieds dans l´eau après les pluies diluviennes qui se sont abattues sans discontinuer dans la nuit de dimanche à lundi. La phase 3 d´urgence, le plan Orsec belge, a été décrétée dans cinq provinces au nord d´une ligne Anvers-Liège. L´armée a dû prêter main forte aux secours. On ne compte plus les maisons inondées, les voitures à la dérive et les caves dégorgeant de boue. Des milliers d´habitants écopent sans relâche et tentent de sauver leurs biens. Albert II, le roi des Belges, a apporté son réconfort dans deux localités particulièrement sinistrées, à Diest en Flandre et Chaudfontaine en Wallonie, englouties sous les eaux. La météo annonçait hier soir de nouvelles précipitations importantes.

4. Extreme events: July 2021 floods

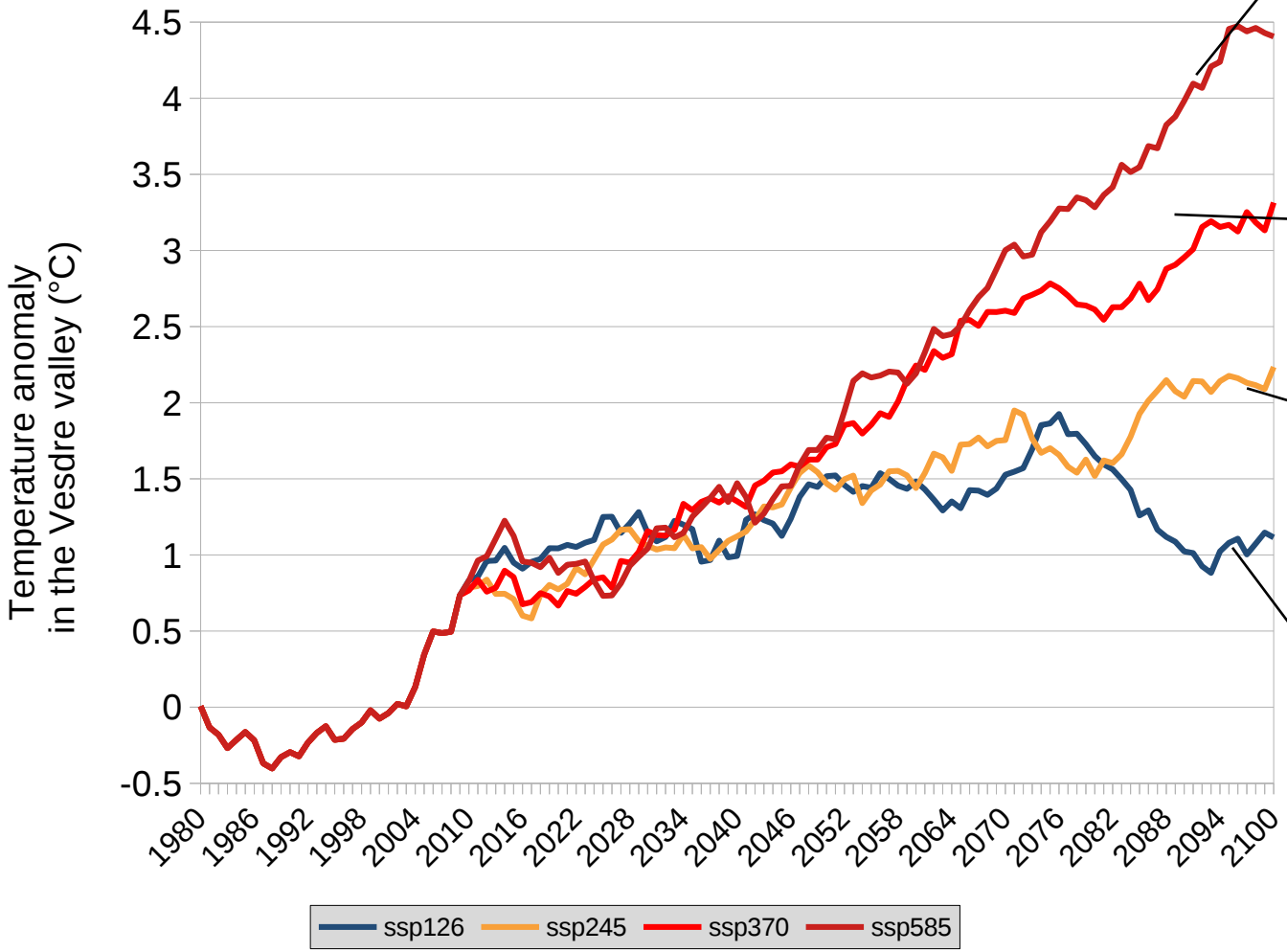


Only 2 scenarios suggest event like July 21

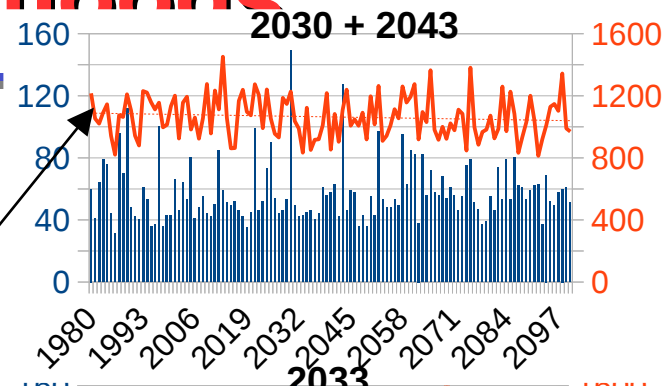
Data : MAR forced par MPI-ESM1-2-HR

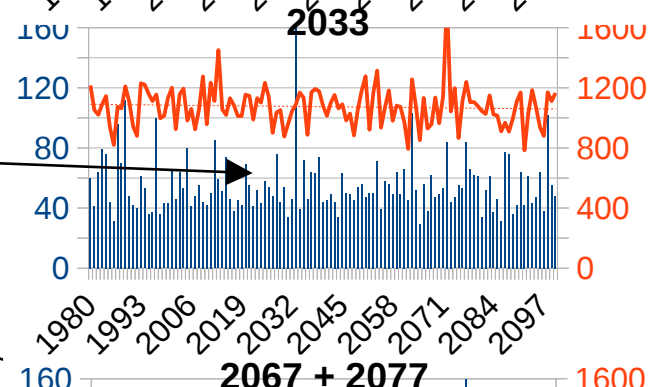
4. Extreme events: July 2021 floods

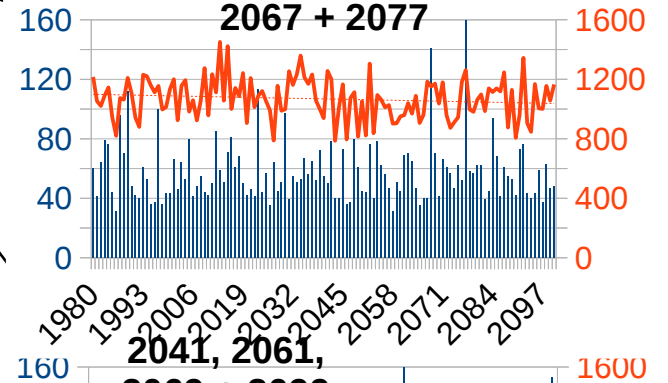
Less optimistic projections

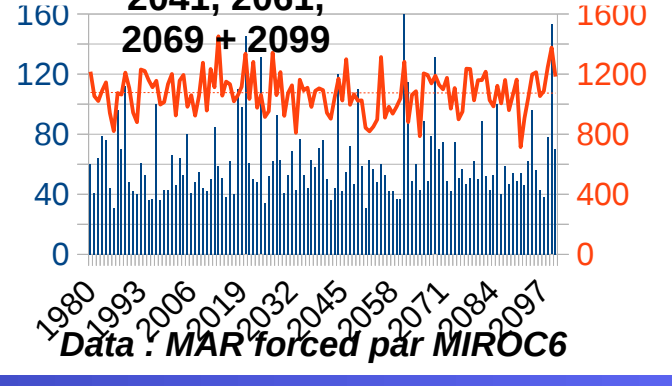


All scenarios suggest events like July 21!









Data : MAR forced par MIROC6

4. Extreme events: July 2021 floods

Occurrence of events like July 21 in the Vesdre Valley

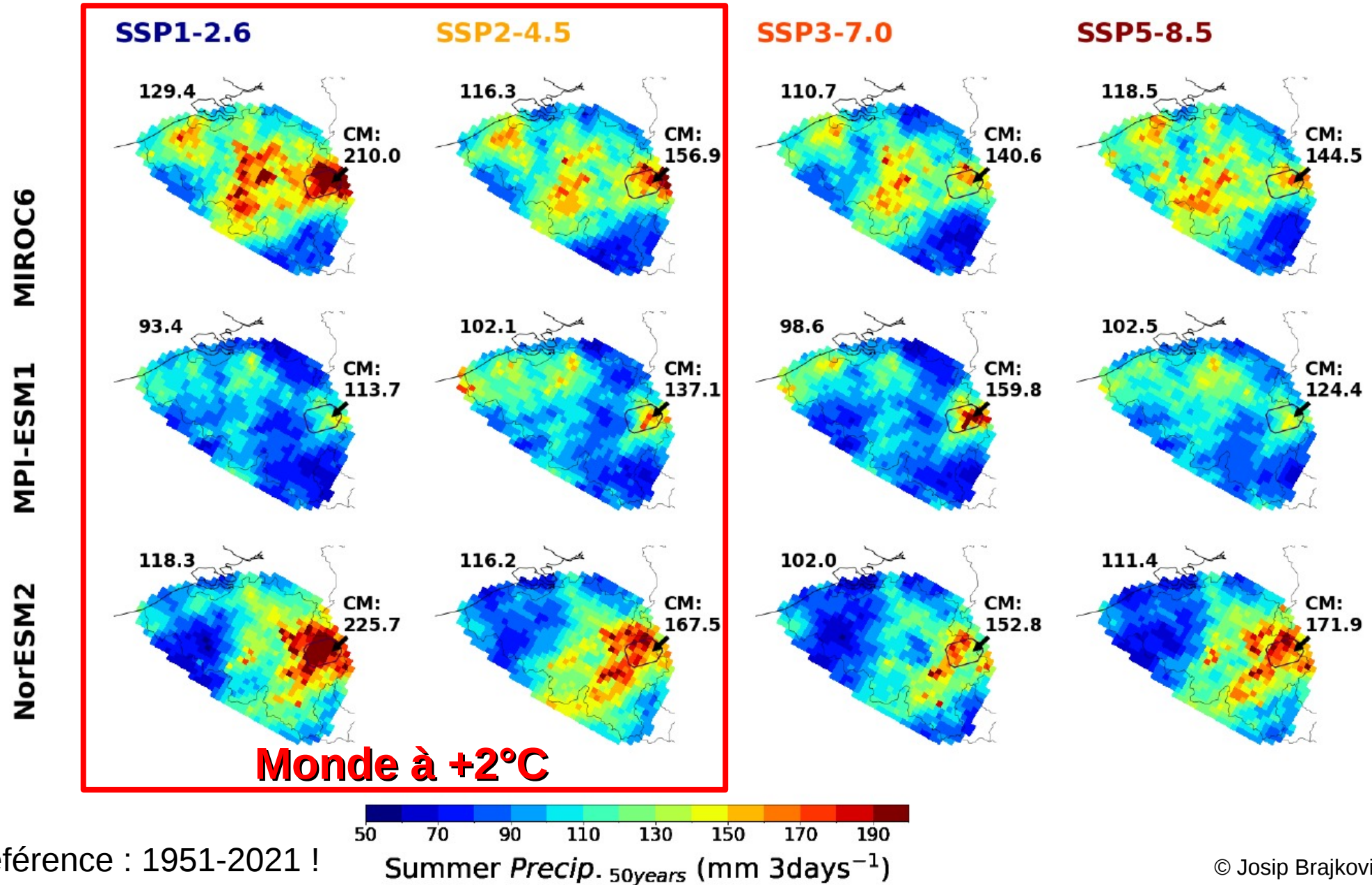
		< 2015 historical > 100 mm/3da	2030 (2020-2040) 100mm/3days	2030 (2020-2040) 150mm/3days	2050 (2040-2060) 100mm/3days	2050 (2040-2060) 150mm/3days	2070 (2060-2080) 100mm/3days	2070 (2060-2080) 150mm/3days	2090 (2080-2100) 100mm/3days	2090 (2080-2100) 150mm/3days
ssp585 (total=13)	BCC-CSM2-MR	1					2			
	MPI-ESM1-2-HR			**1 (2034)**						
	MIROC6	2		1	2					
	UKESM1	3	1		1					
	NorESM2	1					2			
ssp370 (total=9)	CNRM-ESM2		1		1					1
	MPI-ESM1-2-HR		1		1					
	MIROC6			**1 (2033)**			1		1	
	UKESM1									
	NorESM2						2	**1**	1	
ssp245 (total=8)	**MPI-ESM1-2-HR**									
	MIROC6		1				1	**1 (2077)**		
	UKESM1				1					
	NorESM2		1		1				2	
ssp126 (total=15)	**MPI-ESM1-2-HR**									
	MIROC6		3		2		2	**1 (2061)**	1	**1 (2099)**
	UKESM1									
	NorESM2		1				2		2	
	Total	*7*	*9*	*3*	*9*	*0*	*12*	*3*	*7*	*1*

ssp585 et ssp370 : very likely in 2030-2050 and too dry/warm after
ssp245 : idem till 2070
ssp126 : very likely through the whole century

… but model underestimates extremes

4. Extreme events: July 2021 floods

13-15 Juillet 2021 : CM = 160mm/3days



Référence : 1951-2021 !

© Josip Brajkovic

4. Extreme events: rainfall

Can we wave worse event than the July 2021 one ?

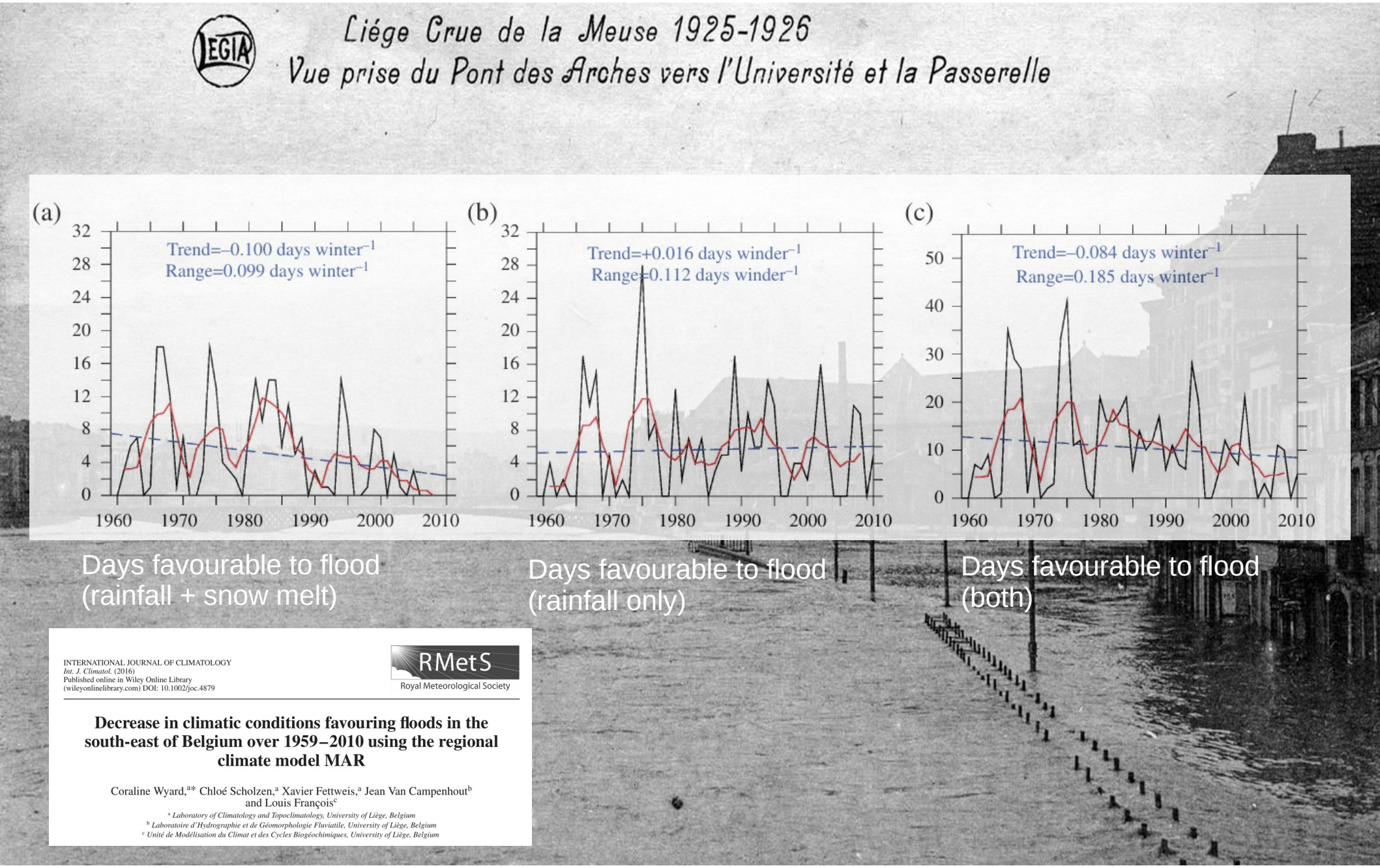
Certainly yes but locally

29 Mai 2008 at Liège (Rénory)

+1°C in surface = + 10 % of the worse event

Currently : max precip ~150 mm/h
In 2050 : max precip ~200 mm/h

4. Extreme events: winter flood



Days favourable to flood (rainfall + snow melt)

Days favourable to flood (rainfall only)

Days favourable to flood (both)

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. (2016)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.4879

RMetS
Royal Meteorological Society

Decrease in climatic conditions favouring floods in the south-east of Belgium over 1959–2010 using the regional climate model MAR

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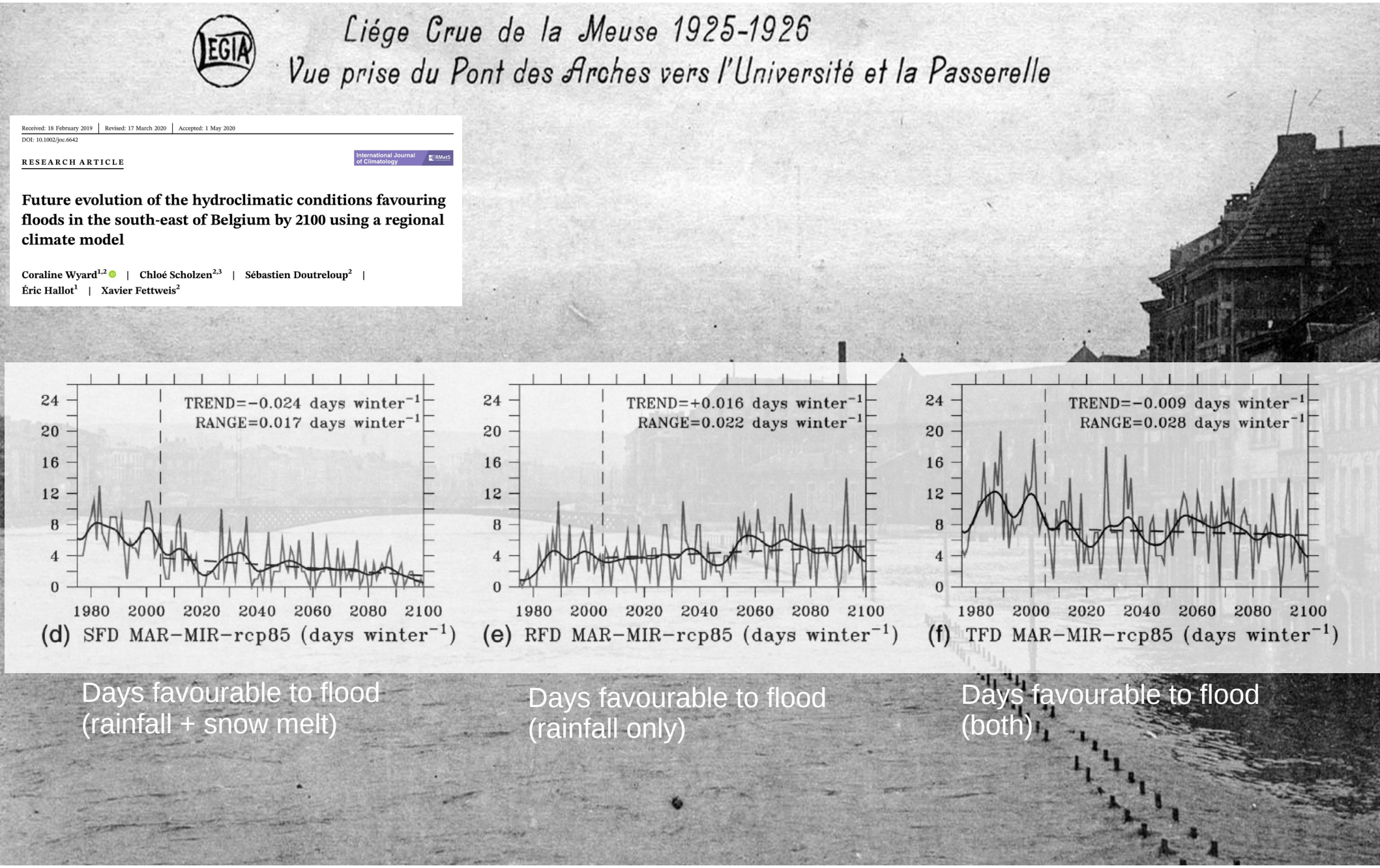
[a] *Laboratory of Climatology and Topoclimatology, University of Liège, Belgium*
[b] *Laboratoire d'Hydrographie et de Géomorphologie Fluviatile, University of Liège, Belgium*
[c] *Unité de Modélisation du Climat et des Cycles Biogéochimiques, University of Liège, Belgium*

4. Extreme events: winter flood



Received: 18 February 2019 | Revised: 17 March 2020 | Accepted: 1 May 2020
DOI: 10.1002/joc.6642

RESEARCH ARTICLE

International Journal of Climatology | RMetS

Future evolution of the hydroclimatic conditions favouring floods in the south-east of Belgium by 2100 using a regional climate model

Coraline Wyard[1,2] | Chloé Scholzen[2,3] | Sébastien Doutreloup[2] | Éric Hallot[1] | Xavier Fettweis[2]

Days favourable to flood (rainfall + snow melt)

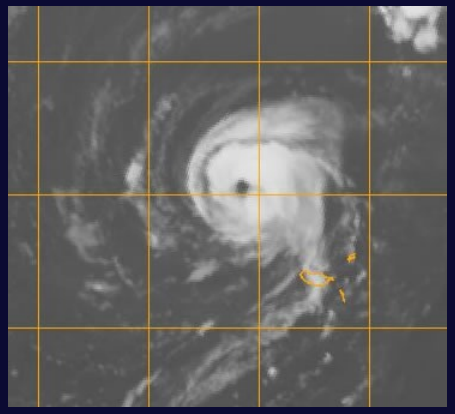
Days favourable to flood (rainfall only)

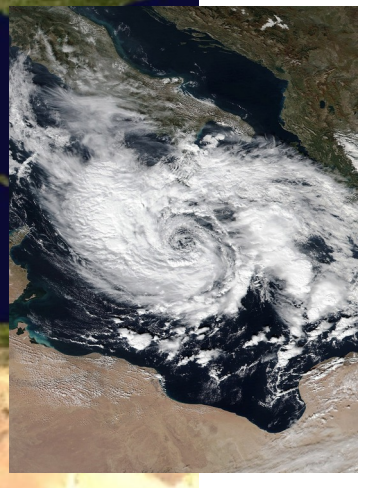
Days favourable to flood (both)

4. Extreme events: hurricanes

Could you have hurricanes in Belgium ?
A priori NOT but:

1) Theory of hurricane still valid ? SST > 26°C?
2) What about Medicanes ?
3) Climate models not able to generate them
4) More energy but more stability

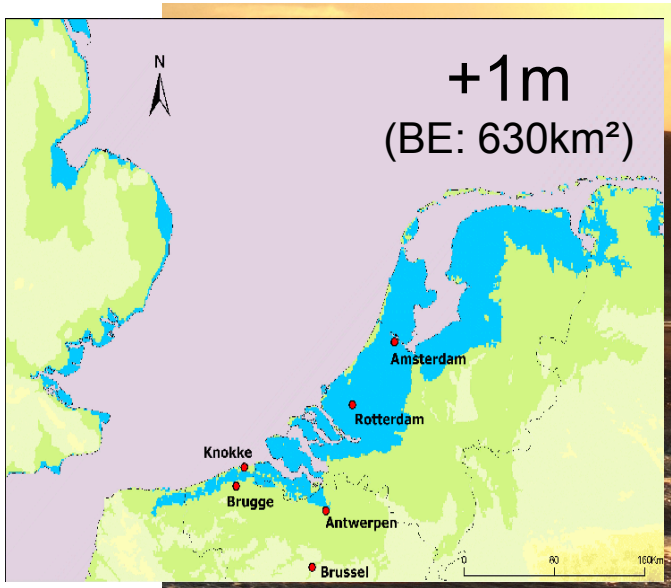




29 October 2021
Medicane Apollo

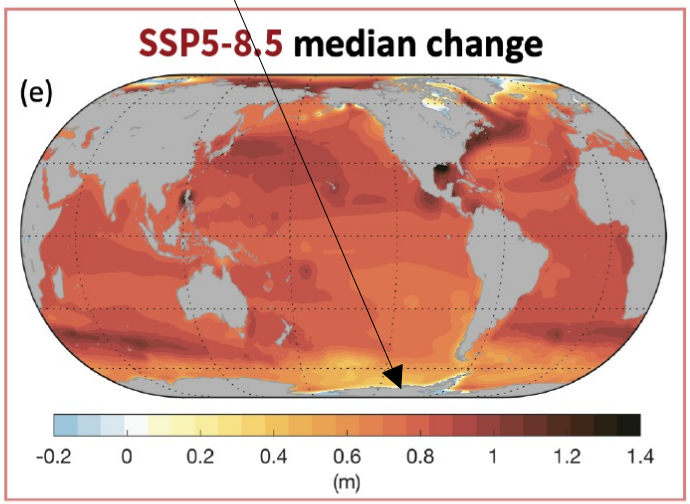
<u>October 2005</u> : Hurricane Vince was born close to Portugal in an area where it can not (SST = 21°C).

4. Extreme events: sea level

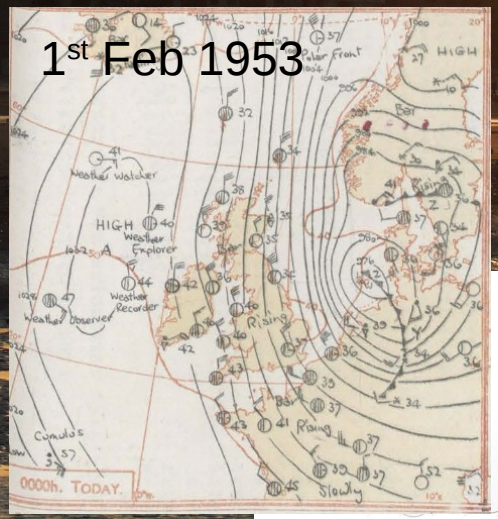


+ 1m is very likely in 2100 in Belgium

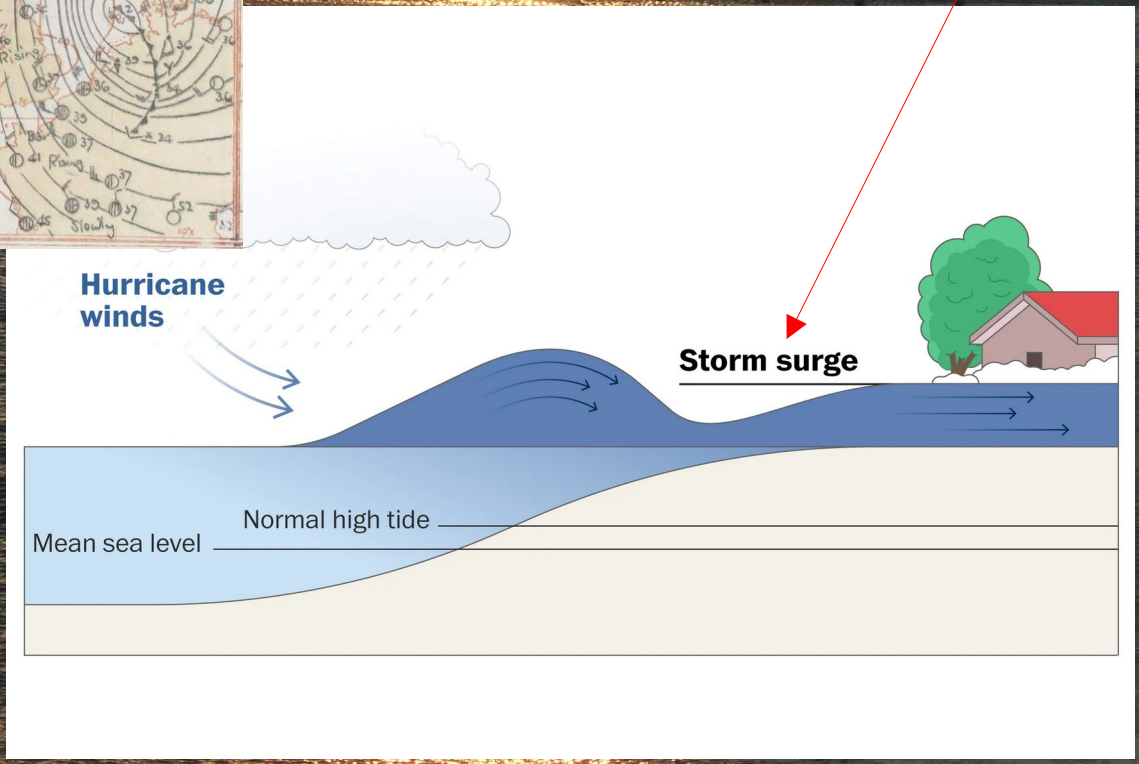
Belgium is mainly sensitive to Antarctica



4. Extreme events: sea level

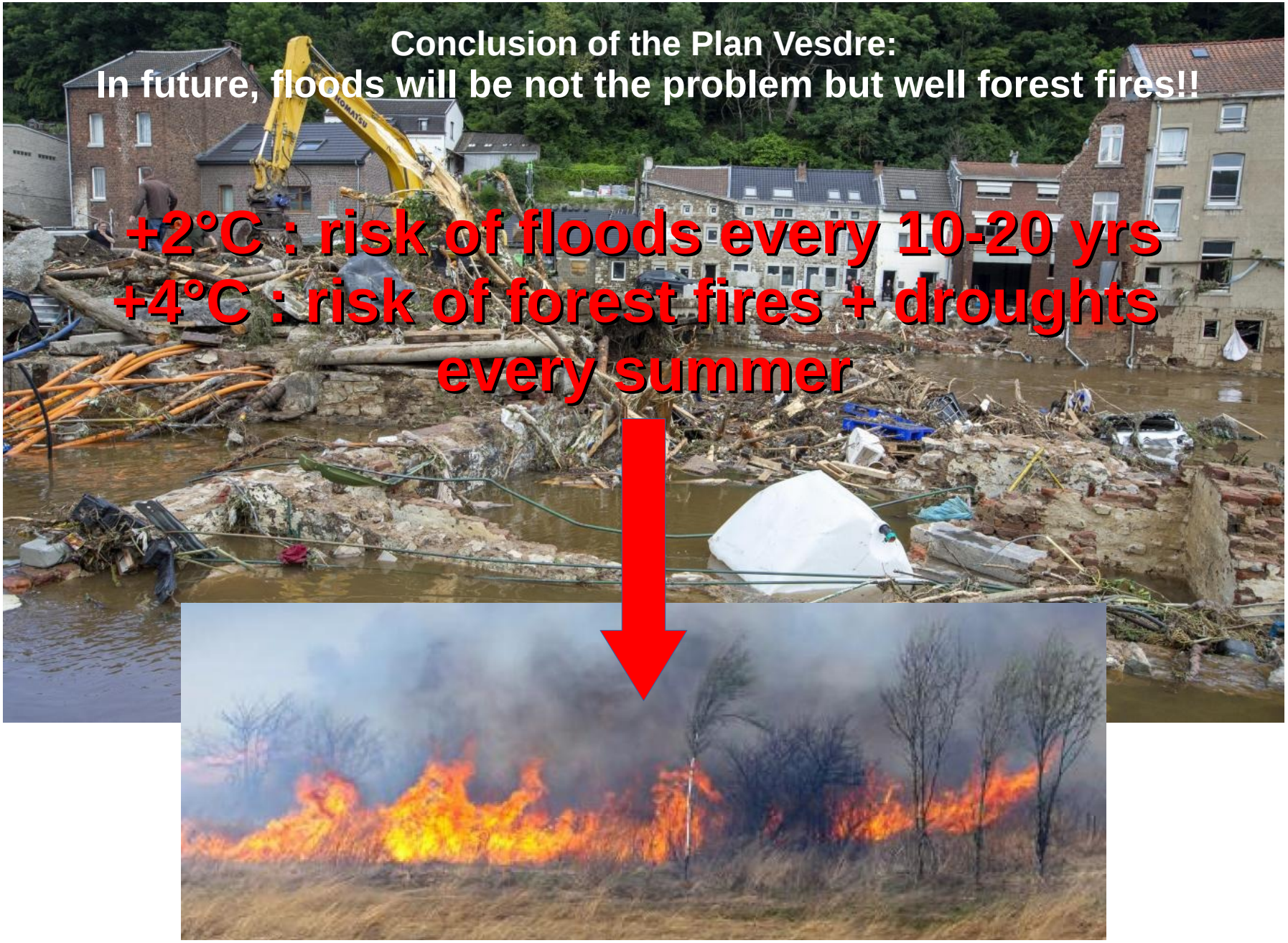


1. Low pressure
2. Wind towards the coast



More severe storm surges are expected

4. Extreme events: forest fire



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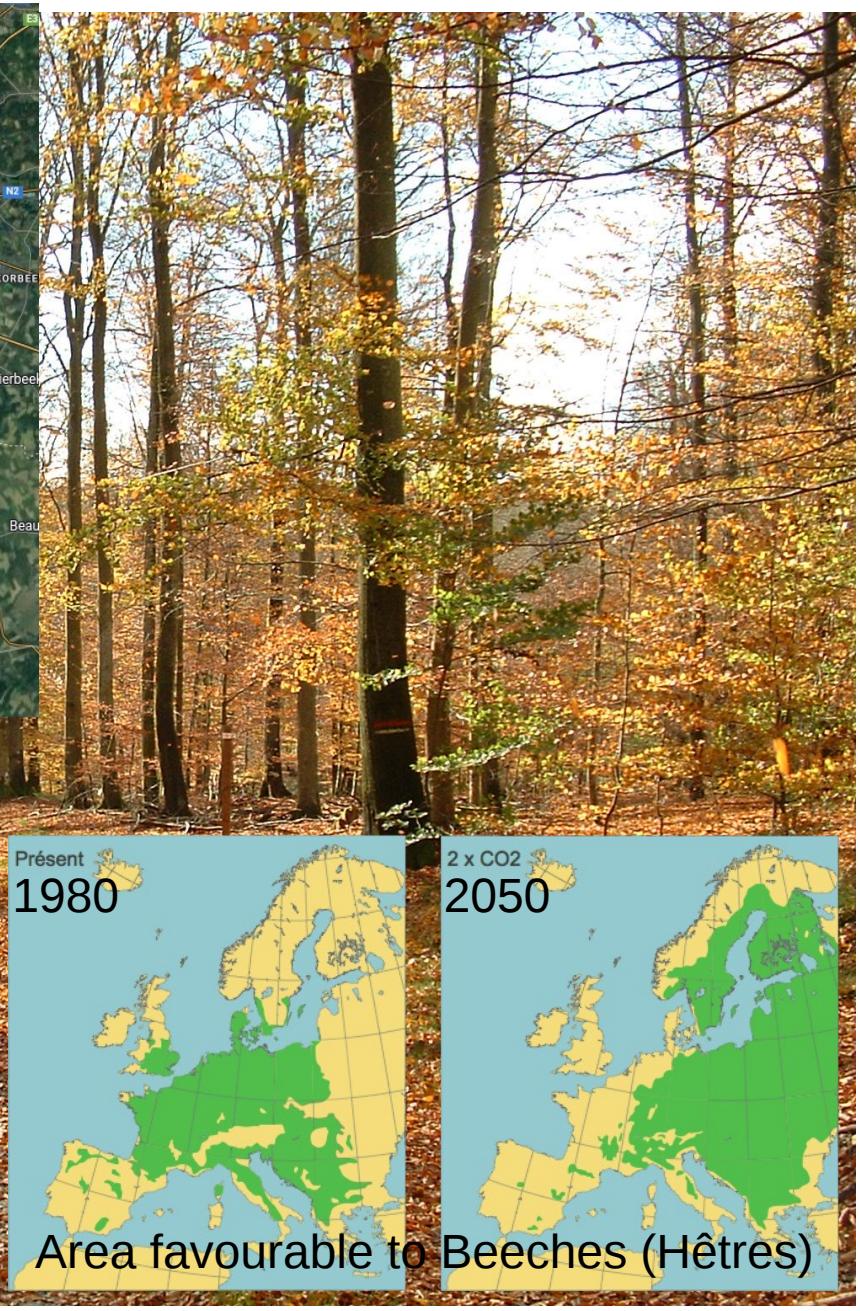
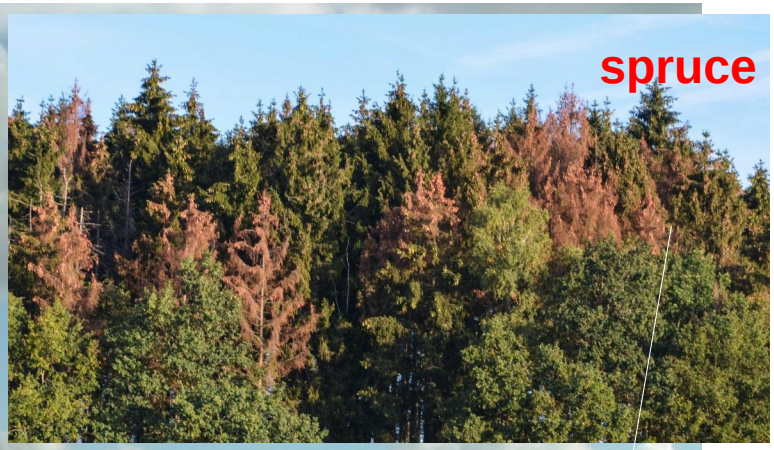


4. Extreme events: forest fire



Scolythes ? Too Dry ?

Hautes-Fagnes will be naturally reforested

End of the Hautes-Fagnes and risk of fire

Climate of Mont-Rigi in 2100 => climate of Liège in 2000