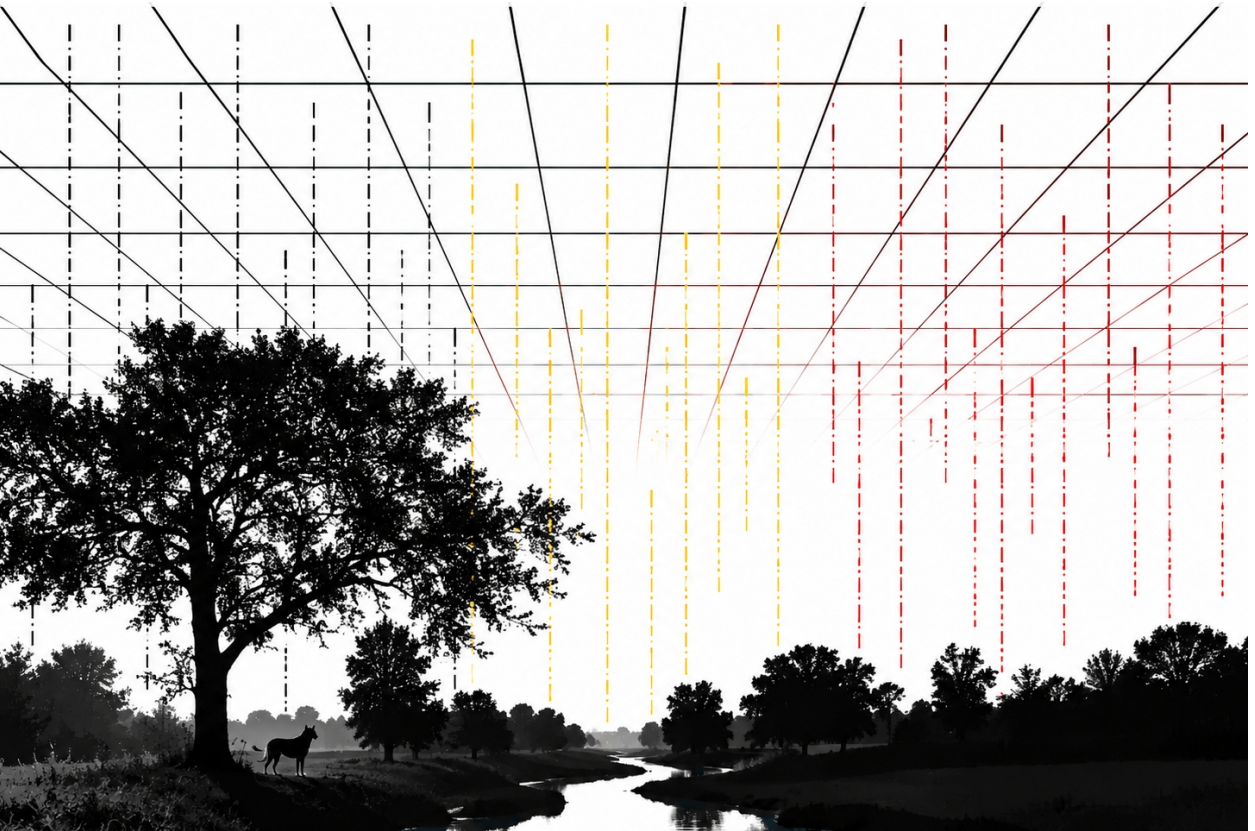
Evolution of extreme precipitation and associated hydrological responses in Belgium using the MAR regional climate model an the WOLFHydro modelling framework



Dissertation by **Josip BRAJKOVIC** for the obtention of the academic degree of *Philosophiae doctor* (College of Geography)

Jury:

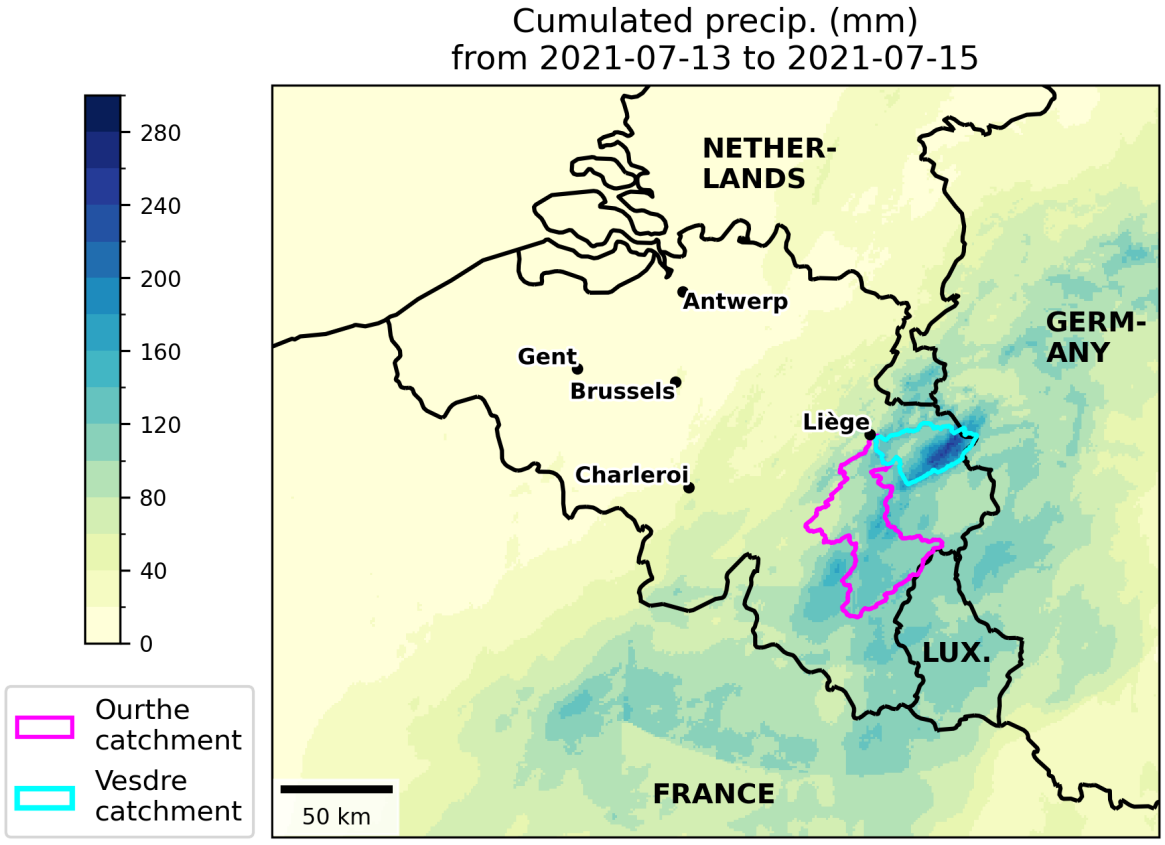
Pr. Ir. Dr. Patrick WILLEMS (KUL)
Dr. Bert VAN SCHAEYBROECK (RMI, UGent)
Pr. Dr. Geoffrey HOUBRECHTS (President)
Pr. Dr. Xavier FETTWEIS (Secretary)
Dr. Sébastien DOUTRELOUP (Supervisor)
Dr. Nicolas GHILAIN (Co-supervisor)
Ir. Dr. Pierre ARCHAMBEAU (Co-supervisor)

LIÈGE université Climatologie & Topoclimatologie

belspo

LIÈGE université Urban & Environmental Engineering

CORDEX.be II



(Journée et al., 2023)

- Locally 300 mm → **20-25%** of the annual precipitation
- Estimated return period → **400 years** (Kreinenkamp et al., 2021)

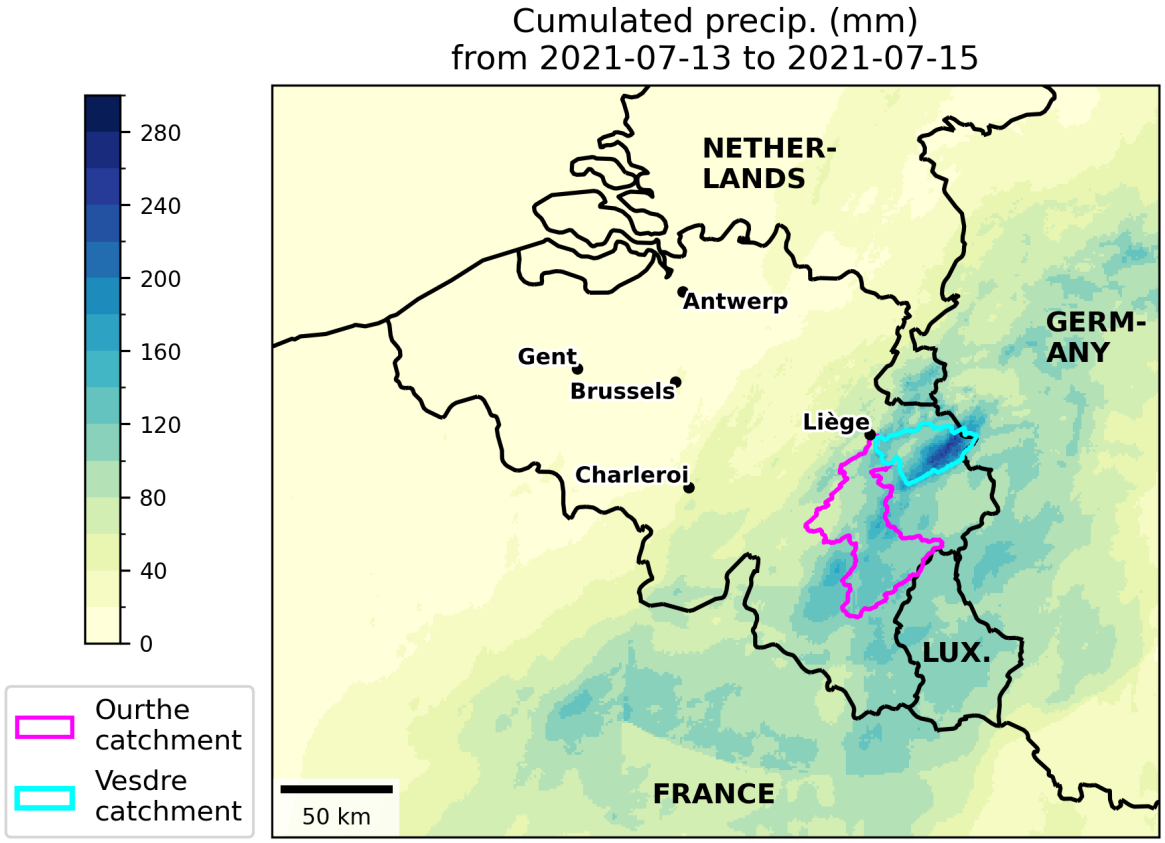
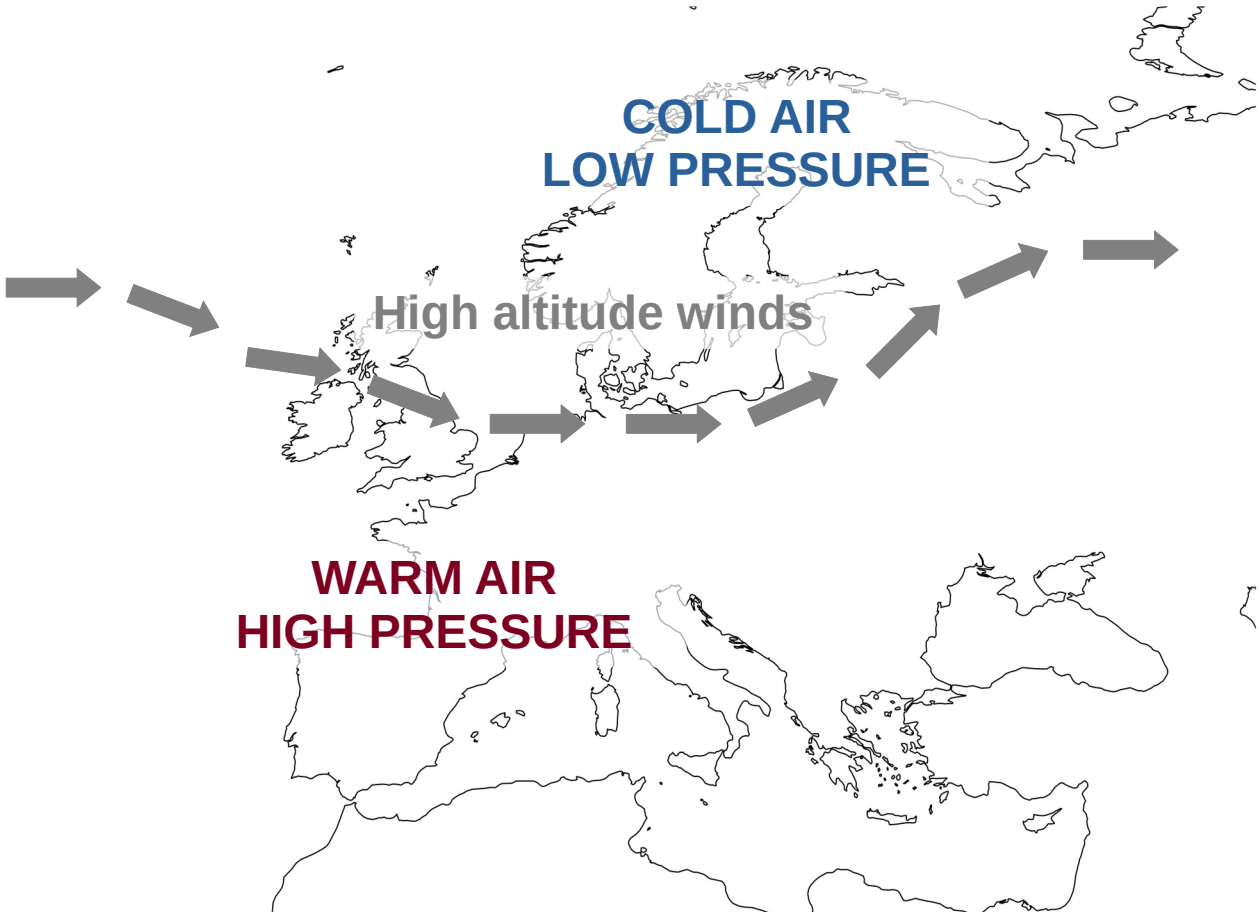


Photo: AP, via 7sur7 (2026).

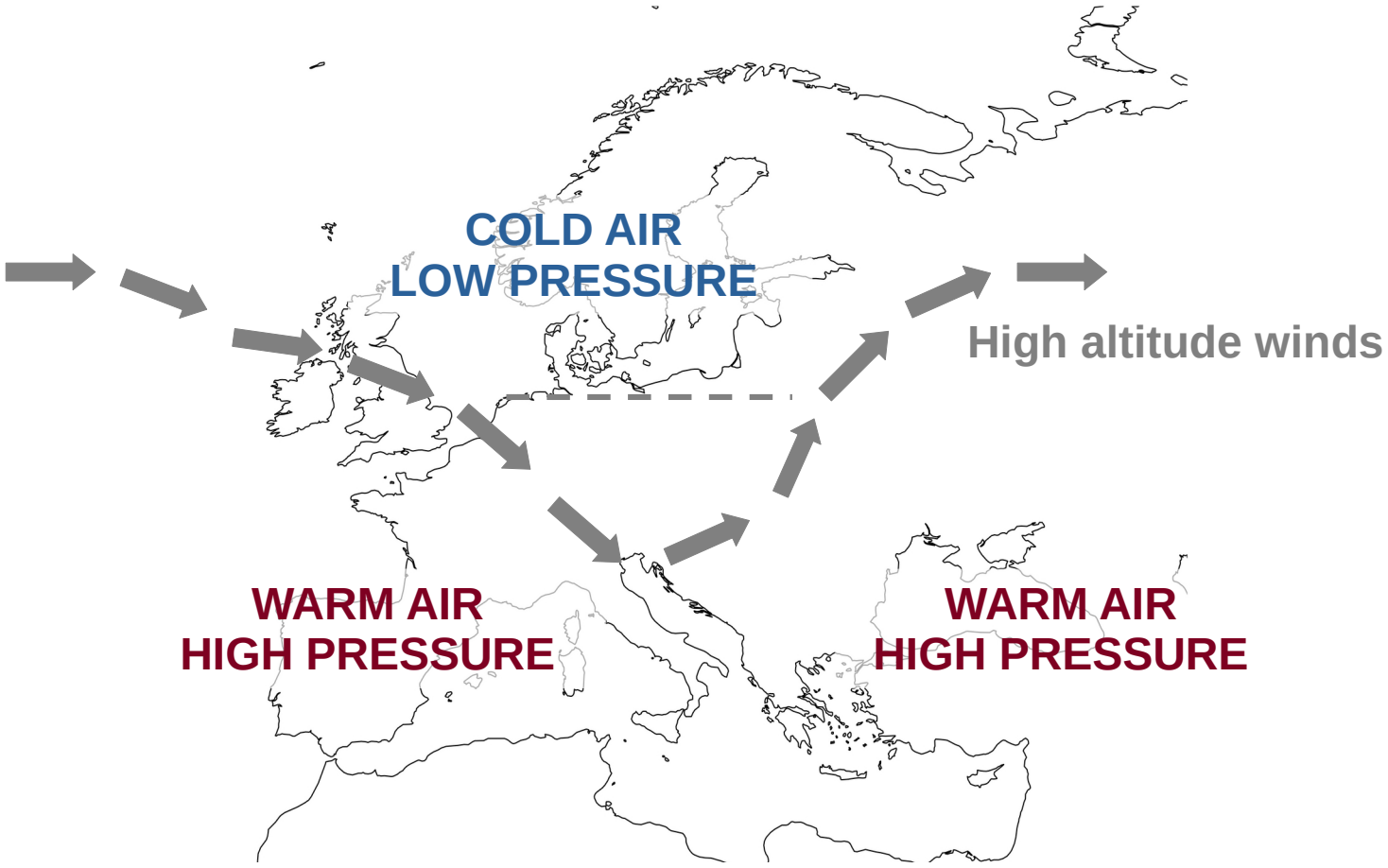


- Observed peak discharges:
  → 677 $m^3 s^{-1}$ in Chaudfontaine (Vesdre)
  → 542 $m^3 s^{-1}$ in Tabreux (Ourthe)
  → **3 to 5 times** the bankfull discharge

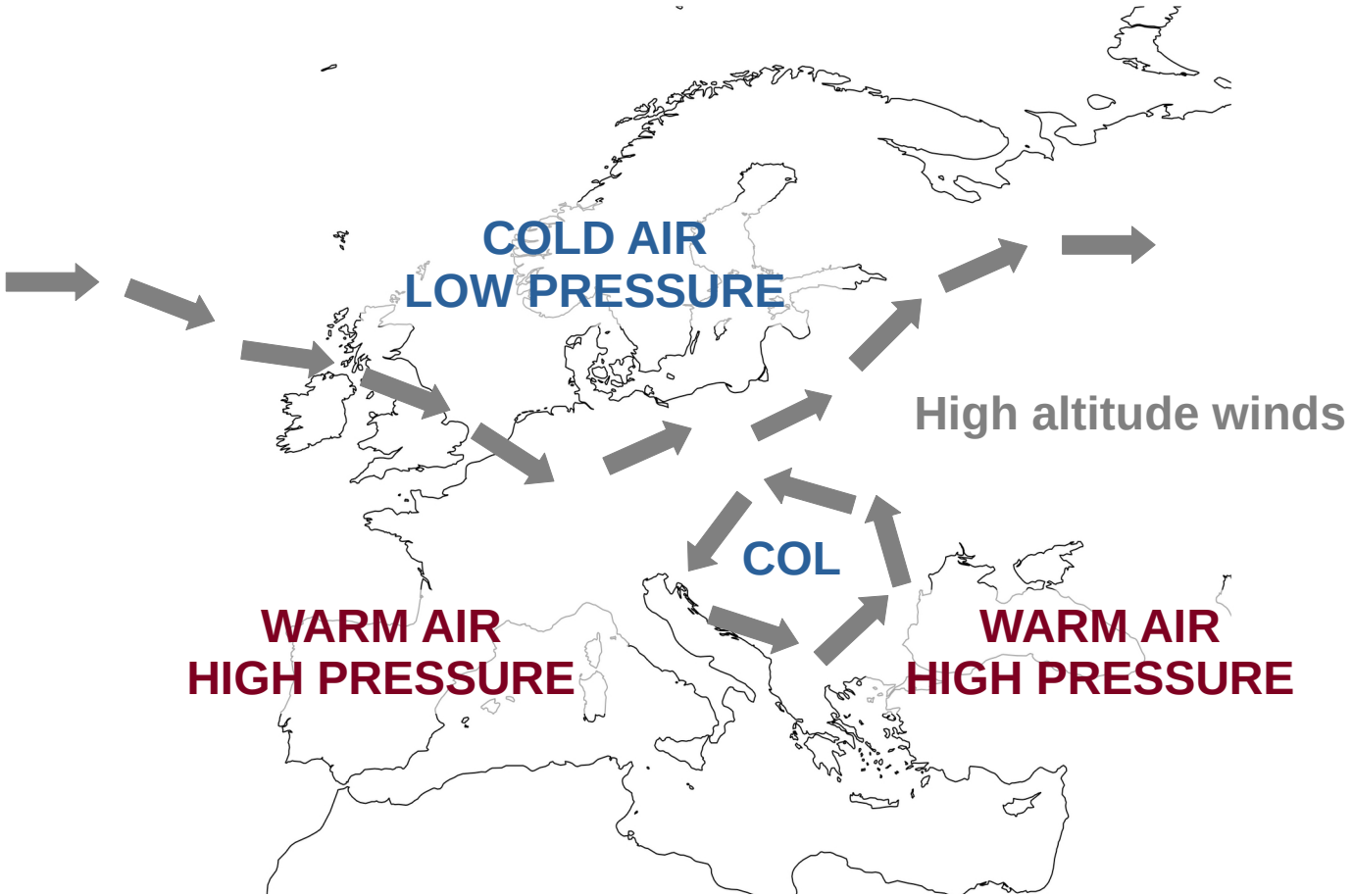
Synoptic Origin: **Cut-off low (COL)**



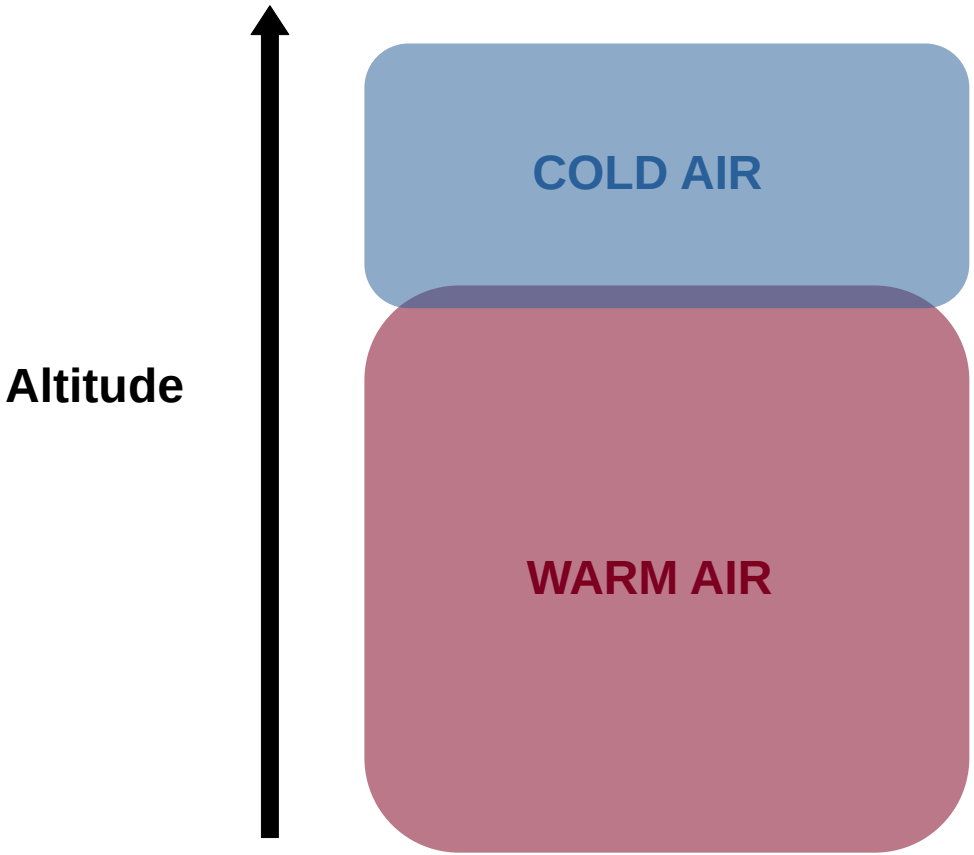
Synoptic Origin: **Cut-off low (COL)**



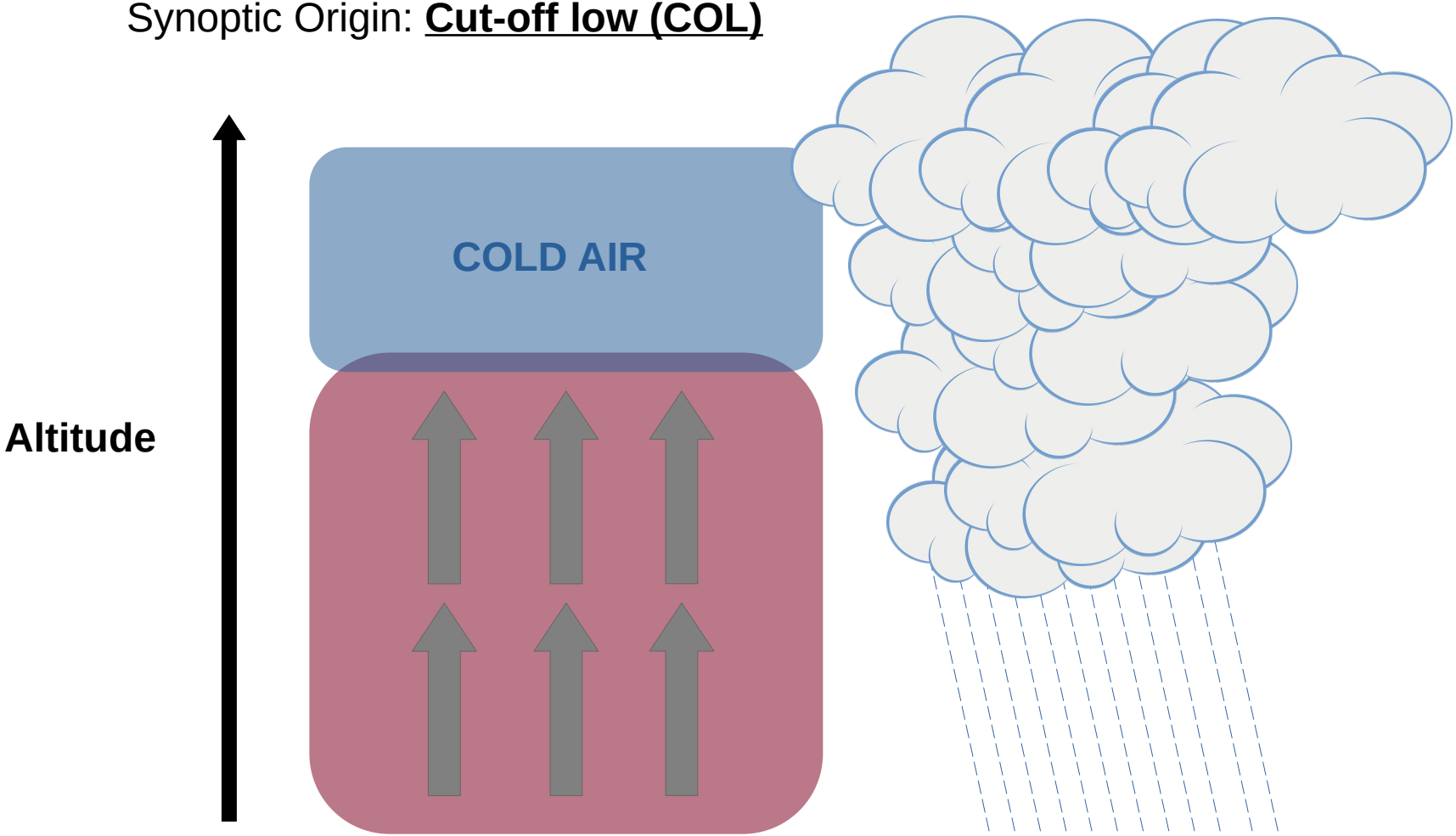
Synoptic Origin: **Cut-off low (COL)**



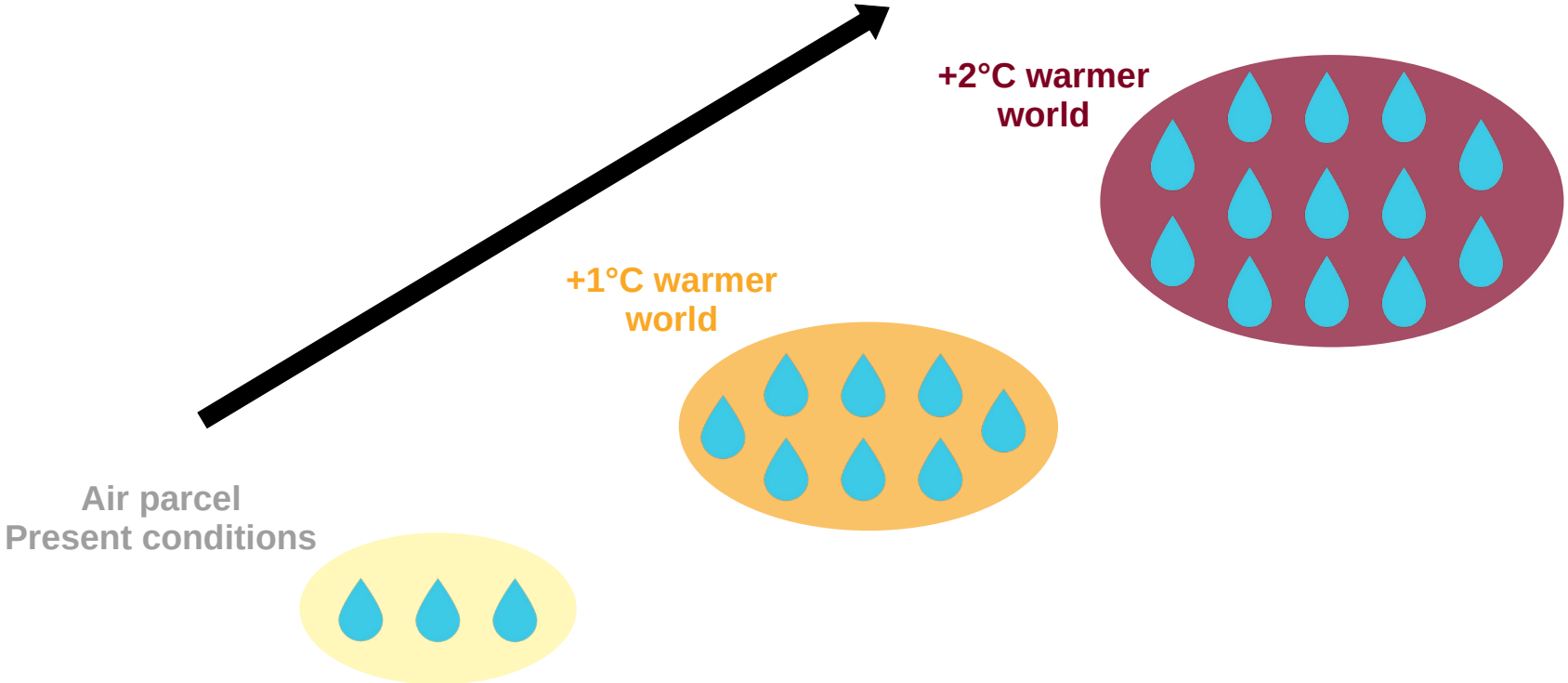
Synoptic Origin: **Cut-off low (COL)**



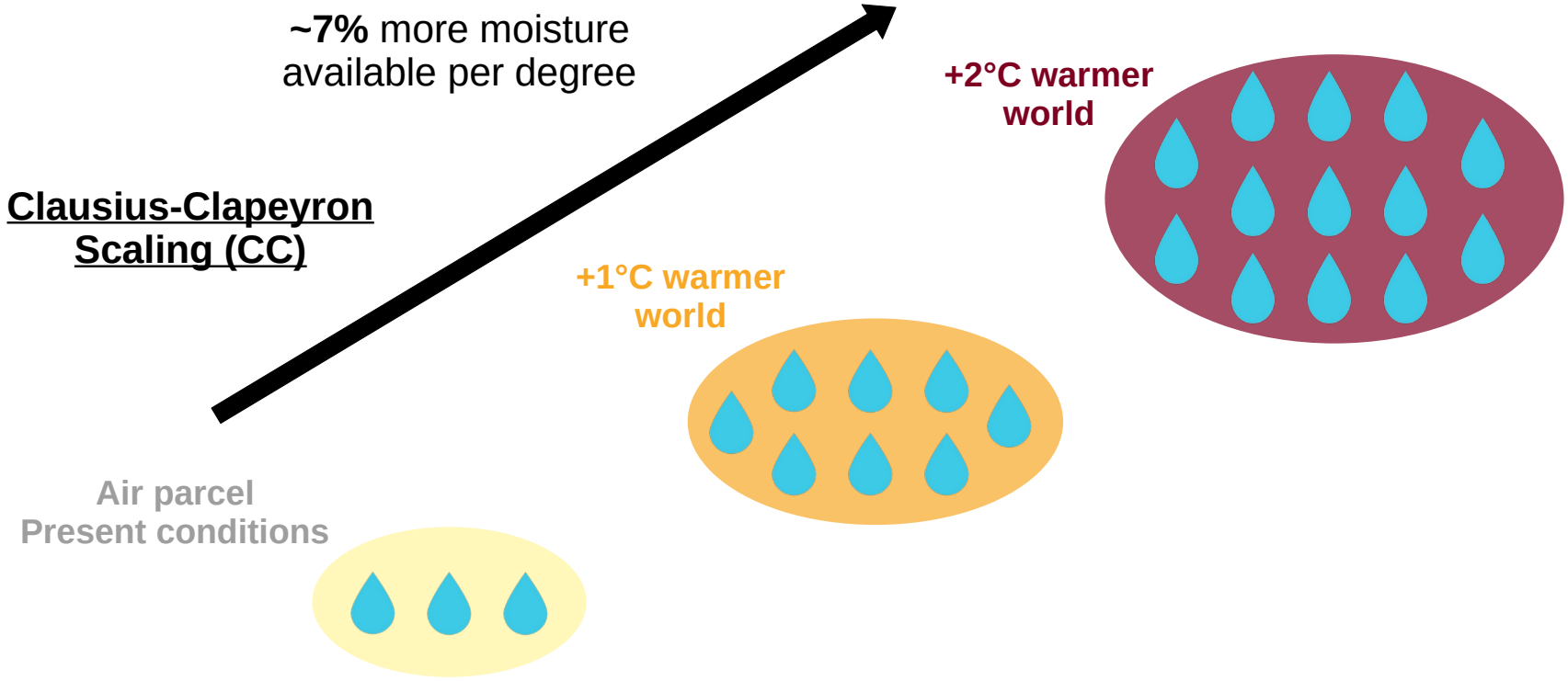
Synoptic Origin: **Cut-off low (COL)**



Intensification of extreme precipitation



Intensification of extreme precipitation



Several unknowns remain...

I. How will extreme precipitation events **intensity** and **frequency** evolve at the Belgian scale?

→ **Part 1 of the presentation**

Several unknowns remain...

I. How will extreme precipitation events **intensity** and **frequency** evolve at the Belgian scale?

→ **Part 1 of the presentation**

II. How have **COLs** contributed and will contribute to extreme precipitation in **Europe** and more specifically **Belgium?**

→ **Part 2 of the presentation**

Several unknowns remain...

I. How will extreme precipitation events **intensity** and **frequency** evolve at the Belgian scale?

→ **Part 1 of the presentation**

II. How have **COLs** contributed and will contribute to extreme precipitation in **Europe** and more specifically **Belgium?**

→ **Part 2 of the presentation**

III. How will these evolutions **translate in the hydrological system**?

→ **Part 3 of the presentation**

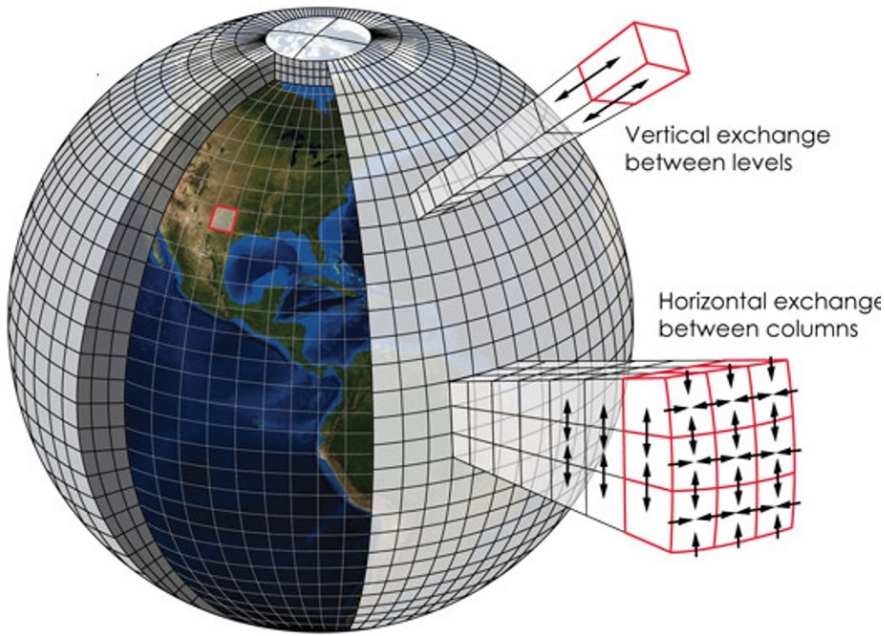
➡ **Several tools are used, tested and discussed**

Climate models: CMIP6 *Earth System Models* (ESMs)

→ **Physically-based** climate models

→ Complexe **interactions** (land-atmosphere, ocean-atmosphere…)

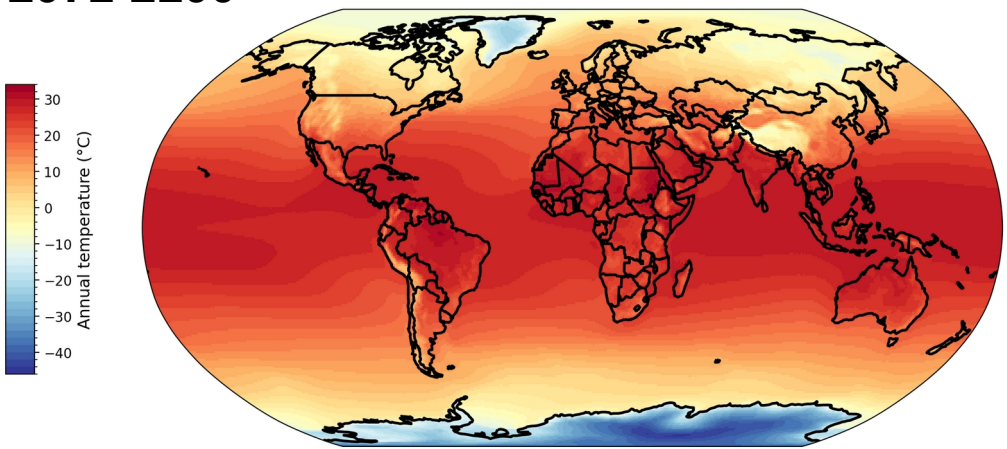
→ Evolution of **several variables** following scenarios (temperatures, precip., SLP, humidity and many many more!)



Source : Climate Modeling Lab, Jeonbuk National University.

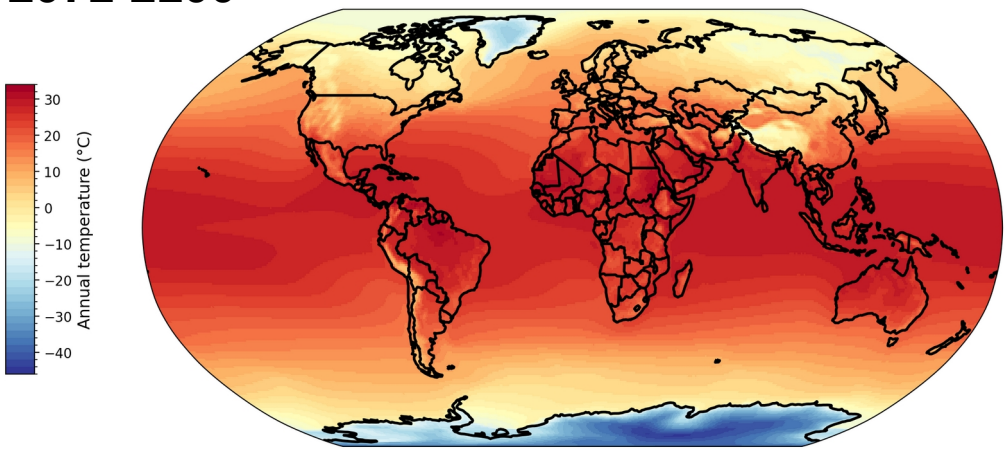
Used ESMs

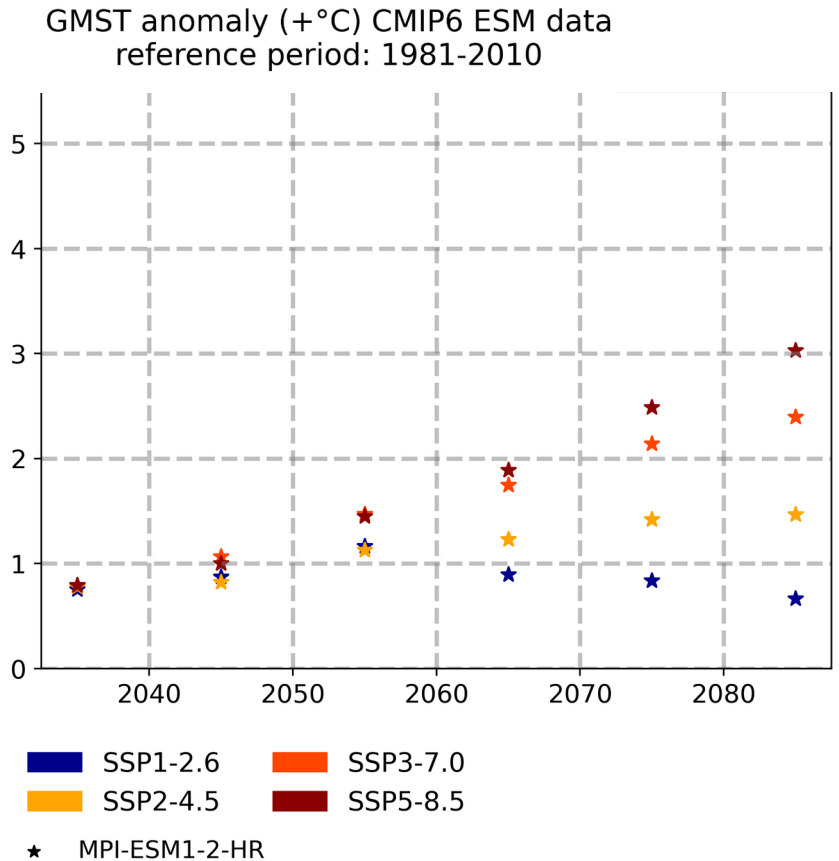
2071-2100



Used ESMs

2071-2100

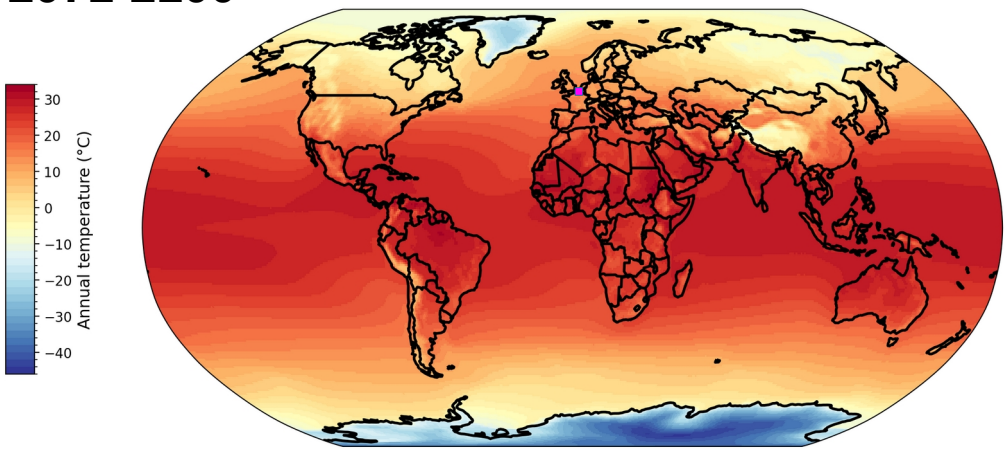


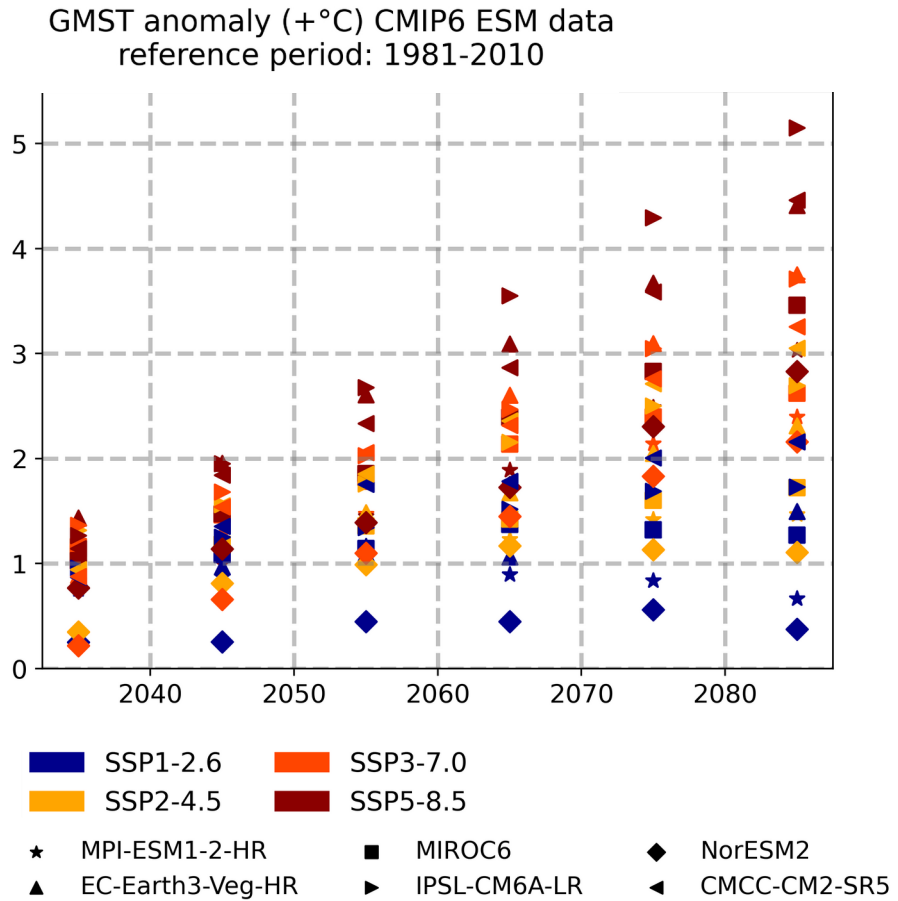


GMST = Global Mean surface temperature

Used ESMs

2071-2100



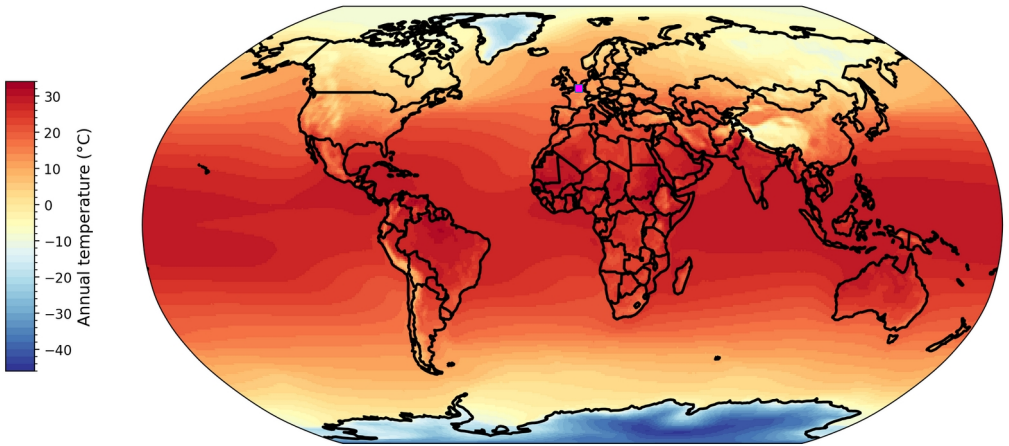


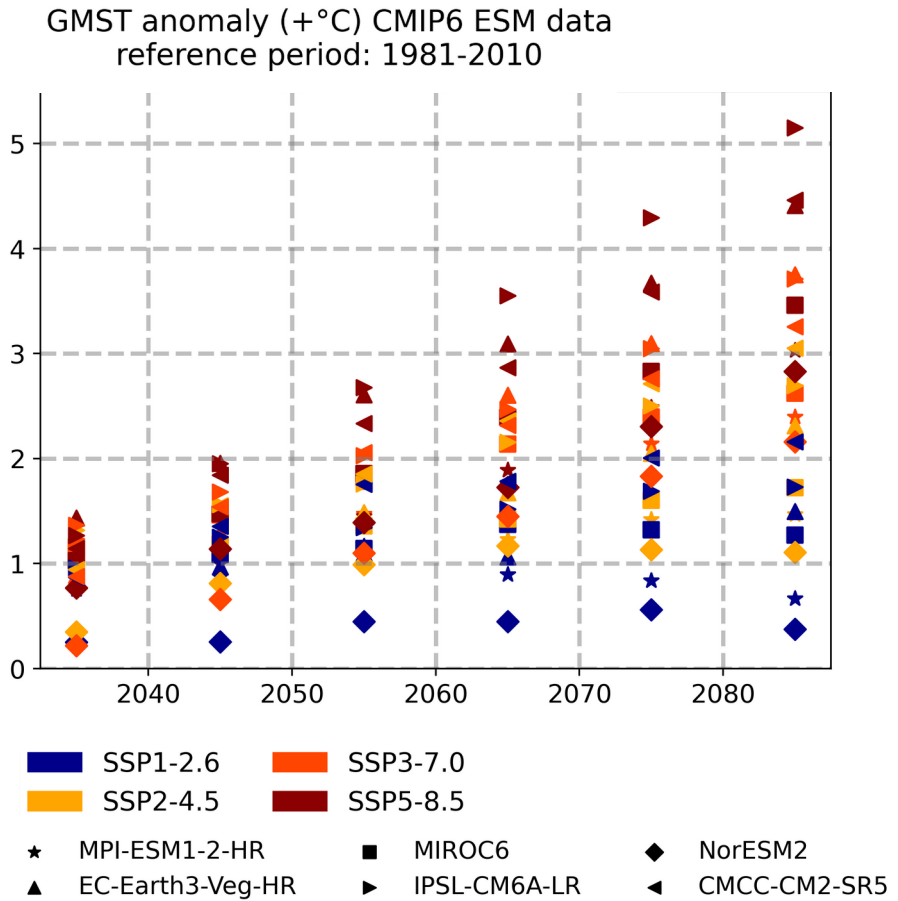
GMST = Global Mean surface temperature

Used ESMs

+ historical scenario using observed greenhouse gases concentrations (1981-2014)

2071-2100

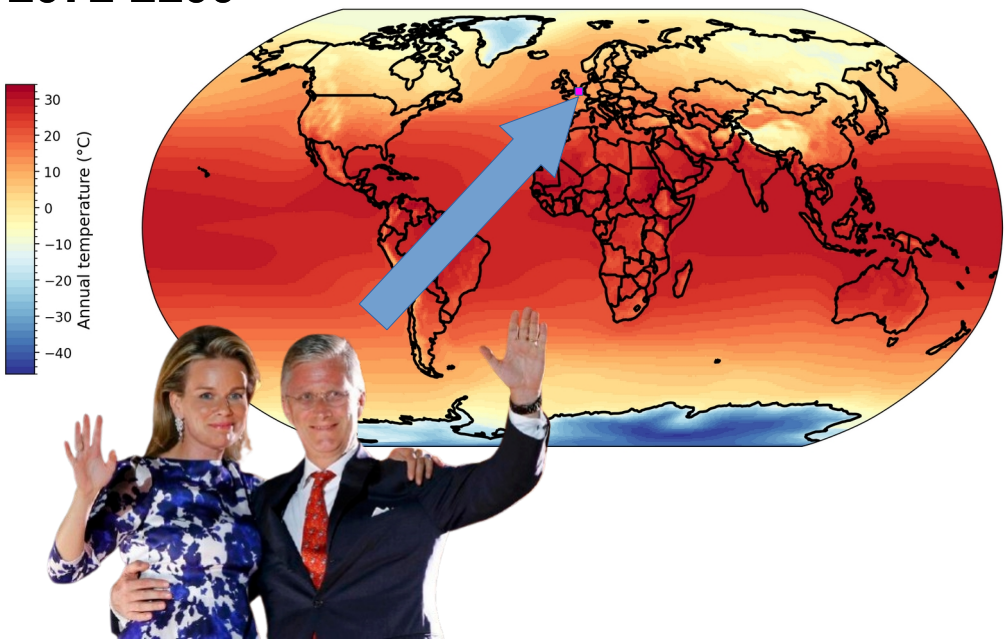


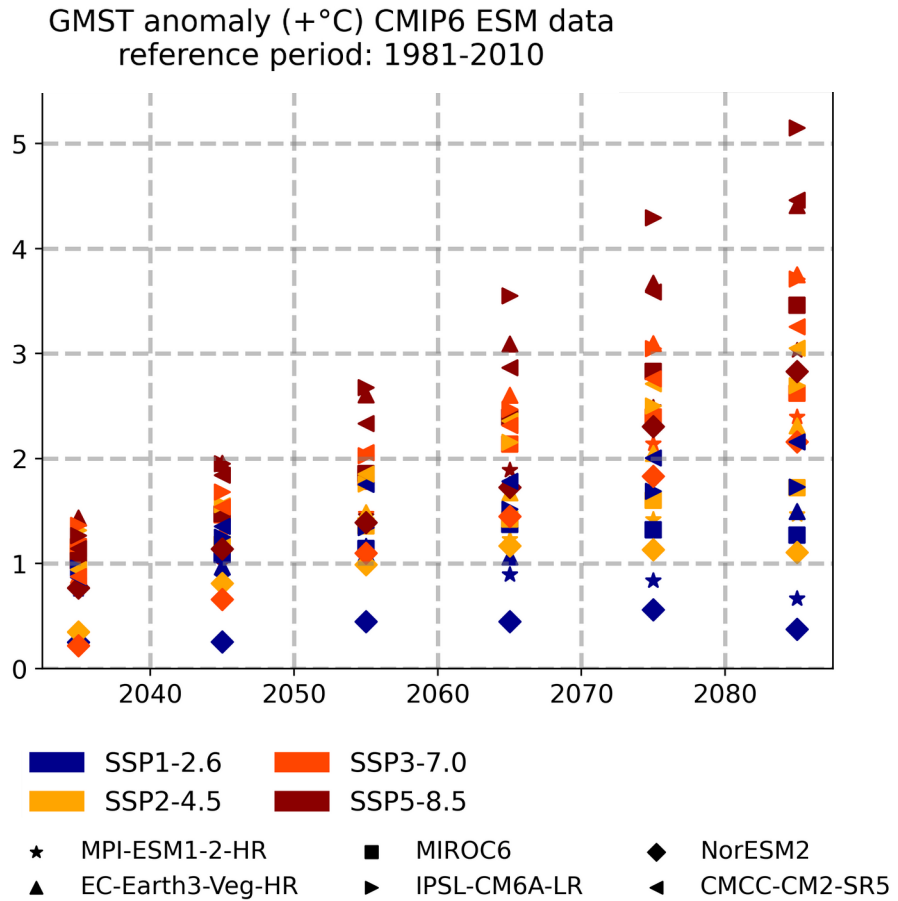


GMST = Global Mean surface temperature

Used ESMs

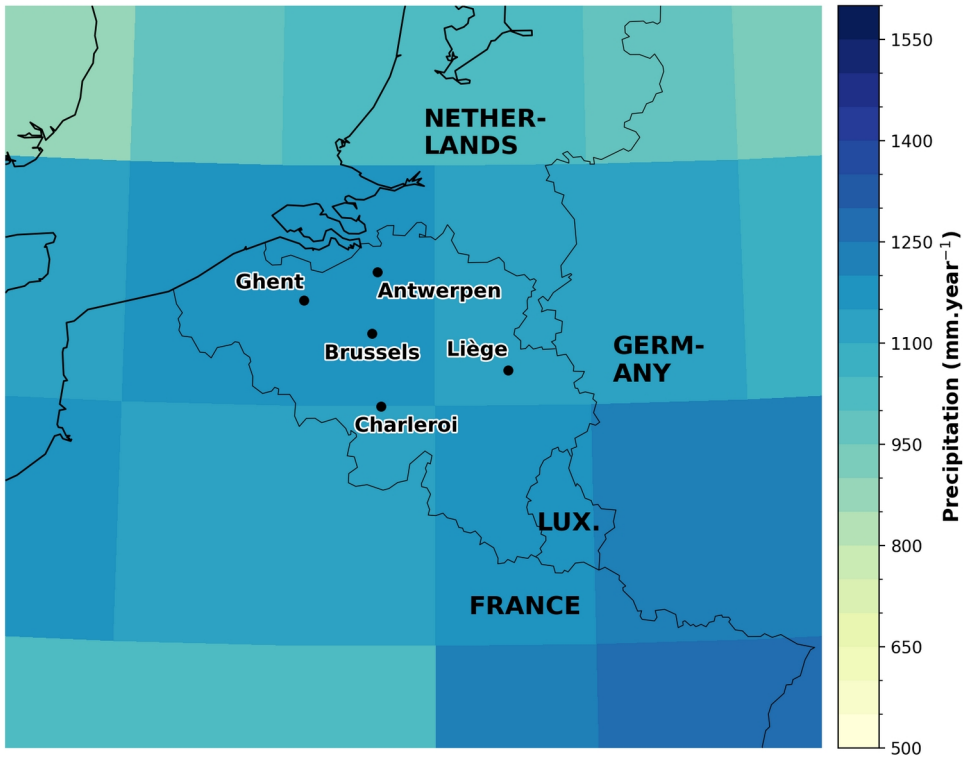
2071-2100



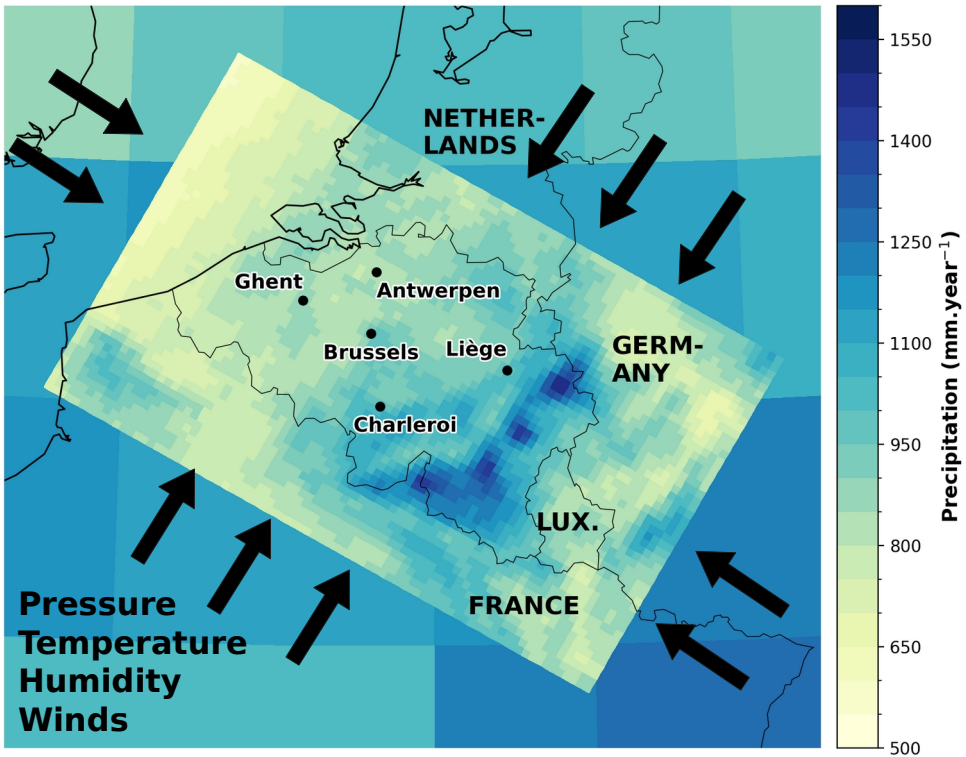


GMST = Global Mean surface temperature

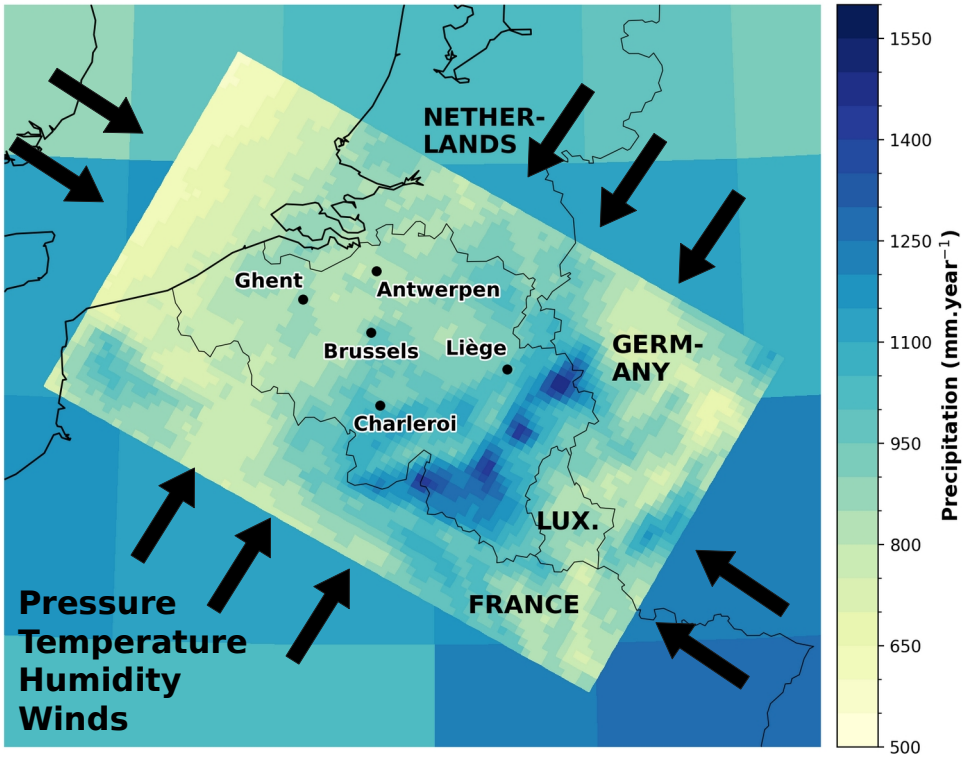
Climate models: ESMs → *Regional Climate Model* (RCM) MAR



Climate models: ESMs → *Regional Climate Model* (RCM) MAR



Climate models: ESMs → *Regional Climate Model* (RCM) MAR



Used ESMs	Model name
MPI-ESM1-2-HR	MAR-MPI
IPSL-CM6A-LR	MAR-IPSL
EC-Earth3-Veg	MAR-EC3
MIROC6	MAR-MIR
CMCC-CM2-SR5	MAR-SR5
NorESM2	MAR-NS2

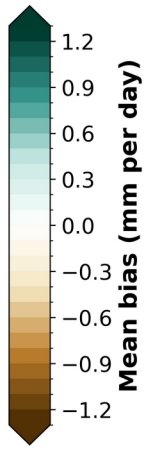
The MAR-ERA5 simulation

Forcing with gridded observations (1940-2023)

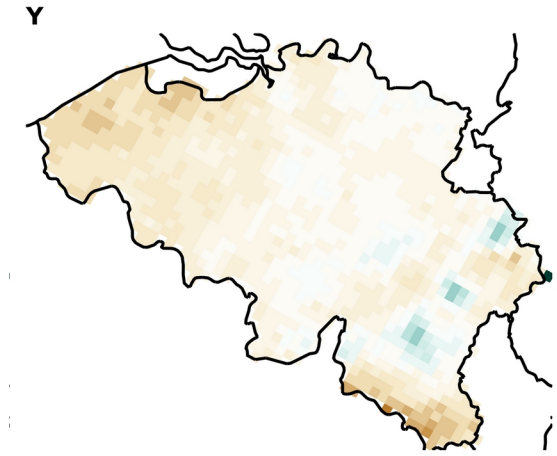
→ The ERA5 reanalysis

→ **MAR-ERA5**

1981-2010



Daily precipitation



vs. RMI observations

The MAR-ERA5 simulation

Forcing with gridded observations (1940-2023)

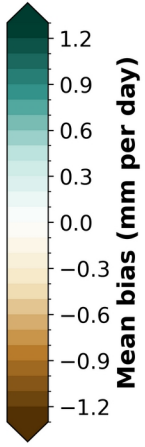
→ The ERA5 reanalysis

→ **MAR-ERA5**

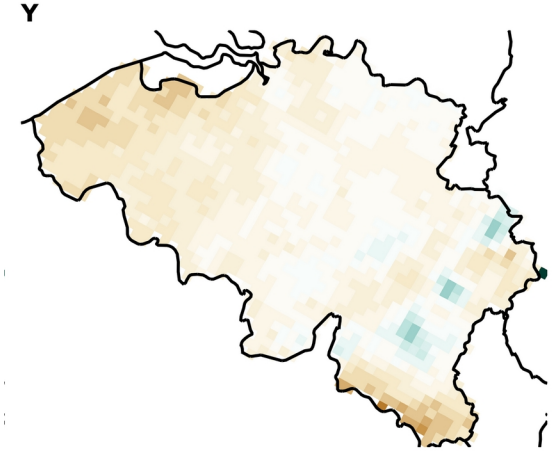


Photo : Vanity Fair France, 2017

1981-2010



Daily precipitation



vs. RMI observations

The MAR-ERA5 simulation

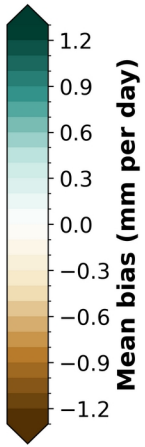
Forcing with gridded observations (1940-2023)

→ The ERA5 reanalysis

→ **MAR-ERA5**

Bias-adjustment with quantile mapping techniques

1981-2010



Daily precipitation



vs. RMI observations



Photo : Reuters, 2025.

PART 1

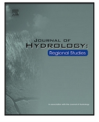
Evolution of daily extreme precipitation frequency and intensity in Belgium using MAR

Journal of Hydrology: Regional Studies 59 (2025) 102399

Contents lists available at ScienceDirect

Journal of Hydrology: Regional Studies

journal homepage: www.elsevier.com/locate/ejrh

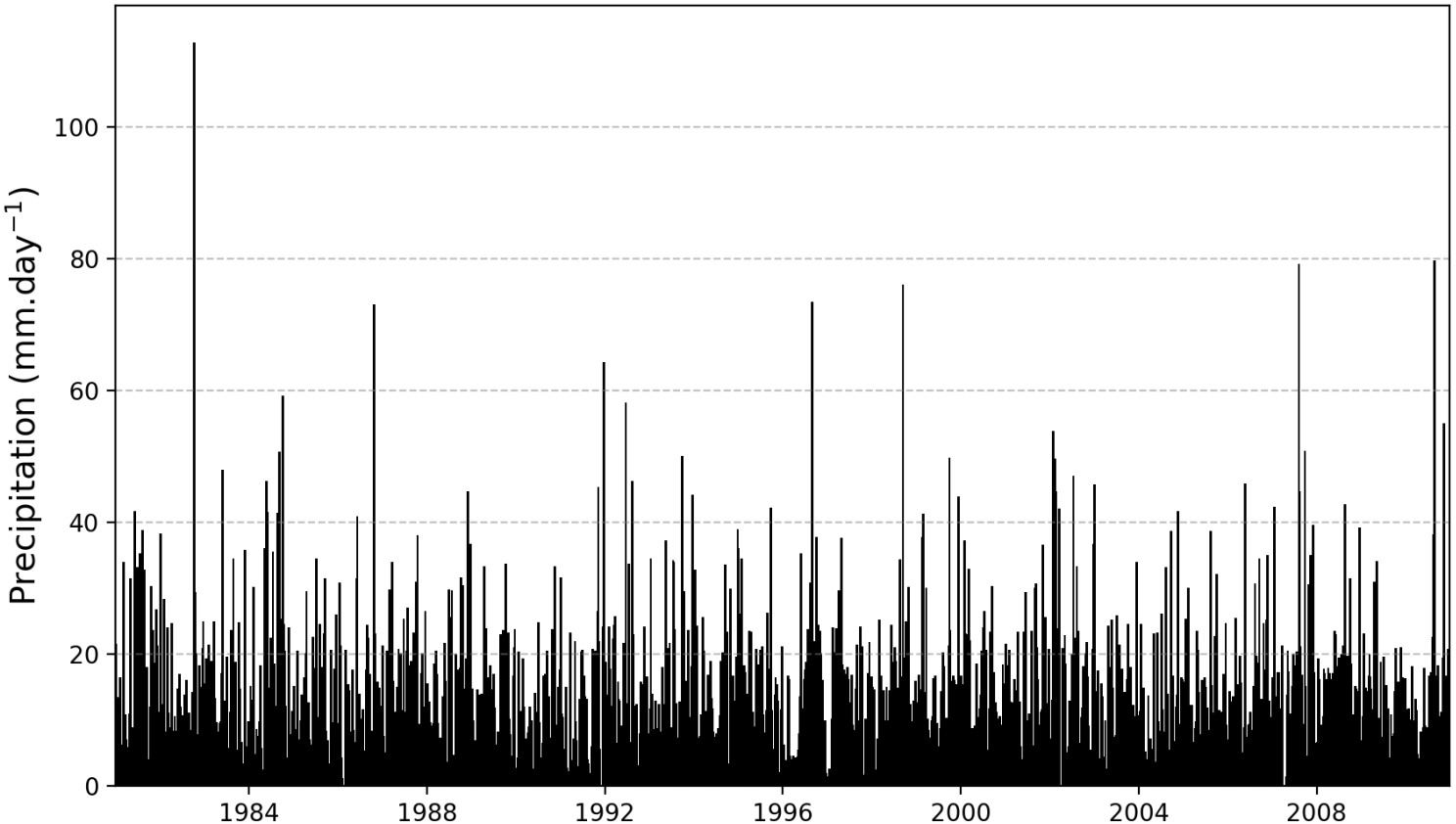


Increased intensity and frequency of extreme precipitation events in Belgium as simulated by the regional climate model MAR

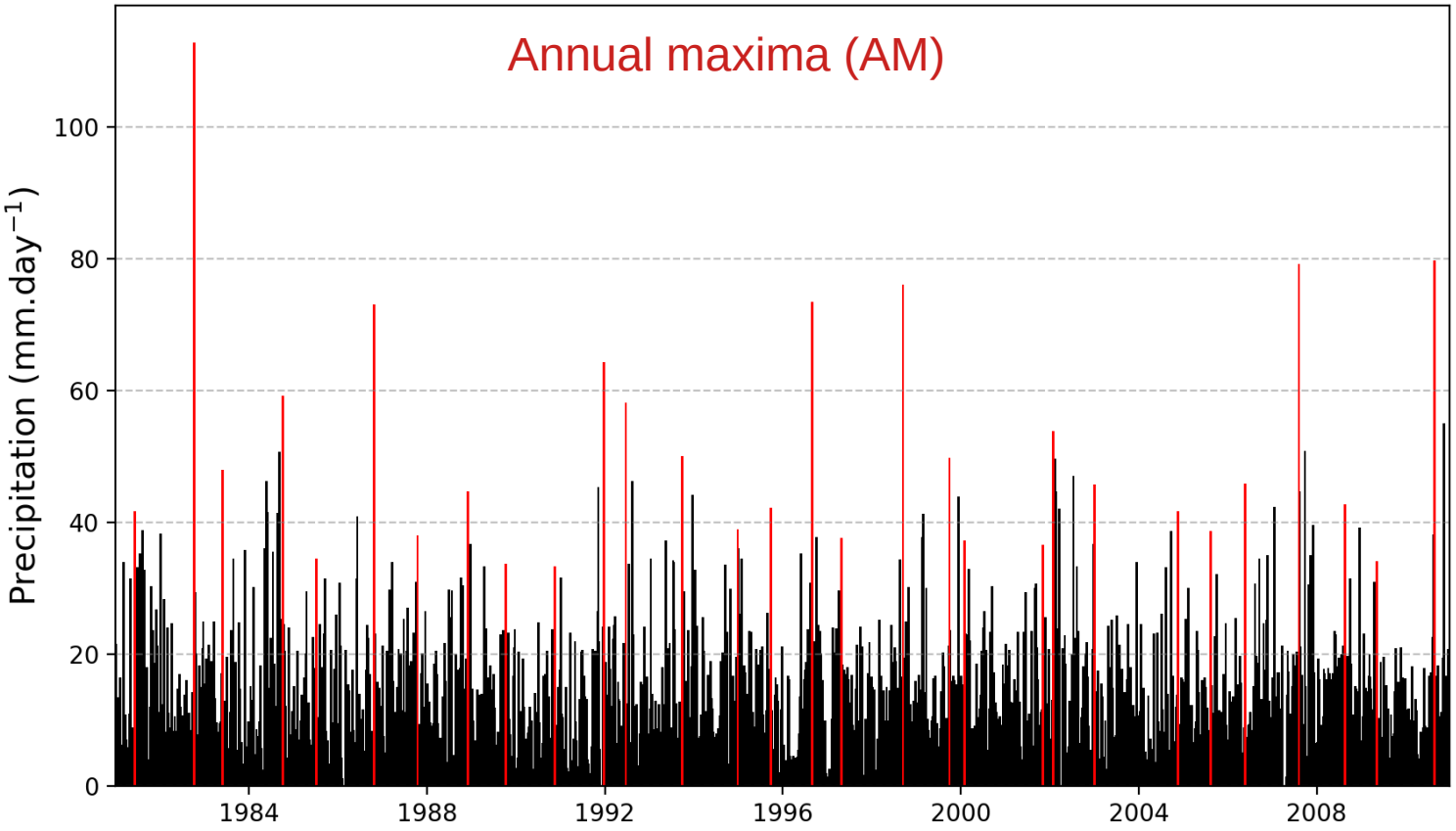
Josip Brajkovic [a,*], Xavier Fettweis [a], Brice Noël [a], Hans Van De Vyver [b], Nicolas Ghilain [a,b], Pierre Archambeau [c], Michel Pirotton [c], Sébastien Doutreloup [a]

[a] Department of Geography, Laboratory of Climatology and Topoclimatology, SPHERES, University of Liege, Liege, Belgium
[b] Royal Meteorological Institute, RMI, Uccle, Belgium
[c] Department of Environmental Engineering, University of Liege, Liege, Belgium

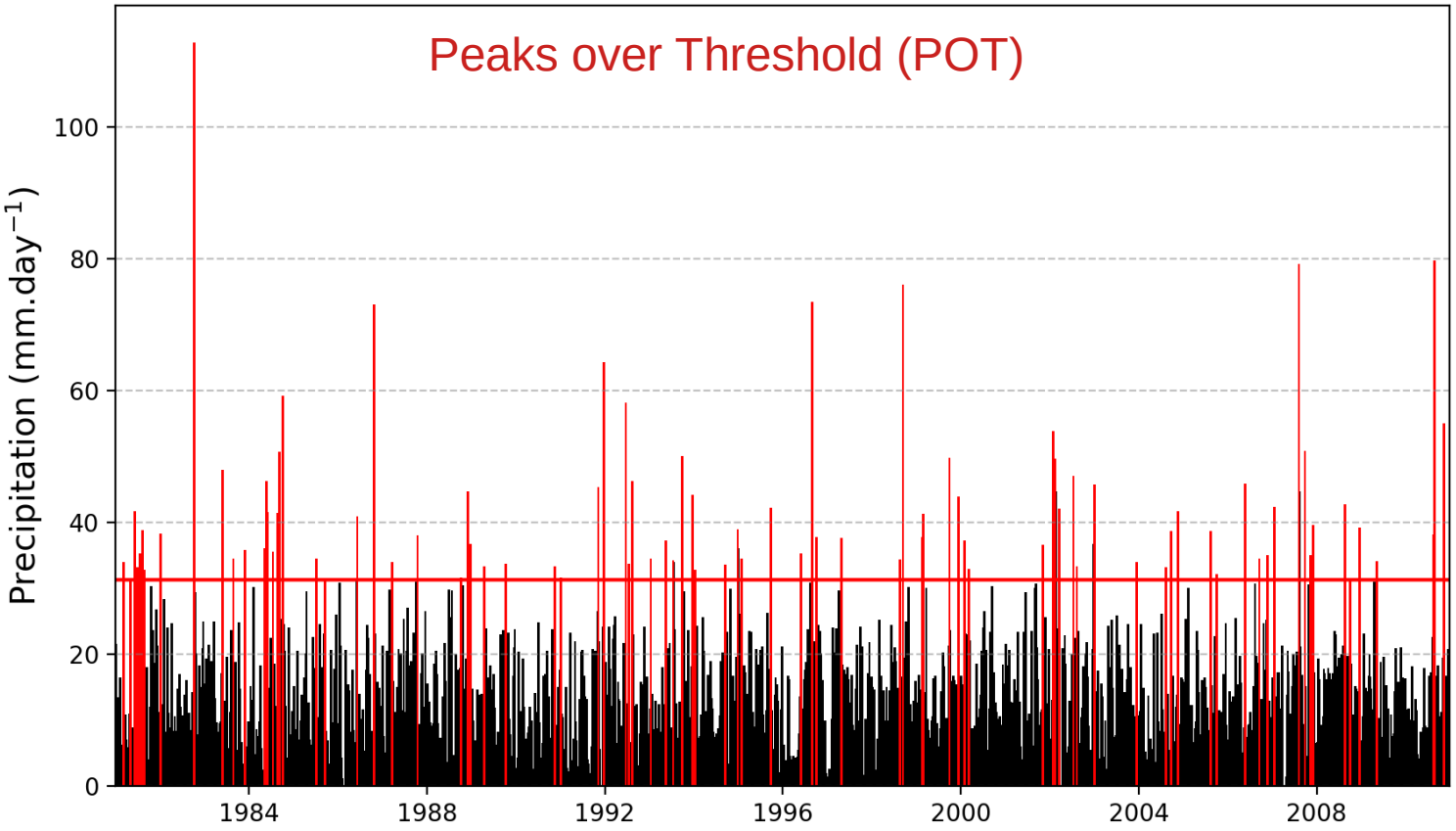
Extreme Value Analyses (EVA) – Events selection

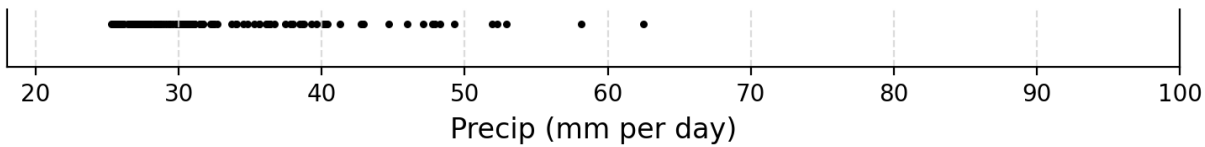


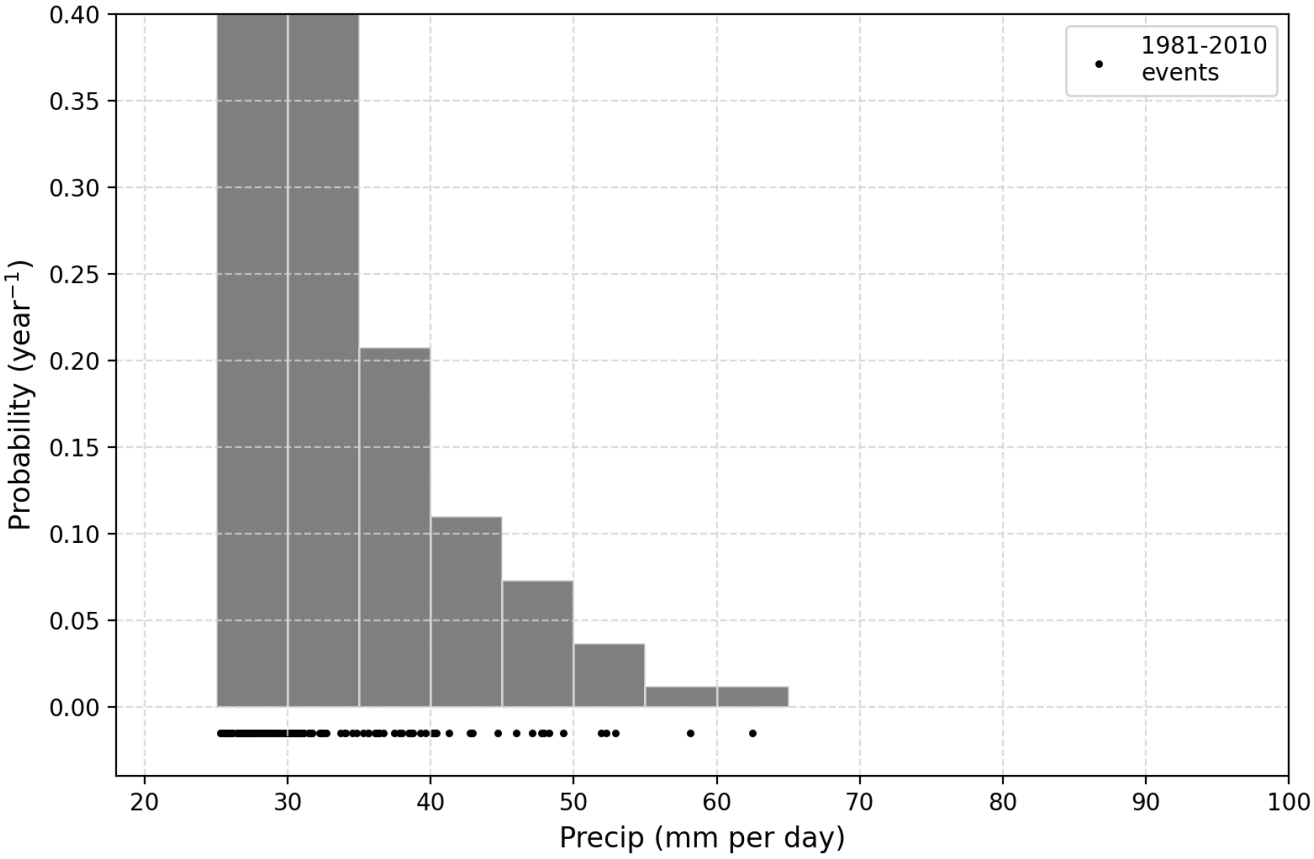
Extreme Value Analyses (EVA) – Events selection

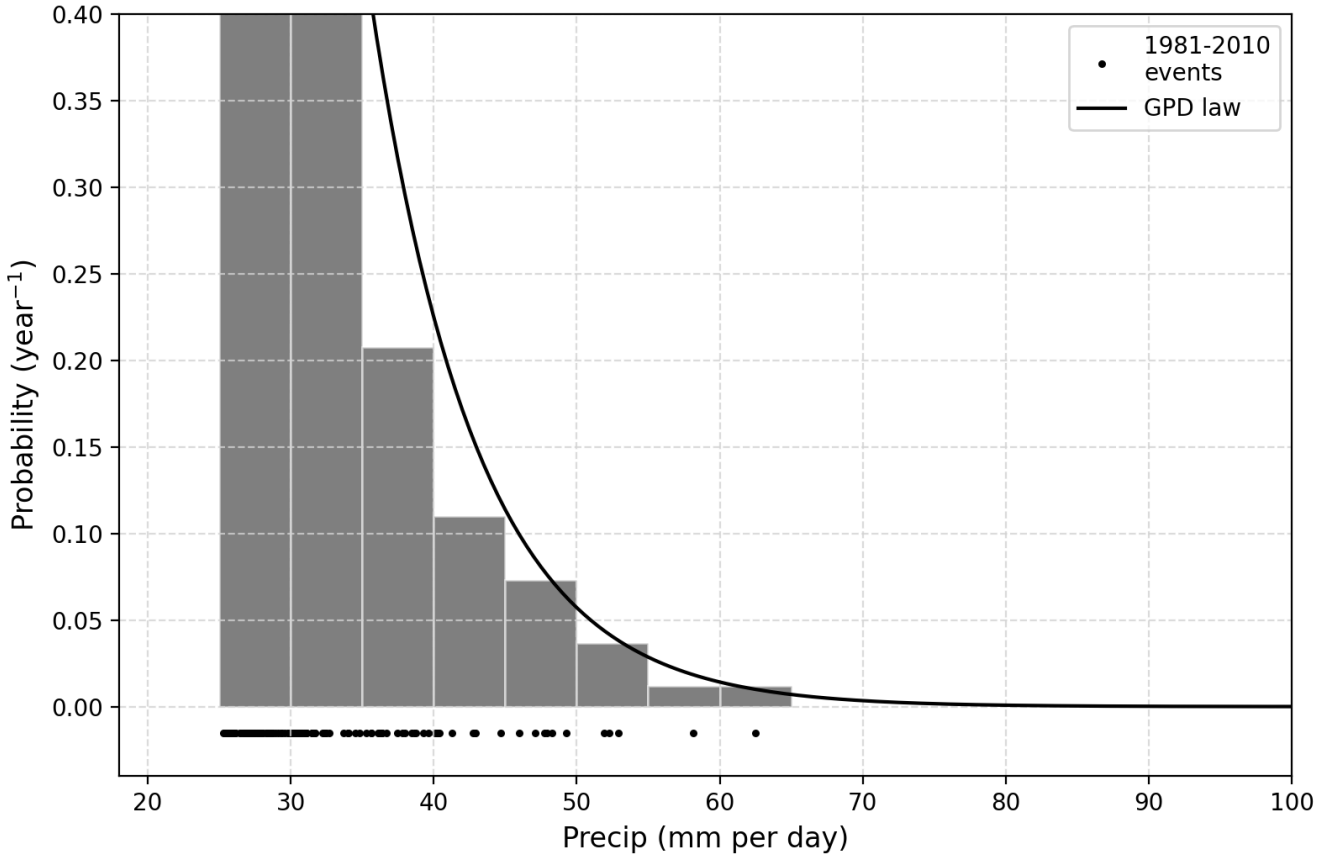


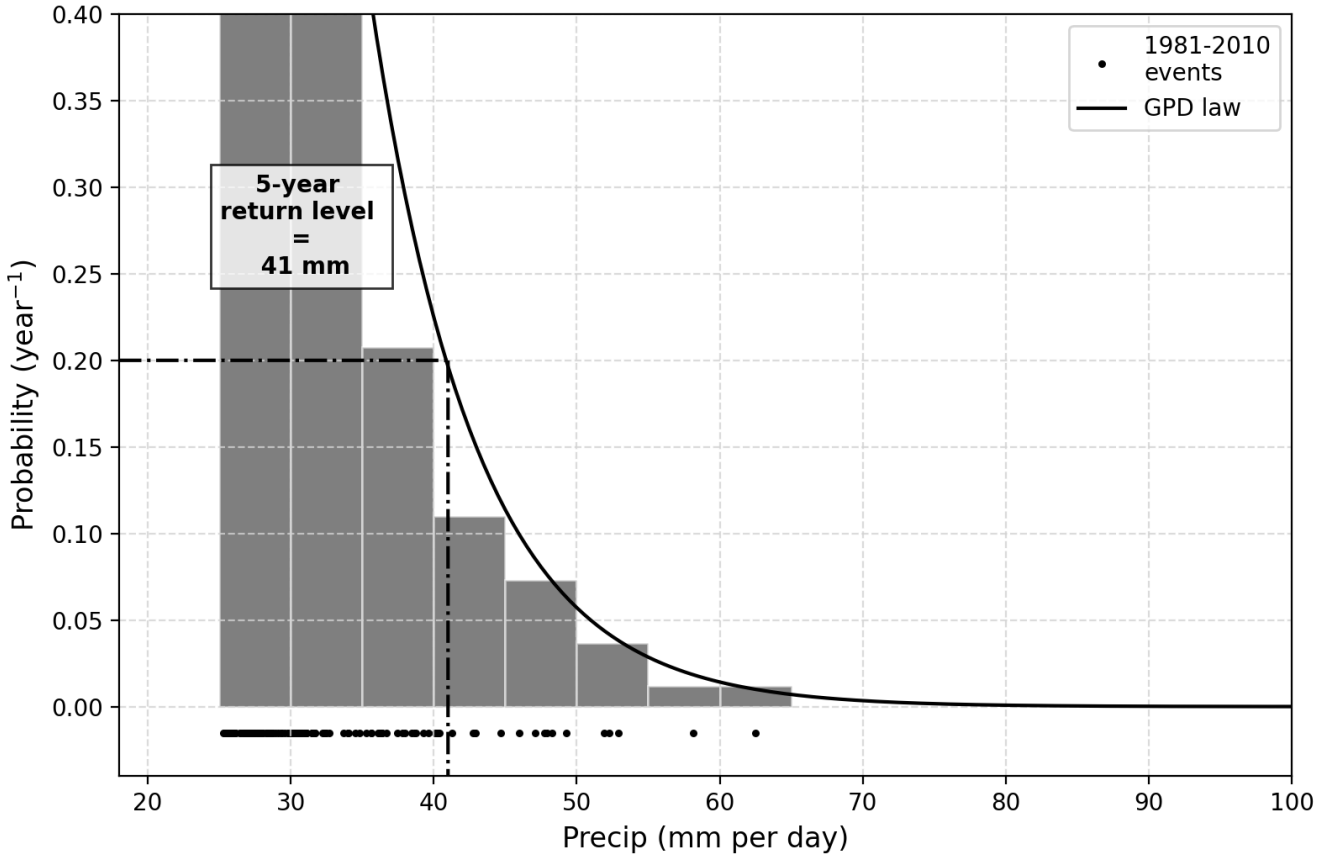
Extreme Value Analyses (EVA) – Events selection

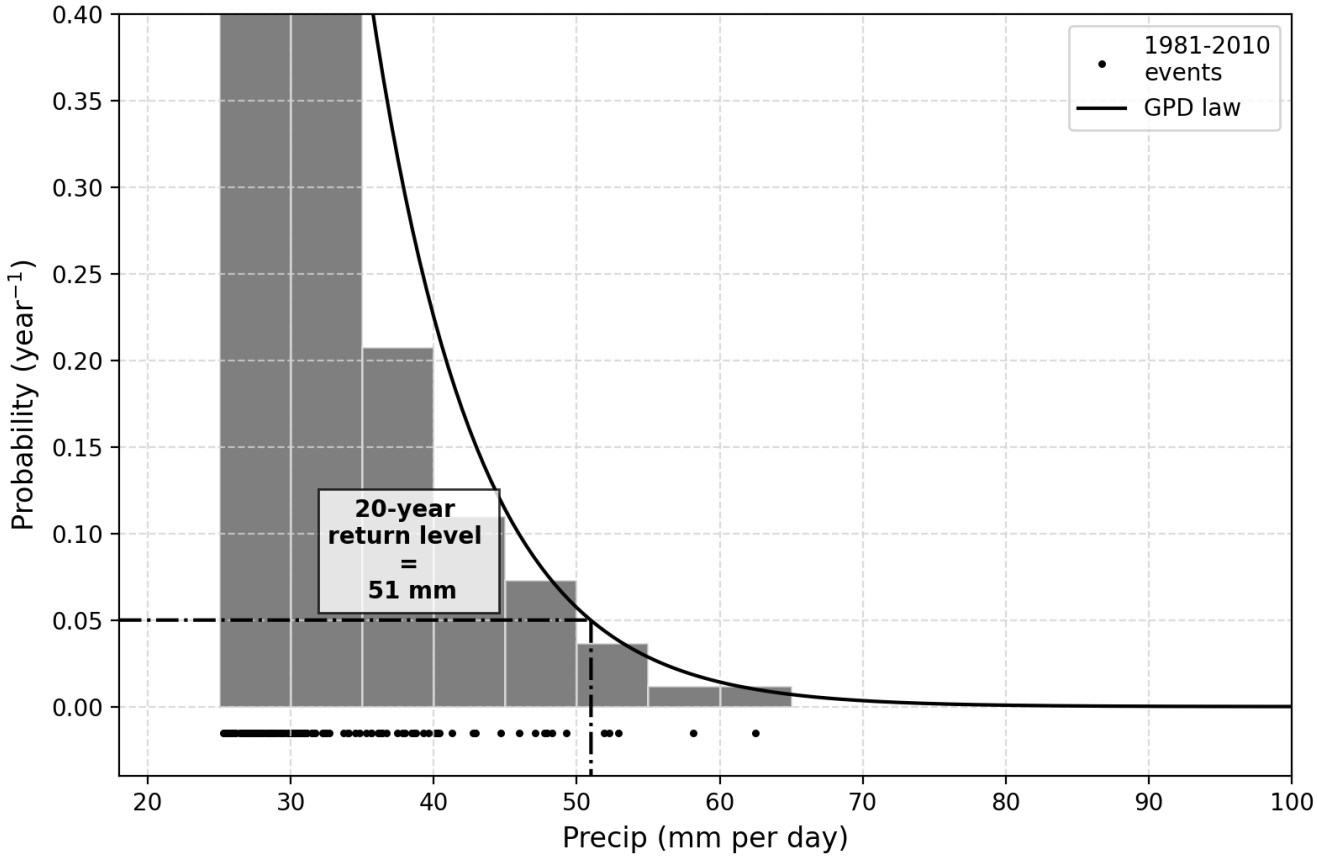


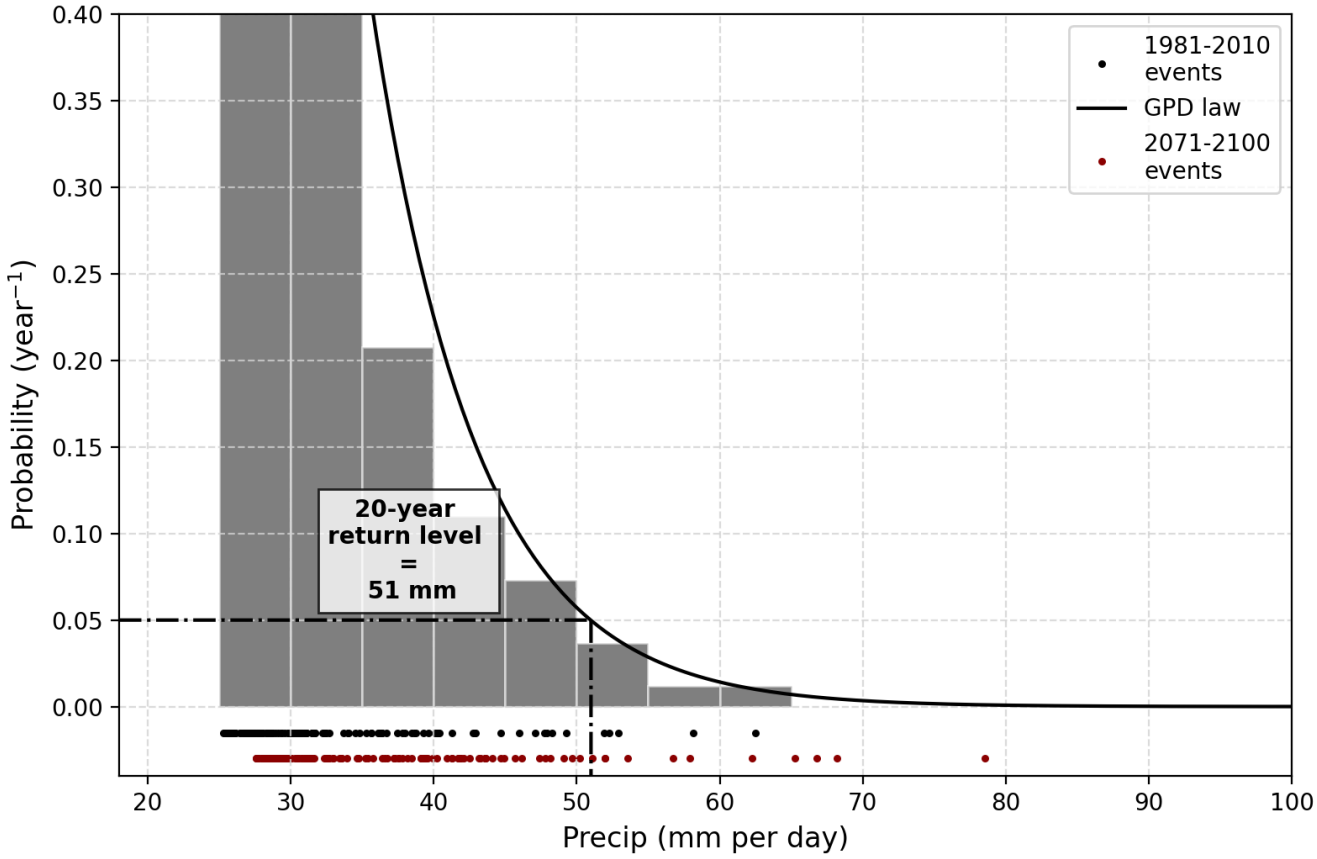

20
30
40
50
60
70
80
90
100
Precip (mm per day)

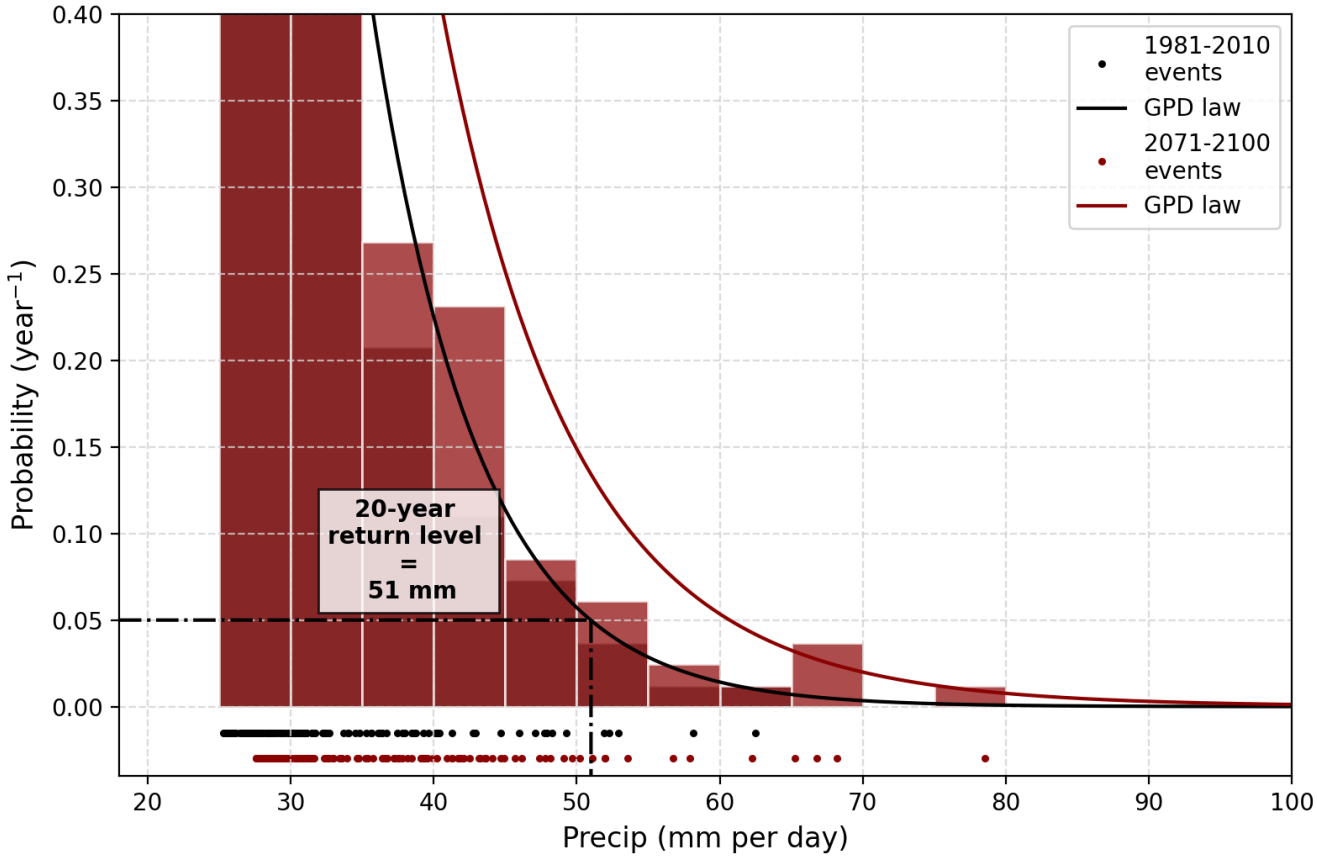

0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Probability (year^{-1})
1981-2010
events
20
30
40
50
60
70
80
90
100
Precip (mm per day)

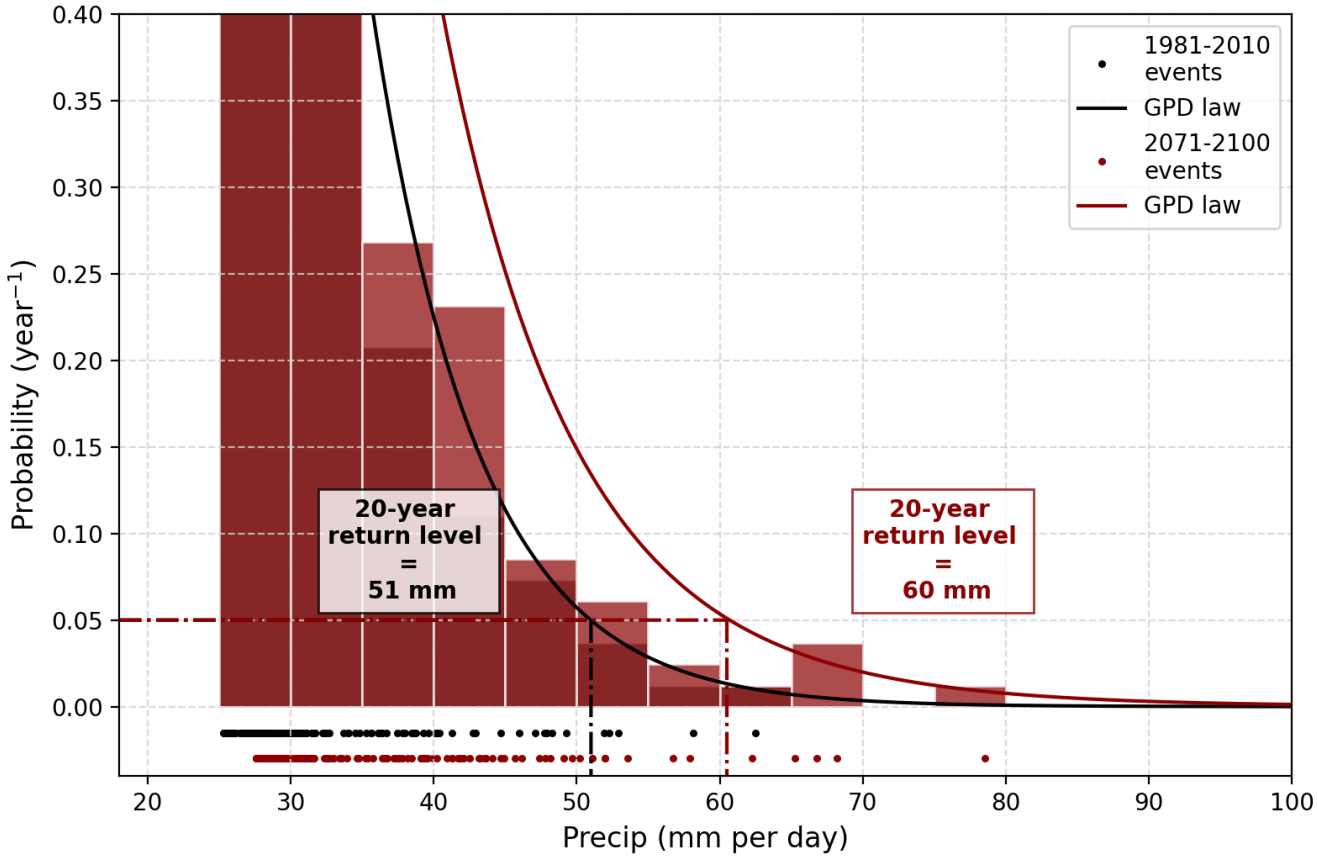

0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Probability (year^{-1})
20
30
40
50
60
70
80
90
100
Precip (mm per day)
1981-2010 events
GPD law

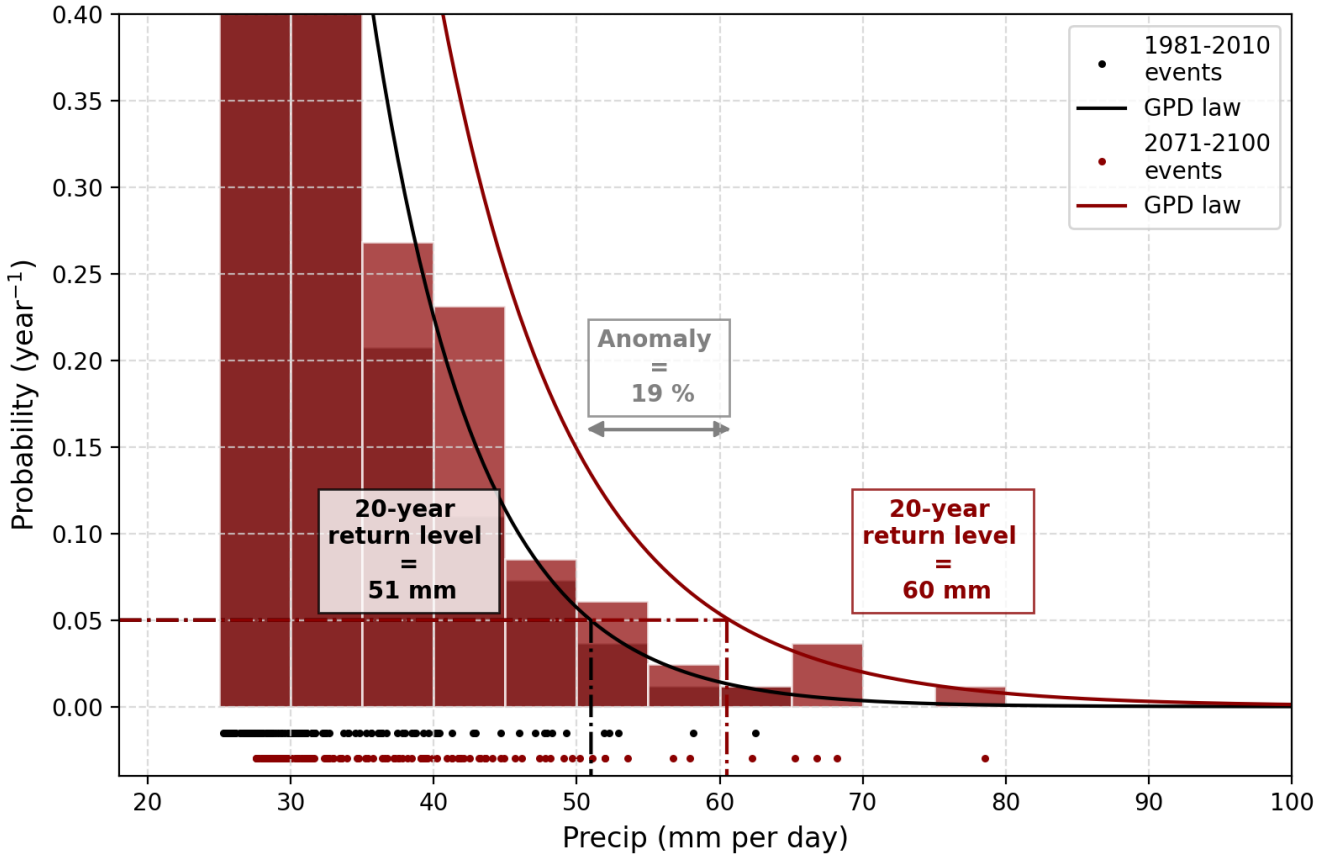

0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Probability (year^{-1})
5-year
return level
=
41 mm
1981-2010
events
GPD law
20
30
40
50
60
70
80
90
100
Precip (mm per day)

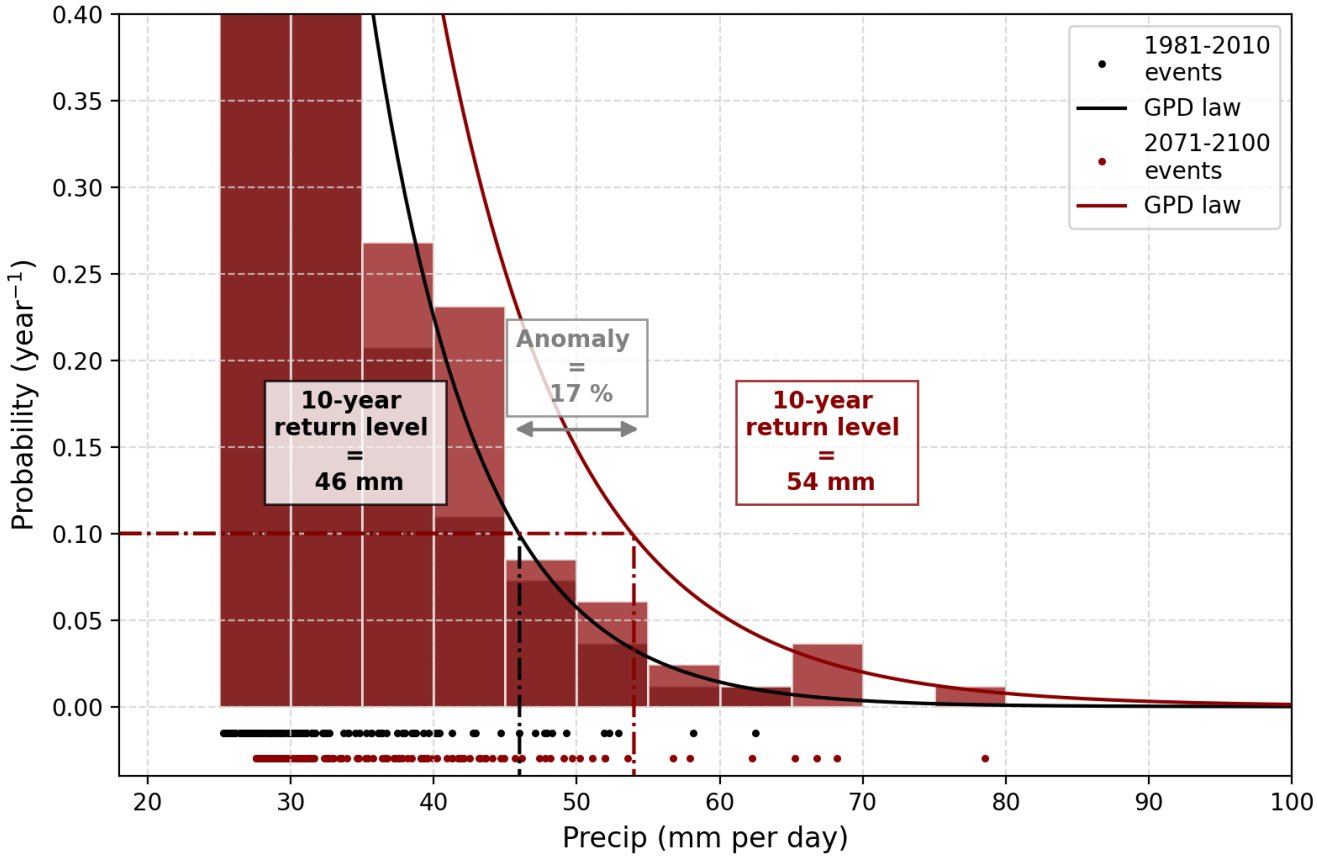

0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Probability (year^{-1})
20
30
40
50
60
70
80
90
100
Precip (mm per day)
1981-2010 events
GPD law
20-year return level = 51 mm


0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Probability (year^{-1})
20
30
40
50
60
70
80
90
100
Precip (mm per day)
1981-2010 events
GPD law
2071-2100 events
20-year return level = 51 mm

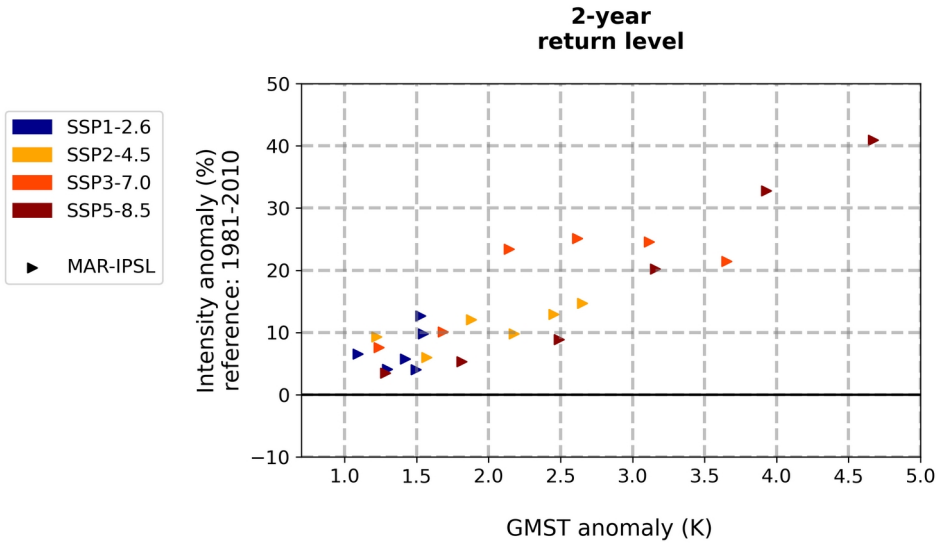

0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Probability (year^{-1})
20
30
40
50
60
70
80
90
100
Precip (mm per day)
1981-2010 events
GPD law
2071-2100 events
GPD law
20-year return level = 51 mm


0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Probability (year^{-1})
20
30
40
50
60
70
80
90
100
Precip (mm per day)
1981-2010 events
GPD law
2071-2100 events
GPD law
20-year return level = 51 mm
20-year return level = 60 mm

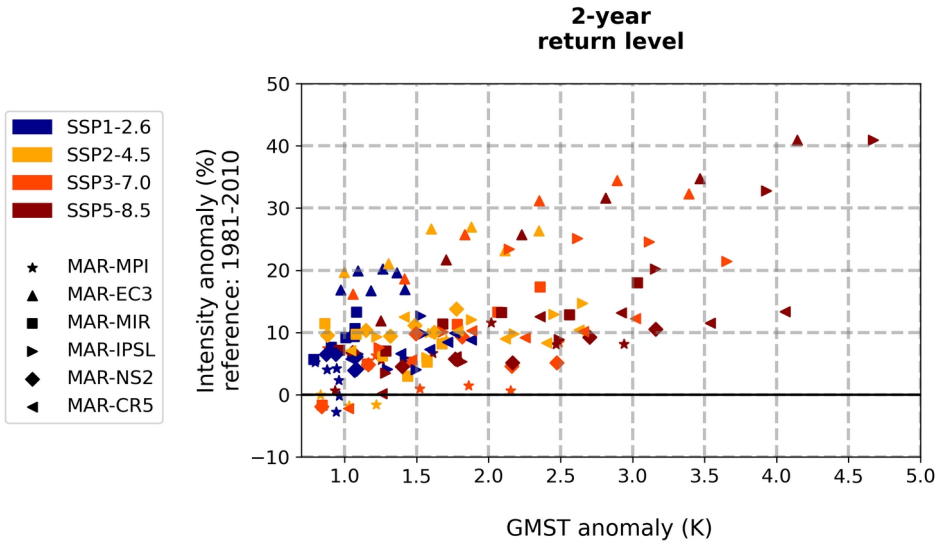

0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Probability (year^{-1})
20
30
40
50
60
70
80
90
100
Precip (mm per day)
1981-2010 events
GPD law
2071-2100 events
GPD law
Anomaly = 19 %
20-year return level = 51 mm
20-year return level = 60 mm


0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Probability (year^{-1})
20
30
40
50
60
70
80
90
100
Precip (mm per day)
1981-2010 events
GPD law
2071-2100 events
GPD law
Anomaly = 17 %
10-year return level = 46 mm
10-year return level = 54 mm

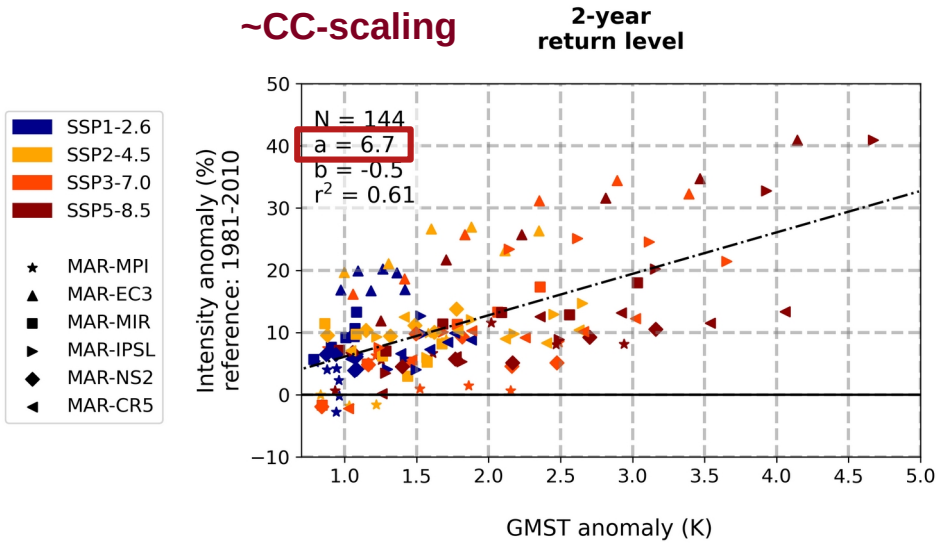
Evolution of extreme precipitation intensity



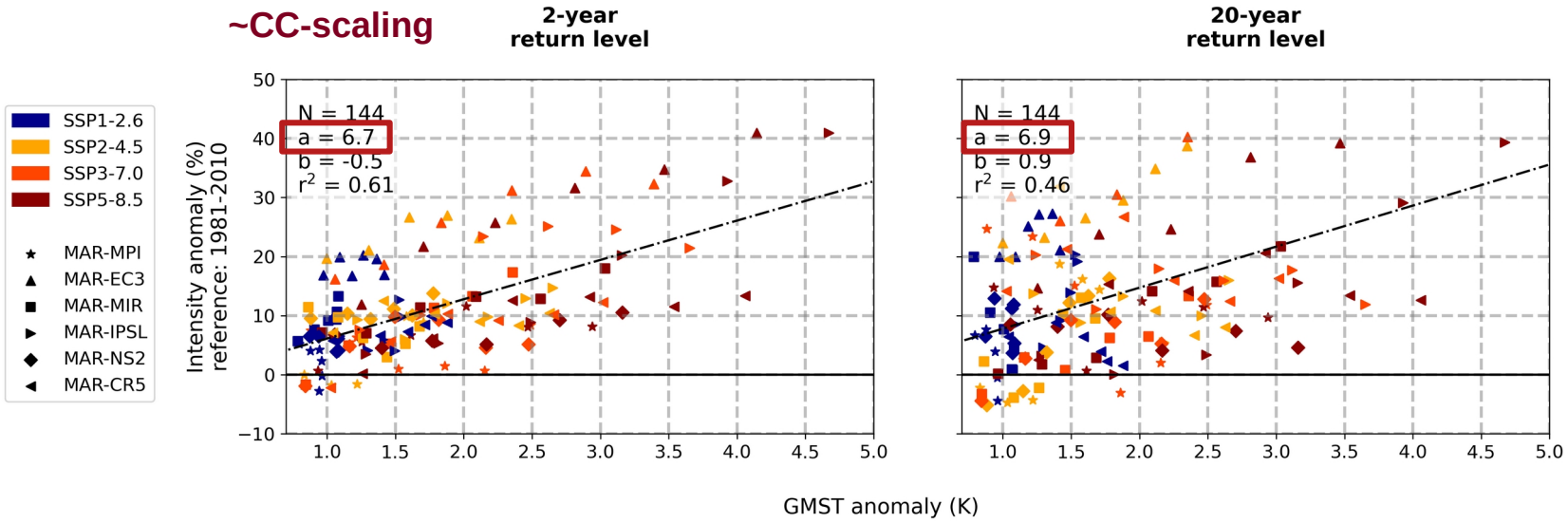
Evolution of extreme precipitation intensity



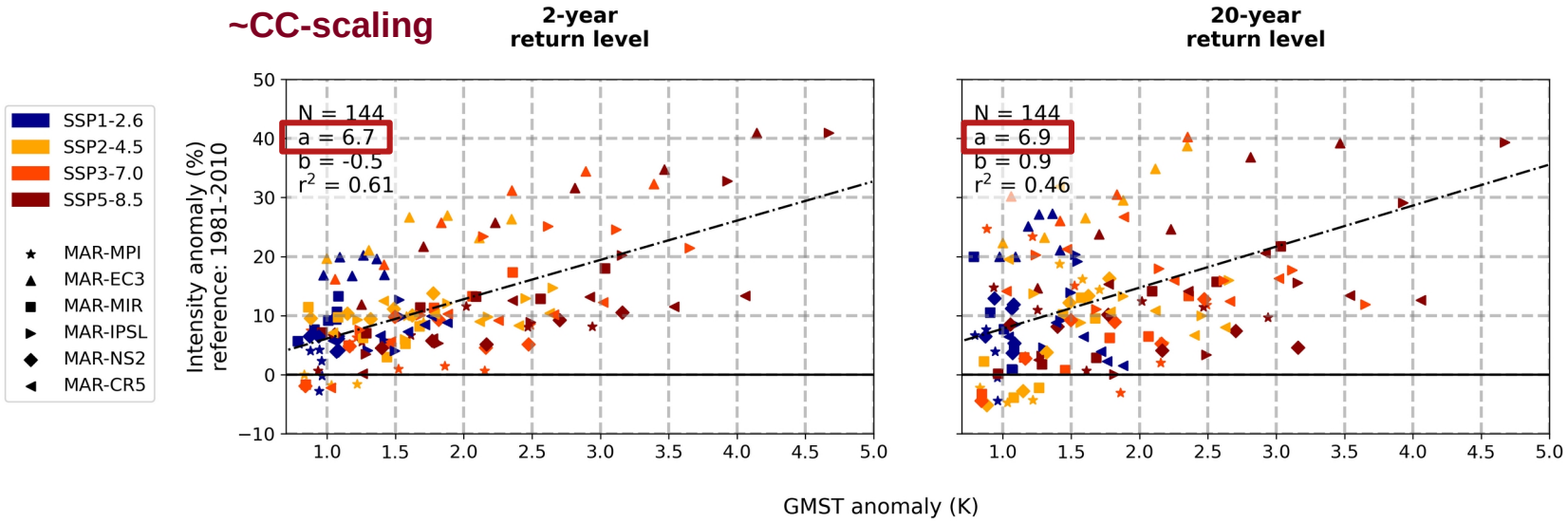
Evolution of extreme precipitation intensity



Evolution of extreme precipitation intensity



Evolution of extreme precipitation intensity

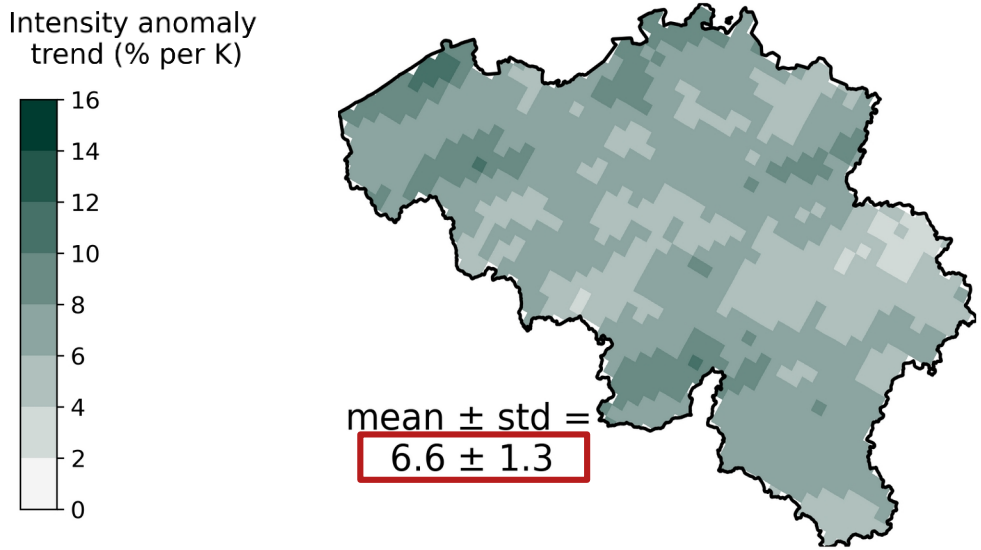


ESMs' internal variability

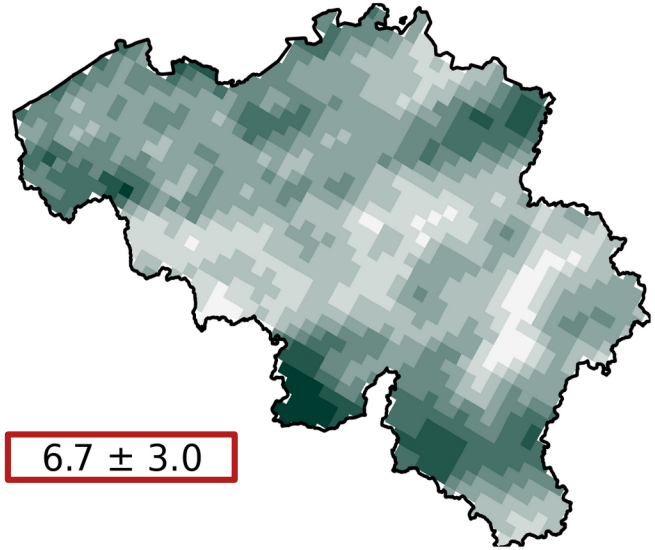
→ **Increase in the non-linearity of the answer**

Mapping the scaling rate

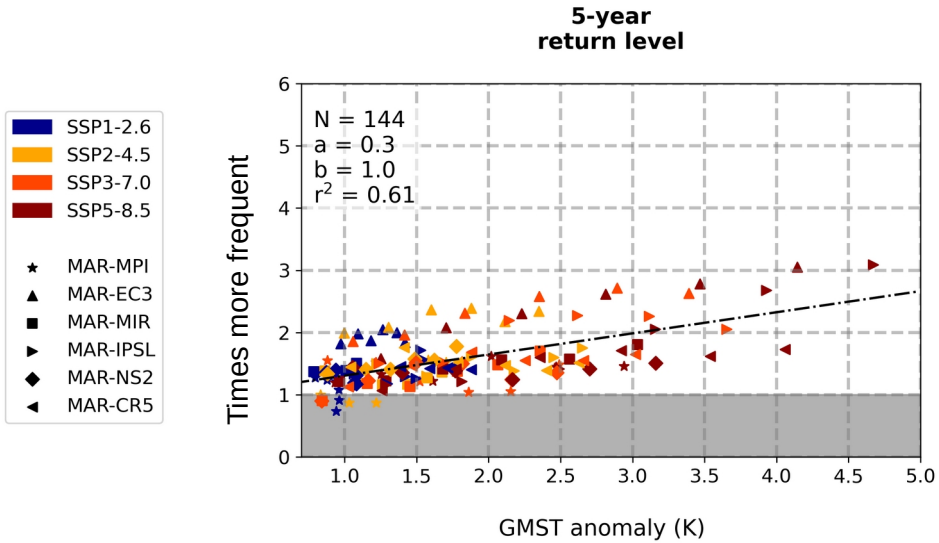
2-year return level



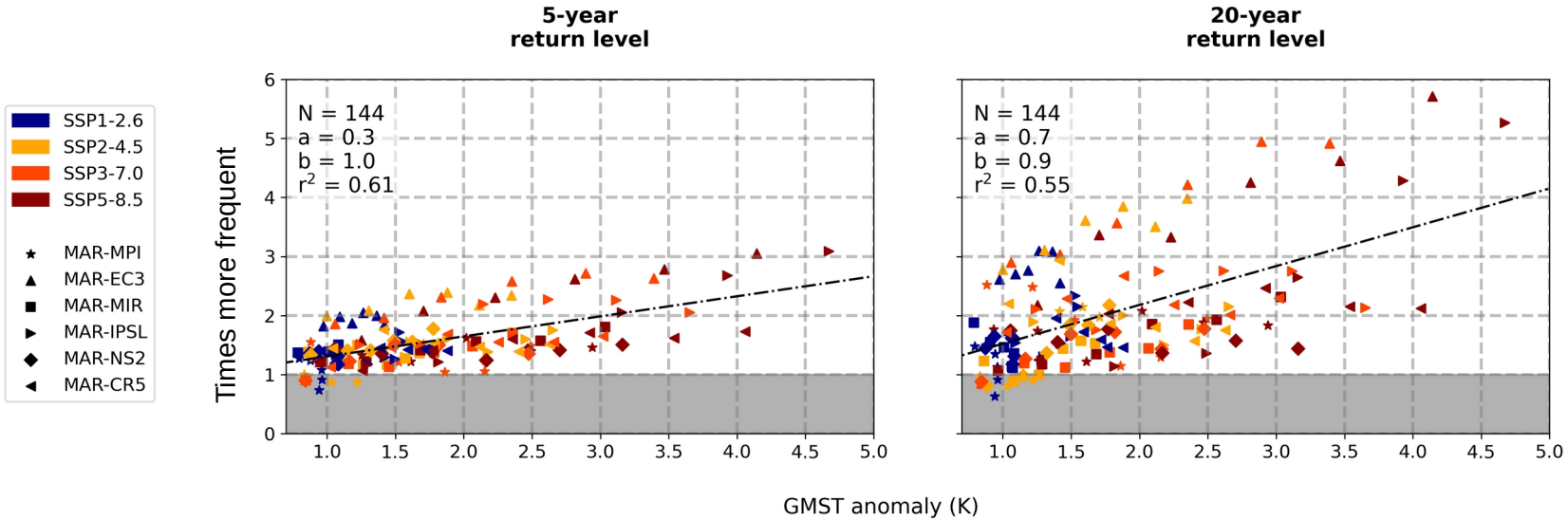
20-year return level



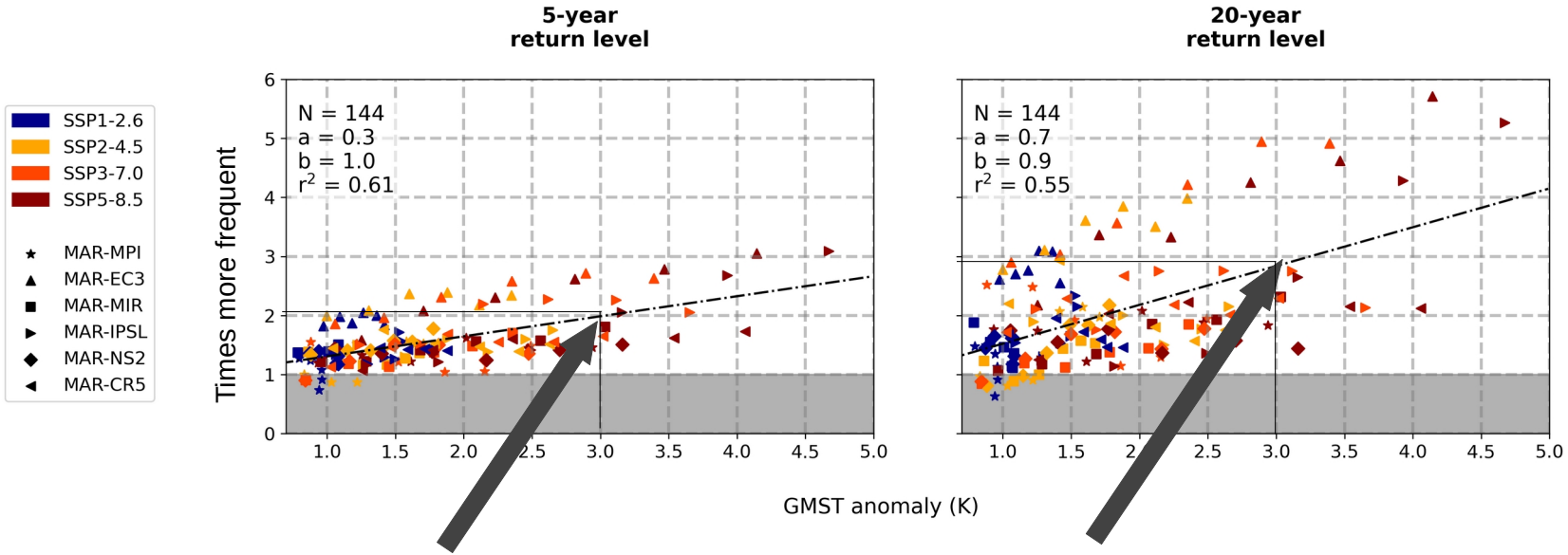
Evolution of extreme precipitation frequency



Evolution of extreme precipitation frequency



Evolution of extreme precipitation frequency



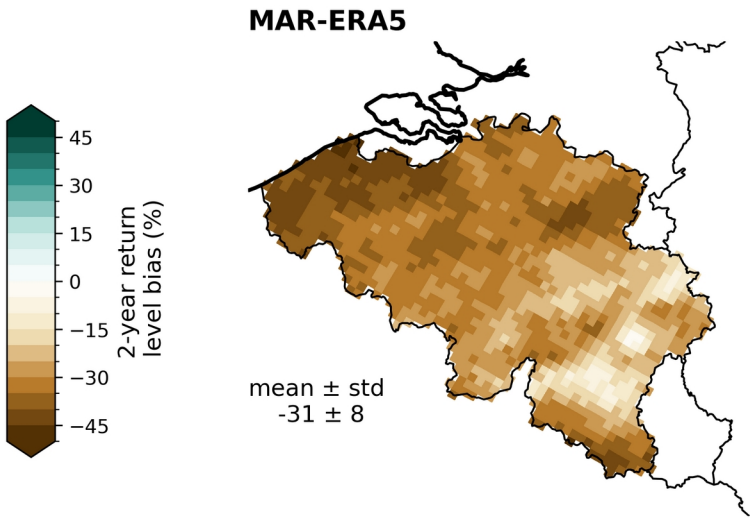
2 times more frequent

3 times more frequent

Despite these results, several **limits** and **questions** remain**:**

I. MAR still **underestimates** extreme precipitation, **especially for higher return periods**

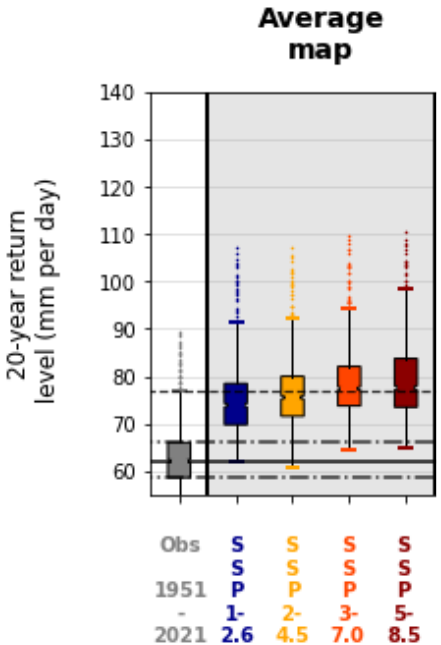
1981-2010



Despite these results, several **limits** and **questions** remain**:**

II. Large differences exist depending on the **ESM** forcing MAR

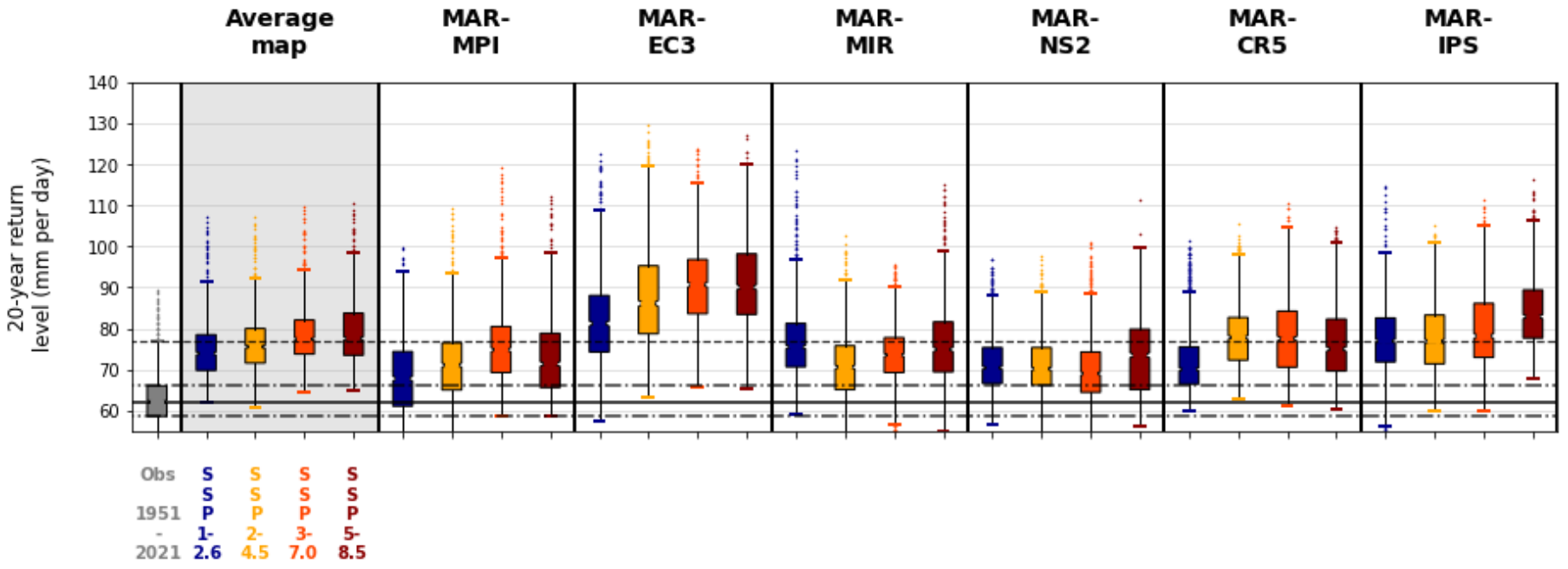
Bias-adjusted return levels over 2015-2100



Despite these results, several **limits** and **questions** remain**:**

II. Large differences exist depending on the **ESM** forcing MAR

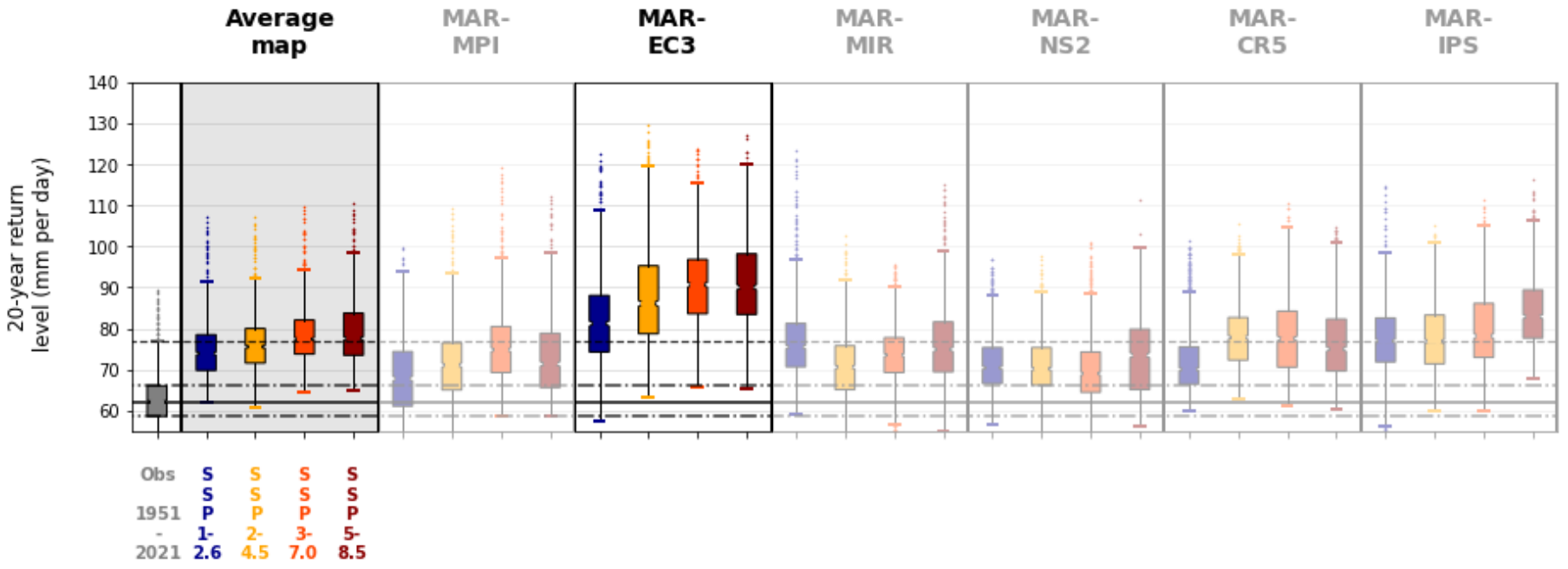
Bias-adjusted return levels over 2015-2100



Despite these results, several **limits** and **questions** remain**:**

II. Large differences exist depending on the **ESM** forcing MAR

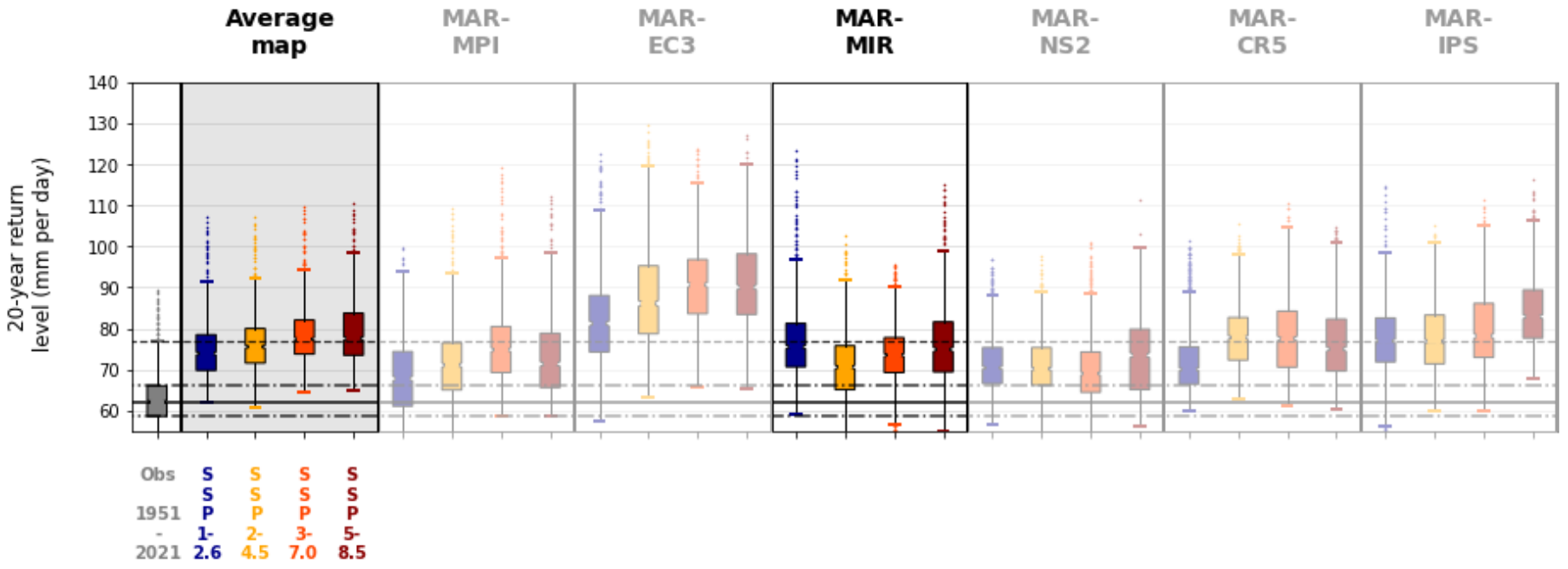
Bias-adjusted return levels over 2015-2100



Despite these results, several **limits** and **questions** remain**:**

II. Large differences exist depending on the **ESM** forcing MAR

Bias-adjusted return levels over 2015-2100



PART 1

Take–home

I. MAR **underestimates** daily extremes by around 30%
→ Need for **bias-adjustment** for impact studies

II. On average extreme precipitation **increases by ~7% per additional degree** of global warming → **CC-scaling**

III. **Natural variability** governs the timing of the most active periods in terms of extreme precipitation events

IV. Large differences appear depending on the **driving ESM**

PART 2

Past and future evolution of COL-associated precipitation events in Europe and Belgium

https://doi.org/10.5194/egusphere-2026-2315
Preprint. Discussion started: 20 May 2026
© Author(s) 2026. CC BY 4.0 License.



EGUsphere Preprint repository

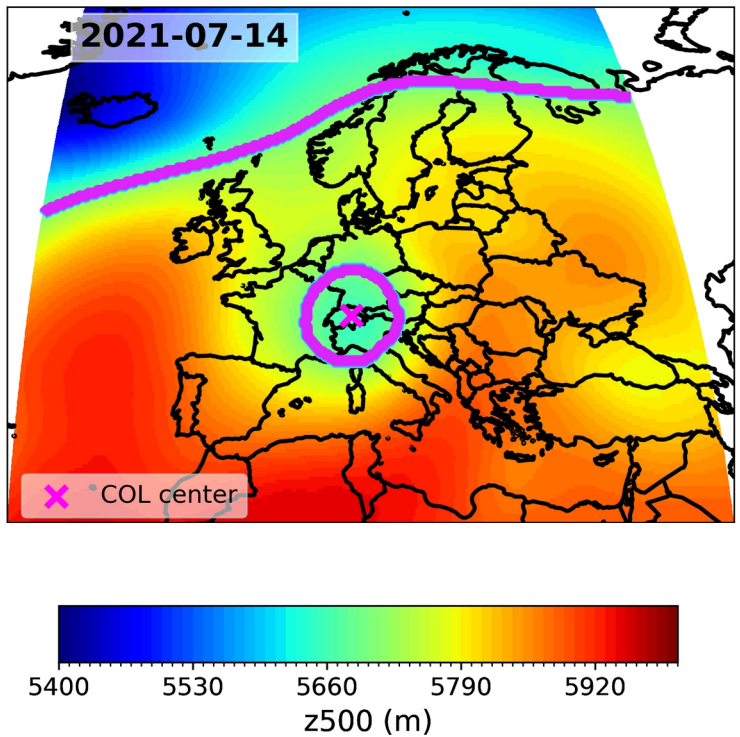
Past and future evolution of cut-off-low-associated extreme precipitation in Europe

Josip Brajkovic[1], Pierre Archambeau[3], Nicolas Ghilain[1,2], and Sébastien Doutreloup[1]

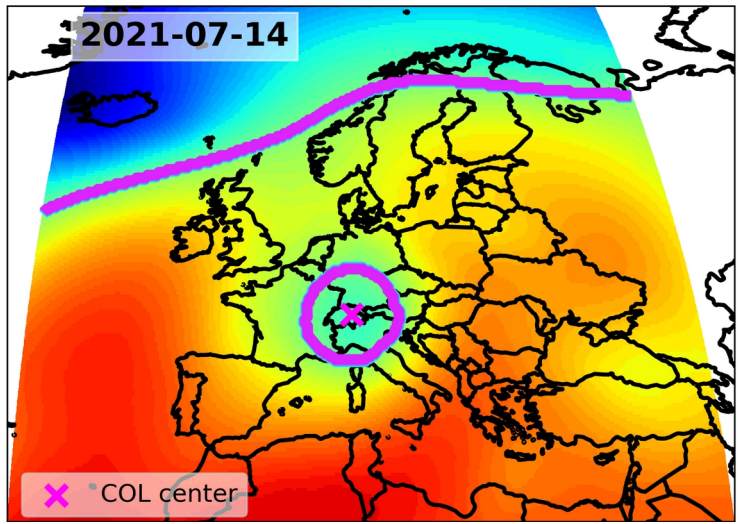
[1]Laboratory of Climatology, Department of Geography, SPHERES research unit, University of Liège, Liège, Belgium.
[2]Royal Meteorological Institute, RMI, Uccle, Belgium
[3]Department of Environmental Engineering, University of Liege, Liege, Belgium

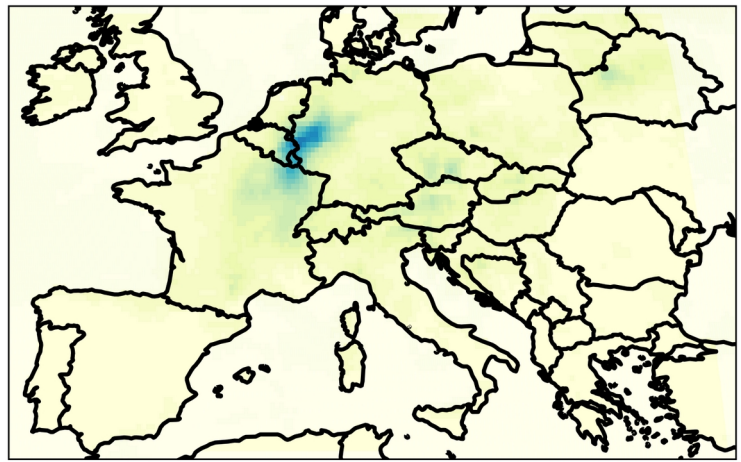
Correspondence: Josip Brajkovic (josip.brajkovic@uliege.be)

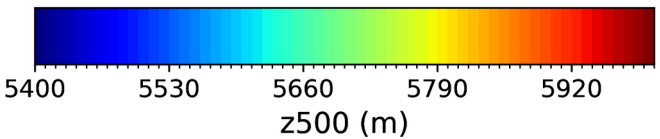
Recent high-impact COLs

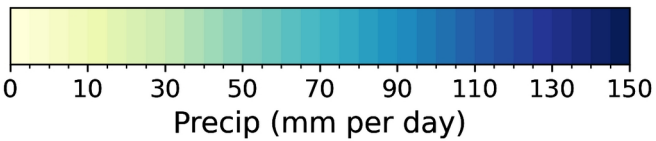


Recent high-impact COLs

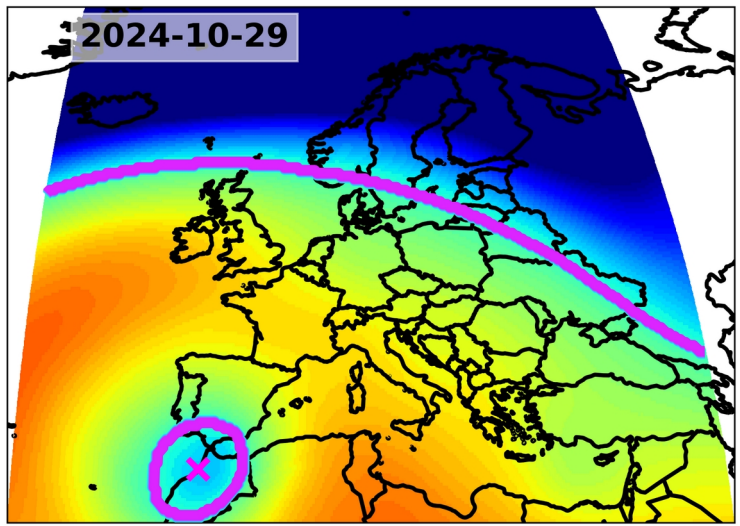


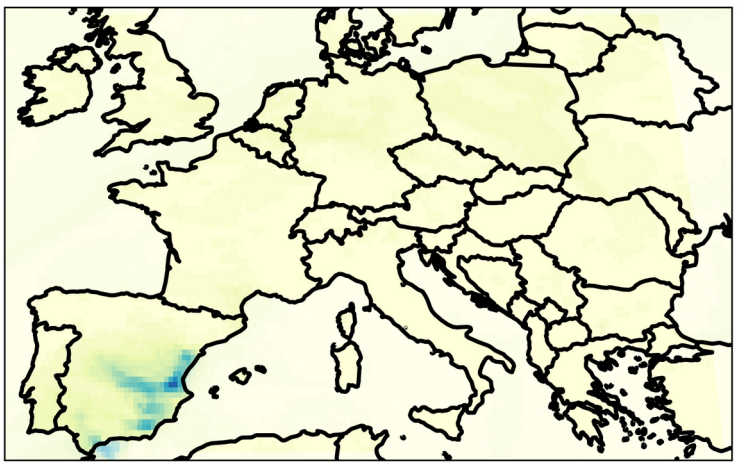




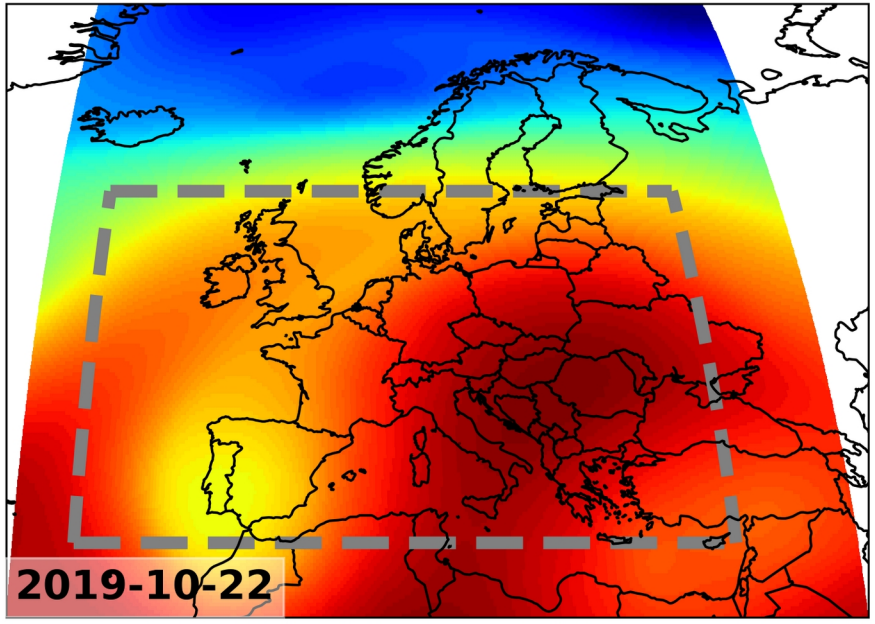


Recent high-impact COLs

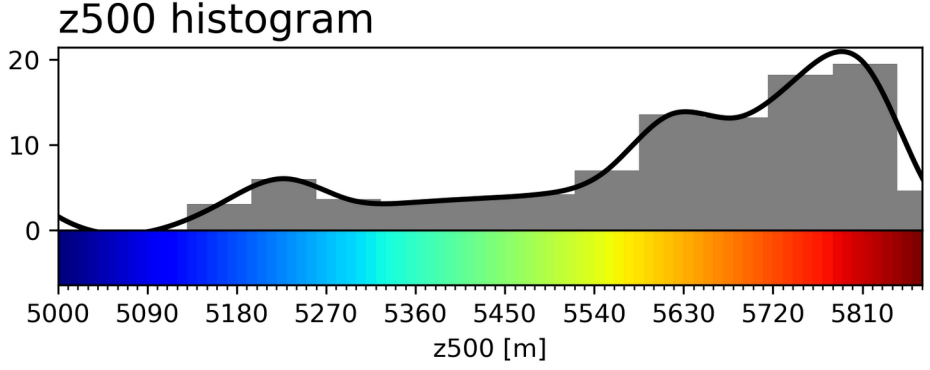




COL detection



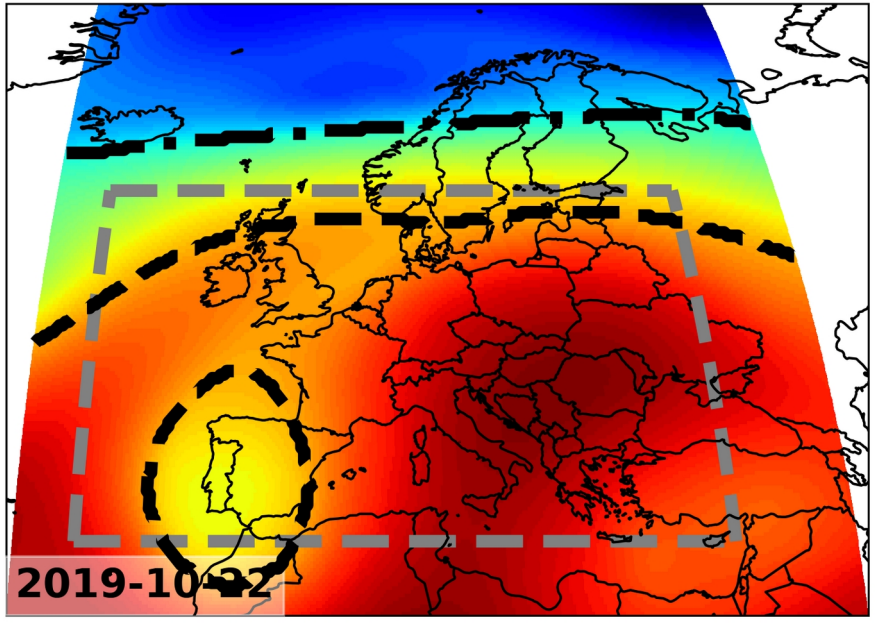
Research perimeter

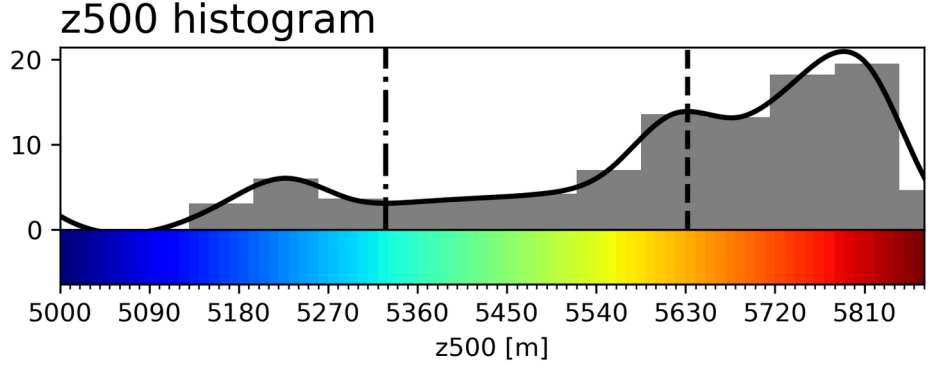


COL detection

Lower threshold
Upper threshold

Research perimeter

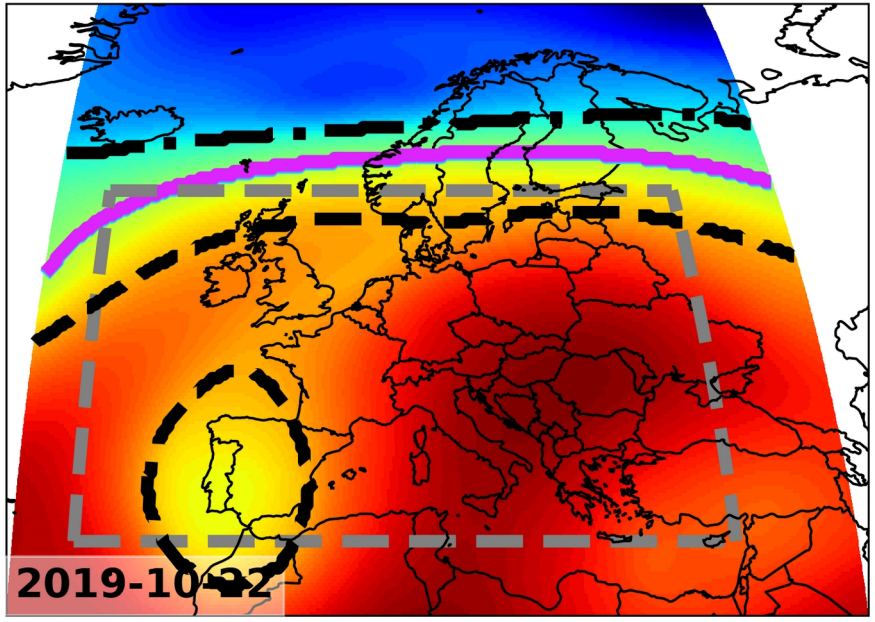


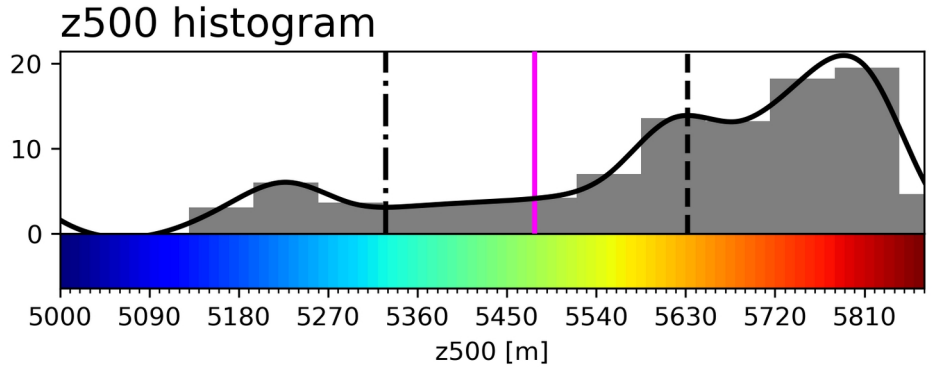


COL detection

Lower threshold
Upper threshold
Drawn isohypse

Research perimeter

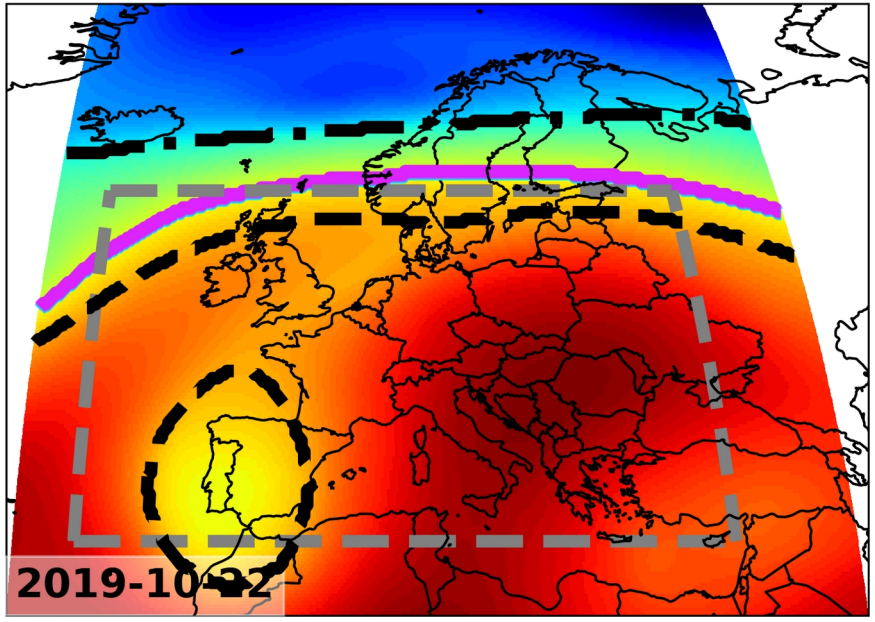


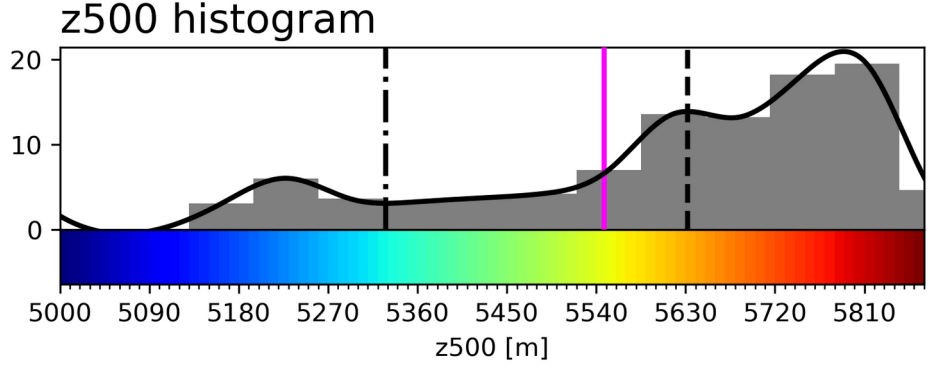


COL detection

Lower threshold
Upper threshold
Drawn isohypse

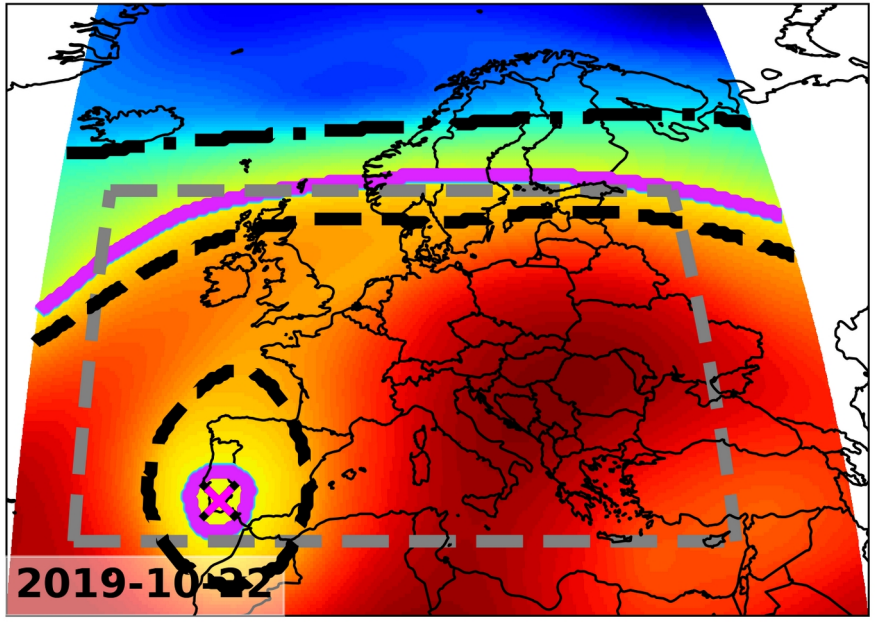
Research perimeter



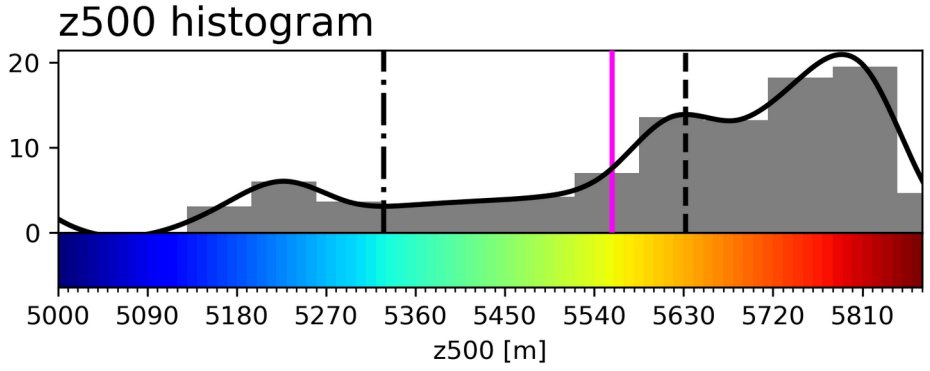


COL detection

Lower threshold
Upper threshold
Drawn isohypse

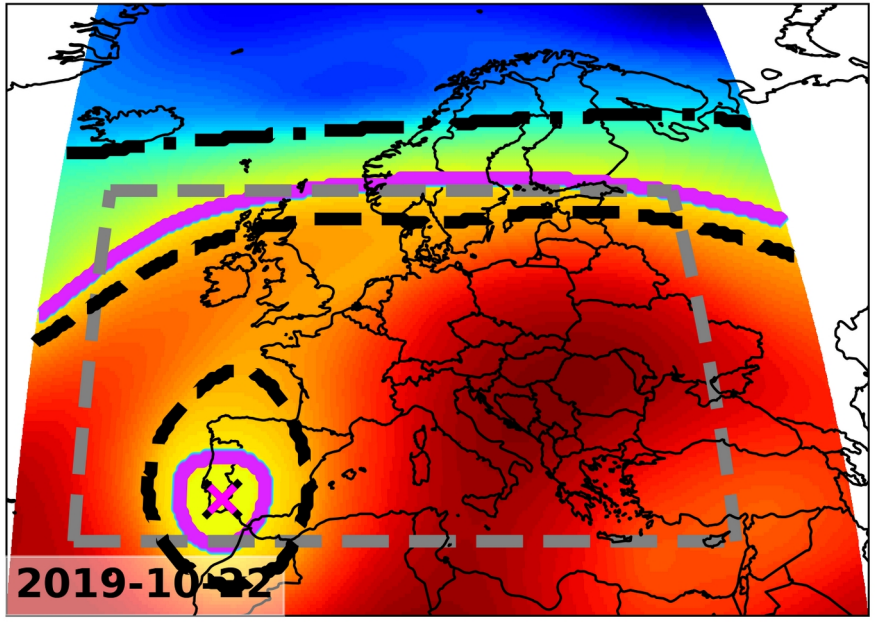


Research perimeter
COL center

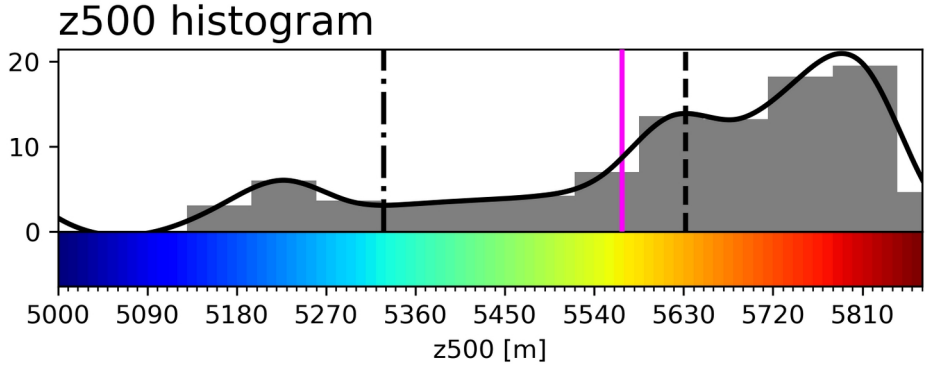


COL detection

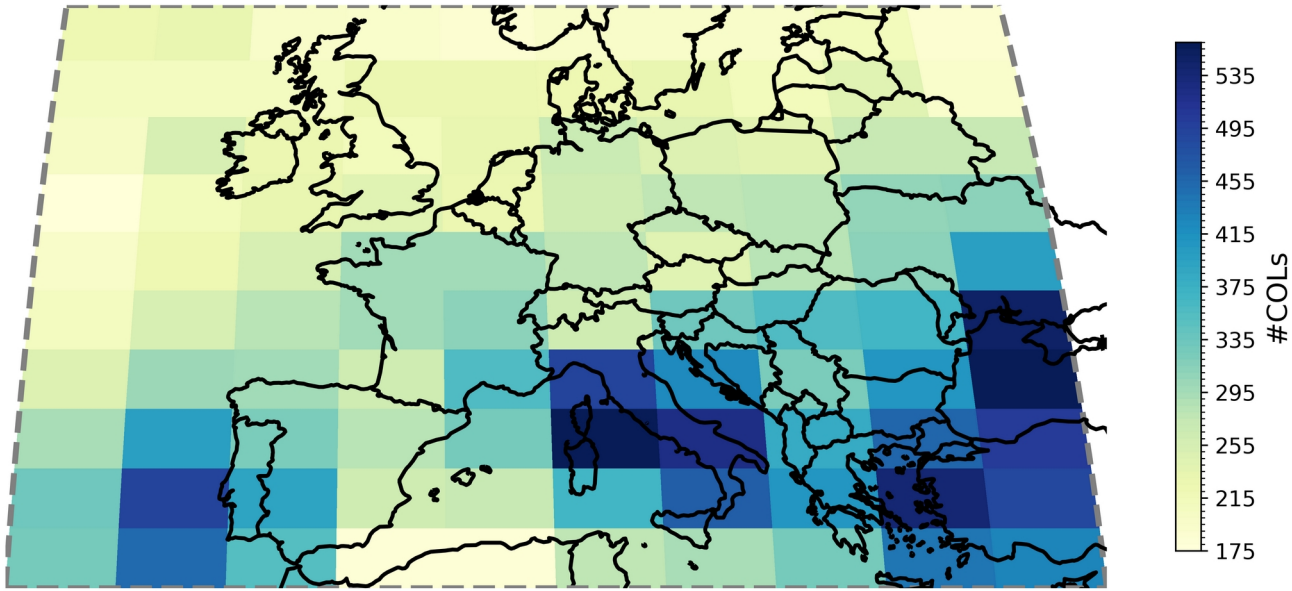
Lower threshold
Upper threshold
Drawn isohypse



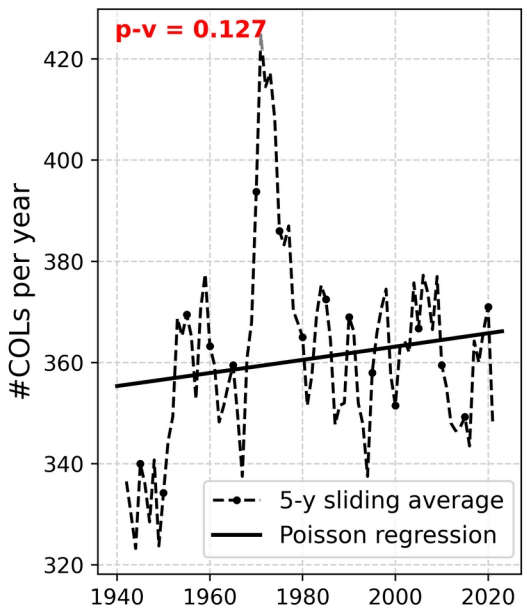
Research perimeter
COL center

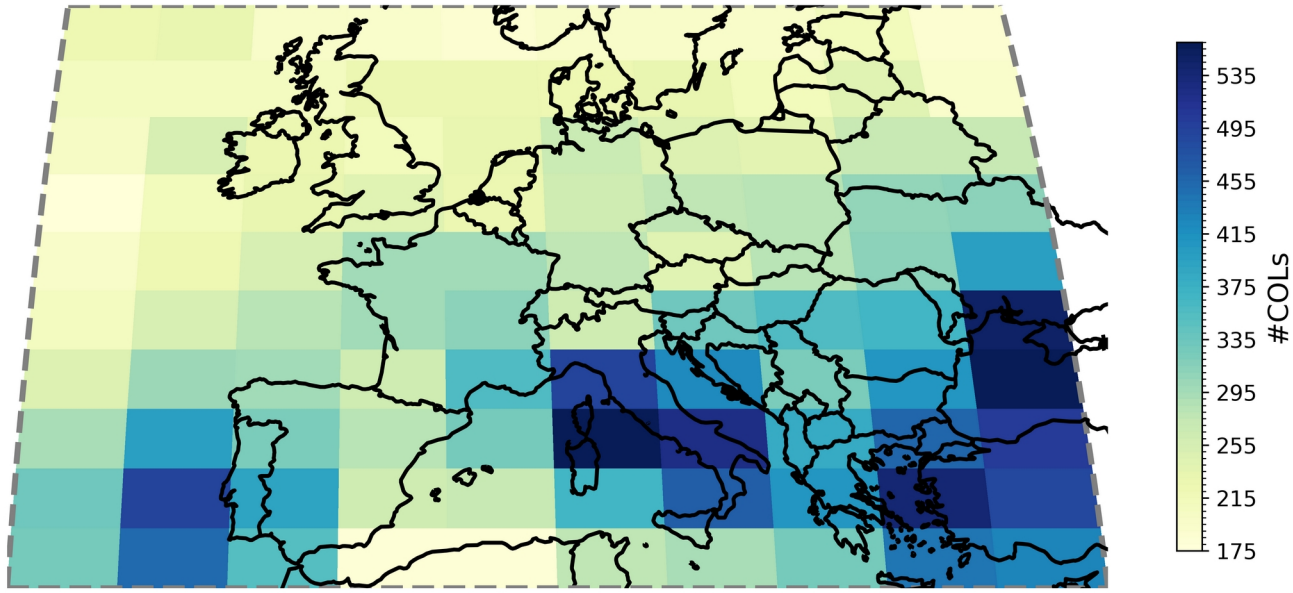


COL detection – detected COLs over 1940-2023

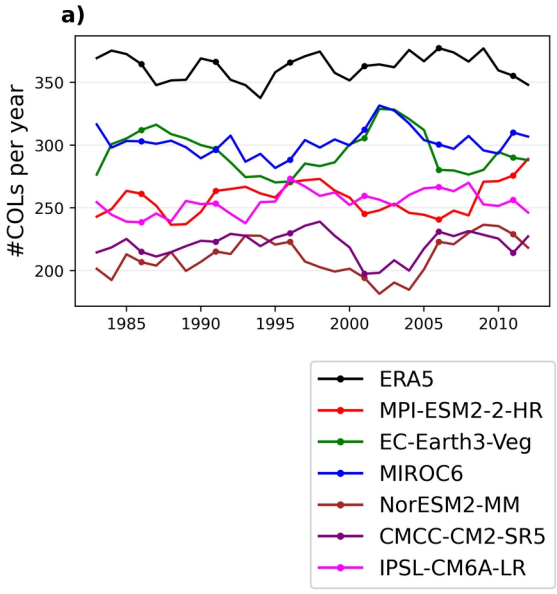


COL detection – detected COLs over 1940-2023

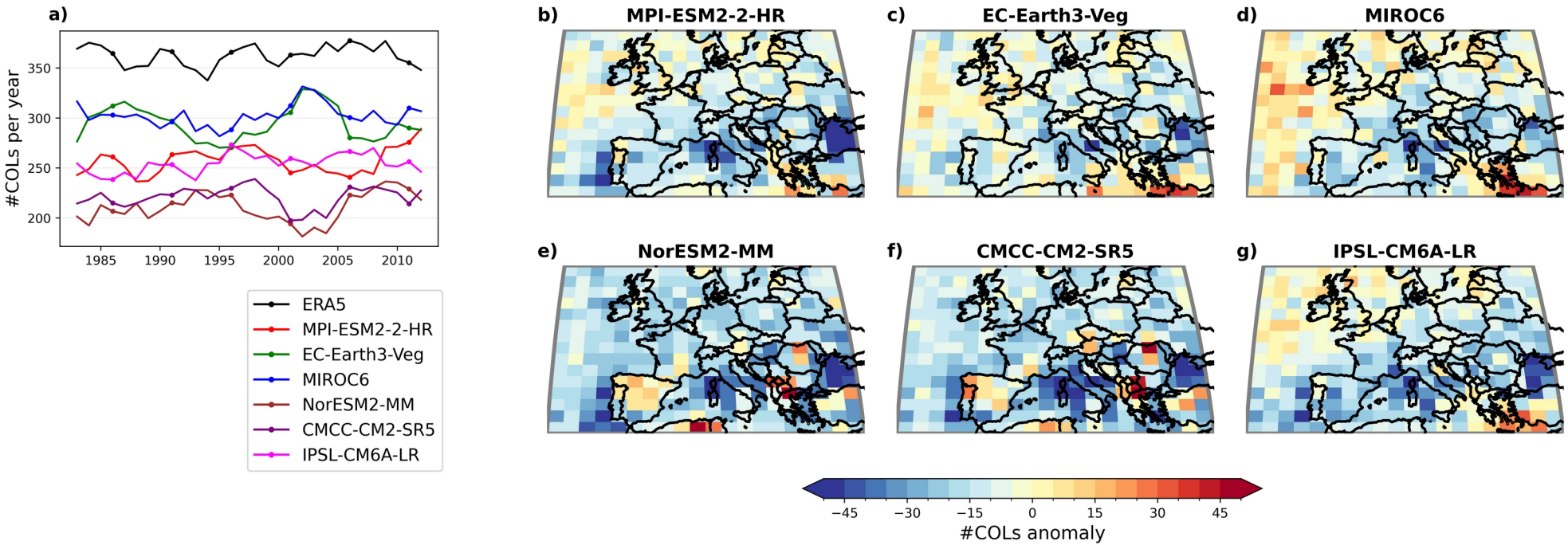




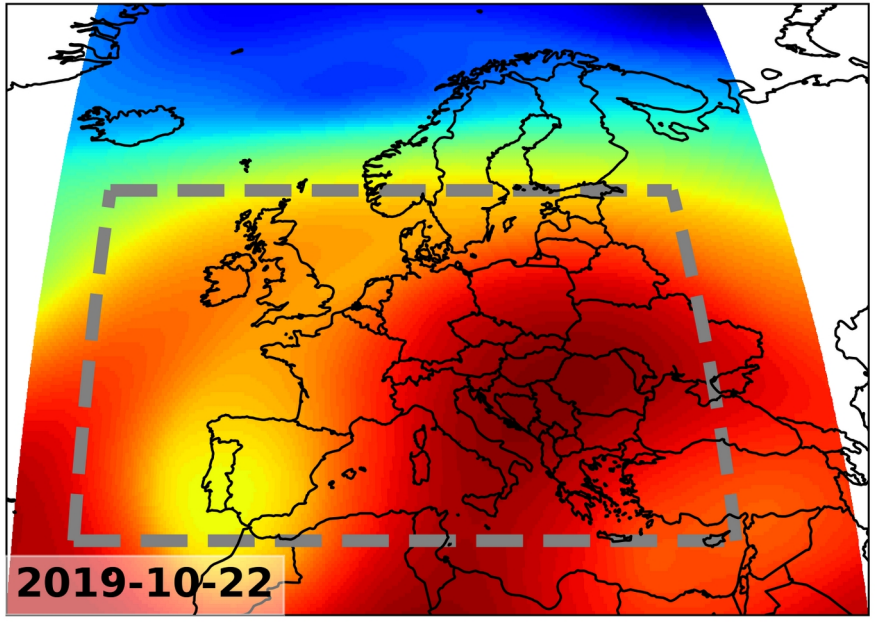
COL detection – Representation by ESMs (1981-2014)



COL detection – Representation by ESMs (1981-2014)

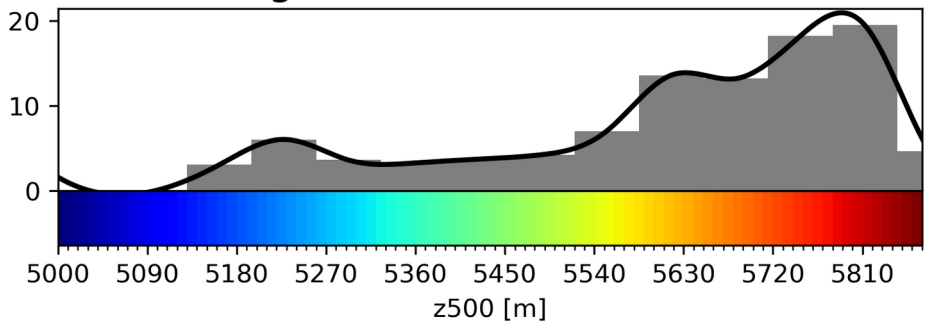


Precipitation association methodology

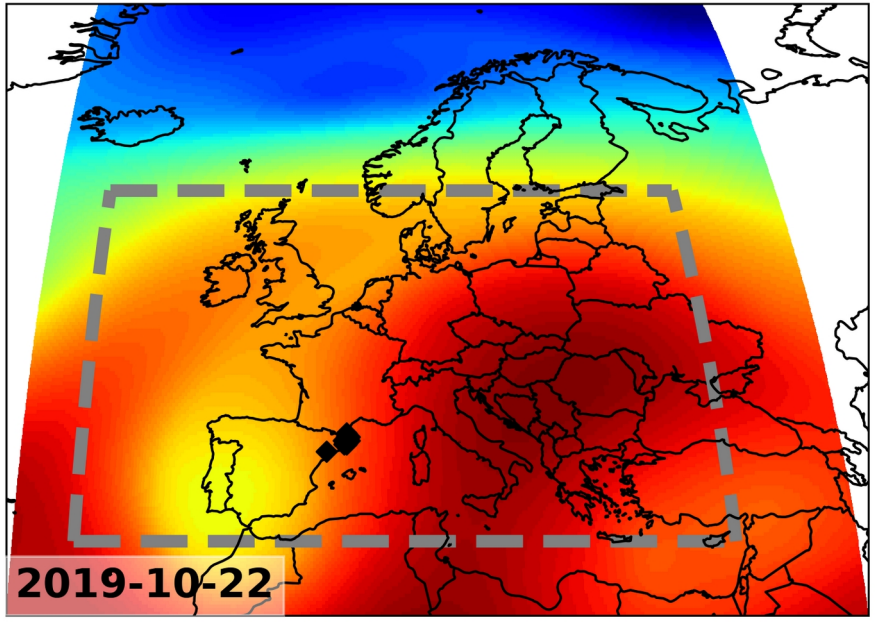


Research perimeter

z500 histogram



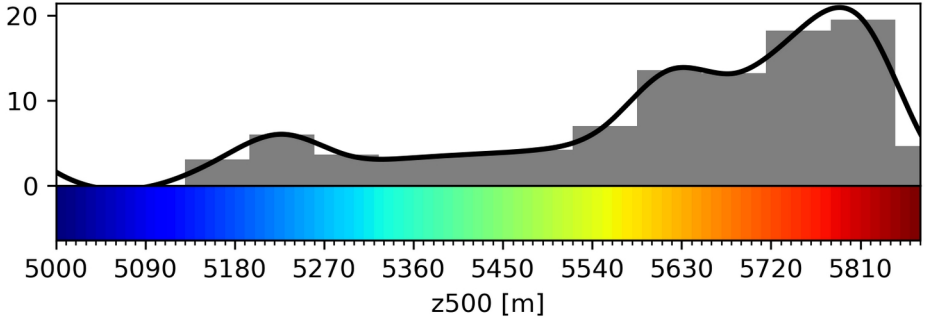
Precipitation association methodology



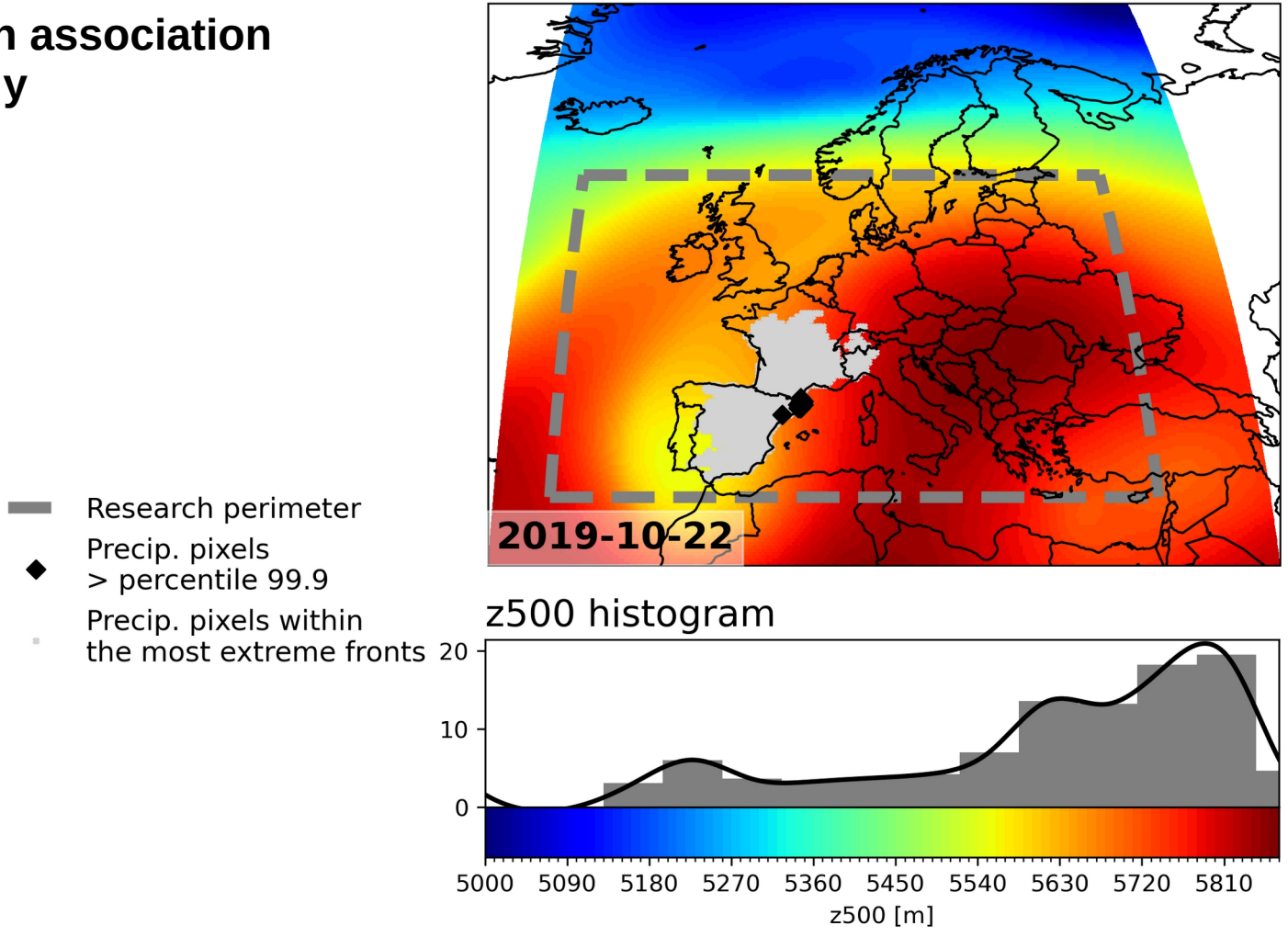
Research perimeter

Precip. pixels
> percentile 99.9

z500 histogram



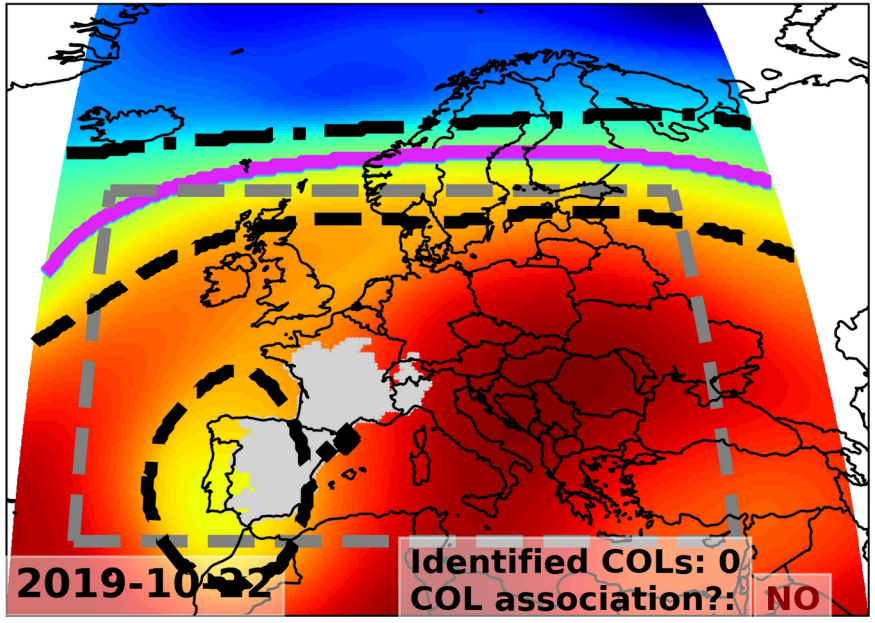
Precipitation association methodology

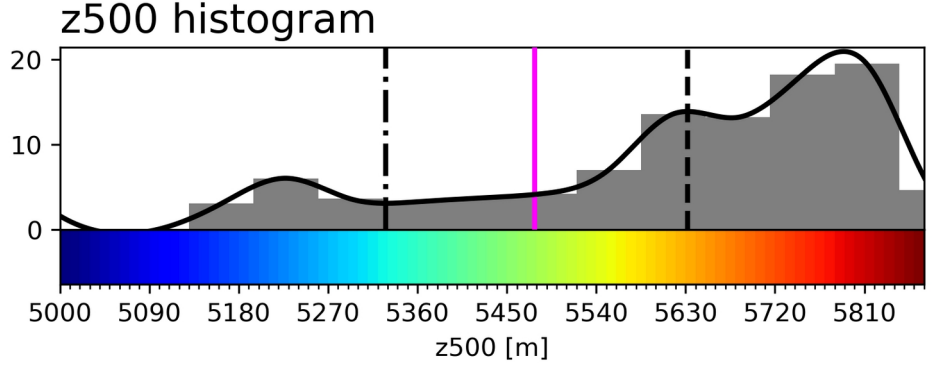


Precipitation association methodology

Lower threshold
Upper threshold
Drawn isohypse

Research perimeter
Precip. pixels > percentile 99.9
Precip. pixels within the most extreme fronts

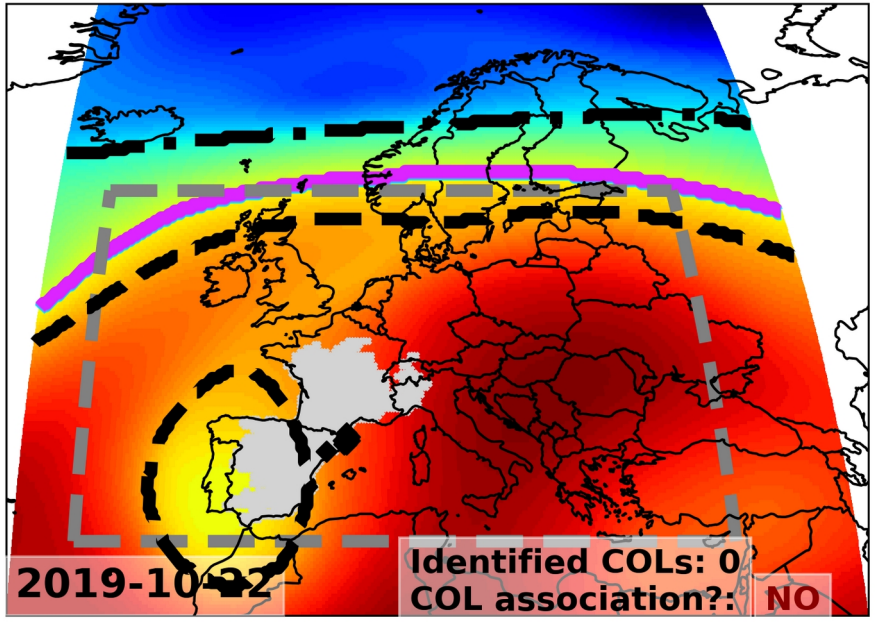


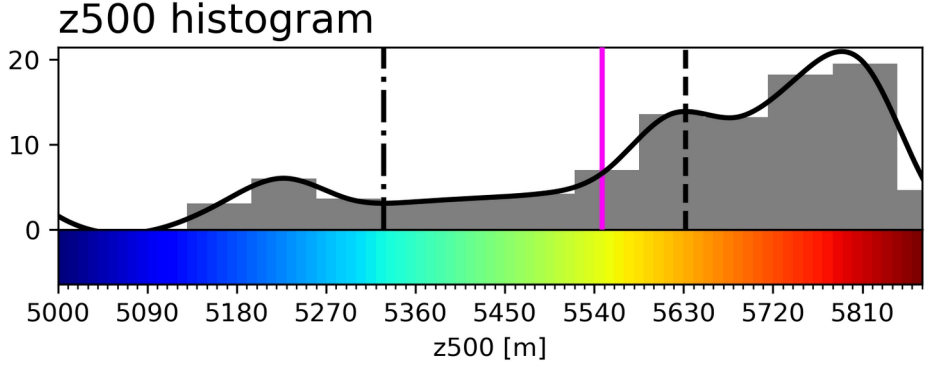


Precipitation association methodology

Lower threshold
Upper threshold
Drawn isohypse

Research perimeter
Precip. pixels > percentile 99.9
Precip. pixels within the most extreme fronts

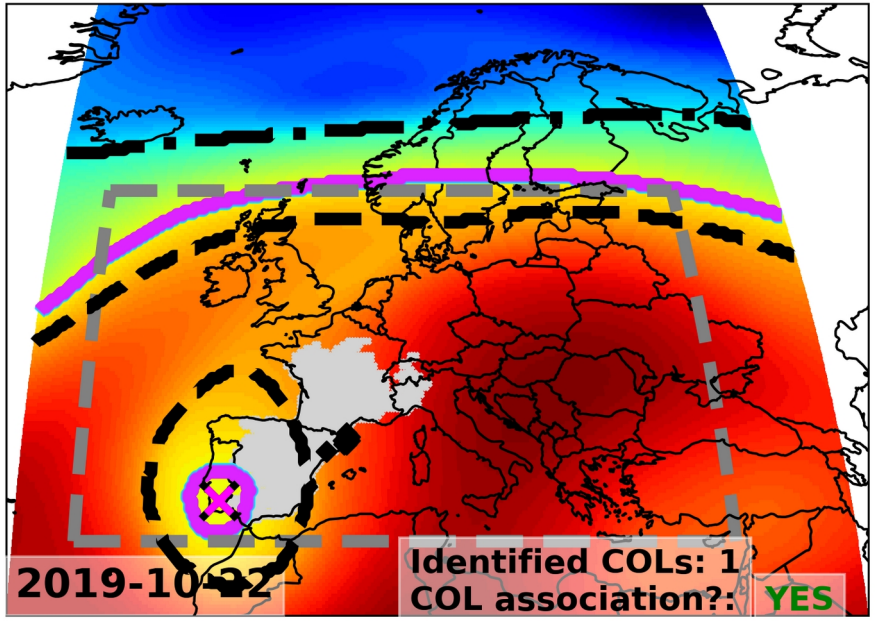


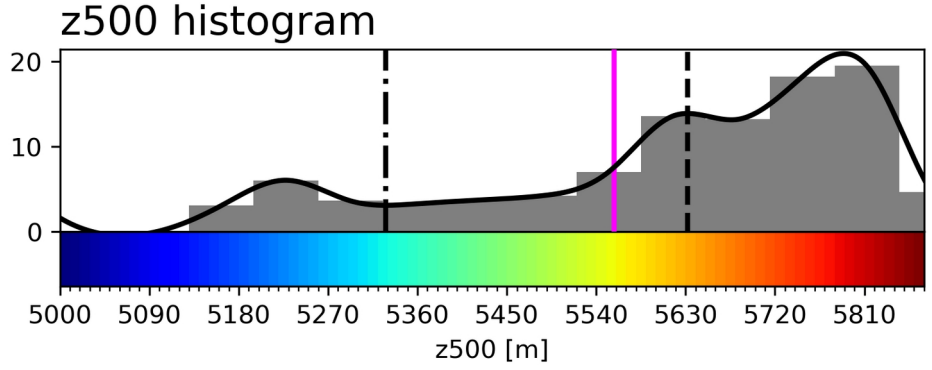


Precipitation association methodology

Lower threshold
Upper threshold
Drawn isohypse

Research perimeter
Precip. pixels > percentile 99.9
COL center
Precip. pixels within the most extreme fronts

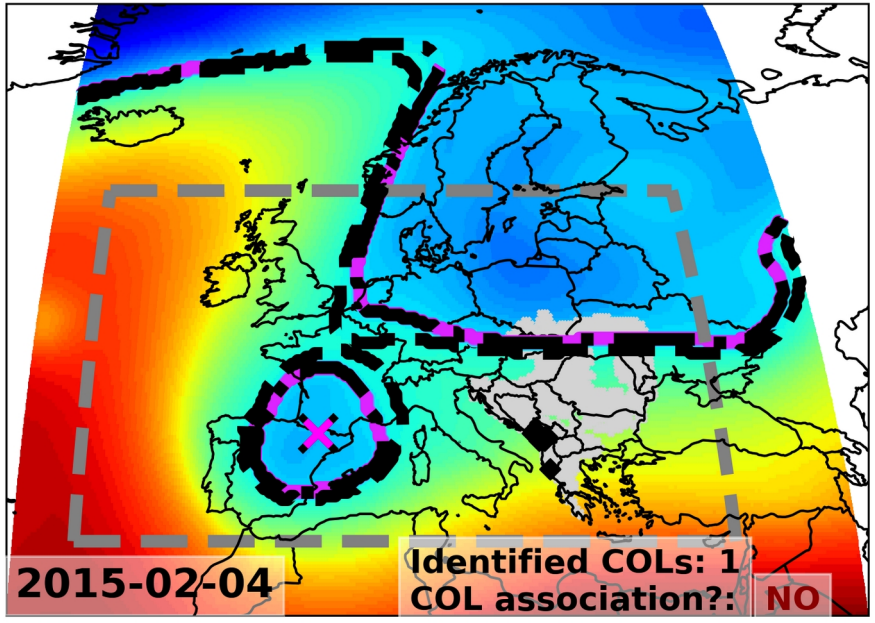


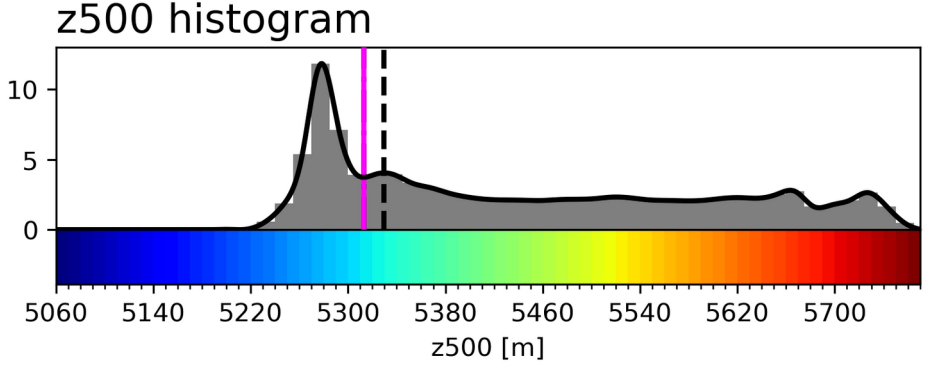


Precipitation association methodology

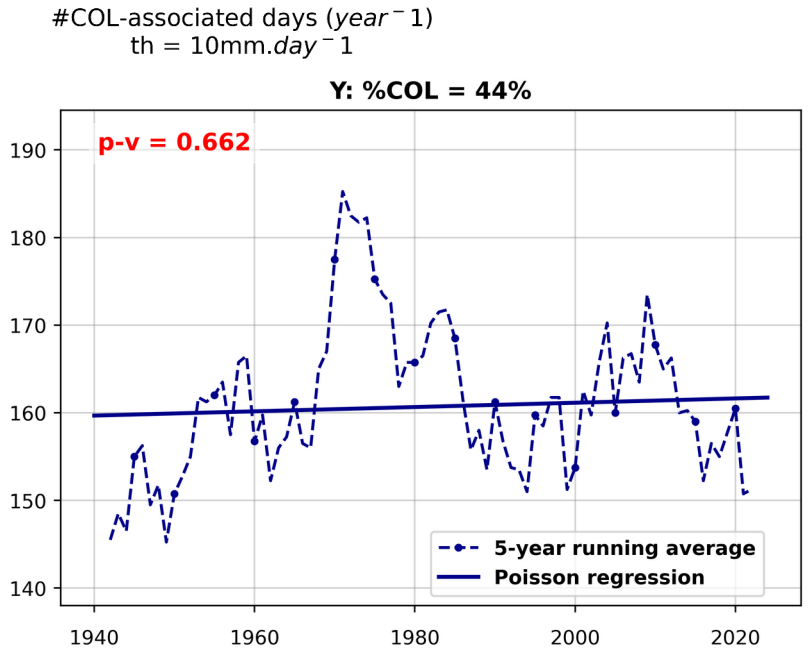
Lower threshold
Upper threshold
Drawn isohypse

Research perimeter
Precip. pixels > percentile 99.9
COL center
Precip. pixels within the most extreme fronts



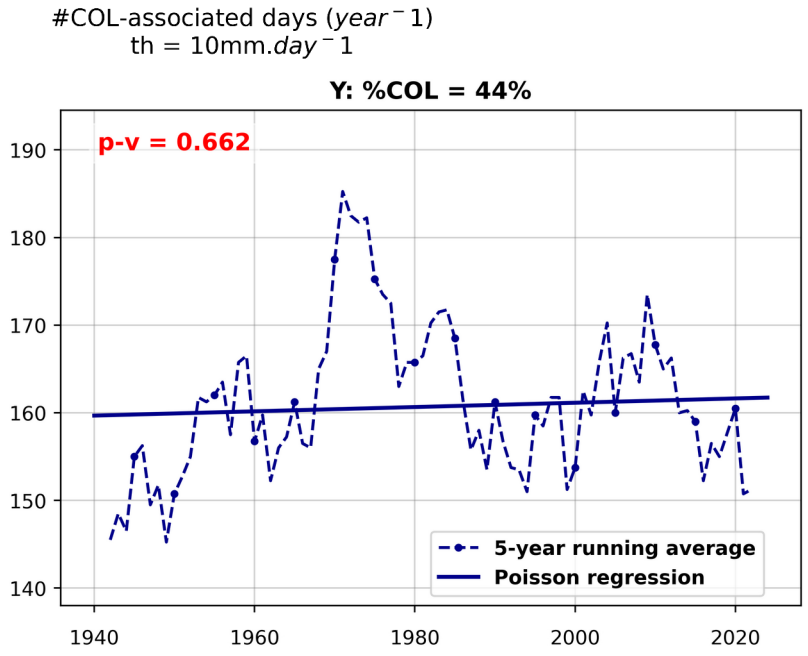


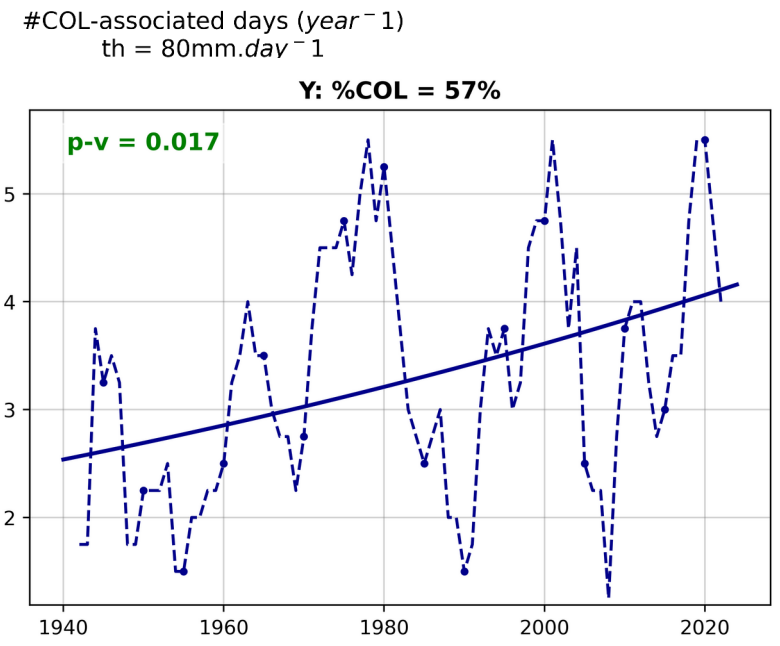
Past evolution in Europe



99.9th spatial daily precipitation percentile is used

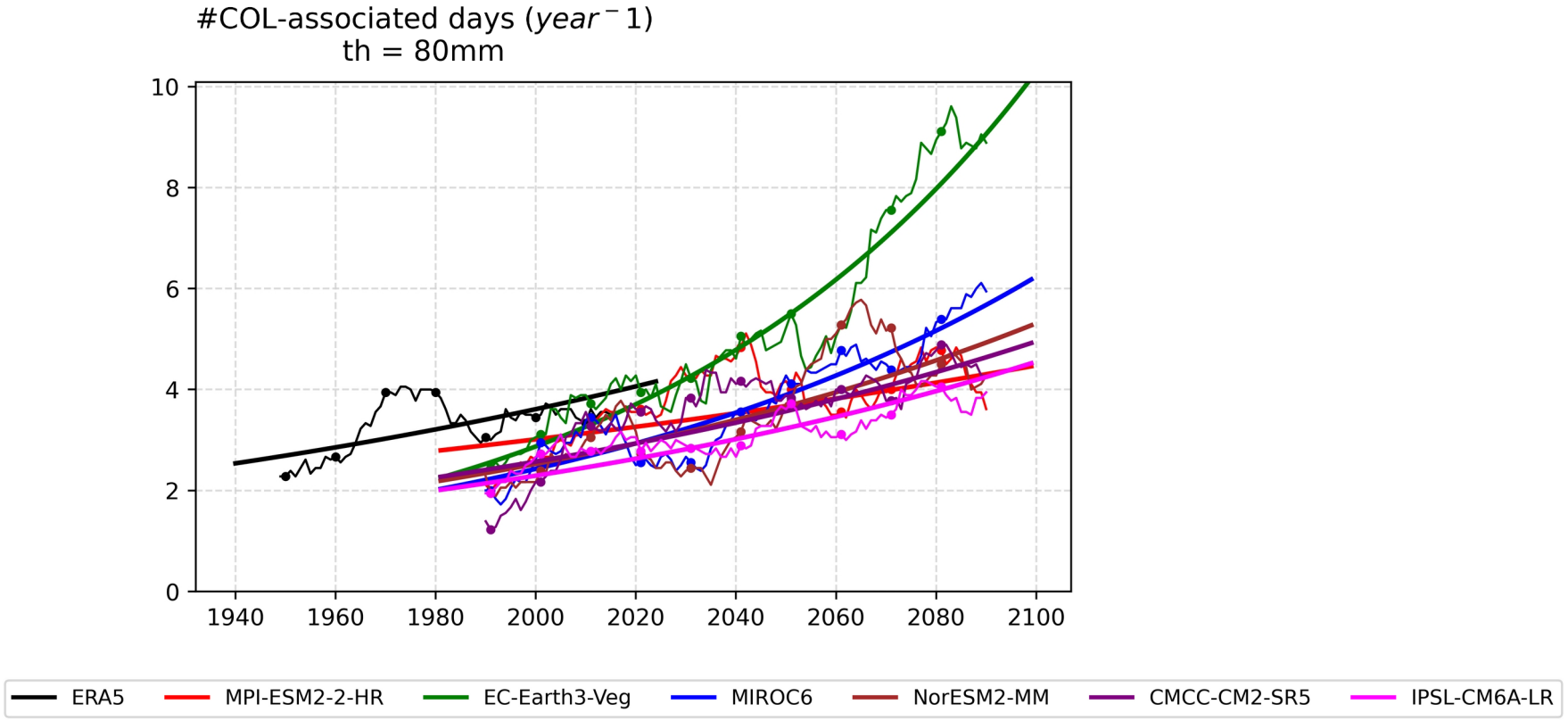
Past evolution in Europe



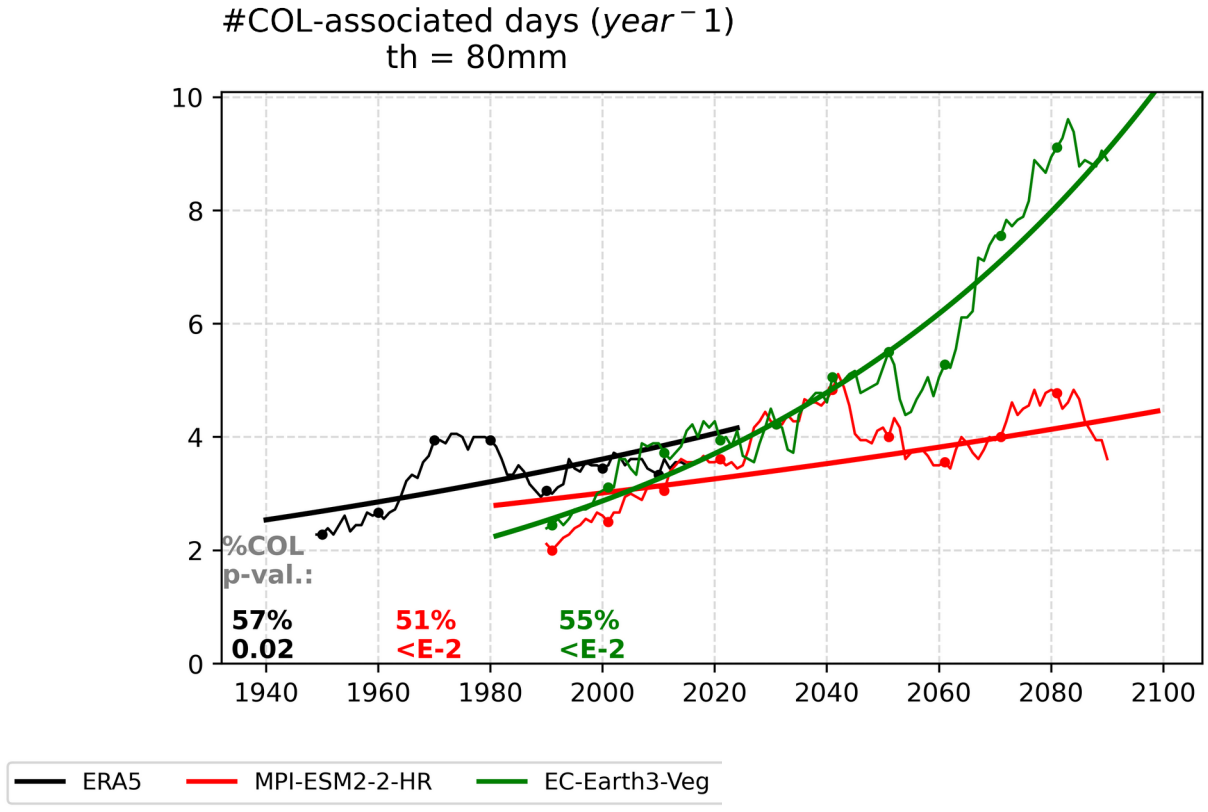


99.9th spatial daily precipitation percentile is used

Future evolution in Europe – SSP5-8.5



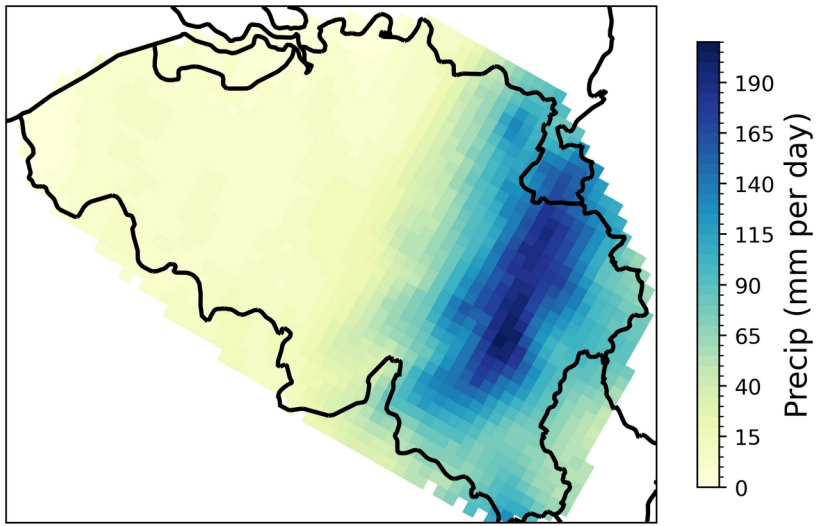
Future evolution in Europe – SSP5-8.5



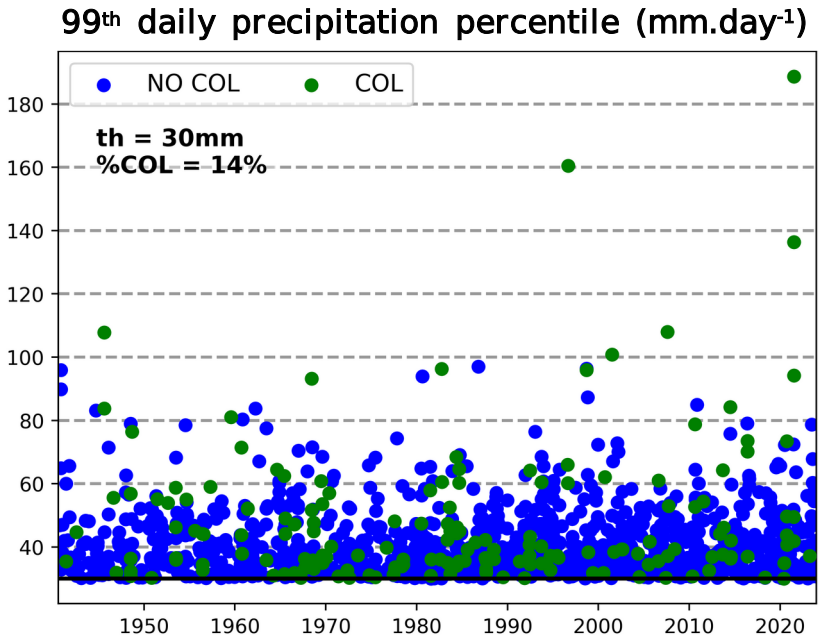
Past and future evolution in Belgium using bias-adjusted MAR-ERA5 data

99th daily precipitation percentile (mm.day^{-1}) = 183mm

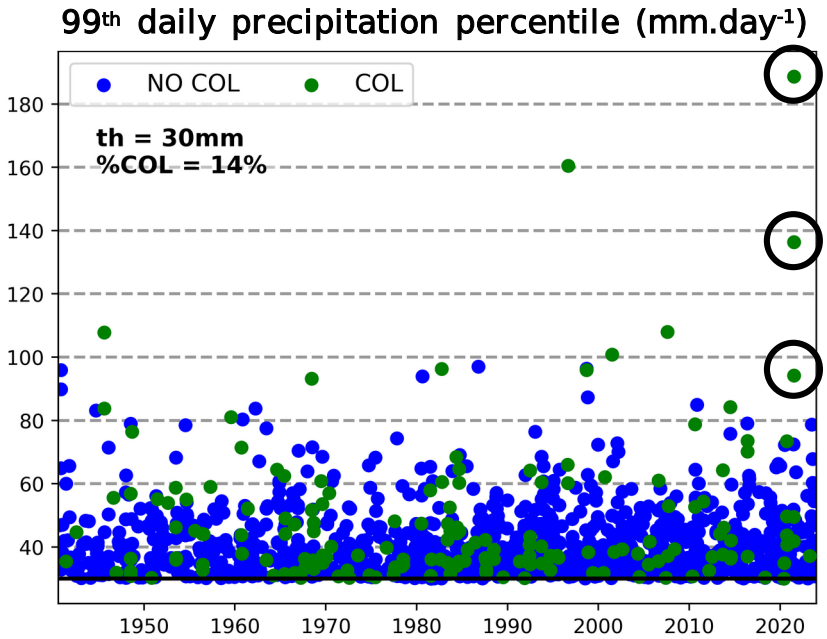
14-7-2021



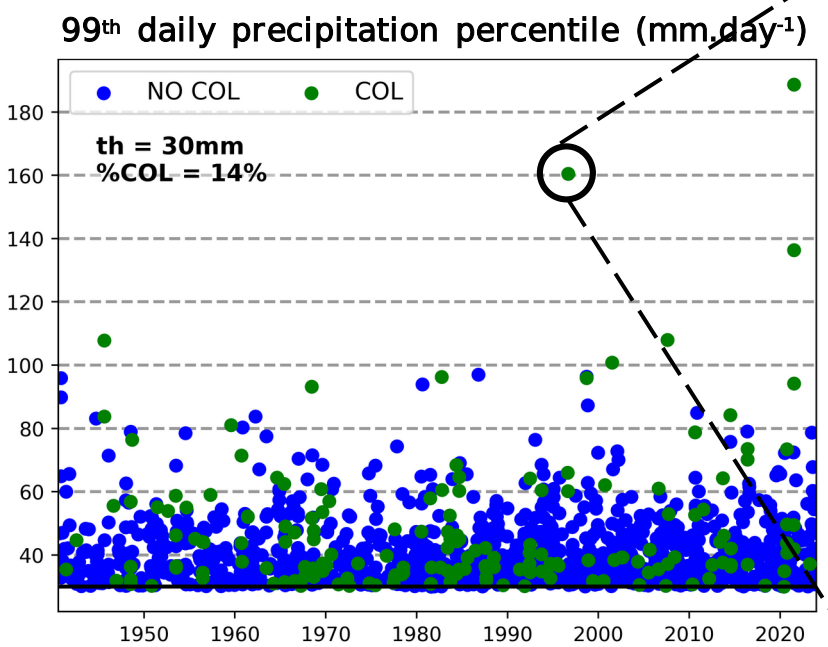
Past and future evolution in Belgium using bias-adjusted MAR-ERA5 data

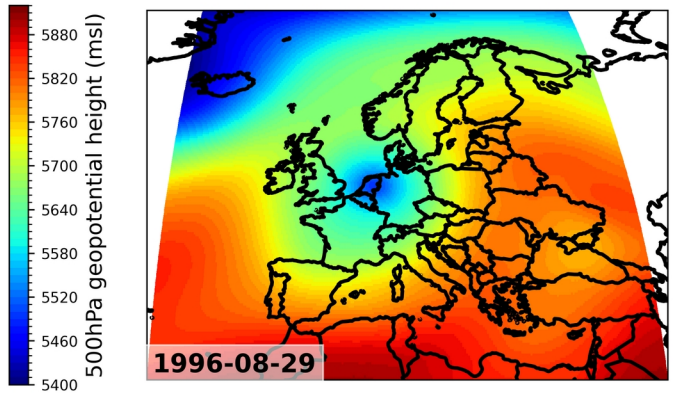


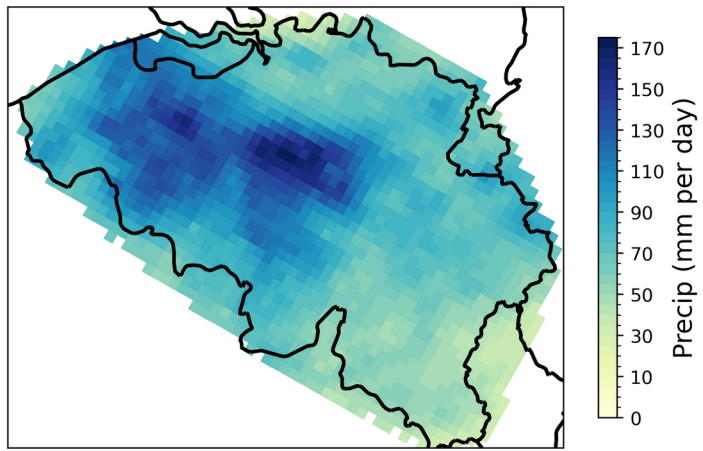
Past and future evolution in Belgium using bias-adjusted MAR-ERA5 data



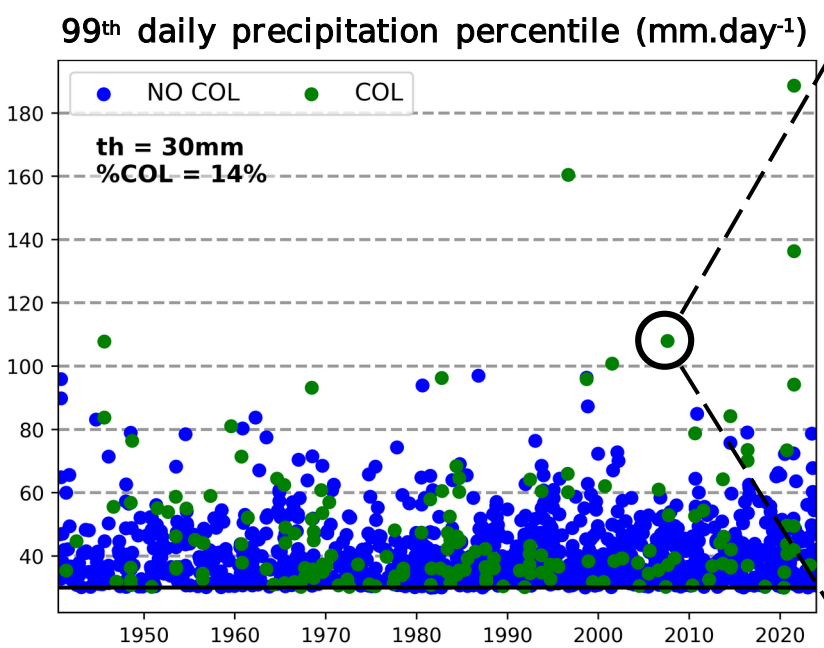
Past and future evolution in Belgium

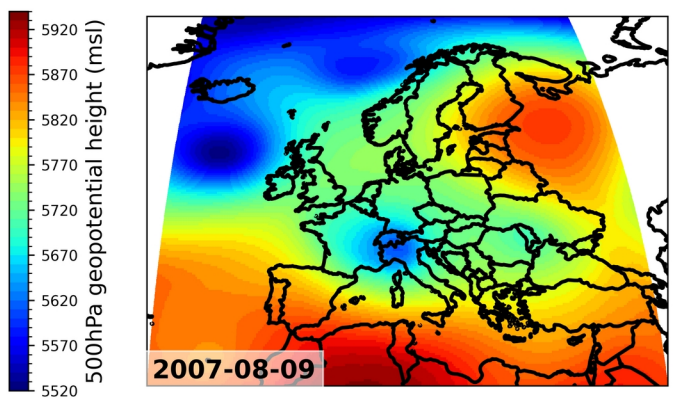


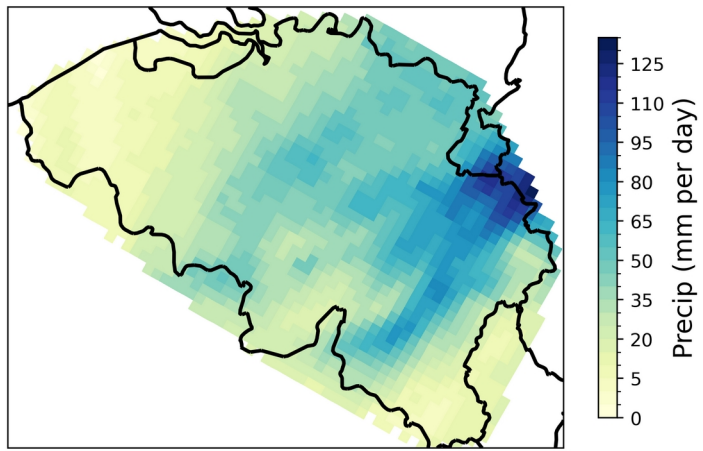




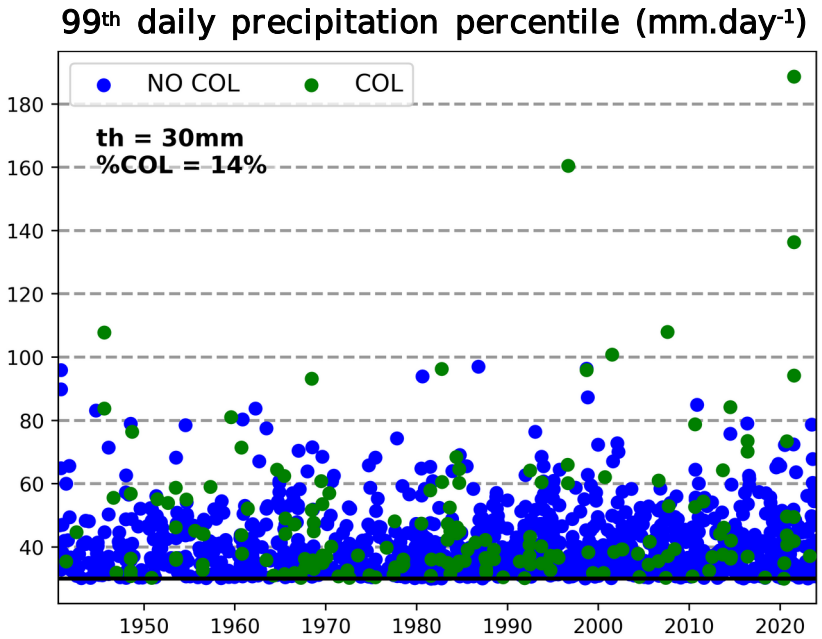
Past and future evolution in Belgium

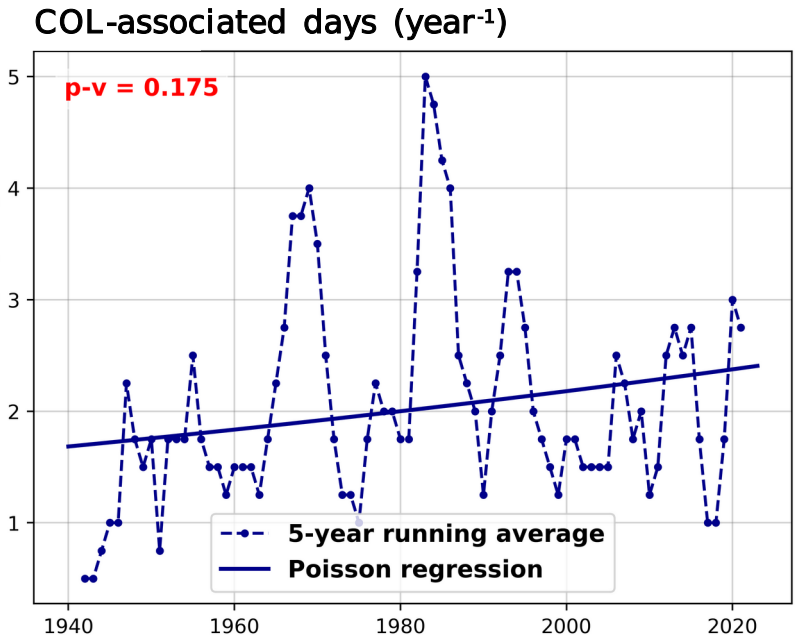




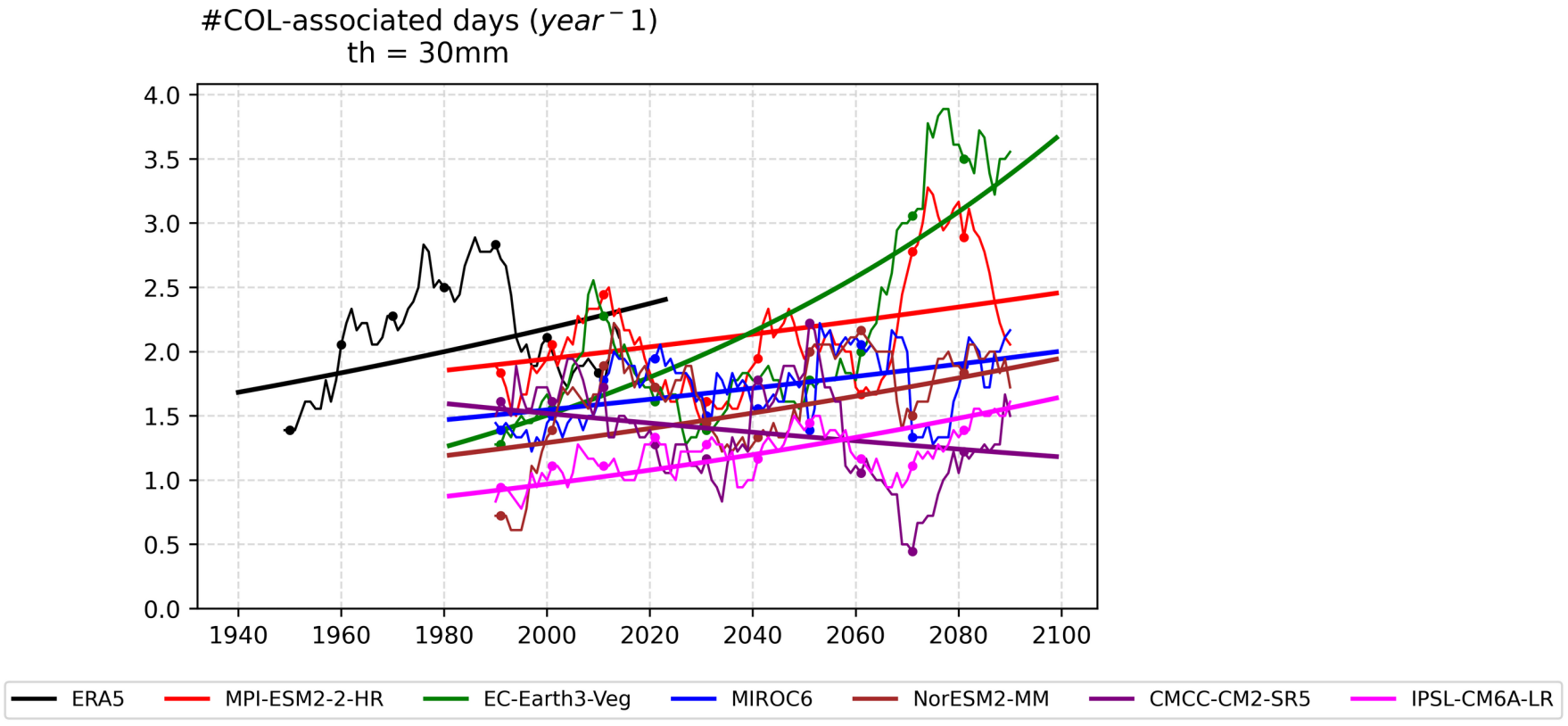


Past and future evolution in Belgium

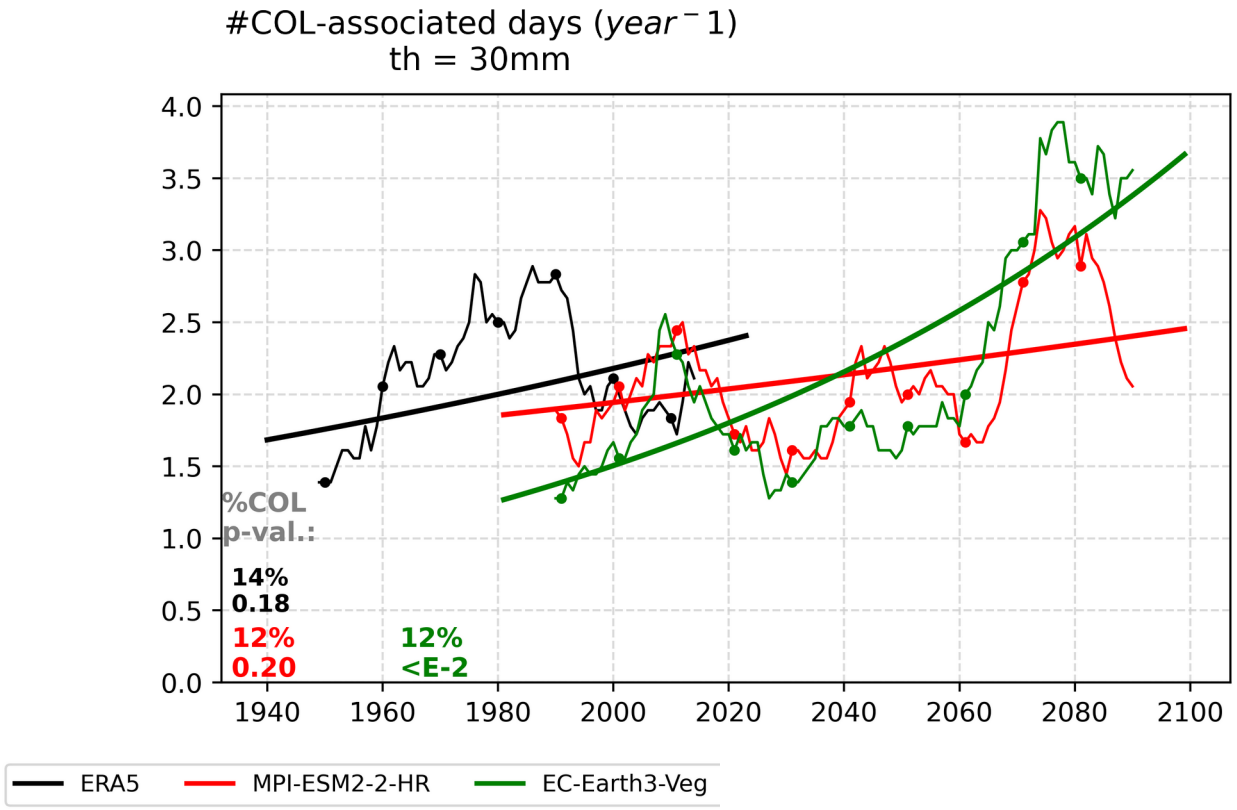




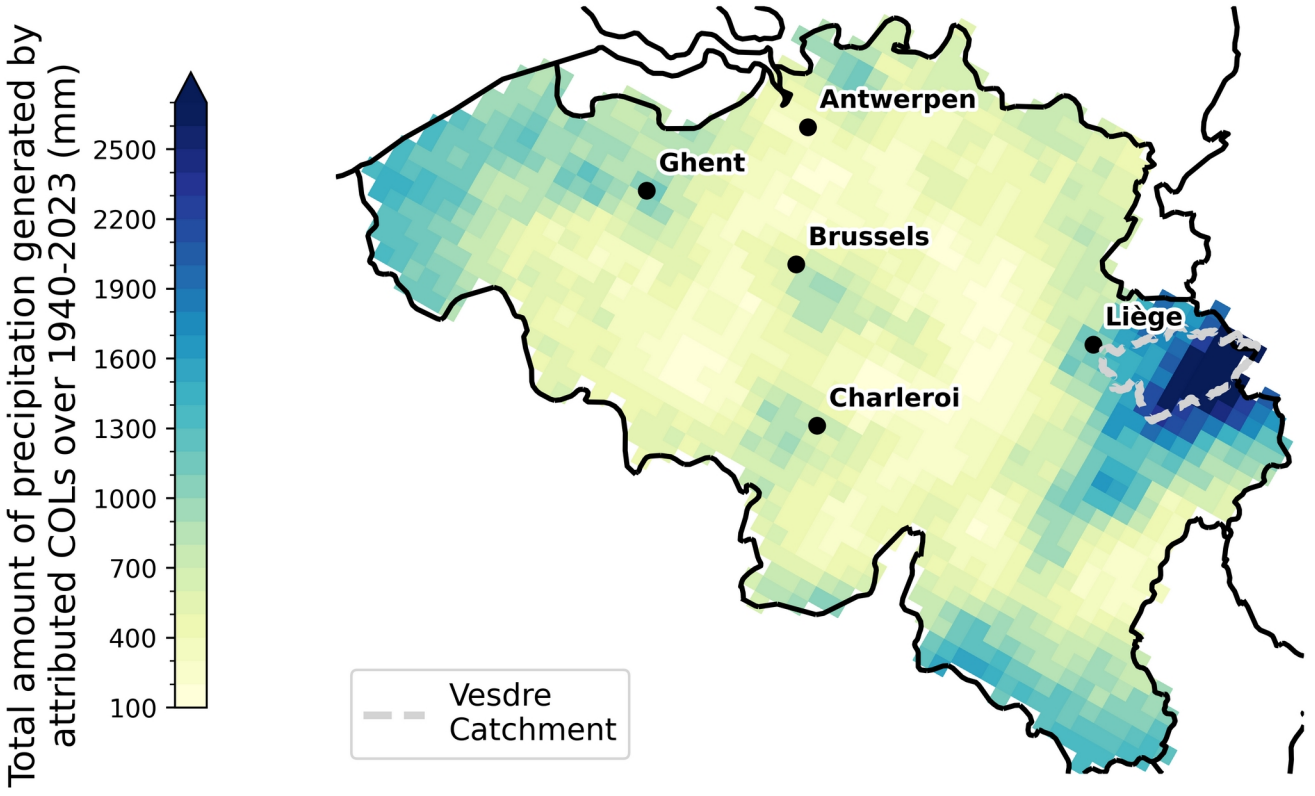
Future evolution in Belgium – SSP5-8.5



Future evolution in Belgium – SSP5-8.5



Cumulated COL-associated precipitation (1940-2023)



PART 2

Take–home

I. **COLs** represent an **important part** of extreme precipitatipn events, especially at the European scale (**up to 57%)**

II. The increasing trends in extreme COL-associated events are likely **not explained by large-scale** atmospheric changes

III. COL occurrence is dominated by **interdecadal variability**

IV. Most **ESMs struggle** to represent the **frequency of COLs** and COL-associated events

PART 3

Hydrological response in the Ourthe watershed using MAR-WolfHydro

Hydrological modelling with WOLFHydro

- **Conceptual lumped rainfall-run-off models**
- Lumped **precipitation** and **evapotranspiration** → **Discharge** at one outlet

Hydrological modelling with WOLFHydro

- **Conceptual lumped rainfall-run-off models**
- Lumped **precipitation** and **evapotranspiration** → **Discharge** at one outlet

Hydrological model	Conceptual complexity	Represented processes
GR4H (Mathevet, 2005)	Low	Soil-storage + routing
HBV (Bergström and Forsman, 1973)	Medium	Soil moisture + quick/slow flow
VHM (Willems, 2014)	Medium-high	Overland flow + interflow + baseflow
SAC-SMA (Burnash et al., 1973)	High	Detailed soil moisture accounting and multiple runoff components

Hydrological modelling with WOLFHydro

- **Conceptual lumped rainfall-run-off models**
- Lumped **precipitation** and **evapotranspiration** → **Discharge** at one outlet

Hydrological model	Conceptual complexity	Represented processes
GR4H (Mathevet, 2005)	**Low**	**Soil-storage + routing**
HBV (Bergström and Forsman, 1973)	Medium	Soil moisture + quick/slow flow
VHM (Willems, 2014)	Medium-high	Overland flow + interflow + baseflow
SAC-SMA (Burnash et al., 1973)	High	Detailed soil moisture accounting and multiple runoff components

→ **2 reservoirs**
4 parameters

Hydrological modelling with WOLFHydro

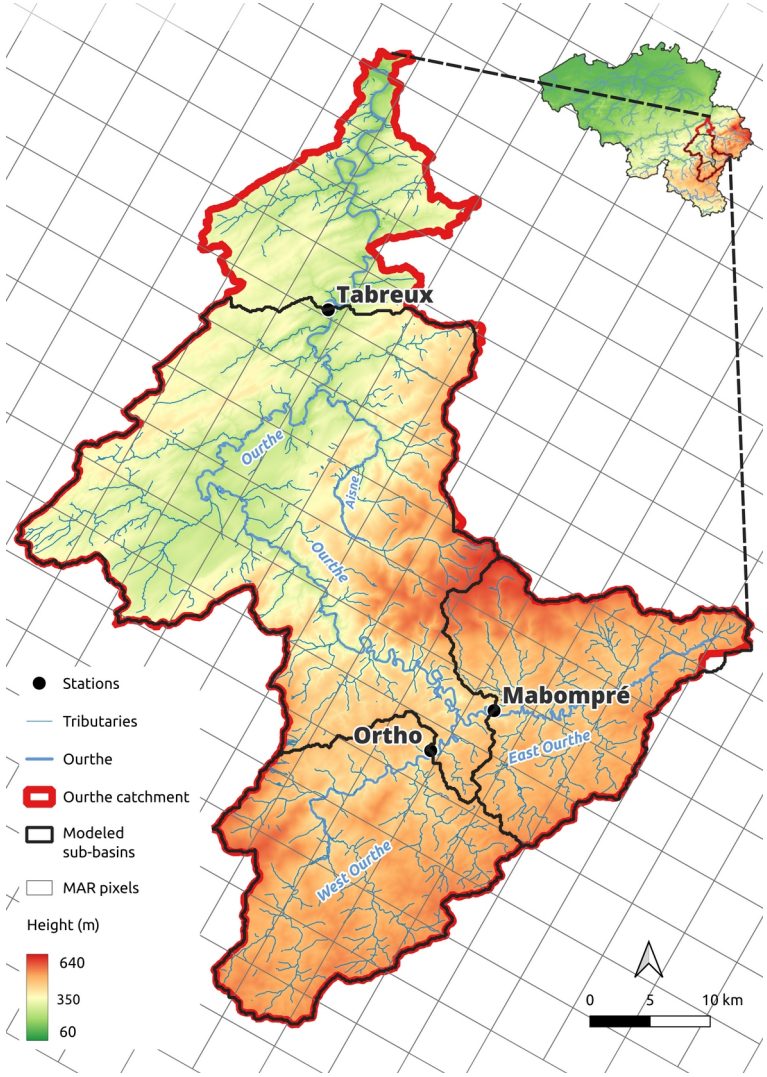
- **Conceptual lumped rainfall-run-off models**
- Lumped **precipitation** and **evapotranspiration** → **Discharge** at one outlet

Hydrological model	Conceptual complexity	Represented processes
GR4H (Mathevet, 2005)	Low	Soil-storage + routing
HBV (Bergström and Forsman, 1973)	Medium	Soil moisture + quick/slow flow
VHM (Willems, 2014)	Medium-high	Overland flow + interflow + baseflow
SAC-SMA (Burnash et al., 1973)	**High**	**Detailed soil moisture accounting and multiple runoff components**

→ **5 reservoirs**
17 parameters

MAR-WOLFhydro on the Ourthe

- **Bias-adjusted MAR-ERA5 temperatures**
  → Daily potential Evapotranspiration
  +
  Bias-adjusted MAR-ERA5 hourly precip
  → Daily bias-adjustment
  + Hourly signal correction



MAR-WOLFhydro on the Ourthe

- **Bias-adjusted MAR-ERA5 temperatures**
  → Daily potential Evapotranspiration
  +
  Bias-adjusted MAR-ERA5 hourly precip
  → Daily bias-adjustment
  + Hourly signal correction

- **Semi-distributed** approach:
  one lumped model per sub-basin

- **Calibration** over 1990-2010
  with MAR-ERA5 with SPW
  hourly discharge data



Photo : SPW Hydrométrie, station de Ortho.

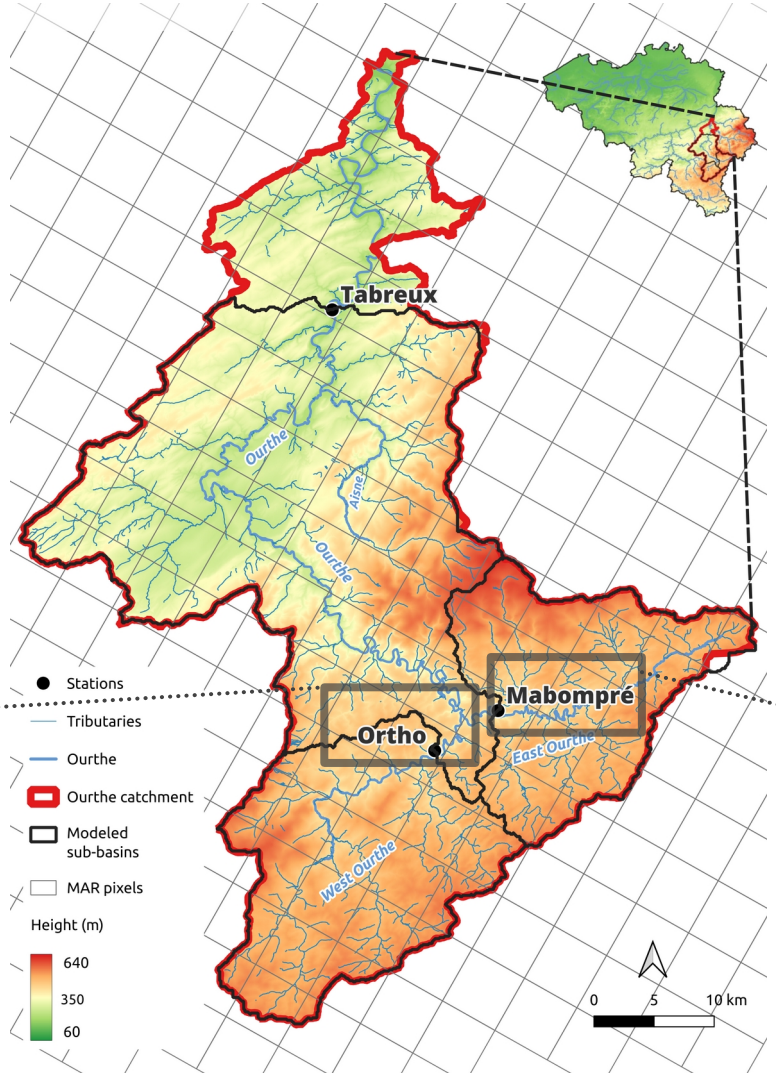




Photo : SPW Hydrométrie, station de Mabompré

MAR-WOLFhydro on the Ourthe

- **Bias-adjusted MAR-ERA5 temperatures**
  → Daily potential Evapotranspiration
  +
  Bias-adjusted MAR-ERA5 hourly precip
  → Daily bias-adjustment
  + Hourly signal correction

- **Semi-distributed** approach:
  one lumped model per sub-basin

- **Calibration** over 1990-2010
  with MAR-ERA5 with SPW
  hourly discharge data

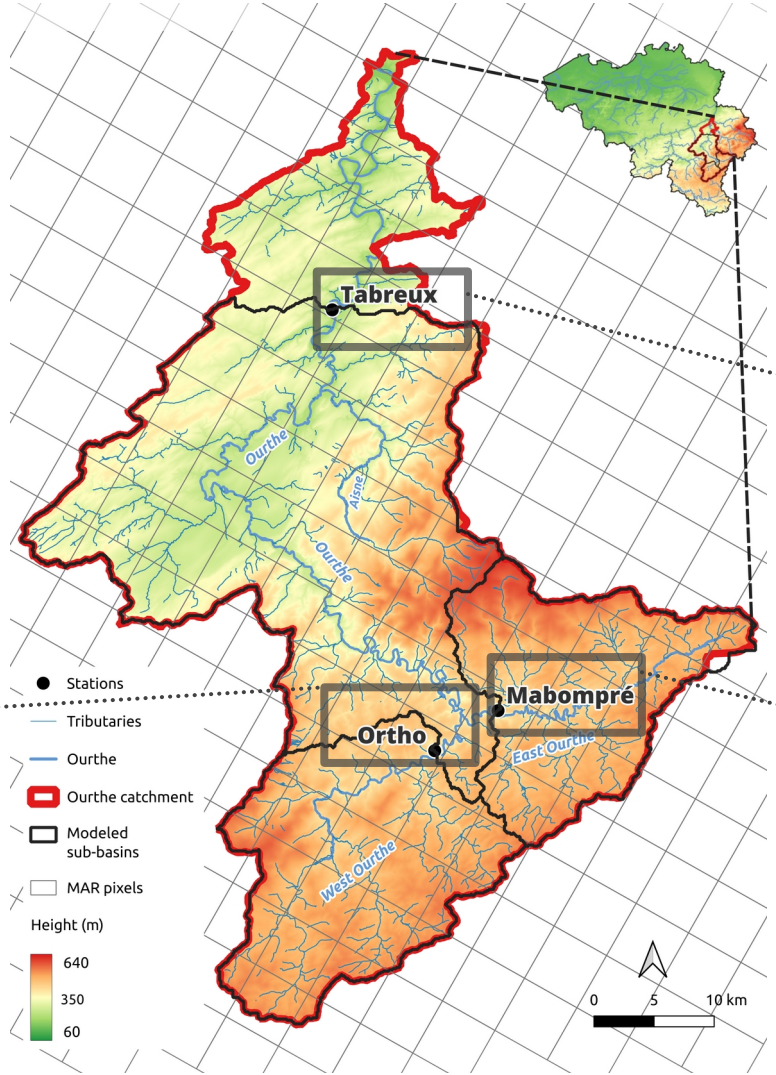




Photo : Pierre-Jacques DESPA, Wikipédia.

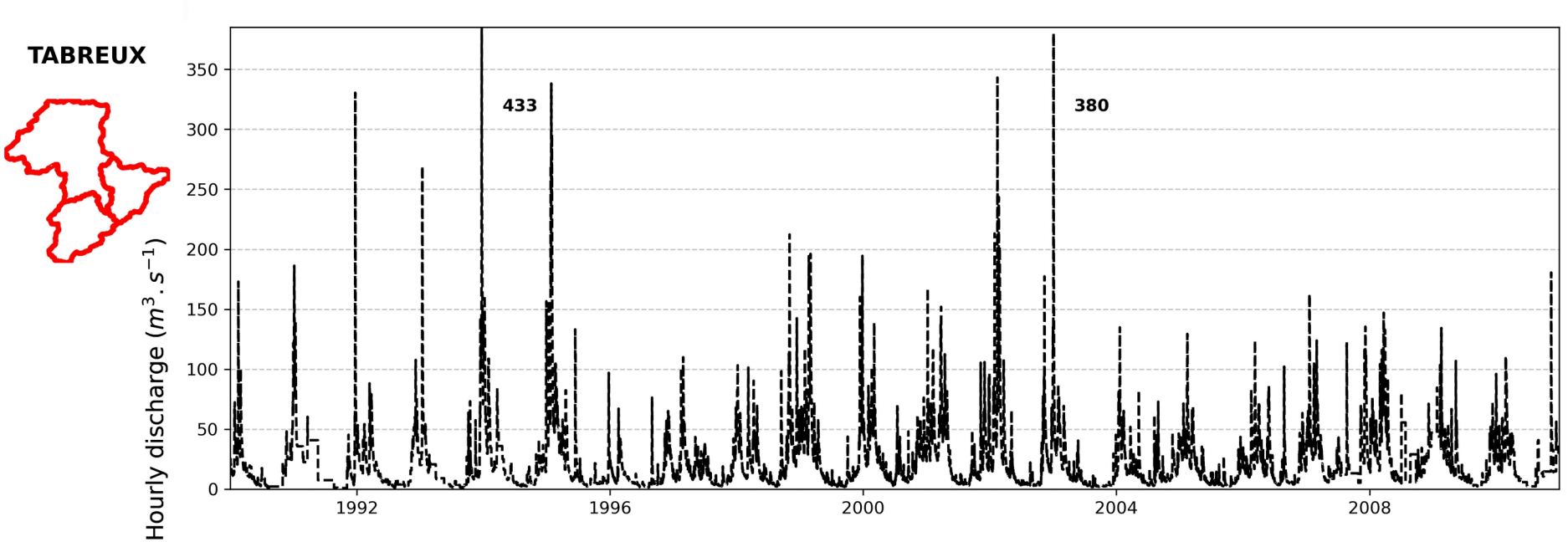


Photo : SPW Hydrométrie, station de Ortho.

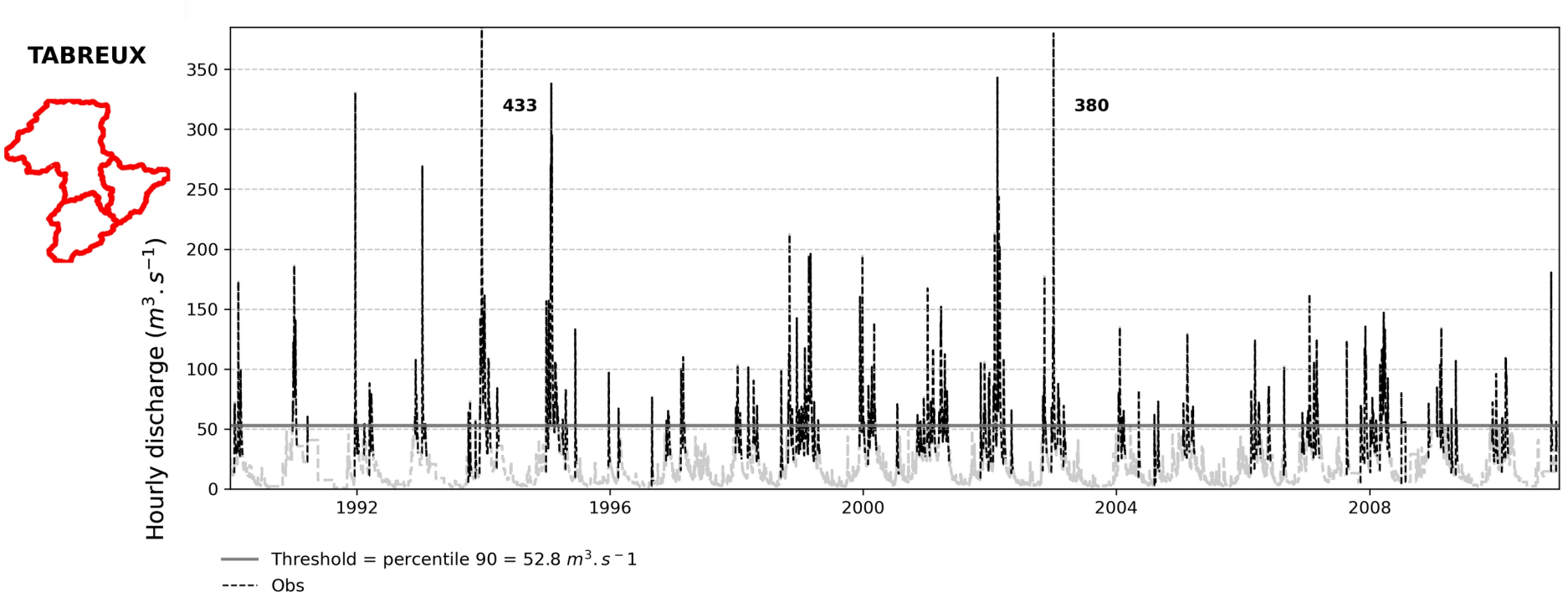


Photo : SPW Hydrométrie, station de Mabompré

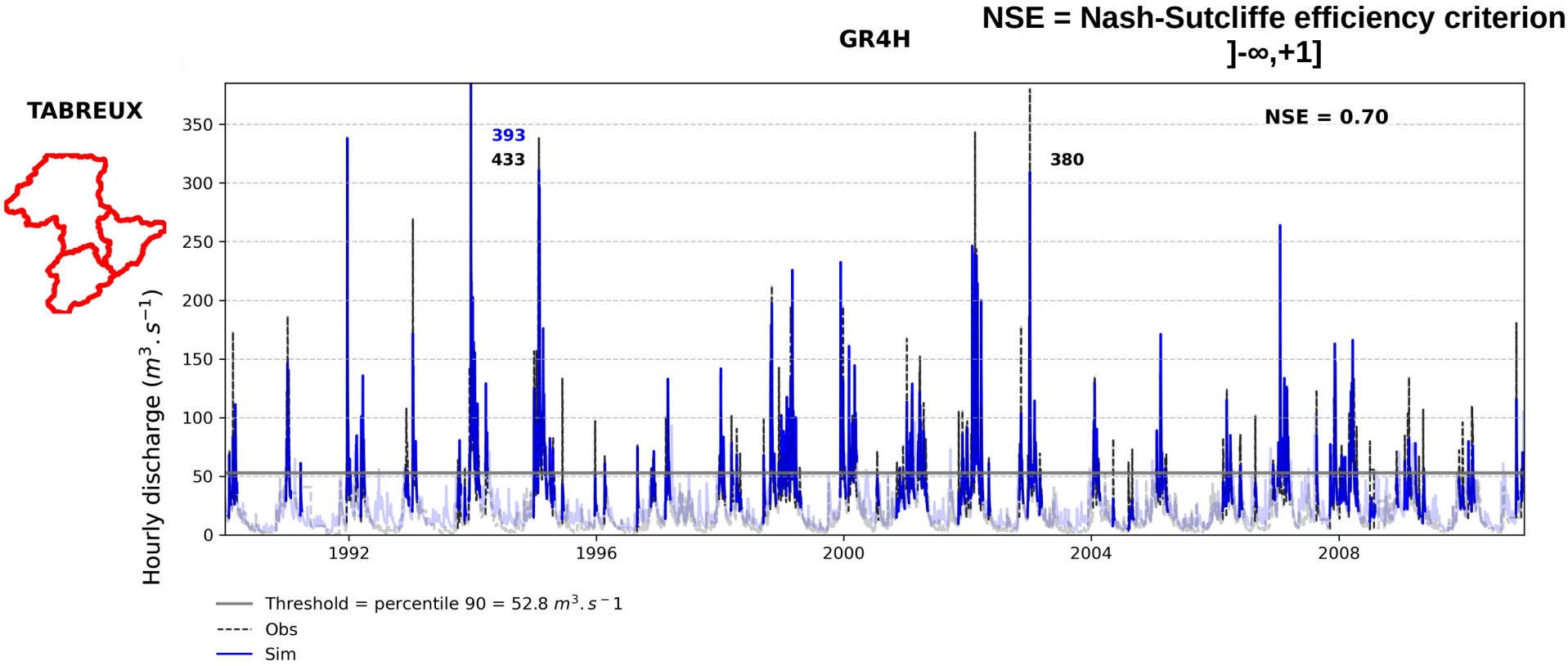
Model Optimization



Model Optimization



Model Optimization



Model optimization vs validation

1990-2010

	TABREUX		
models	**NSE**	**MB_{peak}**	**$RMSE_{peak}$**
GR4H	0.70	-7.8	35.2
HBV	0.68	-1.6	30.5
VHM	0.69	0.7	30.5
SAC-SMA	0.66	-5.3	35.9

MB_{peak} and $RMSE_{peak}$ are expressed in %

Model optimization vs validation

1990-2010

	TABREUX		
models	**NSE**	**MB_{peak}**	**$RMSE_{peak}$**
GR4H	0.70	-7.8	35.2
HBV	0.68	-1.6	30.5
VHM	0.69	0.7	30.5
SAC-SMA	0.66	-5.3	35.9

2011-2020

	TABREUX		
models	**NSE**	**MB_{peak}**	**$RMSE_{peak}$**
GR4H	0.41	-11.9	34.7
HBV	0.39	-3.8	33.2
VHM	0.39	-4.8	31.3
SAC-SMA	0.41	-12.1	36.2

MB_{peak} and $RMSE_{peak}$ are expressed in %

Model optimization vs validation

1990-2010

	TABREUX		
models	**NSE**	**MB_{peak}**	**$RMSE_{peak}$**
GR4H	0.70	-7.8	35.2
HBV	0.68	-1.6	30.5
VHM	0.69	0.7	30.5
SAC-SMA	0.66	-5.3	35.9

2011-2020

	TABREUX		
models	**NSE**	**MB_{peak}**	**$RMSE_{peak}$**
GR4H	0.41	-11.9	34.7
HBV	0.39	-3.8	33.2
VHM	0.39	-4.8	31.3
SAC-SMA	0.41	-12.1	36.2

MB_{peak} and $RMSE_{peak}$ are expressed in %

Model optimization vs validation

1990-2010

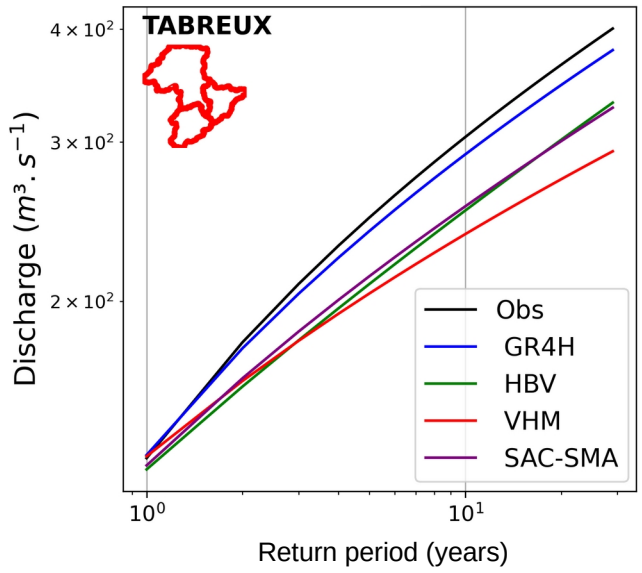
	TABREUX		
models	NSE	MB_{peak}	$RMSE_{peak}$
GR4H	0.70	-7.8	35.2
HBV	0.68	-1.6	30.5
VHM	0.69	0.7	30.5
SAC-SMA	0.66	-5.3	35.9

2011-2020

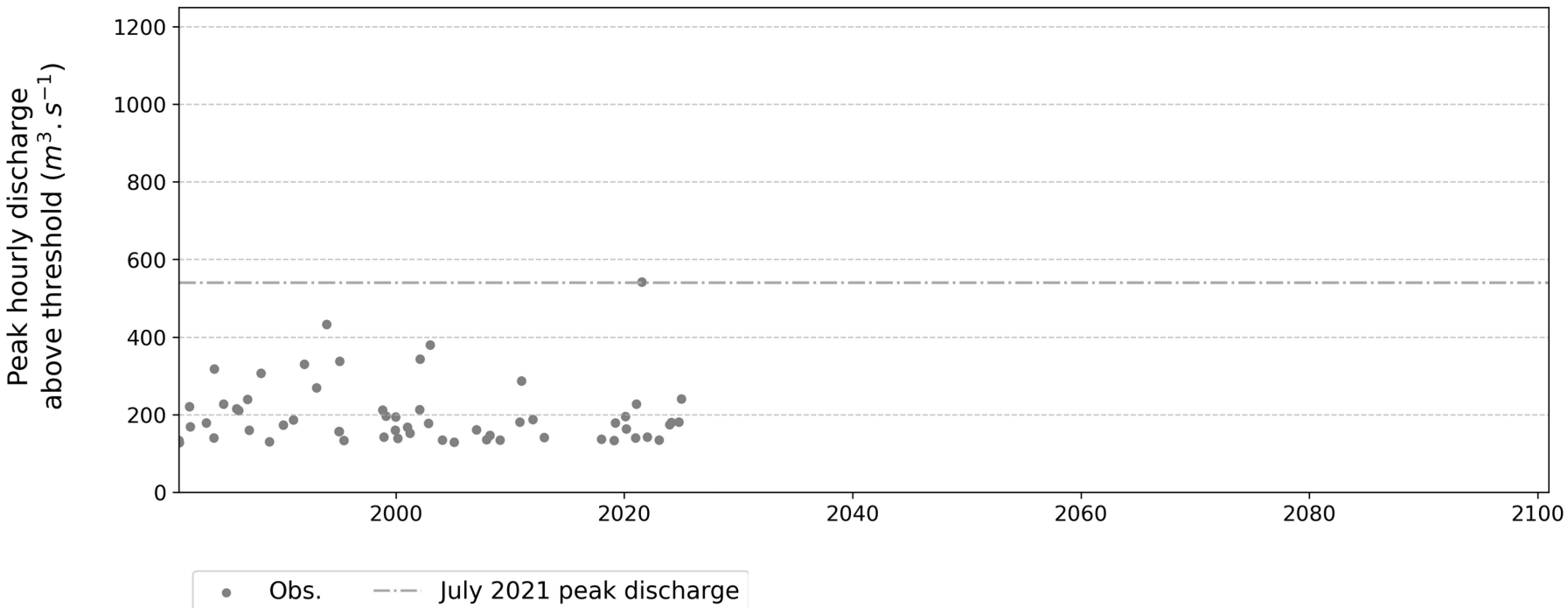
	TABREUX		
models	NSE	MB_{peak}	$RMSE_{peak}$
GR4H	0.41	-11.9	34.7
HBV	0.39	-3.8	33.2
VHM	0.39	-4.8	31.3
SAC-SMA	0.41	-12.1	36.2

MB_{peak} and $RMSE_{peak}$ are expressed in %

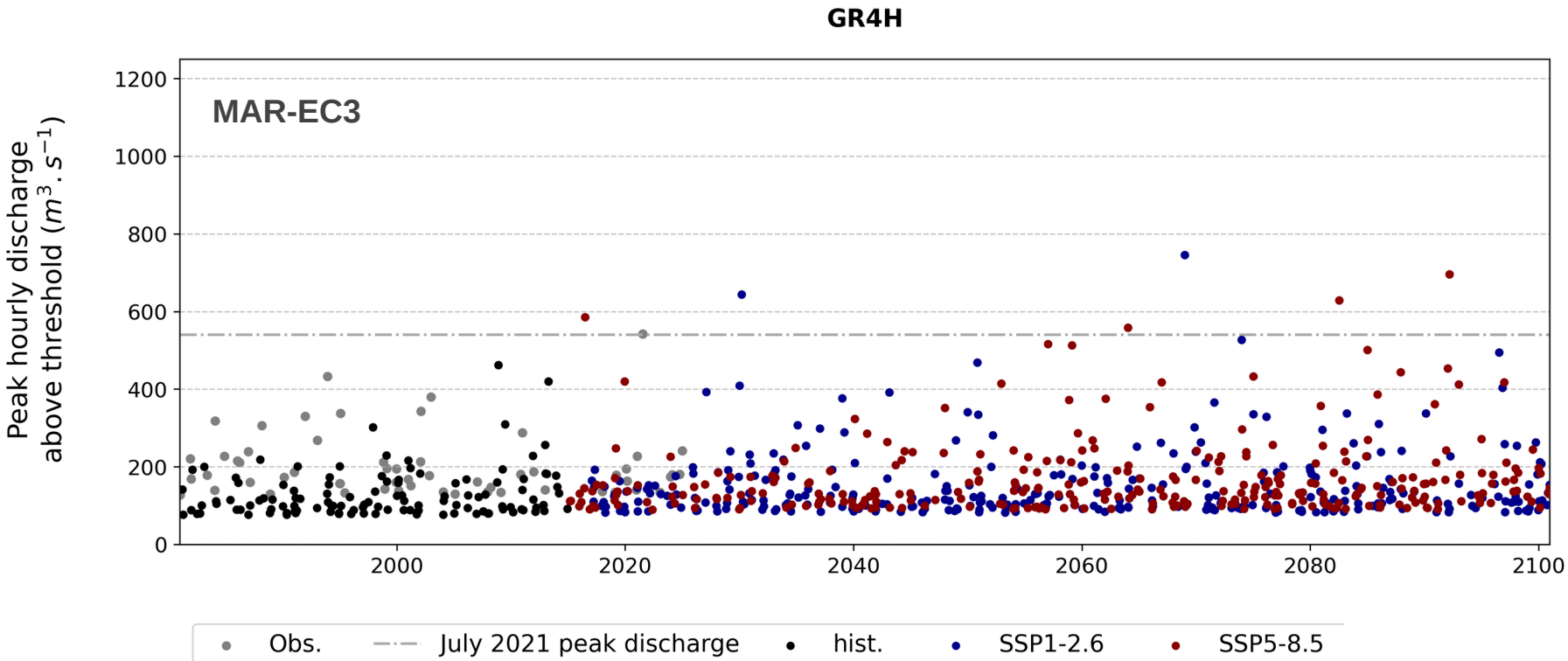
1980-2020



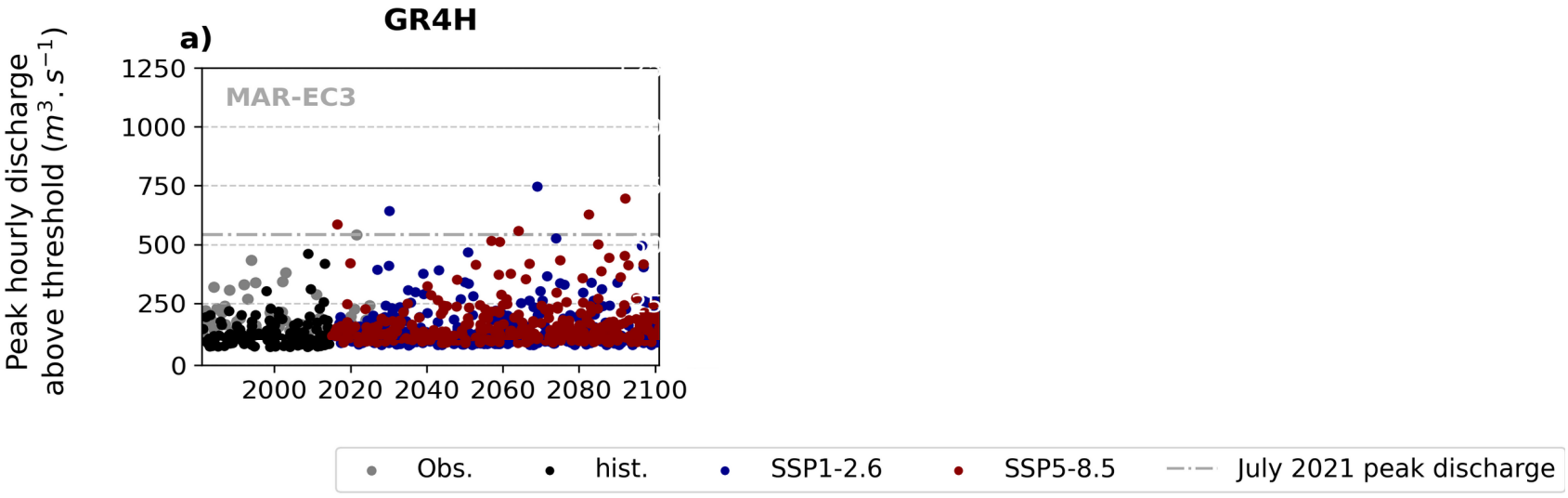
Hydrological projections



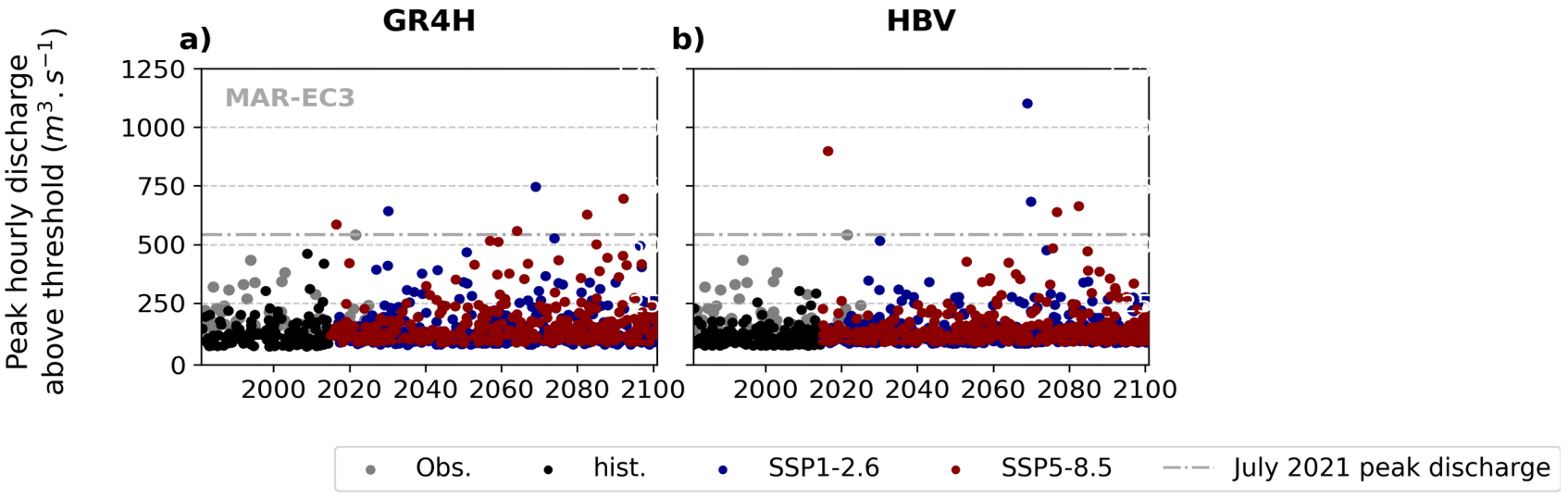
Hydrological projections



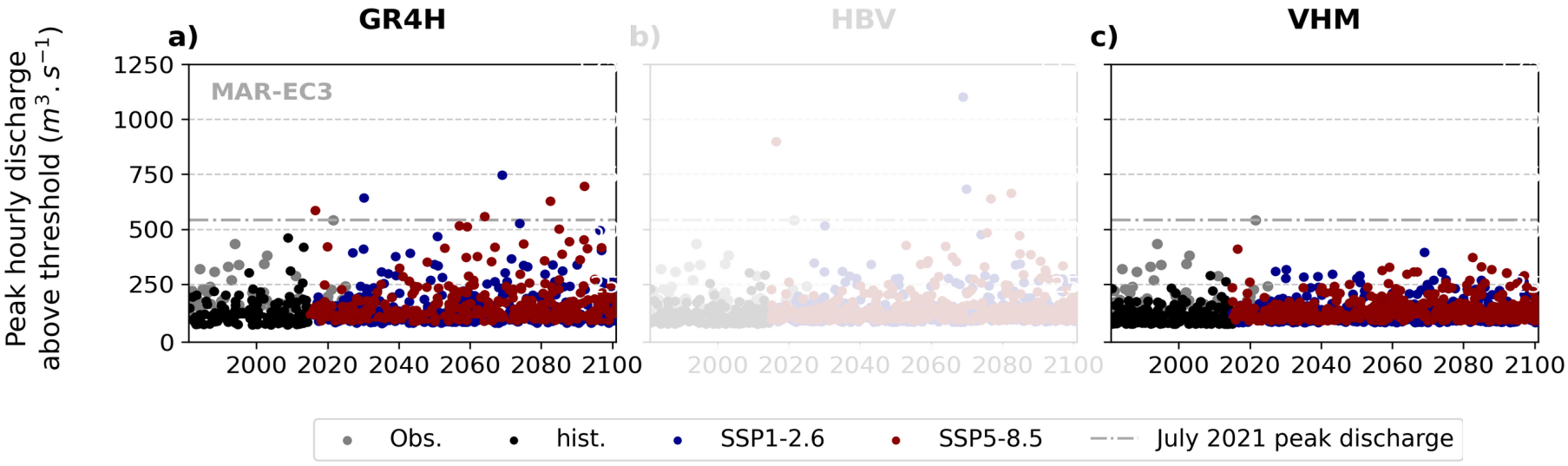
Hydrological projections



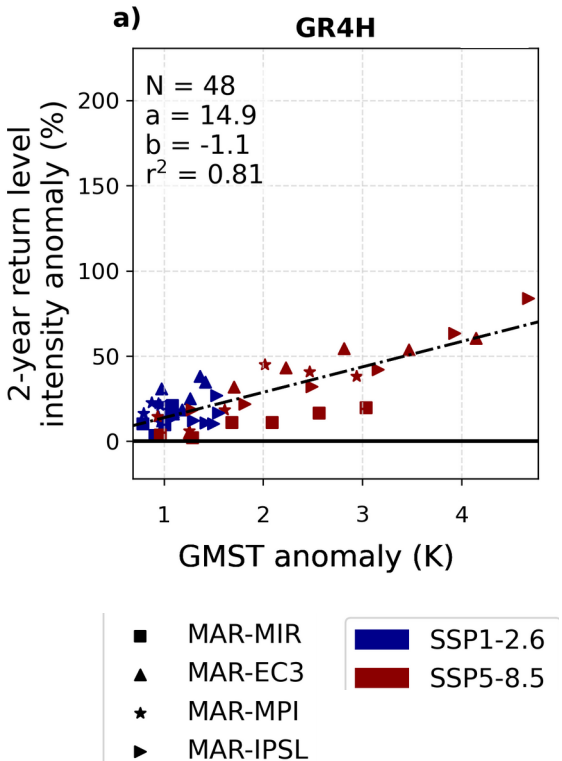
Hydrological projections



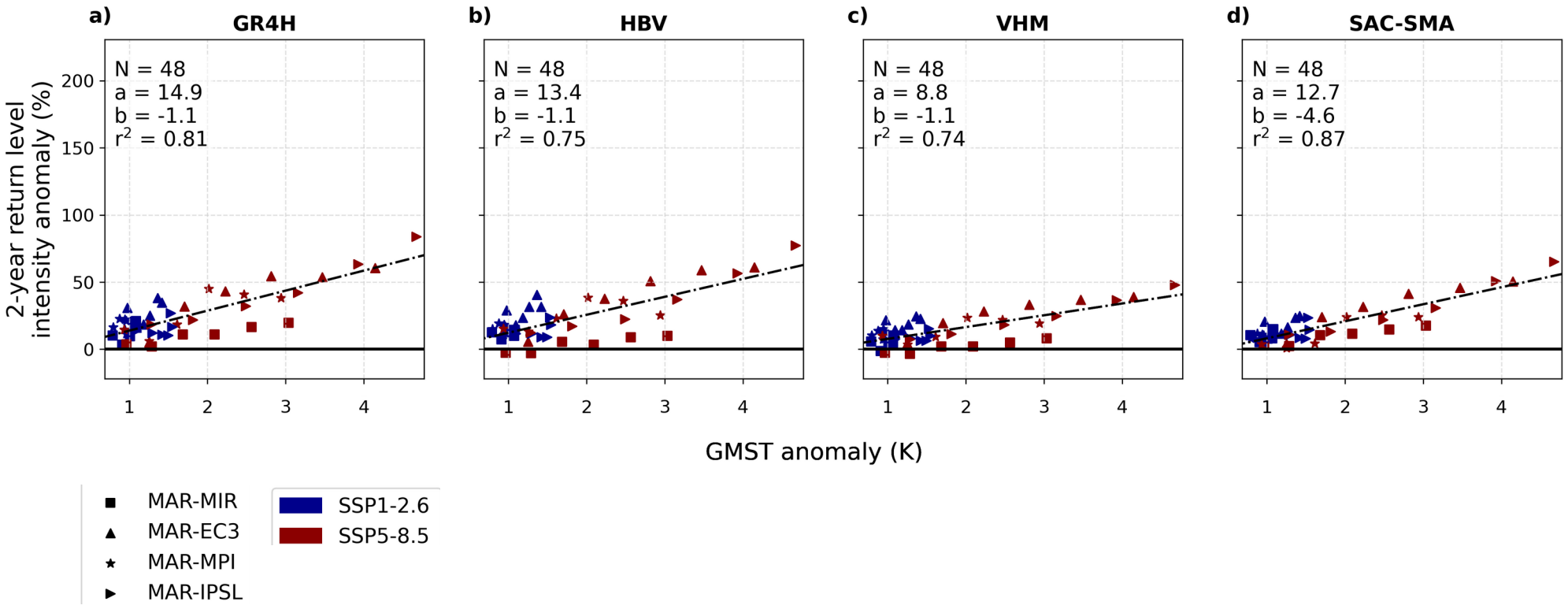
Hydrological projections



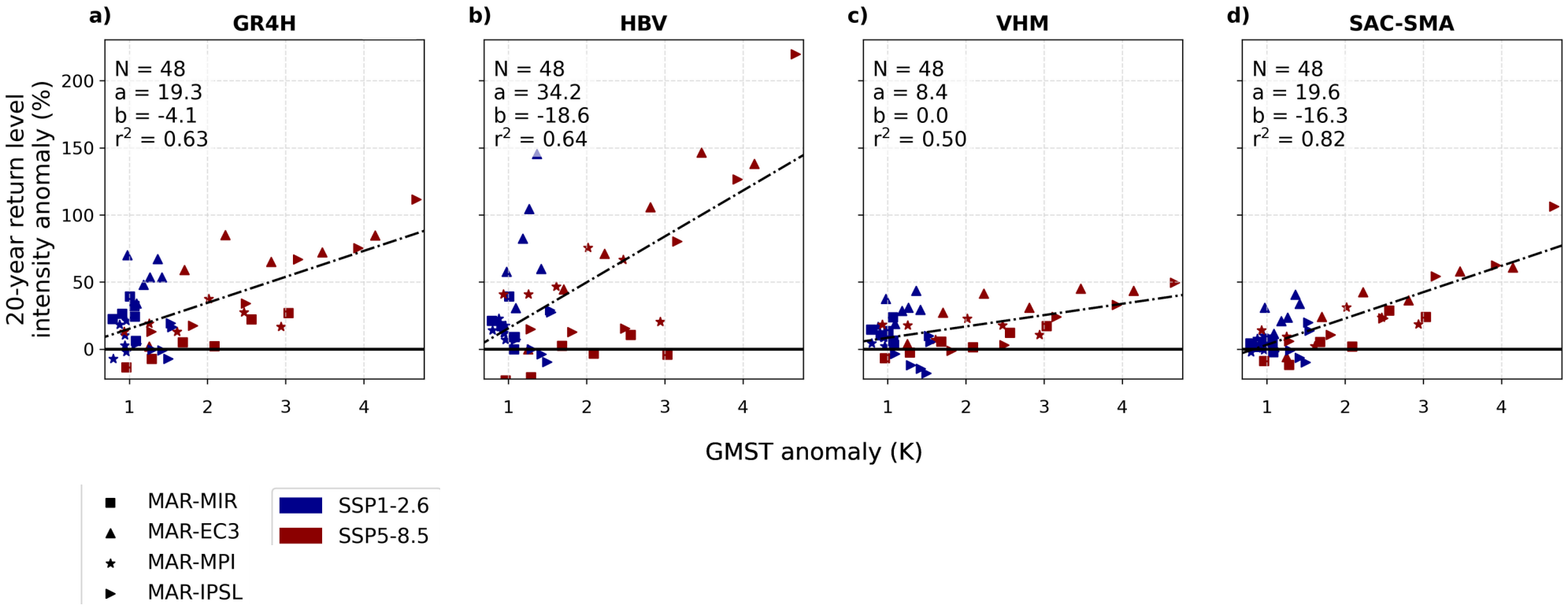
Return levels for peak discharges



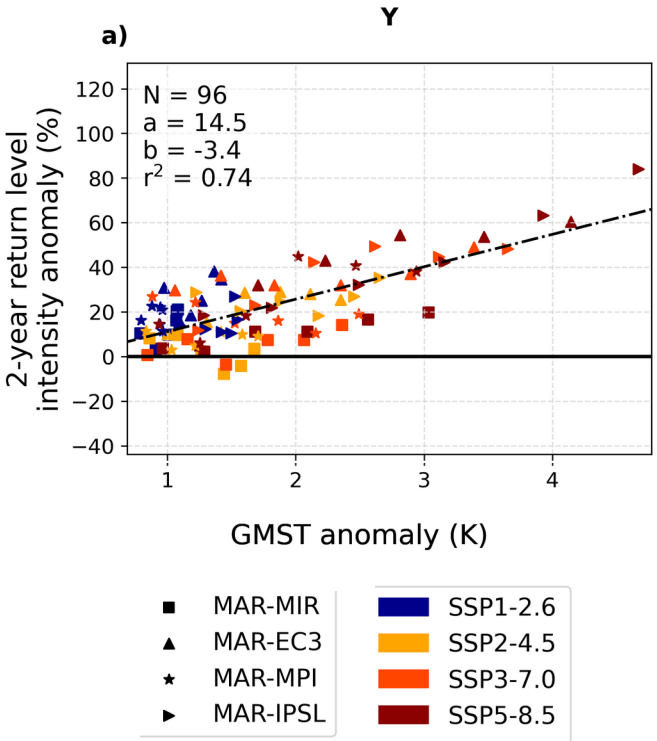
Return levels for peak discharges



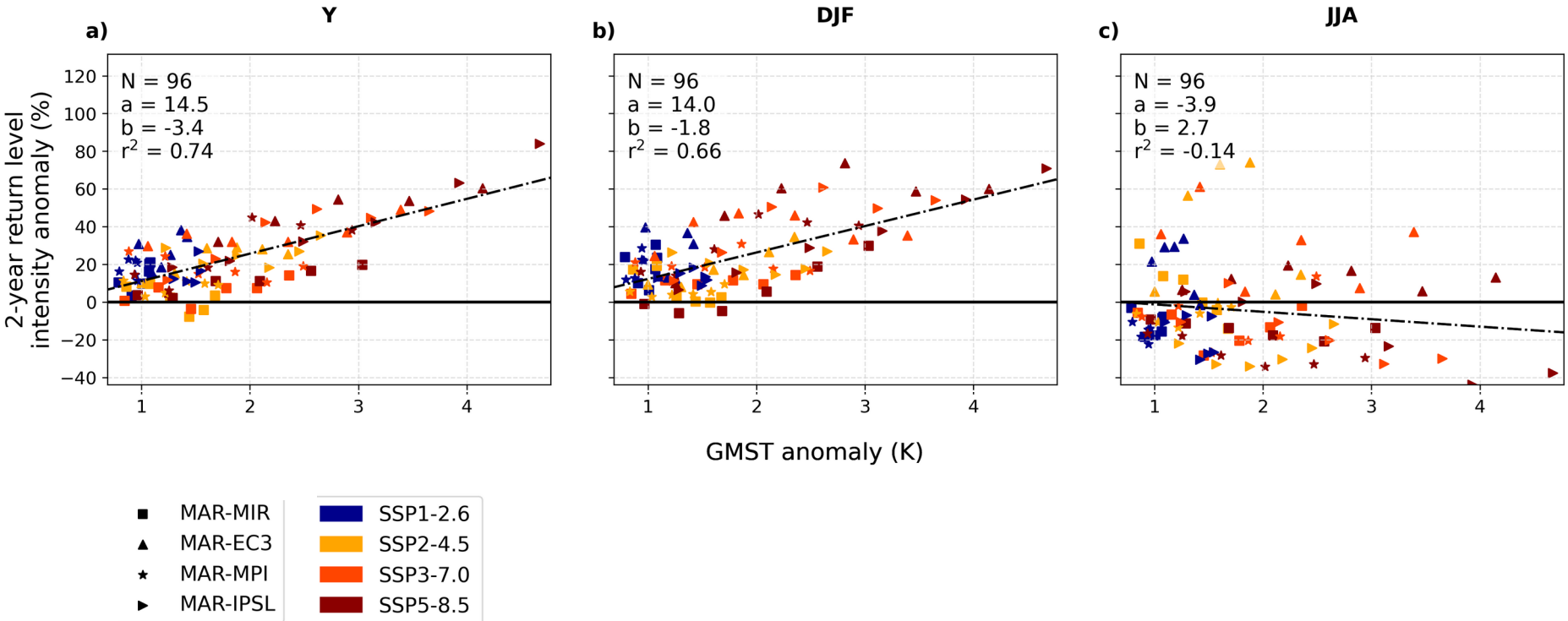
Return levels for peak discharges



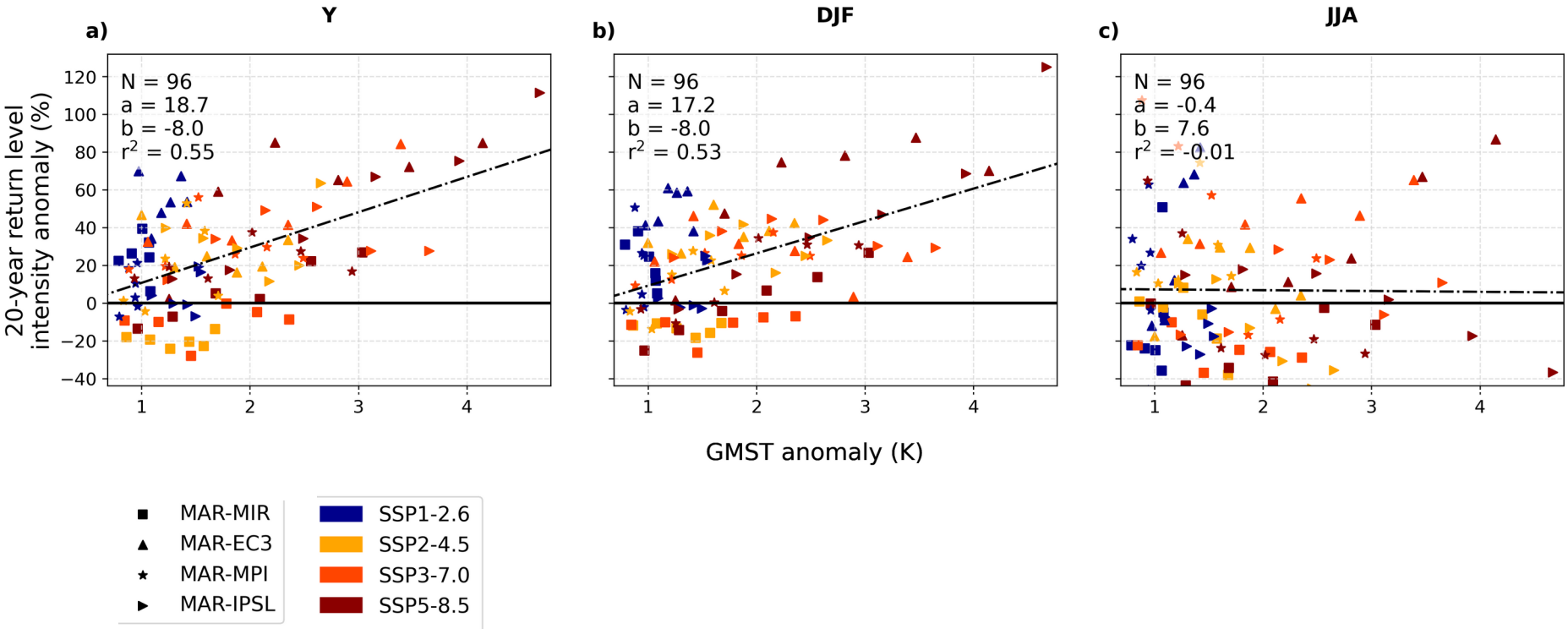
Adding other scenarios with GR4H



Adding other scenarios with GR4H



Adding other scenarios with GR4H



PART 3

Take–home

I. **MAR-WOLFhydro** modeling chain reaches **decent** NSE scores despite the imperfect observational input used

II. Representation of **rare** peak discharges highly depends on the **chosen hydrological model**

III. **Peak discharge** scaling can **exceed extreme precipitation** scaling, and is mainly high **in winter**

PART 4

Discussion and conclusions

Some unknowns are now better understood

I. How will extreme precipitation events **intensity** and **frequency** evolve at the Belgian scale?

→ On average following the **CC-scaling** (cf. Dierickx et al.,2025)

→ But with potential large **regional differences** for higer return periods

Some unknowns are now better understood

I. How will extreme precipitation events **intensity** and **frequency** evolve at the Belgian scale?
   - → On average following the **CC-scaling** (cf. Dierickx et al.,2025)
   - → But with potential large **regional differences** for higer return periods

II. How have **COLs** contributed and will contribute to extreme precipitation in **Europe** and more specifically **Belgium?**
   - → represent **up to 57%** of the most extreme European precipitation events
   - → **significance** of temporal trends in COL-associated events is **threshold dependent** and dominated by **interdecadal variability**
   - → Uncertain future due to **poor representation by ESMs**

Some unknowns are now better understood

I. How will extreme precipitation events **intensity** and **frequency** evolve at the Belgian scale?

→ On average following the **CC-scaling** (cf. Dierickx et al.,2025)
→ But with potential large **regional differences** for higer return periods

II. How have **COLs** contributed and will contribute to extreme precipitation in **Europe** and more specifically **Belgium?**

→ represent **up to 57%** of the most extreme European precipitation events
→ **significance** of temporal trends in COL-associated events is **threshold dependent** and dominated by **interdecadal variability**
→ Uncertain future due to **poor representation by ESMs**

III. How will these evolutions **translate in the hydrological system** ?

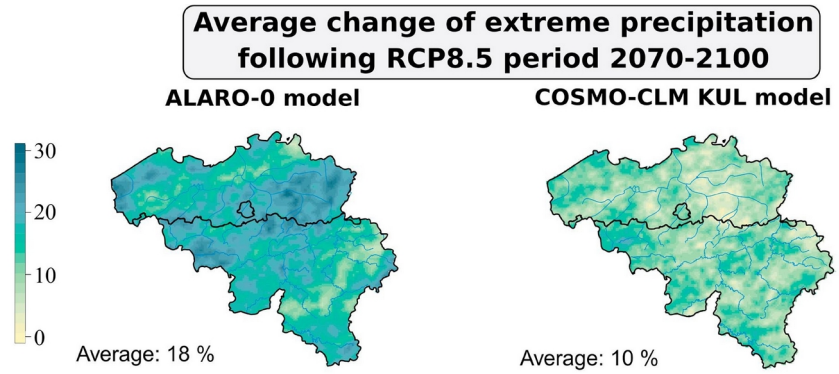
→ Over the Ourthe, scaling of peak discharges with global warming exceeds the scaling of extreme precipitation (cf. Leander et al., 2021)

Next opponents

- What about other models from Cordex-Be.2?



photo : Sky Sports, 2023

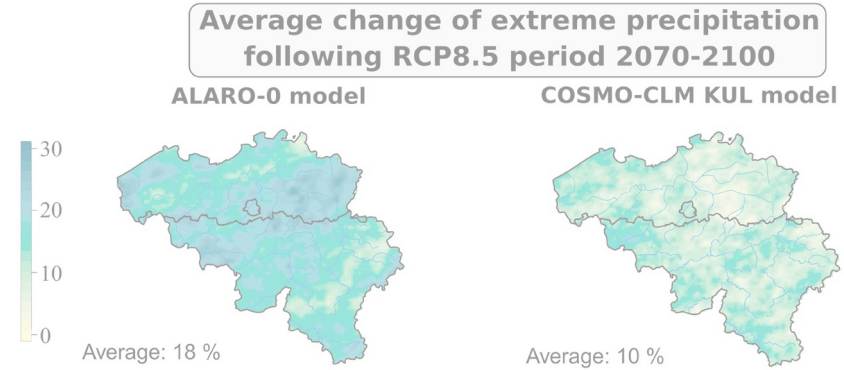


(Adapted from Termonia et al., (2018))

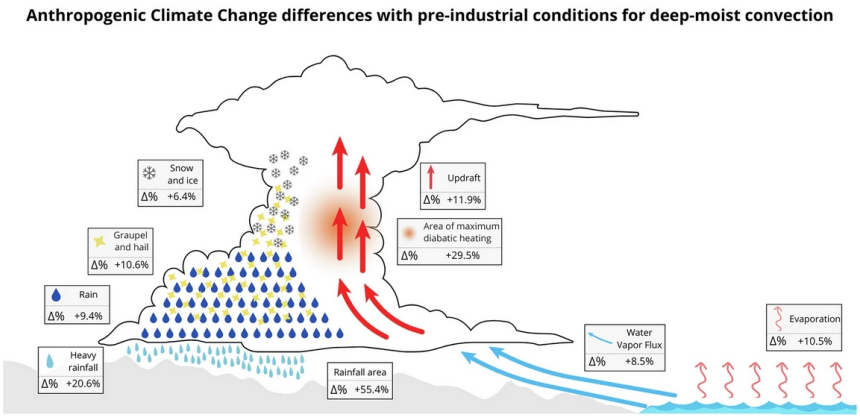
Next opponents

- What about other models from Cordex-Be.2?

- What exactly drives COL-associated extremes?



(Adapted from Termonia et al., (2018))



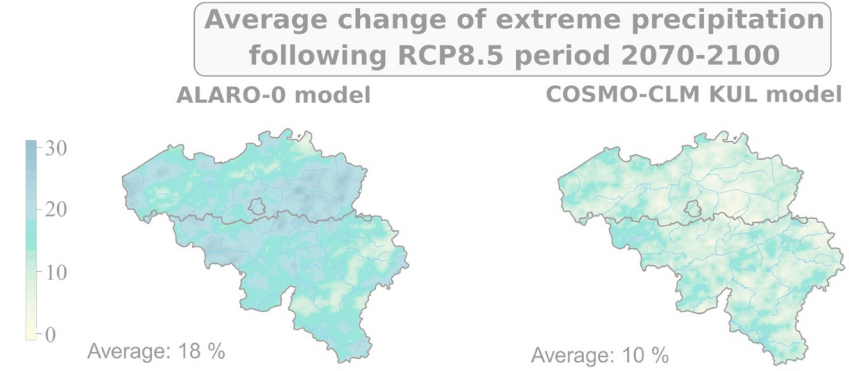
(Calvo-Sancho et al., 2026)



Photo : AFP / Daily Mail, 2015.

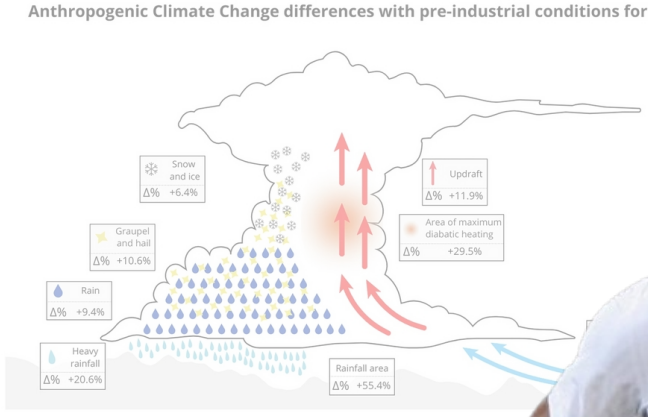
Next opponents

- What about other models from Cordex-Be.2?
- What exactly drives COL-associated extremes?



(Adapted from Termonia et al., (2018))

- Other Catchments? COL-associated floods?



(Calvo-Sancho et al., 2026)

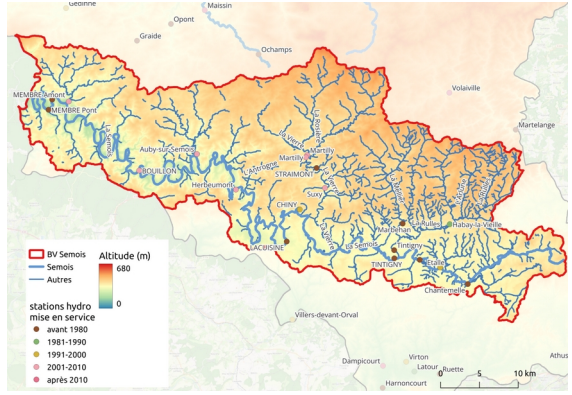
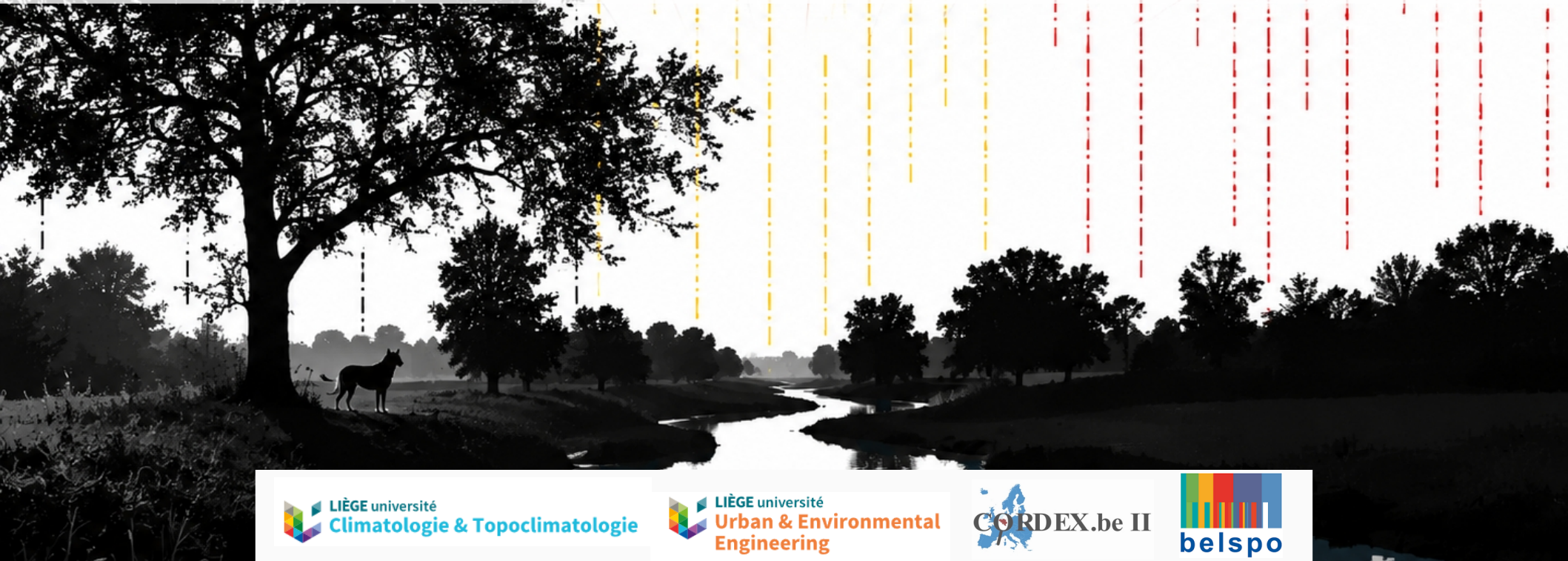




Photo : Paul Gilham / Getty Images.

THANK YOU!



LIÈGE université
Climatologie & Topoclimatologie

LIÈGE université
Urban & Environmental Engineering

CORDEX.be II

belspo

Cited references:

Brajkovic, J., Archambeau, P., Ghilain, N., & Doutreloup, S. (2026). Past and future evolution of cut-off-low-associated extreme precipitation in Europe. EGUsphere [preprint]. https://doi.org/10.5194/egusphere-2026-2315

Brajkovic, J., Fettweis, X., Noël, B., Van De Vyver, H., Ghilain, N., Archambeau, P., Pirotton, M., & Doutreloup, S. (2025). Increased intensity and frequency of extreme precipitation events in Belgium as simulated by the regional climate model MAR. Journal of Hydrology: Regional Studies, 59, 102399. https://doi.org/10.1016/j.ejrh.2025.102399

Calvo-Sancho, C., Díaz-Fernández, J., González-Alemán, J. J., Halifa-Marín, A., Miglietta, M. M., Azorin-Molina, C., Prein, A. F., Montoro-Mendoza, A., Bolgiani, P., Morata, A., & Martín, M. L. L. (2026). Human-induced climate change amplification on storm dynamics in Valencia's 2024 catastrophic flash flood. Nature Communications, 17, 1492. https://doi.org/10.1038/s41467-026-68929-9

Dierickx, A., Dewettinck, W., Van Schaeybroeck, B., De Cruz, L., Caluwaerts, S., Termonia, P., & Van de Vyver, H. (2025). EURO-SUPREME: Sub-daily precipitation extremes in the EURO-CORDEX ensemble. Earth System Science Data, 17, 6747–6762. https://doi.org/10.5194/essd-17-6747-2025

Journée, M., Goudenhoofdt, E., Vannitsem, S., & Delobbe, L. (2023). Quantitative rainfall analysis of the 2021 mid-July flood event in Belgium. EGUsphere, 1–24. https://doi.org/10.5194/egusphere-2023-542

Kreienkamp, F., Philip, S. Y., Tradowsky, J. S., Kew, S. F., Lorenz, P., Arrighi, J., Belleflamme, A., Bettmann, T., Caluwaerts, S., Chan, S. C., Ciavarella, A., De Cruz, L., de Vries, H., Demuth, N., Ferrone, A., Fischer, R. M., Fowler, H. J., Goergen, K., Heinrich, D., Henrichs, Y., Lenderink, G., Kaspar, F., Nilson, E., Otto, F. E. L., Ragone, F., Seneviratne, S. I., Singh, R. K., Skålevåg, A., Termonia, P., Thalheimer, L., van Aalst, M., Van den Bergh, J., Van de Vyver, H., Vannitsem, S., van Oldenborgh, G. J., Van Schaeybroeck, B., Vautard, R., Vonk, D., & Wanders, N. (2021). Rapid attribution of heavy rainfall events leading to the severe flooding in Western Europe during July 2021. World Weather Attribution. https://www.worldweatherattribution.org/rapid-attribution-of-heavy-rainfall-events-leading-to-the-severe-flooding-in-western-europe-during-july-2021/

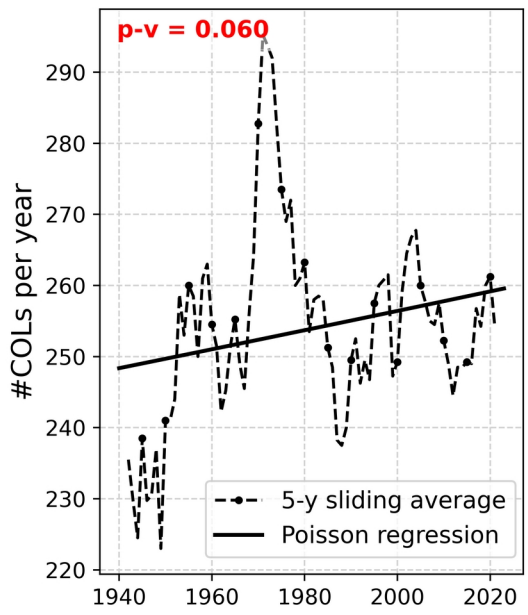
Termonia, P., Van Schaeybroeck, B., De Cruz, L., De Troch, R., Caluwaerts, S., Giot, O., Hamdi, R., Vannitsem, S., Duchêne, F., Willems, P., Tabari, H., Van Uytven, E., Hosseinzadehtalaei, P., Van Lipzig, N., Wouters, H., Vanden Broucke, S., Van Ypersele, J.-P., Marbaix, P., Villanueva-Birriel, C., ... Pottiaux, E. (2018). The CORDEX.be initiative as a foundation for climate services in Belgium. Climate Services, 11, 49–61. https://doi.org/10.1016/j.cliser.2018.05.001

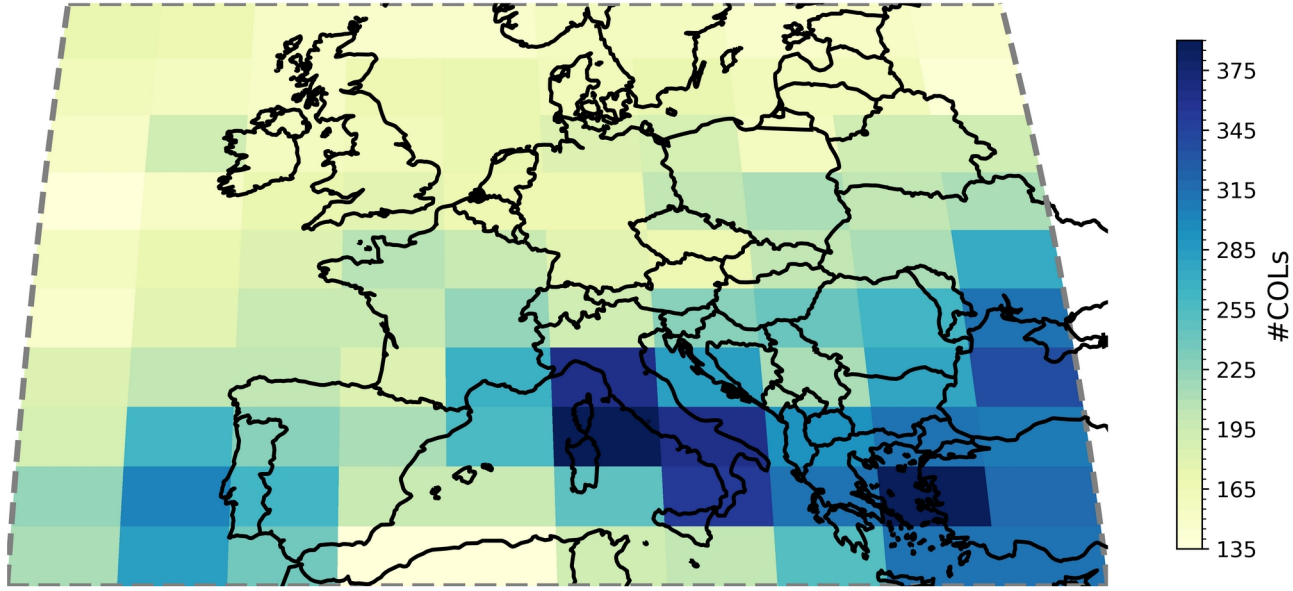
Supplementary slides



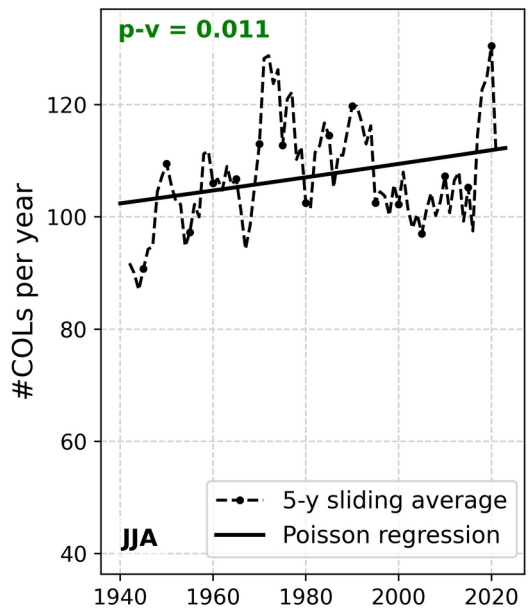
COL detection – detected COLs over 1940-2023

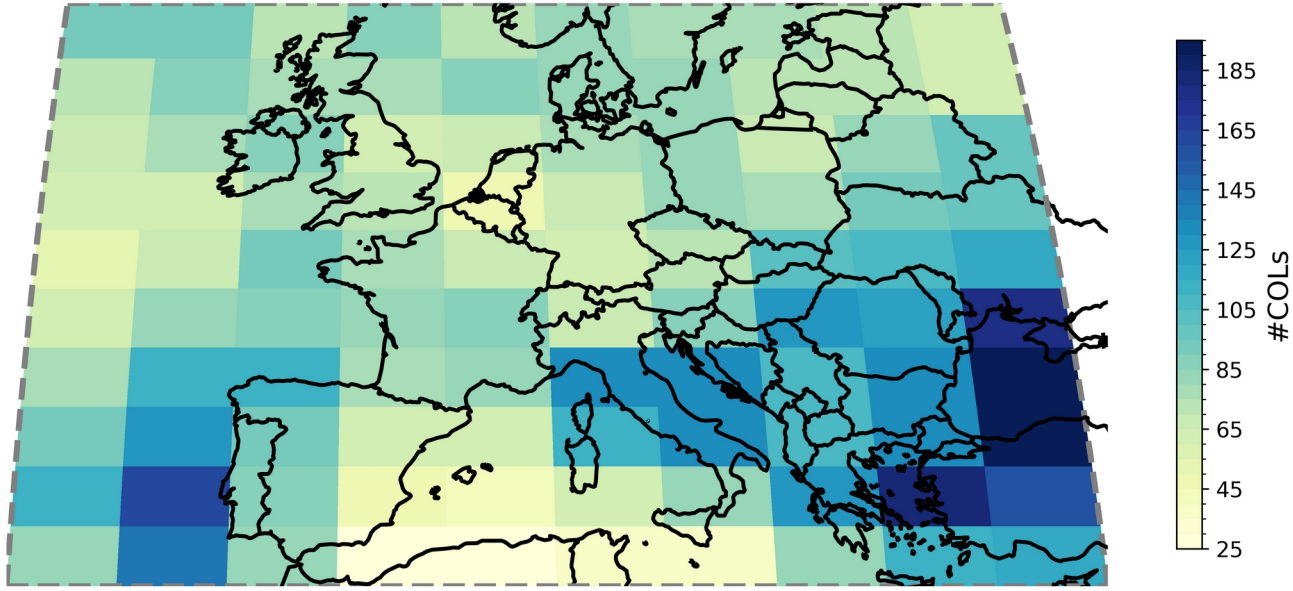
With spatio-temporal declustering!

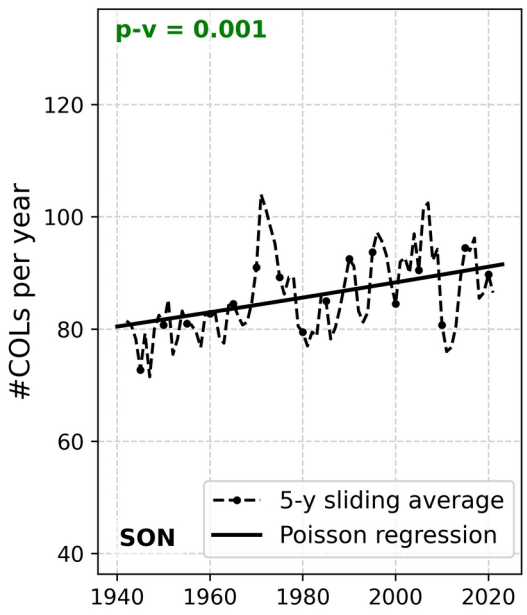


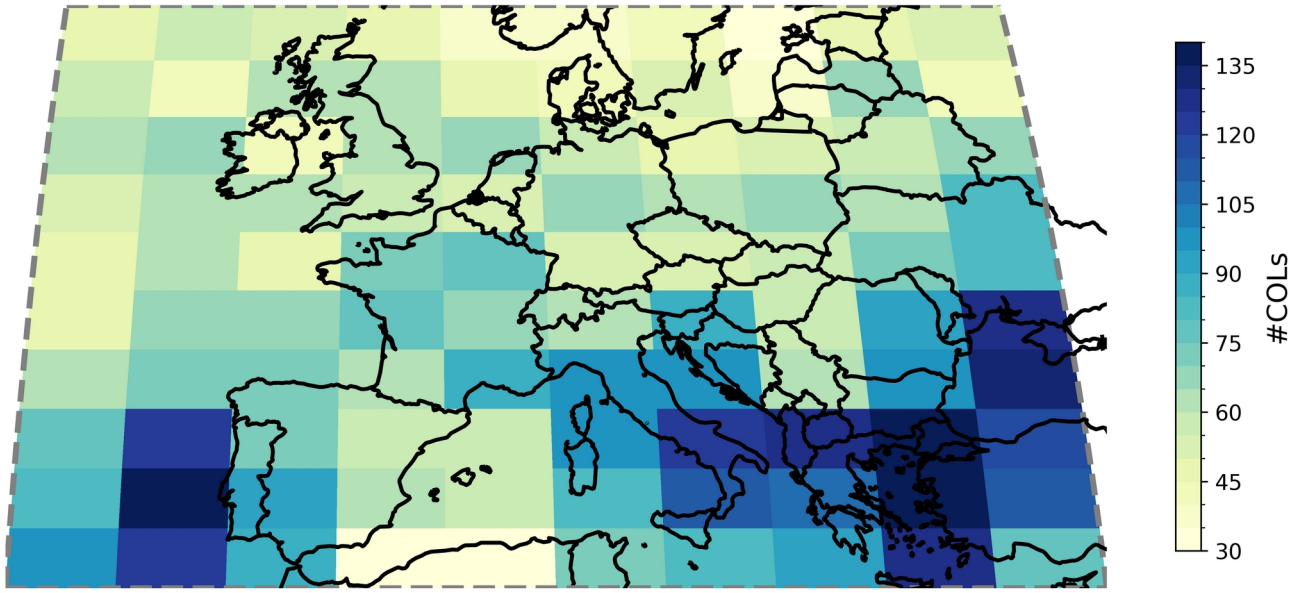


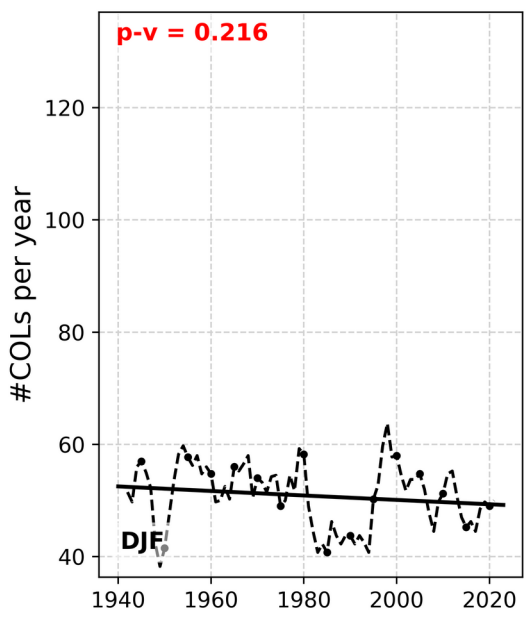
COL detection – detected COLs over 1940-2023

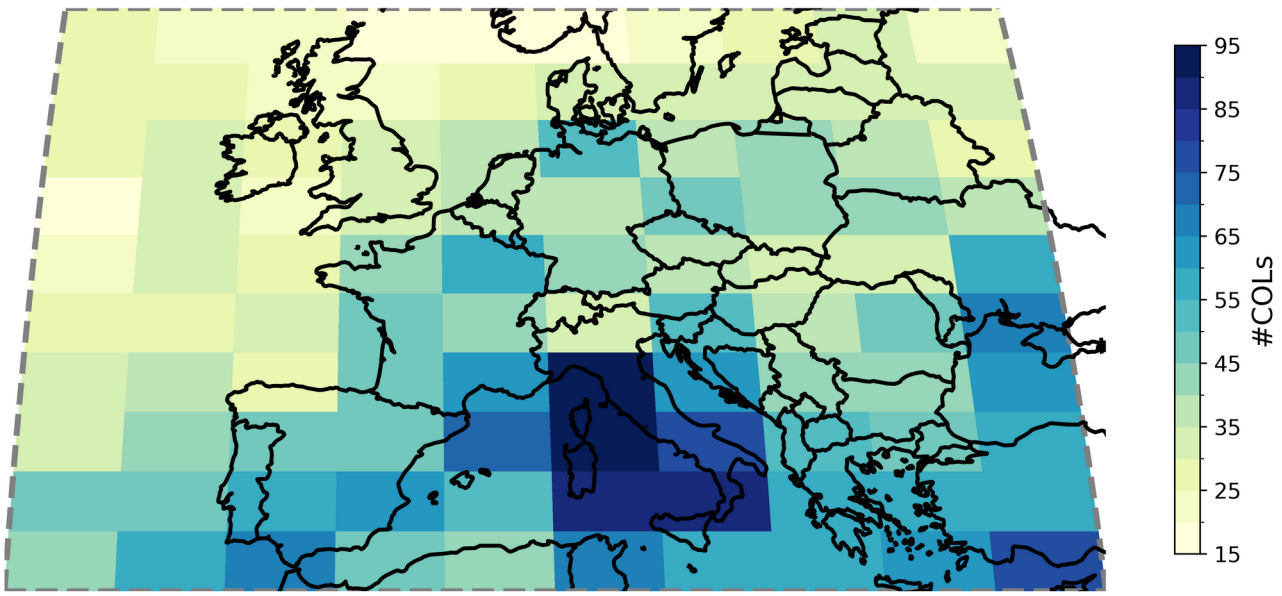





p-v = 0.001
#COLs per year
120
100
80
60
40
1940
1960
1980
2000
2020
5-y sliding average
Poisson regression
SON

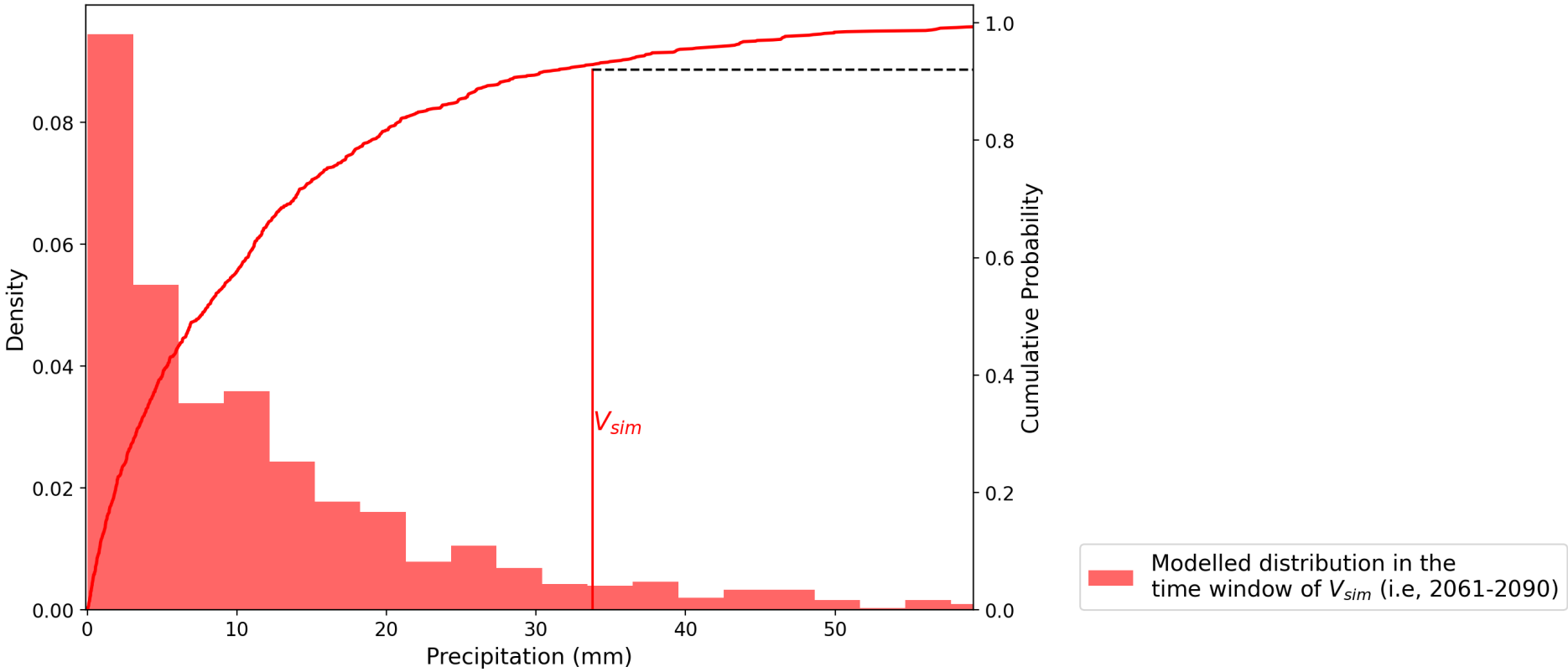

135
120
105
90
75
60
45
30
#COLs


p-v = 0.216
#COLs per year
120
100
80
60
40
1940
1960
1980
2000
2020
DJF


95
85
75
65
55
45
35
25
15
#COLs

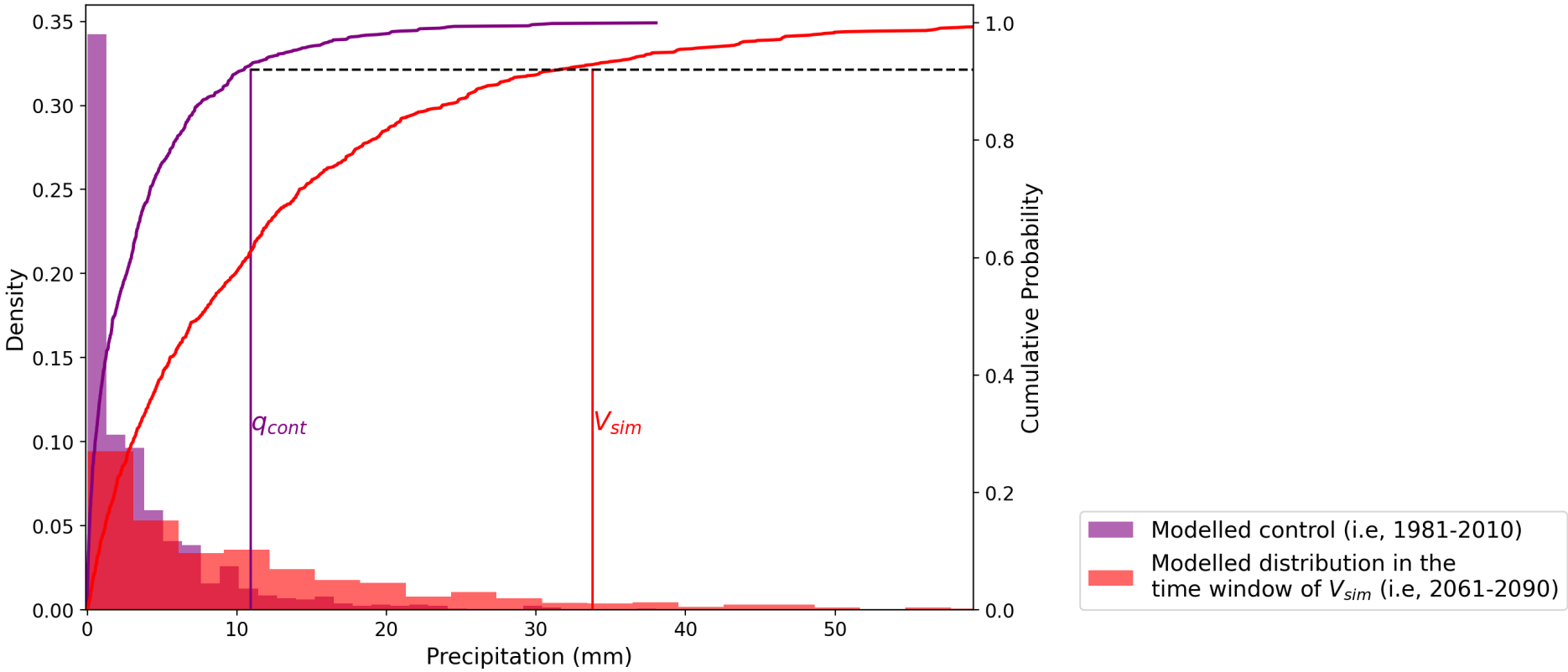
Bias-adjustment procedure (example for daily precipitation)

Example of the correction of $\mathbf{V_{sim}}$



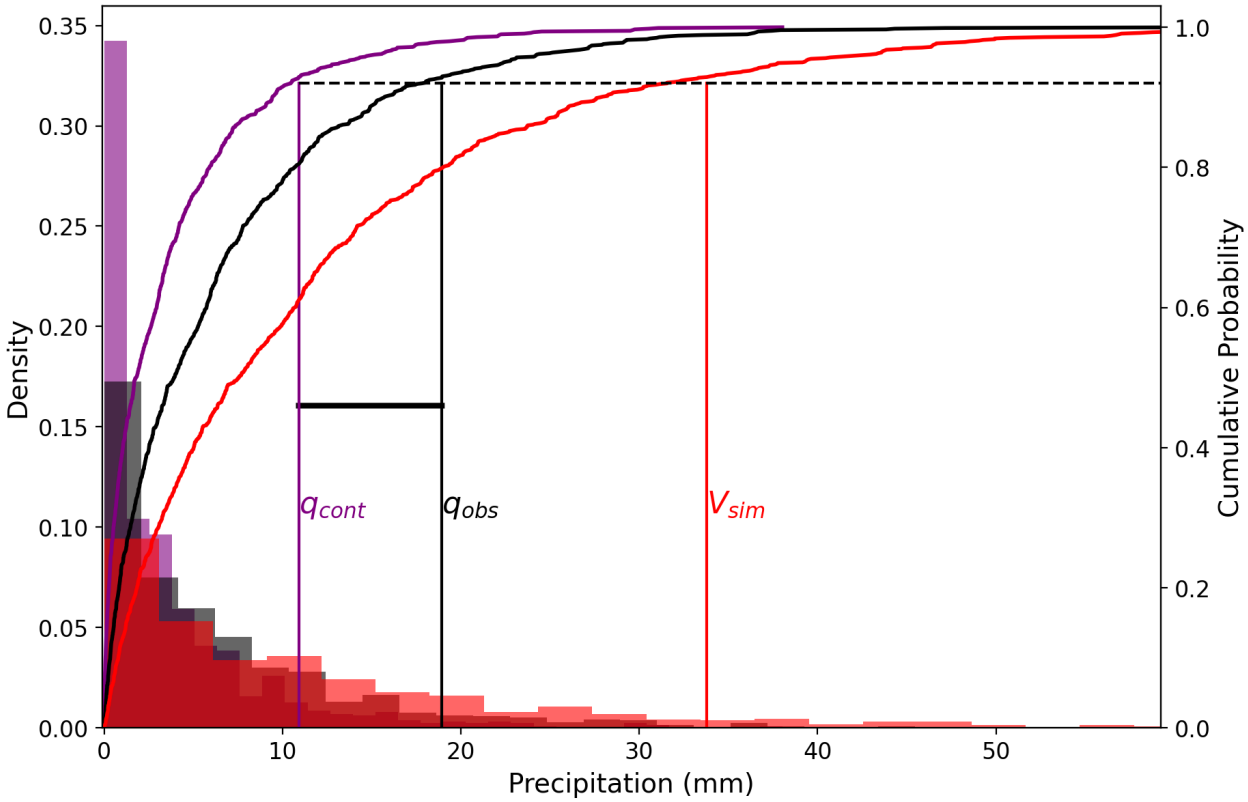
Bias-adjustment procedure (example for daily precipitation)

Example of the correction of $\mathbf{V_{sim}}$



Bias-adjustment procedure (example for daily precipitation)

Example of the correction of V_{sim}



$$CF = \frac{q_{obs}}{q_{cont}}$$

$$V_{corr} = CF \cdot V_{sim}$$

$$= \frac{q_{obs}}{q_{cont}} \cdot V_{sim}$$

$$= \frac{V_{sim}}{q_{cont}} \cdot q_{obs}$$

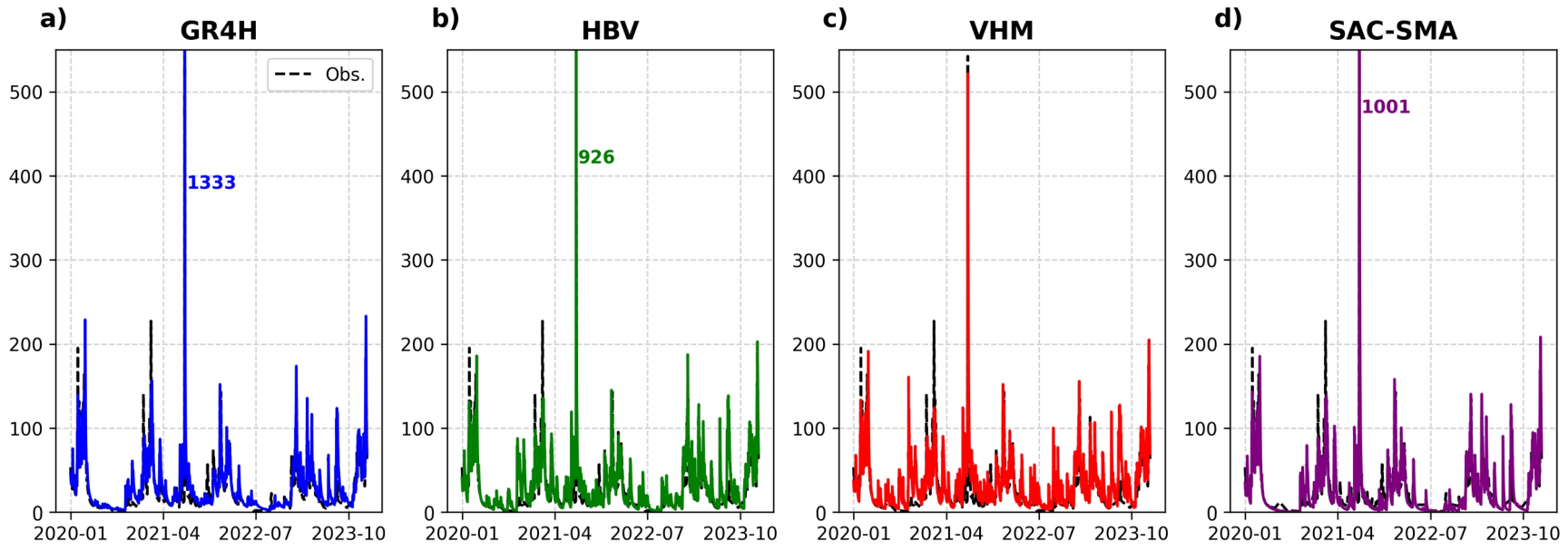


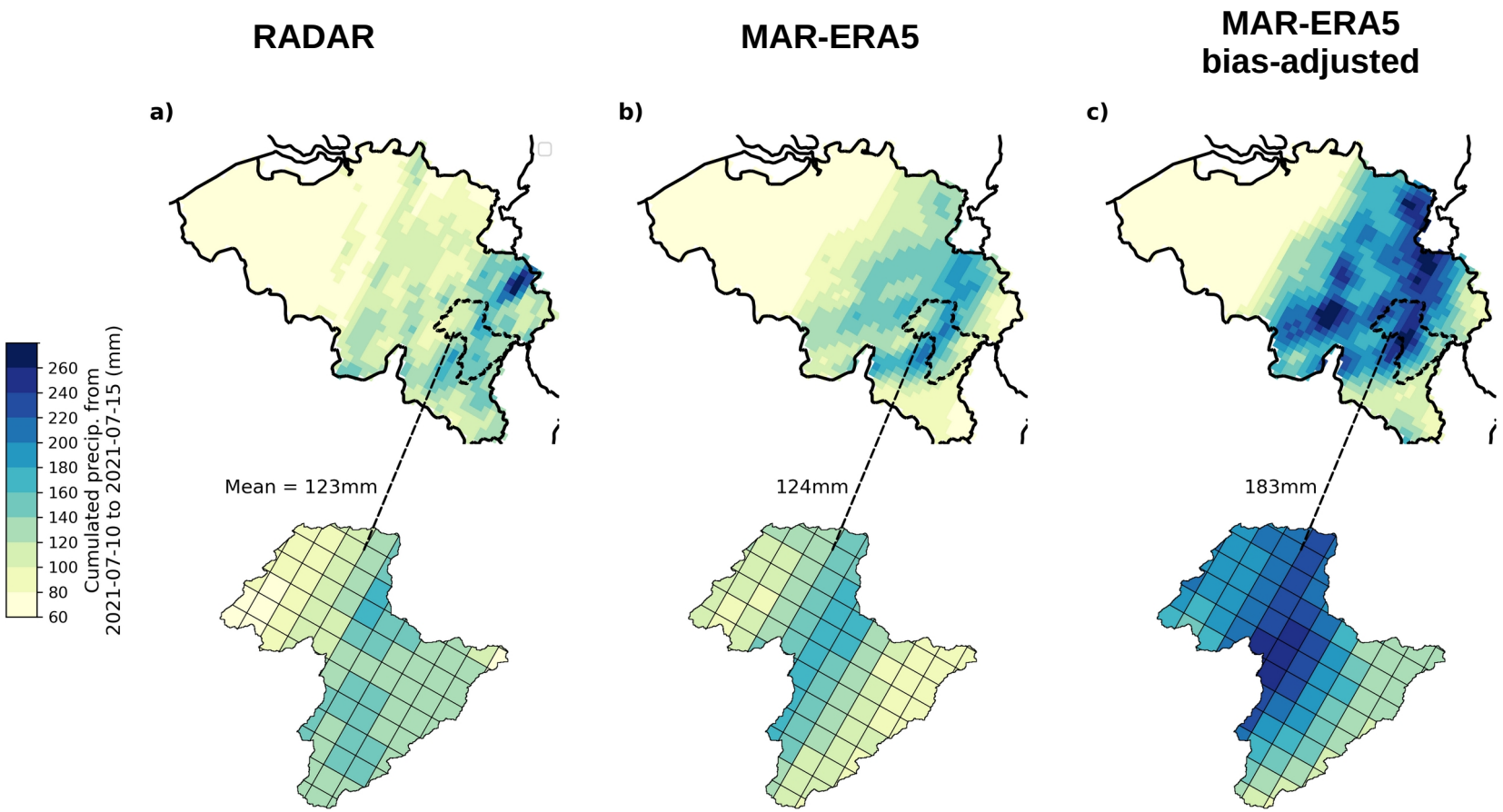




models	TABREUX			MABOMPRE			ORTHO		
	NSE	**MB**$_{peak}$	**RMSE**$_{peak}$	**NSE**	**MB**$_{peak}$	**RMSE**$_{peak}$	**NSE**	**MB**$_{peak}$	**RMSE**$_{peak}$
GR4H	0.70	-7.8	35.2	0.56	6.9	44.5	0.56	3.1	40.9
HBV	0.68	-1.6	30.5	0.57	-6.4	35.4	0.57	-5.9	36.6
VHM	0.69	0.7	30.5	0.57	-1.4	42.4	0.60	-4.4	39.4
SAC-SMA	0.66	-5.3	35.9	0.56	-6.5	38.6	0.53	1.8	40.5

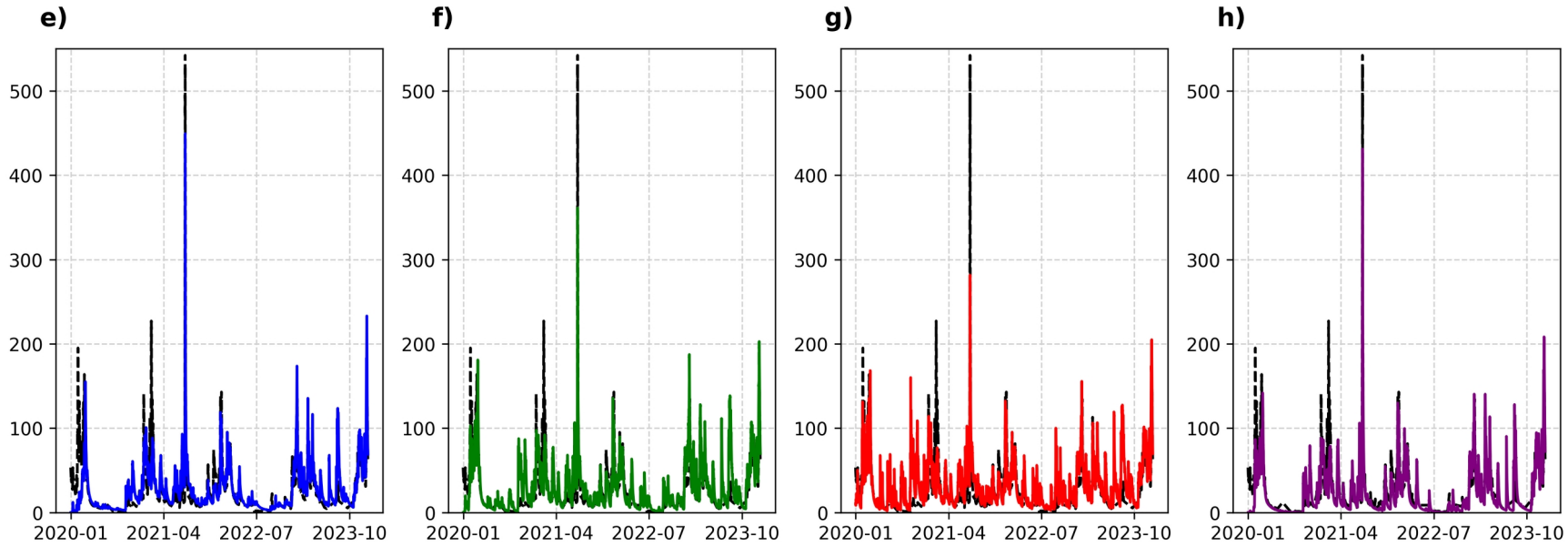
Model validation (2011-2023) – the July 2021 case

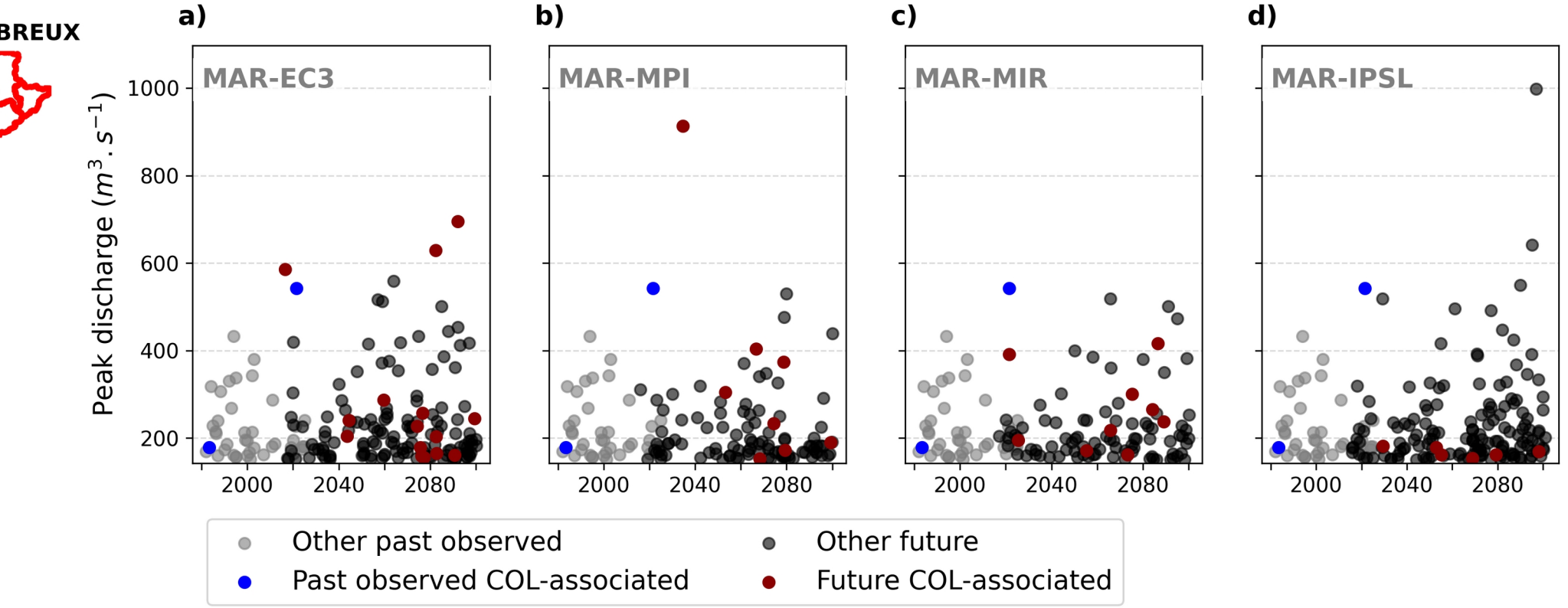



RADAR
MAR-ERA5
MAR-ERA5
bias-adjusted
a)
b)
c)
Cumulated precip. from
2021-07-10 to 2021-07-15 (mm)
260
240
220
200
180
160
140
120
100
80
60
Mean = 123mm
124mm
183mm

Model validation (2011-2023) – the July 2021 case

Forcing = Radar data




BREUX
a)
b)
c)
d)
MAR-EC3
MAR-MPI
MAR-MIR
MAR-IPSL
Peak discharge ($m^3.s^{-1}$)
1000
800
600
400
200
2000
2040
2080
Other past observed
Past observed COL-associated
Other future
Future COL-associated

Recent high-impact COLs

