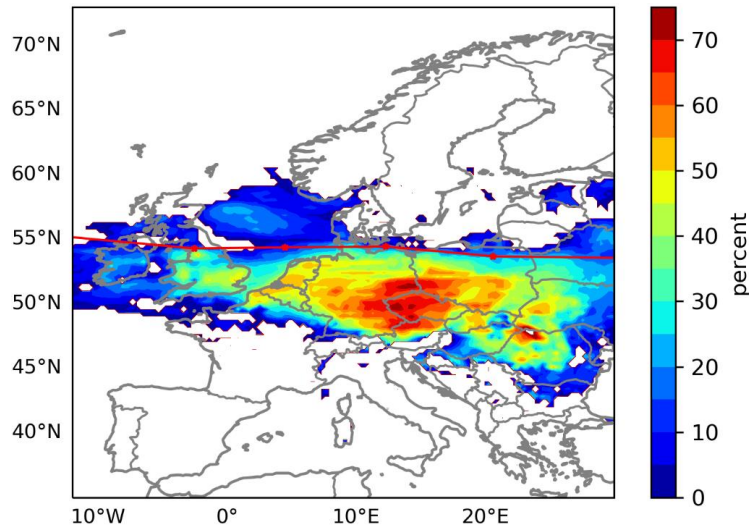


Future changes of European windstorm losses in EURO-CORDEX simulations

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Institute of Meteorology and Climate Research Troposphere Research (IMKTRO)

Storm Kyrill (Gust footprint)



<https://doi.org/10.5194/nhess-24-3445-2024>

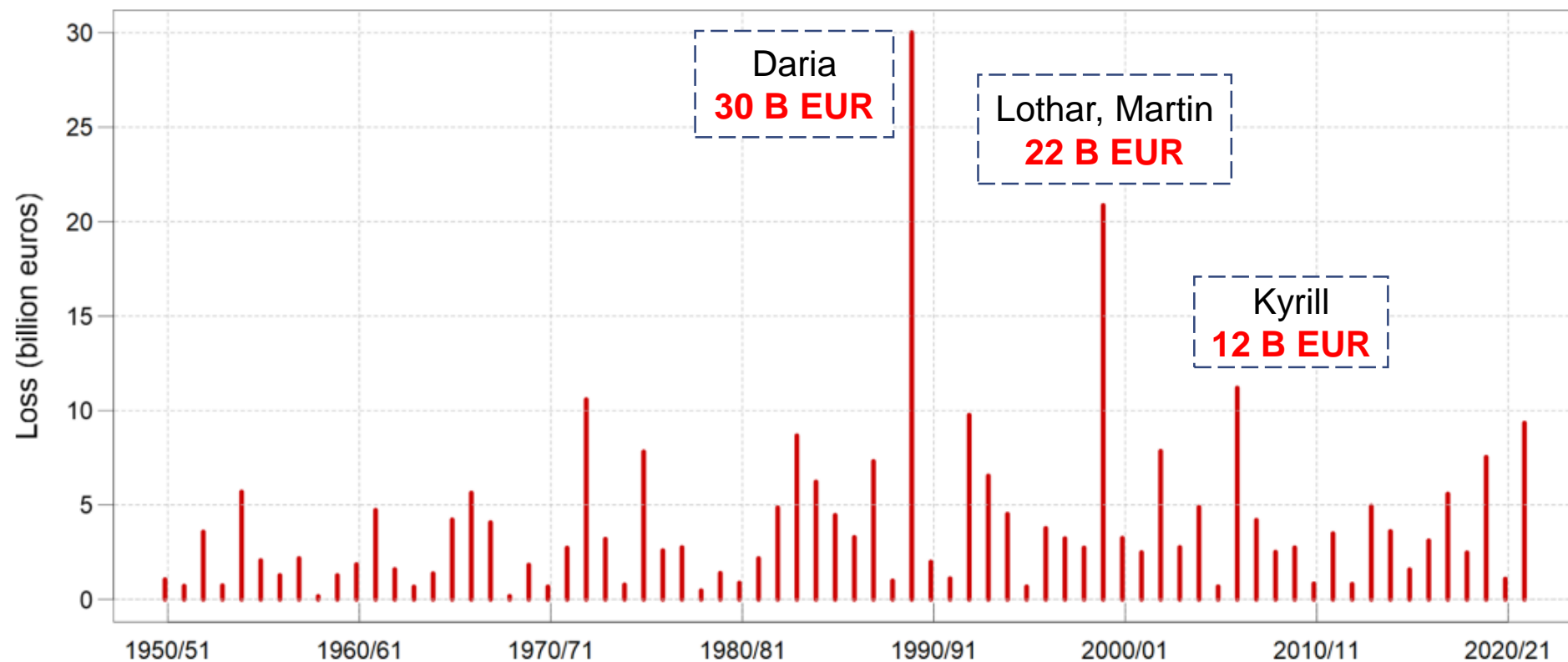
Storm Kyrill damaged cars in Berlin



https://commons.wikimedia.org/wiki/File:Sturmschaden_Berlin_Kyrill_01.jpg

Historical windstorm loss over Europe

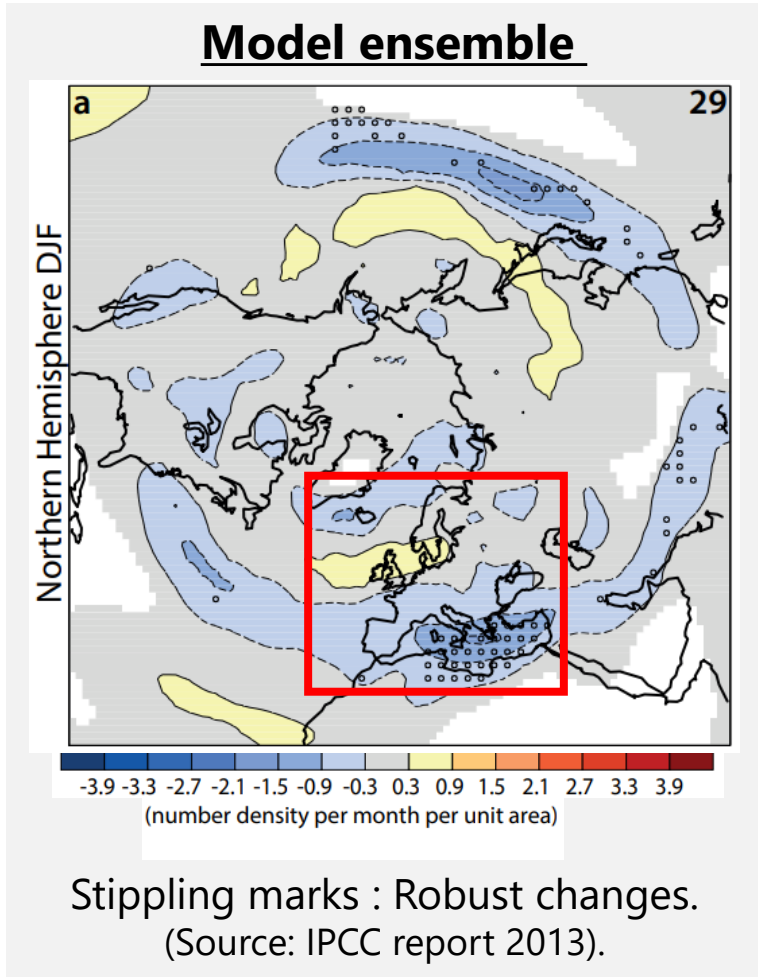
Loss per season (October to March)



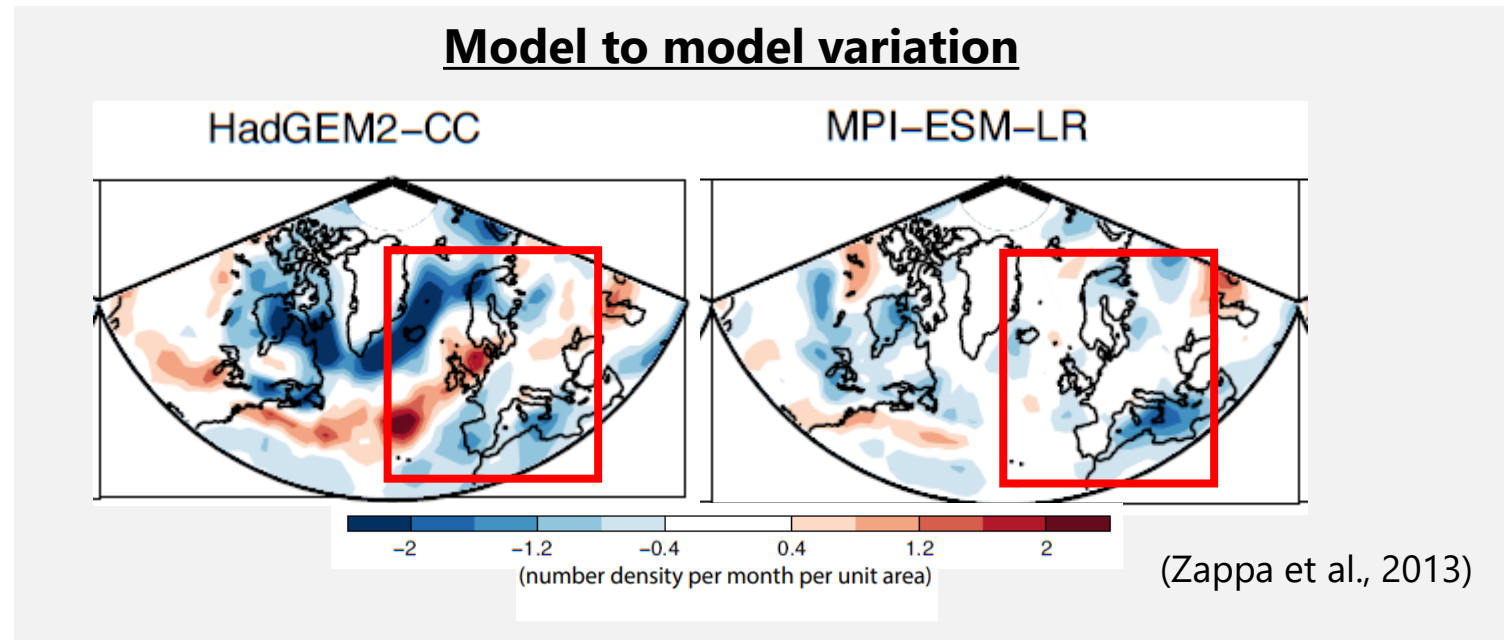
(Cusack, 2023)

European windstorms can result in very large aggregated economic loss.

Uncertainty of windstorm changes



Change in storm track density from CMIP5 model
Future (RCP4.5) minus historical period



Uncertainty in windstorm changes can result in uncertain loss under climate change

Future windstorm losses

How does **climate change** affect **windstorm losses** across Europe ?

1

**Evaluation of EURO-CORDEX
historical simulations**

(Alifdini et al. 2024)

2

Changes under future climate

windstorm

intensity

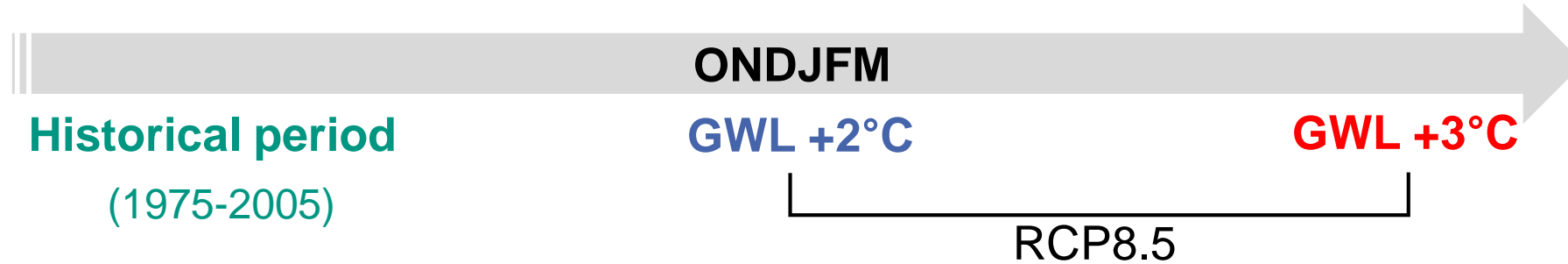
frequency

losses

rare extreme loss

(Data) EURO-CORDEX (EUR-11)

- Daily maximum 10m wind gust
- Bias corrected (Empirical quantile mapping with ERA5 wind gust) **EURO-CORDEX** (12km)



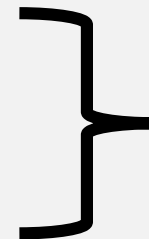
EUR-11 MODEL CHAINS (20 model ensembles) :

Global Climate Model (GCM) :

NorESM1-M (2031 – 2060) (2057 – 2086)
 EC-EARTH (2026 – 2055) (2051 – 2080)
 HadGEM2-ES (2016 – 2045) (2037 – 2066)
 CNRM-CM5 (2029 – 2058) (2052 – 2081)
 MPI-ESM-LR (2029 – 2058) (2052 – 2081)

Regional Climate Model (RCM) :

COSMO-crCLIM-v1-1
 RACMO22E
 HadREM3-GA7-05
 RCA4



*GWL +2°C *GWL +3°C

(Alifdini et al. 2024)

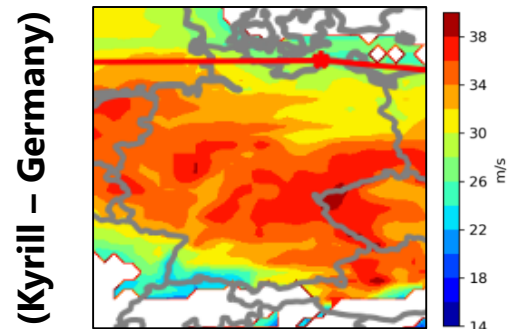
(Method) Loss Index

- Impact of storms was calculated using **Loss index** (LI).

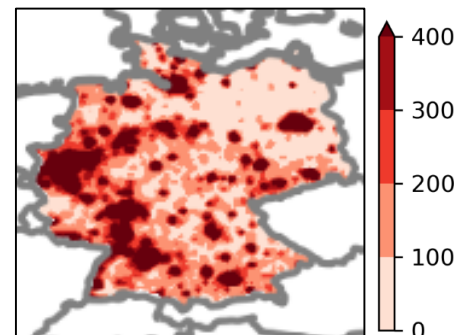
$$LI = \sum_{i=1}^N \sum_{j=1}^M \left(\frac{v_{ij}}{v_{98ij}} \right)^3 \cdot P_{i,j} \cdot I(v_{ij}, v_{98ij}) \cdot L_{i,j}$$

maximum wind gust within 3 days
population density data in 2020 (CIESIN & CIAT, 2022)
0 if seas and 1 if land
0 if $v_{ij} < v_{98th}$ and 1 if $v_{ij} > v_{98th}$
98th percentile of daily maximum wind gust ONDJFM (correspond to the gust above 20 m/s).

Hazard v_{ij} when ($v_{ij} > v_{98ij}$)



Exposure $P_{i,j}$



LI for storm Kyrill in Germany

Pinto et al (2012) : <https://doi.org/10.3354/cr01111>

CIESIN & CIAT (2022) : <https://sedac.ciesin.columbia.edu/data/collection/gpw-v4>

Part 1

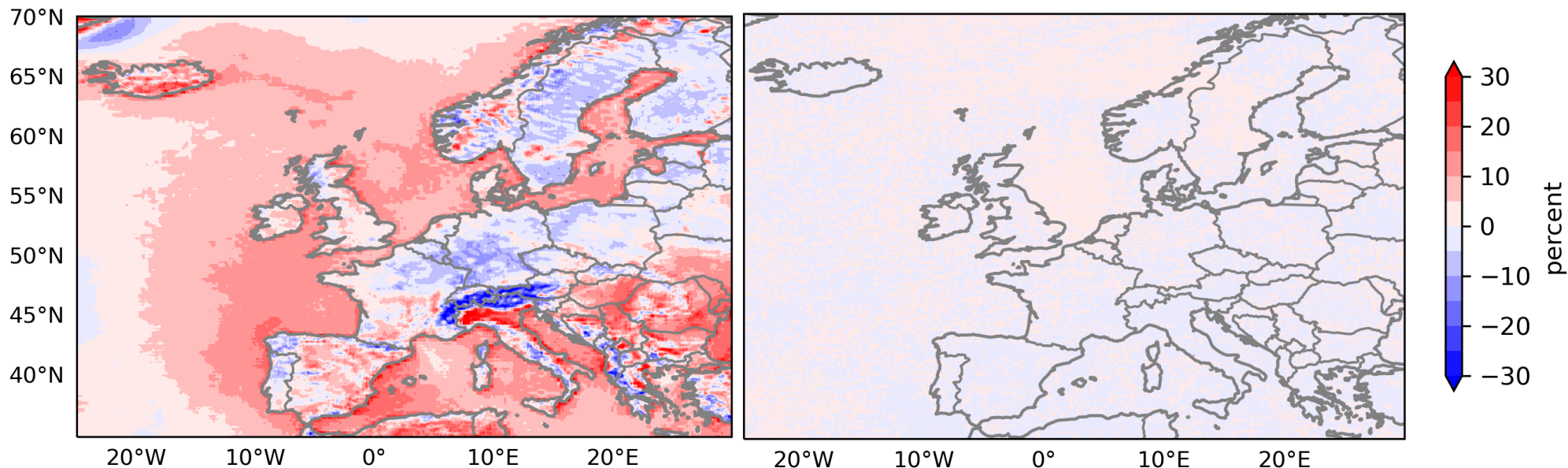
How accurate are EURO-CORDEX wind gusts compared to reanalysis data, and what is the benefit of bias correction ?

(Alifdini et al. 2024)

Evaluation of historical simulations

BEFORE bias correction

AFTER bias correction
(Empirical quantile mapping)



Mean bias of the 98th percentile of daily max wind gusts speed (**EURO-CORDEX ensemble minus ERA5**) for ONDJFM.

- **EURO-CORDEX** shows **significant biases** compared to ERA5.
- **Bias correction improved accuracy**, even in mountainous regions.

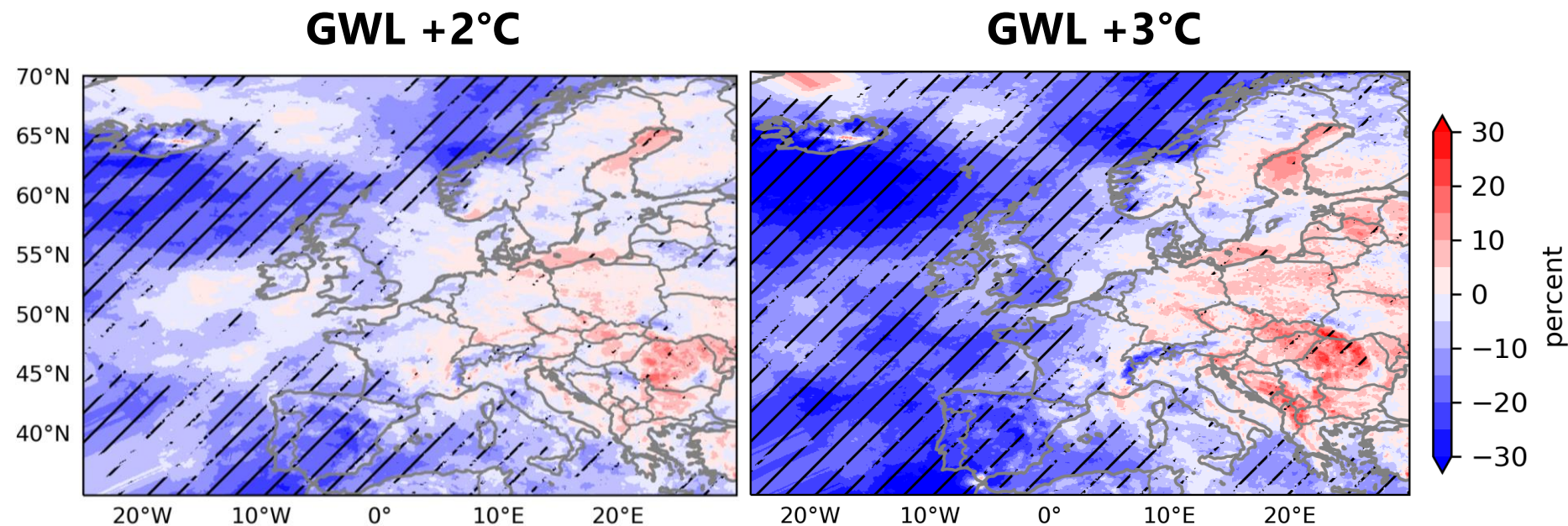
(Alifdini et al. 2024)

Part 2 :

How does **climate change** affect **European windstorm** intensity, frequency, and associated losses ?

(Alifdini et al. 2024)

Changes in windstorm intensity



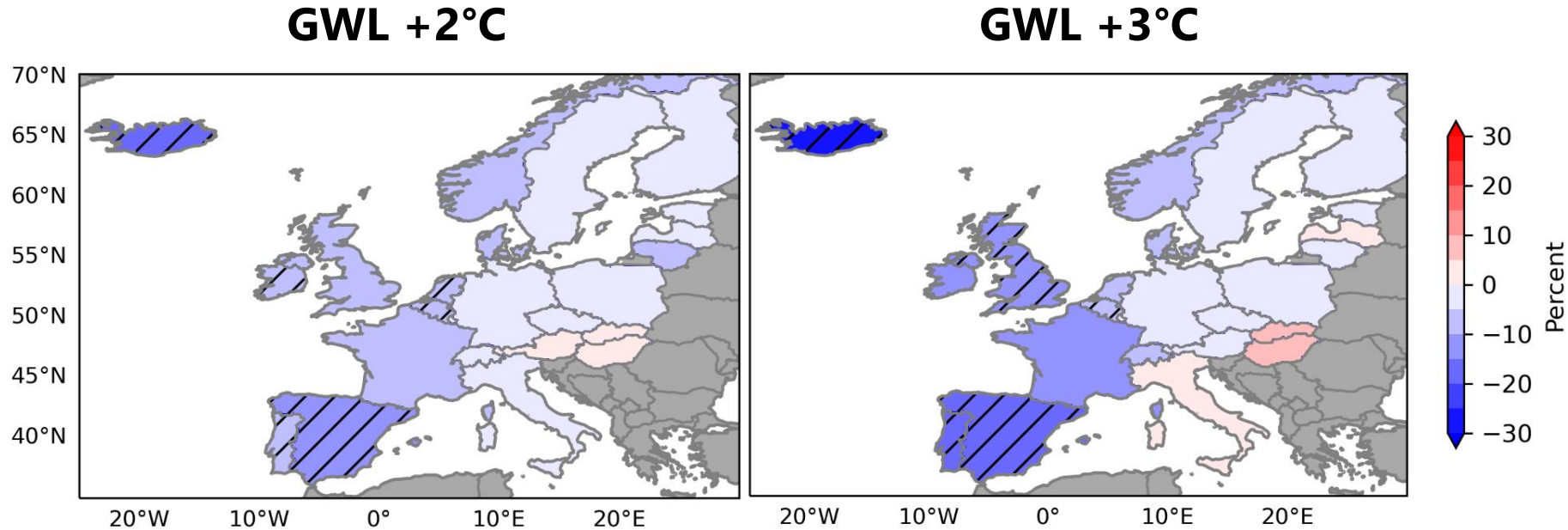
Mean changes in wind gusts (speed) above the 98th percentile (EURO-CORDEX ensembles RCP8.5 minus historical period).

Slash : More than 14 models agree on the sign of change.

The magnitudes of extreme windstorms are expected to decrease in western Europe and increase in eastern Europe.

(Alifdini et al. 2024)

Changes in windstorm frequency

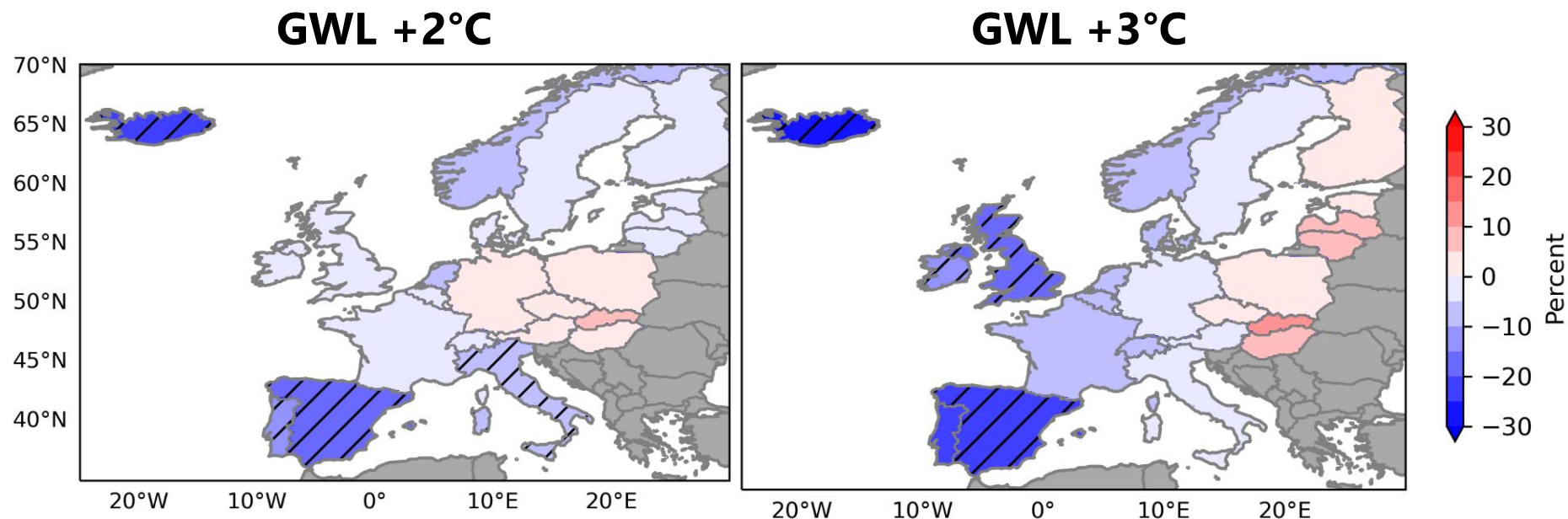


Changes in windstorm frequency from EURO-CORDEX ensemble (GWLs minus historical).
Slash : More than 14 models agree on the sign of change.

Windstorm frequency is projected to decrease (non-robust) under future climate for large parts of Europe.

(Alifdini et al. 2024)

Changes in windstorm loss



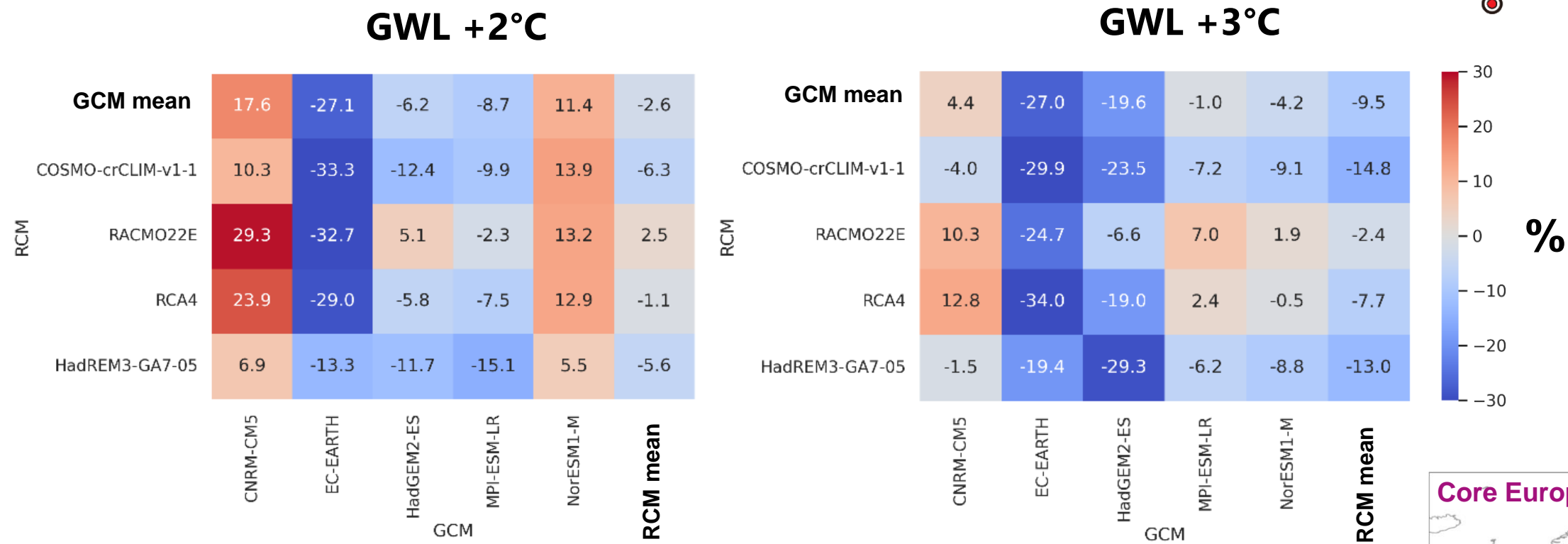
Changes in **LI** from EURO-CORDEX ensemble (GWLs minus historical).

Slash : More than 14 models agree on the sign of change.

- **A decrease** in **LI** occurs over **Western Europe**, while **an increase** is **generally** observed over **Eastern Europe**.
- **Non-robust changes** prevail in **most countries**.

(Alifdini et al. 2024)

Model to model variation



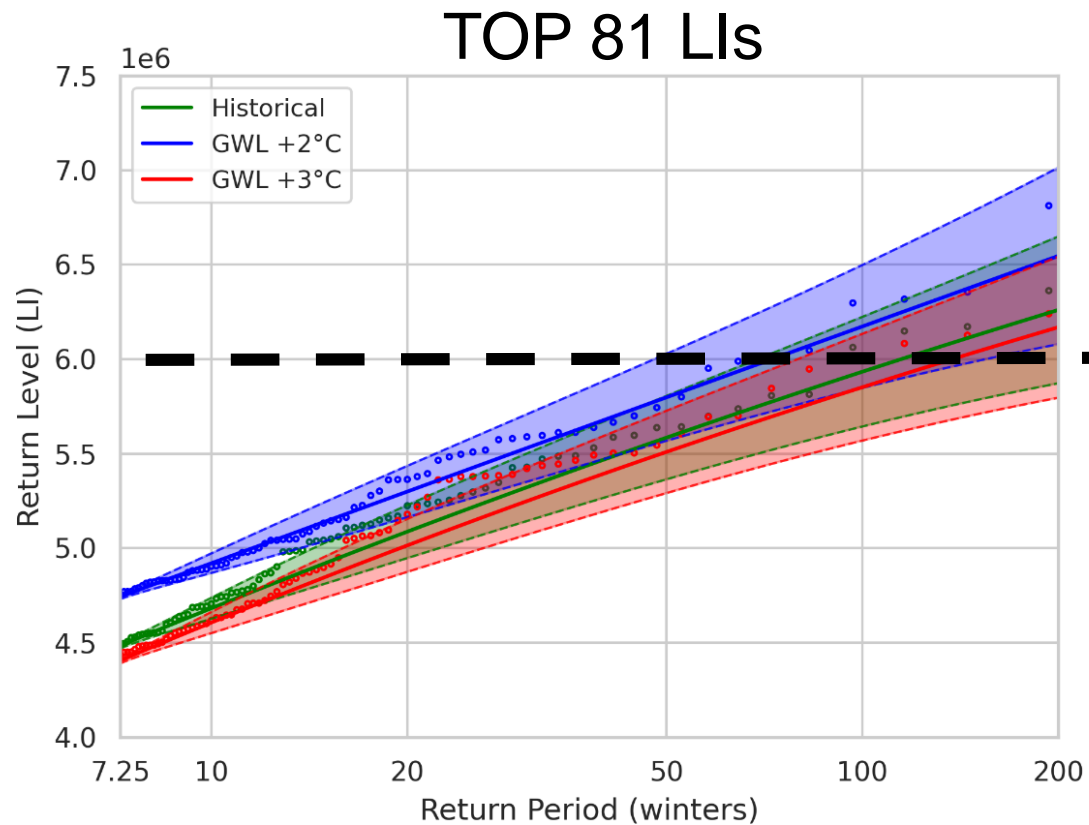
Changes in LI (GWLs minus historical), for **Core Europe**.

The **variation** of changes are **model-dependent**.



(Alifdini et al. 2024)

Changes in rare extreme loss (Core Europe)



Example :

For LI level = 6×10^6

Historical : 110 winters

GWL+2°C : 75 winters

GWL+3°C : 150 winters

Return value of rare extreme LI for Core Europe, from EURO-CORDEX ensemble.

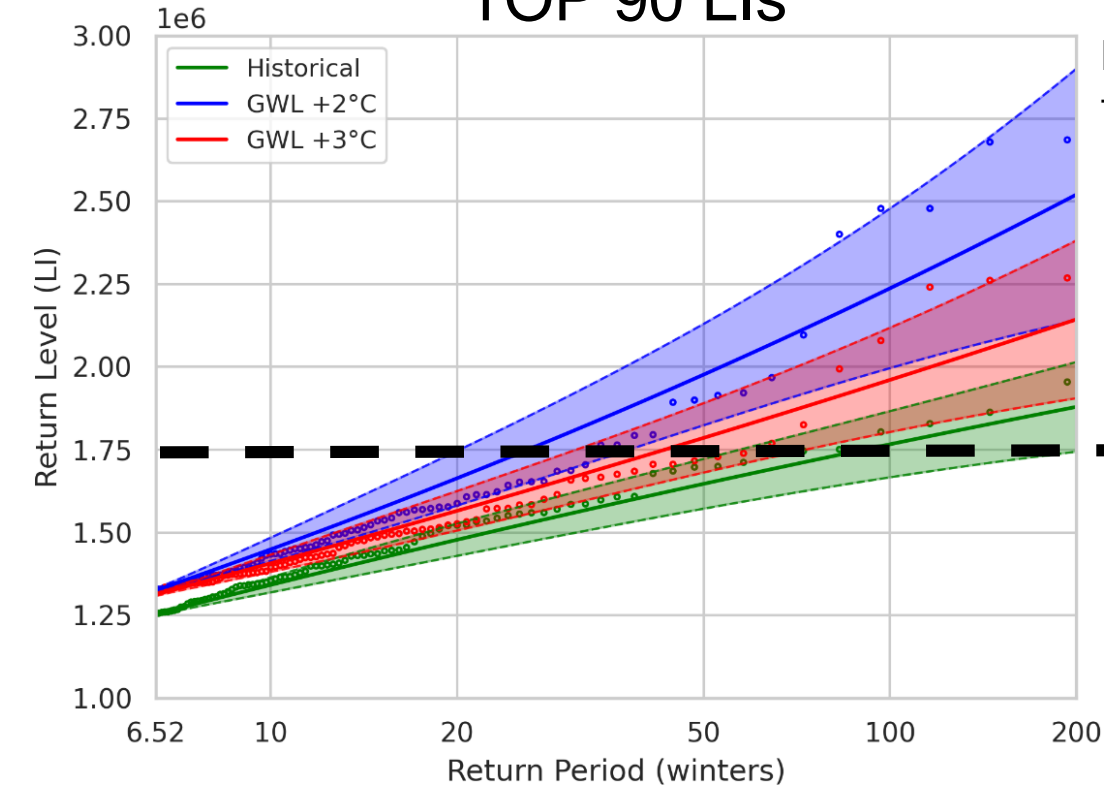


For Core Europe, the impact of GWLs on rare extreme loss is unclear

(Alifdini et al. 2024)

Changes in rare extreme loss (Eastern Europe)

TOP 90 LIs



Return value of rare extreme LI for Eastern Europe, from EURO-CORDEX ensemble.



Example :
 For LI level = 1.75×10^6

- Historical : 100 winters
- GWL +2°C : 22 winters
- GWL +3°C : 45 winters

For Eastern Europe, GWLs clearly shorten return periods for rare extreme loss.

(Alifdini et al. 2024)

Conclusion

How does **climate change** affect **windstorm losses** across Europe ?

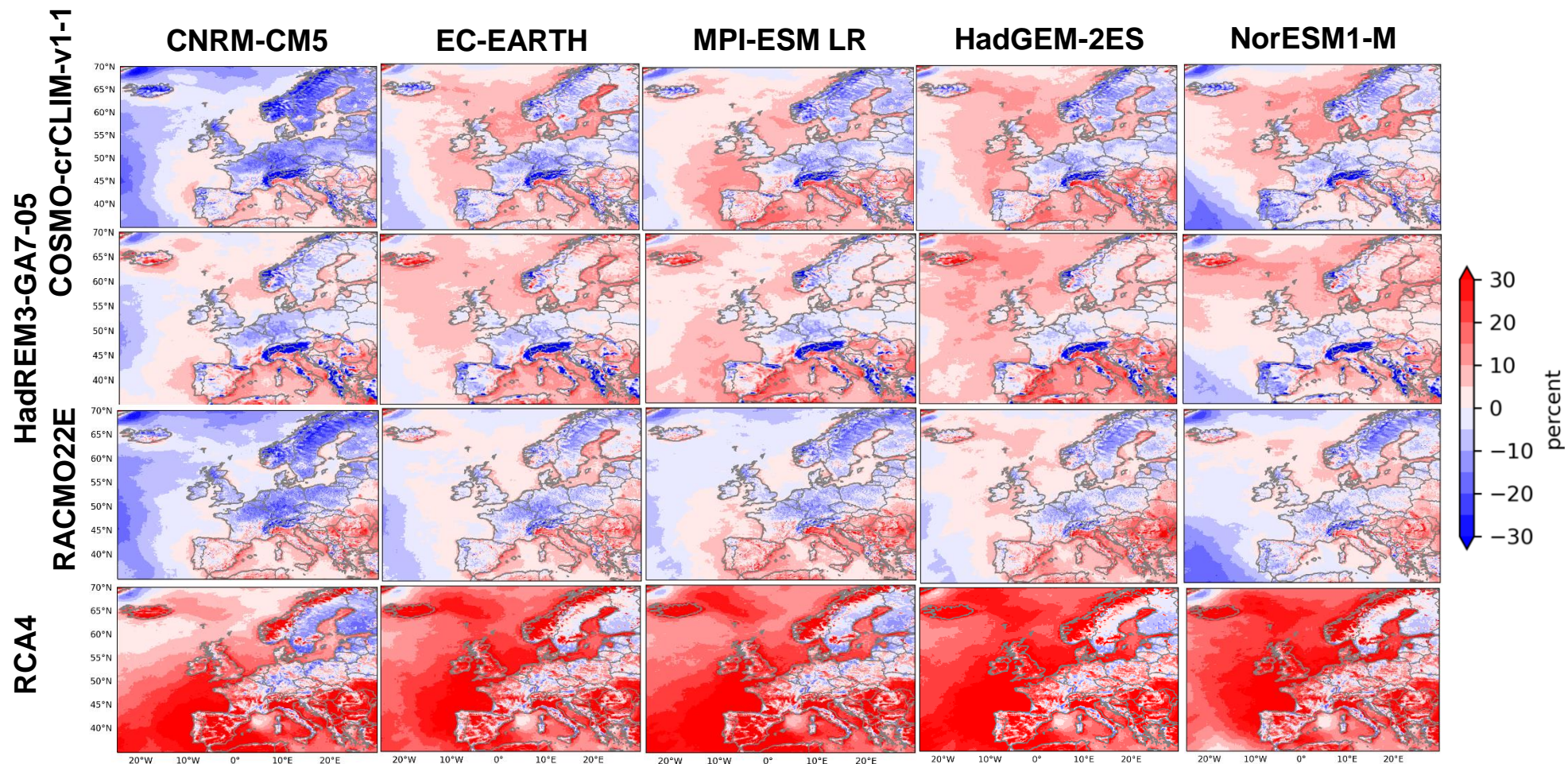
- The **projected changes** in **windstorm losses** are **small** and **mostly non-robust**, with generally small **negative trends for Core Europe** and small **positive trends for Eastern Europe**.
- For **the most extreme loss**, the model ensemble projects **shorter return periods for Eastern Europe** regardless of the GWLs, while **no clear trends emerge for Core Europe**.



Alifdini, I., Moemken, J., Ramos, A.M., and Pinto, J.G. 2024. Future Changes of European Windstorm Losses in EURO-CORDEX Simulations. *Tellus A: Dynamic Meteorology and Oceanography* (under review).

Supporting slides

(v98th) BEFORE bias correction

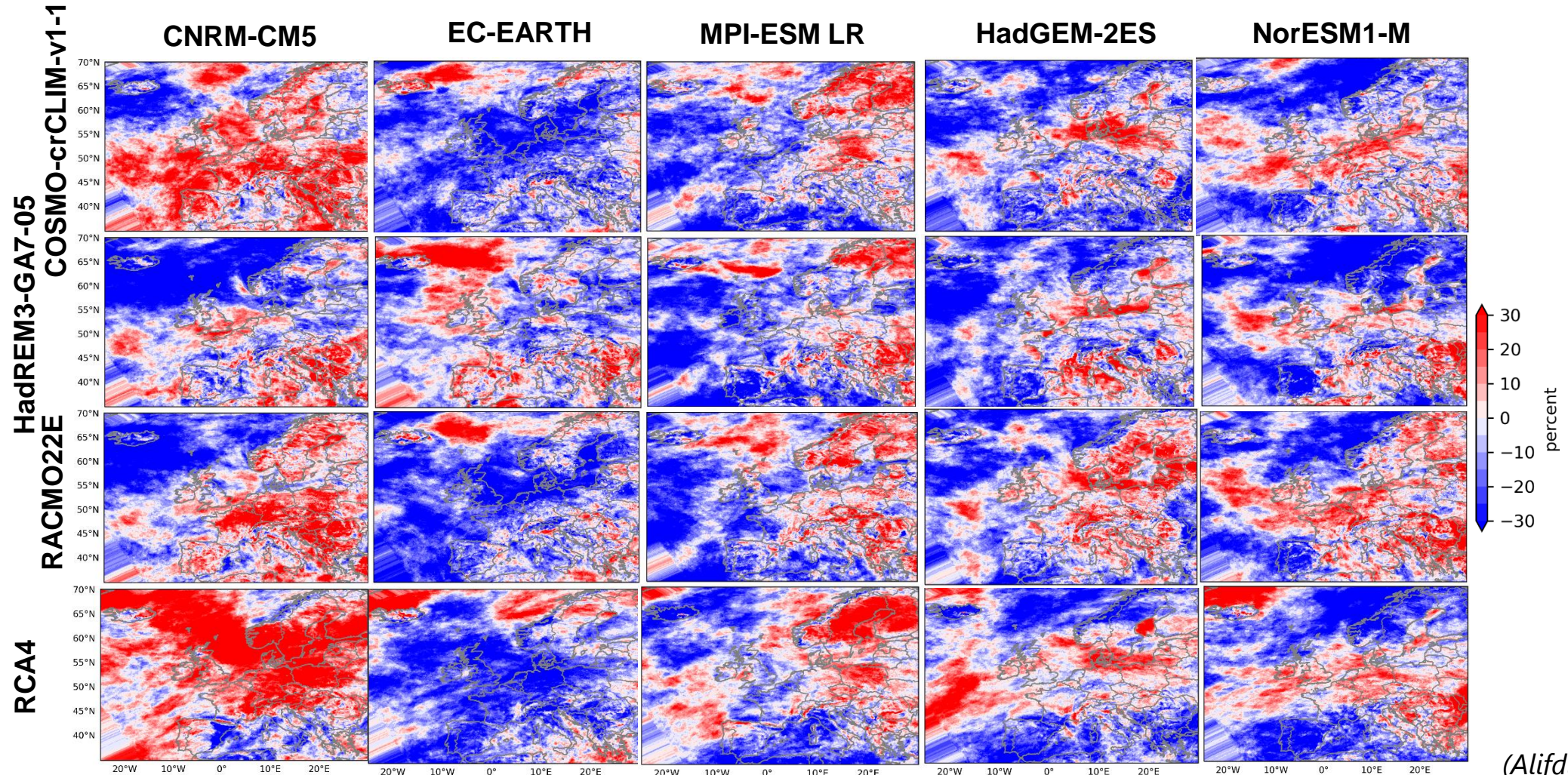


(Alifdini et al. 2024)

Bias of the 98th percentile of daily max wind gusts speed (EURO-CORDEX ensemble minus ERA5) for ONDJFM.

Changes in windstorm intensity

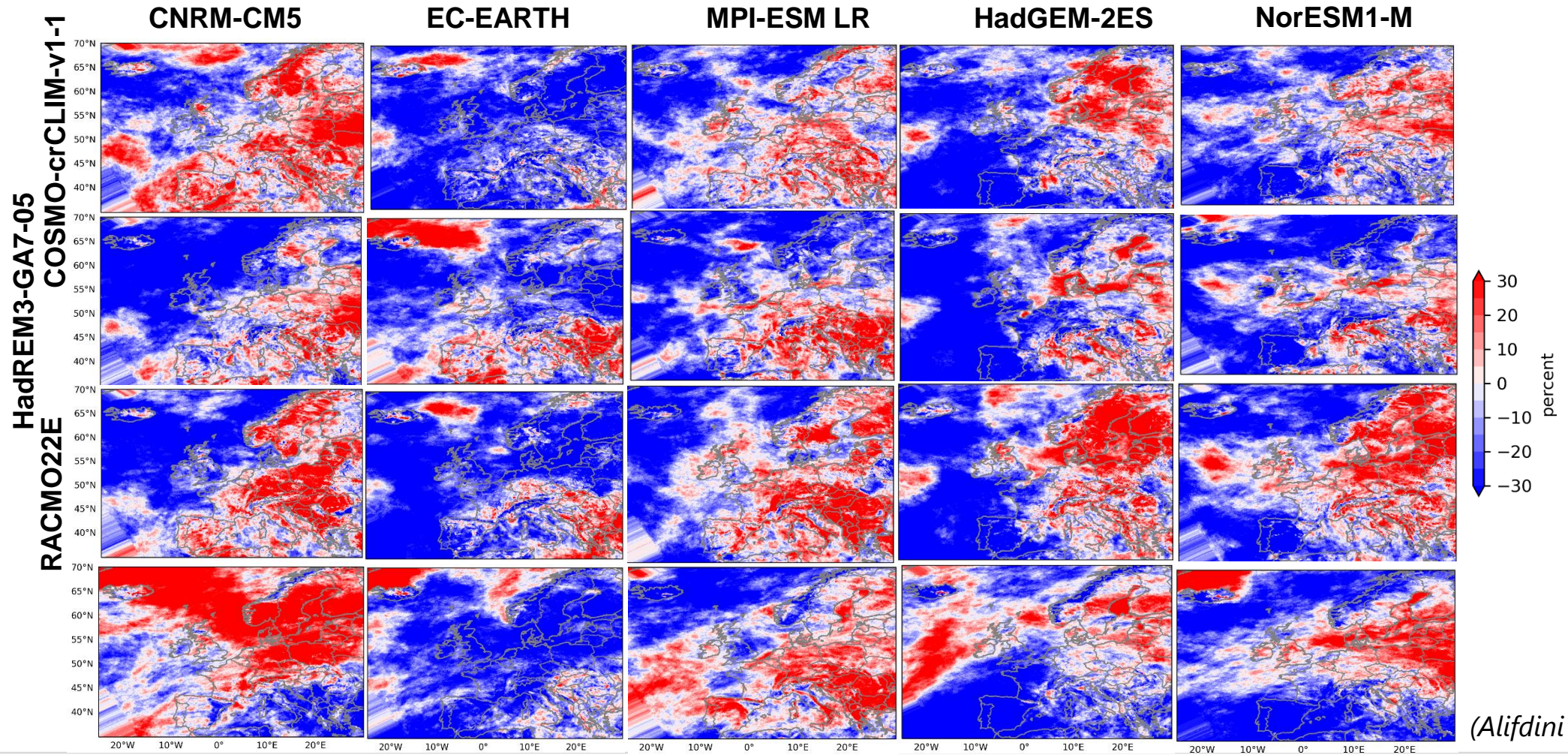
GWL2



(Alifdini et al. 2024)

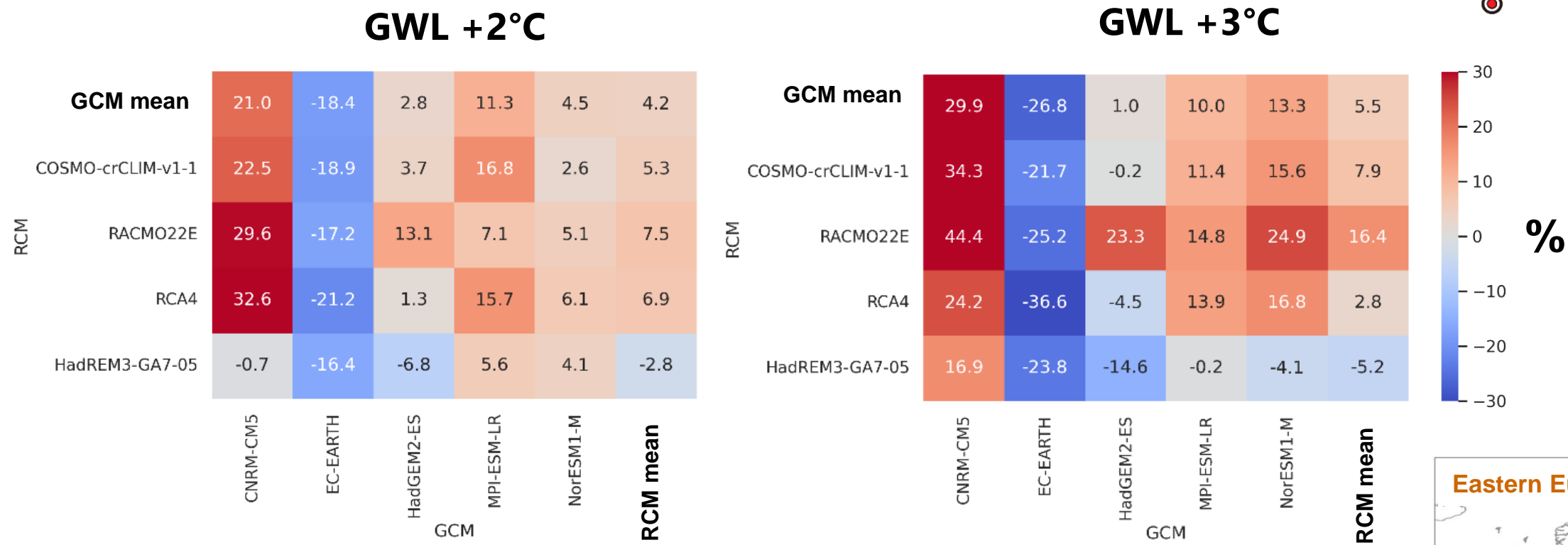
Changes in windstorm intensity

GWL3



(Alifdini et al. 2024)

Model to model variation



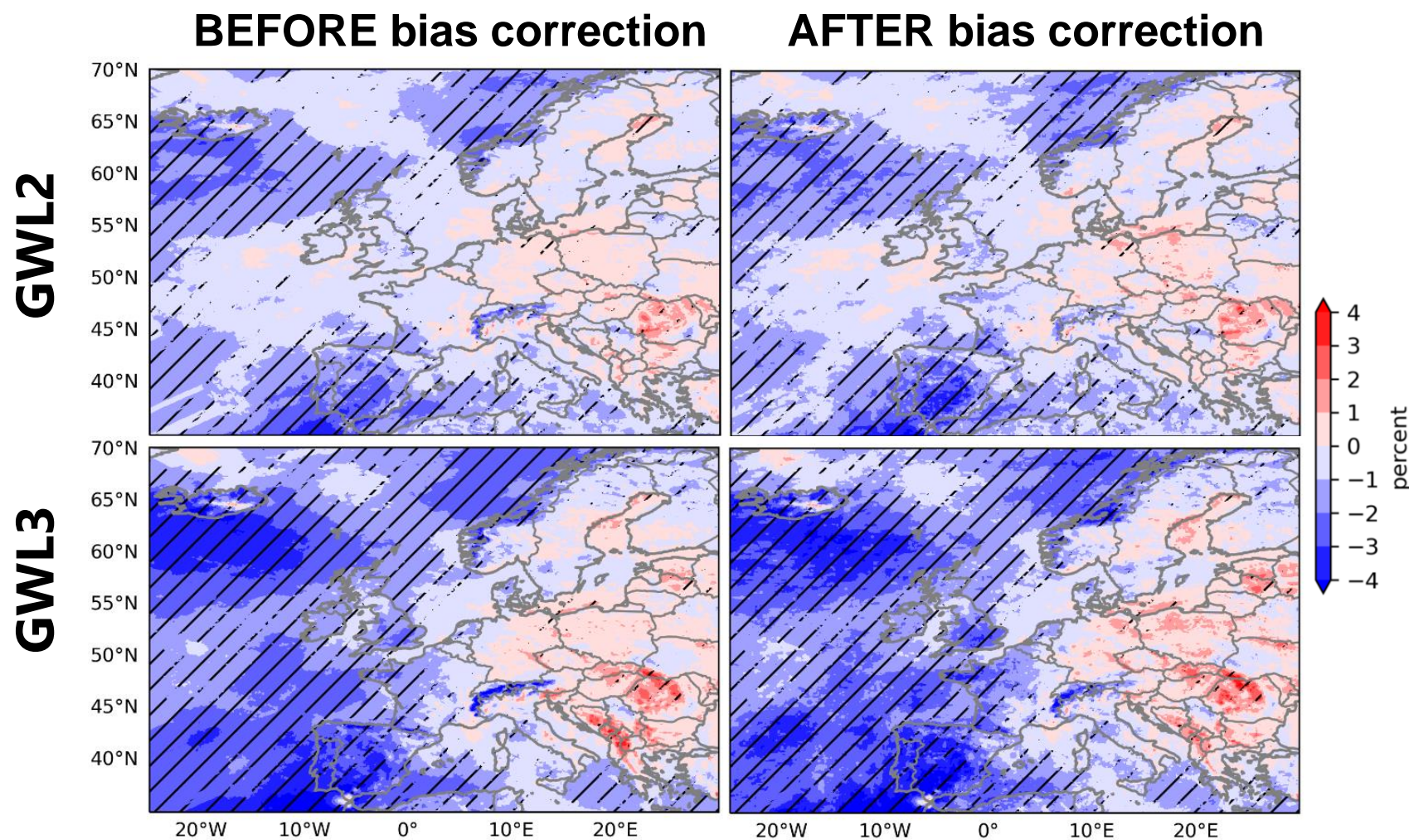
Changes in LI (GWLs minus historical), for Eastern Europe.

The **variation** of changes are **model-dependent**.



(Alifdini et al. 2024)

Impact of bias correction on climate change signal

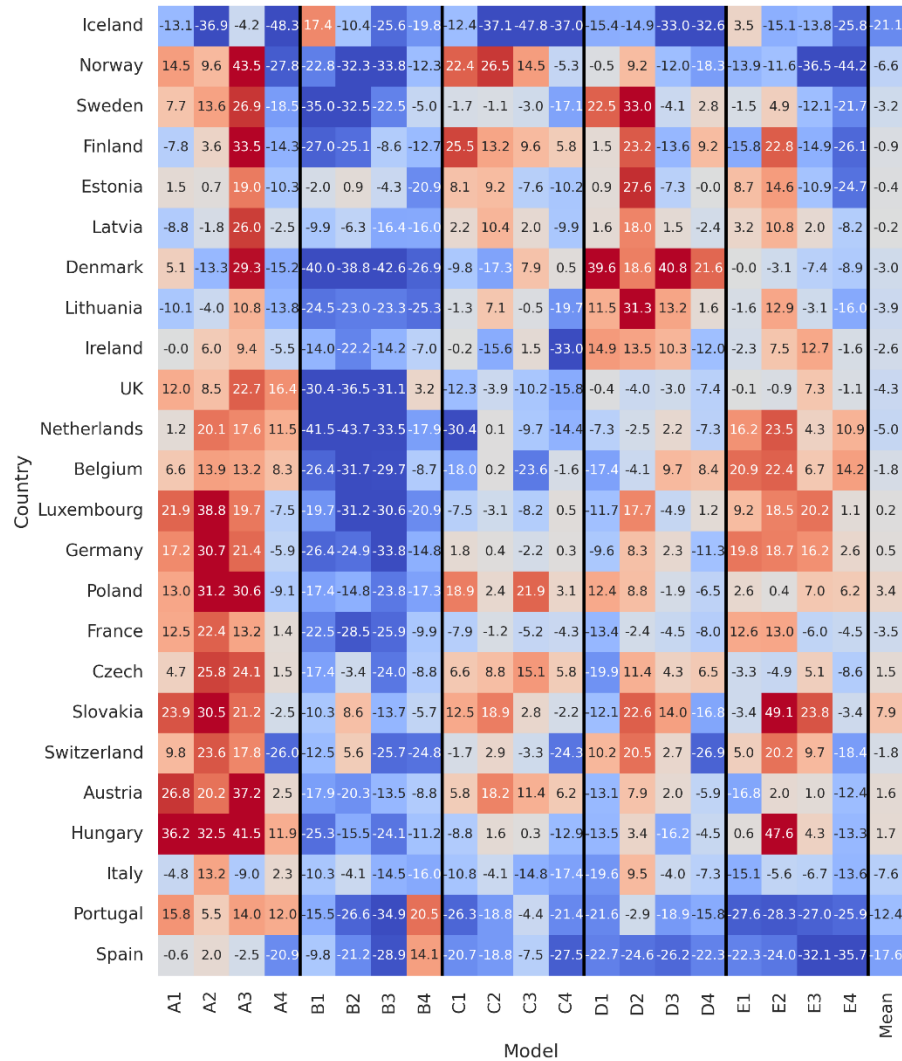


(Alifdini et al. 2024)

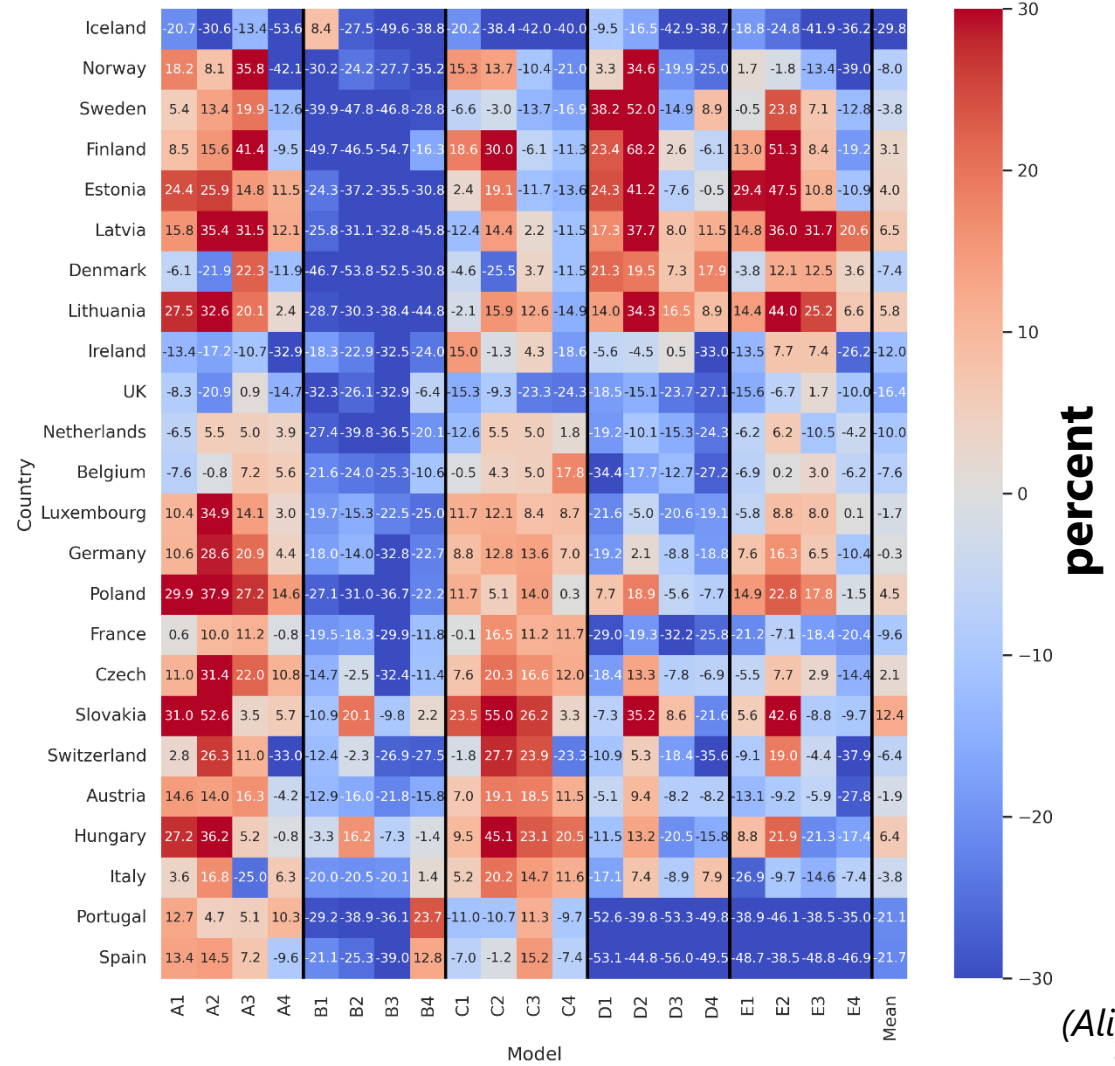
Mean differences (20 models) of the 98th percentile of daily maximum wind gust EURO-CORDEX RCP8.5 minus historical period ONDJFM.

Changes in LI

(a) LI GWL2

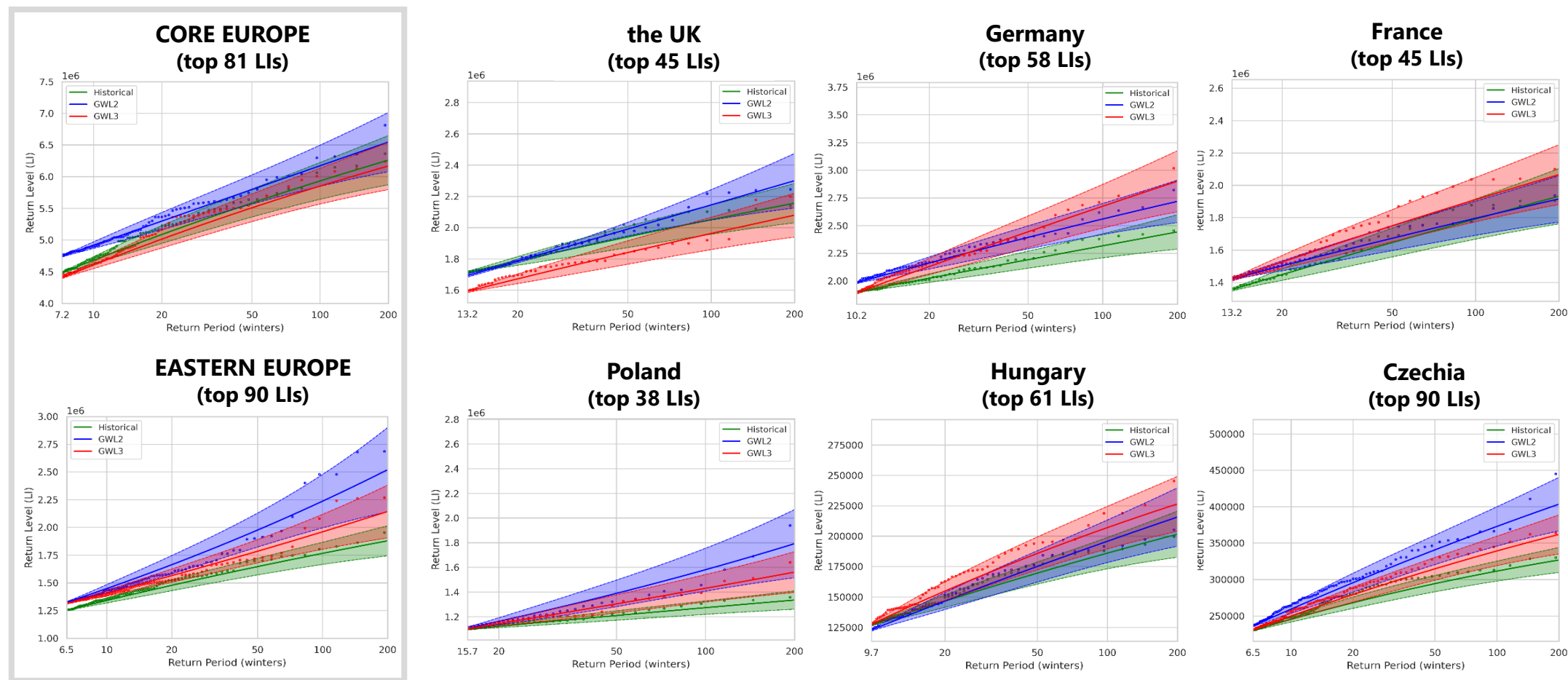


(b) LI GWL3



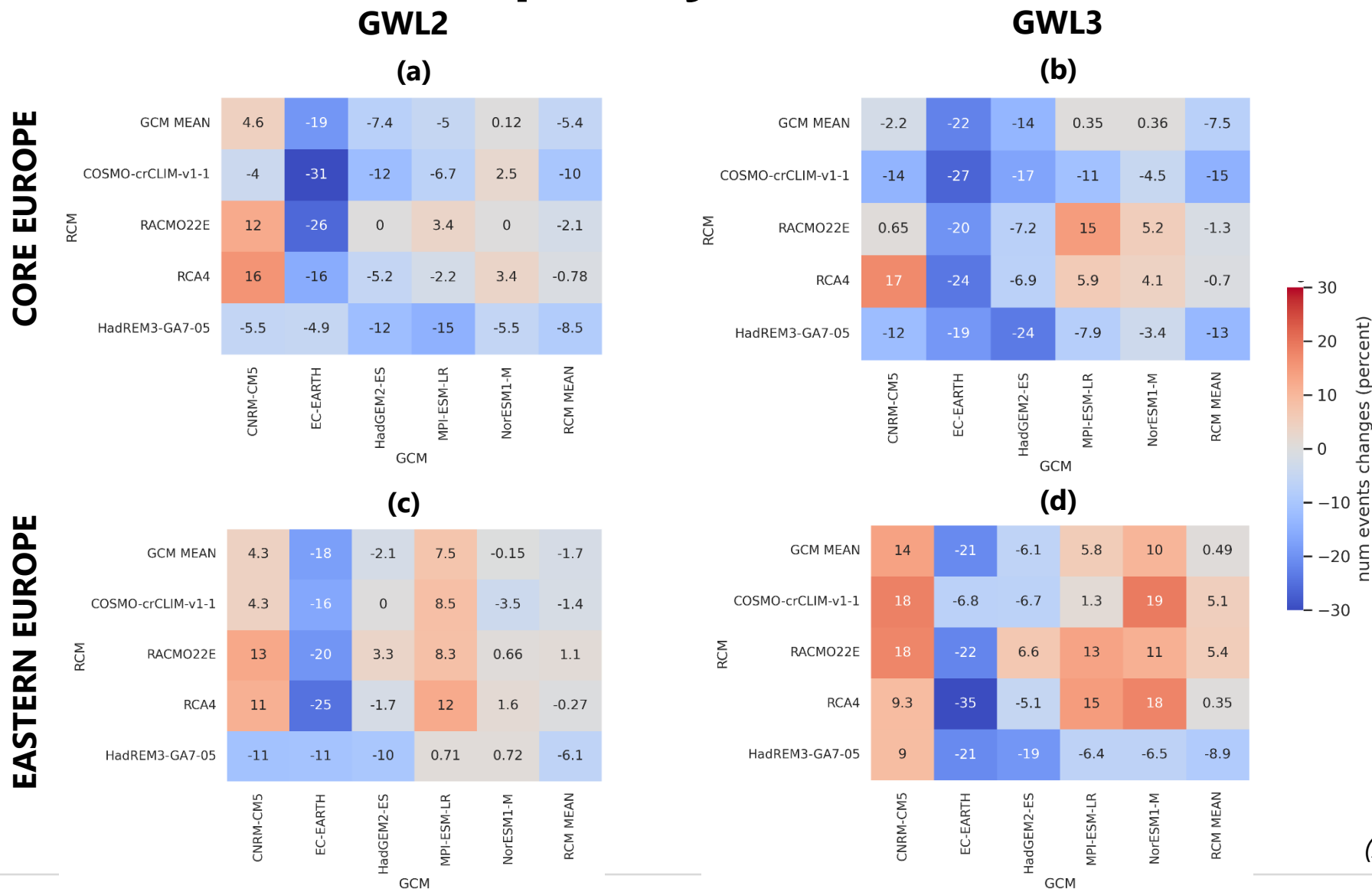
(Alifdini et al. 2024)

Changes in rare extreme loss



(Alifdini et al. 2024)

Changes in windstorm frequency



(Alifdini et al. 2024)