Future projections of river floods over the European region using EURO-CORDEX simulations

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Introduction

Our study is namely inspired by three facts:

- Floods are among the most threatening hazard which frequency and magnitude are affected by climate change (Forzieri et al 2017)
- During the last decades the hydrological cycle over Europe has experienced significant shifts linked to climate change (Blöschl et al. 2019)
- The large amount of climate simulations completed under the umbrella of the Euro-CORDEX program gives the opportunity to evaluate the response of the hydrological cycle to the climate change with a greater robustness respect to the past

Three main phenomena are linked to the changes of extreme hydrological events over the European domain:

- increase of extreme precipitation events linked to a warmer atmosphere
- decrease of snow cover and snowmelt during spring season
- increase of evaporation and decrease of precipitation over semi-arid regions

Methods

EURO-CORDEX	Driving Model	Ensembles	Experiments
CLMcom-CCLM4-8-17	CCCma-CanESM2	r1	his, rcp85
	CNRM-CERFACS-CNRM-CM5	r1	his, rcp85
	ICHEC-EC-EARTH	r12	his, rcp85, rcp26
	MIROC-MIROC5	r1	his, rcp85
	MOHC-HadGEM2-ES	r1	his, rcp85
	MPI-M-MPI-ESM-LR	r1	his, rcp85
CLMcom-ETH-COSMO-crCLIM-v1-1	MPI-M-MPI-ESM-LR	r1	his, rcp85
CNRM-ALADIN63	CNRM-CERFACS-CNRM-CM5	r1	his, rcp85, rcp26
	MOHC-HadGEM2-ES	r1	his, rcp85
DMI-HIRHAM5	CNRM-CERFACS-CNRM-CM5	r1	his, rcp85
	ICHEC-EC-EARTH	r12	his, rcp85
	ICHEC-EC-EARTH	r1	his, rcp85
	ICHEC-EC-EARTH	r3	his, rcp85, rcp26
	MOHC-HadGEM2-ES	r1	his, rcp85
	NCC-NorESM1-M	r1	his, rcp85
GERICS-REMO2015	CCCma-CanESM2	r1	his, rcp85
	CNRM-CERFACS-CNRM-CM5	r1	his, rcp85
	ICHEC-EC-EARTH	r12	his, rcp85, rcp26
	MIROC-MIROC5	r1	his, rcp85, rcp26
	MOHC-HadGEM2-ES	r1	his, rcp85, rcp26
	MPI-M-MPI-ESM-LR	r3	his, rcp85
	NCC-NorESM1-M	r1	his, rcp85, rcp26
ICTP-RegCM4-6	MOHC-HadGEM2-ES	r1	his, rcp85, rcp26
	MPI-M-MPI-ESM-LR	r1	his, rcp85
IPSL-WRF381P	CNRM-CERFACS-CNRM-CM5	r1	his, rcp85
	NCC-NorESM1-M	r1	his, rcp85
KNMI-RACMO22E	CNRM-CERFACS-CNRM-CM5	r1	his, rcp85, rcp26
	ICHEC-EC-EARTH	r12	his, rcp85, rcp26
	ICHEC-EC-EARTH	r1	his, rcp85
	ICHEC-EC-EARTH	r3	his, rcp85
	MOHC-HadGEM2-ES	r1	his, rcp85, rcp26
	MPI-M-MPI-ESM-LR	r1	his, rcp85
	NCC-NorESM1-M	r1	his, rcp85
MPI-CSC-REMO2009	MPI-M-MPI-ESM-LR	r1	his, rcp85
	MPI-M-MPI-ESM-LR	r2	his, rcp85
SMHI-RCA4	CNRM-CERFACS-CNRM-CM5	r1	his, rcp85
	ICHEC-EC-EARTH	r12	his, rcp85, rcp26
	ICHEC-EC-EARTH	r1	his, rcp85
	IPSL-IPSL-CM5A-MR	r1	his, rcp85
	MOHC-HadGEM2-ES	r1	his, rcp85, rcp26
	MPI-M-MPI-ESM-LR	r1	his, rcp85, rcp26
	MPI-M-MPI-ESM-LR	r3	his, rcp85
	NCC-NorESM1-M	r1	his, rcp85, rcp26
UHOH-WRF361H	ICHEC-EC-EARTH	r12	his, rcp85

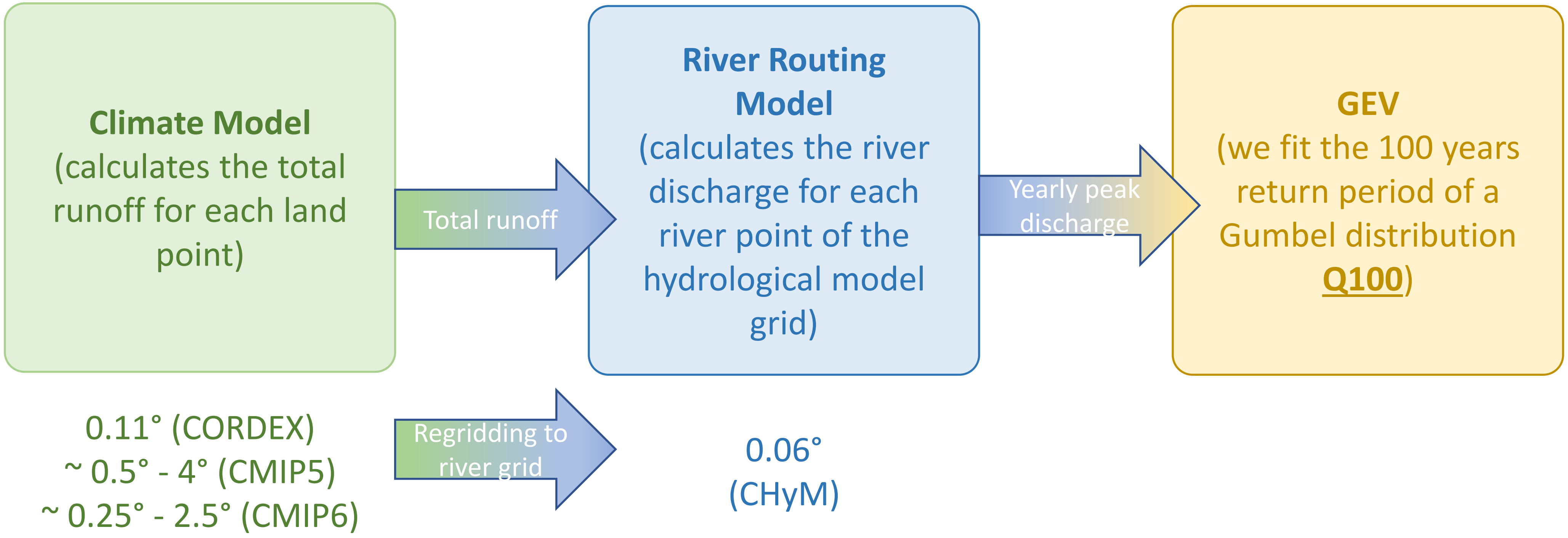
CMIP5	Ensembles	Experiments
CNRM-CM5	r1	his, rcp85, rcp26
CanESM2	r1, r2, r3, r4, r5	his, rcp85, rcp26
MIROC-ESM	r1	his, rcp85, rcp26
MIROC5	r1	his, rcp85, rcp26
MPI-ESM-LR	r1, r2, r3	his, rcp85, rcp26
MPI-ESM-MR	r1	his, rcp85, rcp26
NorESM1-M	r1	his, rcp85, rcp26

CMIP6	Ensembles	Experiments
CanESM5	r1	ssp585
EC-Earth3	r1	ssp585, ssp126
GFDL-CM4	r1	ssp585
IPSL-CM6A-LR	r1	ssp585, ssp126
MIROC6	r1	ssp585, ssp126
MPI-ESM1-2-HR	r1	ssp585, ssp126
UKESM1-0-LL	r1	ssp585, ssp126

In this study we use a very large number of the most recent Regional Climate Simulations (**Euro-CORDEX**) available for the European domain to study the possible effect of climate change on floods intensity.
For a comparison, we forced our model also with two sets of Global Climate Model Simulations, **CMIP5** and **CMIP6**.

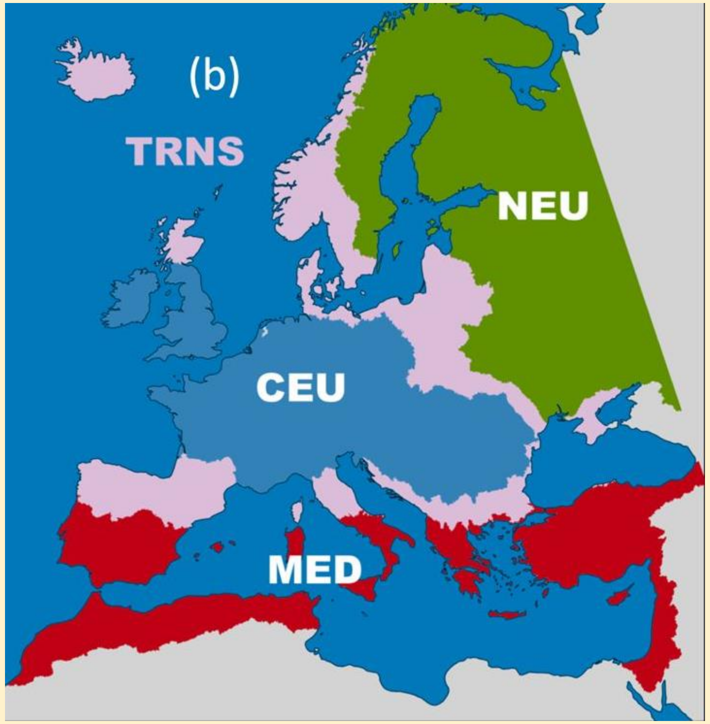
Methods

To simulate the river discharge we made use of a river routing model derived from a distributed hydrological model (CHyM). The CHyM model has been already coupled (off-line and on-line) with an RCM to simulate the river discharge of the Italian Po river (Coppola et al. 2014) and that of the South Asia region (Di Sante et al. 2019).



Methods

The high resolution grid of the CHyM model allows to reproduce a fine drainage network with small rivers also represented.
This allows in the analysis to take into account flash floods happening in small river catchments.



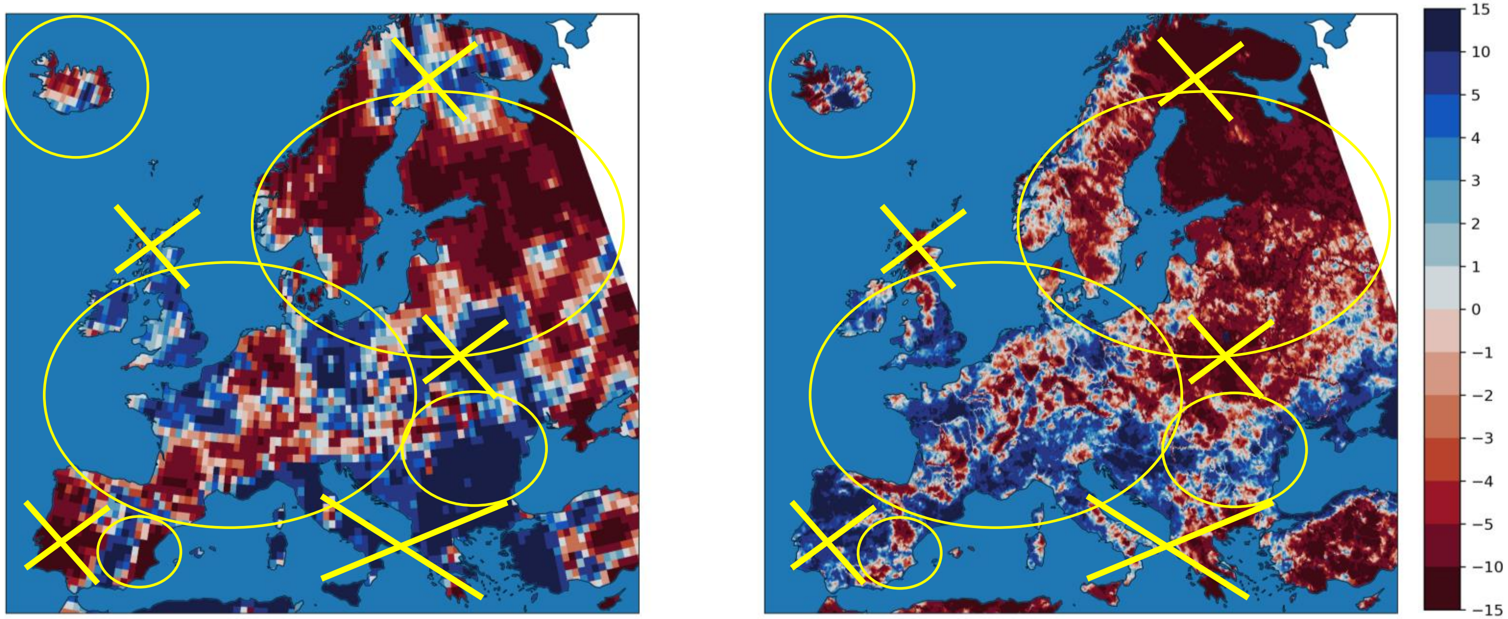
TRS: Transient
NEU: North-East Europe
CEU: Central Europe
MED: Mediterranean

Based on common characteristics and our results, we selected three main areas and a transient one as a buffer zone. In the analysis we tried to consider this three areas separately and compare the common characteristics and discuss the motivation of the observed and projected climatic signals.

We considered three time periods and two different Representative Concentration Pathway (RCP; rcp2.6 and rcp8.5): the historic (**his**; 1985-2014), the mid future (**mid**; 2036-2065) and the far future periods (**far**; 2070-2099). The two RCP scenarios are selected based on their characteristics. The rcp2.6 is seen as the optimistic one where there will be a strong human response to fight the climate change. The rcp8.5 is instead the most pessimistic one, also named “business as usual”.

European domain (validation of the trend for Q100)

GRUN (OBS) CORDEX (MODEL)



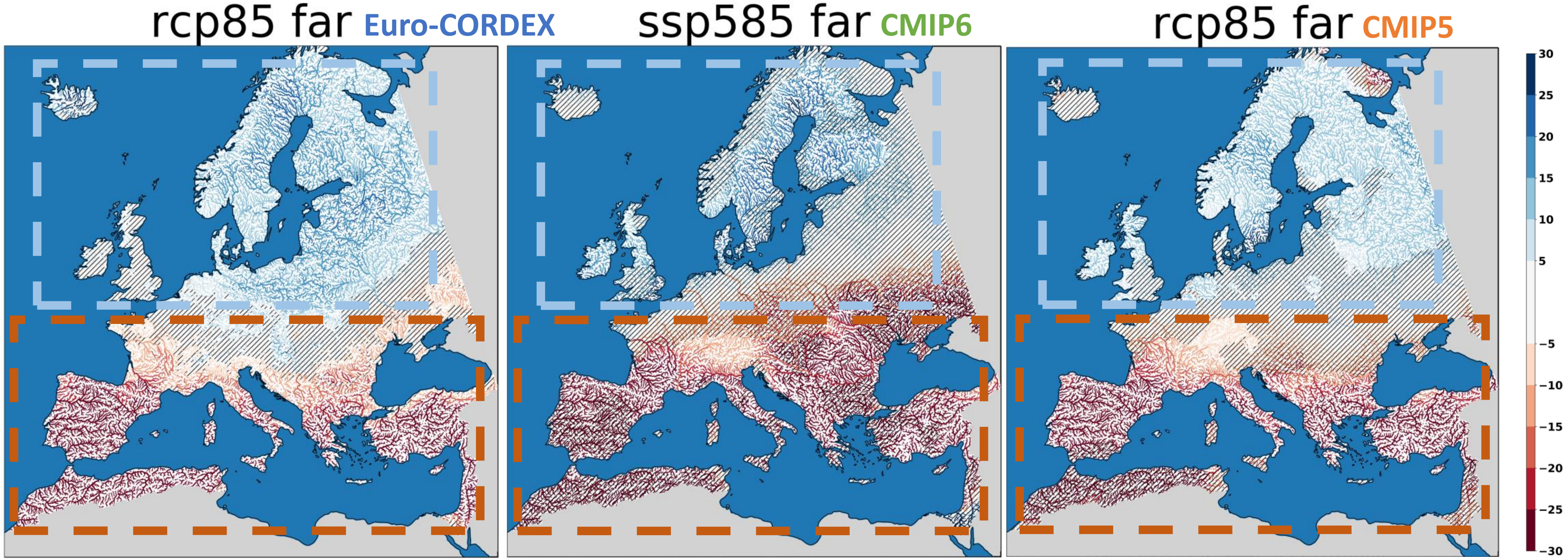
1

Observed (GRUN; Ghiggi et al. 2019) and simulated trend for the **His** period. The circles indicate where the modeled trend is in agreement with the observations, the opposite is true for the crosses

2

The negative trend over high latitude regions could be linked to a decrease snow thickness whereas the increase observed over the north part of Italy, the north of France, and the British Islands could be linked to an increase of soil moisture and precipitation during the autumn season (Blöschl et al 2019)

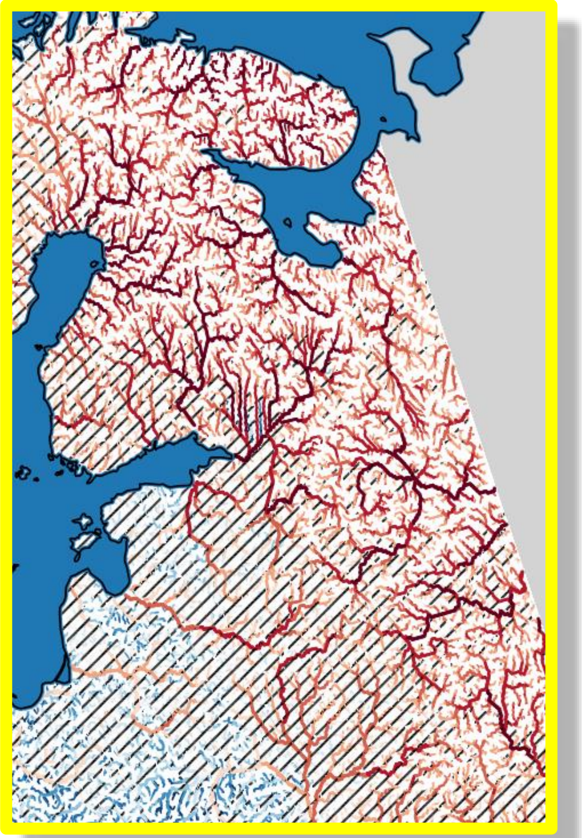
Results – Mean flow changes Far-His(%) rcp85

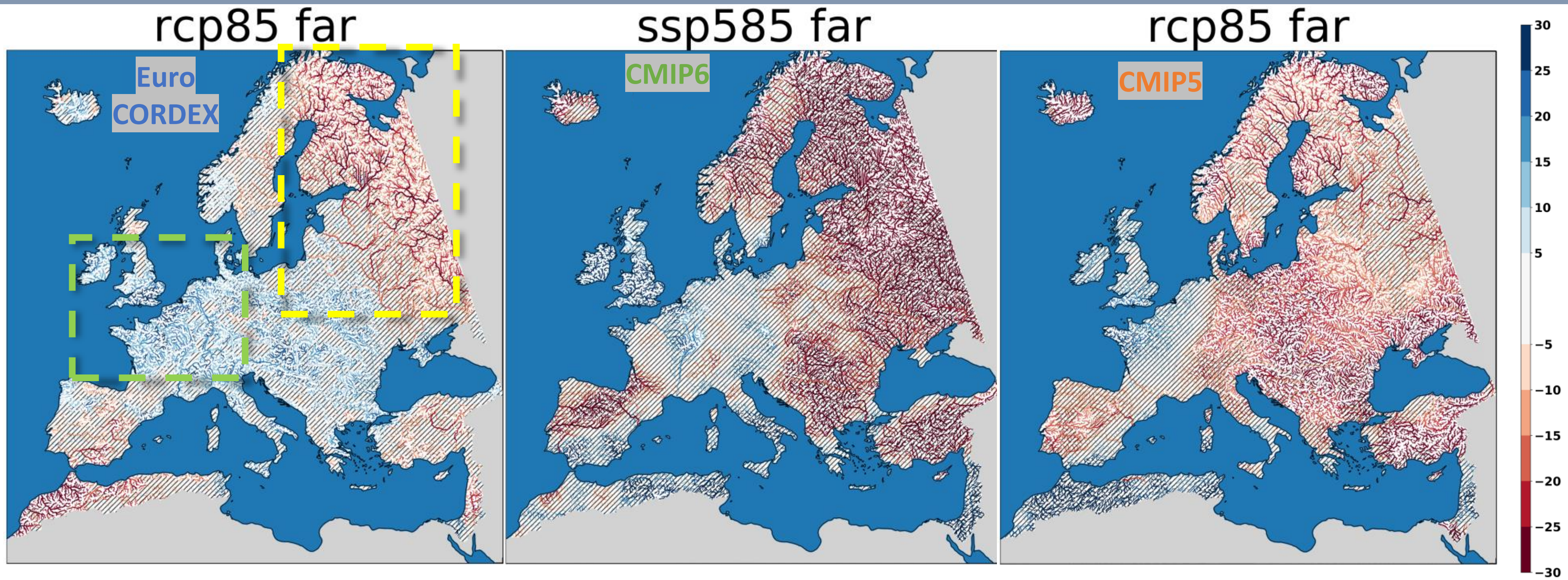


The three different simulation ensembles are in good agreement with each other. It can be observed a gradient from south to north. A strong decrease up to 30% on the 30 years mean can be observed on the MED region by the end of the century. Although less marked, an increase (around 10-20%) can be instead observed over the high latitude region, in particular over the north-east.

The hatching represents areas where the change is not statistical significant at 0.05 level.

Results – Q100 changes for rcp85 and far

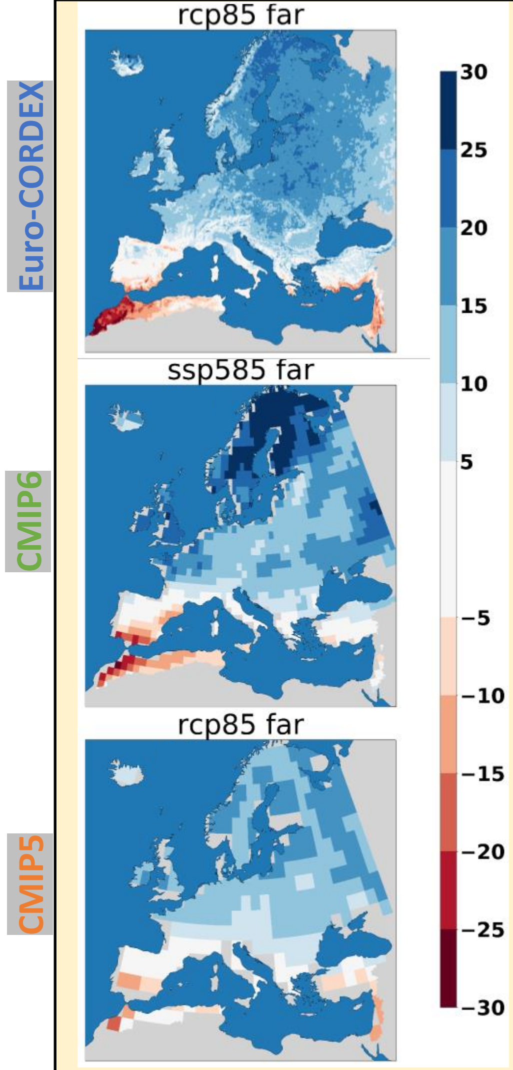




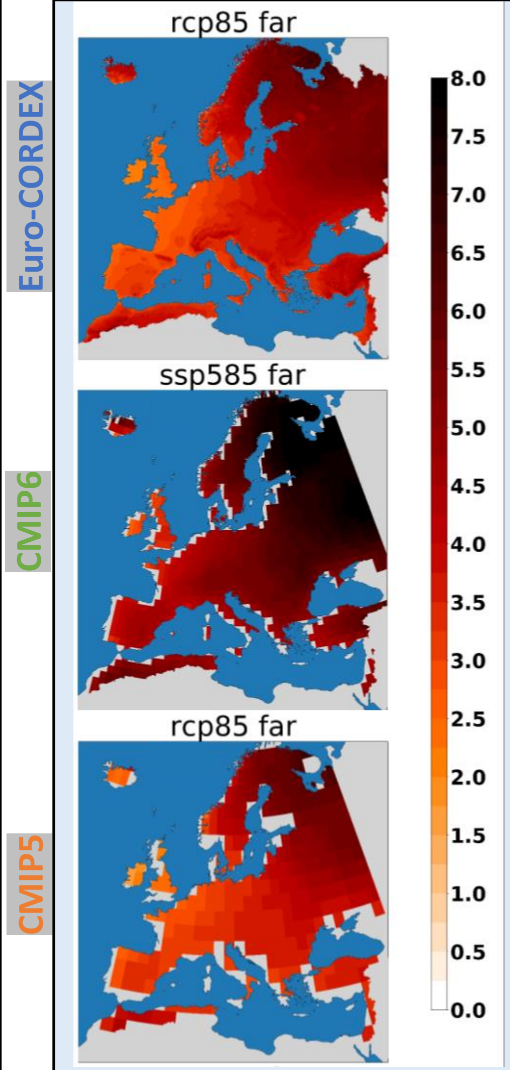
The hatching represents areas where the change is not statistical significant at 0.05 level

Over the NEU, a general decrease can be observed by the three ensembles. From the two zoomed boxes can be clearly seen as the strongest changes are related to the large rivers (median change of -19% against -4% for small rivers). On the other hand, if we focus on the CEU region, we can see as the greatest positive changes are related to middle and small rivers (median change of 19% against 11% for large rivers).

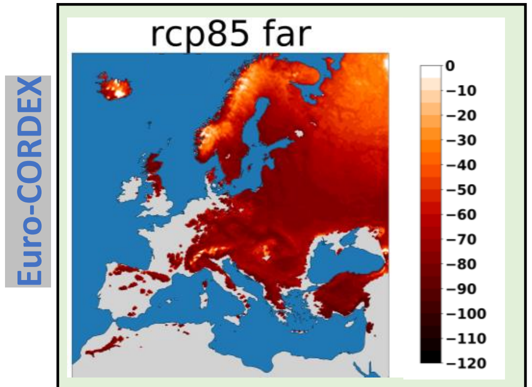
Discussion (rcp85 far)



7 day maximum-precipitation change



JFMA mean temperature change



JFMA mean snow change

An increase of the 7 days maximum precipitation change can be clearly observed in all the three ensembles in the central and north part of the domain, a reduction is instead observed on the south.

This could partially explain the increase of flood risk over the CEU, the decrease over the MED but not the decrease over the NEU. To explain the decrease over NEU we need to look at the mean JFMA temperatures and at the mean JFMA snow changes. The floods in the NEU region are mainly linked to snow melt. A reduction of snow cover and thickness on JFMA months could be the reason of the robust decrease on floods risk for the large rivers in all the three ensembles.

Summary and conclusions

- Results are in good agreement with the previous studies. Three main areas are highlighted. The MED area where a decrease of flood risk is projected by the end of the century. The CEU area where is projected an increase of floods risk, probably linked to increase of extreme precipitation events. The NEU area where the increase of temperature linked to global warming and the related less amount of snow accumulated during winter can lead to a decrease of the floods.

- The different underlying nature of the floods over the CEU and NEU regions could be the reason of the correlation between the intensity of the flood signal with the dimension of the river catchments. CEU much prone to flash floods and NEU much more sensitive to snow melt.

- This study is one of the largest hydroclimatic study ever with more than 160 hydroclimatic simulations completed. This gives the possibility to estimate the robustness of the climate change signal on floods hazard in Europe.

- The ever increasing resolution and complexity of the RCMs allows the use of a pretty simple and fast approach, without the needs of any bias correction to evaluate the flood risk signal linked to climate change.

- This allows to easily apply this approach to an even larger ensemble and to different domains (like the others CORDEX domains) without much computational expenses (Di Sante et al. in preparation).

References

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