Statistical Downscaling of EURO-CORDEX climate change scenarios: Projections of droughts, heavy precipitation, heat waves and cold spells

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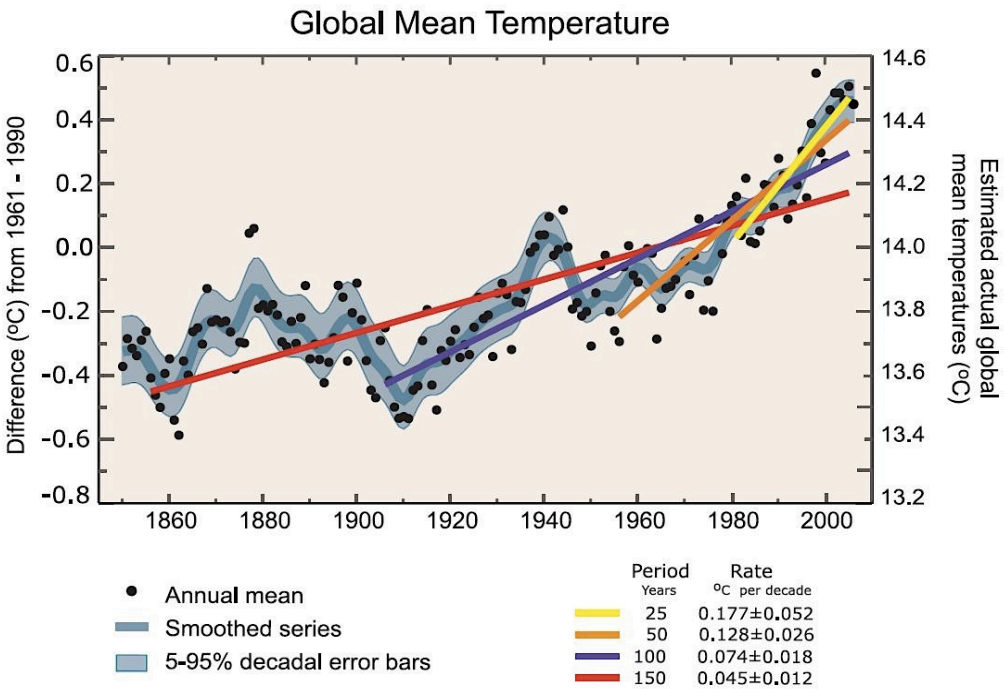
1. Motivations and objectives

Climate change: current evidences



- Global mean surface air temperature has risen by about 0.74°C (1906-2005)
- 11 of the 12 warmest years on record have occurred in the past 12 years
- Important regional variations
- Redistribution of rainfall and other variables

Extreme weather events

Summary for Policymakers (IPCC)

- ⬇ cold days and nights (99%)
- ⬆ hot days and nights (99%)
- ⬆ frequent and/or intense heavy rainfall events (90%)

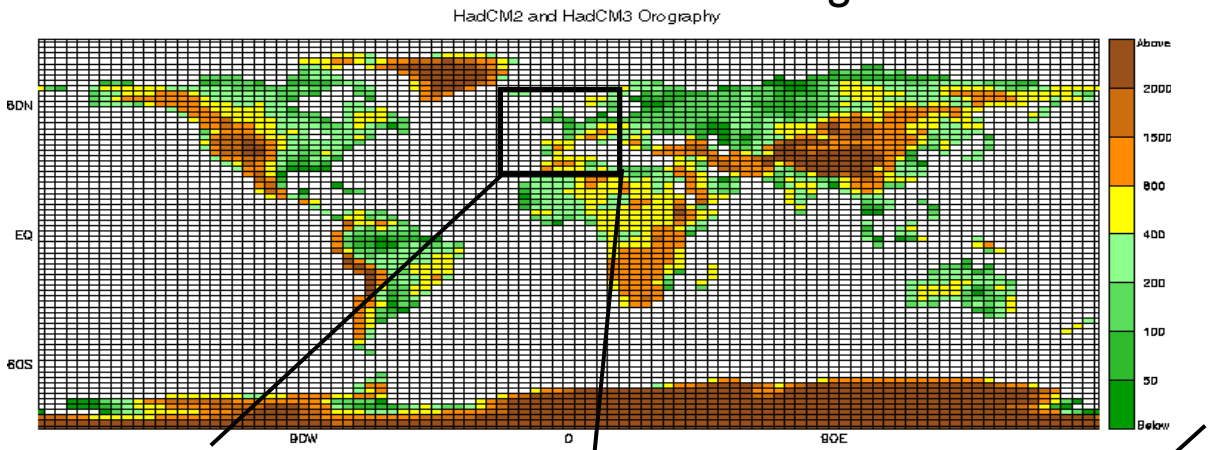
  Longer and/or more intense droughts (66%)
- ⬆ hurricane activity (50%) (western north pacific and north atlantic)

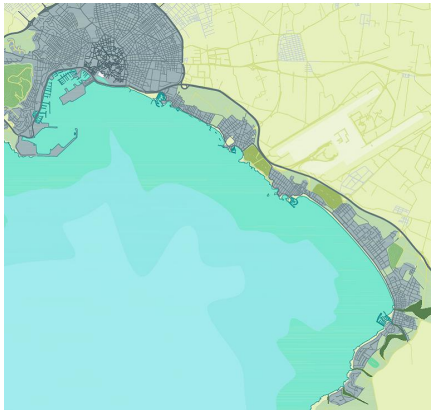
Tools for exploring climate change impacts

- GCMs → RCMs

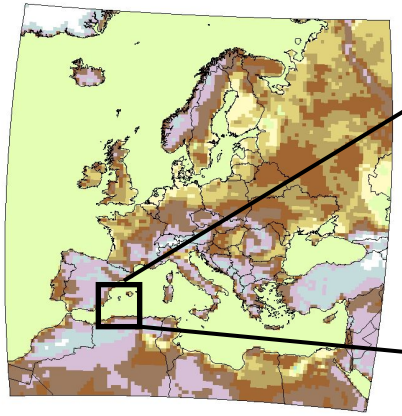
  -Regional scales: Dynamical downscaling. Regional Climate Models (RCMs)

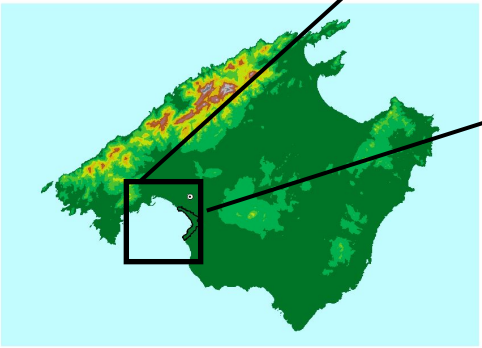
  -Local scales: Statistical downscaling and model calibration from RCMs





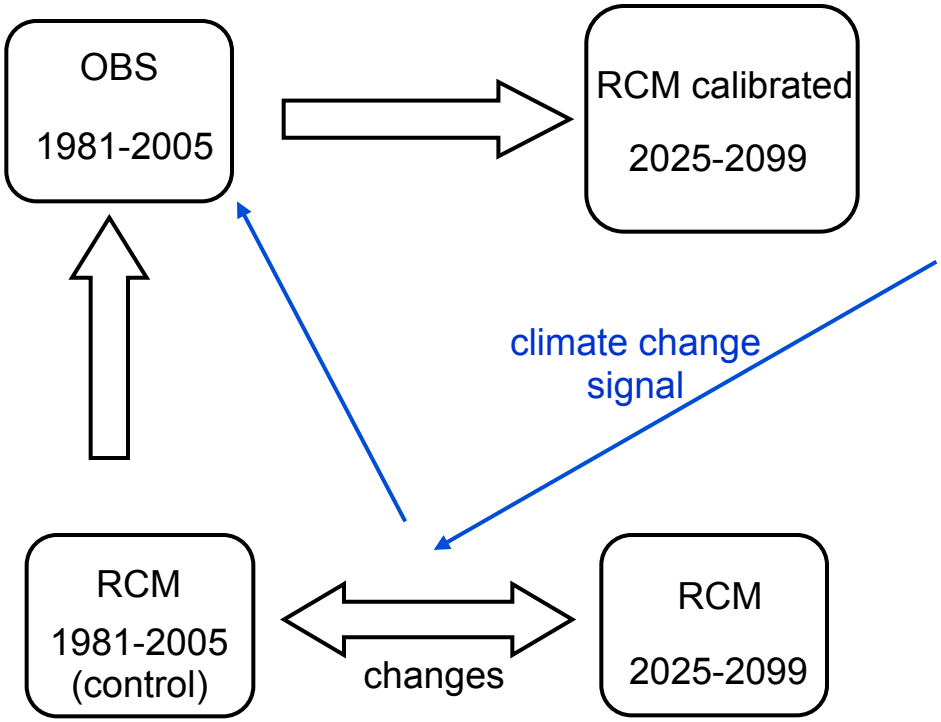
GCMs
⇩
Dynamical Downscaling
⇩
RCMs

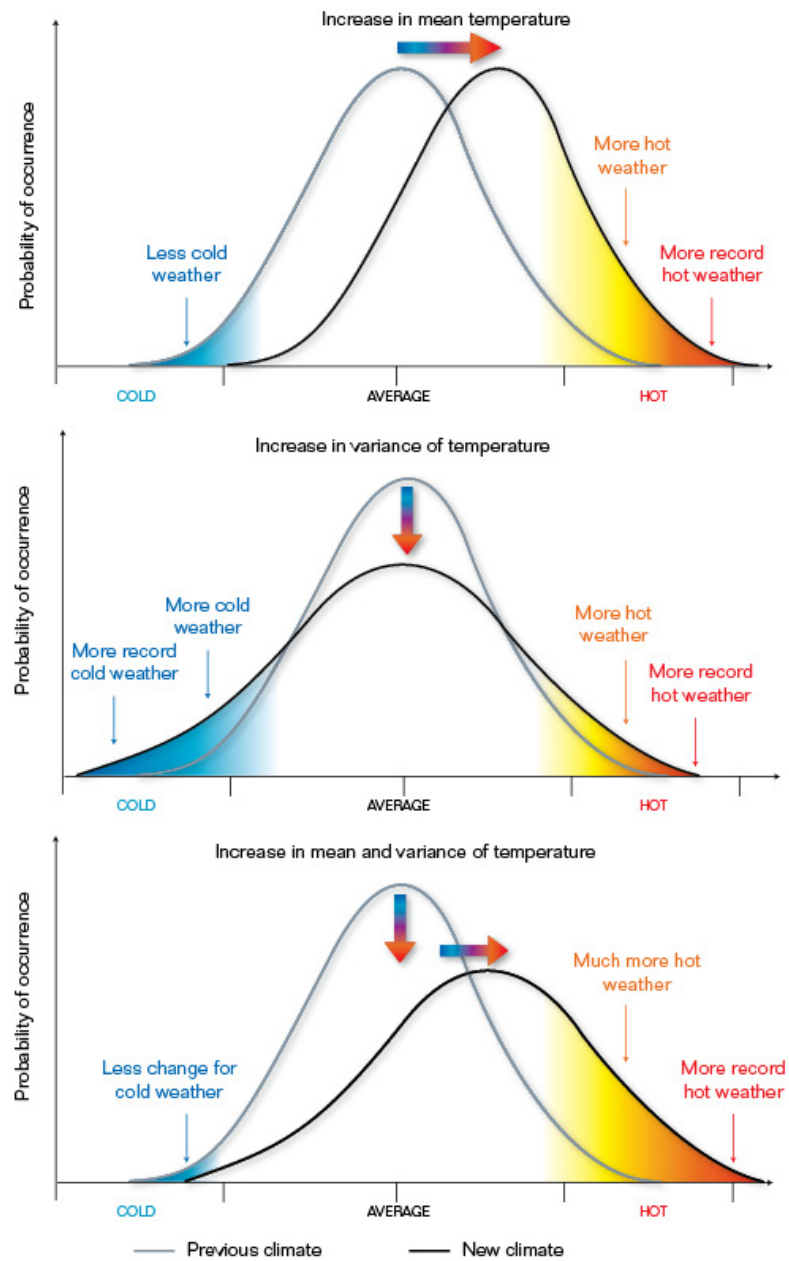




Statistical downscaling

Statistical downscaling of RCM outputs





Statistical downscaling of RCM outputs: Quantile-Quantile adjustment *(Amengual et al. 2012)*

$$p_i = o_i + g\overline{\Delta} + f\Delta'_i,$$

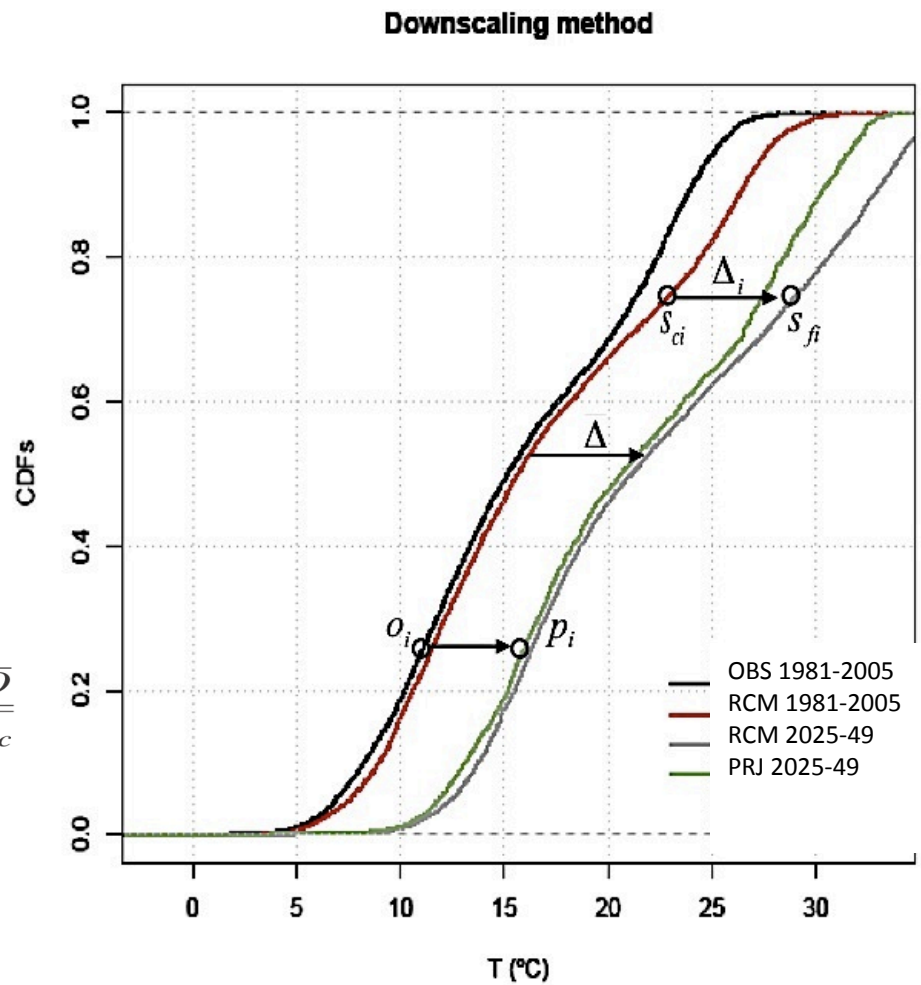
$$\Delta_i = s_{\mathrm{fi}} - s_{\mathrm{ci}}$$

$$\overline{\Delta} = \frac{\sum_{i=1}^{N}\Delta_i}{N} = \frac{\sum_{i=1}^{N}(s_{\mathrm{fi}} - s_{\mathrm{ci}})}{N} = \overline{S_f} - \overline{S_c}$$

$$\Delta'_i = \Delta_i - \overline{\Delta} \qquad g = \frac{\left(\sum_{i=1}^{N} o_i\right)\Big/N}{\left(\sum_{i=1}^{N} s_{\mathrm{ci}}\right)\Big/N} = \frac{\overline{O}}{\overline{S_c}}$$

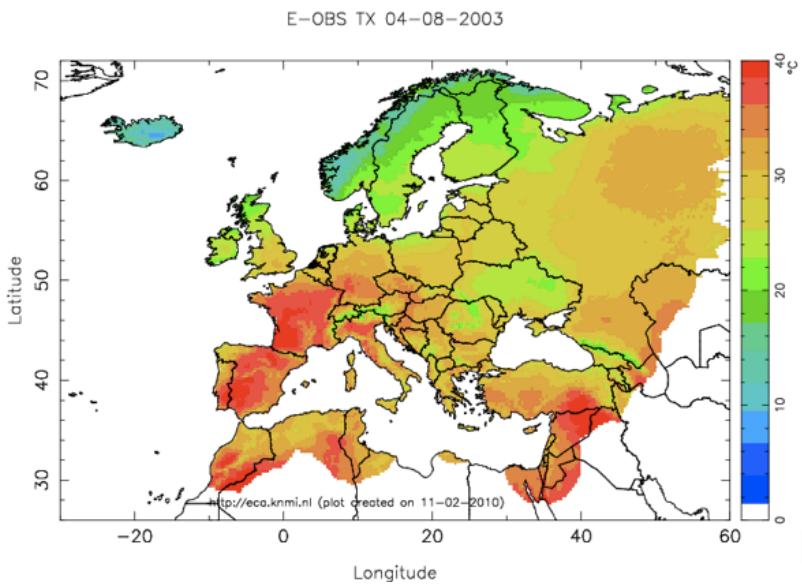
$$f = \frac{\sigma_O}{\sigma_{S_c}} = \frac{\mathrm{IQR}|_O}{\mathrm{IQR}|_{S_c}}. \qquad f = \frac{\sigma_{O'i}}{\sigma_{S_c'i}}$$

Global **Local**

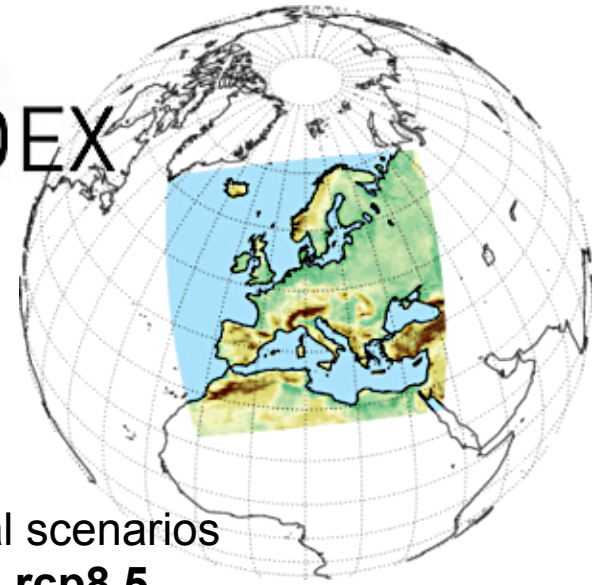


2. Database and methodology

E-OBS gridded dataset (25 km)



EURO-CORDEX (12,5 km)



Future regional scenarios
rcp4.5 and **rcp8.5**

Validation task

Evaluation of raw and calibrated data compared against observations for the 1956-1980 interval. Control period (1981-2005)

Climate change projections

Compute changes in calibrated CDFs between a 25-year past (i.e. control/ observed; 1981-2005) and successive 25-year RCM time-slices (2021-2045; 2046-2070; **2071-2095**)

Future regional scenario rcp4.5 and **rcp8.5**

Driving GCM	RCM	Institute
CNRM-CM5-LR	CCLM4-8-17	CLMcom
EC-EARTH	CCLM4-8-17	CLMcom
HadGEM2-ES	CCLM4-8-17	CLMcom
MPI-ESM-LR	CCLM4-8-17	CLMcom
EC-EARTH	RACMO22E	KNMI
HadGEM2-ES	RACMO22E	KNMI
EC-EARTH	HIRHAM5	DMI
NorESM1-M	HIRHAM5	DMI
CNRM-CM5	ALADIN53	CNRM
CNRM-CM5	RCA4	SMHI
EC-EARTH	RCA4	SMHI
HadGEM2-ES	RCA4	SMHI
MPI-ESM-LR	RCA4	SMHI
IPSL-CM5A-MR	RCA4	SMHI

Extreme weather events

1. Heat Waves
2. Cold Spells
3. Heavy precipitation
4. Droughts

We characterize their attributes with the following parameters:

•Number of extreme events that occur in a given time interval

•Frequency: the number of days under extreme conditions in a given time interval

•Duration exceedance: the total number of consecutive days exceeding the duration threshold for all events in a given time interval. It accounts for the whole amount of excess days.

•Amplitude exceedance: the accumulated stress exceedance for all the days under extreme conditions in a given time interval.

3. Results

3.1 Heat waves

- A spell lasting dth = 3 or more consecutive days with *daily maximum temperature* above 95th percentile of observed daily maximum temperature in summer.

HWA = HWT−Tth HWF

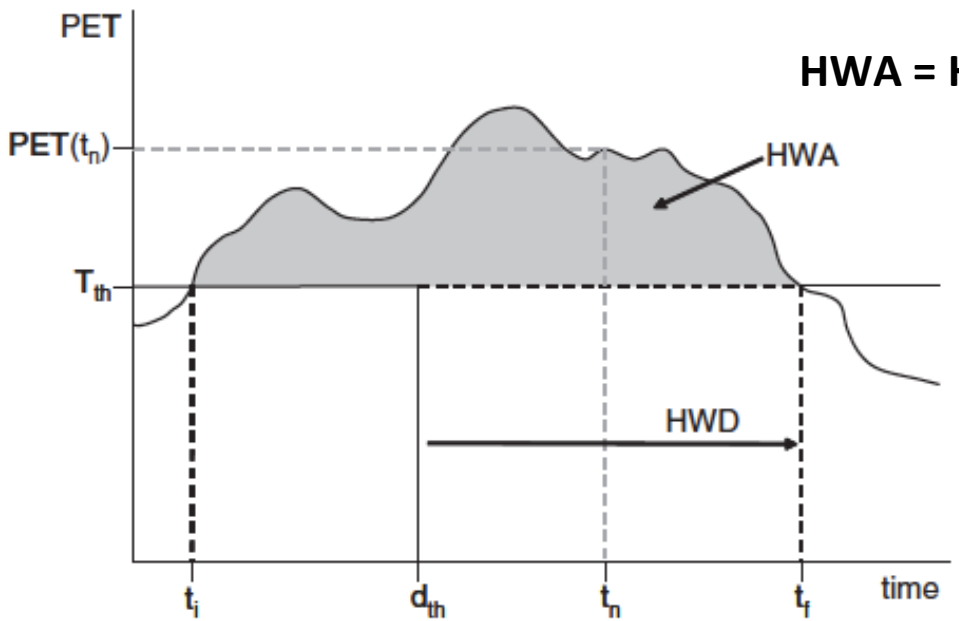
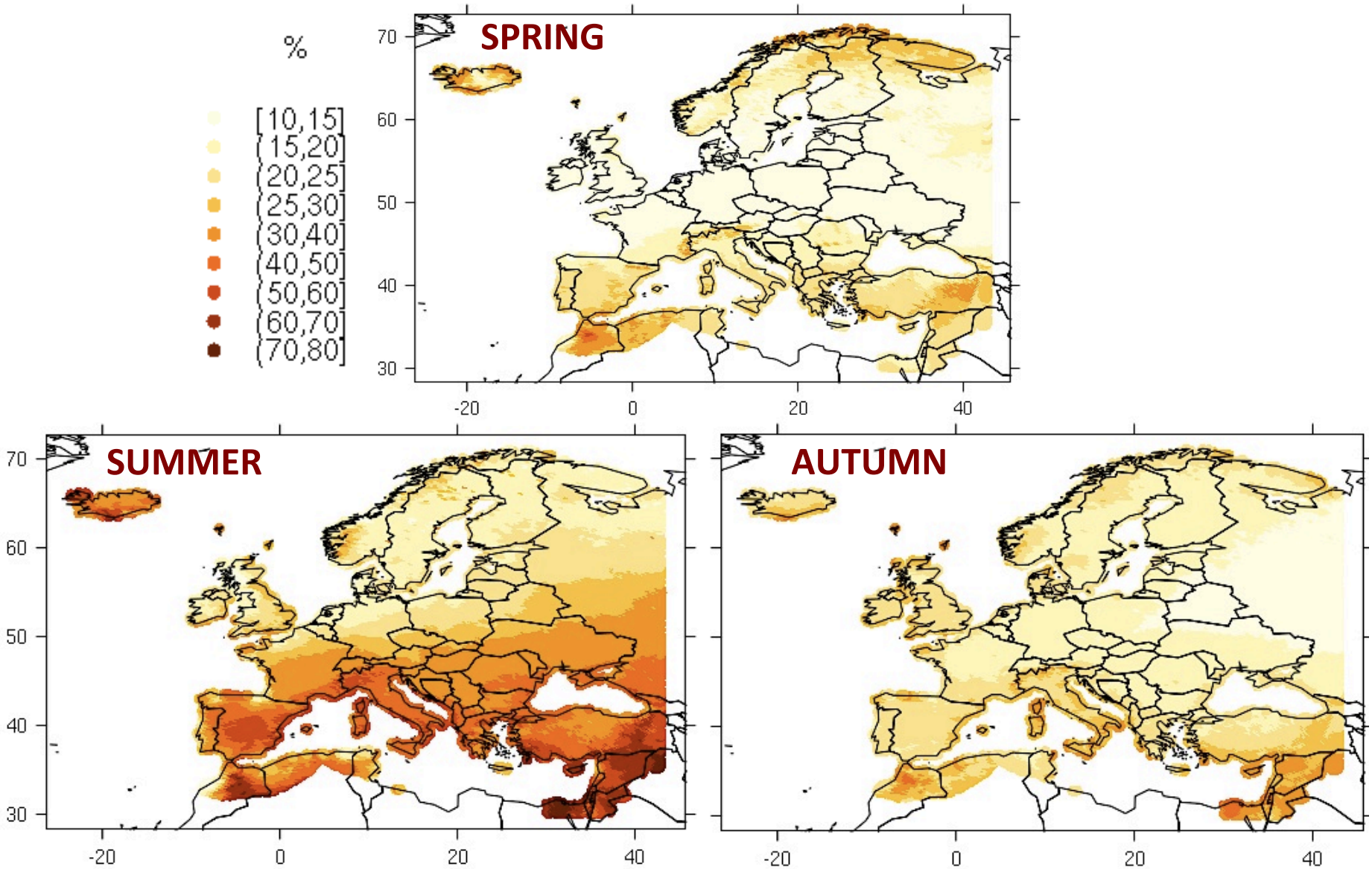


Fig. 1. Graphical sketch of heat wave duration (HWD) and amplitude (HWA, gray shading) exceedances. T_{th} and d_{th} denote the thermal stress and duration thresholds, respectively.

Events over P95 of daily maximum temperature

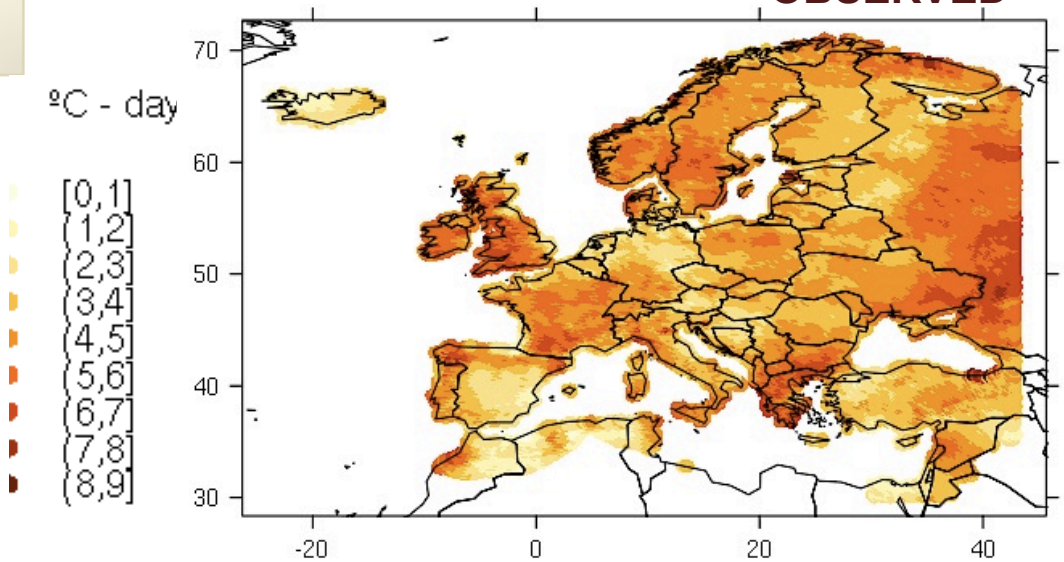
FUTURE CHANGE



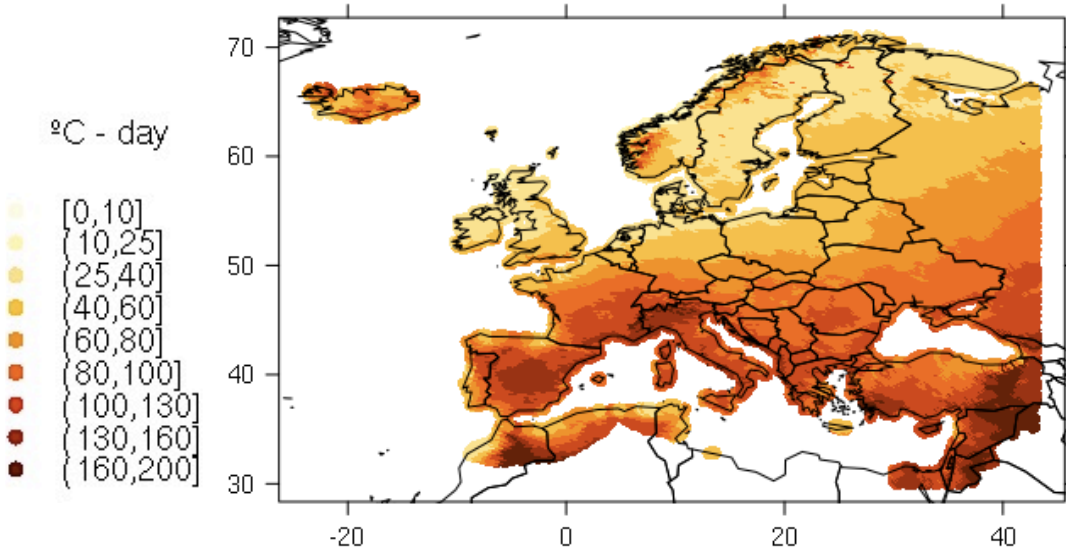
HEAT WAVE AMPLITUDE

SUMMER

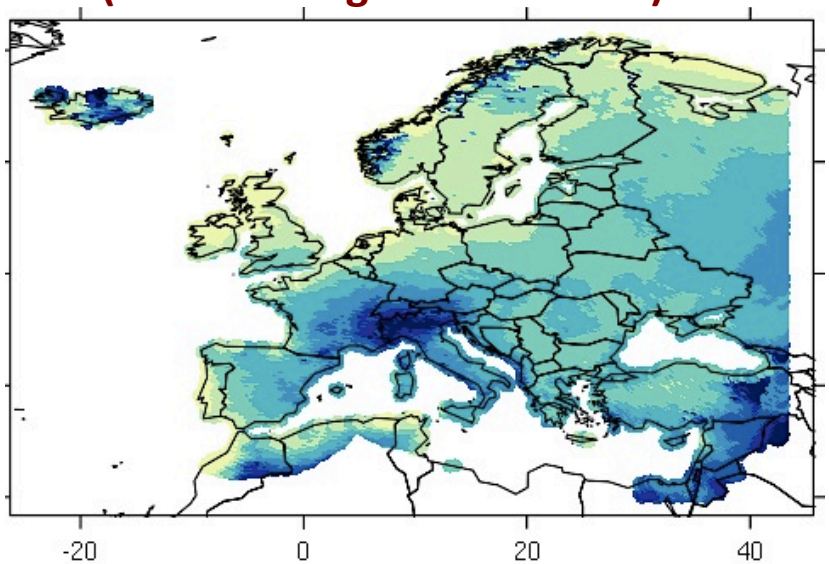
OBSERVED



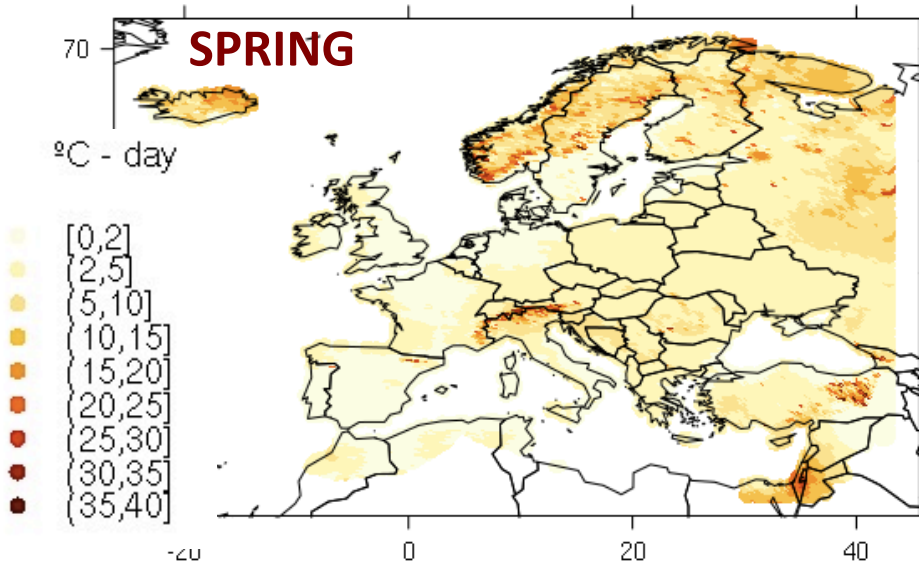
Future change (multi-model mean)

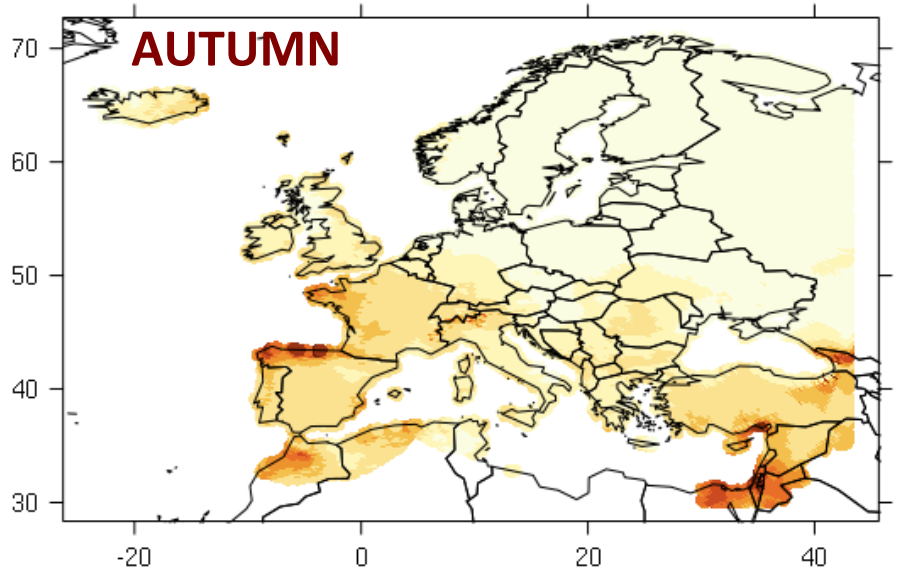


Std (future change multi-model)

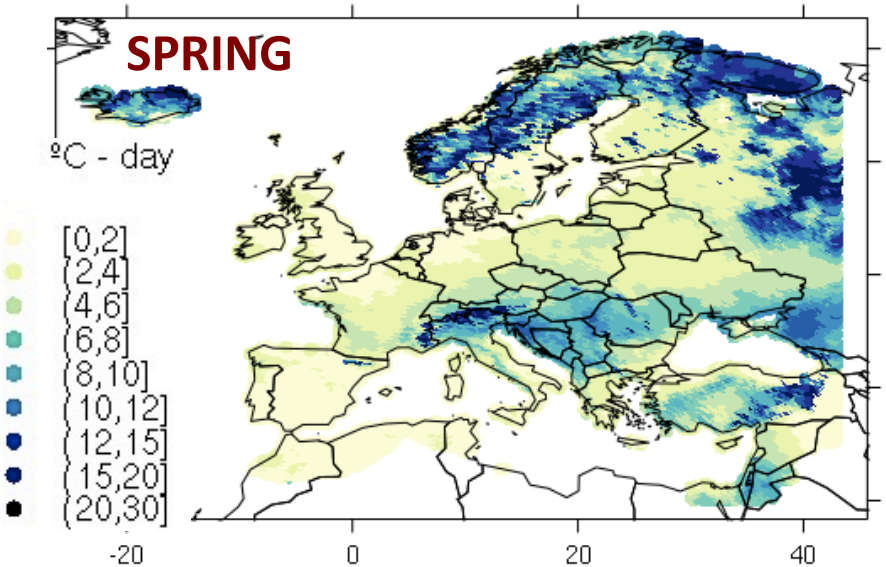


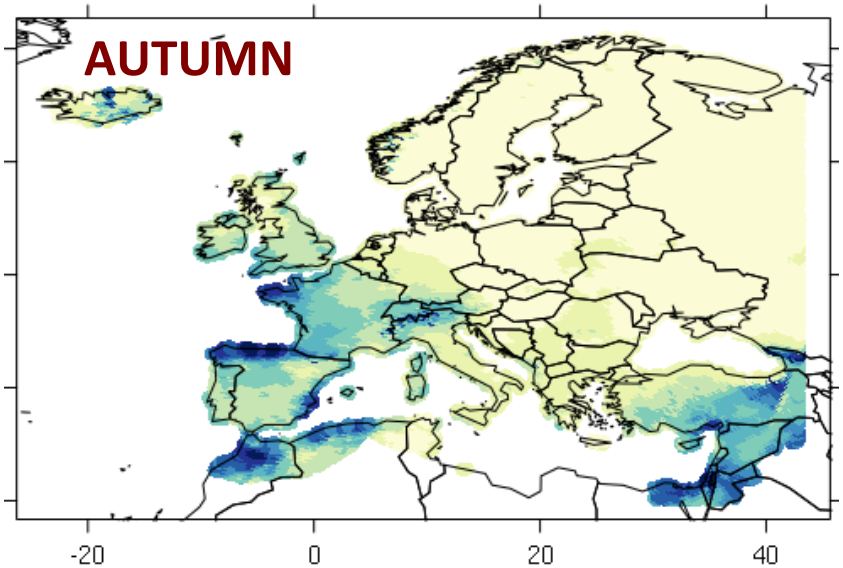
Future change (multi-model mean)





Std (future change multi-model)





3. Results

3.2 Cold spells

- A spell lasting dth = 3 or more consecutive days with *daily minimum temperature* under 5th percentile of observed daily minimum temperature in winter.

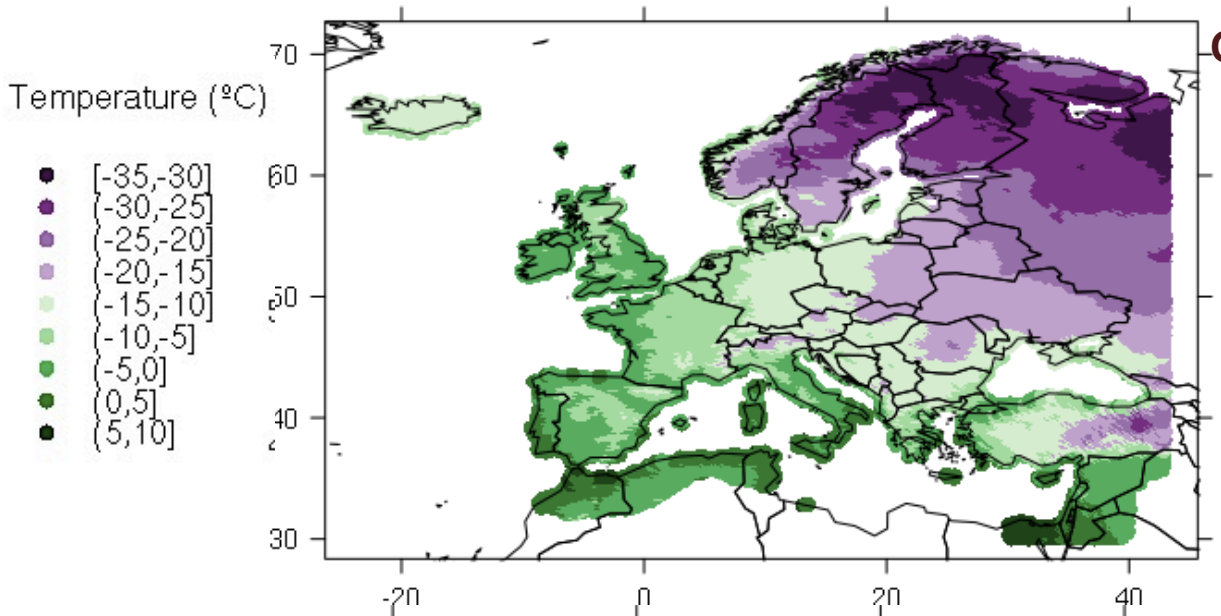
- Future events under P5 of daily observed minimum temperature in winter.

- Cold Spell Amplitude (CSA)

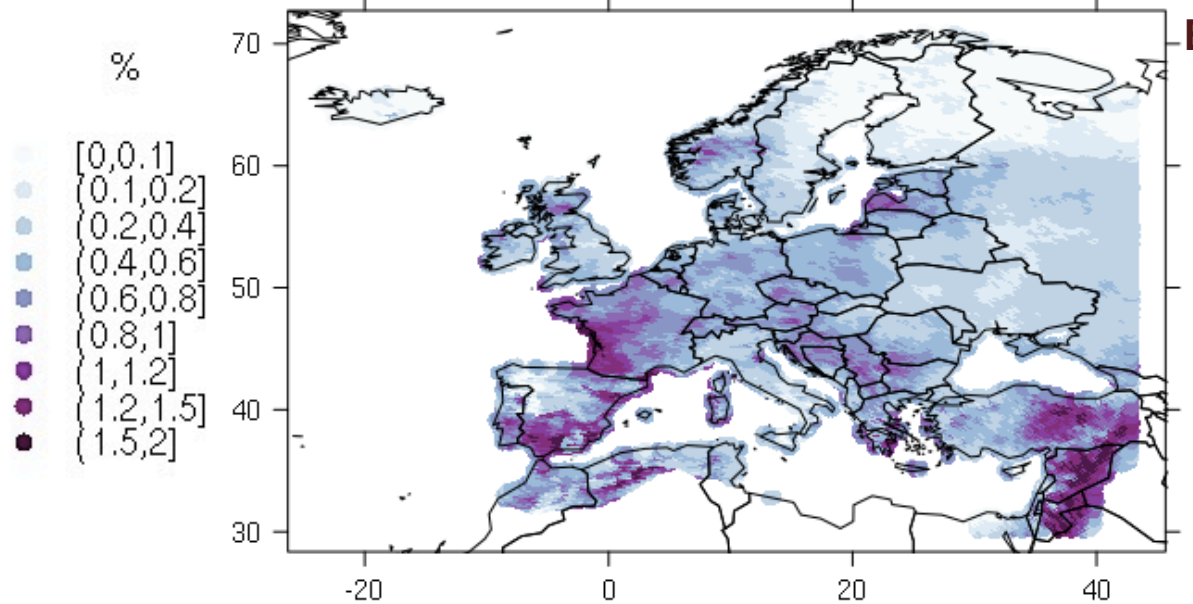
$$\mathbf{CSA = T_{th}\ \ CSF - CST}$$

T_{th}: thermal stress
CSF: cold spell frequency
CST: integral of the minimum daily temperatures over the duration of each individual cold spell, and accumulated for all cold spells in a given time interval

P5 of daily minimum temperature (WINTER)



OBSERVED

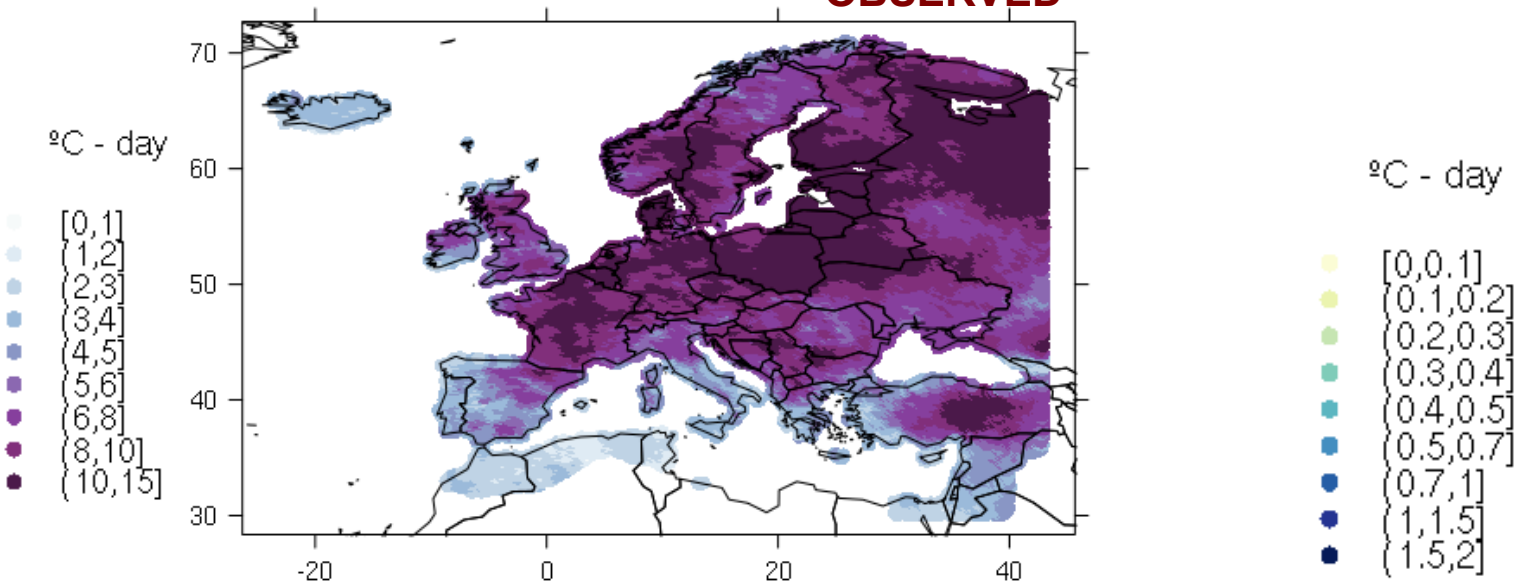


EVENTS UNDER P5: Future change (multi-model mean)

COLD SPELL AMPLITUDE

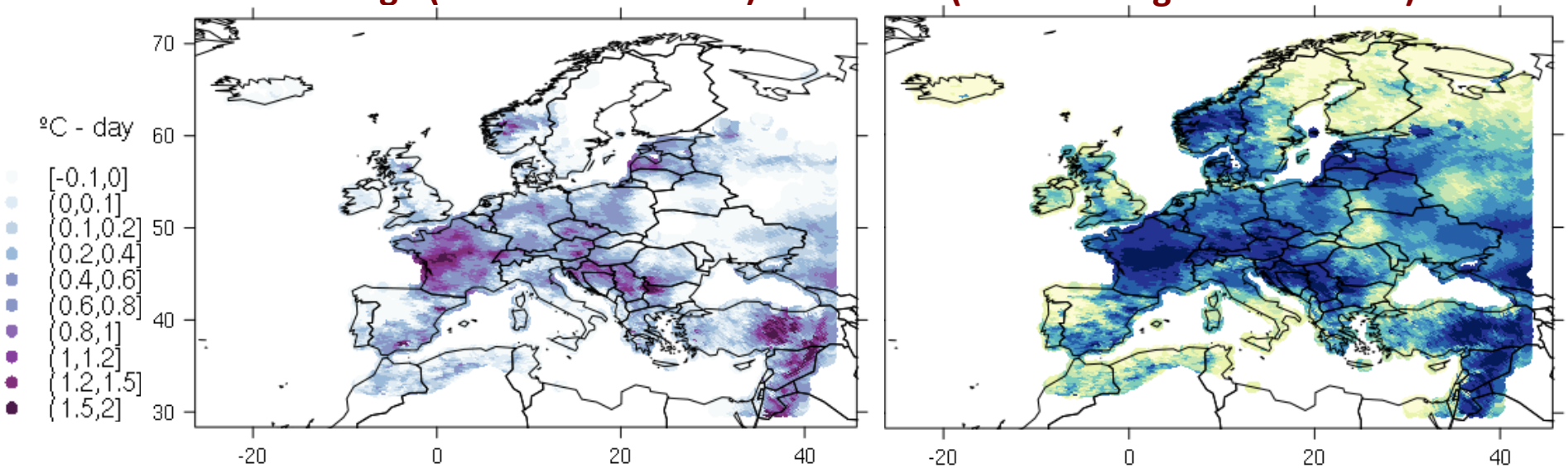
WINTER

OBSERVED



Future change (multi-model mean)

Std (future change multi-model)



3. Results

3.3 Heavy precipitation

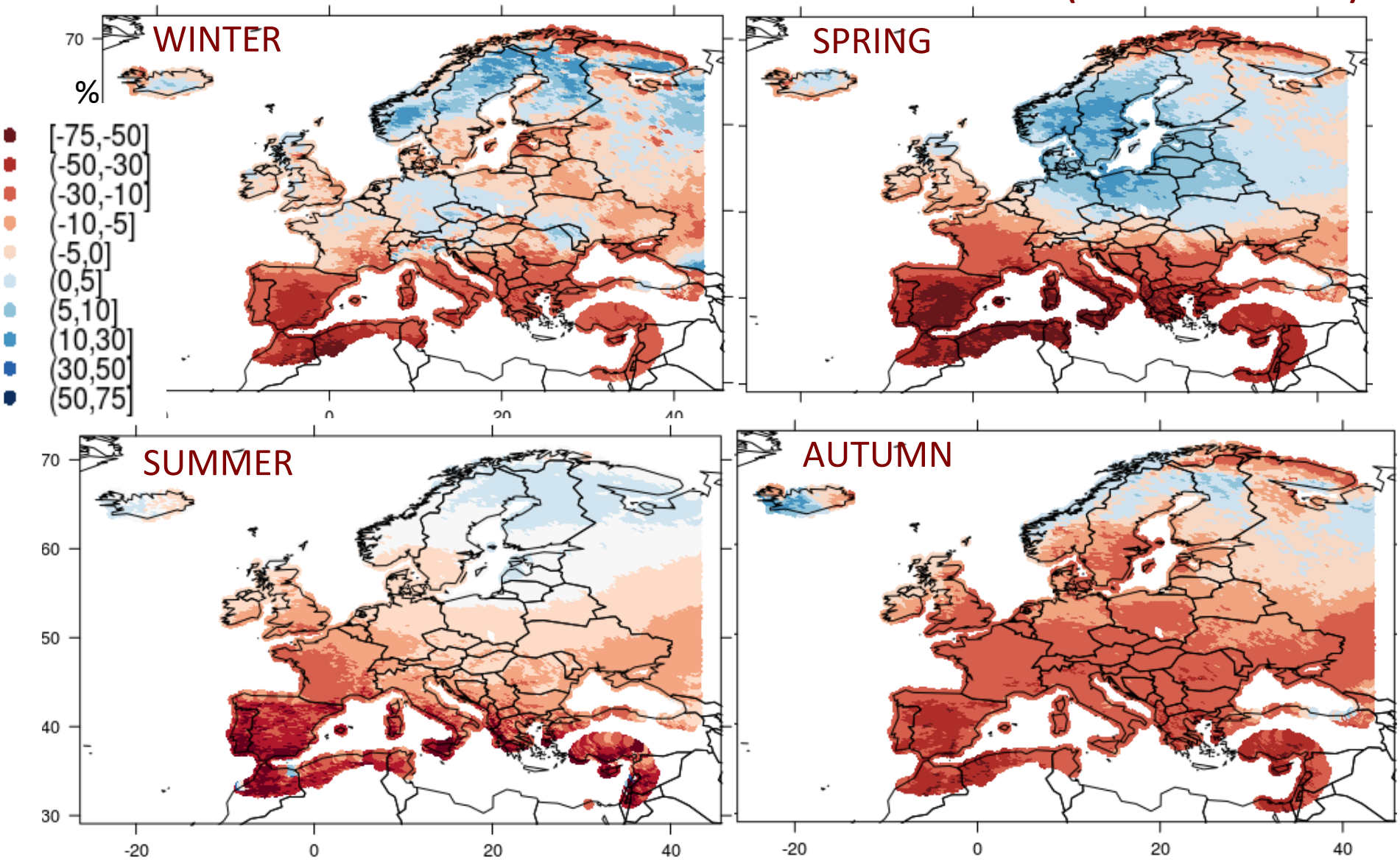
- A spell lasting dth = 2 or more consecutive days with *daily precipitation* above 95th percentile of observed annual daily precipitation

- Future change in seasonal precipitation days.
- Future events over P95 of daily annual observed precipitation.
- Heavy Precipitation Amplitude (HPA)

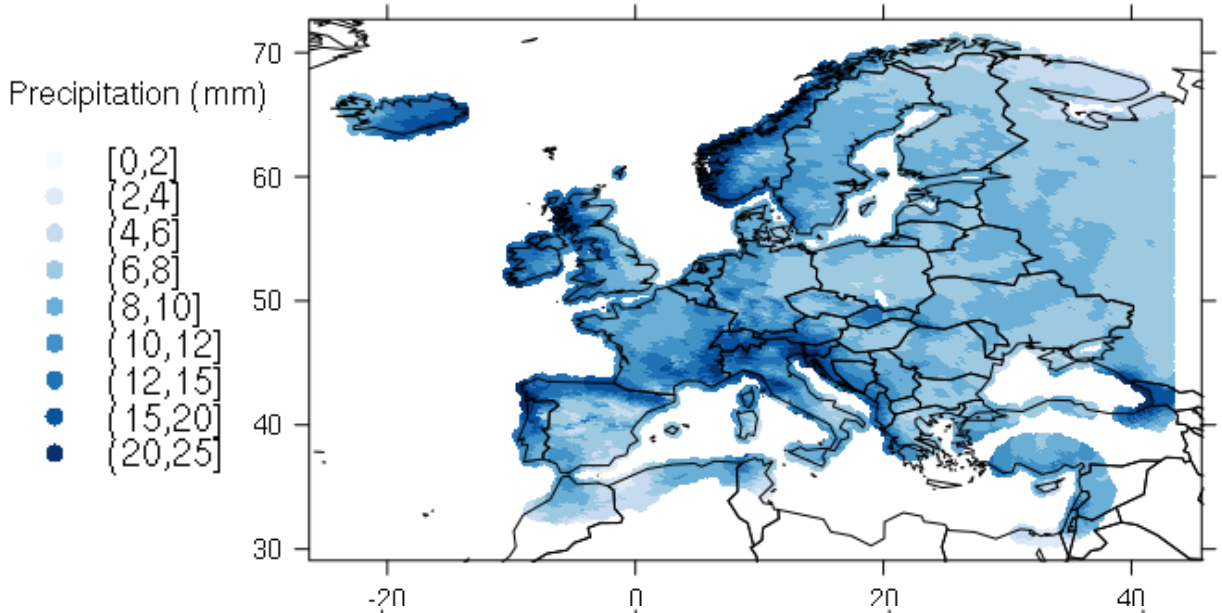
HPA = HPT - Tth HPF

Seasonal precipitation days

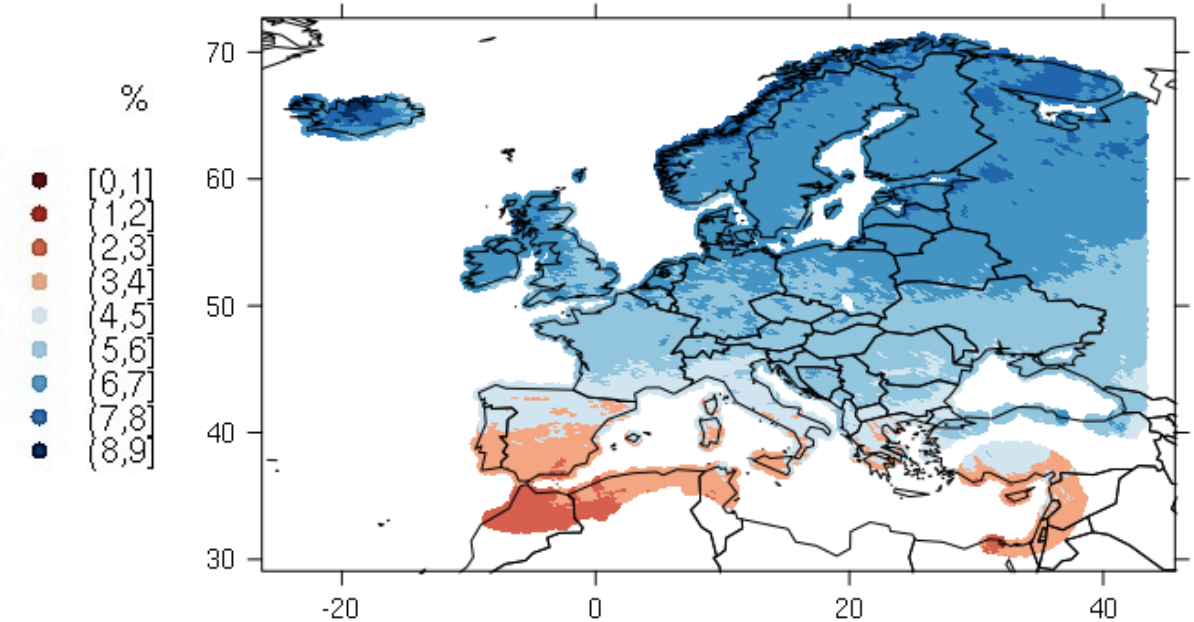
FUTRURE CHANGE (multi-model mean)



P95 of daily precipitation (ANNUAL)



OBSERVED

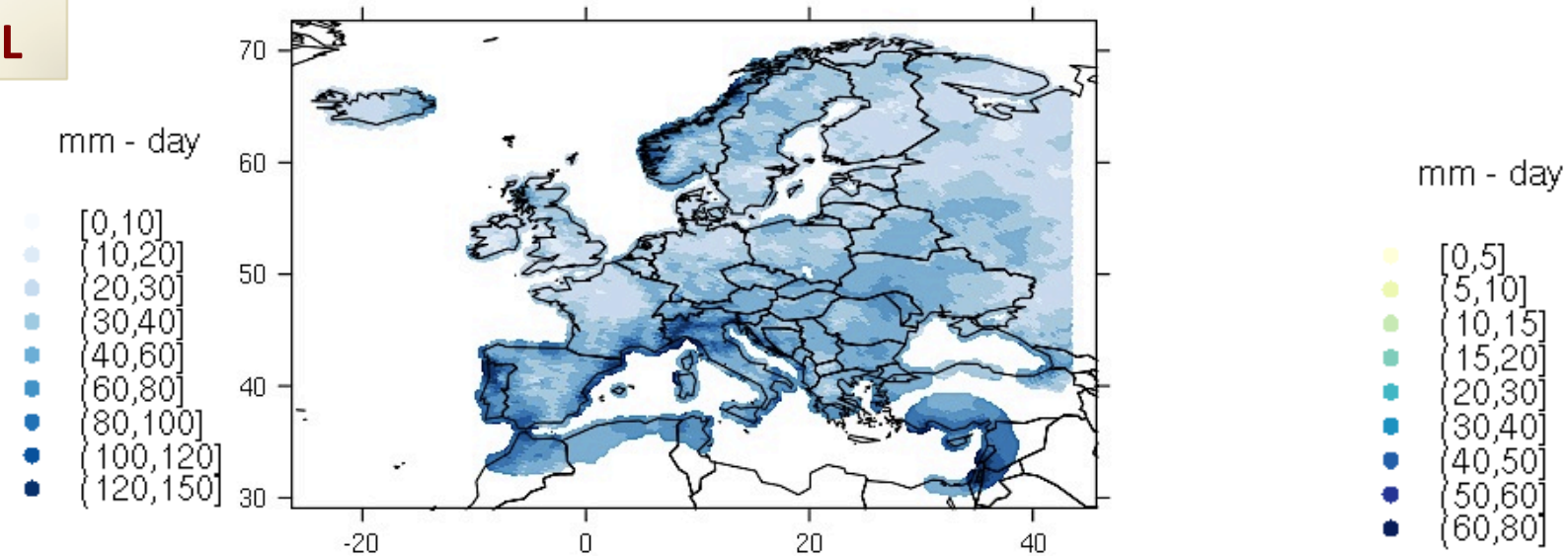


EVENTS OVER P95: Future change (multi-model mean)

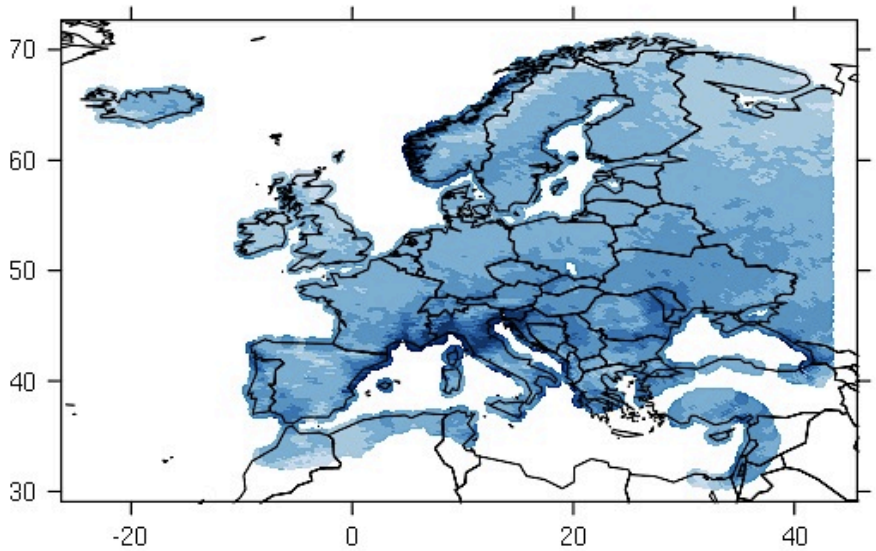
HEAVY PRECIPITATION AMPLITUDE

ANNUAL

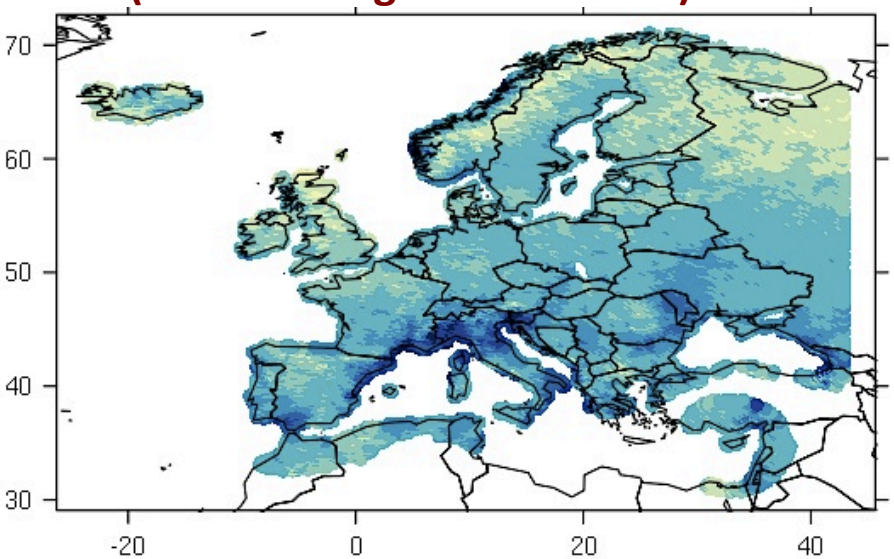
OBSERVED



Future change (multi-model mean)



Std (future change multi-model)



3. Results

3.4 Droughts

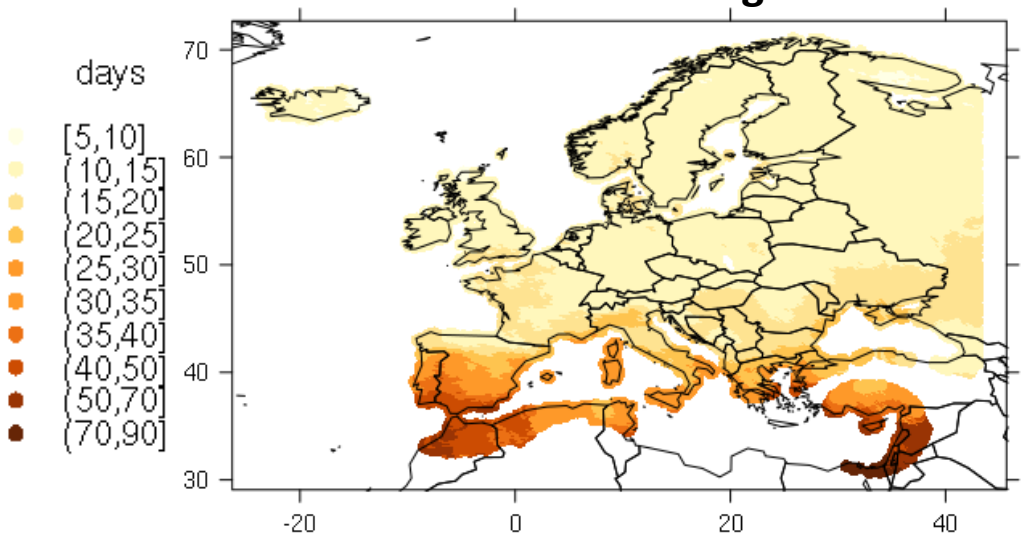
- A spell lasting dth = 3 or more consecutive days with *daily precipitation* <= 0.1 mm

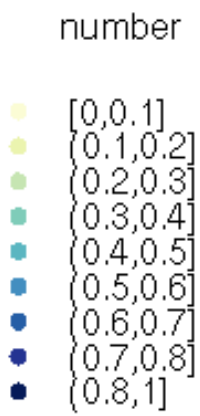
- P95 of observed annual drought duration
- Number of future events with a duration over P95 of observed drought duration

NUMBER OF DROUGHTS

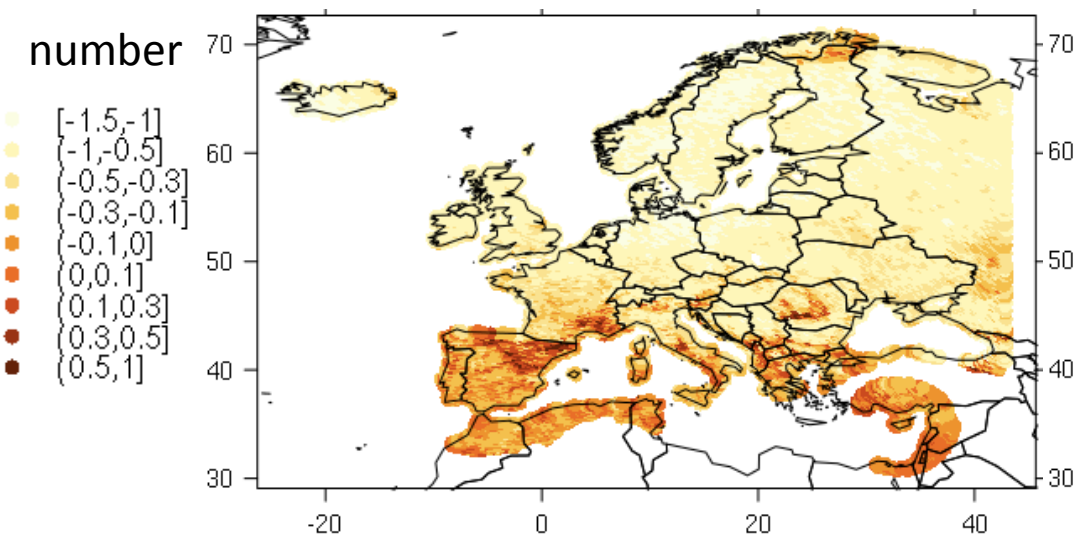
ANNUAL

P95 of observed drought duration

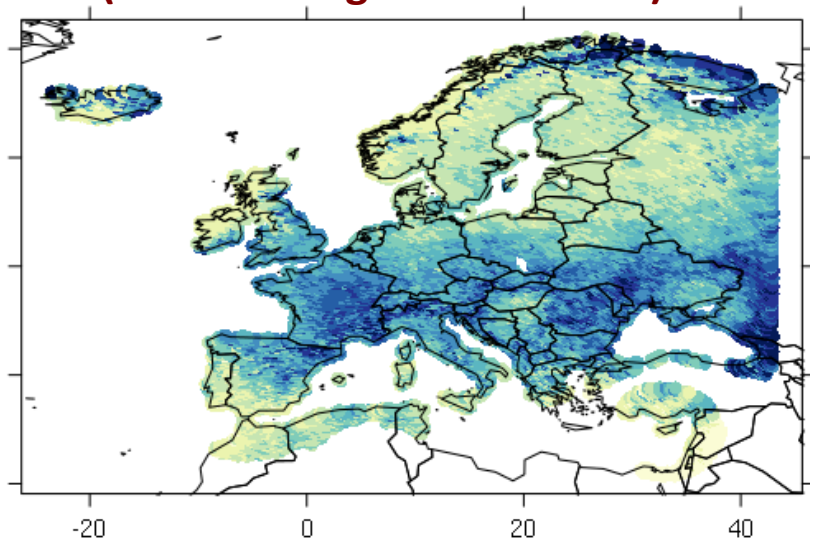




Future change (multi-model mean)



Std (future change multi-model)



Aknowledegments:

EXTREMO

CGL2014-52199-R (AEI/FEDER, UE) MINECO (Spain)

FPI-CAIB (Conselleria d'Innovació, Recerca i Turisme del Govern de les Illes Balears and the Fons Social Europeu)

Amengual A; et al; 2012. A statistical adjustment of regional climate model outputs to local scales: application to Platja de Palma, Spain. J Clim25(3):939–957

Amengual, A., et al; 2014. Projections of heat waves with high impact on human health in Europe . Glob. Planet. Change, 119, 71-84

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