Future extremes of temperature and precipitation in Europe based on the combination of dynamical and statistical approaches

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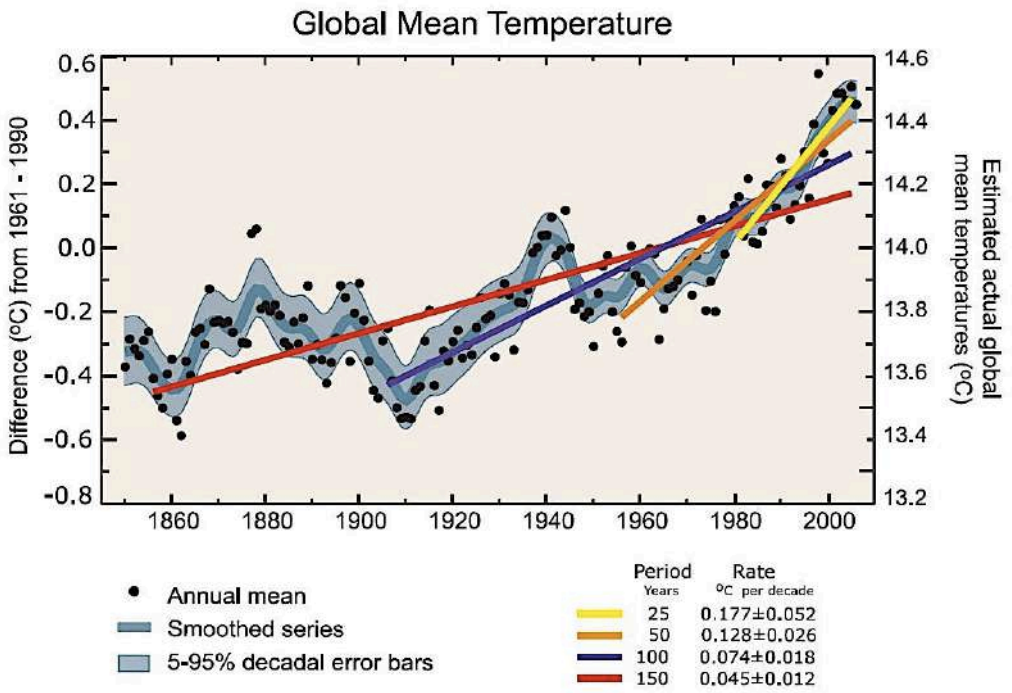
1. Motivations and objectives

Climate change: current evidences



- The average global temperature increased by about 0.85 C from 1880 to 2012
- 1983-2012 was likely the warmest 30-year period of the last 1400 years in the Northern Hemisphere(Stocker et al., 2013).
- Important regional variations
- Redistribution of rainfall and other variables

Extreme weather events

Summary for Policymakers (IPCC)

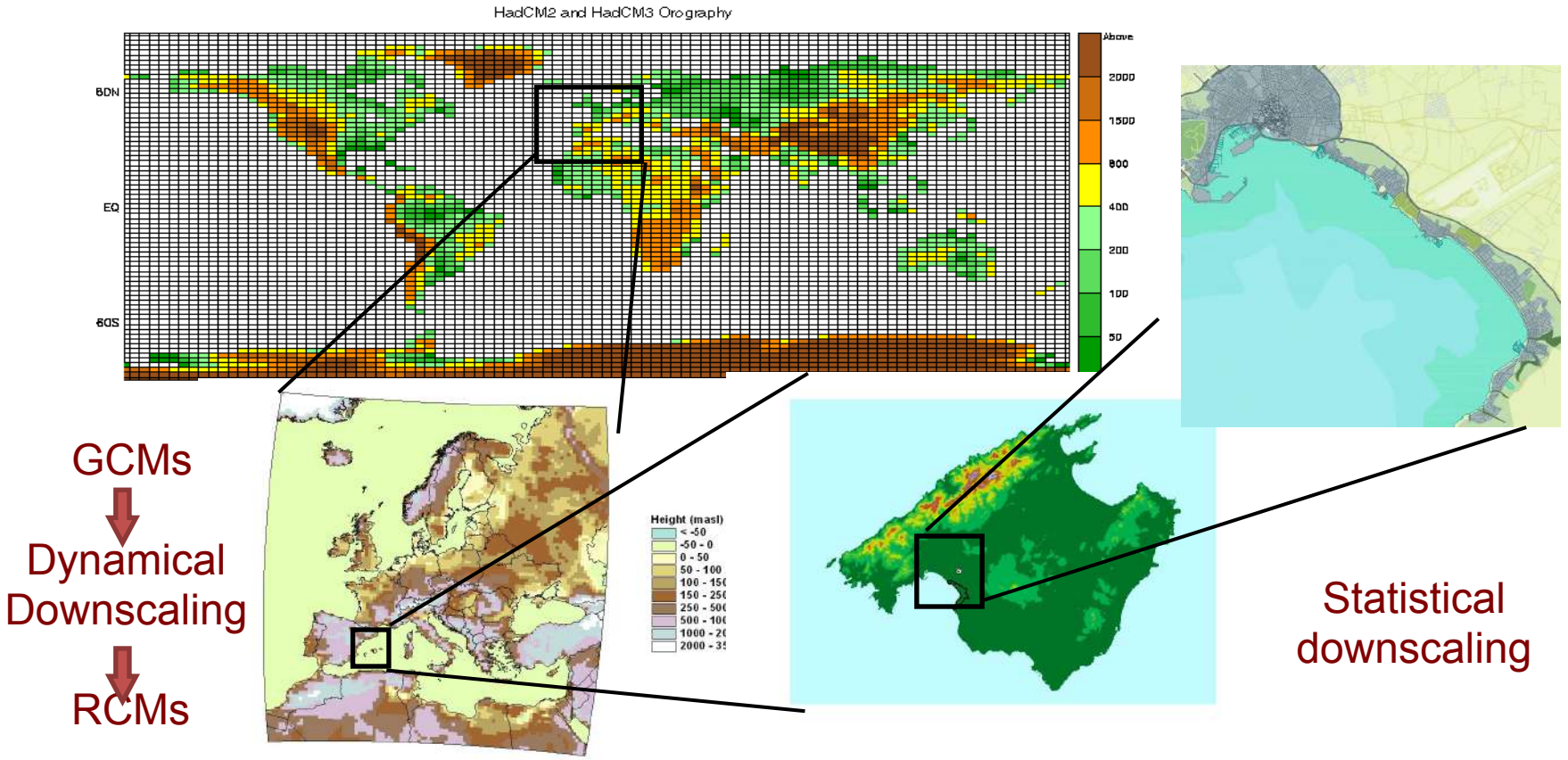
- ↓ cold days and nights (99%)
- ↑ hot days and nights (99%)
- ↑ frequent and/or intense heavy rainfall events (90%)
- ↑ Longer and/or more intense droughts (66%)
- ↑ hurricane activity (50%) (western north pacific and north atlantic)

Tools for exploring climate change impacts

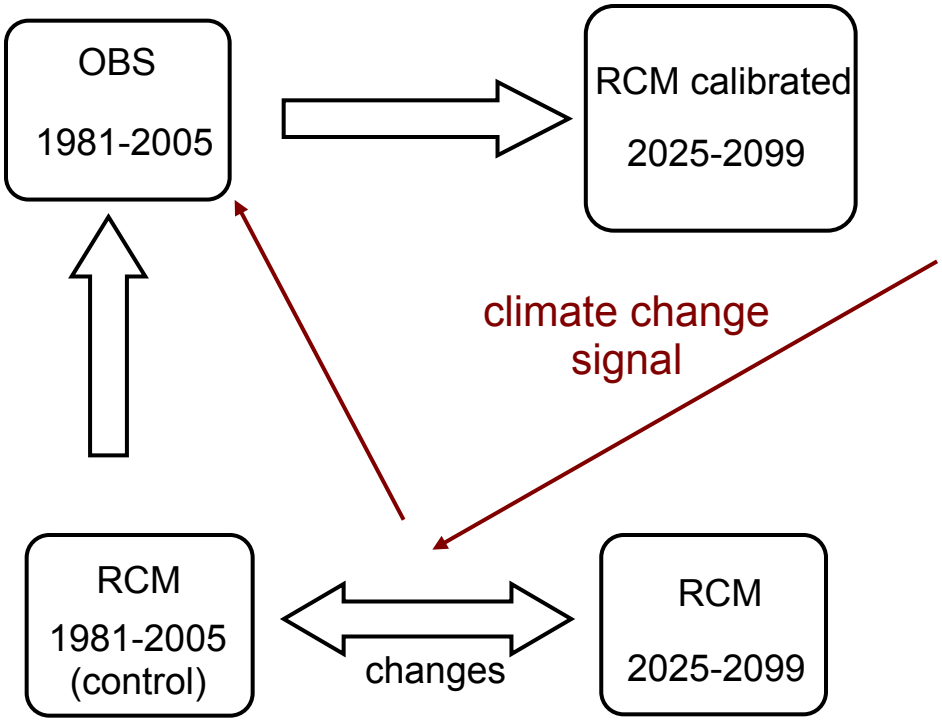
- GCMs → RCMs

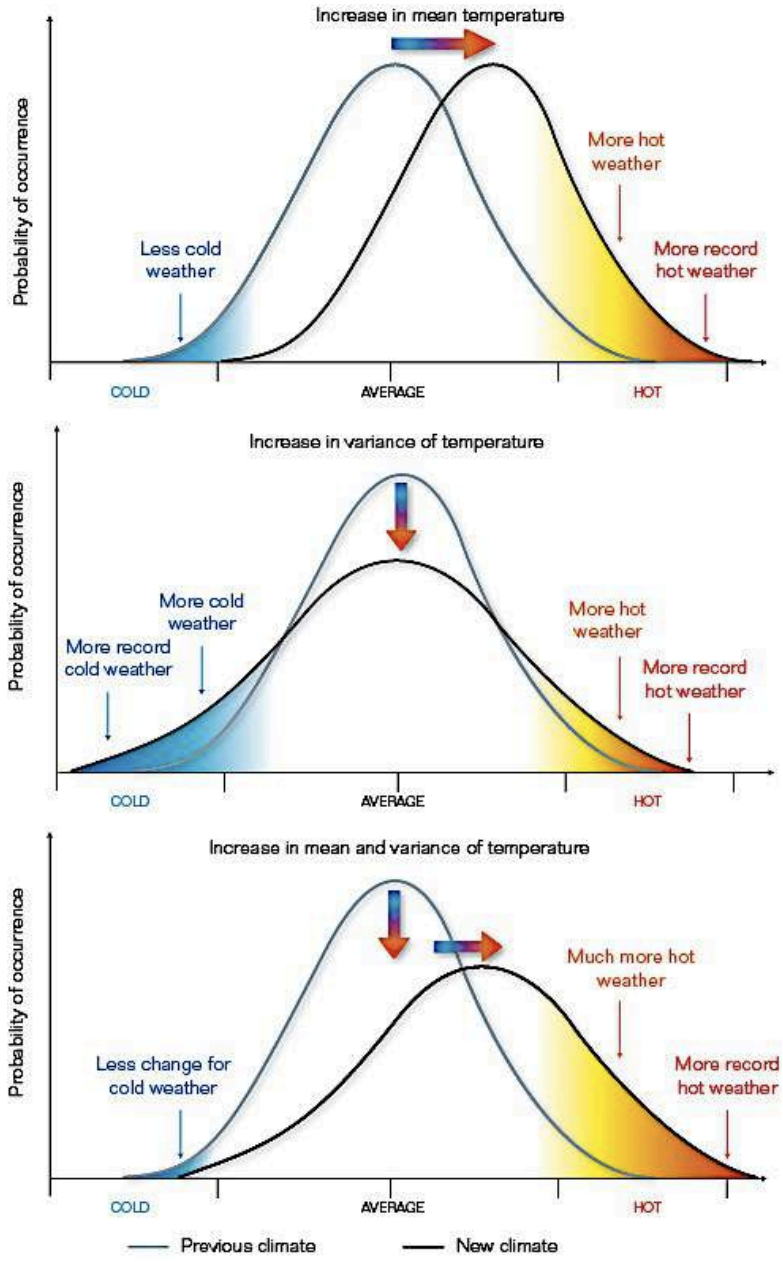
-Regional scales: Dynamical downscaling. Regional Climate Model (RCMs)

-Local scales: Statistical downscaling and model calibration from RCMs



Statistical downscaling of RCM outputs

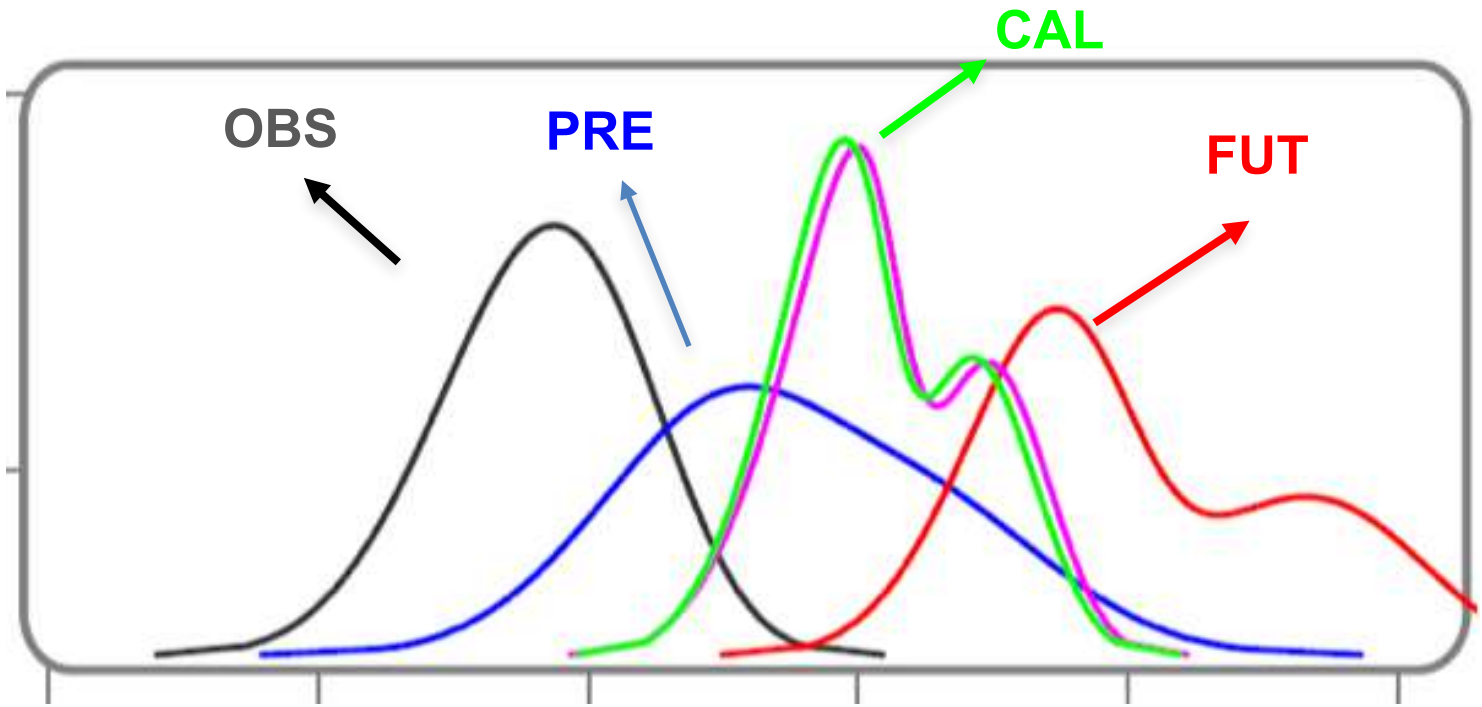




Quantile-Quantile adjustment

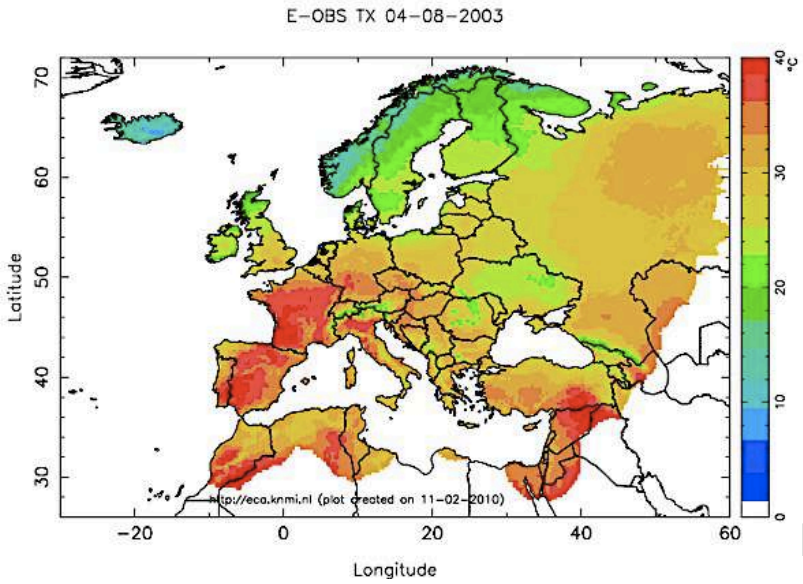
(Cardell et al., 2019a)

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

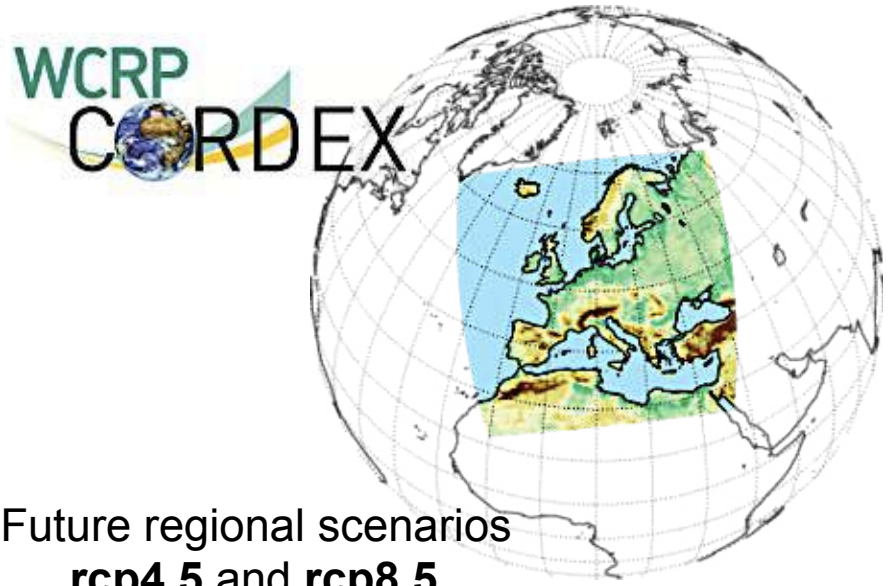


2. Database and methodology

E-OBS gridded dataset (25 km)



EURO-CORDEX (12,5 km)



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

Daily series of:

- 2-m **minimum** and **maximum temperatures**
- **Accumulated precipitation**

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. Temperature extremes	2. Precipitation extremes
1.1 Warm days	2.1 Heavy precipitation days
1.2 Heat waves	**2.2 Heavy precipitation episodes**
1.3 Cold nights	2.3 Dry days
1.4 Cold spells	2.4 Droughts

We characterize their attributes with the following parameters:

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

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

•Duration exceedance: 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.

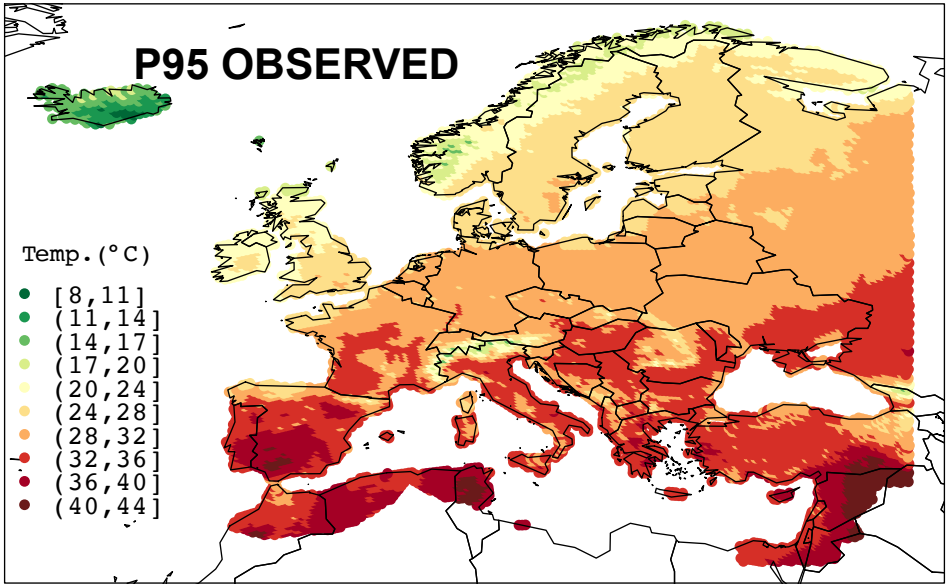
•**Amplitude exceedance: the accumulated stress exceedance for all the days under extreme conditions in a given time interval.**

3. Results. Temperature extremes

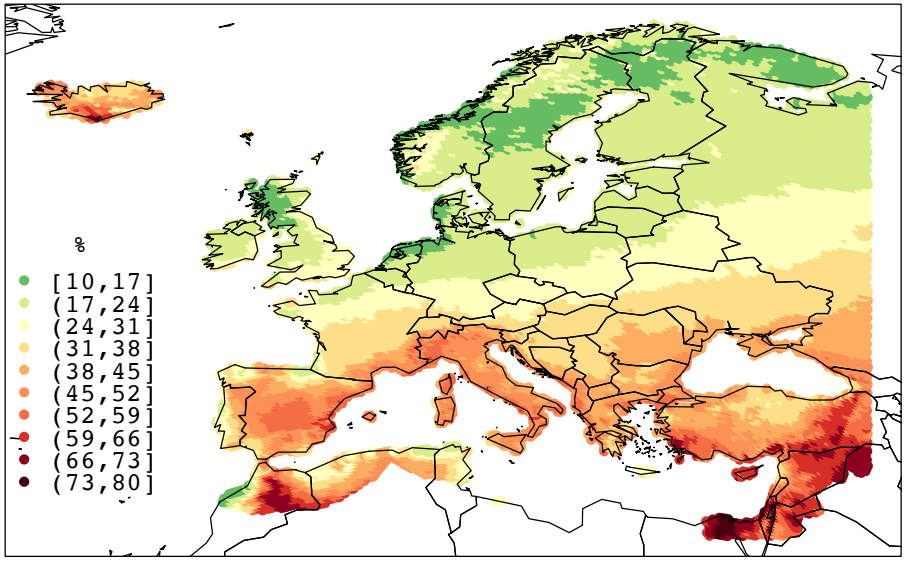
SUMMER

3.1.1 WARM DAYS

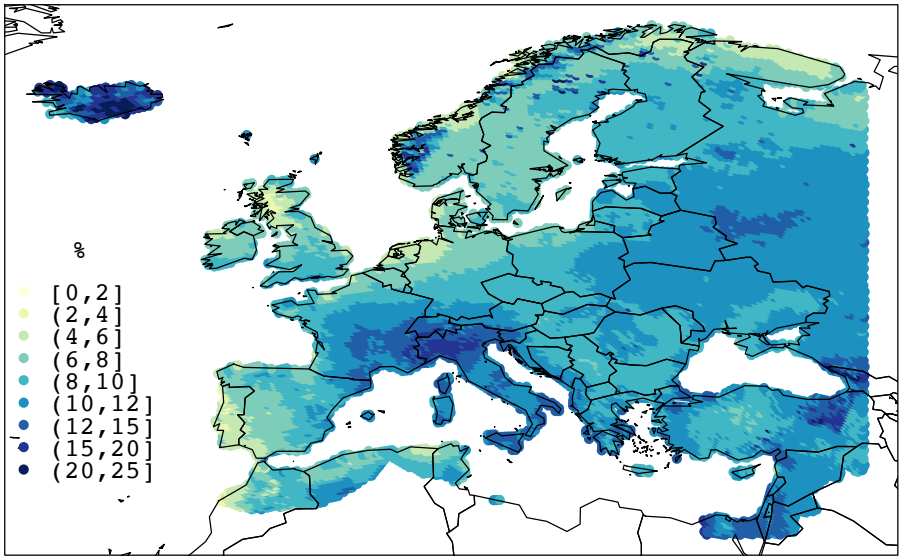
Day in which daily <u>maximum temperature</u> values are in EXCESS of the observed P95 of maximum temperature in summer



FUTURE MULTI-MODEL MEAN



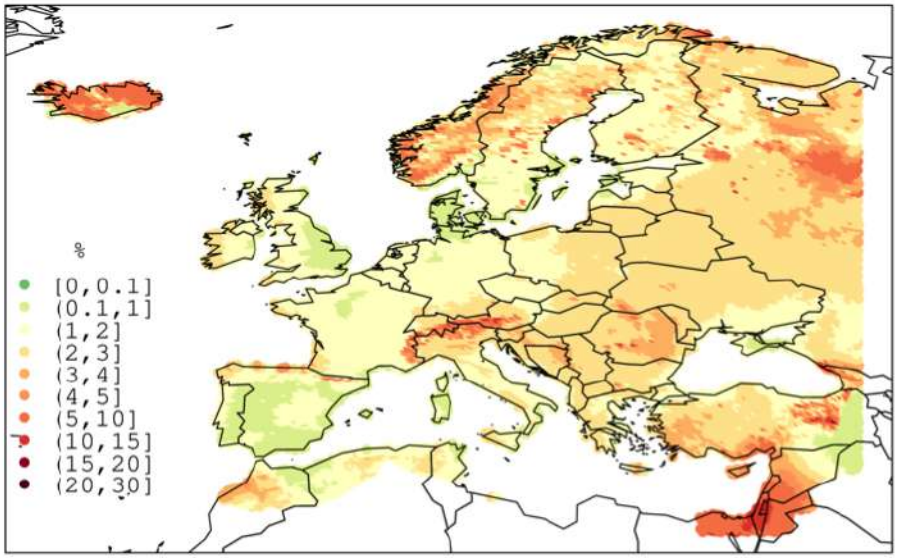
SD (FUTURE MULTI-MODEL MEAN)



3.1.1 WARM DAYS

SPRING

FUTURE MULTI-MODEL MEAN



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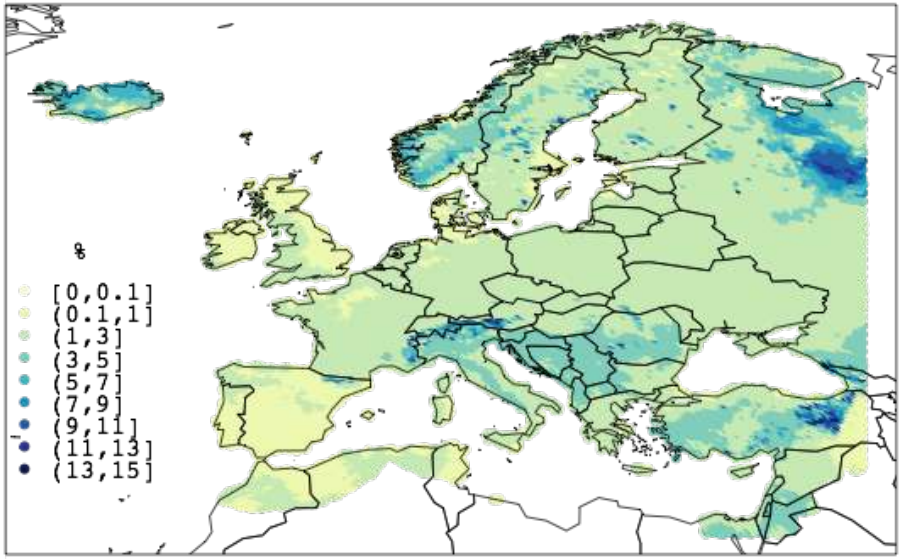
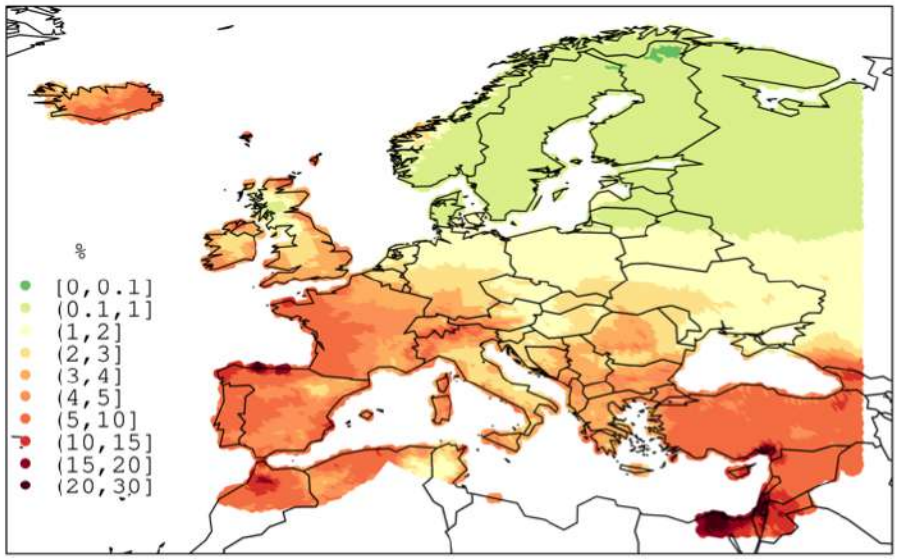


FUTURE MULTI-MODEL MEAN AUTUMN



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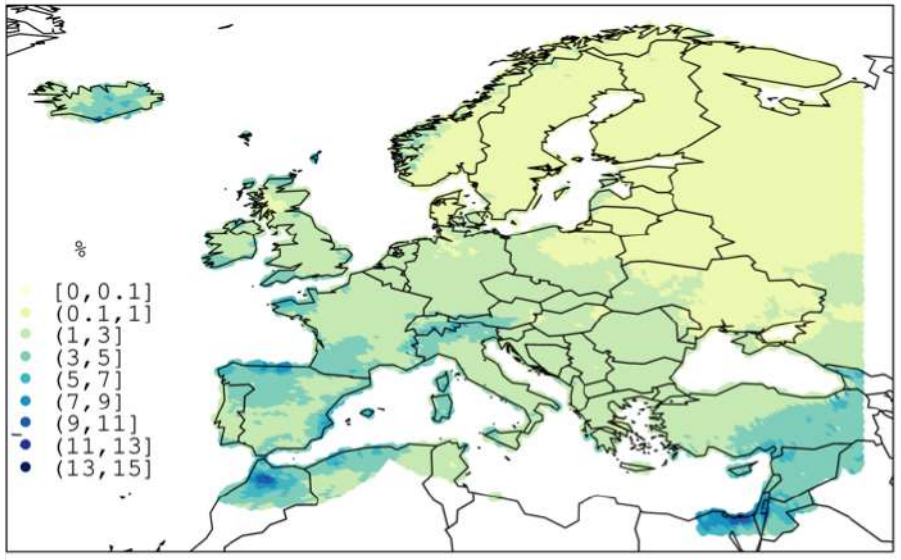


3.1.2 HEAT WAVES

A spell lasting dth = 3 or more consecutive days with *daily mean temperature* above 90th percentile of observed daily mean temperature in summer.

HEAT WAVE AMPLITUDE (HWA)

The accumulated heat stress exceedance for all the days under extreme conditions in a given time interval.

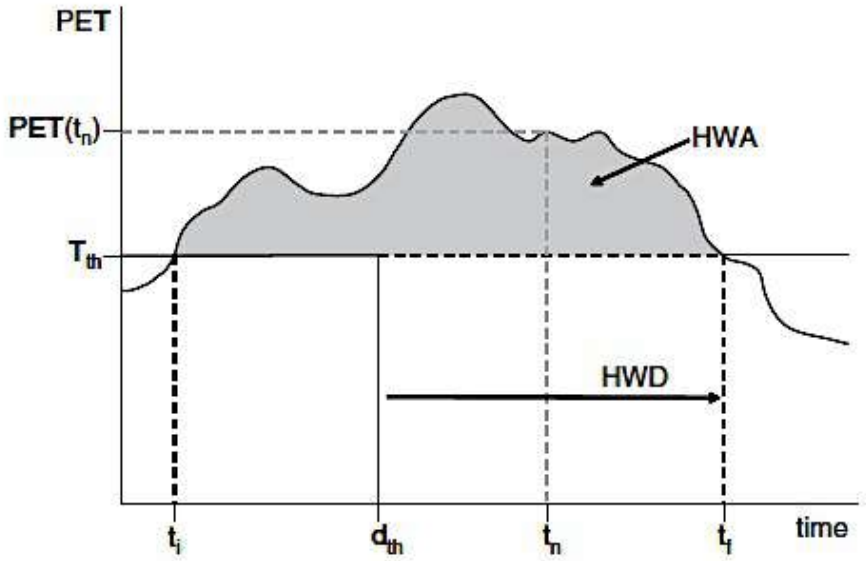


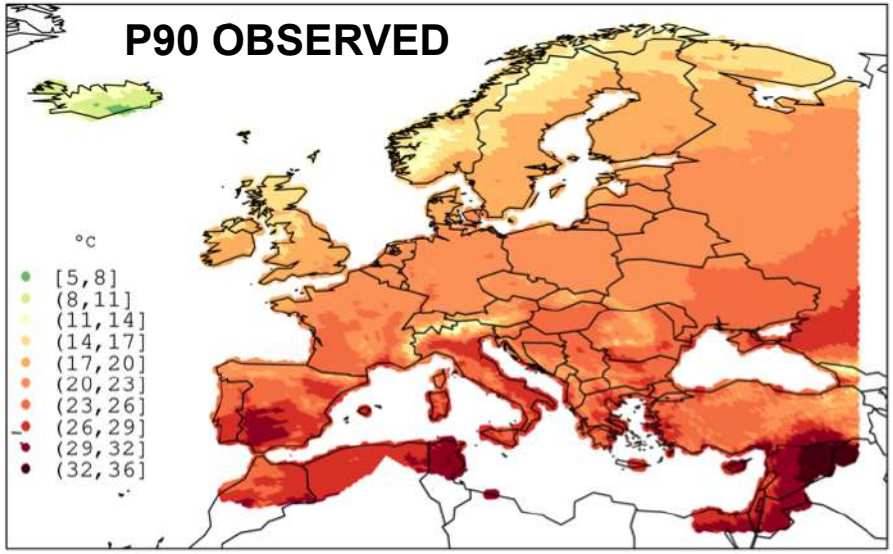
Fig. 1. Graphical sketch of heat wave duration (HWD) and amplitude (HWA, gray shading) exceedances. T_{th} and d_{th} denote the thermal stress and duration thresholds, respectively.

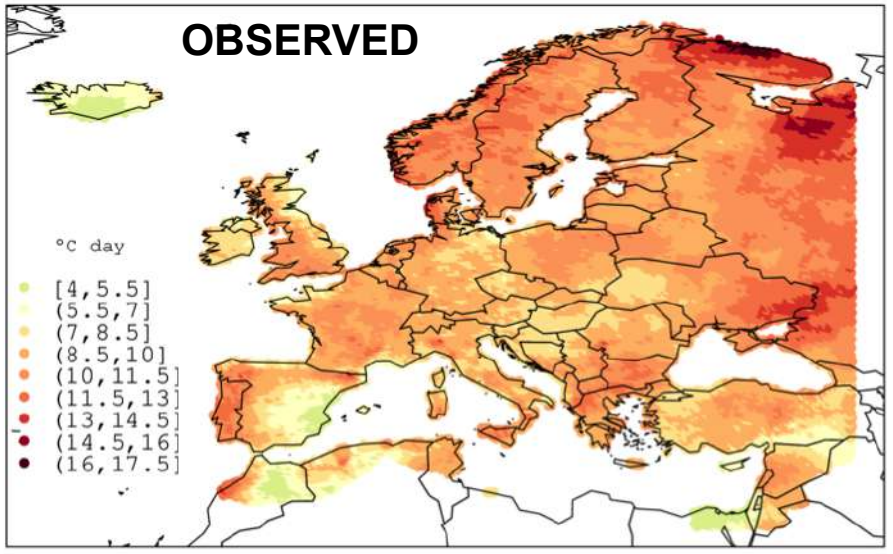
HWA = HWT−Tth HWF

T_{th}: thermal stress
HWF: heat wave day frequency
HWT: integral of the maximum daily temperatures over the duration of each individual heat wave, and accumulated for all heat waves in a given time interval

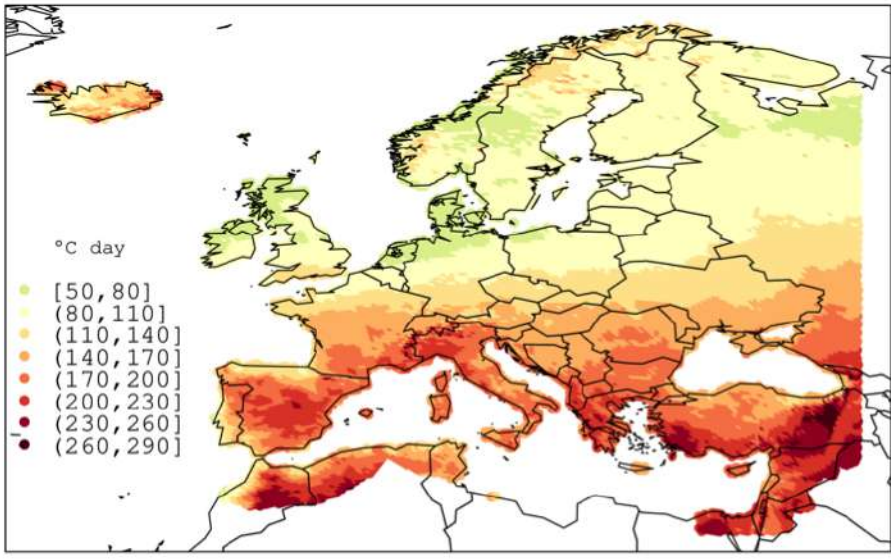
3.1.2 HEAT WAVES. HWA

SUMMER

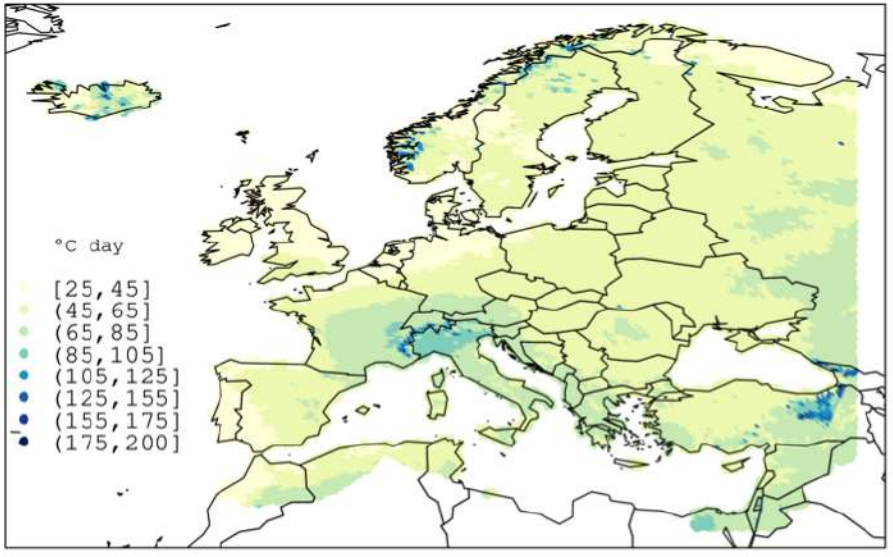




FUTURE MULTI-MODEL MEAN CHANGE



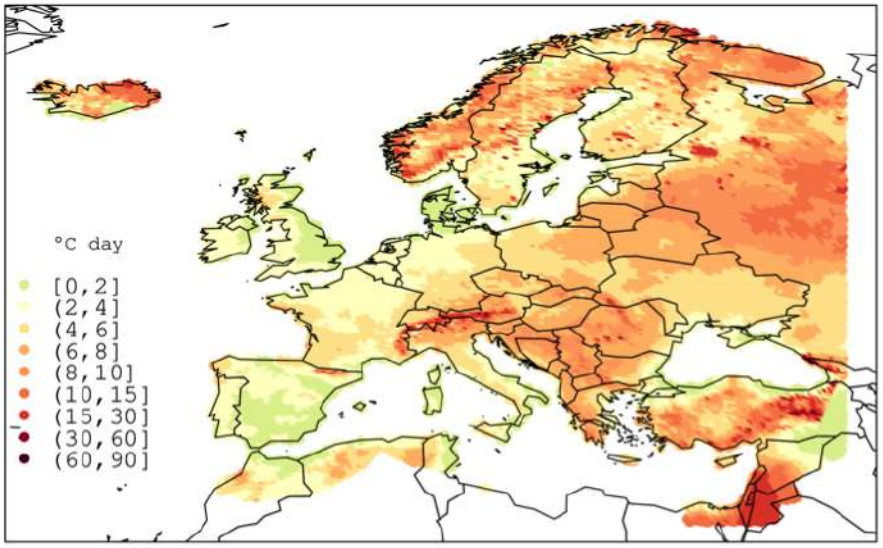
SD (FUTURE MULTI-MODEL MEAN CHANGE)



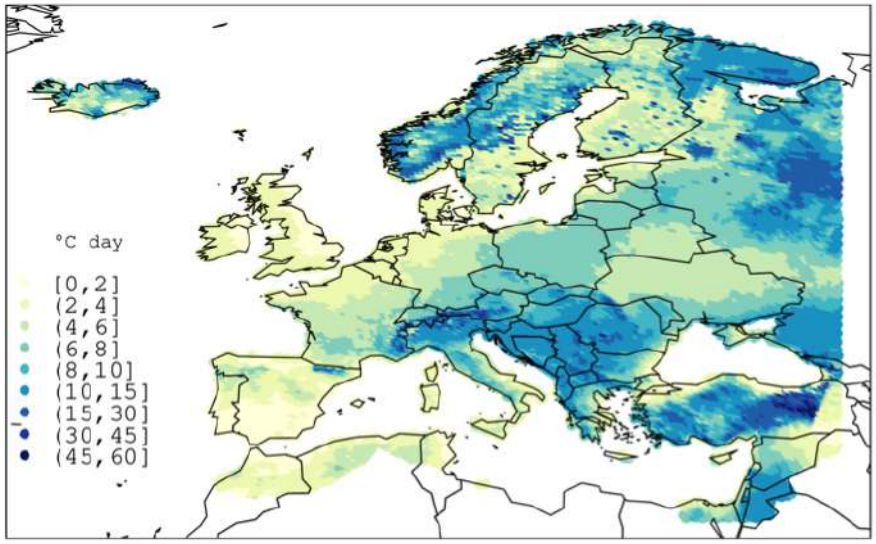
3.1.2 HEAT WAVES

SPRING

FUTURE MULTI-MODEL MEAN CHANGE

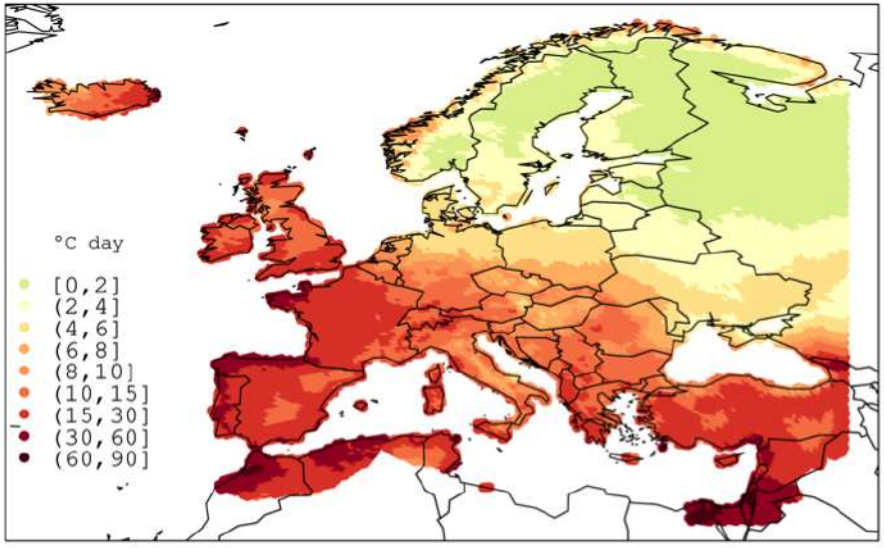


SD (FUTURE MULTI-MODEL MEAN CHANGE)

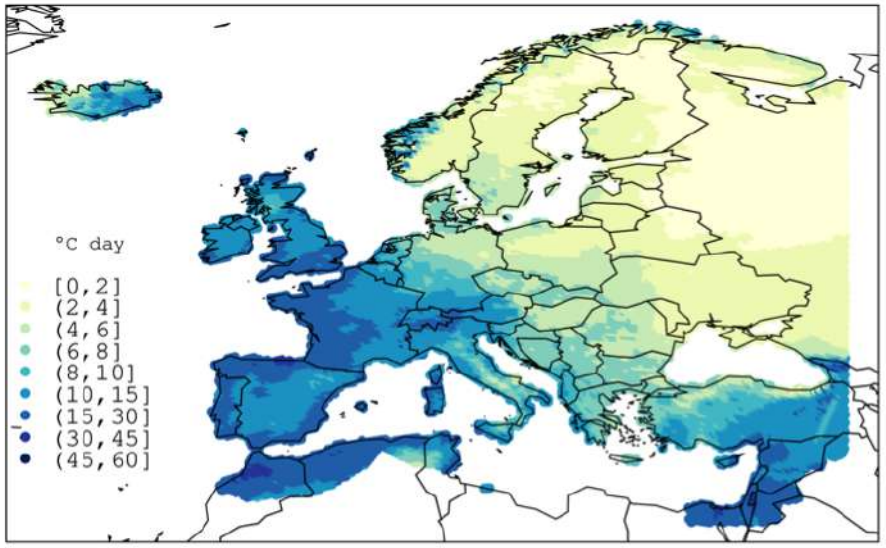


AUTUMN

FUTURE MULTI-MODEL MEAN CHANGE



SD (FUTURE MULTI-MODEL MEAN CHANGE)

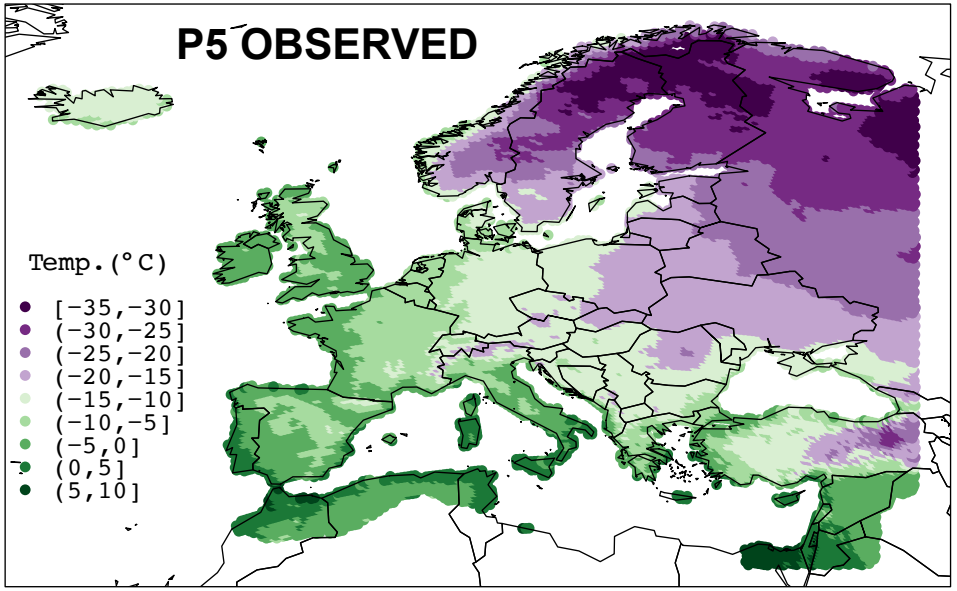


3. Results. Temperature extremes

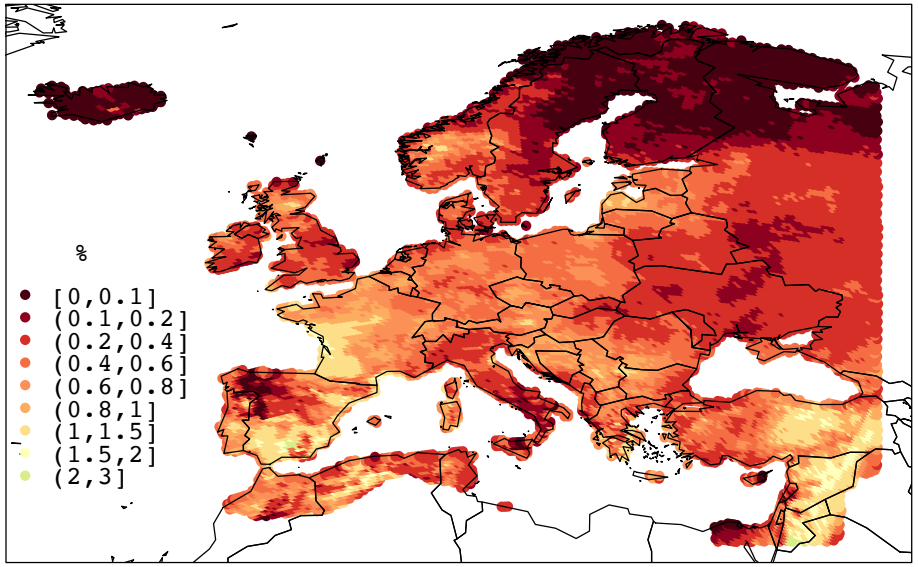
WINTER

3.1.3 COLD NIGHTS

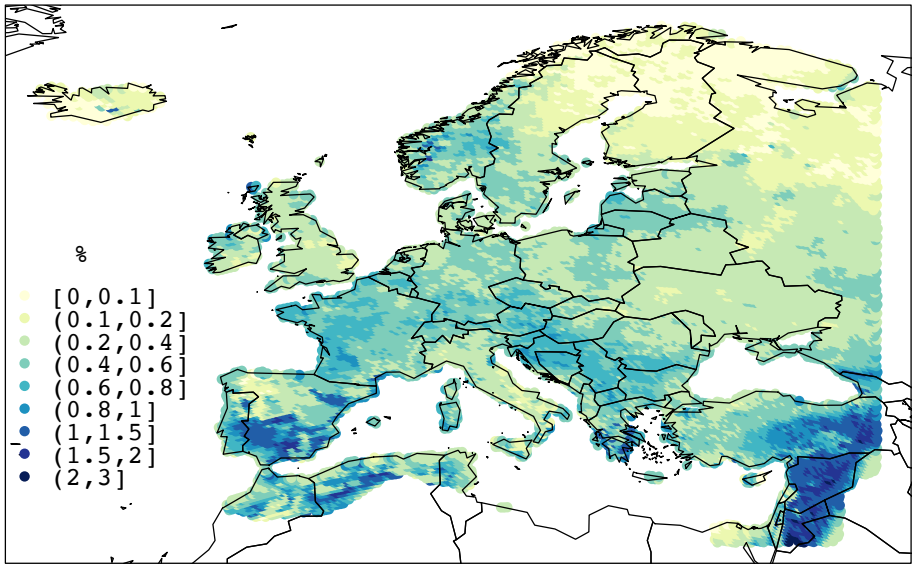
Day in which daily <u>minimum temperature</u> values are UNDER the observed P5 of minimum temperature in winter



FUTURE MULTI-MODEL MEAN



SD (FUTURE MULTI-MODEL MEAN)



3.1.4 COLD SPELL

A spell lasting dth = 3 or more consecutive days with *daily mean temperature* under 10th percentile of observed daily mean temperature in winter.

COLD SPELL AMPLITUDE (CSA)

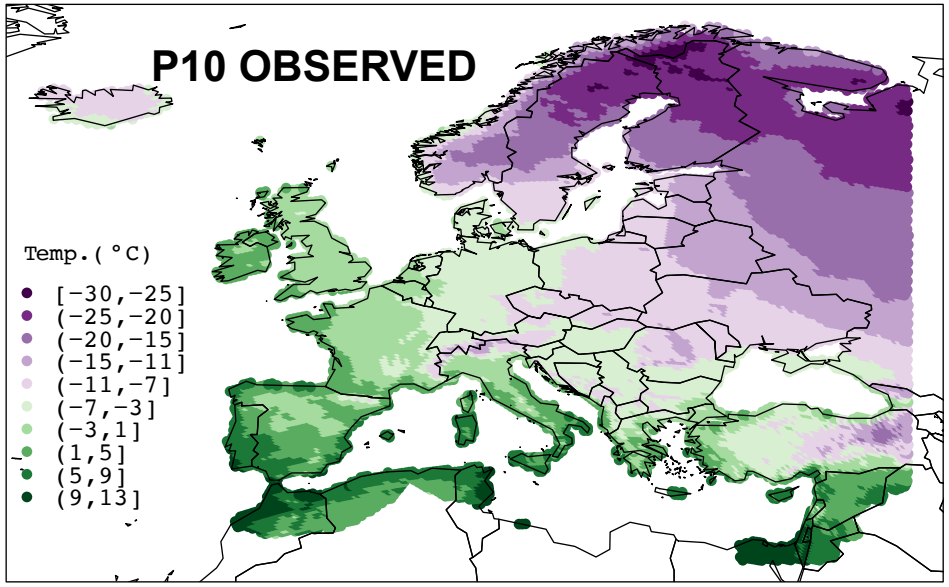
The accumulated cold stress exceedance for all the days under extreme conditions in a given time interval.

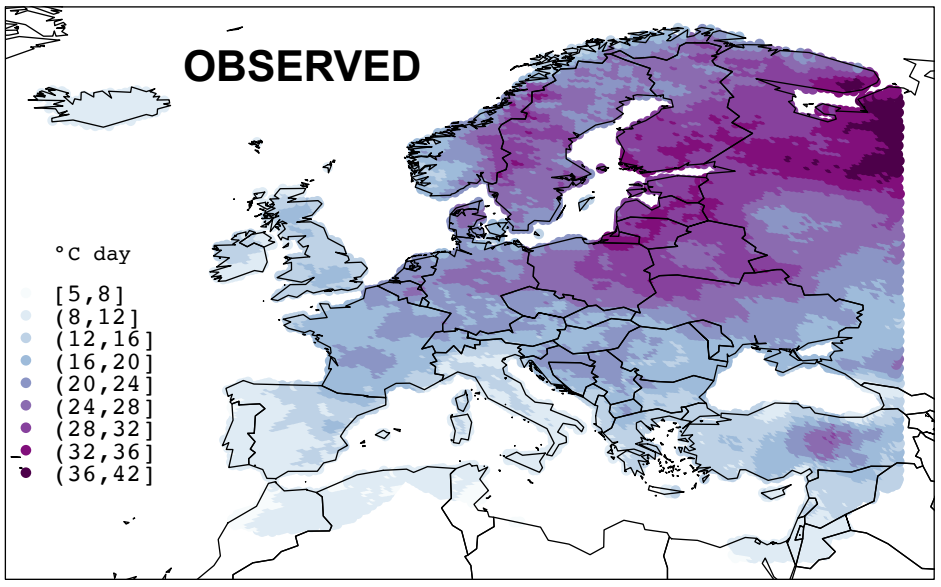
$$CSA = T_{th}\ \ CSF - CST$$

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

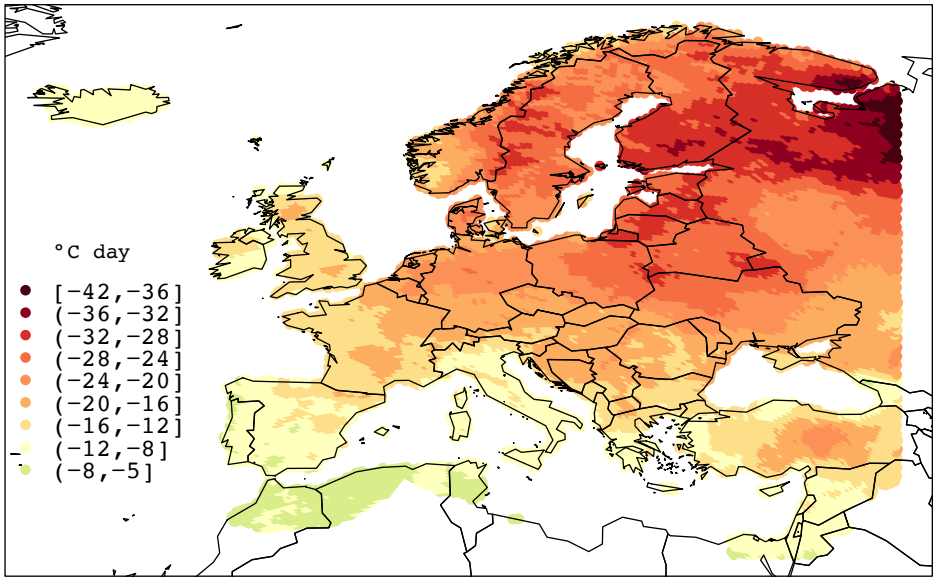
3.1.4 COLD SPELLS. CSA

WINTER

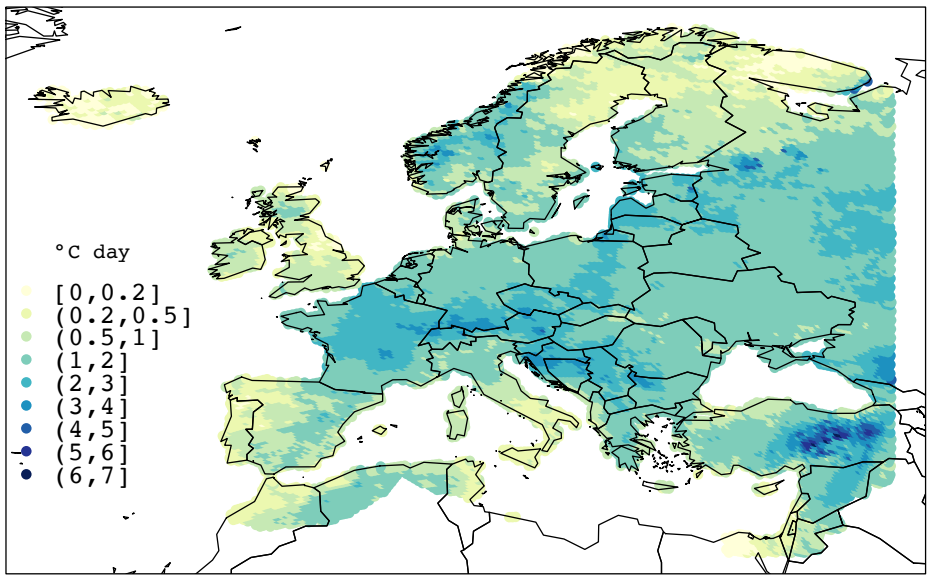




FUTURE MULTI-MODEL MEAN CHANGE



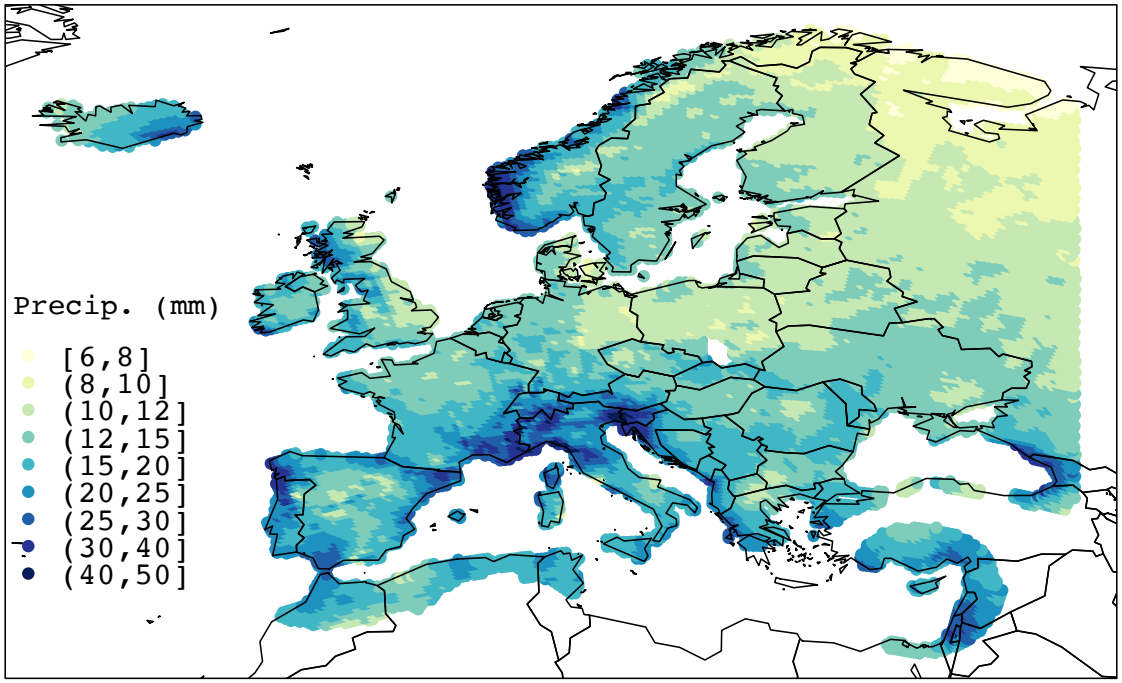
SD (FUTURE MULTI-MODEL MEAN CHANGE)



3. Results. Precipitation extremes

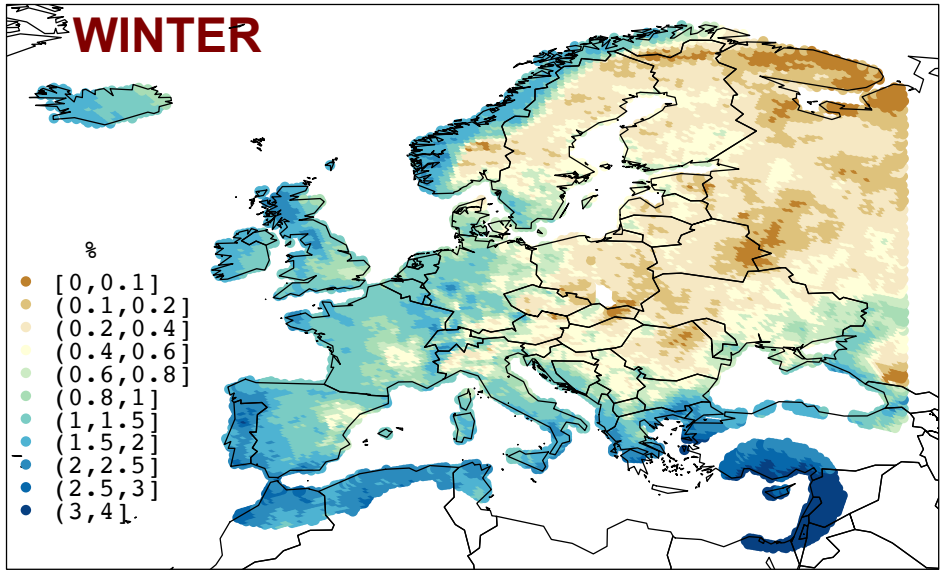
3.2.1 HEAVY PRECIPITATION DAY

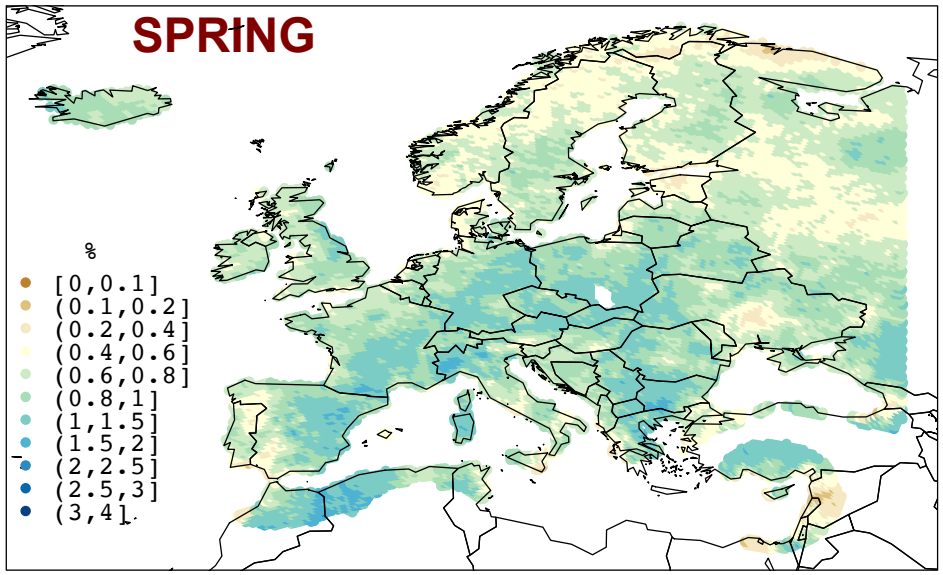
Day in which daily accumulated precipitation values are in EXCESS of the observed annual P95 (only days with precipitation >= 0.1mm).

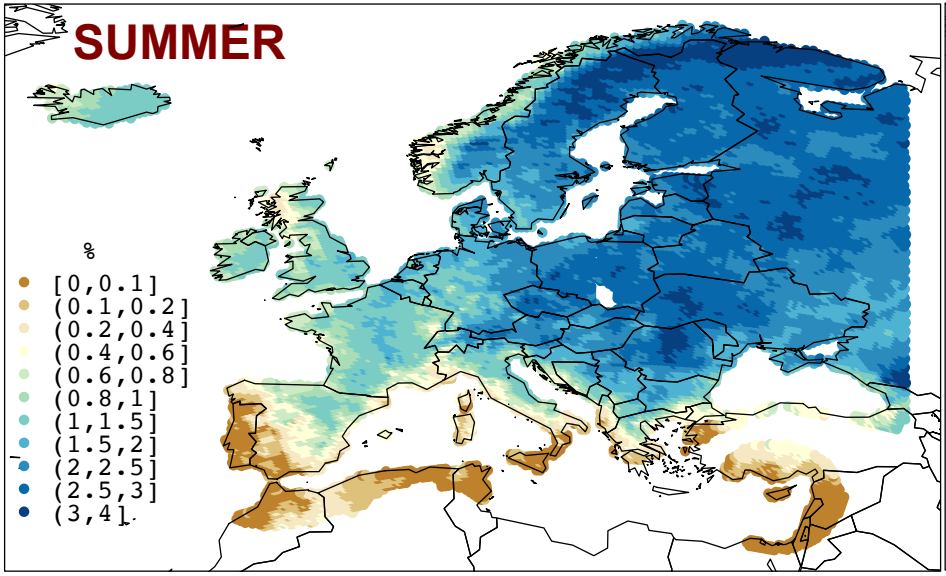


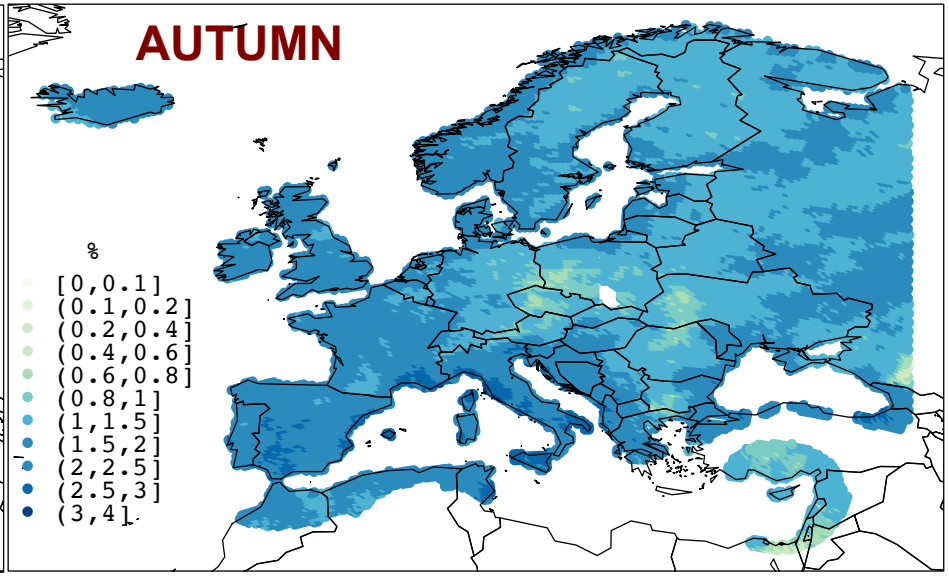
3.2.1 HEAVY PRECIPITATION DAYS.

OBSERVED



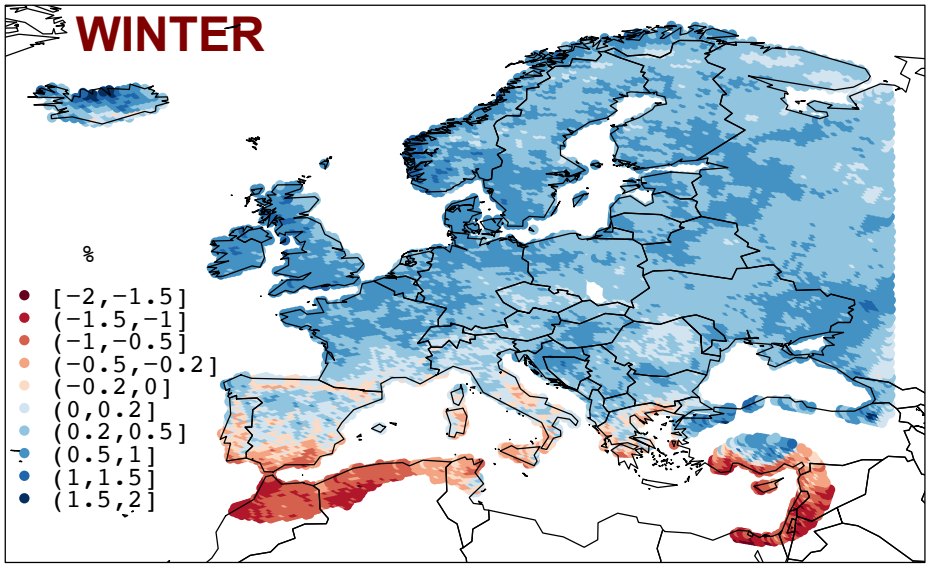


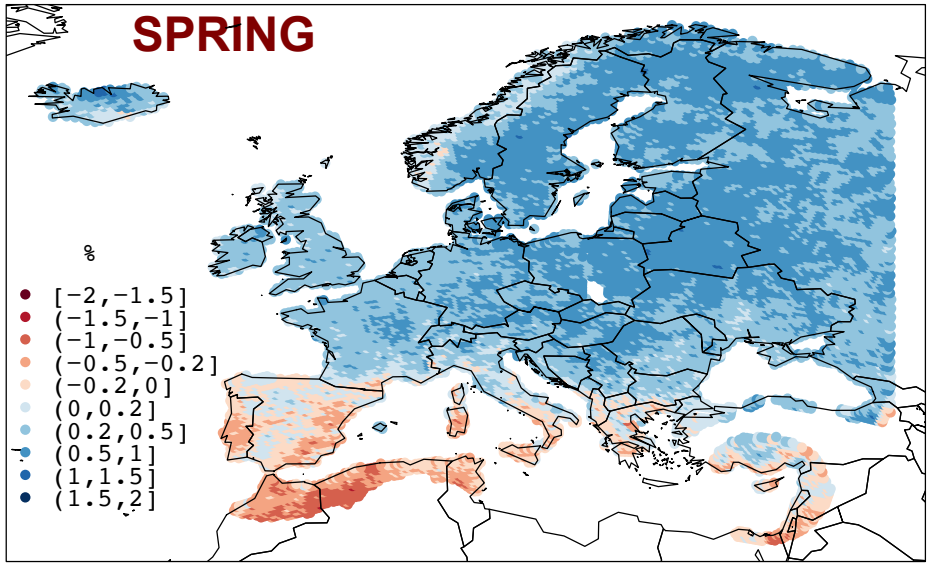


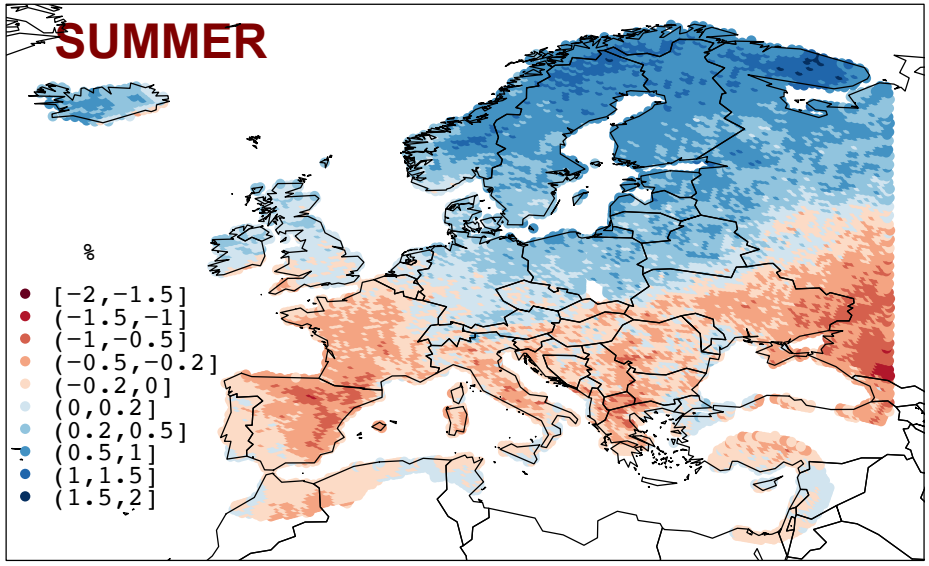


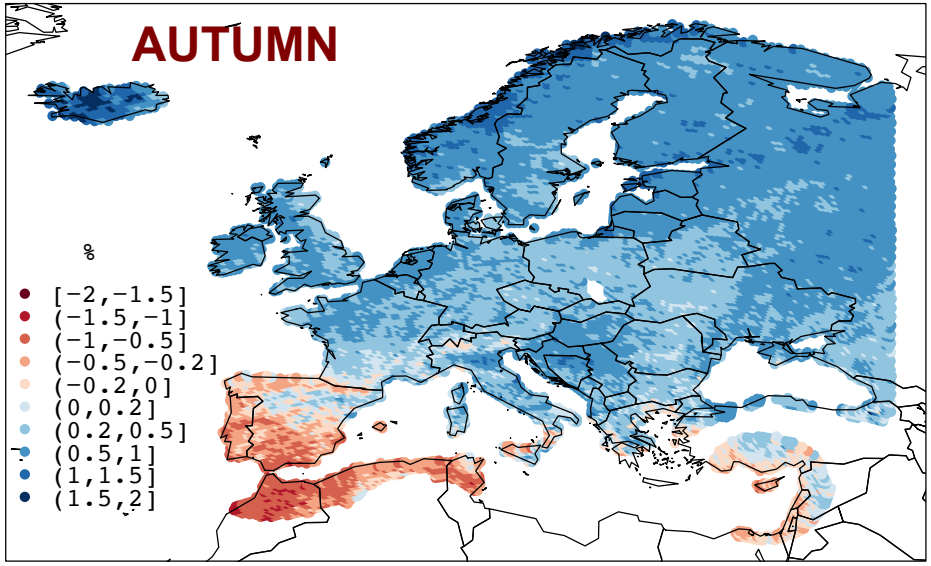
3.2.1 HEAVY PRECIPITATION DAYS.

FUTURE MULTI-MODEL MEAN CHANGE

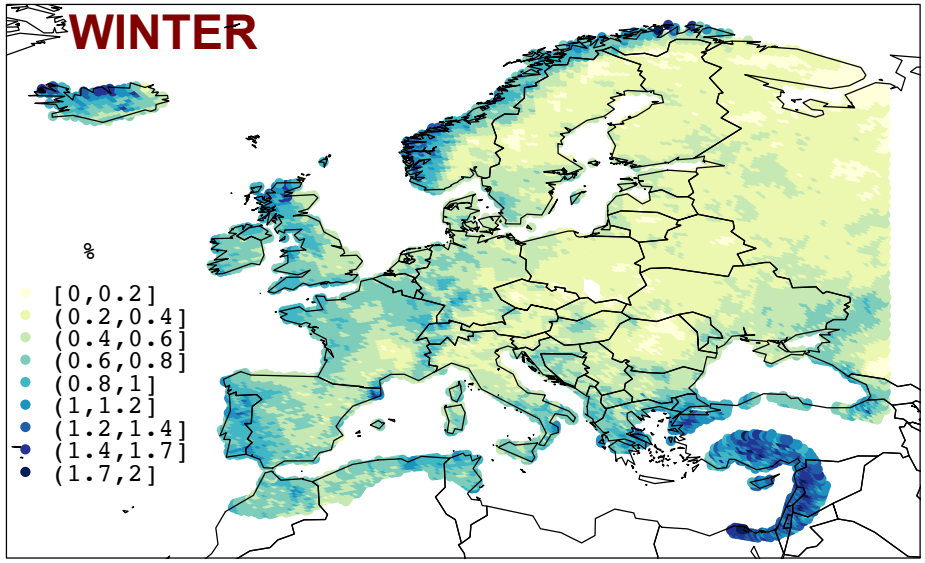


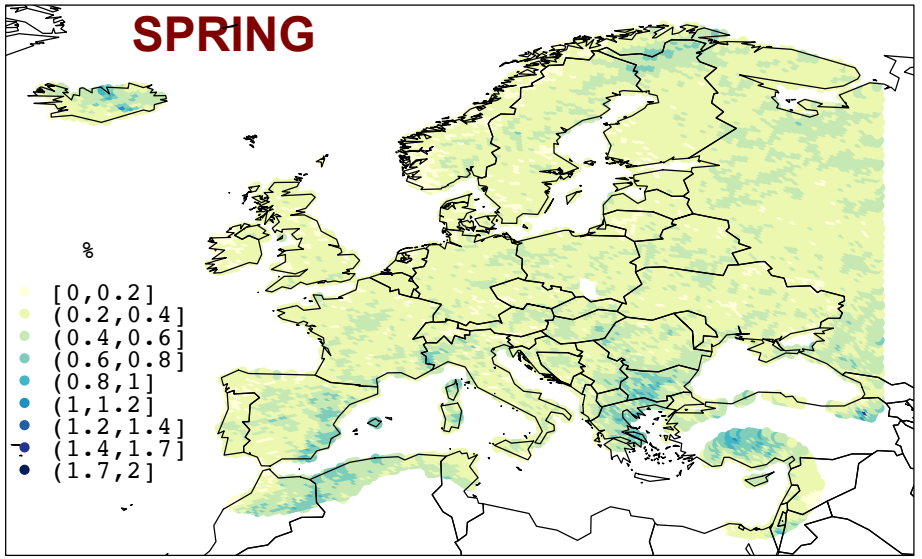


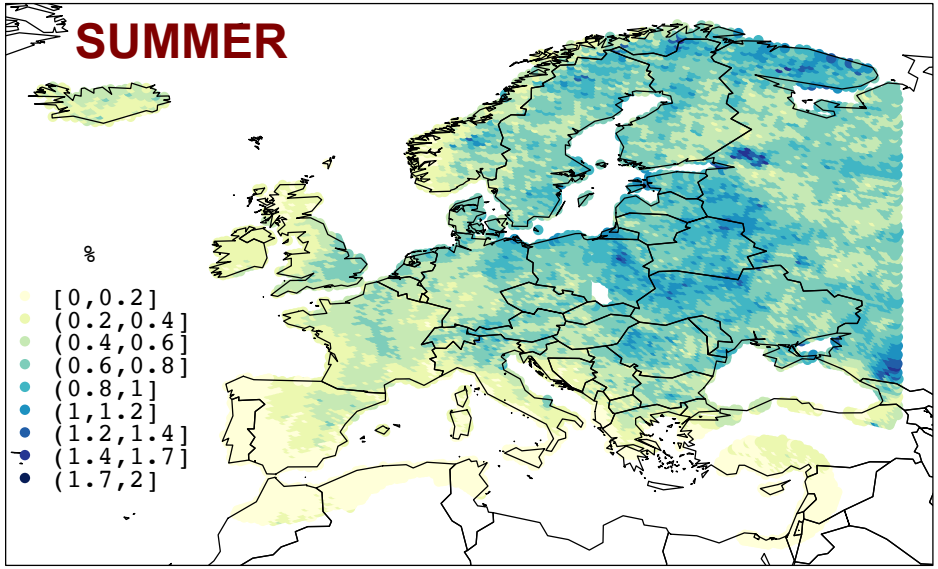


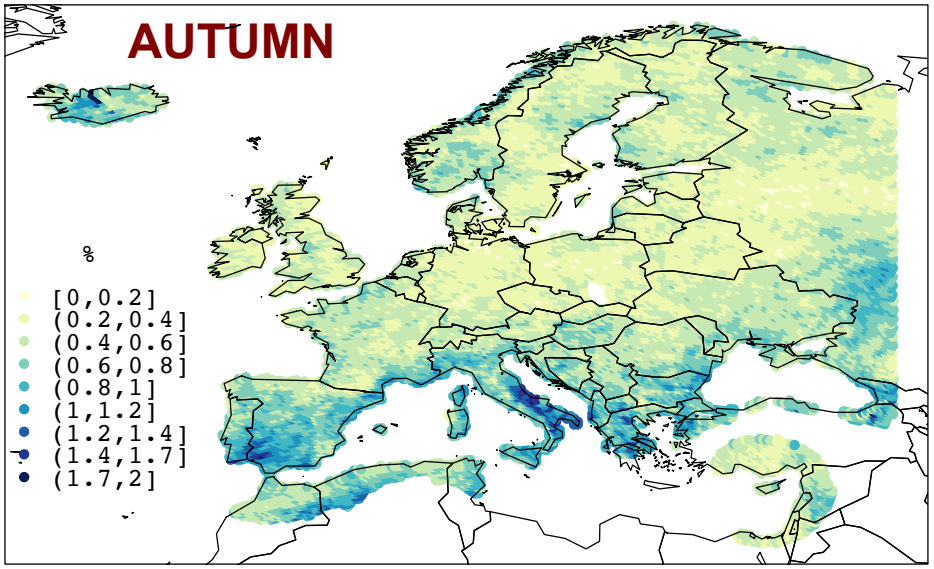


3.2.1 HEAVY PRECIPITATION DAYS. SD (FUTURE MULTI-MODEL MEAN CHANGE)









3. Results

3.2.2 HEAVY PRECIPITATION EPISODE

A spell lasting dth = 2 or more consecutive days with *daily precipitation above* 95th percentile (pr >=0.1mm) of observed daily annual precipitation

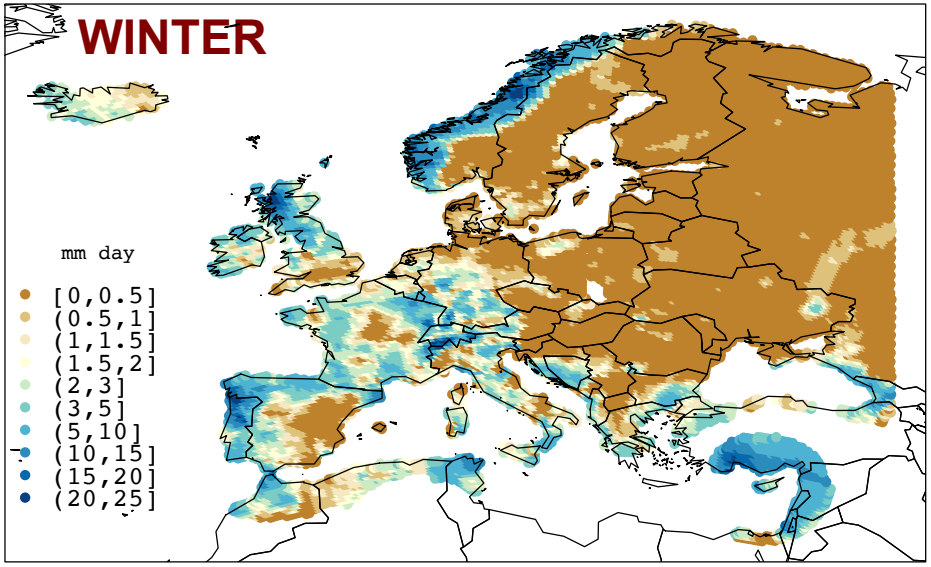
HEAVY PRECIPITATION AMPLITUDE (HPA)

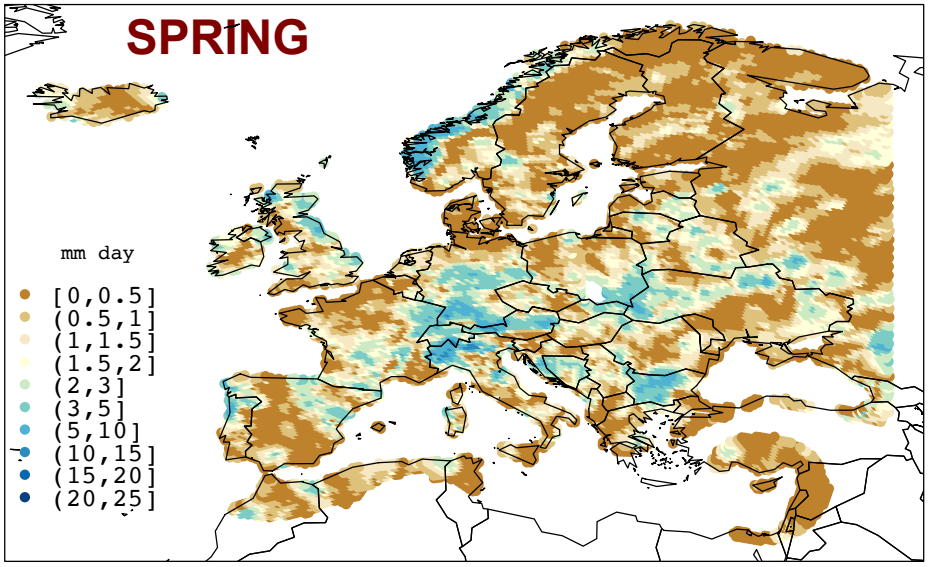
The accumulated precipitation stress exceedance for all the days under extreme conditions in a given time interval.

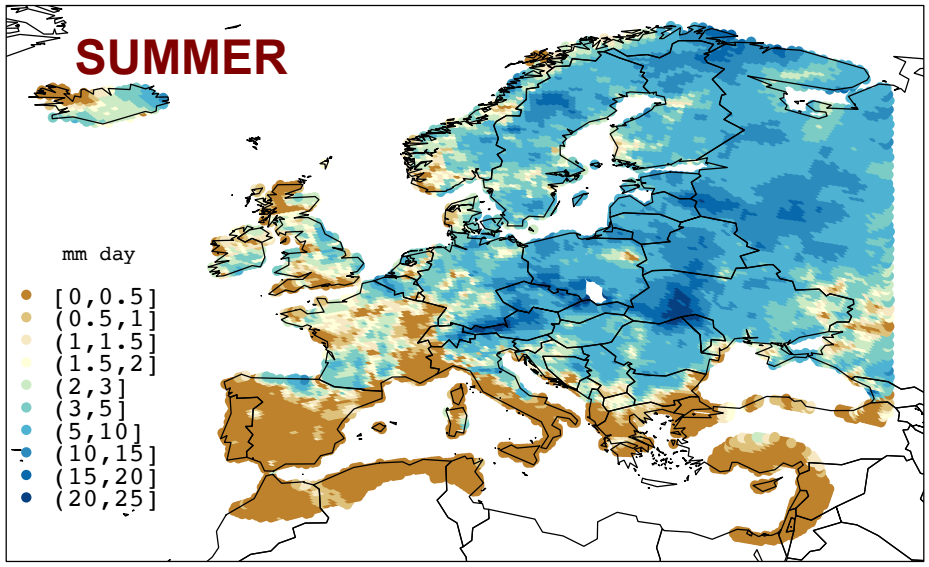
$$HPA = HPT - Tth \;\; HPF$$

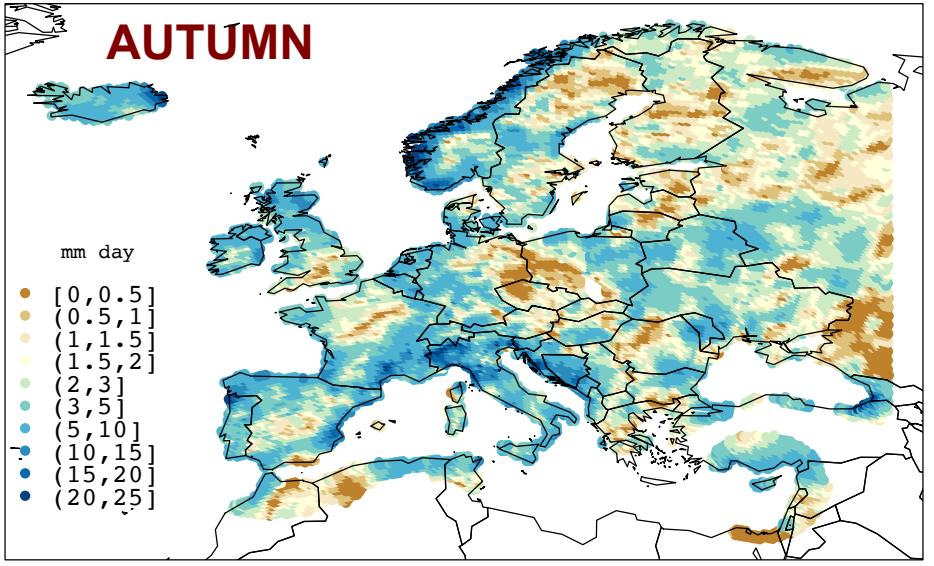
3.2.2 HEAVY PRECIPITATION EPISODE. HPA

OBSERVED



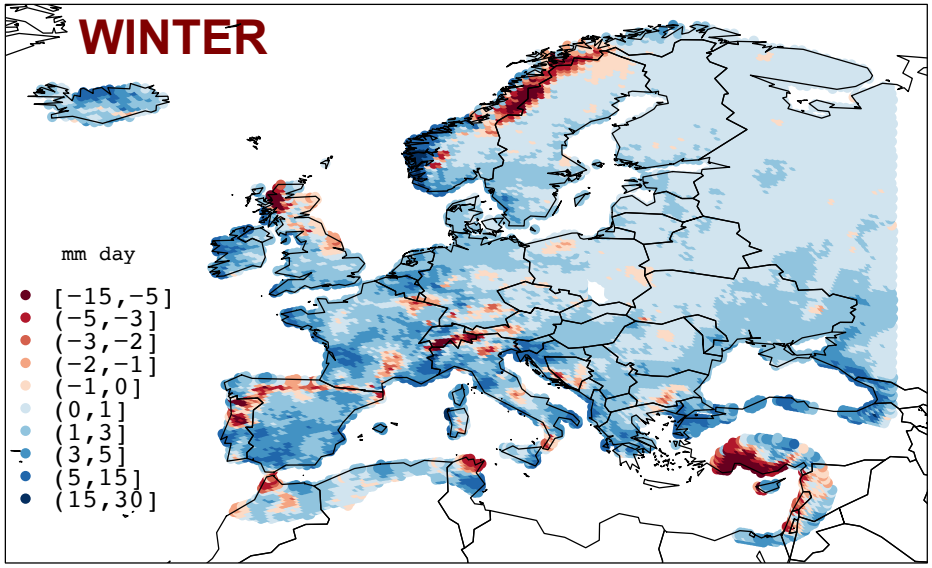


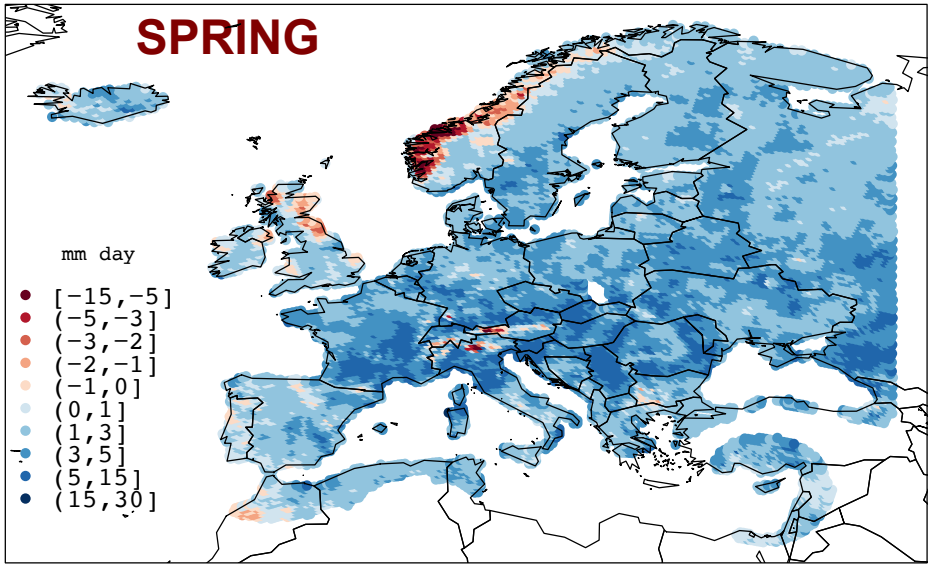


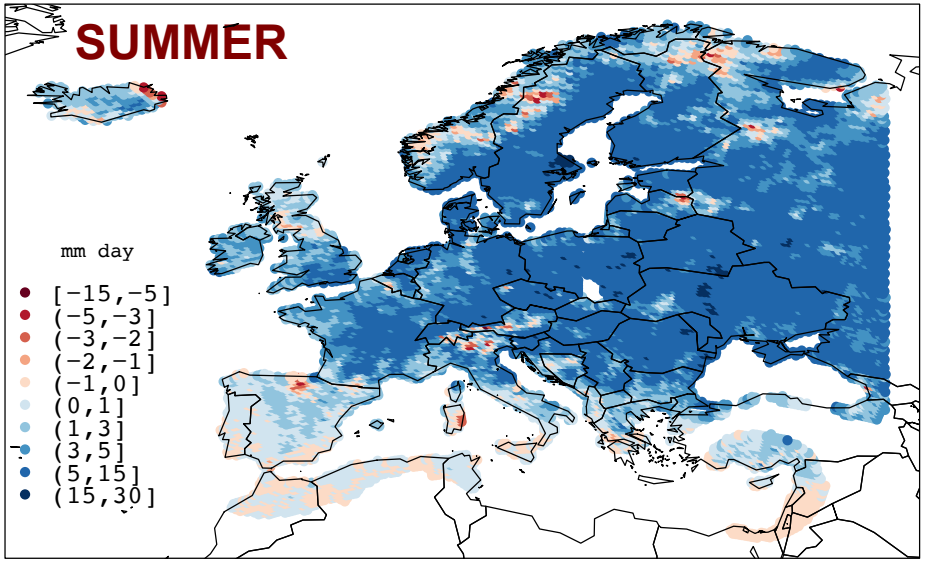


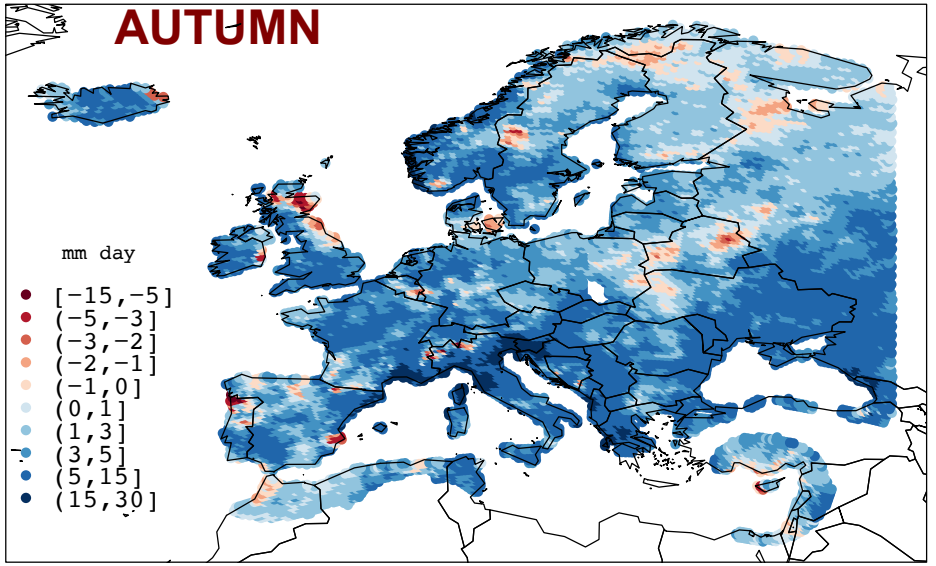
3.2.2 HEAVY PRECIPITATION EPISODE. HPA

FUTURE MULTI-MODEL MEAN CHANGE



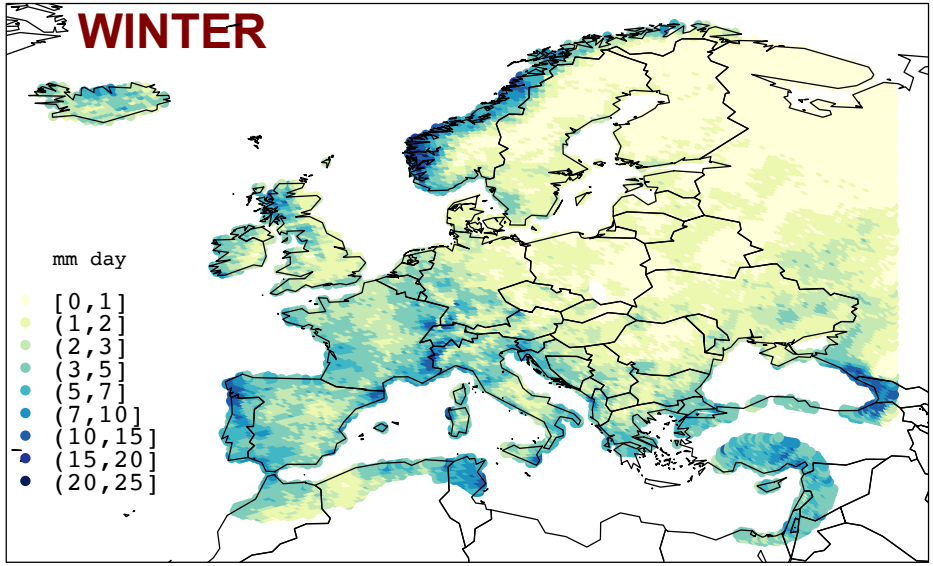


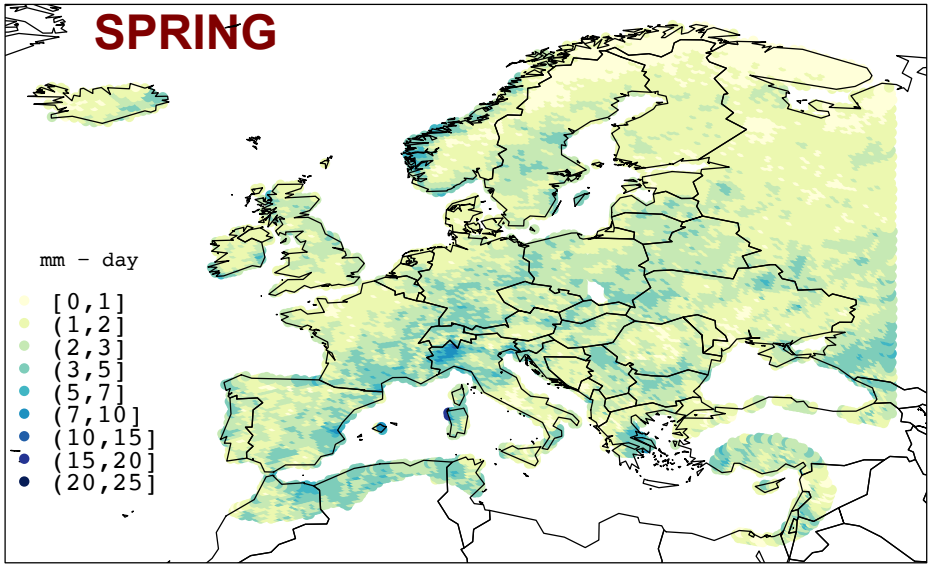


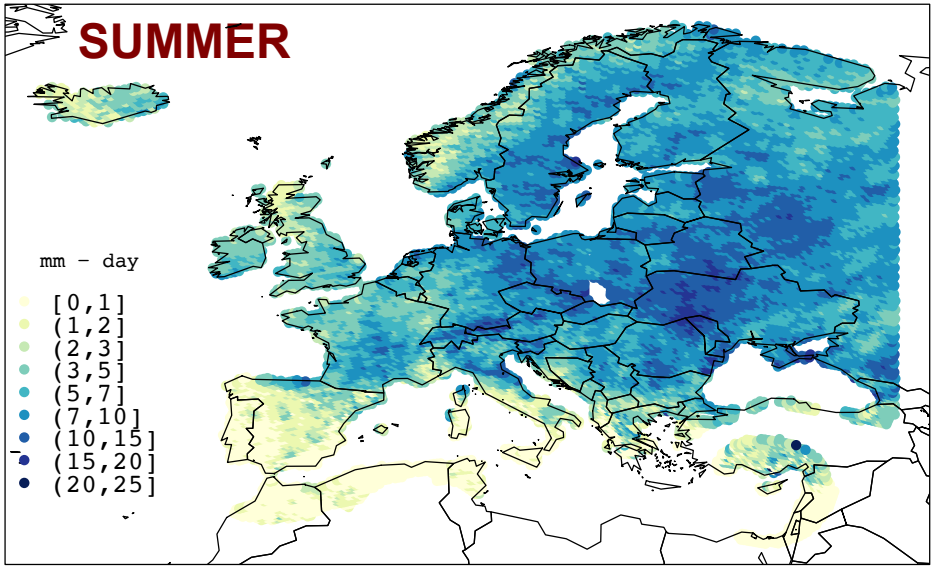


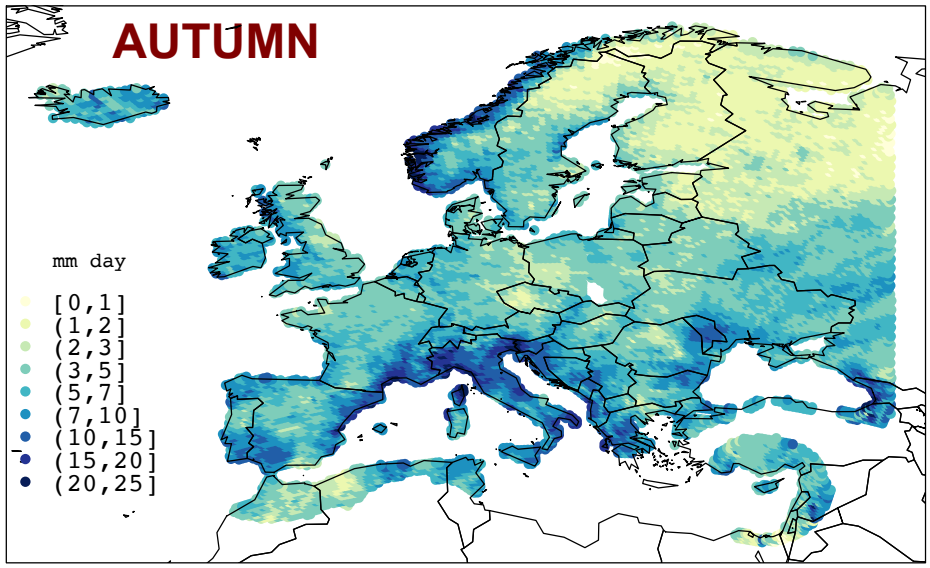
3.2.2 HEAVY PRECIPITATION EPISODE. HPA

SD FUTURE MULTI-MODEL MEAN CHANGE







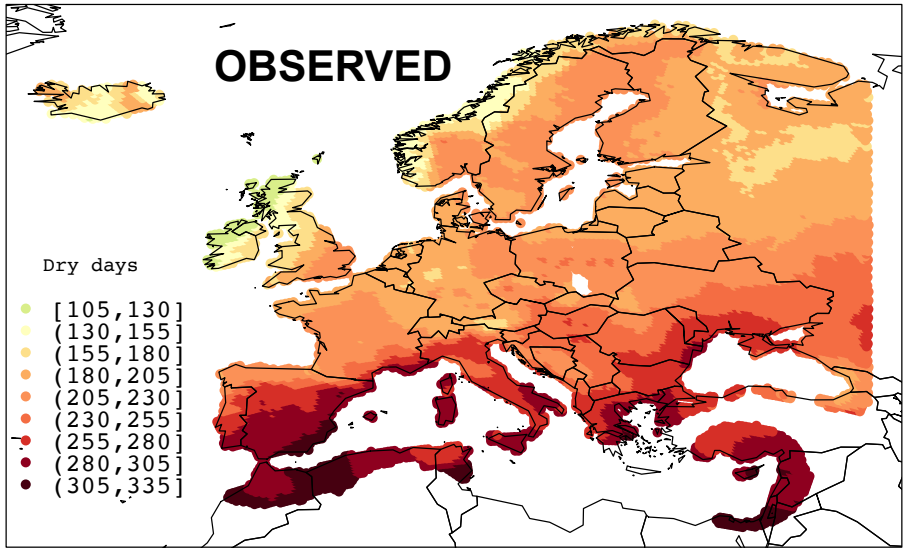


3. Results. Precipitation extremes

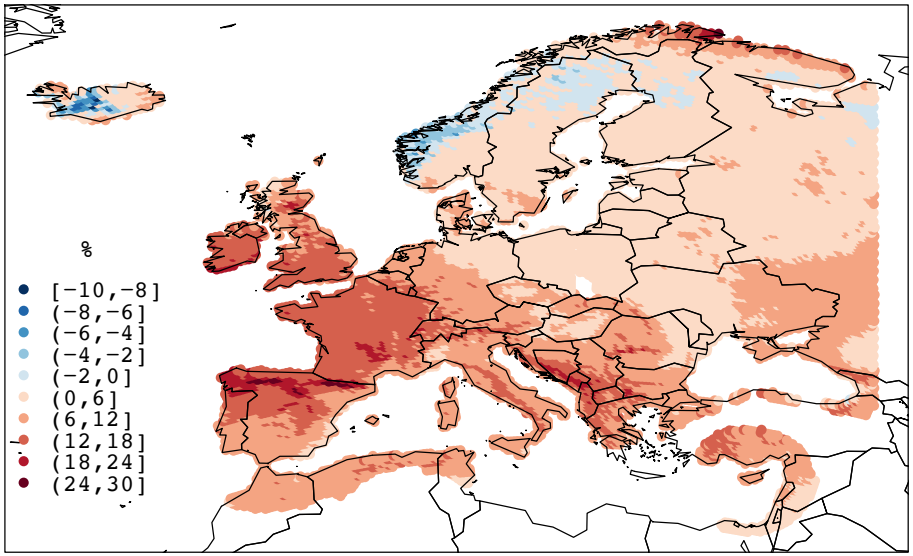
ANNUAL

3.2.3 DRY DAYS

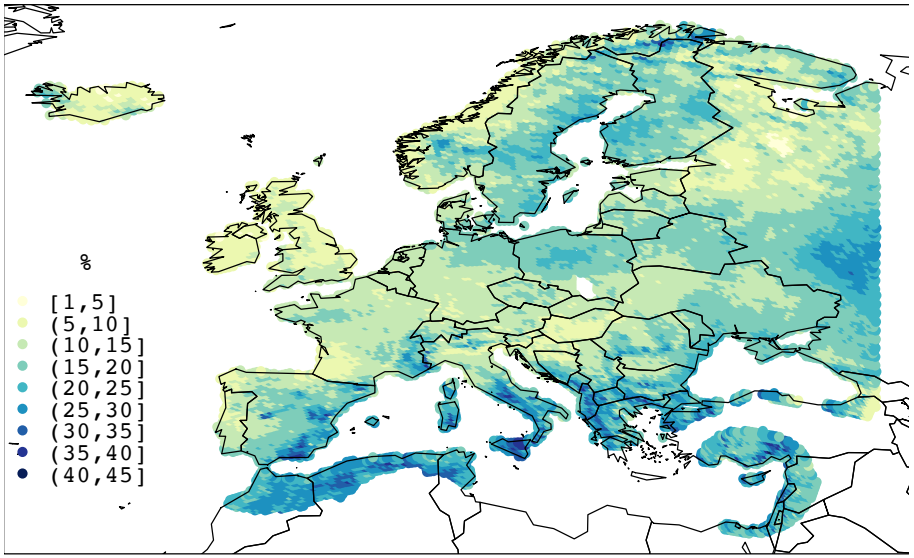
Day in which daily accumalted precipitation values are UNDER 0.1 mm



FUTURE MULTI-MODEL MEAN CHANGE

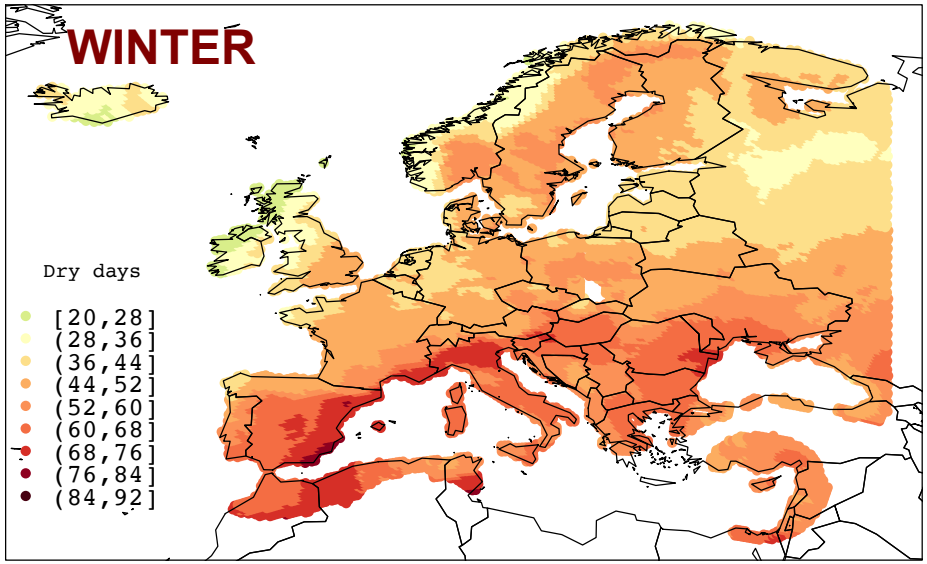


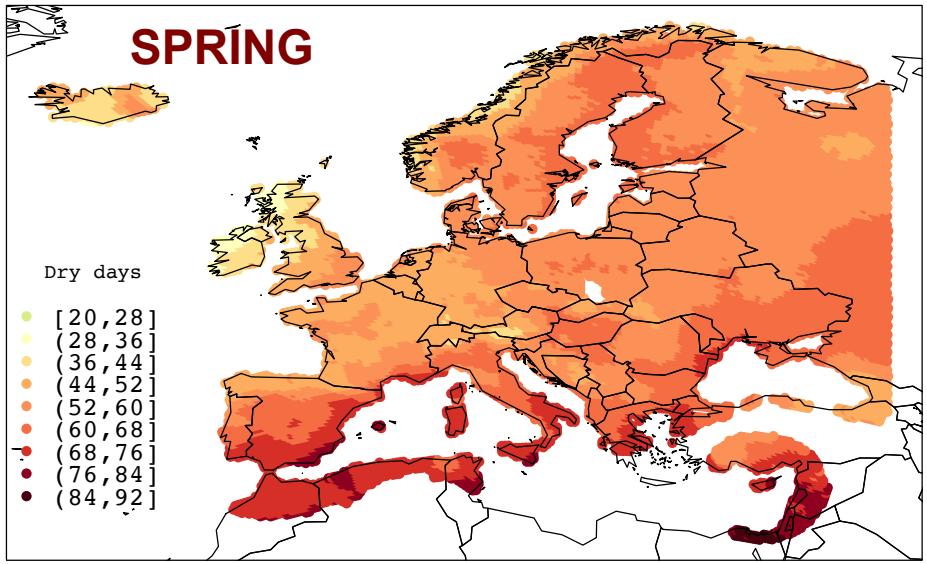
SD (FUTURE MULTI-MODEL MEAN CHANGE)

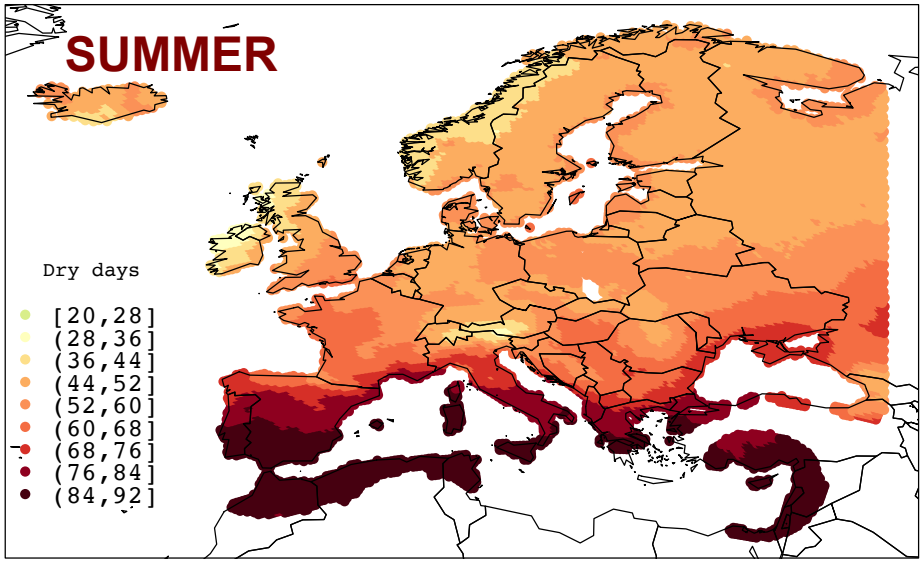


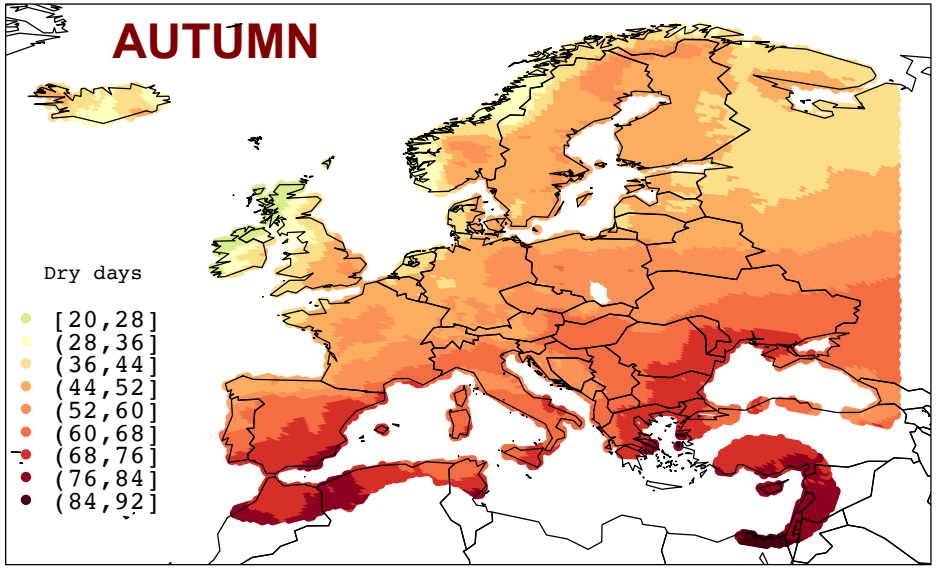
3.2.3 DRY DAYS.

OBSERVED



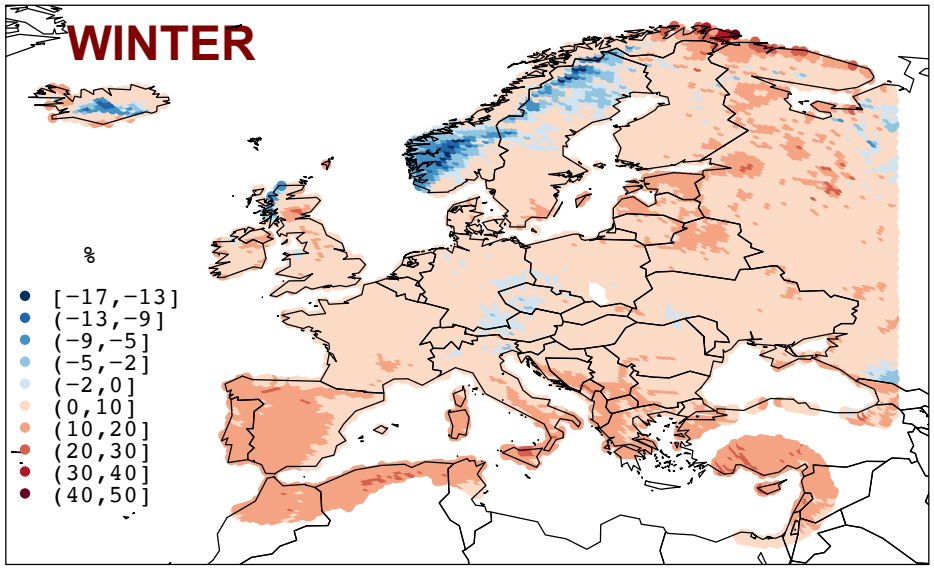


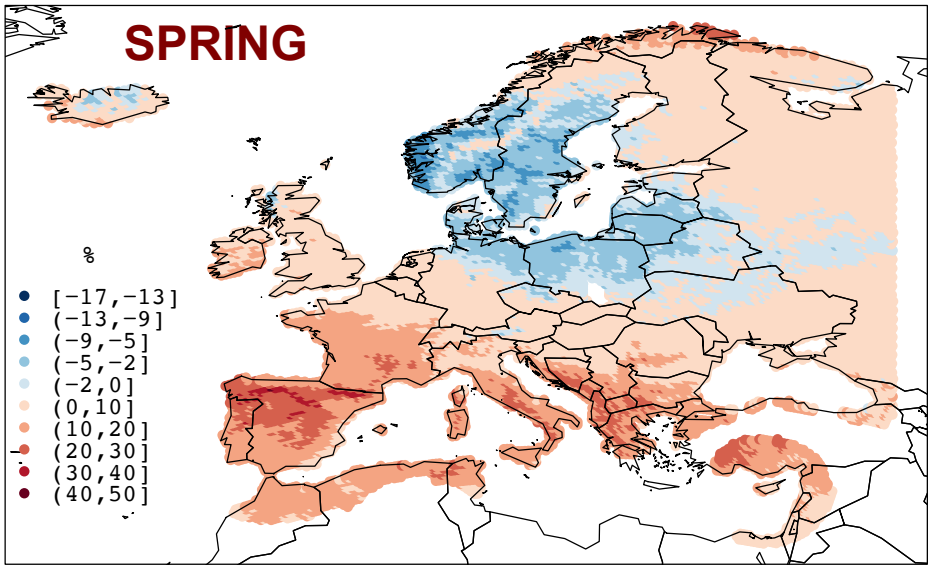


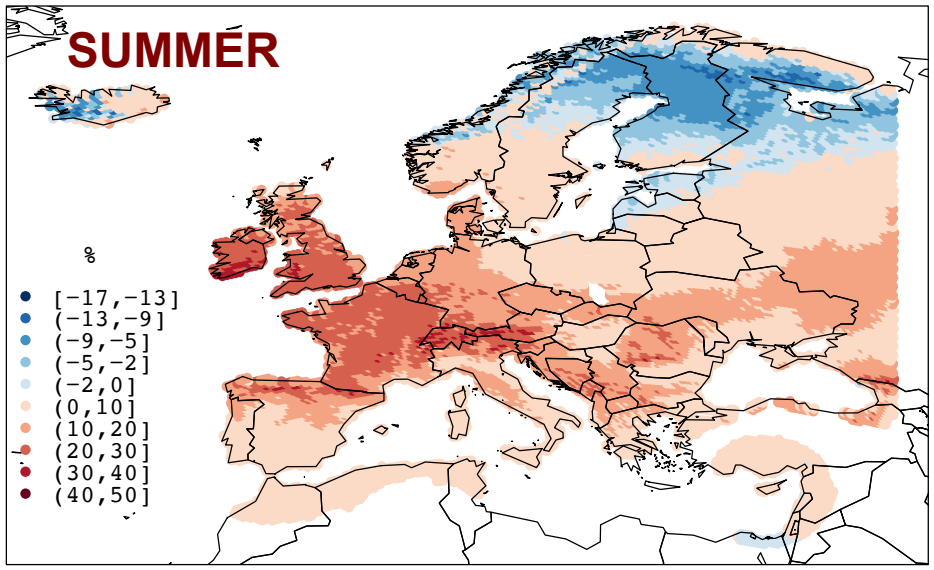


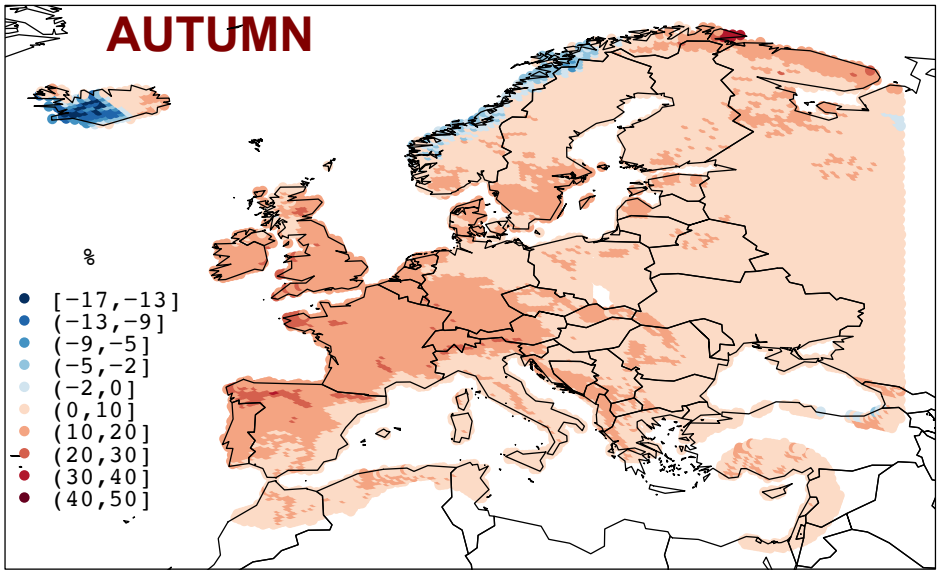
3.2.3 DRY DAYS.

FUTURE MULTI-MODEL MEAN CHANGE



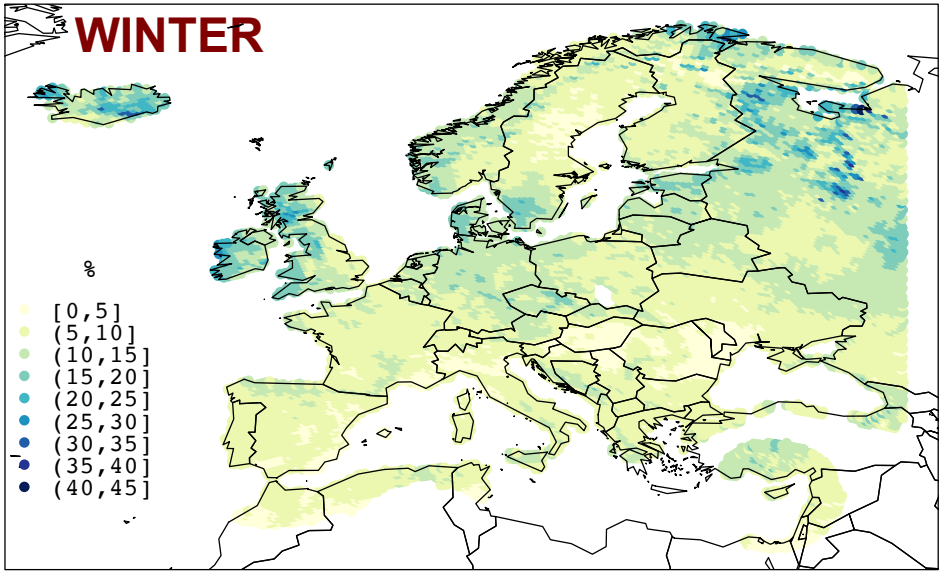


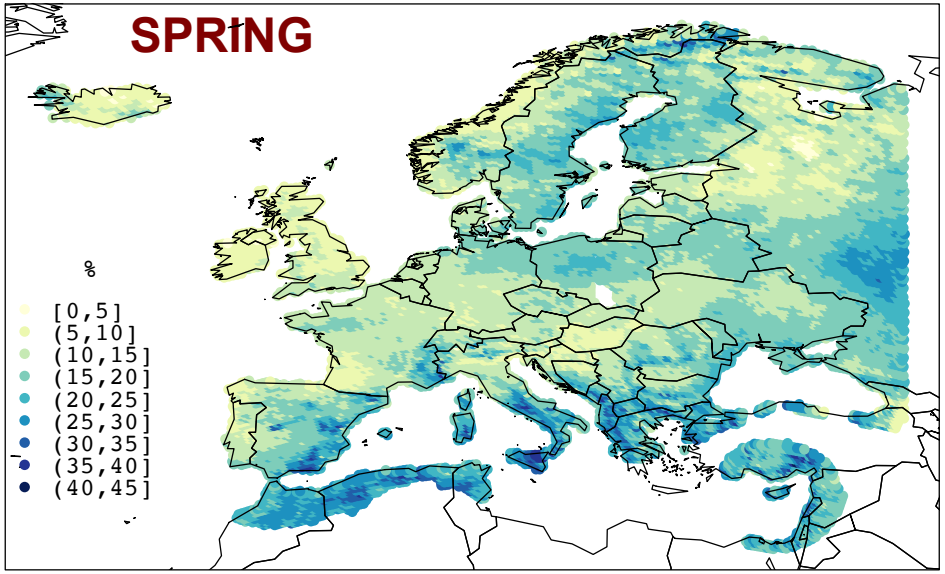


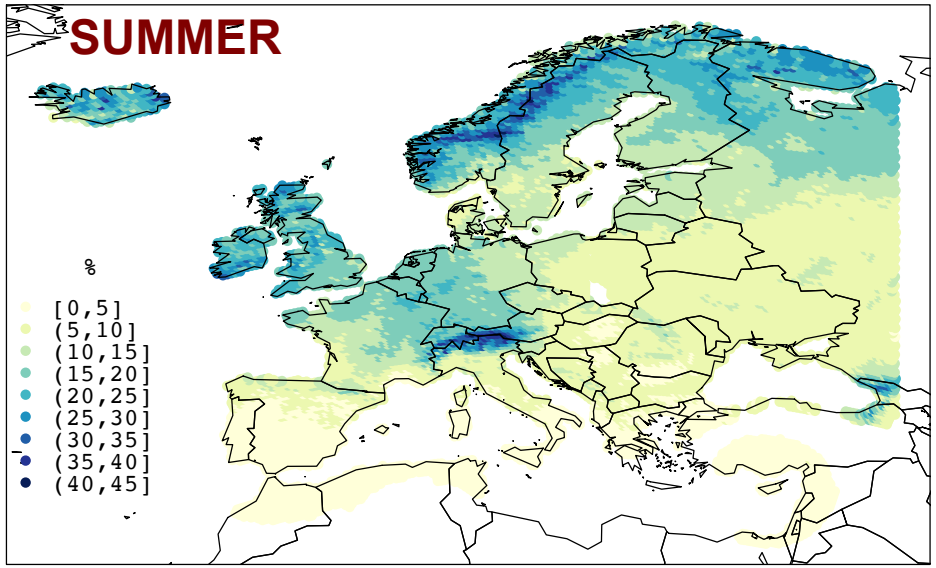


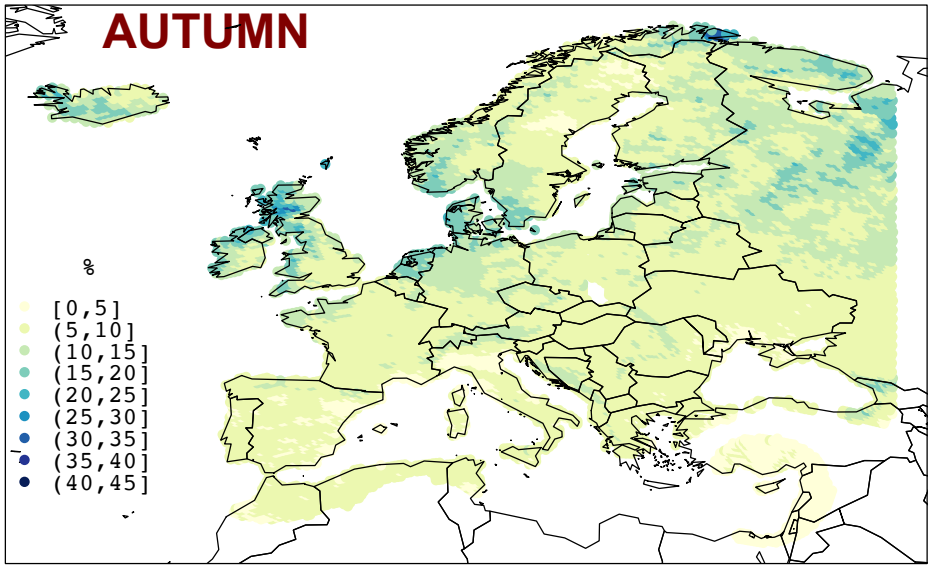
3.2.3 DRY DAYS.

SD FUTURE MULTI-MODEL MEAN CHANGE









3. Results

We firstly define **a dry spell** as period of at least 3 consecutive days with daily precipitation below 0.1 mm. The 95th percentile of the length of all identified dry spells in 1981-2005 is considered to analyse extended dry spells.

3.2.4 Droughts

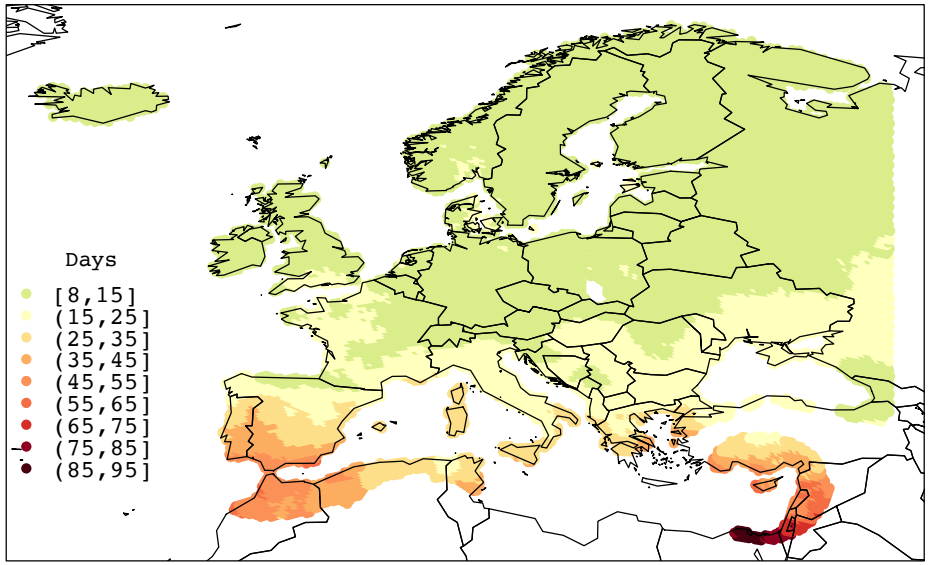
Dry spells with a length over the observed P95 of dry spell

Number of drougths with a duration over P95 of observed dry spell duration

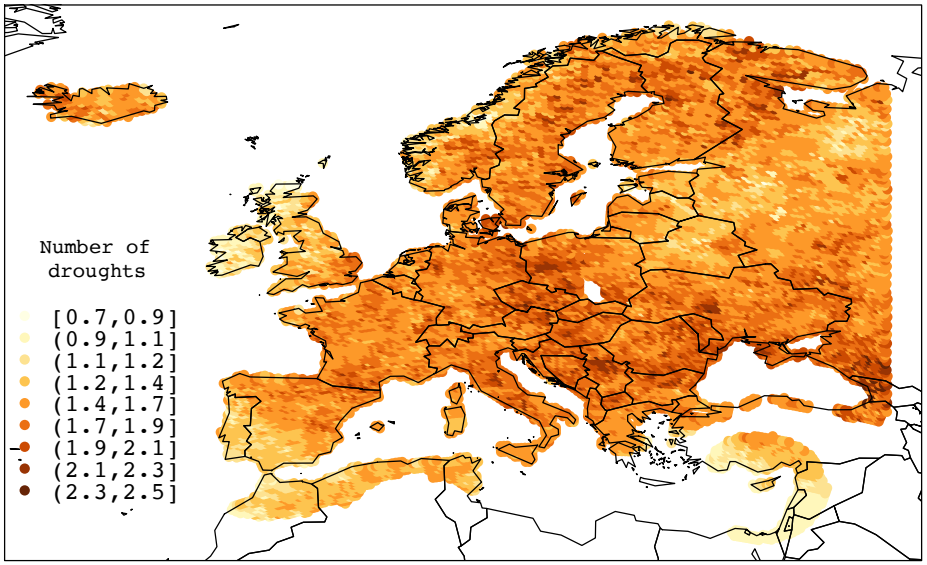
3.2.4 DROUGHTS.

ANNUAL

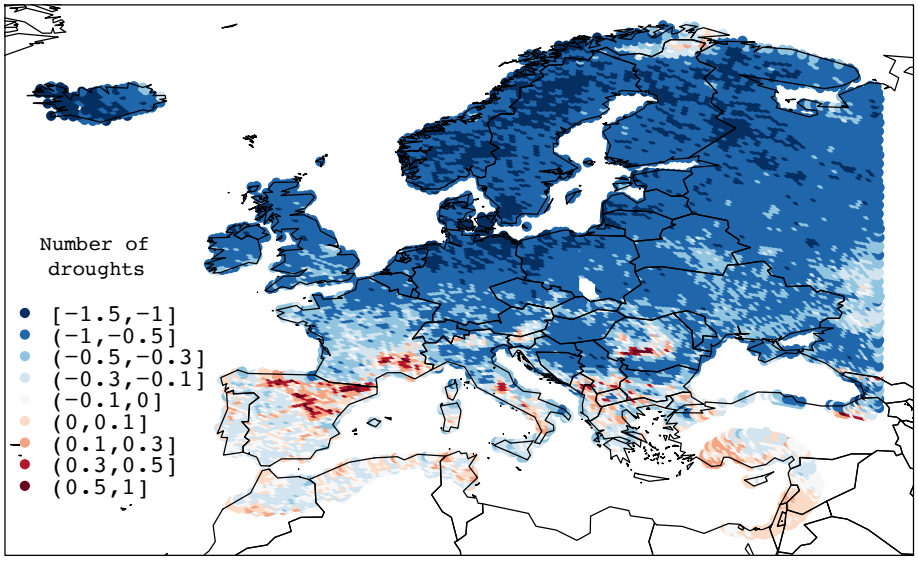
P95 OBSERVED dry spell duration



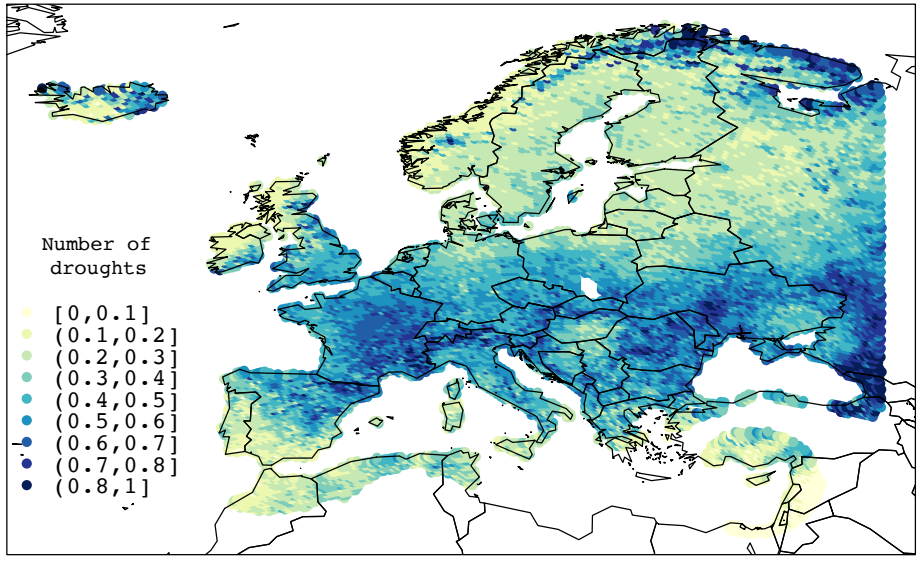
OBSERVED



FUTURE MULTI-MODEL MEAN CHANGE



SD (FUTURE MULTI-MODEL MEAN CHANGE)



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

Cardell, M., Romero, R., Amengual, A., Homar, V., and Ramis, C. (2019a). A quantile-quantile adjustment of the EURO-CORDEX projections for temperatures and precipitation. International Journal of Climatology, 39(6):2901–2918. https://doi.org/10.1002/joc.5991.

Cardell, M., Amengual, A., Romero, R. and Ramis, C. (2019c). Future extremes of temperature and precipitation in Europe based on a combination of dynamical an statistical approaches.

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