WHAT KIND OF
ENVIRONMENTAL
TRANSITION
FOR THE MEDITERRANEAN REGION?

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The future climate of the Mediterranean region

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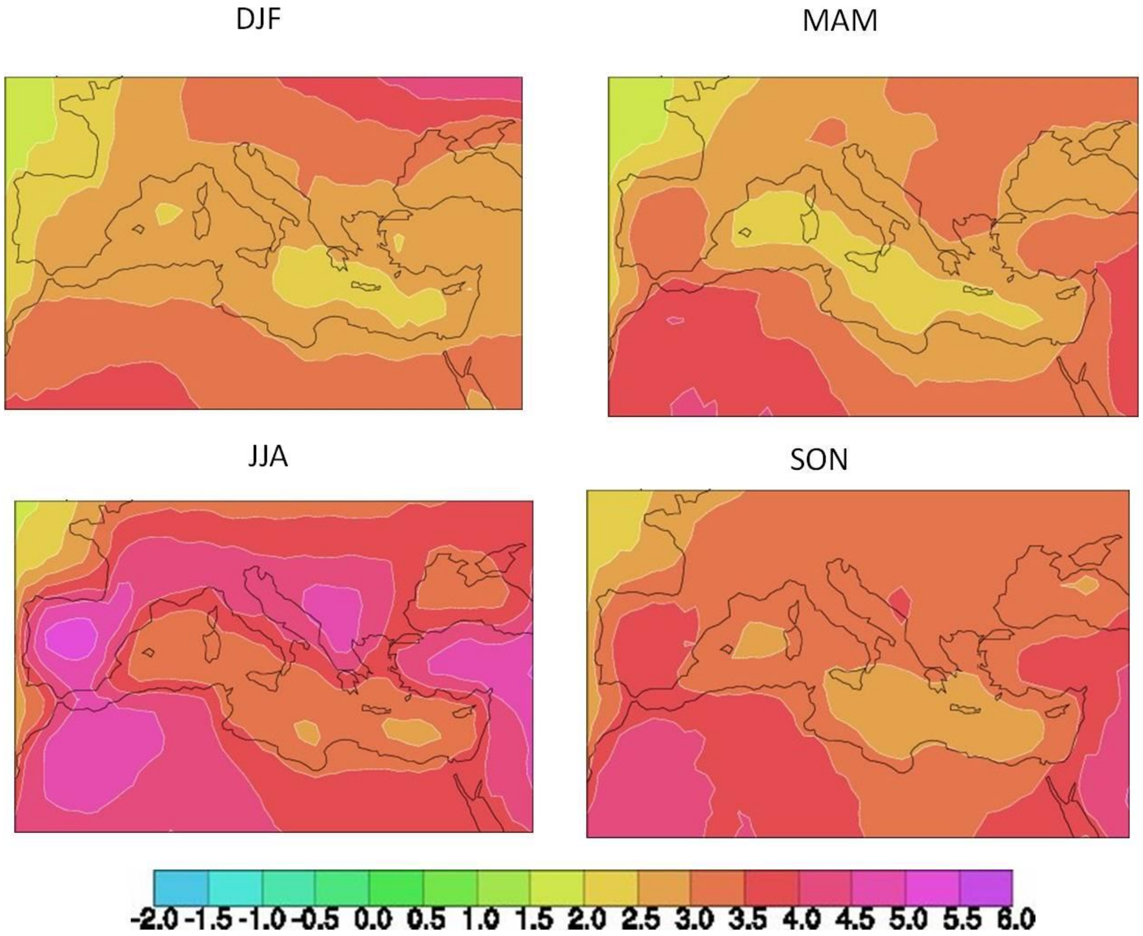
CMCC (Centro Euro Mediterraneo sui cambiamenti climatici)

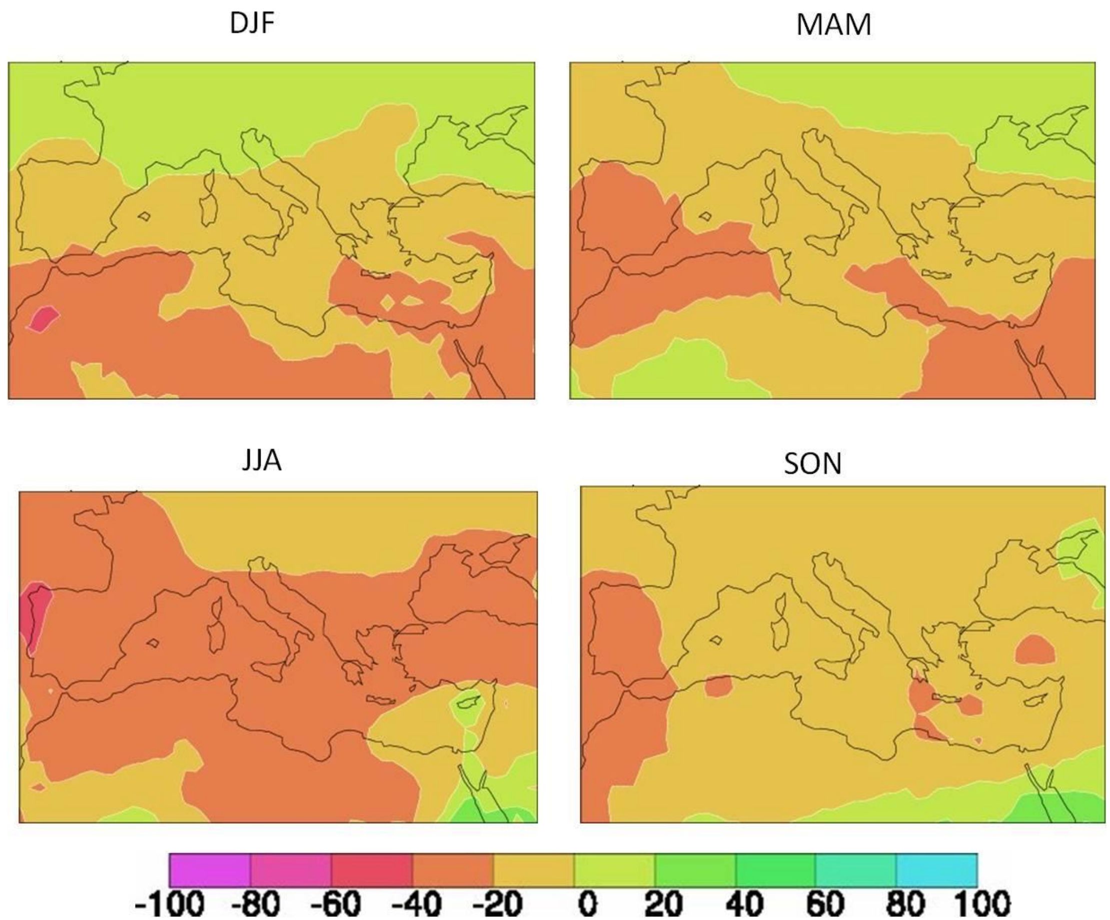
WITH SUPPORT BY :

temperature change at the end of the 21st century



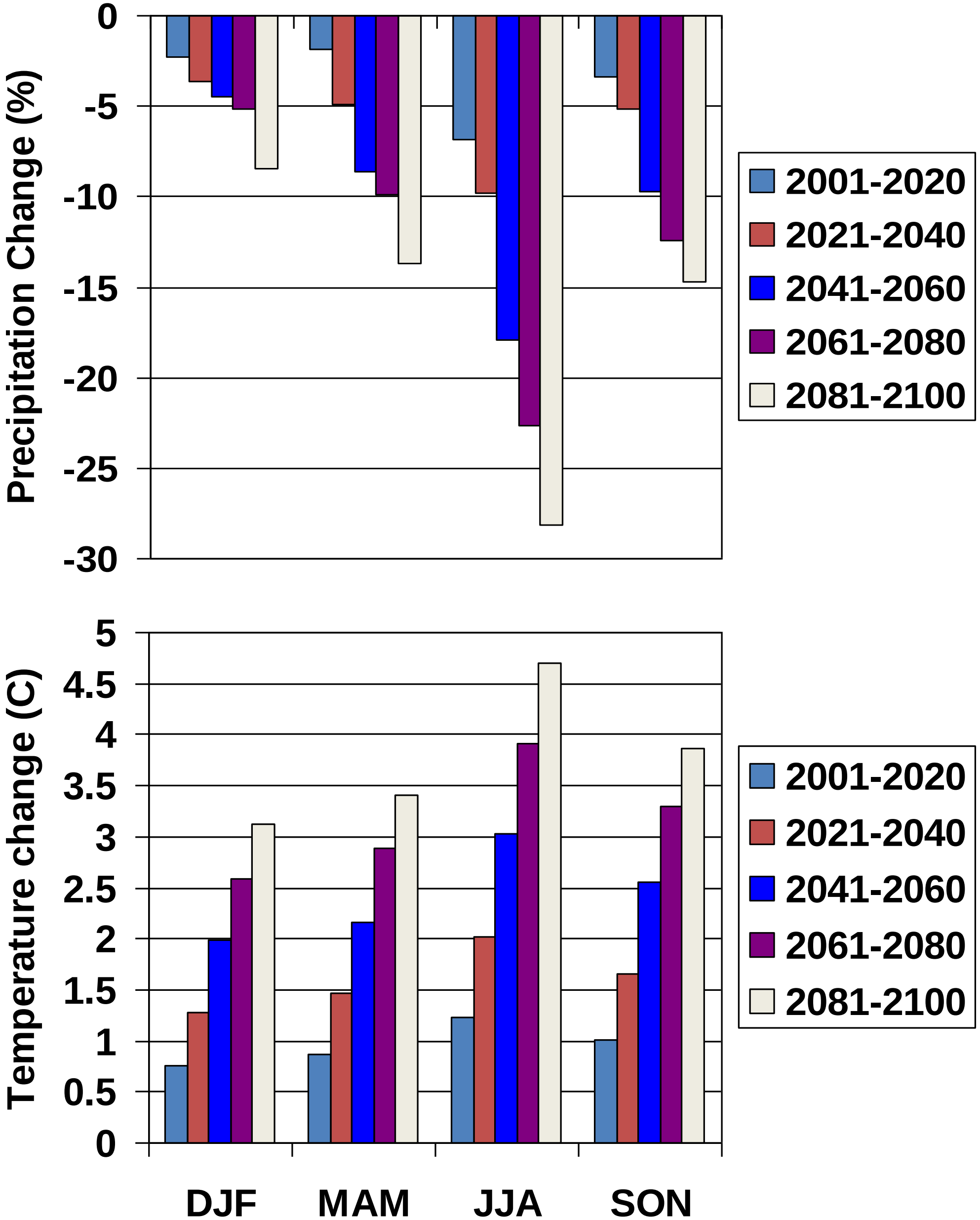
A1B scenario,: Seasonal (DJF, MAM, JJA, SON) map of temperature (K) climate change (difference 2071-2100 minus 1961-1990) from an ensemble of GCMs. (adapted from Giorgi and Lionello, 2008).

Precipitation change at the end of 21st century



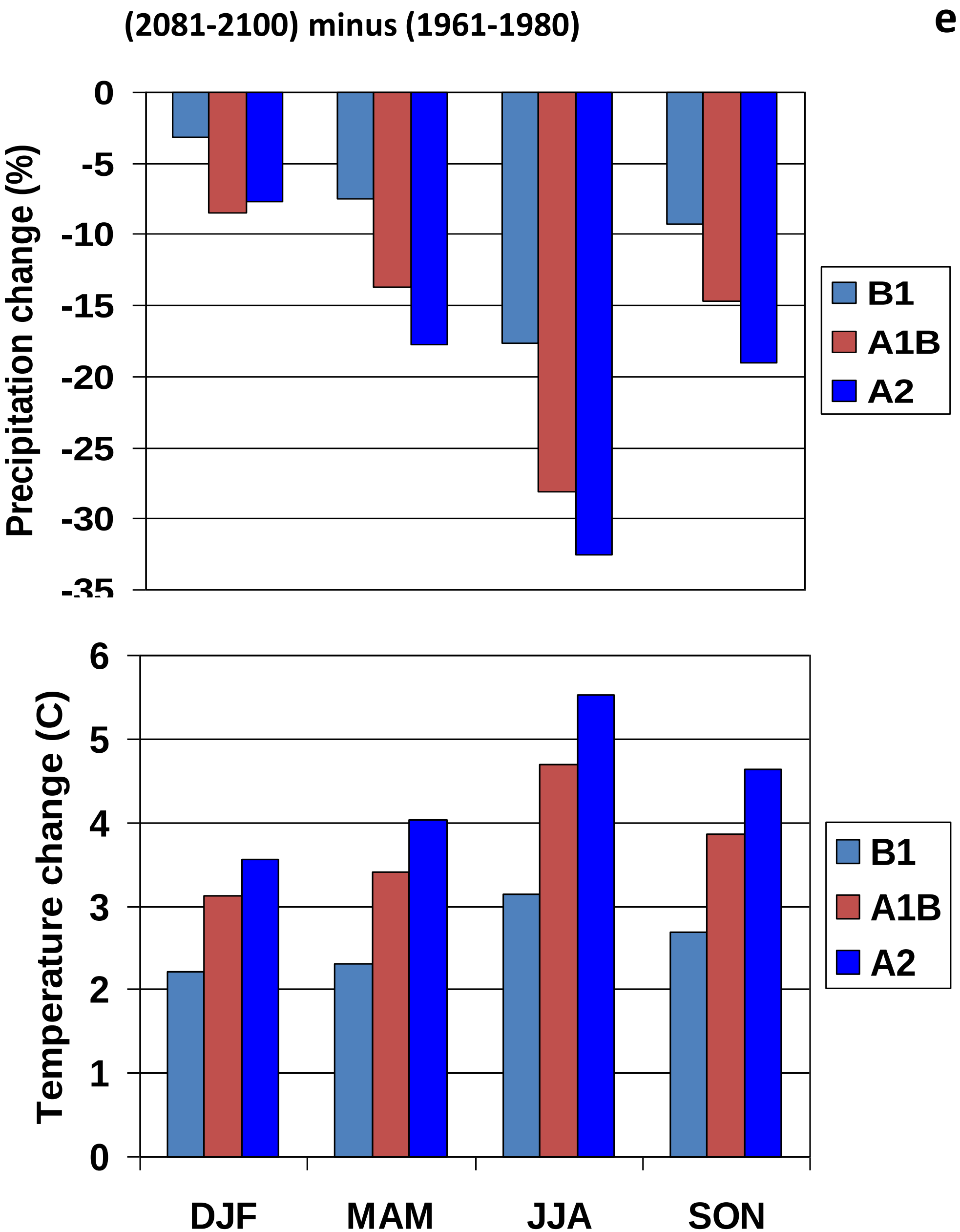
A1B scenario: Seasonal (DJF, MAM, JJA, SON) map seasonal precipitation (%) climate change (difference 2071-2100 minus 1961-1990) from an ensemble of GCMs.
(adapted from Giorgi and Lionello, 2008).

Future evolution of climate change



MGME ensemble average change in mean precipitation (upper panel) and mean surface air temperature (lower panel) for the full Mediterranean region, the four seasons as function oftime. The changes are calculated with respect to the 1981-2000. Units are % of 1981-2000 value for precipitation and degrees C for temperature

Dependence of climate change on emission scenario



MGME ensemble average change in mean precipitation (upper panel) and mean surface air temperature (lower panel) for the full Mediterranean region, the four seasons and different scenario. The changes are calculated between the periods 2081-2100 and 1961-1980 and include only land points. Units are % of 1961-1980 value for precipitation and degrees C for temperature

The previous slides describes the future of the Mediterranean climate as function of time and emission scenario. This was the first study of a long series. Later papers have been based on RCP scenarios, and on regional climate models and confirmed these results

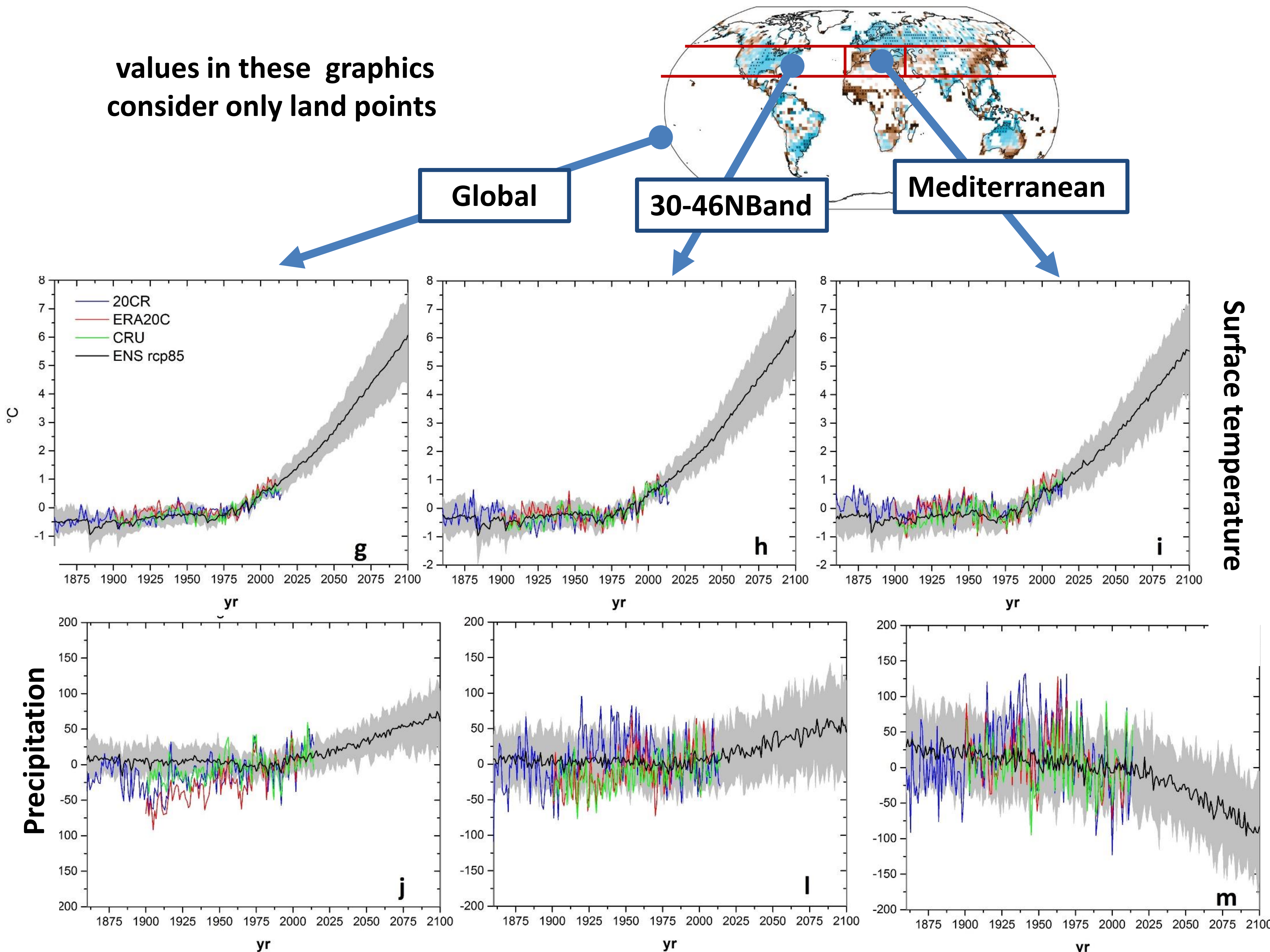
This approach disregards regional climate change from global climate change. It is not optimal for discussing international policies which are needs to be based on global thresholds and targets, such as limiting GLOBAL annual mean temperature increase to 1.5 ^{o}C or 2^{o}C above the pre-industrial level

- **Is the Mediterranean a hot-spot of climate change?**
- **How is the regional climate change in the Mediterranean related to the global mean temperature change?**
- **How extremes will change?**

DATA

This analysis is based on 28 CMIP5 **(GLOBAL)** simulations (Taylor et al. 2012), all including the historical period and RCP8.5 projections, thus covering the period from 1901-2100 in total.

The analysis also considers two 20th Century Re-Analysis: NOAA ESRL (20CR, Compo et al. 2011, covering the period 1871-2008), ECMWF (ERA20C, Poli et al. 2016, covering the period 1900-2010)



values in these graphics consider only land points
Global
30-46NBand
Mediterranean
20CR
ERA20C
CRU
ENS rcp85
°C
g
h
i
Surface temperature
Precipitation
j
l
m
yr

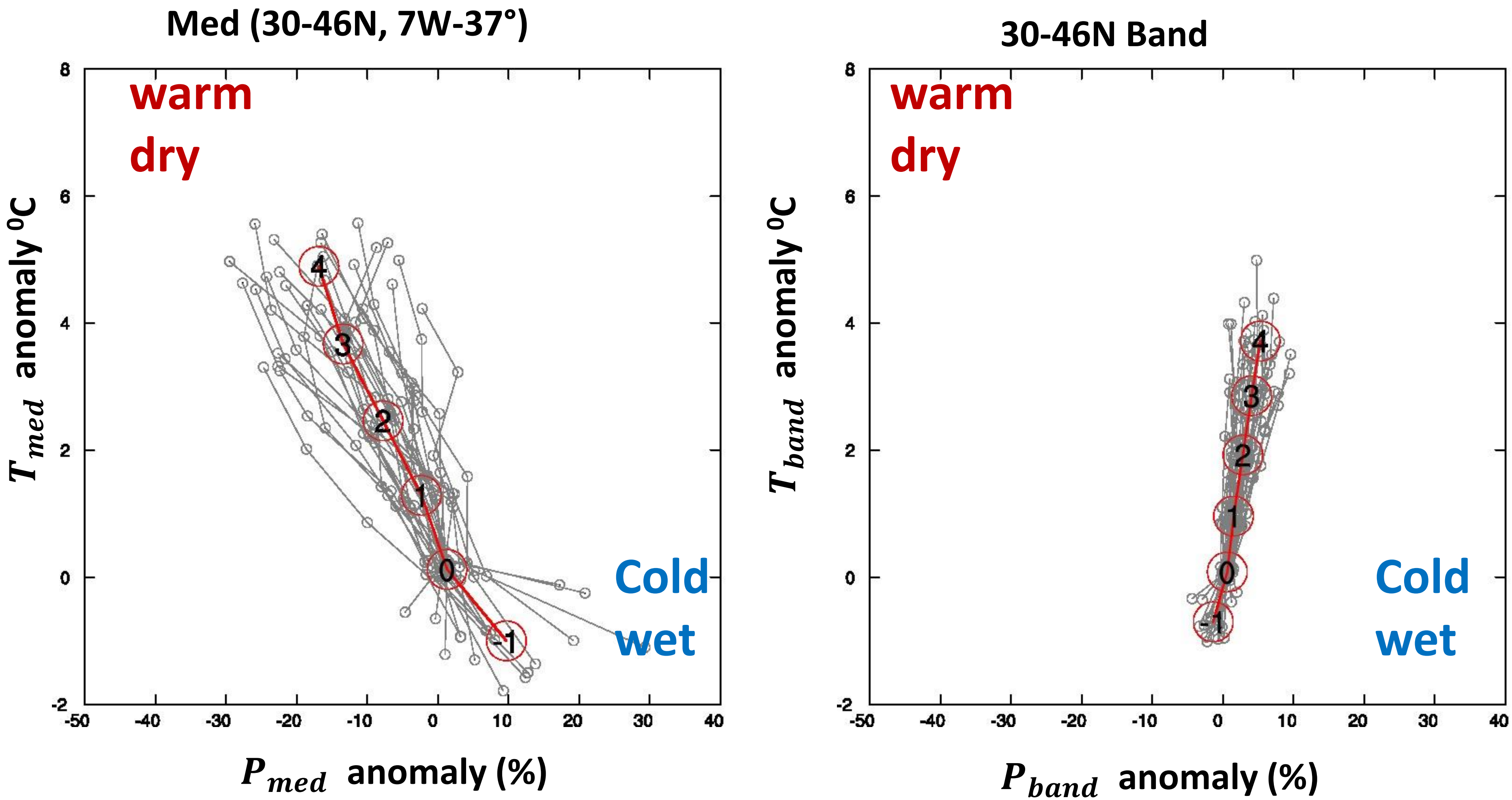
METHODS (part I):

Evolution of local climate variables as a function of global temperature

for each model simulation data are grouped in 1K wide bins according to the corresponding Global Mean Annual Temperature value anomaly T_{GL}

Bins centered from -1 to 4K $Tgl_{i,m}$ anomalies with respect to 1971-2000 mean the are considered for each model *m*(for *i*=-1 to 4, *m*=1 to 28). For each model bin the average values of temperature and precipitation anomalies $\overline{Tmed}_{i,m}$ and $\overline{Pmed}_{i,m}$ in the Mediterranean region are computed. For both temperature and precipitation, the result of the procedure are 6 pairs ($\overline{Tmed}_{i,m}, Tgl_{i,m}$) and ($\overline{Pmed}_{i,m}, Tgl_{i,m}$)for each model *m.*

With global warming , the Mediterranean region will become warmer and drier than presently



Trajectory (grey lines) describing the evolution of the climate of the Mediterranean region towards warmer and drier conditions as function of global mean temperature change whose anomalies are shown by the white labels along the ensemble mean trajectory (red line).

METHOD (part II)

to estimate the local rate of change regional temperature and precipitation on Global Mean Annual Temperature T_{GL}

$$\frac{dTmed}{dTgl} \quad , \quad \frac{dPmed}{dTgl}$$

This estimate is applied

- to local (grid point) time series to produce maps showing the spatial variation of the rate of change

and

- to the whole Mediterranean region .

… to be more precise ….

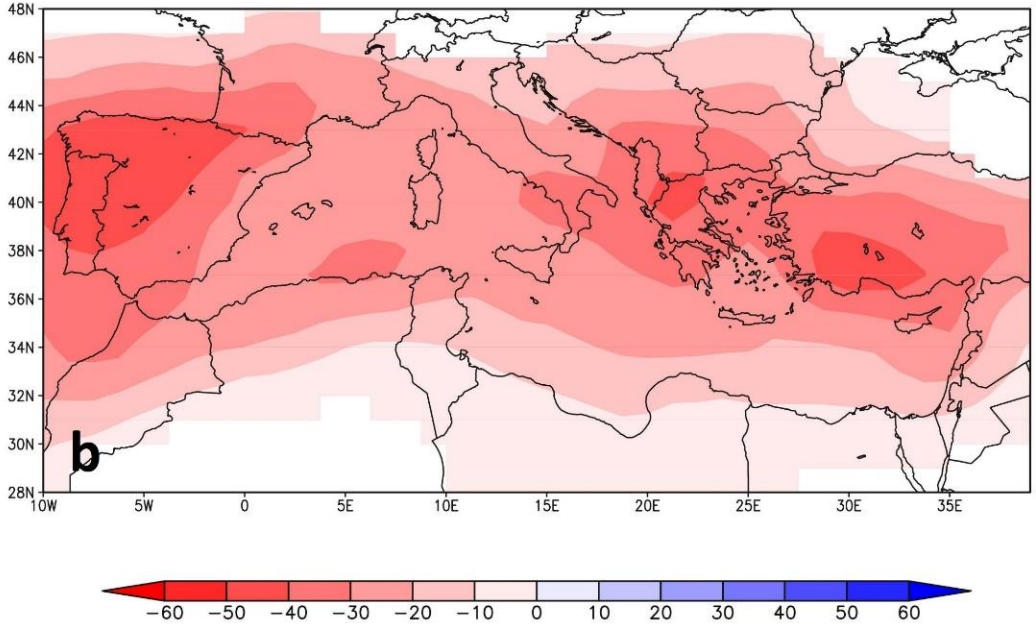
the median (Theil-Sen estimate) of

$$\frac{Tmed_i - Tmed_j}{Tgl_i - Tgl_j} \quad , \quad \frac{Pmed_i - Pmed_j}{Tgl_i - Tgl_j}$$

is computed for each model.

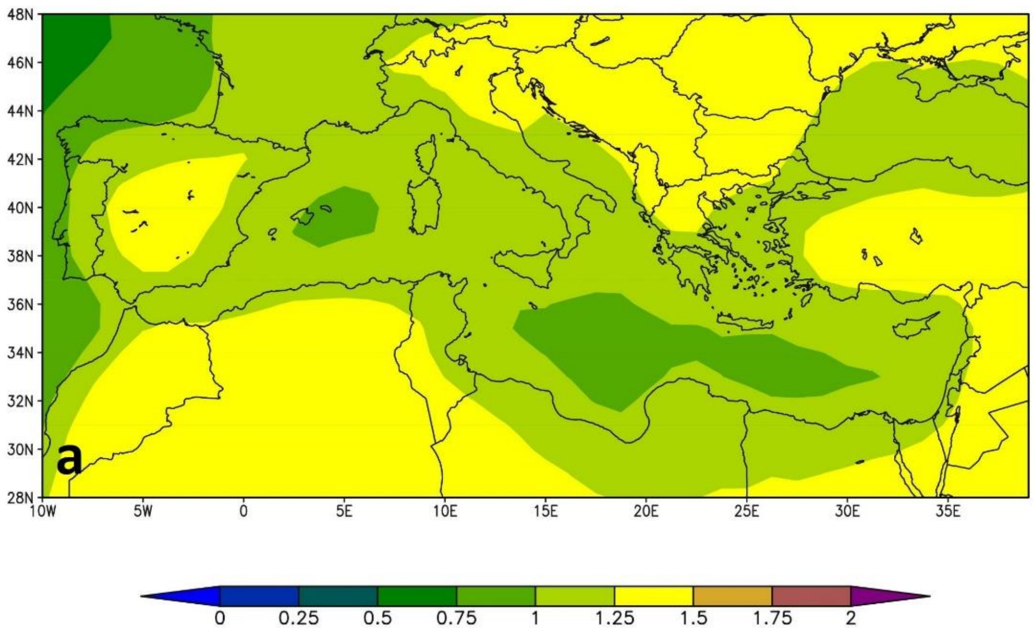
The median the inter-model distribution is used as best estimate and it is considered significant if the 10th and 90th percentile have the same sign

Precipitation (mm/K)

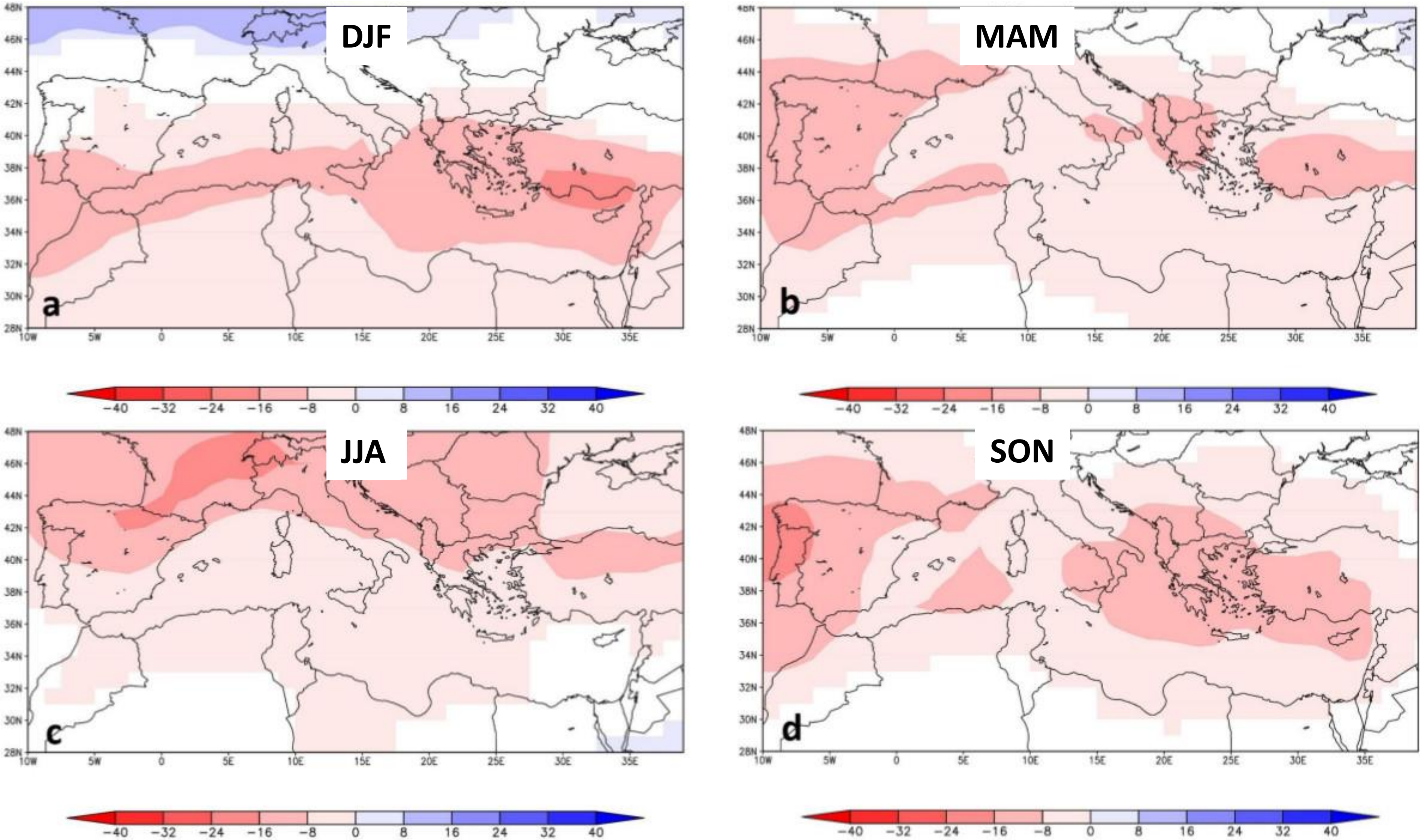


Maps with local rate of change of total annual precipitation (top) and mean annual temperature (bottom) as a function of the mean global temperature.

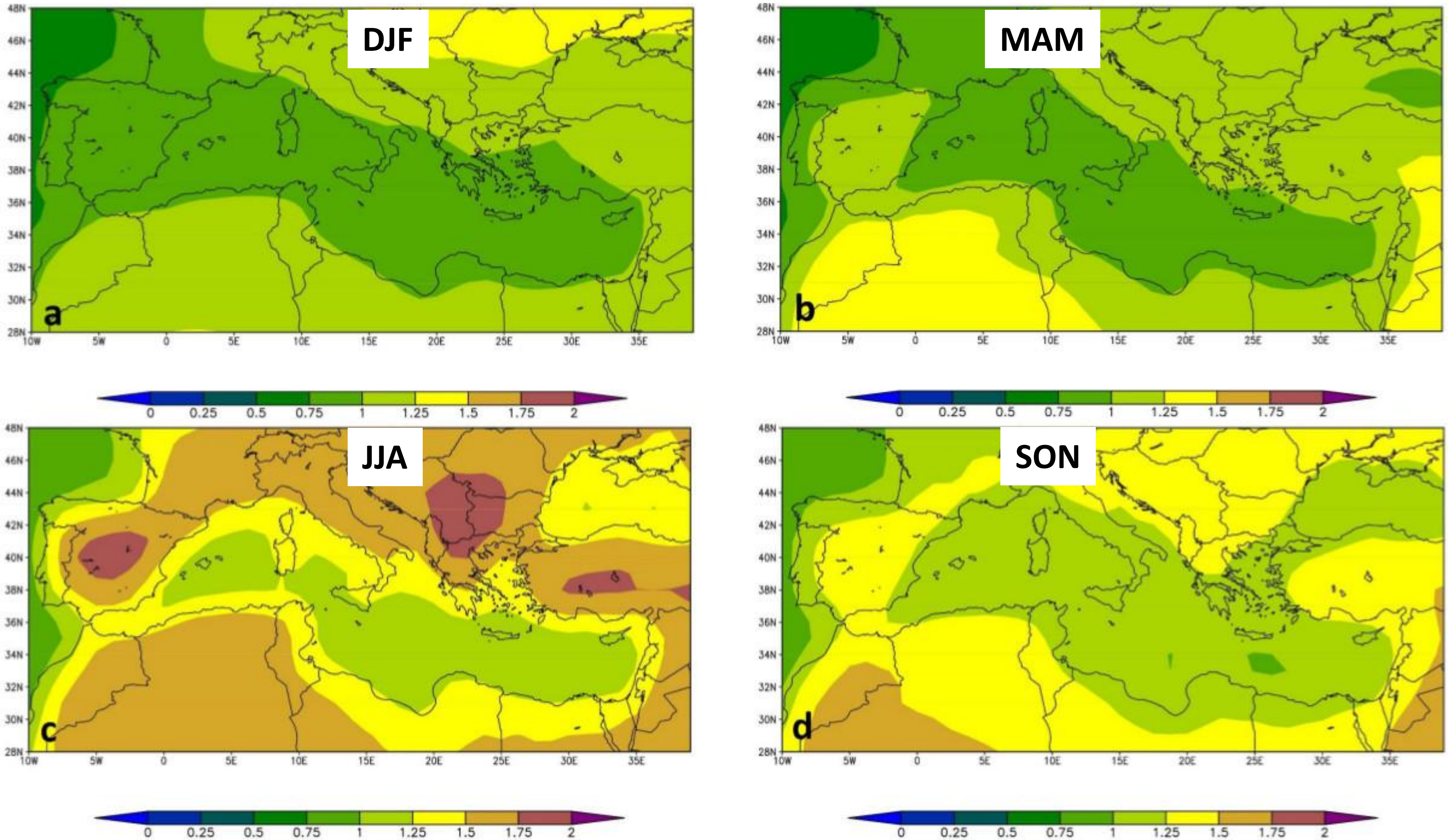
Temperature



rate of change of total seasonal precipitation as a function of the mean global temperature (mm/K)



rate of change of mean seasonal temperature as a function the mean global temperature.



Indices of climate EXTREMES

SDII, *Simple precipitation intensity index*: average precipitation during wet days

R95pTOT, *Very wet day precipitation* or *Annual total precipitation during very wet days*. Contribution to the total precipitation associated with intense events

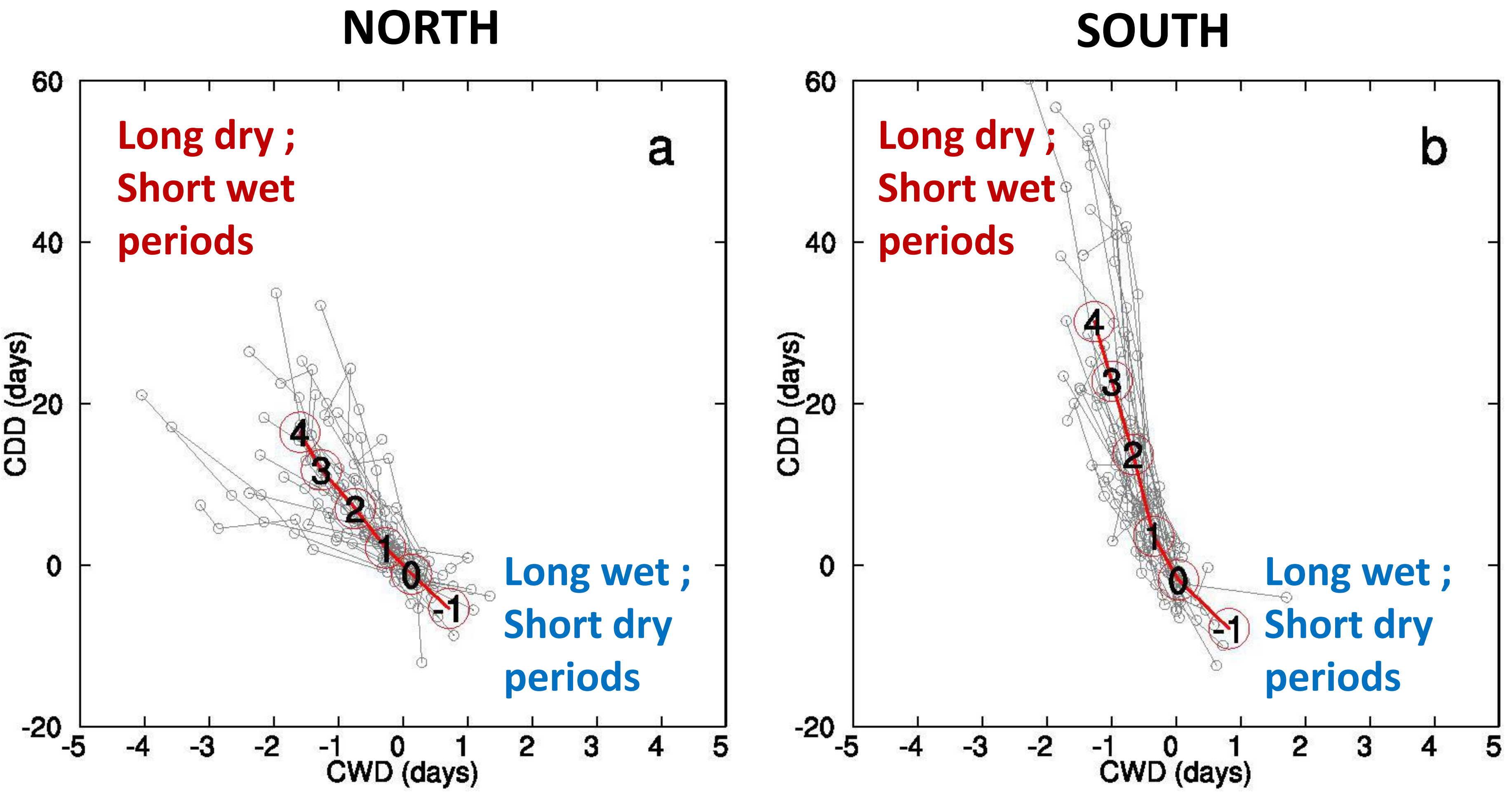
CDD, *Maximum length of dry spell*, duration of the longest annual meteorological drought

CWD, *Maximum length of wet spell*, duration of the annual longest continuous sequence of rainy days

TN90p, *Percentage of days when TN > 90th percentile or percentage of warm nights* (reference for warm nights is the base period 1961-1990).

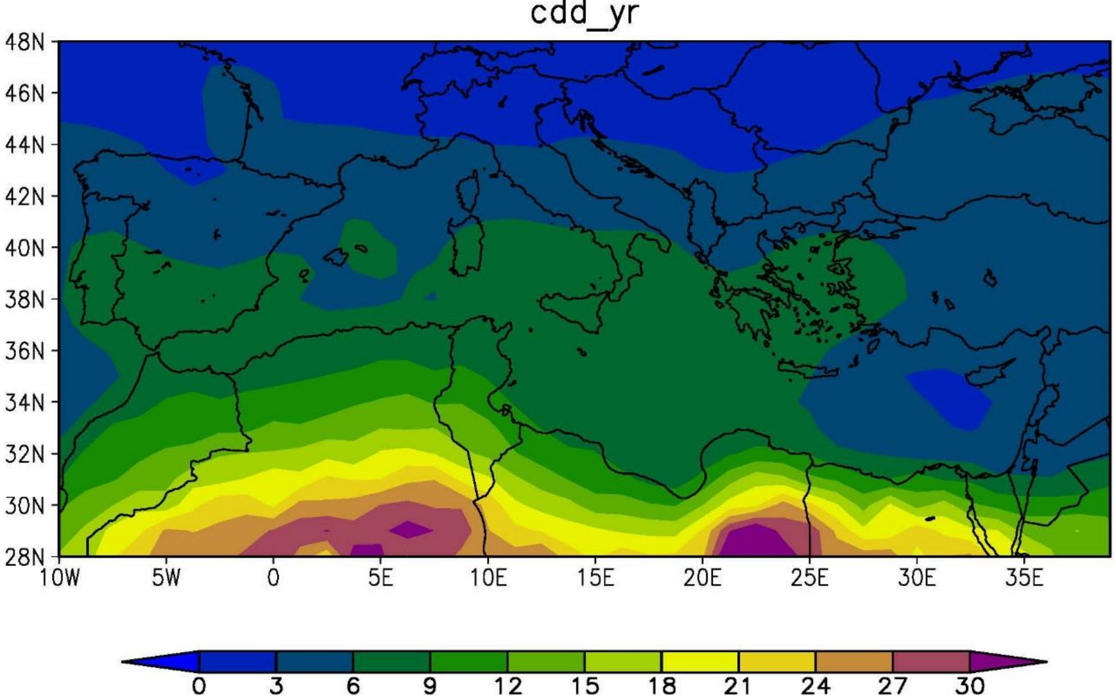
TX10p, *Percentage of days when TX < 10th percentile or percentage of cold days* (reference for cold days is the base period 1961-1990).

Maximum length of dry and wet periods

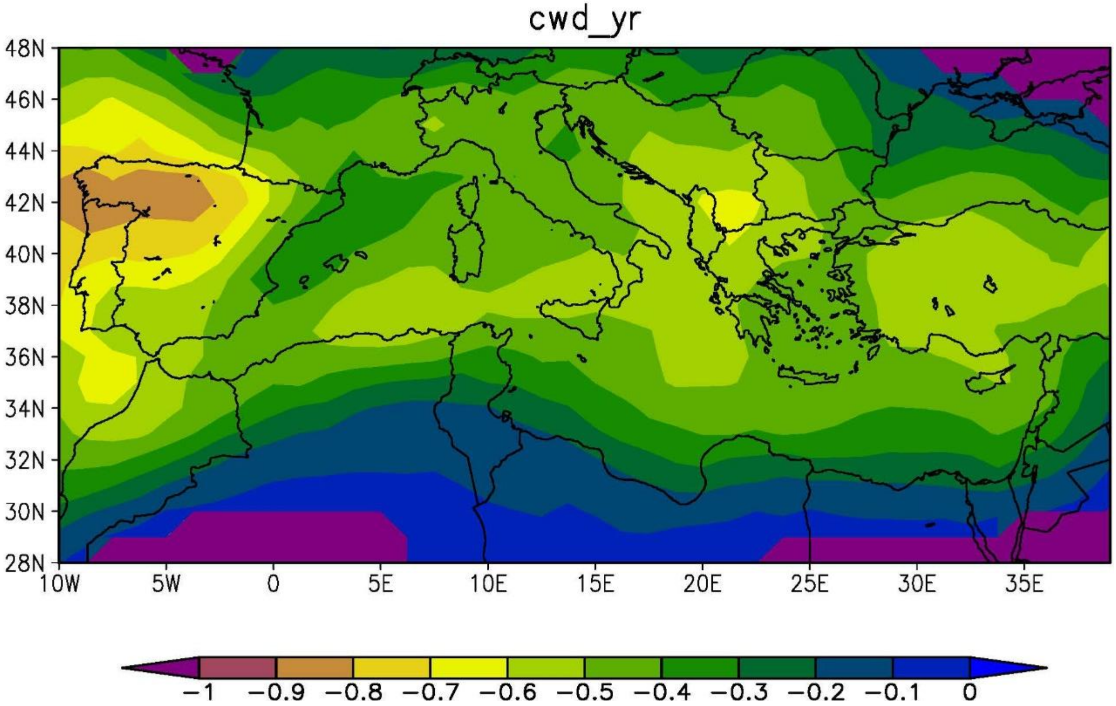


Evolution of maximum dry (CDD) versus maximum wet spell (CWD) duration as a function of global annual mean temperature anomaly: individual models (gray lines), ensemble mean (red thick line), global temperature anomalies (red circles)

Values represent anomalies with respect to the 1971-2000 reference mean.

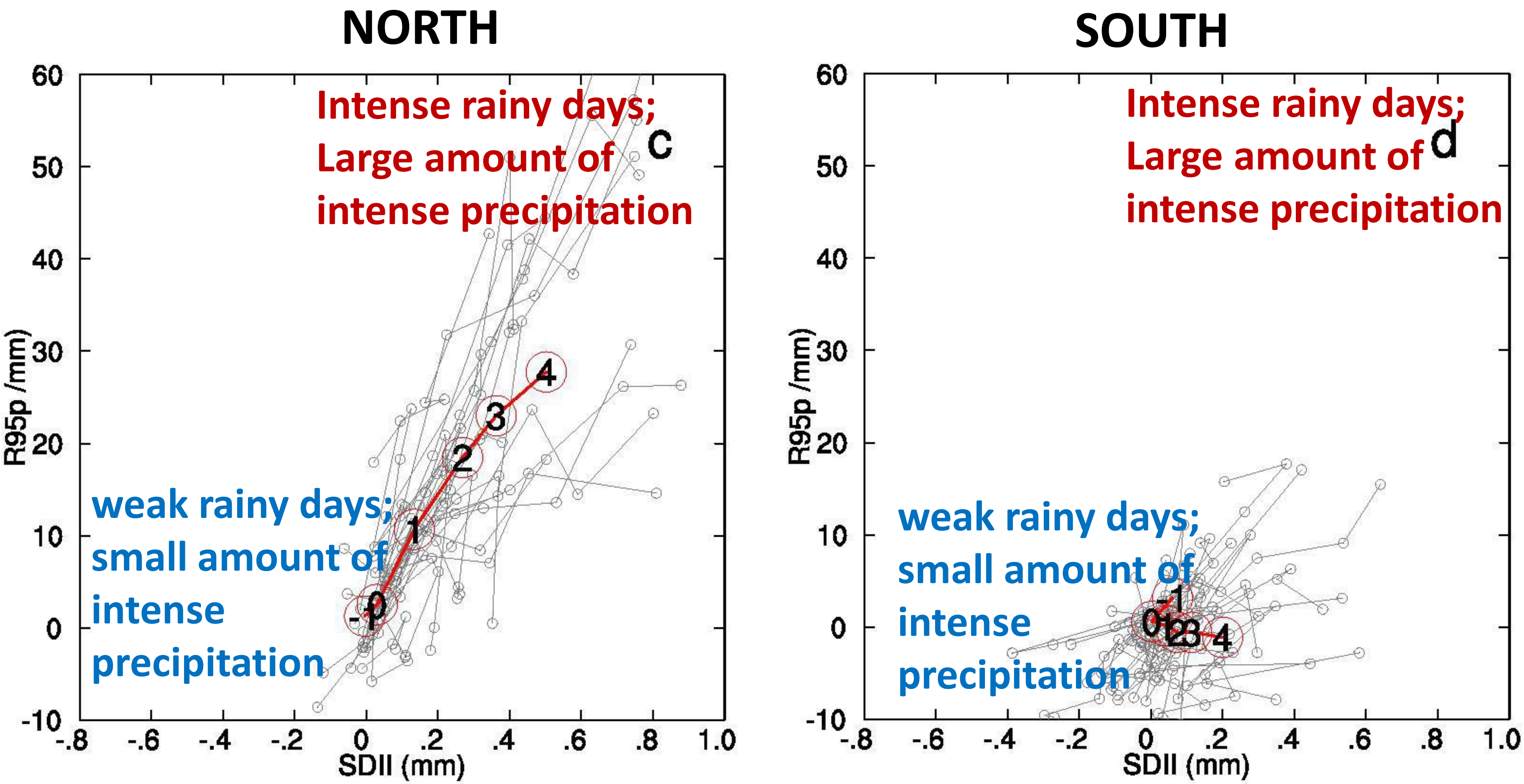


Change of maximum length of dry periods (day/K)



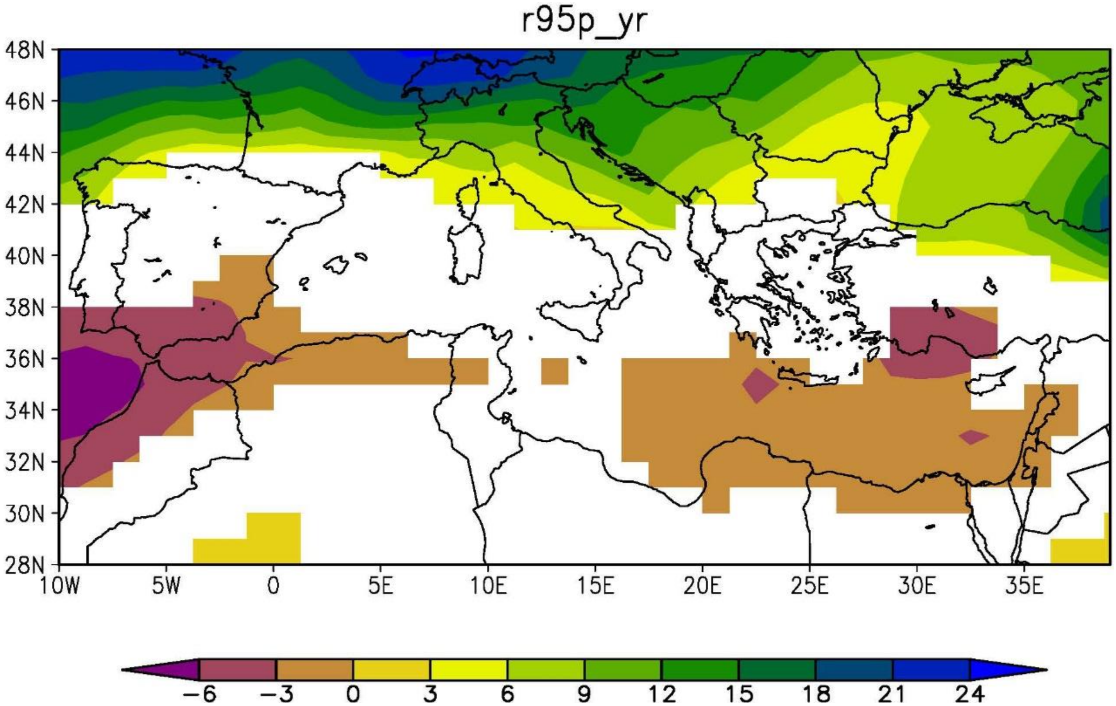
Change of maximum length of wet periods (day/K)

Intensity of precipitation

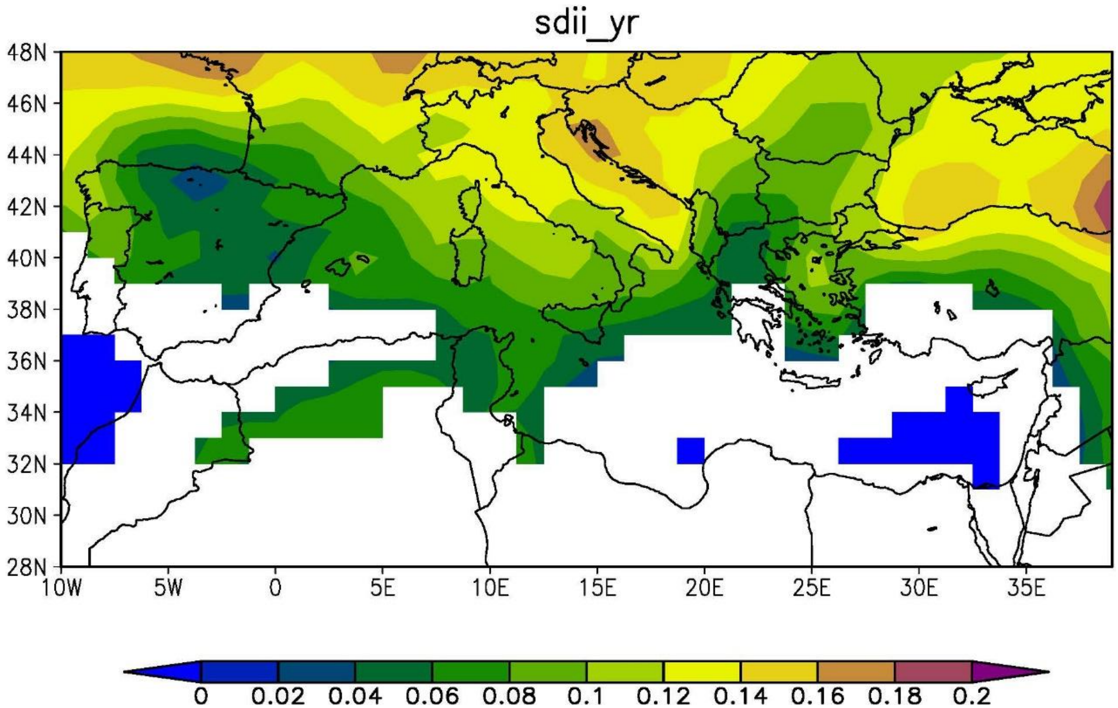


Evolution of Annual total precipitation during intense events (R95pTOT) versus mean daily precipitation in wet days (SDII) as a function of global annual mean temperature anomaly: individual models (gray lines), ensemble mean (red thick line), global temperature anomalies (red circles)

Values represent anomalies with respect to the 1971-2000 reference mean.

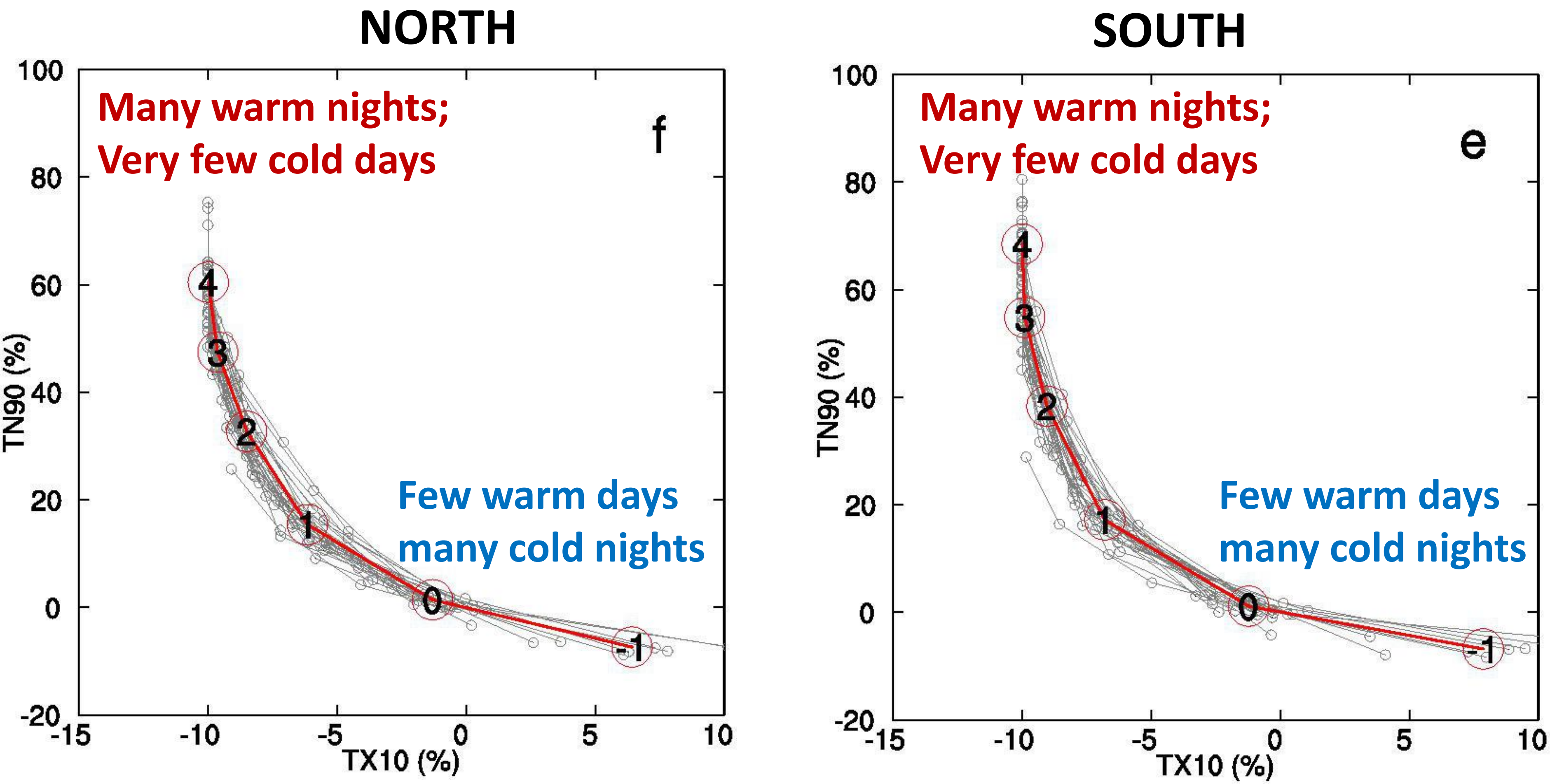


Change of total precipitation during intense events (mm/K)



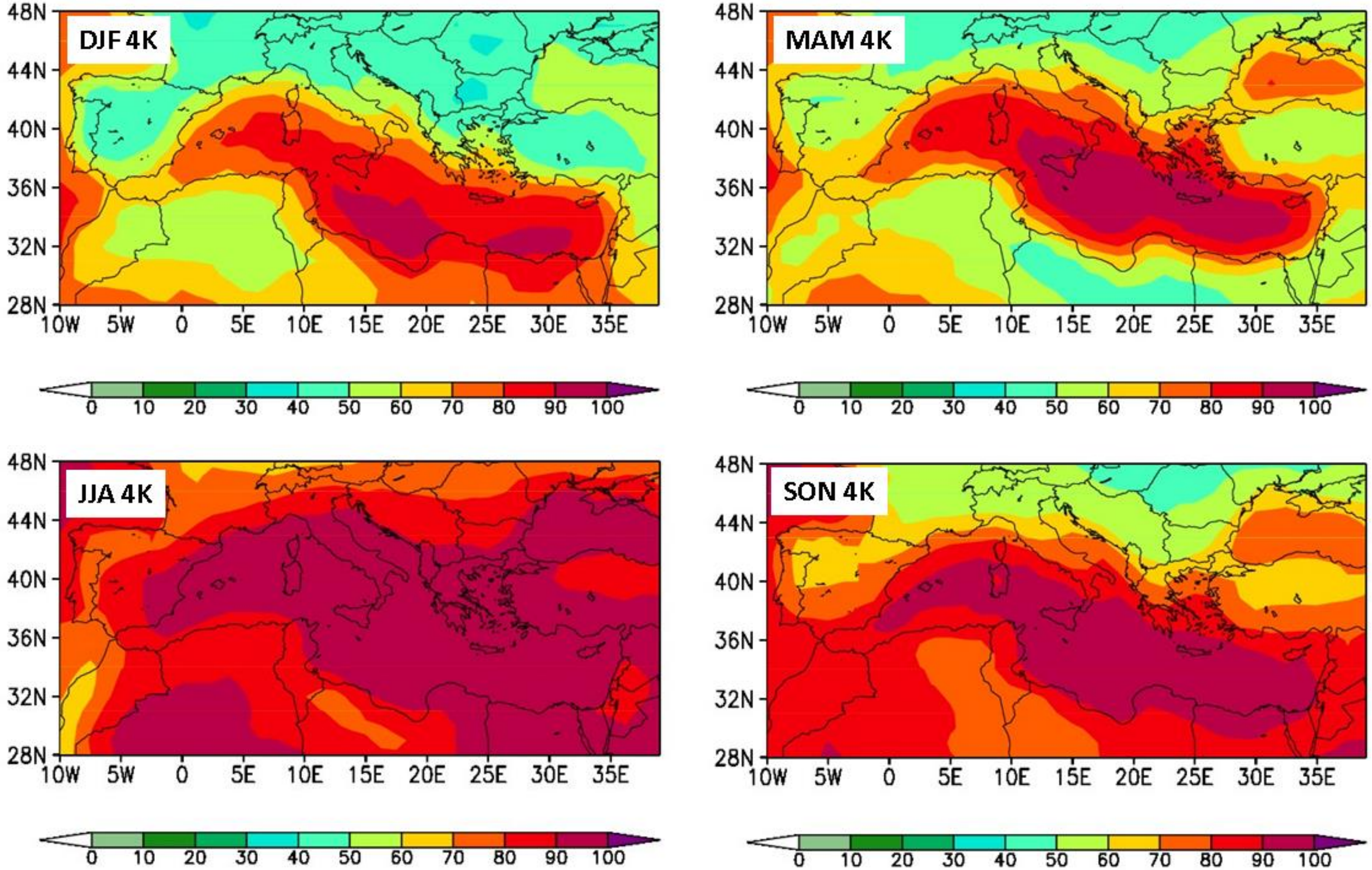
Change mean daily precipitation in wet days (mm/K)

Frequency of warm nights and cold days



Evolution of frequency of warm nights (TN90) versus cold days (TX10) as a function of global annual mean temperature anomaly: individual models (gray lines), ensemble mean (red thick line), global temperature anomalies (red circles)

Values represent anomalies with respect to the 1971-2000 reference mean.



Spatial distribution of the frequency (%) of warm nights when the global mean surface temperature anomaly reaches the 4K thresholds. Each panel refers to a different season: winter (DJF, Dec-Jan-Feb), spring (MAM, Mar-Apr-May), summer (JJA, Jun-Jul-Aug), autumn (SON, Sep-Oct-Nov). All values are statistically significantly different with respect to the 10% reference value. Labels on top-left corner of each panel denote the field.

Temperature:

Mean temperature increase will be 20% larger than global mean (up to 50% larger over interior land areas in summer)

Changes of temperature will be modulated by the land-sea contrast, but, apart from this, they will have comparable importance in the north and south areas of the Mediterranean region.

The increase/decrease of warm/cold temperature extremes will be dramatic and with a 4K global warming almost all nights will be warm and there will be no cold days in summer.

Precipitation

The confidence on capability of climate models to reproduce the observed link of precipitation with mean global temperature is lower than for temperature.

While the intensity of the hydrological cycle will globally increase, precipitation in the Mediterranean will decrease with global warming (This is different from the areas of the globe located in the same latitudinal band). This decrease has different subregional connotation affecting mostly the central Mediterranean in winter and the North Mediterranean in summer.

Global warming will further increase the existing difference in intensity of precipitation and hydrological extremes between North and South Mediterranean

The decrease is large -20mm/K or -4%/K), particularly in the central Mediterranean in winter (-7 mm/k or -9%/k) and north mediterranean in summer (-7 mm/k or -7%/k). There is a unique exception: the increase at the northern border in winter.

In the Northern Mediterranean, the average intensity of precipitation and the total precipitation during intense events are already larger than in the Southern Mediterranean and they will increase with global warming at a rate of approximately 0.1mm/K and 5mm/K.

The maximum length of dry periods will increase more in the southern than in the northern area (8days/K and 5days/K, respectively). Maximum number of consecutive wet days (CWD), will decrease at a similar rate (about 0.5 days/K) in both areas.

Thank you for your attention

Looking forward to the Mediterranean Assessment Report (MedECC) http://www.medecc.org

For an overview of climate and environmental issues in the Mediterranean region
Cramer W, Guiot J, Fader M, Garrabou J, Gattuso J-P, Iglesias A, Lange MA, Lionello P, Llasat MC, Paz S, Peñuelas J, Snoussi M, Toreti A, Tsimplis MN, Xoplaki E (2018) **Climate change and interconnected risks to sustainable development in the Mediterranean.** *Nat Clim Change* 8:972-980, doi: 10.1038/s41558-018-0299-2

Refs used for the figures in this pressentation:
Giorgi F, Lionello P (2008) **Climate Change Projections for the Mediterranean Region.** *Glob Planet Change* 63:90-104. doi: 10.1016/jgloplacha200709005
Lionello P , Scarascia L (2018) **The relation between climate change in the Mediterranean region and global warming.** *Reg Environ Change* 18:1481-1493. doi:10.1007/s10113-018-1290-1
Lionello P , Scarascia L (2018) **The relation of climate extremes with global warming in the Mediterranean region and its North versus South contrast** *Reg Environ Change (submitted)*