The climate of the Mediterranean Region: its recent past and future evolution in the 21st century

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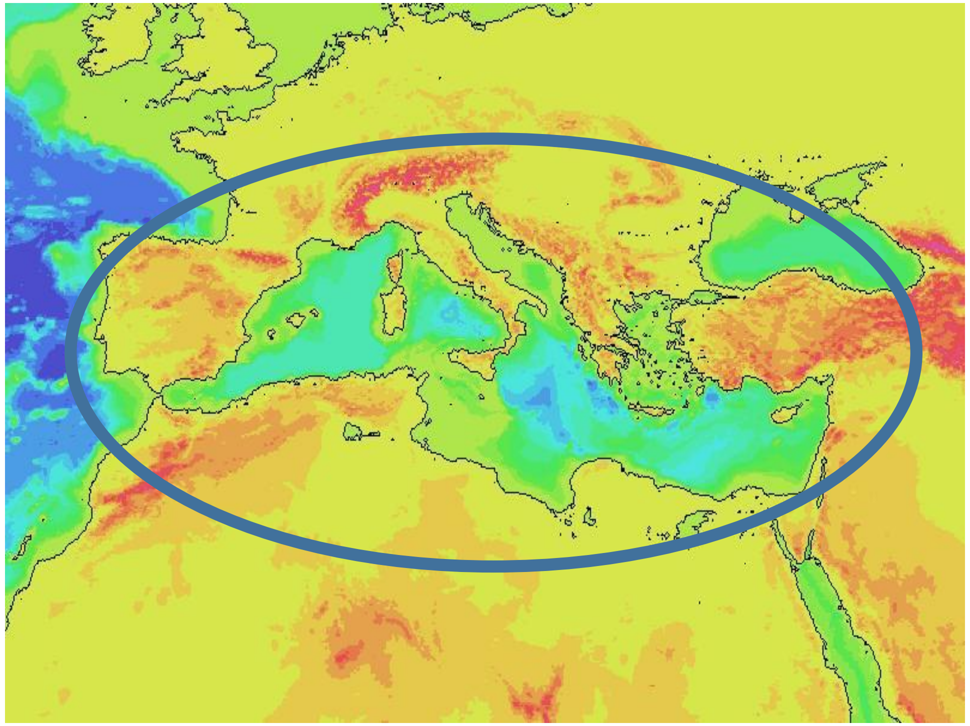
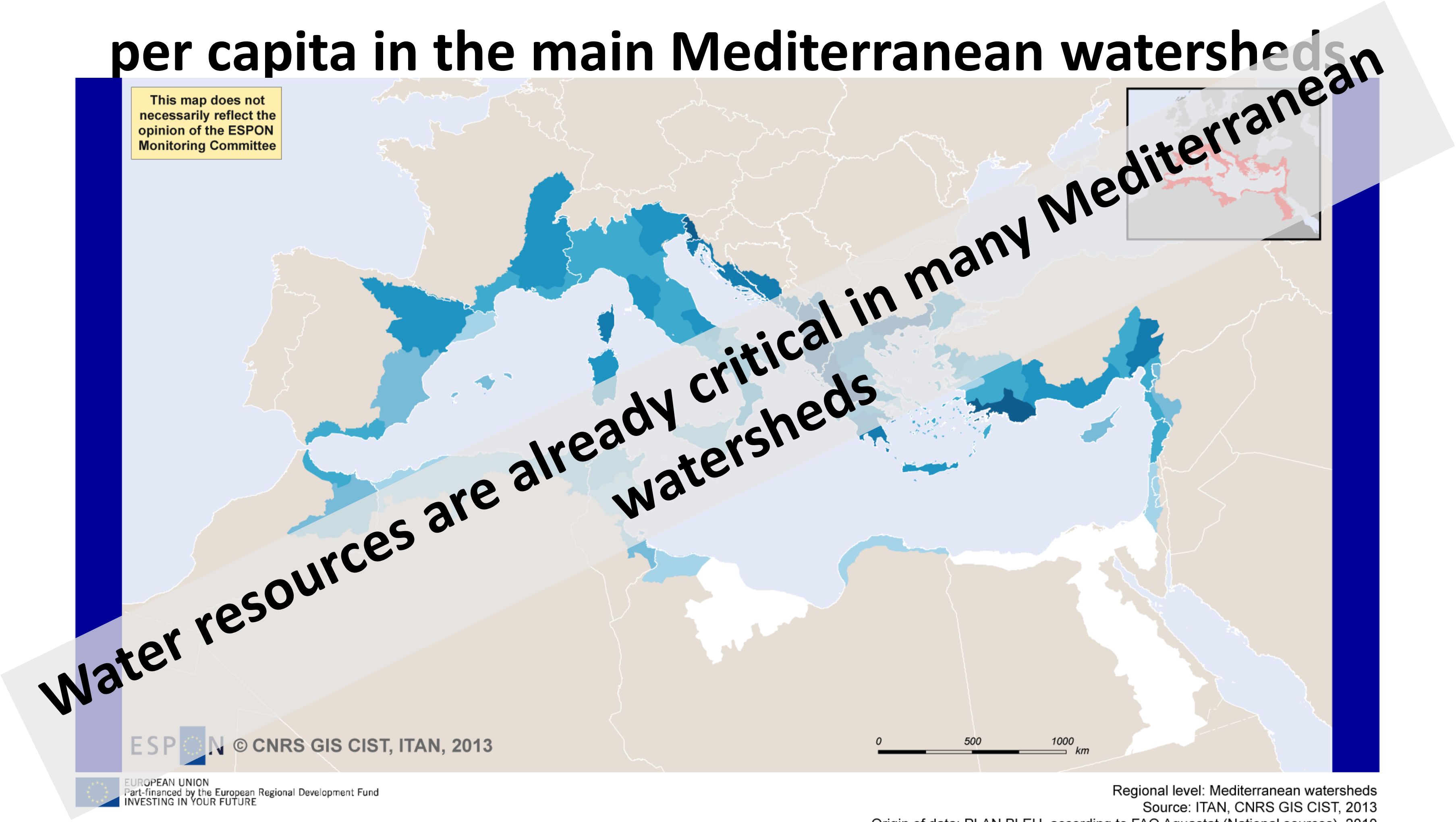


- Part I: and crucial socio-environmental issues
- Part II: characteristics, environmental and morphological gradients, ongoing trends
- Part III: future evolution of regional climate

Part I: and crucial socio-environmental issues

In the Mediterranean region many components of terrestrial and marine environment are already under stress; it has been shown to be very vulnerable to climate change and it is a region with also large socio-economic contrasts.

Annual natural renewable water resources per capita in the main Mediterranean watersheds



Regional level: Mediterranean watersheds
Source: ITAN, CNRS GIS CIST, 2013
Origin of data: PLAN BLEU, according to FAO Aquastat (National sources), 2010
© UMS RIATE for administrative boundaries
© ESPON Database
For some territories no clear international statement exists

Available water resources per capita, in m³/year*: 0 – 500 – 1 000 – 3 000 – 6 000 – 12 000 – 24 000 – 31 000

No data

*Average over 10 years (2000-2010) of the annual water ressources.

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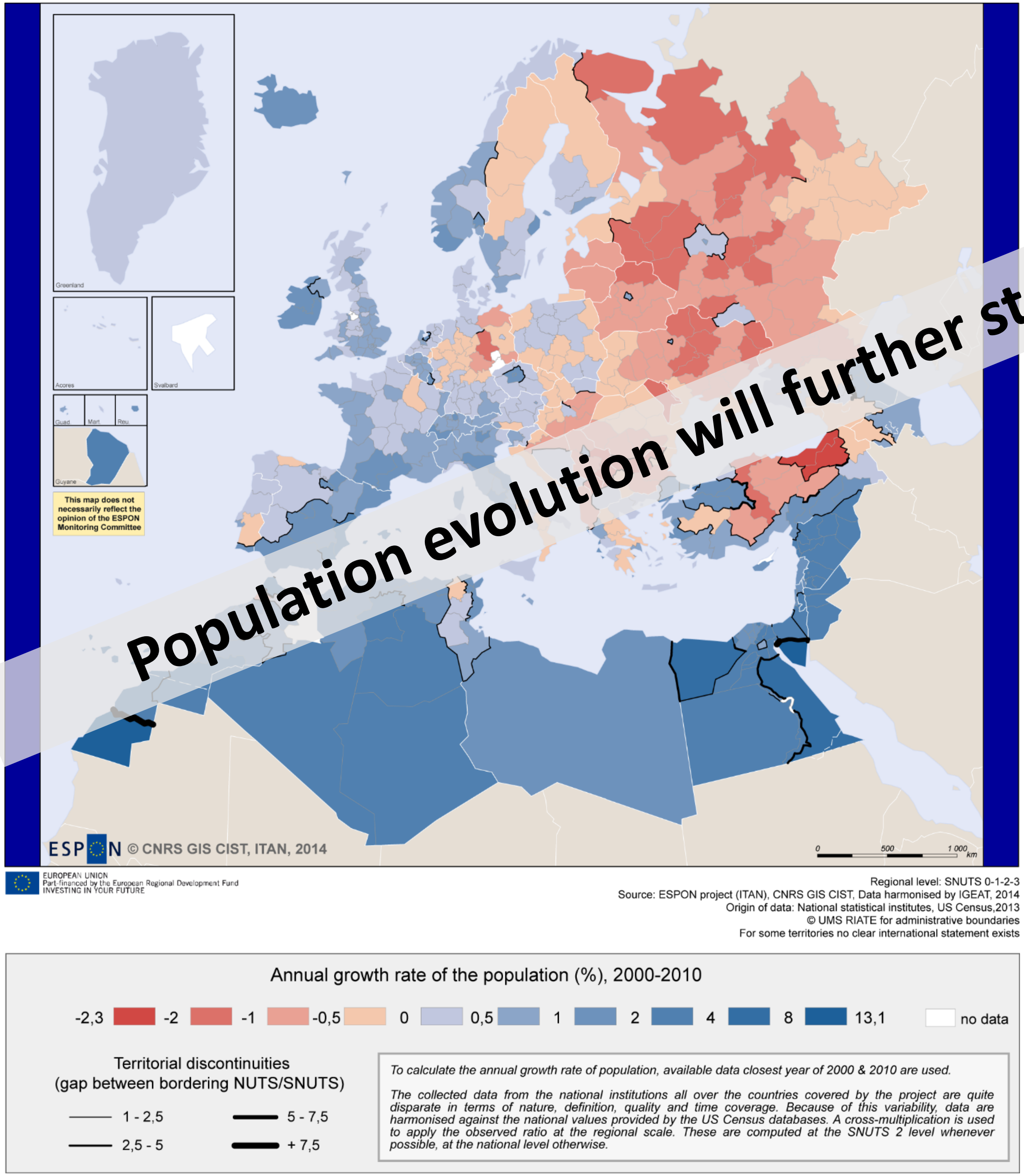
Demographic evolution (2000-2010) : annual growth of population(%)



Population evolution will further stress the system

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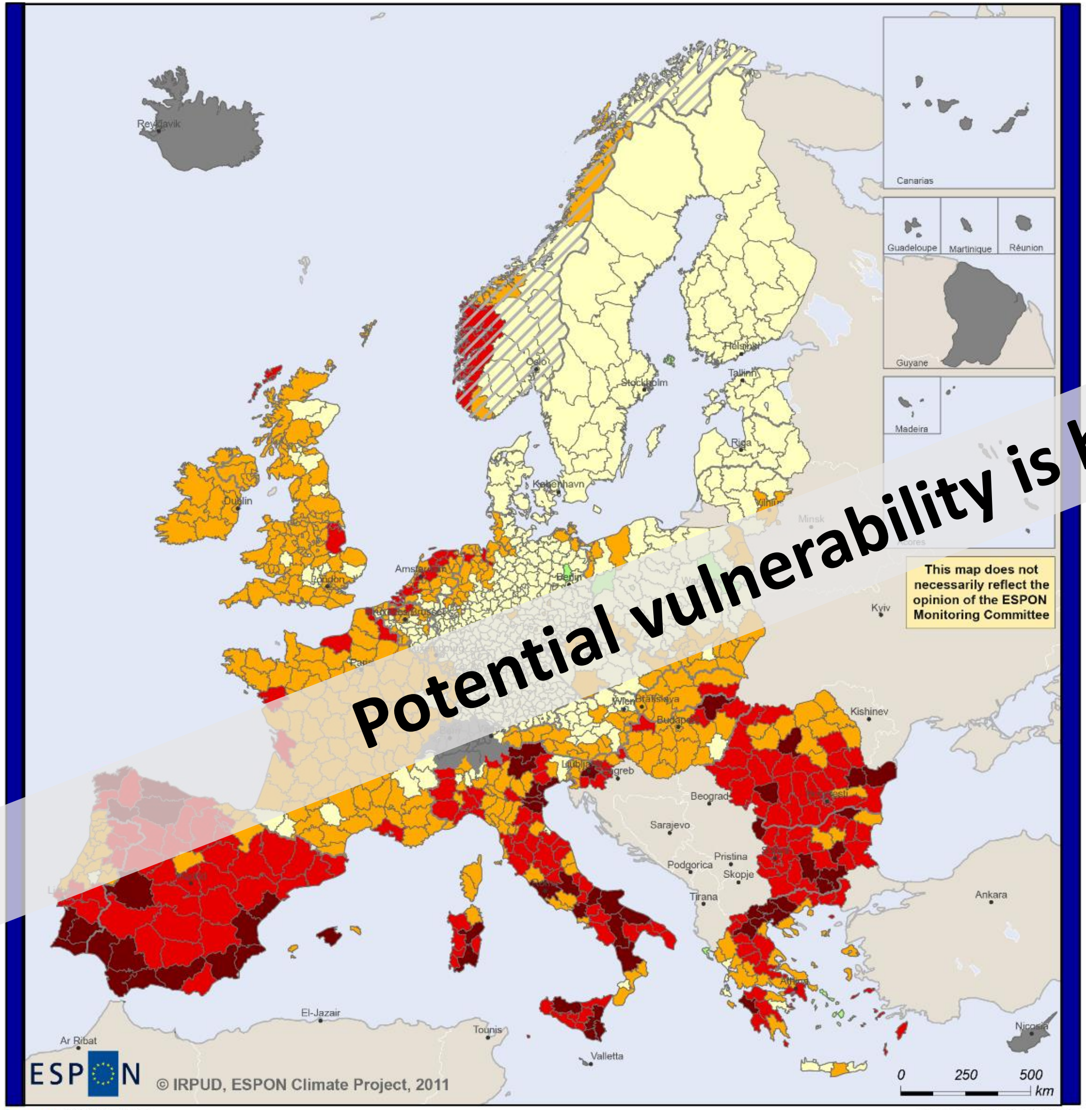
Potential vulnerability to climate change



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Regional level: NUTS3
Origin of data: see data sources of the individual impact and adaptive capacity dimensions
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- Highest negative impact (0.5 - 1.0)
- Medium negative impact (0.3 - <0.5)
- Low negative impact (0.1 - <0.3)
- No/marginal impact (>-0.1 - <0.1)
- Low positive impact (-0.1 - -0.25)
- No data
- Reduced data

* The potential impacts were calculated as combination of regional exposure to climate change and most recent data on weighted dimensions of physical, economical, social, environmental, and cultural sensitivity to climate change

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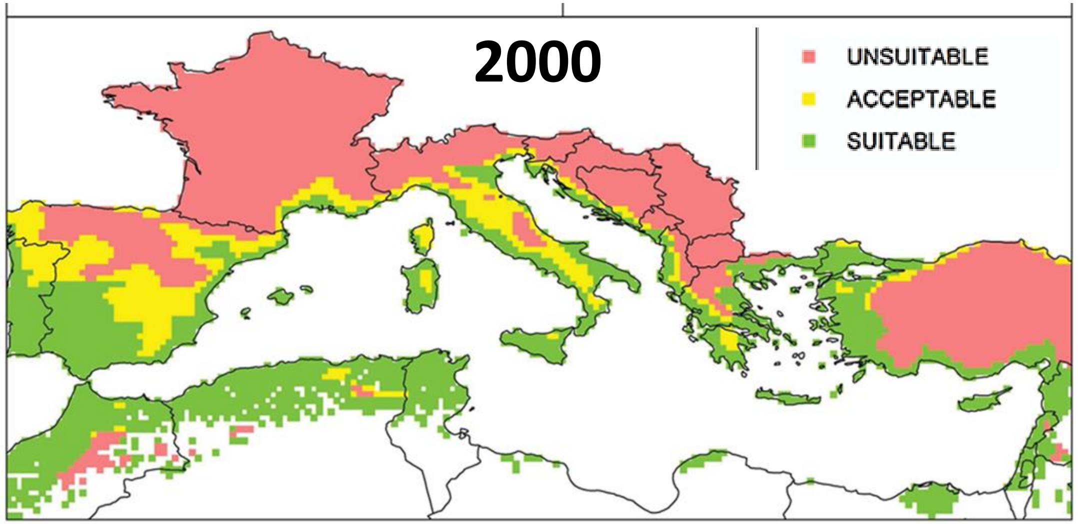
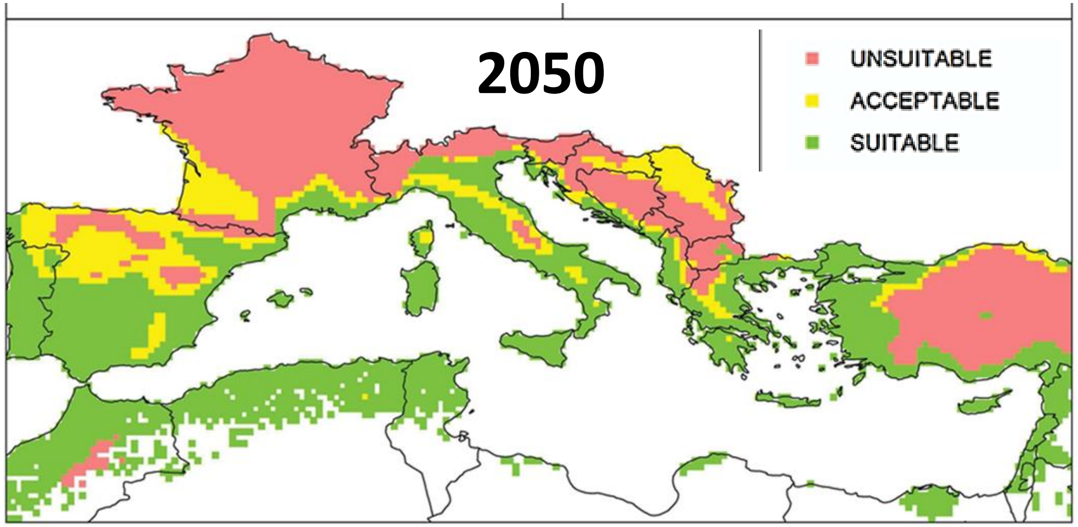
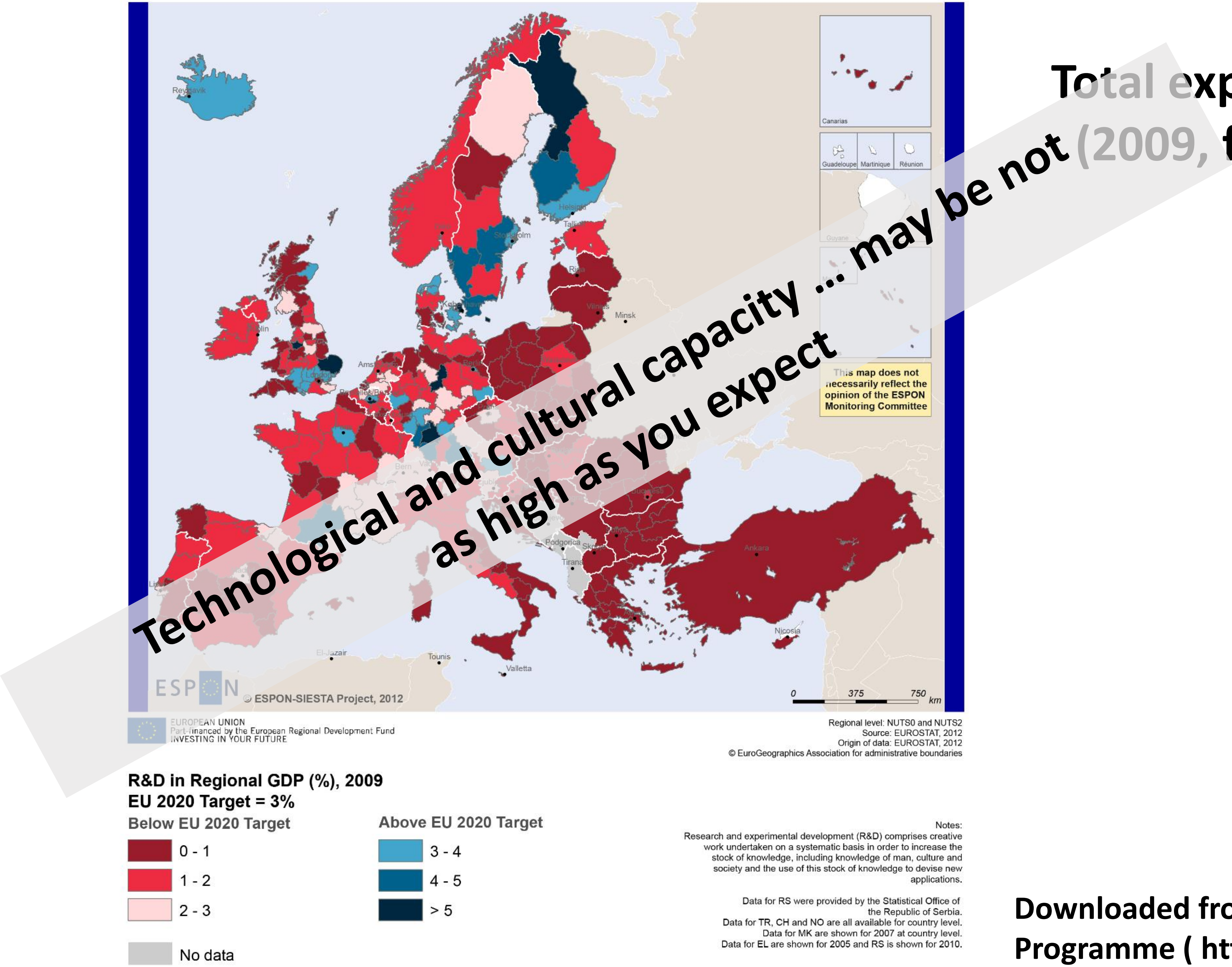
Example: areas suitable for olives





Total expenditure in R&D (2009, fraction of GDP)



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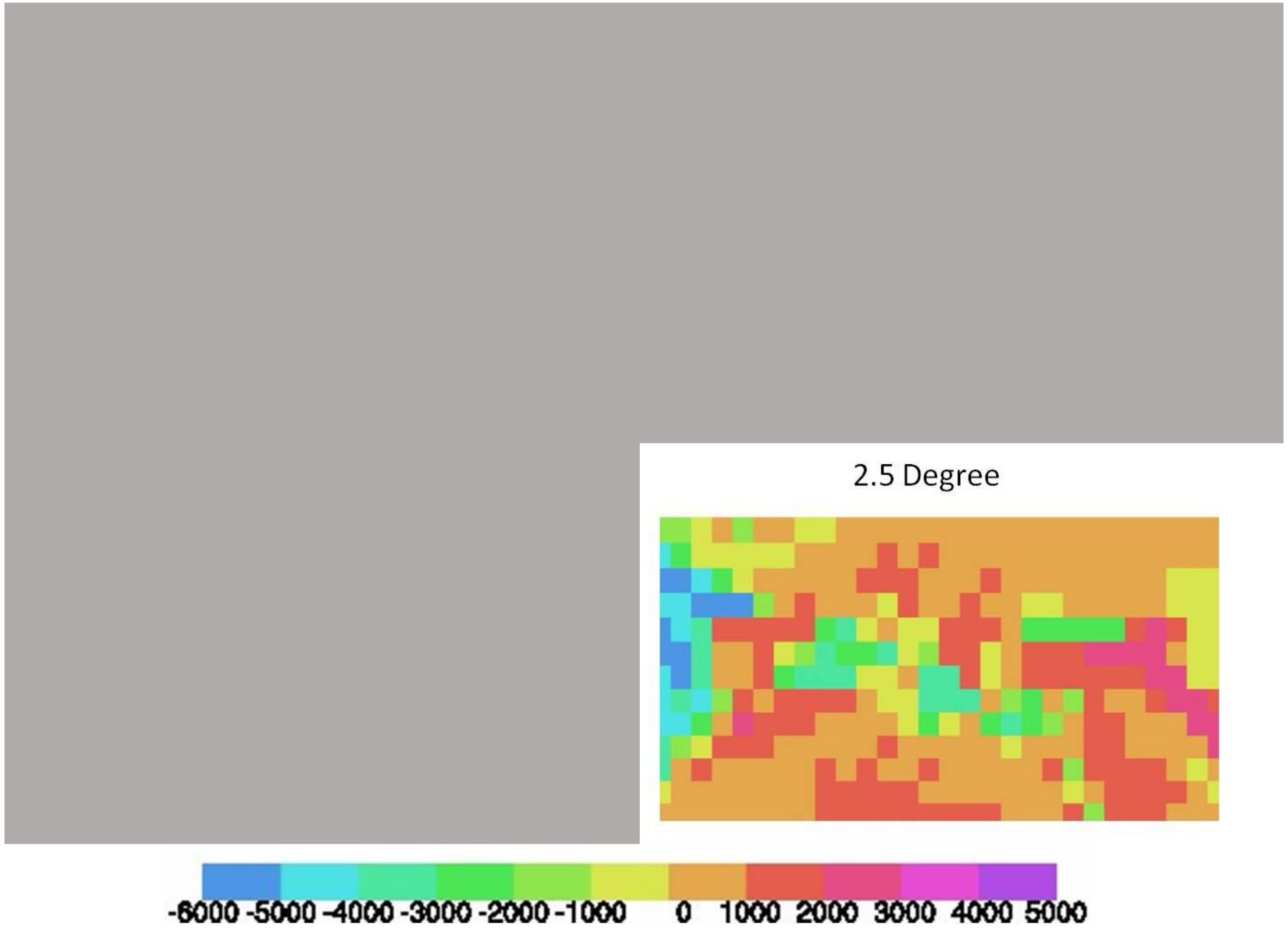
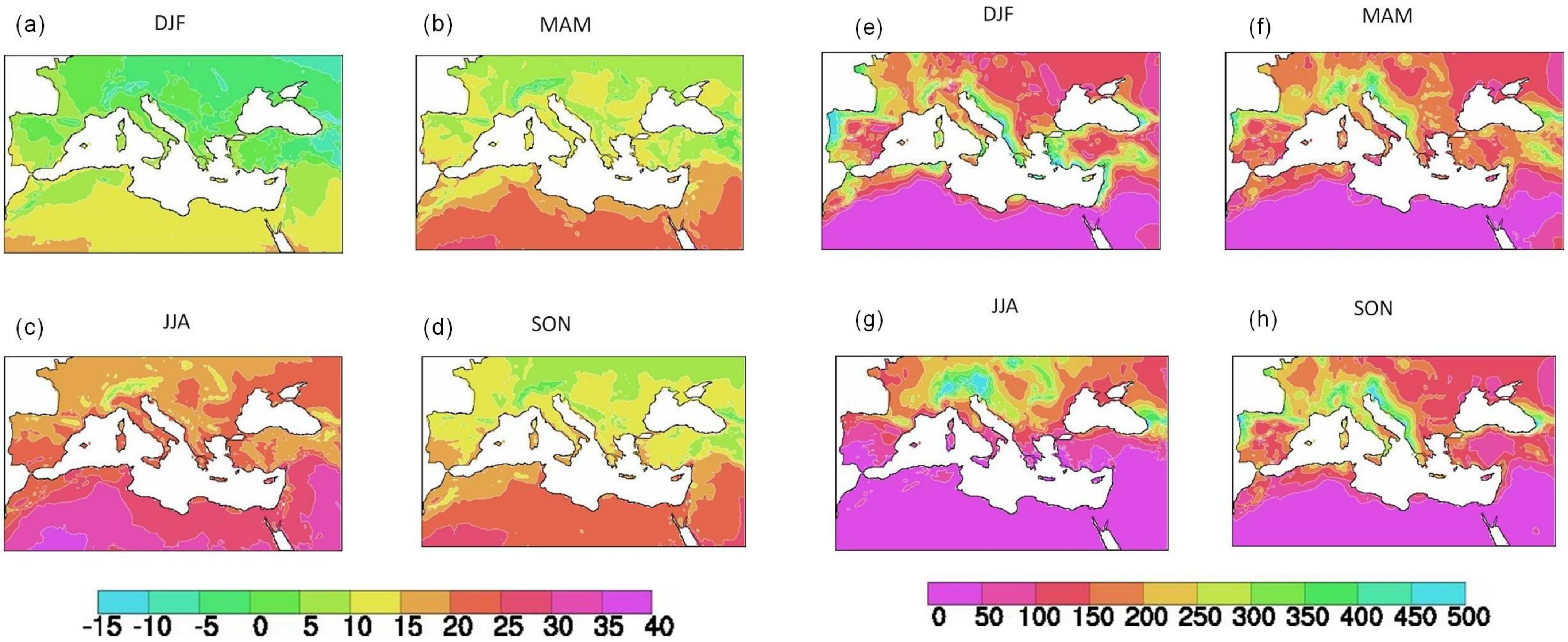
Part II: characteristics, environmental and morphological gradients, ongoing trends

Is the climate of the Mediterranean region uniform?
Is the climate of the Mediterranean region "Mediterranean“?
Is it a mild climate?
Have changes been observed?

Morphological gradient across the Mediterranean region



Representation of bathymetry and topography of the Mediterranean region aggregating data in cells of increasing size: 0.2, 0.5, 1.25,2.5 degs.

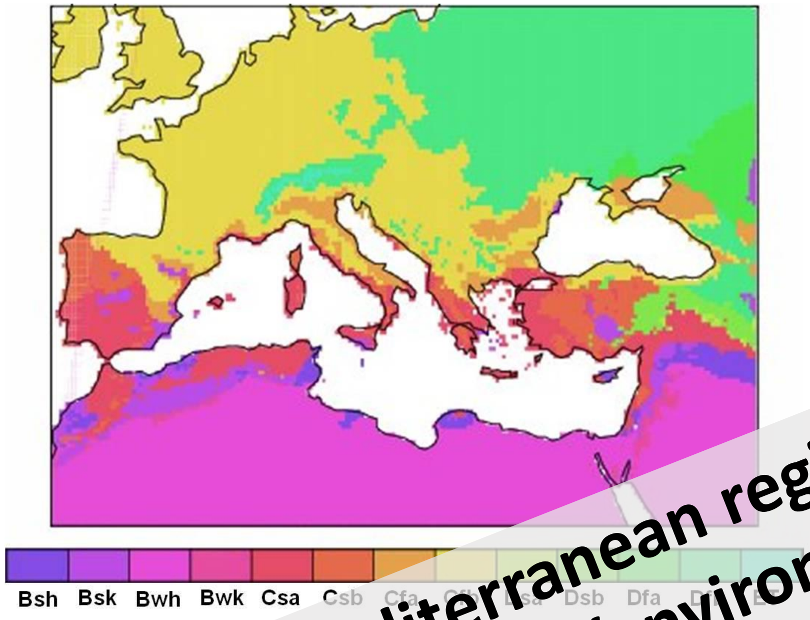


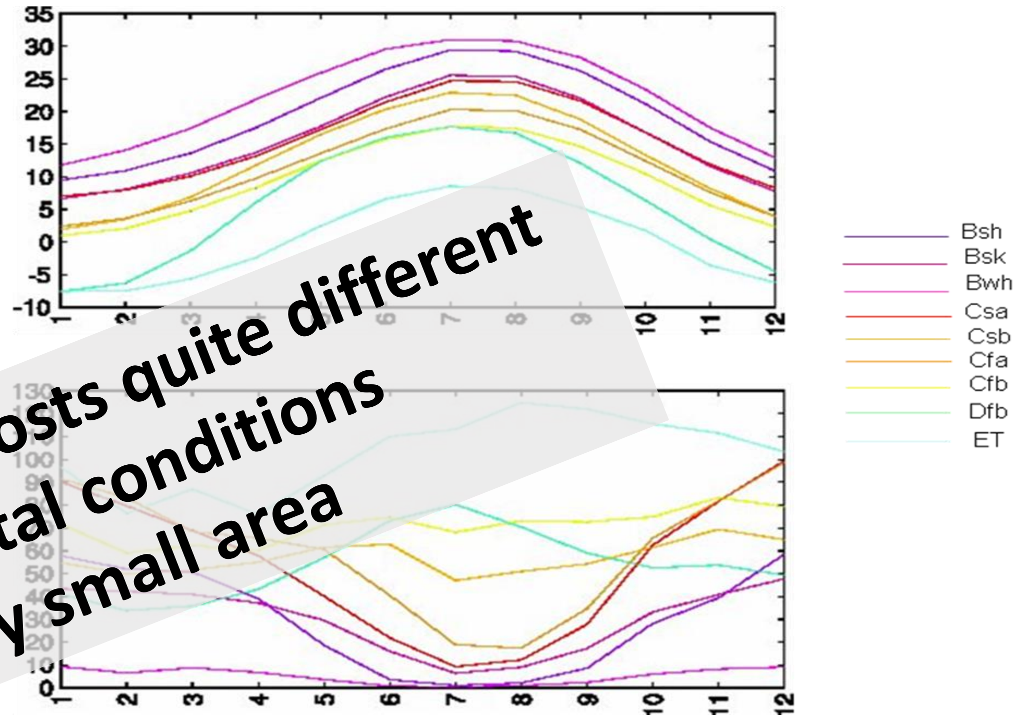
Seasonal (winter: Dec-Jan-Feb, spring: Mar-Apr-May, summer: Jun-Jul-Aug, autumn: Sep-Oct-Nov) maps of temperature (^{0}C, panels a-d) and precipitation (mm/season, panels e-h) for the period 1961-1990 based on the CRU data

Köppen Climate: abbreviations and defining

1st	2nd	3rd	Description	Criteria*
A			Tropical	$T_{cold} \geq 18$
	f		- Rainforest	$P_{dry} \geq 60$
	m		- Monsoon	Not (Af) & $P_{dry} \geq 100 - MAP/25$
	w		- Savannah	Not (Af) & $P_{dry} < 100 - MAP/25$
B			Arid	$MAP < 10 \times P_{threshold}$
	W		- Desert	$MAP < 5 \times P_{threshold}$
	S		- Steppe	$MAP \geq 5 \times P_{threshold}$
		h	- Hot	$MAT \geq 18$
		k	- Cold	$MAT < 18$
C			Temperate	$T_{hot} > 10$ & $0 < T_{cold} < 18$
	s		- Dry Summer	$P_{sdry} < 40$ & $P_{sdry} < P_{wwet}/3$
	w		- Dry Winter	$P_{wdry} < P_{swet}/10$
	f		- Without dry season	Not (Cs) or (Cw)
		a	- Hot Summer	$T_{hot} \geq 22$
		b	- Warm Summer	Not (a) & $T_{mon10} \geq 4$
		c	- Cold Summer	Not (a or b) & $1 \leq T_{mon10} < 4$
D			Cold	$T_{hot} > 10$ & $T_{cold} \leq 0$
	s		- Dry Summer	$P_{sdry} < 40$ & $P_{sdry} < P_{wwet}/3$
	w		- Dry Winter	$P_{wdry} < P_{swet}/10$
	f		- Without dry season	Not (Ds) or (Dw)
		a	- Hot Summer	$T_{hot} \geq 22$
		b	- Warm Summer	Not (a) & $T_{mon10} \geq 4$
		c	- Cold Summer	Not (a, b or d)
		d	- Very Cold Winter	Not (a or b) & $T_{cold} < -38$
E			Polar	$T_{hot} < 10$
	T		- Tundra	$T_{hot} > 0$
	F		- Frost	$T_{hot} \leq 0$

*MAP = mean annual precipitation, MAT = mean annual temperature, T_{hot} = temperature of the hottest month, T_{cold} = temperature of the coldest month, T_{mon10} = number of months where the temperature is above 10, P_{dry} = precipitation of the driest month, P_{sdry} = precipitation of the driest month in summer, P_{wdry} = precipitation of the driest month in winter, P_{swet} = precipitation of the wettest month in summer, P_{wwet} = precipitation of the wettest month in winter, $P_{threshold}$ = varies according to the following rules (if 70% of MAP occurs in winter then $P_{threshold}$ = 2 x MAT, if 70% of MAP occurs in summer then $P_{threshold}$ = 2 x MAT + 28, otherwise $P_{threshold}$ = 2 x MAT + 14). Summer (winter) is defined as the warmer (cooler) six month period of ONDJFM and AMJJAS.

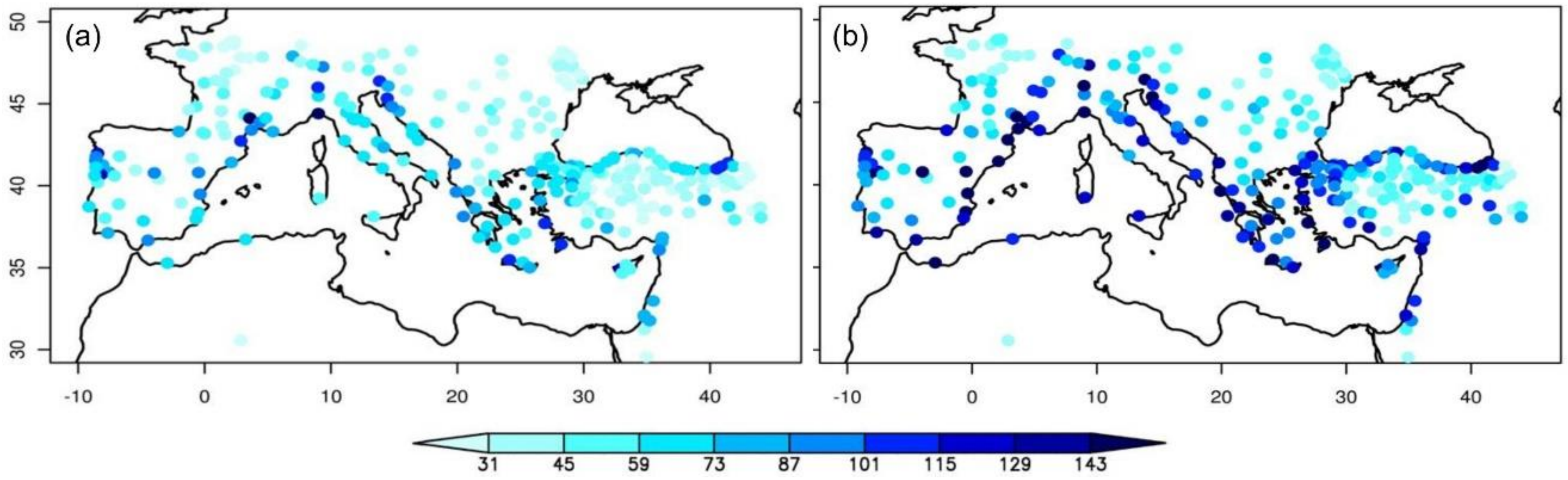




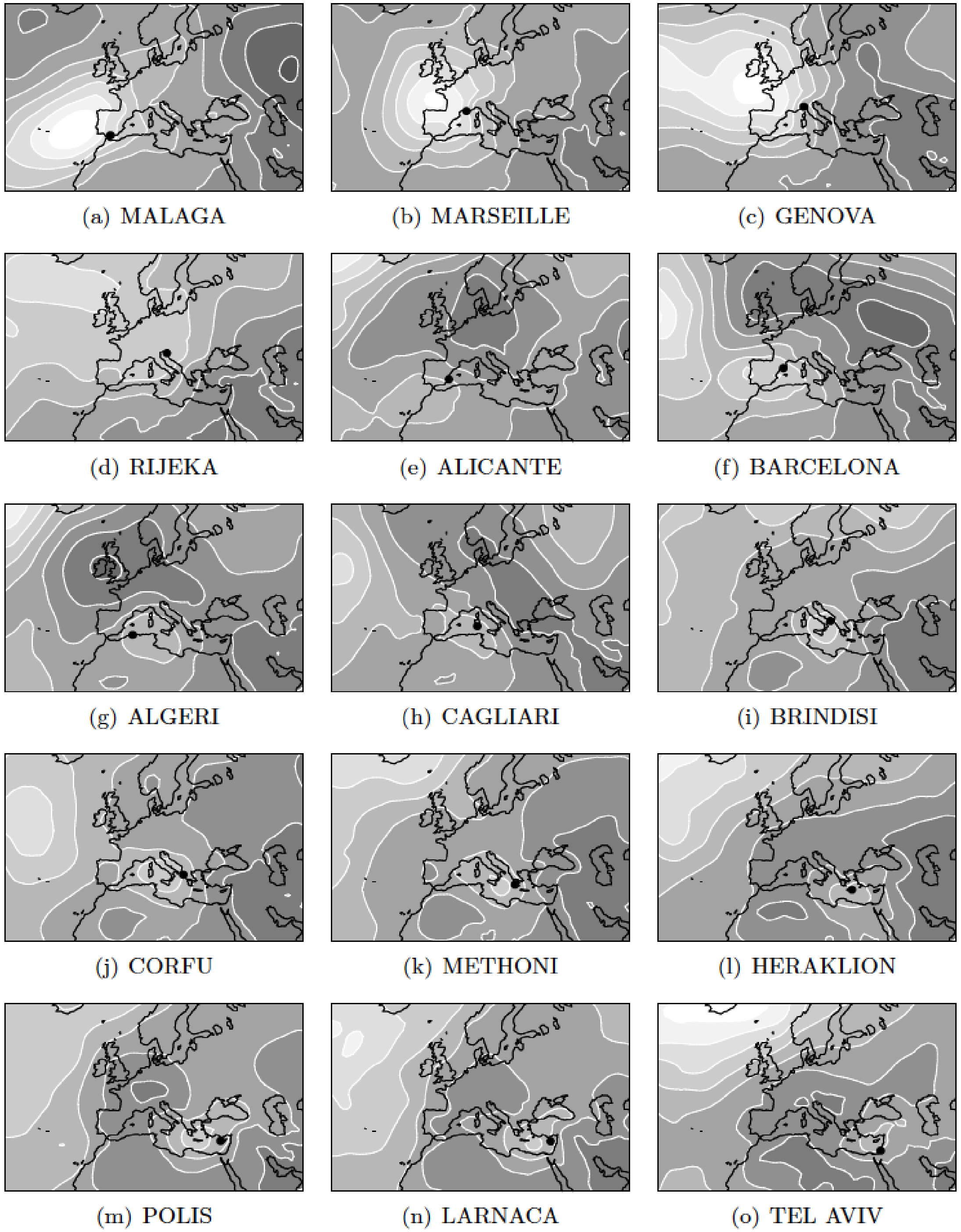
The Mediterranean region hosts quite different climate/environmental conditions within a relatively small area

Köppen climate types in the Mediterranean region: subtropical Steppe (BSh), midlatitude steppe (BSk), subtropical desert (BWh), midlatitude desert (BWk), Mediterranean climate with hot/warm summer (Csa/b), humid subtropical with no dry season (Cfa), Maritime temperate (Cfb), Humid continental with hot/warm summer (Dfa/b), continental with dry hot/warm summer (Dsa/b), Tundra (ET). This figure is based on the CRU temperature and precipitation gridded data (New et al.2000).

Intense precipitation events



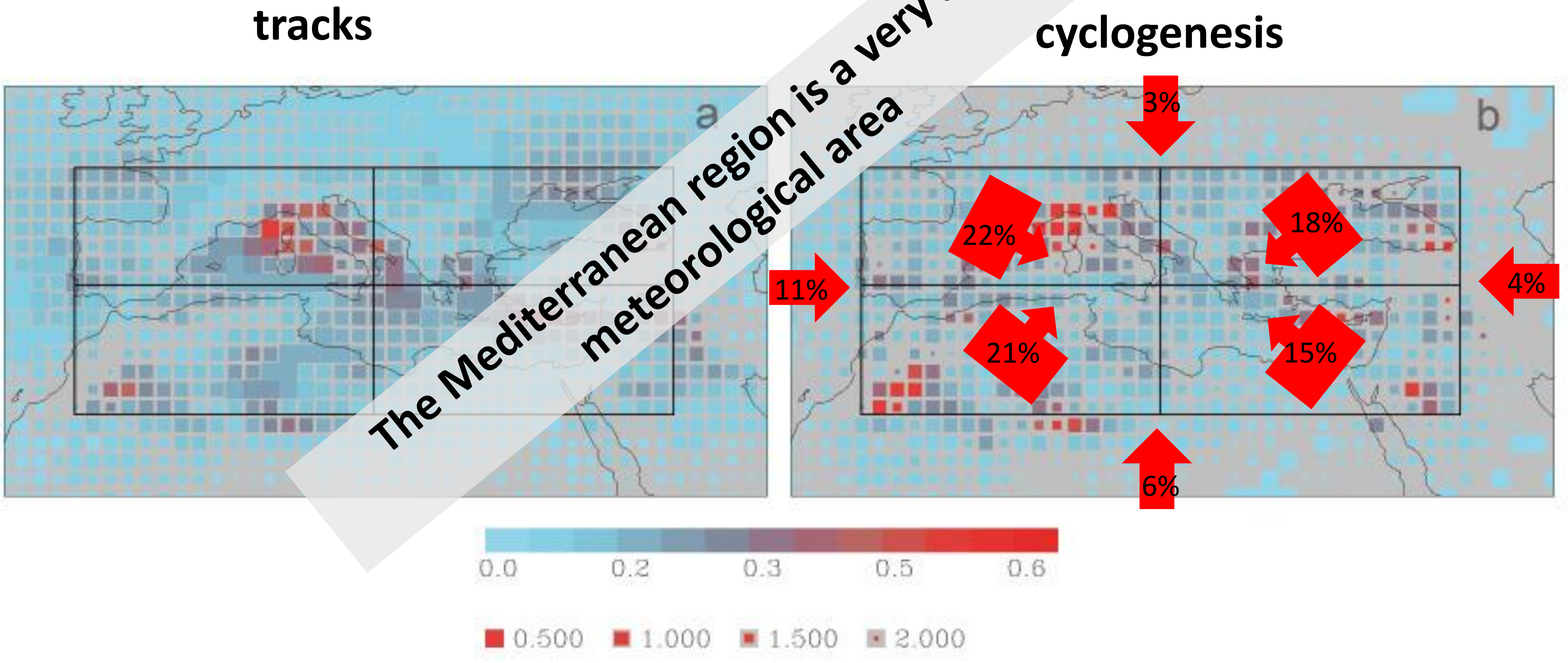
(a) 5-year and (b) 50-year return levels of extended winter (October to March) precipitation (mm) estimated with daily precipitation time series from 1950-2006



Cyclones producing intense precipitation events

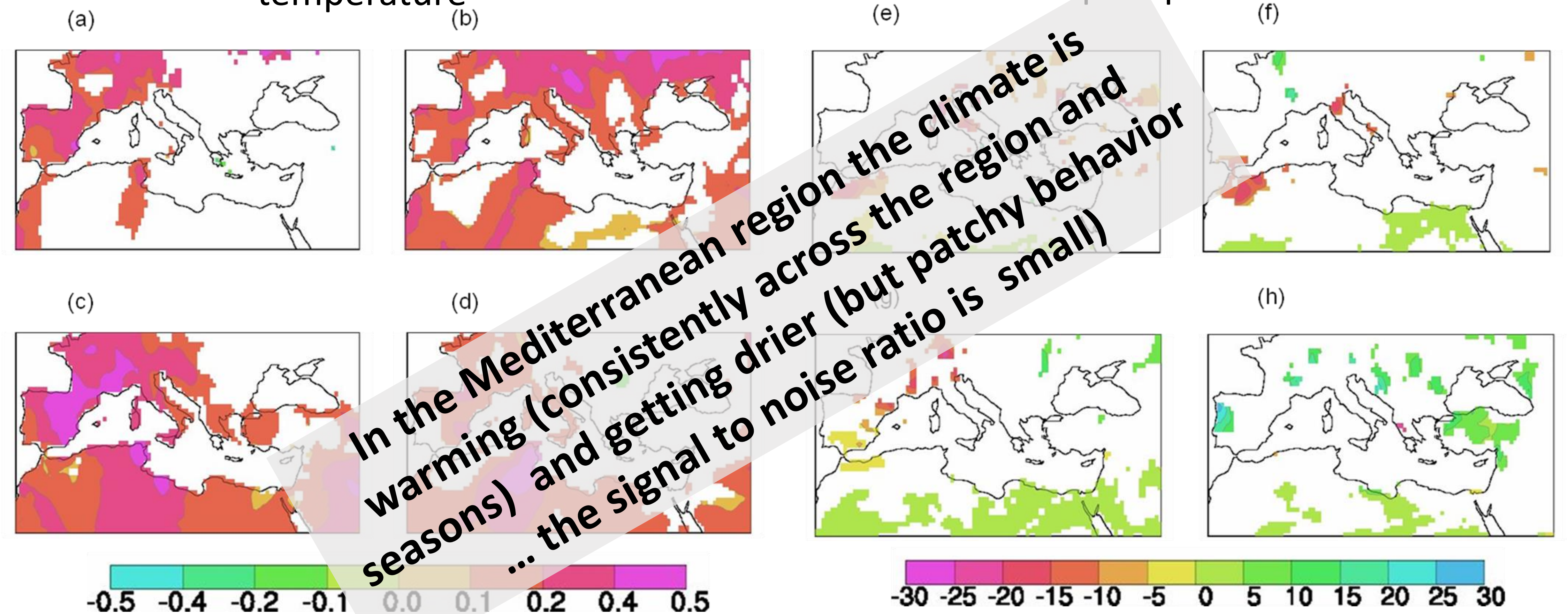
Mediterranean cyclones

About 225 cyclones cross the Mediterranean region every year (7.5% of the cyclones of the Northern hemisphere while its area is about 3.8%)



Observed trends

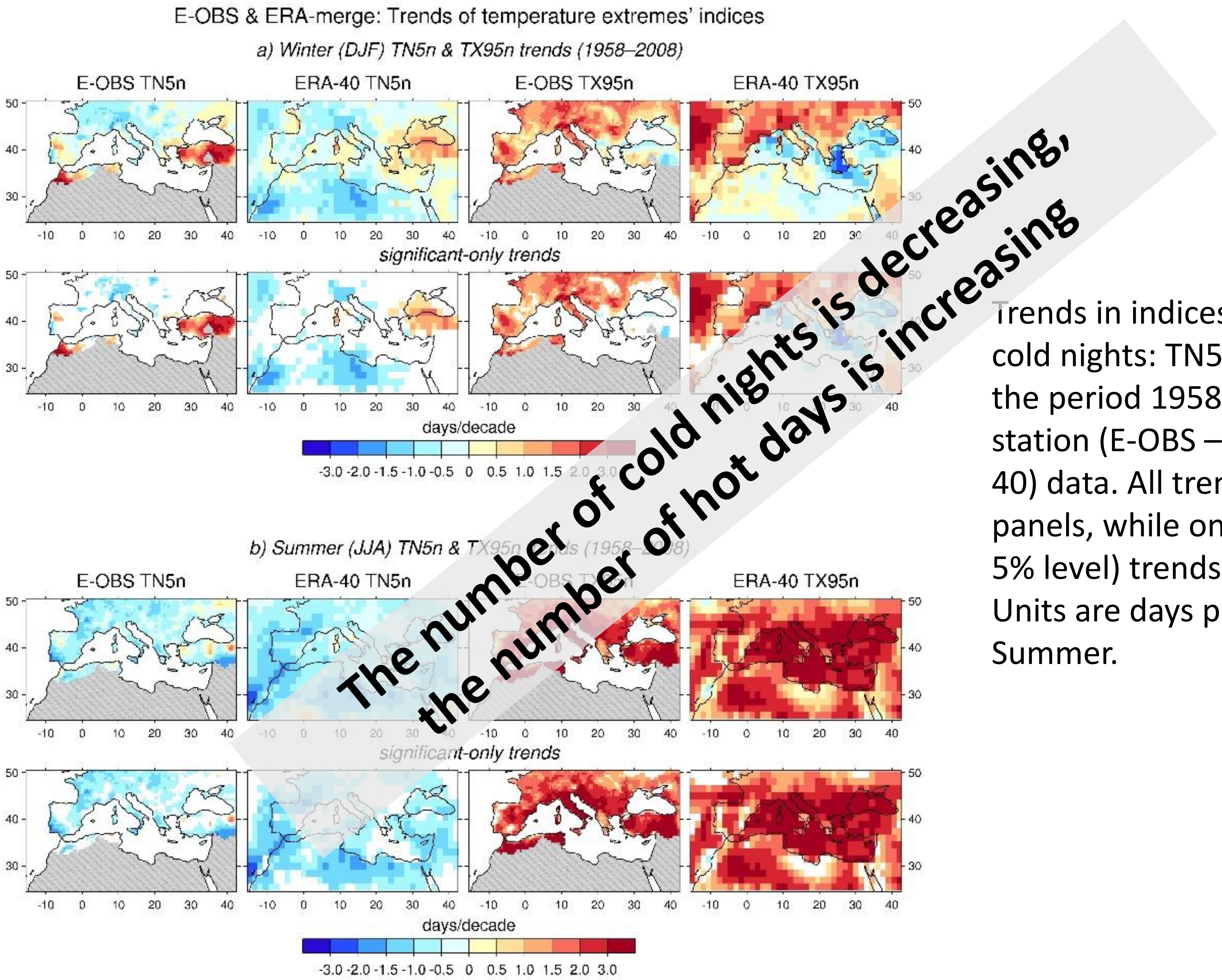
temperature | precipitation



In the Mediterranean region the climate is warming (consistently across the region and seasons) and getting drier (but patchy behavior … the signal to noise ratio is small)

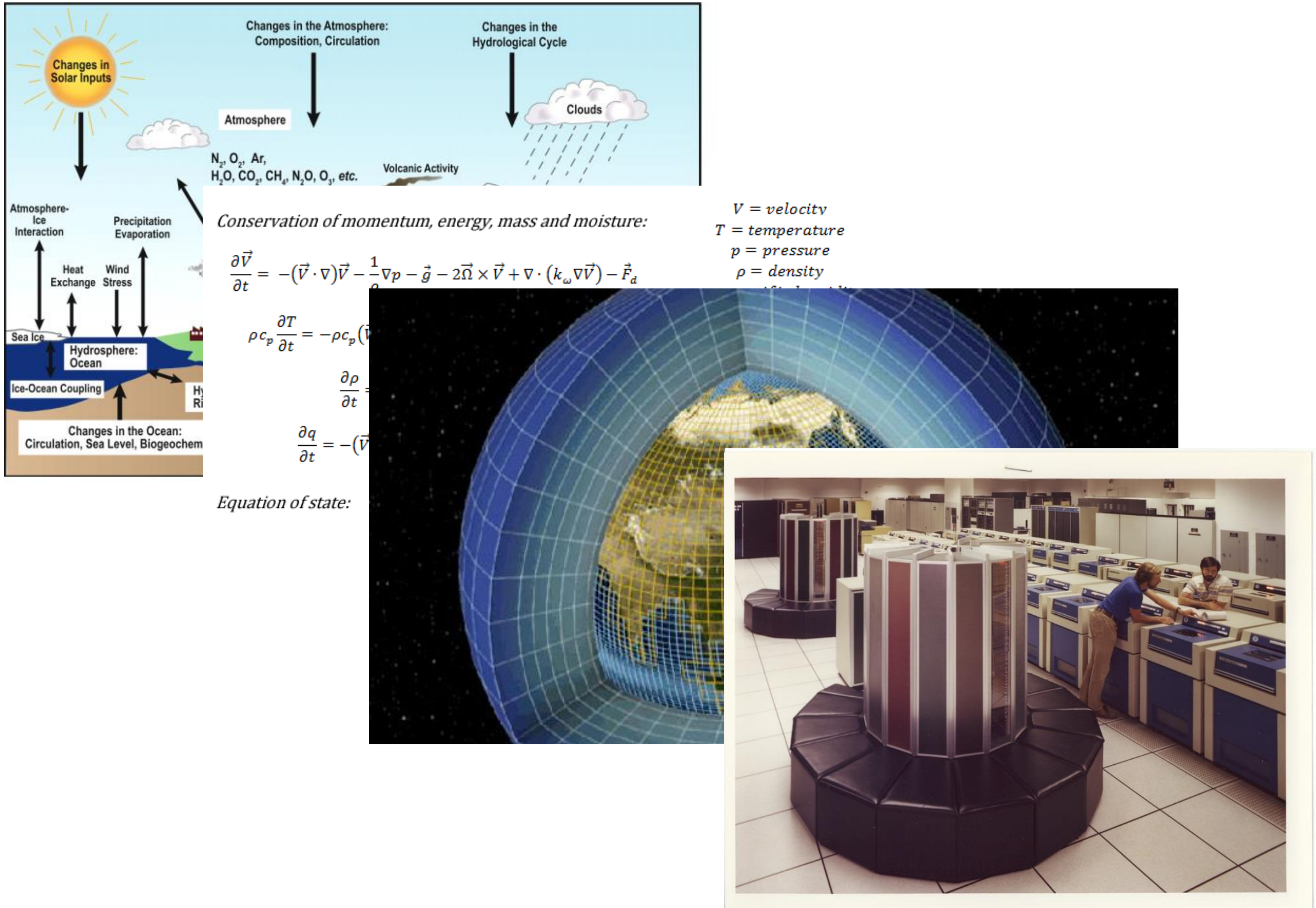
Trends of the seasonal (winter: Dec-Jan-Feb, spring: Mar-Apr-May, summer: Jun-Jul-Aug, autumn: Sep-Oct-Nov) temperature (0C/decade, panels a-d) and precipitation (mm/decade, panels e-h) for the period 1951-2005 based on the CRU data.

Temperature extremes



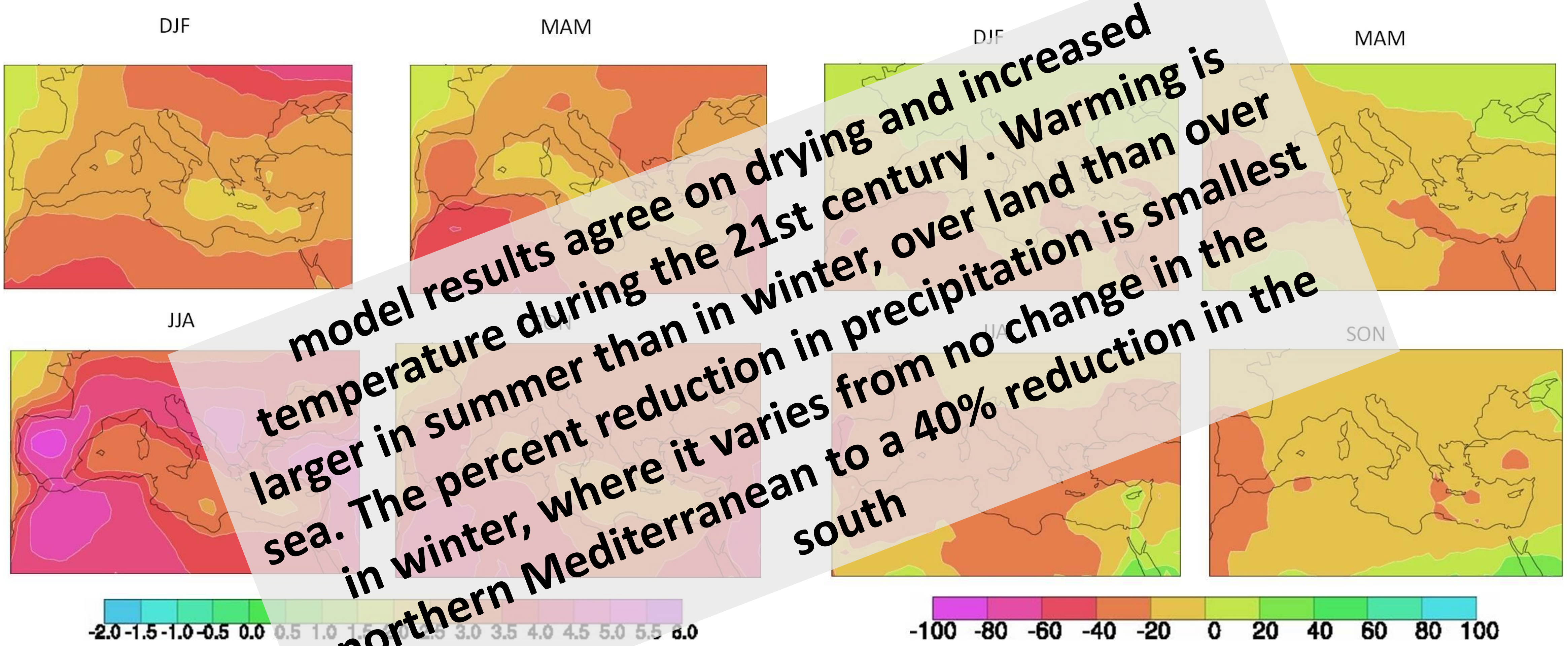
Trends in indices of temperature extremes (Very cold nights: TN5n and Very hot days: TX95n) over the period 1958-2008 calculated from gridded station (E-OBS – land only) and reanalysis (ERA-40) data. All trends are shown in the upper panels, while only statistically significant (at the 5% level) trends are shown in the lower panels. Units are days per decade. (a) Winter, (b) Summer.

Part III: future evolution of regional climate…



Sources of uncertainty

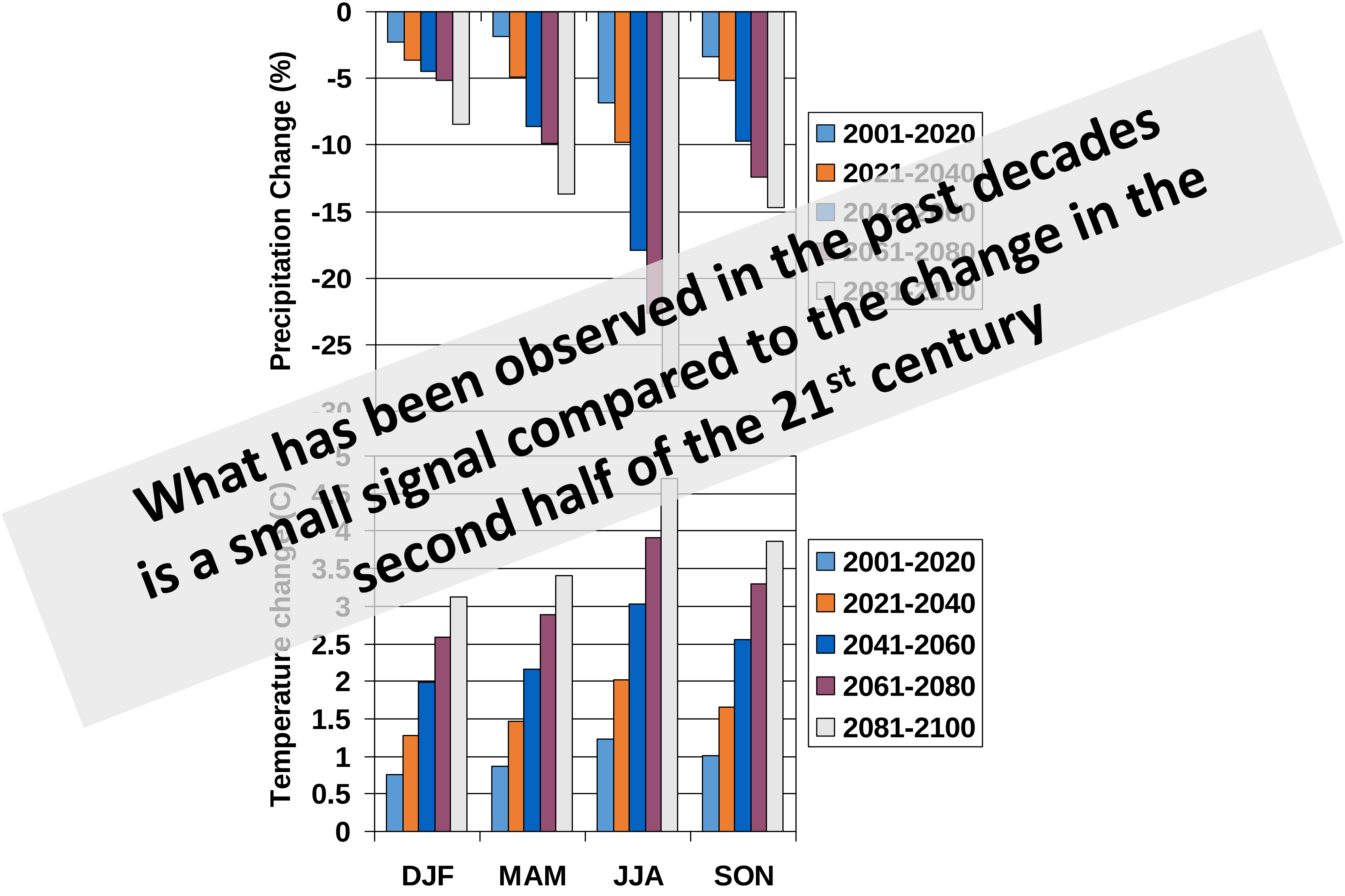
- **Insufficient knowledge of the state of the climate system;**
- **the internal variability of the climate system;**
- **structural uncertainty of models (related to how processes are represented in models);**
- **the future evolution of anthropogenic emission;**



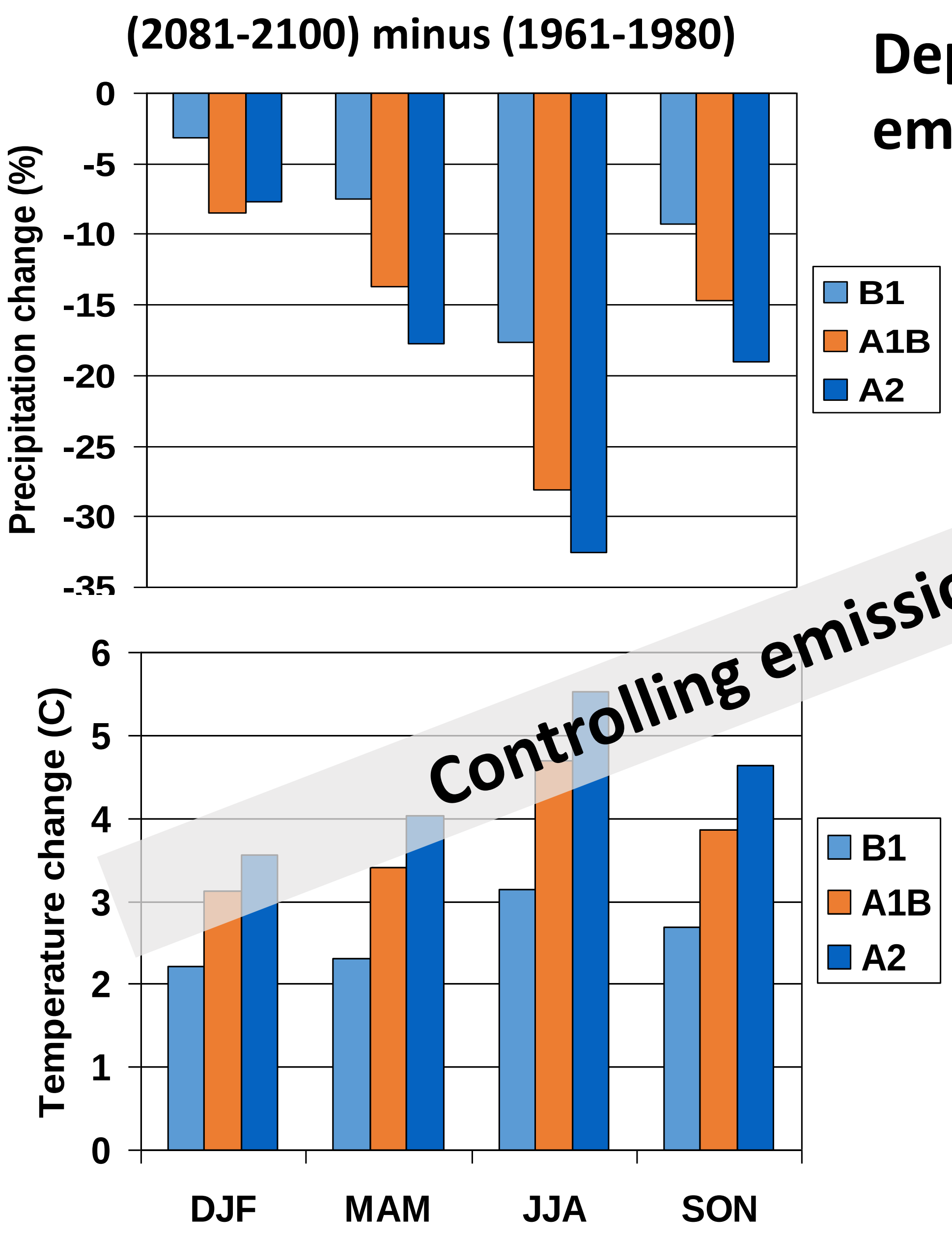
model results agree on drying and increased temperature during the 21st century . Warming is larger in summer than in winter, over land than over sea. The percent reduction in precipitation is smallest in winter, where it varies from no change in the northern Mediterranean to a 40% reduction in the south

Seasonal (DJF, MAM, JJA, SON) map of temperature (0C, top panels) and precipitation signal (percent of the value in the reference period, bottom panels) climate change as resulting from an ensemble of GCMs. The maps show the differences between the 2071-2100 period of the A1B scenario and the reference period 1961-1990 (adapted from Giorgi and Lionello, 2008, in Lionello et al., 2012

Future evolution of climate change

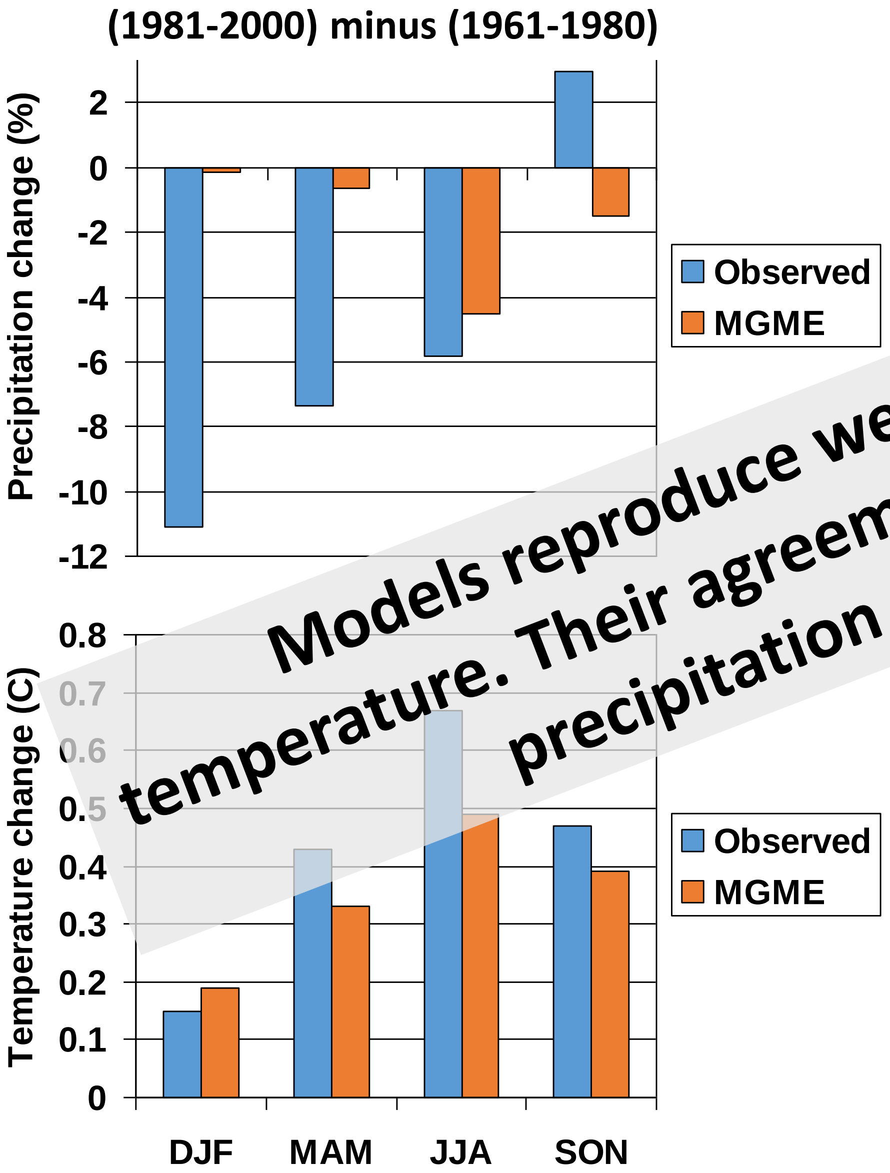


Dependence of climate change on emission scenario



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

Are models reliable

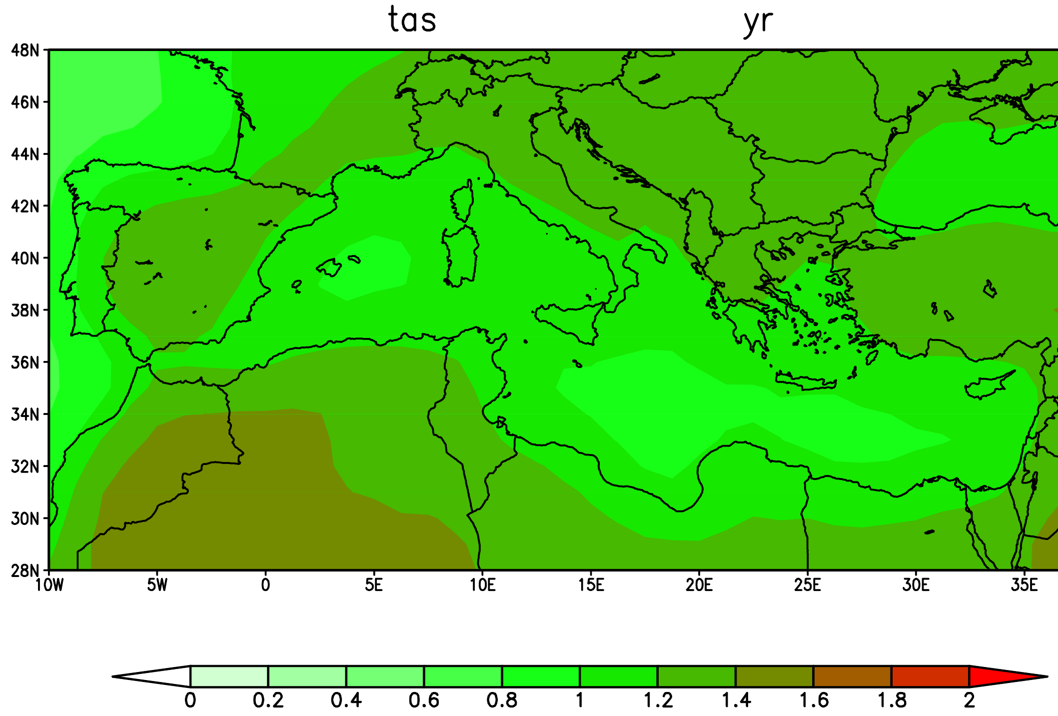


Models reproduce well past evolution of temperature. Their agreement with past evolution of precipitation is controversial

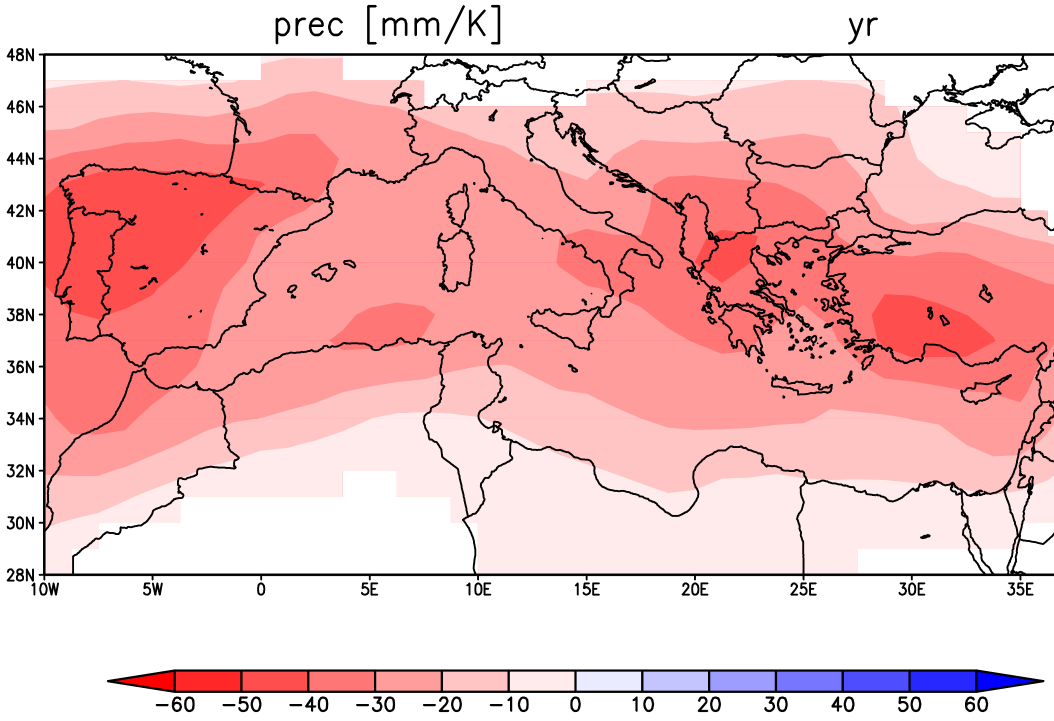
Observed (CRU data) and MGME ensemble average change in precipitation (upper panel) and surface air temperature (lower panel) for the four seasons over the full Mediterranean region (land only) 1981-2000 minus 1961-1980. Units are % of 1961-1980 value for precipitation and degrees C for temperature.

The dependence of regional climate on global climate change

Temperature (fraction)

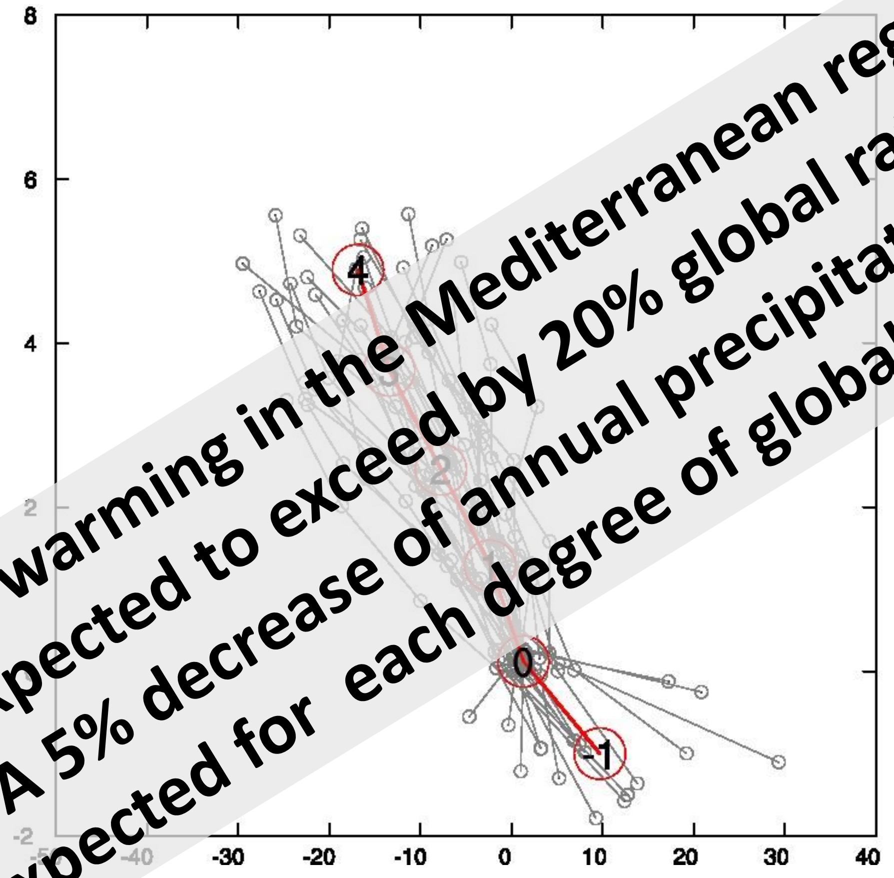


Precipitation (mm/K)



rate of change of mean annual temperature and total annual precipitation with mean global temperature

The “trajectory” of the climate of the Mediterranean region



Future warming in the Mediterranean region is expected to exceed by 20% global rates . A 5% decrease of annual precipitation is expected for each degree of global warming

trajectories showing the change of mean annual precipitation and temperature in the Mediterranean region as function of the global mean annual temperature change

The future amplitude of climate change will depend to a great extent on the actual evolution of anthropogenic emissions. Actual values and the detailed spatial distribution of changes, particularly for precipitation, remain uncertain, as they depend strongly on the adopted climate model. However, this component of the scientific debate, aiming at providing a deeper understanding of processes and a more accurate prediction of the future, should not hide that in the Mediterranean region at the end of the 21st century intense warming is almost certain and substantial drying is very likely. Consequences on the environment will be important and will require all possible effort for mitigation of global climate change and adaptation to new climate conditions at regional scale.