2165-6

International MedCLIVAR-ICTP-ENEA Summer School on the Mediterranean Climate System and Regional Climate Change

13 - 22 September 2010

Atmospheric Obs: The climate of the Mediterranean in the instrumental period; extremes and related atmospheric circulation

XOPLAKI Elena

Cyprus Meteorological Service
L. Nikis 28, 1086 Lefkosia
Lefkosia
CYPRUS

The climate of the Mediterranean in the instrumental period

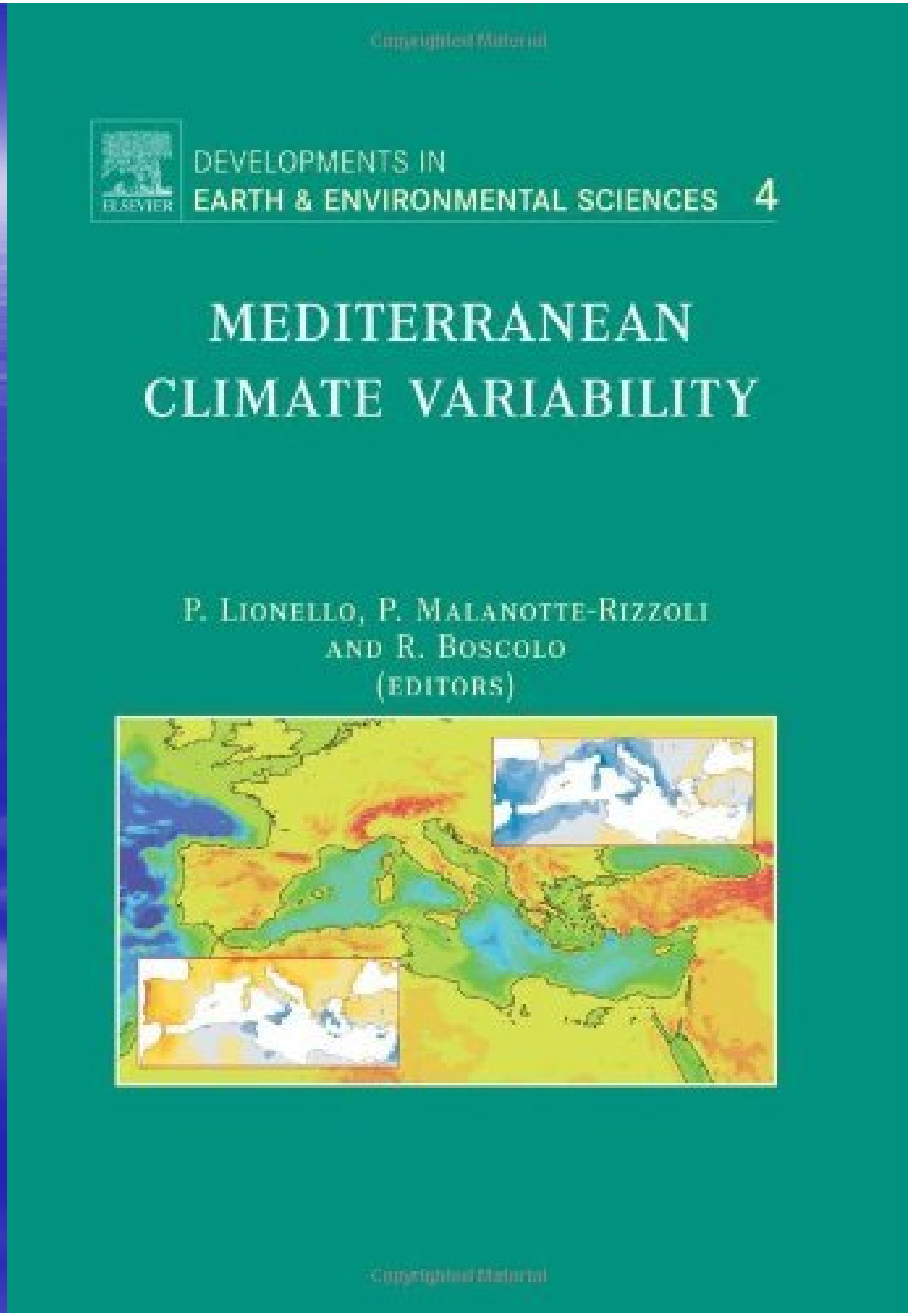
Extremes and related atmospheric circulation

Elena Xoplaki

University of Bern & The Cyprus Institute
elena.xoplaki@giub.unibe.ch

MedCLIVAR

Mediterranean
Climate
Variability



Outline

- Why is the Mediterranean of importance?
- Mediterranean climatological data:
  gridded time series and station observations
- Quality control and homogenization of daily station time series
- Mediterranean climate & climate change: instrumental period
- Links between large scale atmospheric circulation and Mediterranean climate
- Extreme events in the Mediterranean
- Impacts of climate change and extreme events in the Mediterranean societies
- Conclusions

The Greater Mediterranean Region

Source: ESA, 2010

It is influenced by subtropical processes, mid-latitude dynamics[1] …

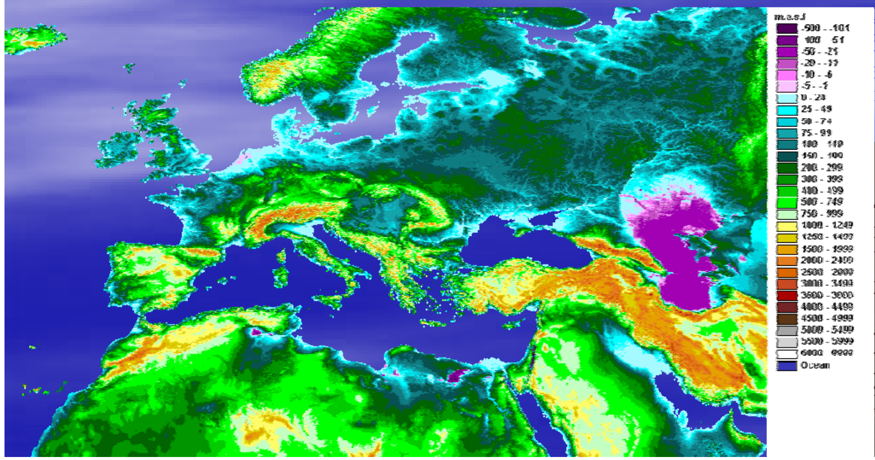
High population density (~60 persons/km^2), vulnerability, exposure to climate change….HOT SPOT[2]

1 Xoplaki, 2002

2 Giorgi, 2006

Why is the Mediterranean of importance?

- A "hotspot" whose climate is especially responsive to global change and where potential climate change impacts are particularly strong
- Spatial distribution of temperature and precipitation
  - Large scale atmospheric circulation, latitude, orography, land-sea interactions, SSTs, other smaller scale processes



Vulnerability in the Mediterranean

- Hydrologic cycle – Rainy season
  - Water resources & water quality
  - Agriculture & environment
  - Economics & social development & behaviour
- Temperature extremes – Heat waves
  - Mortality & air pollution
  - Tourism

Vulnerability in the Mediterranean

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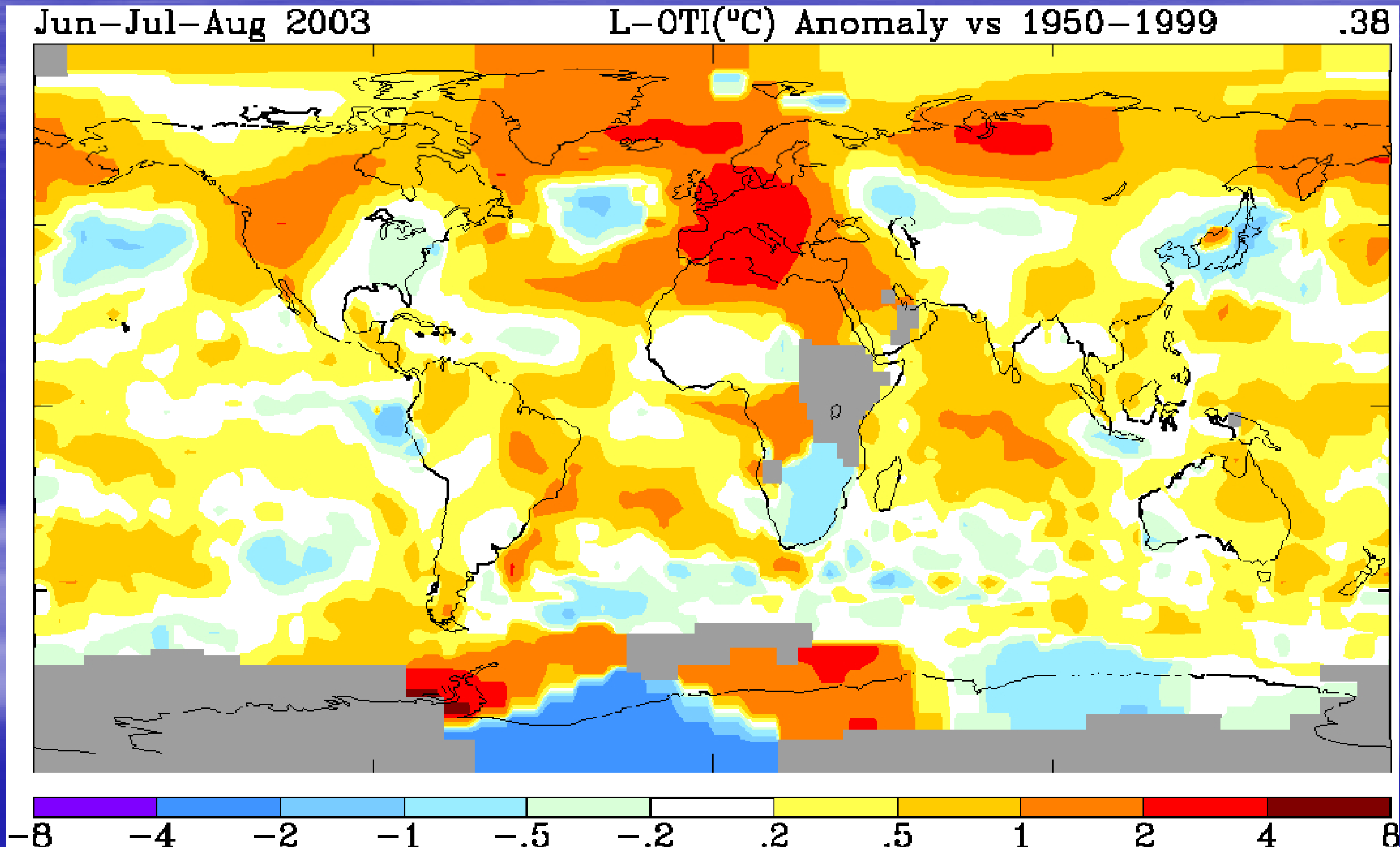
Summer 2003; one of the hottest European summers over past centuries



Fires during summer 2003

Extreme temperature events

Impacts of extreme temperature events


SPIEGEL ONLINE WISSENSCHAFT

Klimawandel

2003

Hitze forderte mindestens 35.000 Tote

Die Hitzewelle im August hat nach neuen Berechnungen allein in acht europäischen Ländern mindestens 35.000 Menschen getötet. Für die Zukunft sagen Wissenschaftler noch heißere Sommer voraus.

2005

NEWS.at

Italien von Hitzewelle lahmgelegt: Hohe Temperaturen forderten schon zig Tote!

- Frankreich und Spanien atmen auf: Erste Abkühlung
- KLICKEN: So wird das Wetter in den nächsten Tagen

sueddeutsche.de

Südosteuropa

Zahl der Hitzetoten steigt

26.06.2007, 12:01

2007

Durch den Südosten Europas rollt eine Hitzewelle mit Werten nahe 50 Grad Celsius. Mindestens zehn Menschen sind ihr bereits zum Opfer gefallen.

Costa Blanca floods, autumn 2007

Mediterranean climatological data
Gridded time series

- E-OBS (Haylock et al. 2008)
- EMULATE (Ansell et al. 2006)
- CRUTEM3 (Brohan et al. 2006)
- CPC GHCN/CAMS (Fan and van den Dool 2008)
- CRU TS 3 (Mitchel and Jones 2005)
- APRHODITE (E. Mediterranean only, Yatagai et al. 2008)
- GPCC V4 (Schneider et al. 2008)
- Tremberth's NH (Trenberth and Paolino 1980)
- HadSLP2 (Allan and Ansell, 2006)
- NCEP/NCAR-Reanalysis (Kistler et al. 2001)
- ERA-40-Reanalysis (Uppala et al. 2005)

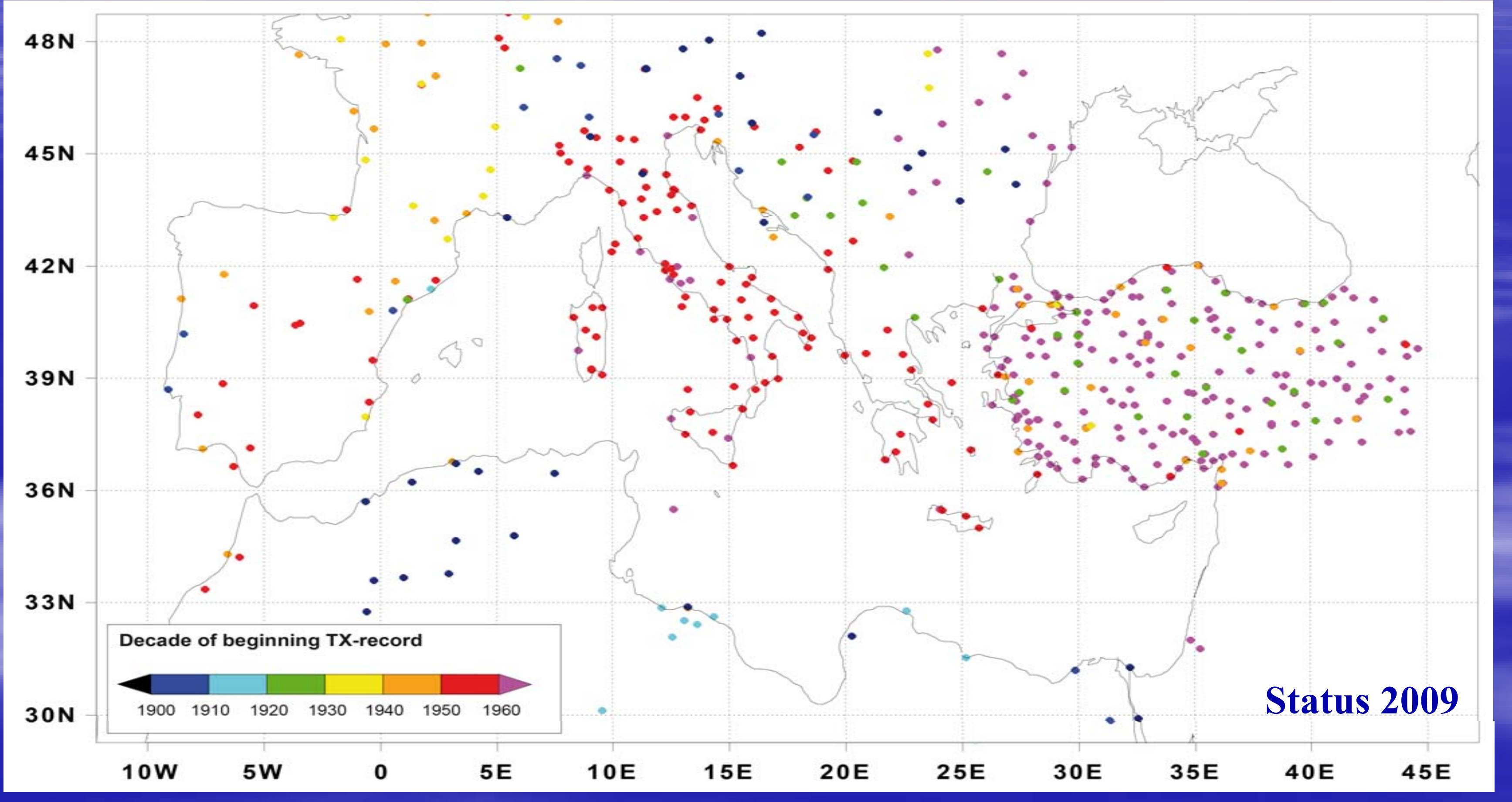
Mediterranean climatological data Observations

- Daily and monthly station time series from 22 countries across the Greater Mediterranean Region – up to 2006

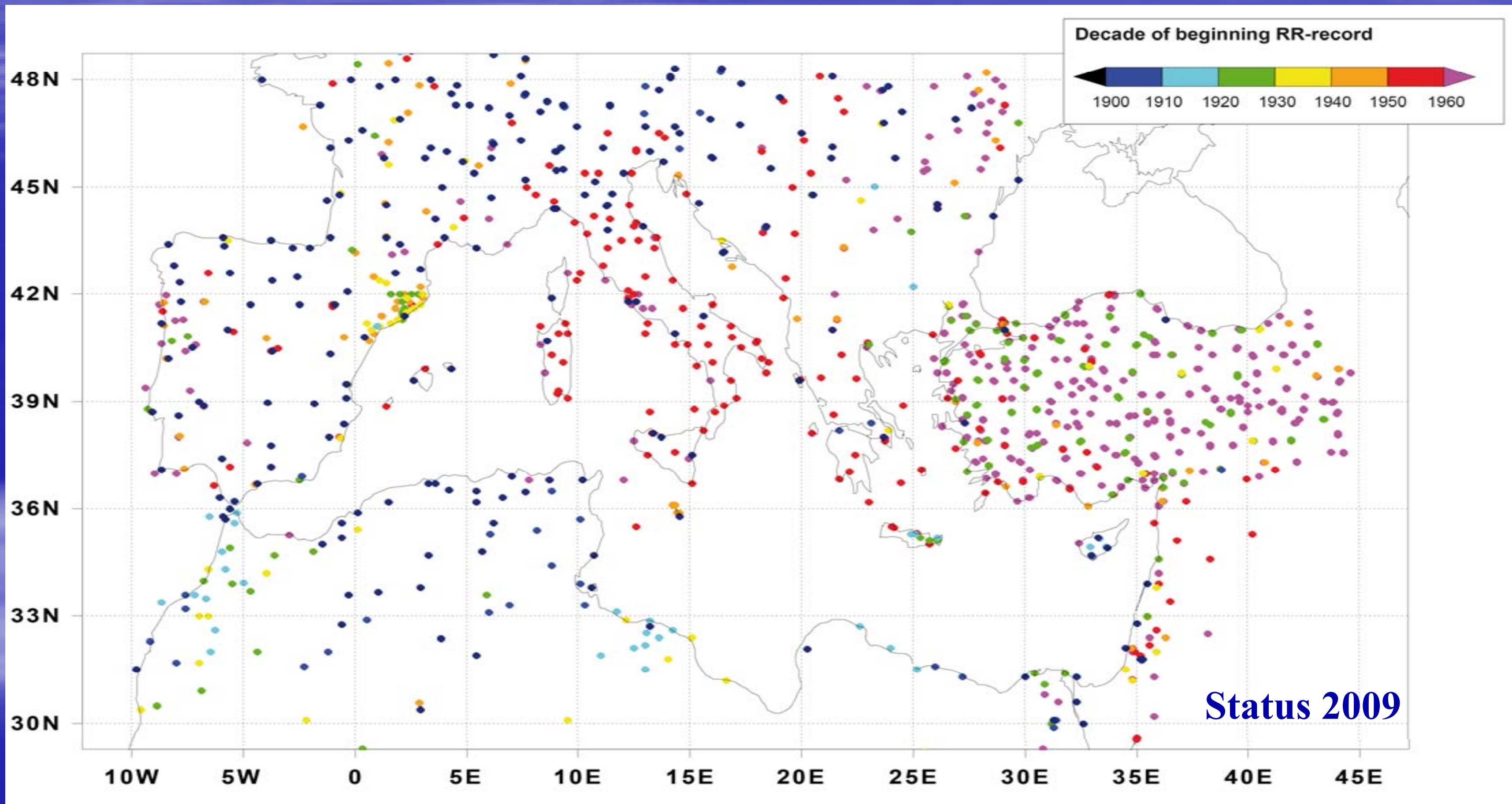
- Global Historical Climatology Network (GHCN)
- European Climate Assessment & Data set (ECA&D)
- WMO–Initiative on Mediterranean Climate Data Rescue (WMO-MEDARE)
- National Meteorological and Hydrological Services (NMHSs)

- Algeria, Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Egypt, France, FYROM, Greece, Hungary, Israel, Italy, Jordan, Libya, Moldova, Morocco, Portugal, Romania, Serbia, Slovenia, Spain, Switzerland, Syria, Tunisia, Turkey

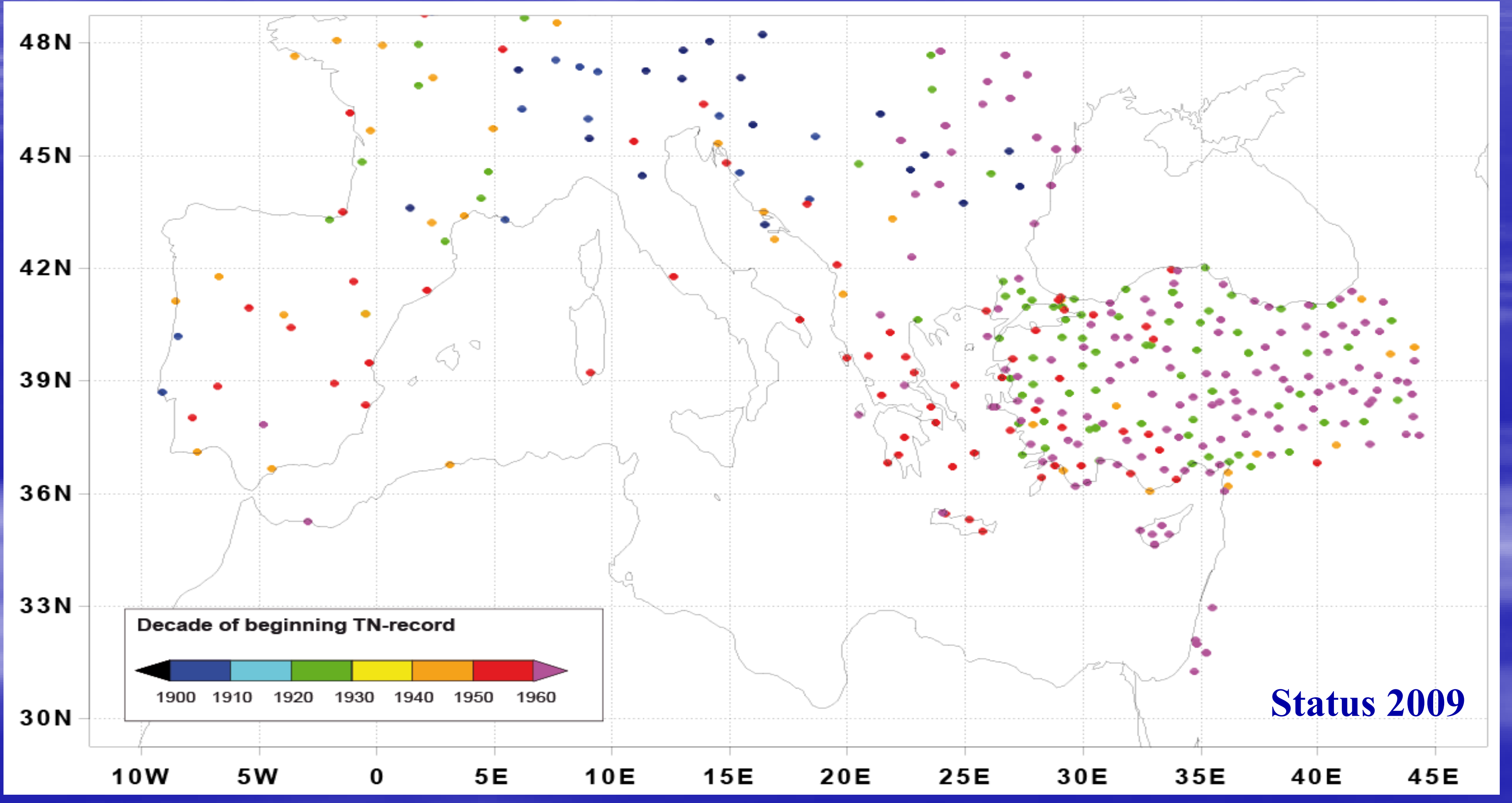
Mediterranean climatological data
Monthly observations – Tmax & Tmin



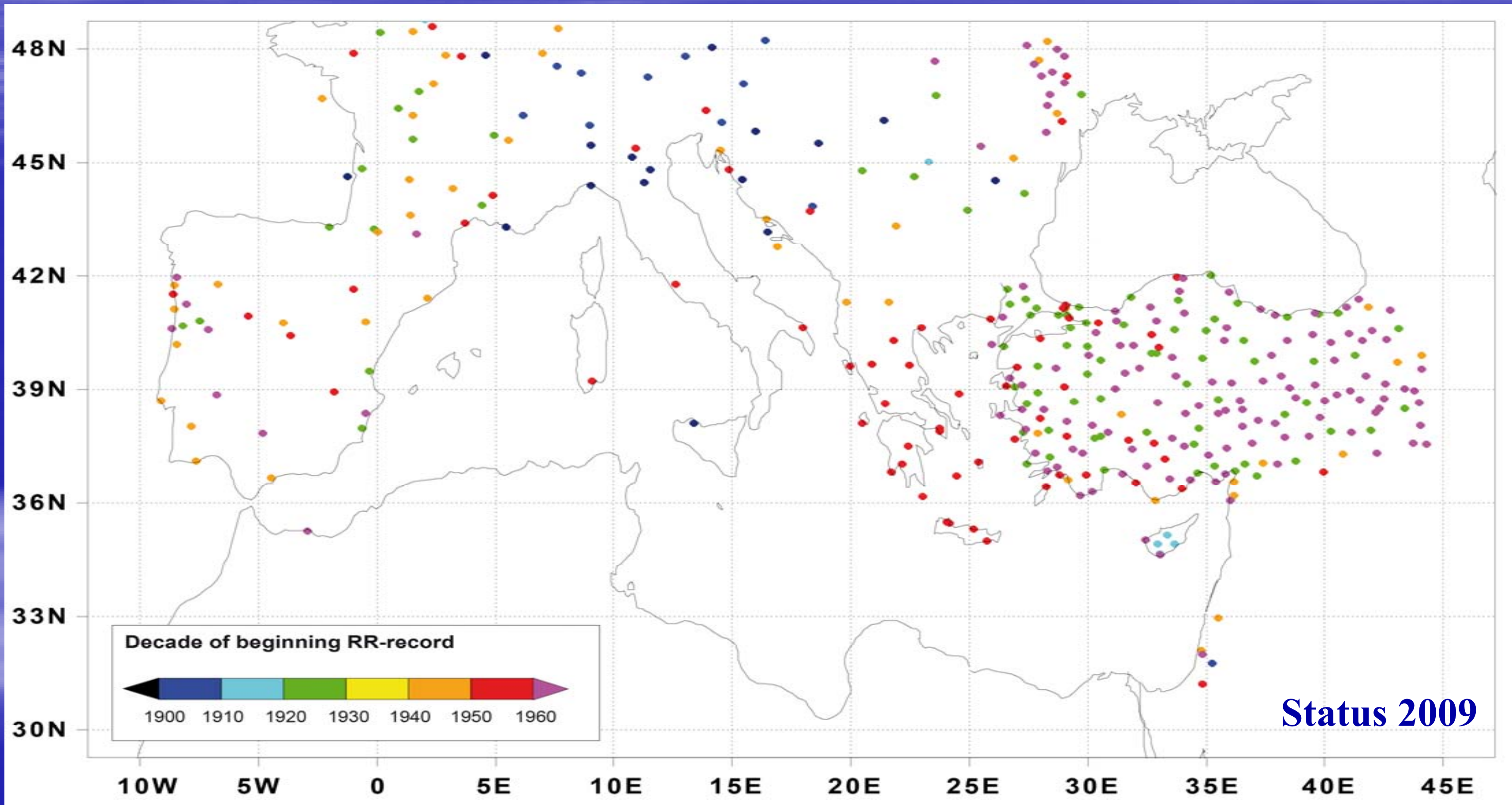
Mediterranean climatological data
Monthly observations - Precipitation



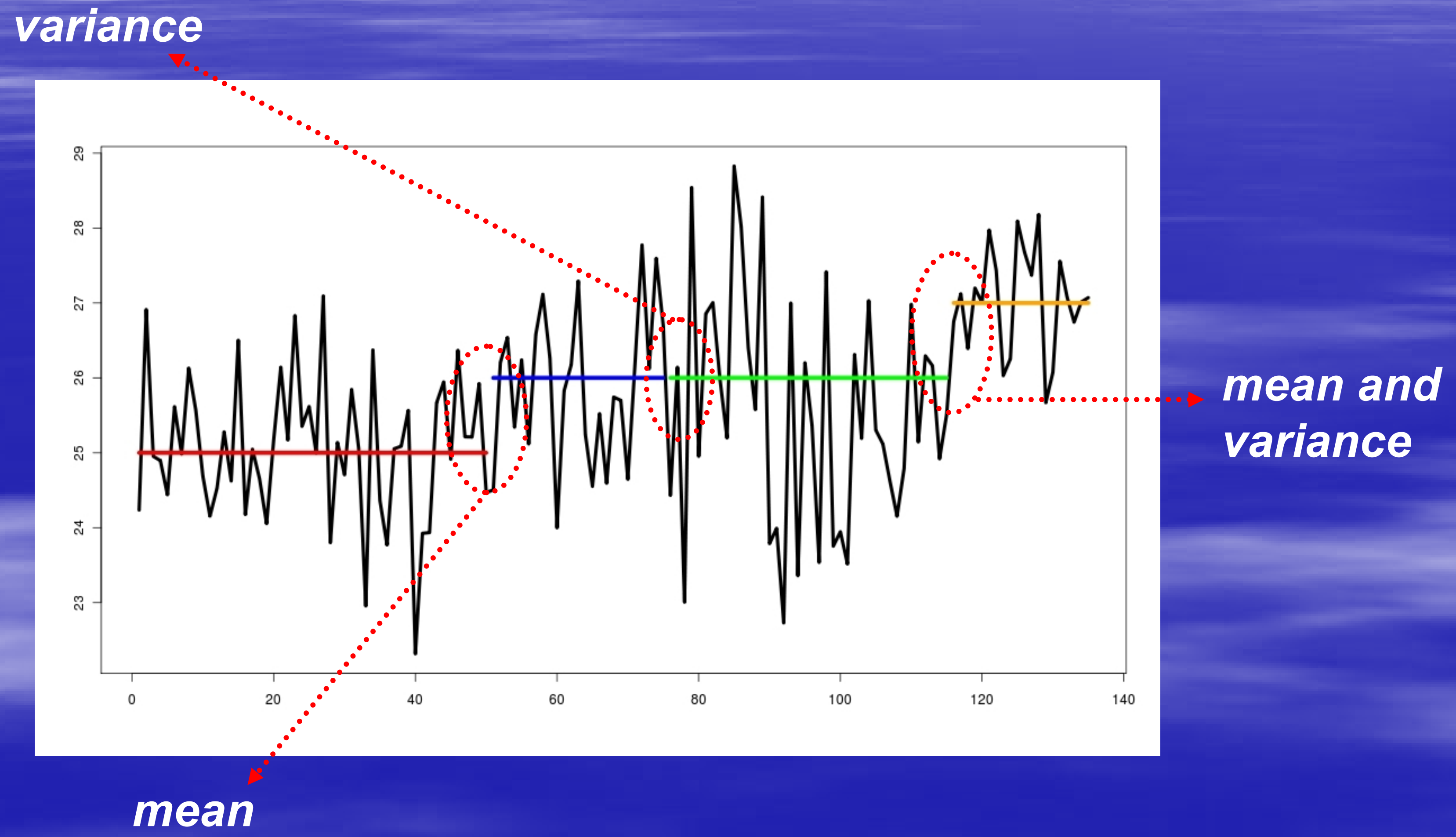
Mediterranean climatological data
Daily observations – Tmax & Tmin



Mediterranean climatological data
Daily observations – Precipitation



Errors in climatological time series



Quality control & homogenization
Daily data

- **Break Detection**
  Caussinus and Mestre 2004
  Wang et al. 2007
  Wang 2008
  Toreti et al. 2011

- **Correction**
  PENHOM (Kuglitsch et al. 2009)
  HOMAD (Toreti et al. 2010)

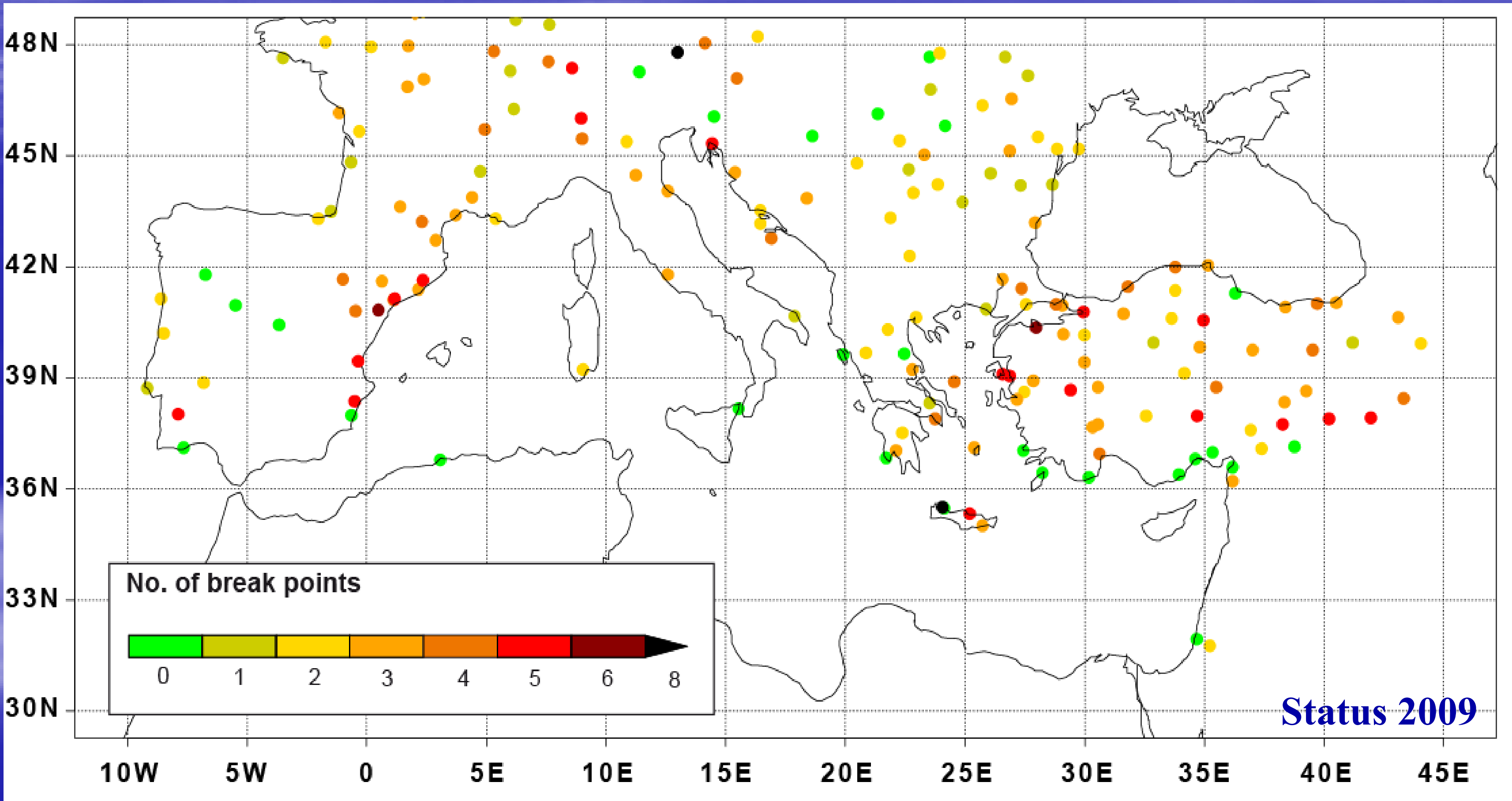
  Della-Marta and Wanner 2006

Quality control & homogenization
Daily data

- **Break Detection**
- No metadata needed
- Detection of unknown number of Break Points (BP) possible
- Time series between 2 break points assumed to be homogeneous

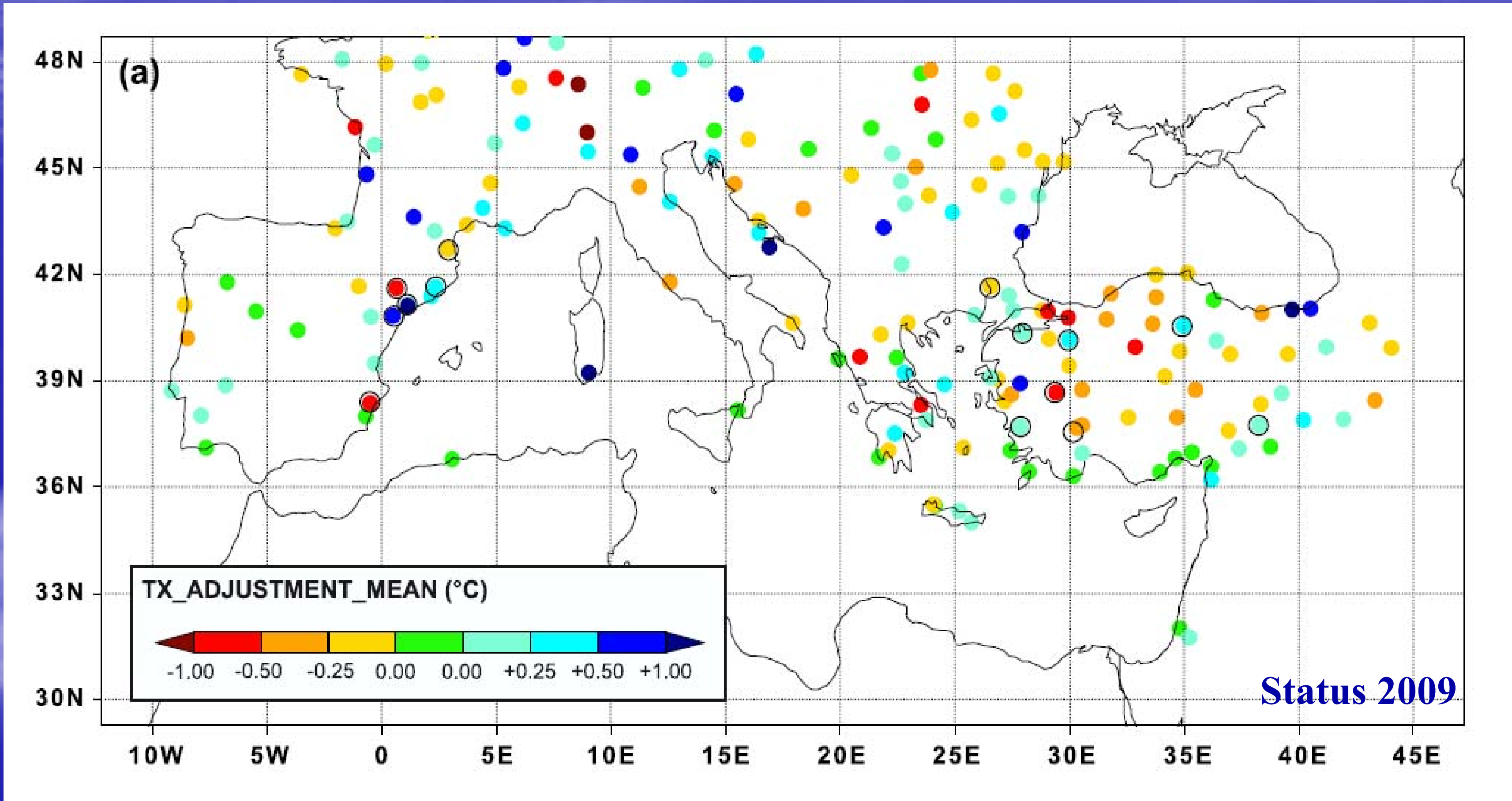
- **Correction**
- Adjustments of daily values, variance, skewness and higher-order moments, taking into consideration autocorrelation of the time series

Quality control & homogenization
Break detection



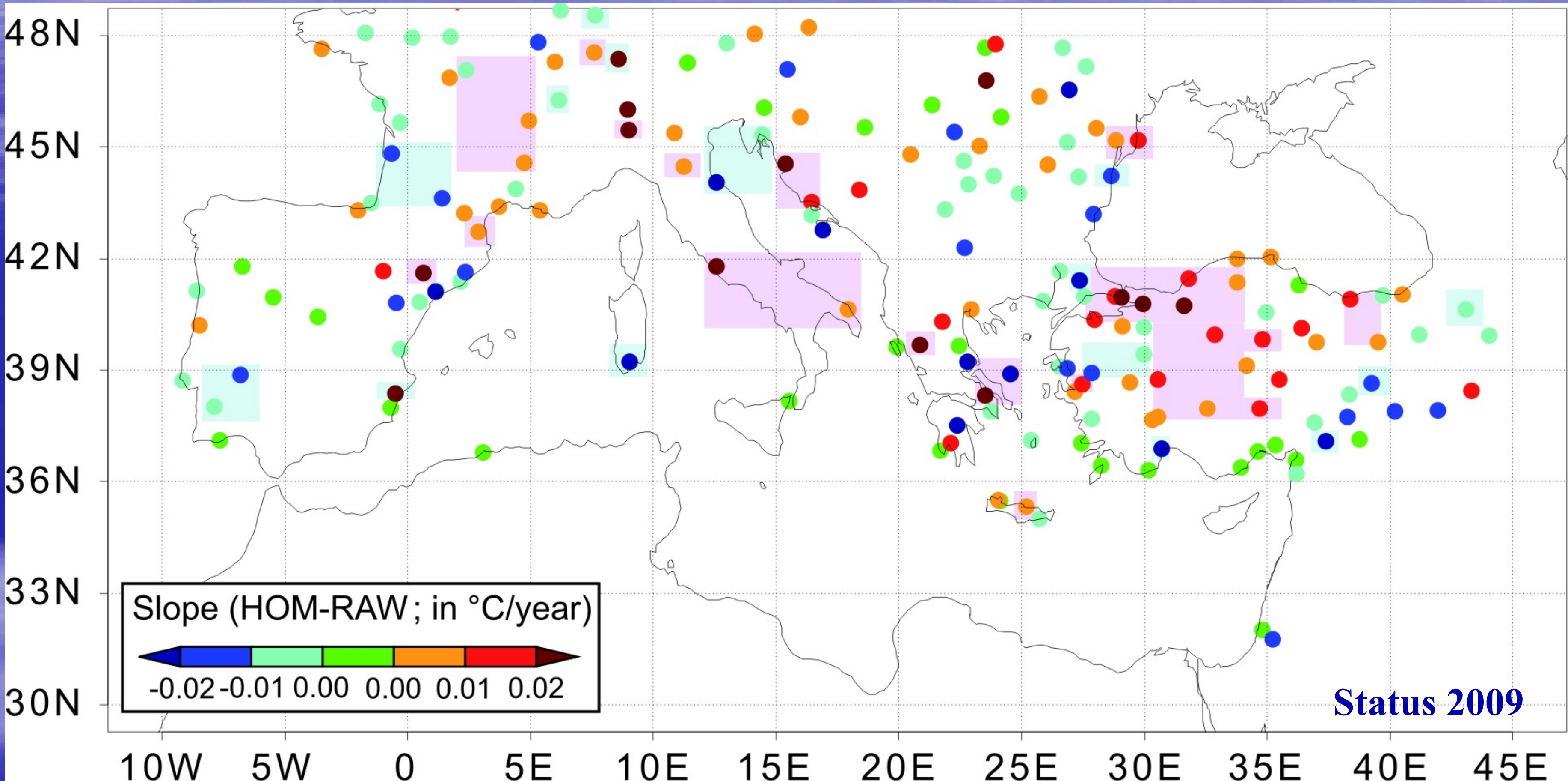
Kuglitsch et al. 2009

Quality control & homogenization
Break correction



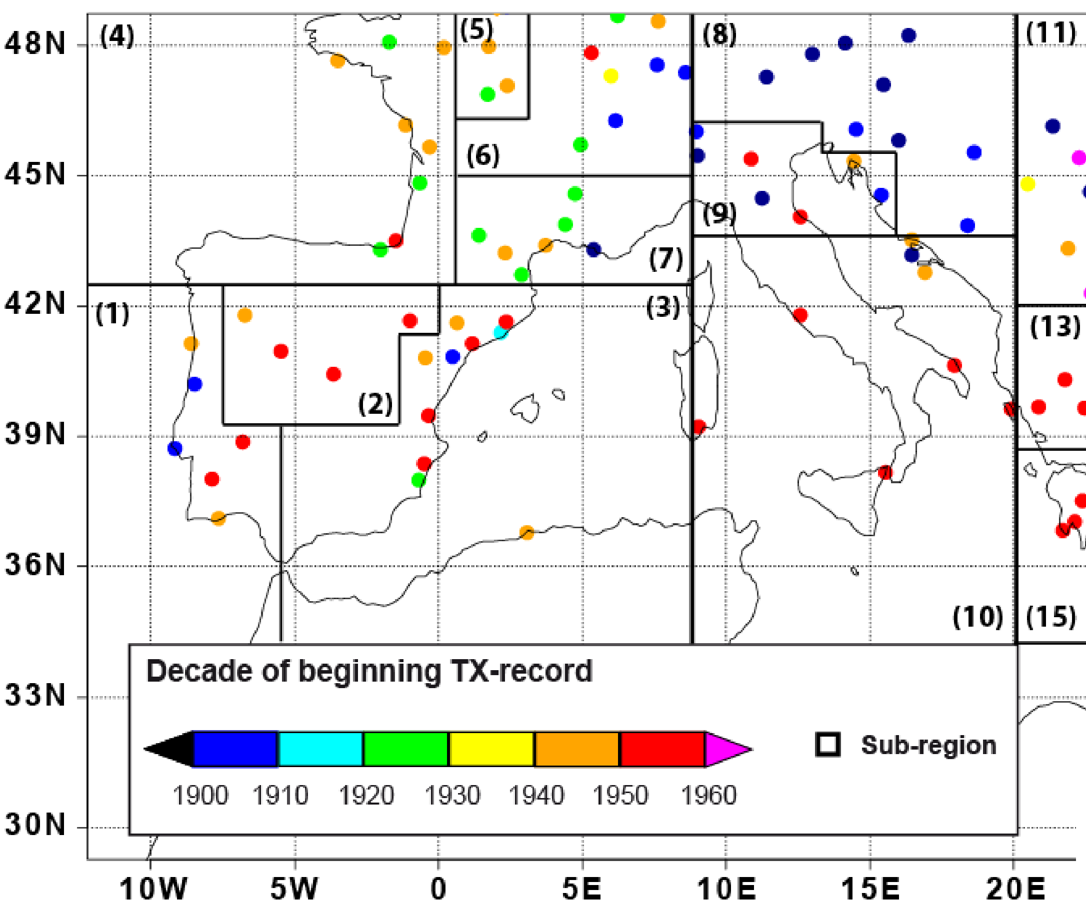
Kuglitsch et al. 2009

Slope changes



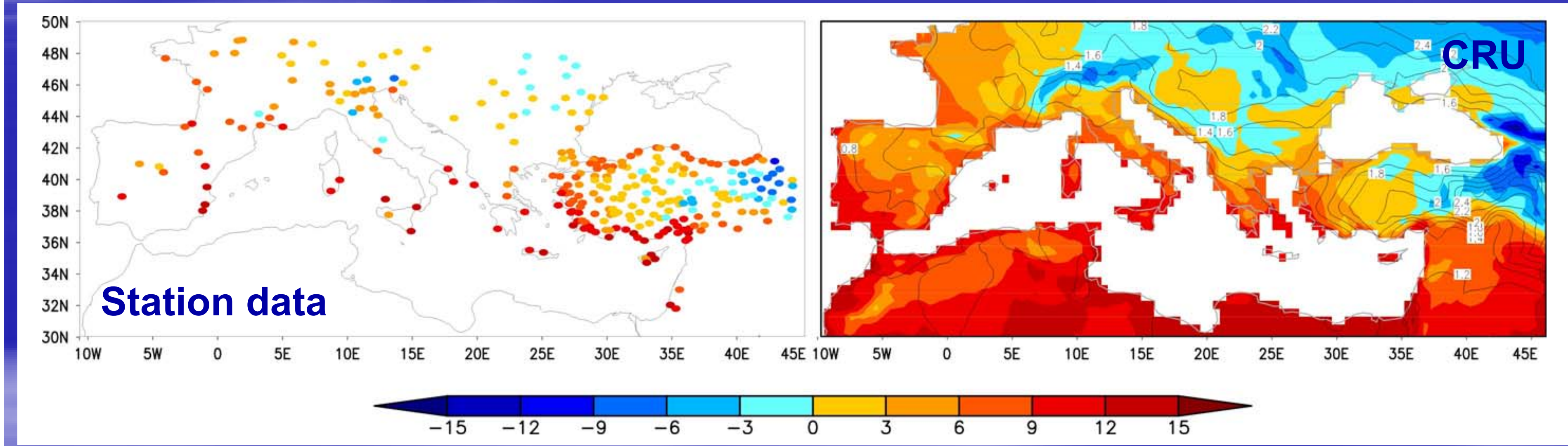
Kuglitsch et al. 2009

Quality control & homogenization
Break correction



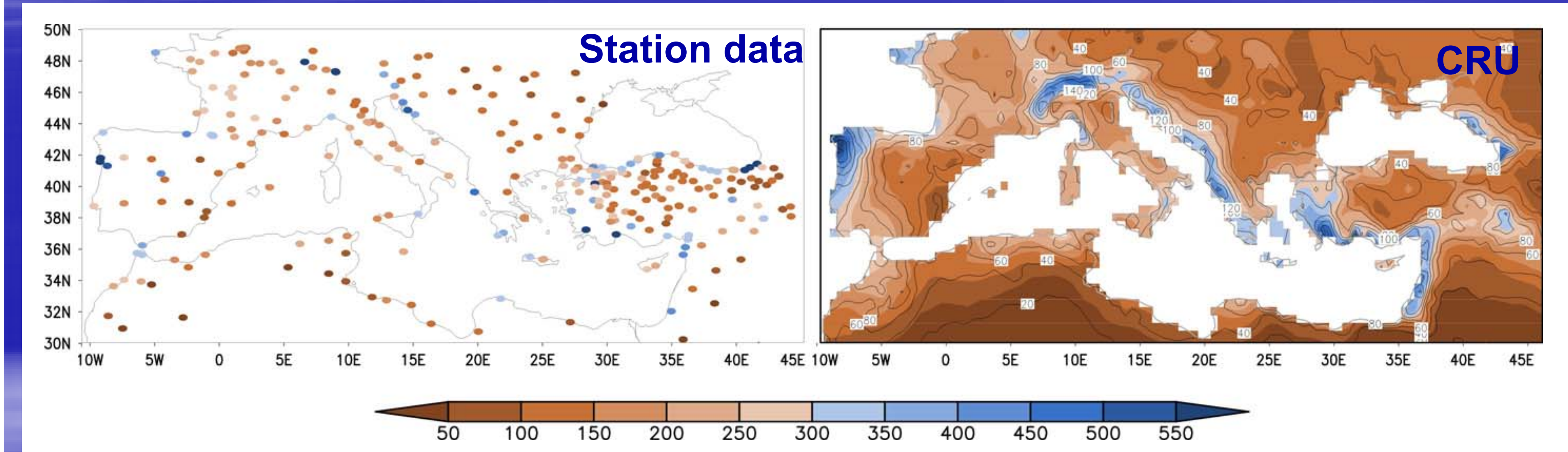
Homogenised Max temperature
Kuglitsch et al. 2009

The Mediterranean Climate
Winter temperature, 1951-2005



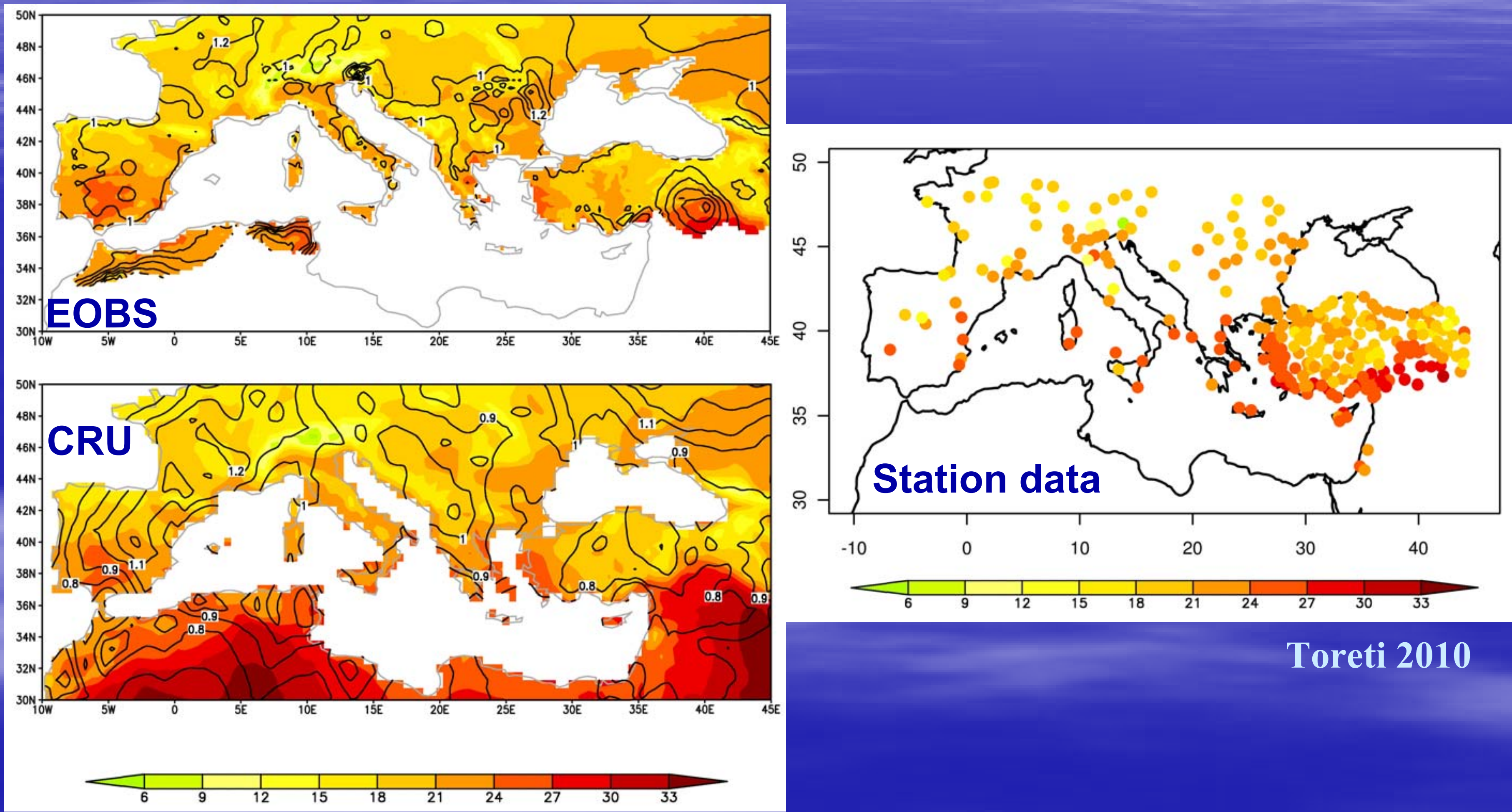
Toreti 2010

The Mediterranean Climate
Winter precipitation, 1951-2005



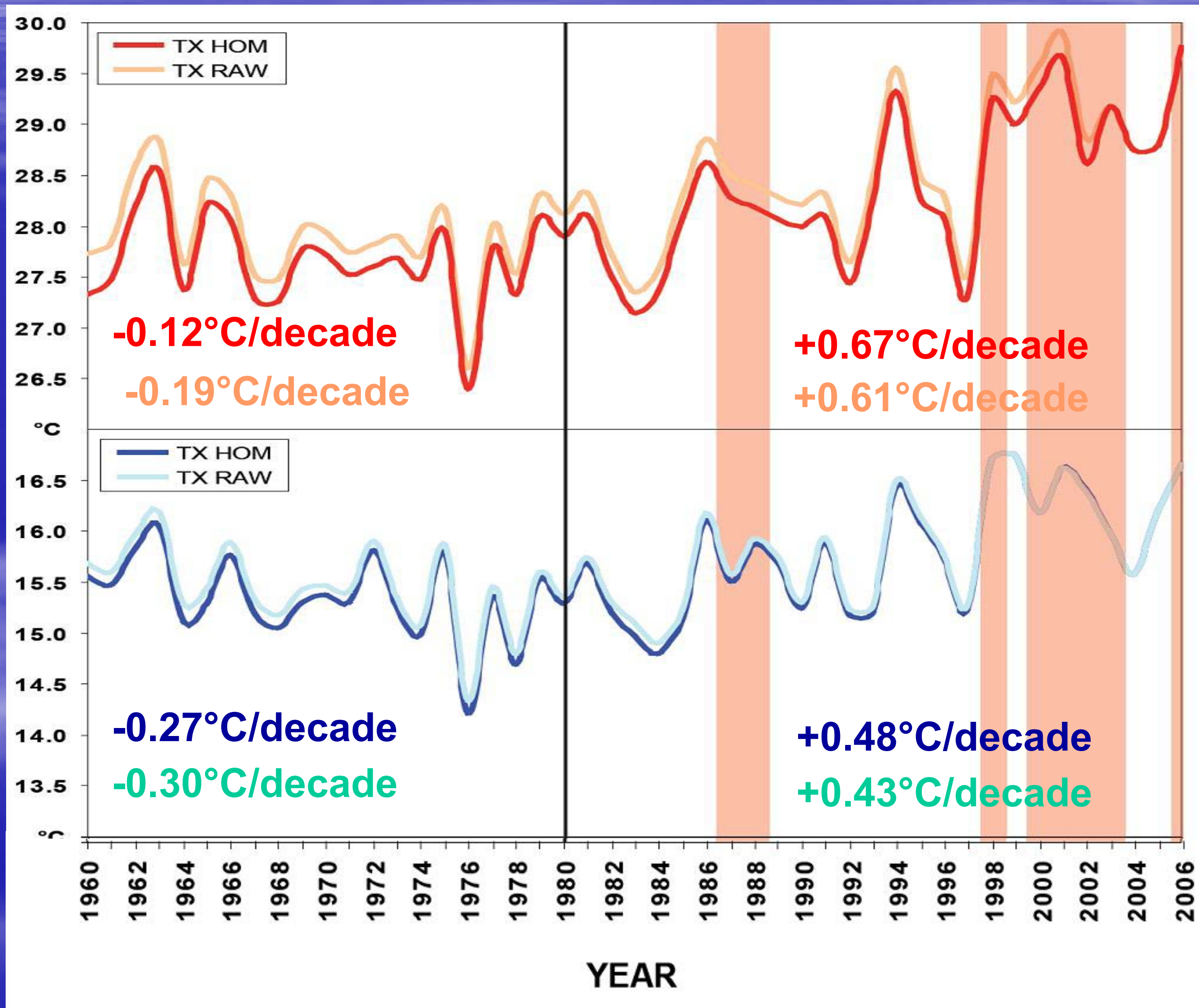
Toreti 2010

The Mediterranean Climate
Summer temperature, 1951-2005



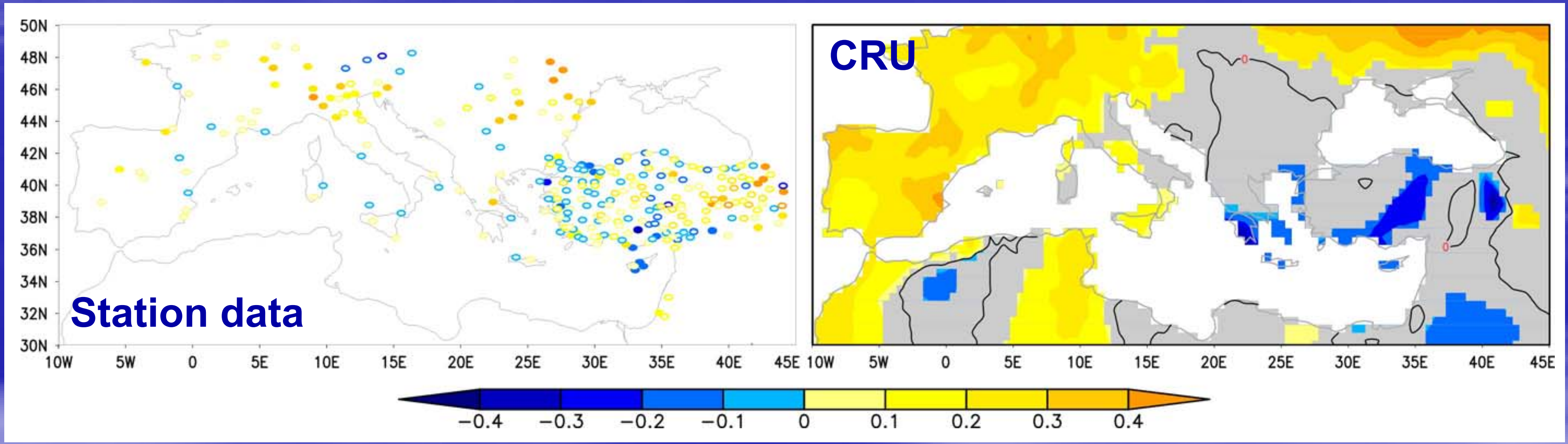
Toreti 2010

Mediterranean summer Tmax & Tmin



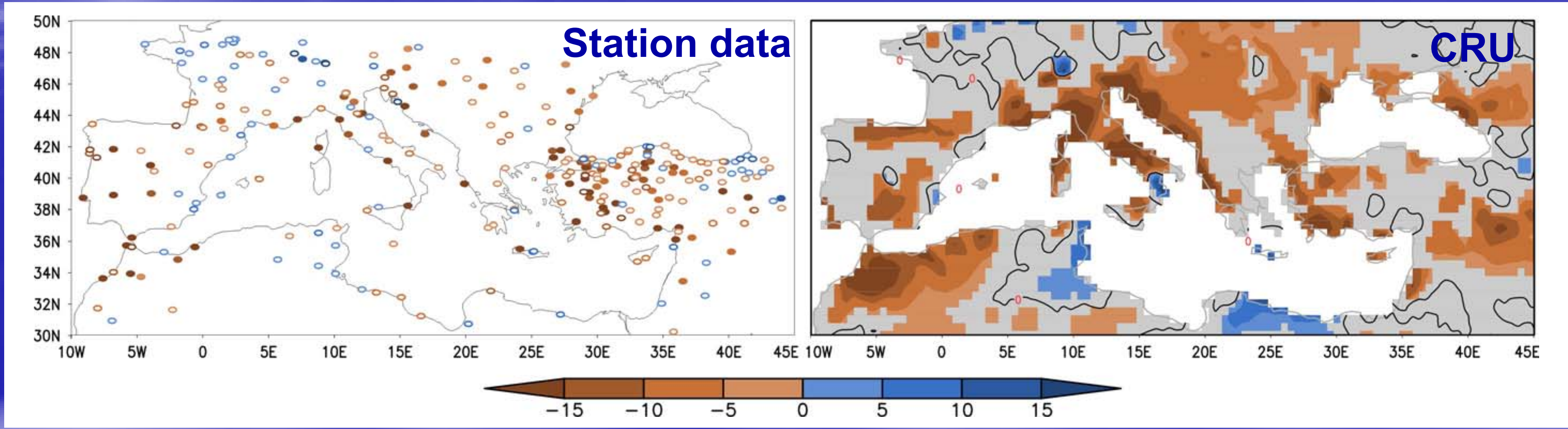
Kuglitsch 2010

Mediterranean Climate Change
Winter temperature, 1951-2005



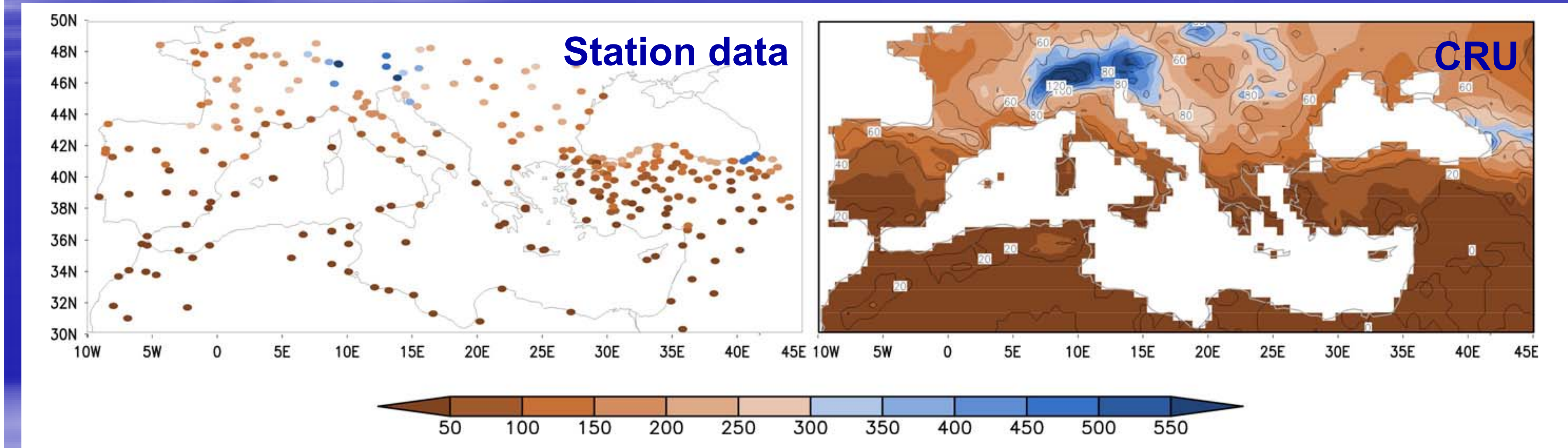
Toreti 2010

Mediterranean Climate Change
Winter precipitation, 1951-2005



Toreti 2010

The Mediterranean Climate
Summer precipitation, 1951-2005



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Data and Methods

Independent climate data for the Mediterranean

- Gridded temperature 1750-2006
  Luterbacher et al. 2004 & Xoplaki et al. 2005, updated; Brohan et al. 2006

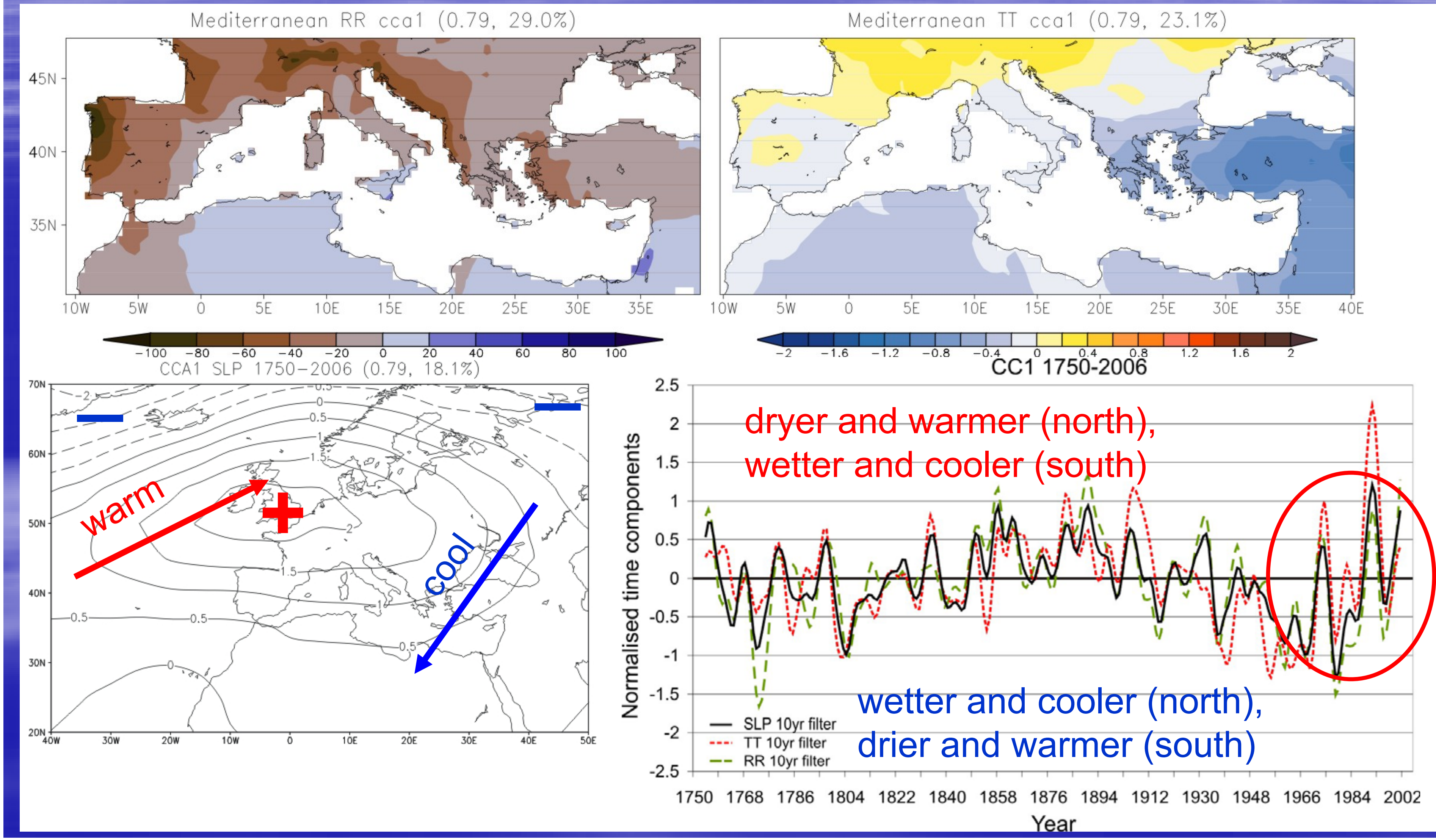
- Gridded precipitation 1750-2006
  Pauling et al. 2006; Brohan et al. 2006

- Large-scale gridded sea level pressure 1750-2006, combined station pressure and CLIWOC/ICOADS data
  Küttel et al. 2010 & Allan and Ansell 2006

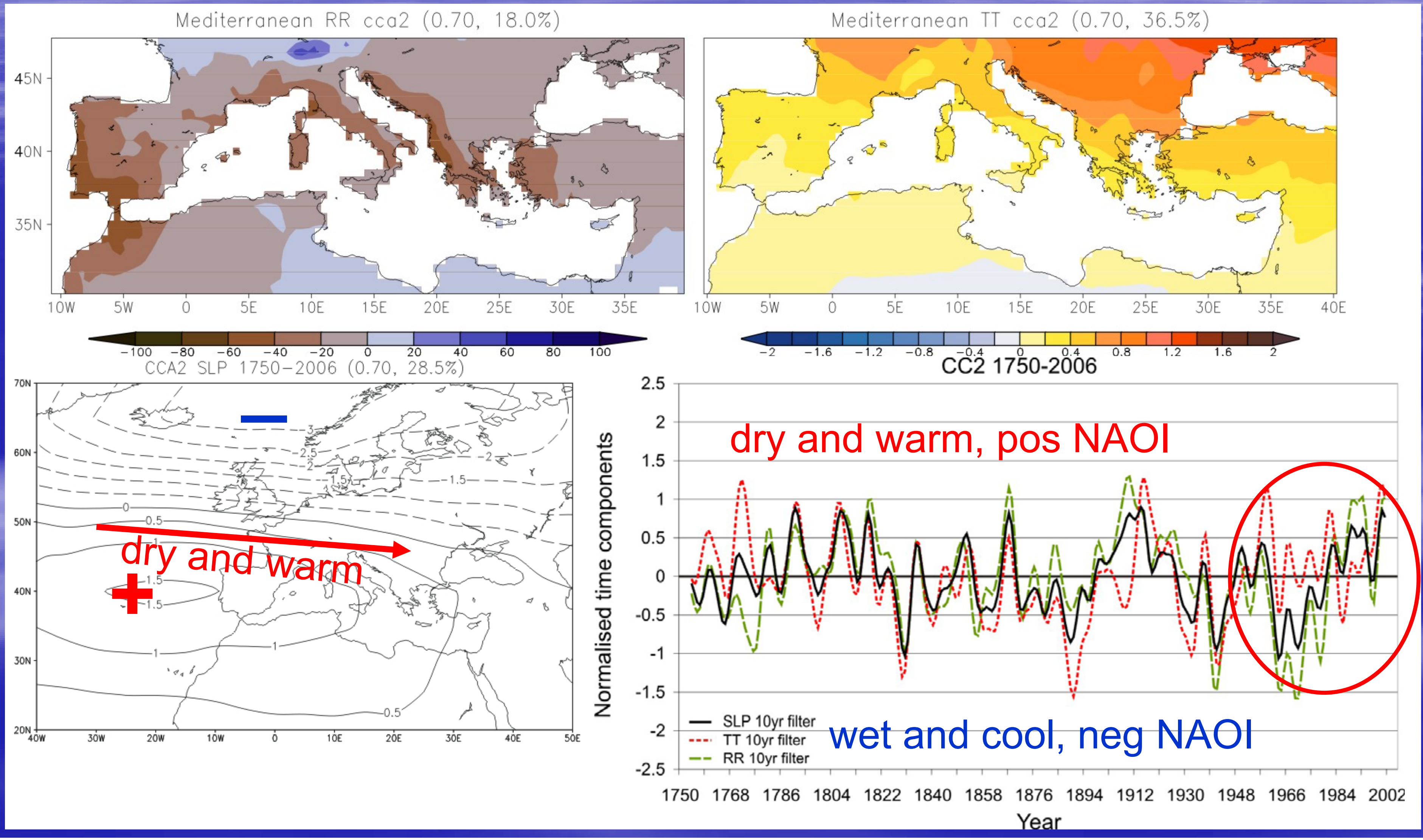
Method

- Canonical Correlation Analysis (CCA)
  → selection of optimally correlated patterns between SLP and Mediterranean temperature & precipitation

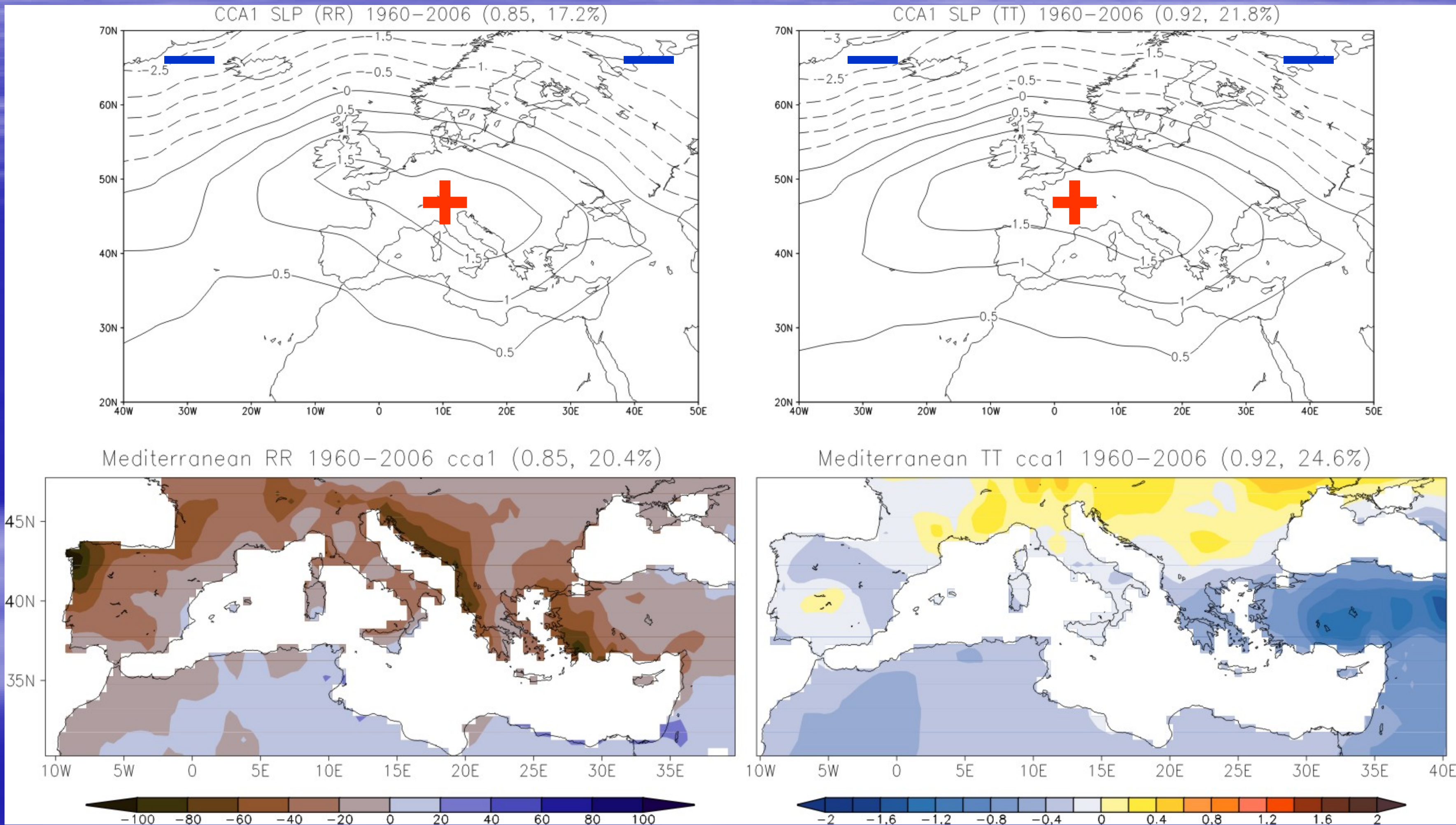
CCA1, 1750-2006
The EA/WRUS-like pattern



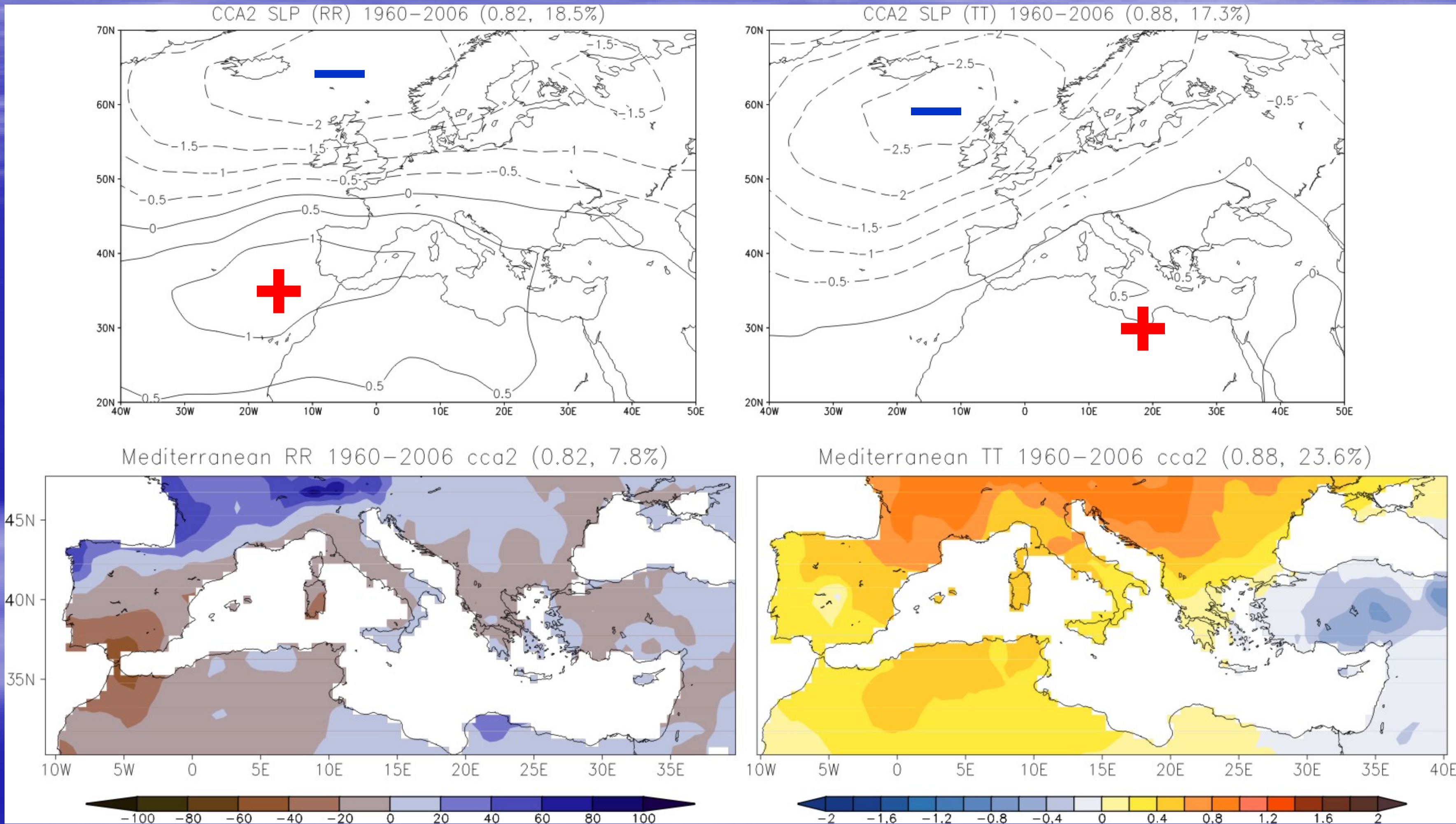
CCA2, 1750-2006
The NAO-like pattern



CCA1, 1960-2006
The EA/WRUS-like pattern



CCA2, 1960-2006
The partly NAO-like pattern



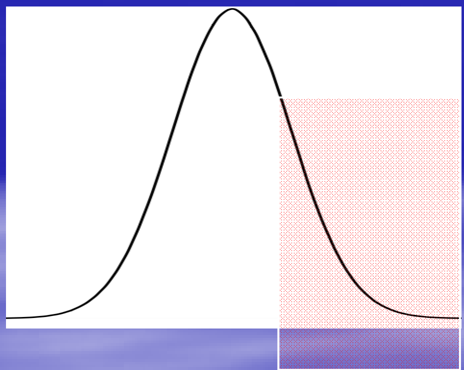
Conclusions

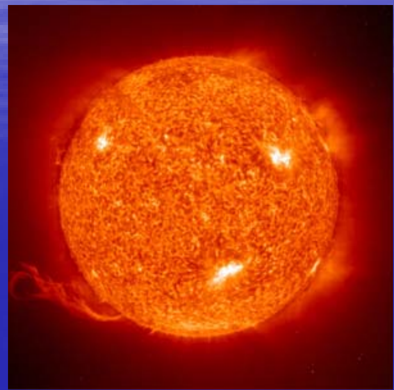
- Importance of Mediterranean data availability & quality
- The most important atmospheric modes to account for Mediterranean winter climate variability over the past 250 years are the NAO and EA/WRUS with changing influence over time and different impacts at regional scales
- Recent winter dryness is exceptional, although dry periods were also experienced within the last 250 years
- Positive NAO and EA/WRUS strongly contributed to the recent overall winter dryness, especially over the Iberian Peninsula, and warming to the north of the Basin
- Lesser warming to the west and even cooling to the east can be partly attributed to the different impact of the NAO and EA/WRUS patterns in these regions

Extreme events in the Mediterranean

Climate extremes

Climate extremes: the tail is important

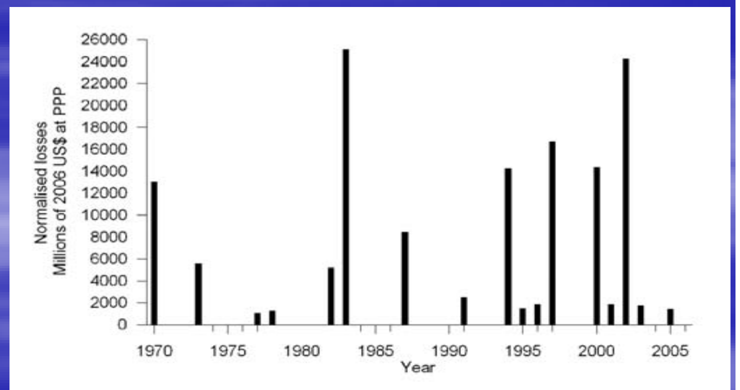




Source: Nasa

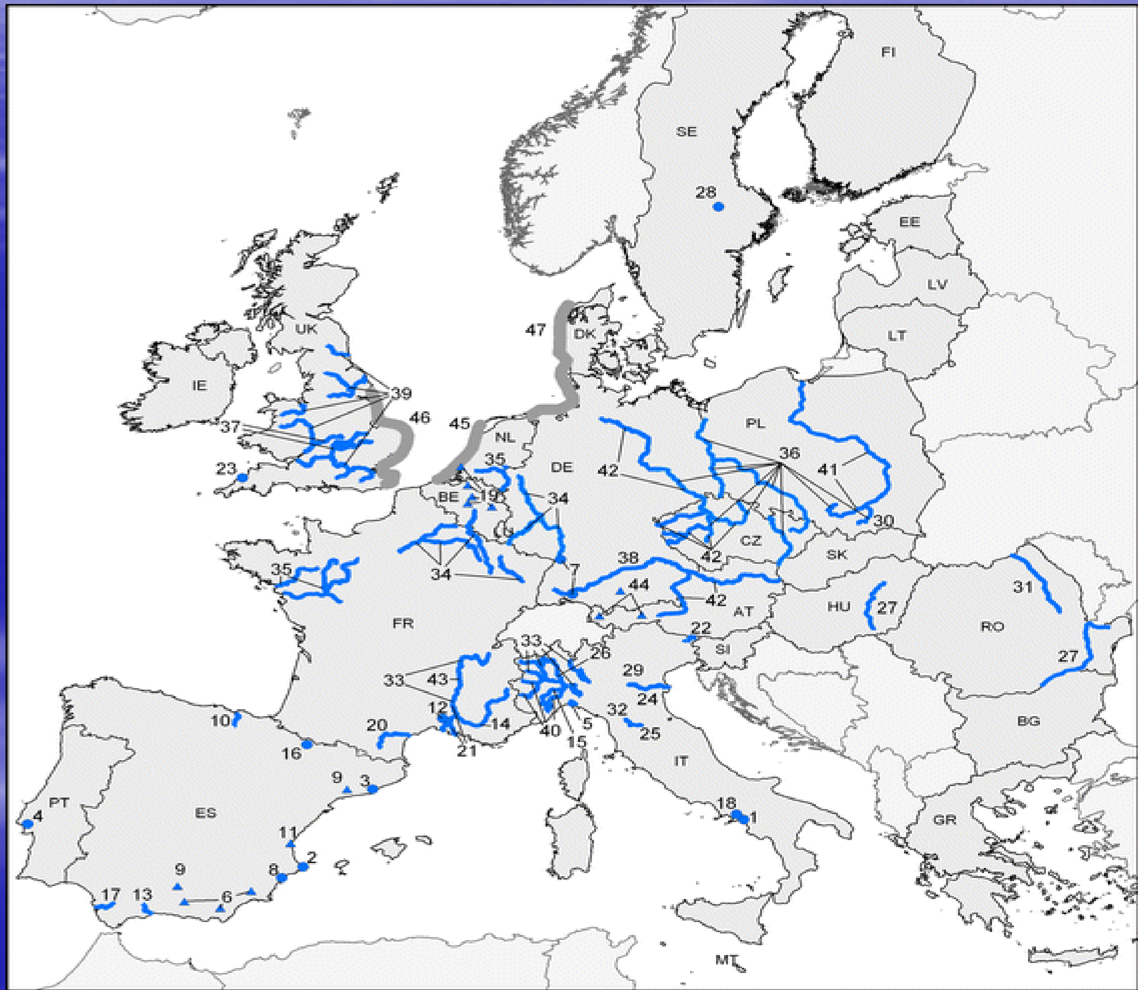
Source: La Repubblica

Source: WHO, 2008



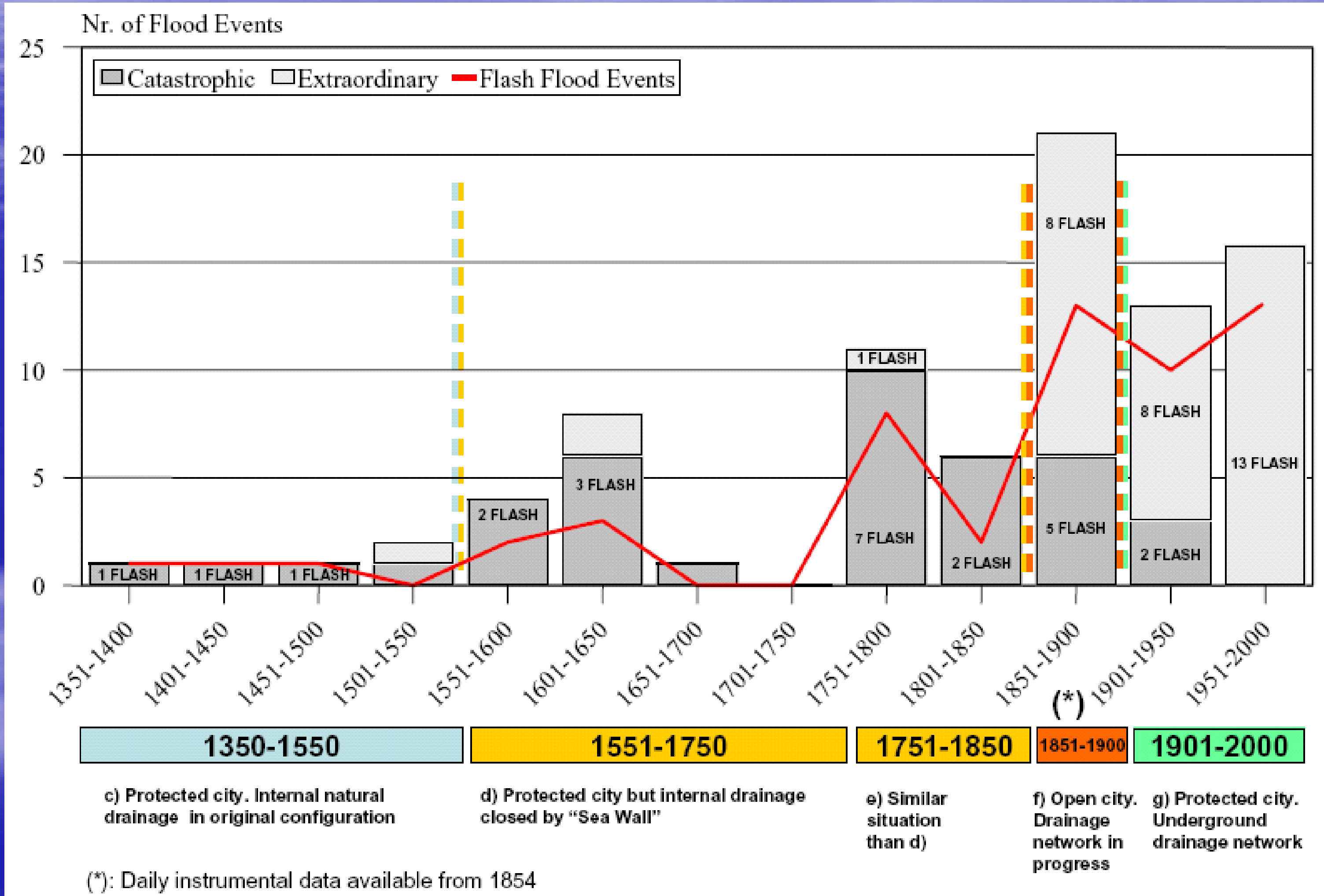
Source: Barredo, 2009

Major flood disasters in the EU 1950- 2005



Barredo 2007

50-year period flood distribution in Barcelona county from AD 1351 to 2000

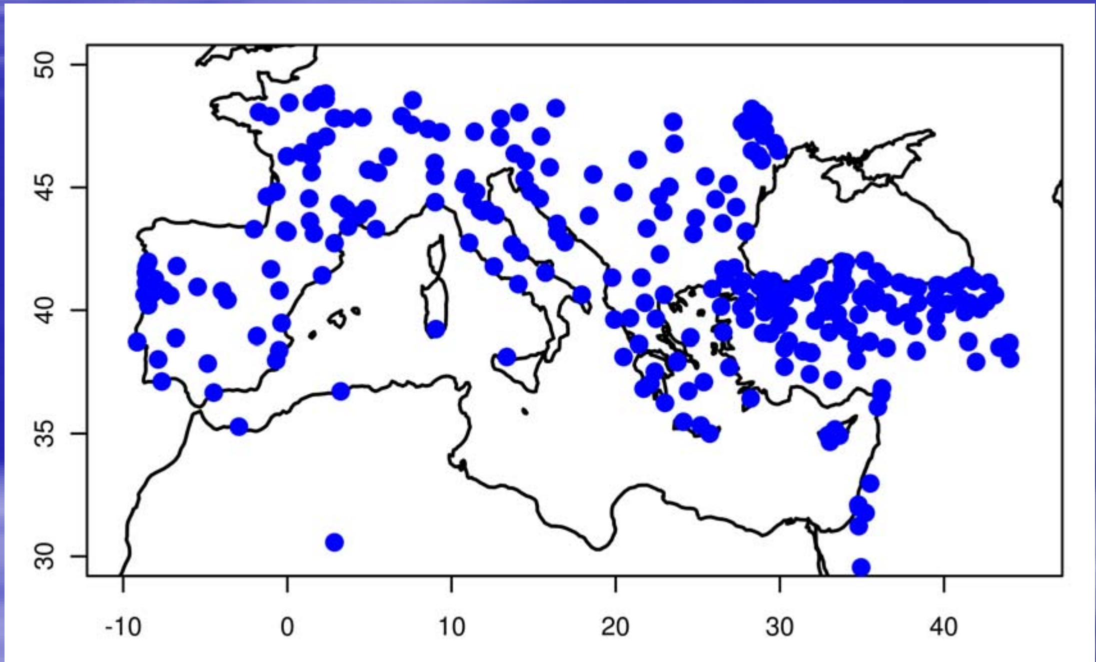


Barrera et al. 2005

Trends & extremes – Methodology

- Slope estimation
  Mann-Kendal (modified for indices: replication of values)
  Theil-Sen (non-parametric, robust with outliers and errors; modified for indices: replication of values)
- Change-Point Analysis (detection of more complex trends)
- **dePOT** (declustered Peaks Over Threshold; return values)
  stationary model – without imposing trends to the parameters of the distribution
- Precipitation
  (missing values, too short time series)
  Iterated Cumulative Sum of Squares, change in variance
- **Extreme event indices** (HWDI, HW3 duration & intensity, HWmax duration and intensity)

Extreme precipitation
Data



Daily preci series

↓

GAHMM
CauMe

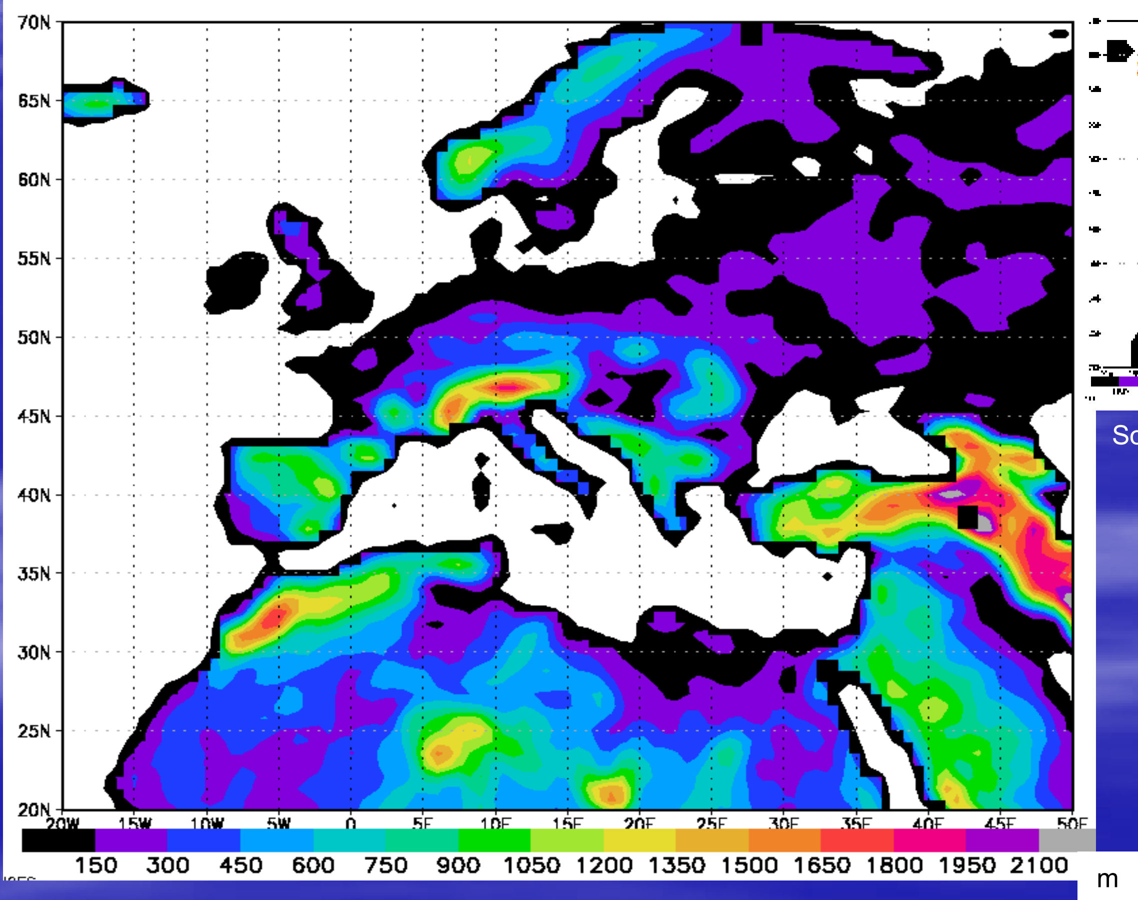
↓

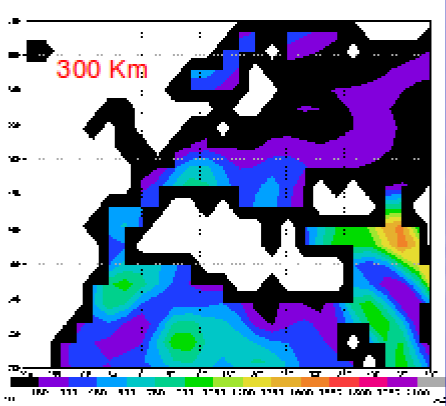
286 daily preci series
1950-2006
Oct - March

Toreti 2010

Extreme precipitation
Data

INGV-CMCC GCM. 1950-2050 A1B scenario





Source: Gualdi et al., 2010

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Extreme precipitation: methods

X_t daily time series → *X-u conditional on X > u*

→ **Generalized Pareto Distribution[1,2]** →

$$H(y) = 1 - \left(1 + \frac{\xi y}{\sigma}\right)^{-1/\xi}$$

ξ shape parameter

>0 → heavy tail

=0 → exponential

<0 → finite right end point

σ scale parameter

1 Davison and Smith, 1990

2 Pickands, 1975

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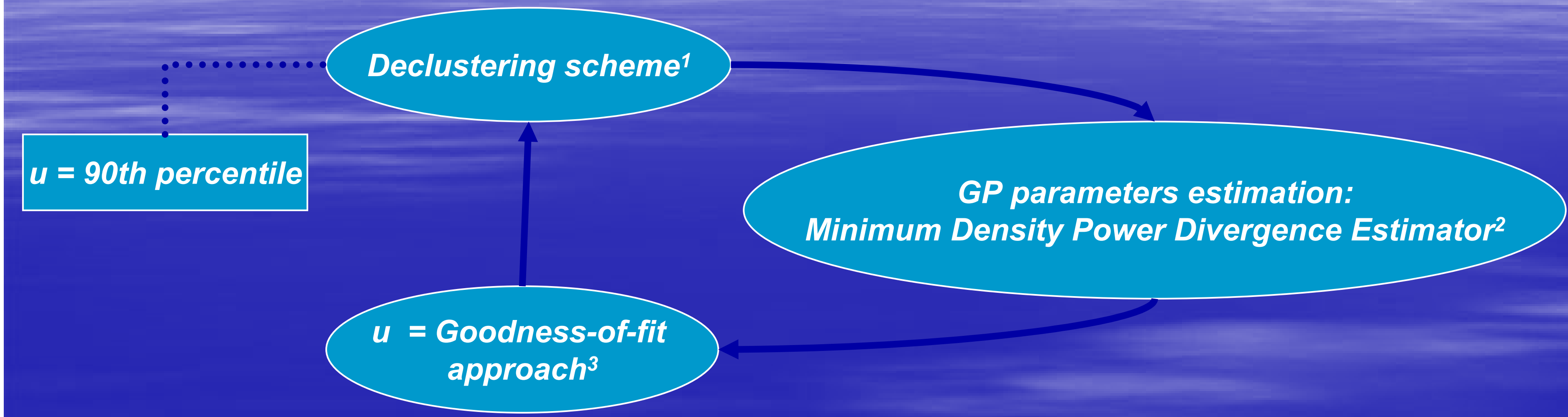
Extreme precipitation: methods



$$z_R = u + \hat{\sigma}\hat{\xi}^{-1}\left[\left(R\zeta_u\hat{\theta}\right)^{\hat{\xi}} - 1\right]$$

Std errors: var-covariance matrix and delta method[4]

1 Ferro and Segers, 2003

2 Juárez and Schucany, 2004

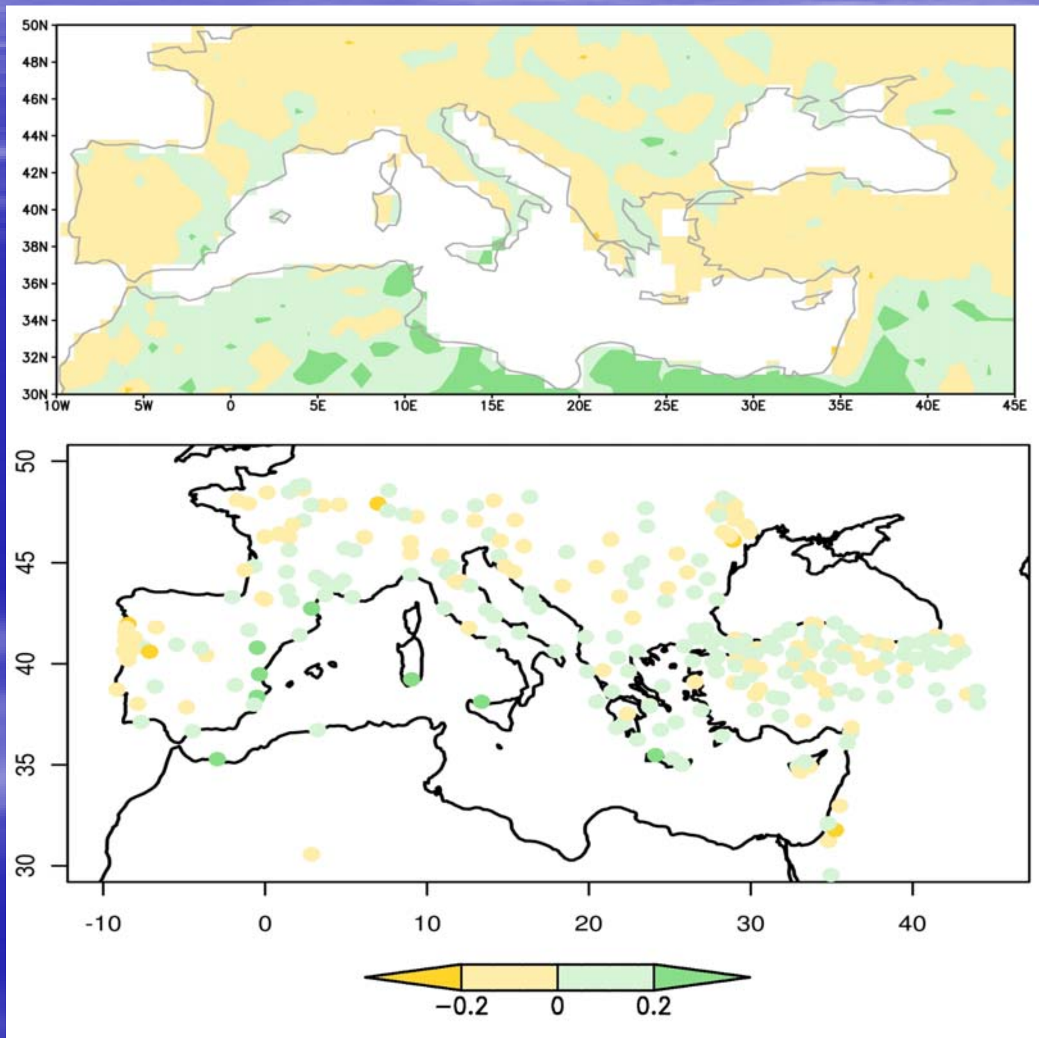
3 Choulakian and Stephens, 2001

4 Shao, 2003

Toreti 2010

Extreme precipitation

Shape



INGV-CMCC

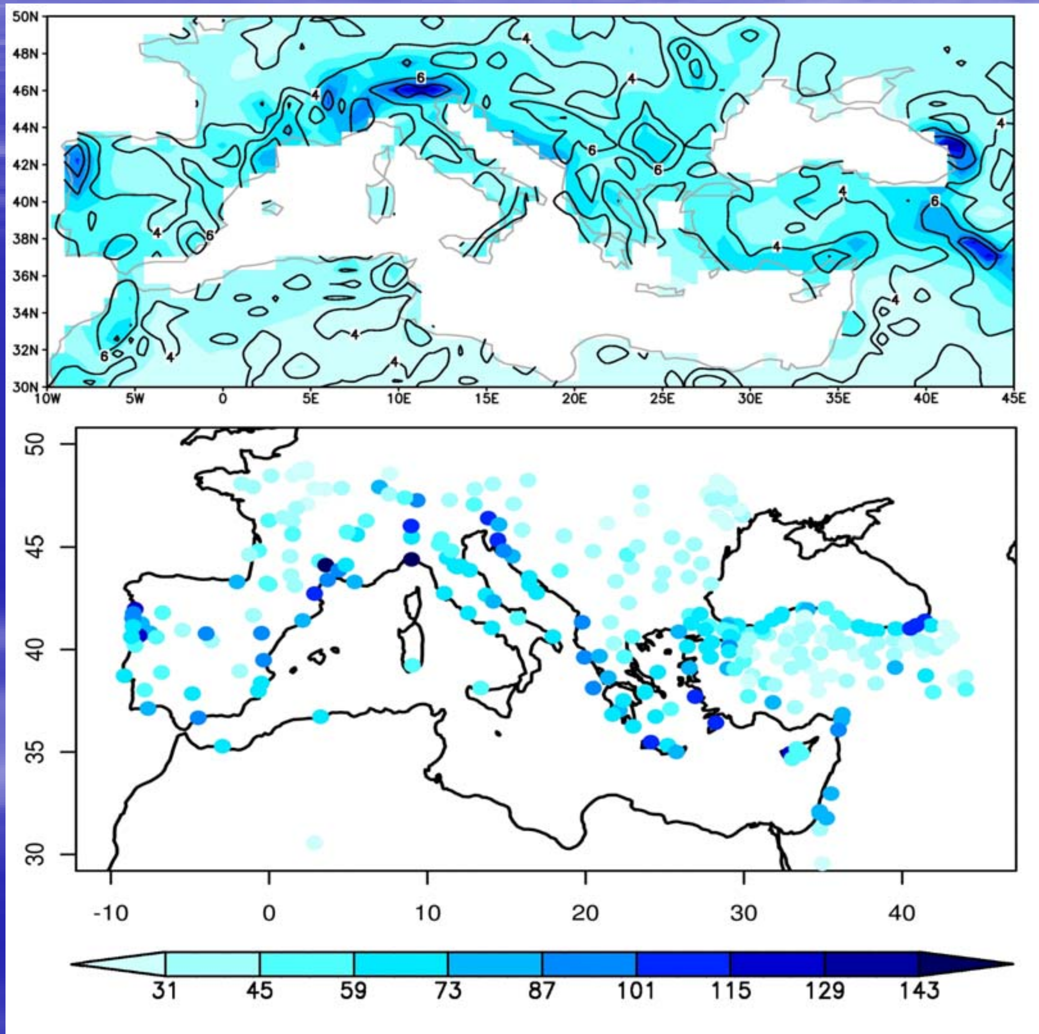
model

Instrumental time series

Toreti et al. 2010

Extreme precipitation

5-year return level



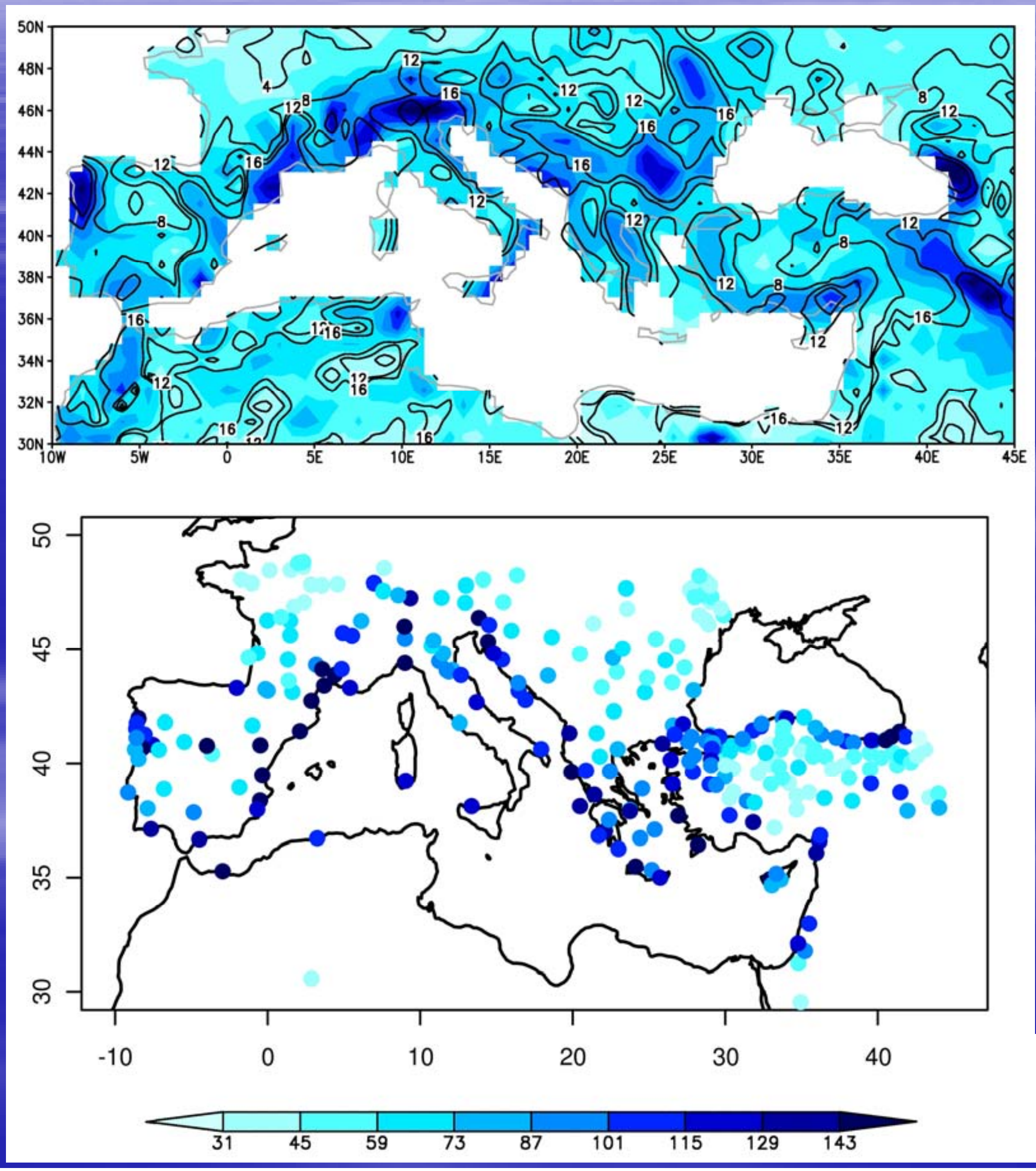
INGV-CMCC model

Instrumental time series

Toreti et al. 2010

Extreme precipitation

50-year return level



INGV-CMCC model

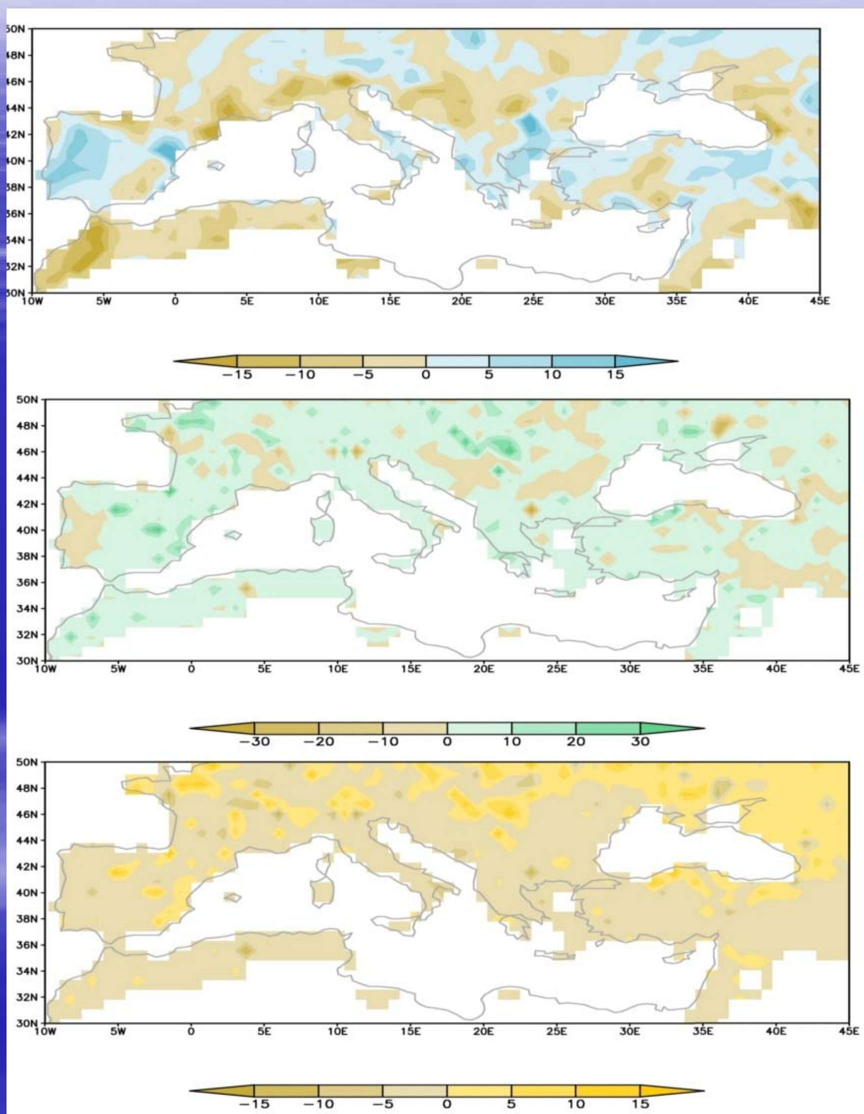
Instrumental time series

Toreti et al. 2010

Extreme precipitation

INGV-CMCC GCM

2031-2050 compared to 20th century



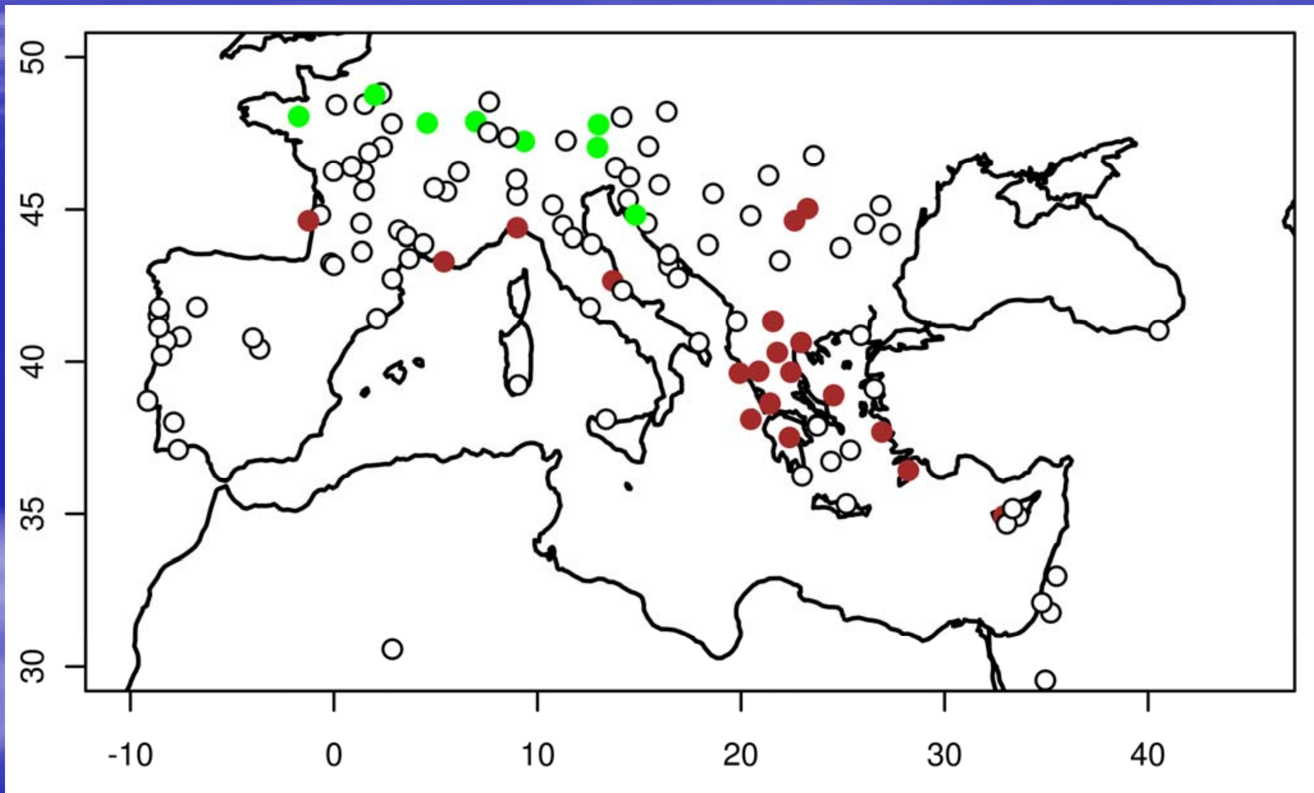
5-year return level (mm)

Winter preci due to extreme events (%)

Number of days with extreme daily precipitation

Toreti et al. 2010

Extreme precipitation



Probability of occurrence of extreme events. Estimated tendency

sign increase *sign decrease* *no significance*

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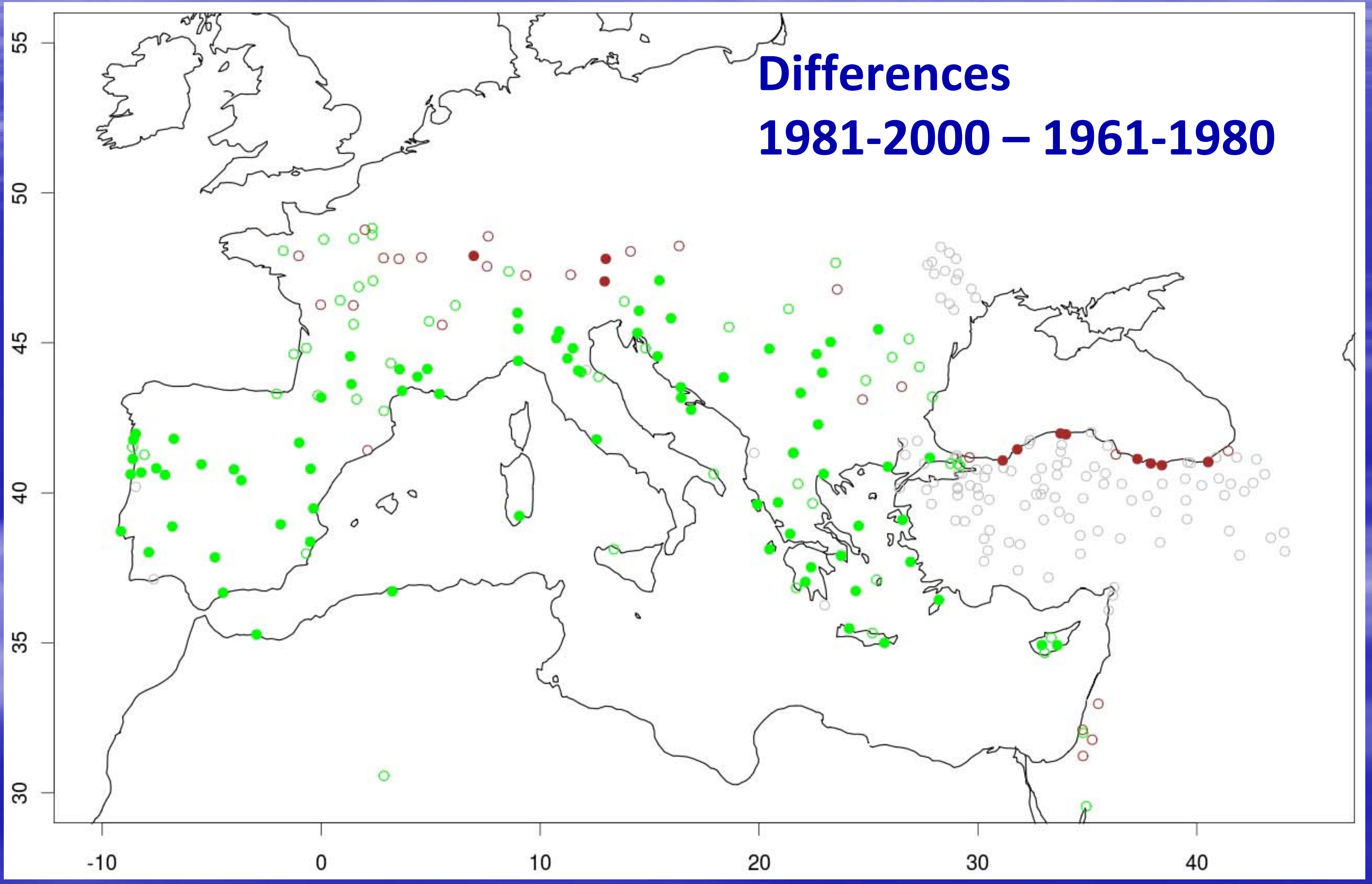
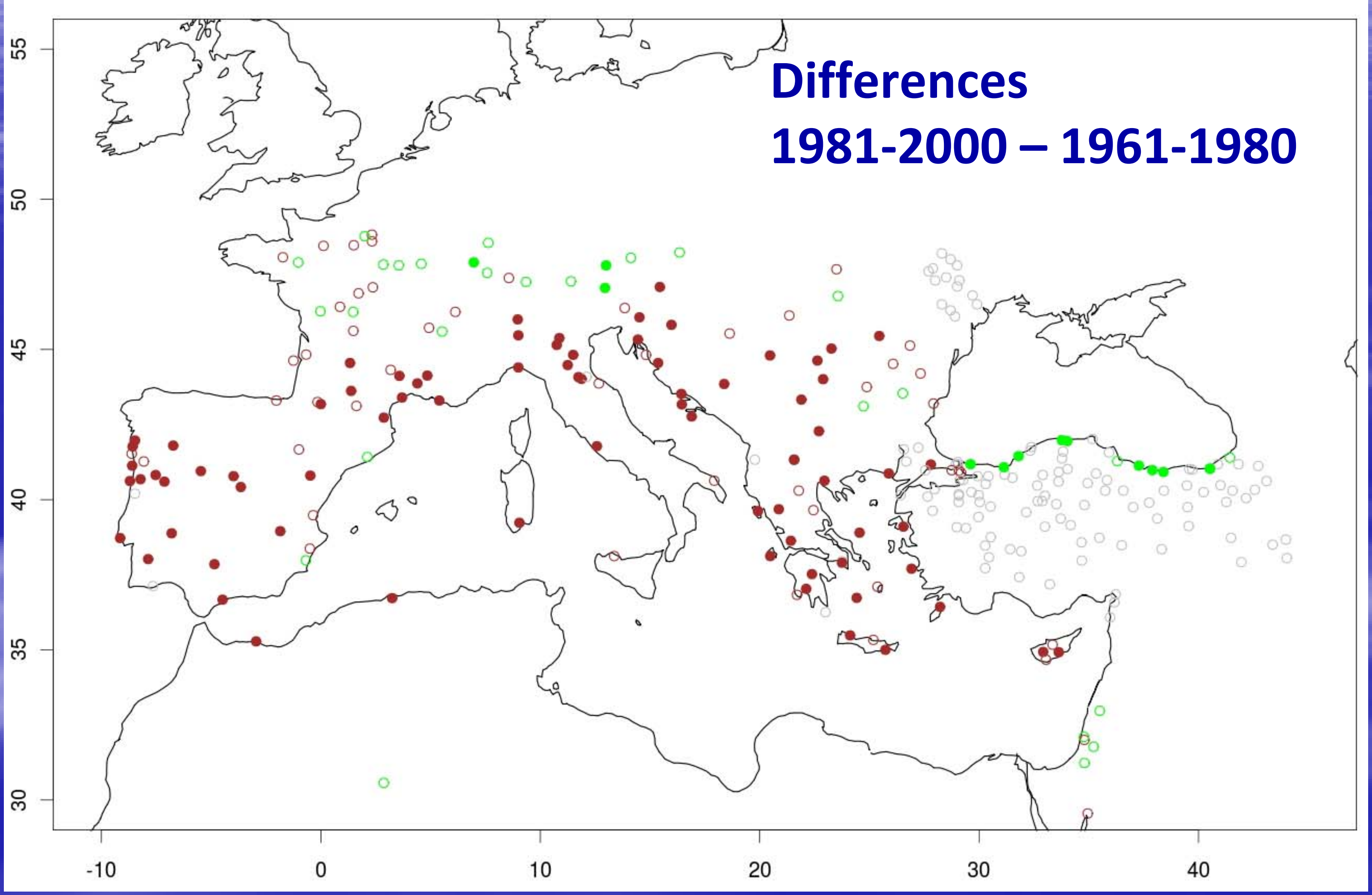
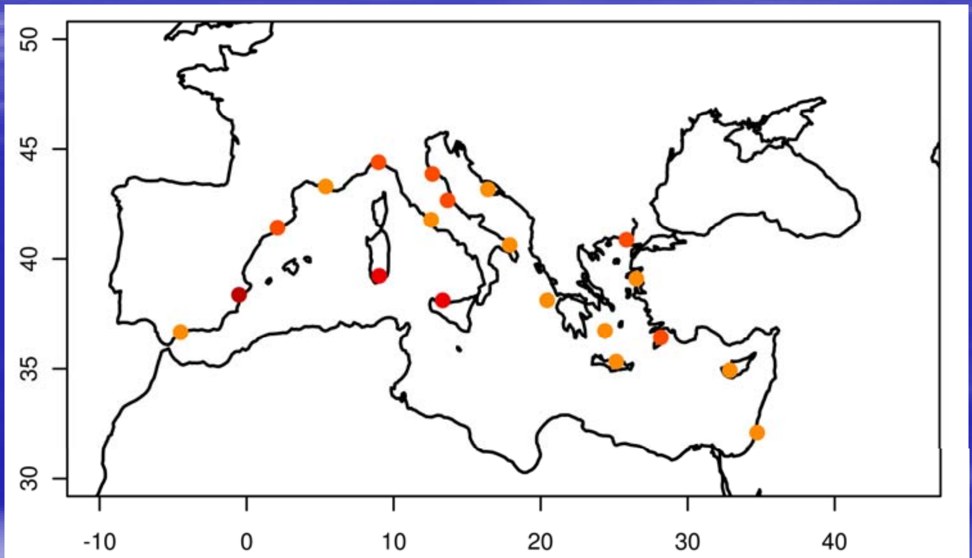
Dry days (< 1 mm), October – March



Wet days (> 1 mm), October – March



Extreme precipitation and atmospheric circulation



20 coastal stations

Anomalies of Z500, SLP From NCEP-NCAR reanalysis[1]

Daily anomaly fieds associated with extreme precipitation days

1 Kistler et al., 2001

Toreti et al. 2010

Extreme precipitation and atmospheric circulation

Classification algorithm

$$\text{TWCV} = \sum_{k=1}^{K} \sum_{x \in k} \| \boldsymbol{x} - \boldsymbol{c}_k \|$$

Self Organized Maps[1]

Singular Value Decomposition similarity measure[3]

Genetic K-means[2]

Significance: comparison with clusters associated with dry days and non-extreme wet days → Brunner-Munzel test[4]

1 Kohonen, 2001

2 Krishna and Narasimha Murty, 1999

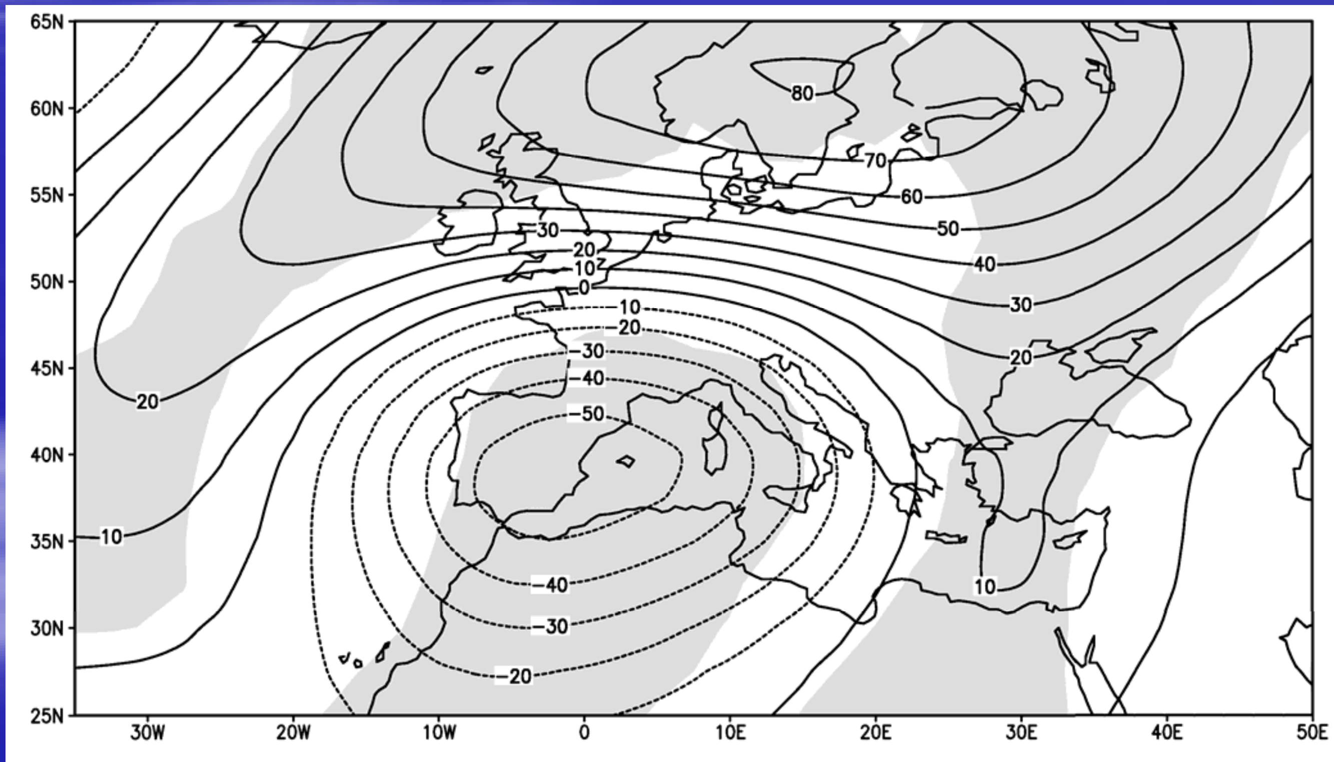
3 Dray, 2008

4 Brunner and Munzel, 2000

Toreti et al. 2010

Extreme precipitation and atmospheric circulation

Z500 Western Mediterranean



Dipole structure

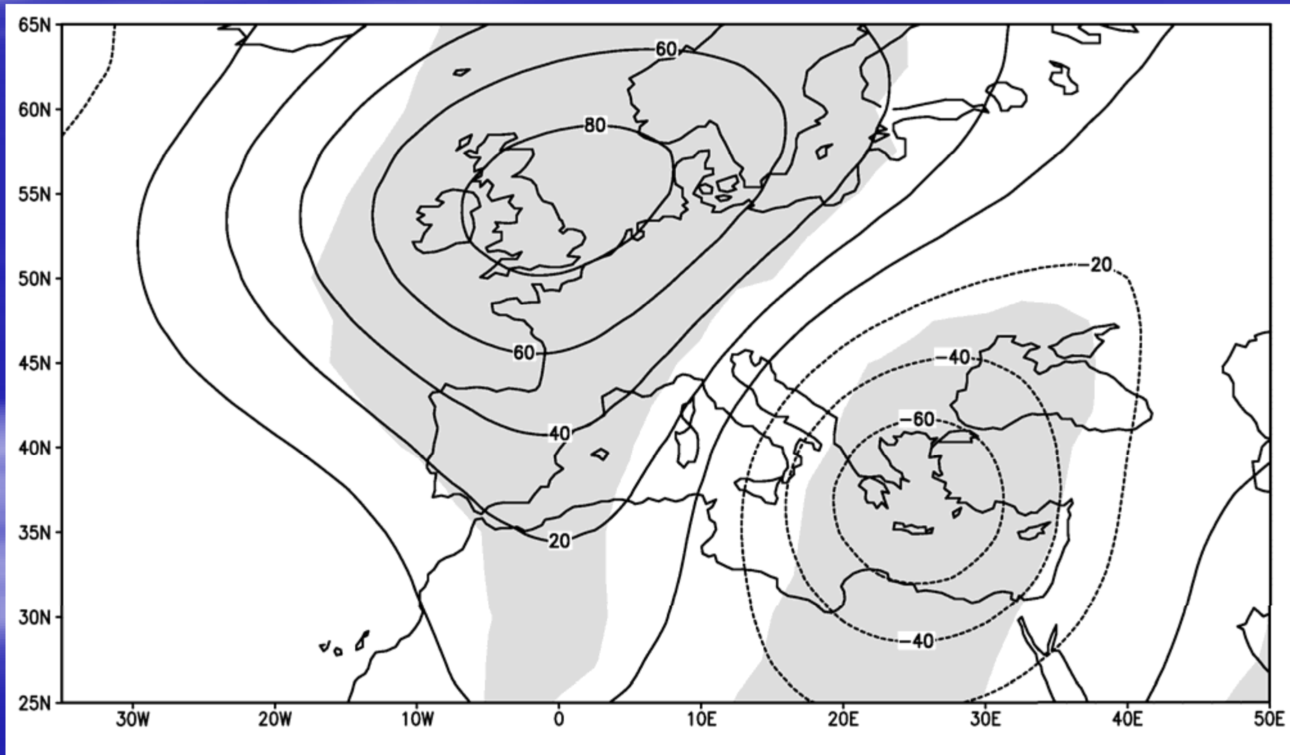
southwesterly flow

moisture transport from the Atlantic

Toreti et al. 2010

Extreme precipitation and atmospheric circulation

Z500 Eastern Mediterranean



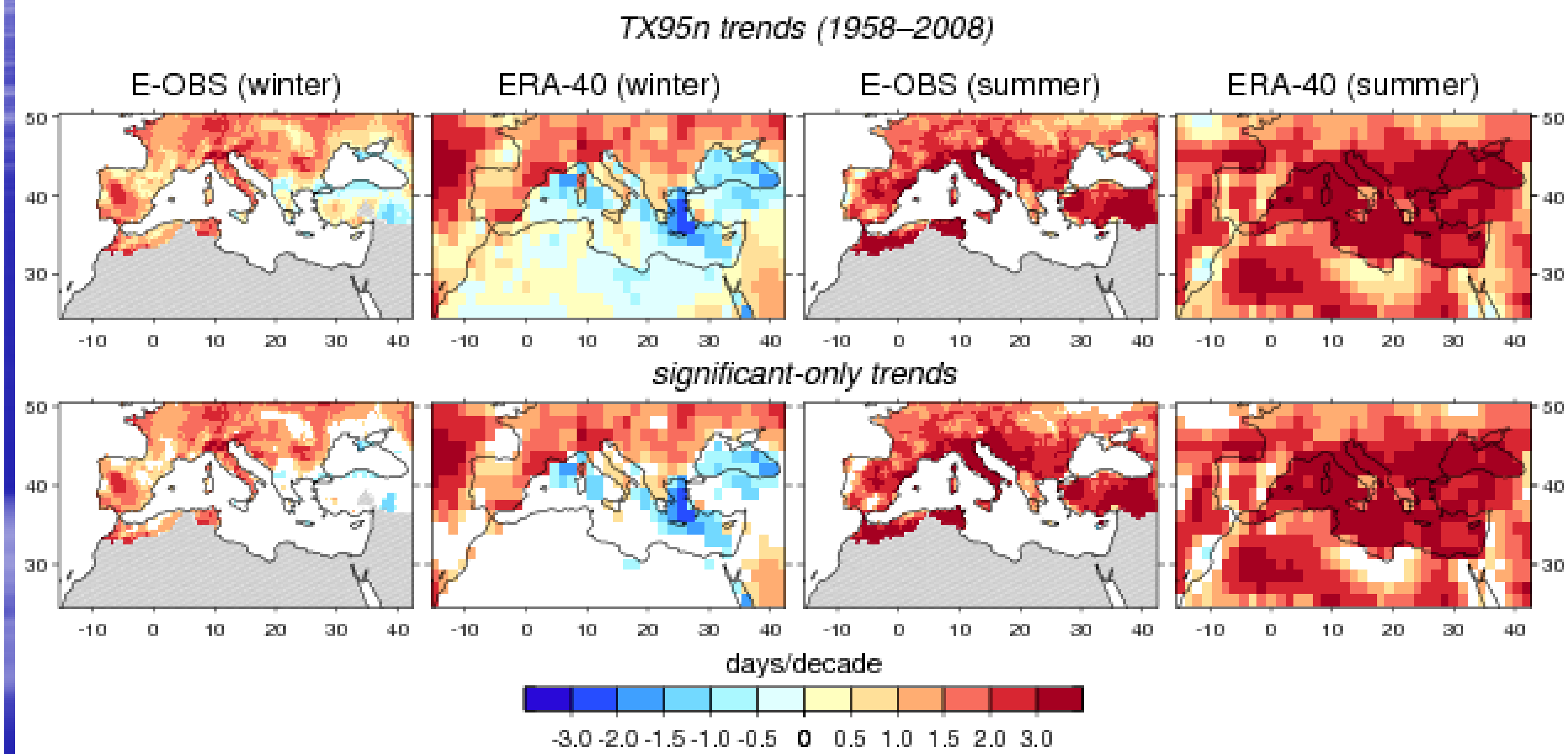
Warm air advection & anomalous vertical motion

instability

moisture transport from western basin

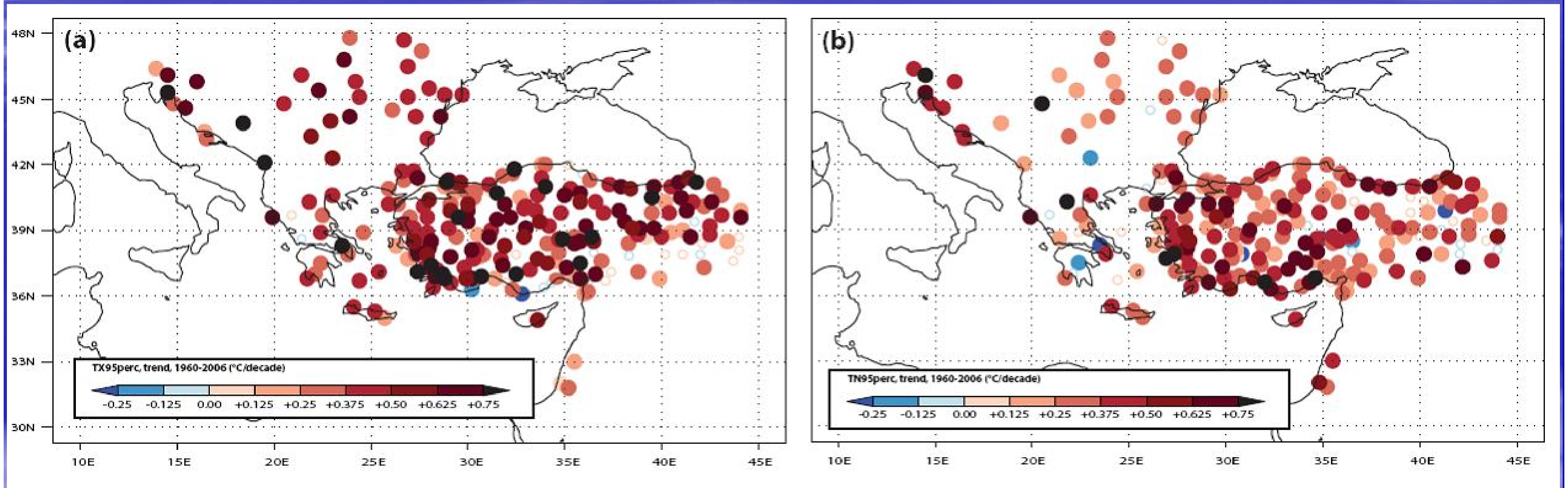
Toreti et al. 2010

Winter and summer TX95n trends, 1958-2008



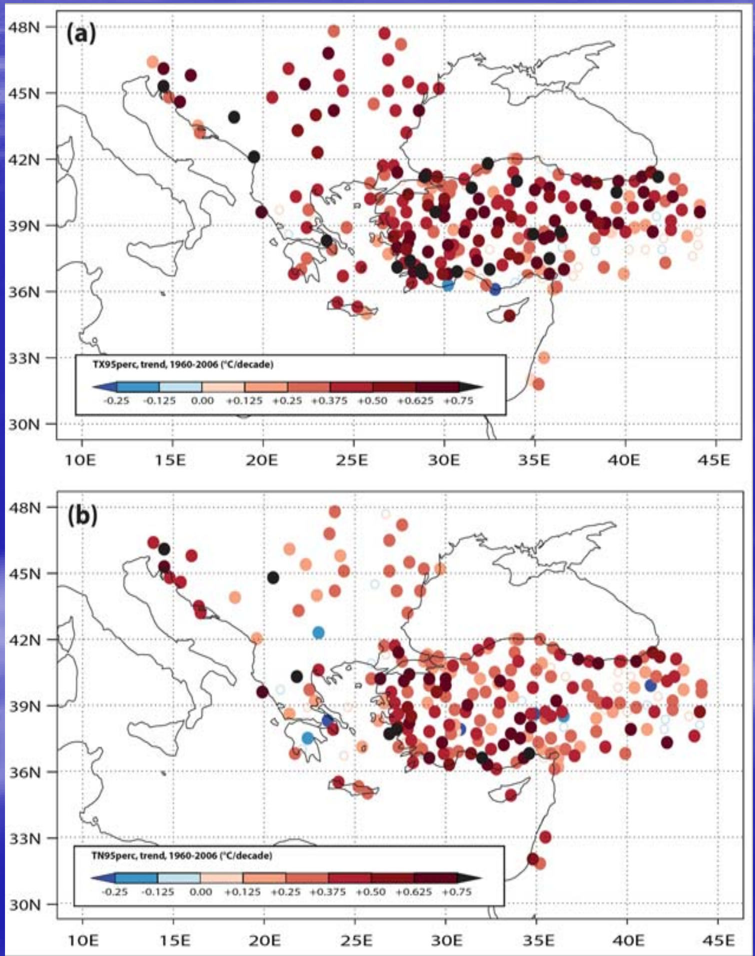
Goodess and Efthymiadis
in Garcia-Herrera et al. 2011

Summer Tmax & Tmin trends, 1960-2006



Kuglitsch et al. 2010

Trends: summer TX/TN 95% percentile

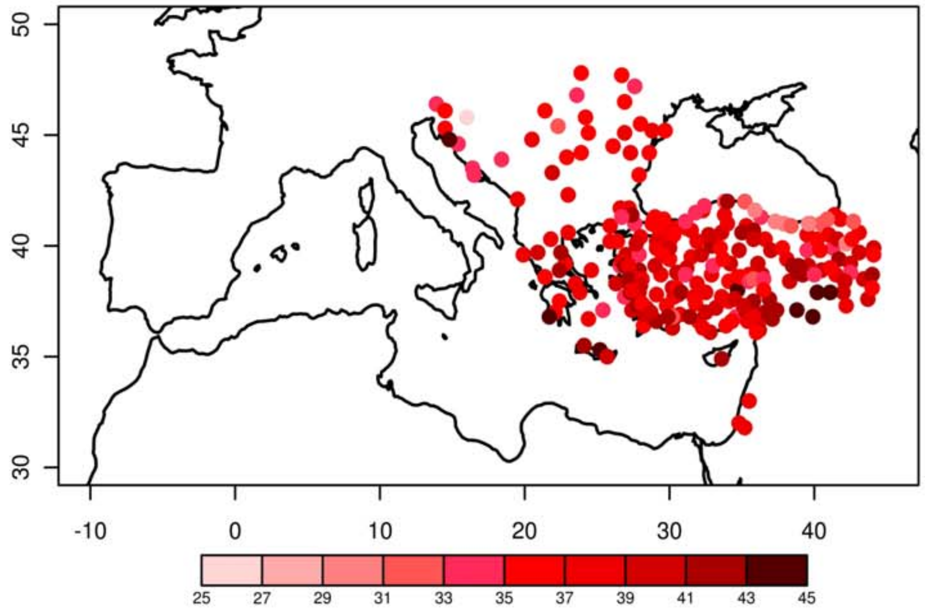


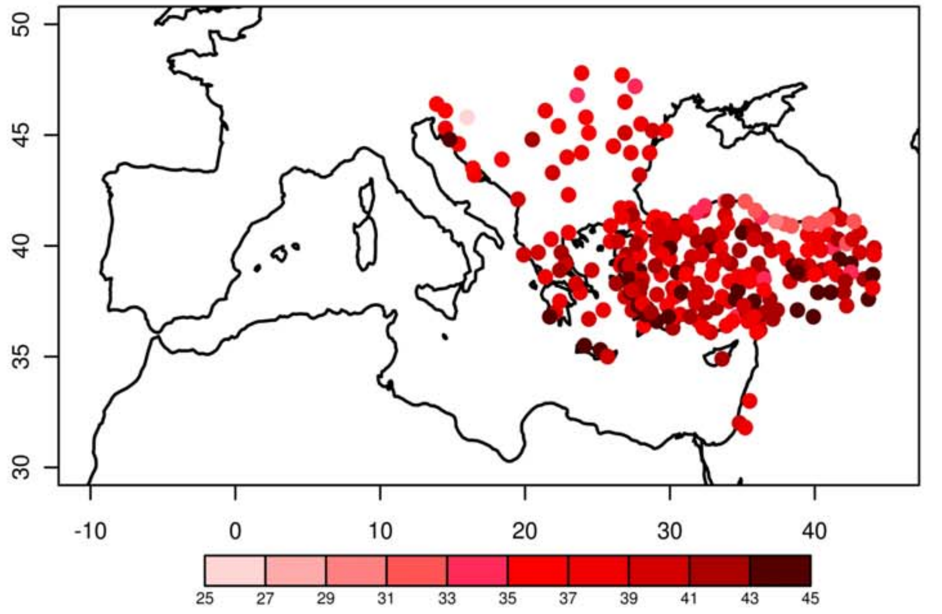
- **TX95perc: +0.38 ± 0.04°C/decade**
  - Max. increase in continental areas

- **TN95perc: +0.30 ± 0.02°C/decade**
  - Max. increase in coastal areas

Kuglitsch et al. 2010

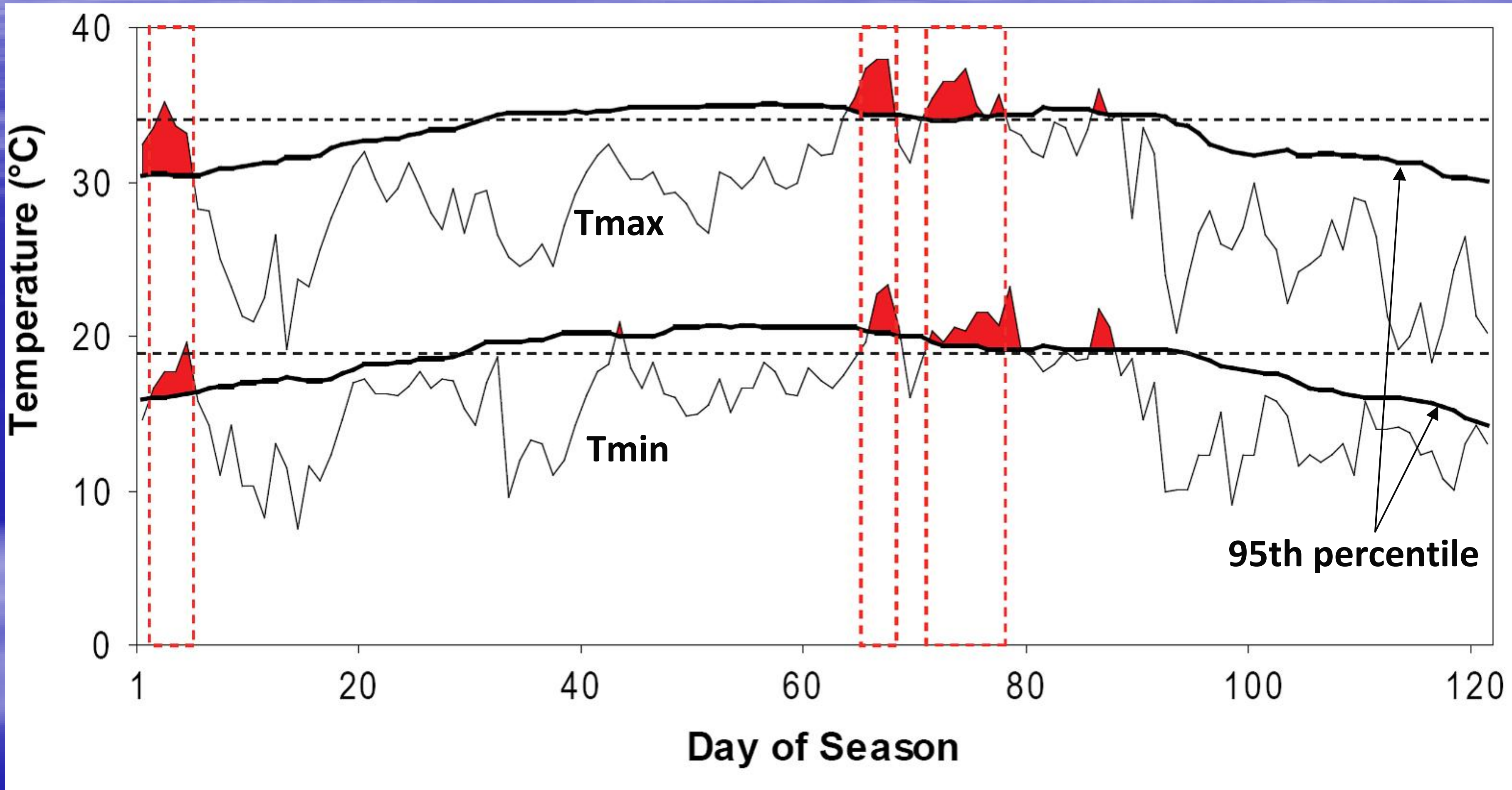
5-year return levels, summer temperature





Toreti 2010

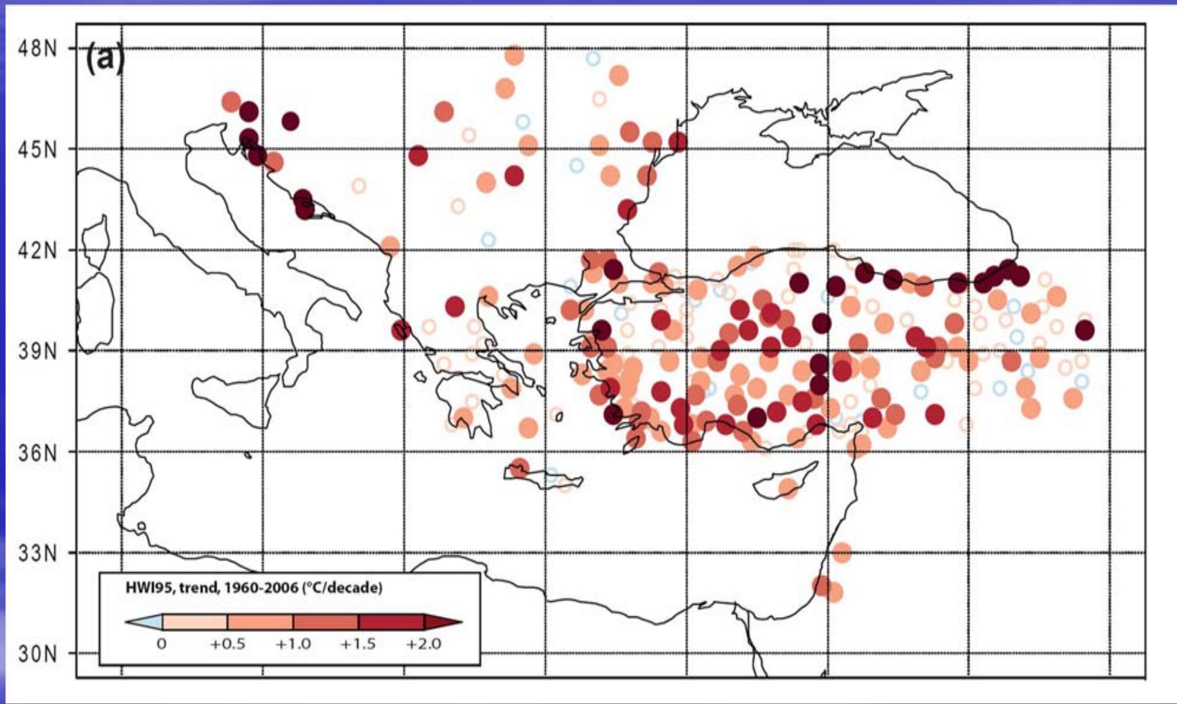
Heatwave definition



HW ≥ 3 consecutive hot days and nights

Kuglitsch et al. 2010

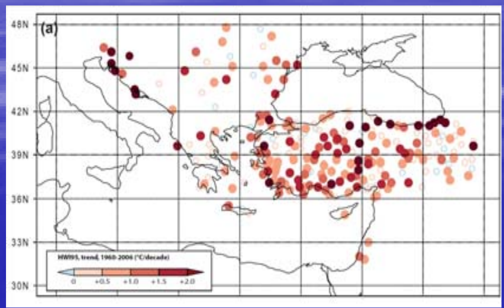
Heatwave intensity trend

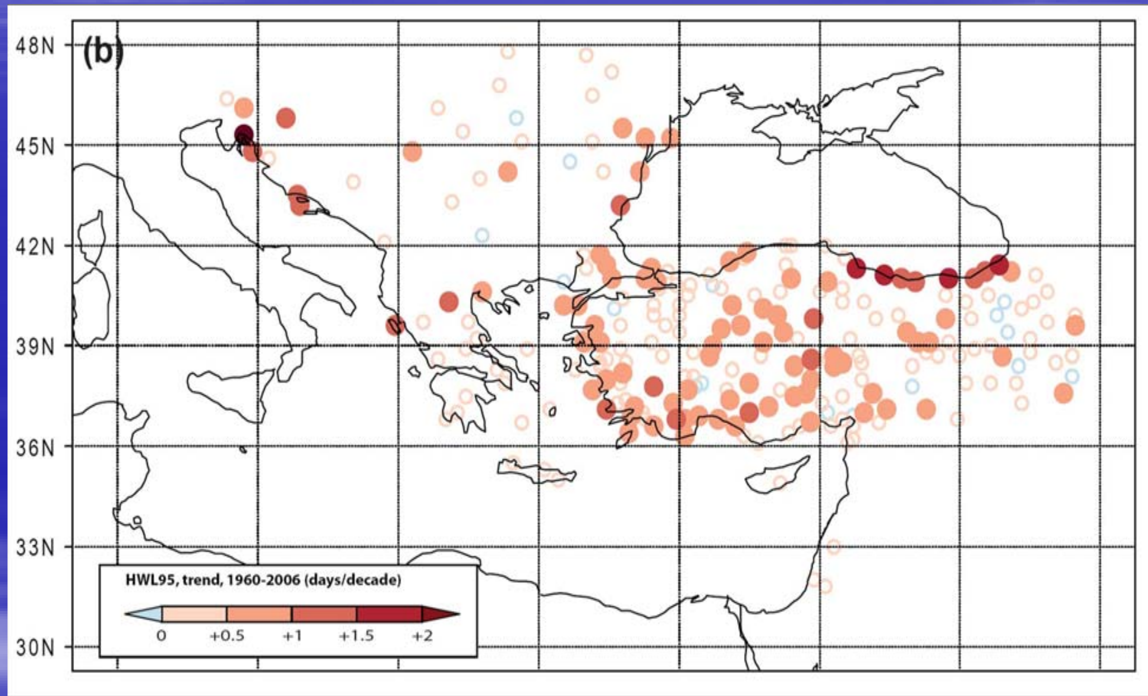


- **HWI95: +1.33 ± 0.06°C/decade**
  - 56% significant

Kuglitsch et al. 2010

Heatwave duration trend

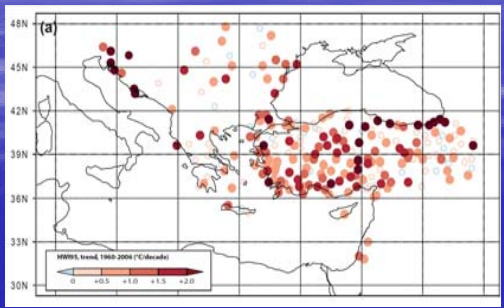


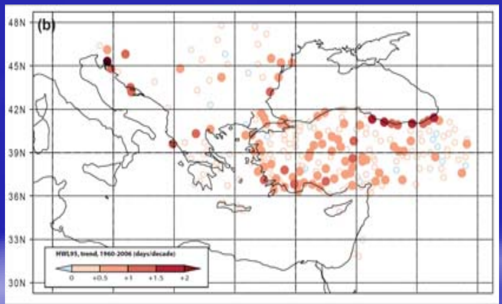


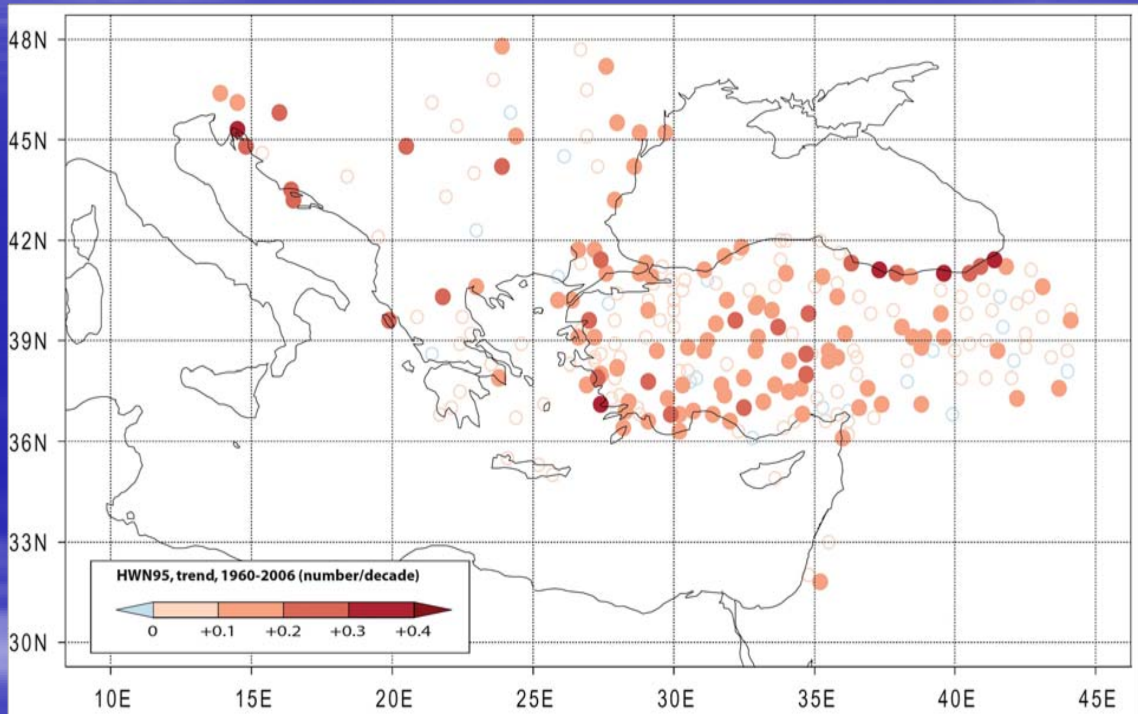
- **HWL95: +0.85 ± 0.02 days/decade**
  - 37% significant

Kuglitsch et al. 2010

Heatwave number trend



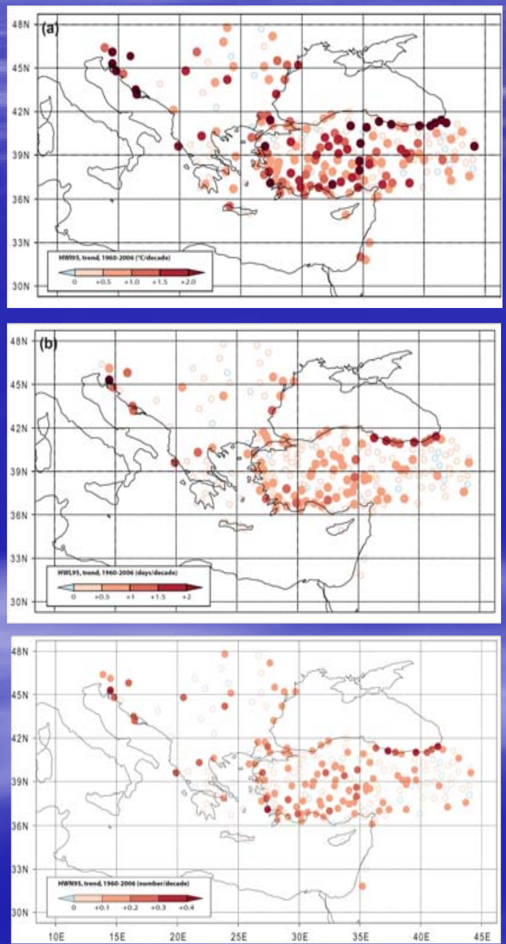




- **HWN95: +0.17 ± 0.01/decade**
  - 47% significant

Kuglitsch et al. 2010

Trends in heatwaves number, duration, intensity

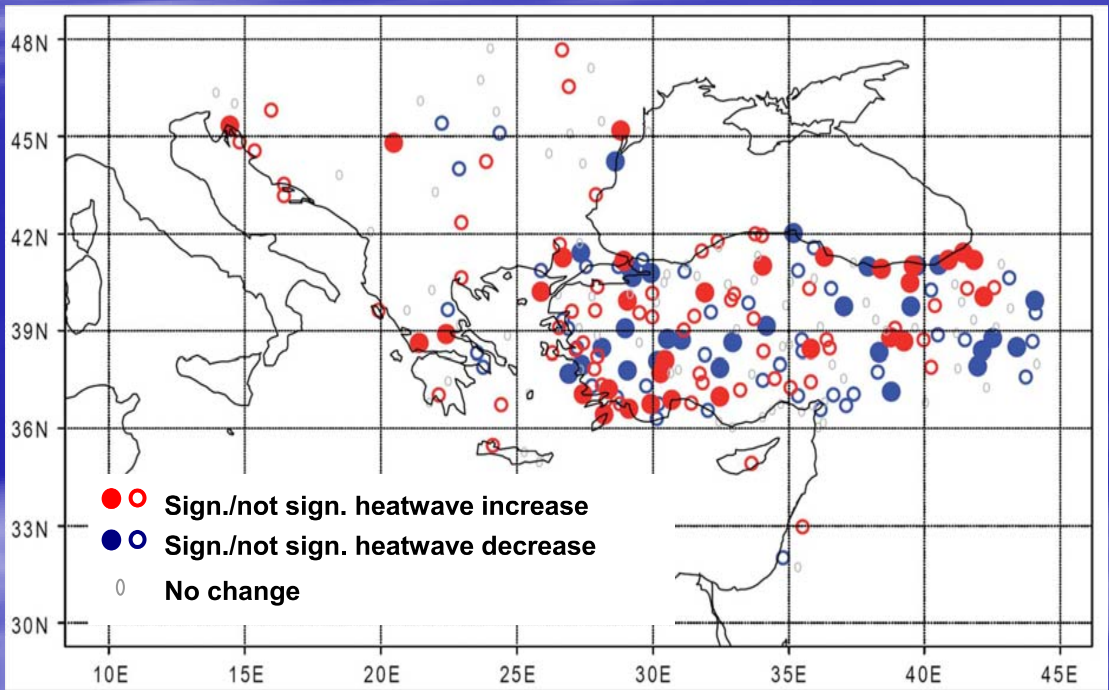


- **HWI95: +1.33 ± 0.06°C/decade**
  - 56% significant
- **HWN95: +0.17 ± 0.01/decade**
  - 47% significant
- **HWL95: +0.85 ± 0.02 days/decade**
  - 37% significant
- **Heatwaves „Hot-Spot“?**
  - Western Balkans
  - Western Turkey
  - Black Sea Coast

Kuglitsch et al. 2010

Influence of data homogenisation in heatwave trend

1960s, 1970s



- 24% significant changes in HWN95 trends

Kuglitsch et al. 2010

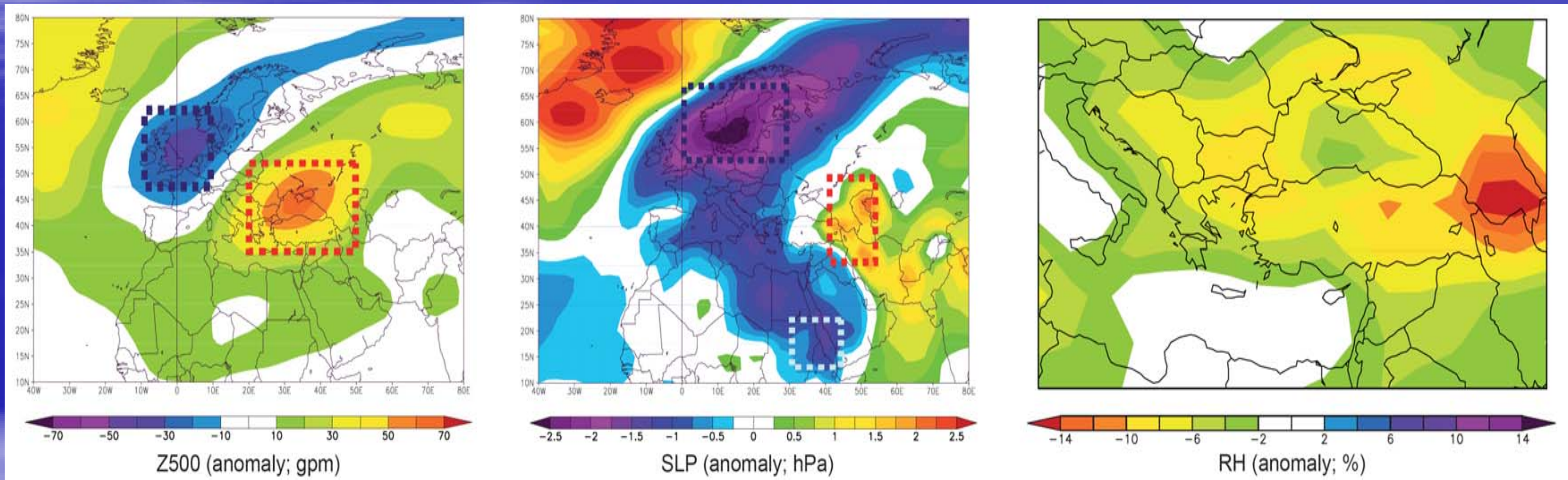
- Overstimated temperature
- Measurement procedures
  - weather screens
    - Stevenson
- TX95%: -0.05°C ± 0.03°C
- TN95%: -0.07°C ± 0.02°C
- HWN95: -0.2 ± 0.01
- HWL95: -0.5 days ± 0.02
- HWI95: -2.0°C ± 0.11°C

Heatwave fatalities in Eastern Mediterranean

COUNTRY	1987	1988	1998	1999	2000	2001	2002	2003	2005	2006	ALL YEARS
Albania	NA	NA	8	6	0	0	NA	NA	NA	NA	**14**
Bulgaria	NA	NA	54	35	56	27	90	NA	NA	NA	**262**
Croatia	NA	NA	15	0	40	0	0	788	22	69	**934**
Cyprus	NA	NA	52	NA	5	NA	NA	NA	NA	0	**57**
FYROM	NA	NA	0	0	0	NA	NA	NA	NA	NA	**0**
Greece	$> 2,000$	56	1,976	378	27	0	NA	NA	NA	NA	$> 4,437$
Israel	NA	NA	160	33	0	0	0	37	0	NA	**230**
Romania	NA	38	20	280	123	84	129	220	368	611	**1,873**
Serbia	NA	NA	50	0	3	0	0	55	0	116	**224**
Slovenia	NA	NA	0	0	0	0	0	289	0	12	**301**
Turkey	NA	NA	NA	NA	11	NA	NA	NA	NA	NA	**11**
ALL COUNTRIES	$> 2,000$	**94**	**2,335**	**732**	**265**	**111**	**219**	**1,389**	**390**	**808**	$> 8,343$

Kuglitsch et al. in prep.

Eastern Mediterranean heatwaves
Atmospheric circulation



Xoplaki and Kuglitsch
in Trigo et al. 2011

Impacts of climate change & extreme events in Mediterranean societies

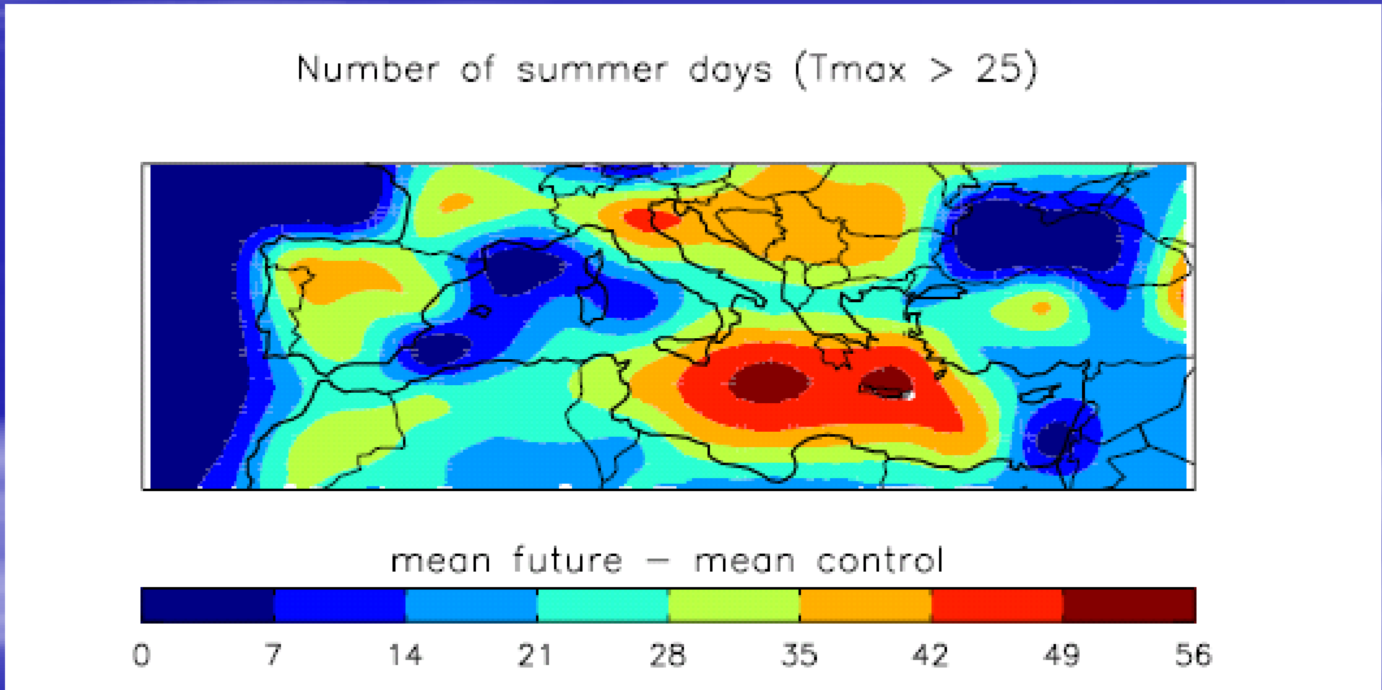
IPCC fourth assessment report

- Impacts are occurring now as a consequence of climate change
- Future possible impacts have been identified
- We can now detect the global effects of anthropogenic warming

- Sectors impacted:
  – Water
  – Ecosystems
  – Food
  – Coasts
  – Industry, Settlement and Society
  – Human health

Future climate; Europe & Mediterranean

2100: temperature will rise between 2 and 6.3°C above 1990 levels. Greater frequency and intensity of extreme weather events are expected.

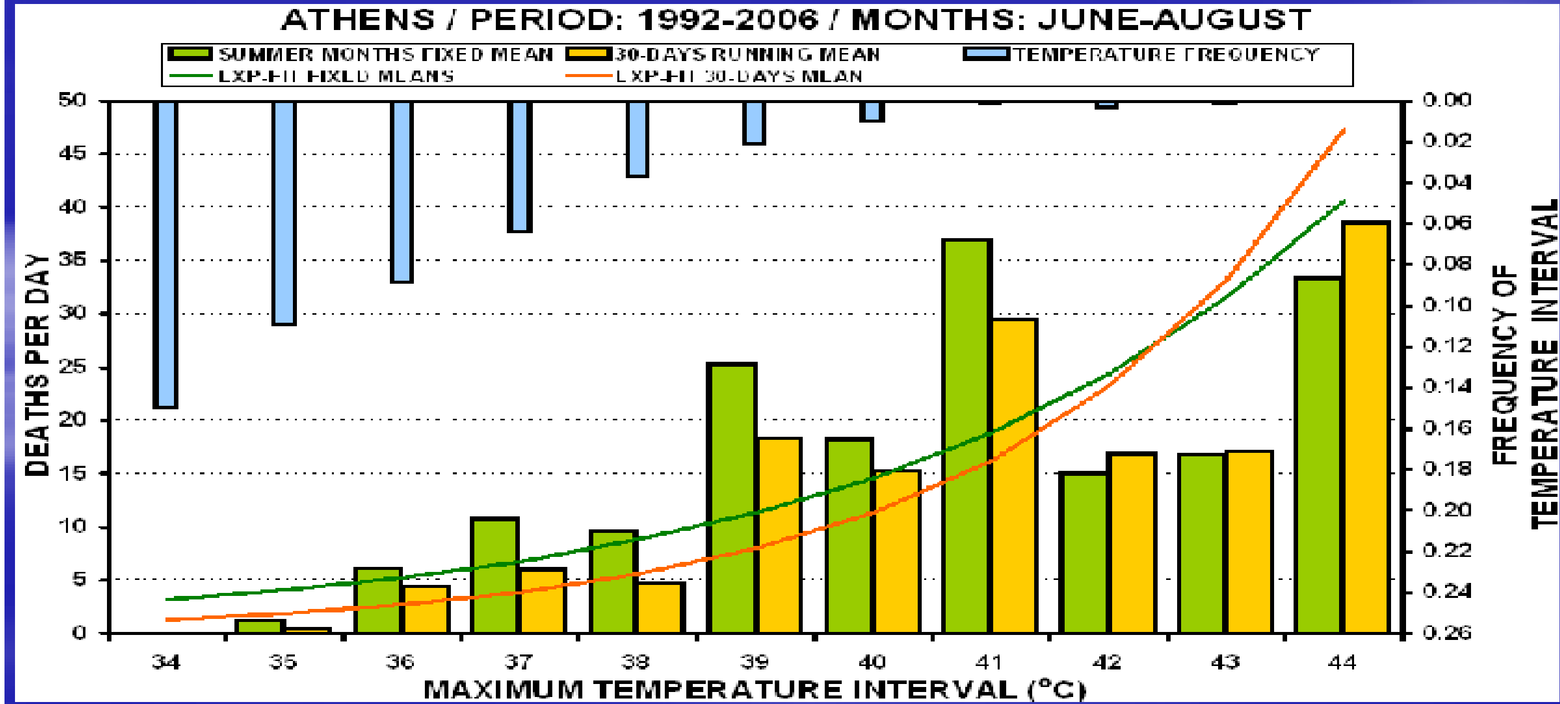


Changes in the number of summer days (Tmax > 25°C) between 2030 and 1990

Giannakopoulos et al. 2009

Human health

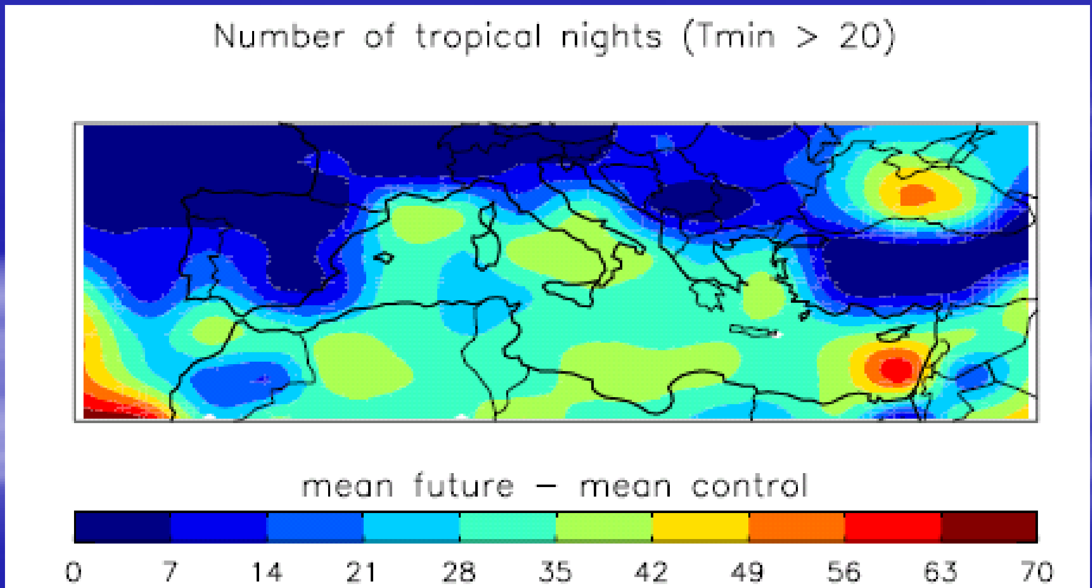
Changes in frequency and intensity of extreme weather and climate events could pose a serious threat to human health. These threats may either be direct, such as heat waves and flooding, or indirect, for example by the spread of tick-borne diseases. Particularly vulnerable sections of the population would be elderly people with limited access to health care services



Giannakopoulos pers. comm.

Tourism

Unreliable snow cover resulting from temperature rise is likely to lead to a loss in winter tourism. Water shortage, water quality problems, and more frequent & intense heat waves in southern Europe could cause notable reductions in summer tourism.
New opportunities for tourism may arise in other areas.

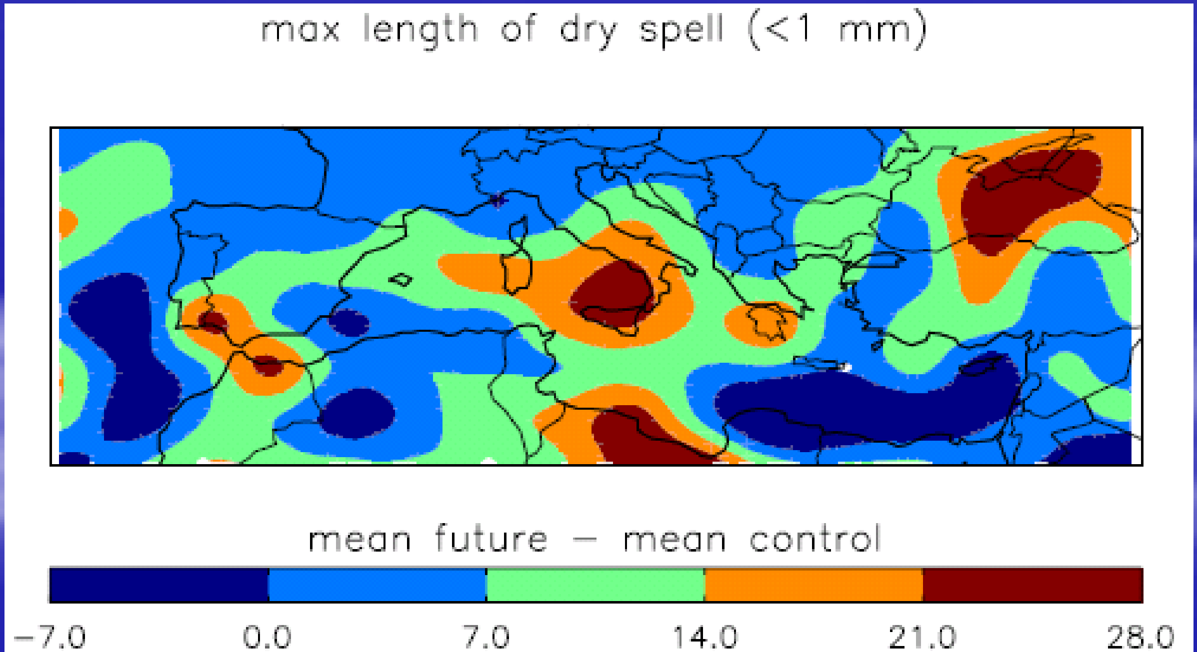


Changes in the number of tropical nights (Tmin >20ºC) between 2030 and 1990

Giannakopoulos et al. 2009

Water resources

Temperature rise and changing precipitation patterns are expected to exacerbate the already acute water shortage problem in southern and south-eastern regions. Changes in frequency and intensity of droughts & floods are projected, which could cause significant financial and human losses throughout Europe



Changes in the maximum length of dry spell in days between 2030 and 1990

Giannakopoulos et al. 2009

Climate change adaptation

Developing and implementing adaptation measures is a relatively new issue. Existing measures are very much concentrated in flood defense. Therefore, there is considerable scope for adaptation planning and implementation in areas such as public health, water resources and management of ecosystems. Currently, there is a number of challenges facing climate change adaptation.

Climate change adaptation challenges

improving climate models and scenarios at regional level, especially for extreme weather events, to reduce the high level of uncertainty;

advancing understanding on 'good practice' in adaptation measures through exchange and information sharing on feasibility, costs and benefits;

involving the public and private sectors, and the general public at both local and national levels;

enhancing coordination and collaboration both within and between countries to ensure the coherence of adaptation measures with other policy objectives, and the allocation of appropriate resources.

Conclusions

- Increased occurrence probability of extreme precipitation events
- Less wet and more dry days, Oct-Mar, 1981-2000 – 1961-1980
- West Mediterranean extreme precipitation events are connected with intensified moisture transport of Atlantic origin
- East Mediterranean extreme precipitation events are connected with warm air advection and instability
- Upward trends of Eastern Mediterranean heatwave intensity, number and duration
- 10 most severe Eastern Mediterranean heatwaves are connected with increased atmospheric stability resulting in clear skies and maximum insolation and reduced relative air humidity


Thank you very much
for your attention!