Meteorological stations-based European climatological database for the identification of heat-waves

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CARISMAND Culture And RISk management in Man-made And Natural Disasters

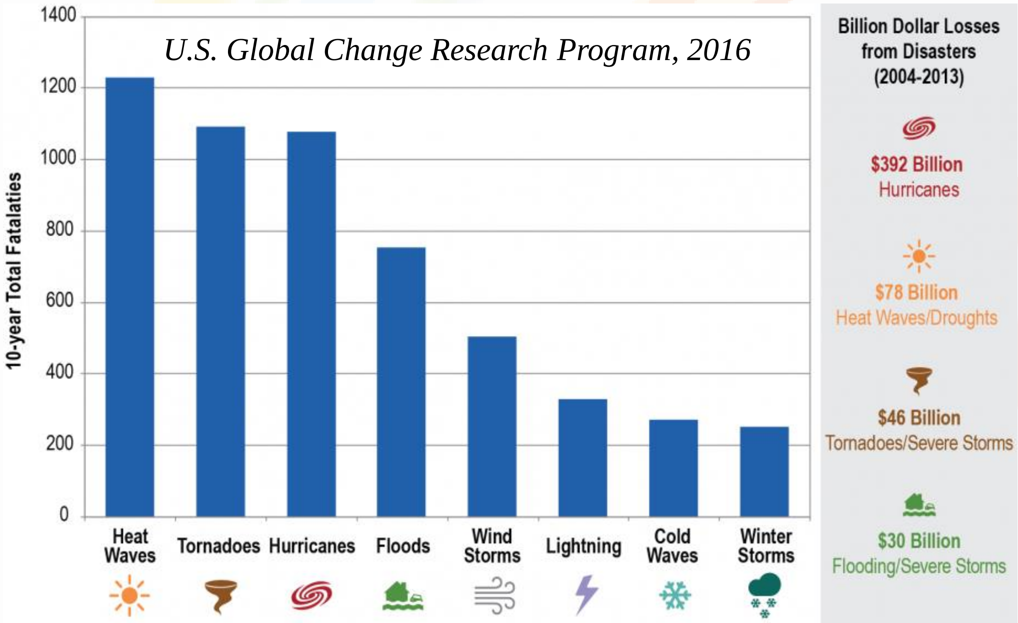
Introduction

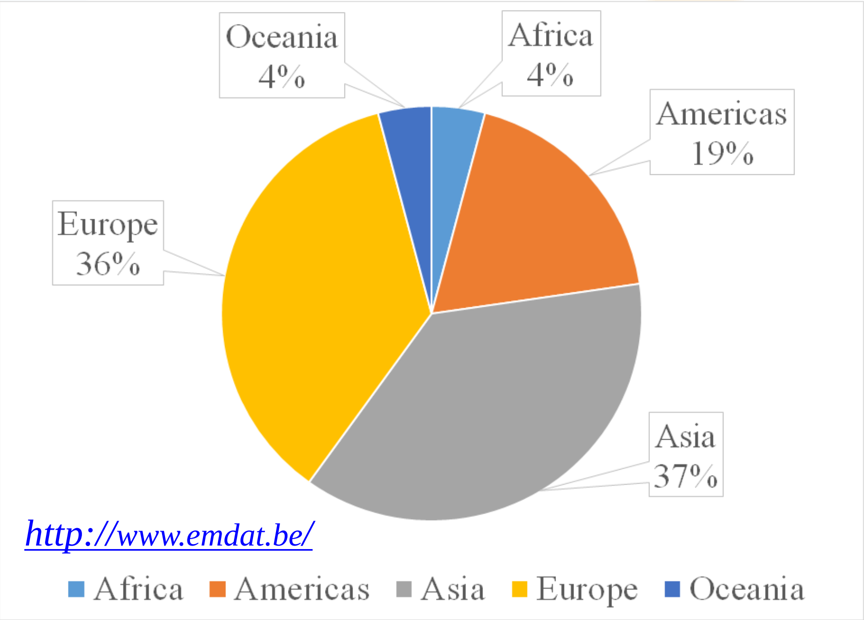
This study was carried out in the field of the CARISMAND Project:
Culture And RISkmanagement in Man-made And Natural Disasters

Introduction

Heat-waves (HWs) are one of the “natural” hazard with the greatest impact worldwide in terms of mortality and economic losses

The impact of HWs on mortality is particularly high in Europe, accounting for over 80% of the total heat-wave-related deaths worldwide





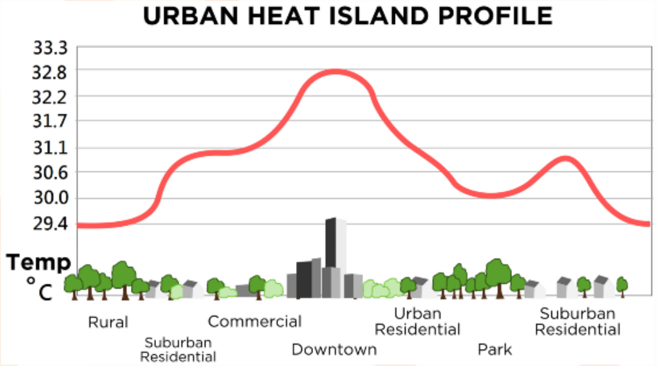
Nevertheless, HWs rarely receive adequate attention as a public-health problem, maybe because this meteorological hazard lacks the spectacular and sudden violence of other extreme events.

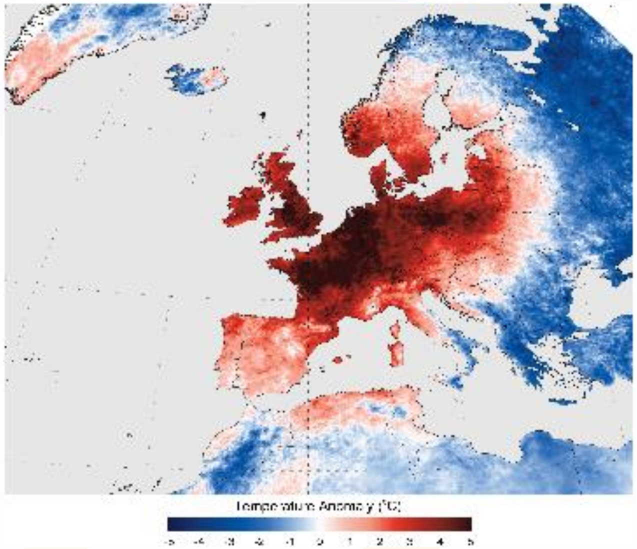
HEAT: THE SILENT KILLER!

Introduction

Unlike other extreme events, HWs generally occur over large geographical areas where many vulnerable subjects may be exposed.

HWs effect may be exacerbated in large urban areas because of the urban heat island phenomenon.





For these reasons, more and more detailed and updated analyses on HW trends and on the heat-risk assessment for the most vulnerable people (i.e. the oldest and youngest population) represent a priority that can not be neglected.

Urban environments

Long time-serie

Geographically extended

What is the best heat-wave definition?

There is no universally accepted heat-wave definition

Based on IPCC report (IPCC, 2012):

Heat-waves are period of **abnormally hot** weather.

Based on WMO description (WMO-No. 1142, 2015):

Heat-waves are understood to be periods of **unusually hot and dry or hot and humid** weather with a detailed **onset and cessation**, a **duration of at least two–three days**, usually with a discernible **impact on human and natural systems**.

There is agreement that HWs are relative to a location's climate and its classification should be geographically-related:

the same meteorological conditions can constitute a HW in one place but not in another

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Review article

Impact of heatwave on mortality under different heatwave definitions: A systematic review and meta-analysis

Zhiwei Xu [a], Gerard FitzGerald [a], Yuming Guo [b], Bin Jalaludin [c,d], Shilu Tong [a,*]

The most appropriate HW definition should be based on the sector (i.e. health, infrastructure, agriculture, …) potentially affected by HWs

The HW definition used in this study

At European level, a useful contribution to define a HW in a human health context was provided by the **EU-funded project EuroHEAT** (*Improving Public Health Responses to extreme weather/heat-waves*) which also aimed to develop a standardized definition of a HW event

D'Ippoliti et al., 2010

We used an improved version of the EuroHEAT HW definition

Heat wave (HW) definition

- Periods of at least 2 days with T_{appmax} exceeding the 90th percentile centered on a 31-day window

or

- Periods of at least 2 days in which T_{min} exceeds the 90th percentile & T_{appmax} exceeds the median centered on a 31-day window

HW characteristics

Duration
- Short HW: duration < the median
- Long HW: duration ≥ the median

Intensity
- Low intensity HW: T_{appmax} < 95th perc
- High intensity HW: T_{appmax} ≥ 95th perc

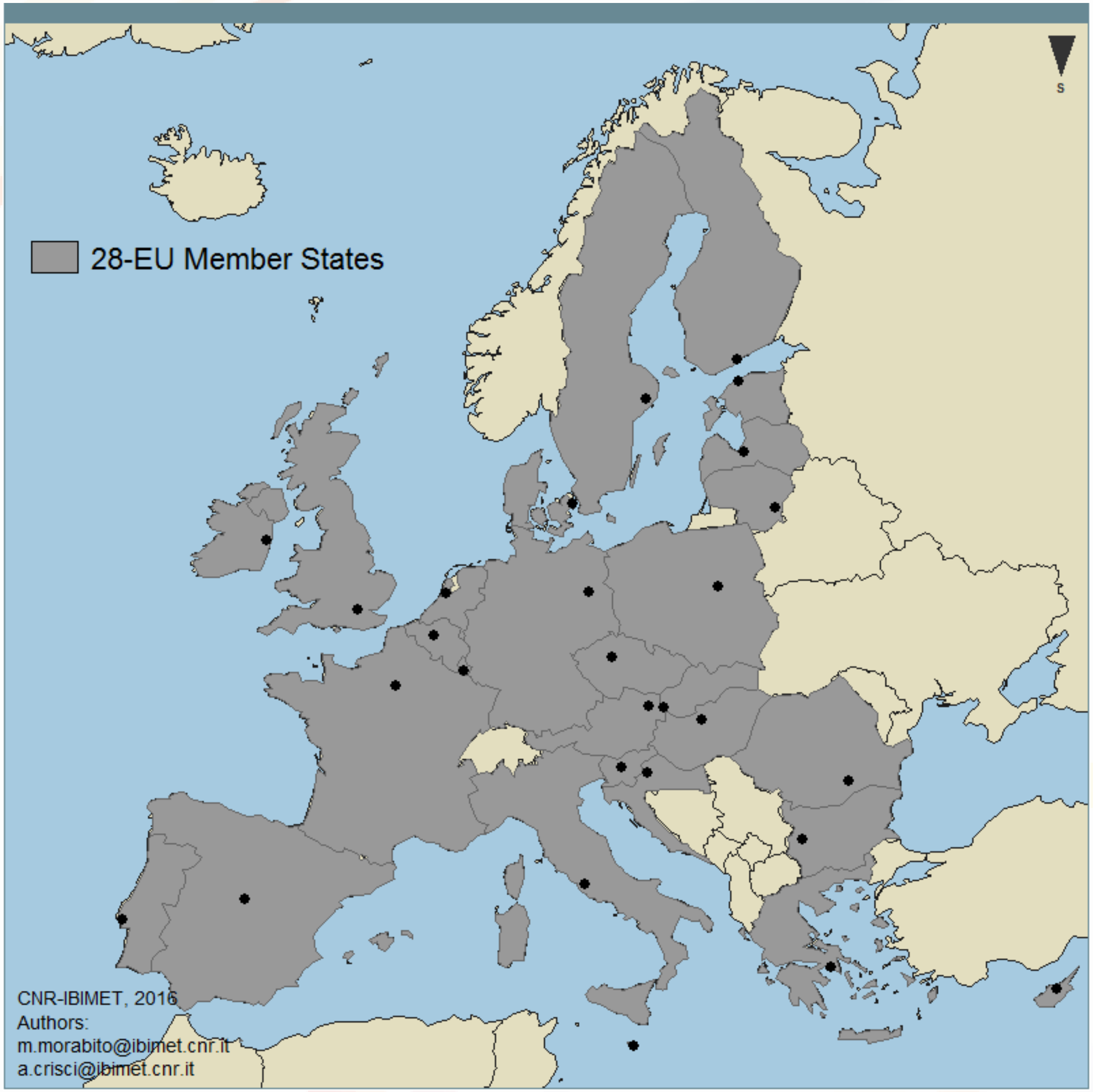
Timing
- The first HW of each summer
- HWs that occurred between 1 and 3 days after the previous one;
- HWs that occurred 3 or more days after the previous one

Study description

A **HW hazard index (HWHI)** accounting for the duration, intensity and timing of HWs has been developed.

Trends and spatial distributions of the HWHI were investigated on a long historical time-series (36-year period) of daily ground meteorological data collected over the densely populated capitals of the 28-EU Member States.

Comparisons of HW characteristics between two 18-year periods were carried out: 1980-1997 vs. 1998-2015



Materials and Methods

Daily meteorological data were collected over the capitals of the 28-EU Member States during a 36-year period (1980–2015) by using the Global Surface Summary of the Day (GSOD) dataset produced by the National Climatic Data Center (NCDC) (ftp://ftp.ncdc.noaa.gov/pub/data/gsod/).

HWs were defined during the warmest period of the year (May-September, 1980-2015) by using the improved version of the EuroHEAT HW definition previously described.

Heat-Wave Hazard Index (HWHI) assessment

HW days (HW_D)	Duration (HW_L)	Intensity (HW_I)	Timing (HW_T)
Median No. of HW days (scaled 0 - 1) Weighted 25%	Median No. of long HWs (scaled 0 - 1) Weighted 25%	Median No. of high intensity HWs (scaled 0 - 1) Weighted 25%	Median day of the first long&high intensity HW (scaled 0 - 1) Weighted 25%

$$HWHI = (HW_D \times 0.25) + (HW_L \times 0.25) + (HW_I \times 0.25) + (HW_T \times 0.25)$$

HWHI MAPPING
(scaled 0 - 1)
HWHI split into five equal risk levels:
Very low - Low – Medium - High - Very high

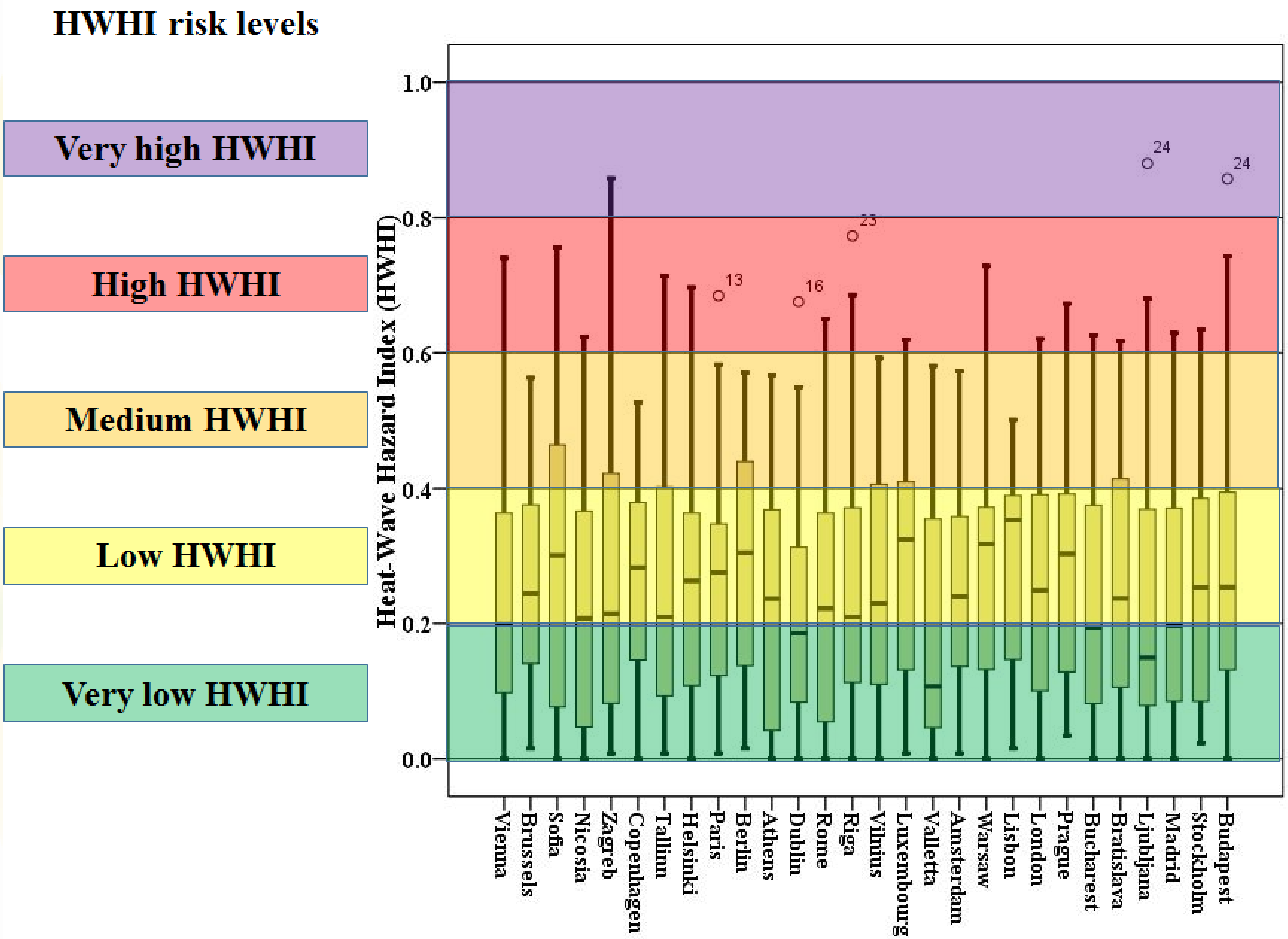
Statistical analyses

- Descriptive statistic (boxplot graphs) of the city-specific Heat-Wave Hazard Index (HWHI)

- The Trend-Package (Ver. 0.2.0) of the open source R statistical software "*Non-Parametric Trend Tests and Change-Point Detection*" (*https://cran.r-project.org/web/packages/trend/index.html*) *(Pohlert, 2016)* was used to investigate the Heat-Wave Hazard Index (HWHI) trend over the period 1980-2015:
  - Mann-Kendall Trend Test *(Kendall coefficients of correlation and p-value)*
  - Sen's slope

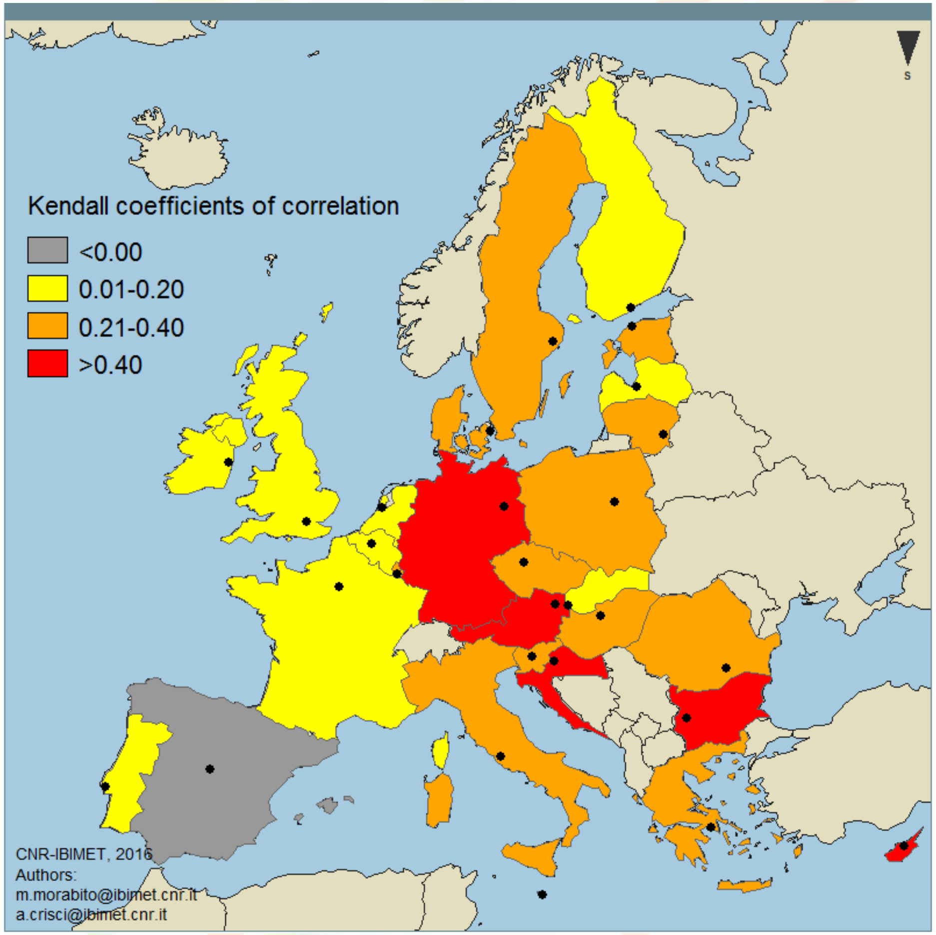
- The % change of the HW characteristics (HW_D, HW_L and HW_I) and the variation of median days of HW_T between two 36-year periods (1980-1997 vs 1998-2015) were assessed:
  - the Kruskal-Wallis Test *(Kruskal and Wallis, 1952)* was used to determine if there were statistically significant HW characteristics differences between the two periods

Results – Boxplot of HWHI

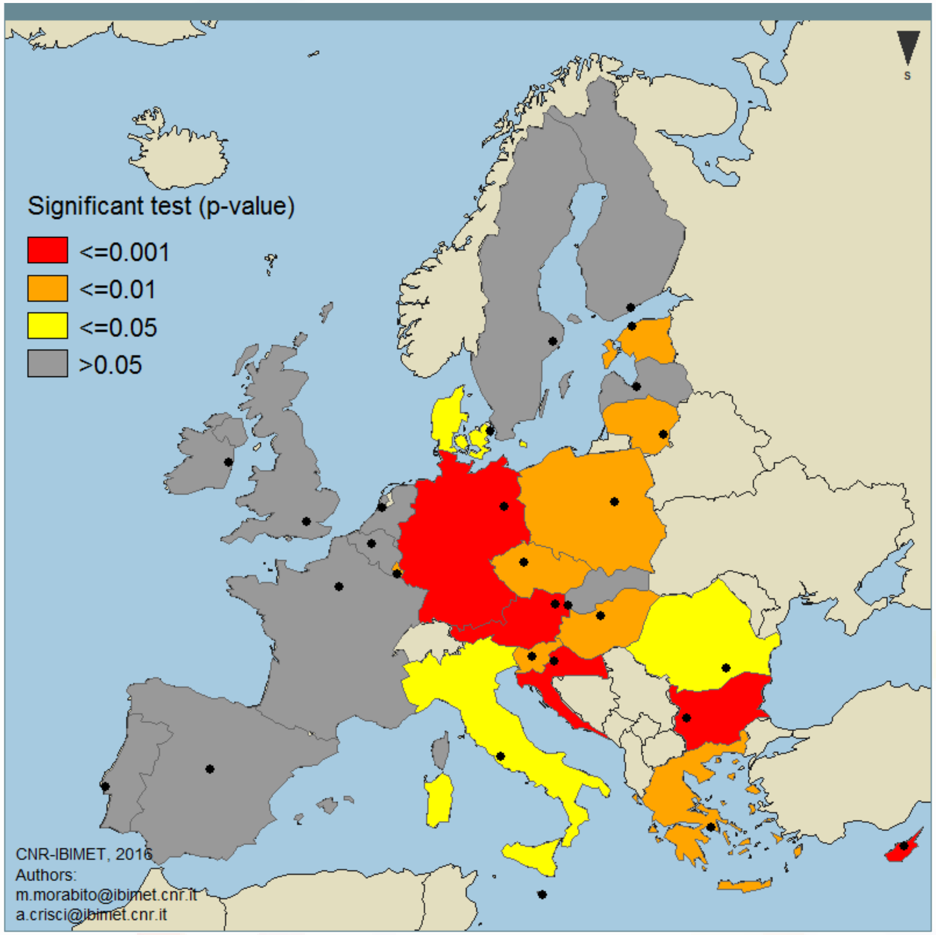


Results – Trend analyses (1980-2015)

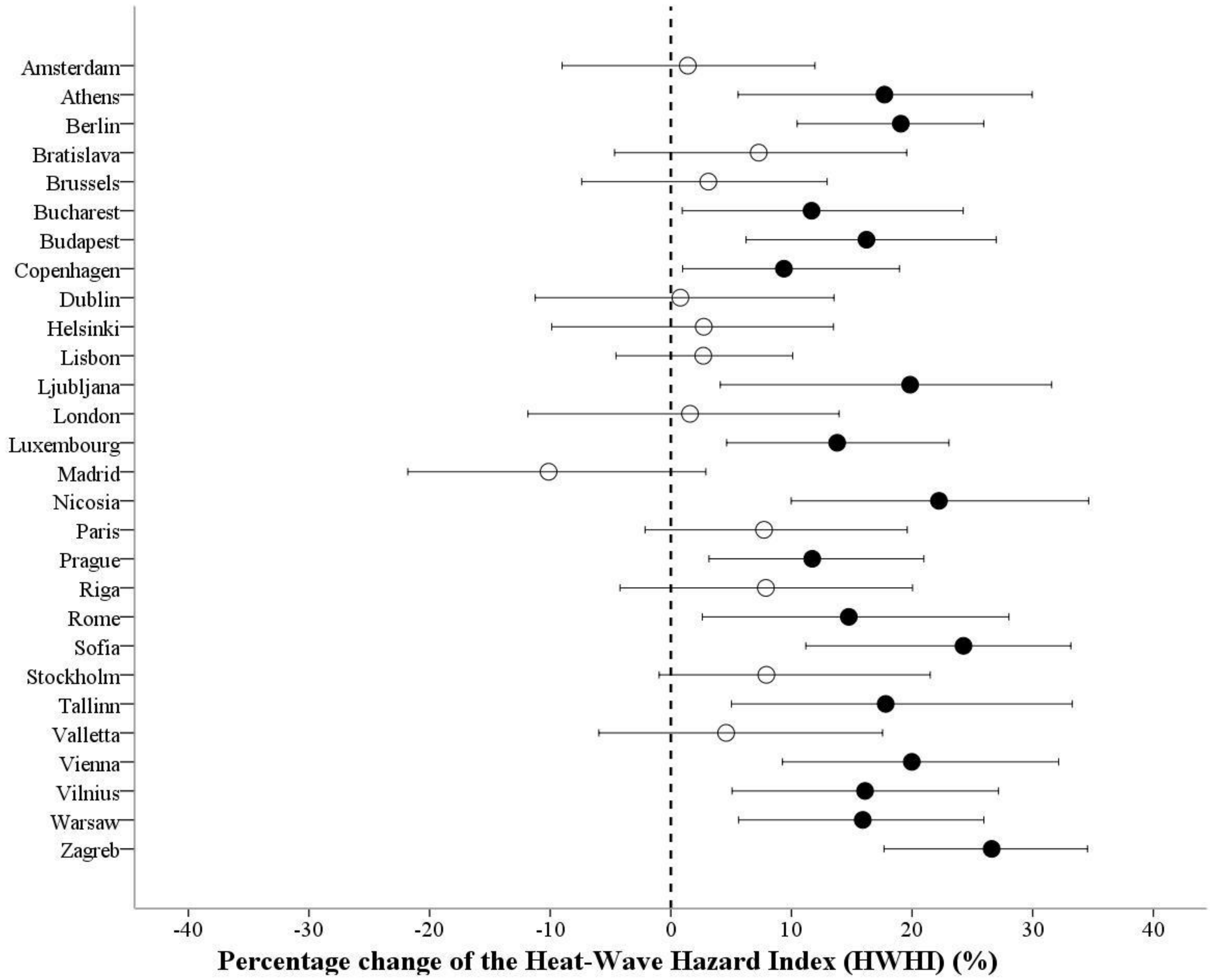
Kendall coefficients of correlation



Significant test (p-value)



Results – HWHI scenario by 2020



Results
% change of HW characteristics

Northern European Countries/Cities		1980-1997 Median				1998-2015 Median				% Change (HW_D, HW_L and HW_I) Variation in median days (HW_T) Significant change (red if p<0.05)			
		HW_D	HW_L	HW_I	HW_T	HW_D	HW_L	HW_I	HW_T	HW_D	HW_L	HW_I	HW_T
Ireland	Dublin	14.0	2.0	1.0	143.5	12.0	2.0	1.0	113.5	-14%	0%	0%	-30.0
United Kingdom	London	13.0	2.0	1.0	70.0	17.0	3.0	1.0	118.5	31%	50%	0%	+48.5
Denmark	Copenhagen	12.5	2.0	1.0	73.0	18.5	3.0	1.0	74.0	**48%**	**50%**	0%	+1.0
Sweden	Stockholm	13.0	2.0	1.0	137.5	15.0	3.0	1.0	105.5	15%	**50%**	0%	-32.0
Estonia	Tallinn	12.0	2.0	1.0	153.0	18.0	3.0	2.0	68.5	**50%**	**50%**	**100%**	**-84.5**
Finland	Helsinki	11.5	2.5	1.5	76.0	19.5	3.5	1.0	152.0	**70%**	40%	-33%	+76.0
Latvia	Riga	11.5	2.0	1.0	134.5	20.5	2.0	2.0	85.0	**78%**	0%	**100%**	-49.5
Lithuania	Vilnius	13.0	2.0	1.0	147.5	17.5	3.0	2.0	63.5	**35%**	**50%**	**100%**	-84.0

Results
% change of HW characteristics

Southern European Countries/Cities		1980-1997 Median				1998-2015 Median				% Change (HW_D, HW_L and HW_I) Variation in median days (HW_T) Significant change (red if $p<0.05$)			
		HW_D	HW_L	HW_I	HW_T	HW_D	HW_L	HW_I	HW_T	HW_D	HW_L	HW_I	HW_T
Portugal	Lisbon	15.0	3.0	2.0	77.0	13.5	2.5	1.5	70.0	-10%	-17%	-25%	-7.0
Spain	Madrid	16.5	3.0	2.0	92.0	12.0	2.0	0.0	153.0	-27%	-33%	**-100%**	**+61.0**
Italy	Rome	7.5	1.0	1.0	149.0	20.0	2.0	2.0	84.0	**167%**	**100%**	**100%**	-65.0
Malta	La Valletta	11.5	2.0	1.0	153.0	16.5	2.5	1.0	153.0	44%	25%	0%	0.0
Slovenia	Ljubljana	11.5	2.0	0.5	153.0	19.5	4.0	2.0	70.5	**70%**	**100%**	**300%**	**-82.5**
Croatia	Zagreb	8.0	1.0	1.0	153.0	27.5	4.0	2.5	56.5	**244%**	**300%**	**150%**	**-96.5**
Greece	Athens	6.5	1.0	0.5	153.0	27.0	4.0	2.0	89.0	**315%**	**300%**	300%	**-64.0**
Cyprus	Nicosia	6.0	0.5	1.0	153.0	23.5	4.0	1.0	100.5	**292%**	**700%**	0%	-52.5

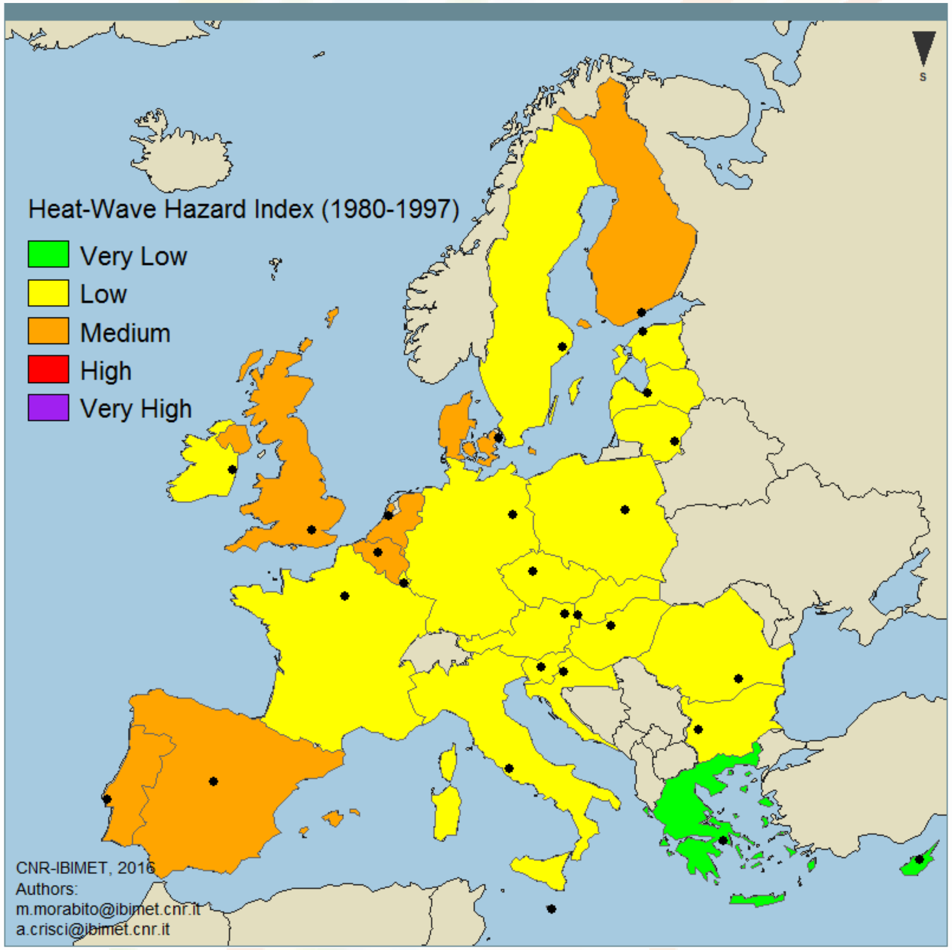
Results
% change of HW characteristics

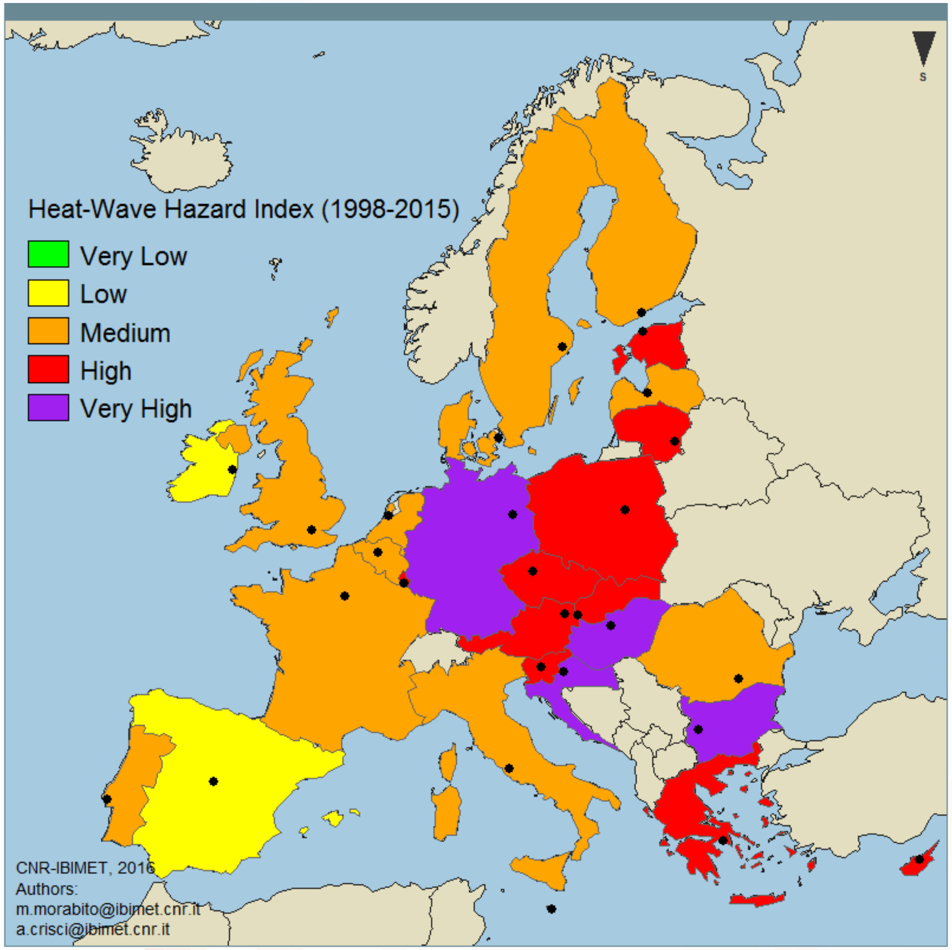
Western European Countries/Cities		1980-1997 Median				1998-2015 Median				% Change (HW_D, HW_L and HW_I) Variation in median days (HW_T) Significant change (red if p<0.05)			
		HW_D	HW_L	HW_I	HW_T	HW_D	HW_L	HW_I	HW_T	HW_D	HW_L	HW_I	HW_T
France	Paris	15.0	2.5	1.0	130.0	14.5	2.5	2.0	93.0	-3%	0%	100%	-37.0
Belgium	Brussels	12.5	3.0	1.0	114.0	17.5	3.5	1.0	123.5	40%	17%	0%	+9.5
Netherlands	Amsterdam	11.5	3.0	2.0	111.0	19.0	3.0	1.0	123.5	65%	0%	-50%	+12.5
Luxembourg	Luxembourg	11.5	1.5	1.5	102.0	18.0	3.5	2.5	61.5	**57%**	**133%**	67%	-40.5
Germany	Berlin	14.5	2.0	1.0	153.0	21.0	4.0	3.0	46.0	**45%**	**100%**	**200%**	**-107**
Austria	Vienna	11.5	2.0	0.5	153.0	23.0	4.0	2.5	72.5	**100%**	**100%**	**400%**	**-80.5**

Results
% change of HW characteristics

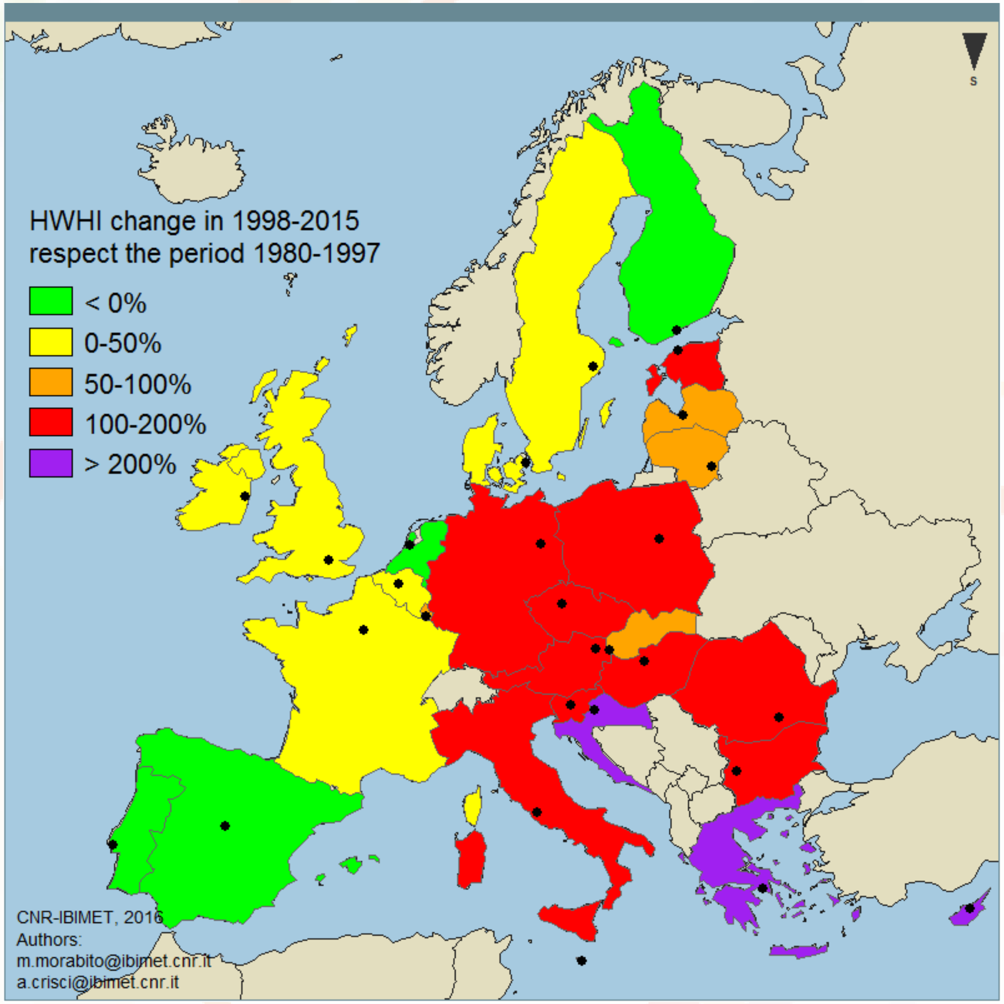
Eastern European Countries/Cities		1980-1997 Median				1998-2015 Median				% Change (HW_D, HW_L and HW_I) Variation in median days (HW_T) Significant change (red if p<0.05)			
		HW_D	HW_L	HW_I	HW_T	HW_D	HW_L	HW_I	HW_T	HW_D	HW_L	HW_I	HW_T
Czech Republic	Prague	11.5	2.0	1.0	133.5	20.5	4.0	2.0	53.5	**78%**	**100%**	**100%**	-80.0
Slovakia	Bratislava	14.0	2.5	1.0	141.0	21.0	4.0	1.5	98.5	**50%**	60%	50%	-42.5
Hungary	Budapest	13.0	2.0	1.0	150.0	22.5	4.0	3.0	54.5	**73%**	**100%**	**200%**	**-95.5**
Poland	Warsaw	13.0	2.0	1.0	141.5	22.0	4.0	2.0	63.0	**69%**	**100%**	100%	**-78.5**
Bulgaria	Sofia	10.0	2.0	1.0	153.0	24.5	4.5	2.5	65.5	**145%**	**125%**	**150%**	**-87.5**
Romania	Bucharest	11.0	1.5	1.0	153.0	20.0	3.0	2.0	115.0	**82%**	**100%**	100%	-38.0

Results
HWHI 1980-1997 vs. HWHI 1998-2015

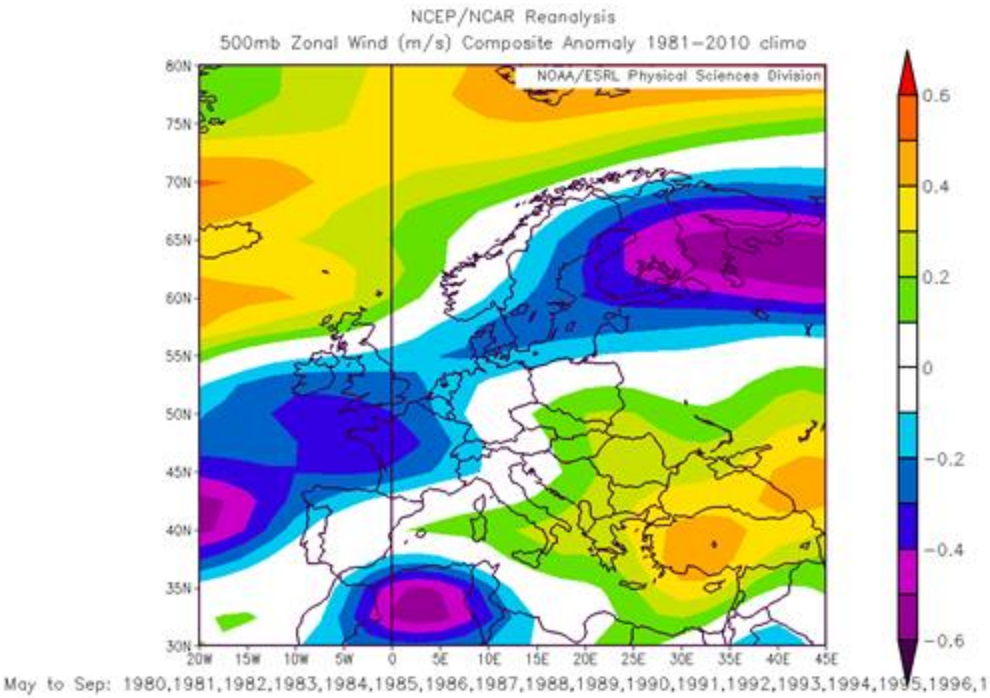


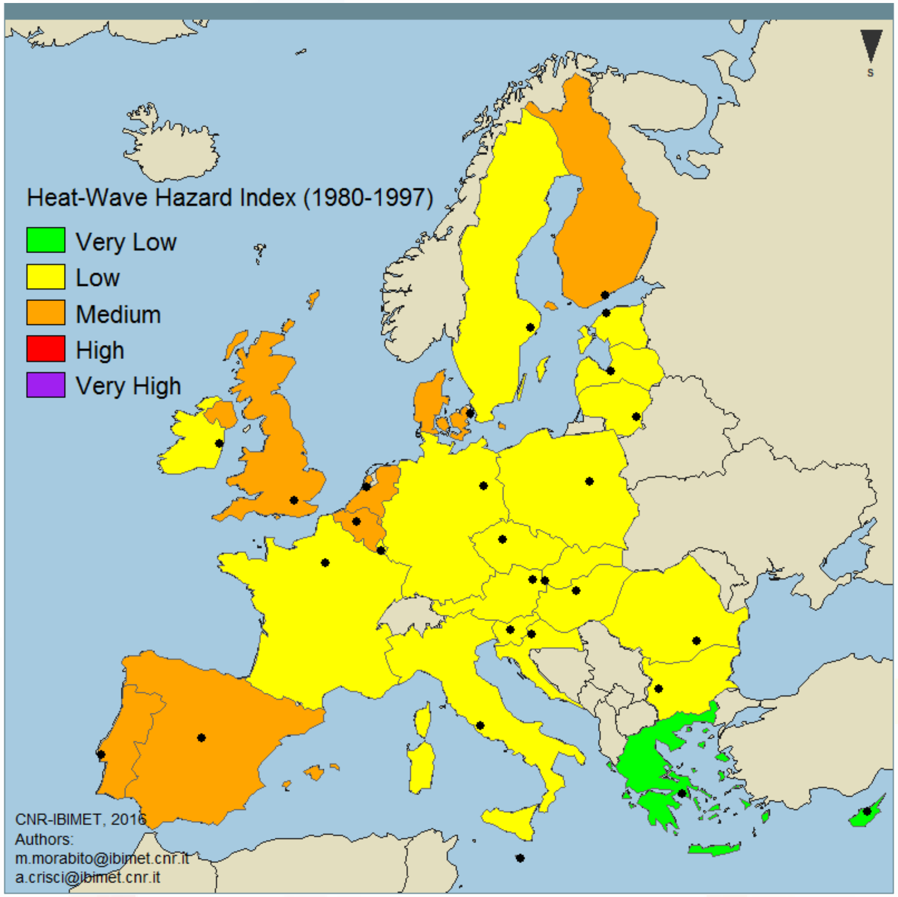


Results
HWHI % change in 1998-2015



Climatological interpretation of the HWHI-geographical shift over Europe

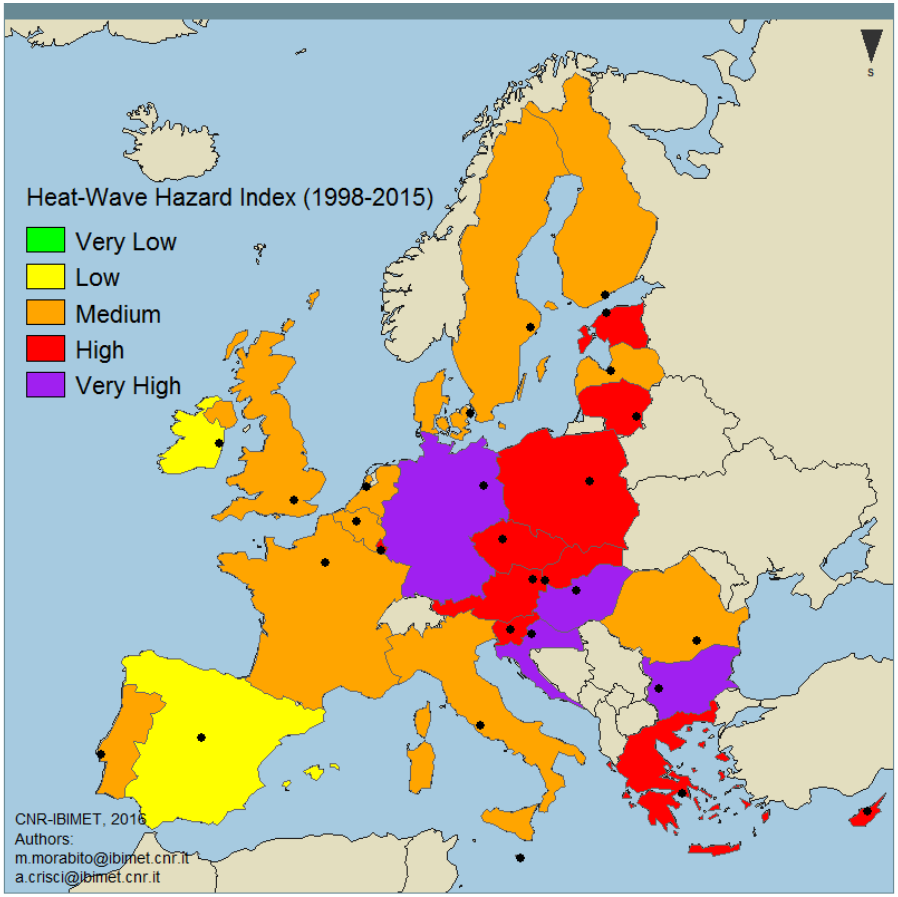




Period 1980-1997

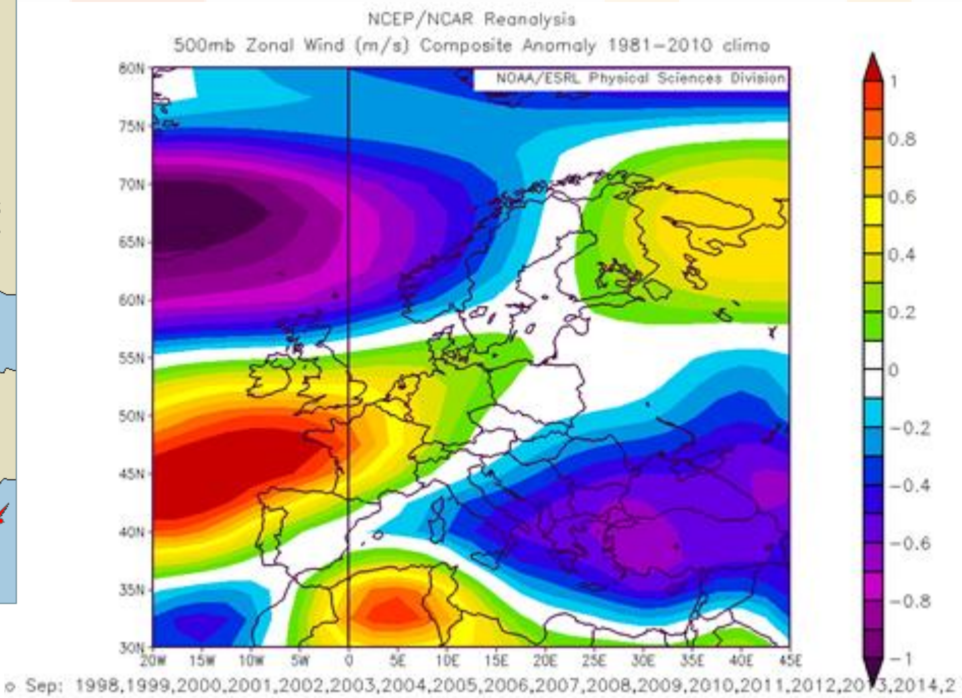
Decrease of the zonal flux over the N Europe	⇨	High pressure
Increase over the SE Europe	⇨	Low pressure

Climatological interpretation of the HWHI-geographical shift over Europe

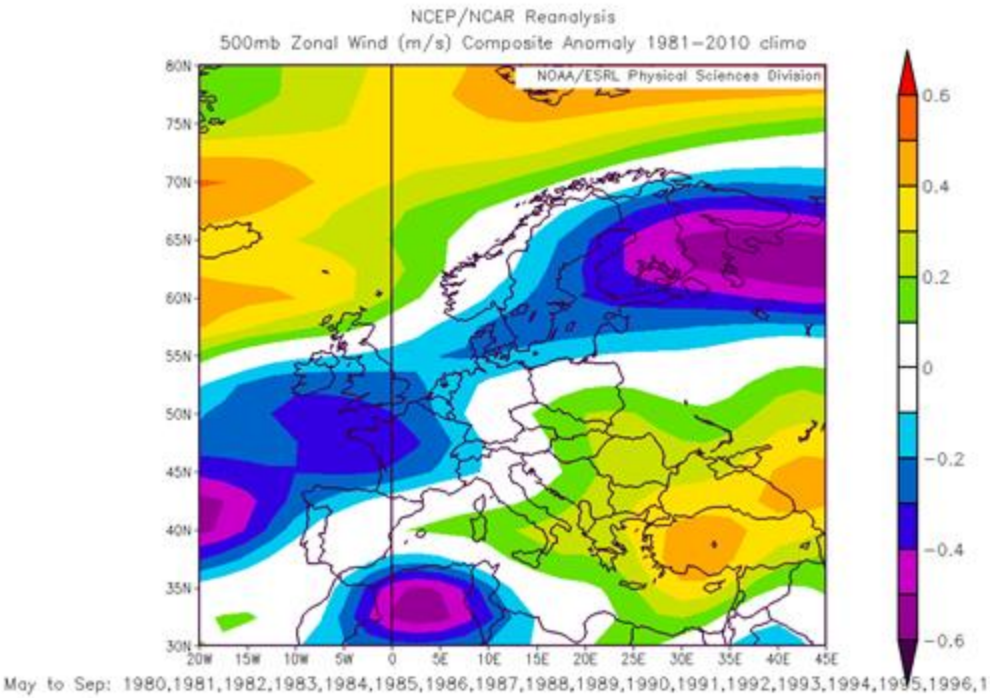


Period 1998-2015

Increase of the zonal flux over the W & NE Europe	⇒	Low pressure
Decrease over the SE & N Europe	⇒	High pressure



Climatological interpretation of the HWHI-geographical shift (from west to east) over Europe

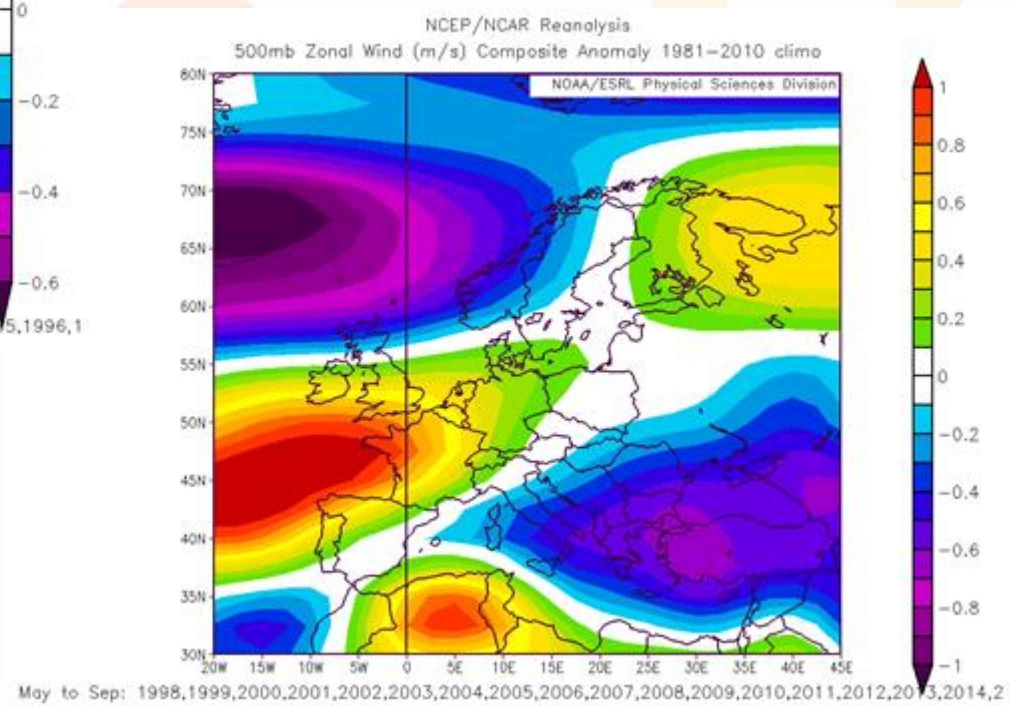


Period 1980-1997

Decrease of the zonal flux over the N Europe	⇨	High pressure
Increase over the SE Europe	⇨	Low pressure

Period 1998-2015

Increase of the zonal flux over the W & NE Europe	⇨	Low pressure
Decrease over the SE & N Europe	⇨	High pressure



Conclusions

- Most of the city showed a significant increase in the HWHI, especially in the capitals of EU central-eastern Member States

- The % change of the HWHI expected in 2020 was the highest in the eastern cities (from 20 to 30% of HWHI increase)

- Most of cities showed HWHI increases going from 1980-1997 to 1998-2015:
  - the highest increases (> 200%) were observed in the capitals of Greece, Cyprus and Croatia;
  - the lowest increases (0-50%) were observed in several western and northern capitals;
  - HWHI decreases were observed in capitals of the western EU Member States (Spain and Portugal) and several Northern countries (Netherlands and Finland)

- Two completely different synoptic sytuations were observed in the periods 1980-1997 and 1998-2015

- These results are especially important for local authorities, urban planners and generally policy-makers, which should work to allocate funds to support environmental modifications to mitigate urban microclimate and pedestrian thermal comfort conditions.

THANK YOU FOR THE ATTENTION!!!

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CARISMAND

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