Analysis of temperature trends, heat and cold waves in Central Italy (1952-2008)

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Abstract. Minimum and maximum daily temperature data (1952-2008) registered in Umbria Region (Tiber Basin, Central Italy) have been analyzed to estimate mean trends and possible increases in the extreme events (heat and cold waves). Possible trends have been sought by means of the sequential Mann-Kendall test

Study area and dataset

- Study area: Umbria Region (Tiber, Basin, Central Italy) (Fig 1).
- Reference period: 1952-2008
- 78 stations analyzed, most of them with a high number of missing data (Fig. 2).
- Only stations with at least 45 years of data (75%), even not consecutive, have been retained for trend analysis (5 stations).
- Missing data were calculated as the average of the available daily temperature values over the region.

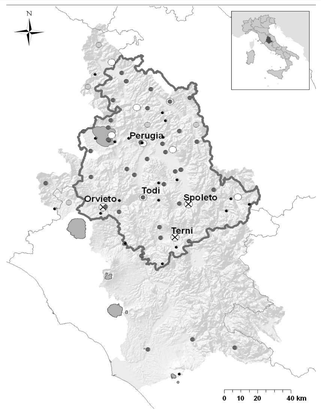

Fig 1. Available temperature stations characterized by the fraction of recorded data (%) . The names of the 5 stations considered in the analysis are in bold font.

Fig 2. Available annual data for each station

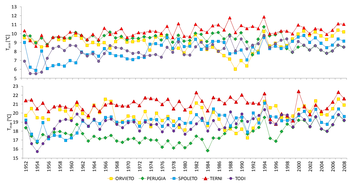

Fig 3. Mean annual daily T_{min} (above) and mean annual daily T_{max} (below) of selected stations

State of the art

At Italian scale it is widely recognized scale that a general increase of temperature is occurring (Brunetti et al. 2006, Toreti and Desiato 2010). Also at European scale, many studies claimed that temperatures have increased in the last century, with a trend more evident in the last 30-40 years. Some studies at national and continental scale have been specifically devoted to heat and cold waves, although adopting different methodologies. A significant increase in heat waves has been enhanced also at European scale (Della Marta et al. 2007).

Methodology

Heat wave is defined as the period of at least 5 consecutive days in summer that exceed the long-term 90th percentile of daily T_{max}

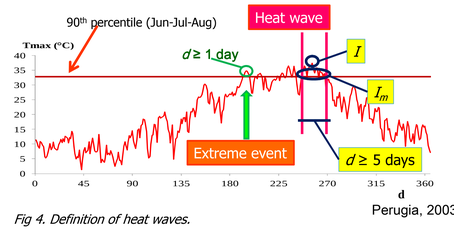

Fig 4. Definition of heat waves.

Cold wave is defined as the period of at least 5 consecutive days in winter that does not exceed the long-term 10th percentile of daily T_{min}

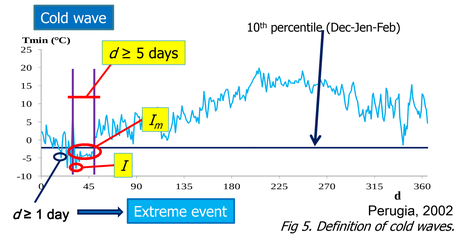

Fig 5. Definition of cold waves.

The Mann-Kendall test has been applied to the sequential annual time series progressively increased by 1 year to verify the existence of trend. Trends have been also investigated by means of a change point detection algorithm based on the singular-spectrum analysis (Moskvina and Zhighjavsky, 2003). This method is based on the singular-value decomposition of the lag-covariance matrix computed on the trajectory matrix

Trend analysis – Sequential Mann-Kendall results

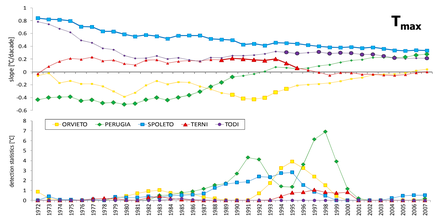

Fig 6. Behavior of slope and detection algorithm for T_{max}.

Considering the whole period, our findings show a positive trend of T_{max} and T_{min}, enhanced in 3 stations out of 5 (although not the same stations for both the indices). Significant break points have been pointed out approximately at the end of 1980's.

The signal in terms of trend is very different from station to station; differences are more evident for T_{max} then for $T_{min.}$
The coherence between T_{max} and T_{min} varies in relation to the considered station (T_{min} and T_{max} present similar trends for 3 stations out of 5)

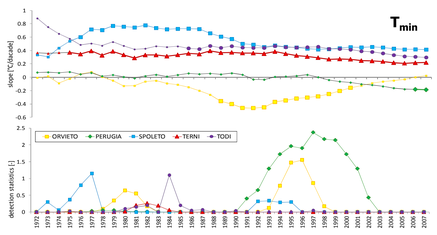

Fig 7. Behavior of slope and detection algorithm for T_{min}.

Discussion and conclusions

- The climatic signal detected over the Umbria Region in terms of the mean annual daily temperature (T_{max} and T_{min}) appears to be inhomogeneous; differences among the stations are more evident for T_{max} then for $T_{min.}$ Trends are not constant along the whole period, neither for T_{min} nor for T_{max}; indeed, the adopted algorithm individuates significant break points.
- A positive trend can be detected for both T_{max} and T_{min} along the whole period for 3 stations out of 5; it spans in the range 0.21÷0.41 °C/decade, which is comparable to previous literature findings both at the Italian (Brunetti et al. 2006; Toreti and Desiato 2010) and regional scales (Bartolini et al. 2008; Ceccarelli et al. 2008; Vergni and Todisco 2011).
- Accordingly, extreme events analysis has revealed a significant increase of the number and duration of heat waves and of mean and extreme temperatures for cold waves, moving from the first (1952-1980) to the second half (1981-2008) of the considered period.
- Anthropic factors could influence very much the variations of temperatures in the last 60 years and preventing from using such data, like they are, as climatic indicators.

Heat and cold waves analysis

- Occurrence and maximum duration of heat waves increase with time, while decrease for cold waves (Fig 8 and 9, respectively).
- The mean and extreme intensities of heat waves remain almost constant, while a significant increase of temperatures can be detected for cold waves (Tab 1 and 2 respectively) .
- The climatic behavior in terms of heat and cold waves is substantially homogenous over the region.
- There is not a full correspondence between the events selected on the base of T_{min} and T_{max} (compare Tab 3 and 1 and Tab 4 and 2).

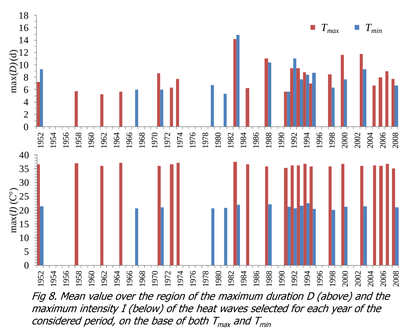

Fig 8. Mean value over the region of the maximum duration D (above) and the maximum intensity I (below) of the heat waves selected for each year of the considered period, on the base of both T_{max} and T_{min}

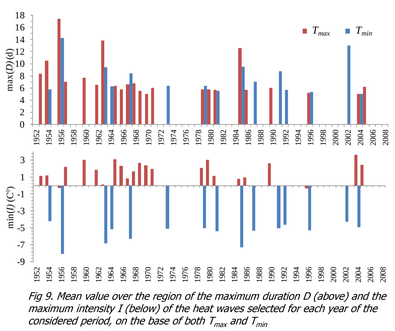

Fig 9. Mean value over the region of the maximum duration D (above) and the maximum intensity I (below) of the heat waves selected for each year of the considered period, on the base of both T_{max} and T_{min}

Table 1. Heat waves results computed on the base of T_{max}

STATION	Number of events N		Mean duration D (d)		Mean extreme intensity I (°C)		Mean intensity I_m (°C)	
	1952-1980	1981-2008	1952-1980	1981-2008	1952-1980	1981-2008	1952-1980	1981-2008
Orvieto	13	20	6.1	7.4	38.7	38.5	37.5	37.0
Perugia	8	29	6.2	8.2	36.1	35.8	34.7	34.5
Spoleto	13	26	6.0	7.5	37.0	37.5	35.7	36.1
Terni	15	12	7.0	8.1	39.6	39.0	38.0	37.8
Todi	8	22	5.7	8.2	37.0	37.0	35.6	35.9

Table 2. Heat waves results computed on the base of T_{min}

STATION	Number of events N		Mean duration D (d)		Mean extreme intensity I (°C)		Mean intensity I_m (°C)	
	1952-1980	1981-2008	1952-1980	1981-2008	1952-1980	1981-2008	1952-1980	1981-2008
Orvieto	5	21	6.4	6.7	21.4	21.9	20.4	20.7
Perugia	15	10	6.3	8.5	23.3	23.1	22.0	22.0
Spoleto	4	20	6.5	6.4	21.0	22.1	20.1	20.6
Terni	1	15	9.0	8.5	23.6	23.9	22.2	22.5
Todi	5	24	6.0	7.4	22.7	21.7	20.1	20.3

Table 3. Cold waves results computed on the ground of T_{min}

STATION	Number of events N		Mean duration D (d)		Mean extreme intensity I (°C)		Mean intensity I_m (°C)	
	1952-1980	1981-2008	1952-1980	1981-2008	1952-1980	1981-2008	1952-1980	1981-2008
Orvieto	11	19	7.0	7.1	-8.0	-6.3	-5.5	-4.7
Perugia	9	14	8.3	7.2	-6.6	-6.3	-4.5	-4.5
Spoleto	15	7	8.0	6.4	-8.5	-7.5	-6.3	-5.3
Terni	15	8	6.2	6.9	-6.3	-5.0	-4.4	-3.7
Todi	12	11	7.2	6.3	-8.1	-7.0	-5.9	-5.5

Table 4. Cold waves results computed on the ground of T_{max}

STATION	Number of events N		Mean duration D (d)		Mean extreme intensity I (°C)		Mean intensity I_m (°C)	
	1952-1980	1981-2008	1952-1980	1981-2008	1952-1980	1981-2008	1952-1980	1981-2008
Orvieto	21	9	7.3	6.1	0.5	-0.5	2.8	2.3
Perugia	26	11	6.6	6.7	-1.2	-1.0	0.8	1.3
Spoleto	21	5	6.9	6.8	-0.6	-1.4	1.5	1.4
Terni	17	6	7.5	6.6	1.0	1.1	3.4	3.5
Todi	15	9	8.3	6.4	-1.0	-0.8	1.2	1.2

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