MedCLIVAR: Mediterranean Climate Variability -
Temperature data homogenization and its impact on heatwave changes in the Eastern Mediterranean

F.G. Kuglitsch (1), A. Toreti (1,5), E. Xoplaki (1,5), P.M. Della-Marta (2), C.S. Zerefos (3), M. Türkes (4), and J. Luterbacher (5)

(1) Institute of Geography and Oeschger Centre for Climate Change Research (OCCR), University of Bern, Switzerland (2) Federal Office for Meteorology and Climatology, MeteoSwiss, Zurich, Switzerland (3) Biomedical Research Foundation, Academy of Athens, Athens, Greece (4) Physical Geography Division, Department of Geography, Canakkale Onsekiz Mart University, Canakkale, Turkey (5) Department of Geography, Climatology, Climate Dynamics and Climate Change, Justus-Liebig University of Giessen, Giessen, Germany

INTRODUCTION:

Extreme temperature events such as the 2003 European summer heat wave have a strong impact on the environment, society and economy (1,2). In order to perform reliable and detailed analysis of extreme temperature events it is important to use long daily, high quality and homogenized temperature series (3). The Mediterranean region is considered as a „Hot Spot" of climate change which will suffer from even more severe and frequent heat waves in the future (4). However, most climate studies are based on non-homogenized data that are not necessarily appropriate for climate analysis and could also lead to inaccurate or even wrong results. To address this problem we (i) developed and applied a new homogenization technique to daily temperature series in the eastern Mediterranean, (ii) proposed a new heat wave definition and (iii) estimated changes in heat waves number, length and intensity.

DATA AND METHODS:

Three independent break detection methods (5-7) to detect an unknown number of break points (BPs) are used in combination with a non linear model (8) to correct daily summer (JJAS) maximum (TX) and minimum temperature (TN) series of 246 stations across the eastern Mediterranean covering the period 1960-2006. Advantages of this method are (i) no metadata is needed for break detection (Fig. 2) and (ii) a correction (Figs. 3-5) of mean DAILY values, variance, skewness and higher order moments is possible. A limiting factor is that the break detection and the correction model need highly correlated (>0.80) reference series. After data homogenization, changes in heat wave number, length and intensity are estimated.

HEAT WAVE ANALYSIS

Heat Waves:

A hot day or night is defined as a day or night when the daily TX or TN exceeds the long-term 95th percentile within a summer (JJAS) season. For each of the 122 summer days, the 95th percentile is calculated from a sample of 15 days (seven days either side of the day) using data from the 1969 to 1998 period (Fig. 1). A **heat wave** is defined as a period of three or more consecutive hot days and nights not interrupted by more than one non hot day or night, respectively. The heat wave number (HWN95), length (HWL95) and intensity (HWI95) is calculated for each summer.

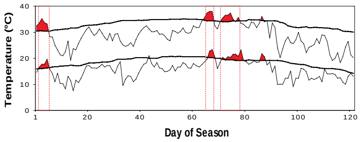


Fig. 1
Schematic overview of heat wave detection. The thick black line (thin dashed black line) indicates the daily (seasonal) 95th percentile and daily values of 2006 (thin black lines) for TX and TN for the station Ankara, Turkey. Red areas characterize hot days and nights. Red dotted frames indicate the three 2006 heat waves.

Heat Wave Intensity: $HWI_{95} = \sum_i max(TX_i - TX_{95,i}, 0) + \sum_i max(TNc_i - TNc_{95,i}, 0)$

During heat waves the local TX exceedances (i.e., degree days in °C) are computed. Since TX and TN are highly correlated we replace TN with TN conditional (TNc) on TX (TNc = TN|TX) and sum the TX exceedances with TNc exceedances. The new variable TNc is derived estimating the relationship between TN and TX, i.e., TN = f(TX) + e.

DATA HOMOGENIZATION

Break Detection:

We apply the methods of (5-7) to the mean annual TX/TN difference series of the candidate and its 10 highest correlated reference series. The correlation is calculated for the common period 1969-1998. Years of break points are assumed to be valid when (i) three or more shifts (Fig. 2, red dots) are detected amongst all difference series within two consecutive years and (ii) the detected year is confirmed by at least one other method.

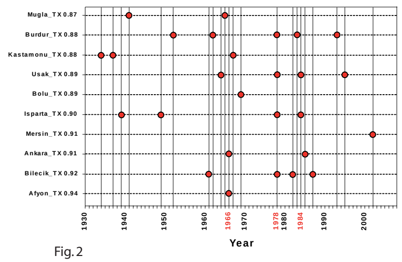


Fig. 2
The result of pairwise comparisons with 10 highest correlated neighbouring stations for Kutahya, TR, Tmax.

Break Correction:

The correction model uses the highest correlated reference series for adjusting the candidate series. The reference must not show any break points in the same year as the candidate or 3 years before/after, respectively. The period between two break points is assumed to be homogeneous (HSP) (Fig. 3).

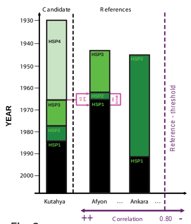


Fig. 3
Assumptions for applying the correction model.

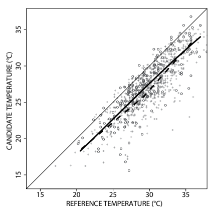


Fig. 4
The relationship between Kutahya and the reference station Ankara before (solid black line) and after the first break (dashed black line) for July.

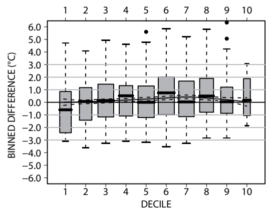
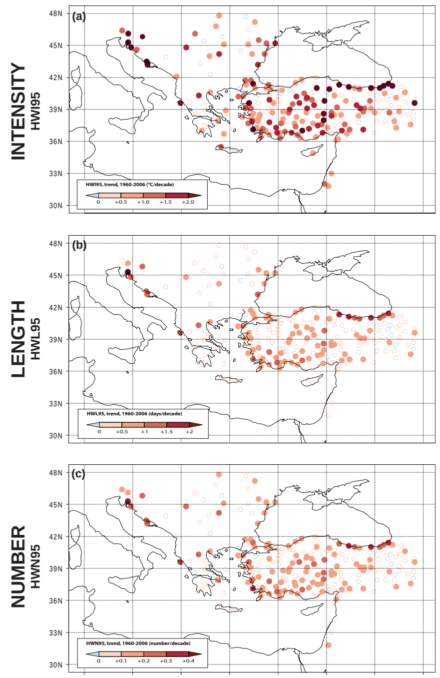


Fig. 5
The smoothed adjustments (°C) to Kutahya for each decile to HSP2 for July.

The relationship between the candidate and the reference is modelled before and after the first break point (Fig. 4). This procedure is repeated for each break point and each month.
The temperature of HSP2 is predicted using observations from the reference station. The differences between the predicted temperature and the temperature in HSP2 are binned into deciles and applied for HSP2 (Fig. 5).

RESULTS:

Daily TX and TN series of 246 stations across the eastern Mediterranean are homogenized and used for estimating heat wave changes between 1960 and 2006 (c.f., also 9). 61% and 74% of the TX and TN time series are affected by artificial non climatic break points caused by site displacements, new instrumentation or land-use changes. Daily temperature homogeneity analyses suggest that many instrumental measurements in the 1960s are warm-biased. Correcting for these biases regionally averaged temperature and heat wave trends are up to 8% higher (9). During the 1960s many screens were changed in terms of type, size and ventilation, the latter latter making measured temperatures closer to the ambient temperature (10). The hot summer daytime and nighttime temperatures (95th percentile of TX and TN) have increased by +0.38 ± 0.04°C/decade and +0.30 ± 0.02°C/decade, respectively since the 1960s. While the TX increase is highest in continental areas, the maximum increase of TN is generally found in coastal areas (not shown) (9).



„Hot spots" of heat wave changes are identified across the western Balkans, southwestern and western Turkey, and along the southern Black Sea coastline (Figs. 6a-c). There, the trends of heat wave intensity, number and length exceed +2.0°C, +0.4 and +2.0 days/decade, respectively (9).
Since the 1960s, the mean heat wave intensity, heat wave length and heat wave number across the eastern Mediterranean have increased by a factor of 7.6 ± 1.3, 7.5 ± 1.3 and 6.2 ± 1.1, respectively (not shown). Fig. 7 presents the changes of trends in heat wave number (HWN95) before and after homogenization. Fig. 8 demonstrates, based on the raw and homogenized data, the changes in (a) mean summer TX and (b) TN before and after data homogenization. Between 1960 and 1980, TX and TN of the homogenized temperature series decreased by -0.12 and -0.27°C/decade (RAW data: TX: -0.19°C/decade, TN: -0.30°C/decade). Between 1980 and 2006, TX and TN increased significantly by +0.67 and +0.48°C (RAW data: TX: +0.61°C/decade, TN: +0.43°C/decade)

Fig. 6
Linear trends of (a) HWI95 (°C/decade), (b) HWL95 (days/decade) and (c) HWN95 (number/decade) from 1960 to 2006 using the OLS method. Red- (blue-) colored dots indicate significant positive (negative) linear trends at the 5% significance level (Mann-Kendall test). Open circles characterize non-significant trends.

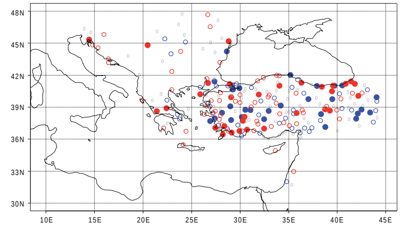


Fig. 7
Differences in linear trends of HWN95 (homogenized data minus non-homogenized data) from 1960 to 2006 using the OLS method. Red- (blue-) colored dots indicate a significant increase (decrease) of HWN95 trends at the 5% significance level (Mann-Kendall test) after the data homogenization. Red- (blue-) colored open circles characterize non-significant positive (negative) trends. Grey colored open circles indicate stations with no change in trend.

CONCLUSION & OUTLOOK:

A new heat wave definition for estimating heat wave number, duration and intensity is proposed and applied to homogenized daily TX and TN series. The Mediterranean climate is becoming more extreme than previously thought when analyzing raw data, underlining the importance of homogenizing climate data for extreme event analysis. Since the 1960s, a significant increase in heat wave number, length and intensity has been detected in most parts of the eastern Mediterranean. The changes are largest across the West Balkan and smallest along the Turkish Mediterranean coastline. The estimated increase in TX is generally higher than in TN. Further research of heat wave impacts on human health, livestock, ecosystem vitality, agricultural production, or water supply is needed.

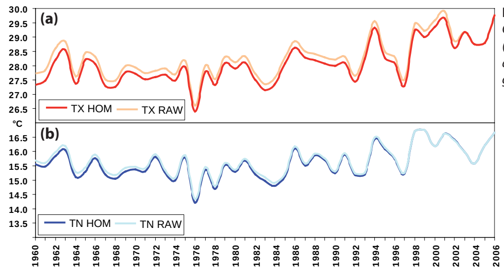


Fig. 8
Changes in (a) mean summer TX and (b) TN before (light blue and light red line) and after (red and blue line) data homogenization in the eastern Mediterranean.

ACKNOWLEDGEMENTS:

This work is supported by the EU IP CIRCE (Climate Change and Impact Research: The Mediterranean Environment). We appreciate the strong collaboration with all our partners from the National Meteorological and Hydrological Services, the WMO/MEDARE (Mediterranean Data Rescue) community and the ECA&D (European Climate Assessment & Dataset, KNMI).

REFERENCES:

(1) R.S. Kovats and C. Koppe, *Taylor &Francis*, 136-160 (2005)
(2) M. Poumadere et al., *Risk Anal.* **25**, 1483-1494 (2005)
(3) F.G. Kuglitsch et al., *J. Geophys. Res.* **144**, D15108 (2009)
(4) F. Giorgi, *Geophys. Res. Lett.* **33**, L08707 (2006)
(5) X.L. Wang, *J. Climate* **16**, 3383-3385 (2003)
(6) H. Caussinus and O. Mestre, *J. Roy. Stat. Soc. C-App.* **53**, 405-425 (2004)
(7) A. Toreti et al., *J. Appl. Meteorol. Climatol.* (2011), in press
(8) A. Toreti et al., *J. Clim.* **23**, 5325-5331 (2010)
(9) F. G. Kuglitsch et al., *Geophys. Res. Lett.* **37**, L04802 (2010)
(10) E. Aguilar et al., *WMO-TD* **1186**, (2003)