Observations-Based Analysis of Moscow Heat Spells

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Problem

The Russian summer heat wave of 2010 was one of the strongest among recently observed heat waves. A strong blocking anticyclone developed over European Russia in the third decade of June 2010 and persisted for almost two months until mid August.

Recent studies suggest that under global warming scenarios temperature extremes will be more frequent, longer-lasting and more severe compared to current conditions. So, an improved understanding of the physical mechanisms, which produce regional high temperature extremes, could enhance our capability in predicting regional climate anomalies during the warm season and could focus adaptation strategies.

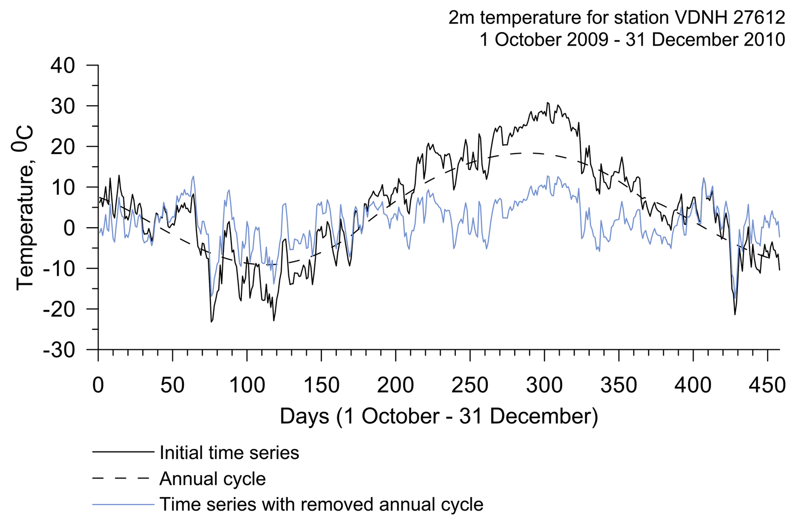
Data

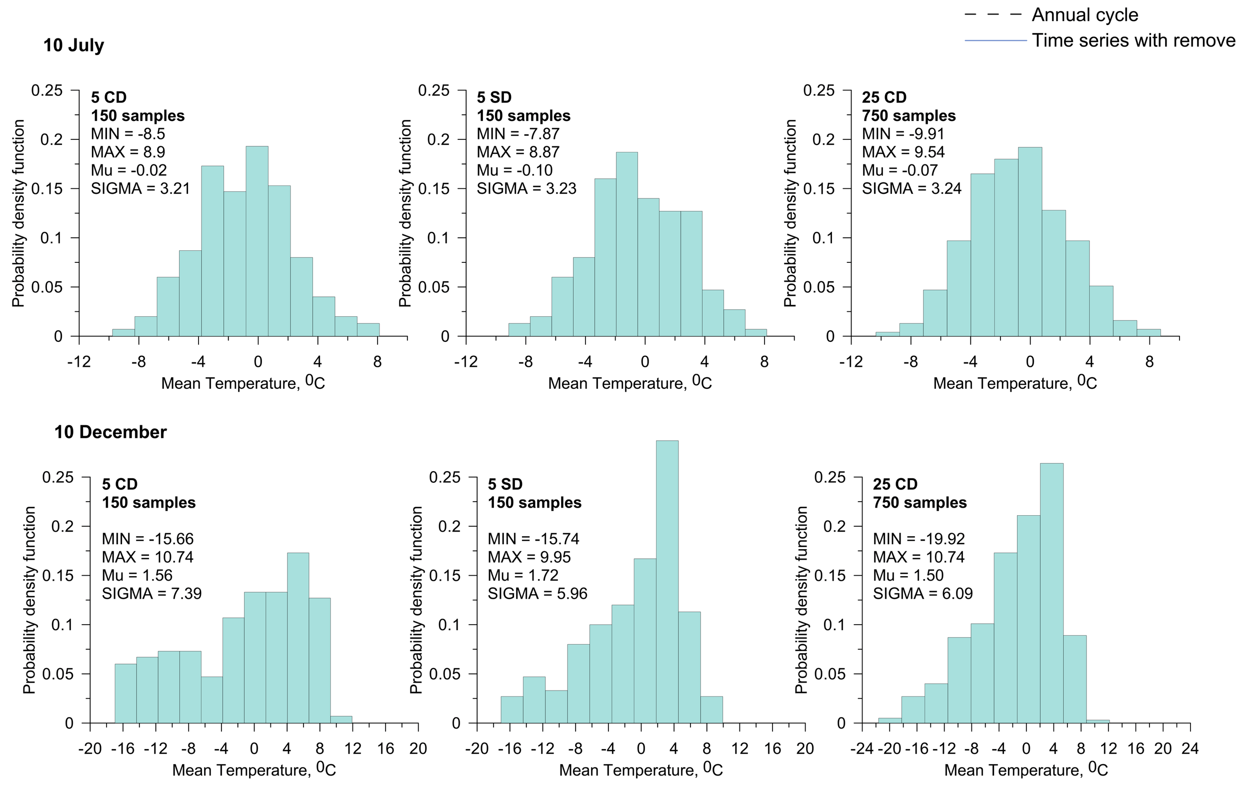
Observational daily air temperature data at 2m level (AT) (*Razuvaev et al., 1993*)
Moscow VDNH station (WMO code 27612) 64 summers for the period 1949-2012

Method

AT anomalies into percentiles

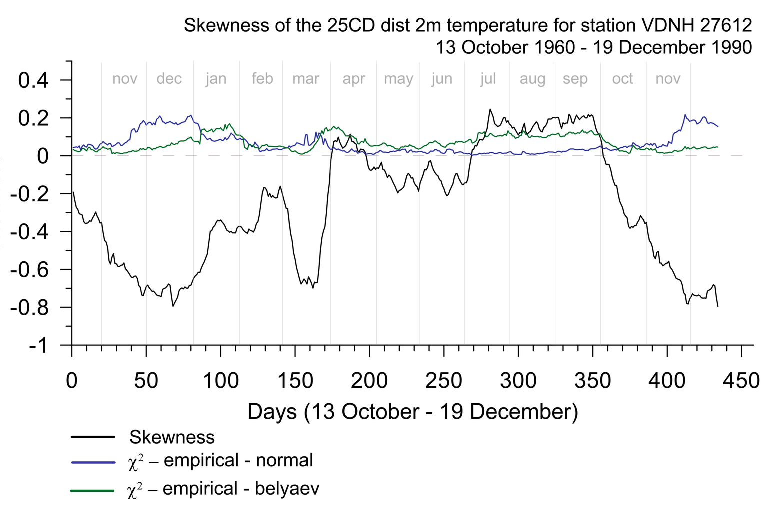
- Daily AT anomalies - removing annual cycle approximated by a polynomial of the fourth degree (estimated for 1961-1990)
- Construct empirical occurrence histograms (EOH)
- Fit EOH with an analytical PDF
- Using special CDF (based on the sample mean and sigma) converted AT anomalies into percentiles.



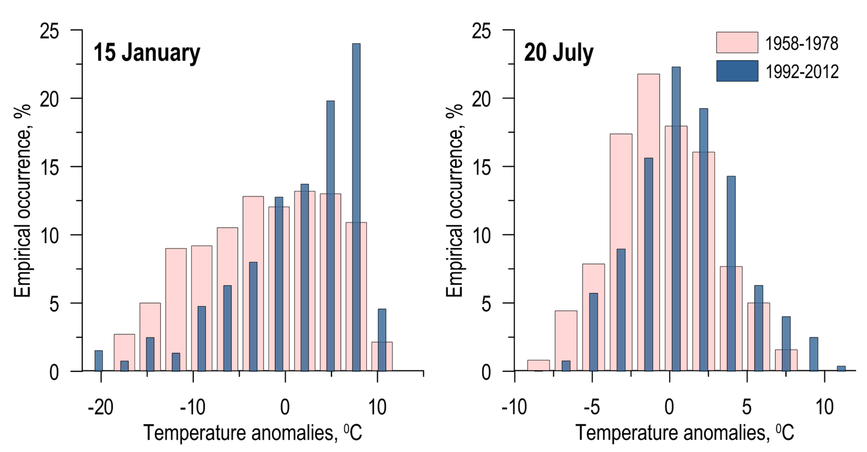


To improve the stability of the probability distribution parameters 25CD subsampling type were used. For example, to construct EOH for June 1 AT anomalies data from May 20 to June 13 for 1961-1990 were taken. Thus, to construct EOH for each day we have 25x30=750 sample size.

It appeared that in the domain of analysis EOHs for summer daily AT anomalies are best fitted (with probability exceeding 99% according to Pierson criteria) by the Gaussian (normal) distribution. But for November and December temperature anomalies asimmetric distribution is more appropriate.

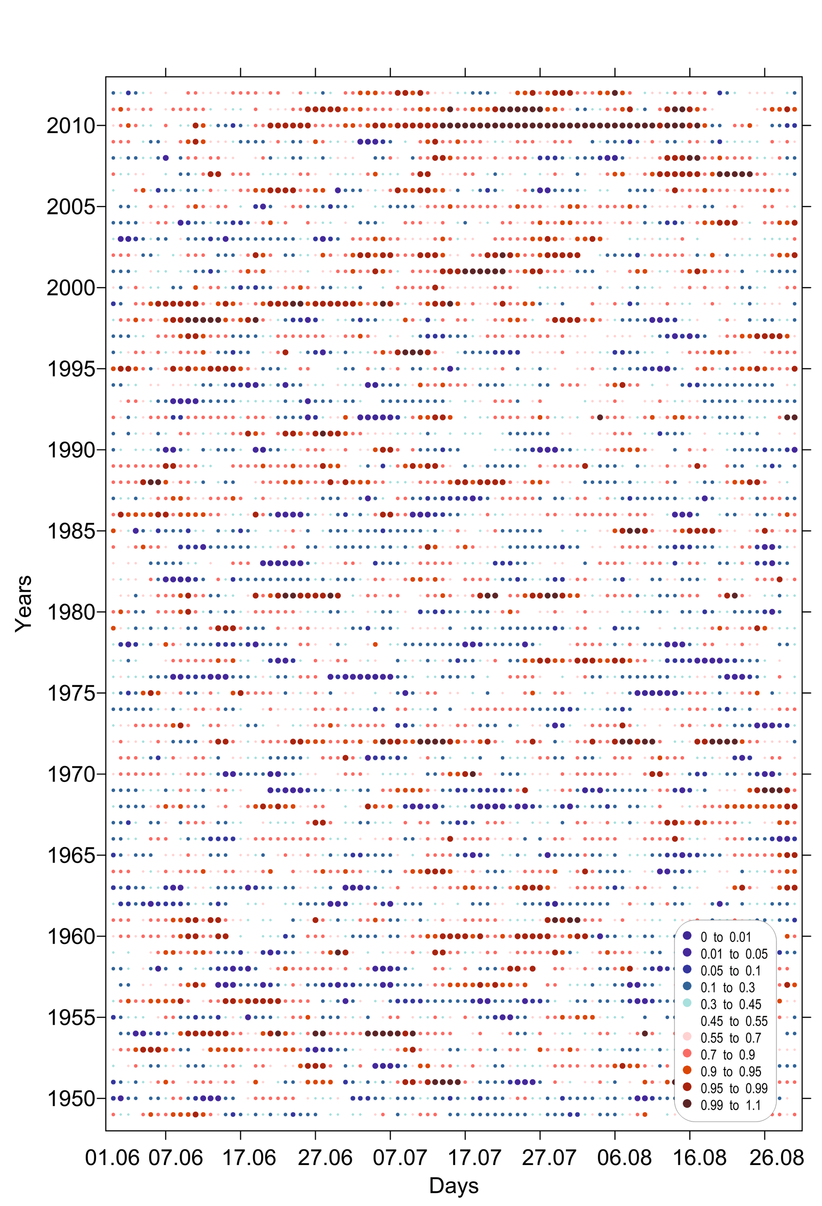


Method discussion

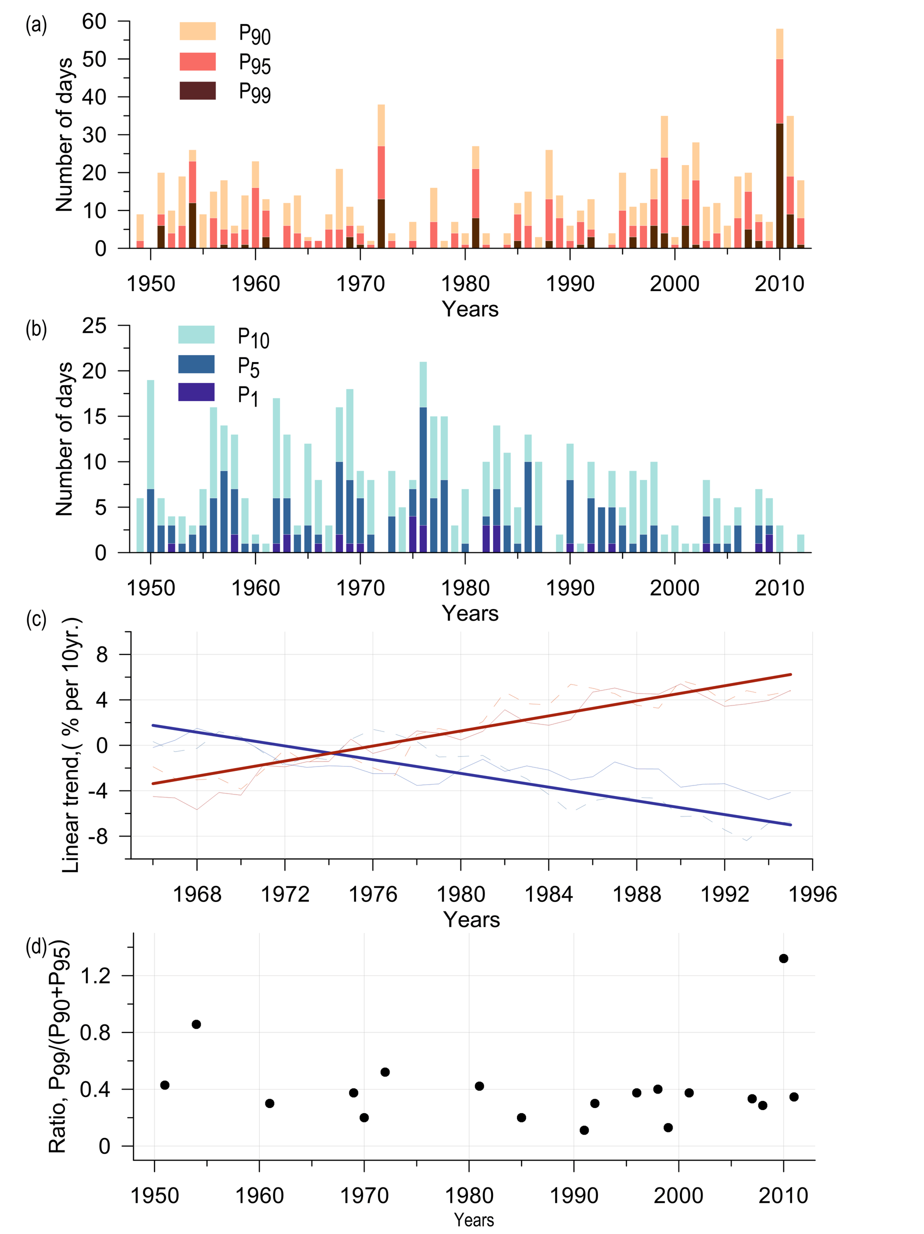


For the summer season there is a positive trend of the mean values of PDFs. The most prominent trend is observed for the period mid July – mid August. The probability of the positive anomalies is growing in the mid-late-summer. STDs are quite stable demonstrating small year-to-year variability during 1949-2012. According to Katz and Brown (1992) the probability of the extreme events is more sensitive to the changes in standard deviation then to the changes in mean. Therefore, the usage of the base period 1961-1990 in the present study seems quite reasonable.

Total number of days (hot/ cold)



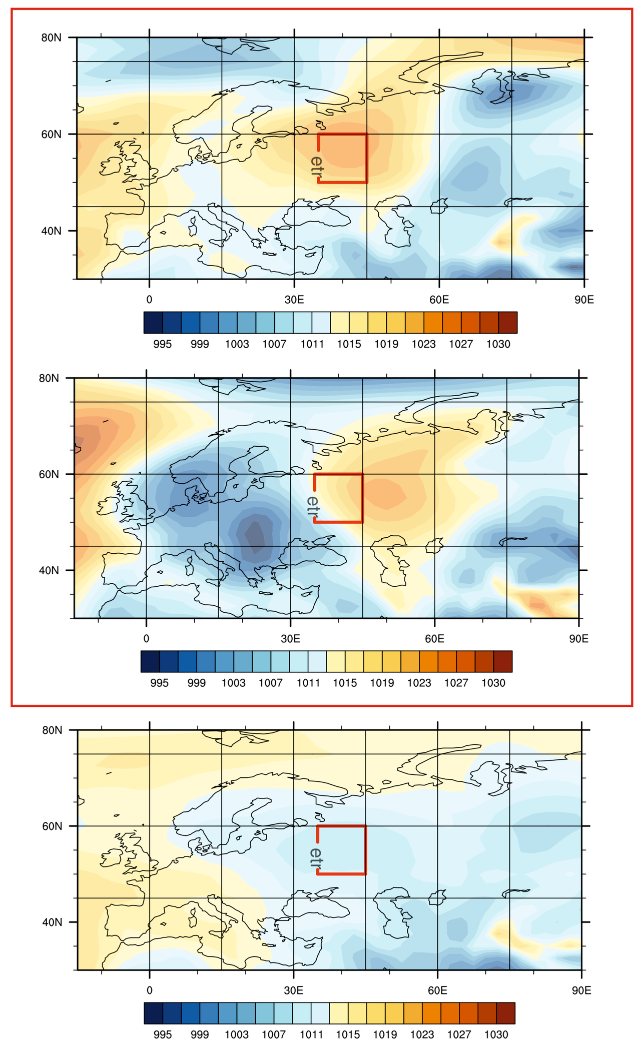
Starting from early 1970s here is the evident increase of the number of extremely hot days over Moscow. Changes in the sign of trends that occurred in the 1970s are well seen. During the same climate periods opposite tendencies are revealed for the extremely cold days.



Total number of days (JJA) with positive (a) and negative (b) AT anomalies. Time series of linear trends of the hot and cold days number estimated for the 35-yr running window with 1 year lag (c). Ratios between number of extremely hot days (i.e., with AT anomalies exceeding 99th percentile threshold) and number of moderately hot days (i.e., with AT anomalies exceeding 90th and 95th percentiles

We constructed a calendar of temperature anomalies (expressed in percentile) over Moscow. Looking at this calendar potential users may easily detect when the heat waves (or "cold" waves) occurred and assess their duration, evolution and intensity.

Typical sea level pressure patterns associated with heat waves over Moscow Region



- SLP pattern represents a high pressure system (blocking) located exactly over Moscow. Such pattern generally implies enhanced local heating associated with increased solar radiation income caused by reduced cloudiness typical for anti-cyclone conditions. This pattern is consistent with so-called "Russian cluster" described in Stefanon et al. (2012).
- The blocking anticyclone is shifted eastward resulting in southeasterly winds which bring hot and dry air from Central Asia into the region of interest. Therefore, associated with this SLP pattern heat wave had mostly advective origin.
- The pattern represents a low pressure (cyclonic) system located over the region of our study, implying advection of warm air from the Mediterranean region caused by southwesterly winds. Structurally this pattern resembles the "Iberian cluster" described in Stefanon et al. (2012). Generally, the heat waves over European Russia associated with such SLP patterns are characterized by the relatively short duration.

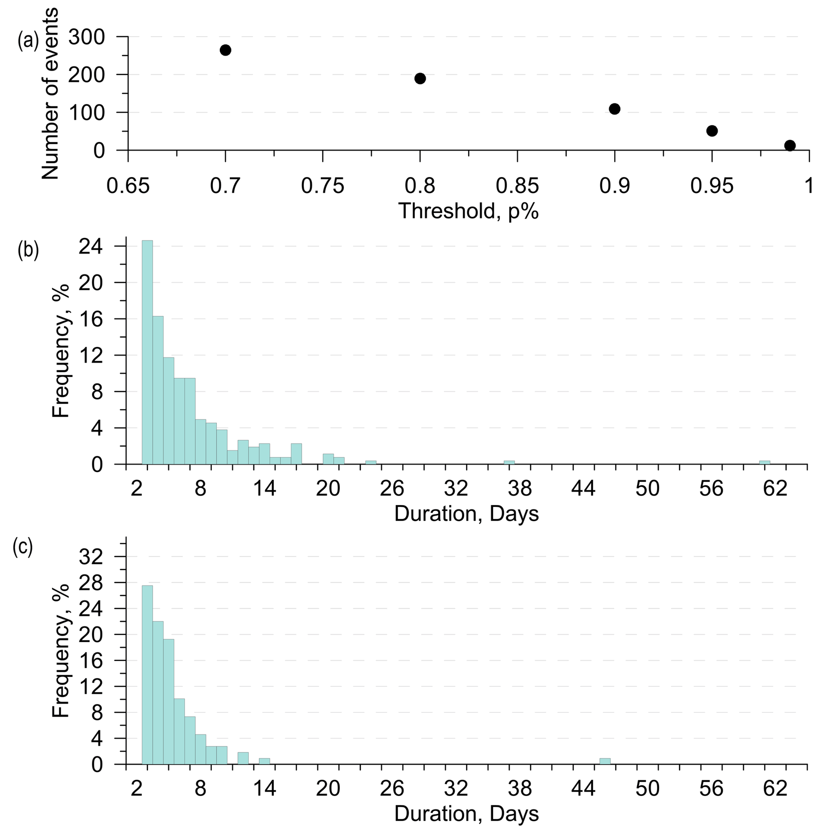
References

Razuvayev V.N., Apasova E.G., Martuganov R.A., Steurer P., Vose R., 1993. Daily Temperature and Precipitation Data for 223 U.S.S.R. Stations. ORNL/CDIAC, Numerical data package – 040, Oak Ridge National laboratory, Oak Ridge, Tennessee, USA

Stefanon M, D'Andrea F, Drobinski P. 2012. Heat wave classification over Europe and the Mediterranean region. Environ Res Lett 7, DOI: 10.1088/1748-9326/7/1/014023.

Katz RW, Brown BG. 1992. Extreme events in a changing climate: variability is more important than averages. Climatic change 21(3): 289-302.

Duration of the heat spells

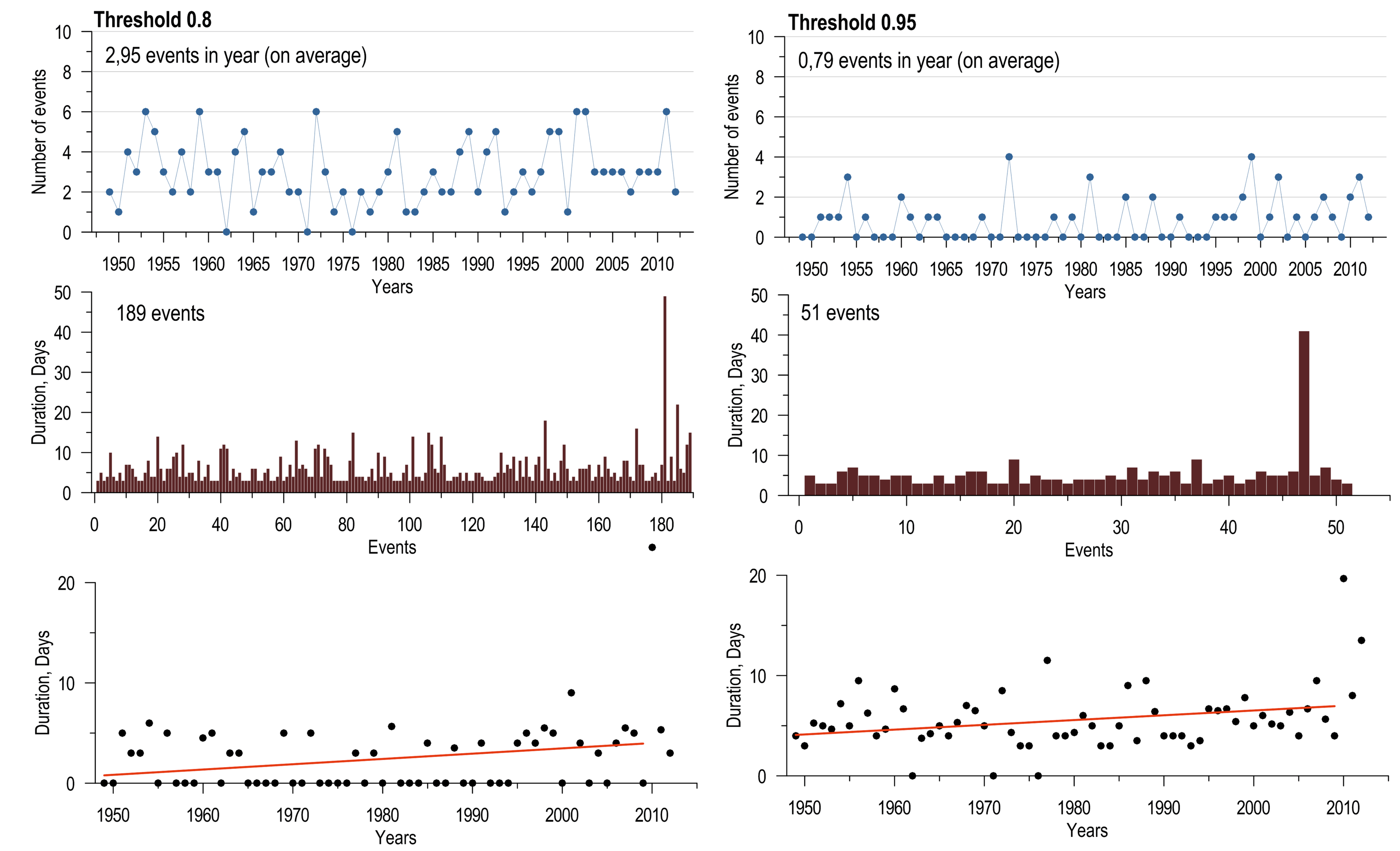


Number of events meeting certain thresholds (a). Empirical occurrence histograms of duration of the extreme events with AT anomalies exceeding thresholds 70th (b) and 90th (c) percentiles.

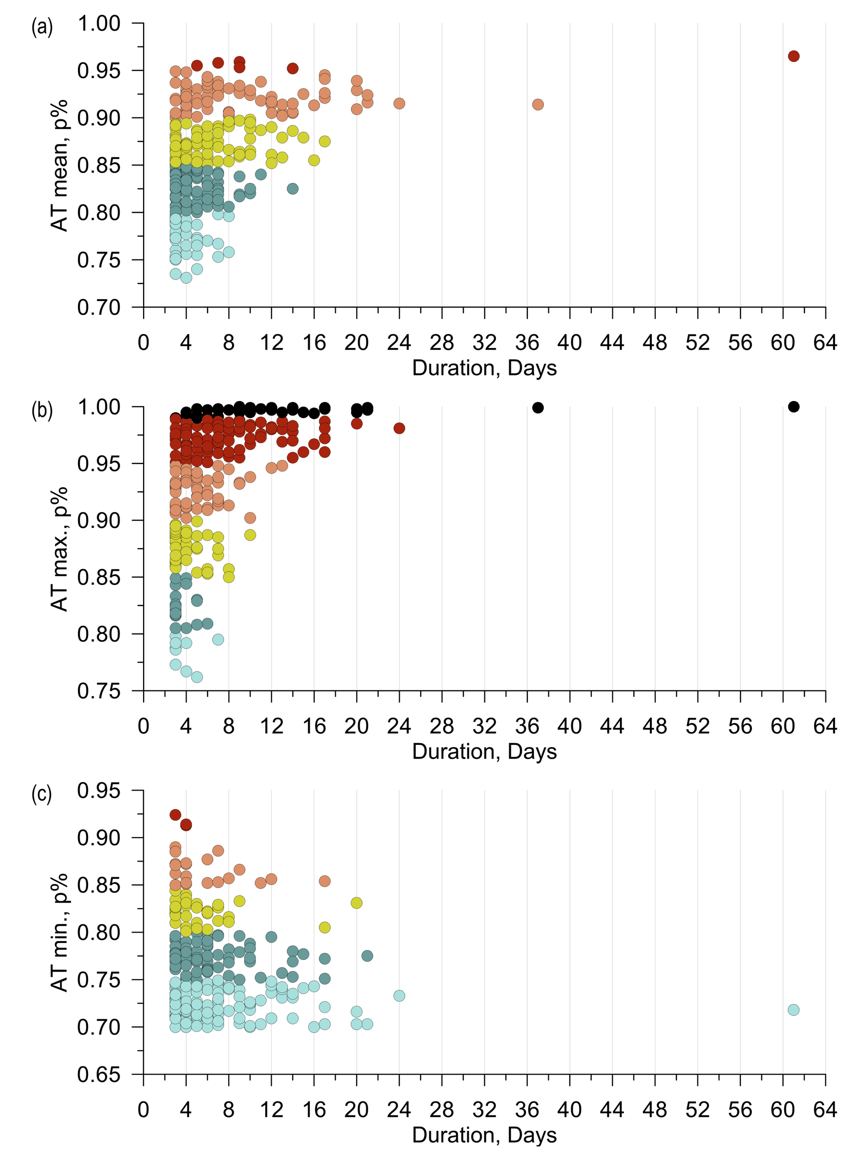
We consider particular event as a heat spell when the AT anomalies exceed established threshold during at least 3 consecutive days.

There are 264 events meeting the 70th percentile threshold, 109 events for the 90th percentile threshold and 12 events meeting the 99th percentile threshold (i.e., the hottest conditions).

EOHs of duration of the extreme events with different thresholds. In general, we observe almost linear decrease of the number of events with the growth of the threshold. The EOH of duration of the extreme events meeting the threshold 70th percentile. The graph shows an exponential decrease in the amount of events with the increase of their duration.



Intensity of the heat spell in dependence of duration



. Mean (a), maximum (b) and minimum (c) AT anomalies (in percentiles) of events (with daily AT anomalies exceeding threshold 70th percentile) in dependence of their duration.

Figure shows events (meeting threshold 70th percentile) characteristics (namely, mean, maximum and minimum of the AT anomalies for each event expressed in terms of percentiles) in dependence of the event duration. An evident tendency for the mean AT is that for the longer-lasting events we observe large AT anomalies (i.e., more extreme conditions). A similar tendency can be seen for the maximum AT anomalies of events (Figure b). For the minimum AT anomalies of events the tendency is generally opposite. It is worth noting that the largest values of the minimum AT anomalies are revealed for the very short (3-4 days duration) events, thus implying very fast development of the anomaly (and its fast decay) associated with regional atmospheric dynamics.

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