Subseasonal temperature trends in Europe (1961-2000) and their links to atmospheric circulation

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1. Motivation

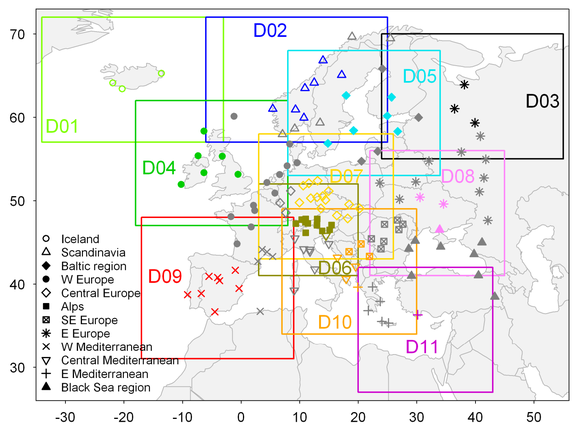
➢ Recent global warming has not been ubiquitous – there might be seasons, regions, and time periods with clearly discernible zero or downward air temperature trends. Regions that are not warming or are even cooling – also known as "warming holes" (*Pan et al. 2004*) – were previously detected mainly in autumn in the second half of the 20th century in large parts of North America as well as in Central and Eastern Europe.

➢ In this study we use daily maximum and minimum temperature (TX and TN) and daily temperature range (DTR) at 136 stations in Europe and the Mediterranean in the period 1961–2000 to precisely locate their seasonal and sub-seasonal trends in space and within the course of the year, and to assess the effect of atmospheric circulation changes on these observed trends.

2. Data and methods

➢ We use daily data of TX, TN, and DTR from 136 stations from the ECA&D database (*Klein Tank et al. 2002*) in the period 1961–2000.

Figure 1: Map of stations and spatial domains of atmospheric circulation. Colored stations are located near the centers of the domains, and were used for comparison with circulation changes.



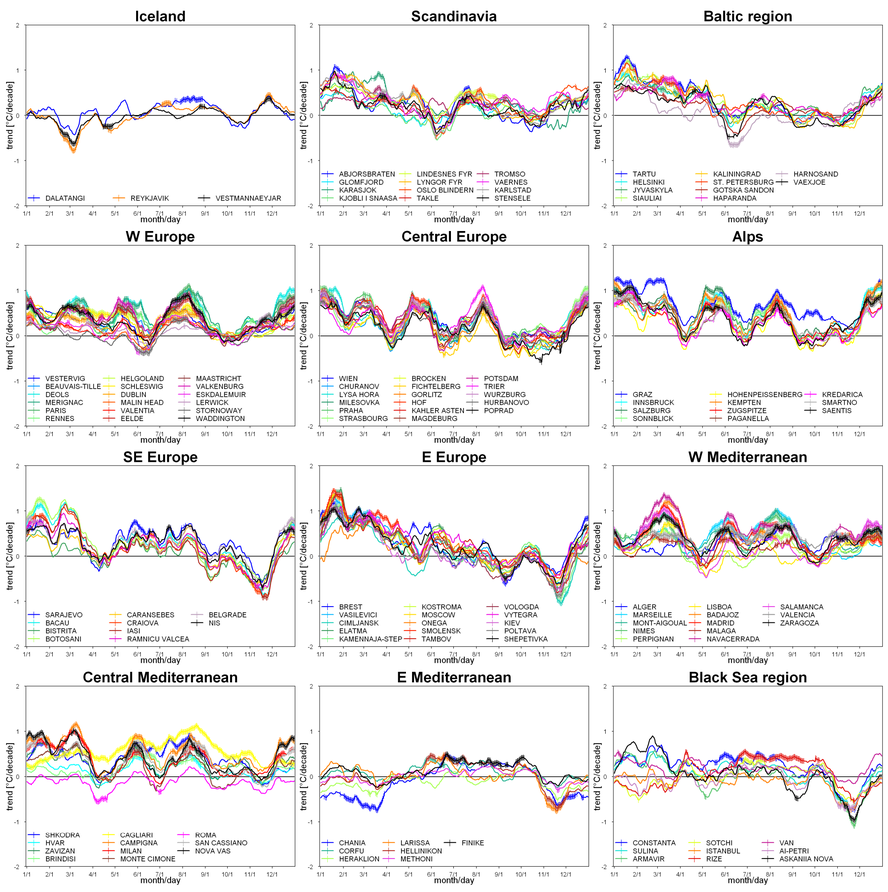
➢ Linear trends of TX, TN, and DTR were estimated for annual averages of subseasons of length 10, 20, 30, 60, and 90 days, moving with a step of one day. Thus we obtain 365 values of "moving trends" for each station and each variant of subseason length. Trends significant at the 95% level according to Mann-Kendall trend test were further studied.

➢ One classification of atmospheric circulation from the COST733cat database was used to study changes in atmospheric circulation (SANDRA – optimized cluster analysis, see *Philipp et al. 2010*). We used several variants of this classification: the number of classifed circulation types was set to 9, 18, and 27; and the input variables were sea-level pressure (SP), 500 hPa geopotential height (Z5), vorticity at 500 hPa level (Y5), and thickness between 850 hPa and 500 hPa levels (K5).

➢ The influence of changes in the frequency of circulation types on subseasonal trends of TX, TN, and DTR was studied using a simple decomposition method (e.g. *Huth 2001*). For each *x*-day period, we substitute each day's climatic element by the element's long-term mean in that *x*-day period under the circulation type that is present on that day. We then estimate a linear trend of this "reconstructed" time series, and divide it by the observed climatic trend. A ratio close to 1 suggests that circulation changes are the only cause of the observed climatic trends, while values close to 0 show that circulation changes do not influence the observed trends at all.

3. Results

Fig. 2: Trends of 30-day subseasons of TX at individual stations from regions denoted by different symbols in Fig. 1. Trends significant at the 95% level are highlighted by vertical bars. Winter warming is even more pronounced in case of TN in Northern and Eastern Europe.



➢ Trends of TN exhibit lower regional variability in spring and summer compared to TX, and higher variability in autumn and winter. Insignificant cooling takes place at a few stations any time of the year. In autumn, cooling affects more than half of the stations.

➢ Trends of DTR are spatially and temporally heterogeneous; both positive and negative trends occur and no general pattern is found.

➢ Changes in the frequency of circulation types usually explain a substantial part of the observed temperature trends. The ratio of circulation-induced and observed trends varies among regions and seasons: the highest ratio is found over the British Isles in winter, and the lowest in central and eastern Mediterranean all year round. Temperature trends in Central Europe and the Alpine region are fairly well connected to circulation changes, with explained ratio around 0.5.

➢ The rate of influence of circulation changes on climatic trends depends on the input variables used for classification of circulation types, as well as on the number of circulation types. The greatest influence is usually achieved by a classification with 27 types, using a combination of all input variables (SP-Z5-Y5-K5).

Fig. 3: Ratio of circulation-induced and observed trends showing the effect of input variables and number of circulation types.

(Example for TX, 30-day subseasons, SANDRA classification, mean of all days when the observed trend is significant, mean of 69 stations located near centers of the spatial domains used for classification.)

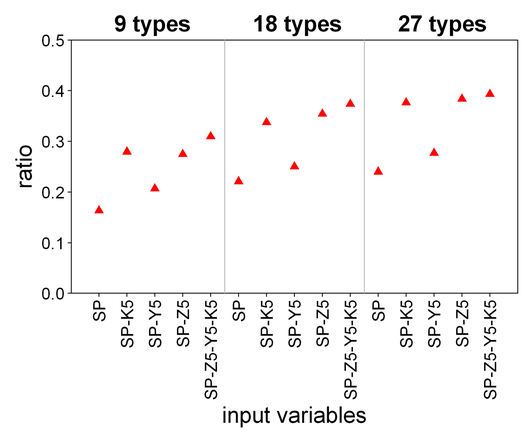
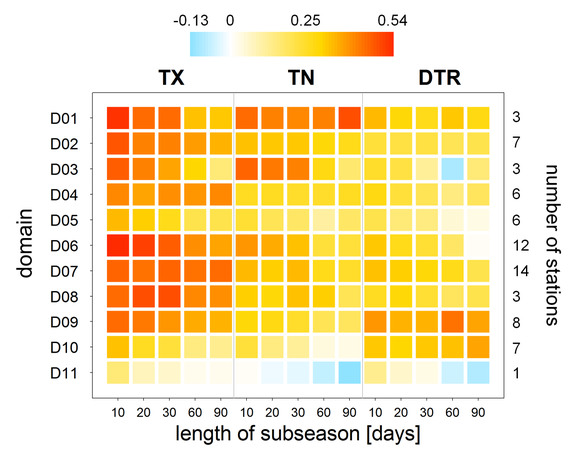


Fig. 4: The influence of circulation changes on climatic trends decreases with increasing subseason length. (Example for SANDRA classification using a combination of SP-Z5-Y5-K5 as input data, mean of all subseasons when the observed trend is significant.)



4. Conclusions

➢ Linear trends of daily maximum and minimum temperature and daily temperature range in the period 1961–2000 were estimated for moving "subseasons" of differing lengths (10, 20, 30, 60, and 90 days), each shifted by one day. The day-to-day variability of these "moving trends" is greatest for short subseasons of 10 and 20 days.

➢ The annual course of "moving trends" shows relatively well-defined regions with similar trend behavior. Over most of Europe, the observed warming is greatest in winter, and the highest trend magnitudes are reached by TN in Eastern Europe. Two regions stand out: in Iceland and the Mediterranean, winter shows almost no trends, while in summer we see a pronounced warming.

➢ Significant autumn cooling centered on mid-November was found in Eastern and Southeastern Europe for both TX and TN; in many other regions trends are close to zero in the same period. Other clearly non-warming (or even cooling) periods occur in Western and Central Europe in February, April, and late June.

➢ Trends of DTR are largely inconclusive and no general picture can be drawn.

➢ To assess the influence of circulation changes on temperature and DTR trends, we use one classification of daily circulation types from the COST733cat collection, computed over 11 European domains. The classification comes in 15 variants, using 5 combinations of input variables and 3 fixed numbers of types. Circulation changes usually explain a substantial part of the observed climatic trends. The rate of influence depends not only on the geographical location of stations and time of year, but also on the definition of circulation types (i.e. their number and input variables used for classification).

➢ Our results suggest that using different time scales apart from the conventional three-month seasons is highly desirable for a proper location of trends within the course of the year.

Acknowledgements

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