



A probabilistic approach to attribute warming to changes in atmospheric circulation

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Europe has been warming over the past decades, especially in southern Europe in summer and northern Europe in winter. To understand the causes of regional warming, it is common to separate the temperature change signal into changes in atmospheric circulation (or dynamic causes) and other factors, so-called within-type changes (or thermodynamic causes). For example, increasing temperatures due to greenhouse gases may alter the position and strength of the polar jet stream, thus causing a change in the atmospheric circulation signal. On the other hand, warming may be entirely independent of circulation, occurring as a general increase in surface temperature. With the aim to detect regions and time of the year in Europe in which recent warming can either be explained by changes in atmospheric circulation or by within-type changes, we suggest a novel probabilistic approach to calculate the circulation-induced trend, the part of the temperature trend that is induced by changes in atmospheric circulation. Through the use of resampling, in combination with a Monte Carlo test, we assessed the likelihood that the observed temperature trend can be explained entirely by changes in atmospheric circulation frequency. The temperature data originate from the gridded 0.5° Watch Forcing Data Era-Interim (WFDEI), and cover the period 1981–2010. The SynopVis Grosswetterlagen catalogue of circulation types was used to detect circulation-induced trends in the same time period. We analysed trends on the monthly time scale to reveal short-term responses, such as those related to snow or greening. The most wide-spread observed warming was found in summer, with up to 60% of the European land area experiencing a significant warming trend during August, most notable in eastern and northern Europe. In spring and autumn, the percent area with significant temperature increases reduced to 10–30%. In December and January, only 5% of the land area experienced significant warming, most pronounced in northern Scandinavia. The probabilistic approach revealed that changes in atmospheric circulation could not account for all the observed warming. Regions where the observed trend likely can be explained entirely by changes in atmospheric circulation include western Europe in May, eastern Europe in August and Scandinavia in September. In most of the regions and months experiencing significant trends, however, warming must be caused by other factors as well; such within-type changes potentially driven by feedbacks between the land surface and atmosphere. For two cases where the magnitude of the temperature trend was strongest, northern Scandinavia in December and in the Black Sea region in November, circulation types warmed over time. This confirms the role of within-type change, i.e., that circulation types changed their properties over time. This study provides an important contribution toward improved understanding of the causes of synoptic-scale temperature change in Europe, more specifically, the relative role of circulation-induced changes and within-type changes.