Geophysical Research Abstracts
Vol. 15, EGU2013-7338, 2013
EGU General Assembly 2013

Changes in temperature records and extremes: Are they statistically significant?

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We investigate whether the increasing number of warm records and extreme warm values in the extra-tropical northern hemisphere over the last decades are statistically significant. For the extremes we focus on summer mean temperature and for warm records we focus on daily and monthly means. The statistical significance is a highly non-trivial problem because the atmosphere is both spatially and temporally strongly autocorrelated and the records and extremes will therefore have a tendency to appear clustered in both space and time. To deal with this we apply a numerical method to produce a surrogate ensemble of fields that are statistically similar to the observed temperature field except that the surrogates are stationary and do not include the observed secular variations. The significance is then estimated by comparing the annual or seasonal number of records or extremes in the observations to the similar numbers in the surrogates.

We find that the number of warm daily and monthly records as well as the extreme summer mean temperatures have the same general temporal development with a slow decrease from the late 1940s (the beginning of the reanalysis data set used here) to a minimum in the 1970s followed by an increase to the present high values. However, there is a strong difference in the statistical significance of the different quantities. We find with very strong statistical significance that the recent large number of warm daily records as well as the number of summers with extreme mean temperatures cannot be explained as chance occurrences. Both these quantities show a number of recent consecutive years (11 and 10) with values above the 95 % level that is much larger than any similar number found in the ensemble of 1000 surrogates. We do not find any significant change in the number of monthly warm records. The statistical significance weakens when considering the individual seasons or smaller regions like Europe. But for the annual number of daily warm records we still find a significant increase in Europe and for the extra-tropical northern hemisphere a significant increase in all seasons except spring.