Supplemental Material

Supporting Information for Trends in Winter Warm Spells in the Central England Temperature Record

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1 year aggregates,Daily Maxima:DJF

Figure S1. *
The daily maxima of the full Central England Temperature timeseries (CET) from 1878-2019 during winter (DJF) are shown as a time-variation in distribution. The (a) cdf and (b) pdf are formed from each single consecutive winter season (DJF). A cdf and pdf are then plotted for each year. The cdf and pdf values are indicated as colour and are plotted versus temperature (ordinate) and time (abscissa). The legend on the right hand side of each panel indicate values of the (a) cdf and (b) pdf respectively. In panel (b) the white line indicates the mean.
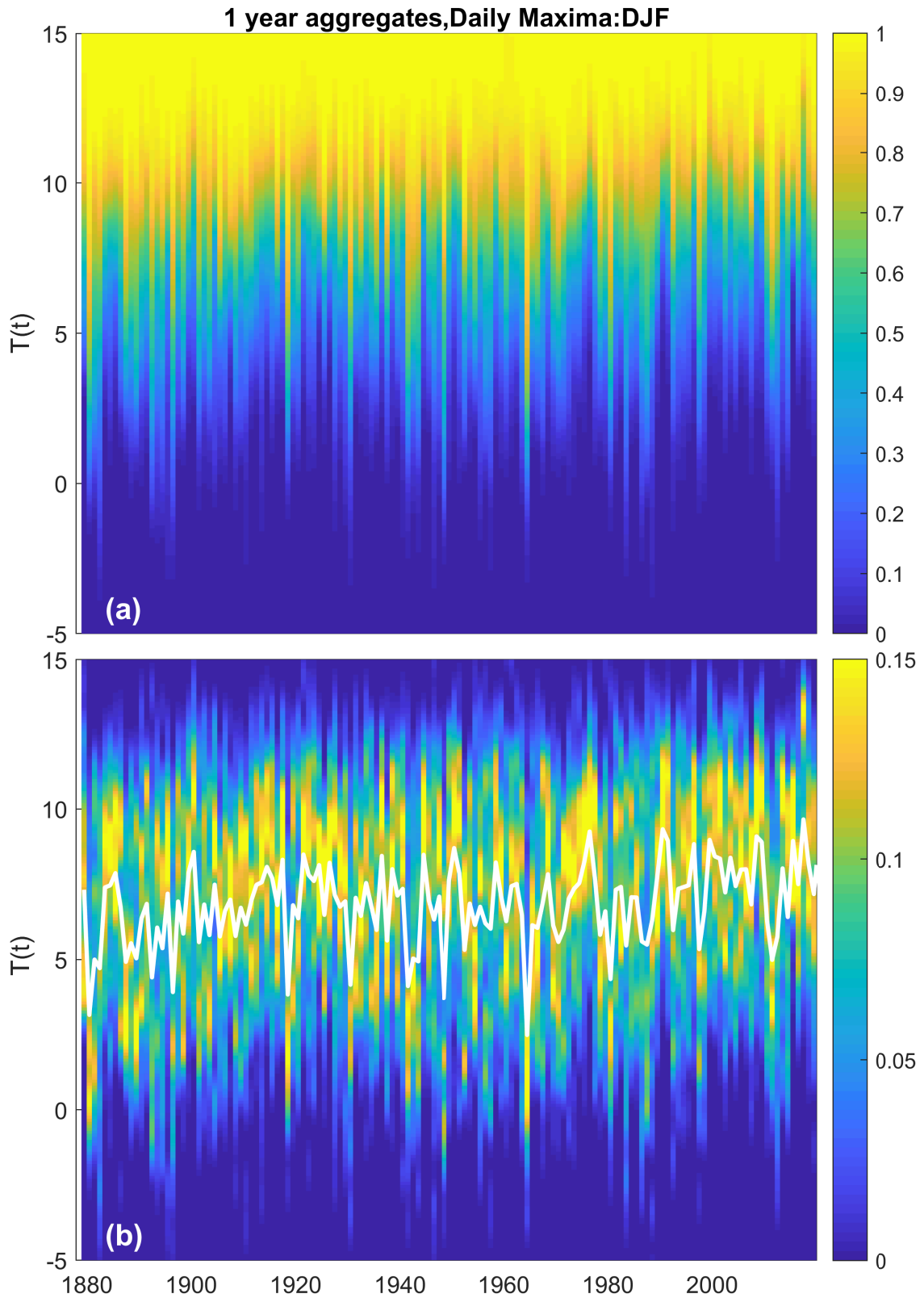
Figure S2. *
The daily maxima of the full Central England Temperature timeseries (CET) from 1878-2019 during winter (DJF) is shown as a time-variation in distribution. The (a) cdf and (b) pdf are formed from 5 consecutive winter seasons and are plotted at the central year of each 5-year interval. The cdf and pdf values are indicated as colour and are plotted versus temperature (ordinate) and time (abscissa). The legend on the right hand side of each panel indicate values of the (a) cdf and (b) pdf respectively. In panel (a) black (upper quantiles) and white (lower quantiles) lines indicate quantiles and in panel (b) the white line indicates the mean.
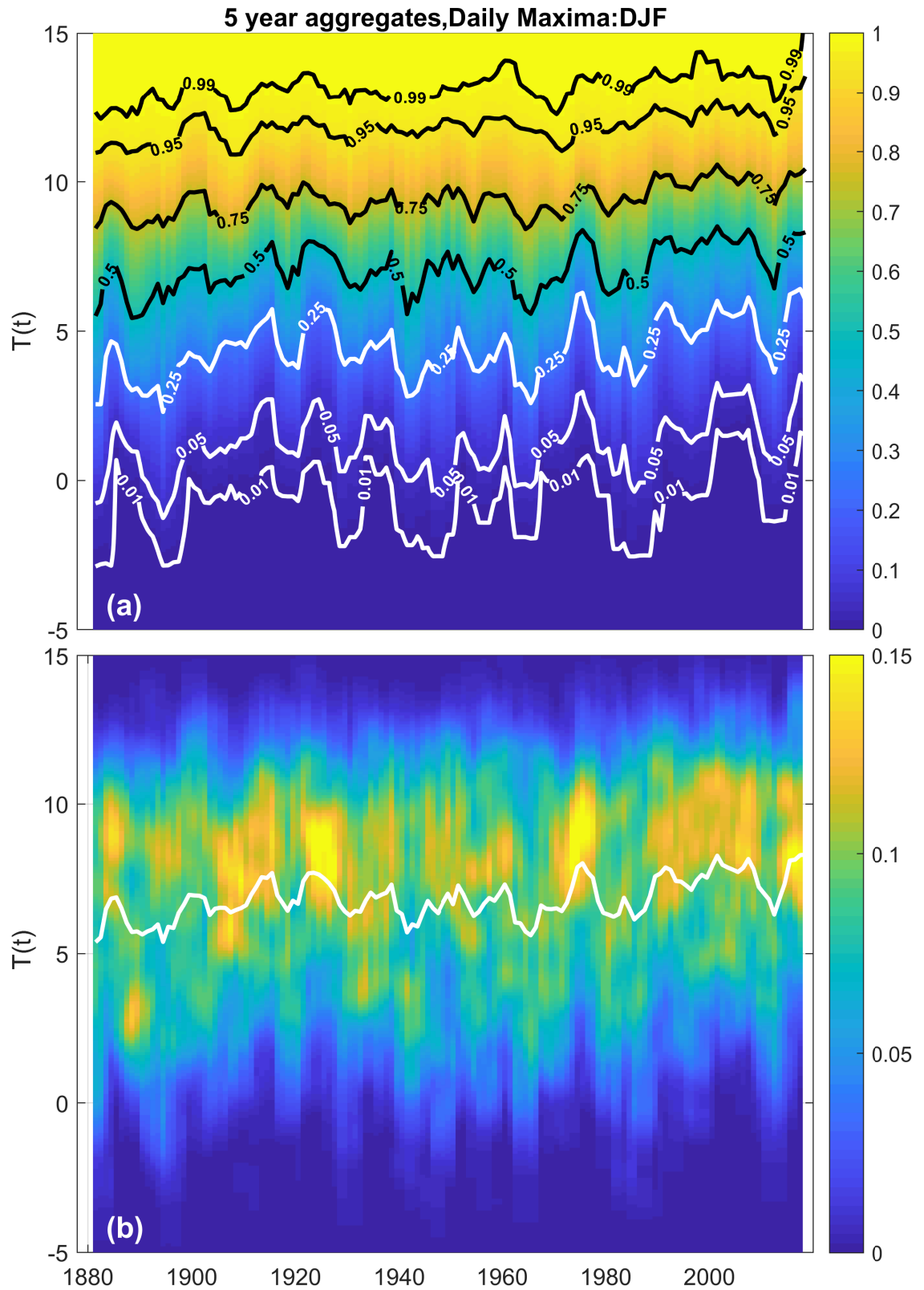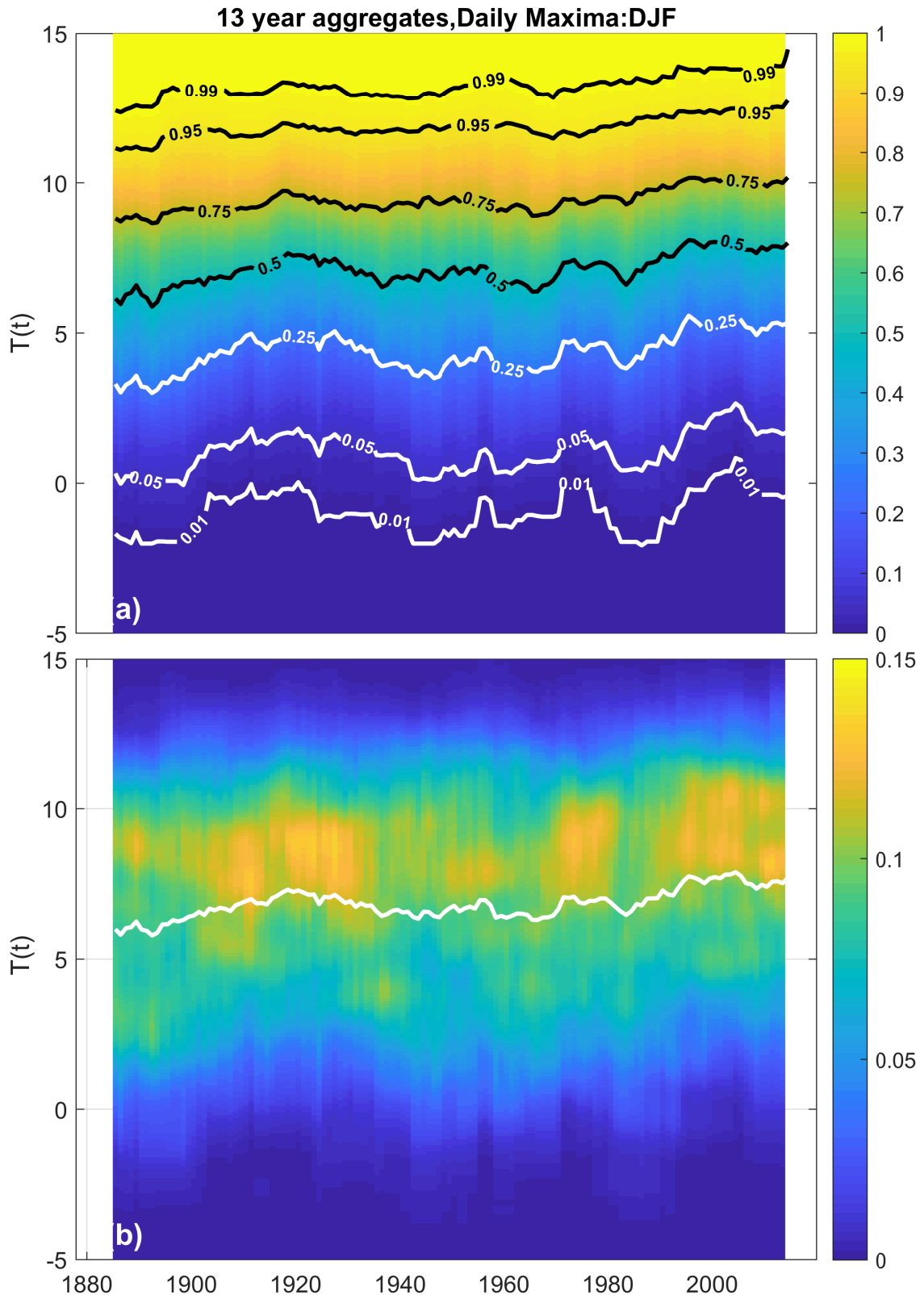
Figure S3. *
The daily maxima of the full Central England Temperature timeseries (CET) from 1878-2019 during winter (DJF) is shown as a time-variation in distribution. The (a) cdf and (b) pdf are formed from 13 consecutive winter seasons and are plotted at the central year of each 13-year interval. The cdf and pdf values are indicated as colour and are plotted versus temperature (ordinate) and time (abscissa). The legend on the right hand side of each panel indicate values of the (a) cdf and (b) pdf respectively. In panel (a) black (upper quantiles) and white (lower quantiles) lines indicate quantiles and in panel (b) the white line indicates the mean.
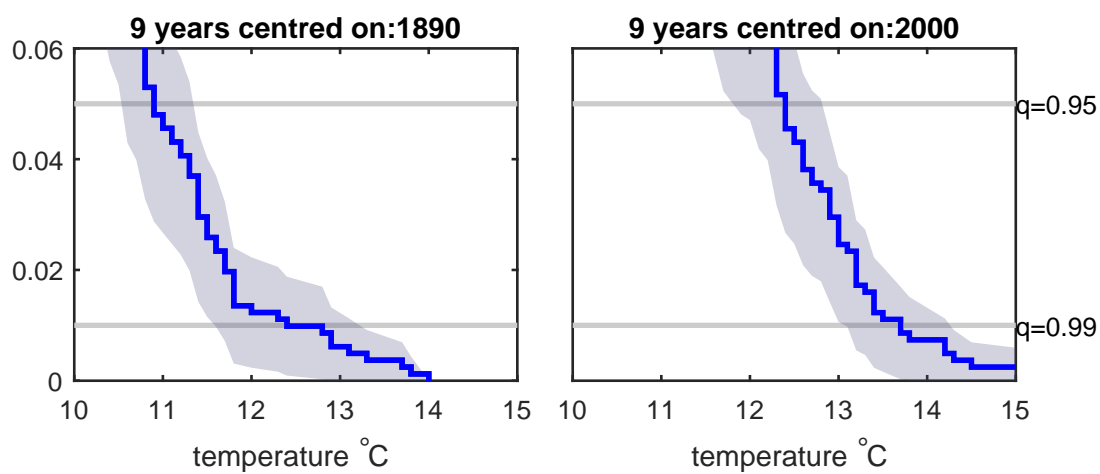
9 years centred on:1890

9 years centred on:2000

q=0.95

q=0.99

temperature °C

temperature °C

Figure S4. *
The empirical ccdf function of observations $1..x_k...x_N$ is $1-C(x_k)$ where the cumulative density function $C(x_k) = k/N$ and the x_k have been arranged in ascending order. These figures directly plot the observed empirical ccdf for 9 consecutive winter seasons (DJF) of CET daily maxima, centred on 1890 (left) and 2000 (right) respectively. The plots are a zoom on the far tail of the distribution around quantiles $q = 0.95 - 0.99$. Grey shading indicates the estimate of the cdf uncertainty, the 95% confidence bounds, using Greenwood's formula.
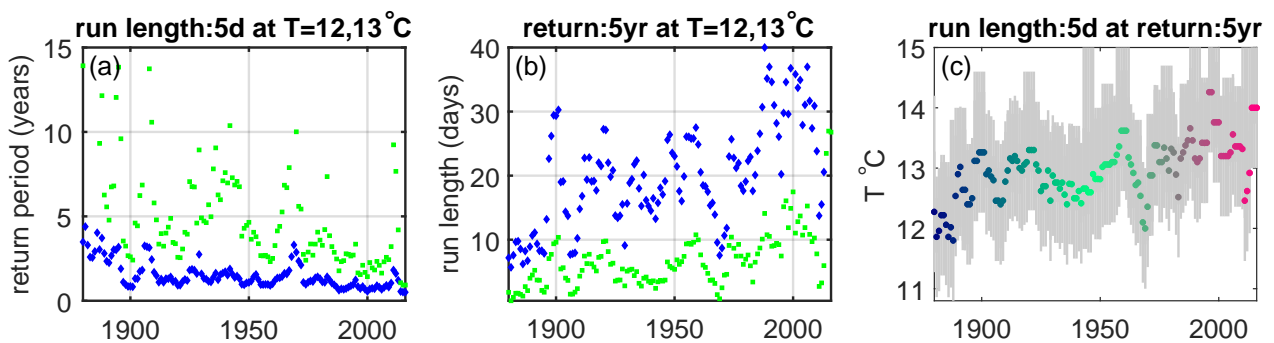
Figure S5. *

Winter warm spell changes over the last 140 years using data sampled over 5 consecutive winter (DJF) seasons centred on each of the years 1882-2015 to form cdfs. (a) average return periods for runs of 5 consecutive days with maximum winter daily temperatures above 12 (blue) and 13 (green)$°C$; (b) the average duration of runs of consecutive days with maximum winter daily temperatures above 12 (blue) and 13 (green)$°C$ with average return period of 5 years; (c) the threshold of maximum daily temperature which is exceeded for 5 consecutive days on average every 5 years. Colour indicates the sample central year in the time sequence as in Figure 2. Equation (3) main text relates these cdfs to average return periods and run lengths where the daily maximum temperature is above a given threshold. Grey shading in (c) indicates uncertanties estimated as the larger of that from 95% confidence bounds in the underlying cdf estimated using Greenwood's formula and from an intrinsic $\pm 1°C$ in the temperature time-series.
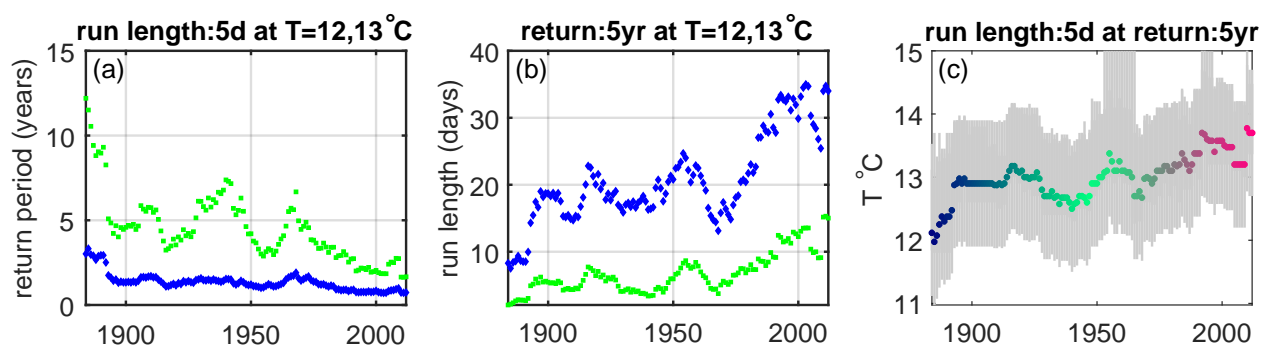
Figure S6. *

Winter warm spell changes over the last 140 years using data sampled over 13 consecutive winter (DJF) seasons centred on each of the years 1882-2015 to form cdfs. (a) average return periods for runs of 5 consecutive days with maximum winter daily temperatures above 12 (blue) and 13 (green)°C; (b) the average duration of runs of consecutive days with maximum winter daily temperatures above 12 (blue) and 13 (green)°C with average return period of 5 years; (c) the threshold of maximum daily temperature which is exceeded for 5 consecutive days on average every 5 years. Colour indicates the sample central year in the time sequence as in Figure 2. Equation (3) main text relates these cdfs to average return periods and run lengths where the daily maximum temperature is above a given threshold. Grey shading in (c) indicates uncertanties estimated as the larger of that from 95% confidence bounds in the underlying cdf estimated using Greenwood's formula and from an intrinsic $\pm 1°C$ in the temperature time-series.