

The exceptional recent warming signal in a long-term central-German observation site

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1) Introduction

Long-term instrumental temperature measurements are important tools to investigate observed climate variations of past centuries. In Germany, only very few meteorological observations are accessible before the end of the 18th century. This contribution investigates homogenised annual temperature data of Frankfurt/Main (Central Germany) since 1758, as well as unprocessed daily data preserved since 1870, to detect change signals.

2) Metadata and artificial effects

- **Comparison:** two sites in Frankfurt/Main with urban (city) and rural (airport) characteristics
- **City site:** data from 1758 (annual) / 1870 (daily); varying locations (table 1 from 1949)
- **Airport site:** daily data since 1949; good reference for site changes and urbanisation effect of the respective city locations (altitude 112 m NN, no larger site change until 11/2014)
- **Annual temperature series:** from 1949 airport data, before based on various city locations homogenised and recalculated to airport site; based on Brinckmann (2005) / Schönwiese (2015)
- **Site change effects:** considerable for even small relocations (average annual deviation between coolest and warmest site 0.9 K for TN and TX; up to 1.3 K in certain months; fig.1)
- **Urbanisation effects:** city warming (strongly) visible for TN (long-term annual average of 1.1 K; up to 1.8 K in certain months), but low for TX (average of 0.1 K; between -0.5 and 0.8; fig.1)

Table 1: Metadata of Frankfurt/Main city observations since 1949; based on Früh et al. (2011), the Climate data centre of Deutscher Wetterdienst (<ftp://ftp-cdc.dwd.de/pub/CDC/>) and own investigations

Location	Time frame	m. NN	Characteristics
Feldbergstraße	Until 11/1961	109	Very high building density
Wöhlerschule	12/1961–3/1973	125	High building density
Waldorfschule	4/1973–9/1984	125	Low building density, shallow dip, nearby meadow
Palmengarten	11/1985–7/2008	107	Park area with greenhouses, nearby street
Unicampus West	Since 8/2008	124	Medium building density, small park area

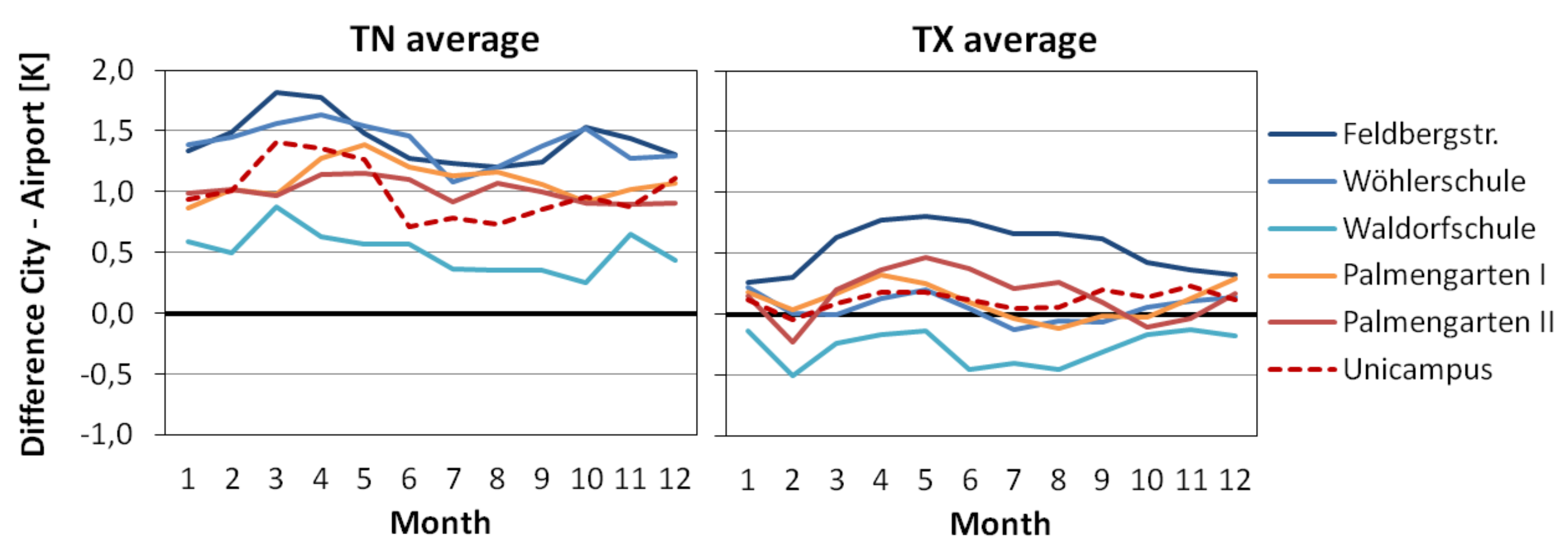


Figure 1: Monthly averages of minimum (TN) and maximum (TX) temperature: difference of selected Frankfurt/Main city locations (see table 1) from Frankfurt/Main airport; location "Palmengarten" split into two periods of similar length for comparison purposes (I: 11/1985–1996; II: 1997–7/2008)

3) Annual temperature time series (1758–2016)

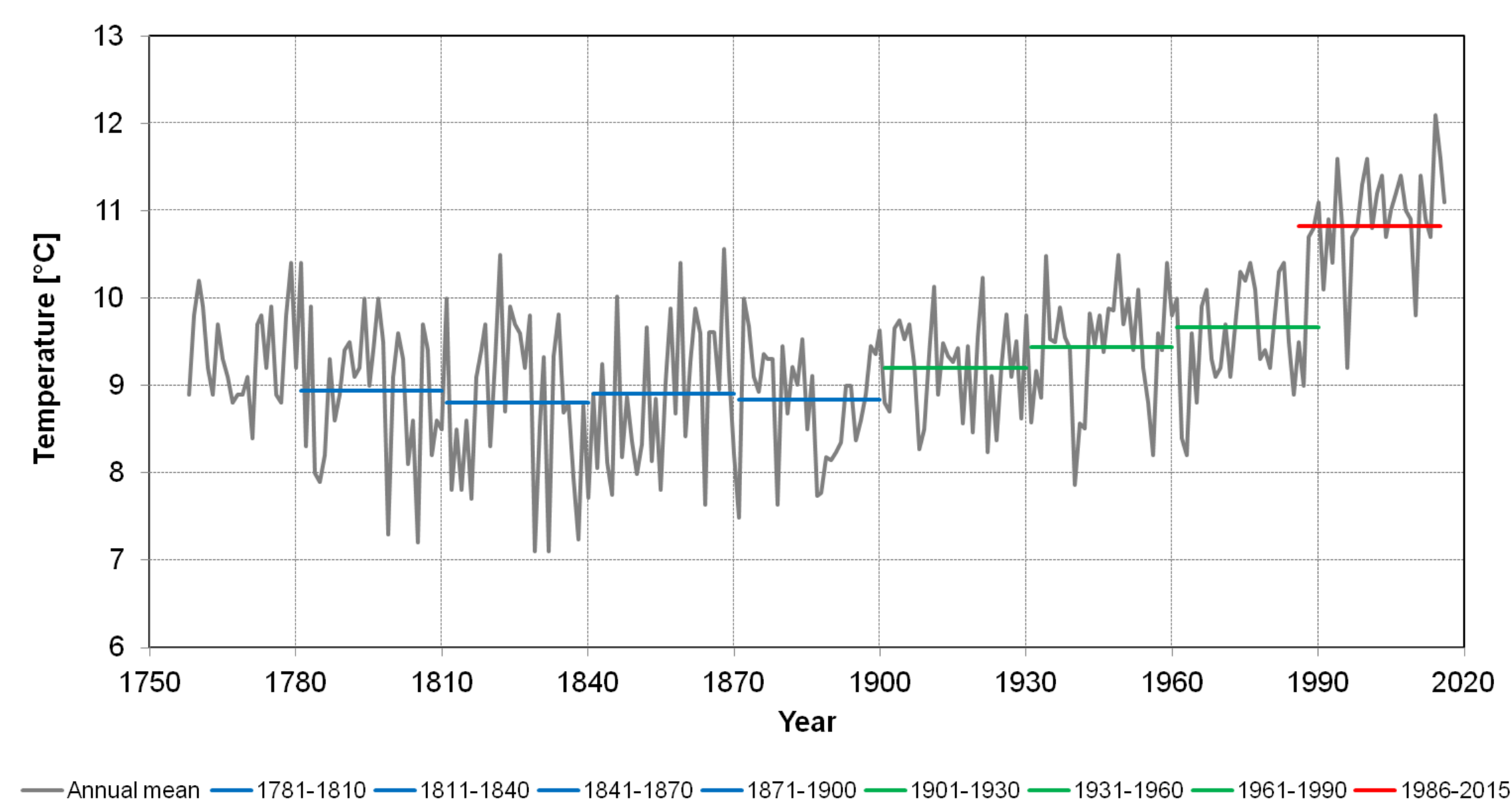


Figure 2: Average annual air temperature for Frankfurt/Main airport site for 1758–2016 (homogenised; until 1948 based on city site); coloured lines: 30-year climate normals

- **Secular temperature variability (1):** decadal-scale and yearly fluctuations dominate long-term trends until 20th century (fig. 2); very similar developments in nearby Karlsruhe and in Prague since ca. 1850 (Paris reflects more maritime climate), earlier times may still be impacted by remaining inhomogenities (fig. 3)
- **Secular temperature variability (2):** only 1 K spread between coldest (1829–1858) and warmest 30-year-periods (1948–1977) up to the 1980s (fig. 2, 3)
- **Recent temperature level:** 30-year-mean 1986–2015 was warmer than any single year before 1988 (10.82°C; earlier annual maximum: 10.6°C; fig. 2, 3)

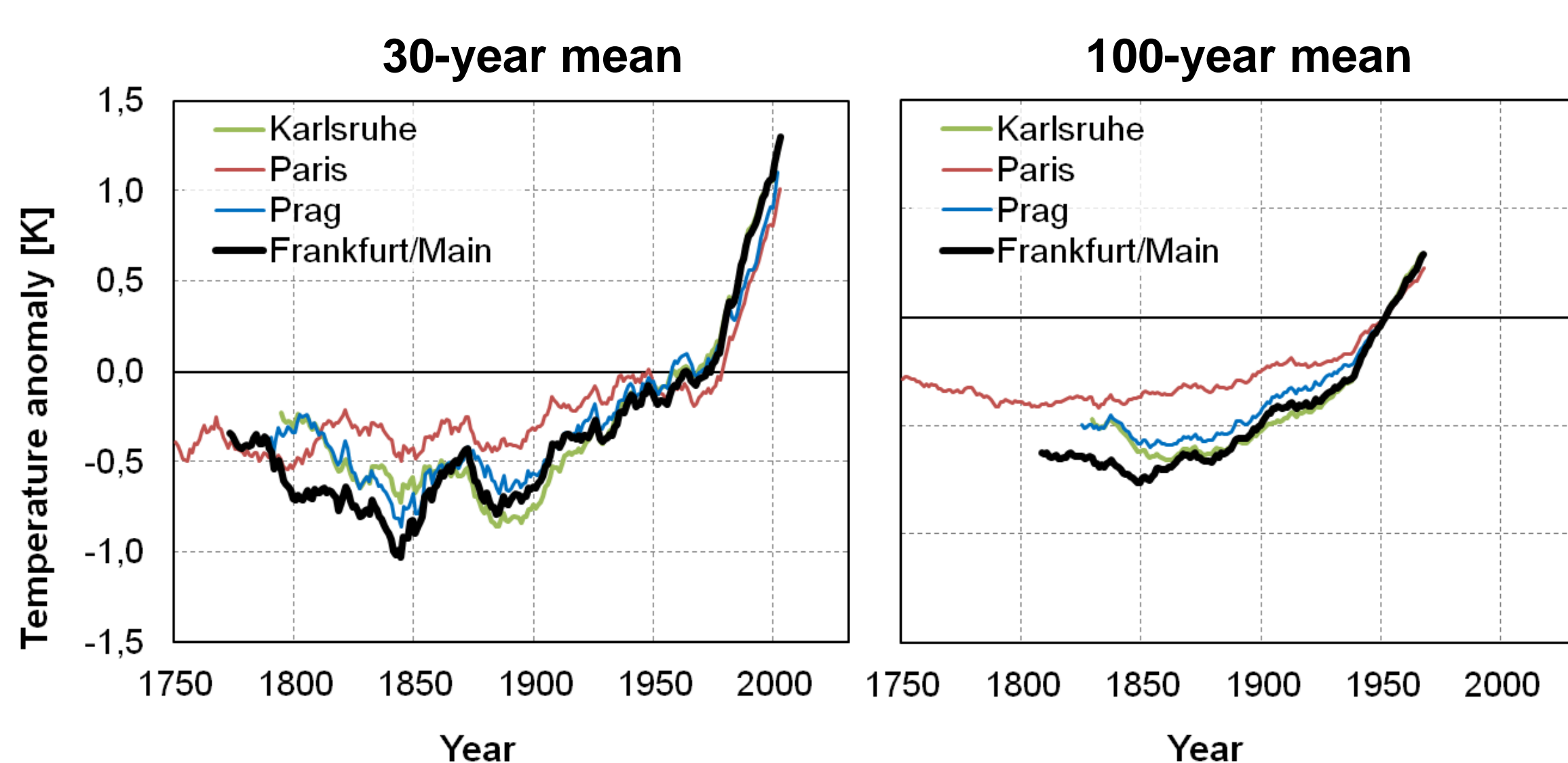


Figure 3: Comparison of long-term annual mean temperature anomalies from 20th century averages of a) Frankfurt/Main (from 1758; black line) with other homogenised time series: b) Karlsruhe (100 km southwards; from 1779; HISTALP project), c) Paris (westwards; 1659; Rousseau 2015), d) Prague (eastwards; 1775; Brazdil et al. 2012)

4) Daily temperature time series (1870–2016)

- **Site change effects:** similar long-term developments in city and city/airport sites, but switch to airport leads to artificial enhancement of cold extremes in 1950s/1960s
- **Cold extremes:** most frequent until the 1920s; suddenly disappear almost completely from 1988 onwards
- **Warm extremes:** well-distributed until the 1980s with notable maximum in 1947; sudden rise from 1989 and again 2002 (only now strong urbanisation effect in the city)

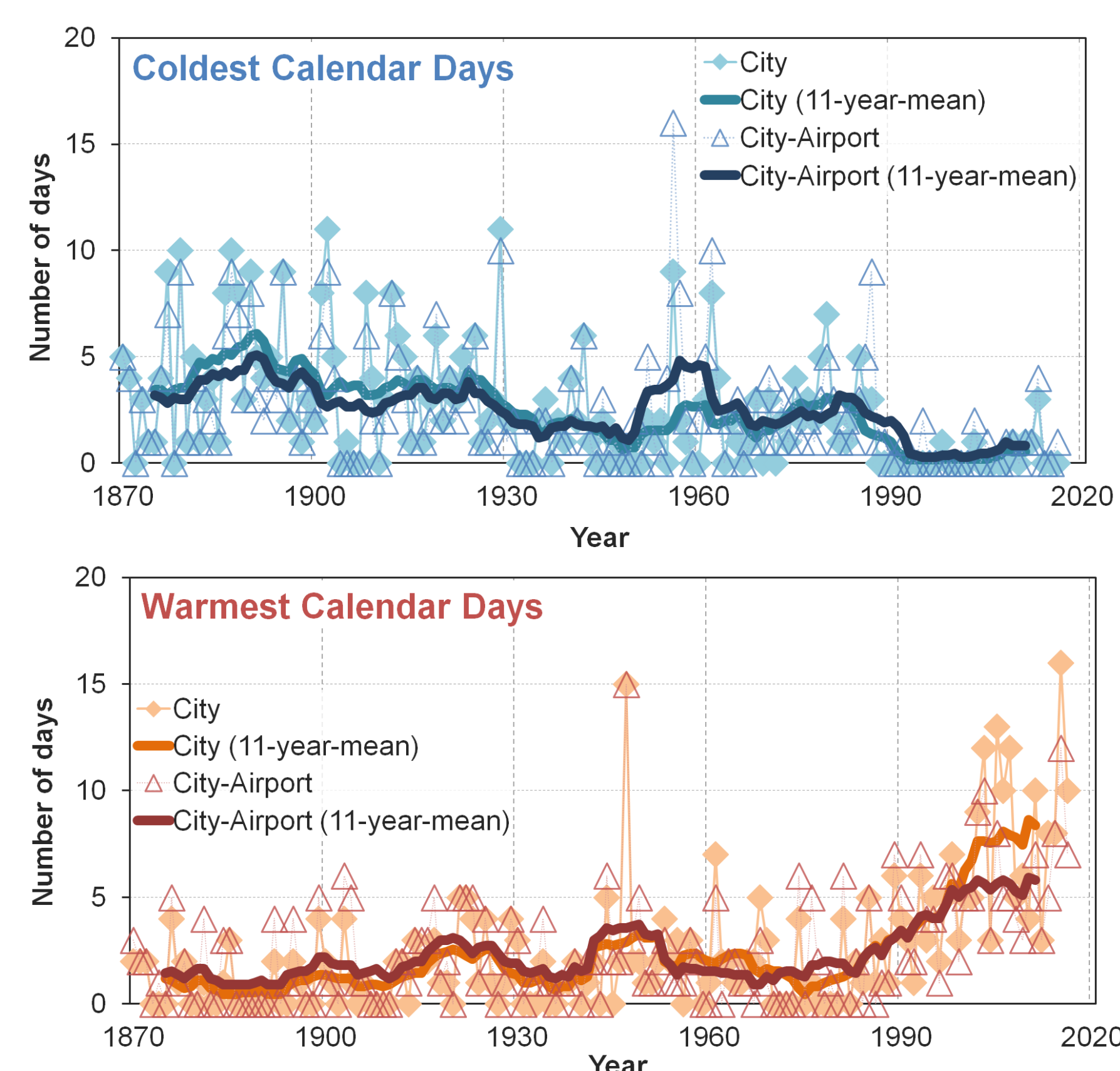


Figure 4: Time series of cold and warm all-time extremes (daily mean temperature; one value per calendar day); evaluations for a) Frankfurt city site and b) combined Frankfurt city site until 1948 / Frankfurt airport site from 1949 onwards

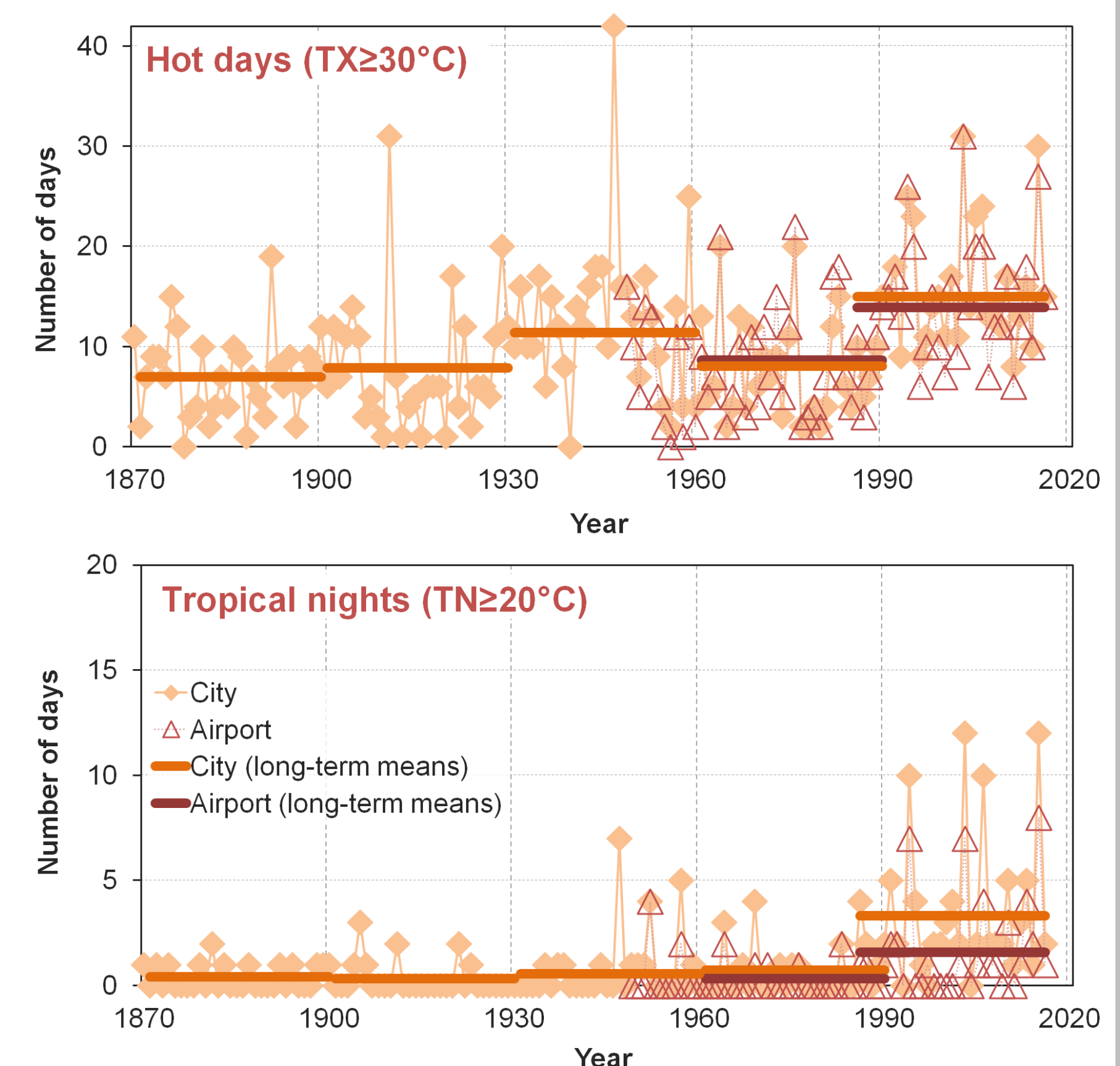


Figure 5: Time series of hot days and tropical nights; evaluations for a) Frankfurt city site from 1870 and b) Frankfurt airport site from 1949; 30-year-means from 1871–1900, last 1986–2015

- **Hot days:** natural decadal variability with warmer 1931–1960 and colder 1961–1990 periods gets visible; recent 30-year-period warmest, but without new extremes (fig. 5)
- **Tropical nights:** hardly relevant until the 1980s; strong increase from the end-1980s with (a few) tropical nights in most years now
- **Urbanisation effect:** very similar results for hot days, but city site shows much stronger rise in tropical nights

5) Conclusions

- **Data validity:** importance of studying metadata prior to climatological evaluations (location changes, urban effect)
- **Recent temperature rise:** robust signal of sustained higher temperature level from 1988 → missing cold, but largely increasing # of warm extremes; enhanced in build-up areas



Für eine lebenswerte Zukunft