The coldest European Winter: a secular perspective

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Andreas Hoy and Stephanie Hänsel

1) MOTIVATION

Cold winters impose manifold impacts towards human societies. Our cultural memory preserves the most severe historical winters – the hardship in every day lives connected to snow and frost as well as spectacular events like ice fairs on rivers like Thames and Rhine. Global warming results in warmer European winters, especially since the late 1980s. Yet, large atmospheric circulation variability regionally still allows for comparably severe cold spells, like recently experienced from 2009 to 2013 and also in January 2017.

Which was the coldest winter since the beginning of instrumental measurements in Europe? This ambitious, multi-layered question motivates this concise contribution, which presents first steps towards a satisfying answer.

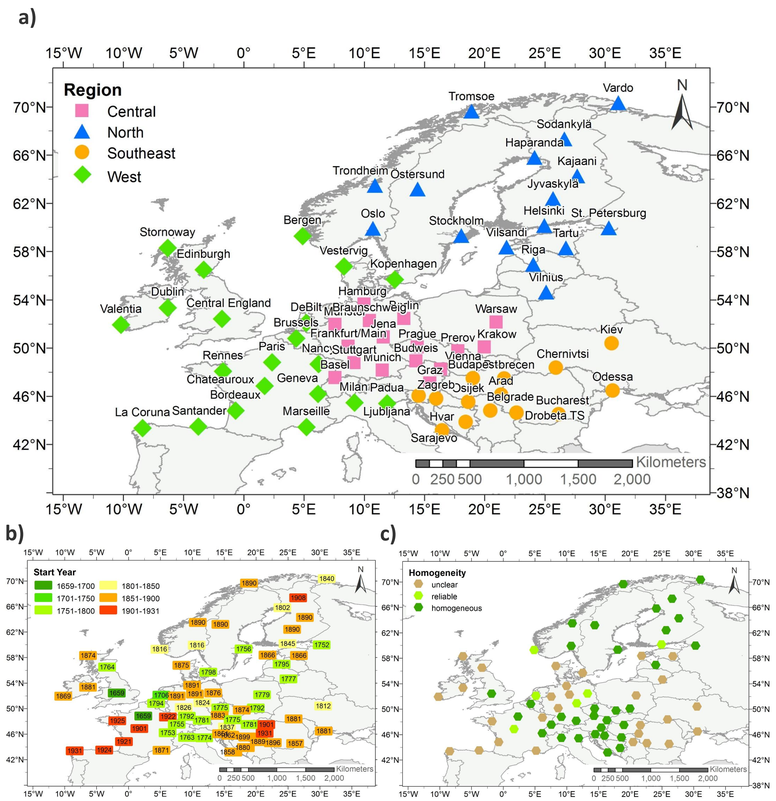

Fig. 1: a) Study area with climate stations and four sub-regions, **b)** start year of observations, **c)** information on time series homogenity based on data source and literature

2) DATA BASE

Selection and ranking of cold winters depends on the chosen parameters and the seasonal definition of "winter". Our goal was to a) involve the longest accessible temperature observations, b) spatially well-distributed over the largest possible European domain, while c) ensuring a high-quality dataset.

- **Parameter:** average winter temperature (December, January, February)
- **Study area:** European domain (43 to 70°N; 10°W to 32°E; fig. 1a)
- **Data set:** 67 stations (monthly time series), located in 27 countries (fig. 1a)
- **Data source:** manifold origins, based on public databases and personal contacts
- **Observation start:** 18th (30%) and 19th (another 60%) centuries, Central England and Paris time series start in 1659 (fig. 1b)
- **Homogeneity:** >50% homogenized time series (37), processed by NORDHOM (Scandinavia) and HISTALP projects (greater Alpine area) as well as national weather services or universities (fig. 1c)

3) CLIMATOLOGY I

- **Spatiotemporal secular variability:** magnitude dependent on continentality and latitude (from <3 K on British Isles to >5 K in NE-Europe; fig. 2a – displayed variability of all time series additionally confirmed by nearby stations)
- **Study area temporal development:** mean of 19th century winters 1 K lower than 20th century; top5 of regionally warmest winters mostly from end 1980s (region North: also first part of 20th century); top5 of regionally coldest winters mainly during 19th century (fig. 2b)
- **Characteristics of warm extremes:** mainly reached up to 1 standard deviation, after 1989 sometimes also 2 standard deviations (most apparent in winters 2007 and 2016; no figure)

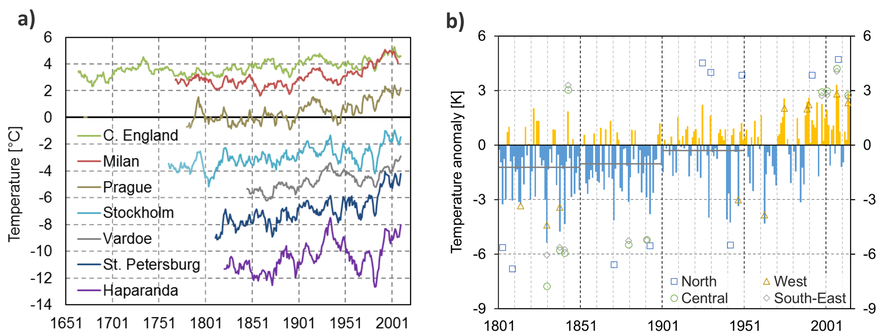

Fig. 2: a) Time series of 7 very long-term homogenous temperature time series (see fig. 1a; 11-year centred winter average); **b)** European winter temperature anomaly since 1801 (based on 1951–2000 mean weighted by sub-regions); 5 coldest/warmest winters depicted by symbols for the sub-regions; grey lines: average of previous 50-year-means

3) CLIMATOLOGY II

- **Characteristics of cold extremes:** average winter temperatures 2 to 3 standard deviations below normal (1951–2000) conditions all over Europe (no figure)
- **Specifics of Central Europe:** strongest signals observed here (sometimes up to 4 standard deviations), due to:
  - Western/Southern Europe: almost missing extreme cold air mass inflow
  - Northern/Eastern Europe: severe winters more common (comparatively frequent & long cold waves), also visible in large secular variability (fig. 2a)
  - Central Europe: rarely impacted by strong and long-lasting cold outbreaks due to strong maritime influence – but if such cold waves occur, then severe winters are possible

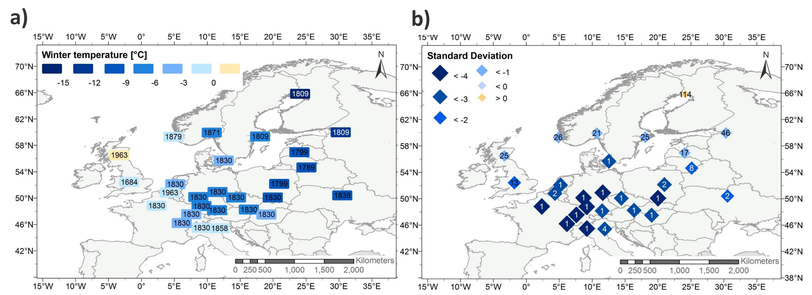

Fig. 3: a) Coldest winters since the beginning of observations (at least since 1830; compare fig. 1b), and **b)** Ranking of winter 1830 since the respective start of observations, with standard deviation of 1830 winter average (based on 1951–2000 values)

4) THE COLDEST WINTER

- **1830 was the coldest European winter south of the Baltic Sea** since beginning of instrumental observations (fig. 2b, 3)
- 1830 was by far the coldest winter in the Paris time series since 1659 (followed by two 17th century winters)
- 1830 was the coldest winter in regions West, Central and Southeast
- 1809 was the coldest winter in region North since observation start (1830 was only moderately cold in northern Europe; fig. 3)
- 1963 was the coldest winter around the British Islands since 1740 (#3 in Central England time series since 1659, after 1684 and 1740)
- Extreme cold winters in Europe deviated up to 4 standard deviations from 1951–2000 average conditions, especially around Central Europe – 1830 was the most extreme case (fig. 3b)

TU Bergakademie Freiberg | Interdisciplinary Environmental Research Centre | Brennhausgasse 14 | 09599 Freiberg | Germany | andreas.hoy@ioez.tu-freiberg.de |

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