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A Climatology of Thunderstorms across Europe

from a Synthesis of Multiple Data Sources

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Key findings

- Thunderstorms are the most frequent over south-central Europe with a local maximum over northeastern Italy.
- Annual peak activity occurs during summer over majority of continental Europe and during fall over the Mediterranean.

Introduction and objectives

Thunderstorms, particularly severe events, pose a considerable risk to society. Knowledge of their local climatology is not only important for weather forecasting, but also for risk assessment. In this work we construct a comprehensive European climatology of (severe) thunderstorms based on a multiple data sources and show how the annual cycles are captured by respective datasets.

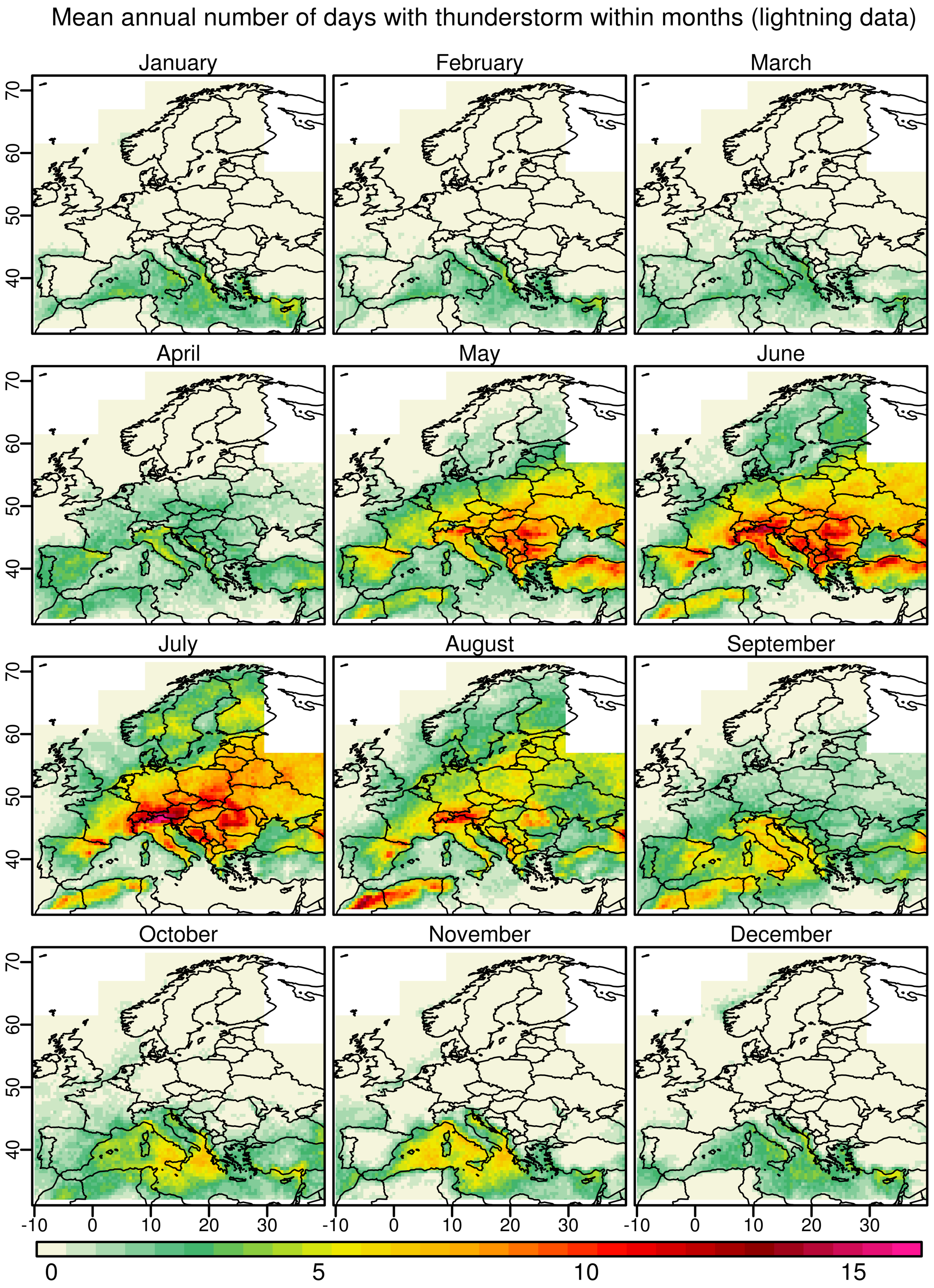

Figure 1. Mean annual number of days with thunderstorm in each month, based on EUCLID and ZEUS lightning data (see Table 1).

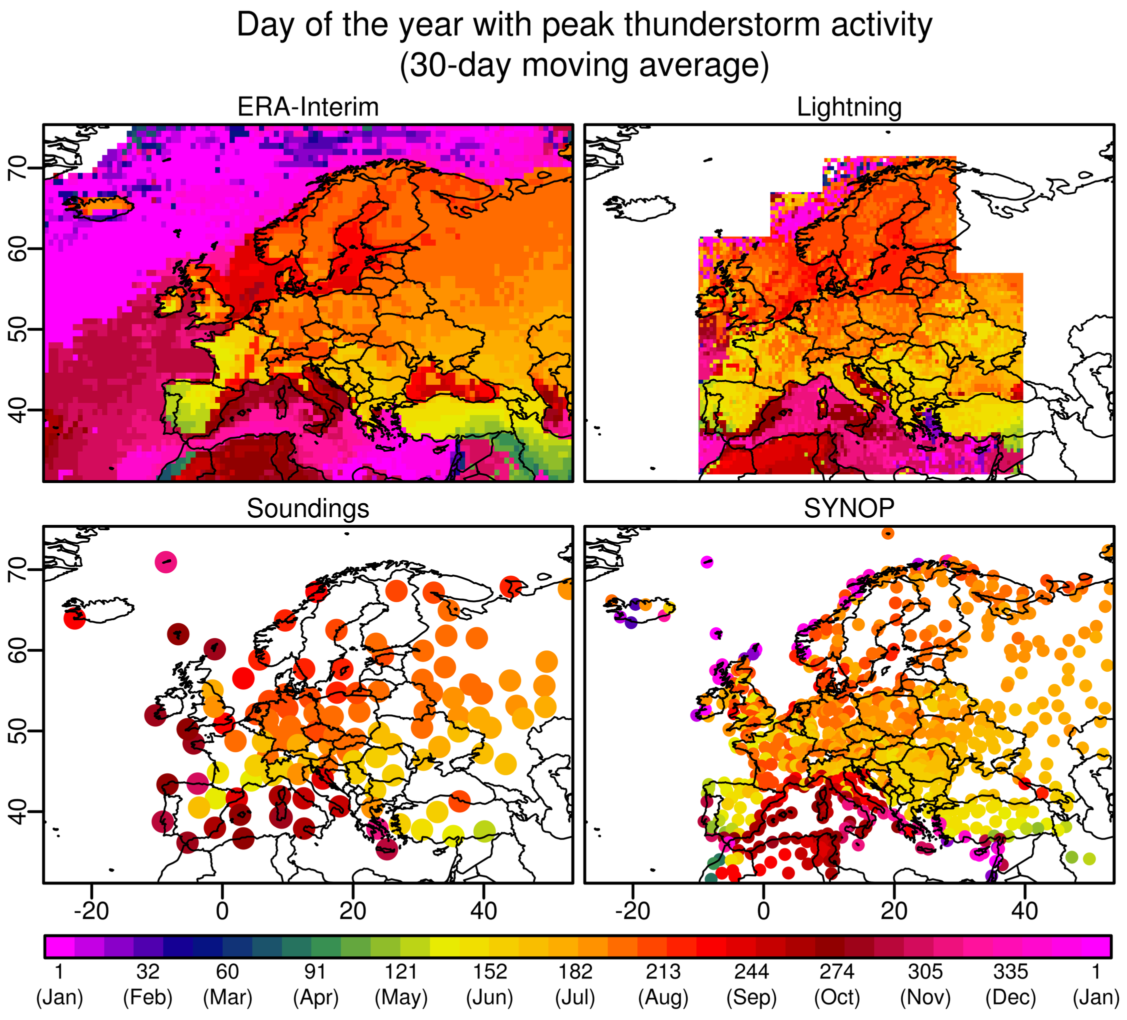

Figure 2. Day of the year with peak thunderstorm activity computed by 30-day moving mean for various data sources (see Table 1).

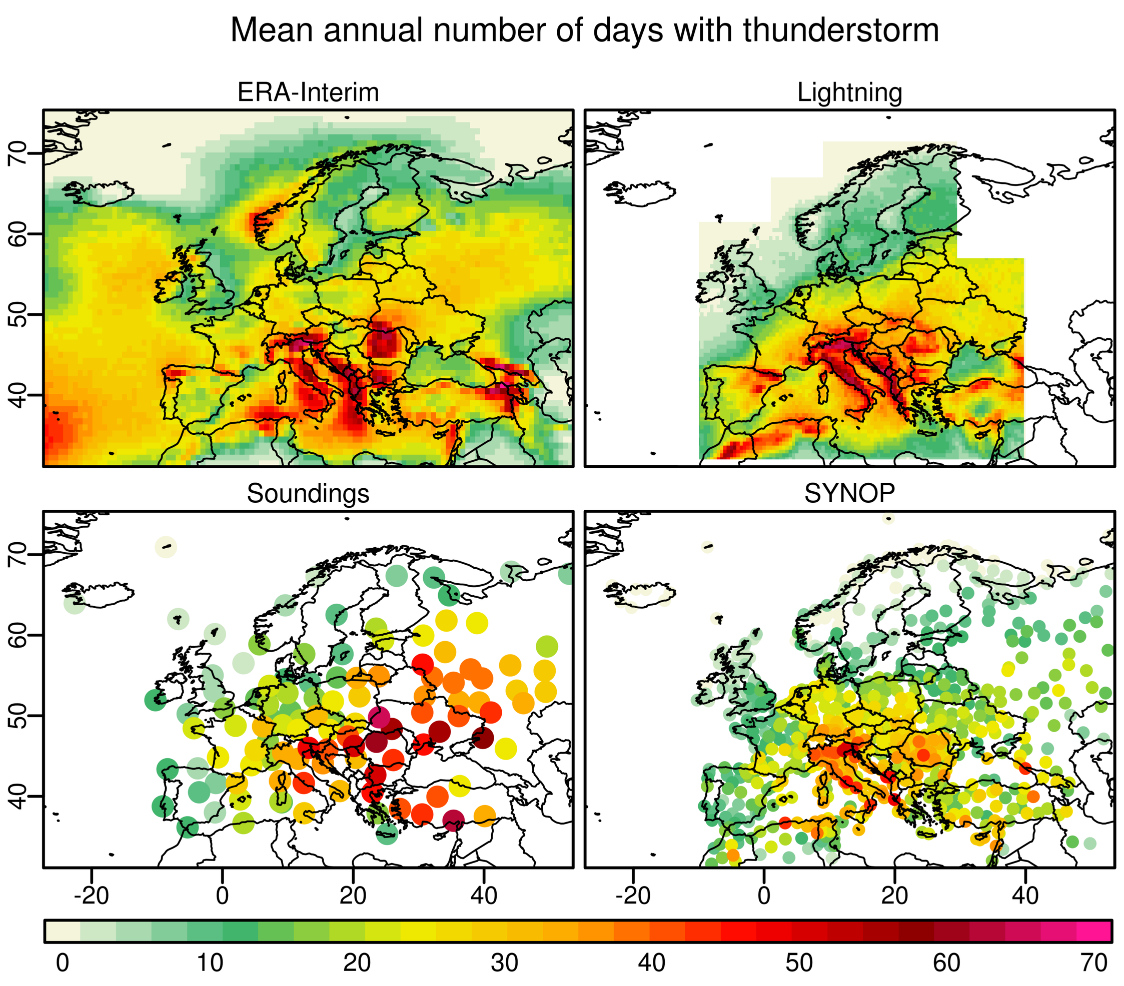

Figure 3. Mean annual number of days with thunderstorms for various data sources (see Table 1).

Datasets and methods

To investigate climatological aspects of thunderstorms, the concept of a thunderstorm day and severe thunderstorm day was adopted. These are derived from sounding measurements, surface observations, ERA-Interim reanalysis, ESWD severe weather reports, and lightning data from ZEUS and EUCLID networks. Further details are presented in Table 1.

Table 1. Databases used in the analysis and the definition of a thunderstorm day and severe thunderstorm day.

Database	Lightning (EUCLID and ZEUS)	Surface observations (SYNOP)	Sounding measurements	ECMWF ERA-Interim reanalysis	European Severe Weather Database (ESWD)
Sample size	~ 100 million detections	~ 50 million reports from 828 stations	~ 1 million soundings from 116 stations	56980 time steps from 6372 grid points	46696 reports
Coverage	2008-2017	1979-2017	1979-2017	1979-2017	2011-2017
Definition of a thunderstorm day	> 2 lightning detections	report of an audible thunder	ML CAPE >150 J kg^{-1}, ML CIN >-75 J kg^{-1}	ML CAPE >150 J kg^{-1}, Conv. prcp. >0.075 mm h^{-1}	N/A
Definition of a sev. thunderstorm day	N/A	N/A	ML CAPE >150 J kg^{-1}, ML CIN >-75 J kg^{-1}, ML WMAXSHEAR >400 m^2 s^{-2}	ML CAPE >150 J kg^{-1}, Conv. prcp. >0.075 mm h^{-1}, ML WMAXSHEAR >400 m^2 s^{-2}	severe convective weather report

Results

- Thunderstorms are the most frequent in the central Mediterranean, Alps, Balkan Peninsula, and Carpathians.
- Severe weather reports have their highest frequency over central Europe, which is linked to reporting inhomogenities.
- Annual peak in thunderstorm activity is in July and August over northern, eastern, and central Europe, contrasting with peaks in May and June over western and southeastern Europe.
- The Mediterranean, driven by the warm waters, has predominant activity in the fall (western part) and winter (eastern part) while the nearby Iberian Peninsula and eastern Turkey have peaks in April and May.

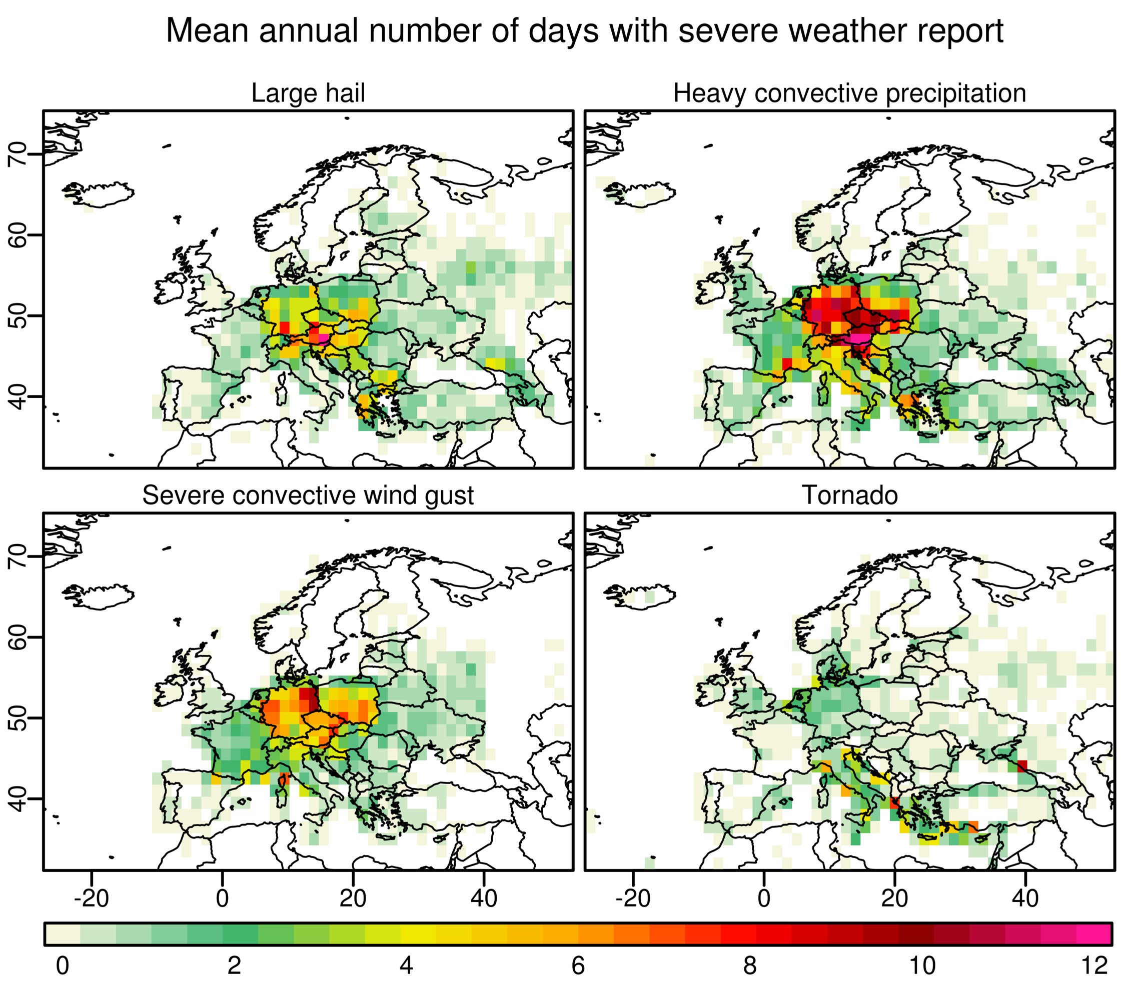

Figure 4. Mean annual number of days with 2cm+ hail, heavy conv. precipitation, severe conv. wind gust, and tornado reports, based on the records from the European Severe Weather Database (ESWD).

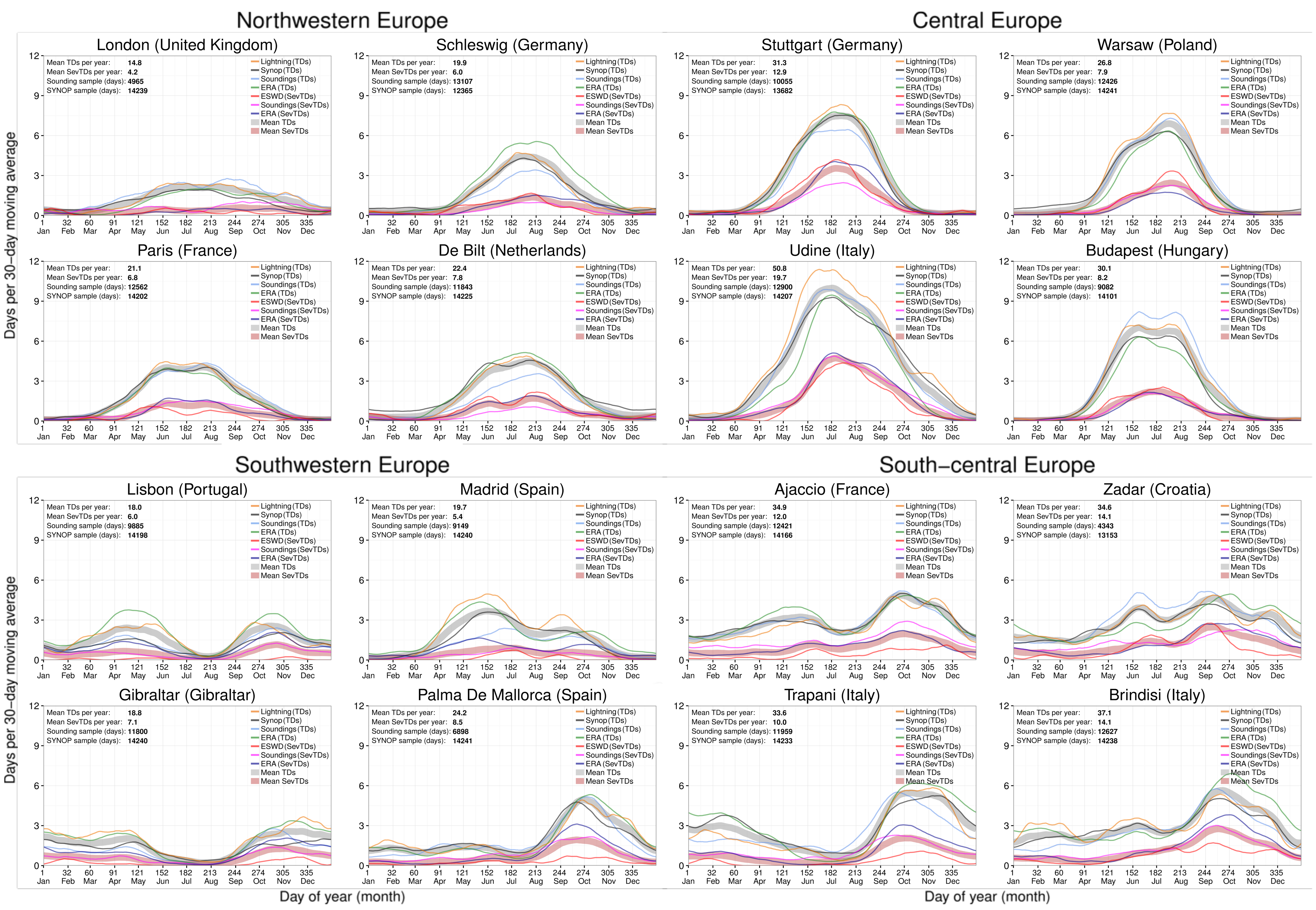

Figure 5. Annual cycle of thunderstorm days (TD) and severe thunderstorm days (SevTD) over chosen stations. Solid lines denote 30-day moving mean of TDs for lightning (orange), SYNOP (black), soundings (blue), ERA-Interim (green), and SevTDs for ESWD (red), soundings (pink), and ERA-Interim (purple). Transparent thick lines denote mean values for TDs (gray) and SevTDs (dark red).

Concluding remarks

Comparison of different data sources revealed that although lightning data provide the most objective sampling of thunderstorm activity, short operating periods and areas devoid of sensors limit their utility. In contrast, reanalysis complements these disadvantages to provide a longer climatology, but is prone to errors related to modeling thunderstorm occurrence and the numerical simulation itself. Severe weather reports on the other hand are biased towards central Europe. Along with the prolonging measurement periods, lightning data will play an increasingly important role. The same applies to reanalysis, which, together with the increasing quality and resolution of the next generation of these datasets, will be able to more reliably sample convection on its own.

Acknowledgments

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