

Long-term changes in the frequency and intensity of thunderstorms in Latvia: analysis based on observations from 14 surface weather stations

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INTRODUCTION

Thunderstorms are the most hazardous meteorological phenomena in Latvia in the summer season, as the impacts caused can be very local and severe. However, so far not much has been known about the climatic characteristics of thunderstorm distribution and intensity in Latvia, and how these have changed under the conditions of recent climate changes. Therefore, the aim of this study is to analyse the spatial and temporal distribution of thunderstorms in Latvia over the period 1960 to 2015 by using surface observation data from 14 major weather stations. In order to assess the severity and possible impacts of thunderstorms in Latvia over the period of interest, the frequency and distribution of thunderstorm intensities according to the national warning and hazard criteria was analysed.

The climatological analysis of thunderstorm occurrence and hazardous weather phenomena associated with them has been performed by analysing the long-term surface observations covered by 14 major meteorological observation stations of the Latvian Environment, Geology and Meteorology Centre (Fig. 1). The analysed data include daily observations of atmospheric phenomena (thunderstorm and hail events), daily amount of precipitation and daily mean wind speed and daily maximum wind gusts over the period 1960 to 2015 (1966-2015 for wind parameters). For the assessment of local features in the distribution of thunderstorms, data interpolation on a 1x1 km grid has been performed by applying Kriging with external drift interpolation routine to the data series using 5 km mean elevation, coordinates, and Gams' continentality index as the explanatory variables.

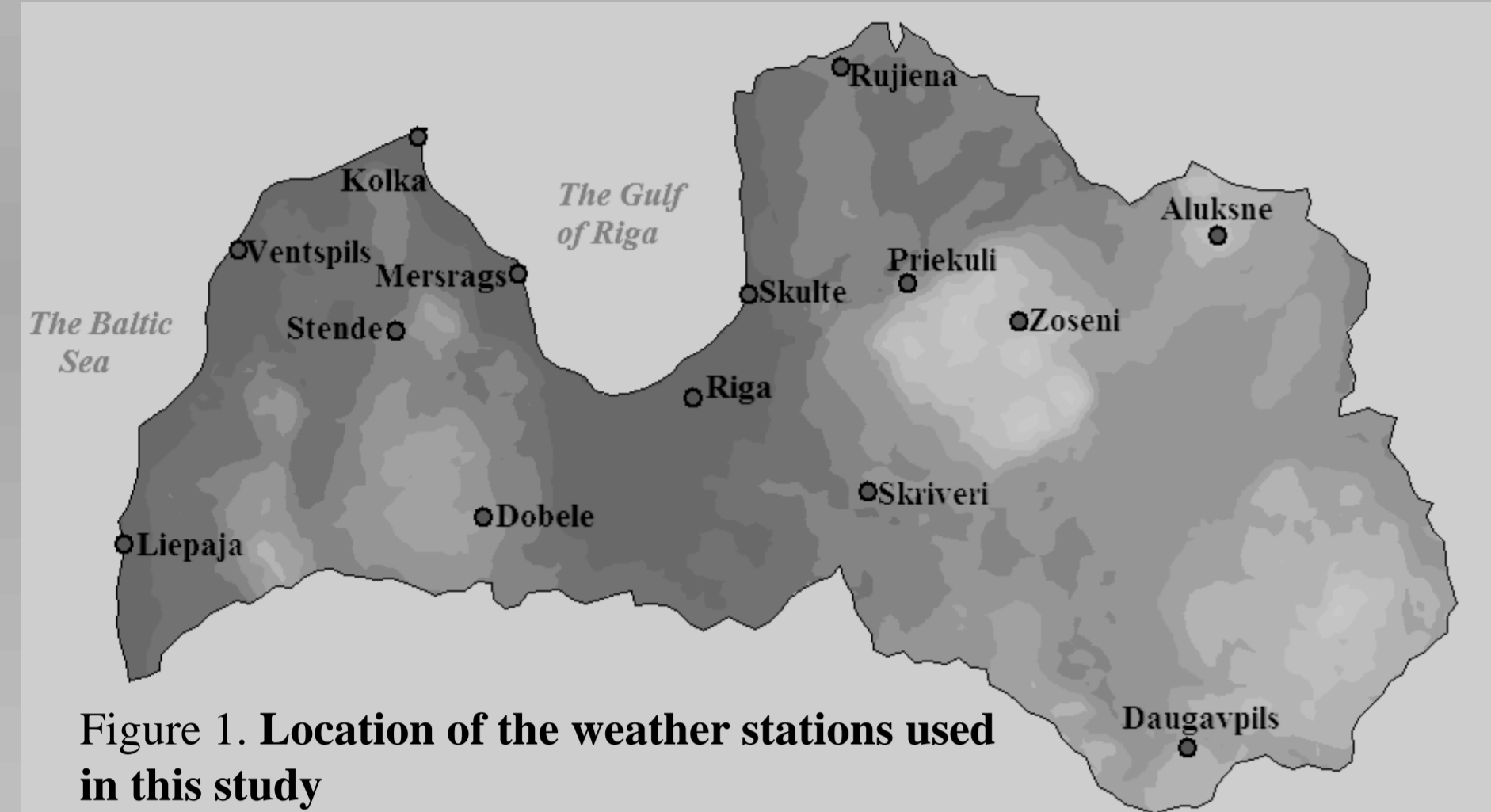


Figure 1. Location of the weather stations used in this study

Analysis of the distribution of thunderstorm frequencies over the country reveals a strong connection with the local orographic features and proximity to the Baltic Sea and the Gulf of Riga (Figs 1-2): thunderstorms on average are less frequent in the coastal areas, but their frequency increases gradually towards the highland areas (note the maximum elevation in Latvia is 311.5 m a.s.l.) of the country. There has also been an expressed variability in the annual number of thunderstorm days in Latvia (Fig. 3) – the minimum annual number of days with thunderstorms has been as low as 4-11 days in all stations analysed, however the maximum observed over the period of interest has been 26-46 thunderstorm days during a year. Thunderstorm day variability expressed as the standard deviation has been 5.4-7.6 days, with the greatest variability in the inland weather stations. For most of the weather stations the distribution of the annual thunderstorm day frequency over the period 1960-2015 has been positively skewed, however for some stations (Daugavpils, Riga, Rujiena, Zoseni) a negative skewness can be observed as well.

For the investigation of thunderstorm severity the national warning criteria of Latvia have been used and applied for the climatological analysis with modifications described in Table 1. The current approach is based on intensity levels of hazardous phenomena distinguishing green, yellow, orange and red severity levels which are in line with Meteoalarm warning levels.

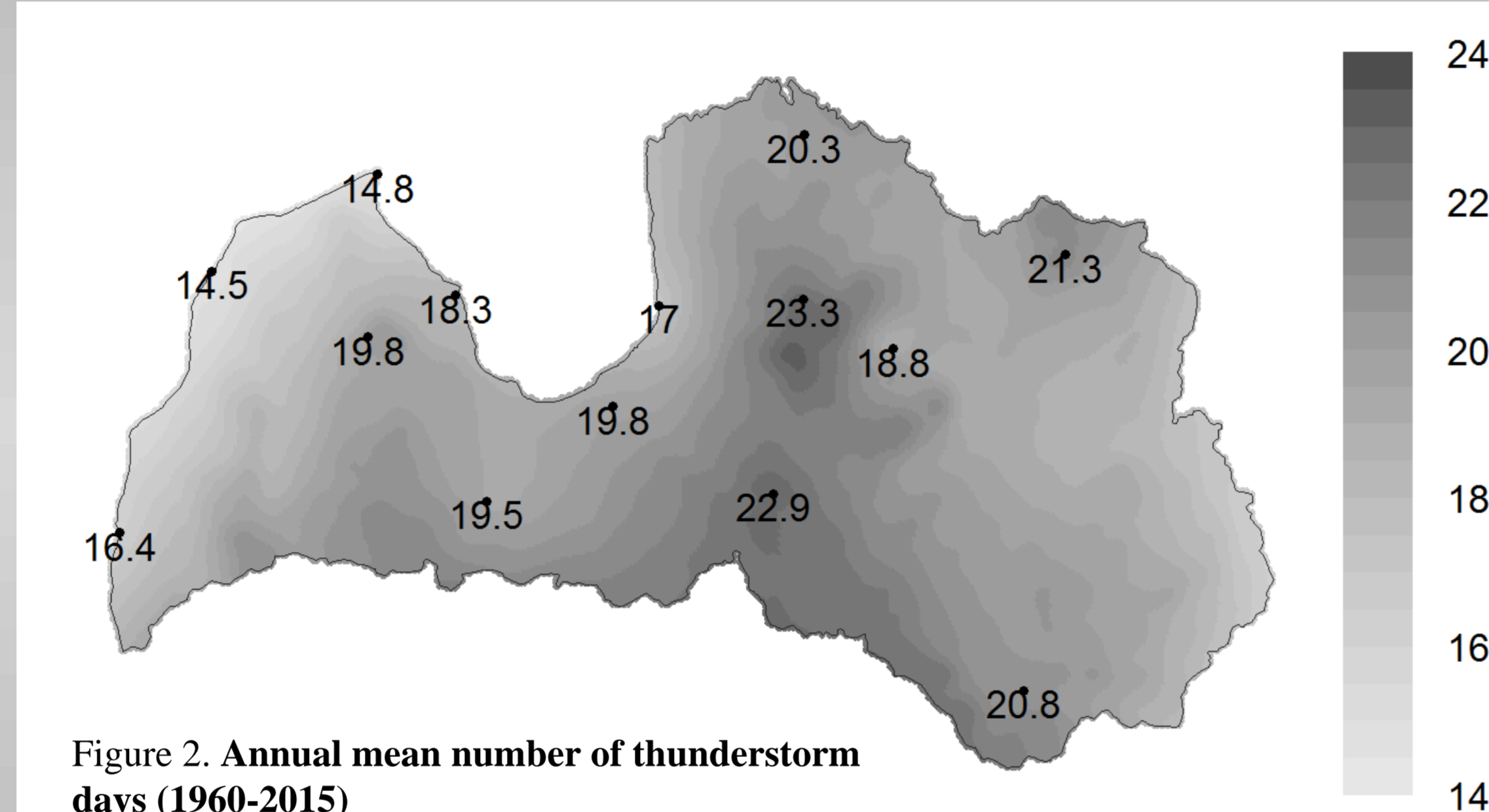


Figure 2. Annual mean number of thunderstorm days (1960-2015)

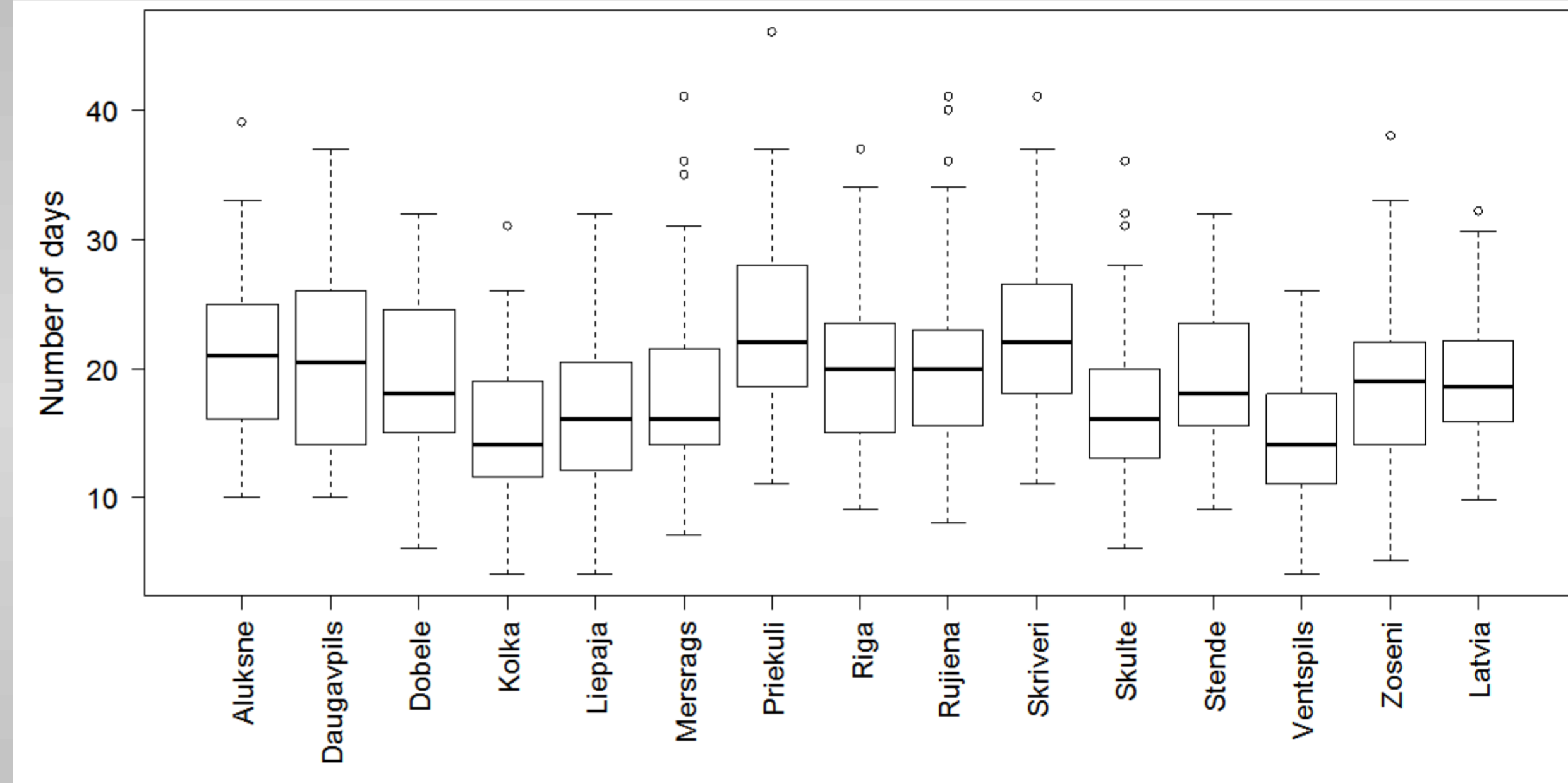


Figure 3. Variations in the annual number of thunderstorm days (1960-2015)

Table 1. National thunderstorm warning criteria and thunderstorm severity criteria used in this study

National thunderstorm warning criteria			
Thunderstorm warning level	Hail diameter	Precipitation accumulation during 12 h	Maximum wind gusts
Green	No hail	< 15 mm / 12 h	< 15 m s ⁻¹
Yellow	No hail or hail with diameter ≤ 5 mm	< 15 mm / 12 h	15-19 m s ⁻¹
Orange	Hail diameter 6-19 mm	15-49 mm / 12 h	20-24 m s ⁻¹
Red	Hail diameter ≥ 20 mm	≥ 50 mm / 12 h	≥ 25 m s ⁻¹
Thunderstorm severity criteria used for climatological analysis			
Thunderstorm severity level	Hail	Precipitation accumulation during 24 h	Maximum wind gusts
Green	No hail	< 15 mm / 24 h	< 15 m s ⁻¹
Yellow	Hail of any diameter	< 15 mm / 24 h	15-19 m s ⁻¹
Orange	Hail of any diameter	15-49 mm / 24 h	20-24 m s ⁻¹
Red	Hail of any diameter	≥ 50 mm / 24 h	≥ 25 m s ⁻¹

According to the national warning criteria of Latvia, hazardous weather phenomena associated with thunderstorms are the indicators of severe thunderstorms, and in most cases – 71 to 85% – no hazardous weather is observed during thunderstorm events in Latvia (Fig. 4). The yellow severity level is associated with wind gusts exceeding 15 m/s, while orange level identifies further increase in wind and precipitation amount of at least 15 mm/24 h. Thunderstorms of yellow and orange severity criteria are observed in Latvia 4 to 14% of the time, but the much rarer (0.2-1.7%) red level thunderstorms are associated with devastating winds and flooding.

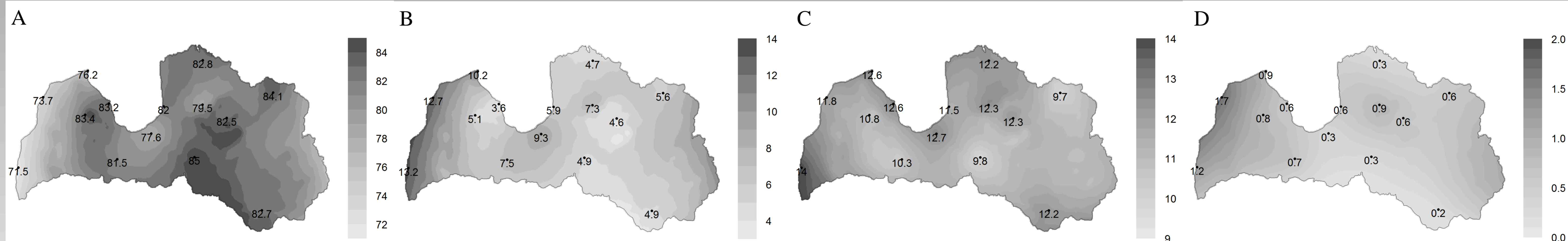


Figure 4. Fraction of thunderstorms (%) of green [A], yellow [B], orange [C] and red [D] level of severity in Latvia over the period 1966-2015

Table 2. Trends in the annual number of thunderstorm events, distribution of thunderstorm severity levels and occurrences of hail, heavy precipitation and wind gusts during thunderstorm events in Latvia over the period 1966-2015 (Mann-Kendall test statistics)

Parameter	Surface meteorological observation station														
	Al	Da	Do	Ko	Li	Me	Pr	Ri	Ru	Si	Sk	St	Ve	Zo	LV
Thunderstorm days	-2.03	-2.44	-0.03	-2.26	-0.11	-0.74	-1.50	-2.50	-2.48	-2.90	-3.38	-0.71	-0.77	-3.22	-2.16
Green warning level	-1.10	1.52	-2.56	-1.66	-0.33	-1.04	-3.21	-3.70	-1.95	-1.76	-0.99	0.28	-0.92	-0.16	-3.09
Yellow warning level	1.44	1.22	2.36	1.69	0.50	0.44	4.78	2.34	3.35	1.96	0.21	-0.27	0.72	1.47	3.54
Orange warning level	0.65	-2.55	1.32	0.32	0.29	0.67	0.41	3.01	-0.41	0.43	1.06	0.31	0.88	-0.45	1.03
Red warning level	1.86	-1.94	0.15	0.88	-0.53	2.43	-1.31	-0.99	-0.16	-0.11	-1.93	0.94	-0.61	-0.58	
Hail events	3.99	-1.48	-0.95	0.27	-0.91	2.95	1.31	-2.15	1.58	-0.02	-2.31	-0.95	0.27	0.06	0.36
Mean precipitation	1.65	-1.19	1.16	2.70	0.39	2.35	1.12	3.01	1.46	1.50	2.11	1.71	0.35	0.87	3.16
Maximum precipitation	0.56	-2.60	1.69	1.06	0.01	1.14	-0.25	0.09	0.57	-0.26	-0.52	1.05	-0.08	-1.47	0.50
Precipitation ≥ 15 mm	0.10	-1.57	1.56	0.43	0.51	1.31	-0.77	1.07	-0.70	-0.33	-0.11	0.57	0.75	-1.19	0.07
Precipitation ≥ 50 mm	0.73		-0.42	1.13	0.30	3.19		0.03		-1.65	2.36	-0.16	-0.14	-0.07	0.57
Mean wind gusts	5.00	0.59	5.60	3.94	-0.47	5.23	4.71	6.76	4.67	4.22	3.45	3.36	3.56	4.01	6.57
Maximum wind gusts	1.75	-1.62	3.96	0.03	-1.47	-0.03	1.21	3.24	1.45	1.22	0.44	-1.35	-1.25	1.47	1.26
Wind gusts 15-19 m s ⁻¹	1.47	-0.56	4.56	1.30	-0.25	0.71	4.12	4.31	2.48	1.48	0.83	-0.99	0.37	0.79	2.54
Wind gusts 20-24 m s ⁻¹	0.74	-3.64	2.32	0.04	-0.66	0.03	2.17	-0.02	0.34	-1.49	-2.29	-0.38	0.07	-0.90	
Wind gusts ≥ 25 m s ⁻¹	-0.66	-1.49	0.96	-0.79	-1.10		-1.05	-1.22		0.64		0.67	0.00	-1.09	

CONCLUSIONS

- The results of this analysis suggest that even though the frequency of thunderstorms in Latvia has been decreasing since the middle of the past century, a significant increase in thunderstorms accompanied by strong wind gusts has been observed. The increasing tendency is observed both for the mean and maximum wind speed and also the frequency of wind gusts of 15-24 m/s during thunderstorm days.
- Due to the observed increase in thunderstorm wind gusts, the overall frequency of yellow severity level thunderstorms has increased.