Observed trends in snow phenology and duration across Romania (1961 to 2020)

Vlad Amihăesei*, Dana Magdalena Micu**, Alexandru Dumitrescu** and Sorin Cheval**

** Alexandru Ioan Cuza University, Department of Geography, Iasi, Romania*
***National Meteorological Administration, Bucharest, Romania*

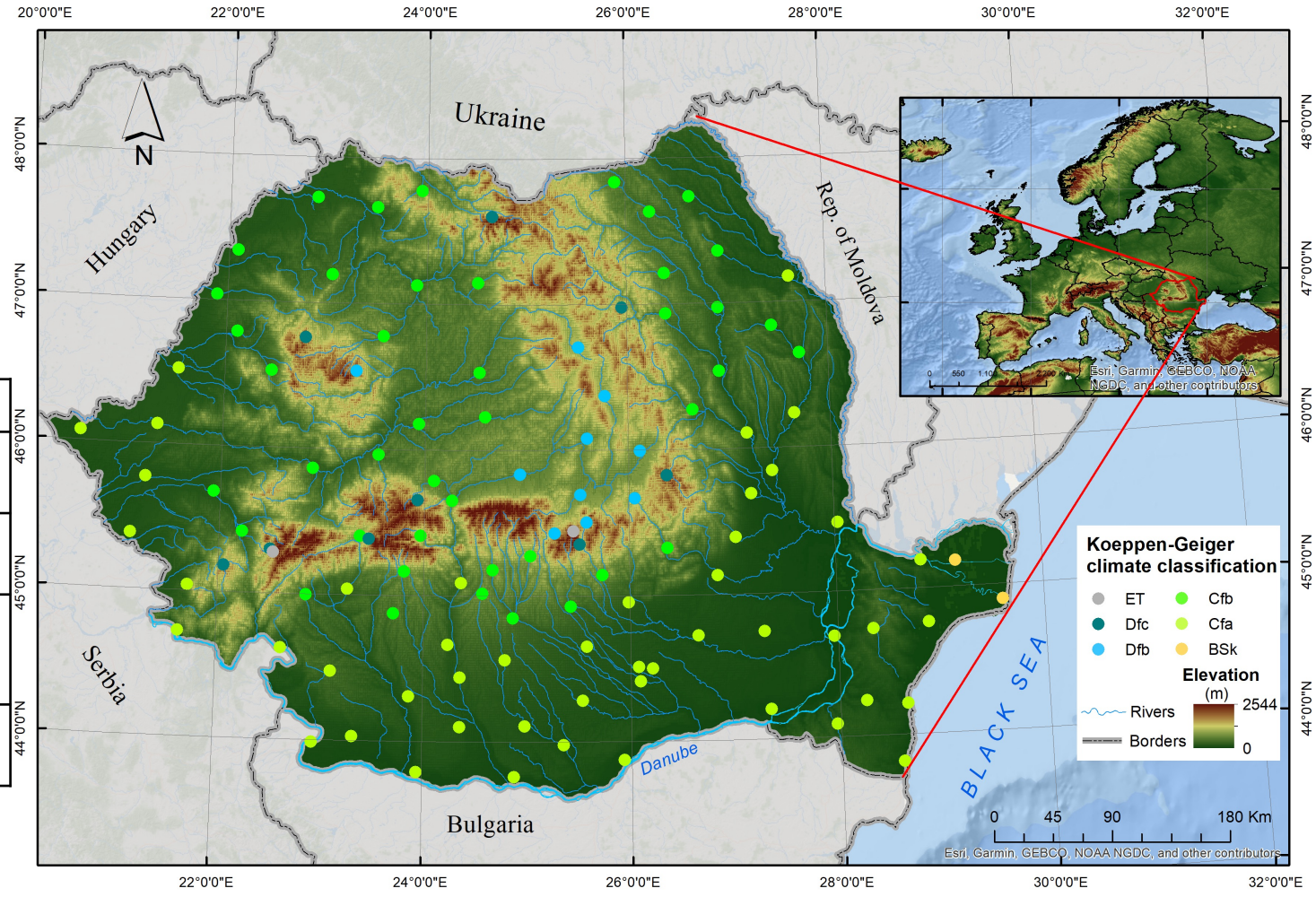
24 May 2022

Study Area

Name: Romania
No. of stations: 114
Spatial extend:
20.1 - 29.8°E și 43.5 - 48.4°N

Snow cover parameters used in the study

Variable	Description	Acronym
First snow cover day	Julian date of the first snow cover day in a snow year (the onset of the snow cover season)	FSC
Last snow cover day	Julian date of the last snow cover day in a snow year (the end of the snow cover season)	LSC
Snow cover duration	Number of days between the first and the last snow cover days. This period of time may include snow cover interruptions over the snow season	SCD
Maximum duration of continuous snow cover	Maximum number of days with a continuous snow depth ≥1 cm	SCDmax

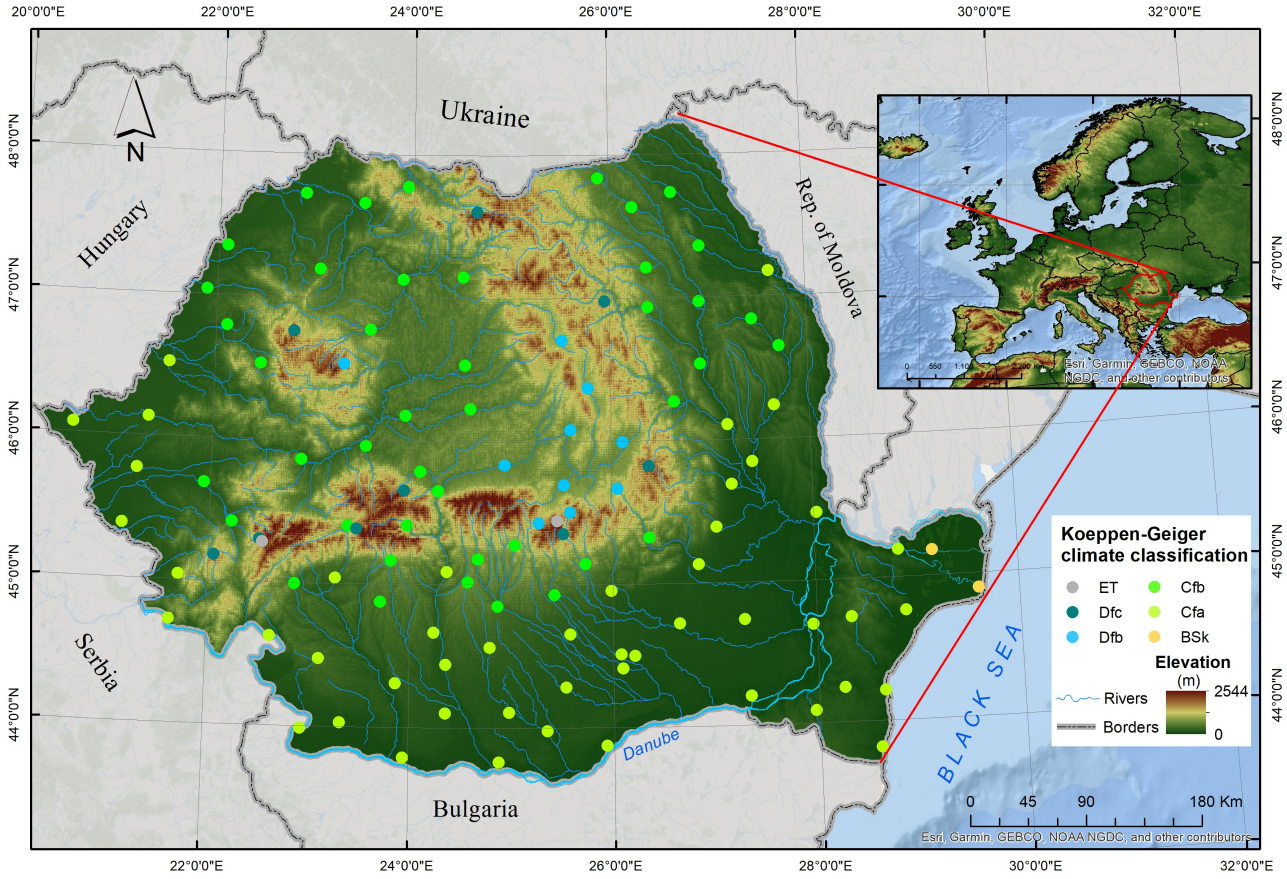


Source: National Meteorological Administration, Climate Data Base

Study Area

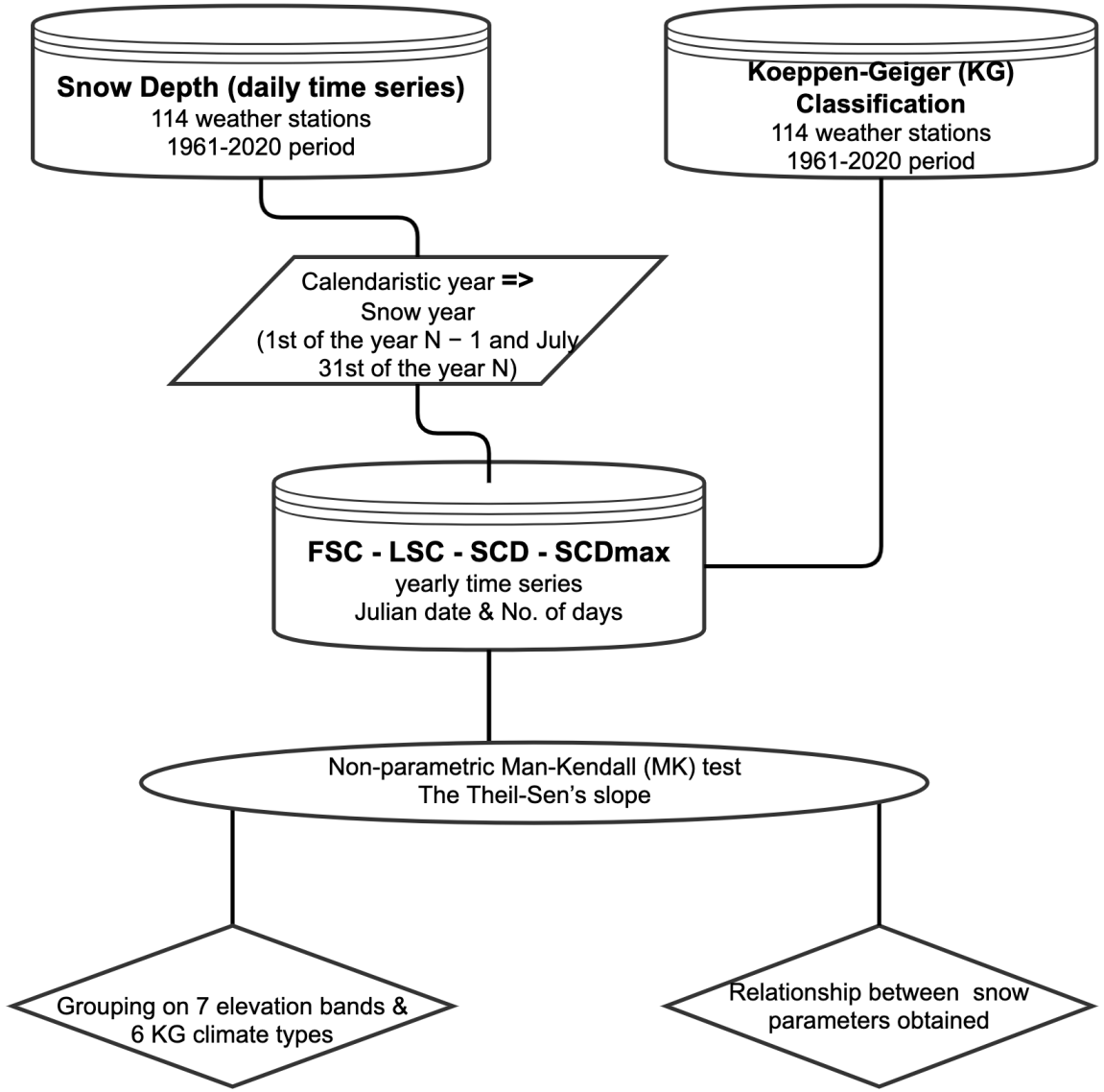
Distribution of weather stations providing long-term daily snow cover time series by Koeppen-Geiger climate types and elevation zones across Romania

Koeppen-Geiger climate regions	Elevation bands	Number of stations	Annual climate		
			Mean snow depth (cm)	Mean temperature (°C)	Mean precipitation (mm)
ET	> 2,500	1	45,4	-2,2	83,5
	2,001–2,500	1	34,7	-0,2	82,2
Dfc	1,501–2,000	6	22,9	2,3	83,1
	1,001–1,500	3	30,2	4,5	89,2
Dfb	1,001–1,500	3	16,6	5,0	75,7
	501–1,000	6	5,3	6,8	48,0
	< 500	1	4,0	8,2	52,6
Cfb	501–1,000	7	5,3	8,6	62,8
	< 500	36	3,8	9,6	53,4
Cfa	< 500	48	3,2	11,1	46,6
Bsk	< 500	2	1,2	11,4	29,9



Methods

Methodological workflow

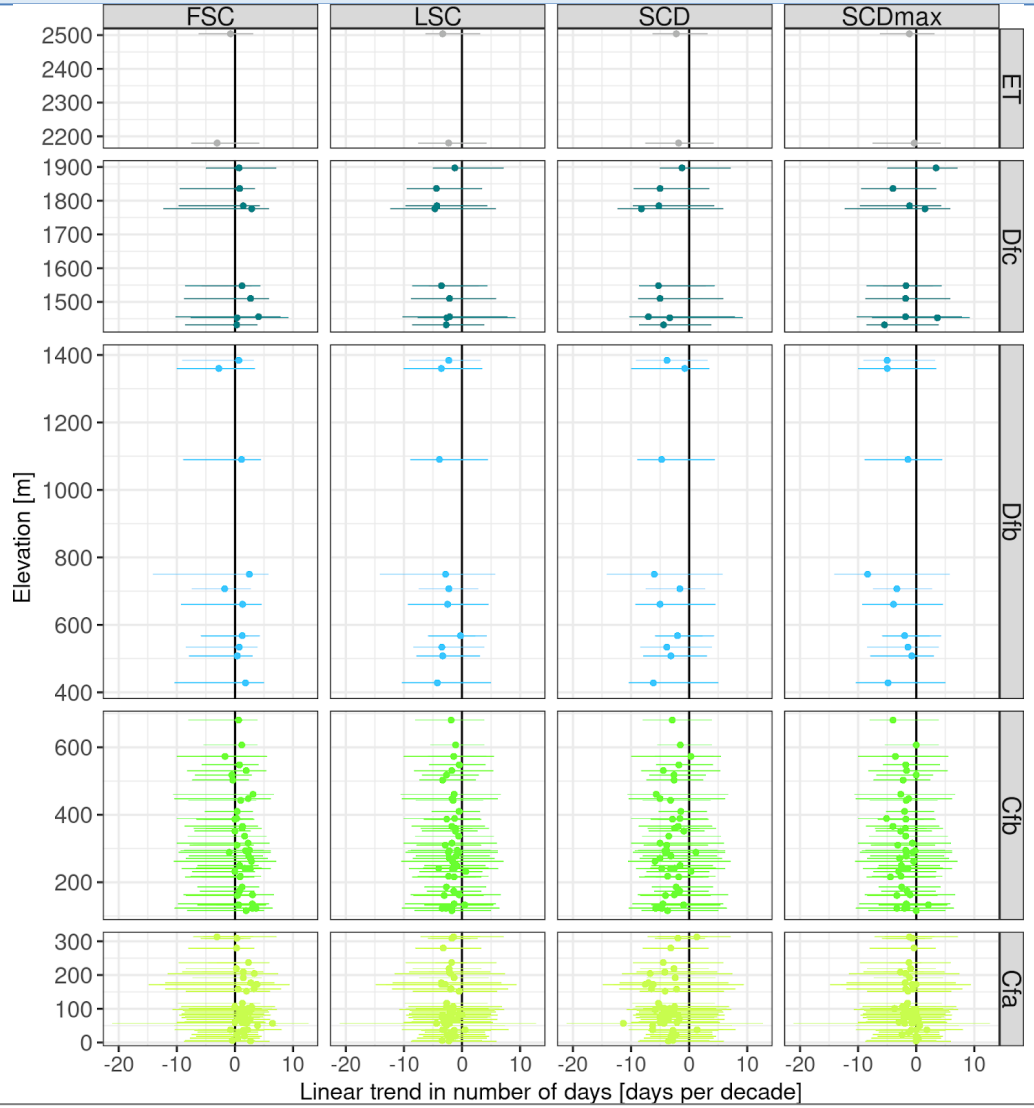


RESULTS

Trends in snow cover phenology and related parameters (FSC, LSC, SCD, SCDmax)

Long-term average trends (with minimum and maximum in parentheses) in snow phenology parameters (days decade) by climate regions of Romania. For comparison, different levels of statistical significance of trends are provided ($p < 0.001$***, < 0.01** and < 0.05*) and marked in **bold**

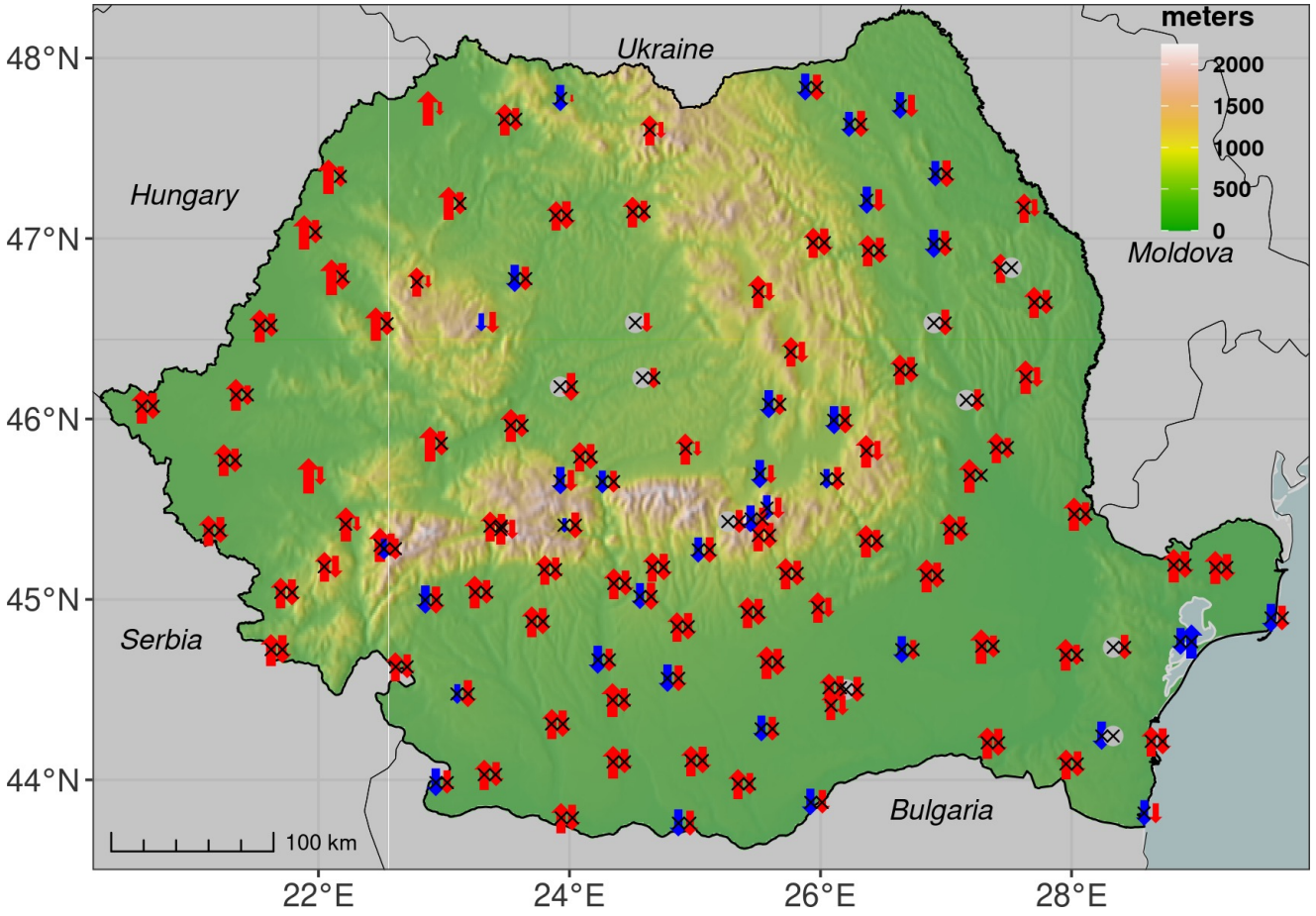
Climate regions	Elevation bands	FSC	LSC	SCD	SCDmax
ET	> 2,500 m	−0.75	**−3.33 ***	−2.22	−1.18
	2,001−2,500 m	−3.06	−2.31	−1.82	−0.33
Dfc	1,501−2,000 m	+1.63 (+0.71,+2.89)	−3.39 (−4.67, −1.25)	−4.99 (−8.21, −1.23)	−0.64 (−4.00, +3.39)
	1,001−1,500 m	+1.58 (+0.32, +4.07)	−2.49 * (−2.73,−2.14)	−4.91 *** (−7.00, −3.33)	−1.22 * (−5.46, +3.64)
Dfb	1,001−1,500 m	−0.32 (−2.78, +1.15)	−3.24 * (−3.89, −2.27)	−3.11 (−4.75, −0.77)	−3.81 (−5.00, −1.43)
	500−1,000 m	+0.36 (−1.77, +2.47)	−2.45 (−3.48, −0.27)	**−3.60 *** (−6.00, −1.60)	−3.30 * (−8.37, −0.77)
	≤ 500 m	+1.25	**−4.25 ****	**−6.15 ****	**−4.86 ****
Cfb	501−1,000 m	+0.27 (−0.53, +3.11)	−1.81 (−3.33, −0.47)	−2.21 (−4.44, +0.30)	−1.91 (−4.00, 0.00)
	≤ 500 m	+1.26 (−3.09, +3.33)	−1.62 (−4.00, +0.67)	−3.19 (−5.88, +1.18)	−1.99 (−5.11, +2.11)
Cfa	≤ 500 m	+1.81 (−0.74, +6.47)	−2.10 (−4.40, +0.53)	−3.93 (−11.33, +1.37)	−1.10 (−3.75, +1.81)
BSk	≤ 500 m	+0.56 (−0.46, +1.58)	**−3.11*** (−3.52, +2.71)	−3.3 (−3.54, −3.06)	No trends



Vertical distribution of trends in first (FSC) and the last snow snow cover day (LSC), snow cover duration (SCD) and the maximum duration of continuous snow cover (SCDmax) for each Koeppen-Geiger climate type of Romania. Each point represents one weather station and the horizontal lines depict the associated 95% confidence interval.

RESULTS

Trends in snow cover phenology and related parameters (FSC, LSC, SCD, SCDmax)



Spatial trends in snow cover onset (left arrow) and snow cover melting (right arrow) over the 1961-2020 period. The red/blue colours of the symbols show a delaying/advancing trend in the snow cover onset/melting, the grey circles show no trend, whereas the "x"-sign overlapping the symbols depicts the cases with no statistically significant trends ($p > 0.05$).

FSC - First snow cover day (the left narrows)

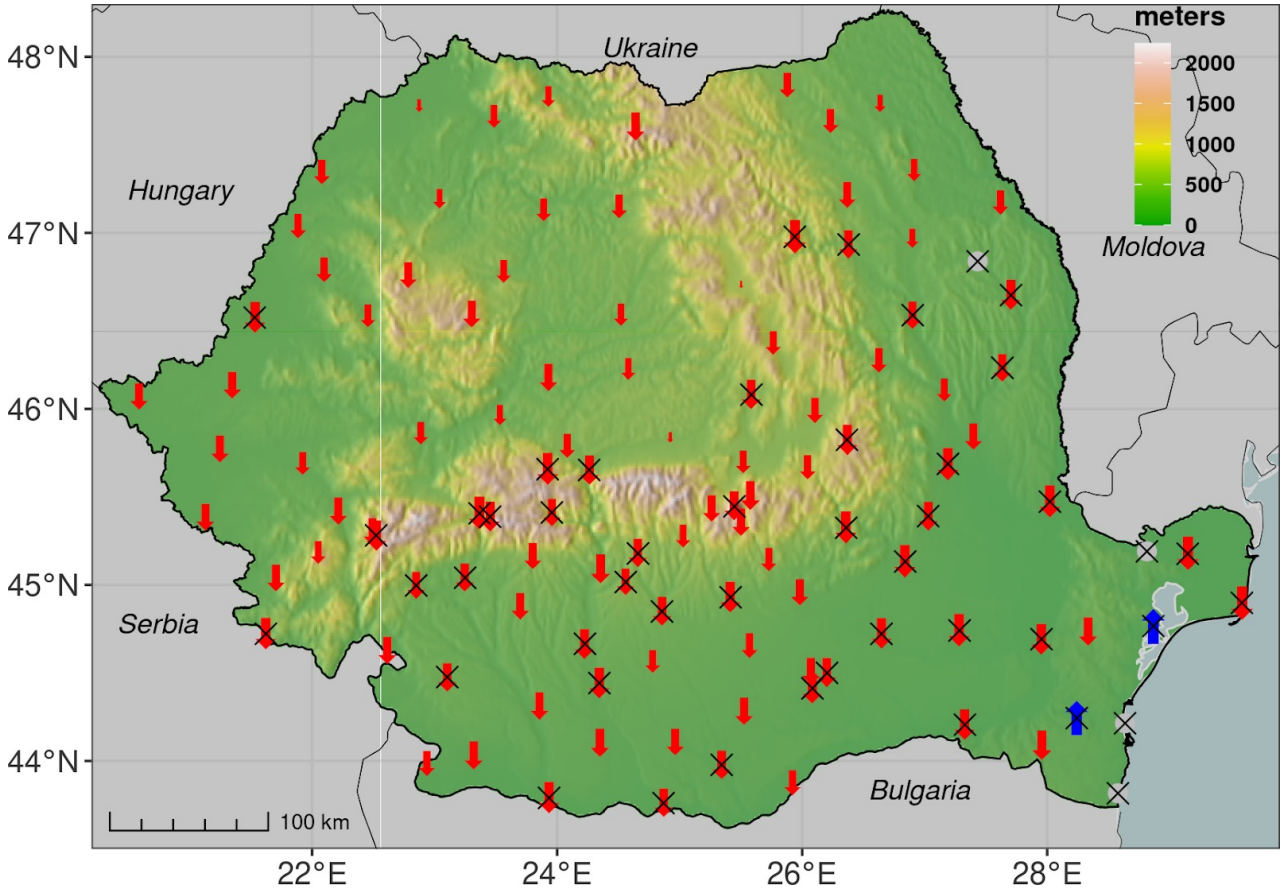
- ✓ the positive trends are dominant indicating a later onset of snow cover in the season throughout most of the country (85% of stations);
- ✓ the statistically significant trends hold only 7% of cases;
- ✓ the positive temporal shift of FSC has different rates across the country, slower in the highlands with 4 days decade^{-1}, and faster in the lowlands with about 7 days decade^{-1}

LSC - Last snow cover day (the right narrows)

- ✓ dominant negative LSC trends (96% of stations);
- ✓ the statistically significant trends hold only 21% of cases mostly located below 500 m;
- ✓ The last snow cover day tends to occur slightly earlier with up to 3-4 days decade^{-1} in the areas above 2,500 m and below 500 m.

RESULTS

Trends in snow cover phenology and related parameters (FSC, LSC, SCD, SCDmax)



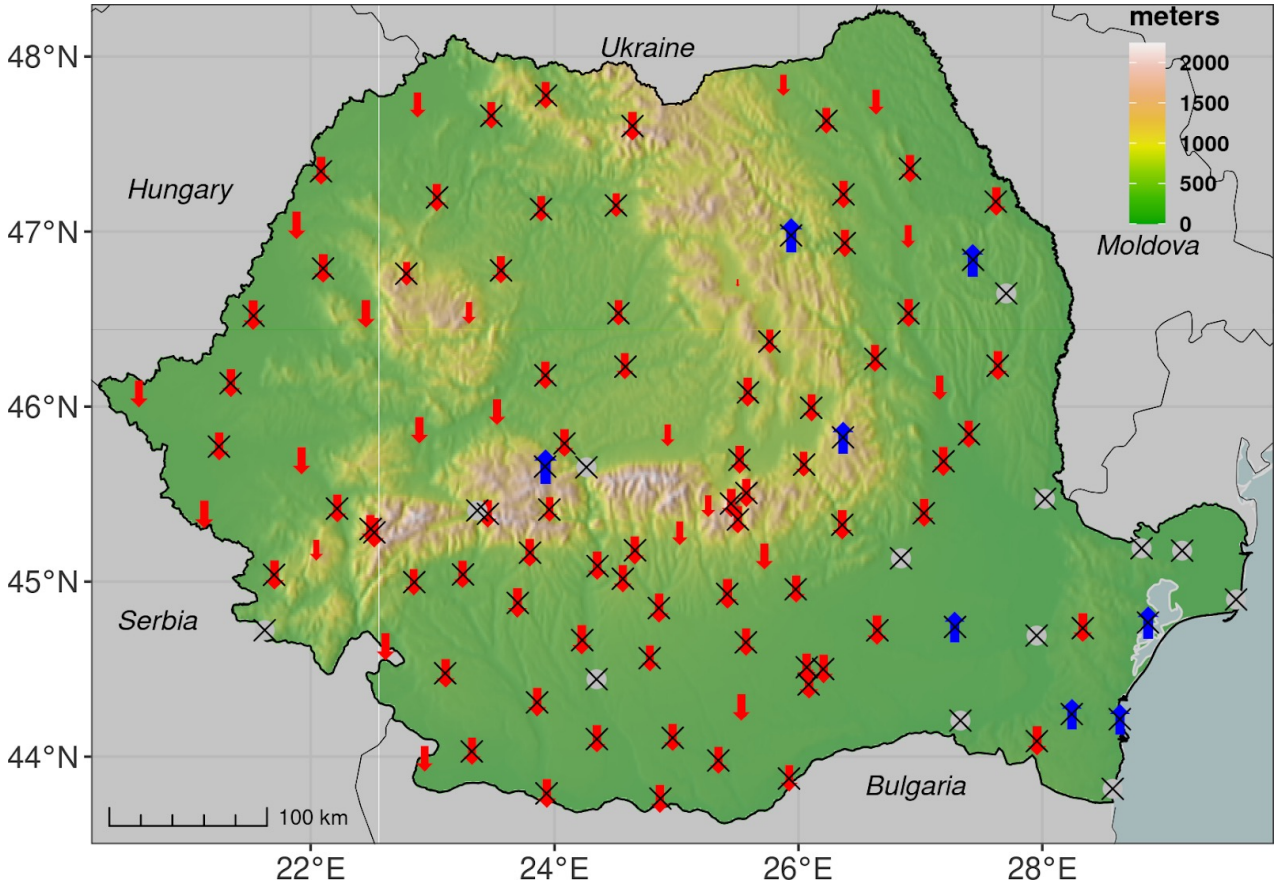
Trends in snow cover duration (SCD). The red/blue filled arrow shows a decreasing/increasing trend, whereas the circle indicates no trend cases. The x-sign depicts the cases with no statistically significant trends ($p > 0.05$).

SCD (Snow cover duration)

- ✓ a widespread decline across Romania, with significant changes at 28% of stations, mostly present in the plain, hilly and tableland areas of central, western and north-eastern parts of the country
- ✓ shows the most significant declines in the mid and mid-to-high mountain areas of 1,000–2,000 m (Dfc climate)

RESULTS

Trends in snow cover phenology and related parameters (FSC, LSC, SCD, SCDmax)



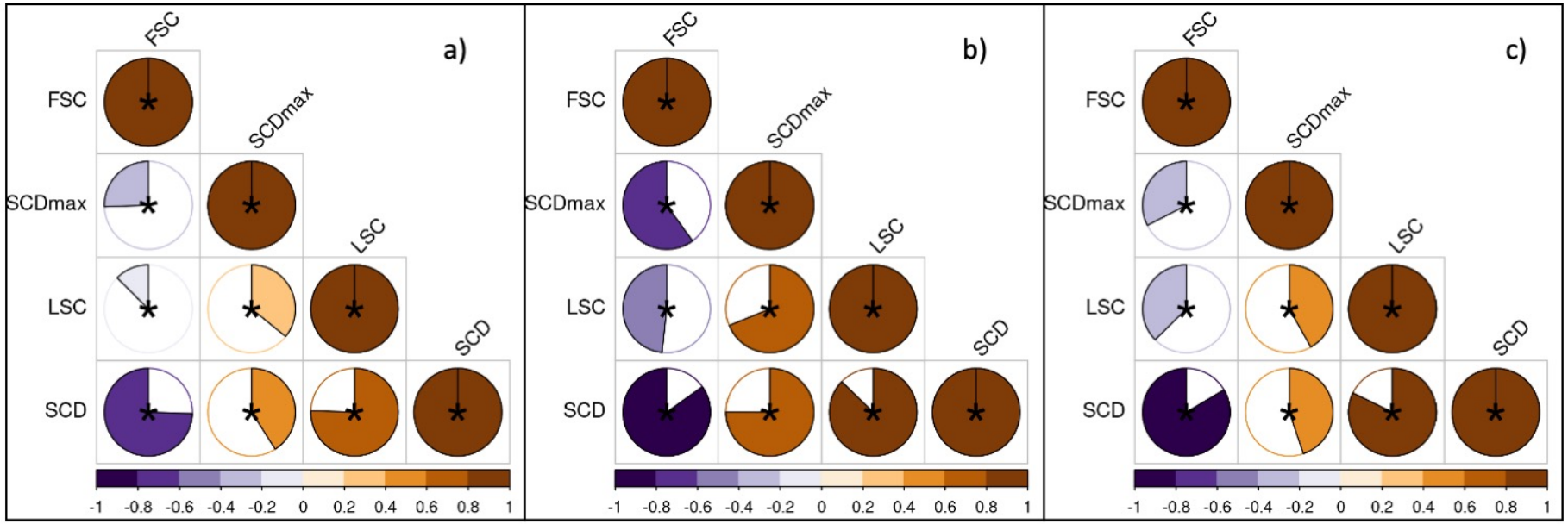
Trends in snow cover maximum duration (SCDmax). The red/blue filled arrow shows a decreasing/increasing trend, whereas the circle indicates no trend cases. The x-sign depicts the cases with no statistically significant trends ($p > 0.05$).

SCDmax (Snow cover maximum duration)

- ✓ trends are mostly negative (about 82% of stations), with a share of statistically significant cases of 20 %, mostly distributed in the lowland areas of the country (below 1,000 m);
- ✓ shows a visible decline across the country;
- ✓ exceptionally high declines were found in the south-western lowlands with the Cfa climate.

RESULTS

The relationship between SCD, SCDmax and FSC and LSC parameter



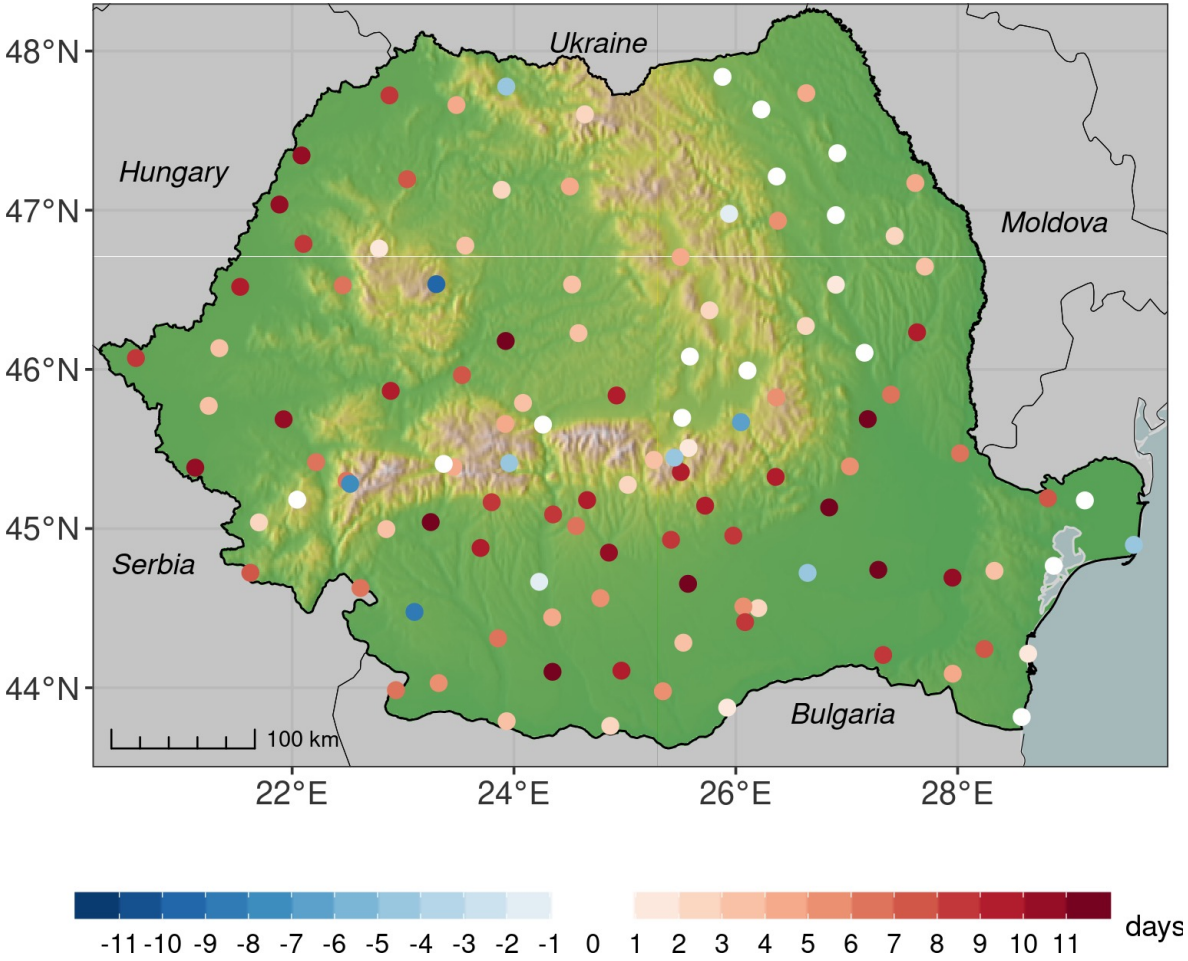
The Pearson's correlations between SCD, FSC, LSC and SCDmax for stations having elevation <= 1000 m (a), all stations (b) and > 1000 m (c) " *" sign shows significant trend ($p < 0.01$).

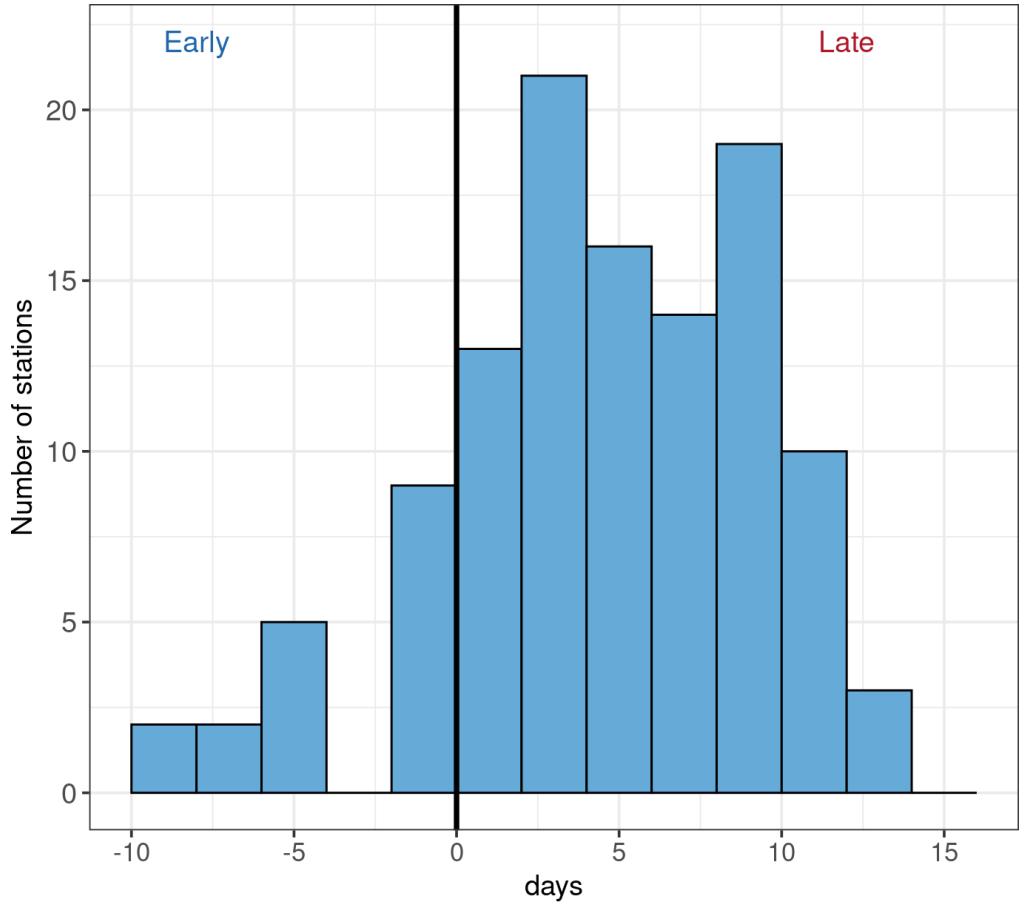
- ✓ The SCD variability is largely significantly explained by the variations in both FSC (negative correlation, r = 0.84, $p<0.05$) and LSC (positive correlation, r = 0.87, $p<0.05$), with stronger relationships generally observed in the mountains

RESULTS

1991-2020 vs 1961-1990 (FSC, LSC, SCD)

First snow cover day	Julian date of the first snow cover day in a snow year (the onset of the snow cover season)	FSC



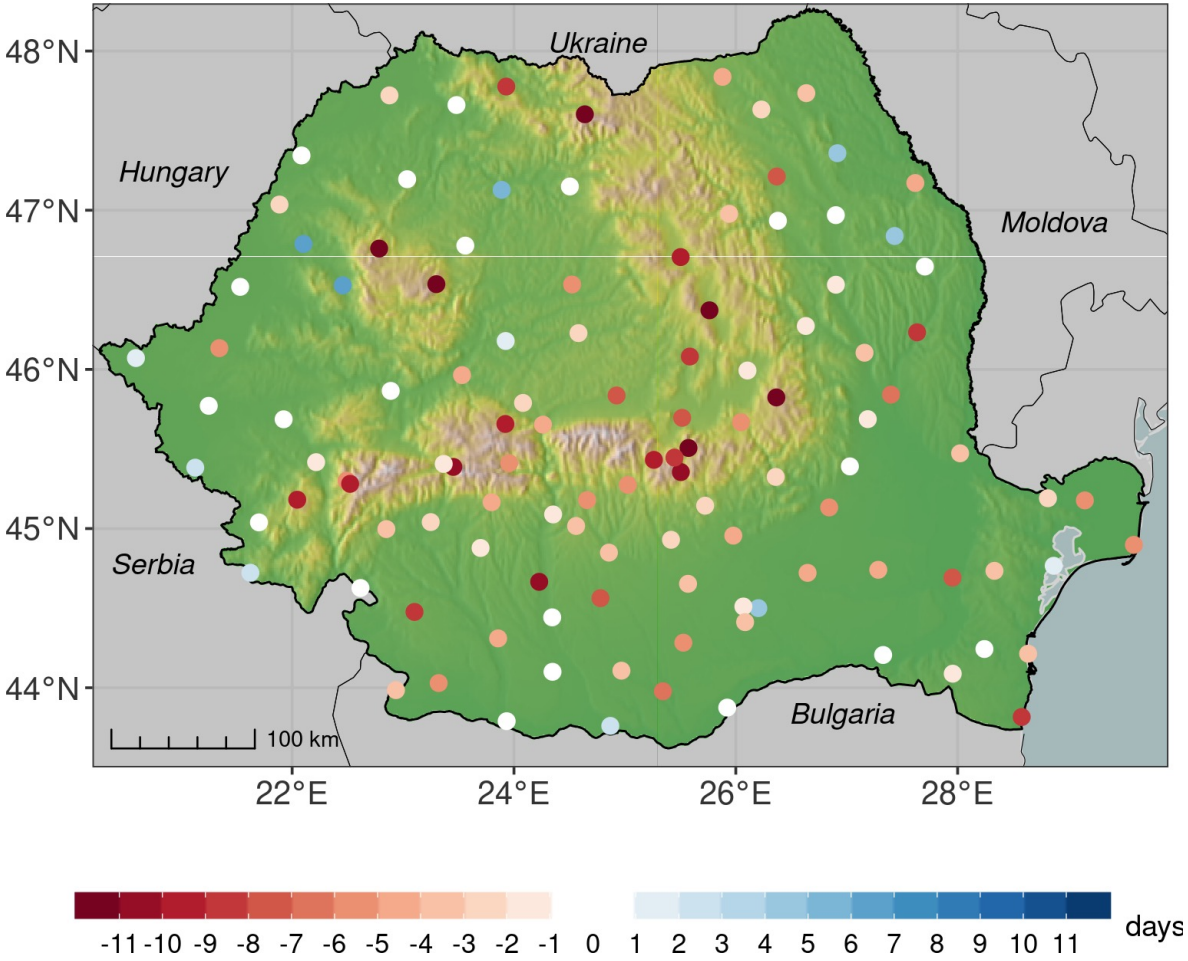


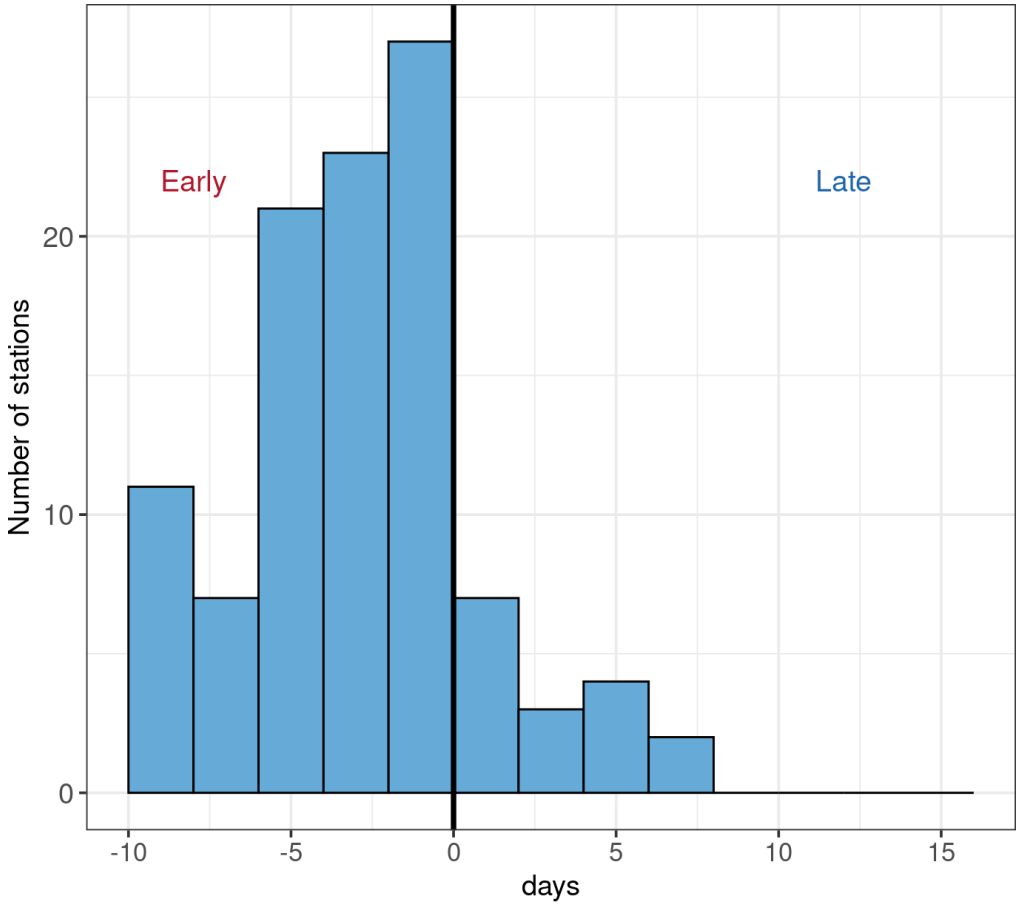
Differences between 1991-2020 and 1961-1990 period in FSC, LSc and SCD

RESULTS

1991-2020 vs 1961-1990 (FSC, LSC, SCD)

Last snow cover day	Julian date of the last snow cover day in a snow year (the end of the snow cover season)	LSC



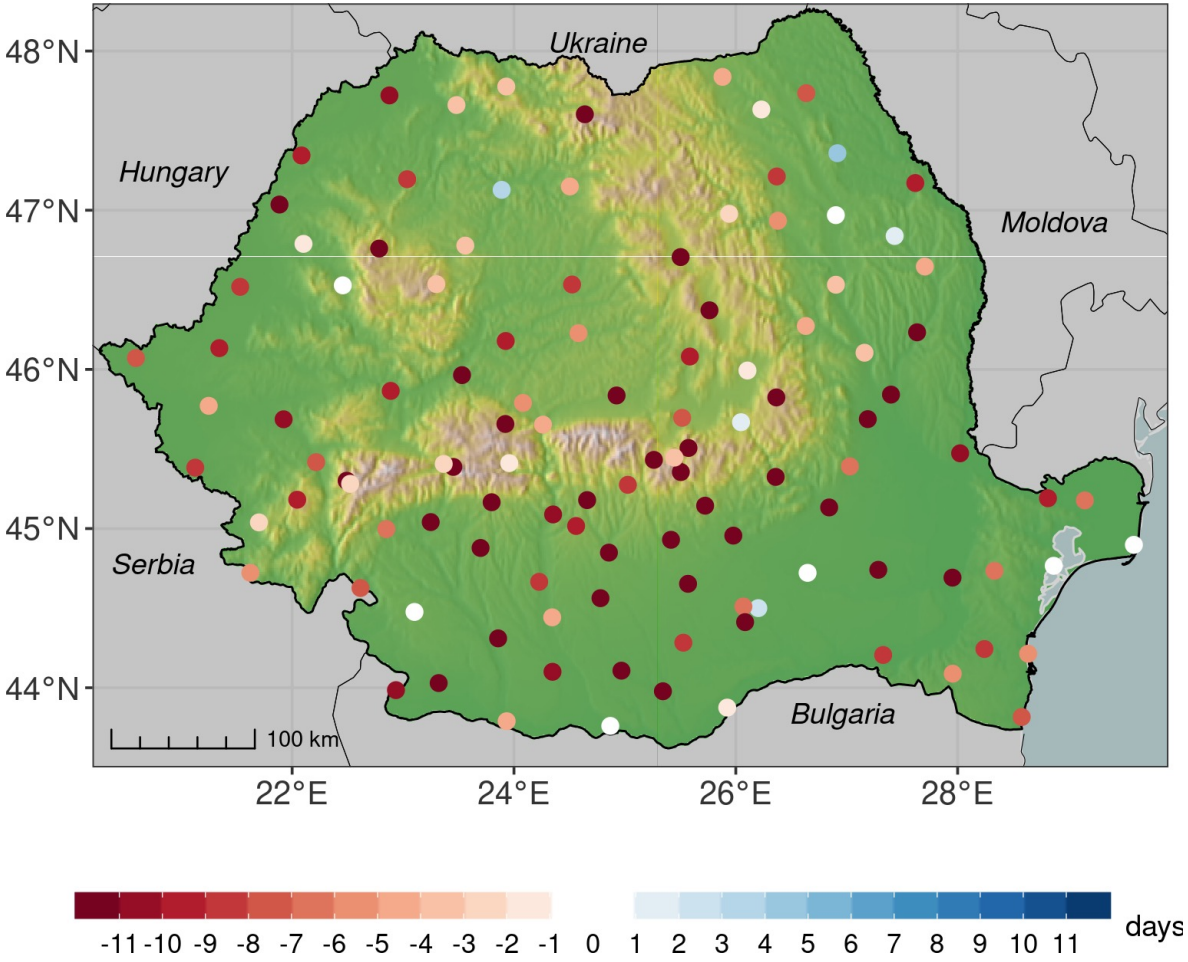


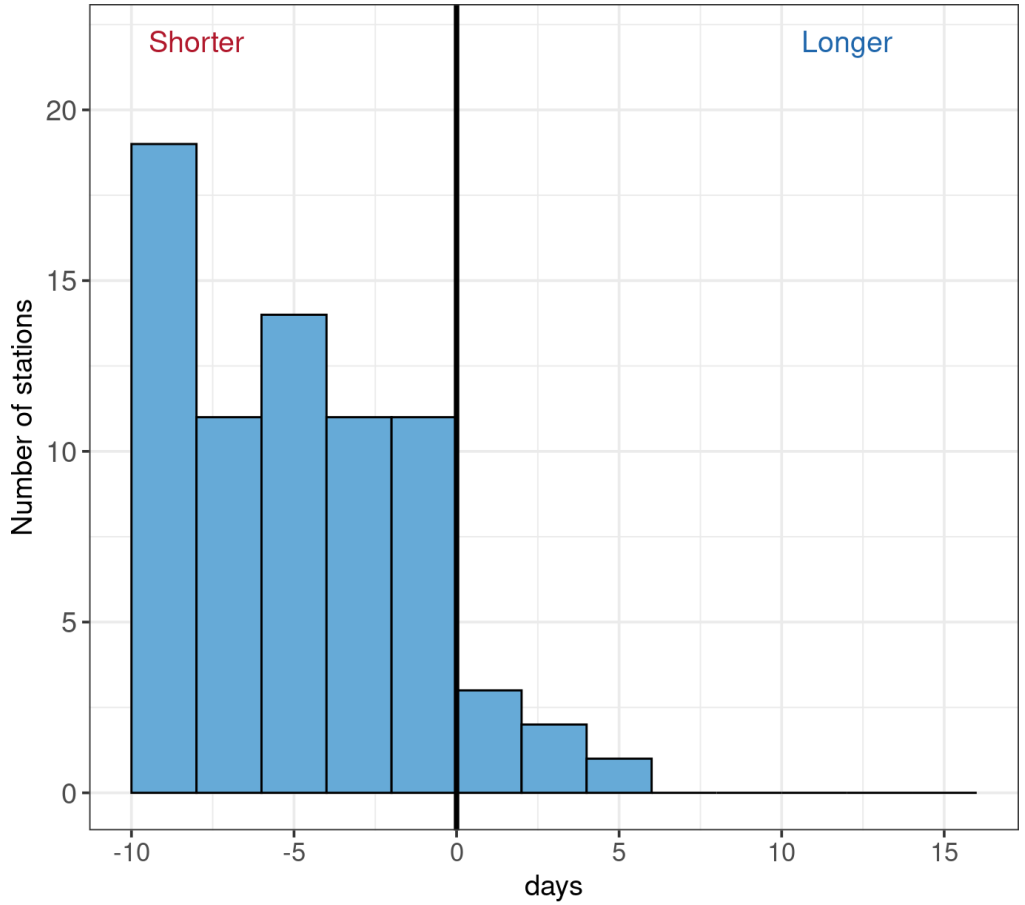
Differences between 1991-2020 and 1961-1990 period in FSC, LSc and SCD

RESULTS

1991-2020 vs 1961-1990 (FSC, LSC, SCD)

Snow cover duration	Number of days between the first and the last snow cover days. This period of time may include snow cover interruptions over the snow season	SCD





Differences between 1991-2020 and 1961-1990 period in FSC, LSC and SCD variables

Conclusions

- ✓ The climate is getting warmer but the process is less faster at high mountain sites (above 1,500-2,000 m) than in the adjacent lowlands;
- ✓ There is no consistent elevation-dependent change profile in snow phenology and duration across Romania, as the rates can both increase or decrease with elevation;
- ✓ Observations provide solid evidence of a changing snow cover phenology with direct effects on the duration of snow cover season in general and of the continuous snow cover in particular;
- ✓ The date of the first snow cover days was found to advance towards winter especially in the areas bellow 1500 meters;
- ✓ The snow cover season declines on long-term is mainly caused by earlier last snow cover dates rather than by later first snow cover throughout most of the country;
- ✓ Topography (elevation) was found to play a role in the snow cover trends over narrow elevation bands with some distinct climate regions of the country (e.g. ET).

Further research

- ➢ Linked the trend results to the atmospheric circulation;
- ➢ Correlation with temperature and precipitation trend, as key controlling factors of both snow accumulation and ablation processes and their timing.

Thank you for your attention!