How to cite: Brâncuș M., Burada C., Velea L., Drîgă F. (2024) Changes in Cold Indices in the Recent Past in Dolj County, Romania. *2024 "Air and Water – Components of the Environment" Conference Proceedings*, Cluj-Napoca, Romania, p. 161-170, DOI: 10.24193/AWC2024_15.

CHANGES IN COLD INDICES IN THE RECENT PAST IN DOLJ COUNTY, ROMANIA

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DOI: 10.24193/AWC2024_15

ABSTRACT. Changes in Cold Indices in the Recent Past in Dolj County, Romania. Socio-economic activity during cold season depends on a large degree by the air temperature and, in some cases, also on ground temperatures. In this context, the present study focused on two cold-season indices with practical applications, namely number of frost days (i.e., with minimum air temperature equal or below 0 °C) and number of frozen soil days (i.e., within minimum ground temperature equal or below 0 °C). The aim of the study was twofold: firstly, to investigate the observed changes of these indices in the last years; secondly, to assess the performance of alternative data sources for deriving information targeting specific beneficiaries of this climate-based information. The analysis concentrated on the area of Dolj county for the period October-April 2011-2022 and three data sources were used: observation data from weather stations, UERRA reanalysis dataset and E-OBS observation-based dataset. The results showed that for both indices the trend was negative. With low values of FD and FSD, autumn was a more favorable period for various activities than the early spring, whereas winter months were mostly unfavorable for outdoor activities. Thus, the study provided useful information for various end-users (*e.g.*, in agriculture, construction sector) for better planning their activities.

Keywords: frost days, frozen soil days, observations, reanalysis data, Romania

1. INTRODUCTION

In the cold season negative temperatures, both the air temperature and the ground level one influence many socio-economical activities like agriculture, construction, transport and tourism. Since 1950, for Europe there was an increase of mean and maximum temperatures, frequencies of warm days and nights or heatwaves, whereas the corresponding cold indices have decreased (IPCC, 2022; Ranasinghe et al. 2021; Seneviratne et al., 2021). In Romania, in the 1961-2000 period, the smallest annual average number of frost days was recorded on the coast of the Black Sea and plain region of south-western Romania (ANM, 2008). For the Oltenia region, the same study showed that the annual average number of frost days ranged between 90 days

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in the southern half and 120 days in the northern half, except for the mountain area, where the number increases up to 150-200 days at the highest altitudes. But, in the last 20 years, these numbers could have changed by decrease.

Changes in the monthly number of days with negative temperatures can have positive effects for some activities, but negative for others. For example, tourism and agriculture sectors can be affected when positive temperature prevails in winter time (lack of snow cover). In a future warmer climate, half of the former Winter Olympic host cities could be unable to sponsor winter games by 2050, due to a lack of snow and ice (Scott et al. 2023). When frost periods are abruptly interrupted by high temperatures, crop development can be affected, making prematurely developed plant vulnerable to frost from cold spells (Green Report, 2023). In contrast, for construction sector it can represent a much-needed period to finish the started projects. Also, when temperature at the ground level is negative, the risk of traffic accidents due to black ice or freezing rain increases. Thus, stakeholders can plan much better their future activities if they have information, such as in what month the number of frost days or frozen soil days is the largest or what are the rates of these indices in every month of the cold season. Such information can contribute to maximization of their profits and minimization of losses. However, observation data is limited because the sparce weather-station network, and thus additional data, like reanalysis, can be used. The question is: "Are these datasets reliable for local-scale analyses?" To answer this question, first the evolution of frost and frozen soil indices in the recent past will be analyzed and then a comparison between observation data and two other datasets will be made in order to assess the performances of these alternative datasets in describing the selected indices for applications targeting stakeholders' needs.

The article continues with the description of the used datasets in section 2. In section 3 the evolution of the frost and frozen soil indices recorded at the weather stations from Dolj county are analyzed and the comparison between datasets is made. Section 4 contains the most important findings of this article.

2. DATA AND METHODS

Frost day is defined as a day with the minimum temperature (*i.e.*, 2 m temperature) equal to or less than 0ºC (WMO, 1992 F1470). Frozen soil day is defined as a day when the soil temperature is equal to or less than 0ºC, containing some ice and water vapor but no liquid water (WMO, 1992 F1570).

The study employs three sources of data. The observational data from the National Meteorological Administration in Romania (ANM) database is used as reference. The dataset consists of daily 2 m minimum temperature and the soil surface (ground) minimum temperature for extended cold season (October-April) during 2011-2022 period. The study employs data from 4 weather stations (Craiova, Băilești, Bechet and Calafat) located in Dolj county, southwestern Romania (Fig.1).

The second dataset used is provided by the regional reanalysis dataset UERRA, freely available from Copernicus Data Store (CDS) (https://cds.climate.copernicus.eu). The data has a spatial resolution of 11km x11km and it is available at 00:00 UTC, 06:00 UTC, 12:00 UTC and 18:00 UTC for the period January 1961 - July 2019.

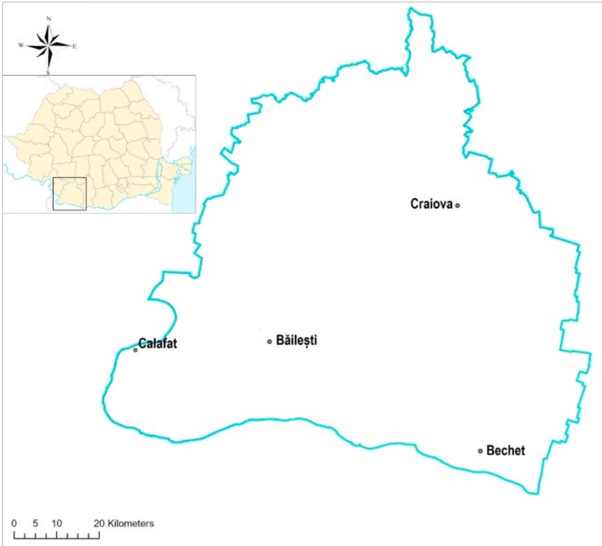

Figure 1. Location of the four meteorological stations (Băilești, Bechet, Calafat, Craiova) from Dolj county used in the study.

For the study, the air temperature at 2m (T2m) and skin temperature (Tskin) from UERRA-HARMONIE dataset, representing instantaneous values at 06:00 UTC, for the period October-April 2011-2018 are used. According to the dataset description (https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-uerra-europe-single-levels?tab=overview) skin temperature represents "Boundary temperature in grid cells between the ground and water surfaces and the atmosphere above", thus being similar to the measurements realized at the meteorological stations.

The third dataset is provided by "E-OBS daily gridded meteorological data for Europe from 1950 to present derived from in-situ observations" (denoted in the study as E-OBS), also available from CDS. It is based on blended time series from the station network of the European Climate Assessment & Dataset (ECA&D) project, provided by the European National Meteorological and Hydrological Services (NMHSs) or other data holding institutions. The dataset has a spatial resolution of 0.1x0.1° and a daily frequency of the data. It contains only atmospheric variables, therefore data on soil surface temperature are not included. Timeseries of daily minimum temperature (Tmin) were used in this study.

In order to compare data from UERRA and E-OBS with observed data from ANM, timeseries of relevant parameters were extracted from the closest gridpoints to the four meteorological stations, the distance between the gridpoint and the station location being in the range 1-5 km (Table 1).

Table 1. ***Distances from the gridpoints in UERRA and E-OBS datasets to the selected weather stations.***

Station	Latitude (station)	Longitude (station)	Distance to closest gridpoint UERRA [km]	Distance to closest gridpoint E-OBS [km]
Craiova	44.310	23.867	4.28	4.61
Băilești	44.029	23.331	1.12	2.75
Bechet	43.789	23.944	4.62	4.46
Calafat	43.985	22.946	3.39	3.92

The timeseries are further used to compute at monthly scale the indices of interest defined as follows:

- Frost Days (FD) represents the monthly number of days with minimum air temperature ≤ 0°C. At the weather stations, this parameter is the minimum temperature during 18-06 UTC interval and reported at 06 UTC. In the case of UERRA dataset, this parameter is not available; the instantaneous value of air temperature at 06:00 UTC is instead used for the computation of the index, which corresponds to the minimum value between those provided in the dataset for each day. Given the difference in the meaning of the two parameters (daily minimum and instantaneous value at 06:00 UTC), differences in the index values derived based on these parameters are expected. The magnitude of these differences is of interest in the context of the study, as they may provide insights on the usefulness of using UERRA dataset for deriving user-oriented information on Frost Days.
- Frozen Soil Days (FSD) represent the monthly number of days with minimum values of soil surface (ground) less or equal to ≤ 0°C. At meteorological stations, this parameter is reported based on observations at 06:00 UTC. Therefore, the use of skin temperature at 06:00 UTC from UERRA is in line with the observations, allowing the comparison between the two datasets.

Following the objectives of the study, the analysis involves trends in the timeseries to emphasize the changes in the selected indices over the analyzed period, as well as correlations between the information derived from the three datasets.

3. RESULTS

For the 2011-2022 analyzed interval it resulted that the cold-season of 2011-2012 was the coldest period when almost for all weather stations (except for Calafat) FD represented at least half of cold-season number of days (Fig. 2). The monthly and seasonal variation of FD was large, but December and January were the months with the highest monthly average for all weather stations Fig. 2 and Fig. 3 c, d).

For Craiova weather station, the maximum FD was in January 2017, when for the entire month air temperature was below freezing level (Fig. 2a). It is worth noting that, in March 2022 FD had the highest value for this month in the entire interval (22 days), the monthly mean being of 9 days (Fig. 3f). The trends were negative in all three datasets, similar for observation and E-OBS and more accentuated for UERRA. The mean number of seasonal FD was 75 days, meaning 35% of a cold-season. Comparing the autumn months with those from the beginning of spring, it resulted that with smaller FD values in autumn, socio-economical activities are not influenced significantly (Fig. 3a, b, f, g). The correlation was much better between E-OBS (mean bias 0.04) and station observations than UERRA and station (-1.05), but these results were expected due to the different ways of calculating the indices (Fig. 3h).

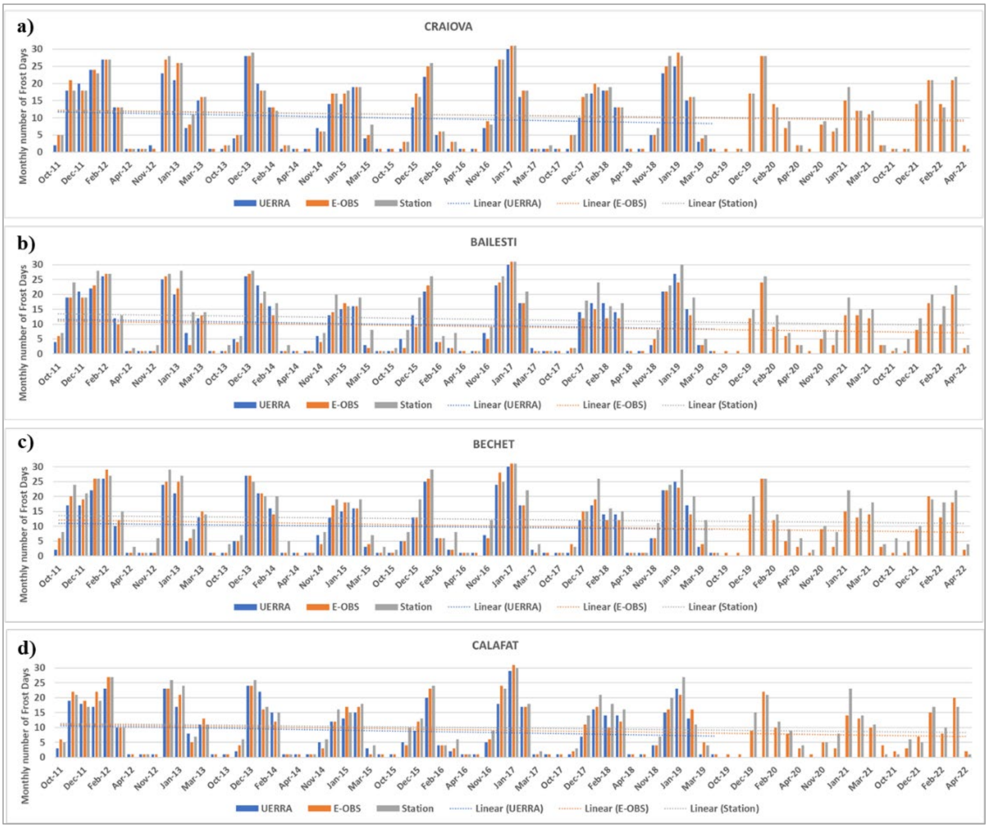

Figure 2. Monthly number of frost days in the cold season 2011-2022 (observation and E-OBS datasets) and 2011-2019 for UERRA dataset.

For Băilești weather station, the multiannual variability was high, but the trend was clearly negative for all three datasets, URRA and E-OBS being similar (Fig. 2b). The maximum FD was in January 2017 (31 days), but January 2019 was very close (30 days). October and April can be considered to have been favorable months for agriculture, construction and transport sectors because FD had, on average, 1-2 days (Fig 5h). Comparing November to March, only for the latter, during a third of the month there were temperatures below 0°C (Fig. 3b, f), resulting in some influences in different activities. There was a similar estimation for reanalysis datasets (UERR-E-OBS, 0.50), but the mean bias between the first two and observation data was less than -2 for both of them, meaning that the reanalysis underestimated the FD (Fig. 3h).

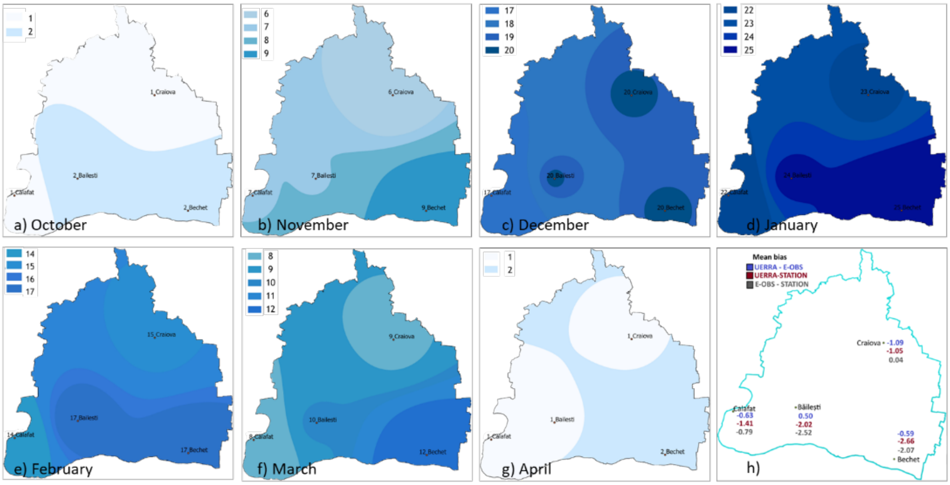

Figure 3. a)-g) Monthly mean of FSD at the weather stations from Dolj county during the cold season 2011-2022 and h) the mean bias of UERRA, E-OBS and station observation datasets.

Bechet was the station for which FD had values larger than or equal to 25 days for 10 months, with a maximum in January 2017 (Fig. 2c). Like Craiova and Băilești, FD had in March 2022 for Bechet station the largest monthly value. For the analyzed period, trend was decreasing, but at a smaller rate than the first two, a possible explanation being that Bechet is the station which records the smallest minimum temperatures during a cold air advection. The seasonal mean number was 86 days, resulting in the highest rate (41% of cold-season days, Fig 3a-g). The mean bias values showed a better correlation between reanalysis datasets and E-OBS and station observation (Fig. 3h).

Having a warmer climate due to Danube proximity, Calafat station had the smallest seasonal mean number of FD (69 days, Fig. 3a-g). Maximum FD was also in January 2017 (30 days), but for March, the largest value was in 2018 (Fig. 2d). The trend was slightly negative for all datasets. The E-OBS data frequently exceeded the observation data, different from the other stations. For this station, the mean bias had a value close to zero for E-OBS and observation, better than for Băilești and Bechet (Fig. 3h). This result could be also because this station is much closer to an international weather station (Vidin, Bulgaria), whose data are included in databases used for reanalysis, and, thus, interpolation is not so big.

Frozen soil days index (FSD) was available to calculate only in the UERRA dataset, thus comparation ends in 2019 and only station observations were plotted until 2022 (Fig. 4). The cold-season of 2011-2022 was the coldest season, FSD representing more than 50% of the season days, with a maximum of 135 days for Băilești station.

For Craiova station, maximum FSD was in January 2017 and January 2020 (31 days), but in another three years FSD was close to maximum (30 days in Jan 2012 and 2019, and Dec 2013 – Fig. 4a). December 2020 stands out with the lowest FSD for this month, only 9 days. The trend was slightly negative, in UERRA dataset the decrease being greater toward the end. The monthly mean of FSD was the largest in January (26 days), with a seasonal average of 11 days (Fig. 5). The mean bias of datasets showed small differences, less than a day (Fig. 5h).

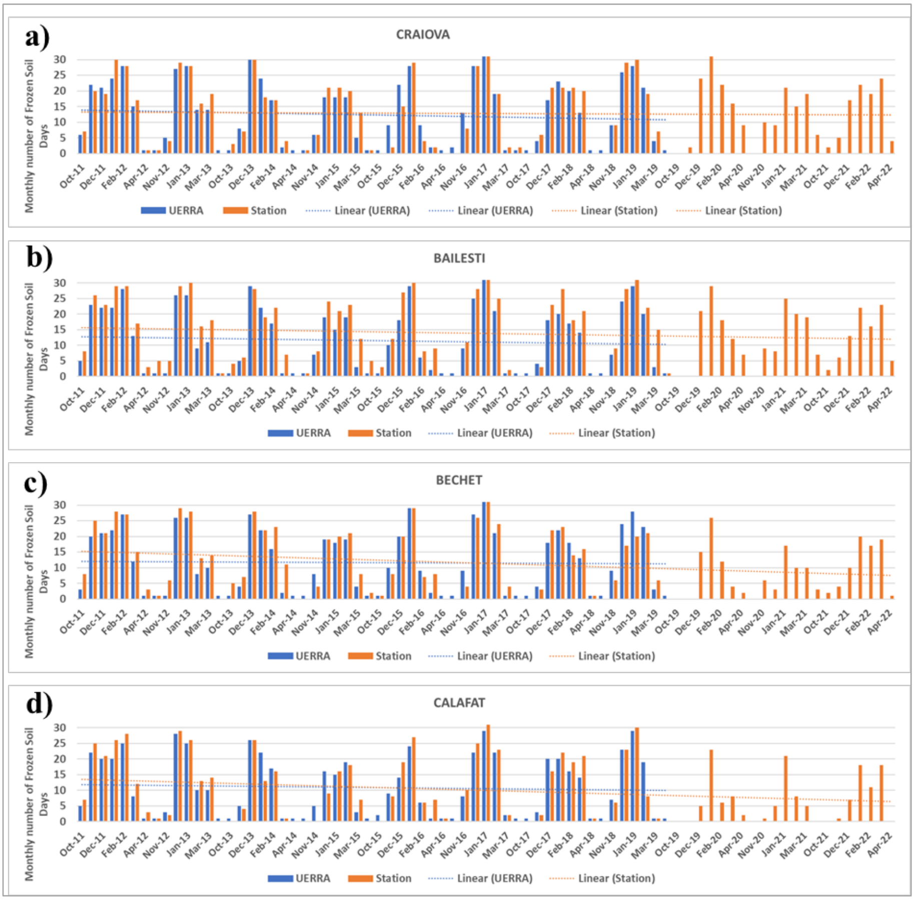

Figure 4. Monthly number of frozen soil days in the cold season 2011-2022 (observation) and 2011-2019 for UERRA dataset.

Comparing the beginning and the ending months of the season, October and April, it resulted that, with values less than 3 days, these two months are favorable for many socio-economical activities (Fig. 5a, g). But for November and March, the balance is tilted towards the former, the latter having much more days with soil temperatures below 0°C (Fig. 5b, f).

For Băilești station the maximum FSD was in January 2017 and 2019, the mean seasonal FSD being of 97 days (46% of season, Fig. 4b). December 2020 stands out as the warmest December of the analyzed period also for Băilești (8 days), Bechet (3 days) and Calafat (5 days) stations. In contrast, March 2022 was the coldest March of the 2011-2022 period for all four stations (Craiova 24 days, Băilești 23 days, Bechet 19 days and Calafat 21 days, Fig. 4). The trend was negative both for UERRA and observation datasets, but the mean bias showed a big difference between datasets, of almost 3 days (Fig. 4b and Fig. 5h). For all months, Băilești, had the largest values of FSD in Dolj county (Fig. 5 a-g).

The FSD had the maximum value only in January 2017 for Bechet station (31 days), the monthly mean for this month being of 24 days (Fig. 4c and Fig. 5d). Only for this station, in the last season of UERRA dataset, FSD had higher values than observation data. Trend was negative for observation dataset, whereas for UERRA were no significant changes (Fig. 4 c).

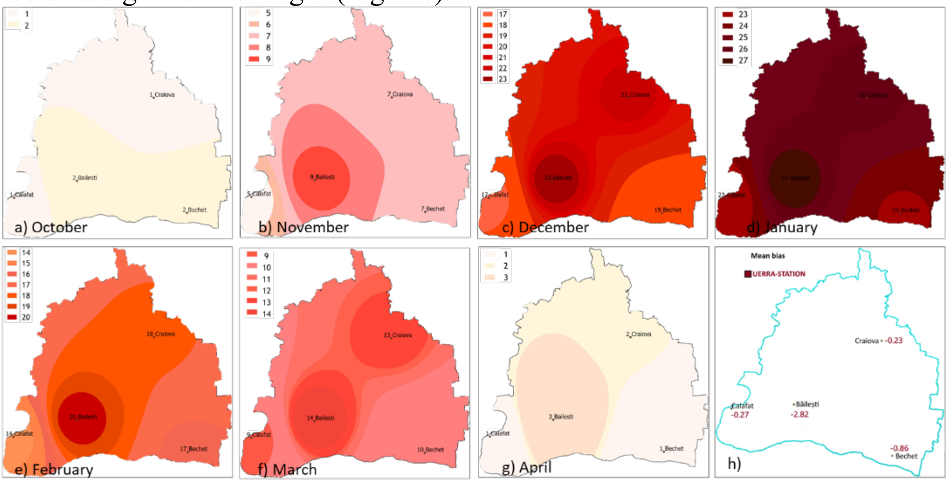

Figure 5. a)-g) Monthly mean of FSD at the weather stations from Dolj county during the cold season 2011-2022 and h) the mean bias of UERRA and station observation datasets.

The coldest months were January 2017 and 2019 (Fig. 4d). Still, the last three winters highlighted a warming, the FDS maintaining similar values to previous years, only in January. The trend was clearly negative, especially in the last years. Calafat has the smallest monthly mean FSD, with a maximum of 23 days for January (fig. 5 a-g).

4. DISCUSIONS AND CONCLUSIONS

In this study, two cold indices of the extended cold-season (October until April) of the 2011-2022 period in Dolj county, Romania were analyzed using three different datasets: station observations, UERRA and E-OBS. Frost days and frozen soil days indices were calculated for all four stations to investigate the changes in the recent past of freezing air and soil temperatures and to assess the performance of alternative data sources for deriving information targeting specific beneficiaries of this climate-based information.

Analyzing the FD and FSD evolution in the recent past, the most important findings were:

a) The season of 2011-2012 was the longest period with high values, both for FD and FSD;
b) January 2017 was highlighted as the coldest month of the entire period, and also March 2022;
c) In December 2020 FSD had the smallest values at all four weather stations;
d) Trends, both for FD and FSD, were negative and more visible in the last years;
e) The highest monthly mean of FD was in the southern half of Dolj county, whereas FSD area was polarized by Băilești and Craiova stations;
f) Activities, like agriculture, constructions and transport weren't too much affected by freezing temperatures in autumn or April, but in March, for about a third of the month, soil and air temperatures were below 0°C;
g) During the winter months (ranked January, December and February), for more than 15-20 days the outdoor activities could have been affected by low temperatures;

The E-OBS dataset had the best correlation with station observation data, as expected, but UERRA had good results too, suggesting that reanalysis datasets can be used for locations where observation data isn't available.

For Calafat station, which is much closer than Băilești or Bechet to another international weather station, the mean bias values were better, supporting the need to extend the national weather-station network. For this matter, the National Meteorological Administration is implementing the Project "Extension of the national observation network within the National Integrated Meteorological System (SIMIN)", financed by the National Recovery and Resilience Plan (PNRR). The project also contains the expansion of the existing national network with 300 automatic and autonomous weather stations until the end of 2026.

The limitations of the study derive mainly from the limited period considered for the analysis, derived from the stakeholders' interest focusing on the latest years. Future research will address the evolution of the selected indices for a longer period (1963 - 2023) in order to provide a more comprehensive characterization of climatic patterns of the indices and their changes and to better answer to long-term decision-making processes in the economic sectors affected by cold weather.

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