

## Inter-annual fluctuations in the internal climate variability of the Eastern Carpathians foreland

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### Introduction

Studies of the multicentennial climate dynamics over the European mountainous regions point to the primary external solar and atmosphere-ocean forcing included in the global climate models (Camenisch et al., 2016). The climate variability model during the period of instrumental records is resolved into several different in duration periods reflected in the regional climate models in response to the boundary forcings (Deque et al., 2007; Birsan et al., 2014). Still, the appropriate inclusion of internal climate variability remains the complicated task in the climate change models and projections (Maraun et al., 2015). The acknowledged methods of trend analysis enabled to detect phases of decrease/increase in Europe that are significant mostly for the thermal regime. The issue of representation of internal short-term fluctuations in the climate trends requires further exploration and unification. The analysis of such periods on the example of the forelands of Eastern Carpathians may provide information for the onset of the climate change phases in response to local features of climate transformation.

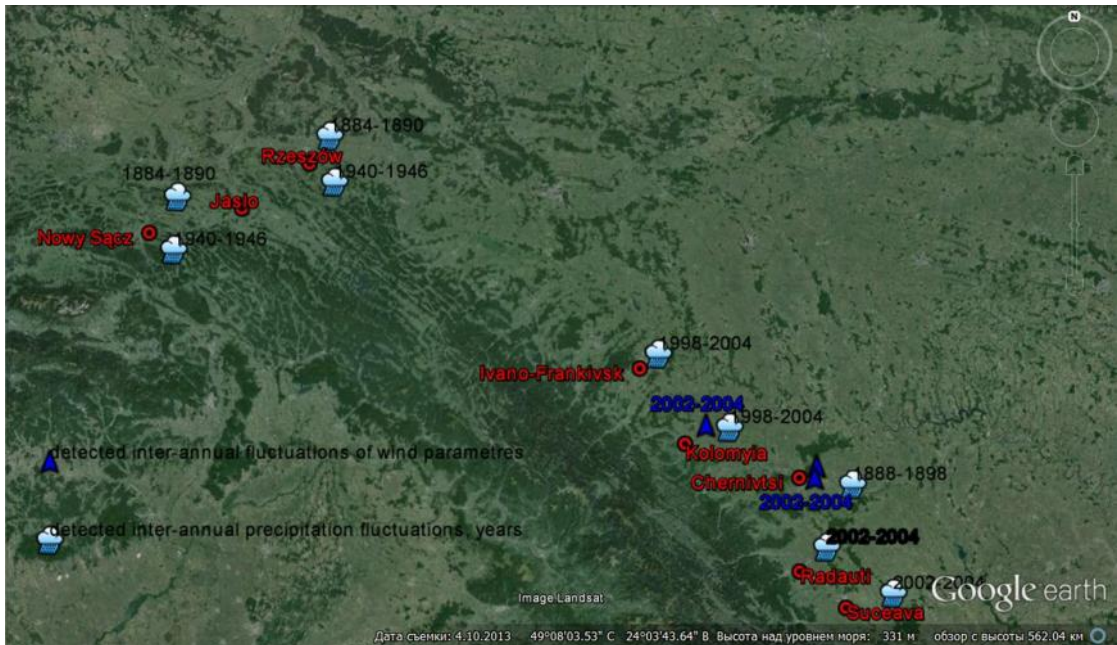
### Materials and Methods

The Carpathian mountainous region is distinguished for controversial manifestations of variability in the last two centuries. Here, certain climate indices (precipitation, wind, extreme values) show insignificant trends complicating to detect the cycle features of temporal distribution. Still, all the regions of the Eastern Carpathians differ in the short-term fluctuations. In particular, the Ukrainian Precarpathian region of foothills serves the contrast area triggering convergence of airflows over the Ukrainian Carpathians and the Volyn-Podolian height. The conditions are manifested in the increased values of wind and precipitation extremes, as well as the range of thermally-generated weather events. In summation, the set of atypical inter-annual fluctuations occur. To discover such temporal and spatial peculiarities the methods of differential integral curves, trend detection and time-varying probability distribution are applied. The short-term periods up to 10 years within the time of instrumental records were analysed for the region using data of Nowy Sacz, Rzeszow, and Jaslo (1881-2015) in Poland; Kolomyia (1876-2013), Chernivtsi (1881-2013), and Ivano-Frankivsk (1951-2013) in Ukraine; Radauti and Suceava (1961-2015) in Romania.

### Results and discussion

Inter-annual fluctuations (3-8 years) are detected to be apparent in the region between multidecadal phases of the 50-60 year duration. Preliminary results of integral curves, trend analysis, and probability distribution show the highest reoccurrence of such periods in the

end of 19<sup>th</sup>, in the middle of 20<sup>th</sup> and on the beginning of the 21 century. The phenomena may indicate the interstate shifts distinctive for extraordinary increase or inhibition of fluctuations of the annual, seasonal, and monthly climate parameters for several years in a row. The most apparent fluctuations are noticed in the dynamics of precipitation, temperature, and wind indices, as well as their extreme manifestations (Fig. 1).



**Fig. 1** Short-term climate fluctuations in the foreland of Eastern Carpathians.

The precipitation trend over the last century in the region is observed to be insignificantly positive in the first half of the 20<sup>th</sup> century and negative – since the 60-s of the 20<sup>th</sup> century. The application of difference integral curves in the study of long-term precipitation variability enabled to distinguish the cycles of short-term periodicity. They are periods with diminished or extreme fluctuations. In particular, the period of 1883-1890 was significant for extreme precipitation in the Polish sites and Chernivtsi (Twardosz et al., 2015). Within the last 60-year period of synoptic background, the 7-8 year fluctuations are apparent for the foreland area represented by the weather stations of Chernivtsi, Kolomyia, and Ivano-Frankivsk. In comparison, in the end of the 19<sup>th</sup> century - on the beginning of the 20<sup>th</sup> century, the 2-3-year cycles within the 50-year cycle were distinguished. The 7-8-year cycles of precipitation regime became apparent after 1981. In the 21<sup>st</sup> century fluctuations with shorter periodicity can be determined in the region too (2003-2004). The latter period corresponds to the atypical annual wind roses of speeds and frequency for most of the sites. These are the years of high temperature ranges and extreme precipitation fluctuations. Other fluctuations of annual and seasonal wind directions and extreme speeds with insignificant range were detected in the 1945-1950 years for the Ukrainian part. The phenomena coincide with the diminished annual precipitation and temperature fluctuations and in all the parts of the region. The quantitative parameters of short-term changes are achieved.

The revealed inter-annual fluctuations seem to reflect the internal climate variability that is specific for the foreland region. They point to the interstate temporal oscillations of climate system related to the boundary belt of the distinct nature environments. The findings may be indicative of the rebuilding of regional circulations and contribute to the identification of centennial climate dynamics of the Eastern Carpathian region.

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