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# SEASONAL CHANGES IN WIND SPEED IN ROMANIA

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*Abstract*. Mean annual and seasonal wind speed data series for the period 1961-2010 from 104 weather stations fairly distributed over Romania (both spatially and with respect to elevation) were analysed for trends with the Mann-Kendall nonparametric test. Annual and seasonal mean wind speed is decreasing. The signal is consistent and statistically significant. Our findings are in agreement with recent studies over many regions of the Earth, that conclude that the recent terrestrial stilling is a globally-spread phenomenon.

*Key words*: wind trends, Mann-Kendall, terrestrial stilling, climate change, Romania.

## 1. INTRODUCTION

Changes in near-surface wind speed have important implications in several disciplines, like wind energy generation, wind erosion, wind transport of pollen and seeds, wind transport of pollution and associated impacts on human health [1–2]. Wind also plays an important role in the evaporation process, the amount of evaporation increasing when drier air masses replace the humid ones accumulated above ground or canopy.

Among the possible causes of the terrestrial stilling, which proves to be widespread across the globe, McVicar *et al.* [1] mention the following:

• the increase in the land surface roughness [3] due to the increase in vegetation cover, the main causes of the vegetation cover increase being: the abandonment of agricultural land [4], temperature warming and atmospheric $CO_2$ concentrations enhancing vegetation growth, as well as the large-scale afforestation [5];

• the increasing water availability by irrigation, so that more available energy is partitioned into the latent heat flux and less into the sensible heat flux and associated turbulent transport [6];

• the warming rate is higher at polar latitudes than at tropical ones [7], with a weakening of the equatorial-polar thermal differential expected to result in decreased equatorial and mid-latitude wind speed [8].

Previous hydroclimatic studies on Romania – at country or regional scale – have focused on changes in precipitation [9–11], temperature [12, 13], cyclonic activity [14], snow [15–17], natural streamflow regime [18, 19], meteorological and hydrological drought [20, 21], floods and flash floods [22], or climate change impacts [23].

This paper presents the first 50-year analysis of seasonal trends in wind speed in Romania.

## 2. DATA AND PERIOD OF STUDY

The data used in this study belongs to Meteo Romania (National Meteorological Administration). The time series consist in high quality data, most of them having continuous records over the 50-year study period. Stations with records with less than 10% missing data have been included in the analysis, for a better spatial coverage.

Prior to the presented analysis, we applied a state-of-the-art quality control and homogenisation procedure, called Multiple Analysis of Series for Homogenization (MASH). The MASH method was developed within the Hungarian Meteorological Service by Szentimrey [24]; it is a relative homogeneity test procedure that does not assume that the reference series are homogeneous. Possible break points and shifts can be detected and adjusted through mutual comparisons of series within the same climatic area [25].

The analysis was conducted over the period 1961–2010, on annual and seasonal basis.

## 3. METHODOLOGY

The local significance of trends has been analysed with the nonparametric Mann-Kendall (MK) test for the annual and seasonal mean wind speed. The MK test is a rank-based procedure, especially suitable for non-normally distributed data, data containing outliers and non-linear trends [26].

The null and the alternative hypothesis of the MK test for trend in the random variable $x$ are:

$$\begin{cases} H_0 : \Pr(x_j > x_i) = 0.5\ , \quad j > i \\ H_A : \Pr(x_j < x_i) \neq 0.5 \quad \text{(two-sided test).} \end{cases} \tag{1}$$

The MK statistic $S$ is calculated as

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k), \tag{2}$$

where $x_j$ and $x_k$ are the data values in years $j$ and $k$, respectively, with $j > k$, $n$ is the total number of years and sgn() is the sign function:

$$\mathrm{sgn}(x_j - x_k) = \begin{cases} 1\text{ , if } x_j - x_k > 0 \\ 0\text{ , if } x_j - x_k = 0 \\ -1\text{ , if } x_j - x_k < 0. \end{cases} \tag{3}$$

For large $n$, the distribution of $S$ can be well approximated by a normal distribution with mean zero and standard deviation given by:

$$\sigma_S = \sqrt{\frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(i)(i-1)(2i+5)}{18}}. \tag{4}$$

Equation (4) gives the standard deviation of $S$ with the correction for ties in data, with $t_i$ denoting the number of ties of extent $i$. The standard normal variate $Z_S$ is then used for hypothesis testing.

$$Z_S = \begin{cases} \frac{S-1}{\sigma_S} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sigma_S} & \text{if } S < 0. \end{cases} \tag{5}$$

The null hypothesis is rejected at significance level $\alpha$ if $|Z| > Z_{\alpha/2}$ (two-tail test), where $Z_{\alpha/2}$ is the value of the standard normal distribution with an exceedance probability $\alpha/2$. In the present analysis we chose two significance levels: 10% and 5% (two-tail test).

## 4. RESULTS AND CONCLUSIONS

The Mann-Kendall trend test applied to annual data series revealed substantial changes (Fig. 1), with 93% of the stations presenting decreasing trends in mean wind annual speed. All significant trends are downward. The intra-Carpathic region is less affected than the rest of the country.

On seasonal basis (Fig. 2), the spatial patterns present some differences. In autumn and winter, the downward trend can be noticed in all extra-Carpathic regions, while in spring the decreasing trends are spreaded all over the country. In summer, the Transylvanian Depression and the Oriental Carpathians have no significant trends in wind speed, while other hilly and depressionary areas do.

Overall, the trend results indicate a consistent country-wide decrease in the average wind speed, more pronounced in the extra-Carpathic regions, and in the Meridional and Curvature Carpathians, and significant in all seasons.

The results are in agreement with most of the recent studies on wind speed, which report a an overall tendency towards terrestrial stilling [1]. They also point out the importance of taking into account the long-term variability of the seasonal mean wind speed, when assessing long-term changes in wind-related variables – like evaporation or climate extremes indices.

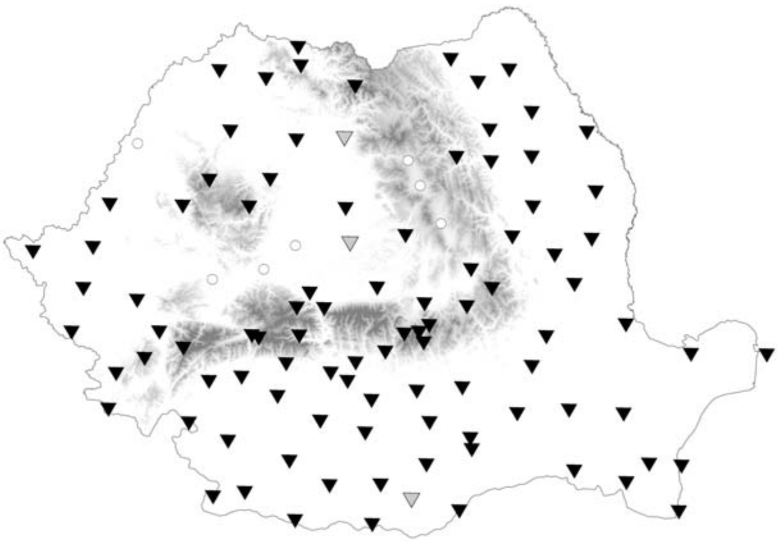
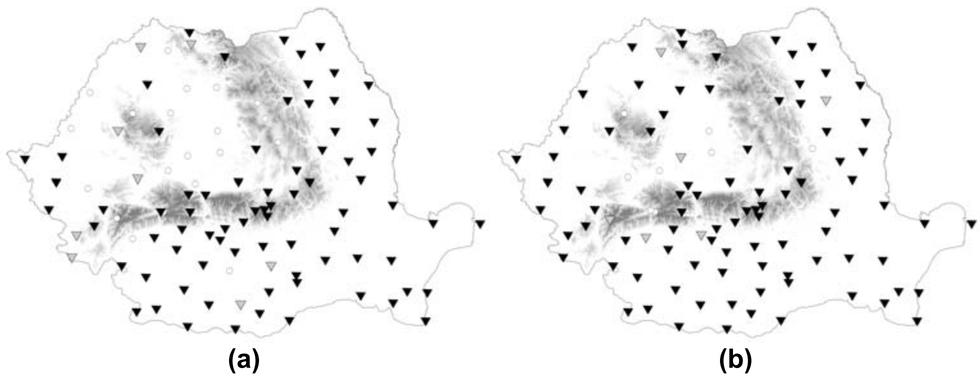


Fig. 1 – Significant trends at 10% level (grey triangles) and 5% level (black triangles) for the annual wind speed. All significant trends are decreasing; circles represent stations with no trend.



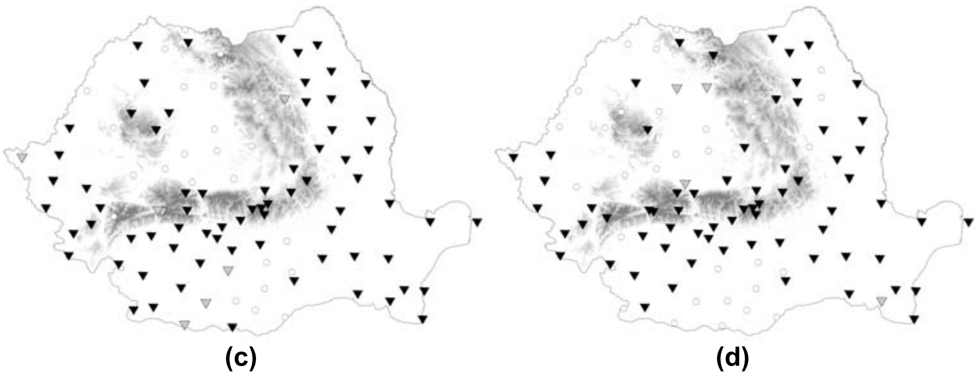



Fig. 2 – Significant trends at 10% level (grey triangles) and 5% level (black triangles) for: a) winter DJF; b) spring MAM; c) summer JJA; d) autumn SON. All significant trends are decreasing; circles represent stations with no trend.

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