

Seasonal Variability of Wind Climate in Hungary

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Abstract – One of the most important effects of climate variability and climate change may come from changes in the intensity and frequency of climatic extremes. Responding to the need of new climatologic analyses, complex wind field research was carried out to study and provide reliable information about the state and variability of wind climate in Hungary. First of all, special attention was paid on creation of a high quality, homogeneous data series. The research is based on 36-year-long (1975–2010) wind data series of 36 Hungarian synoptic meteorological stations. The means and extremes of near-surface wind conditions assist in estimating the regional effects of climate change, therefore a complex wind climate analysis was carried out. Spatial and temporal distribution of mean and extreme wind characteristics were estimated; wind extremes and trends were interpolated and mapped over the country. Furthermore, measured and ERA Interim reanalysis data were compared in order to estimate the effects of regional climate change.

wind climate / climatic extremes / regional tendencies / reanalysed data

Kivonat – A magyarországi szélklíma évszakos változékonysága. Napjainkban megnövekedett az igény a klímaváltozás globális és regionális hatásainak elemzésére, következményeinek becslésére. Az egyes meteorológiai paraméterek átlagos értékeinek elmozdulása mellett kiemelt figyelmet igényel a szélsőséges időjárási és éghajlati események esetleges gyakorisági változása is.

Kutatásaink során a hazai szinoptikus meteorológiai állomások 36 éves, 1975–2010-ig terjedő adatsorainak minőségi és mennyiségi ellenőrzése, feldolgozása után elemeztük a szélmező klimatológiai szempontból lényeges statisztikai jellemzőit. Az órás szélsébség, szélirány és szélirány adatokat tartalmazó idősor felhasználásával becsültük a szélklíma legfontosabb paramétereinek és szélsőértékeinek évek közötti változékonyságát, azok térbeli és időbeli tendenciáit. Az ERA Interim reanalízis adatsor 10 méteres magasságra vonatkoztatott szélsébség idősorán szintén elvégeztük a fent említett vizsgálatokat, melyek eredményét összevetettük egymással annak megállapítása érdekében, hogy a klímamodellek bemenő adataként széleskörűen alkalmazott ERA Interim adatsor klimatikus jellemzői mennyire esnek egybe a mért adatokból levezetett jellemzőkkel

szélklíma / klimatikus szélsőségek / regionális trendek / reanalízis

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1 INTRODUCTION

In view of global warming, changes of extreme climate events are considered a key issue nowadays. Usually it is impossible to connect directly specific weather events to global warming. Instead, global warming is expected to cause changes in the overall distribution and intensity of extreme events, such as changes in the frequency and intensity of heavy precipitation and wind storms.

Hungary occupies the low elevation areas of the Carpathian basin. The country is predominantly flat, two-thirds of the entire territory lies below 200 m and approximately 2% is above 400 m. The latitudinal extension of Hungary – less than three degrees ($45^{\circ} 45' - 48^{\circ} 35' N$) – does not cause significant climatic differences between northern and southern regions. The country was not the subject of extensive wind research in the last century. However, some studies were carried out analyzing the surface and upper-air wind records spanning several decades. The present study is a segment of complex wind climate research of the country, which uses statistical methods to analyze the measured wind records of the Hungarian meteorological stations (Péliné et al. 2008, Radics – Bartholy 2002, 2008, Radics et al. 2010).

Most scientists agree that special attention should be paid applying ERA-40 reanalysis data sets as a reference, e.g. for such model development and validation purposes where wind plays an important role (Punge – Giorgetta 2007). Considering the statistics of differences between observations and hindcasts, furthermore, the fact that no corrections were applied prior to 1980 in ERA-40 data sets (Haimberger 2005), spatially and temporally inhomogeneous wind speed data and reanalyzed data (ERA Interim, Berrisford et al. 2009) were compared for Hungary. In this study some preliminary results are presented demonstrating how the comparison of different datasets can improve the reliability of detected wind variability.

2 DATA SETS

2.1 Measured data

The research is based on 36-year-long (1975–2010) hourly wind data of 36 Hungarian synoptic meteorological stations provided by the HDF Geoinformation Service. The most important feature that has to be provided for the analysis of such long time series is the homogeneity. Generally, homogeneity of data bases is strongly affected by the method of measurements. Before 1997, meteorological observations were made manually in Hungary. Therefore, the data series was split into two parts: “manual data” (1975–1994) and “automatic data” (1997–2010) sets. The consistency of data sets was checked and the values were verified. However data gaps were not filled. In order to be able to compare wind speed data, vertical interpolation (to standard height of 10 metres above the ground) was carried out (*Table 1*). In this paper preliminary results are presented on the detailed analyses of the second time period (1997–2010).

The network of Automatic Weather Stations (AWS) was designed by the national meteorological service (Hungarian Meteorological Service – HMS) to provide real-time observations and measurements for forecasting, warning and information services, as well as to ensure high quality data for the national climate database. During AWS installation the main aim was to settle the stations according to World Meteorological Organisation standards (WMO 1996). Wind observations are most sensitive to shelter by high roughness or nearby obstacles. Hence, wind sensors should in general be located over open terrain, at standard height of 10 metres above the ground in accordance with WMO-Guidelines (WMO 1996). Finding the ideal exposure that produces representative measurements may be difficult to

achieve. Therefore, it is a crucial issue to report on the site conditions, a technical description of the set-up and sensors' heights (metadata).

Due to changing circumstances, in few cases site, method and height of wind measurements have been altered or observations ceased. Therefore, a few stations were excluded from further analysis.

Table 1. Heights of wind instruments at the meteorological stations involved in the analysis

| | Stations | Time series | Heights of wind instruments (m) |
|-----|-----------------|--------------------|---------------------------------|
| 1. | Agárd | 1997 – 2010 | 10,30 |
| 2. | Baja Csávoly | 1997 – 2010 | 10,30 |
| 3. | Budapest/Lőrinc | 1997 – 2010 | 14,68 |
| 4. | Debrecen | 1997 – 2010 | 10,23 |
| 5. | Győr | 1997 – 2010 | 10,17 |
| 6. | Jósvafő | 1997 – 2010 | 9,99 |
| 7. | Kecskemét | 1998 – 2010 | 10,00 |
| 8. | Kékestető | 1997 – 2010 | 25,07 |
| 9. | Miskolc | 1997 – 2010 | 16,25 |
| 10. | Mosonmagyaróvár | 1997 – 2010 | 16,99 |
| 11. | Nagykanizsa | 1997 – 2010 | 13,69 |
| 12. | Nyíregyháza | 1997 – 2003 | 27,00/15,98 |
| 13. | Paks | 1997 – 2010 | 9,80 |
| 14. | Pápa Nyárad | 2002 – 2010 | 12,05 |
| 15. | Poroszló | 1997 – 2010 | 10,45 |
| 16. | Sármellék | 2001 – 2010 | 10,61 |
| 17. | Siófok | 1997 – 2010 | 15,10 |
| 18. | Szécsény | 1997 – 2010 | 10,40 |
| 19. | Szeged | 1997 – 2004 | 8,76/10,59 |
| 20. | Szentgotthárd | 1997 – 2010 | 16,61 |
| 21. | Szolnok | 1997 – 2010 | 10,00 |
| 22. | Szombathely | 1997 – 2010 | 10,56 |
| 24. | Tata | 1997 – 2010 | 19,30 |
| 25. | Záhony | 1997 – 2010 | 16,71 |
| 26. | Zalaegerszeg | 1999 – 2010 | 10,40 |

2.2 Reanalysis of gridded data

ERA-Interim is the latest global atmospheric reanalysis data set produced by the European Centre for Medium-Range Weather Forecasts (ECMWF). ERA-Interim data are available from January 1 1979 to June 30 2011. Gridded data on the data server are normally updated once per month, allowing a two-month delay for quality assurance and for correcting technical problems with the production, if any. The timeline in *Figure 1* summarises the sources of in situ observations used in ERA-Interim. Surface observations from land stations, ships, and drifting buoys were involved throughout the reanalysis period, as were reports from radiosondes, pilot balloons, dropsondes, and aircrafts. Wind profiler data of North American sites became available in 1994, European and Japanese profilers were added in 2002. Hourly METAR airport weather reports have been used since 2004. Pseudo-surface pressure observations, which were used in ERA-40, were not involved in ERA-Interim project (Dee et al. 2011)

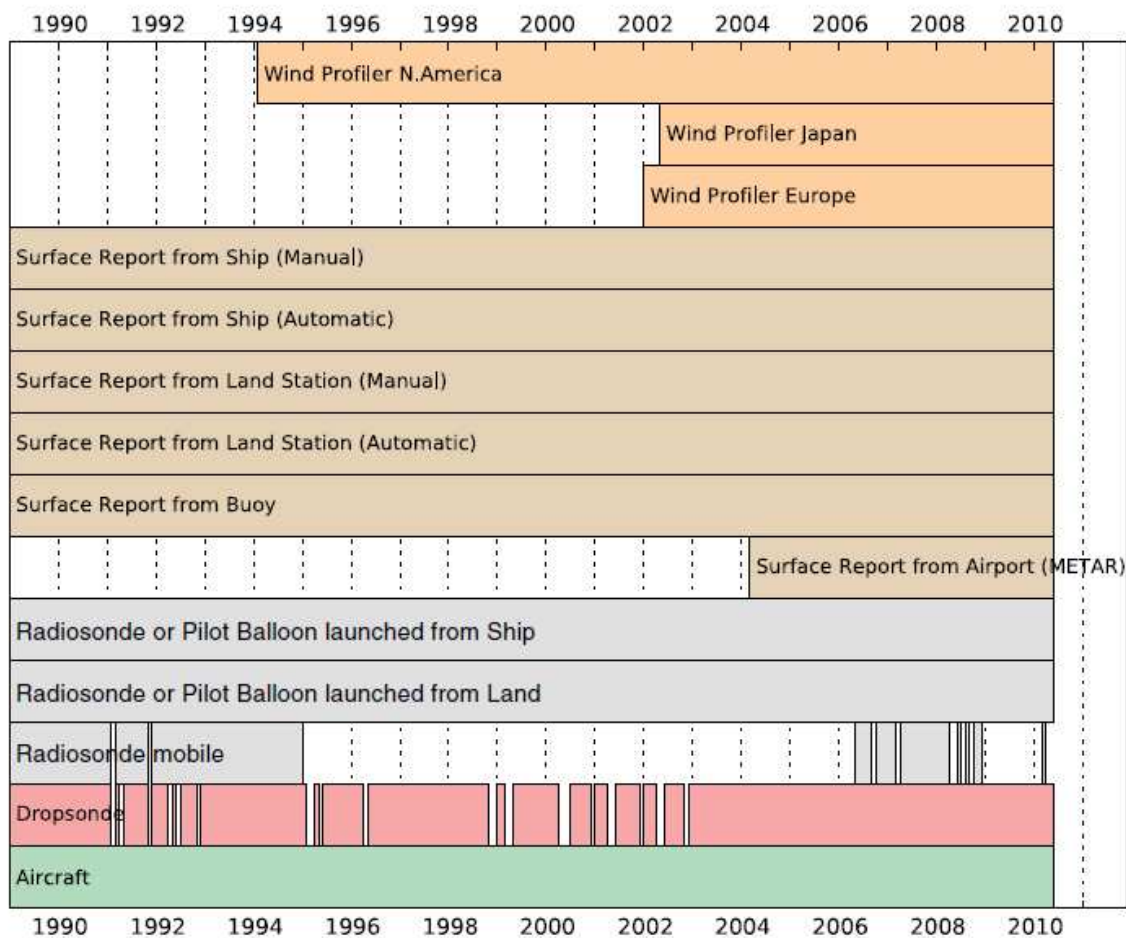


Figure 1. Timeline of conventional observations assimilated in ERA Interim (Dee et al. 2011)

Average wind (u , v) components (at 10 m height) were downloaded for the period 1997–2010 with 6 h temporal and $1.5^\circ \times 1.5^\circ$ spatial resolution from the ECMWF webpage (http://data-portal.ecmwf.int/data/d/interim_daily/) over Hungary (Figure 2).

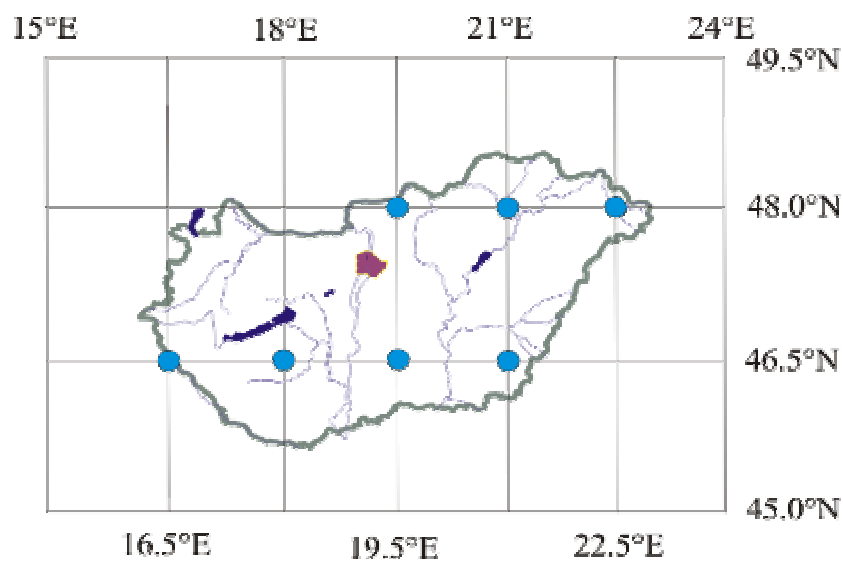


Figure 2. Geographical location of ERA Interim grid points over Hungary

3 ESTIMATIONS AND RESULTS

Hourly wind speed and wind gust data of Hungarian synoptic stations were analysed for the second subseries (1997–2010). Using monthly averages spatial distributions of fitted linear trends are presented in *Figure 3* where, red and blue colours demonstrate increasing and decreasing tendencies, respectively. The sizes of the circles indicate the quality of changes. Contrary to previous analyses (Radics – Bartholy 2008) monthly trends show significant decline in April, but slightly increasing tendencies appear in some stations during December, March and June. Regarding wind gust values, trend coefficients significantly decreased in April almost over the whole territory of Hungary, in January and November in the western part of Transdanubia, moreover in February and June in the middle of the country. In October, March and December wind gust averages show an increasing trend at some measuring sites.

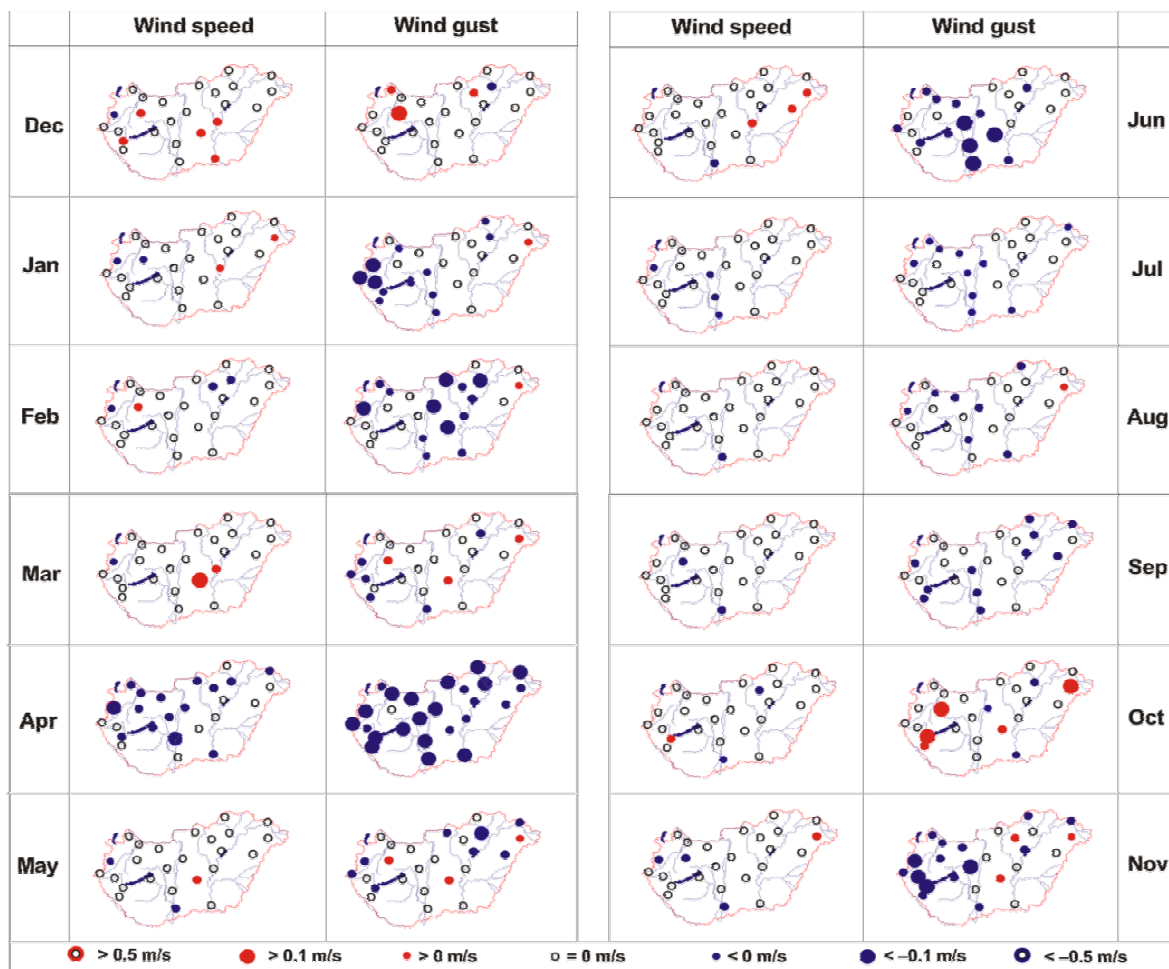


Figure 3. Spatial distribution of linear trends fitted on average wind speed and wind gust values over Hungary (1997–2010)

Similar analysis was carried out for different percentile values of the measured time series. Spatial distribution of trend coefficients of the linear trend fitted on the 0.9 and 0.99 percentile values is presented in *Figure 4* and *5*, respectively. Comparing *Figure 3*, *4*, and *5* it is observable that the higher the percentiles, the bigger the changes. Significant decreasing tendencies (blue dots) reappeared in April, while the number of positive trends (red dots) increased considerably.

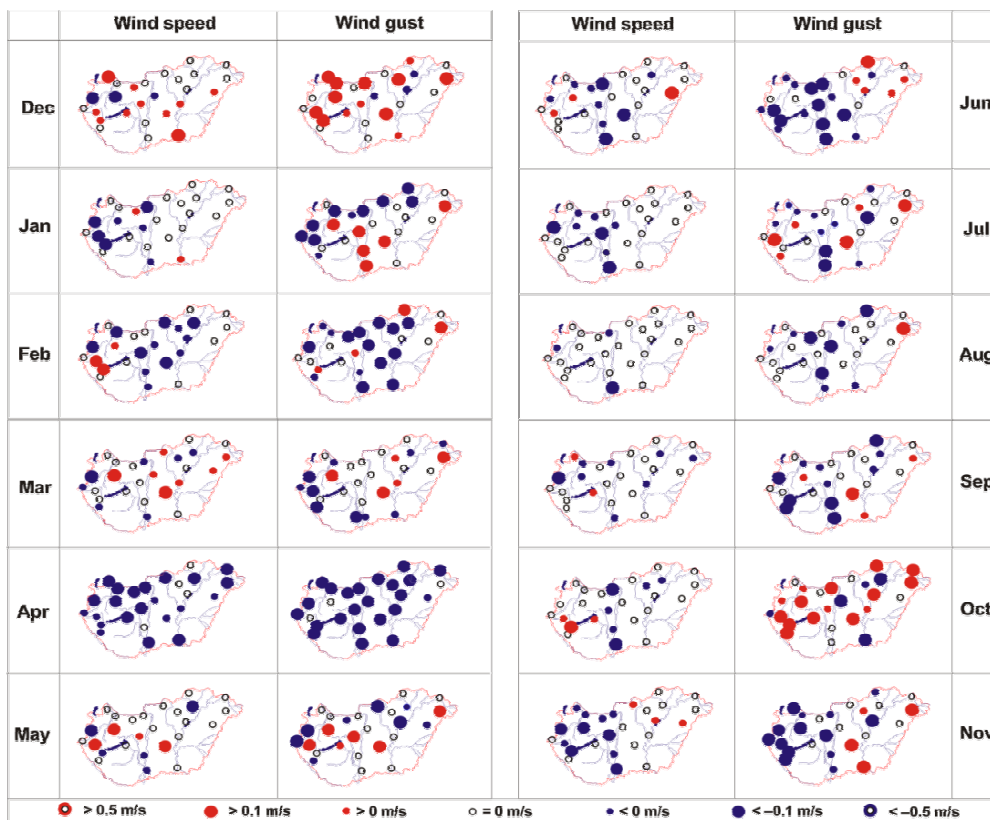


Figure 4. Spatial distribution of linear trends fitted on the 0.9 percentiles of wind speed and wind gust values (1997–2010)

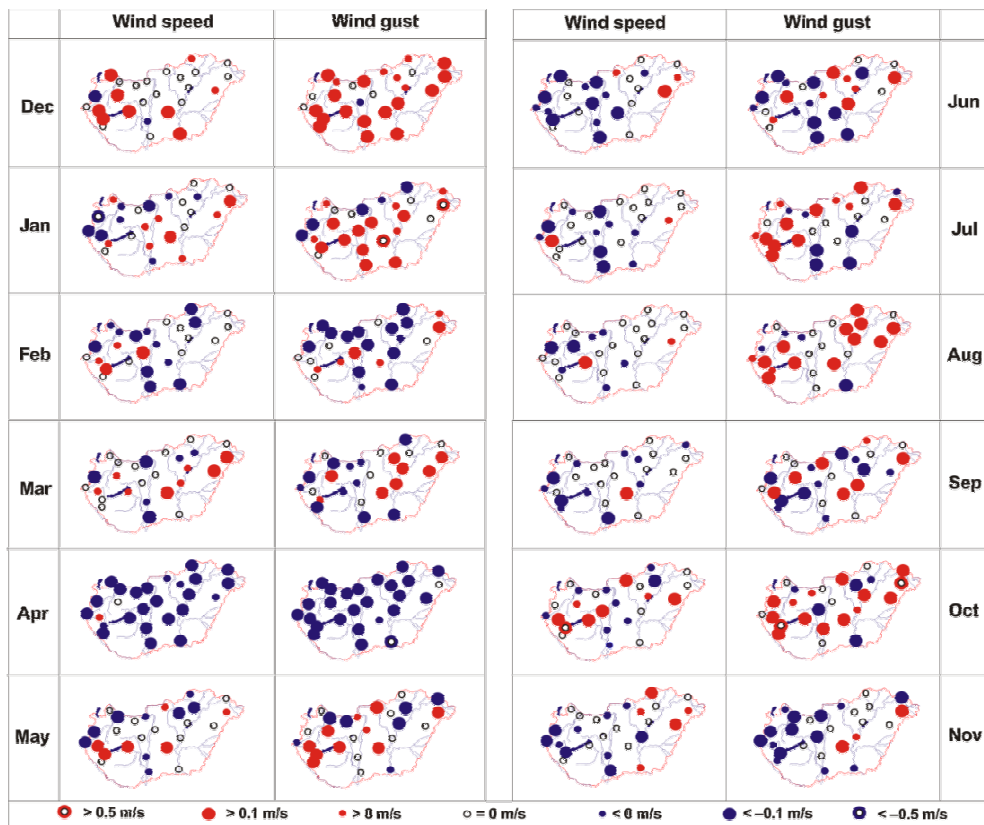


Figure 5. Spatial distribution of linear trends fitted on the 0.99 percentiles of wind speed and wind gust values (1997–2010)

Considering the main results of studies on statistics of differences between observations and hindcasts, spatially and temporally inhomogeneous measured wind speed data and reanalyzed data were compared for Hungary. ERA Interim reanalysis wind speed data were analysed (Figure 6 and 7). Reanalysis data sets were controlled and in some cases corrected, so they can be considered homogeneous data series. In cause of the further study of ERA Interim, spatial distribution of wind speed extremes were analyzed (1997–2010) using three-year moving averages of different percentile values.

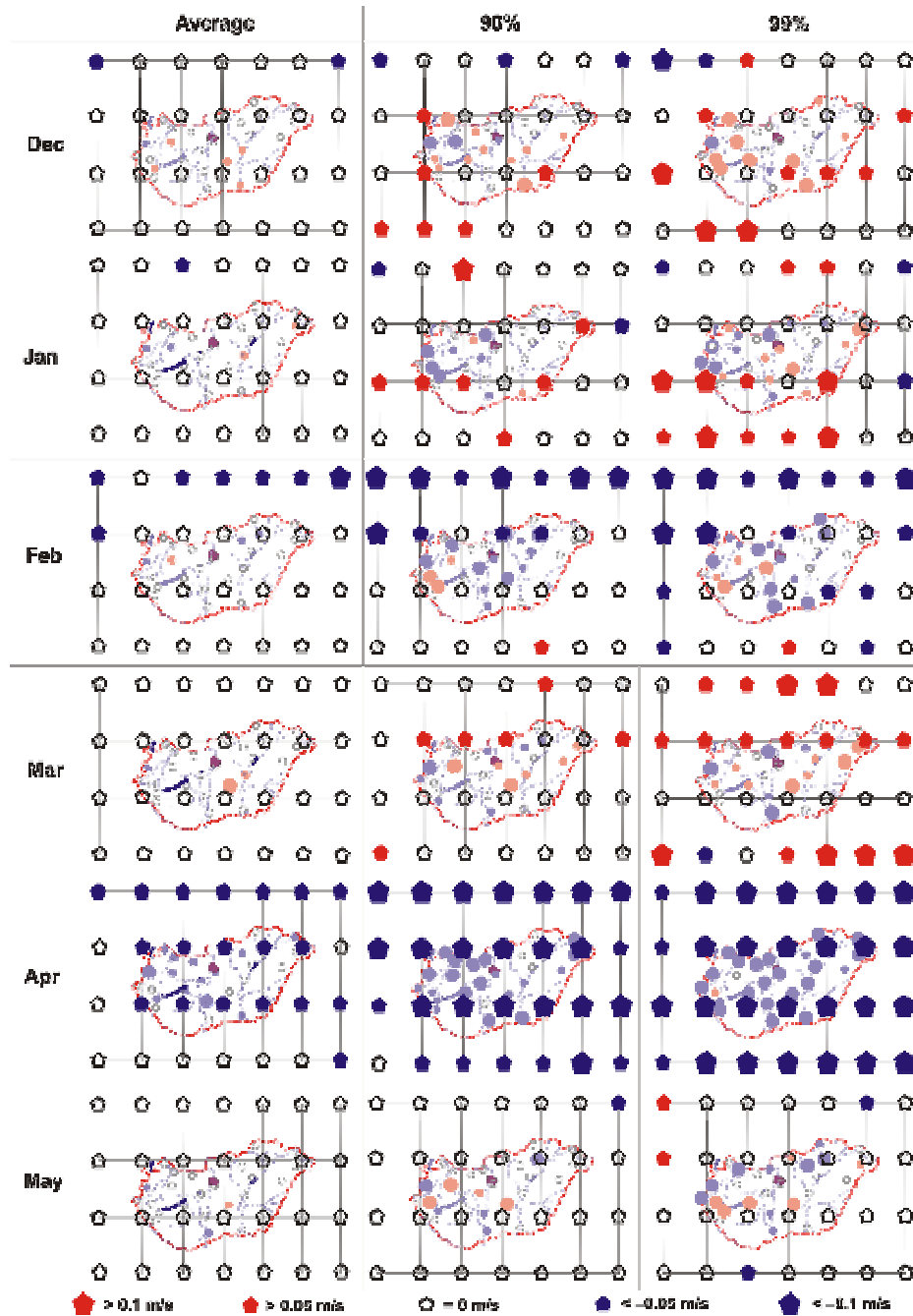


Figure 6. Spatial distribution of trend coefficients of the linear trends fitted on average and the different percentile values (90% and 99%) calculated from the yearly subseries of ERA Interim wind speed values between 1997 and 2010

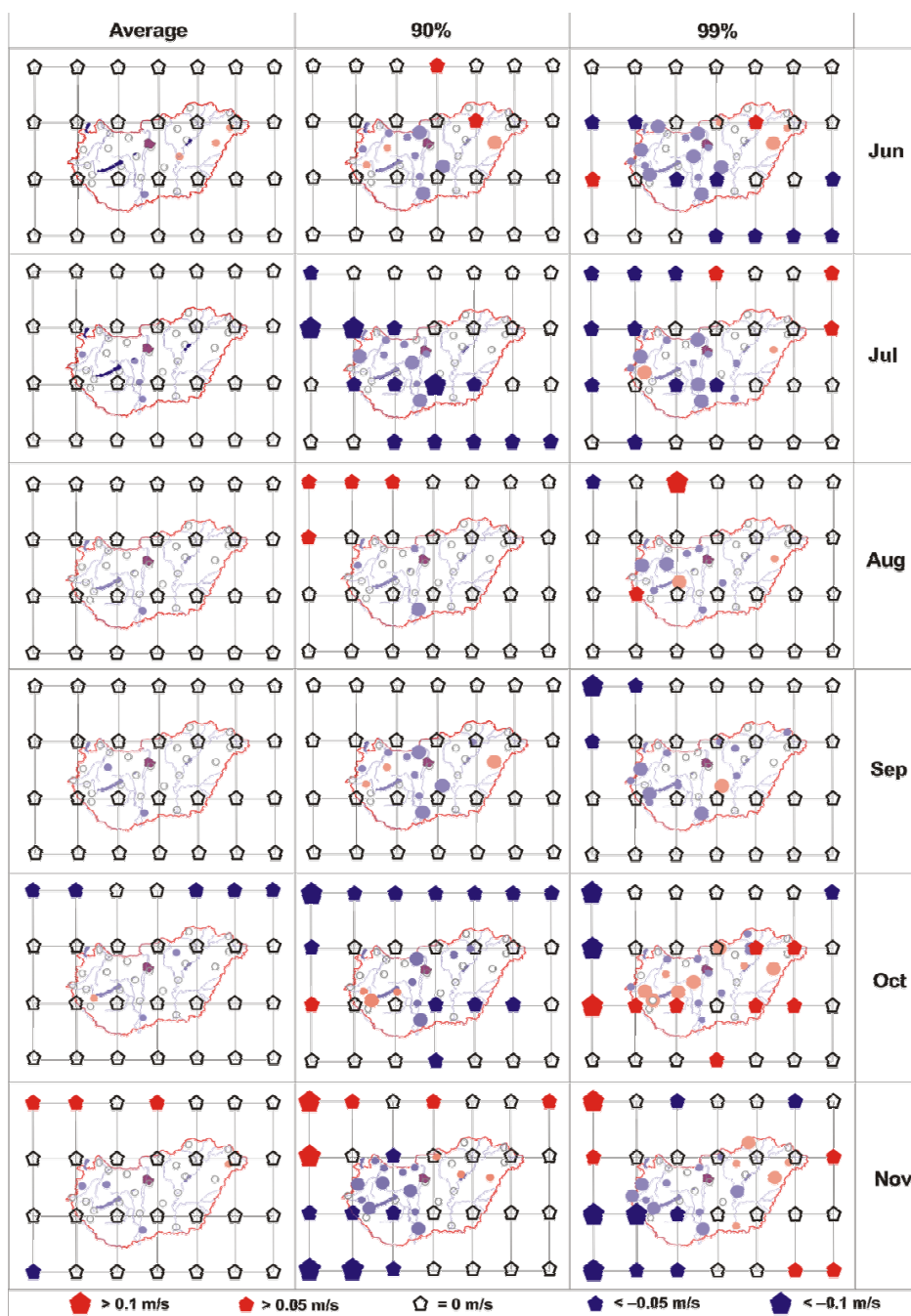


Figure 7. Spatial distribution of trend coefficients of the linear trends fitted on average and the different percentile values (90% and 99%) calculated from the yearly subseries of ERA Interim wind speed values between 1997 and 2010

In Figure 6 and 7 pentagonal symbols were used to demonstrate the changes of wind conditions. Generally it can be stated again that the higher the percentiles, the bigger the changes. In close correspondence with the results of synoptic data, a decreasing trend was found in April, July and November over Hungary. Increasing trends appeared in some cases in January, March, October and December.

Summarizing the main results, the following conclusions can be drawn: (1) The preliminary results show strong relationships between the corresponding periods of ERA and the station data. (2) In order to estimate regional climate change effects, spatially and temporally homogeneous data series of ERA Interim seem to be an appropriate tool to

substitute the measured data over Hungary. (3) Analysing 14-year long (1997–2010) average wind speed and gust values, generally decreasing tendencies were found. A significant trend appeared first of all in April. To answer the question whether the observed tendencies are effects of regional climate change or consequences of climate fluctuation, needs further studies.

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REFERENCES

- BERRISFORD, P. – DEE, D. P. – FIELDING, K. – FUENTES, M. – KÅLLBERG, P. – KOBAYASHI, S. – UPPALA, S. M. (2009): The ERA-Interim Archive. ERA Report Series No. 1. ECMWF: Reading, UK.
- DEE, D. P. – UPPALA, S. M. – SIMMONS – A. J., BERRISFORD – P., POLI, P. – KOBAYASHI, S. – ANDRAE, U. – BALMASEDA, M. A. – BALSAMO, G. – BAUER, P. – BECHTOLD, P. – BELJAARS, A. C. M. – VAN DE BERG, L. – BIDLOT, J. – BORMANN, N. – DELSOL, C. – DRAGANI, R. – FUENTES, M. – GEER, A. J. – HAIMBERGER, L. – HEALY, S. B. – HERSBACH, H. – H'OLM, E. V. – ISAKSEN, L. – KÅLLBERG, P. – KÖHLER, M. – MATRICARDI, M. – MCNALLY, A. P. – MONGE-SANZ, B. M. – MORCRETTE, J.-J. – PARK, B.-K. – PEUBEY, C. – DE ROSNAY, P. – TAVOLATO, C. – THÉPAUT, J.-N. – VITART, F. (2011): The ERA-Interim reanalysis: configuration and performance of the data assimilation system. *Quarterly Journal of The Royal Meteorological Society* 137: 566p.
- HAIMBERGER, L. (2005): Homogenization of the global radiosonde dataset using ERA-40 analysis feedback information, *Reviews*, 7, 175–186.
- PUNGE, H. J. – GIORGETTA, M. A. (2007): Differences between the QBO in the first and in the second half of the ERA-40 reanalysis, *Atmos. Chem. Phys.*, 7, 599–608.
- PÉLINÉ, N. Cs. – RADICS, K. – BARTHOLY, J. – HAJDÚ, M. (2008): A hazai szélmező átlagos és extrém értékeinek térbeli és időbeli változása. *Egyetemi Meteorológiai Füzetek. ELTE, Meteorológiai Tanszék kiadványai*, No. 22, 91p. (in Hungarian)
- RADICS, K. – BARTHOLY, J. (2002): Estimation of climate effects of land use changes with simple wind models. *Physics and Chemistry of the Earth*, Vol. 27, 1073–1076.
- RADICS, K. – BARTHOLY, J. (2008): Estimating and modelling the wind resource of Hungary, *Renew. Sust. Energ. Rev.*, 12, 874–882.
- RADICS, K. – BARTHOLY, J. – PÉLINÉ, N. Cs. (2010): Regional tendencies of extreme wind characteristics in Hungary. *Advances in Science and Research* 4, 43–46.
- WMO (1996): *Guide to Meteorological Instruments and Methods of Observation*. Sixth Edition. No. 8. Secretariat of the World Meteorological Organisation, Geneva, Switzerland.

