ANALYSIS OF GLOBAL CLIMATE CHANGE INFLUENCES ON THE REGIONAL WIND CHARACTERISTICS

Theses of the PhD dissertation

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1. Introduction

On the basis of various scientific evidences related to the climate system, and different climate model simulations increasing concentrations of greenhouse gases are detected, which results in an overall warming globe and global climate change. It is therefore of great interest to analyze global and regional influences of the changing climate, and to estimate consequences of anthropogenic climate change during the 21st century. Besides the changes of wind speed values, the entire distribution is changing, thus influencing intensity and frequency of climate extremes. Various physical processes in the atmosphere lead to extreme values of meteorological elements. Weather and climate extremes (e.g., heat waves, extreme cold/hot conditions, too little/excessive precipitation, extreme winds) may especially affect exposed and vulnerable human and natural systems, therefore, development of appropriate action plans need detailed information on the past and future changes of extremes. It is essential to understand how and why wind extremes have changed recently, and how they will likely to change in the future.

2. Aims

The main purpose of this research is to analyze wind climate in Hungary, specifically, to estimate temporal and spatial distributions of mean and extreme wind speed. In order to enhance reliability of our results, Hungarian synoptic station data sets were homogenized. Analysis of the indices calculated from homogeneous wind speed data series can answer whether the frequencies of windy, gusty days and calm periods have increased or decreased in the recent past. This is especially important from urban aspects since air pollution in cities is a major environmental issue leading to many potential health problems. In addition, comparison of spatial and temporal tendencies of wind speed of ERA Interim reanalysis data and observations may contribute to estimation of the reliability of reanalysis data series. Further aim is to evaluate simulated wind climate variability for the future periods of 2021–2050 and 2071–2100 relative to the 1961–1990 reference period.

The results may serve as a basis for estimating the environmental impacts of regional wind climate change, and hence, adaptation strategies may plan appropriate actions.

3. Applied methodology

In my doctoral research, average and extreme characteristics of the Hungarian wind climate were analysed. First, time series had to be splitted into two parts since the automation in Hungary during the mid-1990's introduced many break points into the wind data series. In order to decrease these inhomogeneities, complete missing data and clarify errors, MASH software was applied to homogenize 19 stations' wind speed (1975–2012) and wind gust (1975–2013) data series. As a result, a good quality, few decade long, homogeneous wind data series can be used for further detailed analysis without splitting the whole period.

Similarly, ERA Interim reanalyzed wind fields (1979–2012) were also checked for inhomogeneity. Parameters of the fitted distributions of station and gridded data series were compared to assess the uncertainty of wind climate analyses and to decide how appropriate these data are for analysis of extremes. Because of significant differences between the statistical distributions of ERA Interim and synoptic station data, extreme value analysis (i.e., frequency occurrence, trend of moderate and strong wind days, and wind related indices) were completed on the homogenized synoptic data series.

In addition to the analysis of the recent past wind fields, projected changes for the future are also important in potential impact analysis. For this purpose, simulated RegCM regional climate model (adapted and available at the Department of Meteorology at the Eötvös Loránd University, and driven by ECHAM global climate model) wind data were evaluated for the future periods of 2021–2050 and 2071–2100 relative to the 1961–1990 reference period. Since projected wind speed is highly overestimated by the simulation of RegCM in the reference period (1961–1990), a bias correction is certainly necessary to apply to the raw simulated wind data using CARPATCLIM as a reference database. The bias correction method is based on fitting the empirical cumulative density functions of simulated daily time series to the observations for each gridcell using monthly multiplicative correction factors. After elimination of the simulation biases, bias corrected wind fields were analyzed for two future periods.

4. Theses

On the basis of the analysis included in the dissertation, the following main conclusions can be drawn.

1. Results of the analysis of the periods of 1975–1994 and 1997–2010 are presented in the dissertation in section 5.1.1. and in [1], [2], [3], [4], and [5]:
   - Yearly maxima are underestimated by ERA-40 in the whole period 1975–1994 and yearly minima are overestimated at the end of this period.
   - Regarding yearly tendencies of the 1997–2010 time period, decreasing trends are found in Transdanubia, whereas increasing trends occurred in some stations in the Great Plain. Monthly averaged wind speed and wind gust decreased in April significantly.
2. Characteristics of gridded ERA Interim data and stations' wind data (1997–2010) were compared. Results are shown in the dissertation in section 5.1.2. and in [5], [6], and [7]:
   - Distributions of data series substantially differ from each other. Significant differences are found in categories of small wind speed, and around the maxima of probability density functions.
   - Significant decreasing tendencies of both station and gridded data are found. However, different seasonal and monthly tendencies are detected in many cases at ERA Interim gridcells compared to the station data.
   - In case of yearly and monthly wind speed distributions, differences among the reanalysis gridcells are smaller compared to the station data.

3. Results of homogenized synoptic data series (1975–2012) are summarized in the dissertation in section 5.1.3., and in [8], [9],[10], and [11]:
   - Homogenization made it possible to analyze the available synoptic data series from 1975 to nowadays as a whole. Data sets had to be splitted into two separate parts (1975–1994 and 1997–2010) before the homogenization of data sets because of the inhomogeneities (mainly caused by automation).
   - Average yearly wind speed is modified significantly by homogenization procedure. The fitted linear trends of average and different percentile values also changed at many stations compared to those before the homogenization. These differences emphasize that inhomogeneities in climatological time series may lead to false trend values and misinterpretations.
   - Different wind characteristics (e.g., mean, percentiles) based on the estimated tendencies decreased in most of the stations, especially in April and November.
4. Testing for homogeneity of ERA Interim reanalysis wind fields (1979–2012) and comparison of the fitted station and gridded data sets' parameters are shown in the dissertation in section 5.1.4. and in [11], [12], and [13]:
   - Results of homogenization proved that ERA Interim gridded data series are homogeneous.
   - Values of Weibull shape parameters of the reanalysis grid points are clearly larger than what is found in case of the stations data. This overestimation of Weibull shape parameters reduces the variability of wind climatic conditions and the probability of extreme wind speed.
   - Variability of scale parameter is smaller in ERA Interim grid points compared to the synoptic stations.
   - The monthly average shape parameters are almost equal in June, however, in all the other months overestimations are found at ERA Interim grid points compared to the station data.

- The larger the percentiles, the larger the bias compared to station data, i.e. underestimation exceeds 20% in case of the 0.99 percentile.
- Spatial differences cannot be well reproduced by reanalysis data unlike in case of station measurements.

5. Significant differences were found between the statistical distributions of ERA Interim and synoptic station data, therefore, the extreme analysis (i.e., frequency occurrence, trend of moderate and strong wind days, wind related indices, and estimation of return periods) have to be all based on the more reliable measured data sets for Hungary. Results and conclusions are drawn in the dissertation in section 5.1.3. and [9], [10], and [13]:

- Trends of the total number of days with low daily average wind speed and the length of consecutive days with average wind speed below several thresholds are increasing. Furthermore, most of the wind climate indices associated with higher daily average and maximum wind speed have decreased.
- Summed yearly numbers of maximum consecutive days below 3 m/s (above 8 m/s) wind speed, have increased (decreased) significantly.
- The smallest 50-year (100-year) return period is 9 m/s (10 m/s), the most frequent return period is between 12 m/s and 17 m/s (13 m/s and 18 m/s), and the highest value is 24 m/s (26 m/s). Yearly 50-year (100-year) return periods estimated from maximum wind gust series are between 31 m/s and 46 m/s (33 m/s and 50 m/s).

6. Validation and bias correction of simulated data of RegCM regional climate model were carried out. Results are presented in the dissertation in section 5.2.1. and in [13]:

- The monthly mean wind speed calculated from CARPATCLIM data is overestimated substantially by the RegCM simulation in the 1961–1990 reference period. The largest and the smallest monthly differences are found in January and June, respectively.

7. In order to evaluate global climate change influences on wind field characteristics, average and extreme parameters of bias corrected simulated wind speed of RegCM experiments were analyzed over Hungary. Projected changes for the future periods (2021–2050 and 2071–2100) compared to the reference period (1961–1990) are summarized in the dissertation in section 5.2.2. and [13]:

- Based on the simulations, wind climate is likely to become more extreme. The climate indices related to low wind speed tend to increase in the future (in case of the length of periods mainly in autumn and in spring, whereas, in case of the numbers of days in every season). Projected changes are likely to increase by the end of the century, except in spring.
- Wind indices associated with higher daily average wind speed are projected to decrease in winter, and increase in the other seasons, especially, in summer.
- Monthly projected changes are relatively small in case of the median and the 0.9 percentile value. However, regarding the higher percentiles (i.e. 0.99) wind speed changes are likely to reach 2 m/s.
- Higher return periods are expected in the future periods based on the simulations.

5. Conclusions

Results of these regional wind climate analyses are consistent with the scientific literature on global scale, most of which concluded to declining trends from the end of the last century in the northern midlatitudes. Analyses for the recent past were carried out using homogenized measured data sets. Reliability of the results is enhanced by applied quality control to the data series.

Evaluation of global and regional climate change with special focus on detected wind climate provides key information for the validation of regional climate model experiments. Using these results together with the projections, they may serve as a basis for estimating the environmental impacts of regional wind climate change.

The presented detailed complex analysis of the Hungarian wind climate, including both the past and the future, can be considered as a novel research. Based on the estimations wind climate in Hungary is likely to become more extreme overall. Results of the dissertation may be used in developing national, regional, and local adaptation strategies and planning appropriate actions in all levels.

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