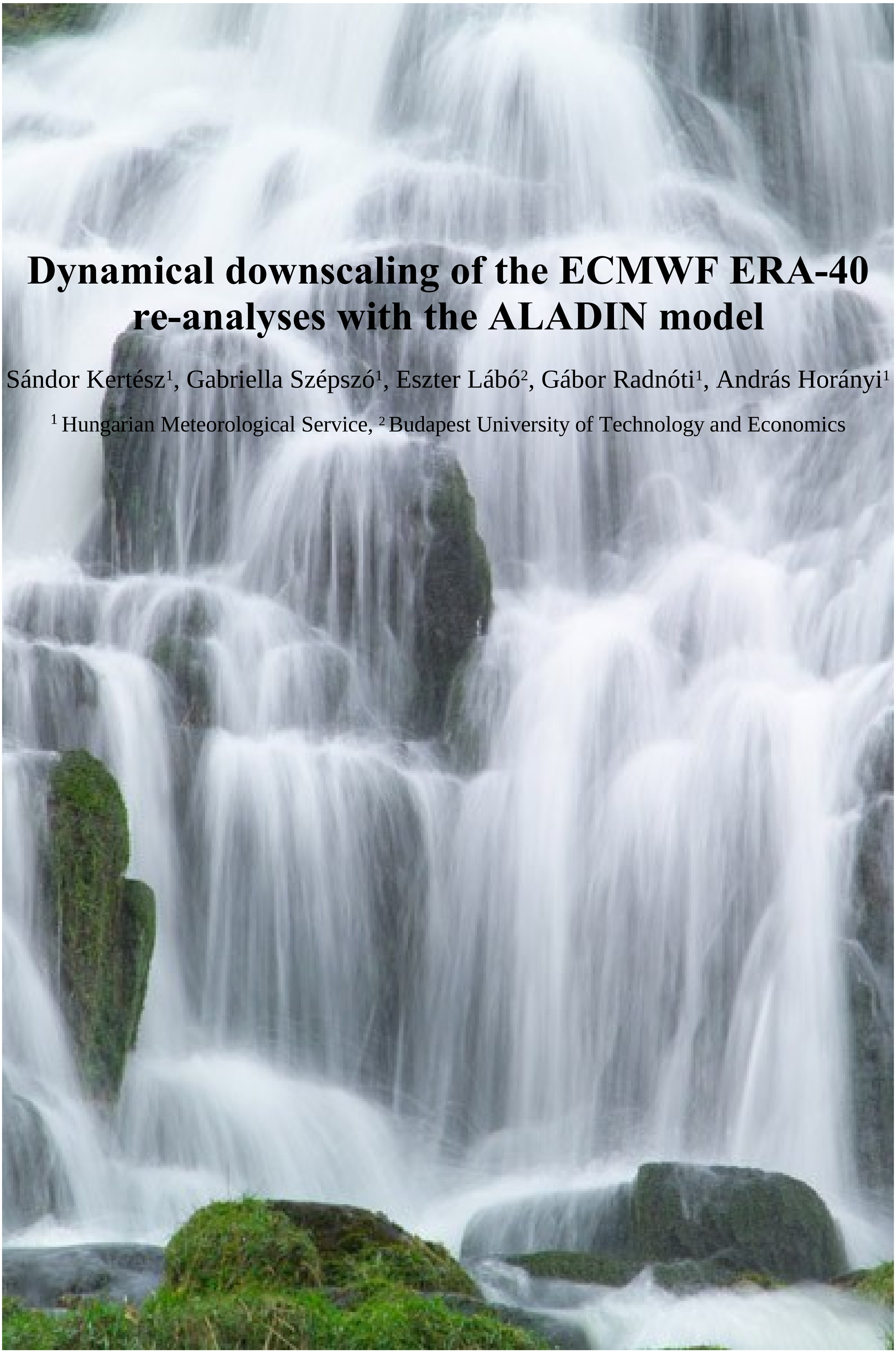

Dynamical downscaling of the ECMWF ERA-40 re-analyses with the ALADIN model

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1. Introduction

The fine scale investigation of the climate of the last few decades was mainly focused on the surface parameters disregarding the upper-level or PBL parameters. This was the straight consequence of the fact that observations of high spatial and temporal resolution were only available at the surface level. Nevertheless, PBL level climate information is of great importance for better understanding the climate and climate change, and there are several economical aspects, as well (e.g. installation of wind power plants requires the exact knowledge of the wind climate in the lower 100-150 m layer of the PBL).

The above problem can be solved using the global re-analyses that have become available at large centres (ECMW, NCEP) in the recent years. These re-analyses were produced by applying advanced data assimilation systems for past periods, reconstructing the full three dimensional fields in a dynamically-physically consistent way. However, the spatial resolution of these data is rather coarse (grid distance is over 100 km) describing only the large-scale features and providing little information of the small scales, highly affected by the orography. Thus, an appropriate downscaling technique is required to achieve the desired fine-scale climate fields.

In our experiments, such a scheme was applied to produce a high resolution wind climate for Hungary for the lowest part of the PBL. Our goal was achieved with the dynamical downscaling of the ECMWF ERA-40 re-analyses using the ALADIN model. The dynamical downscaling was realized in successive steps with nested model integrations. As a result, the wind climate for Hungary on a 5 km grid and 7 vertical levels from 10 m up to 150 m, for a 10-year period (1992-2002) was produced. In this article, a brief overview of the downscaling procedure is provided, and the first results and their inter-comparison with the available observations are presented.

2. The ERA-40 re-analysis

The ERA-40 (ECMWF Re-Analysis) project started in 2000 to produce global re-analyses for the 1957-2002 period with 6 hour of temporal resolution (Simmons and Gibson, 2000). All the available observations including both in-situ and remote-sensing measurements were taken into account. The basic analysed variables included not only the conventional meteorological wind, temperature and humidity fields, but also stratospheric ozone and ocean-wave and soil conditions. The re-analyses were produced on a T159 horizontal spectral resolution (nearly 125 km) and 60 vertical levels (up to 65 km height), using the 3D-FGAT data assimilation technique with 6 hourly frequency throughout the period, supplemented by intermediate 3-hour forecasts. The results are available in the ECMWF MARS database.

3. The downscaling technique

The dynamical downscaling of ERA-40 data was performed for a Hungarian domain of 5 km resolution for the period between January 1, 1992 and August 31, 2002. As the difference between our target resolution (5 km) and the ERA-40 resolution (~125 km) was quite significant, it was not obvious how many intermediate integration steps were needed to reach the optimal result. From a practical point of view, a single nesting and a double nesting solution were considered. The Slovenian colleagues, who were also working on the downscaling of ERA-40 data, carried out some experiments that indicated that double nesting gave better performances. Thus, two nested ALADIN integration steps were included at 45 and 15 km resolutions, respectively. In the final step ALADIN dynamical adaptation (DADA), developed for wind and precipitation (Žagar and Rakovec, 1999), was applied to reach the desired 5 km resolution (Fig.1). The applied DADA included a 30-minute quasi-adiabatic integration to reduce the interpolation errors, and to adapt the wind field to the high resolution orography. This configuration used only physical parametrization packages relevant to the near-surface wind fields (e.g. vertical turbulent diffusion, gravity wave drag). The dynamical downscaling consisted of the following integration, pre- and post-processing steps (for each step AL15 was used):

1. As a first step - naturally - the ERA-40 global data had to be downloaded from the ECMWF

MARS database. Considering the line width at that time, this was a rather slow procedure and lasted for several months.

2. In the next step the raw global data (in GRIB format) was interpolated into a domain of 45 km resolution covering approximately the former LACE domain (see Fig.1). This step started with the run of configuration 901 to convert GRIB to FA format and was followed by configuration 927.

3. In the first dynamical downscaling step, the ALADIN model was run on the 45 km resolution domain, using the fields produced in the previous step as LBCs.

4. In the second dynamical downscaling step, the ALADIN model was run on a 15 km resolution domain that covered only a smaller Central-European area (see Fig.1). The LBCs in this case were provided by the forecasts of the previous - 45 km resolution - step.

5. In the last step, DADA was applied to the results of the 15 km resolution runs to achieve the desired 5 km horizontal resolution over a Hungarian domain (see Fig.1). The results of DADA was then post-processed by Full-Pos to derive fields on 10, 25, 50, 75, 100, 125 and 150 m height levels.

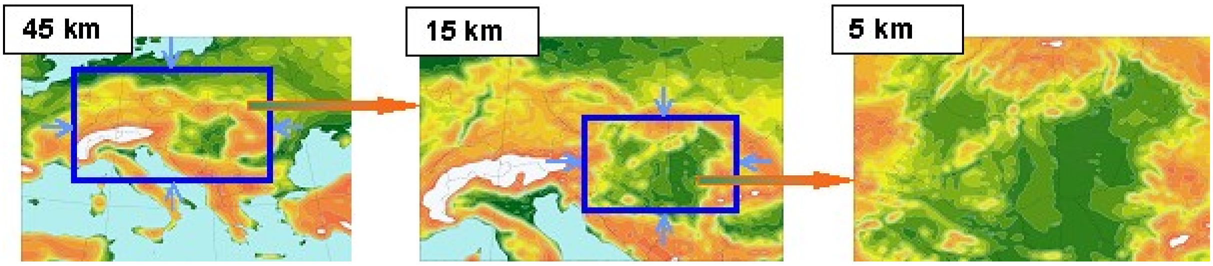

Figure 1. The steps of the dynamical rescaling using nested domains with increasing resolution.

While the coupling of the 45 km resolution runs with the ERA-40 data was quite obvious, it was not the case for the 15 km and 5 km resolution runs. The decision on the length of the individual integrations was not straightforward either. Regarding this question, two aspects were to be considered: if we want to use the re-analysis information as frequently as possible, then, short integration times seem to be optimal, while to avoid spin-up longer integration times should be used. Based on the Slovenian colleagues' experience, even 3 or 6 hour forecasts can be used to produce correct wind climate information. However, at a later stage, we would also like to generate precipitation climatology, and for precipitation, it is better to use longer forecasts (even beyond 12 hours). All things considered, the following configuration has been chosen (see Fig. 2):

- ✗ The integration on both the 45 and 15 km resolutions was started from 00 UTC on each day of the investigated period and lasted for 36 hours.
- ✗ To avoid spin-up only time-steps between 12 and 36 hours of the 45 km resolution runs were used as LBCs for the 15 km resolution runs.
- ✗ The LBCs for the first 12 hours for the 15 km resolution runs were provided by the 24-36 hour forecasts of the 45 km run started on the day before.
- ✗ The 5 km resolution DADA runs were coupled by the 12-36 hour forecasts of the 15 km resolution model runs.

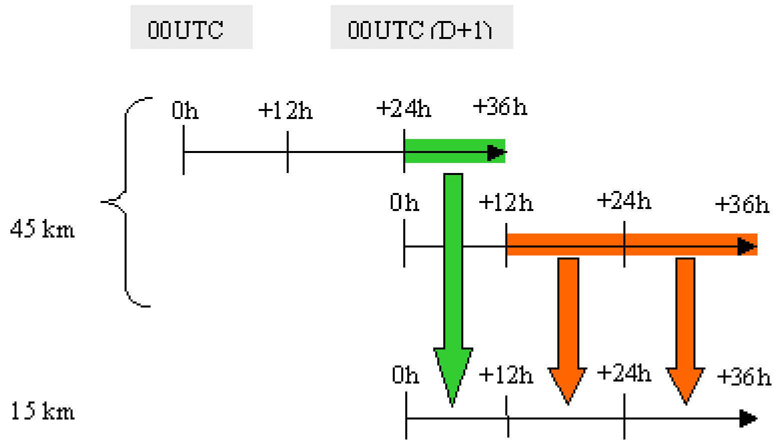

Figure 2. The coupling scheme between the nested 45 km and 15 km resolution ALADIN runs.

4. Preliminary results

Up to now, only a limited evaluation and verification of the computed wind climate has been performed. The 6 hourly wind fields were used to create average wind speed maps for each investigated levels (see Fig.3). It can be seen on the maps that the wind maximum appears in the North Transdanubian region. At the 100-150 m height, the average values exceed even 7 m/s. The spatial distribution of the wind speed is in good accordance with two other wind climate maps produced at HMS. The first map is valid for the 1971-2003 period, and the upper-level winds were derived with the logarithmic wind profile from a grid-based wind climate at 10 m, generated with statistical modelling. The second 5 km resolution map covers the 2003-2004 period and was derived by the dynamical adaptation of the operational ALADIN/HU (AL15 and AL28) forecasts.

Regarding the verification, unfortunately, observations were only available at 10 m for the investigated period. Figure 4 shows the difference between the observed and computed average 10m wind speed values for 19 Hungarian locations. It can be seen from the figure that the dynamical downscaling usually overestimates the average wind speed. Beside the average wind, the wind direction distribution was also investigated. For most of the locations the computed wind direction distribution was in good accordance with the observations (see Fig.5), but there were also severe differences, especially in the vicinity of highly variable terrain.

The differences between the 10m measurements and the downscaled values can arise from at least three sources. Firstly, with dynamical downscaling, we produced wind data only every 6 hours, while the observed average is based on hourly measurements. Secondly, the applied 5 km resolution is obviously too coarse to describe the highly variable local orographic features that can greatly affect the wind field, because it only reflects the average features of a 5x5 km gridbox. Finally, both the ALADIN model and the ERA-40 re-analysis fields can be the source of a trivial error. At present, it is hard to asses the relative effect of the above error sources. Nevertheless, the forecast for upper levels is thought to be better than for 10 m since the effect of the local orographic structures becomes less significant with increasing height.

5. Preliminary conclusions

The dynamical downscaling of the ECMWF ERA-40 re-analyses was performed with the ALADIN model, and a 5 km resolution Hungarian wind climate was derived for a 10-year period for the lowest 10-150 m layer of the PBL. The applied double-nesting technique combined with dynamical adaptation for wind proved to be effective, and resulted in realistic wind fields with a similar spatial distribution to wind climate fields derived with other methods. A preliminary verification was carried out for the 10m level. While the computed and observed wind direction distributions were quite similar in most of the cases, the average wind speed was overestimated at several locations. Du to lack of upper-level measurements, the verification of the upper level fields has not been possible, yet.

6. Future plans

The more detailed evaluation and verification of the derived wind climate fields will be continued. We will compare the PDF of the observed and computed wind values for 10 m, and the wind speed distribution according to the direction will be also investigated. Some short term PBL wind measurements will be also included in the verification. Besides, the ERA-40 downscaling and wind climate investigation will be extended for the full 1957-2002 ERA-40 period.

7. References

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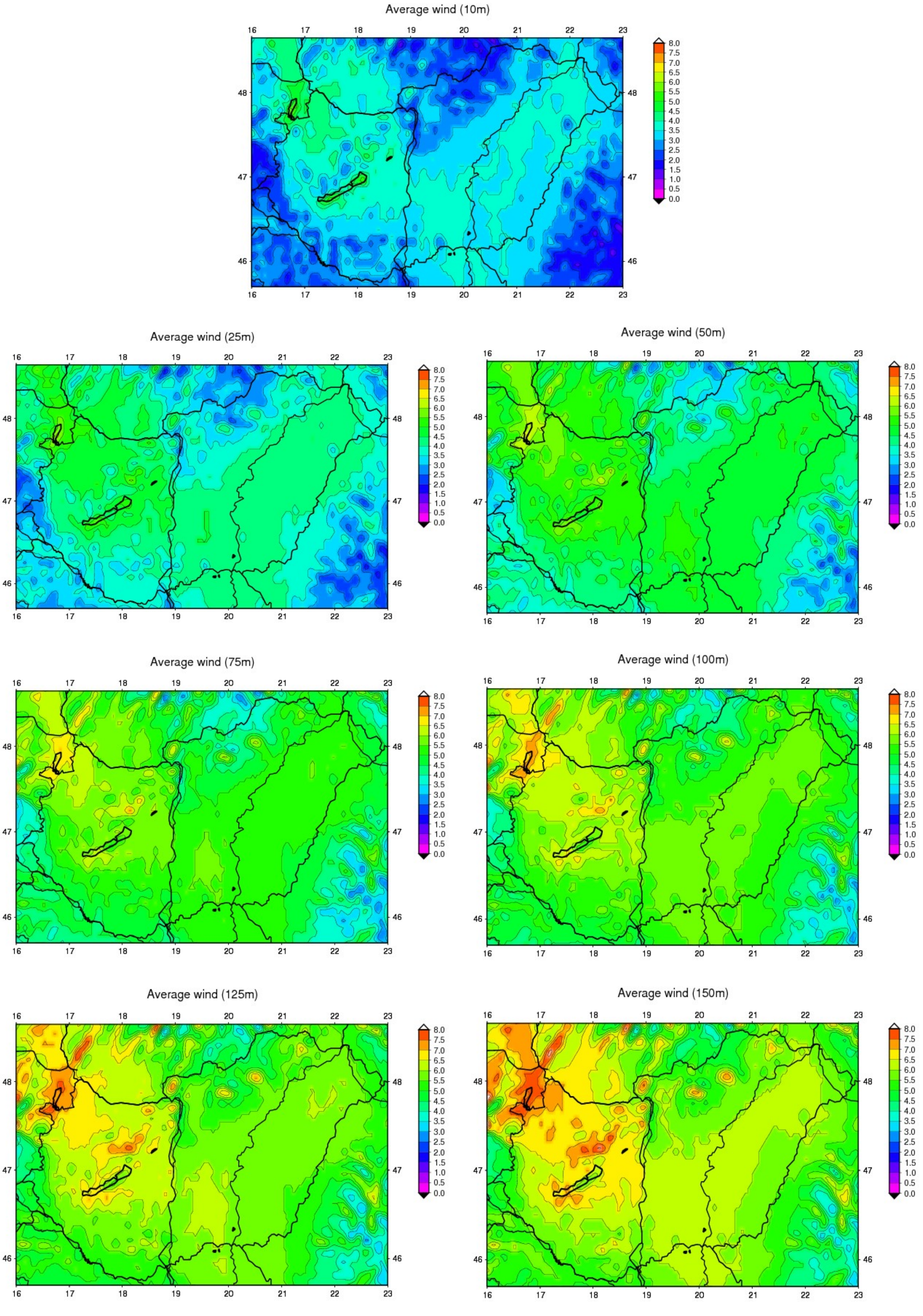

Figure 3. The average wind speed on different height levels between January 1, 1992 and December 31, 2001 derived from the dynamical downscaling of ERA-40 data.

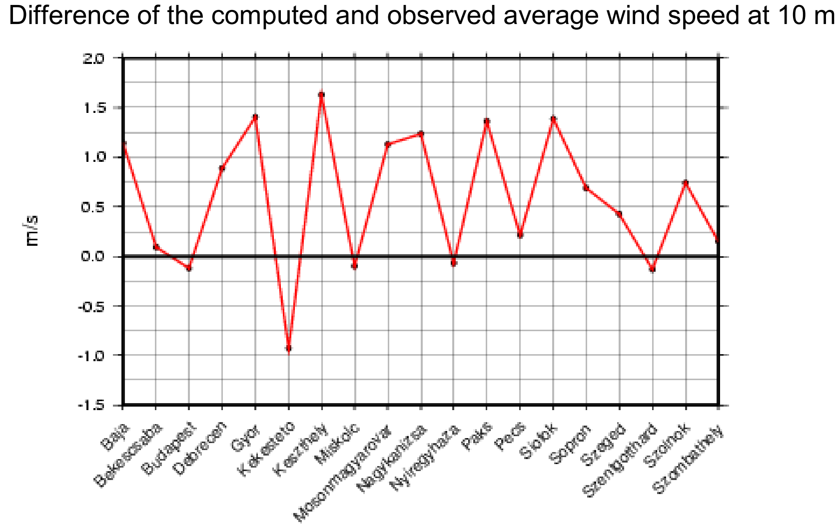

Figure 4. The difference between the computed and observed average 10 m wind speed for 19 Hungarian locations for the period between January 1, 1992 and December 31, 2001.

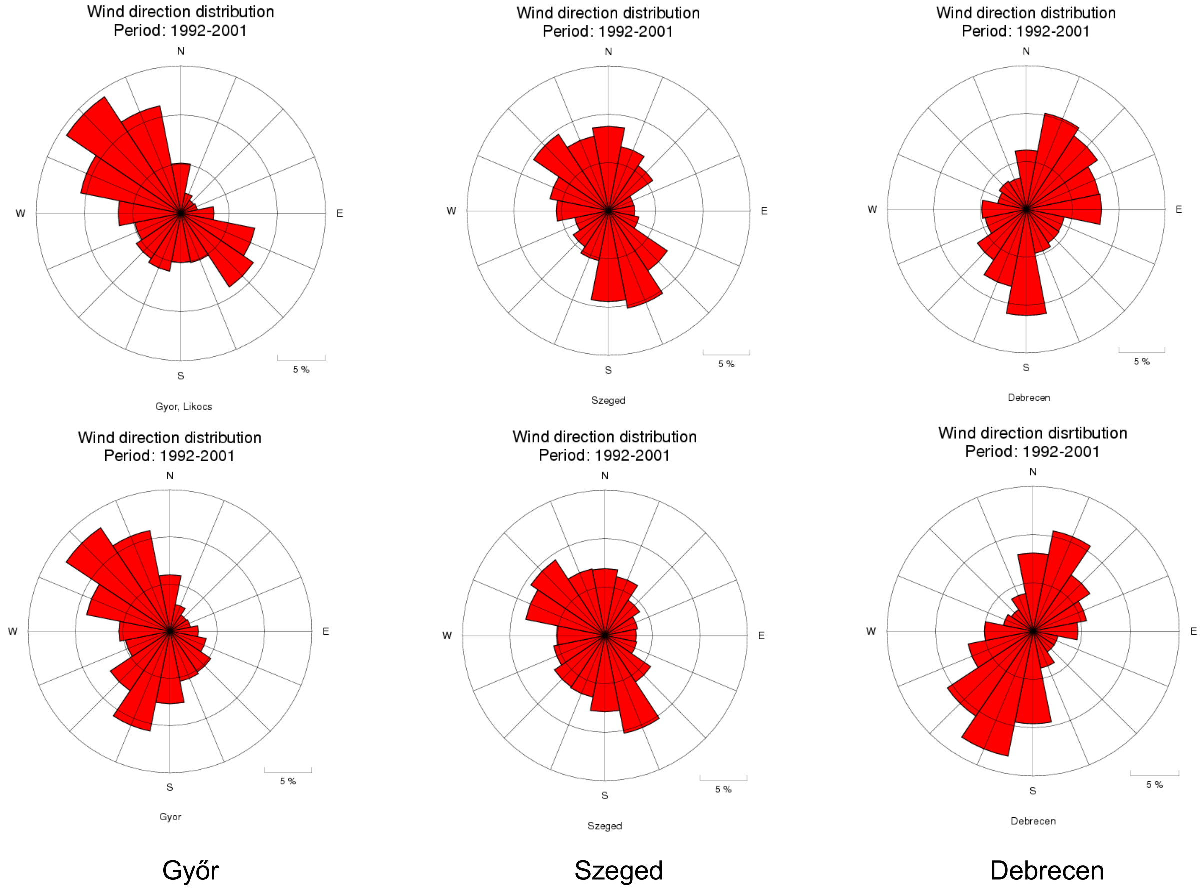

Figure 5. The computed (lower row) and observed (upper row) 10 m wind direction distribution for three Hungarian locations for the period between January 1, 1992 and December 31, 2001.

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