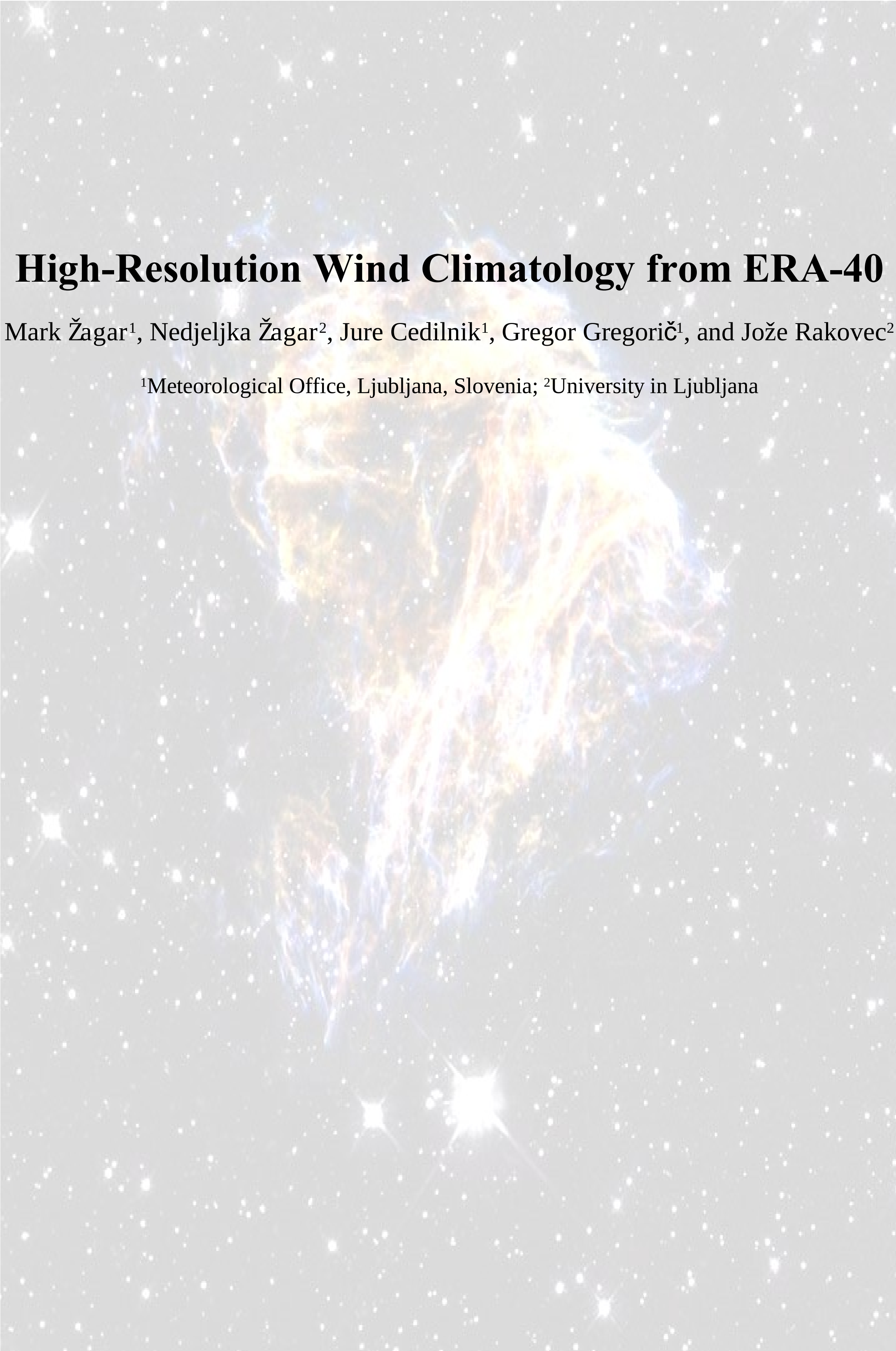

High-Resolution Wind Climatology from ERA-40

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1. Summary

The ALADIN model was used for downscaling of the ECMWF 40-years re-analysis dataset with a goal to produce a high-resolution wind climatology for Slovenia. In this paper results are presented concerning the quality of the obtained climatology. Overall, the downscaled wind climatology is regarded as useful. Characteristics of the observed wind climatology often appear to be controlled by terrain features of smaller scales than the resolution of the finest ALADIN configuration used, 2.5 km. Additionally, an investigation of the model's spectra in the temporal domain has been performed for various ALADIN configurations and compared to the observations. The investigation of the spectral power distribution has revealed that the applied 10 km ALADIN cannot realistically represent the sub-diurnal part of the spectrum in a complex terrain such as Slovenia.

2. Introduction

The ECMWF 40 year re-analysis project (ERA-40) resulted in a consistent data-set of a climatologically meaningful length. Its horizontal resolution of one degree is, however, only sufficient for large-scale analyses. Downscaling methods have to be applied to produce higher resolution data containing the response of the large-scale flow to the local topography. This applies especially to the regions with complex topography as for example Slovenia. The ERA-40's predecessor, ERA-15, was previously used by Heimann (2001) to produce a wind climatology over the large Alpine area.

Our goal was to design, construct and evaluate the downscaling for the purpose of wind and precipitation climatology at a kilometre scale. Such a high-resolution climatography finds many applications, like road construction, pollution prevention, agrometeorological planning and not least the wind-energy harvest.

In this paper, we are presenting our approach, set-up of the simulations and the results in terms of 2.5km wind climatology. Additionally, we conducted research on the influence of the nesting strategy to the quality of the downscaled wind fields through comparison with local observations. Here not only the standard statistics is computed but we have also attempted to get a deeper insight into the model's ability to represent the mesoscale flow features. This is achieved by comparing modelled and observed energy spectra in the frequency domain. In this way we also assess stations' suitability for verification purposes, related to forthcoming evaluations of climate simulations and future climate scenarios.

3. The method

ALADIN is a well-suited limited-area model for downscaling the ERA-40 data. The driving ERA-40 data provide synoptic-scale forcing through the lateral boundary conditions. Various surface forcings, coupled with a high-resolution dynamics in ALADIN provide the mesoscale flow features we are interested in.

The ERA-40 data resides on MARS archiving server at the ECMWF. Ten years data at 6 hour intervals were retrieved and downloaded onto our local archiving server. These data were then used as an input to the IFS/ARPEGE configuration 901. The resulting ARPEGE global fields were than interpolated onto the mesoscale grid using configuration e927. The original design of our downscaling experiment, from which the actual wind climatology was obtained, was such that the resolution of this mesoscale grid was 30 km and the domain covered most of Europe (EU0 in Fig. 1). Following results of earlier studies (e.g. Qian et al., 2003) showing that for regional climate modelling reinitializing the model at certain frequency is advantageous over a continuous run, we chose to reinitialize the model every 2 days. The 10-year period 1991-2000 was broken into 60 hours long integrations with 12 hour overlap and ostracised the first 12 hours of each run. A 10 km nest was used next in the same fashion, initialized from and coupled with the 30 km run. Finally a 2.5 km dynamical adaptation for the wind field only (Žagar and Rakovec, 1999) was carried out on the 10 km fields every 3 hours. Obviously the kilometric scale has not been reached yet using

ALADIN only. Dynamical adaptation to kilometre scale has not yet been tried because the required high resolution topographic database has not yet been constructed. Instead, we took an alternative path of a purely kinematic method, where the divergence of the wind field was minimised through iterations, controlled by only a few parameters, describing the atmosphere's resistance to vertical displacement. The Aiolos model (Focken et al., 1999) was used for this purpose. Some results of this model are shown to illustrate (im)possible improvement of dynamical modelling by a simplistic kinematic approach.

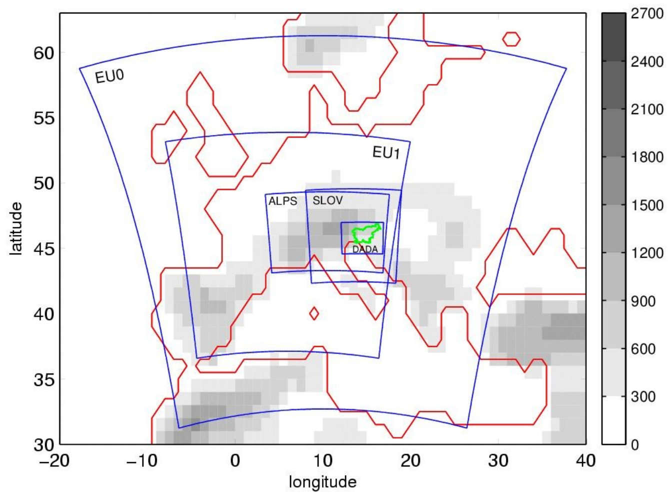

Figure 1. Geographical domains of different ALADIN setups, used for the climatology and the sensitivity studies.

We have furthermore investigated the importance of the nesting strategy of ALADIN to ERA-40. For this purpose, we defined two additional domains, shown in Fig. 1. One is denoted EU1 and it includes 188x188 points at 10-km spacing while the second domain, denoted ALPS, contains 104x68 points at the same resolution as EU1. In this way the model results over Slovenia in these two simulations differ only in the distance from the lateral boundaries. In other words, the model tendency to develop its own solution should be better seen in the results of EU1, as opposed to strong controlling effect of the large-scale model due to vicinity of the lateral boundaries in ALPS. Besides standard statistical scores, we investigated the distribution of the spectral over temporal scales in different set-ups and compared it with these derived from observations.

4. Results

4.1 Average quantities

For comparing different model set-ups with observations we chose to present here six locations around Slovenia: Portorož, situated at an airport some two kilometres from the flat coast, Bilje near the exit of a valley at the pre-alpine transition, Murska Sobota in a flat land near the border with Hungary, Brnik airport at the northern edge of the Ljubljana basin, an exposed location Rogla, at the top of a 1500 m high wooded mountain, and Kredarica, located at a 2515 m high mountain observatory, partly shielded from north and west.

Figures 2-3 show the results of downscaling in three described configurations, ALADIN at 10 and 2.5 km and with a kinematic model, against the observed equivalent. It can be noted that the average wind power “punishes” model errors even more than the RMSE score, but also that the modelled average power can show reverse signal regarding the quality than that of the average speed. Not surprisingly the 10-km ALADIN performs well where the main topographic features affecting the flow (coast, flatland) are sufficiently well described at that horizontal resolution. Results are significantly improved when a higher resolution, 2.5km orography, is incorporated (e.g. at the mountainous stations). On the other hand, results of a kinematic model turned out to be rather difficult to interpret.

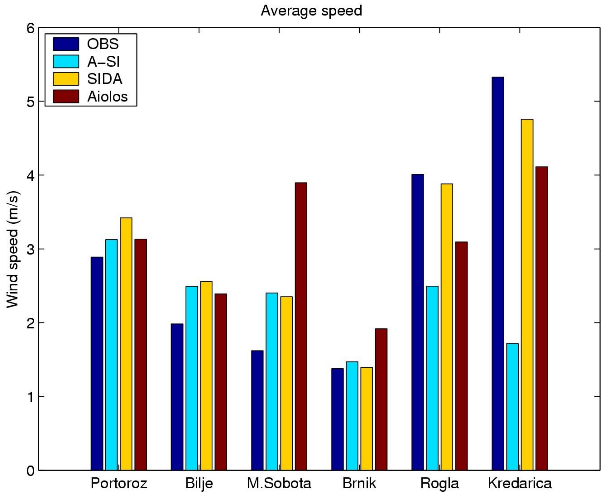

Figure 2: Comparison of the modelled wind speed to the observed one, at six stations.

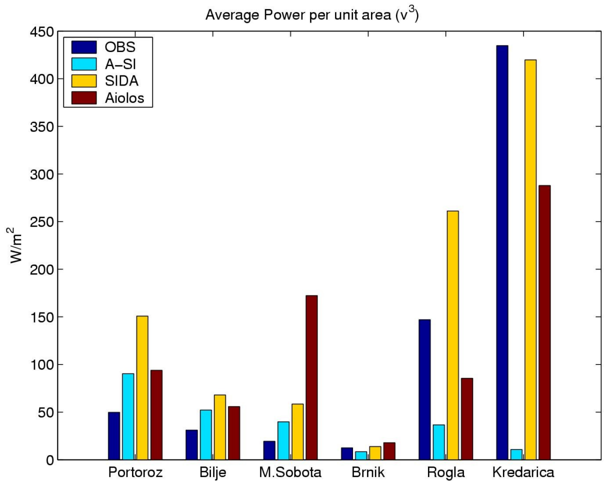

Figure 3: Average wind power (third momentum of the speed divided by the air density).

4.2 Energy spectra

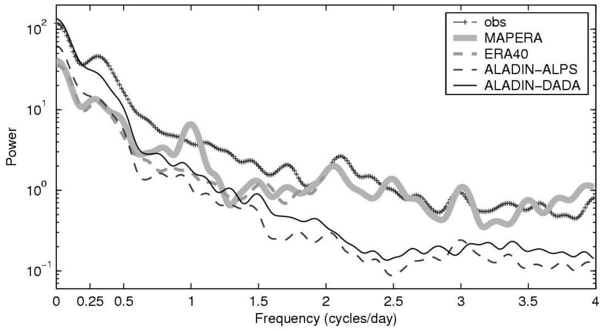

Figure 4: Modelled and observed spectra for the zonal wind component at Rogla.

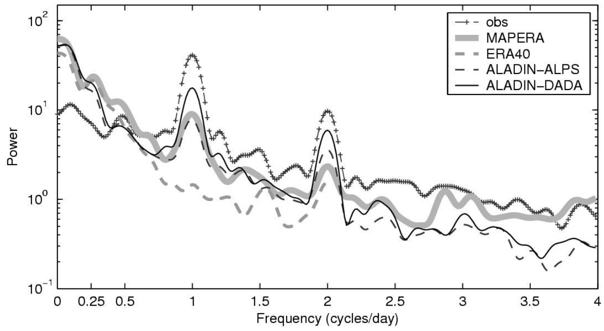

Figure 5: As Fig. 5 but for Portorož.

The spectral energy distribution in various temporal ranges (sub-diurnal, diurnal and longer-than-diurnal periods) should be as close as possible to the observed distribution. Figures 4-5 show the distribution in the temporal domain for two different locations, a mountainous one, Rogla (Fig. 5), and one at the coast, Portorož (Fig. 6). Domain ALADIN-ALPS was designed to include only the Alpine region and it is the smallest domain tested for downscaling. The dynamical adaptation nest (DADA) is driven by the ALPS simulation. Another included curve, denoted MAPERA, represents the best possible estimation of the observed state using the ECMWF re-analysis system during the MAP period (September-November 1999), for which comparison has been performed. The ALADIN spectra show that the model underestimates the spectral power in short temporal scales at Rogla. At Portorož, on the other hand, the model proves its capability to reproduce the diurnal and semi-diurnal peaks, related to the sea- and land-breeze circulation, especially after downscaling from 10 to 2.5 km. The underestimation of the subdiurnal power range is particularly noticed at the stations located in basins and lowlands (not shown). This remains to be further investigated.

5. References

Focken, U., Heinemann, D. and Waldl, H.-P., 1999: Wind Assessment in Complex Terrain with the Numeric Model AIOLOS - Implementation of the Influence of Roughness Changes and Stability, *Proceedings of the European Wind Energy Conference*, Nice, France, 01.-05.03.1999, 1173-1176

Heimann, D., 2001: A Model-Based Wind Climatology of the Eastern Adriatic Coast. *Meteorol. Z.*, **10**, 5-16

Qian, J.-H., Seth, A. and Zebiak, S., 2003: Reinitialized Versus Continuous Simulations for Regional Climate Downscaling. *Mon. Wea. Rev.*, **131**, 2857-2874

Žagar, M. and Rakovec, J., 1999: Small-scale Surface Wind Prediction using Dynamic Adaptation. *Tellus*, **51**, 489-504.

Žagar, N., Žagar, M., Cedilnik, J., Gregorič, G. and Rakovec, J., 2005: Dynamical Downscaling of ERA-40 for the Wind Climatology in the Mountainous Terrain. *Tellus A, under revision*.

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