DOWNSCALING OF ERA40 FOR THE WIND FIELD IN A COMPLEX TERRAIN

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Abstract: This study deals with the optimal strategy for setting up the ALADIN model for the purpose of dynamic downscaling of ERA40 over the Alpine region. The mesoscale model wind field is compared with MAP-SOP reanalysis data and with wind observations at eleven Slovenian stations. As expected, there is an improvement in the conventional statistics at a 10-km grid as compared to the 40-km analyses. However, the differences between the mesoscale model scores at various domains can be greater than the difference between the MAP-SOP reanalyses and a particular mesoscale simulation.

***Keywords** - downscaling, nesting strategy, ALADIN, MAP-SOP reanalyses*

1. INTRODUCTION

Regional wind climates at mesoscale resolutions are usually based on downscaling the global general circulation models or reanalysis data sets. For the purpose of the wind climatology of Slovenia we apply an operational NWP model, the ALADIN model, to dynamically downscale 40-year reanalysis data of the European Centre for Medium-Range Weather Forecast (ECMWF) (ERA40) from ~120 km to ~10 km horizontal resolution. In the present paper, we deal with the optimal strategy for setting up the ALADIN model by investigating the impact of the domain size, the length of the spin-up period and the strategy for reinitialization.

A comparison with observations is carried out for the Mesoscale Alpine Program-Special Observing Period (MAP-SOP), for which reanalysis including MAP-SOP observations (hereafter MAPERA) are available every three hours on a ~40 km grid (Keil and Cardinali, 2004).

2. METHODOLOGY OF DOWNSCALING

Driving ERA40 fields have a higher vertical but a much lower horizontal resolution than ALADIN. The ratio of the horizontal resolutions in ERA40 and ALADIN is 12, a factor that has been found sufficient for the purpose of initializing/coupling regional models (Denis et. al., 2003). The whole Slovenia is situated inside 3×2 grid boxes of ERA40, as can be noticed in Fig. 1 (left). This figure also shows various domains used for simulation experiments. For one out of three simulations, the nesting is carried out in two steps. The outer domain (EURO1) covers Europe with a 30-km grid and contains one-way nested domain SLOV that mimics an earlier operational ALADIN domain for Slovenia with 11.2-km resolution. Two other domains, denoted EURO and ALPS, are nested directly into ERA40 and they have a horizontal resolution of 10 km.

3. RESULTS

Initial conditions for ALADIN are interpolated from ERA40 and they hardly contain significant information on the mesoscale. But after the forecast has started the mesoscale part of the kinetic energy spectrum is expected to develop quickly. This is shown in Fig. 2 (left). The energy is generated at most of scales during the first ten hours and changes after 12 hours are negligible. Thus we take a 12-hour period for the model spin-up time. It can also be noticed in Fig. 2 (middle) that the slope of the average tropospheric kinetic energy spectrum has a wavenumber dependence in the mesoscale range closer to k^{-3} than to the expected $k^{-5/3}$ law.

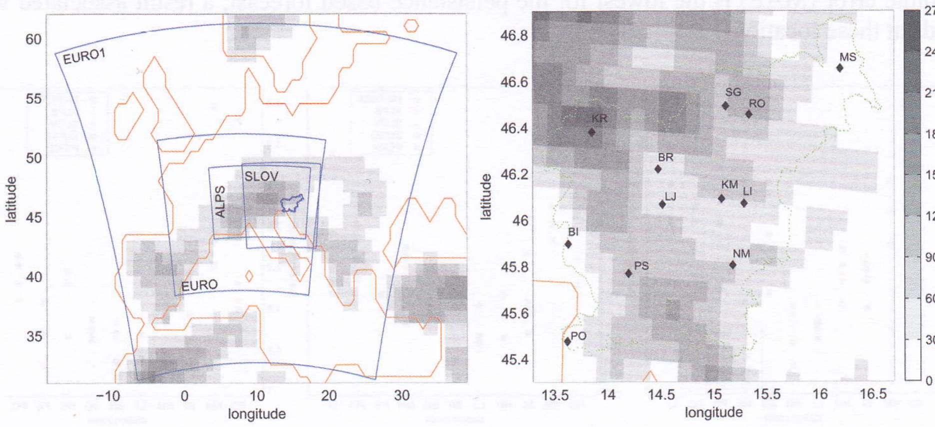

Figure 1. Left: ALADIN domains used for sensitivity experiments, nested in ERA40. Right: The model orography over Slovenia in 10-km resolution with locations of the verification stations overlaid.

However, a very different spectrum is found close to the surface, illustrating the strength of the surface forcing. Here, much less energy, as compared to the tropospheric average, is found above ~100 km (9Δx), and there is relatively more energy below this scale. It is similar for the vorticity and divergence, but the scale is ~180 km; i.e., the divergence dominates over vorticity close to the surface at the mesoscale (Fig. 2, right).

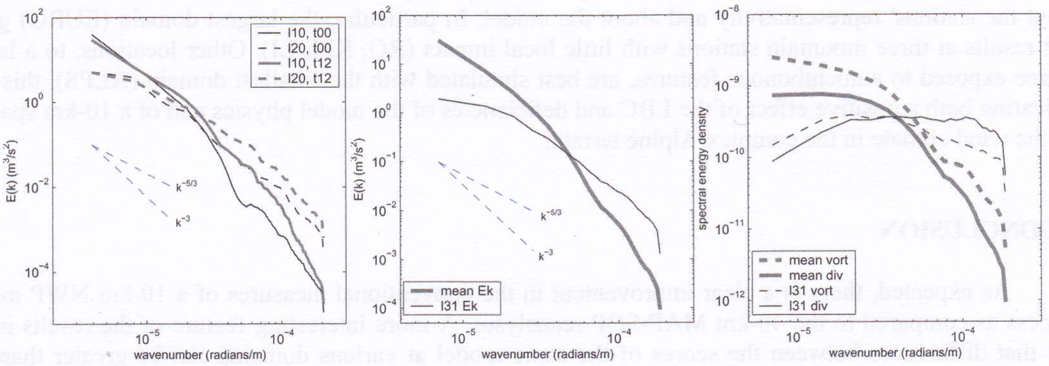

Figure 2. ALADIN spectra. Left: kinetic energy spectra at model levels 10 (thin black) and 20 (thick grey) at the start of the forecast (full line) and after 12 hours (dashed line) for a single simulation experiment. Middle: kinetic energy spectra averaged for the 70-days period and within model levels 8 to 18 (4-9 km) (thick line) and for the lowest model level (level 31, at ~20 m) (thin line). Right: as in the middle figure, but for the vorticity (dashed line) and the divergence (full line).

Downscaling is carried out by reinitializing model every two days. An option with daily reinitialization has been tested but it did not bring improvements. Another option is a continuous run, but the results of this test were negative, in agreement with other studies indicating that periodic reinitialization of regional models provides better downscaling results than the continuous simulation (e.g. Qian et. al., 2003).

Three conventional scores are shown in Fig. 3 for the meridional wind component during the MAP-SOP. They illustrate the impact of the horizontal resolution (MAPERA vs. SLOV/EURO/ALPS) and the impact of the lateral boundary conditions (LBC) (SLOV vs. EURO vs. ALPS). A score based on the 24-hour persistence is also added in figures. Comparing the ALADIN results with the diurnal persistence-based score and MAP-SOP reanalyses, it can be concluded that the downscaling to 10 km has been successful. In particular, stations well exposed to the synoptic forcing (RO, KM, LI) and with mean wind speed over 3 ms^{-1} are characterized by a large anomaly correlation (AC) and a poor persistence score. For other stations the persistence score is between ALADIN and MAPERA. At several stations the mean absolute error (MAE) is the lowest for the persistence-based forecast, a result associated with very weak winds at these locations.

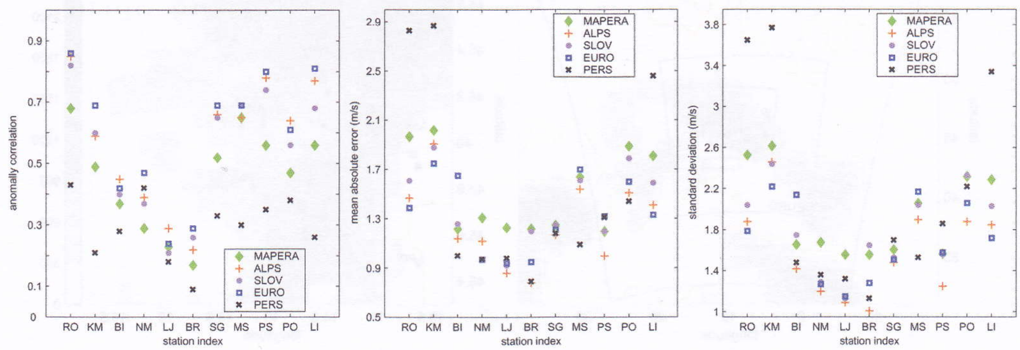

Figure 3. Scores for the meridional wind component during the MAP-SOP. Left: anomaly correlation (AC), middle: mean absolute error (MAE), right: root mean square error (RMSE).

While it is expected that the ALADIN scores are better than MAPERA, a less expected outcome is a spread of scores for various ALADIN domains. The MAE and RMSE scores indicate that differences between ALADIN simulations can be greater than the difference between one of them and MAP-reanalyses at four times lower resolution.

Both ALPS and EURO have a better performance than the SLOV simulation, which suggests that the two-step nesting is not needed. Sensitivity of the statistics to the model domain carries a message about the stations' representativity and about the model. In particular, the largest domain (EURO) gives best results at three mountain stations with little local impact (RO, KM, LI). Other locations, to a larger degree exposed to autochthonous features, are best simulated with the smallest domain (ALPS), this fact indicating both a positive effect of the LBC and deficiencies of the model physics and of a 10-km spacing for the wind climate in the complex Alpine terrain.

4. CONCLUSION

As expected, there is a clear improvement in the conventional measures of a 10-km NWP model success as compared to the 40-km MAP-SOP reanalyses. A more interesting feature of the results is the fact that differences between the scores of the same model at various domains can be greater than the difference between the MAP-SOP reanalysis data and a particular mesoscale simulation. It is thus important to study the optimal mesoscale model domain for the region of interest in prior the downscaling.

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