Preparation of ECMWF LBCs for RC LACE: spectral analysis

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1 Introduction

The horizontal kinetic energy spectra represent a valuable tool for numerical weather prediction (NWP) model evaluation (e.g., Skamarock, 2004). In order to run a limited area weather forecast model, such as the mesoscale model ALADIN, the lateral boundary conditions (LBC) are required. The latter are regularly derived from global models, whereby the meteorological fields from a global domain need to be interpolated onto the finer grid of the target limited-area model (LAM).

Many countries involved in ALADIN consortium use Integrated Forecasting System (IFS) of European Centre for medium-range weather forecast (ECMWF) as LBCs for their operational systems. For members of Regional Cooperation for Limited Area modeling in Central Europe (RC LACE), whose national model domains largely overlap, the preparation of LBCs is a two-step procedure; in order to decrease the data transfer, the global ECMWF forecast is first interpolated to a common LBC-LACE domain, and then interpolated to the final grid at each national service.

In the present article we investigate how various approaches used for operational LBC preparation from IFS/ECMWF affect the information content in spectral space, in the case of Slovenian operational ALADIN model domain.

2 Methods

2.1 Various approaches to LBC preparation

In this investigation using currently operational domain SIS4 of the Slovenian Environment Agency (4.4 km horizontal resolution and 87 vertical levels), three approaches to prepare the LBCs are studied.

The old procedure which was in use for many years (denoted as "old") is designed as follows: firstly, the fields from a global ECMWF model are interpolated to the LBC-LACE domain (15.4 km resolution) via the twofold interpolation path, using the ALADIN/ARPEGE model configurations c901/e927. This implies interpolation from ECMWF to ARPEGE and another interpolation from ARPEGE to ALADIN model geometry. Subsequently, the fields from the LBC-LACE domain are interpolated onto the final SIS4 domain utilizing the ee927 configuration.

In the new version which became operational on 9 June 2020 (denoted as "new"), on the contrary, the fields from a global model are interpolated to the LBC-LACE domain using the onefold interpolation procedure as provided by the ALADIN configuration c903. As in the earlier approach, another ee927 step is needed to reach the final SIS4 domain.

To evaluate both aforementioned approaches, an experimental setup (denoted as "exp"), moreover, interpolates the fields from a global model directly to the target domain SIS4 through c903 pathway. The various interpolation possibilities for the LBC preparation from ECMWF are illustrated on Fig. 1.

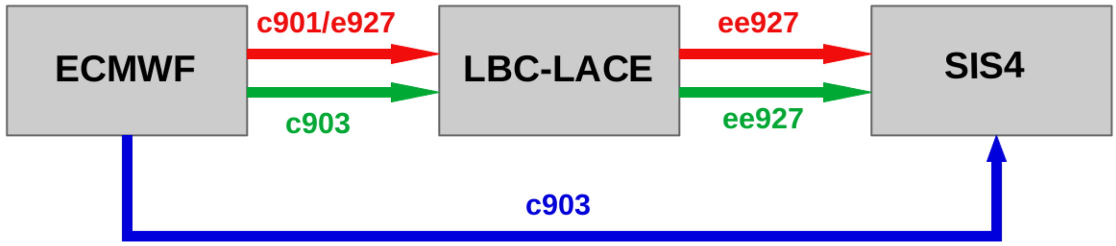

Figure 1: Various interpolation techniques during the course of LBC preparation: the "old" operational version is marked red, the "new" (current) operational version is marked green, whereas the "exp" setup is marked blue.

2.2 Horizontal kinetic energy spectra computation

We investigate how do various LBC preparation techniques affect the information content in spectral space. The horizontal kinetic energy spectra for various vertical model levels are thereby computed as a function of the total horizontal wave number $K = \sqrt{k^2 + l^2}$, where k and l represent the wave numbers in horizontal x in y direction. For a comprehensive explanation of the spectra computation the reader is referred to Blažica et al. (2013), who employed the same approach. The following graphs display the spectral kinetic energy in dependence of the total horizontal wavelength, whereby both axes exhibit logarithmic scale. In addition, the theoretical limits of $K^{-5/3}$ (three-dimensional turbulence; characteristic of mesoscale and smaller scales) and K^{-3} (two-dimensional turbulence; characteristic of larger scales) are shown for comparison. These theoretically derived slope limits have been advocated by several observational studies (e.g., Nastrom and Gage, 1985; Lindborg, 1999) as well as numerical modelling investigations (e.g., Skamarock, 2004; Blažica et al. 2013; Skamarock et al., 2014).

3 Results

The analysis is performed for a single meteorological situation, a 12-hour forecast initialized at 14 May 2020 0 UTC. Figure 2 (top row) shows the horizontal kinetic energy spectra of the LBC-LACE domain for both interpolation possibilities (old and new) for two selected vertical model levels. In the free atmosphere (model level closest to 500 hPa), the spectra follow the K^{-3} line, whereas somewhat more signal is preserved in the new (c903) approach for horizontal scales smaller than around 300 km. Near the ground, the spectra follow the theoretical slope of $K^{-5/3}$, and differences appear to be very small.

In the bottom row of Fig. 2, the spectra at SIS4 model domain are shown, here also including the direct (exp) approach. While the final spectra of old and new operational approaches are very comparable, there is more spectral energy at horizontal scales between 50 and 25 km in the exp approach (blue line). This is visible at 500 hPa and especially near the surface, and corresponds to the resolved scales of ECMWF which is cut off during interpolation to LBC-LACE, due to its resolution and quadratic spectral truncation. The blue line follows the theoretical curves of $K^{-5/3}$ and K^{-3} over these scales, supporting the assumption that they are meteorologically meaningful.

Figure 3 shows the wind speed in the SIS4 domain at the lowest model level in grid-point space, comparing the results of new and exp approaches. This illustrates that the additional spectral energy in the experimental approach results in a wind field exhibiting finer structures compared to those obtained from the new operational approach.

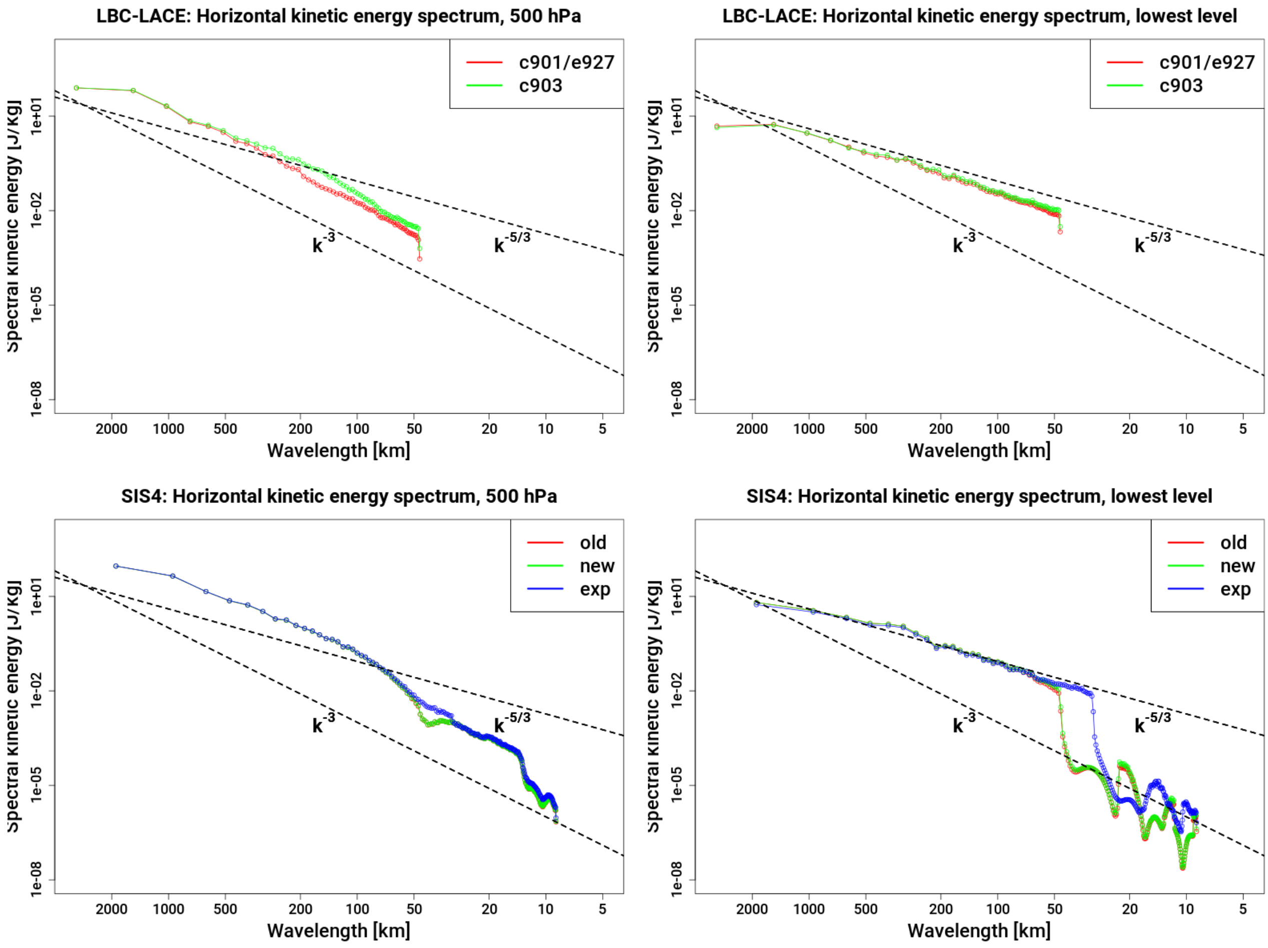

Figure 2: Top row: horizontal kinetic energy spectra for the LBC-LACE domain in conjunction with two different interpolation pathways: c901/e927 and c903. Bottom row: horizontal kinetic energy spectra for various coupling possibilities: old and new operational versions as well as the direct approach (exp). Shown are spectra for the model level closest to 500 hPa (left panels) and the lowest model level (right panels). The theoretical limits $K^{-5/3}$ and K^{-3} (black dotted lines) are displayed for comparison.

4 Discussion and conclusions

The present investigation compares the previous and current operational procedure to prepare LBCs from IFS/ECMWF model, in relation to direct interpolation to the target LAM grid which is meteorologically justified but operationally unfeasible. The resolution of the ALADIN grid used at Slovenian Environment Agency lies in the middle of model resolution range (1-10 km) applied by RC LACE countries.

The comparison of the old and new approach to obtain LBCs at the common LACE domain in terms of kinetic energy spectrum shows that more energy is preserved in the new, c903 approach at scales below around 200 km. From the analysis of spectra it is evident that wave components with wavelength between 25 and 50 km, present in the ECMWF predominantly near the surface, are cut out from the final spectrum of SIS4 at 4.4 km when interpolating through the LBC-LACE domain. This is caused by the relatively coarse resolution of the LACE-LBC domain (15.4 km) and use of quadratic truncation, which means that only wavelengths above 45 km are retained. This may present a deficiency for the quality of the final ALADIN forecast.

This analysis suggests reconsideration of the resolution of the common LBC-LACE domain, in order to better represent the current resolution of ECMWF, at the expense of increased computation cost and data transfer.

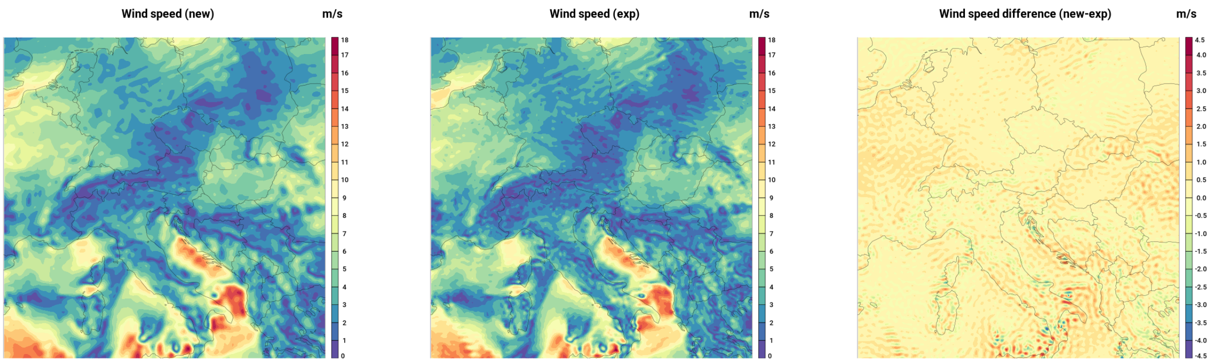

Figure 3: Wind speed at the lowest model level in the SIS4 domain in the new operational version (left panel), in the direct experimental approach (middle panel), and finally the corresponding difference between the two methodologies (right panel).

Otherwise, the presumably useful meteorological signal at part of mesoscales is lost during the two-step interpolation procedure.

5 References

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