HIGH-RESOLUTION WIND CLIMATOLOGY FOR SLOVENIA: A SPATIO-TEMPORAL VERIFICATION

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Abstract: An NWP model ALADIN is applied for dynamical downscaling of ERA40. The purpose is to deduce the wind climatology of Slovenia at horizontal scales around ten kilometers and finer. Verification against MAP-SOP reanalyses indicates that the downscaling has been successful. However, MAP-SOP reanalysis data produce wind roses closer to the observations and contain more energy in the subdiurnal range. On the other hand, a 10-km ALADIN overestimates the amount of energy in longer than diurnal periods.

Keywords *- wind climatology, Slovenia, verification, ALADIN, MAP-SOP reanalysis*

1. INTRODUCTION

The spatial density of surface wind observations is hardly anywhere adequate to deduce the wind climatology at spatial resolutions of few kilometres or finer from measurements alone; this especially applies to the areas with complex orography such as Slovenia. For the purpose of the climate description at locations without measurements, wind field characteristics are often derived using a numerical model of a type used for numerical weather prediction (NWP).

In our study, we apply an NWP model ALADIN to dynamically downscale the 40-year reanalysis data of the European Centre for Medium-Range Weather Forecast (ECMWF) (ERA40). The aim is to deduce the wind climatology of Slovenia at scales around ten kilometres. In the next step, we apply the dynamical downscaling approach of Žagar and Rakovec (1999) to obtain the wind field at the 2.5-km grid covering Slovenia. The main purpose of the present paper is to verify how valuable is the surface wind information provided by an operational NWP model in the complex Alpine terrain at horizontal resolutions of several kilometres.

Dynamical downscaling is done for a ten-year period between 1991-2001, but here we present the results of verification for a selected interval in autumn 1999 - the Mesoscale Alpine Program-Special Observing Period (MAP-SOP) (Bougeault et. al., 2001). The latest ECMWF data assimilation system was employed on MAP-SOP measurements to produce a special reanalysis data set (Keil and Cardinali, 2004). Although few additional measurements were available in Slovenia itself and surface wind observations were not assimilated, MAP-SOP reanalyses (hereafter MAPERA), available every three hours on a ~40 km grid, provide information about the quality of the most state-of-the-art analysis system, as compared to a mesoscale model used as a "magnifying glass" for ERA40 data at a three times lower resolution.

2. METHODOLOGY

The downscaling model ALADIN has been extensively used as an operational forecast and research tool (e.g., Brzović, 1999). It was also one of the operational models used for missions planning during the MAP-SOP. The present nesting of ALADIN to ERA40 includes two domains: an intermediate 3200×3200 km^2 domain covering Europe with a 30-km resolution and an inner nest (denoted SLOV) which mimics an earlier operational ALADIN domain for Slovenia with 72×72 grid points, 11.2-km resolution and Slovenia in the domain centre. Following Žagar and Rakovec (1999), a short time integration (about 30 minutes) is applied on the SLOV results to adjust the low-level wind to new details of the terrain appearing on a 2.5-km grid. This downscaling experiment is denoted SIDA.

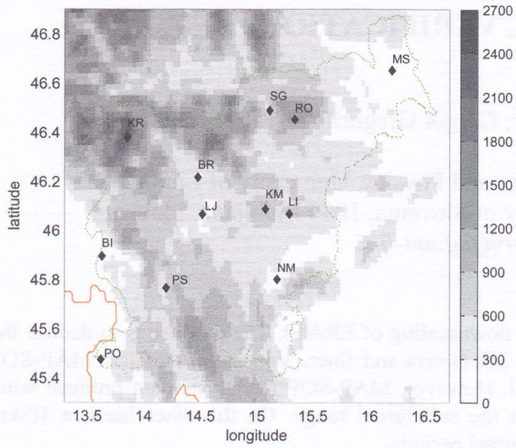

Figure 1. The model orography over Slovenia in 2.5 km resolution (SIDA simulation). Overlaid are locations of the verification stations.

Eleven stations selected for verification are shown in Fig. 1, together with the 2.5-km model orography. The criterion for the station selection was the record completeness; selected stations contain no or only few missing data during the MAP-SOP period. Few missing data were interpolated linearly. Locations of the stations are representative for high elevation plains and mountain summits (stations RO, KR, KM, LI) exposed to upper-air winds, passes (SG), valleys or sheltered basins (NM, BI, PS, BR, LJ), plains (MS) and coastal sites (PO). Besides some conventional statistics, we apply the spectral transformation in the space and time domains. Spectral decomposition in the temporal domain reveals how much of the energy is related to the circulation on subdiurnal scales, on diurnal and longer than diurnal periods.

The subdiurnal portion of the spectra is generated during the model forecast by various landscape forcing and by non-linear interactions (Rife et. al., 2004); it thus provides information about the exposure of measurement locations to non-local features and the model's ability to reconstruct the observations.

3. RESULTS

3.1. Conventional scores

Two conventional scores, anomaly correlation (AC) and root mean square error (RMSE), are shown in Fig. 2 for the meridional wind component, based on three model simulations: MAPERA, SLOV and SIDA. A score based on the 24-hour persistence is also added to illustrate the stations' exposure to the non-local forcing. The main conclusion based on this figure is that the downscaling has been successful as the ALADIN scores are almost everywhere better than MAPERA. Some stations are located in a too complex terrain to be resolved by a 10-km terrain (PS) or are characterized by very weak winds (BR, MS); in these cases RMSE based on the 24-hour persistence is lower than that of any simulation. Well-exposed mountain stations (RO, KM, LI) are characterized by a larger AC and a poor persistence score. However, conventional scores based on the SIDA simulation appear less appealing when compared with

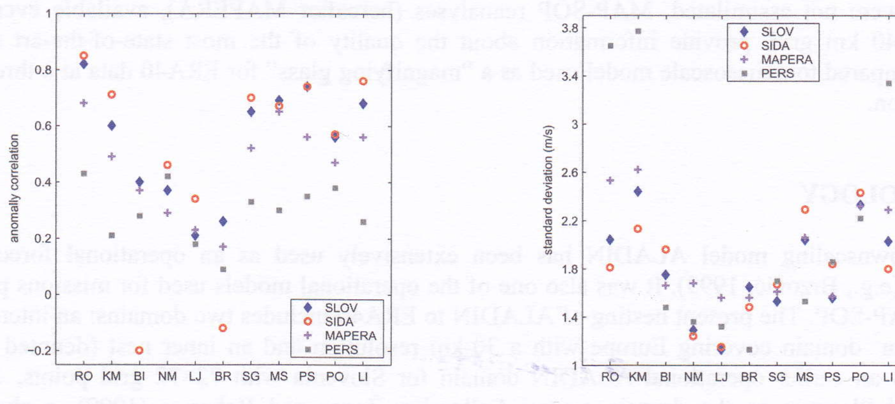

Figure 2. Anomaly correlation and root mean square error for the meridional wind component.

the results of SLOV. Even though some valleys do not appear at 10-km resolution (e.g., valley station SG), this effect is not recognized in the conventional score measures.

3.2. Spectra in the temporal domain

In Fig. 3 we present observed spectral power distribution as a function of frequency. Selected stations are representative of the three wind-climate types in Slovenia: almost 1500 m elevated Rogla (RO), a valley station Slovenj Gradec (SG) and Portorož (PO) at the Adriatic coast. A largest amount of the wind energy is measured at Rogla - twice more energy than in Portorož and about seven times more energy than in Slovenj Gradec.

There is a major difference between the energy distributions in the three temporal ranges at various places. If we define the diurnal range as periods between 22 and 26 hours, then the diurnal circulation on the mountain station is not significant, it is relatively small also in the Slovenj Gradec valley, but it dominates the spectrum at the coast (sea-breeze). The subdiurnal range contributes the largest part of the energy in Slovenj Gradec, while longer than diurnal (LTD) periods are dominant at Rogla.

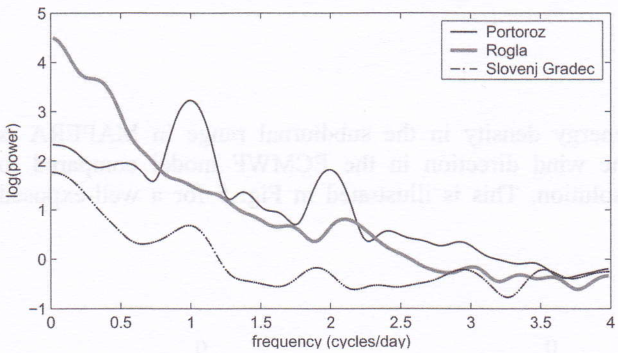

Figure 3. Energy distribution for the zonal wind.

A successful downscaling model should have its energy distribution as close as possible to the observed distribution, and the amount of energy in each time range as similar as possible to the measured amount. These expectations can be checked in Fig. 4 for the three stations.

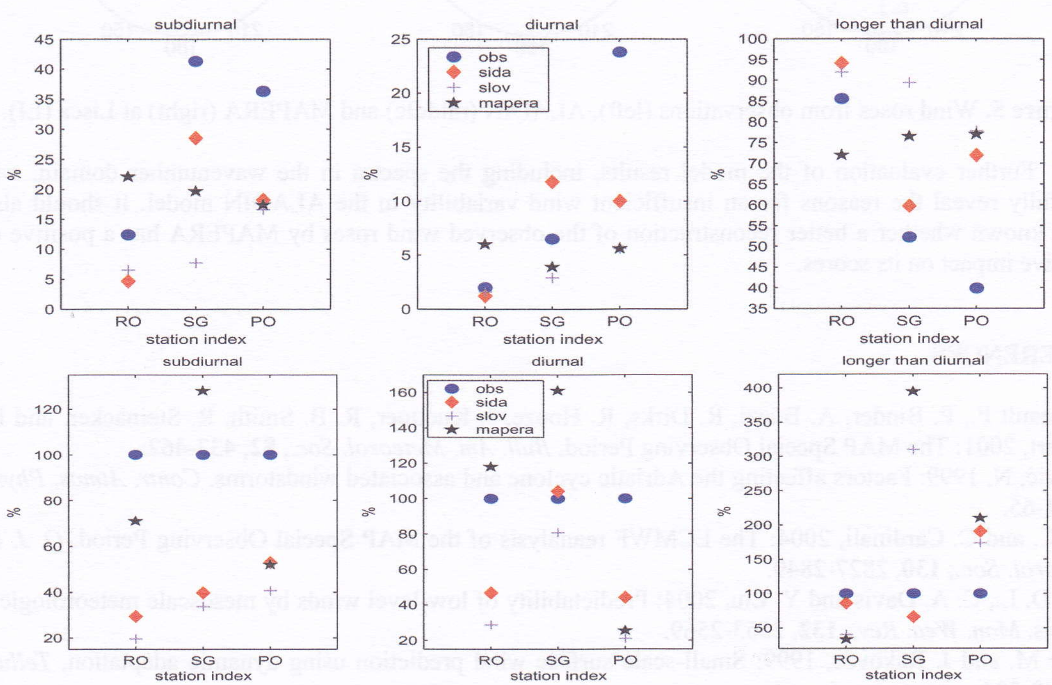

Figure 4. Distribution of the spectral zonal wind energy among the subdiurnal (left), diurnal (middle) and longer than diurnal (right) periods. Values are scales by the own total energy (top figure) and by the observed energy in the same range (bottom figure).

The upper figure shows the percentage of the model's energy with respect to its own total energy, while the lower panel presents percentages of the energy in a particular frequency range compared to the amount of energy in the same range for the observations. First of all, this figure illustrates the impact of an increased resolution in ALADIN with respect to MAPERA as the last contains significantly less spatial variability than the 10-km ALADIN (SLOV). This effect is further enhanced in the SIDA simulation (upper figure). However, the ECMWF model produces relatively more energy in the subdiurnal range compared to ALADIN and is closer to the observed estimates for this range except at very local stations in areas of steep gradients such as SG. The valley with this station appears only in SIDA, which is the reason for its poor simulation by both SLOV and MAPERA. Furthermore, when all stations are analyzed it can be seen that the downscaled fields much overestimate LTD part of the spectra (i.e. the total energy) except at three mountain stations (not shown).

4. OUTLOOK

A significant amount of the spectral energy density in the subdiurnal range in MAPERA is associated with an increased variability of the wind direction in the ECMWF model compared to ALADIN, in spite of the four times lower resolution. This is illustrated in Fig. 5 for a well-exposed mountain station Lisca (LI).

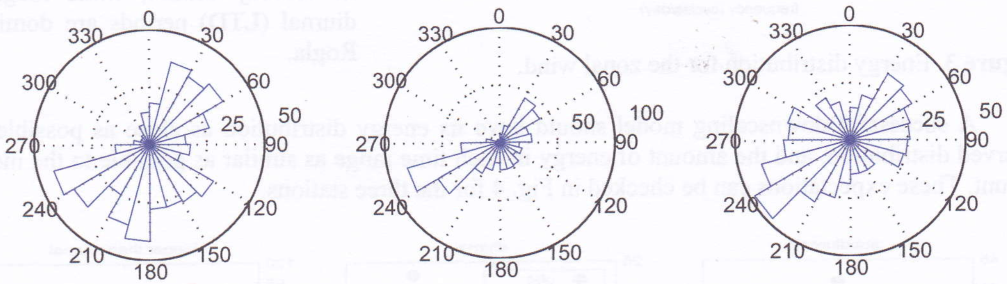

Figure 5. Wind roses from observations (left), ALADIN (middle) and MAPERA (right) at Lisca (LI).

Further evaluation of the model results, including the spectra in the wavenumber domain, will hopefully reveal the reasons for an insufficient wind variability in the ALADIN model. It should also make known whether a better reconstruction of the observed wind roses by MAPERA has a positive or negative impact on its scores.

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