EVALUATION OF THE SKILL AND ADDED VALUE OF A REANALYSIS-DRIVEN REGIONAL SIMULATION FOR ALPINE TEMPERATURE

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Abstract: A high-resolution regional climate simulation has been performed with the REMO model with spectral nudging applied for the whole of Europe for the period 1958-1998. The REMO simulation and the driving ERA40 reanalysis are validated against station data for 2m temperature over the Greater Alpine Region. The temporal variability, as quantified by correlation, is well represented by both ERA and REMO. However, both models show considerable biases. We also analyse the added value of the higher resolution regional simulation compared to the reanalysis. It varies between the seasons and regions but robust features include in summer a better performance of REMO in the inner Alpine subregions and a worse performance to the east of the Alps. The lack of consistent value added by REMO in our hindcast setup may be partly explicable by the fact that meteorological measurements are assimilated only in the ERA reanalysis.

Keywords: *high-resolution regional modelling, REMO, ERA40 Reanalysis, ALP-IMP*

1. INTRODUCTION

The validation of regional climate models (RCMs) has been performed in a number of studies by comparing the simulations for the current climate with observations. In most cases these observations are gridded climatologies or reanalyses representing area means like the simulation. However, these gridded observations can include errors introduced through the interpolation method, which may be of particular concern over mountainous areas. Furthermore, differences between real-world and simulated area means would even occur in a model with “perfect” physics due to differences between real and model orography. The validation against station data is limited to a few studies because only few good quality, high-resolution observations are available.

An important question in the analysis of RCMs is whether the higher resolution of the RCM adds value to the driving global general circulation model (GCM) or the driving reanalysis with a much coarser resolution. However, only a few studies addressed this crucial question. In this study we assess the skill and added value of a high-resolution RCM simulation with respect to 2m temperature for the period 1958-1998 over the Greater Alpine Region (GAR) with its very complex orography.

2. MODEL, DATA AND METHOD

The simulation analysed here has been performed with the regional model REMO (REgional MOdel, Jacob and Podzun, 1997), which has a resolution of 1/6 deg (approx. 17 km) on 20 vertical levels. It is driven by the global ERA40 reanalysis (Uppala et al., 2005) with 1.125 deg resolution through prescribing the values at the lateral boundaries and through forcing the large-scale horizontal wind field within the model domain by spectral nudging (von Storch et al., 2000).

Both REMO and ERA are compared to two temperature datasets over the GAR. One is the HISTALP monthly mean temperature station dataset (Auer et al., 2007), which consists of data from 131 stations and is homogenised and densely and homogeneously distributed. The other one is a daily mean temperature station dataset (ZMmonthly) for Austria (Schöner et al., 2003) and Switzerland, which is provided by the national weather services, consists of 59 stations of which 23 stations also belong to HISTALP and is converted to a monthly mean station dataset.

Due to the very complex orography of the Alps, which is not fully captured by the reanalysis and not even by the high-resolution simulation, large altitude differences may occur between the stations and the corresponding grid boxes of ERA and REMO. Therefore, a mean altitude correction of 0.65K/100m is applied to the ERA and REMO data.

The comparison is performed by calculating the correlation and bias and for the analysis of the added value also the root mean squared error (rmse) between the observed temperature at the stations and the simulated temperature at the corresponding grid boxes over the whole simulation period of 41 years for each month separately. These results at the 131 HISTALP and 59 ZMmonthly stations are averaged over six subregions defined by Böhm et al. (2001) named West, East, South, Po Plain, Central Alpine Low Level (CALL) and High Level (above 1500 m above mean sea level). The subregions are presented in Fig. 1d for the HISTALP dataset. It should be noted that the station data used for the validation probably are at least partly assimilated in ERA.

As the results based on ZMmonthly are very similar to those based on HISTALP, only the HISTALP results are presented here.

3. RESULTS

3.1 The skill of REMO and ERA

The correlation (Fig. 1a) is generally very high for ERA and REMO indicating that the temporal variability of temperature in the GAR is represented quite well. ERA and REMO have similar annual cycles, but the ERA correlations are slightly higher except in the inner Alpine subregions CALL and High Level with the most complex orography. Largest correlations are found north of the Alps where orography is less complex and circulation is less influenced by the mountains than south of the Alps, especially in subregion Po Plain. The low correlations in the inner Alps in winter might be caused by the altitude differences between the stations and REMO and ERA leading to differences in snow cover and therefore different temperature variability.

The bias for ERA and REMO presented in Fig. 1b is positive for all subregions except High Level in the winter half year. For REMO the positive bias is largest in summer and smallest in winter for subregions West, East, South and Po Plain. The most pronounced positive summer bias occurs in subregion East, which is a common feature for many RCMs in south-eastern Europe (e.g. Noguer et al., 1998; Hagemann et al., 2001) and is caused by too dry conditions. For ERA the bias in subregions West, East, South and Po Plain has different annual cycles than for REMO showing that the strongly positive bias of REMO in summer is a clear feature of the regional model and identifies problematic regions.

In the inner Alpine subregions both the REMO and ERA biases have very similar annual cycles, which are probably caused by the comparison between grid boxes and station data. In subregion High Level the bias is strongly negative in winter and positive in summer and can therefore partly be explained by the altitude correction. As all grid boxes are lower than the stations in this subregion, the simulated temperature is reduced with the mean lapse rate. However, the real lapse rate is smaller in winter and larger in summer due to the atmospheric layering, which leads to a too much reduced temperature in winter and too little reduced in summer.

3.2 The added value of REMO compared to ERA

To analyse whether the higher resolution of REMO leads to an improvement in comparison to the ERA40 reanalysis, the reduction of error (RE) is calculated by the following equation:

$$RE = 1 - \frac{rmse_{REMO}}{rmse_{ERA}} \quad (1)$$

Negative values indicate that the performance of REMO is worse than that of ERA and positive values indicate the magnitude of improvement of REMO.

For subregions West, East, South, Po Plain and CALL the reduction of error (Fig. 1c) shows a slight improvement of REMO compared to ERA in winter and early spring. For CALL this improvement ranges even from November to August. In subregion High Level REMO shows no improvement in winter but from April to November. As the difference between ERA and REMO correlations is very small, the performance of REMO compared to ERA is mainly caused by the bias.

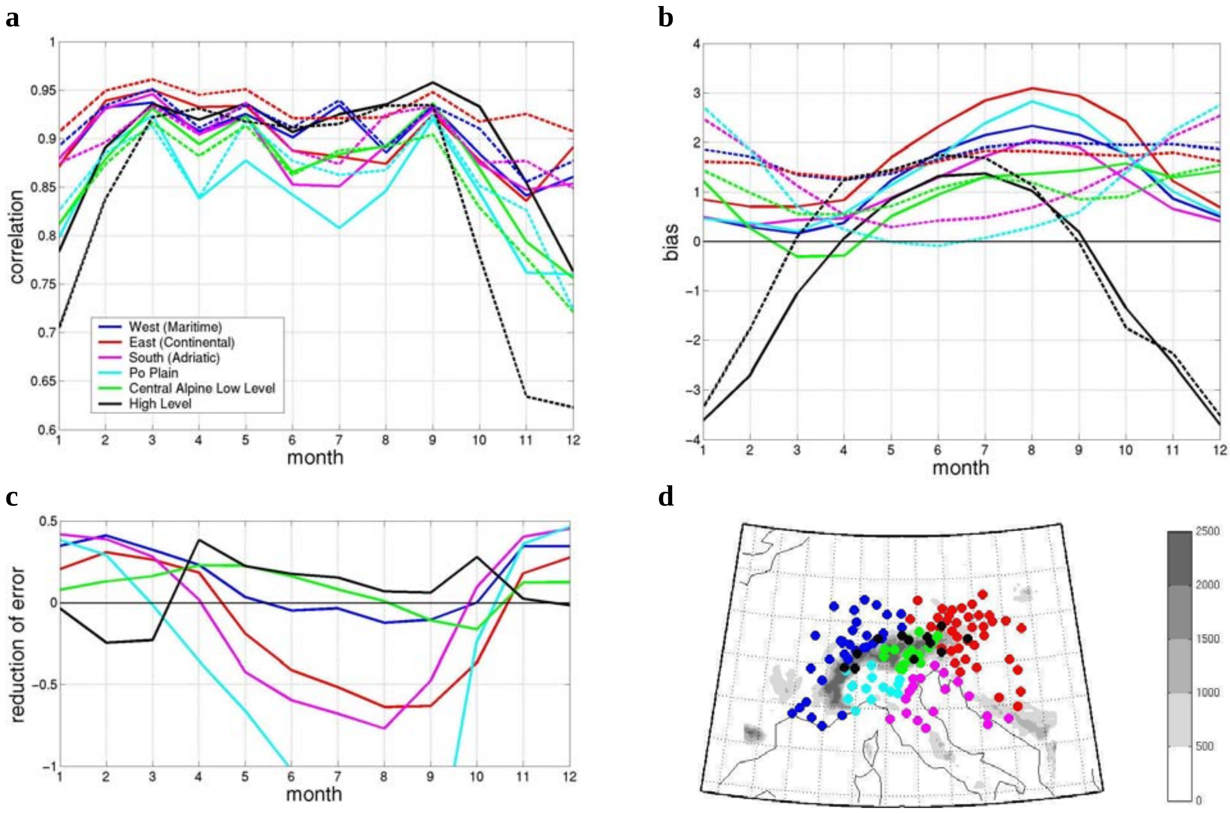

Figure 1: Annual cycle of the results of the comparison of the HISTALP station data with REMO (solid lines) and ERA (dashed lines) for correlation (a), bias (b) and reduction of error (c) for the six subregions (d) West (blue), East (red), South (magenta), Po Plain (cyan), Central Alpine Low Level (green) and High Level (black).

4. CONCLUSIONS

In this study the high-resolution regional simulation performed with REMO for the GAR for the period 1958-1998 has been validated and the performance of the model compared to the driving ERA40 reanalysis has been analysed. The validation has been performed against densely and homogeneously distributed station data and shows that the temporal variability of temperature is represented quite well. The bias however reaches in some regions and seasons large values.

The reduction of error as a measure of added value of REMO compared to ERA varies between different subregions and different seasons not allowing a general statement about the improvement of the higher resolution. For subregion CALL REMO performs better than ERA, which might be due to fewer stations assimilated in ERA leading to a stronger influence of the better resolved orography in REMO. However, in subregion Po Plain REMO performs worse than ERA even though REMO reproduces the orographical details of this region quit well unlike ERA. Maybe the frequently occurring convective instabilities in this region in summer can not be captured by REMO but their effect on temperature may be included in ERA through the assimilation of observations.

It could be shown that despite the very high resolution of REMO it is difficult to represent Alpine temperature better than ERA. This missing clear added value has also been found in other studies (Roads et al., 2003; Duffy et al., 2006; Seth et al., 2006). However, the high-resolution simulation represents local temperatures in the GAR as well as the driving reanalysis, in which observations are assimilated but not in the regional model.

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