Modelle für Wetter & Umwelt

COSMO-CLM: Influence of Grid Resolution on Precipitation Forecast

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1 Introduction

In 1952, the *Met Office*, i.e., the UK's national weather service, successfully completed its first numerical weather prediction forecast using a model with a 12×8 grid and grid point spacing of 260 km [1]. Since then, weather forecasts have improved tremendously, not least because of an increase in grid resolution. This development has been made possible by the continued growth of available computational power. While, on the one hand, increased grid resolution undoubtedly improved the numerical weather forecast, on the other hand, it also increased the need for adequate computational resources. The CFL criterion introduces an upper limit for the time step proportional to the grid point separation—a high grid resolution thus demands a short time step, which is computationally more expensive. Therefore, it is of interest to understand the influence of grid resolution on numerical weather prediction in order to find the best compromise of grid point spacing in terms of computing time and forecast quality.

In this study, a regional weather model calculates one-month forecasts on three different spatial resolutions. Then, the change in precipitation patterns across the different simulations is analysed. Generally speaking, precipitation plays a major role in weather forecasts, hence, it seems natural to use this variable in order to compare grid resolution. On top, as a diagnostic variable, it is based on direct predictions of the model and hopefully captures the effects of resolution-dependent internal model dynamics.

2 Model setup & data

The COSMO model in CLimate Mode (COSMO-CLM) has been designed both for operational numerical weather prediction and scientific applications on the meso-β and meso-γ scale. The limited-area atmospheric model receives boundary and initial conditions from a driving host model, or, in our case study, from ERA-Interim reanalysis data (resolution of 0.75°). Time integration relies on a third-order Runge-Kutta scheme. The number of both vertical and soil levels is equal to 10. The model equations are formulated in rotated geographical coordinates to reduce the effect of varying grid cell size. Parametrization for grid-scale clouds and precipitation is based on a Kessler-type bulk formulation, which uses specific grouping of particles into broad categories of water substance (e.g., cloud water) that interact by various microphysical processes. The implemented cloud ice scheme allows explicit representation of ice clouds. While vertical turbulent diffusion parametrization is based on a prognostic equation for turbulent kinetic energy, as far as I am concerned, no subgrid-scale (deep) convection scheme is included by default[1]. The time step has been set to 150 s for all resolutions. For further information about the COSMO model please refer to Schättler et al. [2].

The study is composed of three COSMO-CLM simulations during January 1990, as introduced in table 1. This period of time has been chosen as grid definition files and appropriately scaled boundary conditions were already available. Figure 1 displays the mean

[1] `itype_conv` undefined in model namelists

Experiment name	Resolution [°]	Grid	Spacing [≈km]
02°	0.2	280 × 230	25
05°	0.5	100 × 80	65
1°	1	56 × 46	130

Table 1: COSMO-CLM simulations of this study

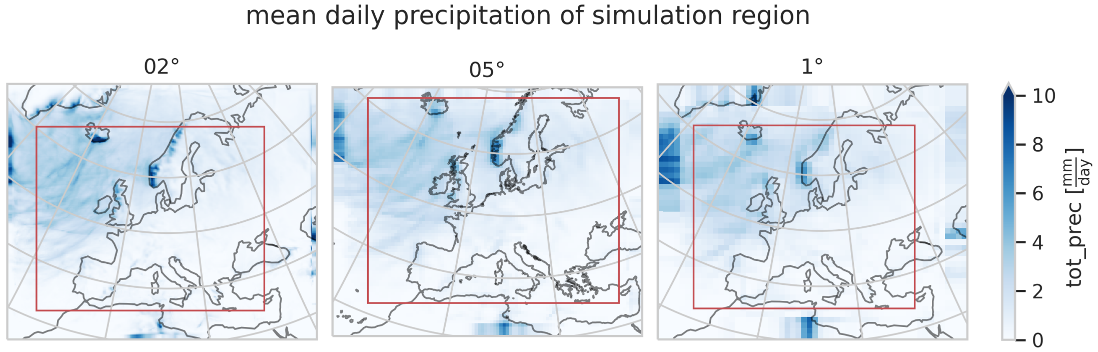

Figure 1: Spatial domains of simulations. Red rectangle indicates area of analysis. Please note that here and in the following figures pointed ends of a colourbar indicate out-of-range values.

precipitation within the entire model domain, however, structures of 'unphysical' values are clearly visible at the edges, where interpolation between model output and constraining boundary conditions alters the results. In the following, the region of interest is reduced to the area of the red rectangle. It is notable that the 05°-simulation region seems to be cropped in the north and east compared to the other simulations. This is due to an erroneous value in the number of grid points during grid definition, but will not affect the results as the region of analysis is still sufficiently large.

In this study, ERA5 reanalysis data produced by the ECMWF serves as a reference. Although also a model product themselves, reanalyses assimilate observational records and thus are a reasonable choice to compare simulation output with. ERA5 data is provided on a 0.28° grid, however, here, the data is remapped to a 0.2° rotated grid to be able to cut the same region as in the COSMO-CLM simulations (see fig. 1).

The shell script for data processing, python code for re-creating all figures as well as further

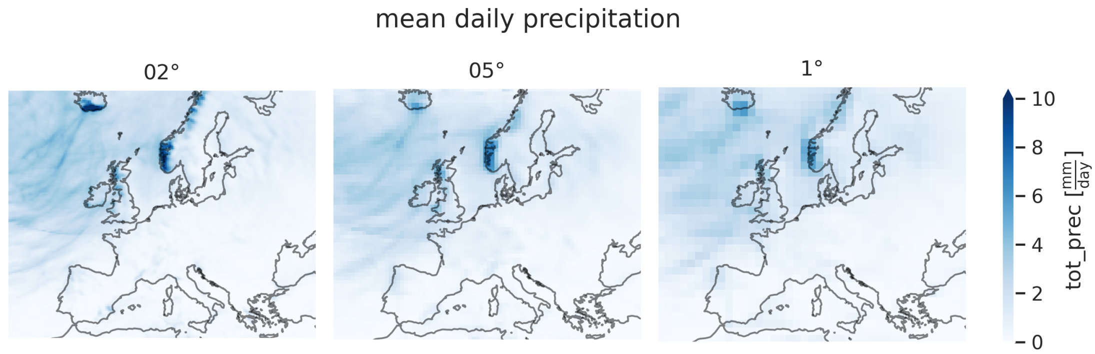

Figure 2: Temporal mean of daily precipitation sum for different grid resolutions. Simulations ran throughout January 1990.

comments can be found in the related online repository[2]. Much data processing has been realized by using *Climate Data Operators* of Schulzweida [3].

3 Results

Figure 2 illustrates the spatial distribution of mean precipitation: The general pattern of different grid resolutions is similar, depicting high precipitation rates over the Northern Atlantic and at the coasts of Iceland, Norway and Scotland. However, it is evident that high grid resolution locally increases the intensity of precipitation.

When focussing on the temporal domain, the daily precipitation signals of the COSMO-CLM simulations are—generally speaking—similar, indicating that the daily sum over the entire (cropped) model region does not change considerably with model resolution. In fig. 3, precipitation is split into a grid-scale and convective component, and ERA5 data is included as a reference. In both subplots, simulations underestimate the observed daily precipitation sum, although the difference between reference and simulation is more pronounced for convective precipitation. The underlying trend in reference and simulation of grid-scale precipitation is comparable, which validates the model results on broader scales. It is important to note though that the simulations have been driven with ERA-Interim data

[2]`https://gitlab.met.fu-berlin.de/rw0064fu/mwu-gridres`

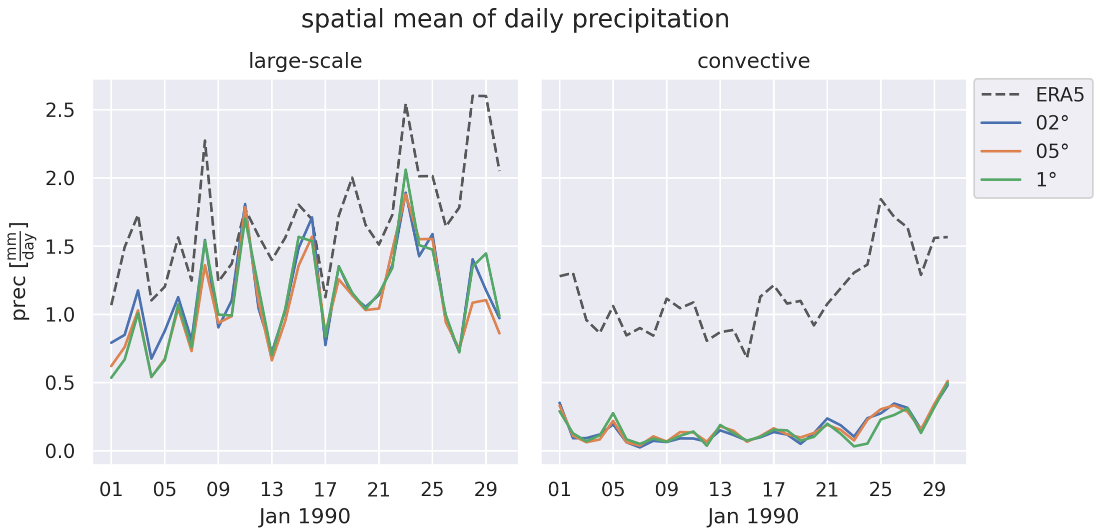

Figure 3: Spatial mean of daily precipitation sum split into large-scale (i.e., grid-scale) and convective signal for different grid resolutions. ERA5 reanalysis data as reference.

and are now compared to ERA5 data, which might introduce additional biases triggered by different data assimilation procedures of the reanalyses.

The *absolute* difference in precipitation between grid resolutions is more pronounced in the grid-scale precipitation, although without a consistent signal. E.g., in the beginning of January, 0.2°-resolution shows more grid-scale precipitation compared to the remaining resolutions, in the end of the month though, 0.2°- and 1°-resolution show a similar signal, while 0.5°-resolution simulates less grid-scale precipitation. In contrast, variation in the convective part is relatively small. I figure that the missing deep convection scheme is the reason, since all convective precipitation is derived from vertical turbulance only. Consequently

4 Discussion & Outlook

Naturally, high grid resolution improves localization of the precipitation signal, hence, differences in precipitation intensity are visible on maps, but disappear when averaging over all grid boxes. Better localization of precipitation events implies higher number of grid boxes without precipitation, which diminishes the signal when averaging.

References

[1] Meteorological Office. *History of numerical weather prediction*. 2023. URL: https://www.metoffice.gov.uk/weather/learn-about/how-forecasts-are-made/computer-models/history-of-numerical-weather-prediction (visited on 24/07/2023).

[2] U. Schättler et al. *COSMO-Model Version 6.00: A Description of the Nonhydrostatic Regional COSMO-Model - Part VII: User's Guide*. COSMO Consortium for Small-Scale Modelling, 2021. DOI: 10.5676/DWD_PUB/NWV/COSMO-DOC_6.00_VII.

[3] U. Schulzweida. *CDO User Guide*. Version 2.1.0. Oct. 2022. DOI: 10.5281/zenodo.7112925.