Hindcasts of historic storms with GME, COSMO-LMQ, and COSMO-LMK

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Introduction

NLWKN (`www.nlwkn.de`), the Coastal Research Station of Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency, contracted Deutscher Wetterdienst (German Weather Service, DWD) to provide high resolution wind fields during strong storms for flood predictions near the Ems river estuary in northwestern Germany. NLWKN chose 22 storms from the famous Hamburg Storm in February 1962 to a storm in October 2002.
DWD produced wind fields during these storms using its model chain GME, COSMO-LMQ, and COSMO-LMK starting from ERA-40 reanalysis data (Frank and Majewski, 2006). The wind fields will be used by NLWKN for coastal protection studies.
A series of 18 hour forecasts starting from 00 and 12 UTC analysis data was used to obtain high resolution hourly wind fields along the German North sea coast with a grid spacing as small as 2.8 km. To allow for an adaptation of the models to the initial fields only forecasts from 6 to 18 hours are provided to NLWKN. The 6 and 18 hour forecasts for the same verification time are averaged.

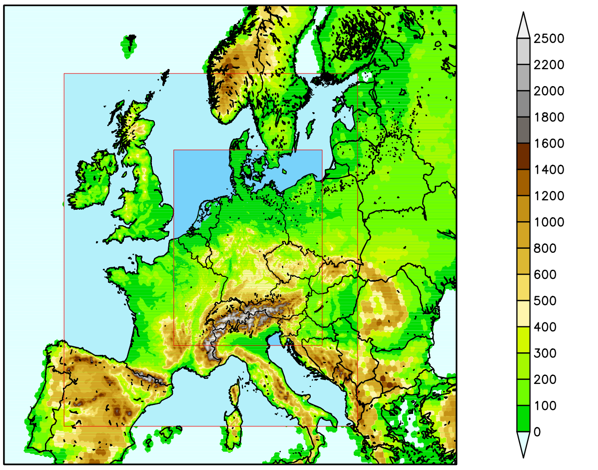

Figure 1: Model orography and nesting of LMQ in GME and LMK in LMQ.

Model description and setup

The global model GME is a hydrostatic weather prediction model (Majewski et al., 2002). It operates on the icosahedral-hexagonal grid. The model has a mesh size of approximately 40 km and 40 layers up to 10 hPa with a hybrid vertical coordinate system. For these hindcasts the initial state was interpolated from the ECMWF ERA-40 reanalysis (Uppala and et al., 2005) to the GME grid.
The ERA-40 reanalysis was done with ECMWF's IFS model using a spherical harmonics representation T_L159 and a reduced Gaussian grid corresponding approximately to a mesh size of 125 km
The COSMO model (Steppeler et al., 2003, `www.cosmo-model.org`) is a non-hydrostatic limited-area atmospheric prediction model operating on the meso-β and meso-γ scale. It uses a regular C-grid in rotated geographical coordinates. It is used here in two different setups.

The COSMO-LMQ model has a mesh size of 7 km (0.0625°). A leap-frog scheme with a time step of 40 s is used for time integration. Deep and shallow convection are parameterized using the mass flux approach of Tiedtke (1989). The model domain consists of 333×333 grid points.
The COSMO-LMK model has a mesh size of only 2.8 km (0.025°). It is assumed that deep convection can be explicitly resolved by the model. Only shallow convection is parameterized through moisture convergence in the planetary boundary layer similar. For time stepping a Runge-Kutta scheme of 3rd order with time step 30 s is used.
The initial state for LMQ is interpolated from the GME, and the initial state for LMK from LMQ. Lateral boundary values are updated hourly from GME, and LMQ, respectively. The nesting of LMK in LMQ and of LMQ in GME is shown in Figure 1.

The storm on 3 December 1999

As an example we present a few results for the storm on 3 December 1999. This was the strongest observed storm in Denmark. Sea level pressure dropped to 952 hPa.

The observed sea level pressure and 10 m wind on the island Norderney is compared with the different model hindcasts in Figure 2. Breaks in the curves show the difference from one 18 h forecast to the 6 h forecast of the following run. The small scale COSMO models LMQ and LMK show lower the minimum pressure than the global models. GME, LMQ, and LMK calculate similar wind maxima. However, the maximum occurs one or two hours too early in the model runs. The ERA-40 forecast gives much weaker 10 m winds because the pressure gradient is weaker. In addition, the sea surface roughness, z_0, is greater – over 5 cm compared to approximately 2 mm for the DWD models.

The strongest winds occur in the cold sector south and southwest of the center (Figure 3). Naturally, LMK shows much more details than the other models. Also, it is the only model to resolve the east Friesian islands off the German and Dutch North Sea coast.

The ERA-40 resolution is too coarse to capture the small cyclone. Buizza and Hollingsworth (Winter 2000/01) showed that a high-resolution ensemble prediction system (T_L255) predicted this storm much better than the ensemble prediction system with then T_L159 which is the same resolution as the ERA-40 reanalysis.

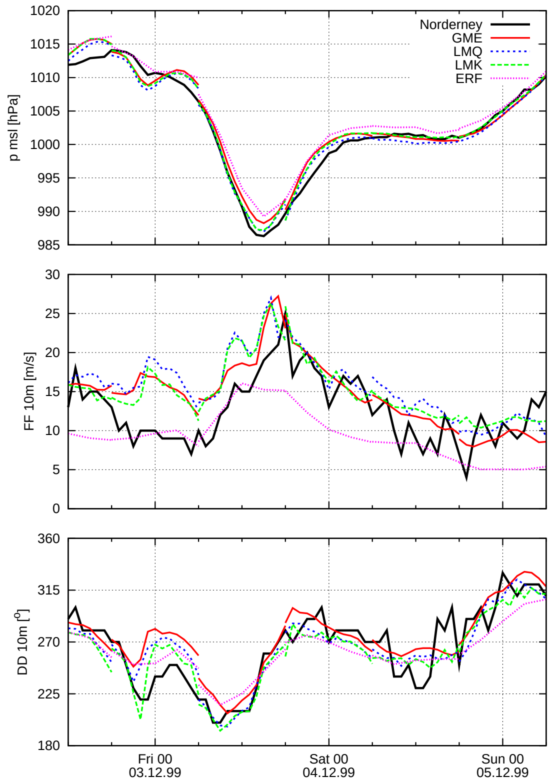

Figure 2: Time series of sea level pressure, wind speed FF, and wind direction DD observed at DWD station Norderney and predicted by the models. ERF is the ERA-40 forecast data every 3 hours.

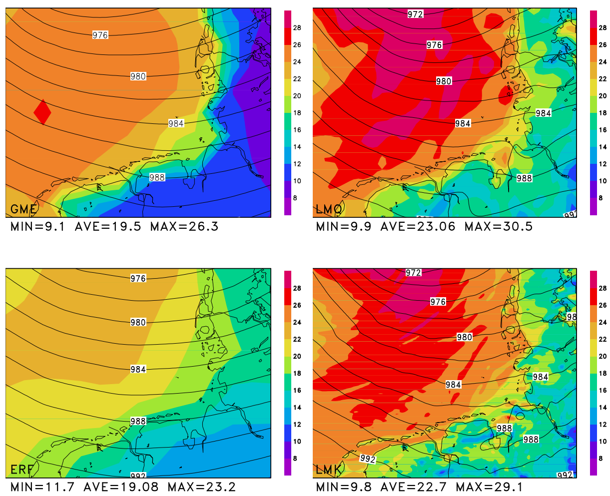

Figure 3: Mean wind speed at 10 m in $\mathrm{m\,s^{-1}}$ at 15 UTC on 1999-12-03 simulated by GME (top left), LMQ (top right), LMK (bottom right), and the ERA-40 forecast (bottom left) initialised at 15 UTC on 1999-12-03.

Acknowledgments

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