EVALUATION OF THE WRF METEOROLOGICAL MODEL RESULTS FOR HIGH OZONE EPISODE IN SW POLAND – THE ROLE OF MODEL INITIAL CONDITIONS

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Abstract:
In meteorological, as well as air quality modelling, input data plays an important role in the accuracy of the results, next to the model configuration. There are many sources of meteorological data available, both global and regional, and they differ not only by spatial and temporal resolution, but also by the number of observations included in the reanalysis and method of data assimilation used.
In this study, the performance of the Weather Research and Forecasting (WRF) model with two global reanalyses used as input datasets was assessed. First of them is ERA-Interim, developed by European Centre for Medium-Range Weather Forecasts, available for the period 1979 – present. It uses 4D variational data assimilation, providing 6-hourly data of spatial resolution of 0.7°x0.7° and 38 vertical levels. The other dataset is GFS final (FNL) analysis, produced by National Centers for Environmental Prediction in a resolution of 1°x1° with 26 vertical levels and 6h output times; the data is developed with 3D-VAR.
Here, the WRF model was configured with three one-way nested domains, with the outermost domain covering Europe with a 50 km x 50 km grid, the first nest covering Central Europe with a 10 km x 10 km grid and the inner nest focused on SW area of Poland (2 km x 2 km grid). Each of three domains consist of 35 vertical layers, with the model top at 10 hPa. A period of high ozone concentration from July 3rd to August 3rd, 2006 was chosen for the analysis. For the selected period, two WRF model runs were performed and compared with measurements. For the first WRF model run, GFS data were used and ERA-Interim for the second. Both simulations were run with the same physics options, established earlier as the optimal configuration for the analyzed region.
Both WRF model runs are in good agreement with observations, with IOA statistic ranging from 0.78 for wind speed to 0.98 for surface pressure. The ERA-Interim simulation showed better results for surface pressure, temperature and wind speed, while parameters related to atmospheric moisture (e.g. dew point temperature) showed comparable performance for both datasets.

Key words: *tropospheric ozone, meteorological modelling, atmospheric reanalysis, WRF*

INTRODUCTION

The results of meteorological modelling are useful for various applications. The accuracy of the model is of great importance especially for air quality modelling, as the errors are passed on to air quality simulation results (Gilliam et al., 2006, Seaman, 2000). There are various factors influencing the quality of meteorological modelling results, including the selection of the model and its configuration, and the source of initial and boundary conditions datasets. Global reanalyses are growing in significance in both meteorological and climatological studies. Due to their spatial and temporal consistency they are widely used in analyzing trends in global and regional climate and as input to meteorological models (e.g. Carvalho et al., 2012, Heikkila et al., 2011, Lo et al., 2008). As reanalyses are made with different assimilation methods, based on a variety of observational data, such as surface stations, satellite, radar, radiosonde, etc., and present different spatial and temporal resolutions, there may be some discrepancies in the data they provide (Bao and Zhang, 2013).

The main aim of this study is to evaluate the WRF mesoscale meteorological model results obtained for the same period and model configuration, but initialized with different global analysis datasets. The results are compared with measurements from eight meteorological stations located in the innermost domain of the model.

DATA AND METHODS

Study area and period

The study area covers the Lower Silesian voivodeship, located in south-western Poland, which is one of the regions of the country with very high risk of ozone pollution. The calculations are performed for a test period of June 3rd to August 3rd, 2006, when extremely high O_3 concentrations were observed at all air quality stations in the analyzed region, exceeding the European threshold for informing the public (1-hour average of 180 μgm^{-3}) multiple times. High ozone levels persisted for a long time, which was mainly a result of high ozone precursors emission combined with meteorological conditions favourable for ozone formation (a stagnant high pressure system with low wind speed and cloud cover, and high temperature), which was not compensated by its destruction at night.

Reanalysis data

Two global meteorological reanalysis datasets were used in the study – NCEP Final Analysis (FNL; National Centers for Environmental Prediction, 2000) and ERA-Interim (Dee et al., 2011). The NCEP FNL data, developed using 3-dimensional variational data assimilation method, consists of 40 meteorological fields for the surface and 26 upper air levels with the top at 10 hPa. It has a horizontal resolution of 1°x1° and the data is available every 6 hours. ERA-Interim has been generated by ECMWF as a transition between ERA-40 and a future reanalysis project. Compared to its predecessor, ERA-Interim uses an improved atmospheric model and a more sophisticated data assimilation method, 4D-Var. It provides information on a large variety of surface fields (3-hourly) and 37 pressure levels, up to 1 hPa (6-hourly), on a 0.7°x0.7° grid.

The WRF model description

The Advanced Research Weather Research and Forecasting model (WRF ARW; Skamarock et al., 2008) version 3.4 was used in the study. The model runs were performed for three one-way nested domains, presented in fig. 1. The resolution of the outer domain is 50 km x 50 km, the middle one 10 km x10 km and the innermost – 2 km x 2 km. Vertically, the domain consists of 35 pressure levels from 1000 to 0.1 hPa. Physics options used in the simulations include Goddard microphysics, Kain-Fritsch cumulus scheme, unified Noah land-surface model, YSU PBL parameterization and Goddard and RRTM for shortwave and longwave radiation, respectively (Kryza et al., 2012).

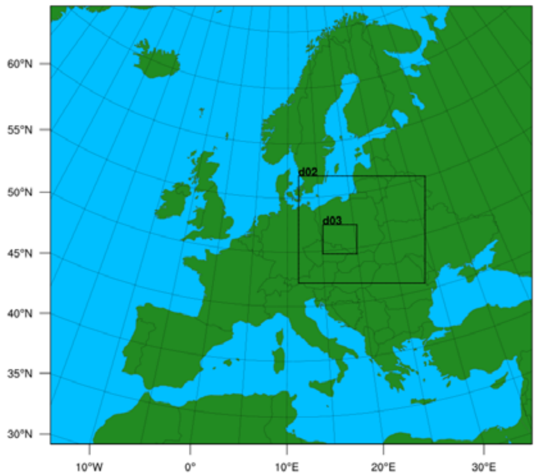


Figure 1. WRF model domain

Evaluation of the results

Hourly data from 8 synoptic stations located in the innermost model domain were used for the verification of the results. Meteorological parameters included in the analysis were 2m temperature and dew point temperature, wind speed and specific humidity. The evaluation was based on mean bias (MB), mean absolute error (MAE) and index of agreement (IOA) statistics, calculated for each station. Temporal changes in estimates-measurements agreement for temperature and wind speed, which are vital factors influencing ozone formation, were also examined.

RESULTS AND DISCUSSION

The values of mean bias, mean absolute error and index of agreement average for all available stations, as well as performance benchmarks for each meteorological parameter and error statistic, established by

Emery et al., 2001, are presented in table 1. In general, both simulations meet the acceptability criteria for IOA, but dew point exceeds the threshold value for MAE and MB. MB is also exceeded for 2m temperature. There is a large underestimation of temperature and overestimation of dew point for both analyses. The model shows good representation of wind speed, with slight underestimation and ERA-Interim simulation more accurate than NCEP-FNL. Specific humidity is also in good agreement with the measurements, with all error measures within the set limits.

Table 1. Average values of mean bias (MB), mean absolute error (MAE) and index of agreement (IOA) for all measurement stations for ERA-Interim (EI) and NCEP FNL (NCEP) simulations, calculated for temperature, dew point, wind velocity and specific humidity and compared to acceptability criteria (AC).

Parameter	MB			MAE			IOA		
	EI	NCEP	AC	EI	NCEP	AC	EI	NCEP	AC
T2m (°C)	-1.29	-1.24	±0.5	1.99	1.94	2.0	0.95	0.96	0.7
DPT (°C)	1.72	1.65	±0.5	2.12	2.17	2.0	0.85	0.84	0.7
V10m (ms^{-1})	-0.26	-0.45	-	1.07	1.08	-	0.79	0.78	0.6
SPFH (gkg^{-1})	0.94	0.88	±1.0	1.26	1.28	2.0	0.86	0.85	0.7

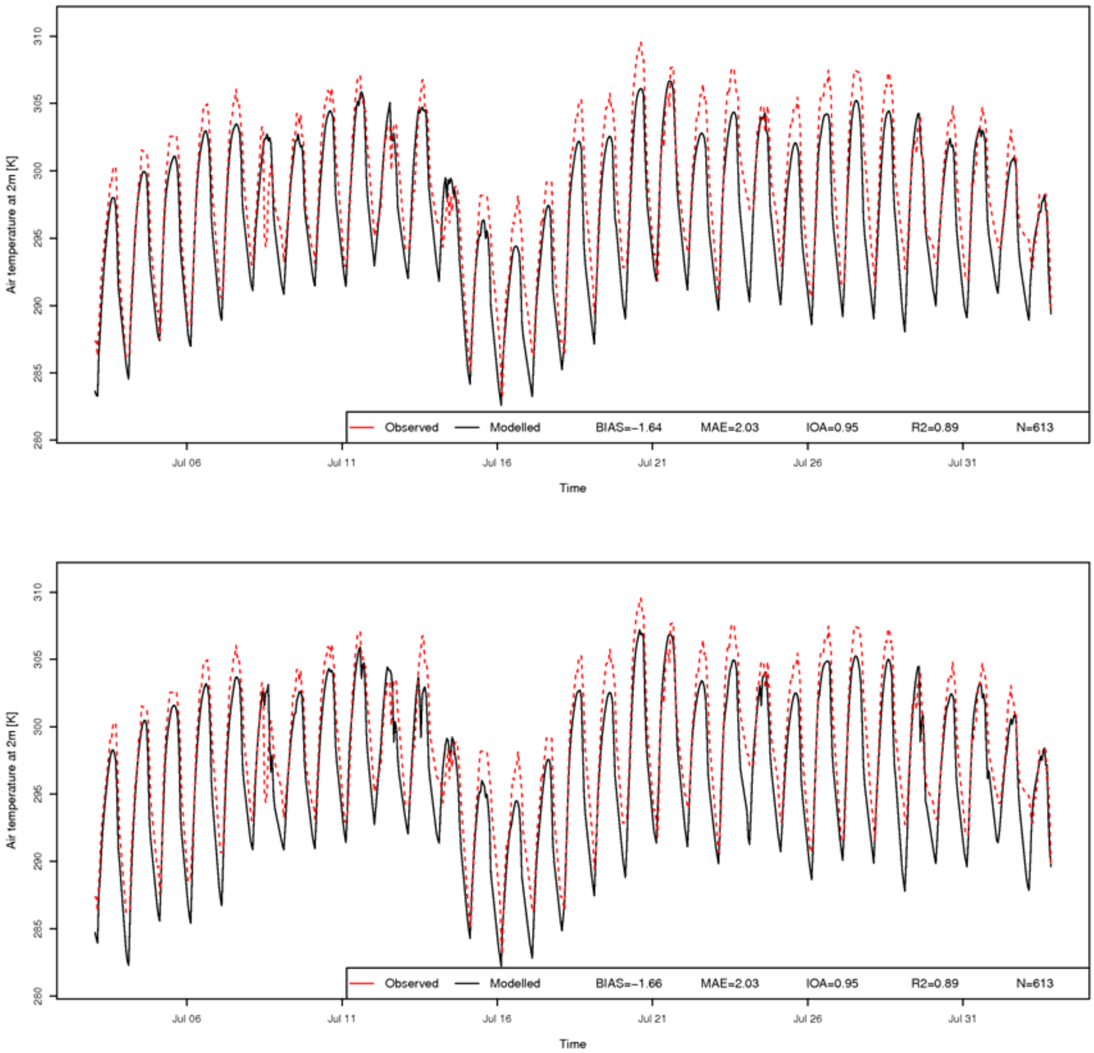
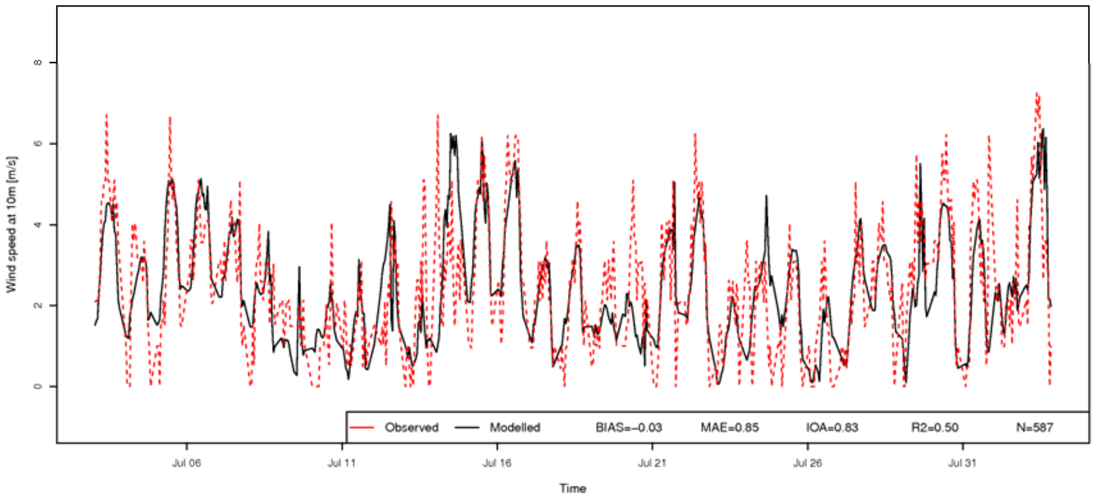


Figure 2. Modelled vs. measured 2m temperature in Wrocław: ERA-Interim (top) and NCEP FNL (bottom).



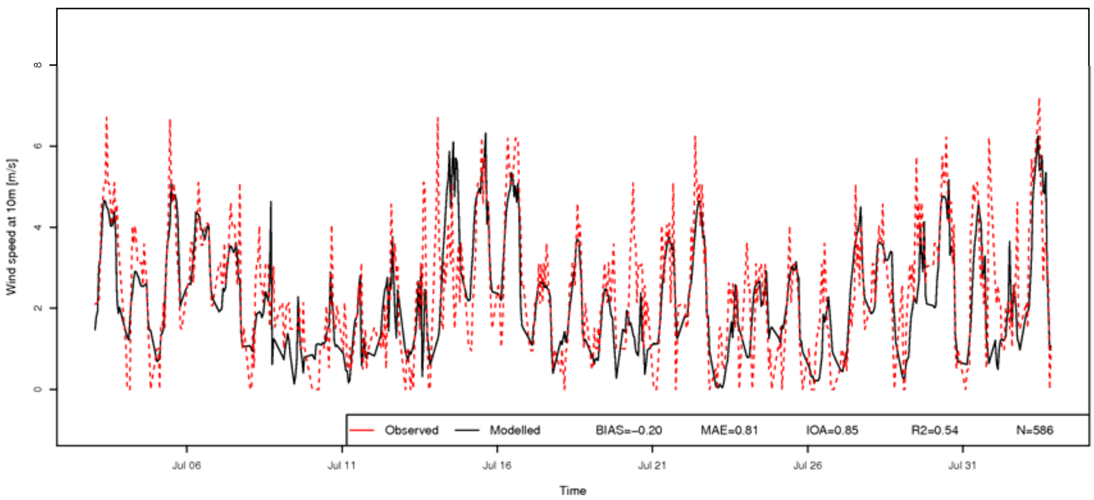


Figure 3. Modelled vs. measured wind speed in Wrocław: ERA-Interim (top) and NCEP FNL (bottom).

Temporal variability of the analyzed meteorological parameters is similar for most stations, except those located in mountainous terrain, which show significant discrepancies, for wind speed in particular, which are most likely a result of local factors, especially varied topography, which is known to modify airflow patterns. Figures 2 and 3 present modelled and measured temperature and wind speed trends over the analysed period at Wrocław station. The temperature chart shows a pattern typical for anticyclonic weather, with daily maxima and minima clearly distinguished. The simulations show very similar patterns and underestimate both the daily maxima and minima throughout the entire test period. When considering temporal patterns of wind velocity, the model generally represents good agreement with measurements. Some peak values are underestimated, but all of them are represented in model estimates, both for ERA-Interim and NCEP FNL simulations. Additionally, the ERA-Interim shows better fit to measurement curve.

SUMMARY AND CONCLUSIONS

In this paper, two global reanalysis datasets were compared for use with the WRF model applied for a high ozone episode in SW Poland. Two sets of simulations were performed for the same period and model settings, one using the ERA-Interim reanalysis as initial conditions, and the other one used NCEP FNL data. The results were then compared against observational data using grid-to-point analysis.

The study shows similar bias of both simulations for all analyzed parameters, which is most likely related to the model settings. There is a need for a sensitivity study to determine optimum model parameterization for high ozone episodes, which would significantly improve the results. Variability of temperature and wind speed throughout the test period has also been examined, which showed very similar results for both datasets, including the underestimation of daily temperature minima and maxima, which can also be attributed to model parameterization. That is also the case in underpredicted wind speed peaks, particularly those of short duration. The ERA-Interim simulation reproduces the wind speed variability more accurately and is less biased. In summary, the simulations performed with ERA-Interim reanalysis present somewhat better agreement with the observations, therefore this data will be used for further studies.

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