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AIR QUALITY FORECASTS FOR POLAND - APPLICATION OF THE WRF-CHEM MODEL WITHIN THE LIFE/APIS PROJECT

Małgorzata Werner, Maciej Kryza, Hanna Ojrzyńska, Kinga Wałaszek, Anetta Drzeniecka-Osiadacz

Wrocław University, Department of Climatology and Atmosphere Protection, Wrocław, Poland

Abstract: In this work we present the air quality forecasting system which is running operationally for the area of Poland since December 2015. The system is based on the online WRF-Chem model, which is configured using two nested domains covering Europe (12km x 12km grid mesh) and Poland (4km x 4km grid mesh). For meteorology, the system uses GFS forecasts as boundary and initial conditions. TNO-MACC 3 emission inventory for the year 2011 is used for both domains. The system calculates hourly emissions taking into account country and SNAP sector dependent emission factors, bank holidays and winter/summer time. During the post-processing of the forecasts, the Air Quality Indices are calculated. The results are disseminated using the OGC services. The comparison of the WRF-Chem forecasts with hourly measurements of PM10 and NO2 for the heating season on December 2015-February 2016 shows that there is a large underestimation of PM10, and the model resolves well temporal changes in NO2 concentrations.

Key words: *air quality, forecasting, WRF-Chem, Poland*

INTRODUCTION

Despite a significant reduction of pollutant emissions in past years, many European regions still touch problems in complying with the European Union's (EU) air quality directive (European Commission (EC), 2008). It also concerns one of the biggest European countries – Poland, for which the air quality is especially problematic in winter seasons. During winter months, episodes of poor air quality, related to e.g. high concentrations of particulate matter (PM) are frequent in Poland. These episodes are due to both high coal consumption used for residential heating and meteorological conditions preventing mixing and dilution of air pollutants.

Poor air quality has an adverse impact on human health (Pope et al., 2002), ecosystems (Serengil et al., 2011) and climate (Menon et al., 2008). A constant finding is that air pollutants contribute to increased mortality and hospital admissions (Brunekreef and Holgate, 2002). The different composition of air pollutants, the dose and time of exposure and the fact that humans are exposed to pollutant mixtures can lead to diverse impacts on human health. Human health effects can range from nausea and difficulty in breathing or skin irritation to cancer (Kampa and Castanas, 2008). Atmospheric aerosols are currently a subject of extensive research and from an environmental standpoint, aerosols constitute an important policy issue in air quality and climate science. Particulate matter pollution is one of the most pressing issue in air quality regulation, and at the same time it represents one of the biggest sources of uncertainty in chemical transport model simulations. Besides PM, nitrogen dioxide (NO2) has also received a special attention due to several reasons – it acts as a precursor of both particulate matter and tropospheric ozone (Beelen et al., 2014) as well as has an adverse respiratory effects (WHO 2013).

Nitrogen oxides are emitted as NO, which reacts rapidly with ozone or free radicals in the atmosphere forming NO2. The main anthropogenic sources are mobile and stationary combustion sources. Particulate matter consists of complex mixtures of particles suspended in the air, which vary in size and composition, and are produced by a variety of natural and anthropogenic activities. Major sources of PM are combustion processes in power plants, households, factories, motor vehicles, as well as construction activity, fire and natural sources of aerosols (wind blown dust and sea salt).

The ability to forecast regional and local air pollution events is challenging since the processes governing the production and accumulation of pollutants are complex and nonlinear. Comprehensive atmospheric models, by representing in as much detail as possible the various dynamical, physical, and chemical processes regulating the atmospheric fate of pollutants, provide a scientifically sound tool for providing air quality forecast guidance (Mathur et al., 2008).

The air pollution forecasting in Poland is still limited and in this work we present the air quality forecasting system which is developed within the LIFE/APIS (http://life-apis.meteo.uni.wroc.pl/) project and is running operationally for the area of Poland since the 1st of December 2015. The system is based on the online WRF-Chem model, which is configured using two nested domains covering Europe (12km x 12km grid mesh) and Poland (4km x 4km grid mesh) with the main focus on the south-west Poland (Lower Silesia). Within this first stage of the system existence the forecasts are not presented to the public but the main effort is towards evaluation of the results. Here, we used the air pollution concentrations (PM10 and NO2) measured at the Lower Silesia stations and evaluated the model results for the first 3 months of the forecasts (December 2015 – February 2016).

DATA AND METHODS

The WRF-Chem model version 3.5.1 is used with the configuration similar to Werner et al. (2016). These include the Noah Land Surface Model (Chen and Dudhia, 2001), YSU boundary layer physics (Hong et al., 2006), RRTMG long and short wave radiation scheme (Iacono et al., 2008), Grell 3D parameterisation with radiative feedback and shallow convection (Grell, 2002), the Lin microphysics scheme (Lin et al., 1983). The simulations are driven by the GFS meteorological data, available every 3h, at a 0.5^{o} x 0.5^{o} spatial resolution. Previous work of Werner et al. (2016) has shown the performance of the forecasting system with a flat emission inventory and TNO MACC II emission data. Here, we used the newest TNO MACC III emission inventory for the year 2011 and included hourly emission profiles taking into account country and SNAP sector dependent emission, bank holidays and winter/summer time. The first 48-h forecasting cycle on the 1st of December uses a 2-week spin-up, with the model simulations initialized with the GFS FNL meteorology for initial and boundary conditions. From the 2nd day of December, the model uses chemistry cycling, and the WRF-Chem run from the last hour on the previous day are used to initialize the next day's forecasting simulation.

The PM10 and NO2 concentrations' forecasts were compared with hourly observations gathered by the Voivodeship Inspectorate of Environmental Protection at 16 stations in the Lower Silesia region in SW Poland. We used here basic error statistics to summarize the system performance for the 16 December 2015 - 28 February 2016. It included: bias (BIAS), mean absolute error (MAE) and index of agreement (IOA). For NO2, data from 13 measuring sites and for PM10 7 measuring sites were available. Forecasts are compared with the measurements separately for the <24h and 48-72h lead time. For February 2016, the measurements were used with no detailed quality control.

RESULTS

Examples of PM10 and NO2 forecasts are presented in Figure 1 for the SW Poland (Dolnośląskie province). Both maps show the highest concentrations of atmospheric pollutants for the emission source areas. These are both the main cities (e.g. Wrocław) or the large industrial or energy production sites (e.g. Turoszów at the SW boundary of Poland). Modelled atmospheric concentrations in the closest vicinity of the large point sources are too high if compared with the measurements. This should be linked with a lack of vertical emission profile, which is currently under the development for the LIFE/APIS forecasting system.

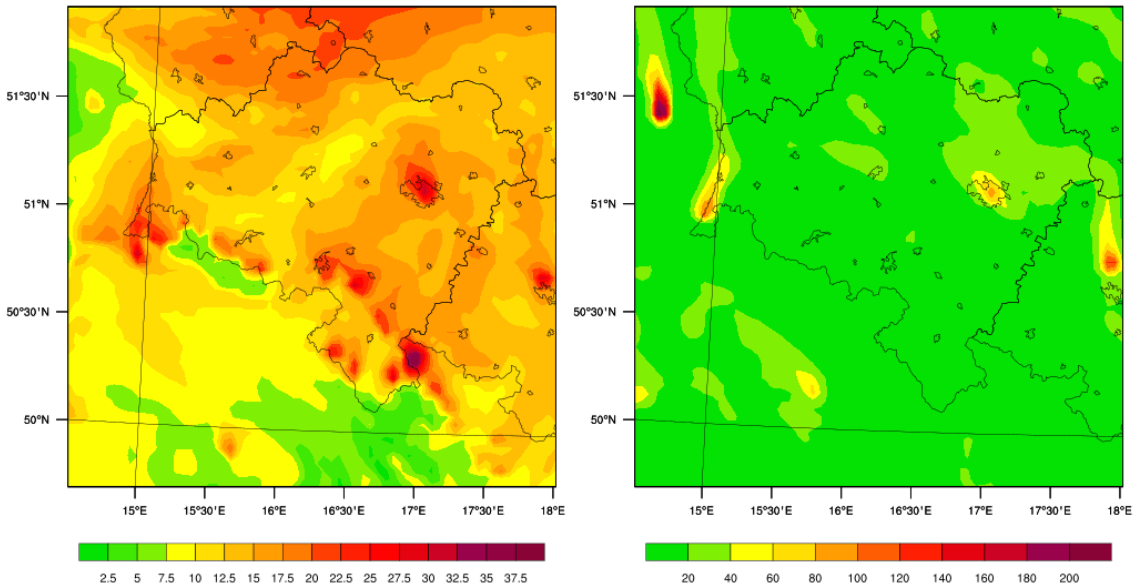

Figure 1. Examples of PM10 (left, time valid 06.01.2016 13:00 UTC) and NO2 (right, time valid 11.01.2016 07:00 UTC). Units are µg m^{-3}

The PM10 concentrations are to the large extent underestimated for the majority of the measuring sites. Especially the peaks, which are of a large concern in terms of human health, are underestimated. This is shown with the example of the Działoszyn station (Figure 2). Temporal variability of the observed PM10 concentrations is well resolved, but the measured values, and especially the peaks, are underestimated. This is also shown in Table 1. The bias for hourly PM10 concentrations, calculated for all the stations for the period of December 2015 – February 2016 is -26.7 µg m^{-3}.

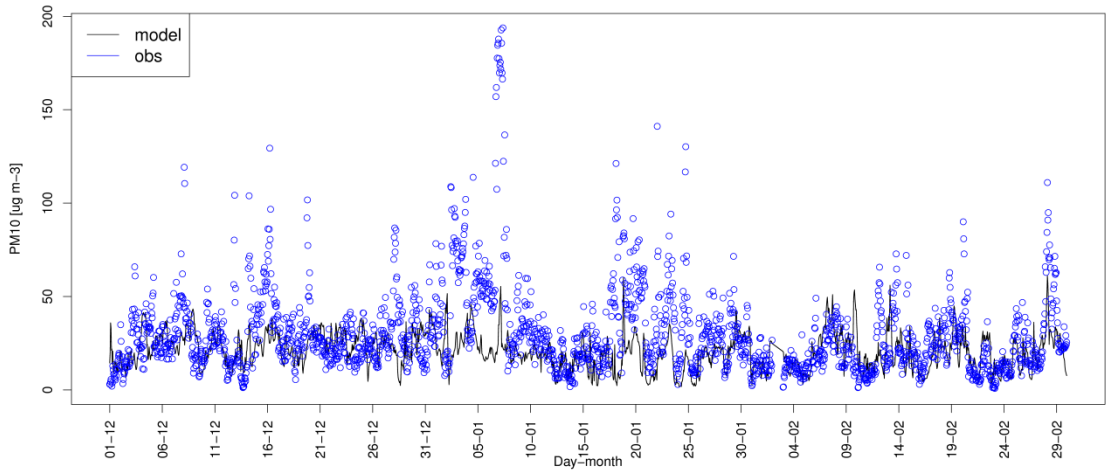

Figure 2. Modelled and measured hourly PM10 concentrations at rural station (Działoszyn), lead time <24h

The forecasting system was able to reproduce the observed NO2 air concentrations during the analysed period. The bias is relatively small, concerning the absolute values of measured NO2, and the temporal variability of modelled NO2 is similar to the measurements, as shown in Figure 3 at Legnica station as an example.

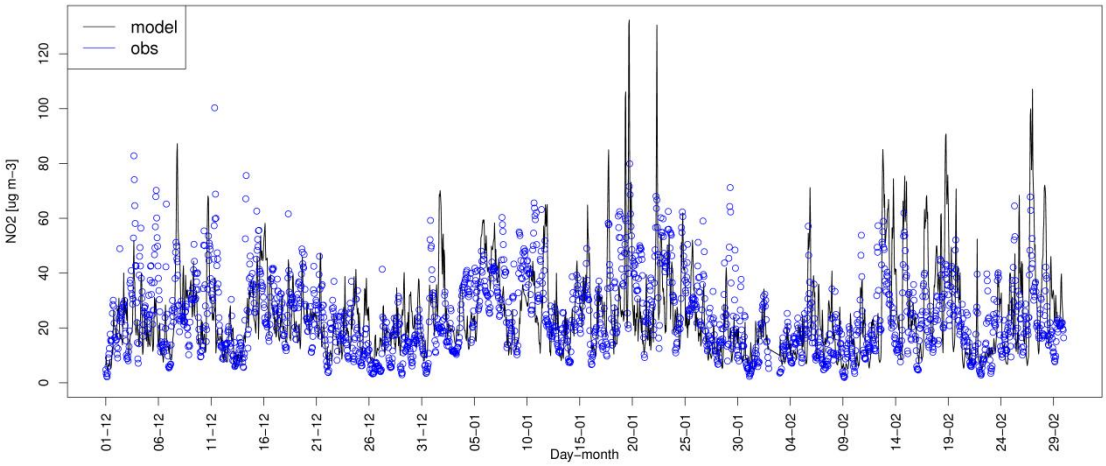

Figure 3. Modelled and measured hourly NO2 concentrations at suburban station (Legnica), lead time <24h

The error statistics, calculated for the entire period and all the available stations, are summarized in Table 1 for two lead times: <24h and >48h. The results confirm large underestimation by the model of the measured PM10 values. NO2 is also underestimated. There are relatively small changes in the model performance if the two lead times are compared.

Table 1. Error statistics for PM10 and NO2, lead time <24h and lead time>48h, all stations

	PM10 LT<24h	**PM10 LT>48h**	**NO2 LT<24h**	**NO2 LT>48h**
BIAS [μg m^{-3}]	-26.7	-27.2	-19.6	-19.8
MAE [μg m^{-3}]	31.9	32.5	20.0	20.0
IOA	0.36	0.36	0.42	0.43

SUMMARY AND CONCLUSIONS

We have presented here the results of the improved version of the air pollution forecasting system for SW Poland developed within the LIFE/APIS project. In comparison to the first version of the system (Werner et al. 2016), the main change includes the application of the hourly temporal emission profile, which vary between weekday, weekend and holidays and is SNAP sector dependent. This change improved temporal and spatial variability of modelled NO2 concentrations, which are related, in a high degree, with emissions from road transport. The bias is relatively small and the temporal variability of modelled NO2 is similar to the measurements. The improvement for PM10 concentrations is not so clear as for NO2. In fact temporal variability of the observed PM10 concentrations is well resolved, but the measured values, and especially the peaks, are underestimated. The underestimation of the PM10 concentrations might be linked with the uncertainty in primary particulates emission inventory. National emission database, developed for the year 2015 by the Chief Inspectorate of Environment Protection, shows that the PM10 emission from residential combustion is c.a. two times higher if compared with TNO MACC III data.

Moreover, for both pollutants modelled concentrations in the closest vicinity of the large point sources are too high if compared with the measurements. We link this with a lack of vertical emission profile, which is currently under the development for the LIFE/APIS forecasting system.

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