1. Introduction

Meteorological models are widely used to derive spatially continuous meteorological parameters at various temporal scales. The models are used for both: weather forecasting and air quality analysis. The output of the meteorological models is also a key component for regional air pollution modelling, as the meteorological processes are important for emission, dispersion and removal of atmospheric pollutants (Borga et al., 2009). Moreover, high concentrations of atmospheric pollutants of adverse effect on human health, are often related with specific meteorological conditions, e.g. fogs or heatwaves, low wind speeds, thermal inversion within the boundary layer or type and mobility of the atmospheric air mass.

This paper presents the results of application and evaluation of the Weather Research and Forecasting (WRF, Skamarock et al., 2008) model for calculation of meteorological parameters at relatively high spatial resolution at the regional scale. The WRF model was performed for the winter period with the air quality standards exceeded for particulate matter in SW area of Poland (PM10: 01-30.12.2009). The WRF model results were evaluated with both surface and ravisonde measurements collected in the innermost model domain.

5. Results

The model is able to correctly resolve temporal changes of surface PRES, TMP and SPFH, with the IOA calculated for all measurements >0.9 (Table 1, Fig. 2 and Fig. 3). There is a general tendency of the model to underestimate the observed TMP and SPFH for the selected period, described by the negative MB values for the majority of the stations. The meteorological parameters are overestimated for Śnieżka station, and in case of PRES, for Kłodzko. For Śnieżka, the overestimation can be attributed to the specific location of the station – at the isolated mountain top. The grid height at Śnieżka station is ~1200m, while the real station elevation is ~1615m a.s.l. This can explain the overestimation of PRES and TMP for Śnieżka, and suggest insufficient spatial resolution of the model for the areas of complex terrain. The terrain features are smoothed at ~2km x~2km model grid, and actual deformations of air streamlines produced by topography is more significant than estimated by the model.

The IOA calculated for WIND is lower than for the remaining meteorological parameters used for comparison. The worst results, in terms of IOA, are calculated for Rudniki station, which is situated in plain in terms of e.g. topographic position of the measuring post (Fig. 2 and 3). The model performance for Śnieżka station is also rather poor, and the wind speed values are significantly underestimated by the model. The reasons for the underestimation calculated for Śnieżka are expected to be the same as provided above for PRES and TMP.

The modelled TMP, SPFH and WIND are in good agreement with ravisonde measurements collected in Wroclaw. The IOA for all meteorological parameters (PRES, TMP and SPFH) is also calculated for all meteorological stations operating in d03 domain (Fig. 4). The results indicate that the model is not able to reproduce the vertical profile of air temperature. A period of large errors for PRES is evident for days 17 – 21 Dec 2009 for all stations (time series for Wrocław are presented in Fig. 4). The model is not able to reproduce the significant decrease in atmospheric pressure. For the coldest day of the selected period (20 Dec), the modelled air temperature is close to the measured value, but the lowest modelled TMP value is calculated for the next day and not confirmed in the measurements. For WIND, the model is capable in reproducing the time of observed peaks of increased wind speed.

6. Summary and conclusions

In this paper Weather Research and Forecasting model was applied to estimate meteorological parameters in SW Poland for the selected period of high concentrations of PM10. The main findings are:

- The model is capable of reproducing the temporal changes of atmospheric pressure, temperature and humidity for the majority of the stations.
- The sites for which the model performed worse are located in the mountainous area of the domain, and insufficient spatial resolution is expected to be the reason for this.
- The model constantly underestimates the measured air temperature at 2m and overestimates the wind speed.
- The model capabilities of reproducing observed wind speed below 1ms⁻¹ thresholds are limited (15% of successful cases). This is important in terms of dispersion of atmospheric pollutants, including PM10.
- The model failed to reproduce the vertical profile of air temperature for several cases of strong inversion layer was measured near the ground. This is also crucial for air quality modelling and may suggest insufficient vertical resolution of the domain. Further studies will be undertaken for different model settings and cases with poor air quality standards.

Table 1 Error statistics for PRES, TMP, SPFH and WIND for surface and ravisonde measurements (N – number of measurements)

<table>
<thead>
<tr>
<th>Site</th>
<th>PRES [hPa]</th>
<th>MAE</th>
<th>MB</th>
<th>SPFH [g/kg]</th>
<th>MAE</th>
<th>MB</th>
<th>WIND [m/s]</th>
<th>MAE</th>
<th>MB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrocław</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Śnieżka</td>
<td>0.72 - 1.02</td>
<td></td>
<td></td>
<td>3.82 - 4.17</td>
<td></td>
<td></td>
<td>1.02 - 1.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rudniki</td>
<td>0.41 - 0.86</td>
<td></td>
<td></td>
<td>0.34 - 0.58</td>
<td></td>
<td></td>
<td>0.10 - 0.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrocław</td>
<td>0.19 - 0.20</td>
<td></td>
<td></td>
<td>2.99 - 3.82</td>
<td></td>
<td></td>
<td>0.89 - 1.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Śnieżka</td>
<td>0.30 - 0.37</td>
<td></td>
<td></td>
<td>1.59 - 2.32</td>
<td></td>
<td></td>
<td>0.93 - 1.00</td>
<td></td>
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</tr>
<tr>
<td>Rudniki</td>
<td>0.11 - 0.25</td>
<td></td>
<td></td>
<td>0.84 - 1.19</td>
<td></td>
<td></td>
<td>0.96 - 1.10</td>
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</tr>
</tbody>
</table>

Fig. 1 Configuration of the WRF model domains (left & labels) and the highest daily average PM10 concentrations measured over the domain (d0) during the period 1 – 30 Dec 2009 (PPM).

Fig. 2 Mean bias for the meteorological stations operating in d03

Fig. 3 Index of agreement for the meteorological stations operating in d03

Fig. 4 Modelled and observed PRES (top left), TMP (bottom left), SPFH (top right) and WIND (bottom right) at Wrocław station

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References:


