Data assimilation experiment on SO₂ initial conditions in the Pearl River Delta

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Introduction

As the air pollution problem becomes more and more severe, many air quality models were developed and applied to research and forecast operation. However, there are many uncertainties in the model, which affect the forecast result. Data assimilation is a state-of-the-art approach to reduce the uncertainties in input data, such as initial conditions or boundary conditions, by using observations. It can combine both advantages of model results and observations to improve the prediction.

In order to provide a more precise initial condition of SO₂ in the Pearl River Delta (PRD) region, data assimilation methods were introduced to the WRF-CMAQ model. Sensitivity experiments were carried out to examine the number of assimilation sites and correlation scale. The comparative experiment on the optimal effect of different assimilation methods were conducted.

Methodology

The method used here is the Optimal Interpolation method (OI) and the Ensemble Square Root Filter method (EnSRF). The formula as follows:

\[ \text{EnSRF} \quad x^a = x^b + \frac{K}{\text{H}}(y^o - x^o) \]

\[ \text{OI} \quad x^a = x^o + \frac{K}{\text{H}}(y^o - x^o) \]

where, \( x^a \) is the analysis of the initial conditions or boundary conditions, \( x^b \) is the background field, \( K \) is the observational operator, \( B \) is the background error covariance matrix, \( \text{H} \) is the observation error covariance matrix, and \( y^o \) is the observation.

Results and Discussion

Correlation Scale

The correlation scale decides the radius of the observation. The error of the analysis field increases with the correlation scale. Setting 20 km will be more reasonable.

Table 2: Statistical comparison of simulated and observed meteorological parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Forecast</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>20.93</td>
<td>19.68</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>16.75</td>
<td>18.42</td>
</tr>
<tr>
<td>Humidity</td>
<td>40.00</td>
<td>38.90</td>
</tr>
</tbody>
</table>

Fig. 1: Nesting domain setting of the WRF

Fig. 2: Comparison of RMSE with and without assimilation using different methods

Fig. 3: Vertical profile of monthly average concentration of SO₂

Fig. 4: Distribution pattern of SO₂ concentration

Fig. 5: Comparison of RMSE with and without assimilation using different methods

Fig. 6: Distribution pattern of SO₂ concentration

Background Analyses

Generally, diurnal variations of temperature and relatively humidity are well captured by model, the simulation of wind speed and SO₂ are relatively high.

Different Methods

- The simulation of temperature and relative humidity were well, but higher for simulation of the wind speed and SO₂ is relatively high by WRF-CMAQ.
- The high values of the background error was mainly located in southwest region in horizontal direction. It was nearly constant below 400 m and decreased with height above 400 m.
- The sensitivity test showed that the optimal horizontal scale was 20 km. With the number of the assimilation sites increasing, the optimization of the assimilation sites had a declining trend.
- Under the same conditions, the optimization of EnSRF method is better than that of OI method. Both methods can provide an analysis field closer to reality.

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