研究报告

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2013年1月华北地区重霾污染过程SO_2和NO_x的CMAQ源同化模拟研究

Inverse modeling of SO_2 and NO_x emissions using an adaptive nudging scheme implemented in CMAQ model in North China during heavy haze episodes in January 2013

关键词：华北地区 重霾污染 源同化反演 SO_2、NO_2模拟 CMAQ模式

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摘要：以2006年中国地区的INTEX-B排放清单为基础,采用CMAQ模式污染源同化方法,反演更新了2013年1月重霾污染过程华北地区的SO_2和NO_x排放源;应用WRF-CMAQ模式以及2006年INTEX-B初始排放源和2013年1月改进的排放源,分别模拟了1月9-15日和28-31日两次持续重霾污染过程的SO_2和NO_2浓度,并与华北地区47个环境监测站点实测值进行对比,重点分析了基于初始源和同化反演源的模拟效果及其改进原因;本文亦采用2012年清华大学编制的东亚地区MEIC排放清单评估了SO_2和NO_x同化反演源的合理性.分析结果表明:①CMAQ模式污染源同化方法可适用于重霾污染过程,即采用同化反演源模拟的SO_2、NO_2浓度时空变化特征与实测值较一致,而且可反映SO_2、NO_x排放源强的动态变化特征;②基于同化反演源的SO_2、NO_2浓度模拟效果明显优于2006年INTEX-B排放源,其时间变化趋势与实测值较一致,而且可模拟重霾污染过程SO_2、NO_2浓度的峰值;③采用反演源模拟的SO_2、NO_2浓度空间区分布特征与实测值较一致,而且可较好反映重污染区的极值分布特征;④经污染源同化改进后SO_2、NO_2模拟浓度与实测值的相关系数有所提高,误差明显减小;SO_2的改进效果略优于NO_2,这与污染源对两种污染物浓度的影响差异有关;⑤初始源中SO_2、NO_x排放源的空间分布和强度与2012年清华大学编制的排放源强差异较大,而同化反演源的空间分布和强度均接近于上述2012年排放源,较好反映出重点地区的高污染源分布特征.本文研究结果将为改进重霾污染过程的空气质量预报、减小自下而上建立的排放源清单不确定性、评估SO_2、NO_x等排放源的影响效应以及不同气象条件下区域排放源的动态调控等提供新技术途径和研究思路.

Abstract: In this study, SO_2 and NO_x emission sources in North China during a heavy haze episode in January 2013 are retrieved using an adaptive nudging scheme implemented in the Community Multiscale Air Quality (CMAQ) modeling system based on the 2006 INTEX-B emission inventory. SO_2 and NO_2 concentrations during two sustaining heavy haze episodes on 9-15 and 28-31 January are simulated using the Weather Research Forecasting (WRF)-CMAQ model system. Emissions are essentially from INTEX-B for 2006 with improved emission estimates for January 2013. Simulated results are compared with the observations at 47 stations from the China National Environmental Monitoring Centre (CNEMC), and the difference caused by the two emission estimates and the advantage of nudging source over the initial emission inventory are analyzed. Inversed SO_2 and NO_x emissions are evaluated using the 2012 MEIC emission inventory developed by the Tsinghua University (MEIC v1.2 inventory). Results showsthat ① the adaptive nudging scheme based on CMAQ model is suitable for simulating the heavy haze pollution processes. Temporal and spatial variations of simulated SO_2 and NO_2 concentrations are consistent with those of observations, and the dynamic variations of SO_2 and NO_x emission sources can also be captured. ② Inversed source is obviously superior to the initial 2006 INTEX-B emission inventory for the simulation of SO_2 and NO_2 concentrations. Temporal variation trends and peak values of simulated SO_2 and NO_2 are in good agreement with the observations. ③ The regional SO_2 and NO_2 distributions simulated by inversing emission sources are in accordance with the observations, with the peak values well reproduced. ④ Correlation coefficients between the simulated and observed concentrations of SO_2 and NO_2 increase and biases decrease using the inversed emissions compared to the initial emissions. There are greater improvements in the simulation of SO_2 than NO_2 due to different impacts of emission sources. ⑤ Differences in the spatial distribution and intensity of SO_2 and NO_x emission sources between the initial emission estimate and the MEIC v1.2 inventory are larger, whereas the results with the inversed emission sources are close to those with the MEIC v1.2 inventory with high emission source intensity of SO_2 and NO_2 in the key areas being inversed. The results of this study will provide new technique and idea for

improving air quality forecasting during heavy haze pollution episodes, reducing the uncertainties in the emission inventory developed by bottom-up approach, and assessing the impacts and dynamic control of regional SO_2 and NO_X emission sources under different weather conditions.

Key words：North China heavy haze pollution inversing emission sources SO_2 and NO_2 simulation CMAQ model