Computers, Environment and Urban Systems 62 (2017) 222–232

Contents lists available at ScienceDirect

Computers, Environment and Urban Systems

journal homepage: www.elsevier.com/locate/ceus

A modelling system with adjustable emission inventories for cross-boundary air quality management in Hong Kong and the Pearl River Delta, China

Chunxiao Zhang [a,b], Hui Lin [b,d,e], Min Chen [c,b,f,g], Xinqi Zheng [a,*], Rongrong Li [b], Yulin Ding [b]

[a] School of Information Engineering, China University of Geosciences in Beijing, No. 29, Xueyuan Road, Haidian District, Beijing 100083, China
[b] Institute of Space and Earth Information Science, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong, China
[c] Key Laboratory of Virtual Geographic Environment (Nanjing Normal University), Ministry of Education, Nanjing 210023, China
[d] Department of Geography and Resource Management, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong, China
[e] The Chinese University of Hong Kong Shenzhen Research Institute, Shenzhen 518057, China
[f] Jiangsu Center for Collaborative Innovation in Geographical Information Resource Development and Application, Nanjing 210023, China
[g] State Key Laboratory Cultivation Base of Geographical Environment Evolution, Nanjing 210023, Jiangsu, China

ARTICLE INFO

Article history:
Received 15 December 2015
Received in revised form 12 December 2016
Accepted 14 December 2016
Available online xxxx

Keywords:
Air quality
Modelling management
Adjustable emission inventory
Cyberinfrastructure system
Pearl River Delta (PRD)

ABSTRACT

Air quality problems are attracting much attention in Hong Kong (HK) and the Pearl River Delta (PRD) in China. The complex and regional characteristics of air quality problems call for a comprehensive modelling system with a highly reliable simulation and effective communication tools for decision-makers and participants from multiple disciplines. In this paper, we used a modelling management method to develop a Cyberinfrastructure system that couples meteorological and air quality models with a visual analysis to improve the cognition and management of air quality problems. The database management of both the data and the modelling parameters is an innovative advantage of this system; this will be helpful not only for sharing modelling knowledge but also for improving the acknowledgement of modelling scenarios, which are usually conducted by various stakeholders. On the basis of 19 categories of emission inventories that provide detailed information about multiple pollutants in the 11 cities in the study area, this system provides an authoritative and adjustable emission inventory to draw an accurate scientific picture for decision-makers. We applied this system to a case study to investigate the effects of emission control of nitrogen dioxide from vehicles in HK and the PRD on air quality. The simulation showed that the air quality improvement from emission control was very limited and suggested that regional and super-regional co-operation involving the comprehensive emission control of multiple pollutants may be more effective in creating a better future.

1. Introduction

Air quality problems affect many highly developed cities worldwide, including the Hong Kong Special Administrative Region in China. To mitigate this crisis, the Hong Kong (HK) government has taken many measures to control air pollution emission sources, and dramatic achievements are evident from the emission trend statistics. However, air quality monitored by both general and road stations is not as satisfactory as the control of the emission sources (Clean Air Network, 2011). Such inconsistencies also cause conflicts among the government, organisations and the public regarding the management of this problem (Wang, 2005).

To explain the contrast between the decrease in emissions and continual poor air quality, a regional effect from the surrounding Pearl River Delta (PRD) region (nine cities in Guangdong province) has been identified as the predominant cause of the air quality problems. The PRD, which is geographically adjacent to HK and located in the southern part of China (Fig. 1), is 41,700 km^2 in size, with a population of approximately 65 million (Wang, Wu, & Liang, 2009a). Rapid urbanisation and high energy consumption have recently driven air pollution to harmful levels, which has been a growing concern for both HK and the PRD. It has long been recognised that the air pollution problem in HK is greatly affected by the PRD, particularly if the secondary products O_3 and $PM_{2.5}$ are considered instead of the classical primary pollutants, such as SO_2 and the total suspended particulate matter (Guo et al., 2006; Lam, Wang, Wu, & Li, 2005; Y. H. Zhang et al., 2008).

To address the different local and regional contributions to the air quality problem, extensive studies based on emission inventory data have been conducted during the past several years to analyse the relative individual contributions of the major emission sources in HK and the PRD. Yim, Fung, and Lau (2010) examined the contributions of sources such as major power plants, marine vessels and vehicles in the PRD and HK to the SO_2 concentrations observed at 11 HK

* Corresponding author.
E-mail address: zhengxq@cugb.edu.cn (X. Zheng).

http://dx.doi.org/10.1016/j.compenvurbsys.2016.12.004
0198-9715/

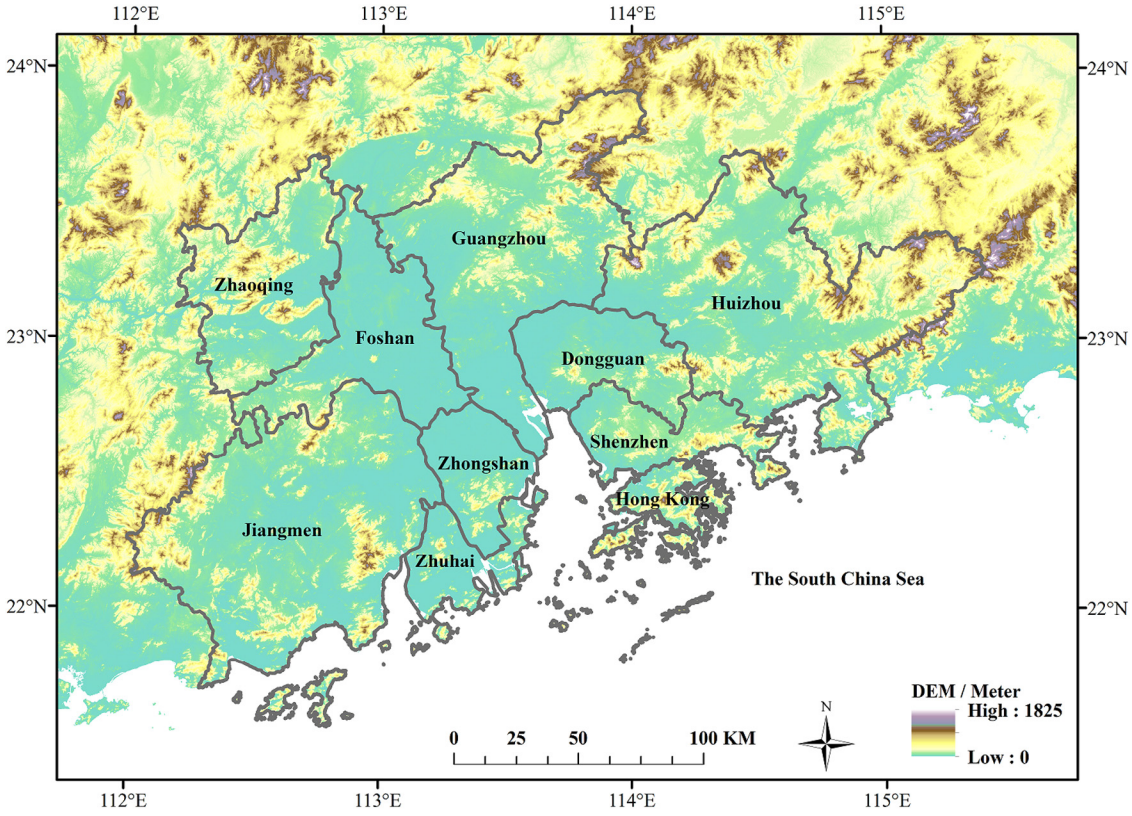

Fig. 1. Geographic location of HK and the PRD.

Environmental Protection Department general stations. Instead of focusing on HK, the impacts of emissions from transportation, industry and power generation on air quality in the PRD were addressed (Wang, Carmichael, Chen, Tang, & Wang, 2005). The scientific results of the contributions of various sources have provided the necessary evidence for government officials to take measures to manage the air quality problem. The findings also suggested that the government should take collaborative measures to manage these regional problems because the individual cities cannot achieve better air quality on their own (Kwok, Fung, Lau, & Fu, 2010; Lam et al., 2005; Nie, Wang, Wang, Wei, & Liu, 2013; Wang et al., 2009b; Wang et al., 2009a; Yim et al., 2010). On the basis of this scientific evidence, HK and the PRD have been collaborating to improve regional air quality since 2002, and a significant improvement in air quality was achieved by 2010 compared to 1997 (Environment Bureau, Transport, & Housing Bureau, Food, & Health Bureau, & Development Bureau, 2013).

To expand the positive effects of the collaborative measures, the two regions (HK and the PRD) are still actively calling for comprehensive studies to better understand the regional air quality problem because a greater understanding is needed to fine-tune the control policies (Environment Bureau et al., 2013). Therefore, an overarching and integral HK and PRD science platform has been proposed for the formulation of regional policy and control measures under the 'one country, two systems' principle to ensure continuous and concerted standards for the implementation of a regional control strategy (Yim et al., 2010; Zhong et al., 2013). Such a statement is concluded in regard of two aspects.

1) To provide a scientific foundation for air quality management policy making, many different scenarios concerning various sensitivity studies and potential policies must be considered (Wang et al., 2005; Yim et al., 2010). In addition, these scenarios are usually conducted by different research institutes or stakeholders, including the environmental protection department, universities in HK and scientific institutes in the PRD (EPDHK, 2014b; Kwok et al., 2010; Yim et al., 2010; Zheng et al., 2009a). Thus, the simulation results may not be widely accepted, and it can be difficult to reproduce a particular simulation given the limitations of the data source or the model setting (Environment Bureau et al., 2013; Jiang, Wang, Wang, Xie, & Zhao, 2008; Kwok et al., 2010; Zhong et al., 2013). Therefore, it is preferable to design an integral HK and PRD modelling system with a modelling management system that will manage the input data, modelling parameters and modelling results to improve the recognition and reproducibility of the modelling output (Zhang, Chen, Li, Fang, & Lin, 2016). Various government agencies can reproduce the simulation scenarios and obtain a consensus about the air quality situation, and then they can consolidate various standards to resolve the air quality problem. Unfortunately, such a requirement is rarely addressed by the current modelling systems (Kwok et al., 2010; Wang et al., 2005; Xu et al., 2010; Zheng et al., 2009a). Although the database system was applied for some support systems, management is still limited to data rather than modelling parameters, which has a considerable effect on the modelling results (Wu, Zhao, Zhu, & Jiang, 2015; Xu et al., 2011; Zhang, Lin, Chen, Li, & Zeng, 2014a; Zhang, Lin, Chen, & Yang, 2014b).
2) To make such a supporting system practical for decision-makers, in addition to the important requirement for integrated models, the emission inventory used for modelling should be comprehensive (multi-pollutants), reliable and acknowledged by all parties involved (i.e. HK and the PRD) (Zhong et al., 2013). Researchers and modellers are mostly focused on a single pollutant, source or specific region using the current systems; some of the parameters included SO_2 and point sources in HK and the PRD or volatile organic compounds (VOCs) and multiple sources in the PRD (Guo et al., 2006; Wang et al., 2005; Xu et al., 2011; Xu et al., 2010; Yim et al., 2010). Such a focus is inefficient for the provision of an integral and scientific picture for decision-makers because the pollutants may affect each other, particularly through chemical reactions (Sillman,