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Numerical model to quantify biogenic volatile organic compound emissions: The Pearl River Delta region as a case study

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ABSTRACT

This article compiles the actual knowledge of the biogenic volatile organic compound (BVOC) emissions estimated using model methods in the Pearl River Delta (PRD) region, one of the most developed regions in China. The developed history of BVOC emission models is presented briefly and three typical emission models are introduced and compared. The results from local studies related to BVOC emissions have been summarized. Based on this analysis, it is recommended that local researchers conduct BVOC emission studies systematically, from the assessment of model inputs, to compiling regional emission inventories to quantifying the uncertainties and evaluating the model results. Beyond that, more basic researches should be conducted in the future to close the gaps in knowledge on BVOC emission mechanisms, to develop the emission models and to refine the inventory results. This paper can provide a perspective on these aspects in the broad field of research associated with BVOC emissions in the PRD region.

Introduction

Biogenic volatile organic compound (BVOC) emissions dominate the global emissions of atmospheric VOCs, and can influence the chemistry and composition of the atmosphere, including aerosols and oxidants. Over the past few decades, more and more studies have been carried out to (1) understand the mechanisms controlling BVOC emissions; (2) measure the BVOC emissions on different spatial and temporal scales; (3) develop BVOC emission models and estimate the emissions; and (4) predict the atmospheric chemistry impacts of BVOC emissions (Wildermuth and Fall, 1996; Guenther et al., 1999; Müller et al., 2008; Tanaka et al., 2012; Curci et al., 2008; Pfister et al., 2008). The results of these studies reveal that BVOCs can be produced by various sources in the terrestrial ecosystem and more than 100 BVOCs have been identified (Guenther et al., 2006). The regional and global air quality or climate models have included the BVOC emissions routinely now, which are estimated as a function of land cover and environmental driving variables. There are considerable challenges to predicting the BVOC emissions accurately due to the diversity of emission sources and chemical compositions. What's more, there are generally high uncertainties associated with the BVOC emissions

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estimated (Guenther et al., 1995; Simpson et al., 1999), which limit the accuracy of the modeling results and the air quality control policy. People make big efforts to ensure the accuracy of BVOC emissions estimated by models, from the model framework to model inputs.

The Pearl River Delta (PRD) region, including nine cities, is the expanse of delta lands of the Pearl River at the South China Sea (Fig. 1). It is one of the most densely urbanized regions in the world and one of the economic hubs in China. The air quality in the PRD region has been deteriorating in recent years, and ozone and fine particles have been the two critical air pollutants in this region. The PRD region has a somewhat separate climate system due to its unique geographical location, featuring a subtropical monsoon climate. The weather in this region is relatively moderate with small annual temperature range, from 13 to 15°C in January to 28°C and above in July. What's more, the precipitation is rich in this region, with annual rainfall over 1800 mm. The rainfall is distributed relatively uniformly, and the wet season is long, from April to October. The fact that rain and hot weather occur during the same period is the most notable characteristic of the climate in this region, which is very favorable for vegetation growth and BVOC emissions. Subtropical evergreen forest is the main vegetation type in the PRD, and some tree species have very high BVOC emission capacities, such as eucalyptus (Winters et al., 2009). The climate feature and vegetation distributed enhance the BVOC emissions in the PRD region. Current local study results show that the regional BVOC emissions contribute at least one third to the total VOC emissions in the PRD (Zheng et al., 2010; Wang et al., 2011). A series of studies have been carried out to clarify the air pollution issue in this region and addressed the importance of BVOC emissions to the air quality (Wei et al., 2007; Situ et al., 2013; Tang et al., 2007; Ding et al., 2012), especially during highly polluted periods (Wei et al., 2007; Situ et al., 2013). As the importance of BVOC emissions has been revealed, it is becoming clear that more rigorous quality control for the BVOC emission inventory is needed in the PRD.

An overview of the BVOC emissions is needed in order to better carry out the related research in the PRD region. The objective of this article is to summarize the current work on BVOC emissions in the PRD region, and point out some of the problems or deficits of these studies. Advice for future work is also presented. Section 1 describes the evolution of BVOC emission models, with particular attention on three typical emission models. Section 2 focuses on an overview of studies related to BVOC emissions in the PRD region. Advice for future work is presented in Section 3.

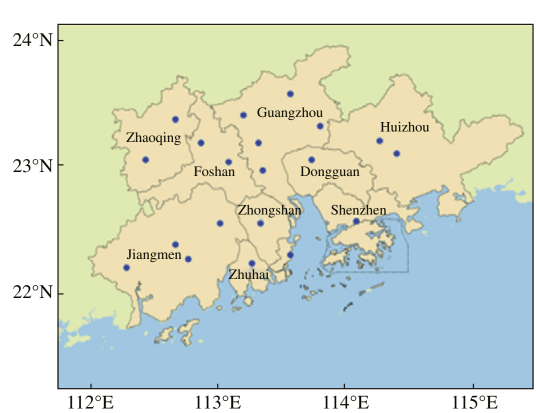

Fig. 1 – Location of the PRD region and meteorological monitoring sites (blue circles represent meteorological monitoring sites). PRD: Pearl River Delta.

1. Evolution of BVOC emission models

1.1. Brief history of emission model development

It is a big challenge to develop a numerical model to represent the processes of BVOC emissions, which are influenced by a large number of factors and are very complex. Fig. 2 shows the history of BVOC emission model development. Sparked by a new line of research into BVOC emissions in 1960 (Went, 1960), early studies tried to describe the emissions by fitting them to temperature using a simple linear relationship expression (Tingey et al., 1980). In the late 1980s and the early 1990s, many studies highlighted the relationship between isoprene emission and photosynthesis (Monson and Fall, 1989; Monson et al., 1992, 1994), and pointed out that there was a link between isoprene synthesis and photosynthesis. This recognition allowed modelers to develop a leaf-scale emission model in the 1990s (Guenther et al., 1991, 1993) including the light and temperature response curves, which were used in photosynthesis models previously (Farquhar and Caemmerer, 1982). Based on these results, global emission models were developed quickly incorporating the schemes of temperature and light dependency; for example, the G95 model, which was the first global model used to estimate BVOC emissions (Guenther et al., 1995). In the 2000s, emission models were also developed to meet the requirements of regional emission estimation, such as the Model of Emissions of Gases and Aerosols from Nature (MEGAN) (Guenther et al., 2006). Emission models continued to include more processes, such as the leaf development status,

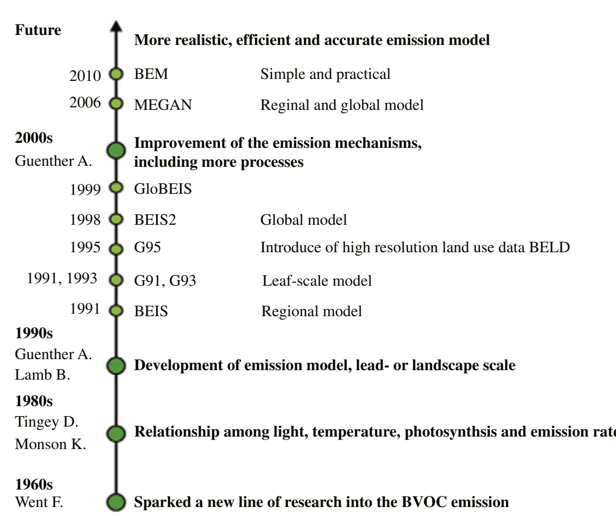

Fig. 2 – History of BVOC emission model development. BVOC: biogenic volatile organic compound.