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Editorial

Air Pollution Modeling: Local, Regional, and Global-Scale Applications

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The *Atmosphere* Special Issue entitled "Air Pollution Modeling: Local, Regional, and Global-Scale Applications" comprises nine original papers.

The problem of air pollution is inevitably accompanied with our human activities. Severe air pollution situations have been reported, especially in emerging countries, and fully satisfying air quality standards is still an underlying issue. Today, modeling research is a valuable approach to promote our understanding on the behavior of air pollutants and can be used for regulatory, policy, and environmental decision making. Such modeling applications are wide ranging with regard to horizontal grid resolution varying from a few km (local), to hundreds of km (regional), to thousands of km (global). To foster our current scientific knowledge on the potential and limitations of modeling, scientific research studies related to air pollution modeling—applied at the urban, regional, and global-scale—have been collected in this Special Issue.

The following three papers in this Special Issue conducted high-resolution modeling studies using computational fluid dynamics (CFD). Kim [1] applied a coupled CFD–chemistry model to examine the sensitivity of nitrate aerosols to vehicular emissions in urban streets. Sensitivity simulations clarified that nitrate concentrations do not show a clear relationship with NO_x emission rates, and show a proportional relationship with vehicular volatile organic compound (VOC) and NH_3 emissions in the street canyon. The results suggest that the control of vehicular VOC and NH_3 emissions might be a more effective way to reduce $PM_{2.5}$ problems, rather than the control of NO_x emissions, when vehicular emissions are dominant in winter. Gonzalez Olivardia et al. [2] presented the airflow patterns and reactive pollutant behavior over 24 h, in a realistic urban canyon in Osaka City, Japan, using a CFD model coupled with a chemical reaction model. The mesoscale model cannot capture the local phenomena because of the coarse grid resolution, and the CFD-coupled chemical reaction model surpassed the mesoscale models in describing the NO, NO_2, and O_3 transport process, representing pollutants concentrations more accurately within the street canyon. This work showed that the concentration of pollutants in the urban canyon is heavily reliant on roadside emissions and airflow patterns, which, in turn, are strongly affected by the heterogeneity of the urban layout. The CFD-coupled chemical reaction model better characterized the complex three-dimensional site and hour-dependent dispersion of contaminants within an urban canyon. Moissseeva and Stull [3] designed a large-eddy simulation of a real-life prescribed burn using a coupled semi-emperical fire–atmosphere model. Large eddy simulation (LES) is a method that uses CFD at a very fine spatial and temporal resolution to simulate wide ranging scales of atmospheric motions, down to the size of large turbulent eddies. The Weather Research and Forecasting (WRF) model, combined with a semi-empirical fire-spread algorithm (WRF-SFIRE), allows for the two-way coupling between a LES and a fire behavior model. WRF-SFIRE was applied to simulate wildfire smoke plume dynamics, and the vertical rise and distribution of emissions on a local scale. The results suggest that the rise and dispersion of fire emissions are reasonably well captured by the model; subject to accurate surface thermal forcing and relatively steady atmospheric conditions.

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For local, regional, and global-scale modeling, the Eulerian model serves as an important approach. There are four papers within this Special Issue related to the topic. Takami et al. [4] focused on biomass burning, which is a major source of atmospheric particle pollution over Indochina during the dry season. Indochina has convoluted meteorological scales, and regional meteorological conditions dominate the transport patterns of pollutants. Based on the Community Multiscale Air Quality (CMAQ) model, the impacts of biomass burning emission inventories and meteorology on simulated PM_{10} over Indochina in 2014 were examined by adopting different emission inventories and an atmospheric re-analysis dataset. The results clarified that the biomass burning emission inventories impact on PM_{10} simulation to a greater degree than atmospheric re-analyses in area highly polluted by biomass burning in Indochina in 2014. Yamaji et al. [5] present a Japanese study on reference air quality modeling (J-STREAM), conducted using 32 model settings for representing $PM_{2.5}$ concentration. A Comprehensive Air Quality Model (CMAQ) with eXtensions (CAMx) and Weather Research and Forecasting-Chemistry (WRF-Chem) were included in the project. Good performances were found in dominant components of $PM_{2.5}$, such as sulfates (SO_4^{2-}) and ammonium (NH_4^+). The other simulated $PM_{2.5}$ components, i.e., nitrates (NO_3^-), elemental carbon (EC), and organic carbon (OC), often showed clear deviations from the observations. This inter-comparison model suggested that these deviations may be owing to a need for further improvements both in the emission inventories and additional formation pathways in chemical transport models, while meteorological conditions also require improvement to simulate elevated atmospheric pollutants. Itahashi et al. [6] presented the possible pathways to solve the subject of model underestimation of SO_4^{2-} during winter found in J-STREAM. A winter haze period in December 2016 was examined by involving aqueous-oxidations and gas-phase oxidation by three stabilized Criegee intermediates into the CMAQ model. Updating the catalyzed aqueous phase metal and NO_2 oxidation pathways led to increased contributions from other sources, and the additional gas phase oxidation by stabilized Criegee intermediates provided a link between fugitive VOC emissions via changes in O_3. Zong et al. [7] performed the WRF-Chem simulation for winter visibility in the Jiangsu Province in China. The result showed that WRF-Chem has a good capability to simulate visibility and the related local meteorological elements and air pollutants in Jiangsu in the winters of 2013–2017. For visibility inversion, the study further adopted the neural network algorithm. Meteorological elements, including wind speed, humidity and temperature, were introduced to improve the performance of WRF-Chem relative to the visibility inversion scheme. The underestimation of the visibility was especially remarkable, but this issue was essentially solved using the neural network algorithm.

Other models such as the dispersion model and the Lagrangian model are also applied and presented in this Special Issue. Prato and Huertas [8] assessed the agricultural burning influence-area using the air dispersion model of AERMOD. Agricultural burning, including short-term climate change forcing pollutants such as black carbon is still a common practice around the world. The legal requirements to commence regulatory actions to control them relate to the identification of the area of influence. However, this task is challenging from the experimental and modeling point of view, since it is a short-term event and the source area of the pollutants moves. Different sizes and geometries of burning areas located on flat terrains, and with several crops burning under worst-case scenarios of meteorological conditions were considered in this study. The influence area was determined as the largest area where the short-term concentrations of pollutants (1 h or one day) exceed the local air quality standards. It was found that this area forms a band around the burning area, the size of which increases with the burning rate but not with its size. Haszpra [9] introduced a Lagrangian model called the Real Particle Lagrangian Trajectory model—Chaos version (RePLaT-Chaos), which specifically aims to demonstrate the chaotic behavior of pollutants, i.e., the advection dynamics of pollutants shows the typical characteristics, such as sensitivity to the initial conditions, irregular motion, and complicated but well-organized (fractal) structures. This study presents possible applications of a RePLaT-Chaos by means of which the characteristics of the long-range atmospheric spreading of volcanic ash clouds and other pollutants can be investigated in an easy and interactive way. This application is also a suitable tool for studying the chaotic features of advection, and determines two quantities which describe the chaotic nature of the advection processes: the stretching rate quantifies the strength of the exponential stretching of pollutant clouds, and the escape rate characterizes the rate of the rapidity by which the settling particles of a pollutant cloud leave the atmosphere.

The goal of this Special Issue is to present a research with a wide perspective, involving multi-scale modeling research studies with different types of modeling applications, and the nine papers in this Special Issue achieve this goal. The research presented in these nine papers demonstrate the usefulness of modeling applications.

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