A Cluster Analysis of PM2.5 Using CMAQ model Results for Representativeness of air quality monitoring networks in Busan, Korea

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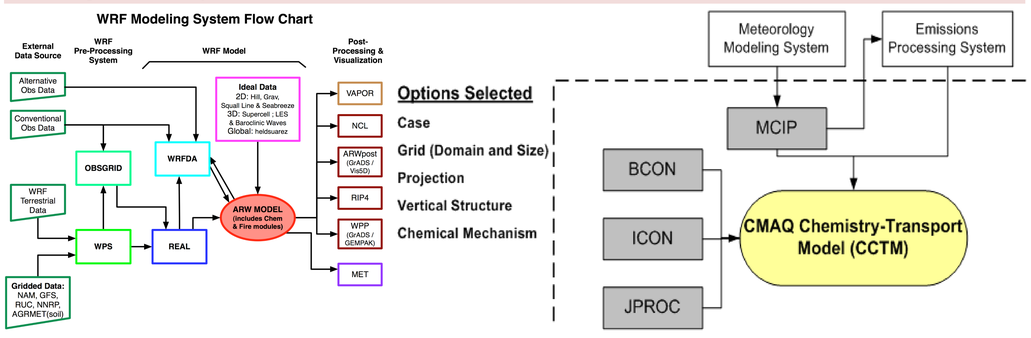
1. Introduction

With the increasing interest in air pollution, the installation of the air quality monitoring networks for the regular measurement is recognized as a very important task in many countries. However, it takes a lot of time and money to operate the air quality monitoring networks. Therefore, the representation of the locations of the quality monitoring networks is always an important issue. So far, many studies have been conducted around the world on the representation of the locations of air quality monitoring networks. Most of these studies are based on statistical analysis or use of GIS in existing air quality monitoring networks data. These methods are useful for identifying the representativeness of existing measuring networks, but it is impossible to verify the need to add additional monitoring stations. With the development of computer technology, numerical air quality models such as CMAQ are becoming an important means of reproducing and diagnosing air pollution.

2. WRF-CMAQ modeling system

The **Weather Research and Forecasting (WRF)** Model is a next-generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications. It features two dynamical cores, a data assimilation system, and a software architecture supporting parallel computation and system extensibility. The model serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometers. The effort to develop WRF began in the latter 1990's and was a collaborative partnership of the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (represented by the National Centers for Environmental Prediction (NCEP) and the Earth System Research Laboratory), the U.S. Air Force, the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA).

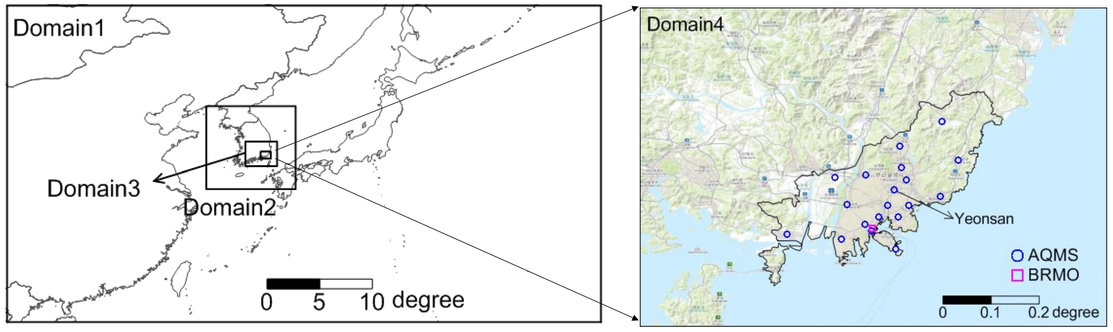
The EPA **Community Multiscale Air Quality (CMAQ)** modeling system is a third-generation air quality model. It is available online at http://www.cmaq-model.org. CMAQ is designed for applications ranging from regulatory and policy analysis to understanding the complex interactions of atmospheric chemistry and physics. It is a three-dimensional Eulerian (i.e., gridded) atmospheric chemistry and transport modeling system that simulates ozone, particulate matter (PM), toxic airborne pollutants, visibility, and acidic and nutrient pollutant species throughout the troposphere. Designed as a "one-atmosphere" model, CMAQ can address the complex couplings among several air quality issues simultaneously across spatial scales ranging from local to hemispheric. The CMAQ source code is highly transparent and modular to facilitate the model's extensibility through community development by all members of the air quality modeling community.

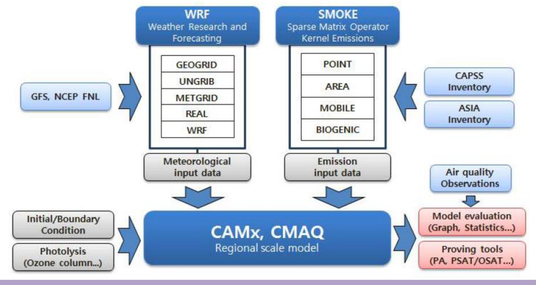


3. Model system set up

Four nested modeling domains both for the meteorological model and the chemical transport model (CTM) in this study. Grid resolutions are 27 km, 9 km, 3 km and 1km respectively, and the corresponding nesting grids are denoted as domain1, domain2, domain3 and domain4. The meteorological input data were made by WRF meteorological model using national centers for environmental prediction (NCEP) final (FNL) global analysis data. The clean air policy support system (CAPSS) made by Ministry of Environment was used as air pollutant emission data within South Korea. For other areas, Model Inter-Comparison Study for Asia (MEIC), Regional Emission inventory in Asia (REAS) were used as input air pollutant emission data. In this study, modelling area was divided into four regions to analyse contribution rates by region.

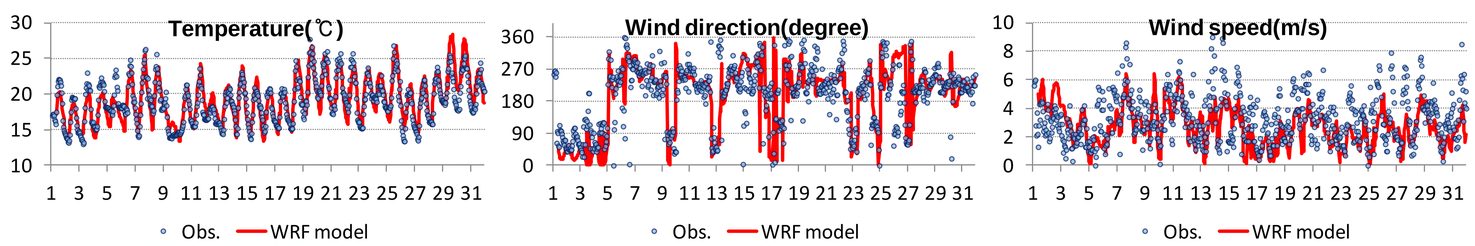
Model option	CMAQ
Model version	Version 4.7.1
Horizontal resolution	27km-9km-3km-1km
Grid nesting	One-way
Vertical layers	15
Horizontal advection	YAMO
Vertical advection	WRF
Horizontal diffusion	Multi-scale
Vertical diffusion	Eddy
Gas-phase chemistry	CB5
Gas-phase chem.solver	EBI
Aerosol chemistry	AE5
Dry deposition	M3Dry

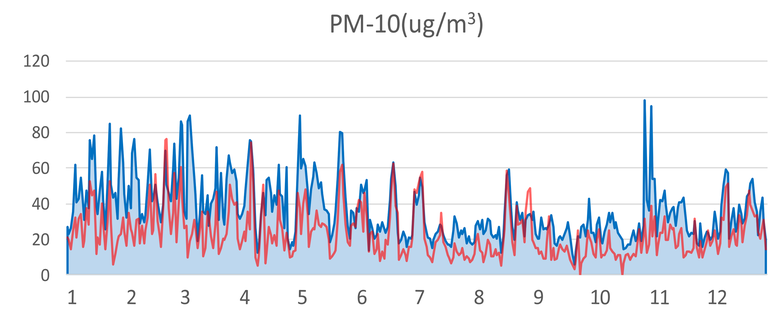


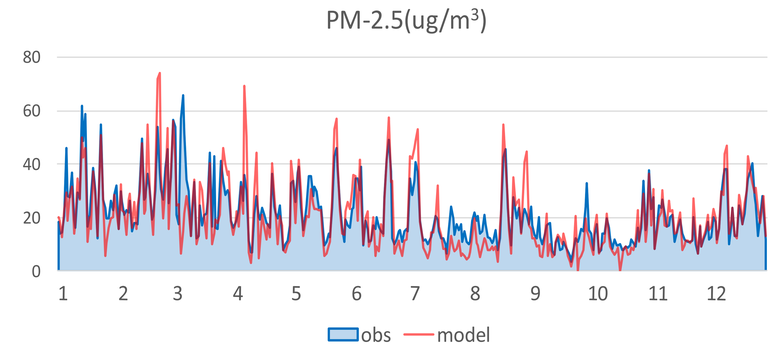


4. Model performance

Temperature, wind direction and wind speed from BRMO and PM2.5 concentration from Yeonsan air quality monitoring site were used for comparison and the model results showed a good agreement with the observations. Calculated average PM2.5 during May 2017 was 27.6 μg/m3 and observed average PM2.5 was 27.5 μg/m^3. PM2.5 distributions in Busan were reproduced as 1km grid spacing by CMAQ model. The model results reflected the actual PM2.5 changes relatively well.







5. Conclusions

With the development of computer technology, numerical air quality models such as CMAQ are becoming an important means of reproducing and diagnosing air pollution. In this study, PM2.5 distributions in Busan were reproduced as 1km grid spacing by CMAQ model. The model results reflected the actual PM2.5 changes relatively well. Then, a cluster analysis was applied to the hourly PM2.5 concentration for all grids in model domain. Cluster analysis is a statistical method that groups similar objects together. There are several ways to measure similarity and distance between objects. K-means clustering uses a non-hierarchical cluster analysis method, which provides the advantage of low calculation time for fast processing of large amounts of data. K-mean cluster was very frequently used in existing studies that grouping air quality data according to the same characteristics. As a result of the cluster analysis, PM2.5 in Busan was able to be divided into groups with the same concentration change characteristics. Finally, the redundancy of the monitoring stations and the need for additional sites were analyzed by comparing the clusters of PM2.5 with the locations of the air quality monitoring networks currently in operation.

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education(2017R1D1A3B03036152)