Integration of the Model of Emissions of Gases and Aerosols from Nature (MEGAN) into the CMAQ Modeling System

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Abstract

Biogenic emissions play a central role in the chemistry of the polluted and pristine (natural) atmosphere and therefore need to be estimated accurately for use in chemical transport models. The Model of Emissions of Gases and Aerosols from Nature (MEGAN) has recently been converted into FORTRAN computer code that is compatible with the Community Multiscale Air Quality (CMAQ) modeling system. The current release of CMAQv4.7 includes the temporal allocation of emissions from the Biogenic Emission Inventory System (BEIS) as an in-line module. We compare the algorithmic differences between these two biogenic emission models as a first step to using MEGAN in the CMAQ modeling system. Our examination of the two biogenic models reveals substantial differences in the algorithms, resulting in significant differences in the emission estimates from the two models that may impact air quality modeling results in the CMAQ modeling system.

Introduction

The NARSTO 2005 assessment report stressed that emissions are at the cornerstone of air quality management decision-making. While the United States Environmental Protection Agency (EPA), Office of Air Quality Planning and Standards (OAQPS) bears the responsibility for maintaining the National Emissions Inventory (NEI) for traditional anthropogenic sources (e.g., electrical generating units and mobile sources), many nontraditional emission categories (such as biogenics) remain poorly characterized. The Biogenic Emissions Inventory System (BEIS) for estimating volatile organic compounds from vegetation and nitric oxide (NO) from soil has been developed at the EPA(Pierce et. al., 2002; Vukovich et. al. 2002; Schwede et al., 2005). The EPA is now collaborating with the National Center for Atmospheric Research (NCAR) to integrate the Model of Emissions of Gases and Aerosols from Nature (MEGAN) (Guenther et. al., 2006) into the CMAQ modeling system. MEGAN represents an evolution of the BEIS system, but was only recently converted into code that is compatible with CMAQ. While BEISv3.14 is the existing operational biogenic emissions processor in the CMAQ system, we are performing rigorous tests with MEGAN since MEGAN has been distributed to the scientific community and is widely used by other modeling groups around the world. This paper summarizes the work to date to integrate the MEGAN system into the CMAQ modeling system. We will focus on the difference in the estimates of isoprene fluxes between the two models and probe the algorithmic reasons for these differences.

Summary of BEIS algorithms

The Biogenic Emissions Inventory System (BEIS) has been updated several times since its introduction in 1988. BEIS estimates volatile organic compound (VOC) emissions from vegetation and nitric oxide (NO) emissions from soils at a spatial resolution as fine as 1 km. BEIS3.14 is currently formally imbedded in the Sparse Matrix Operation Emission (SMOKE) modeling system (v2.5). BEIS3.14 features a 1-km vegetation database for the contiguous United States that resolves forest canopy coverage by tree species; normalized emission factors for 35 chemicals, including 14 monoterpenes, sesquiterpenes and methanol; and, a soil nitric oxide emissions algorithm that accounts for soil moisture, crop canopy coverage, and fertilizer application. Isoprene, methyl butenol, and methanol emissions are assumed to be functions of both temperature and solar radiation and therefore have a light correction factor applied to a normalized emission estimate. The soil NO algorithm distinguishes between agricultural and non-agricultural land use types. Adjustments due to temperature, precipitation, fertilizer application, and crop canopy coverage are limited to the growing season (assumed to be April 1-October 31) and are restricted to areas of agriculture as defined by the Biogenic Emissions Landuse Database. Outside of the growing season and for non-agricultural areas throughout the year, soil NO emissions are assumed to depend only on temperature and the base emission factor is limited to that for grasslands. All other chemical species are assumed to be functions of temperature only. Sesquiterpene emission estimates are assumed to be an exponential function of temperature with an exponential factor of 0.17. All other species have an exponential factor of 0.09. Temperature adjustments to emission estimates are capped at temperatures greater than 315 K to allow for heat stress on the chemical processes within the tree leaves

Summary of MEGAN algorithms

MEGAN estimates the net emission rate of gases and aerosols from terrestrial ecosystems into the above-canopy atmosphere at a specific location and time as a function of normalized emissions (aka standard conditions) and an adjustment factor. The MEGAN canopy scale emission factor differs from BEIS which use a leaf-scale emission factor. Although canopy-scale measurements are becoming more available, the MEGAN canopy-scale emission factors are still primarily based on leaf and branch-scale emission measurements that are extrapolated to the canopy-scale using a canopy environment model. The adjustment factor is equal to unity at standard conditions. The adjustment factor in MEGAN is a combination of several factors that account for emission variations due to leaf area index (LAI); light, temperature, humidity and wind conditions within the canopy environment; and the effects of leaf age.

Differences in the isoprene algorithms

The primary differences in the isoprene algorithm can be summarized into three areas: (1) The standard conditions in MEGAN are estimated as a canopy-scale emission factor whereas BEIS uses a leaf-scale factor. (2) BEIS uses only temperature and light adjustments at the top of the canopy whereas MEGAN estimates temperature and light adjustments within the canopy using a parameterized canopy environment emission model. (3) MEGAN incorporates the effects of leaf age and monthly changes to LAI whereas BEIS does not.

Comparison of annual isoprene emission estimates

Using an annual set of meteorological model outputs for 2003, we have preliminary estimates the total emissions from both BEIS and MEGAN on a 36km grid. Figure 1 shows the annual emission estimates from BEISv3.14 using an annual set of meteorological inputs. The total emissions in the North American domain are approximately 17 Tg. Figure 2 shows the annual emission estimates from MEGANv2.04 using the same annual set of meteorological inputs. The total emissions in the North American domain are approximately 26 Tg. From this preliminary result, we see that the MEGAN estimates of isoprene emissions are about 53% higher than the estimates from BEIS as well as importanr differences in the spatial features

Summary

This paper summarizes the differences in the isoprene algorithm between BEISv3.14 and MEGANv2.04. There are substantial differences in all components of the algorithms that result in a preliminary estimate of a 53% difference in the annual estimate of isoprene emissions over North America.

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Keywords

Emission modeling
Air quality modeling
Biogenic emissions

Figures

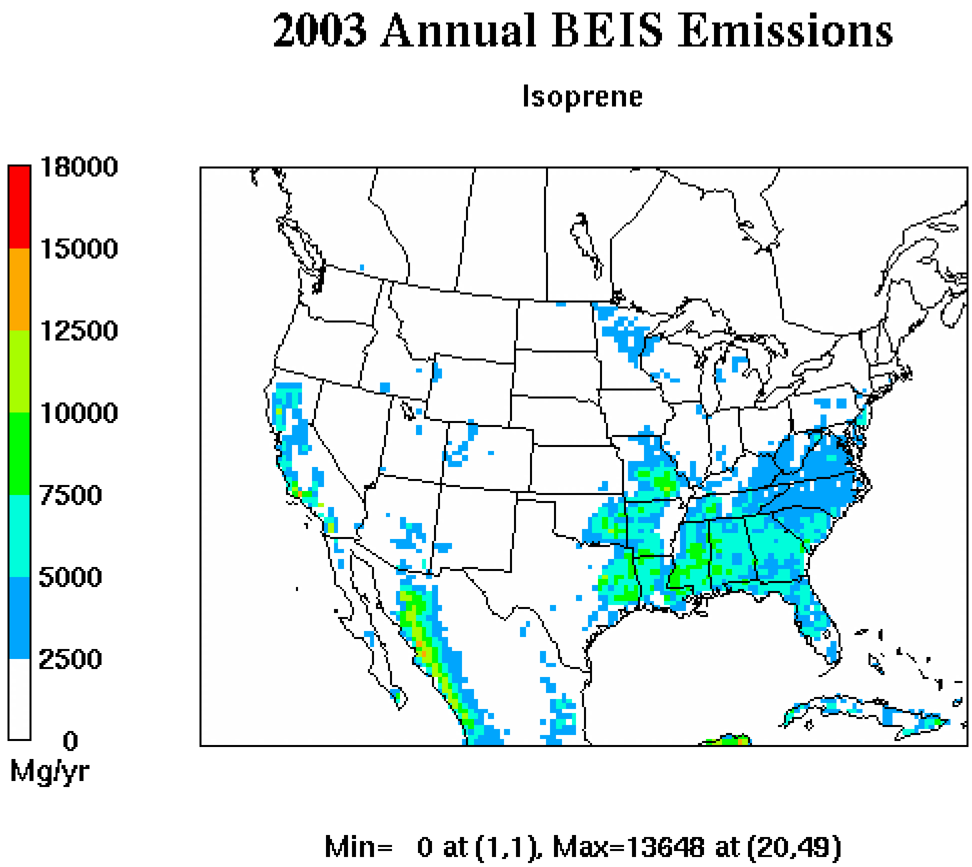

Figure 1: Annual Isoprene Emissions estimated from BEIS3.14

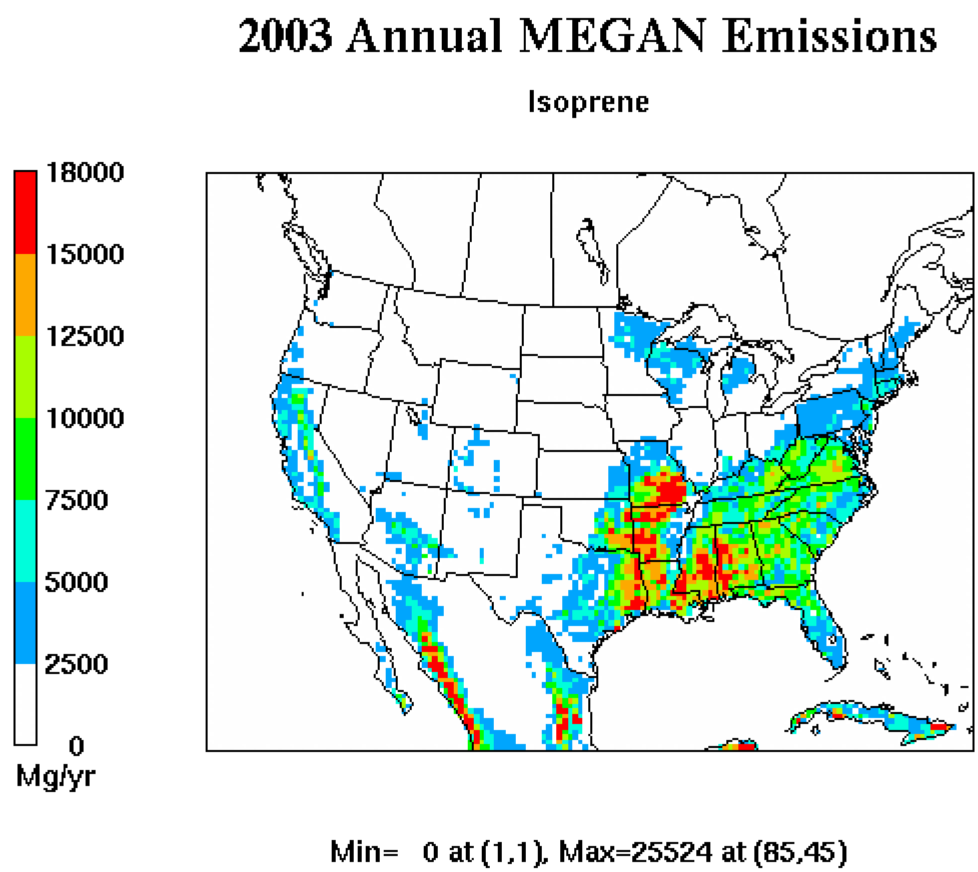

Figure 2: Annual Isoprene Emission Estimates from MEGANv2.04