Modeling the Biogenic Emissions using WRF/MCIP/MEGAN in the South of Chile

Eddio Carimán Linares, Luis A. Diaz-Robles , Cristian Varela-Bruce, and Pablo Etcharren Ulloa
School of Environmental Engineering, College of Engineering, Catholic University of Temuco, Temuco, Chile
8th Annual CMAS Models-3 User's Conference, October 19-21, 2009 Chapel Hill, NC

UNIVERSIDAD CATOLICA DE TEMUCO
50 años

ABSTRACT

In Chile the air pollution problem is becoming stronger each year, mainly for ozone and PM2.5. Some of these photochemical smog precursors are the volatile organic compounds (VOCs) emitted by nature, called Biogenic VOCs (BVOCs). The principal Biogenic sources are vegetation and microbial activity, sources very abundant in the South of Chile. The purpose of this research was to estimate a novel 2005 Biogenic Emissions Inventory with WRF 3.0 (Weather Research and Forecasting)/ MCIP 3.4/MEGAN 2.04 (Model of Emissions of Gases and Aerosols from Nature) models, using Chillan area as a study case. The chosen domain had a grid resolution of 3x3 km, with 28x19 cells. MEGAN was used because it has proved to be the most sophisticated models for biogenic emissions in any area of the planet. In fact, it has an extensive database from global satellite observations, field studies, and inventories, among others. Before, running the model, the temperature at two meters (TEMP2) was introduced at MEGAN FORTRAN code, because the MCIP3.4.1.1 version generates this temperature instead of the temperature at 1.5 meters (TEMP15) as was originally in MEGAN. The results obtained by modeling the estimated annual biogenic emissions were 100.33 tons. Of these emissions, 78.5% were Terpenes, 10% Nitrogen Oxide, 7.1% Isoprene, 2.4% Carbon Monoxide, 1.2% Alquenes, and 0.9% for other biogenic compounds (ketones, aldehydes, alcohols, aromatics, etc.). The Nitric Oxide emissions were particularly high because the Chillan area is an agricultural area. In this study the seasonality of the biogenic emissions are also shown. These results indicated that the WRF/MCIP/MEGAN model can be an effective tool to improve the biogenic emissions accuracy. This approach demonstrates the potential to be applied to biogenic emissions estimates in other areas and countries.

Acknowledgment: Acknowledgments of DGI-CD-2006-2-03 Project.

INTRODUCTION

Within the main precursors of secondary pollutants (O3 and PM2.5) are the volatile organic compounds (VOCs) and nitrogen oxides (NOx). VOCs that are emitted by nature are called Biogenic VOCs (BVOCs). Biogenic emissions are released by ecosystems and natural processes activities, mainly, of vegetation (metabolism, photosynthesis, defense, and other) and microbial activity, where, by the characteristics of the highly reactive BVOCs (terpenes and isoprenes) and in the presence of solar radiation, lead to the formation of these secondary pollutants. This could be the case of Chillán city, (Figure 1), where high particulate matter pollution is produce each year during winter and spring, although the ozone levels are not measured yet.

Despite the importance of the BVOC emissions on the photochemical pollution, in Chile just two states have those emissions. These correspond for the Metropolitan Area of Santiago and the O'Higgins Region estimated by GloBEIS, with 18,030 ton/ year and 39,035 ton/year, respectively. However, several assumptions where used for using that model, producing high levels of uncertainty. Although Chillán is a very agricultural, industrial and forestry area, it does not have these kind of BVOC estimations. This study develops an emissions inventory of Biogenic Sources to the year 2005 for the Chillán county (including Chillán Viejo county). This is achieved using the models WRF (Weather Research and Forecasting) and MEGAN (Model of Emissions of Gases and Aerosols from Nature). WRF generates weather information (temperature and solar radiation) required by MEGAN, for the latter to generate emissions with a domain of spatial resolution of 3x3 km and a temporal resolution of 1 hour. The models are run on a platform of a Beowulf cluster supercomputer architecture, which consists of a group of interconnected computers working in parallel, to solve problems that require high-capacity computing. Compared with previous models (GloBEIS and BEIS2), MEGAN contains global data coverage of soils, emission factors and leaf area index, resulting in a more accurate estimate of emissions.

Figure 1. Typical air pollution at Chillán, Chile.

This work was established as a first complete modeling research study of emissions BVOCs in Chillán. Its aim is to provide information on emission rates of these compounds, mainly terpenes and isoprenes, providing a preliminary estimate of annual emissions of BVOCs, and the temporal and spatial distribution of these emissions in Chillán.

METHODOLOGY

The BVOCs emissions where estimated by using WRF and MEGAN using the structure of the Figure 2 over the modeling domain of the Figure 3, where MCIP3.4.1.1 processed the outputs of WRF. Previous of running MEGAN, the temperature at two meters (TEMP2) was introduced on MEGAN FORTRAN code, because the MCIP generates this temperature instead of the temperature at 1.5 meters (TEMP15) as was originally in MEGAN. This issue helped other MEGAN users all over the world.

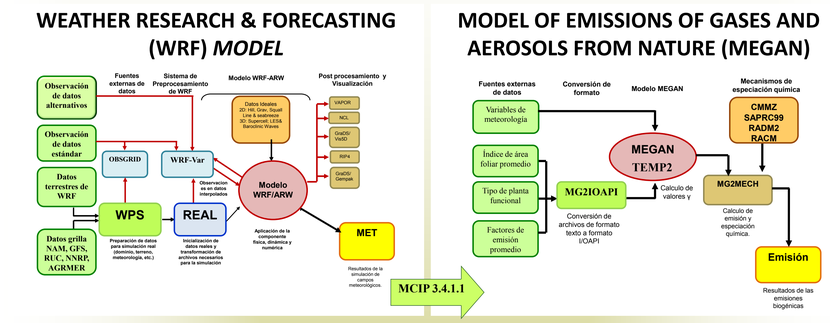


Figure 2. WRF and MEGAN conceptual models

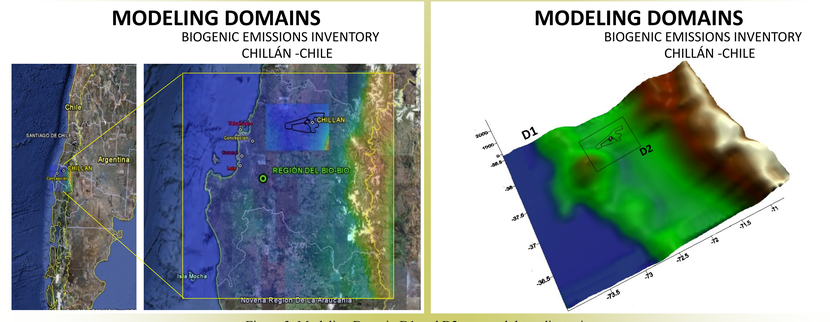
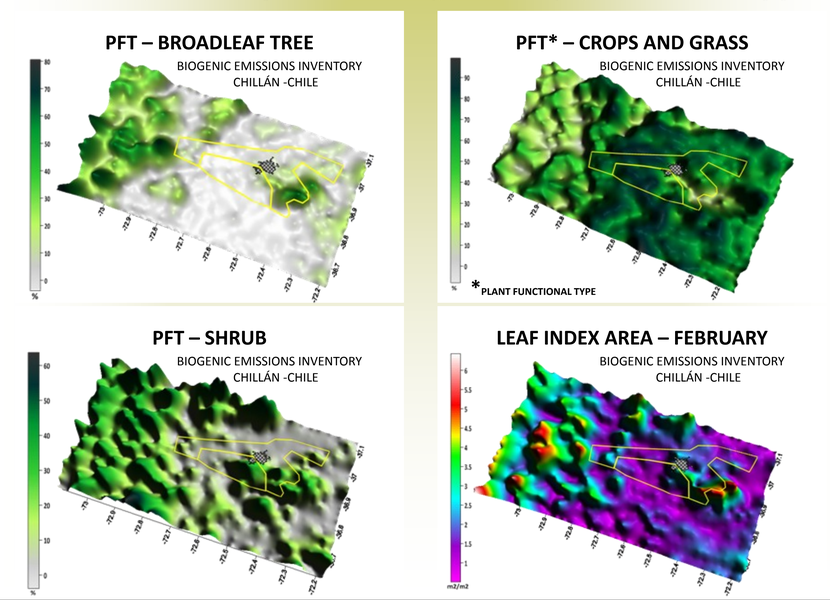


Figure 3. Modeling Domain D1 and D2, two and three dimensions

MEGAN require several inputs from the modeling domain, like Plant Function Type, Leaf Index Area by crops, etc., as shown on the following figures:



DISCUSSIONS AND RESULTS

One of the results by type of pollutants is the Emission Factors, which depends on the type of plant, the temperature, radiation, among others. The Figure 3 shows the nitric oxide and the isoprene emissions factor at the Chillán area. Here it is possible find a Forestry are on the North of the city (high emissions factors of Isoprene) and an agricultural area surrounding the urban area (high emissions factor of Nitric Oxide).

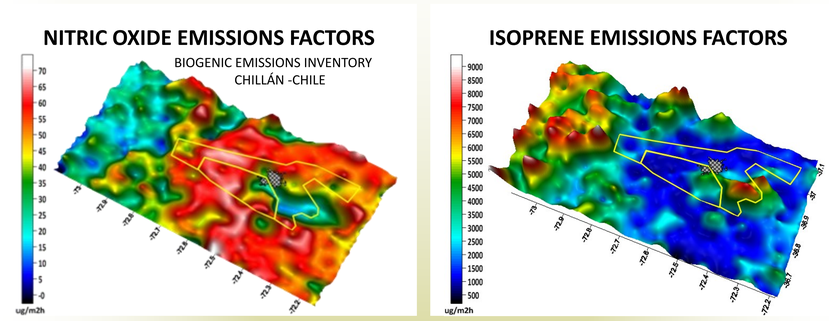


Figure 3. Nitric Oxide and Isoprene Emissions Factor at the Chillán area, 2005.

Figures 4 and 5 shows high terpene emissions compared with isoprene emissions. Those isoprene emissions are not very high because the area has high density of trees juts on the north of the modeling domain. The rest of the area is covered by agricultural crops, grass and shrubs. The BVOCs emissions activity start in November and finish in February, as shown in figure 4. The BVOCs emissions estimated by WRF/MEGAN were 100.33 tons for the year 2005. Of these emissions, 78.5% were Terpenes, 10% Nitrogen Oxide, 7.1% Isoprene, 2.4% Carbon Monoxide, 1.2% Alquenes, and 0.9% for other biogenic compounds (ketones, aldehydes, alcohols, aromatics, etc.).The Nitric Oxide emissions were particularly high because the Chillán area is an agricultural area.

Better emissions factors have to be estimated for using in MEGAN, since it has global emission factors, and some biogenic sources are typical for some areas far away from US or Europe, like Chile.

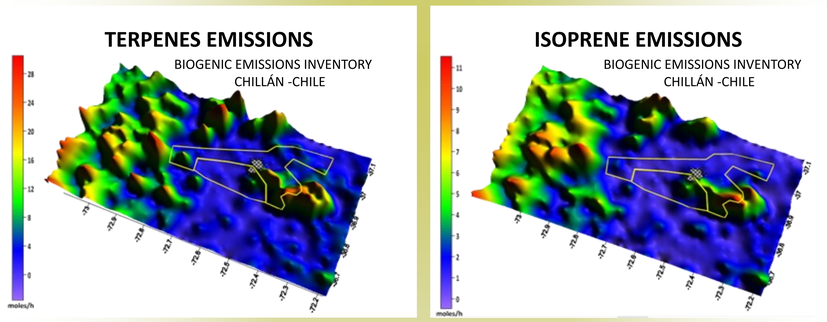


Figure 4. Spatial Terpene and Isoprene emissions at Chillán area, Chile, 2005.

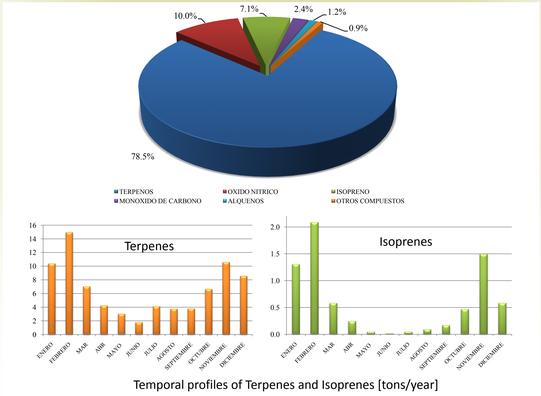


Figure 5. Annual contribution of BVOC species and Temporal profiles of Terpenes and Isoprene Emissions at Chillán area, 2005.