A STUDY ON THE BVOC EMISSIONS IN HONG KONG

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Abstract

The BVOC emissions in Hong Kong were studied using the Model of Emissions of Gases and Aerosols from Nature with the use of high-resolution satellite images. For the year 2006, the total annual BVOC emissions in Hong Kong was determined to be 12,400 metric tons (9.82 x 10^9 g C (BVOC carbon)), in which isoprene emission accounts for 72%, monoterpene emissions account for 8%, and OVOC emissions account for 20%. The annual variation in emission due to weather over the twelve-year period (1995 to 2006) was found to be small, but an increasing trend in the annual variation due to changes in the land cover can be observed.

Key words: volatile organic compounds, plant emissions, isoprene.

1. INTRODUCTION

Volatile Organic Compounds (VOC) in the troposphere reacts photochemically with oxides of nitrogen (NOx) in the presence of solar radiation to form various secondary air pollutants such as ozone and peroxyacetyl nitrate, which cause adverse impact on agricultural products and pose health risk on human health. VOC in the atmosphere comes mainly from anthropogenic sources. However, biogenic sources, such as trees, shrubs and grasses amongst vegetation, should not be neglected as they may emit a significant amount of VOC consisting of different gases to our atmosphere, including isoprene which is more reactive than many anthropogenic VOC.

In 2004, the Environmental Protection Department (EPD) of the HKSAR Government has commissioned a study on the BVOC emissions in Hong Kong. In this study, a BVOC emission model was established using Global Biosphere Emissions and Interactions System (GloBEIS) based on detailed land use, tree distribution and hourly meteorological data. The study was continued by the authors in 2007 to further investigate the BVOC emissions in Hong Kong using high-resolution satellite images and an improved emission inventory model developed by the National Centre of Atmospheric Research (NCAR).

2. DATA PREPARATION

The Model of Emissions of Gases and Aerosols from Nature (MEGAN), developed by the NCAR, was adopted in the present study. The model requires the input of a number of parameters, including the land cover data, plant function types emission factors, leaf area index, and weather data. The following sections explain the preparation of the necessary data for running the program.

2.1 Land cover data from satellite

The habitat map from the report “2006 Terrestrial Habitat Mapping and Ranking Based on Conservation Value” (SDD 2006), a consultant report of the Sustainable Development Division (SDD) of the Hong Kong SAR Government, was adopted for land cover data. The map is based on remote sensing analysis on two SPOT-5 satellite images, and provides a classification of the Hong Kong land area into 24 habitat classes. The map is selected because it is derived from high-resolution satellite images; it has been ground-truthed using aerial photos and field surveys; and the habitat classification matches with that in the SDD field survey data (SDD 2004). Tree species information of the habitat classes is therefore available.

2.2 The plant-functional types (PFT)

Among the 24 habitat classes, 10 of them were selected as plant functional types (PFTs). They are: Fung Shui Forest; Montane Forest; Lowland Forest; Mixed Shrubland; Shrubby Grassland; Grassland; Plantation / Mixed Forest; Mangrove; Golf Course / Urban Park; and Cultivation. The 10 PFTs contribute to 78% of the total land area of Hong Kong. The remaining 14 habitat classes were grouped together as “others”. They were not considered as PFTs since they are either non-vegetation classes or the contributed area is small, leading to negligible emission contributions. Furthermore, among the above 10 PFTs, 4 of them were considered as dominant PFTs by area. They are: Lowland Forest; Mixed Shrubland; Shrubby Grassland; and Grassland. These 4 PFTs contribute to 70% of the total Hong Kong land area. These four area-dominant PFTs were further refined spatially as described in the next section.

2.3 Sub-regions

In order to improve the spatial representation of emission factors, the Hong Kong land area was subdivided into the following six sub-regions: New Territories North, New Territories North-West, New Territories East, Kowloon, Hong Kong Island, and Islands. The sub-regions were setup by grouping regions of adjacent Hong Kong District Councils. In terms of availability of tree survey locations, each sub-regional PFT should have several field survey locations. Too small a sub region may have insufficient field survey data.

2.4 Emission Factors (EF) and Leaf Area Index (LAI)

Spatial variation of EFs (at each grid cell) is required for input into the MEGAN program. This information was estimated from the local PFT (at each grid cell) and the EFs representing the PFT class. The PFT-level EFs were obtained through tree data analysis. The species-level isoprene EFs were determined based on present and previous measurement results (Tsui 2007, Leung et al. 2008), literature values, or taxonomy. The species-level EFs of monoterpene and other VOCs were determined based on vegetation types (broadleaf trees; needle leaf trees; shrubs; or herbaceous cover) and reference MEGAN emission factors except those measured.

Spatial variation of LAI was determined in a similar fashion from the local PFT (at each grid cell) and the LAI representing the PFT class. LAI values were determined for PFT classes as in the previous project (Tsui 2007) based on the approach of Geron et al. (Geron et al. 1994). Noted that the seasonal variation of LAI is not modeled in this methodology.

2.5 Weather data

Hourly averages of wind speed, air temperature, relative humidity, and solar radiation were provided from the Hong Kong Observatory. Except for some weather stations, the data used in this study covers twelve years from 1995 to 2006. The averaged air temperature from 22 weather stations were used together with the hourly solar radiation at the King's Park weather station from 1995 to 2006 for inputting into the MEGAN program.

3. EMISSION MODELING

A grid system is introduced over the whole Hong Kong territories, the MEGAN model was used to calculate hourly emission rates (g/s compound per grid) for 20 chemical species at each grid cell including isoprene, methyl-butenol, myrcene, sabinene, limonene, 3-carene, ocimene, β-pinene, α-pinene, farnesene, β-caryophyllene, methanol, acetone, acetaldehyde, formaldehyde, methane, nitrogen oxides, other monoterpenes, other sequiterpenes, and carbon monoxide. The grid employed in the project has a size of 626 x 453 with 100 m resolution. This covers a rectangular region of 62.6 km x 45.3 km. The grid is aligned with the HK1980 grid system. The net emission rate of VOC species (mg compound m^{-2} earth surface h^{-1}) from terrestrial ecosystems into the above-canopy atmosphere at a specific location and time is described by the following equation (Guenther et al. 2006):

$$Emission = [\varepsilon]\ [\gamma]\ [\rho] \tag{1}$$

where ρ (=1) is a factor that accounts for production and loss within plant canopies; ε (mg m^{-2} h^{-1}) is an emission factor which represents the emission of a compound into the canopy at standard condition. The emission factor is specified by the user at each grid cell for each VOC species based on land cover data and field survey data analysis; γ is an emission activity factor that accounts for emission changes due to deviations from standard conditions and is a product of a set of the following non-dimensional emission activity factors:

$$\gamma = \gamma_{CE} \cdot \gamma_{age} \cdot \gamma_{SM} \tag{2}$$

Here, γ_{CE} is the variation in emission due to LAI, light, temperature, humidity and wind conditions; γ_{age} is the variation due to leaf age; γ_{SM} is the variation due to changes in soil moisture.

4. RESULTS AND DISCUSSIONS

4.1 Seasonal and diurnal variation

The seasonal variations in BVOC emissions in Hong Kong in 2006 are shown in Table 1. Maximum and minimum BVOC emissions were predicted to occur in summer (June to August) (5,450 metric tons, 44%) and winter (December to February) (1,090 metric tons, 9%) respectively. This seasonal variation is mainly due to the change in temperature. The monthly-averaged diurnal variation of BVOC emission in February and July 2006 are shown in Figure 1. It can be observed that the emissions are higher in day time and lower in night time, mainly due to the variation in solar radiation over the day. Noted that isoprene emission was estimated to be zero during night time while there was non-zero emission for monoterpenes and other VOCs. There are different light-dependent factors for various compounds in the model. The observed diurnal variation is mainly due to changes in solar radiation.

Table 1 Seasonal BVOC emissions in Hong Kong (2006)

	BVOC emissions			
	Spring (Mar-May)	Summer (Jun-Aug)	Autumn (Sep-Nov)	Winter (Dec-Feb)
Emissions (tons)	2620	5450	3220	1090
%	21	44	26	9

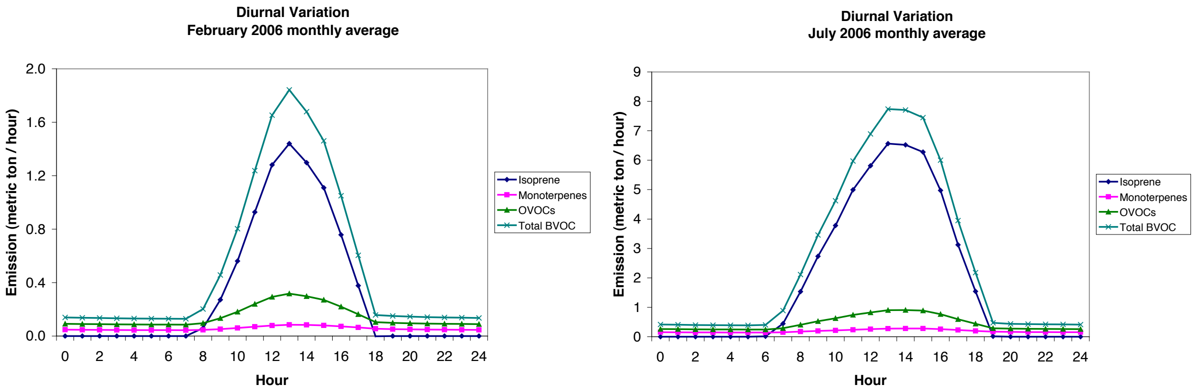

Figure 1. Diurnal variation of BVOC emission in February and July 2006

4.2 Monthly and annual variation

Monthly BVOC emissions were computed for the year 2006 (Fig. 2). As can be seen the isoprene, monoterpene and other VOCs reach their maximum values during the summer months (July and August). Figure 3 shows the annual emissions from 1995 to 2006. For the year 2006, the total annual BVOC emissions in Hong Kong was estimated to be 12,400 metric tons (9.82×10^9 g C (BVOC carbon)), of which isoprene emission accounts for 72% (8,880 metric tons / 7.83×10^9 g C), monoterpene emissions account for 8% (1,020 metric tons / 0.90×10^9 g C), and OVOC emissions account for 20% (2,480 metric tons / 1.09×10^9 g C) of the total annual emissions.

Noting that temperature and solar radiation are the two driving forces for temporal BVOC emission variation of a given land cover. The monthly and annual BVOC emissions from 1995 to 2006 vary because of the variation in temperature and solar radiation.

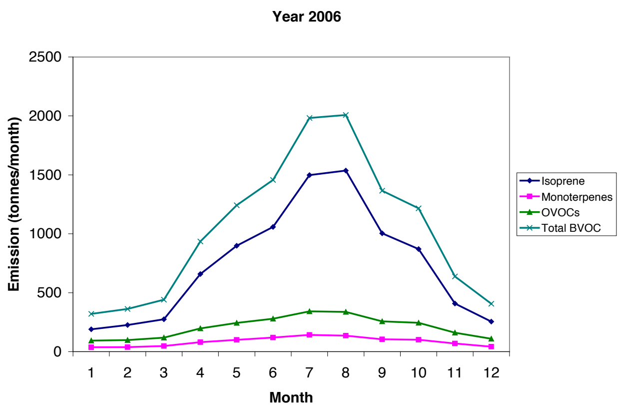

Figure 2. Monthly BVOC emissions in 2006.

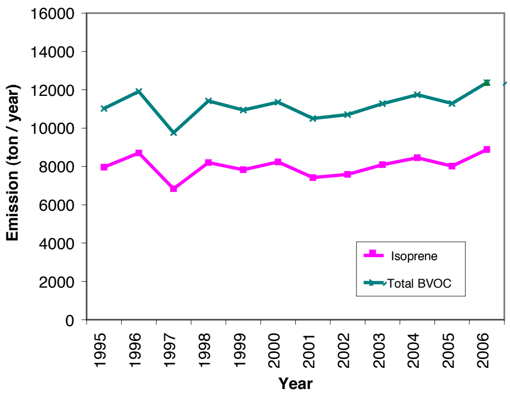

Figure 3. Annual BVOC emissions from 1995 to 2006.

4.3 Spatial variation

The spatial variation of BVOC emission in 2006 is shown in Figure 4. A high emission of isoprene can be observed in regions such as “Lowland Forest - NT North” where emission factors have large values. The highest emission of isoprene (per area) was found in “Shrubby Grassland – Islands” although this PFT region has a relatively low area contribution. The spatial variation of total BVOC (not shown here) is similar to the isoprene spatial variation, since the contribution from isoprene is high (72% for year 2006). On the other hand, the spatial variation of monoterpenes and other VOC emissions are quite different from the isoprene spatial variation. High monoterpenes and other VOCs were observed in “mangrove” where emission factors have large values.

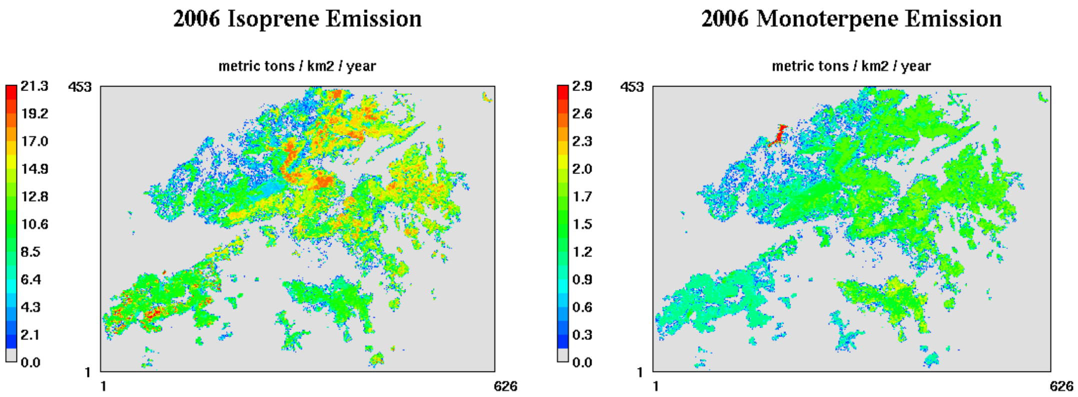

Figure 4. Spatial variation of BVOC emissions in 2006 (a) Isoprene; (b) Monoterpene.

4.4 Result by PFT

The breakdown of BVOC emissions in 2006 by PFT is shown in Figure 5. The top-five BVOC-emitting PFTs of Hong Kong are "Mixed Shrubland – NT North", "Mixed Shrubland – NT East", "Mixed Shrubland – Islands", "Shrubby Grassland – NT North", and "Shrubby Grassland – NT East". Note that a PFT region has high emission contribution if it has a high emission factor (per area) and a large area contribution, i.e., "Shrubby Grassland – Island" has a high emission factor (per area), but the total emission from this PFT is not as large as some other PFTs due to its relatively low area contribution.

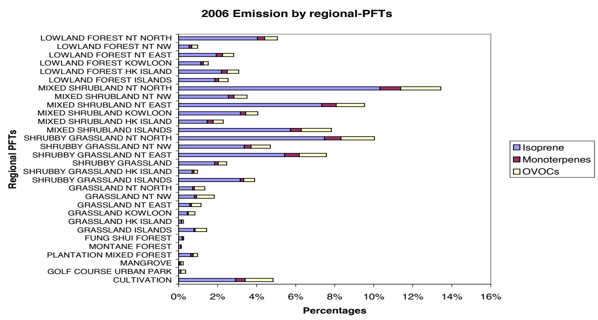

Figure 5. 2006 Emission breakdown by PFTs.

5. CONCLUSIONS

This study used the MEGAN developed by the NCAR to model the emission of BVOC from Hong Kong's vegetation. For the year 2006, the total annual BVOC emissions in Hong Kong was estimated to be 12,400 metric tons (9.82 x 10^9 g C), in which isoprene emission accounts for 72%, monoterpene emissions account for 8%, and OVOC emissions account for 20%. The annual variation in emission due to weather over the twelve-year period (1995 to 2006) was found to be small, but an increasing trend in the annual variation due to changes in the land cover can be observed. The result can provide a good reference to develop effective environmental strategies in large scale tree planting and urban greening programs for improving the quality of the environment.

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