Biogenic Isoprene Emissions and Temporal and Spatial Distribution Characteristics in Tianjin

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Abstract. Based on the localized improved GLOBEIS model, the total amount of biogenic isoprene emissions in Tianjin in 2018 was estimated and the temporal and spatial distribution characteristics were analysed by using the land-use type data interpreted from remote sensing images and the observed hourly meteorological data. The results show that the total amount of biogenic isoprene emission in Tianjin reached 694 t (calculated by C, the same below) in 2018, and the emission intensity was 0.06 t/km²/a. The diurnal, monthly and seasonal variations of biogenic isoprene emissions are obvious: High at noon and low at night; Highest in August and lowest in January; Emissions in summer are the largest while the smallest in winter. The spatial characteristics are closely related to land-use types, and the emissions of biogenic isoprene are mainly concentrated in the forest areas, and the emissions are small in the Urban districts of the city and Binhai New District. Finally, the uncertainty sources of biogenic isoprene emission estimation were analysed.

1. Introduction

Volatile organic compounds (VOCs) play an important role in the process of urban photochemical smog pollution. VOCs are an important precursor of ozone and secondary organic aerosols. Generally speaking, VOCs can be divided into anthropogenic and natural sources. At present, a large number of studies have found that [1-3] biogenic VOCs (BVOCs) have large emissions and strong chemical activity, which play an important role in the process of atmospheric photochemical oxidation and global carbon cycling. At the global scale, biogenic VOC emissions more exceed anthropogenic sources. Therefore, many countries and regions have carried out a large number of biogenic VOCs emission estimation research. In the composition of biogenic VOCs, isoprene accounts for nearly 50% [2], and has high atmospheric activity. The lifetime in the atmosphere is only 1-2h, so it is a very important photochemical reactant. Therefore, the study on the emission of biogenic isoprene (BISOP) can help to further understand the biogenic contribution to the atmospheric environment.

As early as the 1970s and 1980s, the developed countries such as Europe and the United States began to do a lot of research on the emission of biogenic isoprene [4-5]. In recent years, more and more attention has been paid to the estimation of biogenic isoprene emission in China. As early as the 1990s, Zhang Fuzhu et al. [6] measured the emission rates of isoprene from 10 species of arbor and shrub in deciduous broad-leaved forests in North China by closed measuring technique, which filled the gap of biogenic isoprene emission in China. Using the same technique, Wang Xiaoke et al. [7] measured the
major biogenic isoprene emissions in the Taihu Lake Basin, and Bai Jianhui et al. [8] measured isoprene emissions from grassland areas in Inner Mongolia, China. With the development of computer technology, more and more domestic scholars use biogenic estimation models to calculate isoprene emissions because of the more influencing factors and the more complex calculation. Ning Wentao[9] and Situ Shupin[10] used the biogenic estimation model to calculate biogenic isoprene emissions in East Asia and the Pearl River Delta region in summer. However, the calculation of biogenic isoprene emission in Tianjin has not been reported.

Based on the land-use types of Tianjin and the observed hourly meteorological data, the biogenic isoprene emissions in Tianjin in 2018 were estimated and the spatial-temporal distribution of isoprene was analyzed.

2. The fundamental principles and methods

2.1. Research area
Based on Lambert projection, a grid of 3 km×3 km was established by using ArcMAP in Tianjin, and the geographic location of the network was identified by the longitude and latitude coordinates of the central point of each grid. The research area consisted of 1409 grids.

2.2. Model principles
GLOBEIS model was used to estimate the biogenic isoprene emissions in Tianjin in this study. The model has been successfully applied to estimate the biogenic VOCs emission in China. Yan Yan et al. [11] used GLOBEIS model to establish the VOC biogenic emission inventory in China, Zheng Junyu et al. [12] used it to study the temporal and spatial distribution characteristics of biogenic VOCs emission in the Pearl River Delta, and Wu Liping et al. [13] used it to estimate the biogenic VOCs emission in the main urban areas of Chongqing. The basic algorithm of GLOBEIS model refers to the method proposed by Guenther et al. [3, 14], in which the estimation formula of isoprene (ISOP) is as follows:

$$E_{ISO} = \varepsilon \cdot D \cdot \gamma_p \cdot \gamma_t \cdot \rho$$

Where: $E_{ISO}$ is isoprene emission; $\varepsilon$ is the standard emission rate; $D$ is the Leaf biomass density (LMD); $\gamma_p$ and $\gamma_t$ are photosynthetic effective radiation influence factors and temperature influence factors respectively; $\rho$ is escape efficiency.

2.3. Determination of parameters

2.3.1. Land-use data. The land-use data of Tianjin in 2018 were interpreted by satellite remote sensing, and the land-use types in Tianjin were divided into 11 types: paddy field, dry land, woodland, sparse woodland, other woodland, high-cover grassland, medium-cover grassland, low-cover grassland, water area, urban and rural industrial and mining residential land, and unused land. The area of each land-use type is shown in Table 1.

| No. | Land-use type                                      | Area (km²) |
|-----|---------------------------------------------------|-------------|
| 1   | Paddy field                                       | 460.45      |
| 2   | Dry land                                          | 5044.15     |
| 3   | Woodland                                          | 481.89      |
| 4   | Sparse woodland                                   | 10.07       |
| 5   | Other woodlands                                   | 100.31      |
| 6   | High-cover grassland                              | 554.26      |
| 7   | Medium-cover grassland                            | 39.73       |
| 8   | Low-cover grassland                               | 0.52        |
| 9   | Water area                                        | 1823.48     |
| 10  | Urban and rural industrial and mining residential land | 2786.89    |
| 11  | Unused land                                       | 102.85      |
2.3.2. LAI, LMD and emission factors. According to the research results of Guenther et al. [14] and Asner et al. [15] on biogenic VOCs, the LAI of different biogenic types in Tianjin was estimated by referring to relevant literature, which is shown in Table 2.

| Land-use                  | LAI | LMD (g/m²) | Isoprene (μg/m²/h) |
|---------------------------|-----|------------|-------------------|
| Paddy field               | 4   | 500        | 50                |
| Dryland                   | 4   | 740        | 74                |
| Woodland                  | 5   | 785        | 1570              |
| Sparse woodland           | 4   | 31         | 3.1               |
| Other woodlands           | 5   | 650        | 650               |
| High-cover grassland      | 2.5 | 105        | 52.5              |
| Medium-cover grassland    | 2   | 95         | 38                |
| Low-cover grassland       | 2   | 90         | 27                |
| Water area                | 0   | 0          | 3.1               |
| Urban and rural industrial and mining residents | 2   | 31         | 3.1               |
| Unused land               | 1.3 | 31         | 3.1               |

Based on the results of leaf biomass measurement in China by Feng Zongwei et al. [16] and Fang Jingyun et al. [17], referring to the results of LMD studies in China [18], Beijing[19], the Pearl River Delta[20] and the main urban areas of Chongqing[13], the LMD used in this study was determined taking into account the similarity of climatic conditions and other factors, which is shown in Table 2.

For the emission factors of biogenic isoprene, the staging method is usually used to deal with[21] to ensure the rationality of the values. The emission factors of biogenic isoprene are determined according to the results of Wu Liping et al. [13] and Zheng Junyu et al. [20] in China. That is, during the calculation, first, standard emission factors of isoprene from some tree species in China were obtained by literature review, then according to the proportion of each biogenic type in Tianjin forest resources survey, the weighted average was carried out. Then, the weighted average value is compared with the step value of the isoprene standard emission factor, and the step value closest to the value is taken as the standard emission factor of the biogenic isoprene. The emission of isoprene was divided into 6 ranges: 0.1, 1.0, 6.0, 8.0, 34.0, 60, 0μgC/(g•h); 1.5μgC/(g•h) of isoprene was used for the emission of isoprene from forested land. Emission factors are estimated by LMD and emission factors, which is shown in Table 2.

2.3.3. Meteorological data. The atmospheric environmental temperature is assumed to be leaf temperature, and the photosynthetic active radiation (PAR) data in the model are simulated by cloud cover information. Hourly meteorological data such as temperature, humidity and wind speed were obtained from Tianjin Meteorological Observatory in 2018.

3. Results and Discussions

3.1. Total biogenic isoprene emissions in Tianjin
The GLOBEIS model was used to calculate the annual emission of biogenic isoprene in Tianjin in 2018. The results showed that the total annual emission of biogenic isoprene was 694 t (calculated by C, the same below), the emission intensity was 0.06/t/km²/a, and the contribution rates from January to December were 0.17%, 0.29%, 0.84%, 2.07%, 11.18%, 17.20%, 24.19%, 28.43%, 10.85%, 3.41%, 0.99%, 0.39%, respectively. The contribution rate was the highest in August and the lowest in January.
3.2. Temporal distribution of biogenic isoprene emission

Figure 1 shows the change of biogenic isoprene emissions on the 15th day of each month. As can be seen from Figure 1, isoprene exhibits the following change characteristics in each month: The isoprene emission began at 8 a.m. and gradually increased, reached its maximum at noon (12:00, 13:00, 14:00), then decreased gradually until 18 p.m. This is consistent with the results of Situ Shupin and Hu Yongtao, because isoprene is affected by both temperature and radiation, and the effect of radiation is greater than that of temperature [22]. From the point of view of maximum isoprene emission, most of them are at 13 o'clock, and some are at 12 o'clock or 14 o'clock, which shows that isoprene emission is affected by temperature and radiation, humidity, wind speed and other environmental factors.

![Figure 1. BISOP emission in the fifth day of each month](image1)

Figure 2 shows the biogenic isoprene emissions in each month and its contribution rate. From the figure, it can be seen that the emission of isoprene increases gradually with the increase of months, and increases significantly in May, reaches the maximum in August, and then decreases gradually. The results are consistent with those of Zheng Junyu and others, mainly because the emission of biogenic isoprene is affected by radiation and temperature [23-25]. Radiation and temperature were high and emissions were high in August. Moreover, in May, there was a significant increase in temperature and radiation, resulting in a significant increase in isoprene emissions. What’s more, radiation and temperature were low in January, and isoprene emissions were lowest.

![Figure 2. Monthly emission and percentage of BISOP](image2)
Figure 3 shows the quarterly biogenic isoprene emissions and its contribution rate. From the figure, it can be seen that the emission amounts in spring and autumn are 97.78 t and 105.84 t, respectively, and the contribution rates are 14.09% and 15.25%; The summer emission is the largest, reaching 484.48 t, accounting for 69.81% of the total. In winter, the minimum emission was 5.90 t, and the contribution rate was 0.85%. The results of Zheng Junyu et al. [20] are consistent, mainly because the temperature and radiation in summer are much higher than those in winter.

Figure 3. Seasonal emission and percentage of BISOP

3.3. Spatial distribution of biogenic isoprene emissions
Figure 4 is a spatial distribution diagram of seasonal emissions of biogenic isoprene in Tianjin in 2018. From the three maps of spring, summer and autumn, it can be seen that isoprene emission is less in Binhai New District and Urban districts, and more in the northern mountainous area of Jizhou District, the northern Baodi District and the southwest of Jinghai District, which is mainly because of the dense woodland in these areas; The spatial distributions of spring and autumn are similar, but the spatial distributions of summer and winter are significantly different. This is mainly because the meteorological conditions of spring and autumn are similar, but the meteorological conditions of summer and winter are quite different; Compared with spring, the emissions of isoprene increased in summer and decreased in winter. Therefore, the spatial distribution of isoprene is affected by both land-use types and meteorological conditions.
3.4. Uncertainty analysis of biogenic isoprene emission estimation

In the estimation of biogenic isoprene emission in this study, the uncertainties mainly come from the following three aspects: (1) Emission factors: The emission factors used in this study mainly refer to the domestic and foreign literatures, and the emission factors based on the native plants in Tianjin are rarely reported. Therefore, the emission factors may lead to the uncertainty of the results in the research process. (2) LMD: The LMD used in the study also referred to the domestic and foreign literatures, lack of corresponding local measured data in Tianjin, in the use process, may have a certain impact on the results; (3) Land-use types: The land-use types interpreted by remote sensing will also cause some uncertainty to the result due to the error of interpretation.

Figure 4. Spatial distribution of BISOP emission in each season
4. Conclusion

(1) The total biogenic isoprene emissions in Tianjin in 2018 was 694 t, and the emission intensity was 0.06t/km²/a.

(2) The diurnal, monthly and seasonal variations of biogenic isoprene emissions in Tianjin were significant: High emissions at noon and low emissions at night; Emissions peaked in August and peaked in January; Summer emissions are the largest and winter emissions the smallest.

(3) The spatial distribution of biogenic isoprene emission in Tianjin is closely related to biogenic distribution and meteorological conditions. The emission is larger in the northern mountainous area of Jizhou District and smaller in the Urban districts of Tianjin and Binhai New District.

Acknowledgments

This work was financially supported by National Key Scientific Program that the cause and control research of heavy pollution in the atmosphere program (DQGG0209-02) fund.

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