Biogenic volatile organic compound emission from Tokyo urban area, Japan

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Biogenic volatile organic compound (biogenic VOC or BVOC) emissions from urban trees are pointed out as one of the possible causes of regional tropospheric ozone formation. However, the BVOC emission inventory in urban areas such as Tokyo remains uncertain, and must be determined in order to fully clarify the role of those reactive VOCs to the elevated ozone concentration occurring in this megacity. In this study, we estimated an annual BVOC emission from the entire Tokyo urban area (the special wards of Tokyo).

Leaf BVOC emission rate measurement: We measured the BVOC emission rate (i.e. emission per unit leaf area and time; nmol m^{-2} s^{-1}) from the 20 most dominant street lining tree species in the Tokyo special wards. This was done by two methods, namely branch-enclosure method and leaf-cuvette method. The BVOC from leaf was immediately trapped in an absorbent tube and analyzed in the laboratory by GC-MS using thermal desorption technique. The measurements were conducted in spring, summer, autumn, and winter to test a seasonal variability in their BVOC emission rate.

Tree canopy leaf area estimation: We estimated a seasonal tree leaf area in the Tokyo special wards using WorldView-2/3 satellite imagery acquired during different tree phenology periods (leaf-on and leaf-off season). First, the tree canopy was isolated from non-tree land cover by pixel-based analysis. Next, we used field observation data of urban tree leaf area index (LAI) to directly map tree leaf area over the entire Tokyo special wards. Based on the number of tree species planted in the Tokyo special wards, we estimated the total leaf area of each tree species for the both phenology seasons.

Total BVOC emission estimation from Tokyo special wards: Using the aforementioned results, we estimated the total BVOC emission in 2014, 2015 and 2016. Total emissions of the tree species were calculated by multiplying their BVOC emission rates (unit leaf area and time) by the total leaf area of each tree species, respectively. We herein used the BVOC emission rate that was adjusted by temperature/light condition in Tokyo (35.962N, 139.750E) observed by Tokyo Regional Headquarters.

1. Nine in 20 species were found to emit BVOC, and their emission was temperature/light dependent.
2. We obtained their seasonal BVOC emission model, respectively, using the G93 algorism (Fig.1).
3. The total tree canopy leaf area herein was 281 km^2 in leaf-on season, and 97 km^2 in leaf-off season.
4. The calculated BVOC emission over the three years was 468 ± 47 t (mean ± SD) in spring, 2,014 ± 367 t in summer, 17 ± 3 t in autumn, and 0.3 ± 0.03 t in winter, with an annual total of 2,499 ± 416 t/yr.
5. This annual emission corresponds to 4% of the anthropogenic VOC emission from the entire Tokyo area (including the remaining "Tama" region) in 2015.
6. More than 80% of the annual BVOC emission concentrated in summer daytime, which coincides with the timing when ozone concentration elevates significantly in Tokyo.
7. Future studies should incorporate the BVOC inventory data obtained in this study into the atmospheric simulation models, in order to better understand the role of BVOC emissions as a precursor for regional ozone formation in urban area, such as Tokyo.

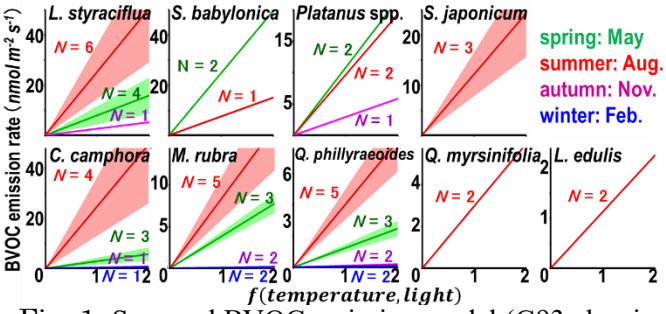

Fig. 1. Seasonal BVOC emission model (G93 algorism)

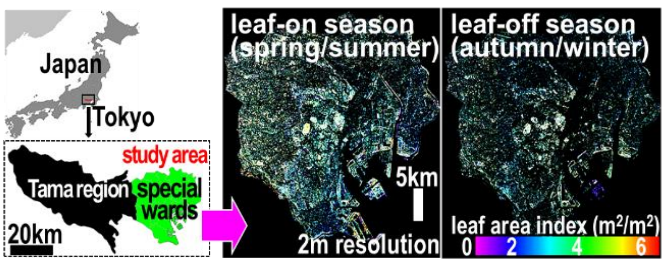

Fig.2. Seasonal map of tree leaf area in Tokyo special wards