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Seasonal variations of isoprene emissions from five oak tree species in East Asia

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ABSTRACT

Emissions of biogenic volatile organic compounds (BVOC) from trees can enhance the photochemical production of tropospheric ozone. Isoprene is one of the most environmentally important BVOCs, since its emission rate from certain tree species can be high and its chemical structure gives it high ozone forming potential. Understanding of isoprene emission rates from many tree species is limited, including influences of tree age, season, and other factors. Five oak species were studied which represent approximately 85 percent of the deciduous trees in South Korean forests. In general, there were obvious seasonal variations of isoprene emissions from five oak trees. Especially, *Quercus aliena* B. and *Quercus mongolica* F showed substantial seasonal variations of isoprene emissions; However, *Quercus serrata* T. and *Quercus acutissima* C. generally did not. It was found that *Q. serrata* T. showed the highest isoprene emission rates among the species tested (up to 130.5 $\mu gC\ gdw^{-1}\ h^{-1}$) and its emission rates were highest during spring followed by summer and fall. The emission rates from two (*Q. acutissima* C., *Quercus variabilis* B.) of the other tested oak species were lower by more than 3 orders of magnitude. Besides, two oak species, *Q. aliena* B. and *Q. mongolica* F. were chosen to determine the effect of tree age on isoprene emissions. Trees at the age of 21 ~ 30 years had significantly higher isoprene emission rates than those at the age of 41 ~ 50.

1. Introduction

Exposure to tropospheric (i.e. ground-level) ozone has been linked to increased risks of adverse human health effects, including inflammation of the upper and lower airways, aggravation of asthma, decreased lung function, and increased incidence of school absenteeism and hospital visitations (U.S. EPA, 2008). Ground-level ozone also adversely impacts vegetation and can result in growth impairment (biomass loss) in forest tree species and losses in commercial crop yields (Salvador et al., 2006; U.S. EPA, 2008). Ground-level ozone is produced through photochemical reactions involving oxides of nitrogen (NOx) and volatile organic compounds (VOCs) (Haggen-Smit, 1952). Industrial, utility, and mobile source controls of VOC and NOx emissions have been implemented in many countries to reduce ground-level ozone concentrations.

Controlled studies of the ozone forming potential of organic compounds emitted from industrial processes and from motor vehicles began in the 1950s and accelerated in the 1980s as the number of people living in cities with high ozone levels was growing (Zielinska et al., 1996). On the other hand, the study of the impacts of biogenic VOCs (BVOCs) on ozone formation began later, and only after the initial investigations of isoprene (2-methyl-1,3-butadiene) and monoterpene emission rates from plants were conducted in the 1970s (Dimitriades, 1981; Kesselmeier and Staudt, 1999).

Numerous reasons have been proposed as to why some plant species direct a significant portion of their carbon fixation into producing volatile organic compounds. BVOC emissions might serve to protect plants from tissue damage caused by airborne oxidants, and they might be sinks for excess carbon fixation during high periods of photosynthesis when growth is limited by metabolism kinetics or other by other nutrients (Sharkey et al., 2001). A large number of chemical compounds, including isoprene, monoterpenes, alkanes, alkenes, alcohols, esters, carbonyls and organic acids, have been identified as BVOCs from trees, grasses, crops, and other plants (Kesselmeier and Staudt, 1999). In terms of tons of BVOC carbon emitted worldwide, isoprene is by far the most emitted compound. It is estimated that global emissions of isoprene from deciduous trees comprise about 33–44% of total worldwide BVOC emissions (Trapp et al., 2001).

Unfortunately, isoprene also has one of the highest ozone forming potentials of any tested VOC compound, including the

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VOCs commonly found in anthropogenic fuels and industrial solvents and chemicals. Proper air quality planning and effective ambient ozone control strategies require accurate BVOC understanding and in particular detailed isoprene emissions inventories (Guenther et al., 1994). Along with the potential importance of BVOCs to ground-level ozone formation, these compounds can also contribute to secondary aerosol formation, and recent studies suggest that they play direct and indirect roles in climate forcing (Coeur et al., 1999; Fehsenfeld et al., 1992; Simpson et al., 1995; Starn et al., 1998; Niinemets et al., 2004).

Anthropogenic VOC emission sources have been extensively studied in South Korea, and high-quality anthropogenic emission inventories are being used for air quality planning purposes. However, biogenic VOC emission inventories are not as sophisticated as the anthropogenic inventories, and empirical data on the impacts of temperature, season, and other factors on BVOC emission rates are very limited, as are BVOC chemical speciation data. Current Korean BVOC emission inventories are largely based on emission factors developed in other countries, and better BVOC inventories could assist air quality planning in the areas of Korea impacted by high summer-time ozone concentrations.

The objective of this research was to investigate variations of isoprene emission rates from oak trees species as a function of species type, tree age, temperature, light intensity, and season. Five Oak species were studied which represent approximately 85 percent of the deciduous trees in South Korean forests (Forestry Research Institute, 1996). Interestingly, these trees are not only native to Korea, but also to Eastern Asia, Siberia, or North America depending upon tree species (Tani and Kawawata, 2008; http://www.pfaf.org/user/default.aspx).

2. Experimental methods

2.1. Species selection and experimental conditions

The geographical area of South Korea is approximately 9,950,000 hectares and forest-covered areas constitute nearly 65% of the total area. The composition of the forests for coniferous, deciduous, mixed (coniferous and deciduous), and other species are 42, 26, 30 and 2.3%, respectively. Because of the high percentage of deciduous species and the evidence collected by researchers in other countries on the high rates of isoprene emissions from deciduous trees, interest has grown about the potential impact of biogenic isoprene on Korean ground-level ozone concentration.

In this work, isoprene emission rates were measured from five oak tree species:

- *Quercus serrata* Thumberg (*Q. serrata* T.)
- *Quercus acutissima* Carruthers (*Q. acutissima* C.)
- *Quercus aliena* Blume (*Q. aliena* B.)
- *Quercus mongolica* Fischer (*Q. mongolica* F.)
- *Quercus variabilis* Blume (*Q. variabilis* B.)

These five species were selected because together they account for approximately 85% of South Korean deciduous tree population. Emission rate sampling was conducted in forests on Gumsung Mountain in Jeonnam Province and in forests on Worak Mountain in Chungbuk Province for 3 years (2002∼2004). Gumsung Mountain is located in a rural area in the southern section of South Korea (35°02′08.4″∼35°03′06.2″N and 126°41′56.2″∼126°43′13.7″E), and Worak Mountain is located in a rural area in central South Korea (36°49′16.7″∼36°52′06.7″N and 128°03′50.4″∼128°05′41.0″E). Two sites display similar climate patterns because of their close proximity to each other (approximately 220 km). Additional site description is given elsewhere (Lim et al., 2008) (Fig. 1).

Tree leaves were accessed using two movable towers with two separate sampling trains. Three to four different tree individuals for each tree species were used in each season. Branches on 2∼3 m height above ground were selected, and about 10–40 leaves were used for enclosure sampling depending upon tree species. They were also sunleaved.

For some species, *Q. serrata* T., *Q. aliena* B., *Q. mongolica* F., and *Q. acutissima* C., samples were taken during the period of May ∼ October to examine seasonal differences in emission rates. Furthermore, to examine trends in isoprene emissions over daily cycles, field sampling was performed on *Q. mongolica* F, *Q. aliena* B,

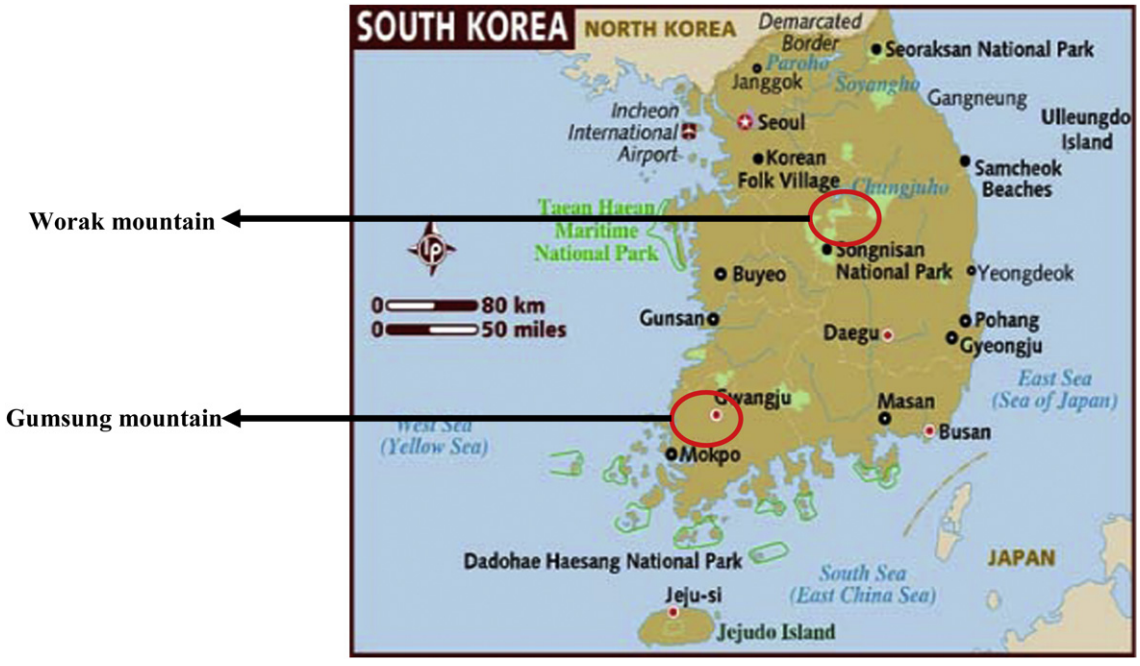

Fig. 1. Sampling sites of Isoprene emitted from oak trees.