IMPECVOC - Results

Impact of phenology and environmental conditions on BVOC emissions from forest ecosystems

DURATION OF THE PROJECT
15/12/2008 - 31/07/2011

BUDGET
1.123.952 €

KEYWORDS
Biogenic volatile organic compounds; BVOCs; atmospheric chemistry; tropospheric ozone formation; terpenes; sesquiterpenes; PTR-MS; GC-MS; Megan

CONTEXT

Forest ecosystems are known to be important sources of Biogenic Volatile Organic Compounds (BVOC). Due to their large emissions and their high reactivity with the main oxidants (OH, O_3, NO_3) in the atmosphere, these BVOCs play an important role in atmospheric chemistry. In order to be able to quantify net formation of oxidants and aerosols from BVOCs, the physicochemical oxidation and aerosol formation and/or growth have to be well understood. Of equal importance, however, is that BVOC emissions need to be well characterized and quantified. Few experimental data are available on the effect of temperature and radiation history on emissions. Measurements are needed to determine the precise dependence of emissions upon radiation and leaf temperature for tree species commonly found in Belgium. The advent of new on-line, rapid and sensitive technologies such as the Proton Transfer Reaction Mass Spectrometer (PTR-MS) has opened new and exciting developments in BVOC emission research. As such direct eddy-covariance BVOC flux measurements at the level of a forest stand became possible. PTR-MS is also very useful to perform long-term continuous BVOC emission measurements from branch enclosures (e.g. leaf cuvettes).

OBJECTIVES

The objectives of the IMPECVOC project are: (1) The collection of BVOC emission data at different levels of biological organisation (leaf emissions from young model trees in climate controlled growth chambers; emissions from horizontal leaf canopy layers observed on the measuring tower at the Aelmoeseneie experimental forest; and emission measurements above the large Vielsalm experimental forest); (2) The validation of new emission algorithms (adaptation of the MOHYCAN canopy model and the MEGAN model which allow spatial upscaling of BVOC emissions from leaf to tree and to stand level); (3) The correction of emission algorithms by inclusion of additional driving variables (e.g. water availability, atmospheric CO_2 concentration and effects of forest functioning (e.g. seasonal leaf area development, leaf age, sunlit and shaded leaves, …); and (4) The estimation of the BVOC emissions from Belgian forests based on the modified emission algorithms and Belgian forest inventories.

During phase 1 of the IMPECVOC-project simultaneous BVOC (PTR-MS and GC-MS), CO_2 and H_2O flux measurements have been carried out on a regular time scale during the branch enclosure experiments in the growth room and at the Aelmoeseneie experimental forest. In order to perform dynamic branch enclosure flux measurements, prototype cuvettes were designed and constructed. In addition, during the first trimester of 2008, in between the experiments in the growth chamber and the field measurements in the Aelmoeseneie forest, laboratory measurements were performed in order to study the influence of instrumental and environmental parameters on the detection of sesquiterpenes with the PTR-MS instrument.

CONCLUSIONS

The results showed that beech (*Fagus sylvatica* L.) is a low isoprene emitter and a rather strong monoterpenoid emitter. A clear link was observed between temperature variation and monoterpenoid emissions, linked to net photosynthesis rates. The results revealed that the potted beech tree under well-watered conditions re-emitted a rather low fraction of the assimilated carbon back into the atmosphere as total monoterpenoids. This fraction increased exponentially from 0.01 to 0.10 % with a temperature rise from 17 °C to 27 °C in growth room conditions.

From the results of the drought experiment it was seen that monoterpenoid emissions were linked to tree physiology; more specific to leaf net photosynthesis rate, to stem diameter growth and to sap flux density. Moreover, interdependence between leaf and tree plant processes was observed. Imposed severe drought caused photosynthesis and monoterpenoid emissions to decrease. Upon photosynthesis inhibition, the emissions of monoterpenoids were inhibited most likely due to the photosynthetic origin of the monoterpenoids. Data of the canopy experiment in the Aelmoeseneie forest clearly showed that there was a difference between sunlit leaves and shade-adapted leaves. Diurnal BVOC emission patterns indicated that shade-adapted leaves for a sunny day show a stronger interaction between monoterpenoid emissions and net photosynthesis than for the sunlit leaves. This interaction was even stronger for a cloudy day. It can, hence, be stated that the physiological leaf status plays a major role when considering monoterpenoid emissions, photosynthesis and transpiration rates. The importance of the physiological status of leaves should therefore be emphasized more in the future.

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CLIMATE

Based on the experimental data, existing emission algorithms could be tested and improved. This work is still ongoing. The observed emissions are more closely approximated using isoprene emission algorithms than by using a light-independent monoterpene emission algorithm developed for coniferous trees. PTR-MS measurements in the growth room under controlled conditions and in the Aelmoeseneie forest under real outdoor conditions already revealed the effect of light history on monoterpenoid emissions by Fagus sylvatica L., which is not correctly incorporated in commonly used emission algorithms. Modifications of these algorithms have been proposed for an accurate description of this effect.

At the end of phase 1, the operational infrastructure at the Vielsalm forest site was established and the stand-scale experiment has been the major focus of phase 2 of the project. This infrastructure includes a meteorological tower fully equipped with adequate sensors, and an equipped shelter. The existing set-up had to be strongly updated for BVOC measurements. Joint efforts of all four partners led to the collection of the large dataset from the site of Vielsalm. Partner 1 focused on spatial and seasonal variation of leaf area index (LAI) in the footprint of the flux measurement tower. Partner 3 and 4 collected BVOC and (micro)meteorological data respectively, from the top of the 52 m high tower while Partner 2 sampled air on a monthly basis for GC-MS analysis. Partner 4 mainly investigated the isoprene, monoterpenes and the methanol fluxes. Since this measurement campaign has finished recently (November 2010) data analysis and interpretation is still ongoing.

CONTRIBUTION OF THE PROJECT TO A SUSTAINABLE DEVELOPMENT POLICY

Policy makers bring the framework to have proper environmental living conditions for the people. In this sense they rely on scientific data to establish a proper policy for a healthy atmosphere. To that extent, European countries like Belgium are forced to make inventories about compounds emitted by mankind and nature that influence the atmospheric quality. It turns out that for the category of volatile organic compounds with quite different impacts such as contribution to tropospheric ozone formation, global warming and human toxicity, forests are quite important contributors. In this sense, emission inventories BVOCs are essential in proper decision making. The emission inventory of BVOCs currently relies on models that are based on measurements and models from the early 1990s.

Our project results provide measurements and models that are a first step towards a better estimation of BVOC emissions. First, we learn that there are more factors than tree species, light and temperature that determine the emission of BVOCs. For example, seasonality, the physiological status of the leaves and infection influence the emissions. Second, we learn that a number of compounds are emitted which do not get proper attention in emission inventories and that may be of interest in further atmospheric chemistry, in particular in ozone formation and particulate matter development. In a further stage, these findings could be the base of a refined BVOC emission estimation providing a sound basis for proper policy with respect to atmospheric quality.

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