Project Number 282910

ÉCLAIRE

Effects of Climate Change on Air Pollution Impacts and Response Strategies for European Ecosystems

Seventh Framework Programme

Theme: Environment

Deliverable 3.4: BVOC emission modelling framework
Type: “Other”

Due date of deliverable: **31/03/2014** Actual submission date: **17/03/2014**

Start Date of Project: **01/10/2011** Duration: **48 months**

Organisation name of lead contractor for this deliverable :
KIT

Project co-funded by the European Commission within the Seventh Framework Programme		
Dissemination Level		
PU	Public	☐
PP	Restricted to other programme participants (including the Commission Services)	☒
RE	Restricted to a group specified by the consortium (including the Commission Services)	☐
CO	Confidential, only for members of the consortium (including the Commission Services)	☐

1. Executive Summary

The deliverable is a short report of updates in the BVOC emission modelling framework, accommodating a deliverable type “other”. We briefly describe developments in some of these aspects that have been made within the frame of Eclaire and add some initial results. Output of initial model simulations is available to project partners upon request; at the moment, these are being updated, with the latest climate provided, also in context of simulations in WP14. In particular, updates were done regarding:

1) Emission factors, and (for Europe) applying the model in a mode that maps PFTs to dominant tree species; CO_2 inhibition in the model can be switched on or off.

2) Accounting for land use change on emissions

3) Testing effects of a coupled carbon-nitrogen cycle on BVOC emissions

What is currently still under development is the interactions between O_3 phytotoxic patterns, vegetation composition and productivity and vegetation composition. This work is in progress, and should be completed by the summer 2014.

Initial simulations with the enhanced model have been performed, and more are currently under way (e.g., contributing to Eclaire WP 14 objectives). Regarding the largest effect, especially human-induced land cover changes have been identified to be of chief importance. Improvement of vegetation-representation was also found to be important. This is especially the case for spatial emission patterns, as the vegetation can be mapped in an improved way to measured emission potentials. It will not affect past-to-future changes (by contrast to accounting for LUC). As expected, adding coupled C-N to the vegetation model did not affect simulated BVOC emissions in a large degree, while effects of O_3 still have to be finalised and tested. Results will be analysed in more detail over the coming weeks, more (refined) simulations with the updated DGVM-BVOC model are planned to contribute to Eclaire WP 14, and model output data will be available to project partners.

2. BVOC emission models, objectives and current challenge

Emissions of biogenic volatile organic compounds (BVOC) are an important set of substances in the climate-change/air quality interplay. The atmospheric oxidation of isoprene and monoterpenes, terpenoid BVOC that are emitted in quantities of tenths to hundreds of Tg C per year (Arneth et al., 2008), takes place by reactions involving the $OH^{\cdot}$ radical. Since $OH^{\cdot}$ is also the chief reactant for the oxidation of CH_4, the emission of BVOC affects the atmospheric lifetime of CH_4 (Lelieveld et al., 1998). In NO_x-rich environments, isoprene (due to its large amount emitted; (Arneth et al., 2008)) fosters formation of tropospheric O_3. Terpenoid BVOC are also a chief precursor substance for the growth of secondary organic aerosol (SOA), and their past, present and future emission patterns thus need to be understood better to narrow the existing large uncertainty associated with SOA radiative forcing (Carslaw et al., 2013).

BVOC emissions from leaves have been shown in numerous studies to increase with temperatures (T), and also with light (Q) in those plant species in which these emissions do not arise from specialised storage organs. As a rule of thumb, many conifers emit from storage organs, many deciduous broadleaf species directly after BVOC production. In case of isoprene, leaf emissions have been found to decrease with enhanced $[CO_2]$ concentrations, in a process not yet understood (Arneth et al., 2011). This latter observation is still under debate, and especially in case of monoterpene emissions, not a lot of studies have addressed the issue and these are inconclusive (Niinemets et al., 2010). Likewise, whether or not changes in leaf nitrogen content affect BVOC emissions is unclear. All of these factors ($[CO_2]$, N, T, Q), integrated over time, affect also plant productivity and leaf growth. BVOC emission models therefore must (1) account for direct, immediate response of emissions to [CO_2], T, Q. But (2) equally important are indirect effects of global environmental change that act via enhanced leaf area and/or changes in vegetation composition. It is in the latter, that important improvements have been made over recent months.

In the dynamic vegetation model framework LPJ-GUESS, we apply a isoprene and monoterpene emissions module that is based on the leaf-level model by Niinemets et al. (Niinemets et al., 1999). The main difference to the commonly used 'Guenther et al. algorithms' lies in the model's explicit link of isoprene production to carbon assimilation, which delivers substrate, energy and redox-equivalents for isoprene synthesis. The link to leaf-photosynthesis provides the basis for the BVOC T and Q-dependence, while the direct “CO_2 inhibition” can only be accounted for by an empirical multiplier. A plant-specific parameter, ε, can be related to widely-reported emission capacity, which denoted leaf-level emissions under a standard light and temperature (typically T = 30°C, and Q = saturating). For model description see e.g., (Arneth et al., 2007;Schurgers et al., 2009)

Being a DGVM, LPJ-GUESS provides a BVOC emission modelling framework to simulate the effects of environmental changes on leaf growth and vegetation dynamics.

3. Activities and example results:

3.1 BVOC, updated emission capacities and vegetation patterns

One of the crucial aspects in all regional-global scale BVOC emission models is to specify emission capacities for the plant and vegetation types used in the models (Niinemets et al., 2010). Because of the multiplicative nature of the leaf-level BVOC algorithms, emission capacities are one of the larges uncertainties regarding the emission totals but also their large-scale spatial patterns (Arneth et al., 2008). Having so-called gap model features, which allows representation of plant structural properties and growth dynamics in a much more refined way than in other DGVMs, the plant functional types in LPJ-GUESS can be parameterised and mapped to represent distribution patterns of important European tree species (Hickler et al., 2012). In other words, the model can represent the (potential natural) vegetation patterns across Europe in a fairly realistic way (Figure, below).

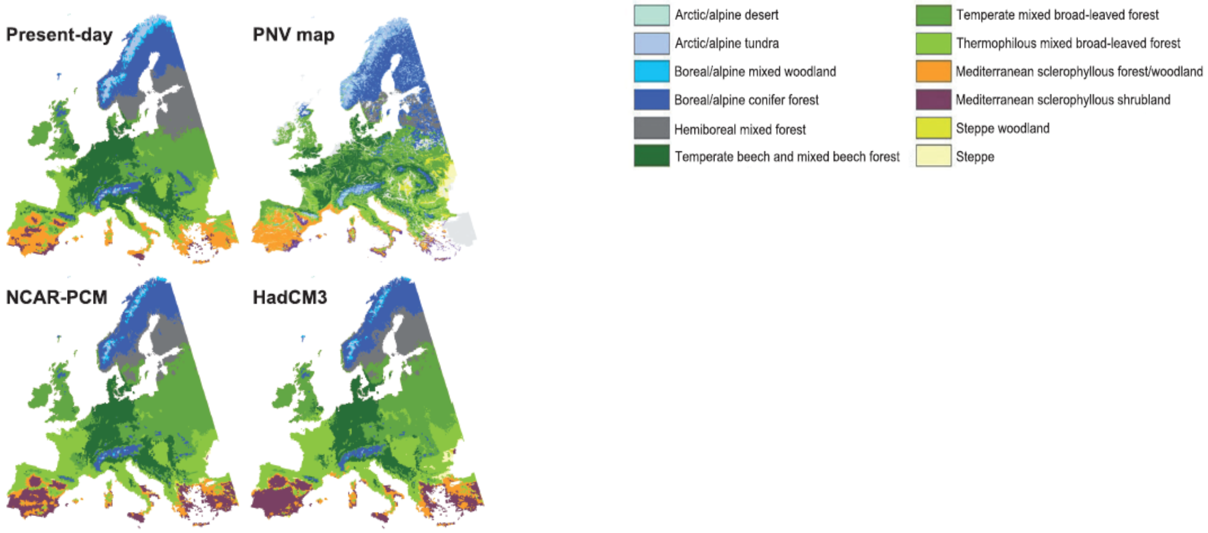

Figure: Modelled potential natural vegetation (present-day), compared to a data- and expert-based estimate (“PNV map”; (Bohn et al., 2003)). The bottom panels show vegetation distribution at the end of the 21st century, using two different global circulation models, driven by SRES A2.

As a result, LPJ-GUESS offers, but only when run on the European scale, the option of mapping measured tree-specific emission capacities in a more refined way than what is possible in other DGVMs. This has already been shown by Schurgers et al., (Schurgers et al., 2011). For Eclaire, the values for emission capacities were updated with latest published data (esp. for the PFTs representing *Fagus syvatica, Q. coccifera, Q. ilex* and the Mediterranean Pine PFT (Blanch et al., 2011;Demarcke et al., 2010;Oderbolz et al., 2013;Poupkou et al., 2010;Staudt and Lhoutellier, 2011). Moreover, two new PFTs were added to the model, a Mediterranean shrub and a Mediterranean mountain conifer. As expected, the distribution of isoprene and monoterpene emissions is much more unevenly spread across the continent when applying the “species” based PFT parameterisation, which is linked to much larger differences between emissions factors prescribed for individual PFTs (Figure, below).

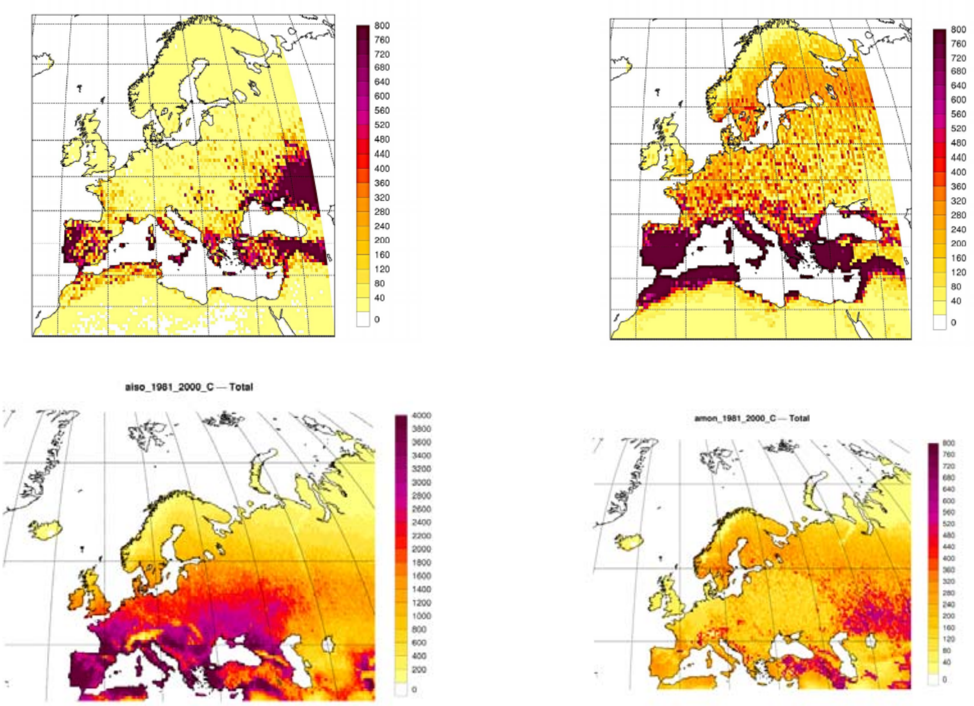

Figure: Annual isoprene (left) and monoterpene (right) emissions (1981-2000). Top panel: using the updated European “species” configuration (in mgC m^{-2} a^{-1}*), vs. (bottom panel) emissions using the global parameterisation.*

The pictures highlight one of the most challenging aspects of BVOC emission modelling: since all of today’s models, including the algorithms in LPJ-GUESS scale linearly with emission factors, the difference between simulations introduced by combining different vegetation maps with different emission factors per vegetation unit can be very large. What is more, data for evaluation of models is still scarce. Space and time-integrated measurements (e.g., via remote sensing) do not exist, and most canopy-scale emission flux measurements are limited to few days, or at most few weeks, only which is not sufficient to robustly test model-data discrepancies.

3.2 Effects on human-induced land cover changes (LUC) on BVOC

This development was mostly performed as contribution to the EU project PEGASOS, but is of relevance for Eclaire as well, and will be further tested, as LUC has a large effect on past and future BVOC emissions (see also needs in WP 14, Eclaire). Conversion of natural vegetation into cropland and pastures is expected to decrease emissions of the terpenoid BVOC isoprene and monoterpenes substantially, especially if this conversion is through deforestation, as woody vegetation has much larger emission potentially than herbaceous or crop vegetation (Kesselmeier et al., 2002).

Crop and pastures can be represented in LPJ-GUESS in an adaptation of work presented by Bondeau et al. ((Bondeau et al., 2007;Lindeskog et al., 2013). Accounting for crop processes such as harvest, sowing or residue removal has been shown to have large effects on the terrestrial carbon cycle (Lindeskog et al., 2013). For emissions of BVOC, they are of no importance, since the chief difference between natural and agricultural vegetation are due to the vegetations’ emission capacity (Kesselmeier and Staudt, 1999). Since crop and pasture vegetation tend to emit little terpenoid BVOC (which are of concern here), the simulations were performed with two generic herbaceous plant functional types for managed ecosystems, one using the C3 and one the C4 photosynthetic pathway. However, accounting for these has been found on the global scale level to be crucial for past and future BVOC emissions. For Eclaire, recent simulations across the European-domain have indentified approximately 50% lower isoprene and 30% lower monoterpene emissions at the early 20th century (see Figure, below), when LUC was accounted for. Moreover, temporal trends over the 20the century are also quite different when simulations with vs. without changes in human-induced land cover are compared; here, as seen in previous experiments, large uncertainties are also introduced by whether or not accounting for BVOC "CO_2-inhibition".

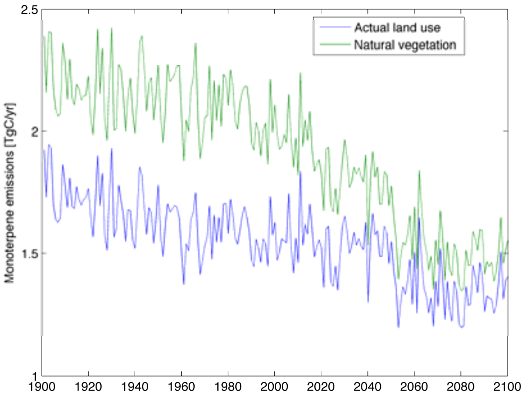

Figure: European monoterpene emissions for potential natural vegetation or actual land use, using MPI-ESM climate data with RCP 4.5 forcing.

3. 3 Effects of coupled carbon-nitrogen interactions on BVOC emissions

LPJ-GUESS has recently updated with a coupled ecosystem carbon-nitrogen cycle (manuscripts in prep.), and implications for the global historical and future carbon balance assessed. For Eclaire, we tested whether vegetation growth response, and BVOC emissions would differ in this version of the model, compared to the "carbon-only" version. We are not aware of any previous model experiment that looked into these effects. Main differences between the C and the CN model version would be expected, if accounting for C-N interactions was to shift the PFT distribution (see point (1) in this document).

For initial test-runs, we applied the model's "global" PFT parameterisation. In Europe, difference between C and CN interactions are minimum (see Figure, below). On global scale, however (not shown), substantial differences occur in some regions. For instance, relatively lower monoterpene emissions in the CN version in parts of north-western U.S.A., and across tropical biomes. This is currently being analysed; most likely the coupled C-N cycles lead to a shift in the relative PFT distributions in certain locations, which affects BVOC emissions.

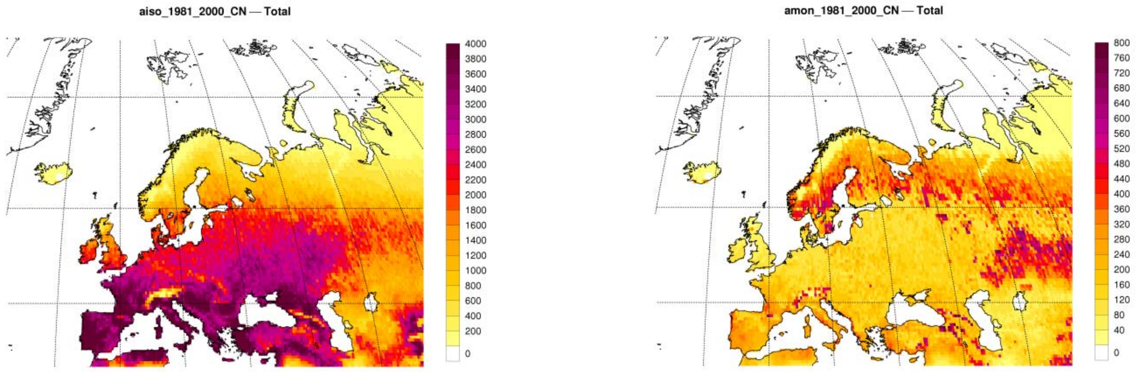

Figure: European, present-day BVOC emissions ($mg_C\ a^{-1}$) with the C-N version of the model.

4. Milestones achieved:

n.a.

5. Deviations and reasons:

n.a.

6. Publications:

n.a.

7. Meetings:

n.a.

8. List of Documents/Annexes:

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