Project Number 282910

ÉCLAIRE

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

Seventh Framework Programme

Theme: Environment

D21.6: Final report on uncertainty in model output due to structural elements

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UEDIN

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Dissemination Level		
PU	Public	☐
PP	Restricted to other programme participants (including the Commission Services)	x
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

There are various activities being undertaken within the project, involving uncertainty in model systems. Due to the wide range of models being employed in this project it is also possible to focus in and look specifically at the issue of the uncertainty in model output due to structural elements. The objective of this deliverable (following on from the groundwork in Deliverable 21.5) is to provide a report on such activities, bringing summary information together information across the project, where such studies exist. More in depth details of the work of each study can therefore be accessed through the related deliverables and journal publications associated with the work and noted in this report.

The report highlights that there were two main areas of uncertainty/intercomparison work, within the ECLAIRE project - one involving Chemical Transport Models (CTMs) and one involving Dynamic Global Vegetation Models (DGVMs). In the case of the CTMs, the modellers involved were able to utilise results not only from the ECLAIRE network, but also through linking their work to other intercomparison studies, maximising the outputs available from the ECLAIRE and other projects.

2. Objectives:

To provide a final report regarding uncertainty in model output due to structural elements across the project.

3. Activities:

A report has been complied to highlight the uncertainty/intercomparison work which has been undertaken in the ECLAIRE project and where to obtain further in-depth information on the work and its context.

4. Results:

The report has been delivered.

5. Milestones achieved:

MS103

6. Deviations and reasons:

There are no deviations.

7. Publications:

N/A

8. Meetings:

The final GA in Edinburgh was attended, during which, information was gathered in support of this task.

9. List of Documents/Annexes:

Annex: Report on uncertainty in model output due to structural elements.

Final report on uncertainty in model output due to structural elements

1. Introduction

The ‘Report on uncertainty in model output due to structural elements’ aims to provide comparative summary information on uncertainty work undertaken in the ECLAIRE project which focussed on uncertainty in model output, in relation to structural elements (i.e . differences in model design and organisation, handling of input data and parameters etc). Whilst it was expected that all models in the project needed to deal with uncertainty in both their output and input data, as noted in the Modelling Protocol (D21.4) and associated document ‘Protocol for an ensemble model assessment of CTMs, DGVMs and DSVMs in scenario analysis in Eclaire’, these models address many different aspects and questions and for these reasons the uncertainty will need to be addressed on a model by model basis. Therefore an overall protocol does not seem necessary for that work and the protocol instead focussed on the ensemble and certain intercomparison work which was undertaken in the project. This report therefore includes summary information on the model experiments which were highlighted as being planned, in the above mentioned protocol.

2. Activities and Model Types Involved

The modelling protocol document (associated with D21.4), highlighted two key areas in the project where uncertainty was to be addressed, through ensemble/intercomparison work:

- WP7 – involving CTMs and CCMs
- WP18 – involving Dynamic Global Vegetation Models (DGVMs)

The outlines of the studies conducted (e.g. models used, harmonization of inputs, key outputs analysed) is outlined below. Also included is information how to access reports containing the scientific conclusions which were drawn regarding the differences in model set-up and the impact of, for example, emissions profiles, on the final results. In summary, three CTM comparison studies and one DGVM comparison study (which also performed an RV co-efficient analysis on the results) are detailed below. These reported studies form the core of the intercomparison work undertaken within this project (however please note that other studies have utilised models which are involved in the ECLAIRE project, but which do not constitute a core part of the project so are not reported here).

3. WP7 – Chemical Transport Models

Initially one ensemble study involving CTMs was planned in ECLAIRE, to investigate the impact of model choice on both predictions of ozone and N-deposition. However, through providing support for various policy initiatives (such as the Task Force on Modelling and Mapping of the UNECE Convention on Long Range Transboundary Air Pollution), models and scientists within ECLAIRE have been involved in several intercomparison studies. The three which became core parts of the ECLAIRE work programme are listed below.

a) CTM-comparison for the year 2009

The focus of this study was the comparison of N-deposition and reactive nitrogen concentrations (Kg N ha^{-1}), with the following 7 CTMs (many of which are detailed in (Cuvelier et al. 2013):

i. CHIMERE
ii. DEHM (hemispheric)
iii. EMEP MSC-W

iv. INCA (global)
v. LOTOS-EUROS
vi. MATCH
vii. RCGC

The following key items were harmonised for each set of model runs:

- Emission profiles*
- Time profiles
- Run for the year 2009
- at 0.5×0.25 °long/lat resolution, ca. 28km**

*Apart from INCA which used its own emissions and time profiles
**Apart from the hemispheric DEHM model which used a resolution of ca. 50km, and the global INCA model used 3.75×1.875 °long/lat, ca. 200 x 200 km^2 over Europe

One key output of the study included an ensemble map of total N-deposition, based on the 7 regional models, along with maps of the relative and absolute standard deviations. Further work included comparing the concentrations of NH_3 to that obtained against observations made in the FP6 NitroEurope IP.

Further details on the analyses, can be found in D7.1, D7.4 (references therein) and more specifically, Langner et al. 2012 and Simpson et al. 2014.

b) Climate-chemistry intercomparison (a cooperation with the Nordic EnsClim project).

This study was conducted in two phases, with Phase 1 assessing the relative impacts of climate and emissions changes on ozone (see also Langner et al. 2012 and section (i)) and Phase 2 focussing on reactive N components (see section (ii)).

The following key items were harmonized for each set of model runs (depending on which part of the study was being conducted):

- Identical meteorology (from Swedish regional climate model RCA3, driven by ECHAM5)
- Driven by the same global projection of future climate under the SRES A1B scenario
- Anthropogenic emissions of ozone precursors from RCP4.5 for year 2000

(i) Phase 1: Ozone Experiments

Phase 1 used the following CTMs;
i. DEHM
ii. EMEP MSC-W
iii. MATCH
iv. SILAM
& CCM EnvClimA for Ozone.

Key outputs included maps of mean of daily maximum ozone values for the period 2000-2009, from five models, and illustrations of the uncertainties in biogenic VOC emissions between the models. Further details can be found in D7.1, D7.4 (references therein) and more specifically, Langner et al. 2012.

(ii) Phase 2: Nitrogen Experiments

Phase 2 used the following CTMs:
i. DEHM
ii. EMEP MSC-W
iii. MATCH

iv. SILAM

The experiments followed a similar methodology to Phase 1, apart from the following aspects:
(i) the emission inventories were updated, making use of the ECLAIRE data-sets for 2005 and 2050, and finer-scale spatial distributions to provide more accurate model inputs,
(ii) the effects of emissions changes as well as of climate change were investigated, and
(iii) the study considered 20-year time-windows of simulation instead of 10-years, in order to provide a better statistical basis for determining the climate change signal.

The maps of oxidised and reduced nitrogen for several time periods and each model were then compared to draw conclusions on the differences from model structure and impact of emissions. Further details can be found in D7.1, D7.4 (references therein) and more specifically, Simpson et al., 2014.

c) Scale dependency exercise

This intercomparison study focussed on the issue of spatial resolution and its effects on the modelling of (PM10), ozone and NO_2. The following CTM's were involved:

i. CHIMERE
ii. CMAQ
iii. EMEP MSC-W
iv. LOTOS-EUROS
v. RCGC

The following spatial resolutions were investigated:

i. 7km
ii. 14km
iii. 28km
iv. 54km

Metrics of importance to human health, both in choice of pollutants (O_3, NO_2 and PM_{10}), and the inclusion of urban and near-urban stations in the evaluation procedure were investigated and a number of general lessons were also learned. Results are detailed in D7.1, D7.4, Cuvelier et al., 2013 and in the published version: Schaap et al., Atmos. Env., 2015.

4. WP18 - Dynamic Global Vegetation Models

A DGVM ensemble modelling study has been performed on models which simulate the impact of ozone and N deposition on ecosystem carbon and water budgets. Results have been harmonised and analysed to provide a summary of estimated impacts at European scale. The models involved in the ensemble study are:

i. LPJ-Guess
ii. OCN
iii. JULES
iv. CLM

Four scenarios were used in the study (Table 1), with each model running as many of those scenarios as was possible (depending on model differences), Table 2 provides an overview.

Name	Climate	CO_2	N deposition	O_3
S0	1901-2050	1901-2050	1901-2050	1901-2050
S1	1901-2050	1901-2050	1901-2050	1901
S2	1901-2050	1901-2050	1901	1901-2050
S10	1901-2050	1901-2050	1901	1901

Table 1. Definitions of the 4 scenarios used with respect to transient atmospheric conditions.

Model	S0	S1	S2	S10
CLM	Yes	Yes	Yes	Yes
LPJ	No	Yes	No	Yes
JULES	No	No	Yes	Yes
OCN	Yes	Yes	Yes	Yes

Table 2. Vegetation models and scenario combinations analysed in WP14.

This setup allowed for the comparison of the effects of ozone and N deposition, in a number of combinations (again not for every model and every case, depending on circumstances) as shown below:

i. Effects of transient N deposition
ii. The effect of O_3
iii. The effects of both N and O_3
iv. The influence of N *alongside that of O_3* (that is, already given that of O3, or, alternatively, the combined influence of N and O3 over and above that of just O3)
v. The influence of O_3 *alongside that of N* (that is, already given that of N, or, alternatively, the combined influence of N and O3 over and above that of just N)

The following variables describing changes in the state and functioning of vegetation and soils were focussed on in the study:

- **Net primary productivity** (NPP) representing the difference between the gross amount of carbon fixed by the vegetation, and the amount of carbon respired by the vegetation (positive values indicate the conversion of more carbon from the atmosphere into plant material, on balance, than from vegetation back into the atmosphere);
- **Evapotranspiration** (ET) representing the cumulative amount of water that evaporates from the land surface and the amount of water transpired by the plant through the stomata to enable the leaf level exchange of gases and ultimately photosynthesis;
- **Water use efficiency** (WUE) here defined as the gross primary productivity divided by the total evapotranspiration, representing the amount of carbon fixed by the vegetation for a 'standardised' amount of water used by the vegetation.

All model outputs were harmonised to have the same units, and describe the same time period. Plots of the three chosen variables, for each model-scenario combination, for the applicable combination of N deposition and ozone effects were analysed to draw conclusions regarding the functioning of the models and sensitivity to specific scenarios and atmospheric drivers.

As well as comparing the European averages of the variables targeted in the study, a comparison of all of the models and scenarios simultaneously, was undertaken. This consisted of applying an RV coefficient (a measure of covariance) to the matrices of simulated variables from each model-scenario combination. This allowed an analysis of the 'similarity' of the sets of model-scenario combination outputs, to be conducted. Following the calculation of the covariance of all of the model-scenario pairs, a conversion to a 'dissimilarity' or distance measure was applied, and formed into a distance matrix. A multidimensional scaling (MDS, e.g. Gower 1966) was then applied, providing a reduced dimensional representation of the dissimilarity between model-scenario combinations.

The full details of how this method was applied and the necessary adjustments to the process, are detailed in D14.7. The resulting output placed the model-scenario combinations into a principle co-ordinates space. Configurations of the model-scenarios in this space were then used to address the question of how the atmospheric drivers, influence vegetation. The results of the analysis can be seen in D14.7. In the final part of the analysis the modelled interactions are then compared to observed interactions of N and Ozone.

6. References

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