Project Number 282910

ÉCLAIRE

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

Seventh Framework Programme

Theme: Environment

D5.4 Provision of future European pollutant boundary conditions

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Dissemination Level		
PU	Public	x
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

This deliverable provides a best estimate and uncertainty range of present and future O_3, O_3 precursors and aerosol as boundary conditions to regional models, for further impact assessment on ecosystems. We report on two ECLAIRE activities: simulations with the global LMDz-INCA model constrained by ECLAIRE/ECLIPSE emission inventories for the period 2010, 2030 and 2050; and ensemble modelling work in the Task Force Hemispheric Transport and EMEP on the evaluation of future emission scenarios. Scenario analysis has focused on the evaluation of the widely used IPCC AR5 RCP scenarios for TH HTAP and ECLAIRE/ECLIPSE emission inventories for boundary condition files.

This deliverable provides the description of the NetCDF files prepared with the LMDz-INCA global model for use by the regional models for the present-day, 2030 and 2030 conditions and for the ECLAIRE/ECLIPSE emission scenarios corresponding to both the *Current Legislation* and *Maximum Feasible Reduction* conditions.

2. Objectives

- To evaluate the transport of atmospheric pollutants (ozone and precursors, aerosols) into Europe, evaluate the relative contributions of long-range-transported and European pollution on atmospheric composition and deposition to the ecosystems in Europe and in other regions, and provide a range of chemical boundary conditions to regional models within ÉCLAIRE (WP7), taking into account changes in global anthropogenic and natural emissions under current and future climate change conditions.
- To provide boundary condition files for regional model simulations based on the new ECLAIRE/ECLIPSE emission inventories.

3. Activities

- Modelling with the LMDz-INCA global model of the present and future atmospheric composition and community modelling within TF Hemispheric Transport Air Pollution.

- Provide boundary condition files with ozone and precursors, and aerosols for use by the regional models for both the present and future conditions.

4. Results

This deliverable provides a best estimate and uncertainty range of present and future O_3, O_3 precursors and aerosol as boundary conditions to regional models, for further impact assessment on ecosystems.

We report on two ECLAIRE activities: simulations with the global LMDz-INCA model constrained by ECLAIRE/ECLIPSE emission inventories for the period 2005, 2010, 2030 and 2050; and ensemble modelling work in the Task Force Hemispheric Transport and EMEP on the evaluation of future emission scenarios. Scenario analysis has focused on the evaluation of the widely used IPCC AR5 RCP scenarios for TH HTAP and ECLAIRE/ECLIPSE emission inventories for boundary condition files.

4.1 Boundary conditions files for use by the regional models

The LMDz-INCA-ORCHIDEE global chemistry-aerosol-climate model couples on-line the LMDz (**L**aboratoire de **M**étéorologie **D**ynamique, version 4) General Circulation Model, the INCA (**IN**teraction with **C**hemistry and **A**erosols, version 3) chemistry model and ORCHIDEE (**OR**ganizing **C**arbon and **H**ydrology **I**n **D**ynamic **E**cosyst**e**ms) version 9 dynamical vegetation model. In the framework of ECLAIRE a new version of the model has been developed to include the NH_3 cycle and the ammonium nitrate and ammonium sulfate particles. A description of the model components is given in Hauglustaine et al. (2014). In D5.1, hindcast simulations for the period 1960, 1970, 1980, 1990, and 2000, have been performed, using ECMWF meteorology for the years 2005-2006. In Hauglustaine et al. (2014) the same model has been used to extend these simulations to 2030, 2050 and 2100 in the framework of the Representative Concentration Pathway (RCP) anthropogenic emission scenarios. The monthly mean results from the LMDz-INCA global model from these past and future simulations to be used as boundary conditions for regional scale models within ECLAIRE are available as NetCDF files upon request.

In the present activity, the LMDz-INCA model has been adapted to the new anthropogenic emission inventories prepared by IIASA (Klimont et al., 2013; Amman et al., 2013) in the framework of the ECLAIRE/ECLIPSE/PEGASOS EU projects. These emissions are better suited to the simulation of air quality in the future than the RCP scenarios designed for climate simulations. Figure 5.4.1 illustrates the evolution of air pollutant emissions used as model input for one of the available scenarios. Two scenarios are available and have been used: Current Legislation (CLE) and scenario Maximum Feasible Reduction (MFR) for the year 2005, 2010, 2030 and 2050.

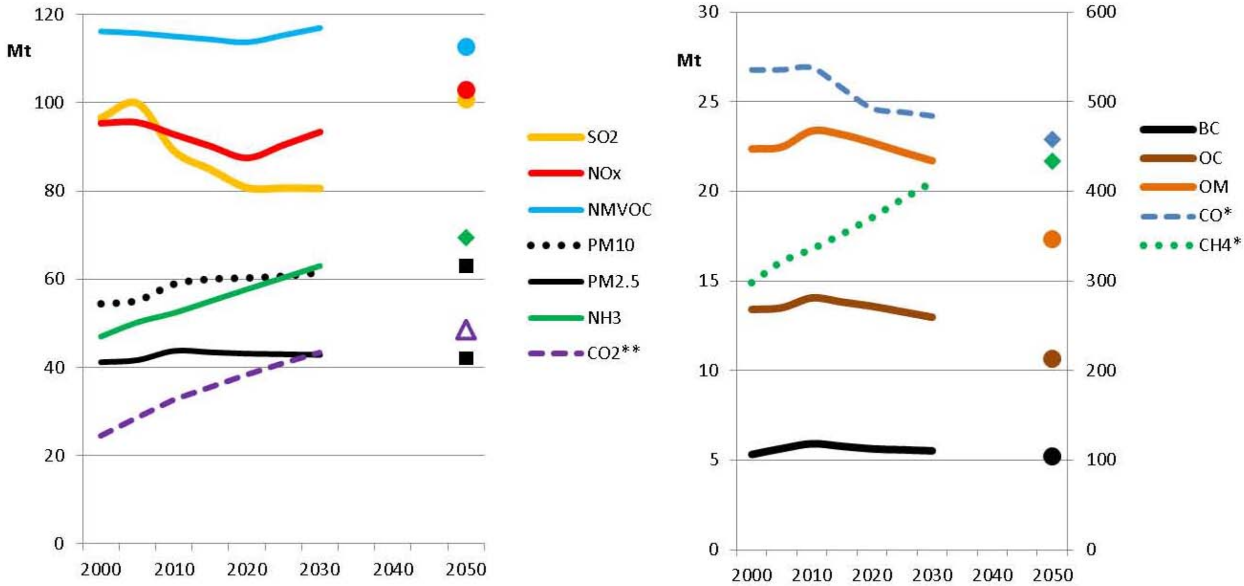

Figure D5.4.1: Global emissions of air pollutants and methane in the baseline scenario CLE for 2005, 2010, 2030 and 2050 (Klimont et al., 2013). (*) For CO and CH_4 the right hand scale is used. (**) For CO_2 units are Gt.

The two scenarios CLE and MFR have been performed with the LMDz-INCA model for the different time horizons (2005, 2010, 2030, and 2050 for scenario CLE and 2030, 2050 for scenario MFR). For each simulation NetCDF files have been prepared with key chemical species and aerosols to be used as boundary conditions for regional model simulations (see below for details on how to retrieve the files). These files are made available to the ECLAIRE participants and can be complemented upon request with the similar files for the RCP simulations for comparison. The sensitivity of the simulated future atmospheric composition to biogenic emissions and climate parameters will be performed and analyzed in a forthcoming ECLAIRE activity and deliverable in preparation (D5.2).

In order to illustrate the model results, Figure 5.4.2 shows the distribution of O_3 surface mixing ratio for the year 2030 and 2050 and compares the results for two extreme scenarios RCP8.5 and RCP2.6 with the CLE and MFR ECLAIRE/ECLIPSE scenarios. Similarly, Figure 5.4.3 illustrates the surface concentration of particulate matter with a diameter lower than 2.5 µm (PM2.5), calculated as the sum of sulfate and nitrate particles, black carbon and organic carbon concentrations in the model, for the same years and scenarios. For both ozone and PM2.5 these figures show that in Europe the surface concentrations calculated are significantly lower in the case of the new emission scenarios involving air quality legislation than in the case of the RCP scenarios. Even in the case of the strong climate mitigation scenario RCP2.6, the surface concentrations are higher than those calculated with the ECLAIRE/ECLIPSE scenarios over Europe and Northern America which account for air quality legislation in those regions. In contrast, higher aerosol concentrations are calculated over Asia and in particular India and China for the CLE scenario. These high emissions and levels of pollutants in Eastern Asia are potentially important for Europe in the future since long-range transport of several longer-lived species can affect the levels of pollutants in Europe and counterbalance the air quality measures taken.

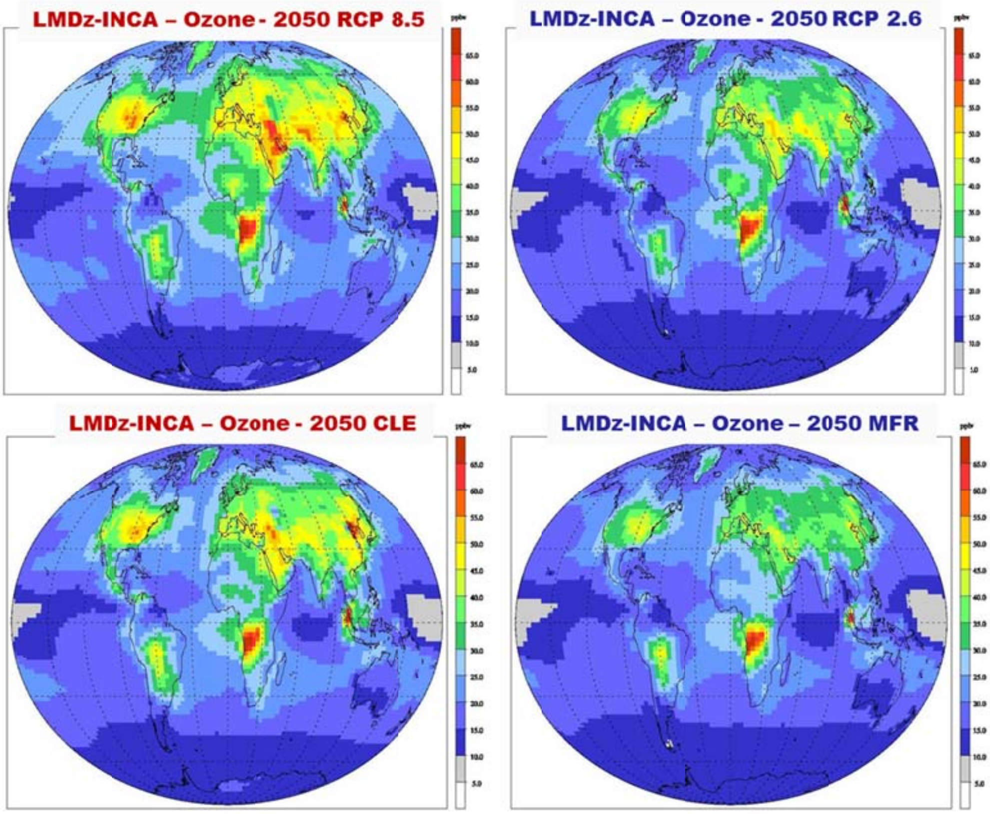

Figure D5.4.2: Surface annual ozone mixing ratio calculated at the surface with the LMDz-INCA model for 2050 conditions. This figure compares the ozone distribution for the RCP8.5 and RCP2.6 extreme scenarios and for the ECLIPSE/ECLAIRE CLE and MFR scenarios.

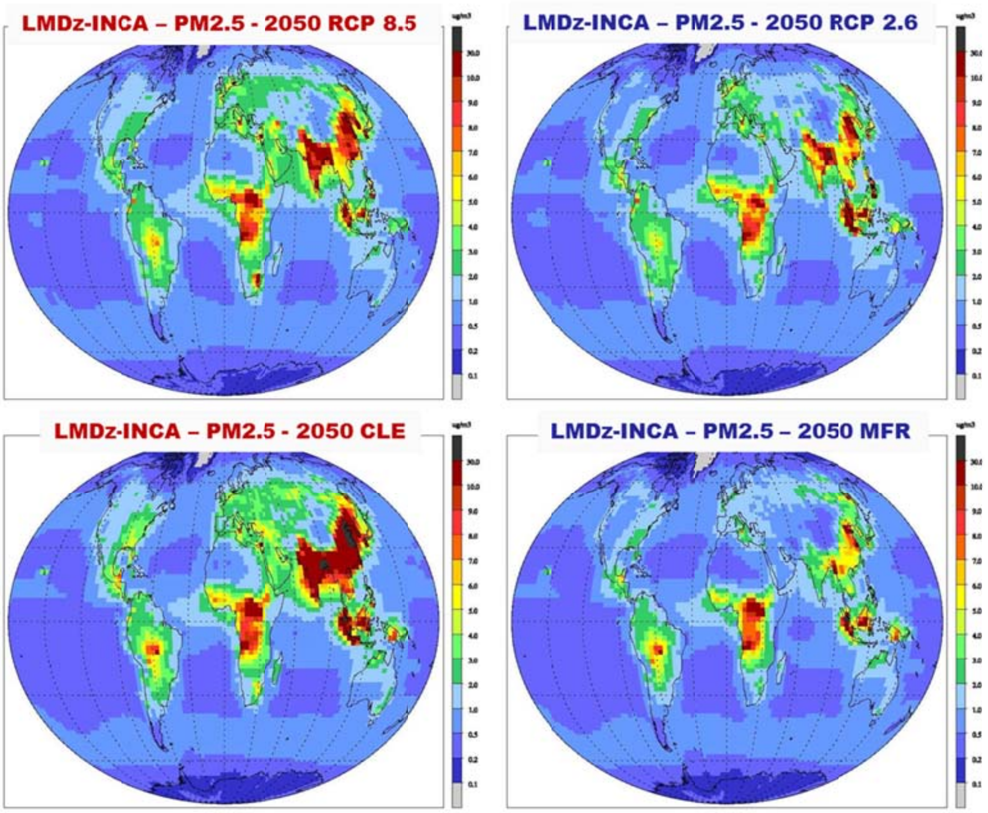

Figure D5.4.3: Surface annual PM2.5 concentration calculated at the surface with the LMDz-INCA model for 2050 conditions. This figure compares the distribution for the RCP8.5 and RCP2.6 extreme scenarios and for the ECLIPSE/ECLAIRE CLE and MFR scenarios. PM2.5 is calculated in the model as the sum of sulfates, nitrates, black carbon and organic carbon concentrations.

4.2 Ensemble modelling within the Task Force Hemispheric Transport and EMEP and evaluation of future emission scenarios

A second activity focuses on the use of multiple model simulations, including LMDZ-INCA and TM5, to provide boundary conditions to the European EMEP policy framework. Emissions from various scenarios including RCP, IIASA GEA (Global Energy Assessment) and IIASA GAINS scenarios were evaluated up to 2050 (Figure 5.4.4) (Wild et al., 2013). Annual average ozone changes for Europe span a wide range depending on the driving scenarios, and especially the development of CH_4 concentrations and emissions. (Wild et al. 2013).

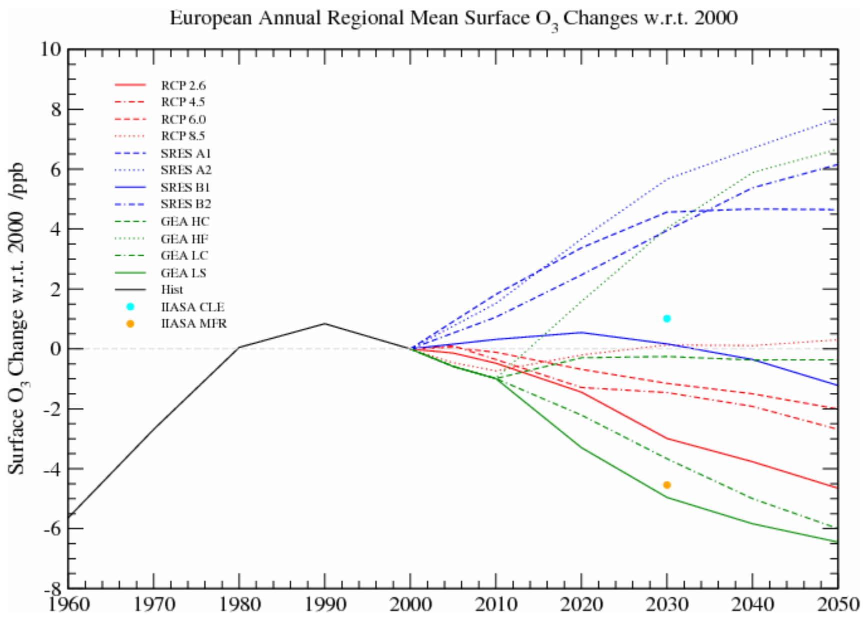

Figure D5.4.4: Development of European ozone for a range of emission scenarios.

Results were made available to policy makers with respect to an advice on changes in boundary conditions for future conditions. The advice consists of a range of future conditions by 2020-2030 and 2040-2050 as displayed in Table 5.4.1. For the 'median' case no changes in O_3 concentrations flowing into Europe were evaluated. This evaluation however did not consider impacts of climate change on baseline O_3 flowing into Europe. The impact of climate change may have various opposing effects (increasing biogenic emissions leading to more ozone, large scale increase in water vapour and temperature which tends to lower ozone over vast ocean regions, and finally increased intensity of stratosphere-troposphere exchange process leading to larger tropospheric ozone abundances- the overall impact of these effects are poorly known (Doherty et al. 2013).

Table 5.4.1: Range of changes of O_3 inflow conditions at Europe's Western Boundary: low-median and high.

	Annual 2030-2030	Annual 2040-2050
Low	-1	-3
Median	0	0
High	3	5

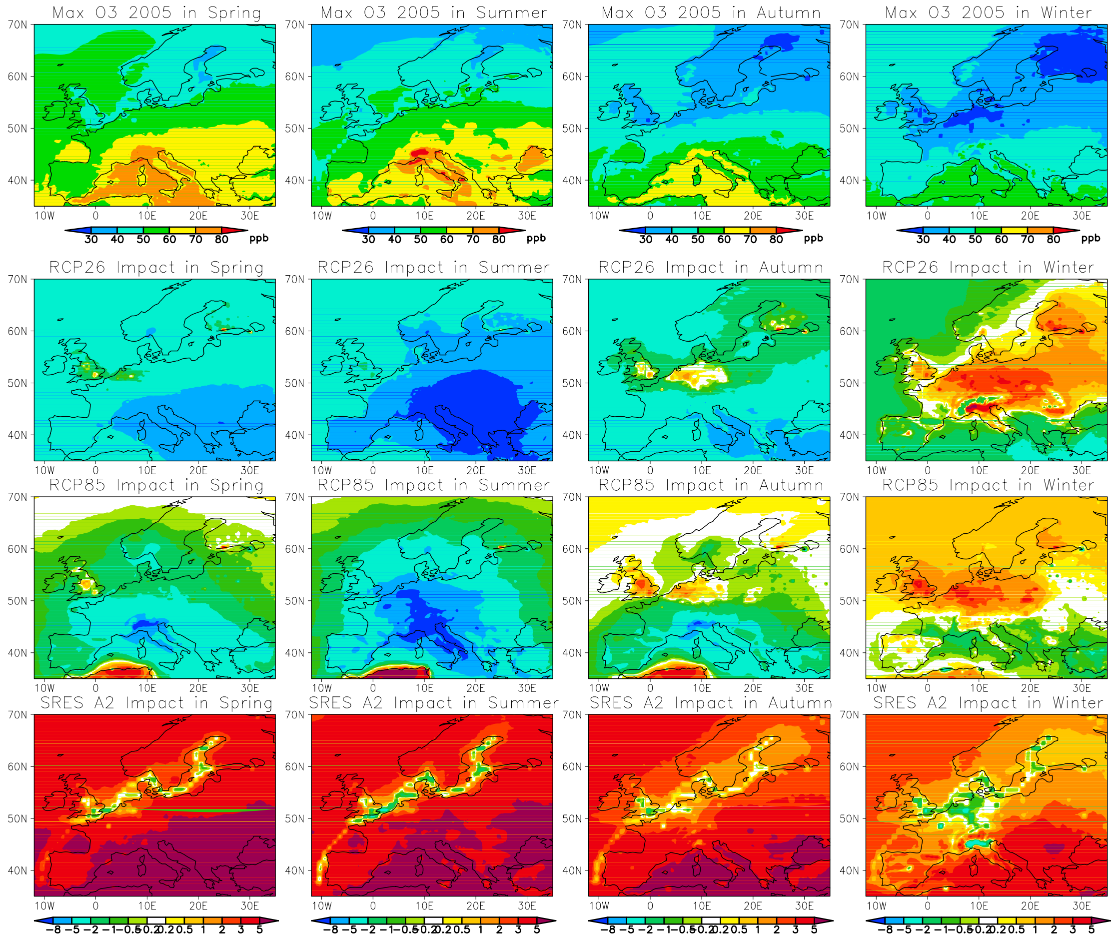

Figure D5.4.5: Seasonal mean daily maximum O3 in ppb for 2005 (top row) and changes between 2005 and 2030 under RCP 2.6, RCP 8.5 and SRES A2 emission scenarios.

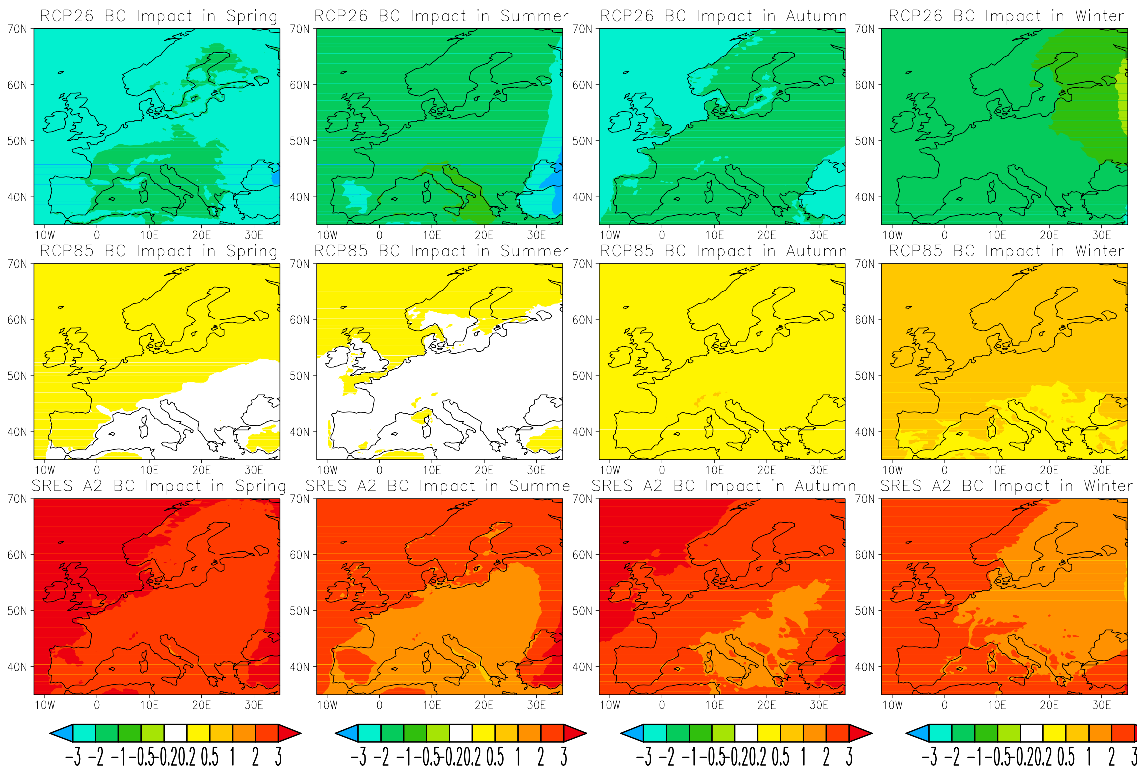

Figure D5.4.6: Differences in seasonal mean daily maximum O3 under RCP 2.6, RCP 8.5 and SRES A2 scenarios due to changes in boundary conditions (BC) alone between 2005 and 2030 (Wild et al., 2013).

In Figure D5.4.5 and Figure D5.4.6 a regionally explicit evaluation of changes in Europe for RCP2.6; RCP8.5 and SRES A2 scenario, and the contribution of O_3 from boundary conditions is presented. RCP2.6 and RCP8.5 lead to substantial seasonal declines of up to 10 ppb in all seasons, but not in winter, in RCP2.6 a hemispheric decline in O_3 contributed to the European decline, while in RCP8.5 a neutral to small positive O_3 change from boundary conditions opposed the overall European decline. The pessimistic A2 scenario leads to ozone increases in the order of 5-10 ppb, with strong contributions from changing ozone boundary conditions.

5. Milestones achieved

Contribution to MS23: Evaluation of AR5 and other simulations with climate and chemistry global models. Provide boundary conditions files for ozone and precursors and aerosols to the regional models.

6. Deviations and reasons

D5.4 was delivered with a delay of about 10 months. The reasons were a change of supercomputer at CNRS which caused a half a year of delay as in D5.1 and a delay in receiving the final set of future emissions to be used in ECLAIRE and ECLIPSE; and a delay of about half a year of community analysis for the Task Force Hemispheric Transport. No major impact expected since the boundary condition files have already been made available and used in the regional models.

7. Publications

Amann, M., Z. Klimont, and F. Wagner, Regional and global emissions of air pollutants: recent trends and future scenarios, Ann. Rev. Environ. Resourc., 38, 31-55, 2013.

Doherty, R. M., O. Wild, D. T.Shindell, G. Zeng, W. J. Collins, I. A. MacKenzie , A. M. Fiore, D. S. Stevenson, F. J. Dentener, M. G. Schultz, P. Hess, R. G. Derwent and T. J. Keating Impacts of climate change on surface ozone and intercontinental ozone pollution: A multi-model study, J. Geophysical Research, 2013, 118, 3744-3763, doi:10.1002/jgrd.50266, 2013.

Hauglustaine, D. A., Balkanski, Y., and Schulz, M.: A global model simulation of present and future nitrate aerosols and their direct radiative forcing of climate, Atmos. Chem. Phys. Discuss., 14, 6863-6949, doi:10.5194/acpd-14-6863-2014, 2014.

Klimont, Z., K. Kupiainen, Ch. Heyes, J. Cofala, P. Rafaj, L. Höglund-Isaksson, J. Borken, W. Schöpp, W. Winiwarter, P. Purohit, I. Bertok, and R. Sander, ECLIPSE V4a: Global emission data set developed with the GAINS model for the period 2005 to 2050: Key features and principal data sources, International Institute for Applied Systems Analysis (IIASA), Schlossplatz 1, 2361 Laxenburg, Austria, 2013.

Wild, O., F.J. Dentener, K.S. Law, J.E. Jonson, V.S. Semeena, C. Andersson, D.D. Parrish, and M. Amann, Changing ozone at Europe’s borders: present-day and future perspectives for air quality, submitted for publication, 2014.

8. Meetings

Participation to ECLAIRE plenary meetings.

9. List of Documents/Annexes:

List of NetCDF files with boundary conditions

LMDzINCA_2010_CLE.nc : Present simulation (2010).
LMDzINCA_2030_CLE.nc : Future simulation for 2030 under *Current Legislation* scenario.

LMDzINCA_2050_CLE.nc : Future simulation for 2050 under *Current Legislation* scenario.
LMDzINCA_2030_MFR.nc : Future simulation for 2030 under *Maximum Feasible Reduction* scenario.
LMDzINCA_2050_MFR.nc : Future simulation for 2050 under *Maximum Feasible Reduction* scenario.

Variables included in the files

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float CH4(time_counter, presnivs, lat, lon) ;
        CH4:units = "VMR" ;
float CO(time_counter, presnivs, lat, lon) ;
        CO:units = "VMR" ;
float NO(time_counter, presnivs, lat, lon) ;
        NO:units = "VMR" ;
float NO2(time_counter, presnivs, lat, lon) ;
        NO2:units = "VMR" ;
float PAN(time_counter, presnivs, lat, lon) ;
        PAN:units = "VMR" ;
float HNO3(time_counter, presnivs, lat, lon) ;
        HNO3:units = "VMR" ;
float NH3(time_counter, presnivs, lat, lon) ;
        NH3:units = "VMR" ;
float O3(time_counter, presnivs, lat, lon) ;
        O3:units = "VMR" ;
float C2H2(time_counter, presnivs, lat, lon) ;
        C2H2:units = "VMR" ;
float C2H4(time_counter, presnivs, lat, lon) ;
        C2H4:units = "VMR" ;
float C2H6(time_counter, presnivs, lat, lon) ;
        C2H6:units = "VMR" ;
float C3H6(time_counter, presnivs, lat, lon) ;
        C3H6:units = "VMR" ;
float C3H8(time_counter, presnivs, lat, lon) ;
        C3H8:units = "VMR" ;
float CH2O(time_counter, presnivs, lat, lon) ;
        CH2O:units = "VMR" ;
float CH3CHO(time_counter, presnivs, lat, lon) ;
        CH3CHO:units = "VMR" ;
float ALKAN(time_counter, presnivs, lat, lon) ;
        ALKAN:units = "VMR" ;
float AROM(time_counter, presnivs, lat, lon) ;
        AROM:units = "VMR" ;
float H2O2(time_counter, presnivs, lat, lon) ;
        H2O2:units = "VMR" ;
float SO2(time_counter, presnivs, lat, lon) ;
        SO2:units = "VMR" ;
float DMS(time_counter, presnivs, lat, lon) ;
        DMS:units = "VMR" ;
float SO4(time_counter, presnivs, lat, lon) ;
        SO4:units = "ug/m3" ;
float NO3(time_counter, presnivs, lat, lon) ;
        NO3:units = "ug/m3" ;
float NH4(time_counter, presnivs, lat, lon) ;
        NH4:units = "ug/m3" ;
float BC(time_counter, presnivs, lat, lon) ;
        BC:units = "ug/m3" ;
float OC(time_counter, presnivs, lat, lon) ;
        OC:units = "ug/m3" ;
float CNO3(time_counter, presnivs, lat, lon) ;
```

```
        CNO3:units = "ug/m3" ;
    float DUST(time_counter, presnivs, lat, lon) ;
        DUST:units = "ug/m3" ;
    float SSALT(time_counter, presnivs, lat, lon) ;
        SSALT:units = "ug/m3" ;
```

How to download the files

ftp ftp.cea.fr
login: anonymous
password: <login>
cd incoming/y2k01/ECLAIRE
mget LMDzINCA*

Contact: didier.hauglustaine@lsce.ipsl.fr