Project Number 282910

ÉCLAIRE

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

Seventh Framework Programme

Theme: Environment

D7.1 Maps of current air pollution metrics (APMs) across Europe, from the EMEP models and five other CTMs

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Norwegian Meteorological Institute

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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)	

Executive summary

The main objective of deliverable D7.1 was to present predictions of ozone and N-deposition from different chemical transport models (CTMs), in order to provide an indication of the robustness and inter-model spread of these metrics. The initial intention was to perform one study during the first phase of ECLAIRE, but, partly driven by the need to support various policy initiatives (e.g. TFMM), models and participants of WP7 have actually been involved in several inter-comparison exercises:

(a) CTM-comparison for 2009: an ECLAIRE initiative to inter-compare Nr-deposition and concentrations among eight CTMs, and to compare with measurements. This study shows that the domain-total depositions from oxidised and reduced nitrogen were approximately equal, with wet versus dry deposition contributions of 45% vs. 55% for NHx compounds, and 35% vs. 65% for NOy compounds.

The seasonal cycles of Nr-deposition are quite similar among the regional models, following the assumed emission time-profiles. The inter-model spread of the modelled total Nr-deposition by the 7 regional CTMs is relatively constant during the year, at about 30-50% over land areas, and 50-100% over seas.

The models have been compared to observations from the NitroEurope IP. In general the CTMs underpredict NH_3 at non-agricultural sites, but correlations are generally good. Further analysis of the model-measurement comparison and reasons for inter-model differences is a priority for the next phase of this study in ECLAIRE.

(b) Climate-chemistry intercomparison (a cooperation with the Nordic EnsClim project). In the first phase of this study, four CTMs (and one regional climate-chemistry model) were used to assess the impact of climate change on predicted ozone concentrations. The results showed climate-induced changes in summertime mean and daily maximum ozone of order 1 ppb, relatively small compared to changes that can be induced by emissions or background ozone changes. An important conclusion is that the models differed substantially in their assumptions concerning biogenic VOC emissions, and that this difference played a significant role in explaining inter-model differences.

In a second phase, the four CTMs from EnsClim have been used to explore N-deposition. The impact of emissions and boundary condition changes, as well as of climate change, have been explored for a future case centred on the ECLAIRE emission projection of 2050. These simulations clearly show that emission changes are the main driver of N-deposition changes between the current period and 2050. Reductions in NOx emissions and hence NOy deposition are very significant. NH_3 emissions on the other hand are almost unchanged in the 2050 scenario, so that deposition of NHx compounds becomes the main source of Nr-deposition in these 2050 scenarios.

The models show generally similar levels of total deposition, but relative contributions from especially dry-deposition can differ significantly between the models.

(c) The scale-dependency exercise (a TFMM initiative) involved running five CTMs at the European scale with spatial resolutions of 7, 14, 28 and 54 km, in an effort to investigate

the importance of grid-size for assessing air quality issues, particularly close to urban agglomerations. This study showed that for large scale modelling of rural concentrations and large agglomerations, grid-sizes of ca. 28km (or if data allows, 14km) seems to be a good compromise between a pure background (rural) application and an application which captures most of the urban signals. The need for accurate emission data at the appropriate scale was seen as a major limitation to finer scale modelling.

(d) The EMEP and EURAD models also took part in an initiative from the EU CityZen project which used an ensemble of six CTMs to look at future ozone, including AOT40 metrics. A unique feature was the use of a statistical method to 'correct' model predictions using measured values. This method was calibrated with measured and modelled data for current years, and enabled better prediction of metric such as AOT40 or SOMO35 in future years.

As far as the relative change of AOT40 is concerned, the indicators of exposure to detrimental ozone levels of vegetation for crops were estimated in 2030 to reach about 60% and 25% of their present levels for the 'reference' and 'sustainable' scenarios, respectively. The projections for AOT40c were expected to meet the current target (18 000 μg m^{-3} h) for the vast majority of stations but these simulations suggested that the long term objective (6000 μg m^{-3} h) will likely not be met over most of Europe if climate policies are not enforced. These estimates seem robust both in terms of model spread (ensemble) and model uncertainty (difference between the raw and distribution-corrected estimates).

These comparison exercises have generated a huge amount of data, and much work remains to understand all the results. The initial aim of deliverable D7.1 was however to provide a first assessment of the robustness of modelled data for metrics such as AOT40 and N-deposition, and the studies outlined here meet that objective. Future ECLAIRE work will concentrate on studies (a) and (b) especially, with extensive comparison to measurements, and evaluation of possible reasons for model differences.

1 Objectives

The main objective of deliverable D7.1 was to present predictions of ozone and N-deposition from different chemical transport models (CTMs), in order to provide an indication of the robustness and inter-model spread of these metrics.

2 Activities

The chemical transport model (CTM) participants of WP7 have actually been involved in a number of inter-comparison exercises (more than anticipated in the ECLAIRE contract) addressing different aspects of air quality and climate change interactions. The main activities can be summarised:

(a) CTM-comparison for 2009: an ECLAIRE initiative to inter-compare Nr-deposition and concentrations among eight CTMs, and to compare with measurements. The models participating are CHIMERE, DEHM (hemispheric), EMEP MSC-W, INCA (global), LOTOS-EUROS, MATCH and RCGC (most of these models are explained in the Cuvelier et al. 2013 cited below).

In this intercomparison, CTM model results for the year 2009, and using as far as possible identical emission inventories (at 0.5×0.25 °long/lat resolution, ca. 28km) have been produced for the year 2009 (the hemispheric DEHM model 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). These model results have been collected into a central database at TNO, and maps of concentrations and deposition fields have been compared. Measurements from the NitroEurope IP have also been collected for evaluation and comparison of the models. Results are presented below.

(b) Climate-chemistry intercomparison (a cooperation with the Nordic EnsClim project). In this intercomparison, four CTMs (and for ozone one regional climate-chemistry model, CCM) are used to assess the relative impacts of climate and emissions changes on O_3 and Nr components. The CTMs used are DEHM, EMEP MSC-W, MATCH and SILAM (and the EnvClimA CCM used for O_3). The CTMs have been driven by identical meteorology, which is produced by the Swedish regional climate model RCA3, driven by ECHAM5. For the first intercomparison, on ozone, two 10-year periods representing current (2000-2009) and future (2040-2049) were compared. In the second intercomparison on Nr, 20-year periods were used (1990-2009, 2040-2059). Emissions for the Nr-comparison are as given by the ECLAIRE 2005 and 2050 scenarios. Results are presented below.

(c) Scale-Dep. This intercomparison was an initiative of the Task Force on Modelling and Mapping (TFMM), and undertaken by both ECLAIRE and EC4MACS participants. Five CTMs (CHIMERE, CMAQ, EMEP MSC-W, LOTOS-EUROS and RCGC, see Cuvelier et al., 2013 for details) were run at four spatial resolutions, 7, 14, 28 and 54 km. The main focus of this work was on particulate matter (PM10), ozone and NO_2.

(d) CTM comparison initiative of the EU CityZen project, also involving PEGASOS and ECLAIRE. Six CTMs were used to look at NO_2, O_3 and AOT40 metrics (Colette et al., 2012).

(e) EURODELTA-3. This intercomparison involves simulations of measurement campaigns (in 2006-2009) and a retrospective analysis of the years 1990, 1999 and 2008. The exercise involves seven CTMs, including EMEP and LOTOS-EUROS. This work, led by INERIS (France) is ongoing and will be reported elsewhere.

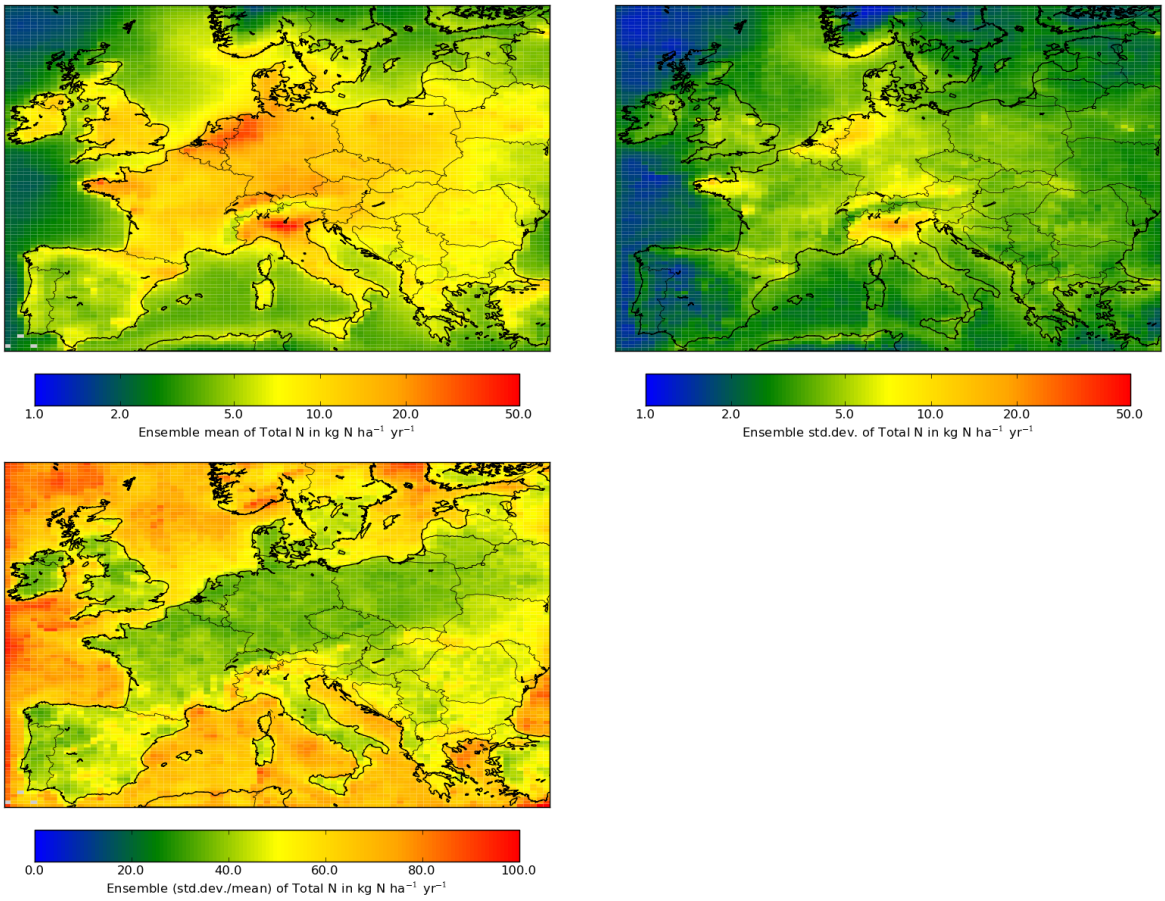


Figure 1: Estimated Nr-deposition from the ECLAIRE 7-model ensemble for 2009, (a) Ensemble mean, (b) standard deviation, (c) relative standard deviation. Units are kg(N)ha^{-1} yr^{-1}.

3 Results

3.1 CTM comparisons for 2009

In this model intercomparison, led by TNO, 7 regional (DEHM was hemispheric, but with resolution ca. 50km)), and one global CTM have delivered their calculations of Nr-deposition and concentrations of reactive nitrogen species. The same emissions and time profiles were used by all CTMs, except the global INCA model which used its own emissions and time profiles. Other driving variables, e.g., land use and meteorology, were not prescribed. An ensemble map of total Nr-deposition was created based on the 7 regional models (Fig. 1a), which were also used to derive the absolute and relative standard deviations (Fig. 1b,c). (The global CTM has a very different spatial resolution to the regional models, so is not included in the ensemble calculations.)

Fig. 1a shows that the areas with highest Nr-deposition in Europe are located in Northwestern and Central Europe, i.e., BeNeLux, Germany, Poland, Czech Republic, Austria, Switzer-

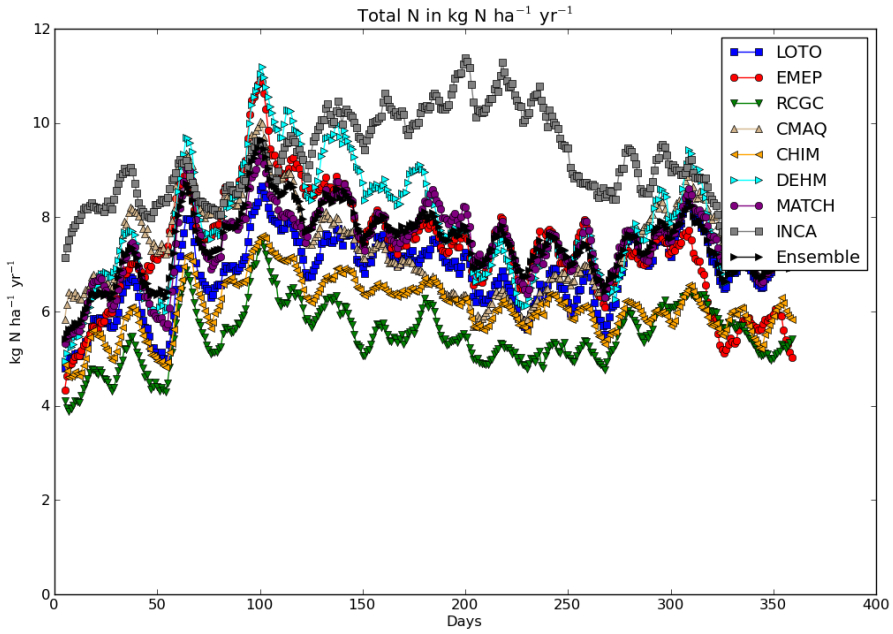
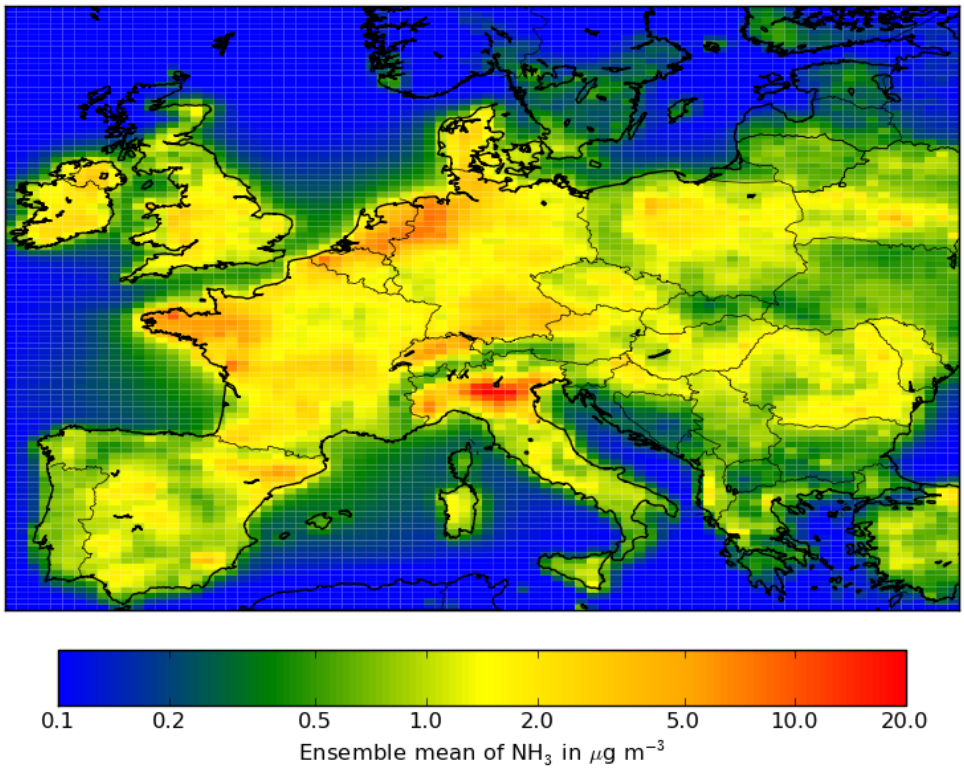


Figure 2: Timeseries (10-day running means) of the total Nr-deposition from 7 regional and one global (INCA) CTM for 2009.

land, France, Great Britain, and Northern Italy. These are generally also the areas with most intensive animal housing and agriculture. Over the whole model domain approximately 3.8 kg(N)ha^{-1} yr^{-1} of the total Nr-deposition is from NHx deposition, while an almost equal amount of 3.7 kg(N)ha^{-1} yr^{-1} is due to deposition of NOy. From the total NHx deposition, approximately 45% is dry deposited, while 55% is wet deposited. From the total NOy deposition approximately 35% is dry deposited and 65% is wet deposited. The absolute standard deviations (Fig. 1b) are largest in the areas with the highest total N deposition. These large deviations are mainly caused by differences in deposition of NHx, where wet and dry NHx deposition are equally uncertain in the model calculations. Over sea the uncertainty is mainly caused by differences in NOy deposition, where the wet deposition of NOy seems to be more uncertain than the dry deposition of NOy. Fig. 2 shows the 10-day running mean of the total Nr-deposition in the model domain. The 7 regional CTMs all show a similar pattern with a peak in the Nr-deposition in spring and a second smaller peak in late autumn. These peaks are mainly related to the timing of the ammonia emissions that are used by the models and are therefore strongly coupled to the dry and wet NHx deposition. Dry and wet NOy deposition do not show a strong seasonal cycle. The global CTM shows a different seasonal pattern with one large peak during the summer. This peak is related to a peak in both NHx and NOy dry deposition and is likely caused by differences in the (timing of the) emissions. The inter-model spread in the modelled total Nr-deposition by the 7 regional CTMs is relatively constant during the year and is approximately 50% for the whole model domain. Over land, the spread is slightly smaller, about 30-50%, while over sea the uncertainty is larger, about 50-100%.

In this study, concentrations of N-compounds from the CTMs have been compared with observed annual concentrations from the NitroEurope IP for the year 2009. As an example of this analysis, the ensemble mean of the calculated NH_3 concentrations from the 7 regional CTMs is presented in Fig. 3a, while the 10-day running mean of the average NH_3 concentration in the model domain is shown in Fig. 3b, for all 8 CTMs and the ensemble mean. Fig. 3a shows the ensemble of the NH_3 concentration as calculated by the 7 regional CTMs. The figure shows that the distribution of the NH_3 concentration is very similar to the distribution of the total Nr-deposition, illustrating the large importance of NH_3 for the total Nr-deposition. The time-series (Fig. 3b) shows that all 7 regional CTMs have a very similar seasonal pattern with a elevated concentrations in spring and autumn. The global CTM shows a different pattern, which is caused by the different (timing of) emissions. One CTM, RCGC, shows about 70% higher NH_3 concentrations than the other 6 regional CTMs, that seem to be rather consistent.

Figure 4 presents a comparison of the modelled NH_3 concentrations (8 CTMs and ensemble) and observed NH_3 from the NitroEurope IP. The different panels in this figure show the different models and the ensemble of all models. Results for croplands (open triangles) are highly influenced by local emissions, and excluded from the regression analysis. Fig. 4 shows that most models underestimate the NH_3 concentrations that were observed in the NitroEurope IP, except RCGC, which is the model with the highest NH_3 concentrations as we have seen already in Fig. 3b. The overestimation by RCGC is in the order of 30%. From the other 6 regional CTMs, LOTOS-EUROS shows the smallest deviation from the observations with a small underestimation of 14% and a relatively good correlation. The scatter in all models is still relatively large though. Remarkable is that the 'ensemble' shows a rather good agreement with the observations, while the underestimation is rather limited with about 20%.



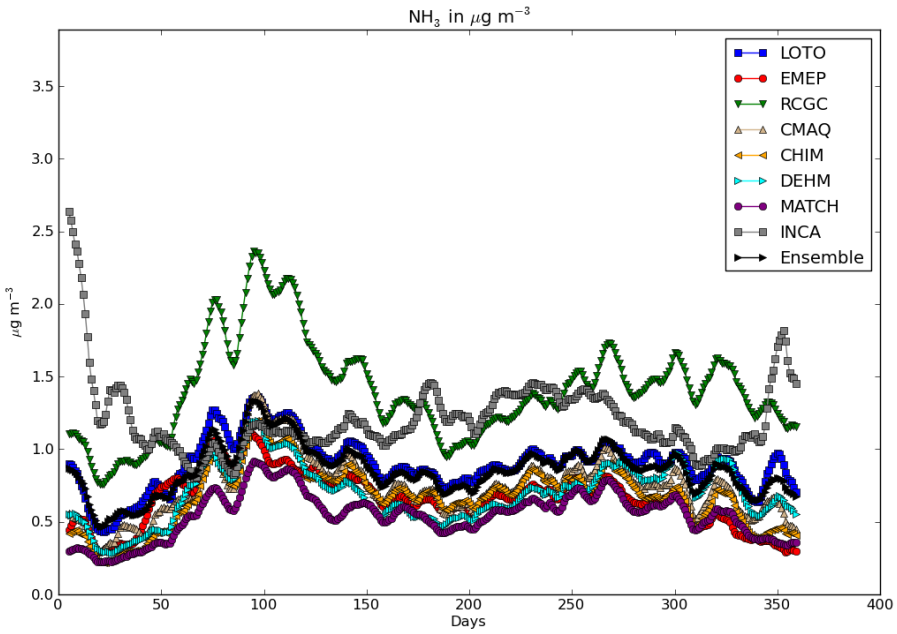


Figure 3: Results of the 7-model CTM for 2009 (a, top) ensemble mean NH_3 concentrations (μg m^{-3}), (b, bottom) time-series.

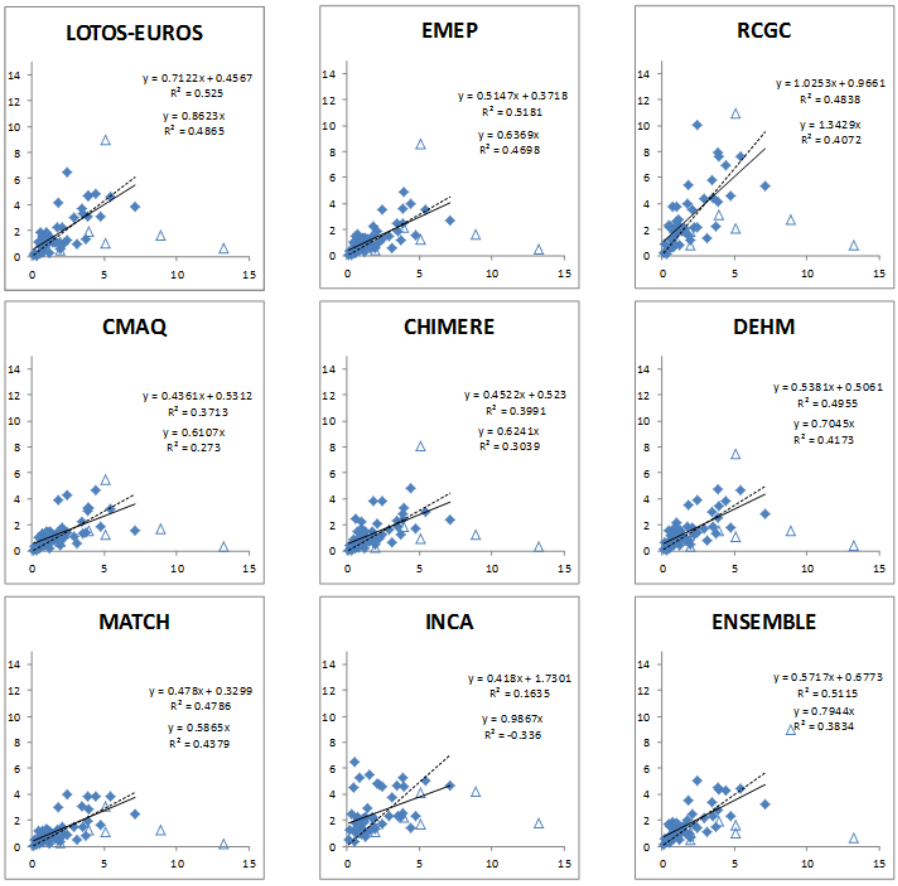


Figure 4: Modelled (y-axis) versus observed (x-axis) NH_3 concentrations from the NitroEurope IP network. Results of 7 regional, 1 global CTM, and the ensemble mean of the regional CTMs are presented. Open triangles represent agricultural sites. The regressions are based upon other sites (diamonds, forest, semi-natural and grassland).

3.2 Climate chemistry comparisons (EnsClim)

The EnsClim exercise aims to estimate the impacts of climate and emissions change on air quality, comparing model results for years around 2050 with those around the year 2000. The first EnsClim study, led by SMHI, focused on ozone, and was published in Langner et al. (2012a). The second EnsClim study, led by MET.NO, addresses changes in Nr deposition due to both emissions and climate-change. We briefly summarise these two studies.

EnsClim Ozone

Fig. 5a illustrates the comparison of mean of daily maximum ozone values for the period 2000-2009, driven by downscaled climate meteorology, from the five models participating in this EnsClim ozone exercise. The general features, with higher O_3 concentrations in the south, especially over the Mediterranean Sea, are evident in all models. In the evaluation presented in Langner et al. (2012a) all of the CTMs showed spatial correlations of 0.8 or higher, and performed generally well for daily maximum ozone (e.g. EMEP had absolute biases of 1-2% for annual or summertime daily max. O_3). (It should be noted though that climate-model meteorology is not driven by observed meteorology, and so models and measurements can only be compared in a statistical sense.) SILAM features higher values in the northern and eastern part of the domain and over Italy, while EMEP displays higher values over to the west and over water. EnvClimA displays a zonal behaviour of average daily maximum concentrations while DEHM, as expected from its larger grid size, shows the smoothest variation with high daily maximum concentrations over Italy and adjacent areas of the Mediterranean Sea. MATCH, on the other hand, shows a patchy picture, indicating shorter residence time of high O_3 and/or strong effects of local processes which are not present to the same extent in the other models.

Fig. 5b shows the changes in summer average daily maximum O_3 concentration brought about when using meteorology from the future case (2040-2049). The sensitivity of the simulated surface ozone to changes in climate between the periods 2000–2009 and 2040–2049 differs by a factor of two between the models, but the general pattern of change with an increase in southern Europe is similar across different models. The larger change in O_3 seen in DEHM model compared to the other models was ascribed partly to the use of different meteorological drivers, with associated differences in emissions of biogenic VOC. Indeed, many of the differences in the climate response of these models were found to be due to very different biogenic VOC emissions among the CTMs; emissions of isoprene ranged from 1.6 to 8.0 Tg yr^{-1} across the models for the current climate (Fig. 6). Also the simulated change in total isoprene emissions varied substantially across models explaining part of the different climate response on surface ozone.

So far, the impact of emissions change versus climate change on ozone has not been investigated with this suite of models, but Langner et al. (2012b) and others have clearly shown that emission changes and changes in the hemispheric background are more important than changes induced by climate change.

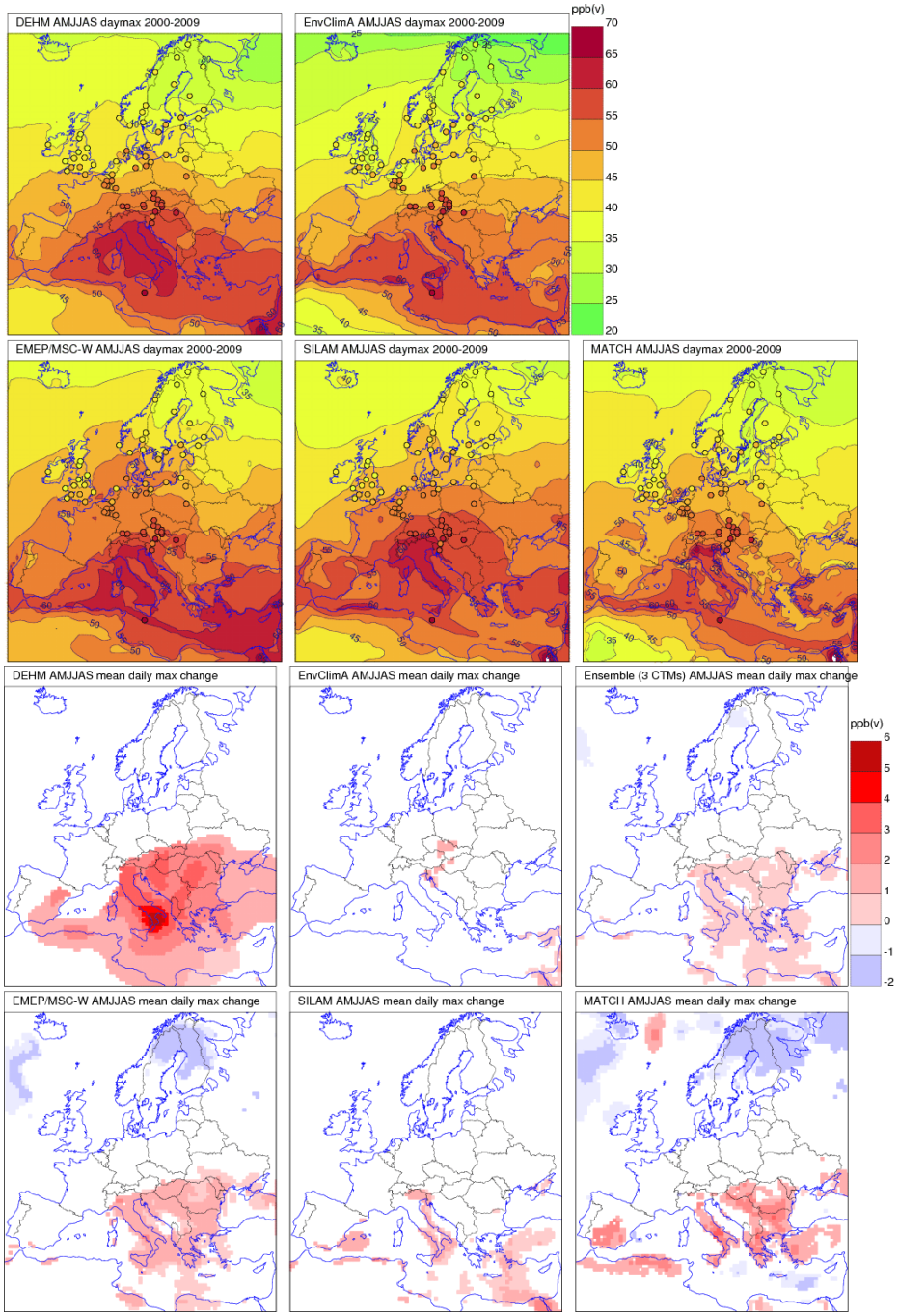


Figure 5: Modelled April-September average daily maximum ozone (a, top), for the period 2000-2009, and (b, bottom) changes in this O_3 predicted using meteorology for 2040-2049 (only statistically significant changes are shown). Results from five CTMs, driven by down-scaled RCA3 climate meteorology for 2000-2009 and 2040-2049. Units are ppb. From Langner et al., 2012a.

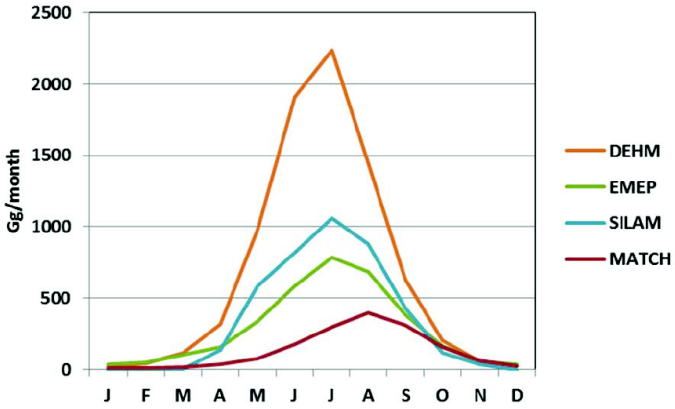


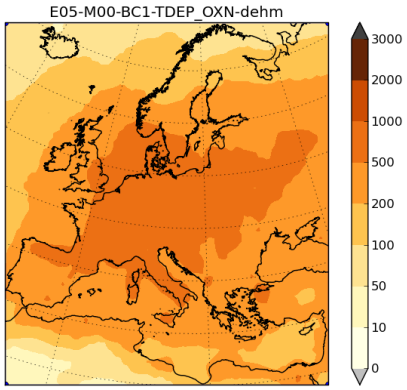
Figure 6: Simulated seasonal variation in biogenic isoprene emissions as an average for 2000–2009 from the models shown in Fig. 5. Units Gg/month. From Langner et al., 2012a.

EnsClim Nitrogen

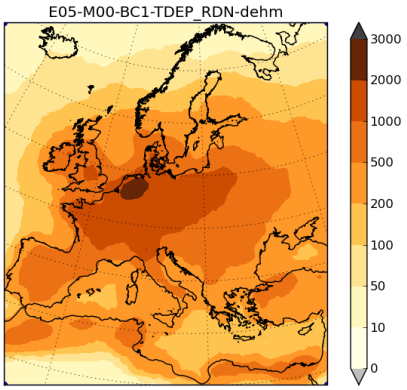
In a second phase of this work, the impacts of climate, emissions, and boundary-condition changes on modelled N-deposition are being investigated using four CTMs (DEHM, EMEP, MATCH, SILAM). This work largely follows the same methodology as for O_3 above, except in three important respects: (i) the emission 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) we have investigated the effects of emissions changes as well as of climate change, and (iii) 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.

Fig. 7 compares DEHM, EMEP and MATCH calculations of oxidised (OXN) and reduced (RDN) N-deposition for the "current" period (1990-2009, with 2005 emissions). The three models show generally similar magnitudes and spatial patterns of N-deposition, but some significant differences also. For oxidised nitrogen, the EMEP model shows somewhat lower levels in north-west Europe compared to DEHM and MATCH, and DEHM shows higher levels of OXN deposition in eastern Europe compared to the other models. For reduced nitrogen, DEHM shows greater deposition loads in much of Europe compared to EMEP and MATCH. The EMEP model's lower deposition amounts in the BeNeLux area may partly be due to assumed zero deposition over agricultural areas; a procedure which is designed to mimic crudely the balance between deposition and soil/crop emissions from such areas.

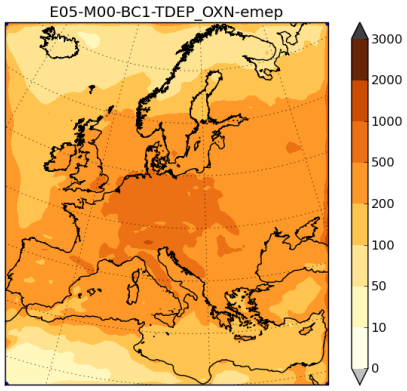
Fig. 8 shows the total Nr depositions of these models for the current years, and the reductions in deposition estimated for the year 2050 situation, taking into account the impact of climate change, and emissions changes on both the European and hemispheric scale. The general level of change in the 3 models is rather similar, with reductions of 300-500 mg(N) m^{-2} across most of the EU region. The MATCH model shows areas of greater change in some NW Europe and north of the Alps. Analysis of the individual contributions of OXN and RDN (not shown) to these changes confirms that reductions in OXN drive the total N-deposition in all models, a simple consequence of the fact that the ECLAIRE emission scenario for 2050 shows dramatic reductions in NOx emissions, but little change in NH_3 emissions, compared to 2005.



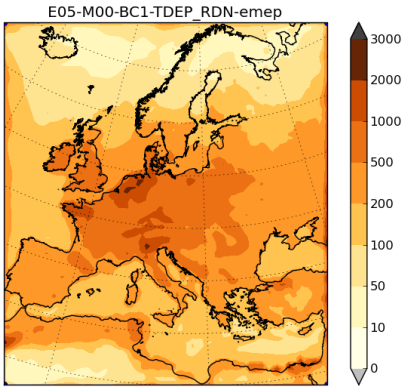
(a) DEHM, TDEP-OXN



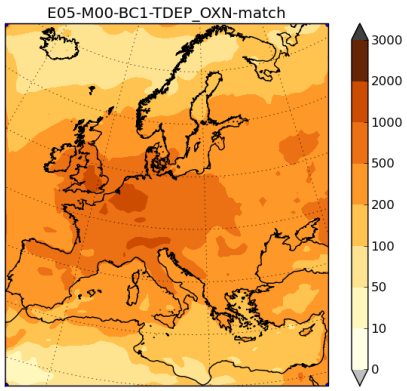
(b) DEHM, TDEP-RDN



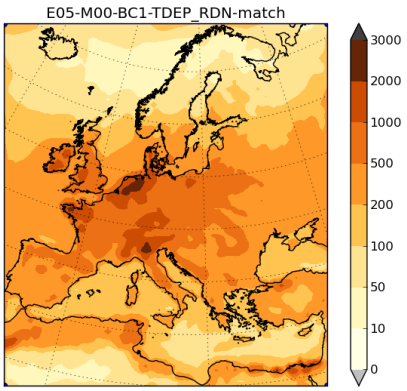
(c) EMEP, TDEP-OXN



(d) EMEP, TDEP-RDN

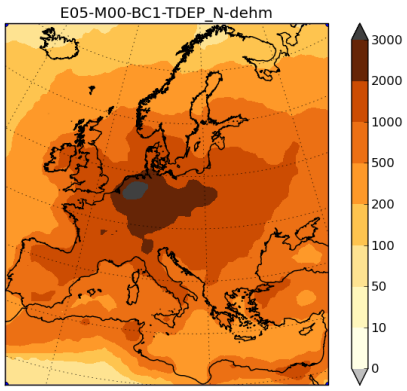


(e) MATCH, TDEP-OXN

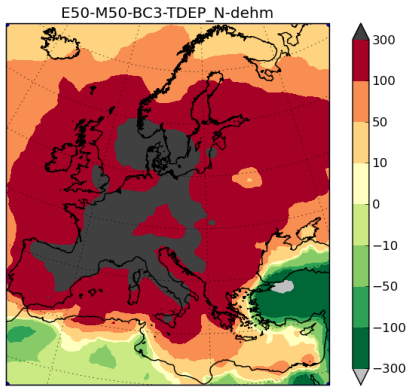


(f) MATCH, TDEP-RDN

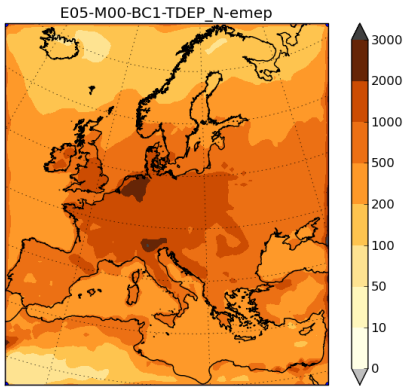
Figure 7: Base-case (1990-2009) calculations of oxidised and reduced N-deposition (OXN, RDN), from three CTMs driven by EnsClim climate model meteorology. Units mg(N) m^{-2}



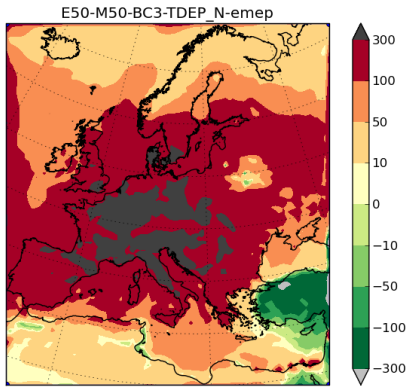
(a) Base case, DEHM



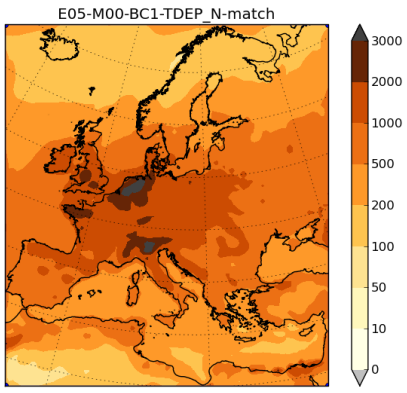
(b) Δ N-dep, DEHM



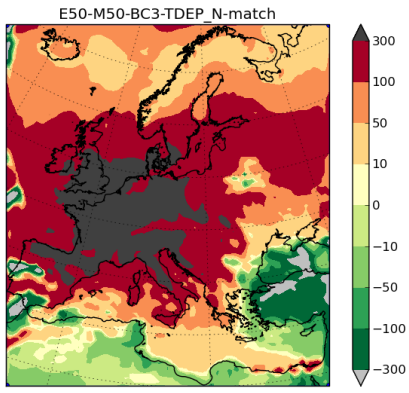
(c) Base case, EMEP



(d) Δ N-dep, EMEP



(e) Base case, MATCH



(f) Δ N-dep, MATCH

Figure 8: Base-case (1990-2009) calculations of total Nr-deposition, and estimated reductions in Nr-deposition for the 2050s (2040-2059) from three CTMs driven by climate model meteorology. Units mg(N) m^{-2}

3.3 Scale-Dep exercise

The "Scale-Dep" (scale dependency) exercise was unique in running a variety of CTM models with consistent emissions at four resolutions, namely 7, 14, 28 and 54 km (approx). Full details are documented in Cuvelier et al., 2013. Much of the Scale-Dep work was aimed at investigating metrics of most importance for human health issues, both in the choice of pollutants (O_3, NO_2 and PM_{10}), and the inclusion of urban and near-urban stations in the evaluation procedure. However, a number of general lessons were learned, and the data collected for this exercise were made available for the ECLAIRE 2009 ensemble study discussed above. Some conclusions from the Cuvelier et al., 2013 can be given:

- Model responses to an increase in resolution show a broadly consistent picture among all models. (CHIMERE was somewhat different because of an urban-area correction.) The grid size does not play a major role for air quality model calculations which are targeted on the determination of the background (non-urban) air quality. Downscaling model resolution does not change concentration estimations and model performance at rural and EMEP sites.
- The grid resolution does play an important role in agglomerations characterized by high emission densities. The urban signal, i.e. the concentration difference between high emission areas and their surroundings, usually increases with decreasing grid size. This grid effect is more pronounced for NO_2 than for PM10, because a large part of the urban PM10 mass consists of secondary components. This part of the PM10 mass is less affected by a decreasing grid size in contrast to the locally emitted primary components.
- As about 70% of the model response to grid resolution is determined by the difference in emission intensities, improved knowledge on spatial variation in emission at high resolution is key for the improvement of modelled urban increments.
- For large scale modelling of rural concentrations and large agglomerations, grid-sizes of ca. 28 km (or if data allows, 14 km) seems to be a good compromise between a pure background (rural) application and an application which captures most of the urban signals. The need for accurate emission data at the appropriate scale was seen as a major limitation to finer scale modelling.

3.4 CityZen inter-comparison

Initiated by the Eu CityZen project, the Colette et al. (2012) study presented a multi-model analysis based on an ensemble of six air quality models (including EMEP and EURAD) covering both regional and global spatial scales. Emission scenarios for the year 2030 were developed in the framework of the Global Energy Assessment, with a focus on climate co-benefits for air quality. One of the scenarios was a baseline, while the other aims to limit global warming to 2°C by the end of the century. The analysis used multi-annual simulations, plus novel downscaling techniques in order to assess exposure changes. Fig. 9 illustrates the base-case ozone calculations from six CTMs. All of the models display a similar geographical pattern

dominated by the land-sea gradient (especially over the Mediterranean) driven by deposition processes. Only BOLCHEM really stands out of the distribution with a much lower ozone background because of higher NO_2 levels, which can be attributed to vertical mixing and heterogeneous chemistry. The magnitude of the local minima over the Benelux hotspot driven by titration processes differs across the models. Further details on ozone and NO_2, and comparison with observations are given in Colette et al. (2012).

A unique feature of the Colette et al. study was the use of a statistical method (CDF-t, see paper for details) to 'correct' model predictions using measured values. This CDF-t method was calibrated with measured and modelled data for current years, and enabled better prediction of metric such as AOT40 or SOMO35 in future years (these metrics are very sensitive to biases because of their use of thresholds, the CDF-t method alleviates this problem).

As an example of the results of this study Fig. 10 shows CDF-t corrected SOMO35 values for 2005 and the two 2030 scenarios. It can be seen here that the CDF-t corrected SOMO35 works very well for the 2005 case, and that the 2030 emission projections lead to substantial decreases in SOMO35.

The GEA scenarios used imply European NOx reductions of about 50% (compared to 2005) in the scenario that includes air quality policies but no measures to mitigate climate change, and about 70% when stringent climate policies are included. Colette et al present results for several metrics, from simple ozone and NO_2 concentrations to metrics for health (SOMO35, Nd120) and ecosystem effects (AOT40c, AOT40dc). The O_3-related metrics SOM35, AOT40c, AOT40dc, are efficiently reduced for both scenarios by 2030. By 2030, SOMO35 levels (average over Europe) were predicted to reach about 80 to 55% of their current value, and these changes were quite consistent across the ensemble (inter-model uncertainty).

As far as the relative change of AOT40 is concerned, the indicators of exposure to detrimental ozone levels of vegetation for crops were estimated in 2030 to reach about 60% and 25% of their present levels for the 'reference' and 'sustainable' scenarios, respectively. The projections for AOT40c were expected to meet the current target (18 000 μg m^{-3} h) for the vast majority of stations but the long term objective (6000 μg m^{-3} h) will likely not be met over most of Europe if climate policies are not enforced. These estimates seem robust both in terms of model spread (ensemble) and model uncertainty (difference between the raw and distribution-corrected estimates). Absolute estimates of AOT40 are very sensitive to the statistical correction but it appears that AOT40 relative changes are less sensitive to model biases.

4 Milestones achieved

MS29: initial ensemble runs for current conditions.

As detailed in this document, the milestone was achieved well within the time-schedule.

5 Deviations and reasons

The original plan for delivery after month 18 was delayed because of the urgent nature of the TFMM Scale-Dep comparison, as well as other intercomparison activities. In compensation,

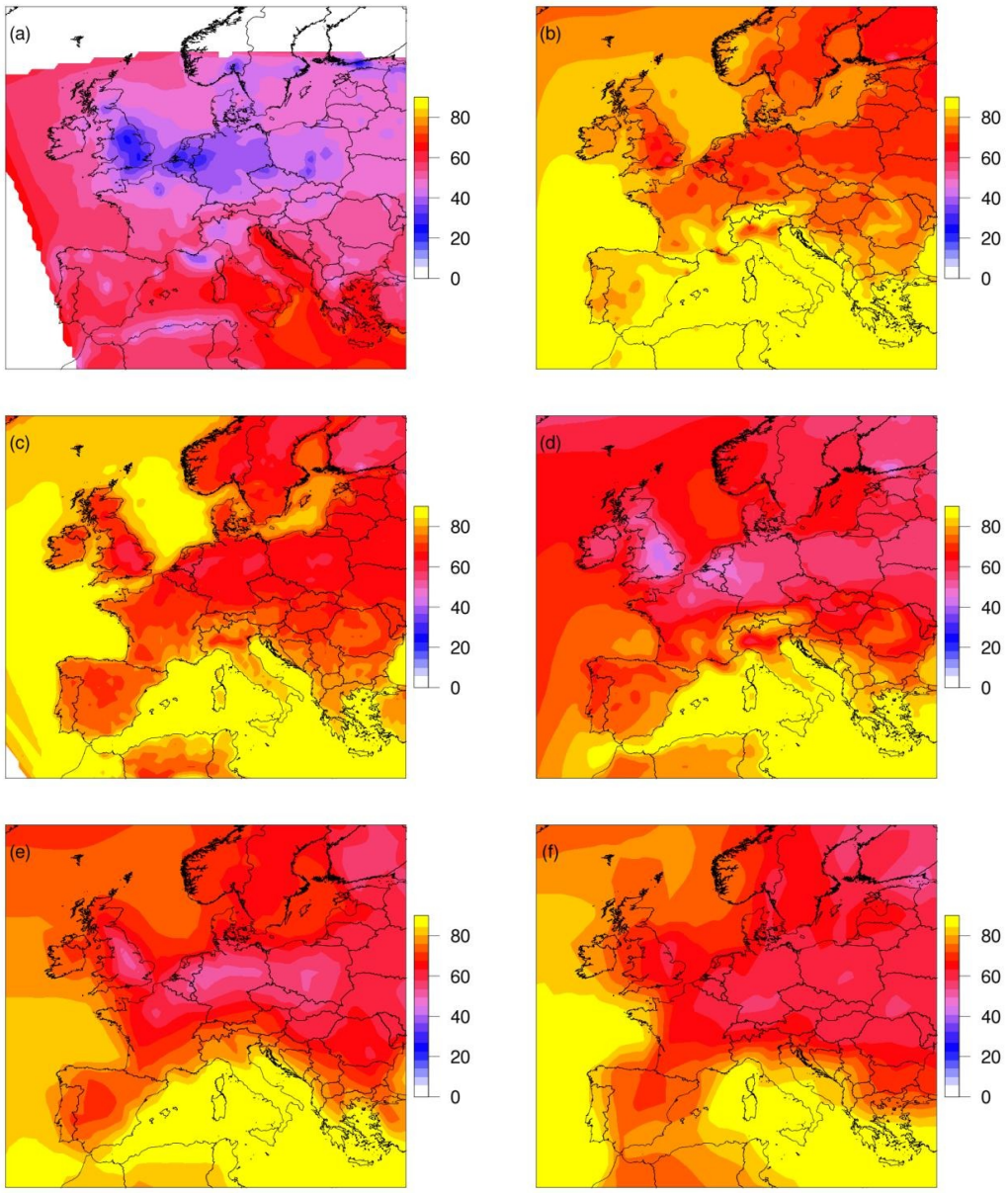


Figure 9: Average summertime (JuneAugust) O_3 (μgm^{-3}) over 10 yr of simulation corresponding to the early 21st century (2005 GEA emissions and 1998–2007 meteorology) for 6 CTMs: (a) BOLCHEM, (b) CHIMERE, (c) EMEP, (d) EURAD, (e) MOZART and (f) OSLOCTM2. From Colette et al., 2012.

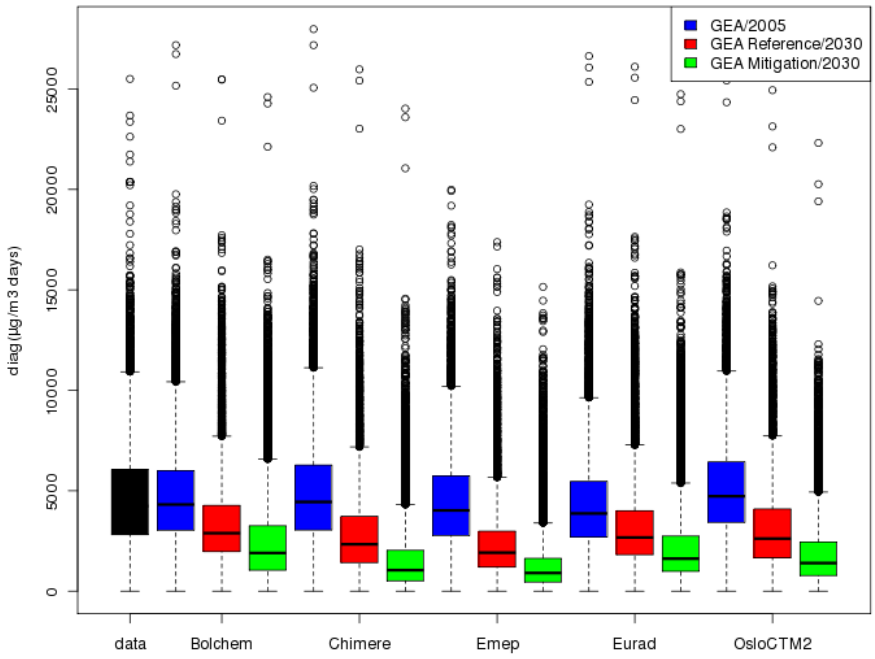


Figure 10: Box and whisker plots of the distribution of SOMO35 (μg m^{-3} days) computed on the CDF-t corrected O_3 time series from five CTMs at the location of AIRBASE stations for the control (GEA/2005) and two scenarios: GEA 'reference' 2030 and GEA 'sustainable' 2030. From Colette et al., 2012.

the ECLAIRE CTMs have now been involved in several different types of comparisons as described above, so a much richer set of results is available.

6 Publications

Colette, A., Granier, C., Hodnebrog, Ø., Jakobs, H., Maurizi, A., Nyiri, A., Rao, S., Amann, M., Bessagnet, B., D'Angiola, A., Gauss, M., Heyes, C., Klimont, Z., Meleux, F., Memmesheimer, M., Mieville, A., Roul, L., Russo, F., Schucht, S., Simpson, D., Stordal, F., Tampieri, F. & Vrac, M. Future air quality in Europe: a multi-model assessment of projected exposure to ozone. **Atmos. Chem. Physics, 2012** *, 12*, 10613-10630

C. Cuvelier, P. Thunis, D. Karam, M. Schaap, C. Hendriks, R. Kranenburg, H. Fagerli, A. Nyiri, D. Simpson, P. Wind, M. Schulz, B. Bessagnet, A. Colette, E. Terrenoire, L. Rouïl, R. Stern, A. Graff, J.M. Baldasano and M.T. Pay, *"ScaleDep: Performance of European chemistry-transport models as function of horizontal spatial resolution", Norwegian Meteorological Institute Report EMEP MSC-W Technical Note 1/2013, Oslo, Norway, 2013.*

Langner, J., Engardt, M., Baklanov, A., Christensen, J. H., Gauss, M., Geels, C.; Hedegaard, G. B.; Nuterman, R.; Simpson, D.; Soares, J.; Sofiev, M.; Wind, P. & Zakey, A. A multi-model study of impacts of climate change on surface ozone in Europe, **Atmos. Chem. Physics, 2012a***, 12*, 10423-10440

Langner, J., Engardt, M. & Andersson, C. European summer surface ozone 1990–2100 **Atmos. Chem. Physics, 2012b***, 12*, 10097-10105

7 Meetings:

As well as annual ECLAIRE/WP7 meetings, the intercomparison exercises have involved:

- 9 Nov. 2012, EnsClim N-deposition, Chalmers, Gothenburg, Sweden.
- 23 Oct. 2012 Meeting of Scale-dep, TNO, Utrecht, Netherlands.
- 14 Feb 2012, EnsClim N-deposition, FMI, Helsinki, Finland.
- 1 Nov. 2011, EnsClim O_3 and N-deposition, DMI, Copenhagen, Denmark.
- 12 Oct. 2010, EnsClim O_3, SMHI, Nörrköping, Sweden.

Plus several tele-meetings.

8 List of Documents/Annexes:

See Publications above.