A. Colette (INERIS), C. Granier (CNRS/IPSL/NOAA), Z. Klimont (IIASA),
Ø. Hodnebrog (CICERO), H. Jakobs (FRIIUK), A. Maurizi (CNR/ISAC),
A. Nyiri (met.no), M. Amann (IIASA), B. Bessagnet (INERIS), A. D'Angiola (CNRS),
M. Gauss (met.no), C. Heyes (IIASA) F. Meleux (INERIS), M. Memmesheimer (FRIUUK),
A. Mieville (CNRS), S. Rao (IIASA), L. Rouïl (INERIS), F. Russo (CNR/ISAC),
S. Schucht (INERIS), D. Simpson (met.no), F. Stordal (UiO), F. Tampieri (CNR/ISAC), M. Vrac (CNRS)

Future Air Quality in Europe: a multi-model assessment of projected exposure to ozone

Abstract :

In order to investigate future air quality in Europe, the **anthropogenic emissions scenarios** developed in the framework of the **Global Energy Assessment** were implemented in **six regional and global atmospheric chemistry transport models**.
Besides the analysis of emission projections, a strong focus is dedicated to the assessment of the **robustness of the projected concentrations of air pollutants**. The present work relies on an ensemble of chemistry transport models giving insight into the model spread. Both regional and global scale models were involved, so that the ensemble benefits from high-resolution approaches as well as accounting for long range transport. For each scenario a whole decade was modeled in order to gain statistical confidence in the results. A statistical downscaling approach is used to compensate for the biases of the models in the projection. Last, the modeling experiment was associated to a hindcast study, where the performances of the model were extensively documented.
The analysis is presented in an **exposure-based framework** in order to discuss policy relevant trends. According to the emission projections, ozone precursors such as **NOx will decrease down to about 60% to 35% of their current levels**. A slight increase of annual mean O3 will result in some places but the O3 burden will decrease substantially. **Exposure to O3 and hence detrimental effects for health and ecosystems will also be significantly reduced.** This reduction is stronger for the scenarios representing a stringent climate policy illustrating the **co-benefits of climate policy for air pollution**. The magnitude of the change varies with the metric. For instance, the **number of days of exceedance of the information threshold is expected to be divided by 2 to 4, depending on the scenario.** The number of stations where the current target is not met will drop from 45% to 6-12%, depending on the scenario.

Emission Projections

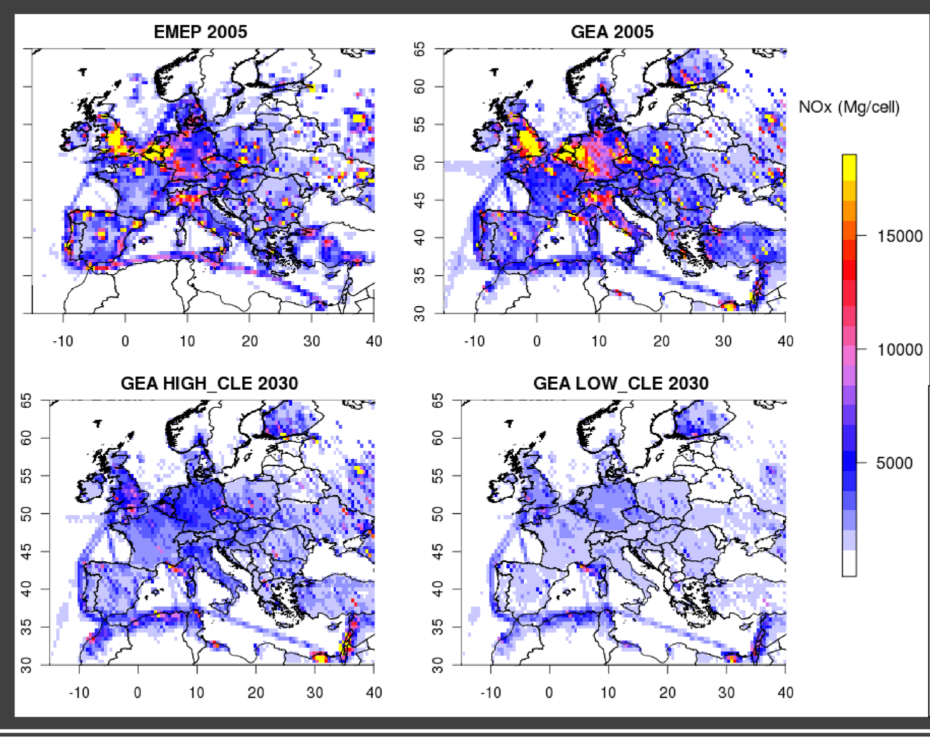
We implement the projections developed in the framework of the Global Energy Assessment (Riahi et al. 2012). They rely on the MESSAGE model of energy use combined with GAINS emission factors to derive emissions of atmospheric pollutants. A special focus was attributed to the representation of air pollution control policies in the development of the GEA projections.

Two scenarios are selected here:

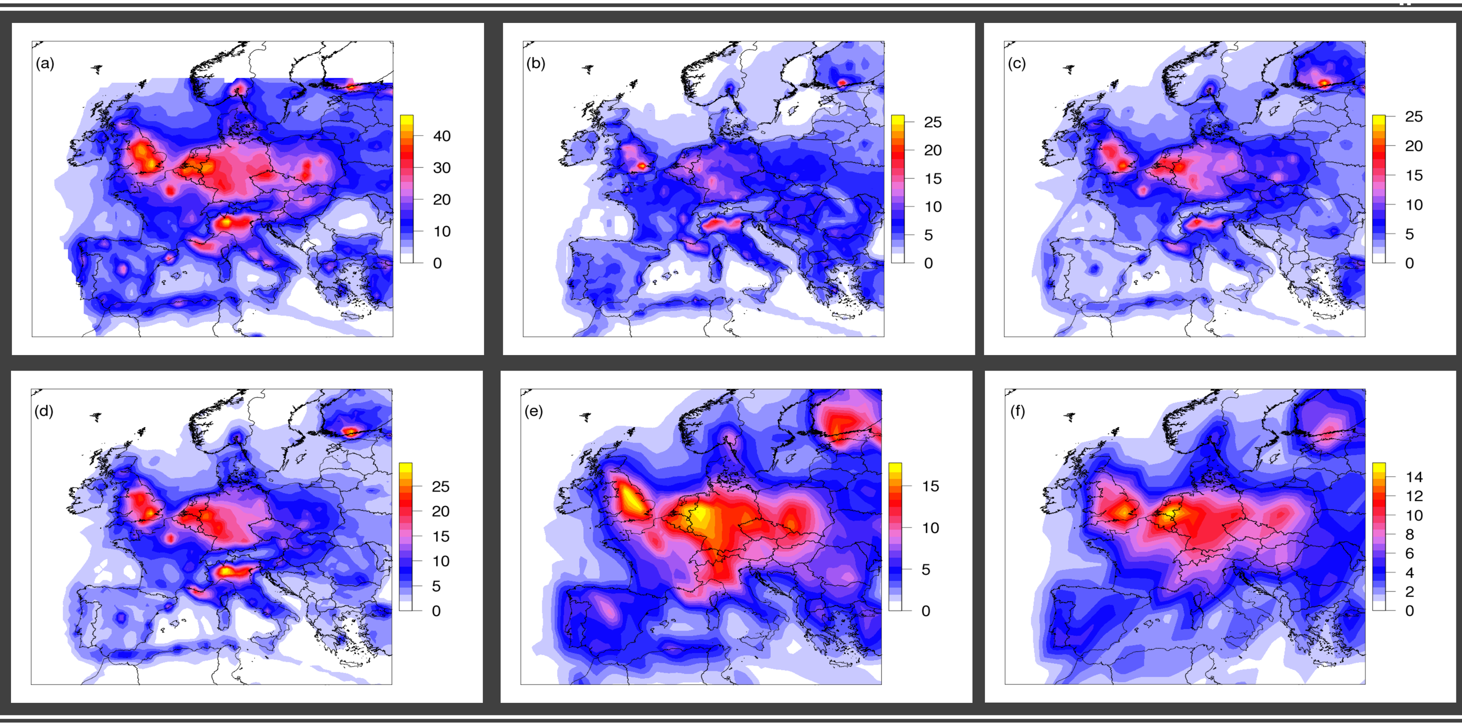
- Reference (HIGH_CLE). Includes all current and planned AQ Legislation until 2030. No policies on climate change and energy access. The climate response in 2100 is comparable to the RCP8.5 in terms of global radiative forcing.
- Sustainable Climate Policy (LOW_CLE). Includes all current and planned AQ Legislation until 2030. Underlying global climate change policy aiming at limiting global warming to 2 degrees C by 2100.

Total annual emissions (Mg/yr) of NOx and non-methane VOCs aggregated over Western Europe in the EMEP inventory for 2005 as well as in the gridded GEA emission projections for 2005 reference year), and 2030 under two scenarios : HIGH_CLE and LOW_CLE.

Pollutant	EMEP_2005	GEA_2005	GEA_2030 HIGH_CLE	GEA_2030 LOW_CLE
NOx	11403072	13127693	6543700	4051497
NMVOC	9364555	9582826	5016072	3471908



Total annual NOx emissions (Mg/cell) according to the EMEP inventory for 2005 as well as in the gridded GEA emission projections for 2005 (reference year), and 2030 under two scenarios : HIGH_CLE and LOW_CLE.



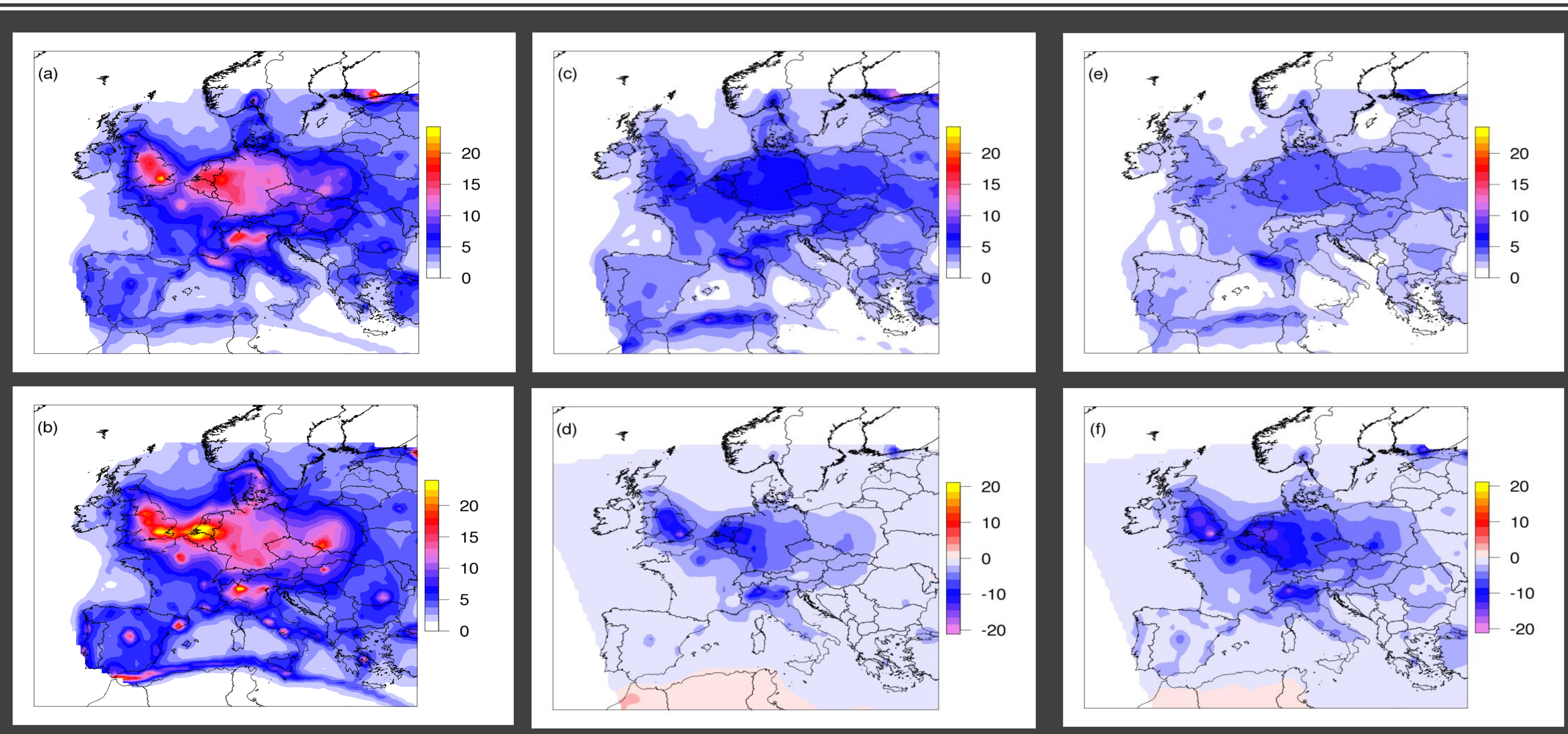
Average NO2 (µg/m3) over 10 years of chemistry transport modelling simulation corresponding to the **early 20th century** (2005 GEA emissions and 1998-2007 meteorology)

Model Setup:

- CTMs involved in the study:
  - Regional: BOLCHEM, CHIMERE, EMEP, EURAD
  - Global: MOZART, OSLOCTM2
- 10-yr simulation using present-day meteorology
- Setup validated in a hindcast experiment with the same ensemble (Colette et al. 2011).

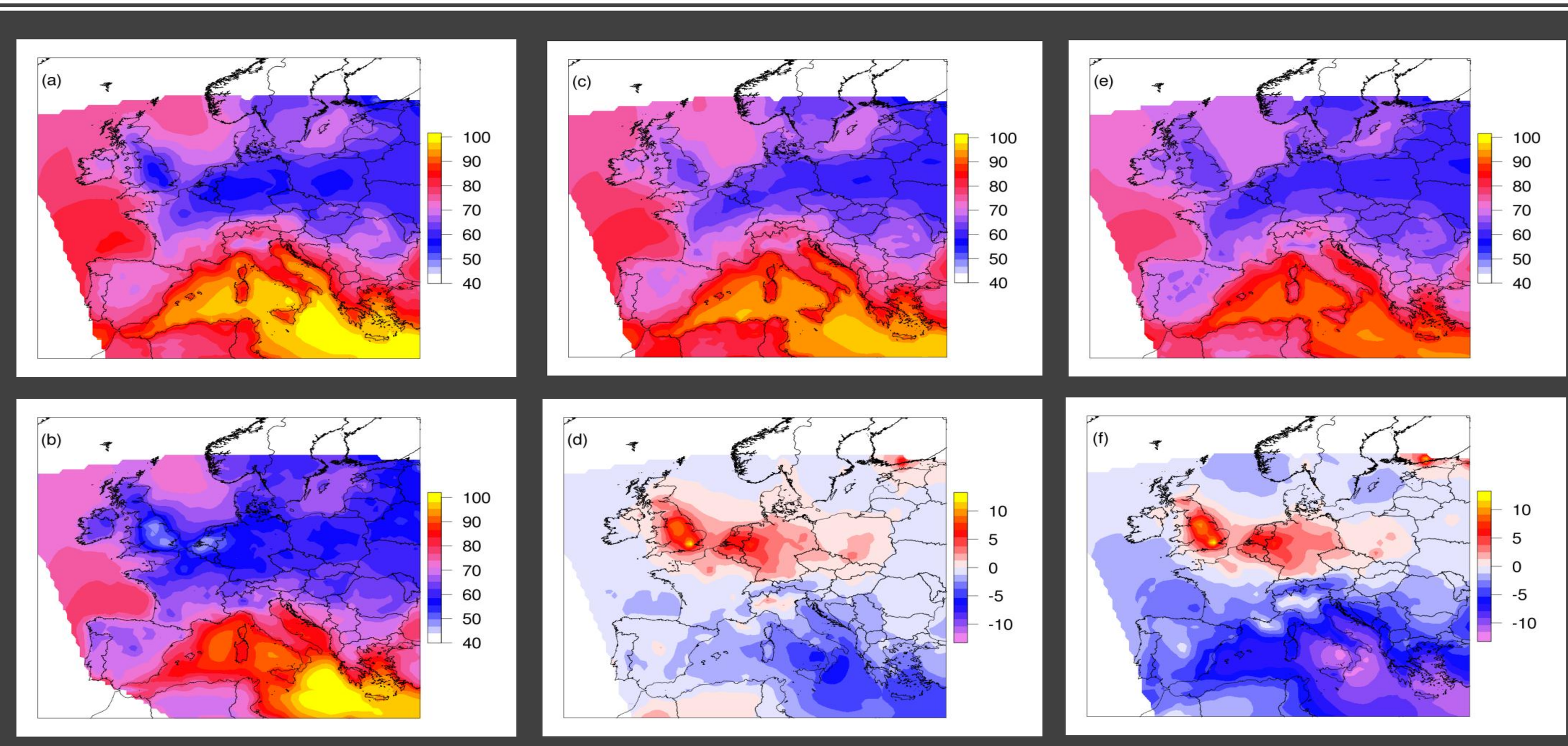
Results:

- The main geographical patterns are consistent for all types of models
- Systematic underestimation of global CTMs, overestimation of one regional CTM.



(a,b,c,e) : Ensemble median of **average NO2 (left) and O3 (right)** concentrations (µg/m3)
(a) GEA 2005,
(b) EMEP 1998-2007,
(c) HIGH_CLE 2030,
(e) LOW_CLE 2030.

Panels (d) and (f) give the difference between:
HIGH_CLE 2030 and 2005
LOW_CLE 2030 and 2005



NO2 change:

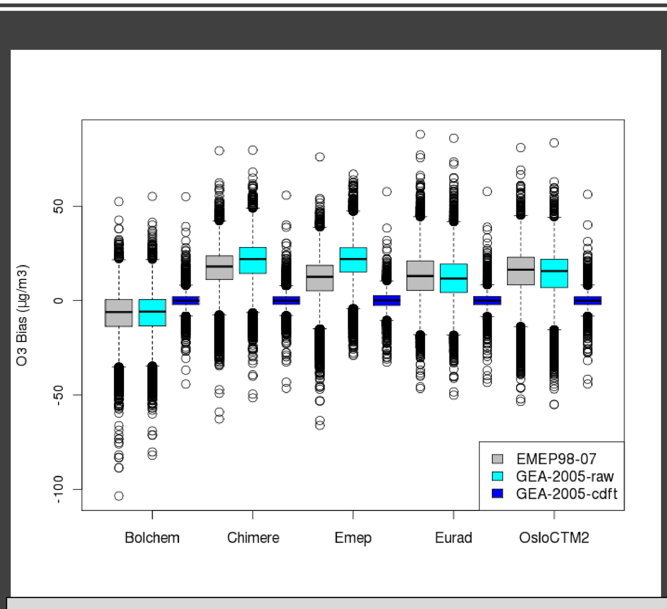
- Emission hotspots are less pronounced with the GEA emissions than with the EMEP data for present-day conditions
- The decrease of NO2 levels is very strong for both scenarios
- The cobenefit (additional relative decrease) brought about by the climate policy is 50%; an identical figure than when using raw emissions.

O3 change:

- Annual mean O3 increases over NOx-saturated areas. Colette et al. 2011 showed that the modeled trend at the continental scale were mostly representative of rural areas.
- Europe-wide aggregated O3 decreases. The cobenefit brought about by the climate policy (comparing HIGH_CLE and LOW_CLE) is larger than 100%.

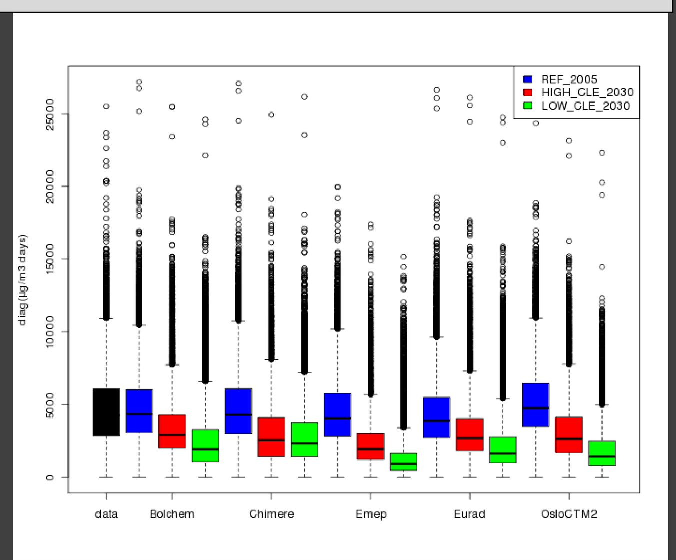
Downscaled exposure to O3:

- A probabilistic downscaling (CDF-t) is applied to match the distribution of modeled time series to monitoring stations.
- Biases are significantly reduced over the control (present-day) simulation.
- The estimates of exposure indicators (here SOMO35) are more robust, giving confidence in the projected changes



Box and whisker plots of the distribution of O3 model biases (µg/m3) when using historical emissions (EMEP 1998-2007), in the raw control simulations with GEA anthropogenic emissions for 2005 (GEA/2005 raw) and after the CDF-t quantile correction (GEA/2005 CDF-t)

Box and whisker plots of the distribution of SOMO35 (µg/m3.days) computed on the CDF-t corrected O3 time series at the location of AIRBASE stations for the control (GEA/2005) and the two 2030 scenarios : GEA HIGH_CLE/2030 and GEA LOW_CLE/2030 .



		GEA 2005	HIGH_CLE 2030	LOW_CLE 2030	HIGH_CLE_2030 /GEA_2005	LOW_CLE_2030 /GEA_2005
SOMO35	Raw	5760(23)	4052(29)	2929(52)	69.5(9)	48.8(17)
(µg/m3)	CDF-t	4264(8)	2541(14)	1642(32)	59.7(9)	38.6(12)
AOT40c	Raw	20165(26)	10373(44)	5880(100)	49.7(12)	25.9(20)
(µg/m3.hr)	CDF-t	15528(21)	6783(37)	3678(67)	42.4(12)	22.6(15)
AOT40df	Raw	34907(26)	19226(41)	11156(88)	53.5(11)	29(19)
(µg/m3.hr)	CDF-t	25968(10)	12108(22)	6622(52)	46.3(8)	25.1(12)
MTDM	Raw	147(10)	124(11)	113(16)	84.1(4)	76.4(7)
(µg/m3)	CDF-t	153(1)	128(4)	115(9)	83.4(4)	75.4(7)
Nd120	Raw	23.2(49)	8.4(93)	5.2(118)	30.8(16)	19.7(15)
(days)	CDF-t	22.8(7)	7.2(39)	4(64)	31.4(12)	17.3(11)

Exposure indicators at the location of air quality monitoring stations. Modelled ozone exposure indicators before (raw) and after (CDF-t) applying the statistical downscaling for the control (2005) and projections for 2030: HIGH_CLE and LOW_CLE. First 3 columns: mean over all models, the proxy for each model being the median of the distribution of each indicator at each station and for 10 years. The number in brackets are the coefficient of variation (in %). Last two columns : ratio between scenario and references (in %) and the standard deviation of this ratio in the ensemble, in brackets.

- Anthropogenic emission of O3 precursors are estimated to be reduced very efficiently by 2030 according to the projections of the Global Energy Assessment
- Using an exposure-based framework and a statistical downscaling approach, we could increase the relevance of future projections for policy relevant issues.
- As a result annual mean O3 will decrease globally over Europe, with isolated areas where increases are found in relation with the NOx titration effect.
- According to the current European regulation, maximum daily ozone should not exceed 120µg/m3 more than 25 days a year. In the control simulation representing current conditions, this limit is exceeded at 45% of the stations. This figure will be divided by 2 to 4, with the HIGH_CLE and LOW_CLE scenarios, respectively.
- Other indicators also exhibit significant decreases: SOMO35 levels in 2030 will be only 60 to 80% of its present level depending on the scenarios. For AOT40, the magnitude of the change is 30 to 60%.

References

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