Contributions of road traffic emissions to tropospheric ozone on global and regional scale

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I) Motivation

Road traffic is an important anthropogenic source for carbon monoxide (CO), non-methane hydrocarbons (NMHCs) and nitric oxides (NO_x). These trace gases act as precursors for tropospheric ozone. Ozone chemistry is highly non-linear and strongly depends on the background atmosphere, which significantly differs in rural and urban areas. However, current global Chemistry-Climate-Models (CCMs) with their coarse resolutions mix emissions from rural and urban areas within one gridbox, similar as in the example of Fig 1.
Due to the nonlinearity this can lead to different ozone production rates compared to high resolution models. Therefore we investigate the effect of the horizontal resolution on complex ozone diagnostics. The focus of our work is the contribution of road traffic emissions, which we quantify using a tagging technique.

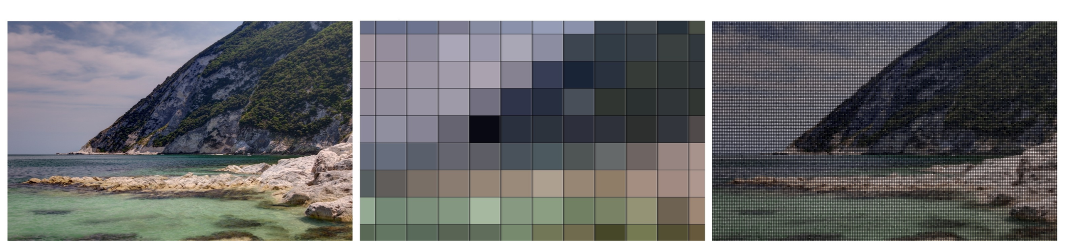

Fig. 1: Adriatic coastline; left original picture, middle "global" and right "regional" resolution. The coarse global resolution leads to a mixing of colors from many pixels.

II) MECO(n) Model System

MECO(n) stands for **M**ESSy-fied **E**CHAM and **CO**SMO models nested **n**-times and combines:

- The global atmospheric chemistry model EMAC

- The regional scale climate and atmosheric chemistry model COSMO/MESSy

MESSy (**M**odular **E**arth **S**ubmodel **Sy**stem) is an interface, which couples processes and diagnostics (as submodels) to different base models;

The same formulation of processes (i.e. submodels) running with different basemodels leads to a highly consitent model chain on different scales.

The coupling between EMAC and COSMO/MESSy is done on-line. Therefore the boundary data must not be stored on disk, but is exchanged directly online via the MMD (**M**ulti **M**odel **D**river)-library (Kerkweg & Jöckel, 2012).

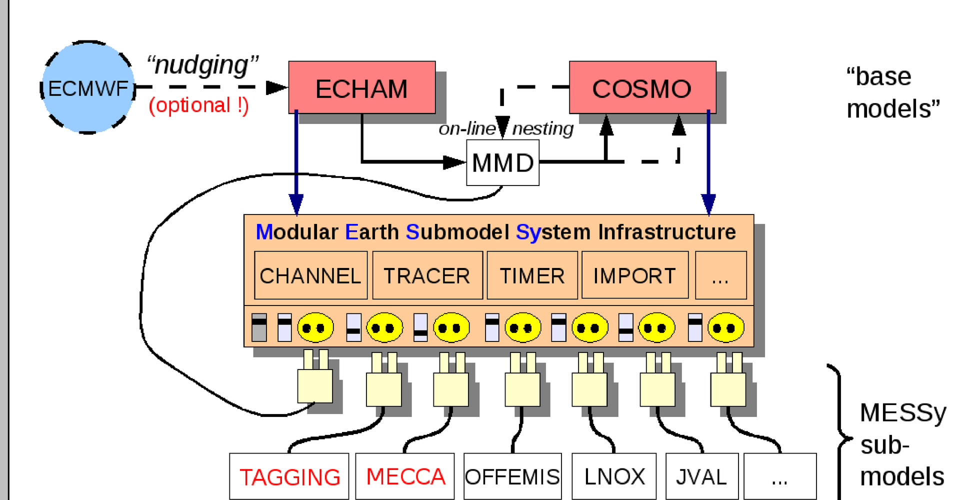

Fig.2: Blockchart of the MECO(n) model system. The individual submodels can be switched on/off in each instance.

III) Tagging method

We implemented the tagging method described by Grewe, 2013 and Grewe at al. ,2010, which is an accounting system following the relevant reactions. Tagged are O_3, No_y, NMHCs, PAN and CO for ten different sectors (i.e. road traffic, ship etc.).

Simple example (HNO_3 formed by sector j):

$$OH + NO_2 \rightarrow HNO_3 \longrightarrow \frac{\partial HNO_3}{\partial t} = \kappa OH \cdot NO_2 = P_{HNO_3} \longrightarrow \frac{\partial HNO_3^j}{\partial t} = \frac{1}{2} P_{HNO_3} \left(\frac{OH^j}{OH} + \frac{NO_2^j}{NO_2} \right)$$

IV) Model Setup

- EMAC in T42L31ECMWF (~ 2.8°; ~ 300 km; up to 10 hPa); timestep 720 s; nudged towards ECMWF operational analysis data
- COSMO/MESSy with 0.44° resolution (~50 km; up to 22 km); timestep 240 s; on-line coupled with new boundary data every 720 s
- MACCity emission dataset for anthropogenic emissions (Granier et al. ,2011)
- Biogenic and lightning emissions calculated in EMAC and transformed to regional domain
- TAGGING and MECCA Atmospheric Chemistry Module (Sander et al. ,2005) running globally and regionally

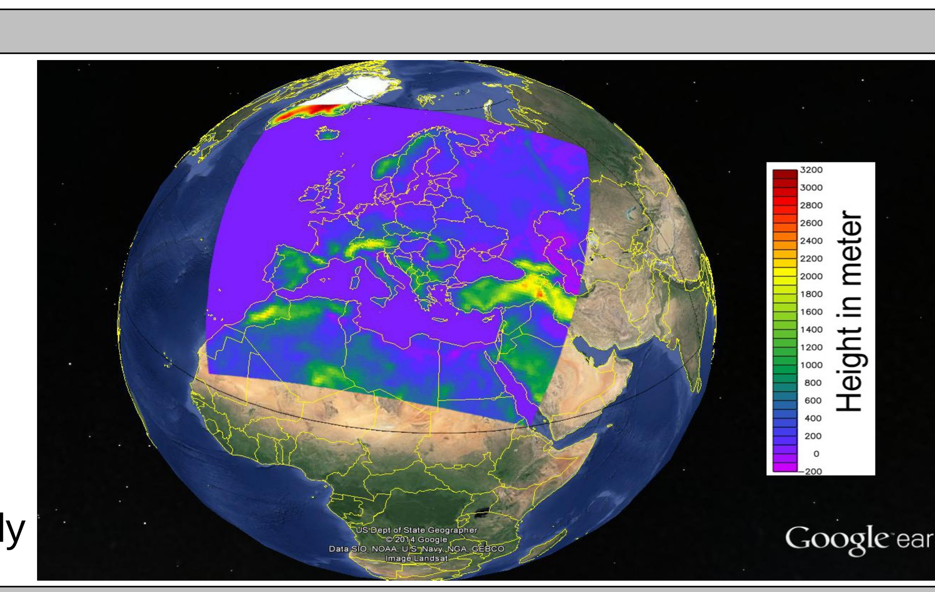

Fig 3: Model domain of the COSMO instance. Displayed is the topography.

V) First steps of the chemical evaluation

The higher resolution of COSMO/MESSy results in a much more detailed ozone distribution compared to EMAC. Compared to observations of ground-level ozone in **January 2008** (see Fig. 4) we see a better agreement especially over Southern France.

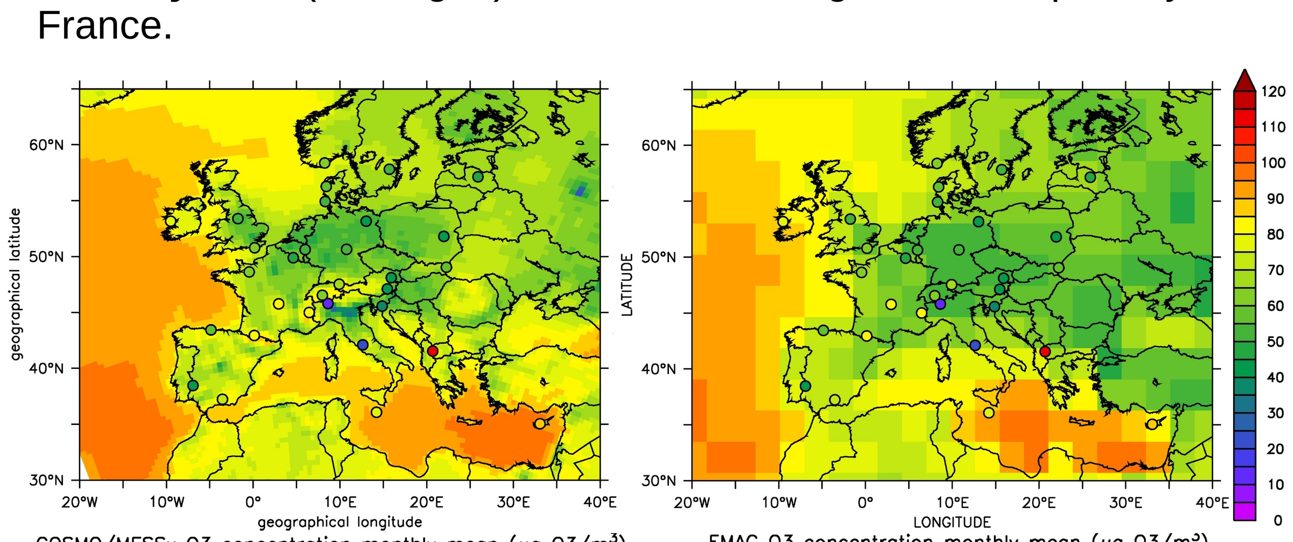

Fig 4: Ground-level ozone concentration as monthly mean for January 2008. Colored dots show measurements (source: ebas.nilu.no).

In **May 2008** (see Fig.5) COSMO/MESSy gives a better agreement over England, Germany and France. However we observe too high ozone concentrations over Northern-/Eastern Europe, which are only present in the planetary boundary layer. **Reason**: Chemistry? Dynamics? Overall there is a positive ozone bias, which will be investigated with different boundary conditions.

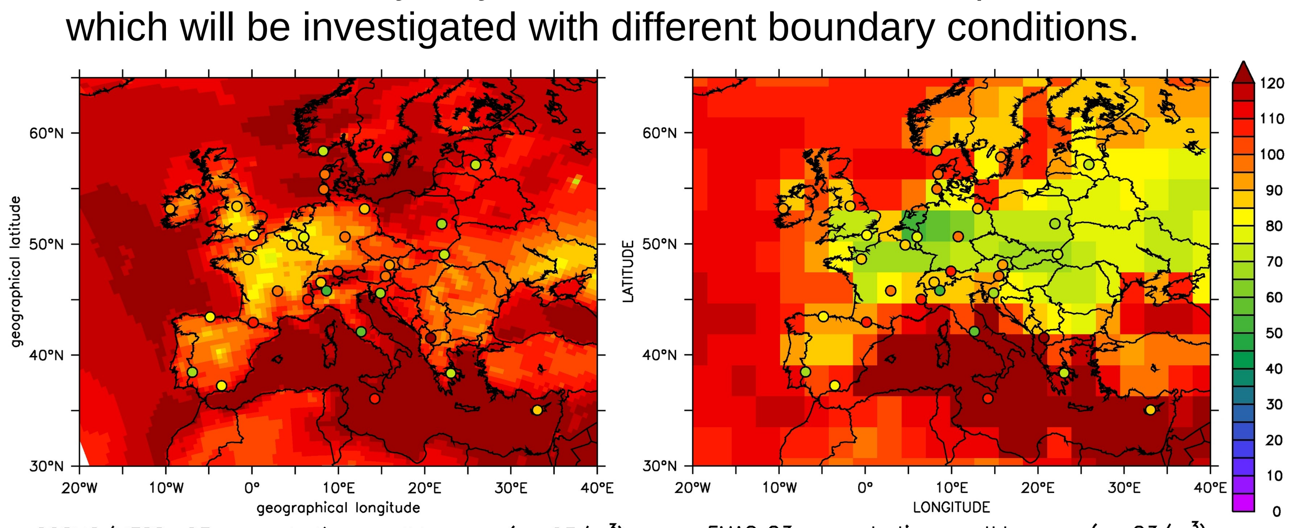

Fig 5: As Fig.4 but for May 2008.

VI) First results

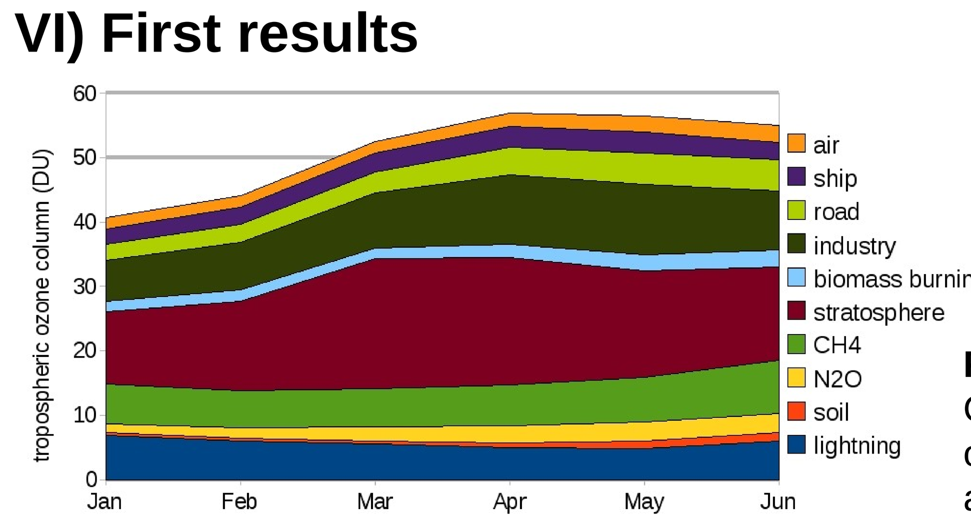

Fig. 6: Contribution to the tropospheric Ozone column (defined up to 200 hPa) of the different sectors for the European area (COSMO/MESSy).

Fig. 6 shows the contribution of the tagged sectors to the tropospheric ozone column. Enhanced photochemistry roughly doubles the contribution of the road sector (5 DU) and industry (11 DU) in June, compared to January. The stratospheric contribution peaks in March (~20 DU). The results of EMAC for the same area are comparable, but the impact of stratospheric ozone is lower in general by ~ 1-3 DU.

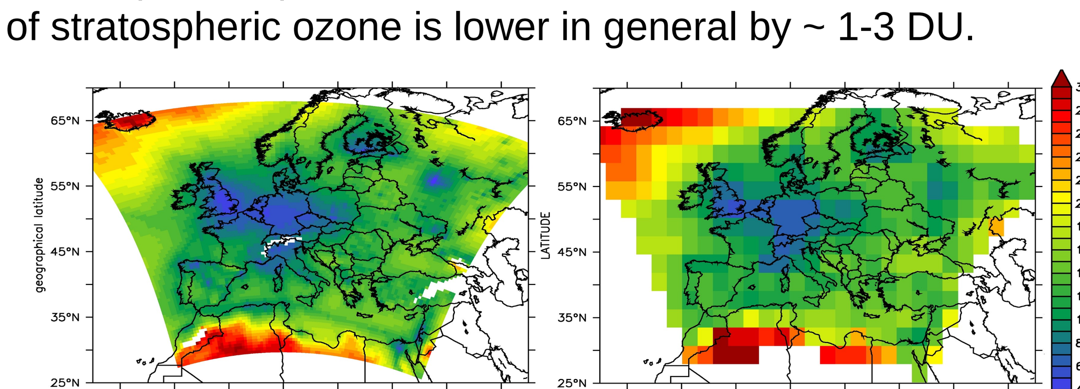

Fig. 7: ozone production efficiency in May 2008 for COSMO/MESSy (left) and EMAC (right). Averaged values up to 850 hPa.

The ozone production efficiency, defined as $\epsilon = \frac{\kappa_1 HO_2 \cdot NO}{\kappa_2 OH \cdot NO_2}$, gives the ratio of produced O3 molecules to consumed NO_x molecules. The comparison (Fig. 7) shows, that the overall pattern in COSMO/MESSy and EMAC look similar. However, the finer resolution reveals more details (e.g. lowered efficiency over the main ship tracks). Generally, COSMO/MESSy shows slightly higher efficiency over North-/East Europe. For the other months between Jan-Jun 2008 we see almost identical patterns (as the NO_x hotspots does not change).

VII) First conclusions

- model chain with MECO(n), MECCA and TAGGING is technically working, allowing a direct comparison of global and regional effects
- comparison with observations benefits from increased resolution
- first simulations suggest, that the contribution of the sectors over the European area doesn't change significantly going from 2.8° - 0.44° resolution

VIII) Outlook

- further evaluation and detailed analysis of TAGGING results
- reason for too high ground-level ozone concentrations in May 2008 will be analyzed
- regional emissions database will be tested (ozone bias)
- calculation of lightning and biogenic emissions in COSMO/MESSy
- Further increase of resolution

IX) References and Acknowledgement

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