Impact of road traffic emissions on tropospheric ozone

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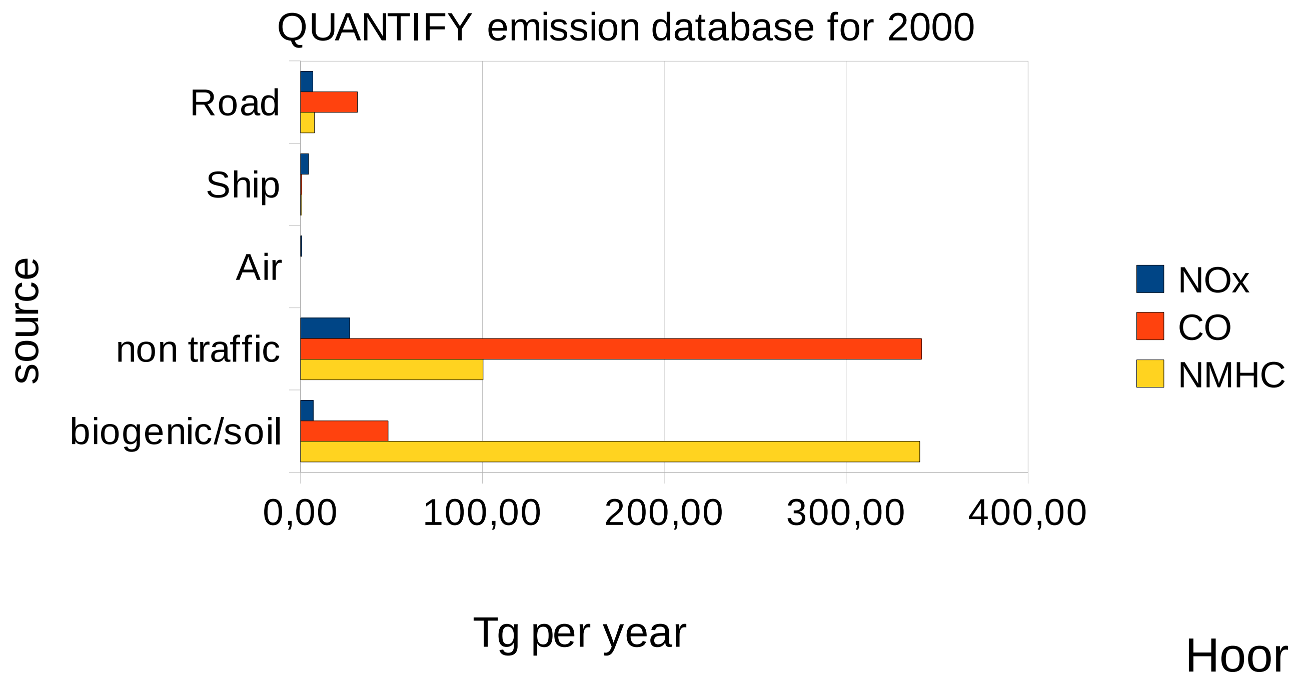
Aim of this study

- What is the contribution of road traffic emissions on the production of ozone in the troposphere over Europe (Germany)?
    - Impact of different resolutions
    - Evaluation of mitigation strategies

- Why ozone?
    - Tropospheric ozone has noxious effects
        - Negative effects on plants and other creatures
    - Ozone acts as greenhouse gas in the troposphere

Road traffic emissions

- Emitted NO_x, CO and NMHC emissions are precursors of ozone
- Road traffic is an important source of anthropogenic emissions



Hoor et al. 2009

Tropospheric ozone chemistry

- Photochemical cycle with NO_x as a catalyst

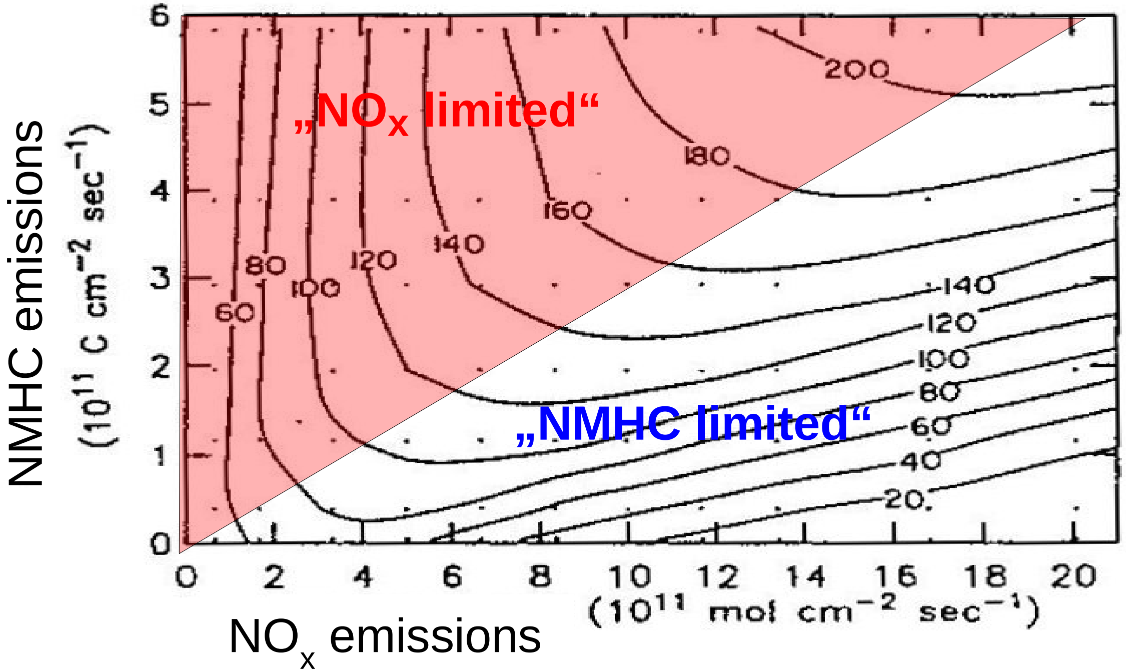
$$NO_2 + h\nu \rightarrow NO + O$$

$$O_2 + O + M \rightarrow O_3 + M$$

$$NO + O_3 \rightarrow NO_2 + O_2$$

- Radicals from CO/NMHC oxidation can affect this cycle, leading to NO_2 production from reactions of NO and oxidation products without destroying O_3

Tropospheric ozone chemistry is strongly non linear



Ozone (nmol/mol) as a function of anthropogenic NO_x and NMHC emissions for a regional model of the USA.
Sillman et al. 1990

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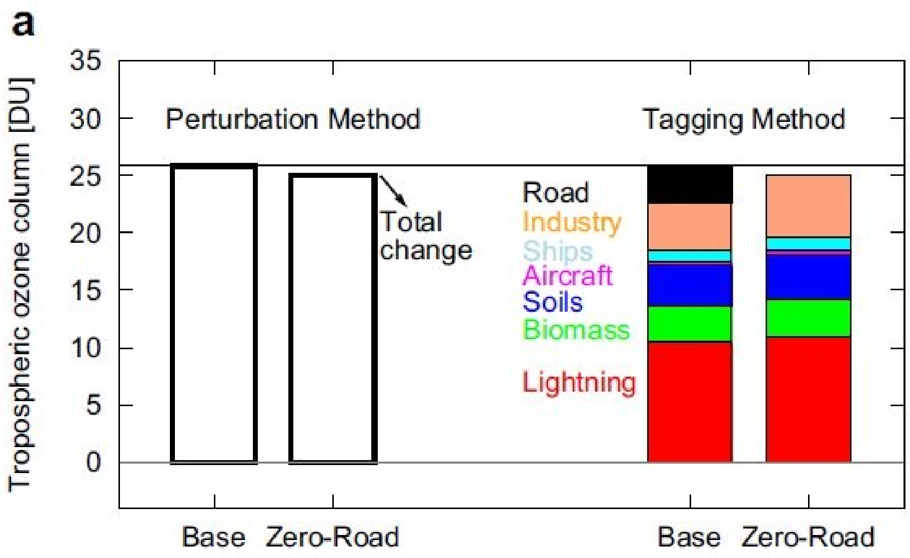
Quantifying the contribution of different sources

- Perturbation approach: Comparison between a base simulation and a simulation with changed emissions
  - Taylor approximation with a linearization around base simulation assuming same chemical background in booth simulations
- Tagging approach: Accounting system following the relevant reaction pathways

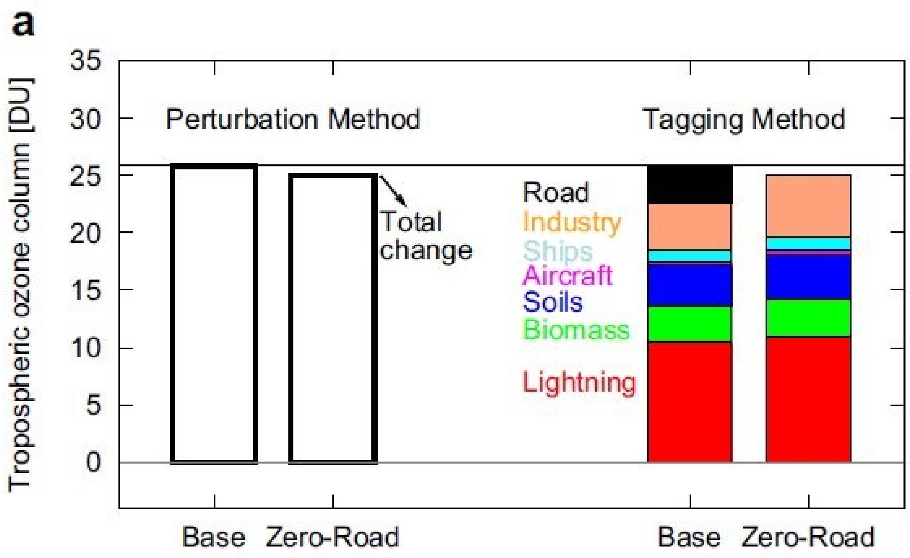


Grewe at al. 2012

Quantifying the contribution of different sources

- Perturbation approach only suitable to investigate the effect of reduced/increased emission scenarios

- Tagging approach suitable to quantify the contribution of a certain emission sector



Grewe at al. 2012

Details of the tagging method

- The basic idea: Track the reaction path of the species from different sources

emissions

$$\frac{\partial}{\partial t}\vec{x} = \vec{P}(t) + \vec{F}(\vec{x})$$

reactions

- Contribution of a certain sector (j) on a specie (i) [for details see Grewe 2013]

$$\frac{\partial}{\partial t} x_i^j = P_i^j(t) + F_i(\vec{x}) \frac{\vec{x}^{j^T} \nabla F_i(\vec{x})}{\vec{x}^T \nabla F_i(\vec{x})}$$

- Simple example:

$$OH + NO_2 \rightarrow HNO_3$$

$$\frac{\partial HNO_3}{\partial t} = \kappa\, OH \cdot NO_2 = P_{HNO_3}$$

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

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Details tagging submodel

- Diagnostic species added to chemical system to calculate production and loss rates
  - With these (and the known emissions) the tagging DGL can be solved

- Problem: Number of different species is very high. To keep memory demand feasible a family approach is chosen (see Grewe 2004)
  - **NMHC and NO_y treated as families**

- **5 tagged species**: O3, NO_y, NMHC, CO and PAN
- **10 tagged categories**: Lightning, biomass burning, industry, traffic, ship, aviation, N2O degradation, CH4 degradation and impact from stratosphere
  - 50 additional tracers for tagging

- Computational costs approx 15% of total walltime

- **Tagging increases largely the demand for memory, but computational costs only slightly**

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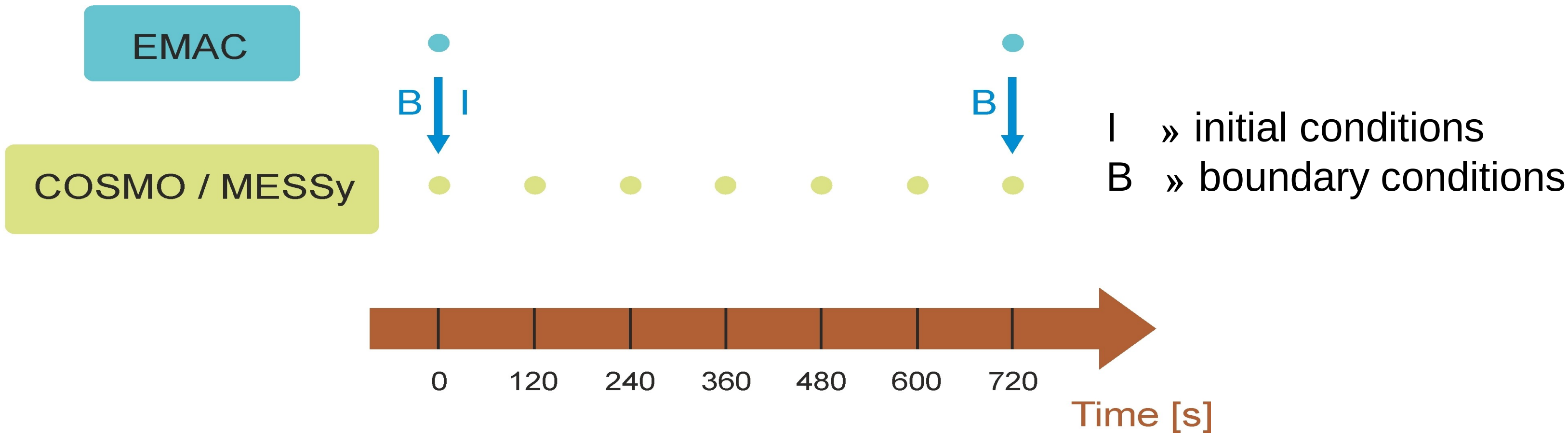
Details of the model system

- MECO(1) setup (Kerkweg & Jöckel 2012a/b)
    - Global EMAC instance with T42L31ECMWF (up to 10 hPa)
    - COSMO/MESSy nest over Europe with 0.5x0.5°resolution
        - 1 way on line coupled
        - tagging submodel working global and regional

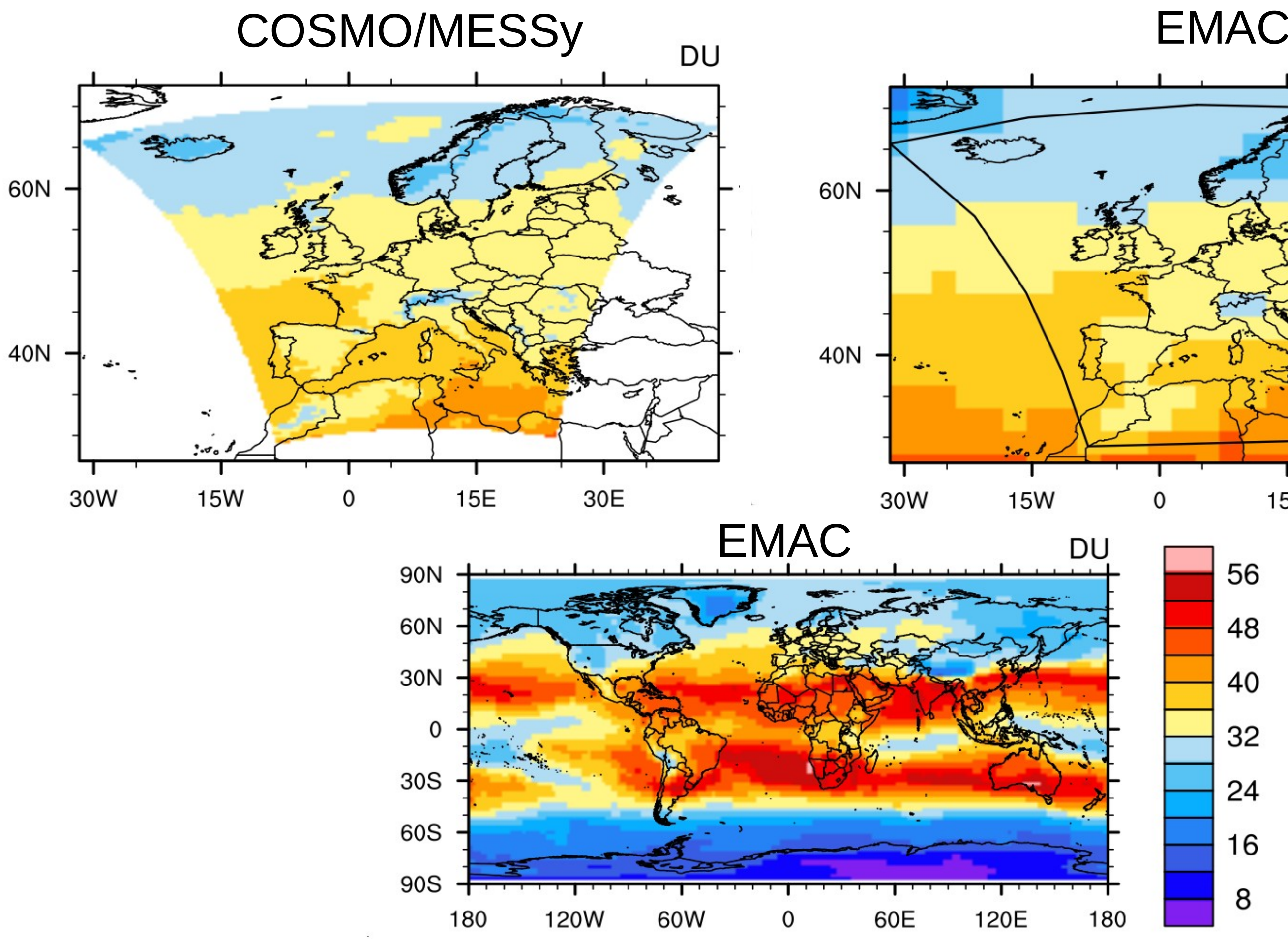


Details of the model system

- Setup is based upon the REFC1 setup for ESCiMo consortia simulations[1]
    - detailed atmospheric chemistry module MECCA (Sander et al. 2005)
    - CCMI emission dataset for anthropogenic emissions (0.5° resolution)
    - EMAC instance is nudged with ECMWF operational analysis data

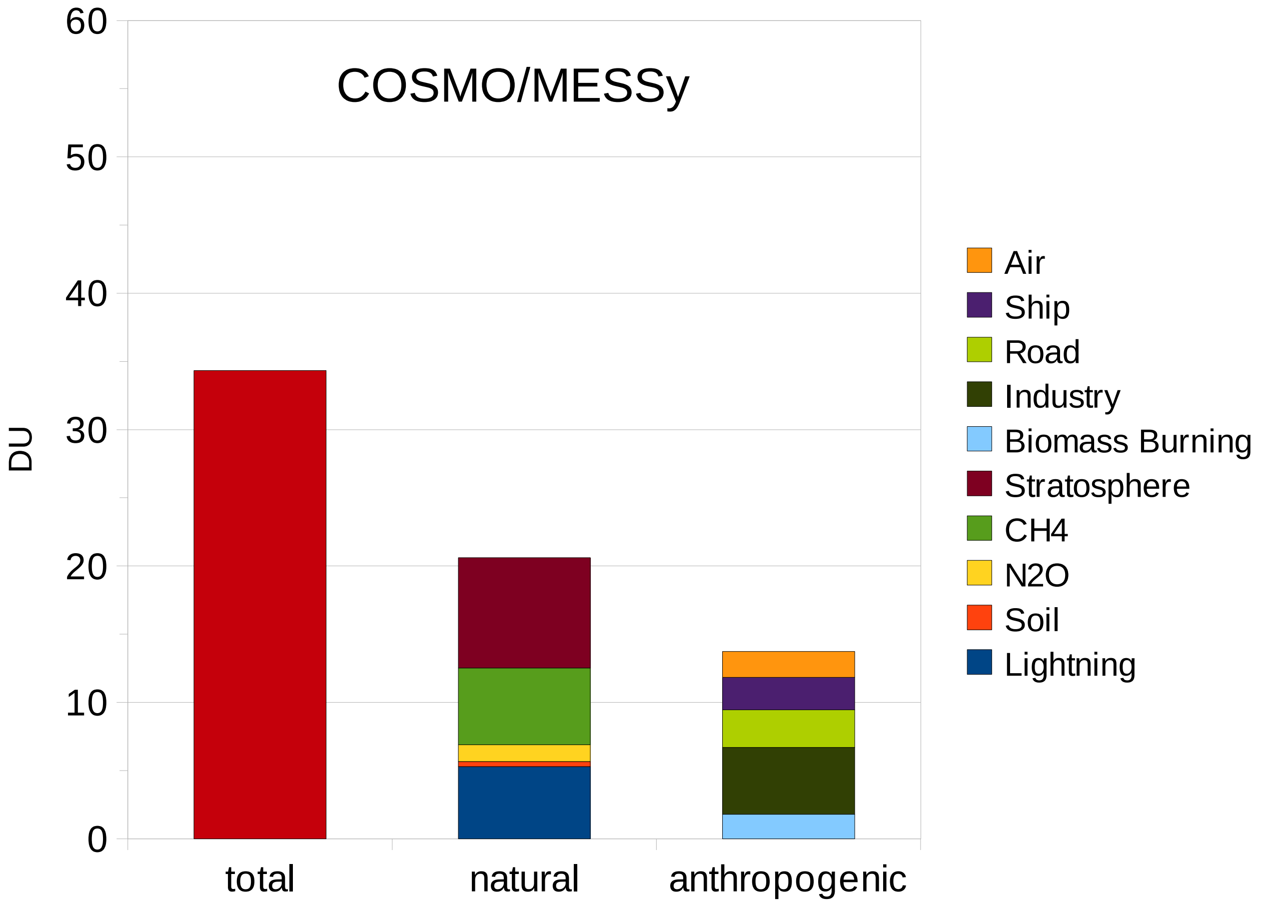
[1] details see: www.pa.op.dlr.de/~PatrickJoeckel/ESCiMo/

Tropospheric ozone column January 2008



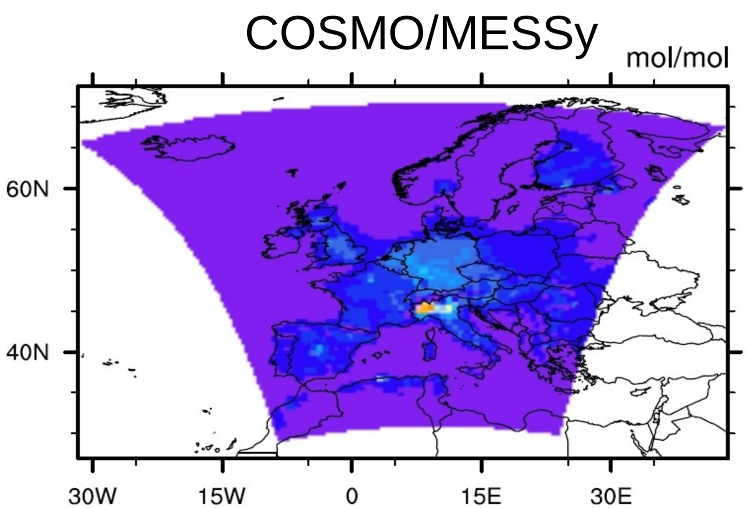
preliminary results!

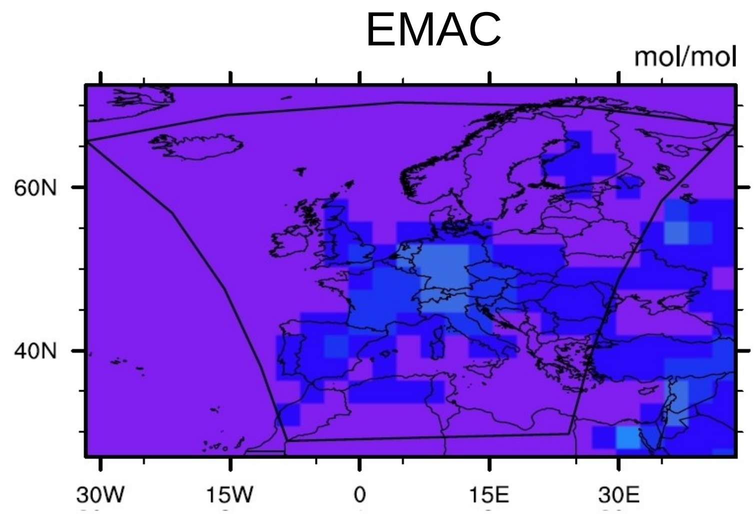
Tropospheric ozone column January 2008

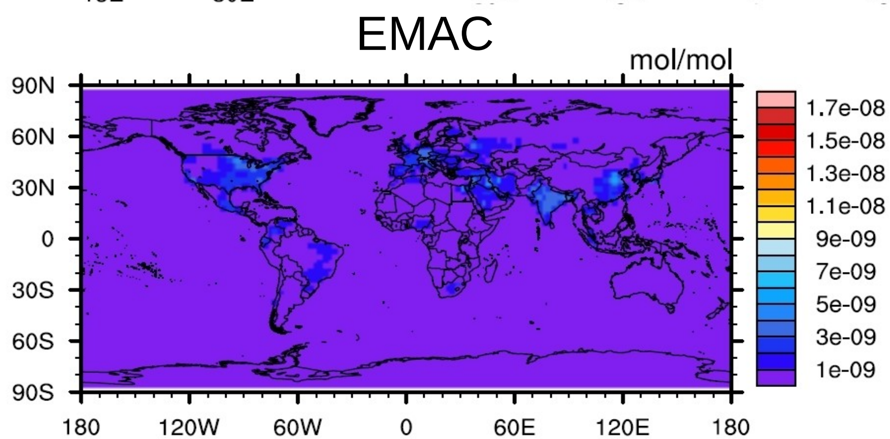


preliminary results!

NOy road sector at lowest model layer (January 2008)

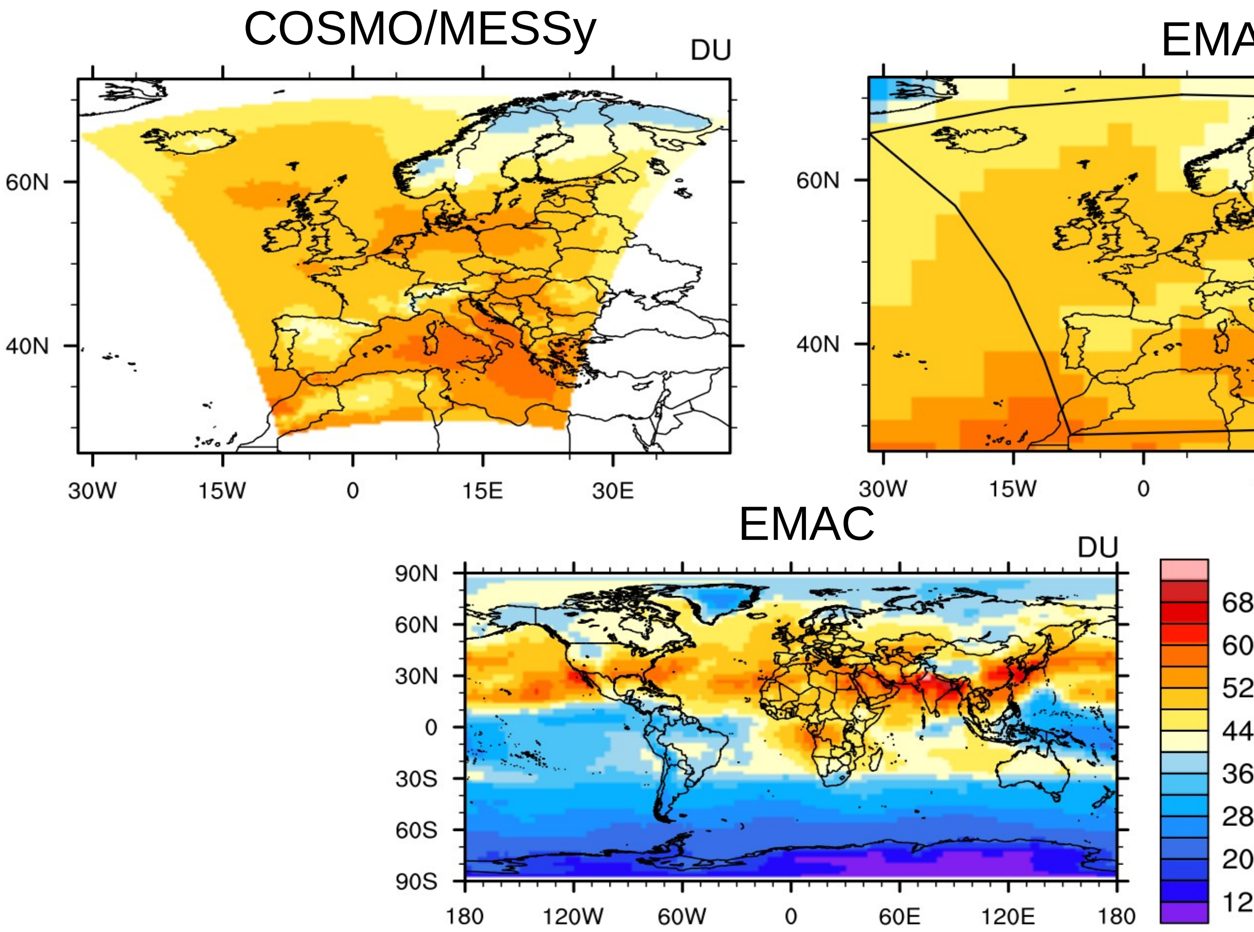






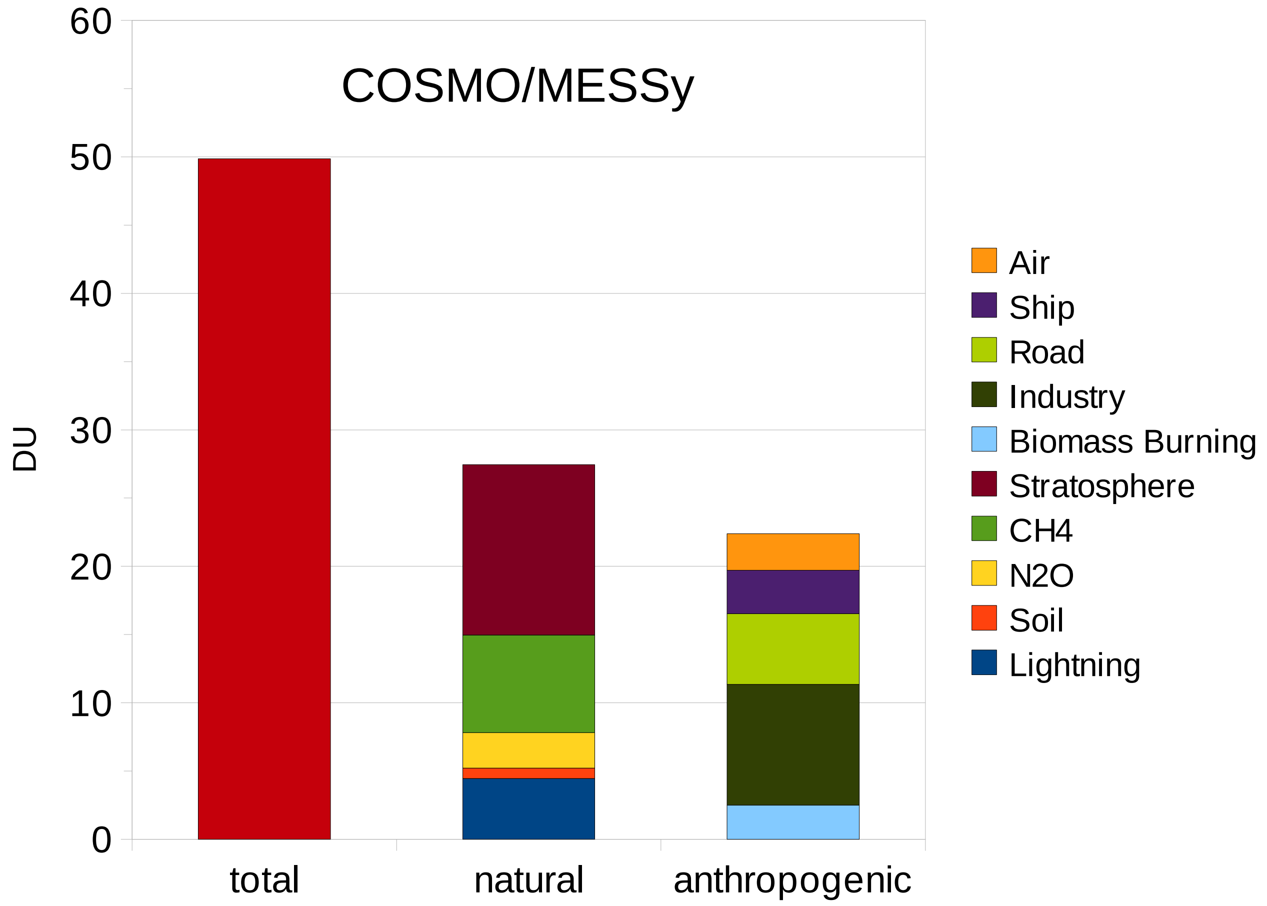
preliminary results!

Tropospheric ozone column May 2008



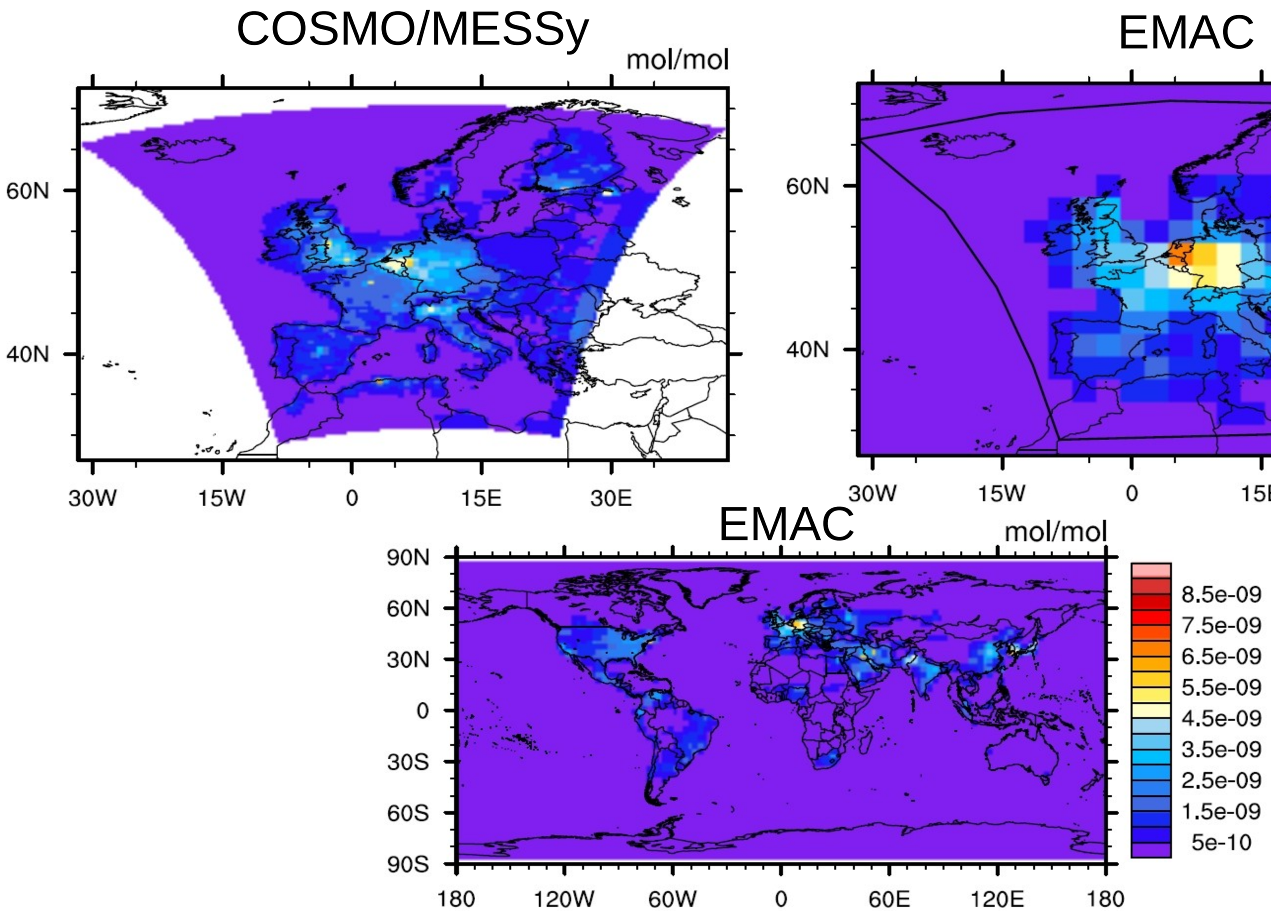
preliminary results!

Tropospheric ozone column May 2008



preliminary results!

NOy road sector at lowest model layer (May 2008)



preliminary results!

Conclusion and outlook

- Tagging submodel allows a detailed study of the contribution from different sources on ozone chemistry
- Consistent model chain from global to regional resolution allows a detailed comparison of global and regional effects
- First results show, that there is only a minor difference between the EMAC model and the COSMO/MESSy nest for the tropospheric ozone column
  - short lived species can show big differences

- Detailed evaluation of the simulation and tagging results
  - comparison with observations
  - difference of long lived and short lived species
  - detailed analysis of production/loss ratios

- Nests with higher resolution over Germany (using detailed regional emissions)