From global to regional scale: Impact of road traffic emissions on tropospheric ozone

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DLR

a long title

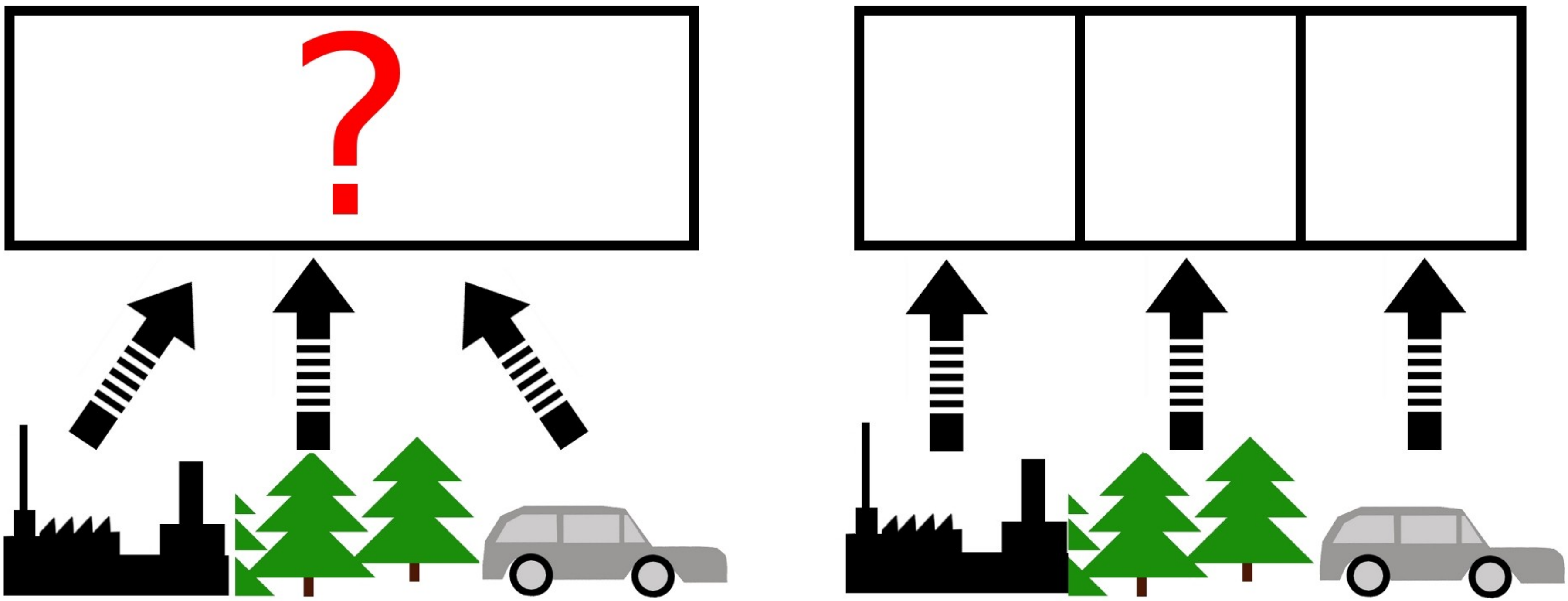
from global to regional scale

impact

road traffic

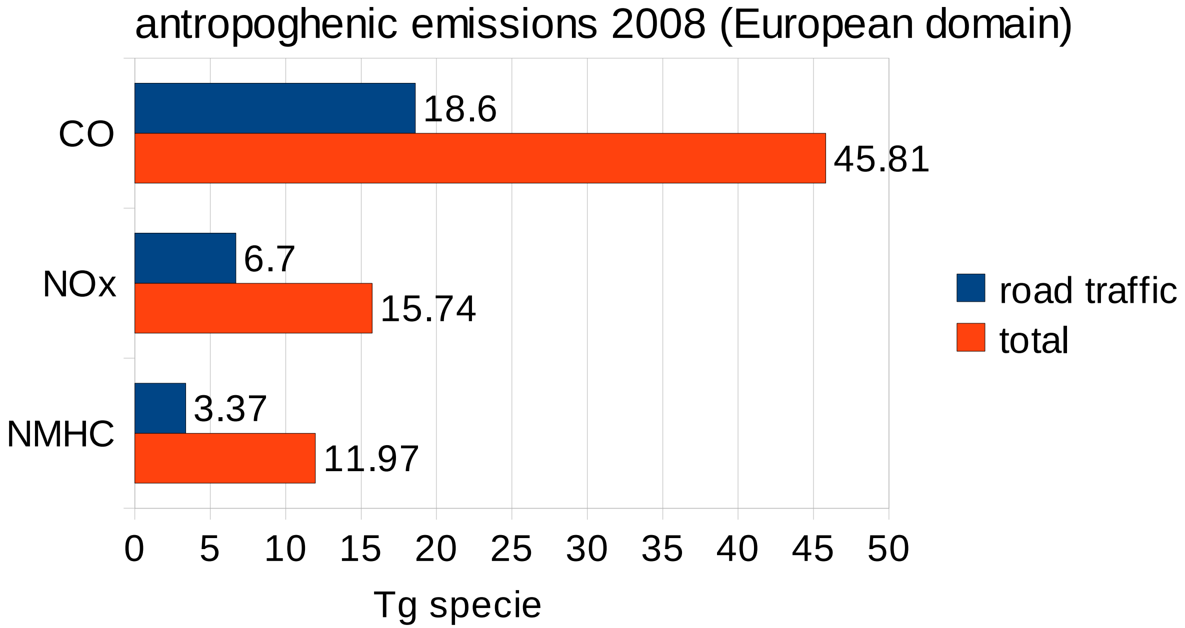
tropospheric ozone

from global to regional scale

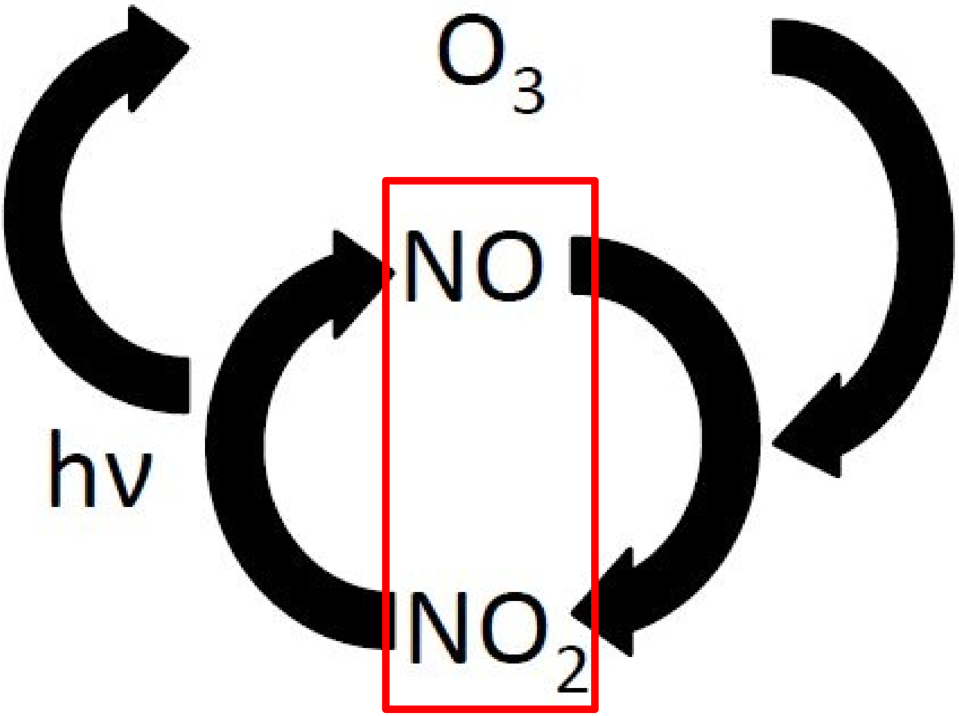


road traffic emissions

- anthropogenic source for CO, NMHCs and NO_x
    - precursors for the formation of tropospheric ozone
        - impact on climate, health and vegetation

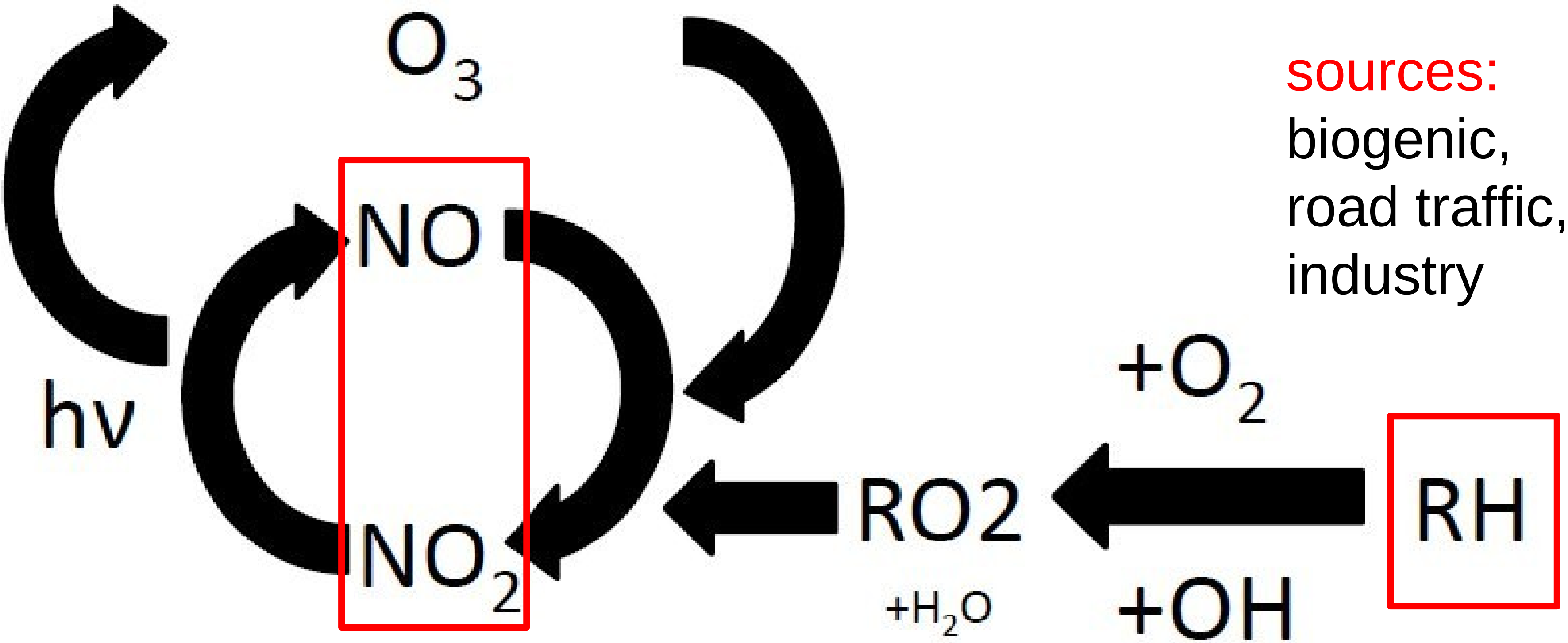


simplified ozone chemistry



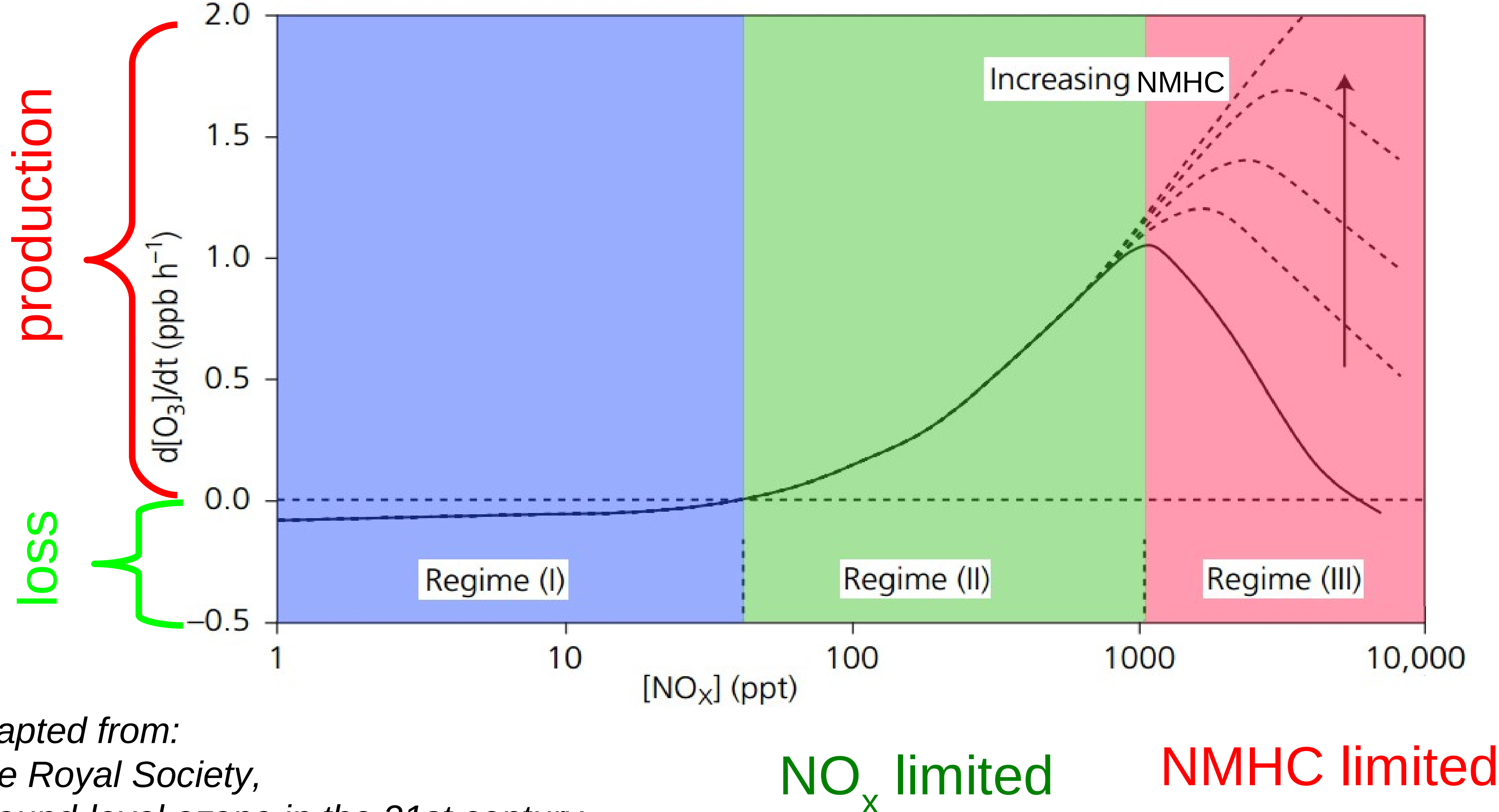
sources:
combustion (industry, road traffic), lightning

simplified ozone chemistry



sources:
combustion (industry, road traffic),
lightning

ozone chemistry is strongly non linear



adapted from:
The Royal Society,
Ground-level ozone in the 21st century

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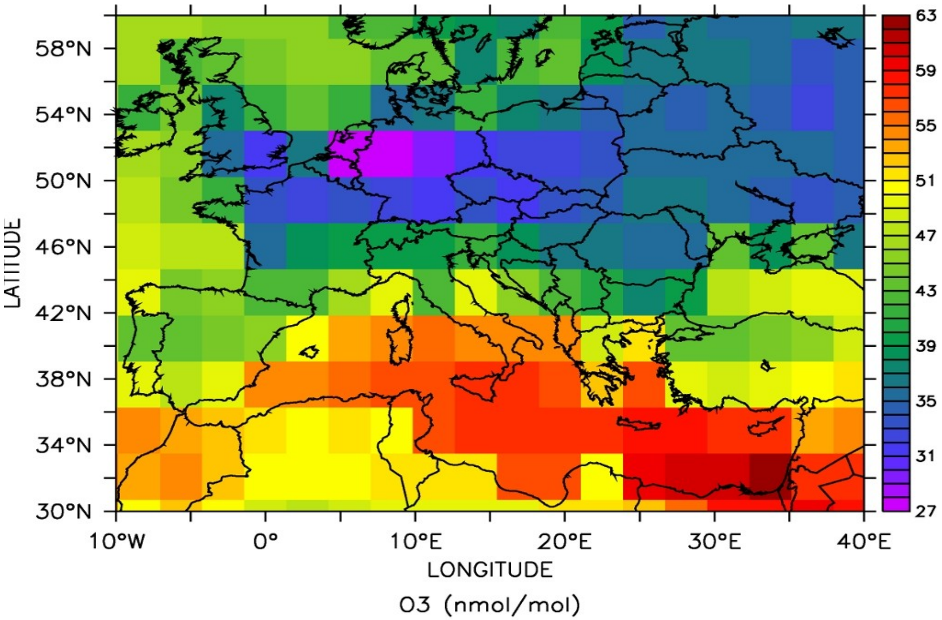
global models

- typical resolution of global CCMs > 200 km
    - cities are not resolved explicitly

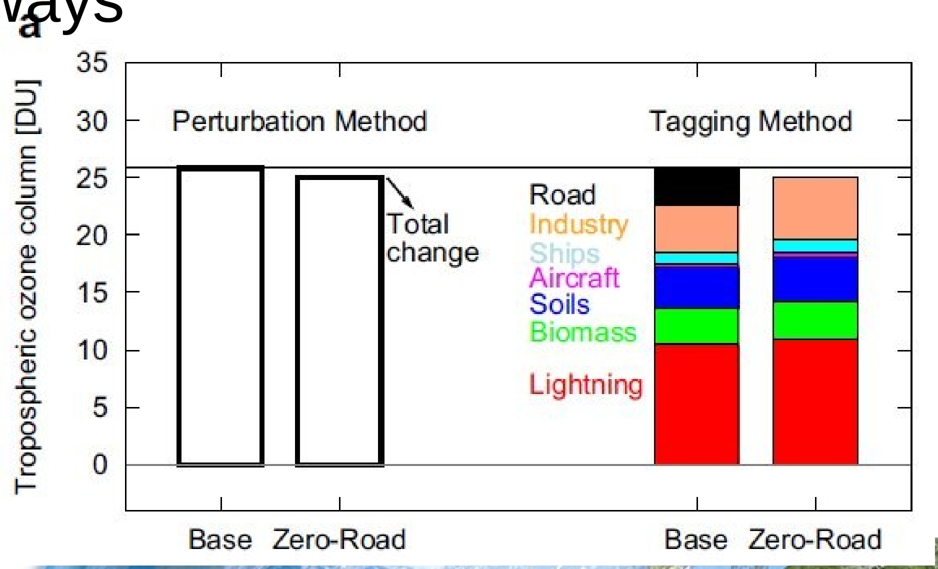


ground-level ozone in Europe (June 08) (T42 resolution)

What happens if the horizontal resolution is increased?

quantifying the impact of different sources

- perturbation approach:
    - comparison of reference and perturbed simulation
    - liniarization assuming same background chemistry
- TAGGING approach:
    - accounting system following the relevant reaction pathways



Grewe at al. 2012

simple example of the TAGGING method

- the basic idea (more details see Grewe, 2013):
    - track the reaction path of the species from different sources

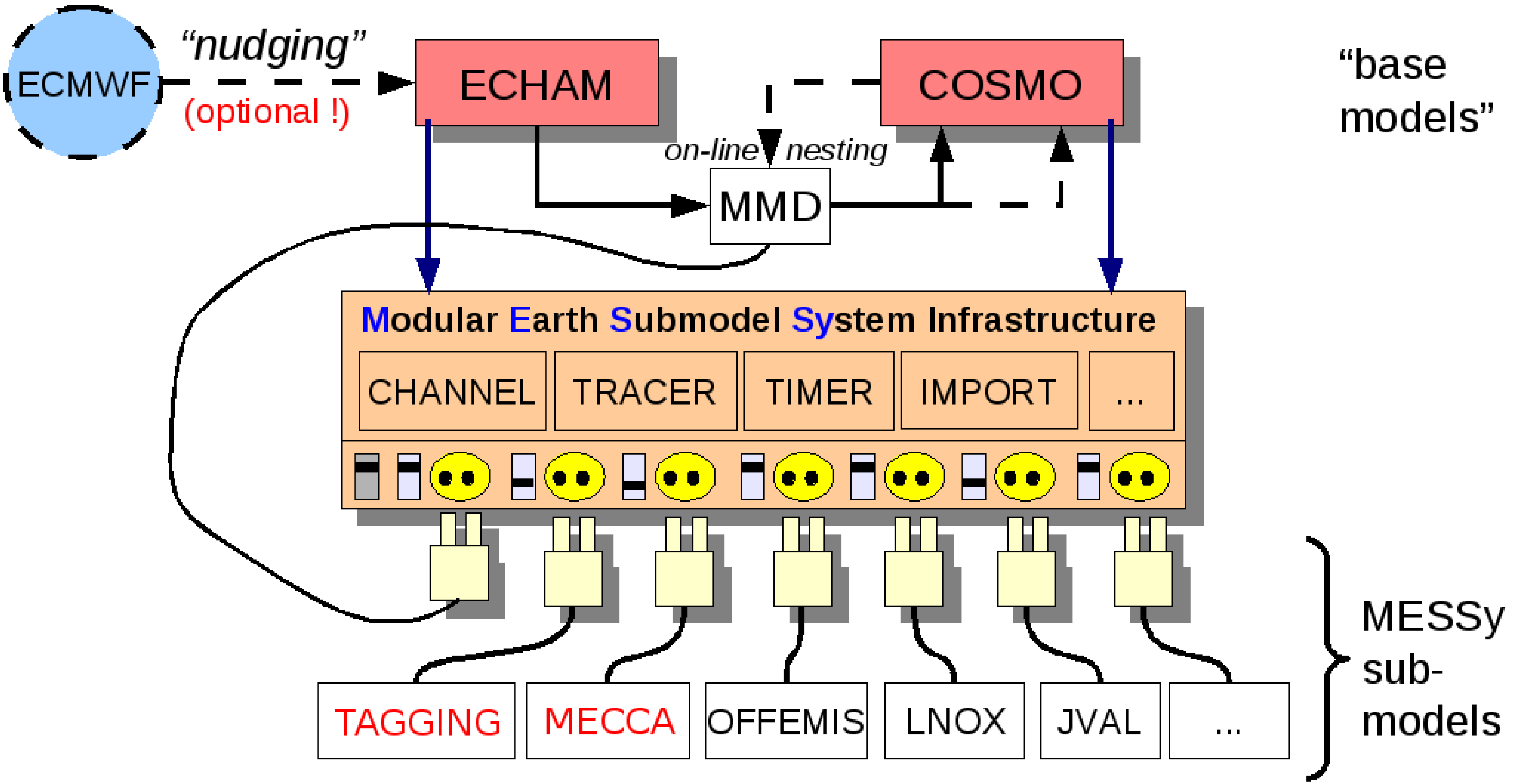
$$OH + NO_2 \rightarrow HNO_3 \xrightarrow[\text{ODE}]{\text{write as}} \frac{\partial HNO_3}{\partial t} = \kappa\, OH \cdot NO_2 = P_{HNO_3}$$

tag it!

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

HNO3 formed by sector j

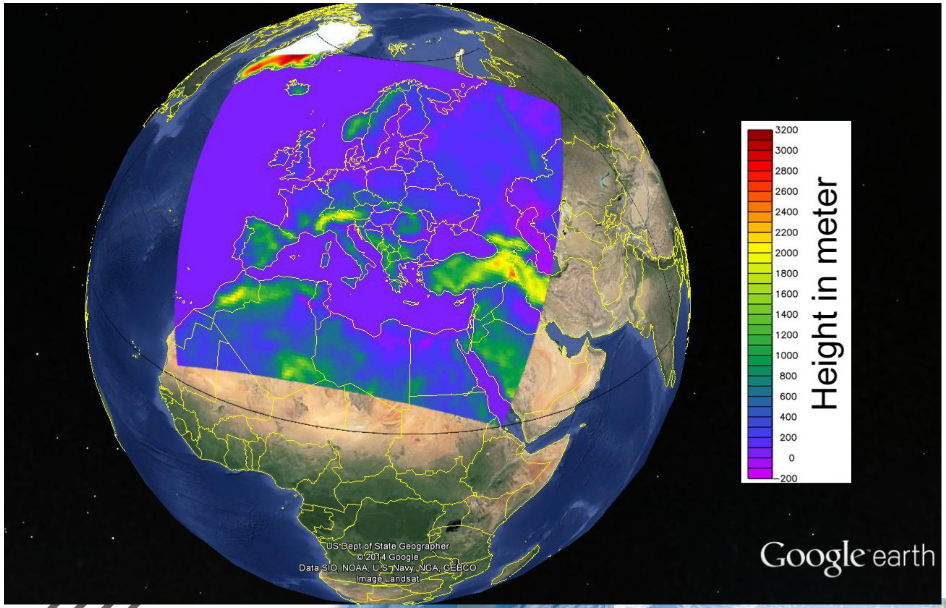
MECO(n) model system



Kerkweg & Jöckel, 2012

setup

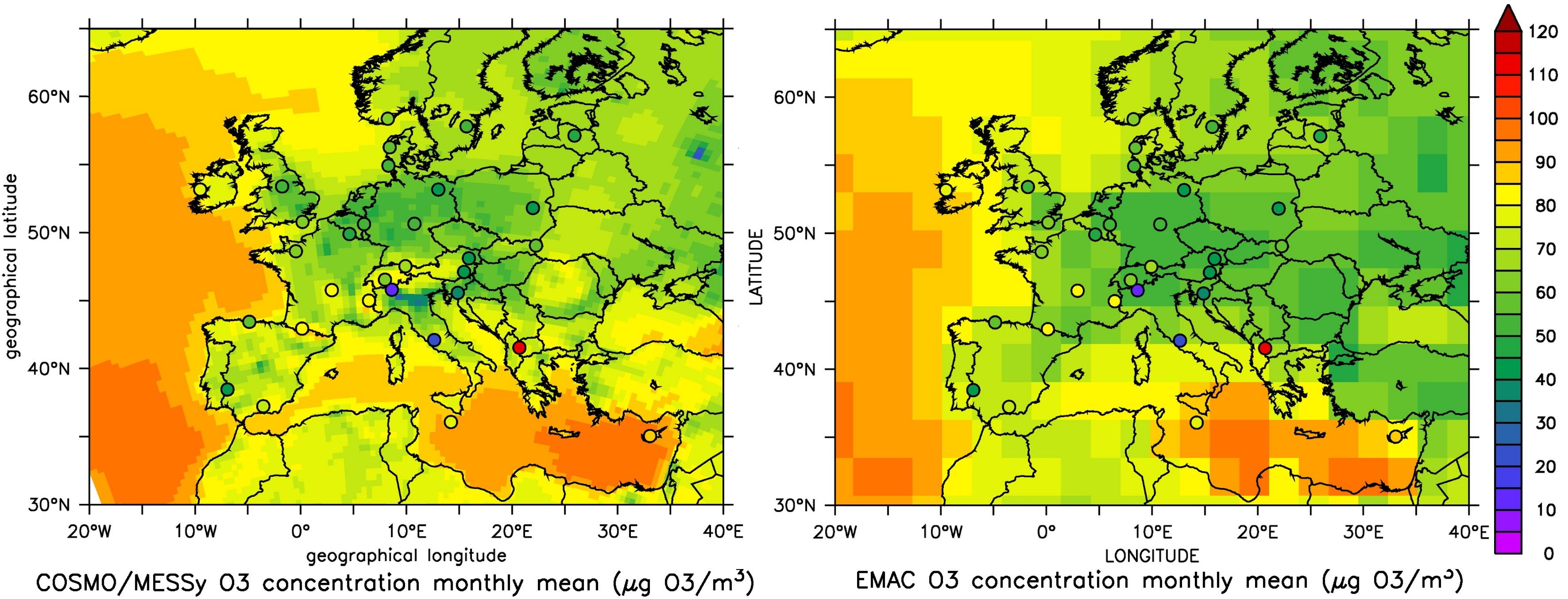
- MECO(1)
- based on the REF-C1SD setup for ESCiMo consortia simulations[1]
- T42L31ECMWF for EMAC
    - Nudged with ECMWF operational analysis data
- 0.44° x 0.44° COSMO/MESSy nest over Europe
- MECCA and TAGGING running regional and global
- LNOX and biogenic emissions calculated globally, transformed to region
- anthropogenic emissions based on MACCity[2] database (0.5° resolution)



[1] http://www.pa.op.dlr.de/~PatrickJoeckel/ESCiMo/
[2] eccad.sedoo.fr

first steps of the chemical evaluation

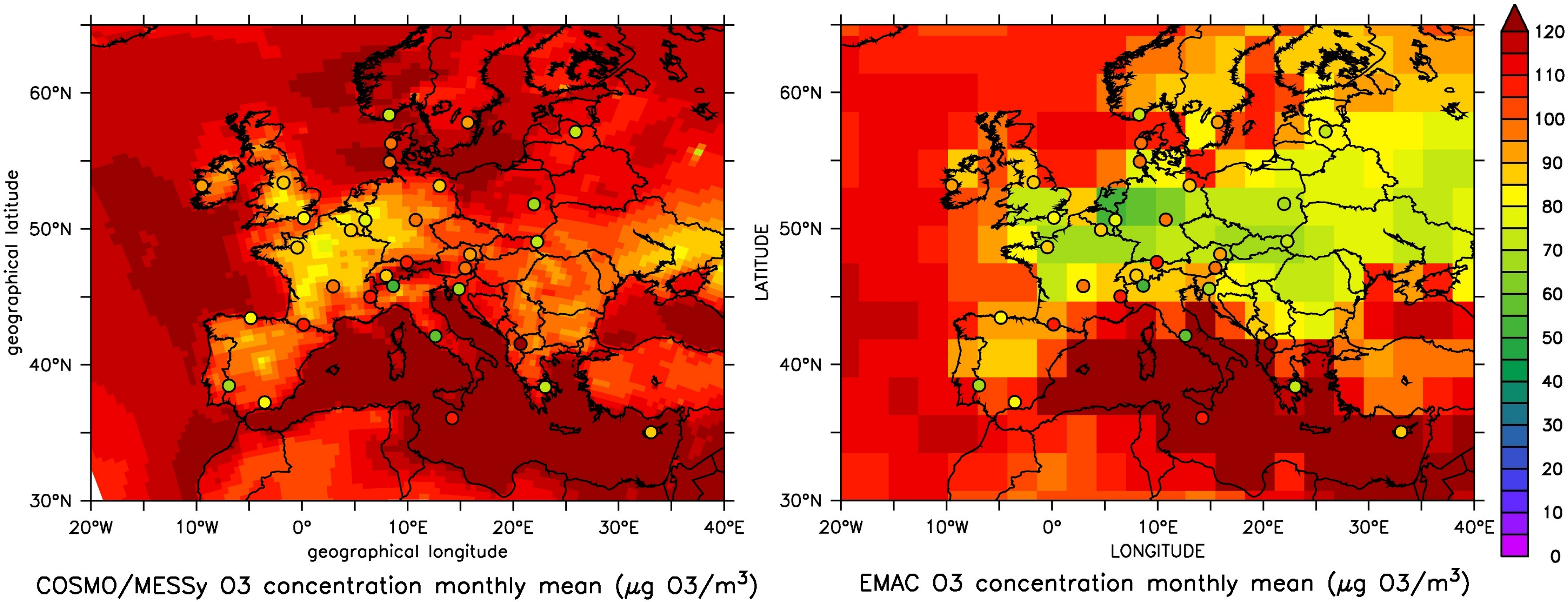
ground-level ozone concentration (January 2008)



general positive ozone bias
COSMO/MESSy with better results especially over the south of France

station data from ebas.nilu.no

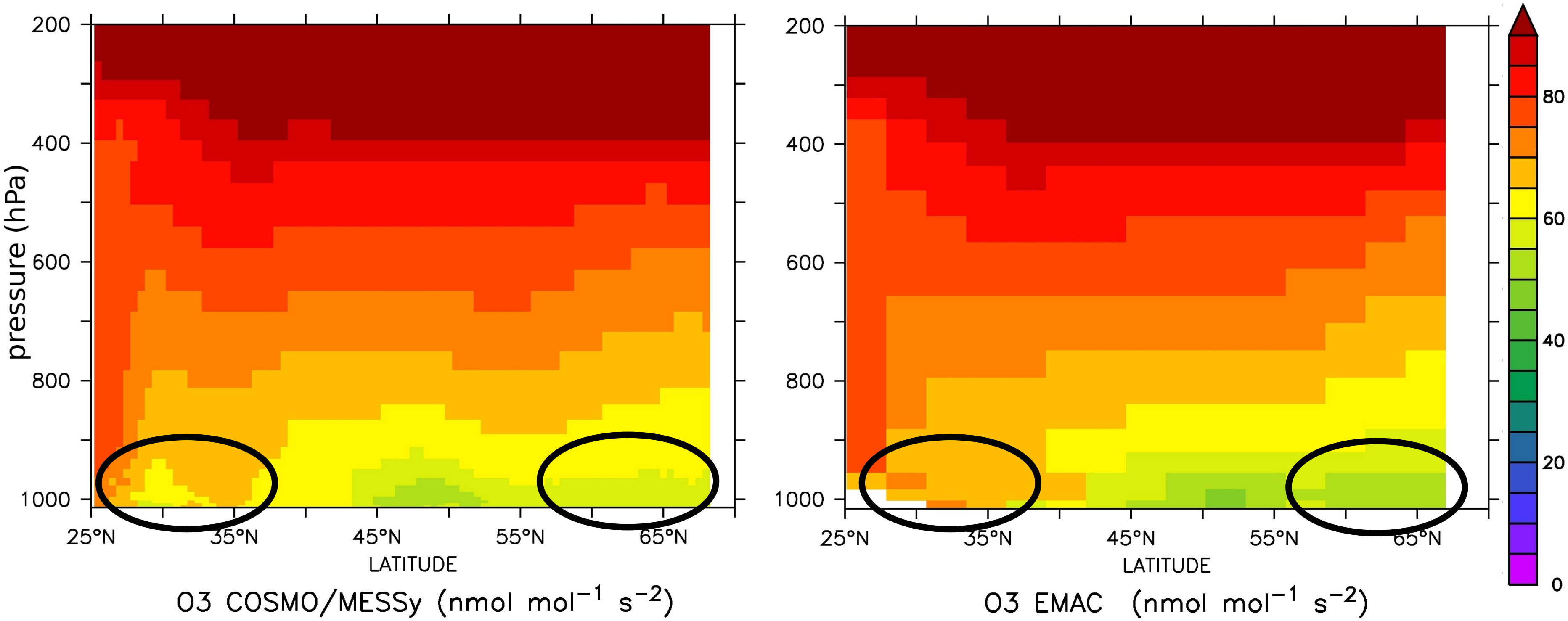
ground-level ozone concentration (May 2008)



COSMO/MESSy with better results over England, France and Germany
too much ozone over Northern and Eastern Europe in COSMO/MESSy

station data from ebas.nilu.no

ozone zonal-mean (May 08)



zonal means look similar; difference only present in pbl

reason: chemistry? dynamics (e.g. too stable boundary layer)?

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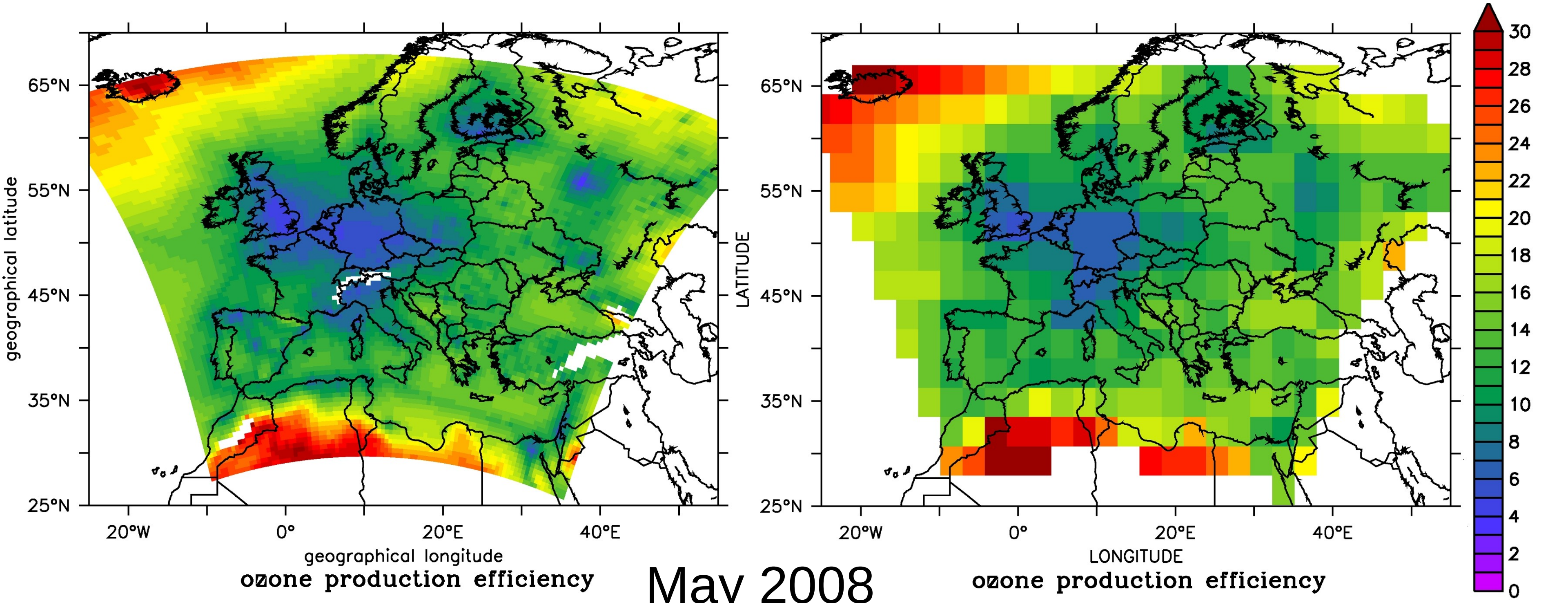
first results

ozone production efficiency (avg. up to 850hPa)

$$\epsilon = \frac{\kappa_1 HO_2 \cdot NO}{\kappa_2 OH \cdot NO_2} = \frac{P_{O_3}}{L_{NOX}}$$

ratio of O_3 molecules produced/ NO_x molecules consumed, assuming reaction with OH is only sink of NO_2 and NO_x steady state

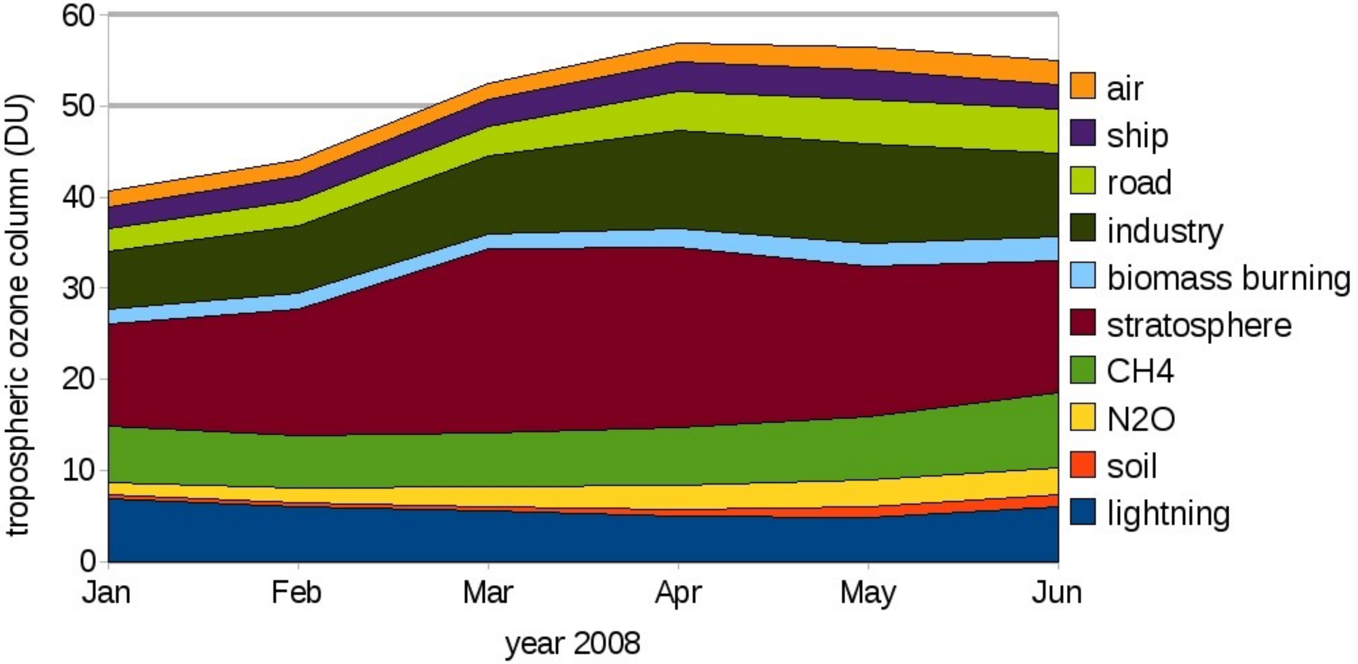
ozone production efficiency (avg. up to 850hPa)



May 2008

pattern looks very similar;
slightly higher values over North-/East Europe in COSMO/MESSy

contribution of different sources (COSMO/MESSy)



- contribution of road traffic doubles (Jan - Jun) from ~ 2.5 – 5 DU
- contribution of industry almost doubles (Jan - Jun) from ~6 – 11 DU
- stratospheric contribution peaks in March (~20 DU)
- results for EMAC are comparable, but less ozone from stratosphere

conclusion & outlook

- model chain with MECO(n), MECCA and TAGGING is technically working
    - allowing direct comparison of global and regional effects
- comparison with observations benefits from increased resolution
- contribution of sectors to ozone in the European area doesn't change significantly going from 2.8° - 0.44° resolution (in the simulated period).

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