On the analysis of impact of chemistry, transport and emission sources on tropospheric ozone production in model SMOG

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Motivation

- A common problem of almost all urban areas in Europe is air-pollution resulting from the cycle of photooxidation reactions - summer photochemical smog with the tropospheric ozone (O3) as the main part. The smog episodes occur in summer months as a consequence of the high emission intensity of ozone precursors and specific meteorological conditions with the impact of solar radiation.
- To accept some appropriate measures that can prevent the high O3 concentration episodes it is necessary to know appropriate contribution of different sources, with respect to their type, height, distance etc. With respect to nonlinearity of the reactions and complexity of the problem this is not so easy task as, for example, it was for much easier sulphur dioxide pollution problem.
Goals

- To study the contribution of individual parts of emission plumes – so called “puffs” – to the places of interest.
- To estimate the role of emission intensity of individual sources, chemistry along the trajectory from the sources and mixing of pollutants from individual sources as well.
- To show how the different types and individual emission sources in particular can affect the O3 ground concentration.
- To study the contribution of biogenic emissions to the anthropogenic sources in the places of interest.
- To estimate the role of emission intensity of biogenic sources in plume of photochemical smog from urban areas.
- To show the overall effect in appropriate period how the biogenic emissions can impact long term averages and behaviour.

SMOG - Chemistry of the model
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- compounds involved: NO, NO$_2$, VOC’s, O$_3$, HNO$_3$, NO$_3^-$, PN (pernitrates), RO$_2$ (peroxy-radicals), OH radicals

- emission data: NO, VOC’s puffs released within regular period
SMOG - Chemistry of the model

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- emission data: NO, VOC’s puffs released within regular period
- VOC’s splitted on source level to the individual groups of organics

Scheme of chemical reactions
REZZO 1,2 – point sources

REZZO 1,2 – area sources
Basic principles of model system

- construction of trajectories and puffs from each of emission source in the wind-field – lagrangian puff model
Basic principles of model

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- turbulent diffusion of puffs (gaussian approximation in two dimensions perpendicularly to the trajectory)
- modelling of mixing between puffs
Basic principles of model

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- turbulent diffusion of puffs (gaussian approximation in two dimensions perpendicularly to the trajectory)
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- dry deposition: NO, NO₂, HNO₃, NO₃⁻
- wet deposition: HNO₃, NO₃⁻, PN
Model system couple ETA-SMOG

trajectories based on ETA NWP model (meteorological preprocessor):

- Semi-staggered Arakawa E-grid
- 0.25°x 0.25° horizontal resolution (rotated)
- 32 model layers
- centre of domain 50°N, 15°E,
- +/- 20° longitude, +/- 15° latitude

Other Choices

- ETA (NCEP) - SMOG
- MM5 (NCAR, PSU) – CAMx
- METRAS (Uni. of Hamburg) - SMOG
- ALADIN/LACE (METEO France, CHMI) – SMOG

QUANTIFY

- RegCM – CAMx
- ALADIN/CLIMATE – CAMx
Objective: To quantify the climate impact of the global and European transport systems for the present situation and for different scenarios of future development.

Participants: 35 from 16 countries
Start: March 2005
Finish: February 2010
Funds: 8.0 M€
Total costs: 12.0 M€
Impact of traffic emissions on climate

- Change of the radiative forcing by
  - the emission of greenhouse gases, including long-lived species like CO$_2$ and N$_2$O, but also of water vapour;
  - the emission ozone precursors;
  - the emission of particles and their precursors;
  - triggering additional clouds (e.g., contrails contrail cirrus) and by modifying natural clouds (e.g., ship tracks).
Further information

- http://www.pa.op.dlr.de/quantify/
- (http://www.quantify.eu/)

Example of results for Prague plume on 19 September 2003
- about 3000 sources
Concentration (μg/m³)

Position of all the puffs contributing to the concentration of O₃ in given point

Puffs contribution in 50.48N, 14.58E
Puff’s contribution in 50.48N, 14.58E

Position of the puffs with more significant contribution to the concentration of O3 in given point

Position of the puffs from significant point sources of REZZO1 (7% of total contr.)

Position of the puffs from traffic sources (64%)
Example of results for remote area of Hruby Jesenik
June 2002

Biogenic emissions

Example of estimate
• based on land use distribution below

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Biogenic emissions

Example of estimate

- for monoterpenes and isoprene
- dependent on temperature and radiation (solar zenith angle and cloudiness) – typical conditions

Impact of biogenic emissions

One day surface ozone concentration in mg/m³ based on simulation with and without biogenic emission
Monthly surface ozone concentration in μg/m³ based on measurement

Monthly surface ozone concentration in μg/m³ based on simulation without biogenic emission

Monthly surface ozone concentration in μg/m³ based on simulation with biogenic emission

Full June 2002 simulation

Daily surface ozone concentration in μg/m³ for measurement point Cervenohorske sedlo
Conclusions

- both traffic and biogenic emissions play an important role in ozone formation
- information on puff’s origin (individual emission source) on the output
- with analysis of ozone precursors contributions as well the possibility to identify emission sources where appropriate measures could be applied to reduce emission impact
- significant improvement of the comparison with measurement – impact of the biogenic emission more important than information on longer transport

Acknowledgement

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