Contribution of land transport emissions to ground level ozone, calculated by means of a multiply online nested model

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Land transport emissions in Europe

- Nitrogen oxides, volatile organic compounds and carbon monoxide are precursors for ozone
- Land transport is a significant source of these precursors
- Production of ozone is highly non-linear

### Anthropogenic emissions 2008 (European domain)

<table>
<thead>
<tr>
<th>Specie</th>
<th>Total</th>
<th>Land Transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMVOC</td>
<td>12.0</td>
<td>3.4</td>
</tr>
<tr>
<td>NOx</td>
<td>15.7</td>
<td>6.7</td>
</tr>
<tr>
<td>CO</td>
<td>45.8</td>
<td>18.6</td>
</tr>
</tbody>
</table>

Note: Tg specie
What is the contribution of land transport emissions on tropospheric ozone?

![Bar chart showing anthropogenic emissions 2008 (European domain)]

- **CO**:
  - Total: 45.8 Tg specie
  - Land transport: 18.6 Tg specie

- **NOx**:
  - Total: 15.7 Tg specie
  - Land transport: 6.7 Tg specie

- **NMVOC**:
  - Total: 12.0 Tg specie
  - Land transport: 3.4 Tg specie

\[\text{DLR.de} \quad \text{Chart 3} \quad \text{Air Quality 2018} \quad \text{Mertens et al.} \quad \text{Contribution of land transport emissions to ozone} \quad 15.3.2018\]
Contribution vs. impact

- **Contribution**: Amount of ozone produced by emissions of a specific source
  
  **Source apportionment method** (e.g. tagging method)

- **Impact**: Change of ozone, if emissions of specific sources are decreased
  
  **Sensitivity method** (e.g. perturbation method)

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Grewe et al., 2012
Tagging method for source apportionment

- Diagnostic method using a combinatoric approach considering O$_3$, NO$_x$, CO and VOC (Grewe et al., 2010, 2017; Tsati, 2014)
  - considered chemical species are fully decomposed (closed budget)
  - family approach for computational reasons

Example:
A + B → C

Emission sectors:
land transport
industry

\[ P(C^{tra}) = \frac{1}{2} k A B \left( \frac{A^{tra}}{A} + \frac{B^{tra}}{B} \right) \]
MECO(n): MESSy-fied ECHAM and COSMO n-times nested

- 1-way on-line nested global-regional atmospheric model system
  - EMAC as global model
  - COSMO/MESSy as regional model
- Meteorological and chemical (incl. contributions) boundary conditions
- Allows for a consistent “zooming” into specific areas.

Kerkweg & Jöckel, GMD, 2012a,b
Hofmann et al., GMD, 2012
Mertens et al., GMD, 2016
Setup of the model system

- MECO(2)
  - Global: EMAC resolution T42L31ECMWF (~300 km resolution)
  - Europe: COSMO ~ 0.44°x0.44° (~50 km)
  - Germany: COSMO ~ 0.10°x0.10° (~12 km)
- Chemical evaluation with various observations (Mertens et al., 2016, GMD)
- Two simulations applying different emission inventories in COSMO
  - Identical emissions are applied in EMAC (MACCity)

**MACCity (RCP8.5, Granier et al. 2010)**

**VEU (Hendricks et al., 2017)**

Land transport NOx emissions (kg m$^{-2}$ s$^{-1}$)
Average contribution of land transport emissions to ozone over Europe

Area averaged relative contribution (in % for Europe, 50km resolution) of land transport emissions to the partial ozone column from the surface up to 850 hPa.
Absolute contribution of land transport exhaust to groundlevel NO$_y$

**MACCity**

DJF

JJA

**VEU**

NO$_y$ due to land transport emissions (nmol mol$^{-1}$)
Absolute contribution of land transport exhaust to groundlevel $O_3$

**MACCity**

**VEU**

**DJF**

**JJA**

$O_3$ due to land transport emissions (nmol mol$^{-1}$)
Relative contribution of land transport exhaust to groundlevel $O_3$
95th percentile of relative contribution of land transport exhaust to groundlevel O₃
95th percentile of relative contribution of land transport exhaust to groundlevel $O_3$ in Germany (12 km)

O$_3$ due to land transport emissions for 2008 (relative, %)
Outlook

MECO(n) is now applied in follow up studies with increasing complexity of the tagging as well as the model resolution.

Contribution of land transport emissions to ozone in July 2017 (7 km resolution)
Conclusions

• MECO(n) model system allows for a consistent evaluation of the contribution of different emission sources on ozone on global down to regional scale
  • Important for air quality as well as climate issues

• Contribution of land transport emissions during summer in Europe
  \( \text{NO}_y \): strongly depending on region and emission inventory; 4—10 nmol mol\(^{-1} \)
  \( \text{O}_3 \): on average \( \sim 11\% \) (5—10 nmol mol\(^{-1} \))
  during summer season in the Po basin up to 15 \%
  95\text{th} percentile; up to 23 \% percent in specific regions

\textbf{Important:} Results refer to ‘regional scale’ not to ‘city scale’