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# An online emission module for atmospheric chemistry transport models: implementation in COSMO-GHG v5.6a and COSMO-ART v5.1-3.1

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## S1 Temporal profiles

The time profiles of emissions were originally published by TNO for SNAP emission categories (Denier van der Gon et al., 2011; Pouliot et al., 2012) and have been mapped to GNFR categories within the CHE project (Haussaire et al., 2018).

**Table S1.** Emission temporal profiles for month-of-year as a function of the GNFR category.

| GNFR Category | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Public Power | 1.2 | 1.15 | 1.05 | 1 | 0.9 | 0.85 | 0.8 | 0.875 | 0.95 | 1 | 1.075 | 1.15 |
| B | Industry | 1.1 | 1.075 | 1.05 | 1 | 0.95 | 0.9 | 0.93 | 0.95 | 0.97 | 1 | 1.025 | 1.05 |
| C | Other Stationary Combustion | 1.7 | 1.5 | 1.3 | 1 | 0.7 | 0.4 | 0.2 | 0.4 | 0.7 | 1.05 | 1.4 | 1.65 |
| D | Fugitives | 1.2 | 1.2 | 1.2 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 1.2 | 1.2 | 1.2 |
| E | Solvents | 0.95 | 0.96 | 1.02 | 1 | 1.01 | 1.03 | 1.03 | 1.01 | 1.04 | 1.03 | 1.01 | 0.91 |
| F | Road Transport | 0.88 | 0.92 | 0.98 | 1.03 | 1.05 | 1.06 | 1.01 | 1.02 | 1.06 | 1.05 | 1.01 | 0.93 |
| G | Shipping | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| H | Aviation | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| I | Off Road | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| J | Waste | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| K | Agricultural Livestock | 0.7 | 0.75 | 0.85 | 0.9 | 1 | 1.1 | 1.2 | 1.25 | 1.3 | 1.1 | 1 | 0.85 |
| L | Agricultural Other | 0 | 2 | 4.75 | 2.9 | 0.5 | 0.4 | 0.2 | 0.5 | 0.75 | 0 | 0 | 0 |

**Table S2.** Emission temporal profiles for day-of-week as a function of the GNFR category.

| GNFR Category | | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
|---|---|---|---|---|---|---|---|---|
| A | Public Power | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 0.85 | 0.85 |
| B | Industry | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 0.8 | 0.8 |
| C | Other Stationary Combustion | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 0.8 | 0.8 |
| D | Fugitives | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| E | Solvents | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 0.5 | 0.5 |
| F | Road Transport | 1.02 | 1.06 | 1.08 | 1.1 | 1.14 | 0.81 | 0.79 |
| G | Shipping | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| H | Aviation | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| I | Off Road | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| J | Waste | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| K | Agricultural Livestock | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| L | Agricultural Other | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Table S3.** Emission temporal profiles for hour-of-day (first 12 hours) as a function of the GNFR category.

| GNFR Category | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Public Power | 0.79 | 0.72 | 0.72 | 0.71 | 0.74 | 0.8 | 0.92 | 1.08 | 1.19 | 1.22 | 1.21 | 1.21 |
| B | Industry | 0.75 | 0.75 | 0.78 | 0.82 | 0.88 | 0.95 | 1.02 | 1.09 | 1.16 | 1.22 | 1.28 | 1.3 |
| C | Other Stationary Combustion | 0.38 | 0.36 | 0.36 | 0.36 | 0.37 | 0.5 | 1.19 | 1.53 | 1.57 | 1.56 | 1.35 | 1.16 |
| D | Fugitives | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| E | Solvents | 0.5 | 0.35 | 0.2 | 0.1 | 0.1 | 0.2 | 0.75 | 1.25 | 1.4 | 1.5 | 1.5 | 1.5 |
| F | Road Transport | 0.19 | 0.09 | 0.06 | 0.05 | 0.09 | 0.22 | 0.86 | 1.84 | 1.86 | 1.41 | 1.24 | 1.2 |
| G | Shipping | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| H | Aviation | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| I | Off Road | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| J | Waste | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| K | Agricultural Livestock | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| L | Agricultural Other | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Table S4.** Emission temporal profiles for hour-of-day (last 12 hours) as a function of the GNFR category.

| GNFR Category | | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Public Power | 1.17 | 1.15 | 1.14 | 1.13 | 1.1 | 1.07 | 1.04 | 1.02 | 1.02 | 1.01 | 0.96 | 0.88 |
| B | Industry | 1.22 | 1.24 | 1.25 | 1.16 | 1.08 | 1.01 | 0.95 | 0.9 | 0.85 | 0.81 | 0.78 | 0.75 |
| C | Other Stationary Combustion | 1.07 | 1.06 | 1 | 0.98 | 0.99 | 1.12 | 1.41 | 1.52 | 1.39 | 1.35 | 1 | 0.42 |
| D | Fugitives | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| E | Solvents | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.25 | 1.1 | 1 | 0.9 | 0.8 | 0.7 |
| F | Road Transport | 1.32 | 1.44 | 1.45 | 1.59 | 2.03 | 2.08 | 1.51 | 1.06 | 0.74 | 0.62 | 0.61 | 0.44 |
| G | Shipping | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| H | Aviation | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| I | Off Road | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| J | Waste | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| K | Agricultural Livestock | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| L | Agricultural Other | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

## S2 Vertical profiles

Vertical profiles are based on source-specific profiles developed for the European Monitoring and Evaluation Program (EMEP) (Bieser et al., 2011) that have been modified for the SMARTCARB project (Brunner et al., 2019).

**Table S5.** Vertical profile of the distribution of emissions as a function of the GNFR category.

| GNFR Category | | 20m | 92m | 184m | 324m | 522m | 781m | 1106m |
|---|---|---|---|---|---|---|---|---|
| A | Public Power | 0 | 0 | 0.0025 | 0.51 | 0.453 | 0.0325 | 0.002 |
| B | Industry | 0.06 | 0.16 | 0.75 | 0.03 | 0 | 0 | 0 |
| C | Other Stationary Combustion | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| D | Fugitives | 0.02 | 0.08 | 0.6 | 0.3 | 0 | 0 | 0 |
| E | Solvents | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| F | Road Transport | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| G | Shipping | 0.2 | 0.8 | 0 | 0 | 0 | 0 | 0 |
| H | Aviation | 0.25 | 0.25 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| I | Off Road | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| J | Waste | 0 | 0 | 0.41 | 0.57 | 0.02 | 0 | 0 |
| K | Agricultural Livestock | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| L | Agricultural Other | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

### S3 COSMO-GHG example namelist INPUT_GHG

```
&GHGCTL
  in_tracers = 1,
/
&TRACER
  yshort_name = "CO2_ALL",
  itype_emiss = 2,
  itype_tscale = 1,
  ycatl = "CO2_A_TNO","CO2_B_TNO","CO2_C_TNO","CO2_F1_TNO","CO2_F2_TNO",
          "CO2_F3_TNO","CO2_D_TNO","CO2_E_TNO","CO2_G_TNO","CO2_H_TNO",
          "CO2_I_TNO","CO2_J_TNO","CO2_K_TNO","CO2_L_TNO", "CO2_B_Carbocount",
          "CO2_C_Carbocount","CO2_J_Carbocount","CO2_L_Carbocount",
          "CO2_F_Carbocount"
  ytpl =  "GNFR_A_TNO","GNFR_B_TNO","GNFR_C_TNO","GNFR_F_TNO","GNFR_F_TNO",
          "GNFR_F_TNO","GNFR_D_TNO","GNFR_E_TNO","GNFR_G_TNO","GNFR_H_TNO",
          "GNFR_I_TNO","GNFR_J_TNO","GNFR_K_TNO","GNFR_L_TNO","GNFR_B_Carbocount"
          "GNFR_C_Carbocount","GNFR_J_Carbocount","GNFR_L_Carbocount",
          "GNFR_F_Carbocount",
  yvpl =  "GNFR_area_sources","GNFR_area_sources","GNFR_area_sources",
          "GNFR_area_sources","GNFR_area_sources","GNFR_area_sources",
          "GNFR_area_sources","GNFR_area_sources","GNFR_area_sources",
          "GNFR_area_sources","GNFR_area_sources","GNFR_area_sources",
          "GNFR_area_sources","GNFR_area_sources","GNFR_area_sources",
          "GNFR_area_sources"
/
.
```

## S4 COSMO-ART example namelist INPUT_OAE

```
&OAECTL
  in_tracers = 1,
/
&TRACER
  yshort_name = 'NO2',
  ycatl =     'NOX_A_AREA', 'NOX_A_POINT', 'NOX_A_ch',
              'NOX_B_AREA', 'NOX_B_POINT', 'NOX_B_ch',
              'NOX_C_AREA', 'NOX_C_ch',
              'NOX_D_AREA', 'NOX_D_POINT', 'NOX_D_ch',
              'NOX_E_AREA', 'NOX_E_ch',
              'NOX_F_AREA', 'NOX_F_ch',
              'NOX_G_AREA', 'NOX_G_ch',
              'NOX_H_AREA', 'NOX_H_POINT', 'NOX_H_ch',
              'NOX_I_AREA', 'NOX_I_ch',
              'NOX_J_AREA', 'NOX_J_POINT', 'NOX_J_ch',
              'NOX_K_AREA', 'NOX_K_ch',
              'NOX_L_AREA', 'NOX_L_ch',
  ytpl =      'GNFR_A_EU', 'GNFR_A_EU', 'GNFR_A_CH',
              'GNFR_B_EU', 'GNFR_B_EU', 'GNFR_B_CH',
              'GNFR_C_EU', 'GNFR_C_CH',
              'GNFR_D_EU', 'GNFR_D_EU', 'GNFR_D_CH',
              'GNFR_E_EU', 'GNFR_E_CH',
              'GNFR_F_EU', 'GNFR_F_CH',
              'GNFR_G_EU', 'GNFR_G_CH',
              'GNFR_H_EU', 'GNFR_H_EU', 'GNFR_H_CH',
              'GNFR_I_EU', 'GNFR_I_CH',
              'GNFR_J_EU', 'GNFR_J_EU', 'GNFR_J_CH',
              'GNFR_K_EU', 'GNFR_K_CH',
              'GNFR_L_EU', 'GNFR_L_CH',
  yvpl =      "GNFR_area_sources", 'GNFR_A', "GNFR_area_sources",
              "GNFR_area_sources", 'GNFR_B', "GNFR_area_sources",
              "GNFR_area_sources", "GNFR_area_sources",
              "GNFR_area_sources", 'GNFR_D', "GNFR_area_sources",
              "GNFR_area_sources", "GNFR_area_sources",
              "GNFR_area_sources", "GNFR_area_sources",
              "GNFR_area_sources", "GNFR_area_sources",
              "GNFR_area_sources", 'GNFR_H', "GNFR_area_sources",
              "GNFR_area_sources", "GNFR_area_sources",
              "GNFR_area_sources", 'GNFR_J', "GNFR_area_sources",
              "GNFR_area_sources", "GNFR_area_sources",
              "GNFR_area_sources", "GNFR_area_sources",
  contribl = 0.18, 0.18, 0.18,
              0.18, 0.18, 0.18,
              0.18, 0.18,
              0.18, 0.18, 0.18,
              0.18, 0.18,
```

```
                0.18, 0.18,
                0.18, 0.18,
                0.18, 0.18, 0.18,
                0.18, 0.18,
5               0.18, 0.18, 0.18,
                0.18, 0.18,
                0.18, 0.18,
  /
  .
```

## S5 COSMO-ART comparison online vs. offline

Fig. S1 shows averaged relative differences between the online and offline simulation for several COSMO-ART output variables. The differences are calculated for the lowest model layer and the averaging is done in the following way:

$$DIFF = \left| \frac{2 \times (\bar{\phi}_{\text{online}} - \bar{\phi}_{\text{offline}})}{\bar{\phi}_{\text{online}} + \bar{\phi}_{\text{offline}}} \right| , \tag{1}$$

where the spatially averaged field $\bar{\phi}$ is

$$\bar{\phi} = \frac{1}{N_i N_j} \sum_{i=1}^{N_i} \sum_{j=1}^{N_j} \phi_{i,j} \, . \tag{2}$$

Here, $i$ and $j$ are the grid indices in zonal and meridional directions, respectively. $N_i$ and $N_j$ are the total number of grid points in both directions and $\phi_{i,j}$ is the grid-point value of the respective variable.

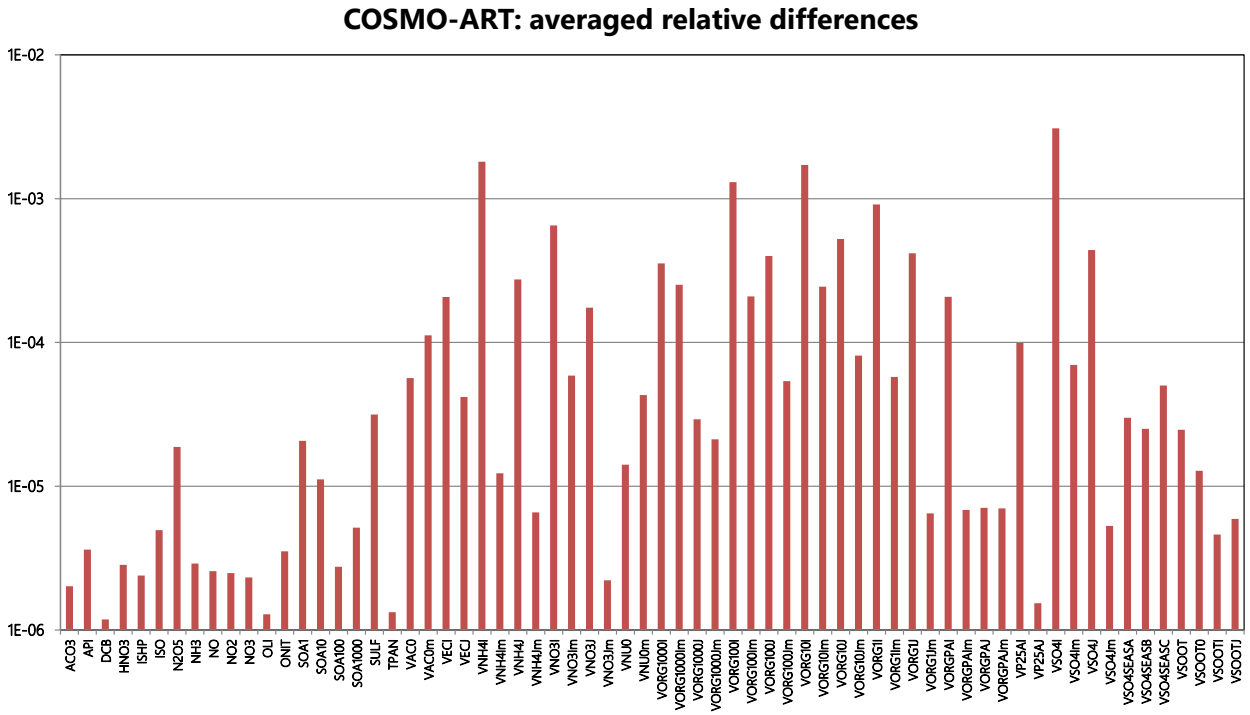


**Figure S1.** Averaged relative differences of COSMO-ART chemical species with values greater than $10^{-6}$. Species starting with a "V" are aerosol compounds.

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