Norwegian Meteorological Institute

Emissions in the EMEP MSC-W model

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Overview

- Anthropogenic emissions provided with the code
- Emission input formats
- Using and combining gridded emissions
- Emissions in the model
- Other anthropogenic emission sources
- Biogenic emission sources

EMEP emissions provided with the code

- Two sets of emission inputs provided for 2015, both include gridded annual emissions of NOx, SOx, NH3, NMVOC, CO, PM2.5 and PMco
  - 50 x 50 km² polar stereographic (PS) projection
    - 7 files: EECCA/gridPOLL
    - ASCII text files with 16 columns (unit is Mg/cell): EMEP_cc i j emis_high emis_low SNAP1-SNAP11
    - EECCA domain: https://www.emep.int/grid/EMEP_domain.pdf
  - 0.1°x0.1° latitude-longitude (30ºN-82ºN; 30ºW-90ºE)
    - EMEP01/GNFRemis_EMEP01_2015.nc
    - GNFR source sectors
    - http://www.ceip.at/ms/ceip_home1/ceip_home/new_emep-grid/grid_definition/
- Data for other years can be downloaded from http://www.ceip.at/ms/ceip_home1/ceip_home/webdab_emepdatabase/emissions_emepmodels/

GNFR versus SNAP source sector

A ‘PublicPower’ (1)
B ‘Industry’ (3)
C ‘OtherStationaryComb’ (2)
D ‘Fugitive’ (4)
E ‘Solvents’ (6)
F ‘RoadTransport’ (7)
G ‘Shipping’ (8)
H ‘Aviation’ (8)
I ‘Offroad’ (8)
J ‘Waste’ (9)
K ‘AgriLivestock’ (10)
L ‘AgriOther’ (10)
M ‘Other’ (5)

SNAP 1 ‘Combustion in energy and transformation industries’
SNAP 2 ‘Non-industrial combustion plants’
SNAP 3 ‘Combustion in manufacturing industry’
SNAP 4 ‘Production processes’
SNAP 5 ‘Extraction & distribution of fossil fuels and geothermal energy’
SNAP 6 ‘Solvent and other product use’
SNAP 7 ‘Road transport’
SNAP 8 ‘Other mobile sources and machinery’
SNAP 9 ‘Waste treatment and disposal’
SNAP 10 ‘Agriculture’
SNAP 11 ‘Other sources and sinks’

Mapping of GNFR sectors to time factor, height distribution and emission split classes (originally defined for SNAP sectors).

Emission input formats - most commonly used

- Since 2015 different formats of gridded annual emissions can be used and mixed under a common framework.
- 'Old' ASCII emissions format with 16 columns (yearly totals)
  - Pros: easy to modify, easy to interpret the numbers
  - Cons: valid only for one specific grid projection, special tools are needed for visualization
- Countrywise NetCDF emisssions (yearly totals, each country and sector has its own field)
  - Pros: all info about the data in one file, the emissions can be reprojected in the code, easy to visualize countrywise with e.g. ncview, easy to add new countries
  - Cons: large number of fields (many zero fields), time-consuming to read in the model

Emission input formats - most commonly used

- Fraction type NetCDF emissions (yearly emission totals are stored in one gridded map per sector, in addition info about country fractions)
  - Pros: all info about the data in one file, the emissions can be reprojected in the code, compact form, faster to read in
  - Cons: difficult to interpret the content of the fields, difficult to add a new country, not possible to visualize countrywise
- Monthly fraction type NetCDF emissions (similar to the above, but with 12 monthly values for each field)
  - Pros and cons as above, but this format can not be combined with other formats

- List of country codes for EMEP domain: https://www.emep.int/grid/country_numbers.txt
- Country codes defined in Country_mod.f90

New emission input format

- A new more general format for emissions has been recently introduced and is still under testing.
- In the new format, emissions are organised in a number of files Emis_sourceFiles(i_file), each file containing a number of sources Emis_sourceFiles(i_file)%source(j_source)
  - A source is any 2D field (possibly+time)
  - The file must have a 'lon' and a 'lat' variable (longitude and latitudes of each grid point)
  - 'lon' and 'lat' must be 1D variables if the projection is 'lon lat', 2D otherwise

New emission input format

- The file and sources can be characterized by a set of variables which can be set by, and in order of increasing priority:
  - Default value
  - Global attribute read in the netcdf file
  - Variable attribute read in the netcdf file
  - Value set for Emis_sourceFiles(i)%XXX in config_emep.nml
  - Value set for Emis_sourceFiles(i)%source(s)%XXX in config_emep.nml
- List of attributes: filename, projection, grid_resolution, periodicity, factor, units, apply_femis, include_in_local_fractions, country_ISO, sector, species, mask_ID, mask_ID_reverse
- List of source attributes: varname, species, factor, units , country_ISO, apply_femis, include_in_local_fractions, mask_ID, mask_ID_reverse

Using and combining gridded emissions

- Emission files are controlled via "config_emep.nml".
  - Include the ASCII emissions files (gridPOLL):
    emis_inputlist(1)%name = 'Datadir/EECCA/gridPOLL',
  - Include the NetCDF emission file (GNFRemis_EMEP01_2015.nc):
    emis_inputlist(2)%name =
    'Datadir/EMEP01/GNFRemis_EMEP01_2015.nc',
  - To avoid double counting we choose which countries to include/exclude from which file
    - E.g. we include only Norway and Italy from the first file (ASCII), the rest is from the second (NetCDF):
      emis_inputlist(1)%incl(1:) = 'NO', 'IT',
      emis_inputlist(2)%excl(1:) = 'NO', 'IT',
  - We can restrict the number of pollutants from the emission files
    - emis_inputlist(1)%PollName(1:2) = 'voc','sox',
    - Pollutant names defined in CM_EmisFiles.inc

Using and combining gridded emissions

- Emission data can be modified using emission factors (e.g. scenario runs)
  - Emission factors can be applied to specific pollutants, countries and emission sectors through the ASCII file femis.dat
  - Set the path in config_emep.nml
    - femisFile = /MyPath/femis.dat
  - E.g. reduce NOx by 20% for all sectors (0) in UK (country code 27):

    Name 7 sox nox co voc nh3 pm25 pmco
    27 0 1.0 0.8 1.0 1.0 1.0 1.0 1.0
  - E.g. reduce NH3 by 40% from sector 10 in Italy (country code 15):

    Name 7 sox nox co voc nh3 pm25 pmco
    15 10 1.0 1.0 1.0 1.0 0.6 1.0 1.0
  - Reductions can also be specified by lon-lat coordinates using the keyword 'lonlat' (e.g. NH3 from Netherlands (country code 17) only removed from the rectangle (3.3ºE-7.2ºE; 50.7ºN-53.5ºN)

    Name 7 sox nox co voc nh3 pm25 pmco
    lonlat 3.3 7.2 50.7 53.5 17 0 1.0 1.0 1.0 1.0 0.0 1.0 1.0

Using and combining gridded emissions

- Combining overlapping emissions using femis.dat
  - It is possible to disregard the "lonlat" reductions introduced by femis.dat for specific emissions by using the "use_lonlat_femis" flag.
  - E.g. switch off all emissions in a region (e.g. Europe, 30ºW-60ºE;30ºN-82ºN;) from Emis_GLOBAL.nc using femis.dat, and replace the emissions in that region with Emis_EUROPE.nc
  - In config_emep.nml we set:
    emis_inputlist(1)%name = '/PathToEmissions/Emis_EUROPE.nc',
    emis_inputlist(1)%use_lonlat_femis = F,
    emis_inputlist(2)%name = '/PathToEmissions/Emis_GLOB_05.nc',
  - In femis.dat we set:

Name					7	sox	nox	co	voc	nh3	pm25	pmco
lonlat	-30.0	60.0	30.0	82.0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Using and combining gridded emissions

- Combining overlapping emissions using “mask” approach
  - Typically used when emissions of a small region (e.g. city) are known in more details, while default emissions are available elsewhere.
  - The “city” emissions are used to set the mask, and the mask is used by the second emission source to turn off emissions within the “city”.
  - In config_emep.nml we set:
    emis_inputlist(1)%name = '/PathToEmissions/Emis_LOCAL.POLL',
    emis_inputlist(1)%set_mask = T,
    emis_inputlist(2)%name = '/PathToEmissions/Emis_GLOBAL.nc',
    emis_inputlist(2)%use_mask = T,
  - Note that the mask should be set before it is used and one should not use monthly emissions to mask yearly emissions.
  - There is only one mask, but several emissions files can set and use the mask.
  - The mask is set for a given position if emissions at that point are larger than 1.0e-20.

Using and combining gridded emissions

- Combining overlapping emissions using new “mask” approach
  - Masks can also be set from any suitable variable that shows the region of interest
  - E.g. mask defined by the PM emissions in the local area (London):

```
EmisMask(1)%filename = '/mypath/myfile.nc' !name of the netcdf file
EmisMask(1)%cdfname  = 'London_PM'         !name of the variable
EmisMask(1)%ID       = 'LONDON'            !the name of mask
EmisMask(1)%threshold = 1.0E-10            !threshold
```

  - Several masks can be defined, each mask is identified by its “ID”
  - Masks defined this way will also be applied on files in old (ASCII) format, if use_mask is set, but it is not possible to set masks by both systems simultaneously.

Emissions in the model - main emission modules

- Main modules to treat standard anthropogenic emissions
  - Emissions_mod.f90
  - EmisGet_mod.f90
  - EmisDef_mod.f90
- Some other emission sources are treated in other modules (e.g. Biogenics_mod.f90, DustProd_mod.f90, ColumnSource_mod.f90)
- Resulting in molecules/(cm^3·sec) for the different pollutant species, which enters the chemistry

Emissions in the model - temporal and vertical distribution

- Temporal distribution
  - Monthly and day-of-week time factors specific to pollutant, country and SNAP source-sector
    - Input files MonthlyFac.POLL and DailyFac.POLL
  - Hourly time factors specific to day-of-week and SNAP sector
    - Input file HOURLY_FACS
    - An additional file defined in HourlyFacSpecialsFile can be created by the user with modified hourly factors to be used for specific countries.
  - Degree-day factors for SNAP2 (function of daily temperatures in grid cells)
    - Input file DegreeDayFactors.nc

- Vertical distribution
  - Default distribution based on SNAP sectors
  - The release heights are defined as layers at specific pressure
  - Input file EmisHeights.txt → EmisGet_mod.f90

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Emissions in the model - chemical speciation

- Chemical speciation of emissions
  - Many of the emission files give emissions of a group of compounds (e.g. VOC, NOx, PMs)
  - Default split specified for each SNAP source-sector
    - Input files emissplit.defaults.POLL
  - Specials files can be used to give speciation for particular countries or SNAP sectors, these are in general optional
    - Input files emissplit.specials.POLL
  - Input file emissplit.specials.voc is required when forest fires are included

Defining own sectors

- Emissions can be assigned to a sector, which will define
  - emission height release distribution
  - split into species
  - timefactors
- Height/split/timefactor for a given sector is defined through a mapping system (predefined mapping: SNAP and GNFR)
- Mapping via three tables (one dimensional arrays) defined in EmisDef_mod.f90 in the arrays "XXX_sec2hfac_map", "XXX_sec2sfac_map","XXX_sec2tfac_map", where "XXX" is the name of the mapping (SNAP or GNFR)
- E.g. GNFR_sec2hfac_map = (/1,3,2,4,6,7,8,8,8,9,10,10,5/), means that GNFR sector 2 is mapped to the 3rd emission height in EmisHeights.txt
- More emission heights can be added in EmisHeights.txt and then accessed by changing the maps
- New mapping can be defined using the "TEST" mapping (EmisDef.f90), then set USE_SECTOR_NAME='TEST' in config_emep.nml

Other anthropogenic emission sources

- Aircraft emissions
  - Aircraft emissions are 'off' by default, if needed set USE_AIRCRAFT_EMIS=.true. in config_emep.nml
  - NOx emissions from aircraft from QUANTIFY can be downloaded from http://www.pa.op.dlr.de/quantify
  - Calculated on annual basis and distributed to monthly files according to seasonal variation, spatial resolution 1º x 1ºx 610m, interpolated to correct grid during model run
  - Input file AircraftEmis_FL.nc (not provided)

- Road dust
  - Set USE_ROADDUST=.true. in config_emep.nml to include road dust
  - Input file RoadMap.nc (Europe, provided)
  - Input file AVG_SMI_2005_2010.nc (global, provided)

Biogenic emission sources

- Natural SO2
  - Dimethyl sulfide (DMS) emissions from sea are computed taking into account sea surface temperature and wind speed
  - Monthly gridded emissions: DMS.nc (OceanicEmissions_GEIA.nc)
  - emis_inputlist(2)%name = 'PathToDMS/DMS.nc',
    emis_inputlist(2)%type = 'DMS',

- Forest fires
  - Global daily emissions stored at 0.2ºx0.2º resolution from “Fire INventory from NCAR” (FINNv1) from year 2005
  - Pollutants included: SO2, CO, NOx, NMHC, PMs, OC and BC
  - To include forest fire emissions set USE_FOREST_FIRES=.true. in config_emep.nml
  - Input file ForestFire_Emis_YYYY.nc (not provided), download data from http://bai.acom.ucar.edu/Data/fire/

Biogenic emission sources

- Biogenic NMVOC
  - Biogenic emissions of isoprene and monoterpene are calculated in the model (function of temperature, solar radiation & land-cover)
  - BVOC emission potentials for four (European) forest types are given in input file EMEP_EuroBVOC.nc
  - Default emission potentials for other land-cover types are included in Inputs_LandDefs.csv
  - Land-cover input files Landuse_PS_5km_LC.nc (EMEP) and glc2000xCLMf18.nc (global)

- Soil NO emissions
  - Emissions of NO from soil are greater in areas with high N-deposition
  - Pre-calculated N-depositions in input file AnnualNdep_PS50x_EECCA2005_2009.nc
  - The file is made based on the results from EMEP MSC-W model runs over a 5-year period

Biogenic emission sources

- Lightning
  - NOx emissions from lightning are included as monthly averages on T21 (5.65º x 5.65º) resolution with global coverage
  - Input files lt21-nox.datMM

- Volcanoes
  - SO2 emissions from passive degassing of volcanoes are included for Etna,Vulcano and Stromboli.
  - Input file columnsource_location.csv contain locations and heights, while columnsource_emission.csv contains emission parameters.
  - To include SO2 and ash emissions from the eruptions of e.g. Eyjafjallajökul (2010) or Grimsvötn (2011) we need to set USE_ASH=.true. in config_emep.nml

Biogenic emission sources

- Sea salt and dust
  - The model calculates sea salt aerosols with diameters up to 10 μm
  - The model include windblown dust within the model domain and dust produced outside, but transported to the model grid
  - Input data in Soil_Tegen.nc (global 0.5 x 0.5deg resolution) used in DustProd_mod.f90, which calculates windblown dust emissions from soil erosion. To include this calculations set USE_DUST=.true. in config_emep.nml
  - Dust from arid surface is accounted for by soil moisture calculations in DustProd_mod.f90 using soil water index from meteo data and permanent wilting point from SoilTypes_IFS.nc
  - To include Saharan dust through boundary conditions set USE_SAHARA=.true. in config_emep.nml

More information about emissions

- EMEP MSC-W Model Unofficial User's Guide
  https://emep-ctm.readthedocs.io/en/latest/

- Section 6 in **"The EMEP MSC-W chemical transport model - technical description."** Atmos. Chem. Phys. 12, 7825-7865, 2012. *Simpson et al.*
  http://www.atmos-chem-phys.net/12/7825/2012/

- More recent EMEP Status Reports in chapter **"Updates to the EMEP MSC-W model"**
  https://www.emep.int/mscw/mscw_publications.html

Thank you for your attention and good luck with the EMEP model!