REPORTED EMISSION DATA IN MODELLING – GAPFILLING AND GRIDDING
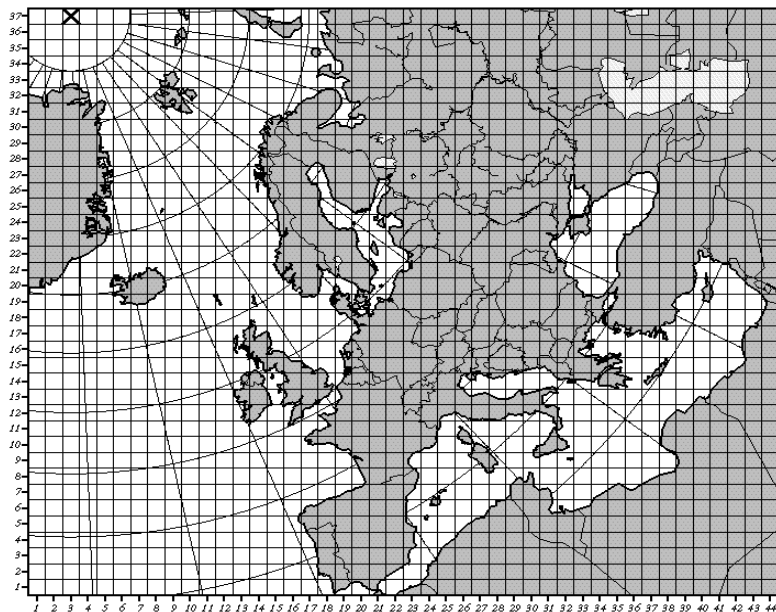
Robert Wankmüller, Bradly Matthews and Sabine Schindlbacher
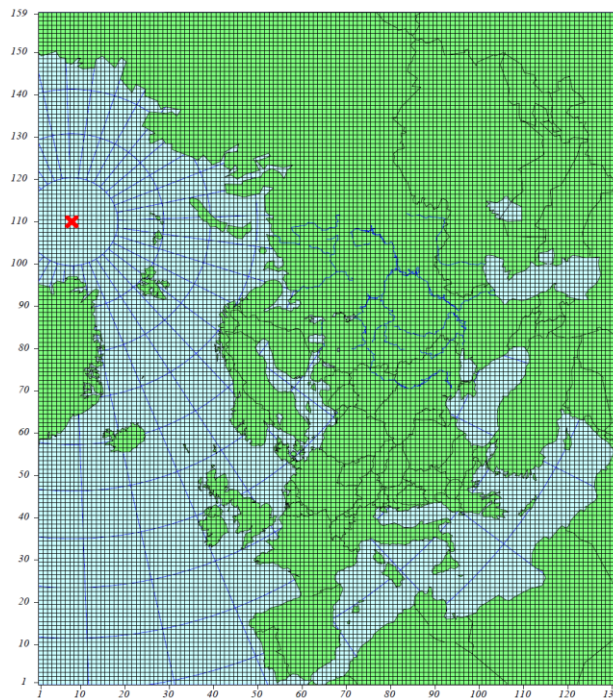
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EMEP DOMAIN - HISTORY

From 1984 to 1998: 150 km² polar-stereographic grid
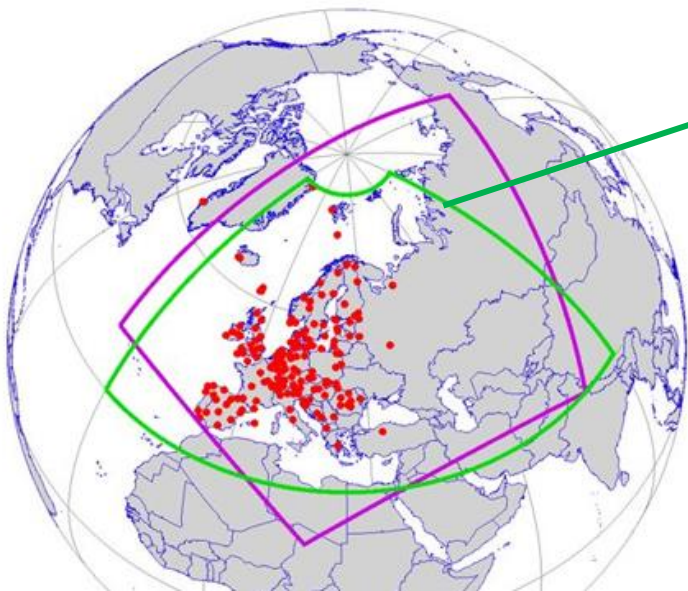
From 1999 on: 50 km² polar-stereographic grid

From 2008 on: Extension to current expansion

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NEW EMEP DOMAIN

From 2013 on: increased spatial resolution to 0.1°x0.1° (long/lat); the new EMEP domain covers the geographic area between 30°N-82°N latitude and 30°W-90°E longitude:

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COUNTRIES WITH REPORTED GRID-DATA

- Until 2022 **37 Parties** reported sectoral gridded emissions for at least one year in 0.1° x 0.1° resolution for main pollutants, particulate matter, heavy metals and persistent organic pollutants

- This covers 80% of the area of all reporting Parties.

- No reported gridded data is available for the 12 Parties that do not report gridded emission data, sea areas, Asian areas, north African areas and the eastern part of the Russian Federation

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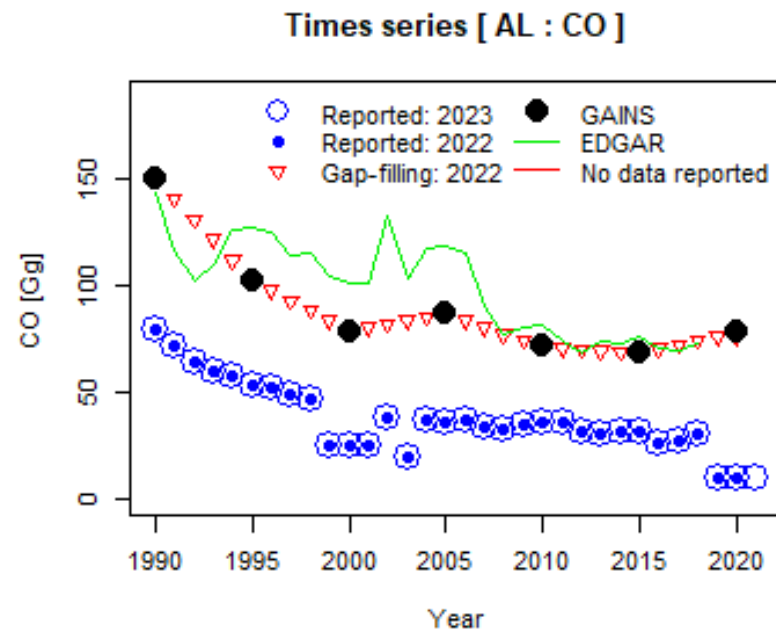
GAP-FILLING AND GRIDDING

- For countries / areas with no reporting, missing data must be filled with data from other sources or by expert estimates

- Gap-filling on national sector emission level is necessary
  - if there is no reported inventory data at all
  - if the reported inventory data is incomplete
  - if the reported inventory (or a part of the inventory) has to be replaced because of quality issues

- Gap-filling of spatial sector emission distribution on grid cell level is necessary
  - if reported gridded data is missing
  - if the reported gridded data (or parts of it) cannot be used because of quality issues

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QUALITY CONTROL AND GAP-FILLING ROUTINE

- The dataset of reported emissions is checked to ascertain where data is missing and to evaluate the plausibility of those emissions.

- To do this a routine, coded in the open source statistical programming environment, R , retrieves the current dataset of reported emissions and processes these data with other datasets like

  ➢ previously reported and gap-filled EMEP datasets

  ➢ independent emissions datasets like EDGAR or GAINS

  ➢ and data on economic indices like GDP or capita

- For each pollutant of each country, quality control graphs are generated, with which assigned experts can evaluate the plausibility of the reported emissions

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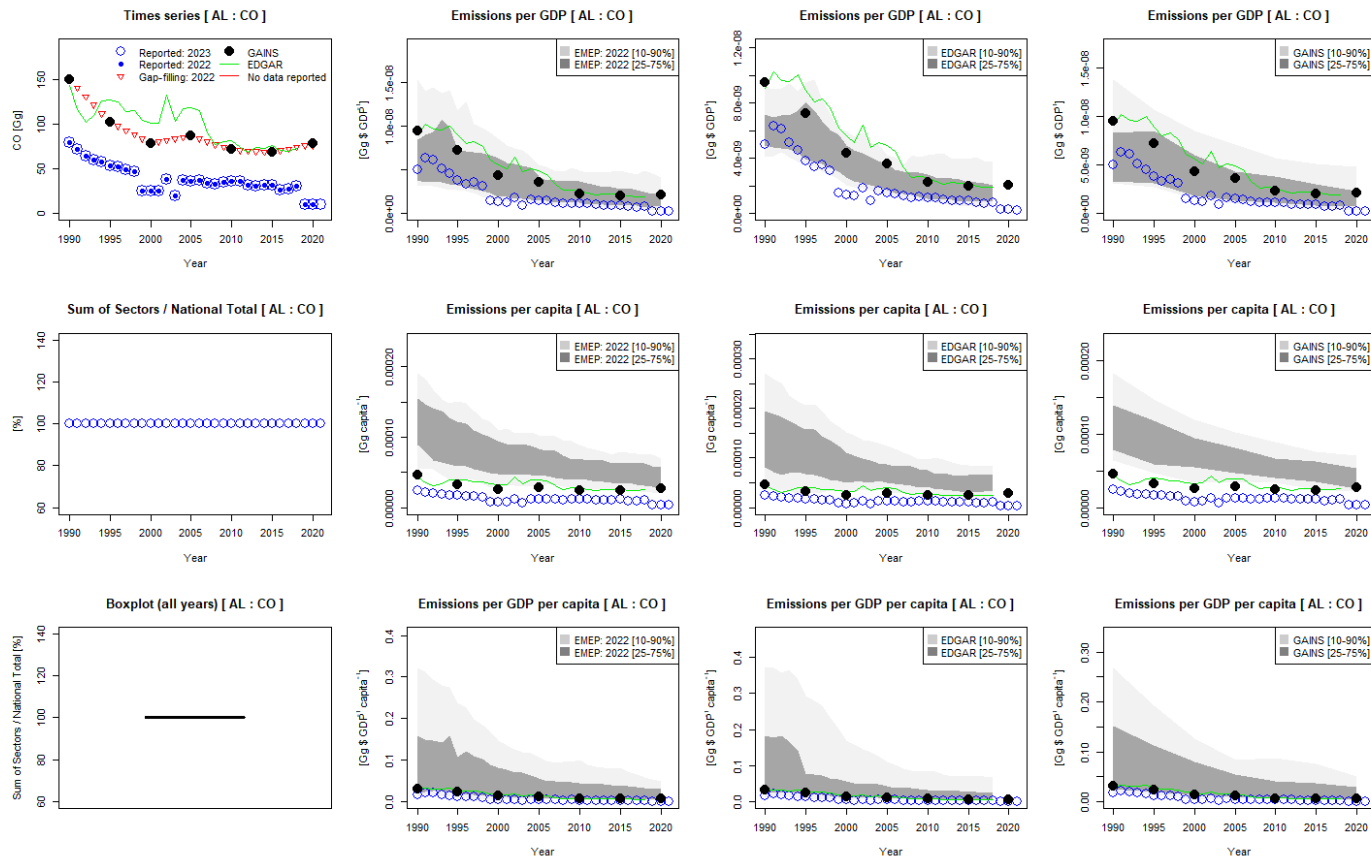
2023 GAP-FILLING – QUALITY CONTROL GRAPHS

- Example Albanias CO emissions

- the time series of the reported national totals are compared against

- the same emissions reported in the previous year

- the time series contained within the gap-filled EMEP dataset of the previous year

- independent datasets v4.3.2 EDGAR dataset*

- and the latest v6b ECLIPSE dataset (2000, 2005, 2010, 2015 and 2020 projection) from GAINS**

Times series [AL : CO]

○ Reported: 2023   ● GAINS
● Reported: 2022   — EDGAR
▽ Gap-filling: 2022   — No data reported

*(1970-2012, Crippa et al. (2018))
** the Greenhouse gas – Air pollution Interactions and Synergies model, (Amann et al., 2011).

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2023 GAP-FILLING – QUALITY CONTROL GRAPHS

AL : CO [Reported: 2023]

AL : CO [GAINS]

AL : CO [EDGAR]
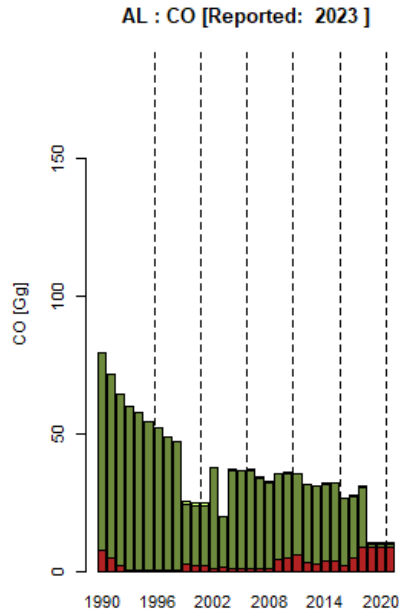
AL : CO [Reported: 2023]
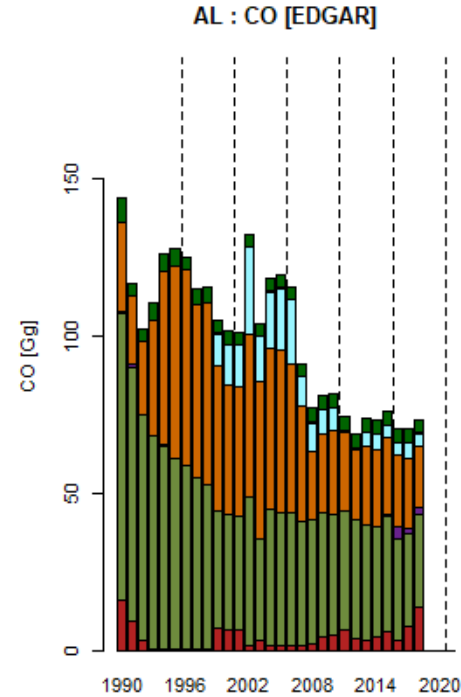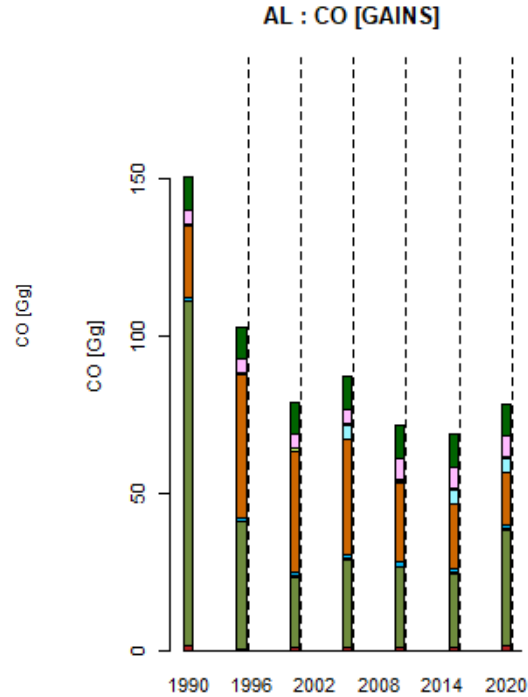
- A_PublicPower
- B_Industry
- C_OtherStatComb
- D_Fugitive
- E_Solvents
- F_RoadTransport
- G_Shipping
- H_Aviation
- I_Offroad
- J_Waste
- K_AgriLivestock
- L_AgriOther
- M_Other

HE EMEP DOMAIN

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GAP-FILLING OPTIONS

- Where data is missing and/or implausible, CEIP experts must select the most appropriate gap-filling/replacement option:
  - ➤ Replacement of all or certain sectors
  - ➤ Single or multi-year Extrapolation
  - ➤ Ratio
  - ➤ Interpolation

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2022 GAP-FILLING – INSTRUCTION SPREADSHEET

- CEIP experts work through a spreadsheet survey summarising
  - the plausibility of the reported emissions
  - noting missing data
  - and selecting the most appropriate gap-filling option.
- Once this spreadsheet is complete, a subsequent R routine reads these instructions and implements the gap-filling procedures thus generating a complete EMEP dataset to be gridded
- **Final steps:**
  - Correction for any residual errors (e.g. rounding errors) by replacing all national totals with the respective sum of totals.
  - Any instances where sectoral emissions of $PM_{2.5} > PM_{10}$ are corrected by replacing the PM_{10} emissions with corresponding $PM_{2.5}$ emissions.

After gap-filling is complete, the territorial sector emissions are then mapped spatially using the CEIP gridding system.

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2022 GAP-FILLING – INSTRUCTION SPREADSHEET

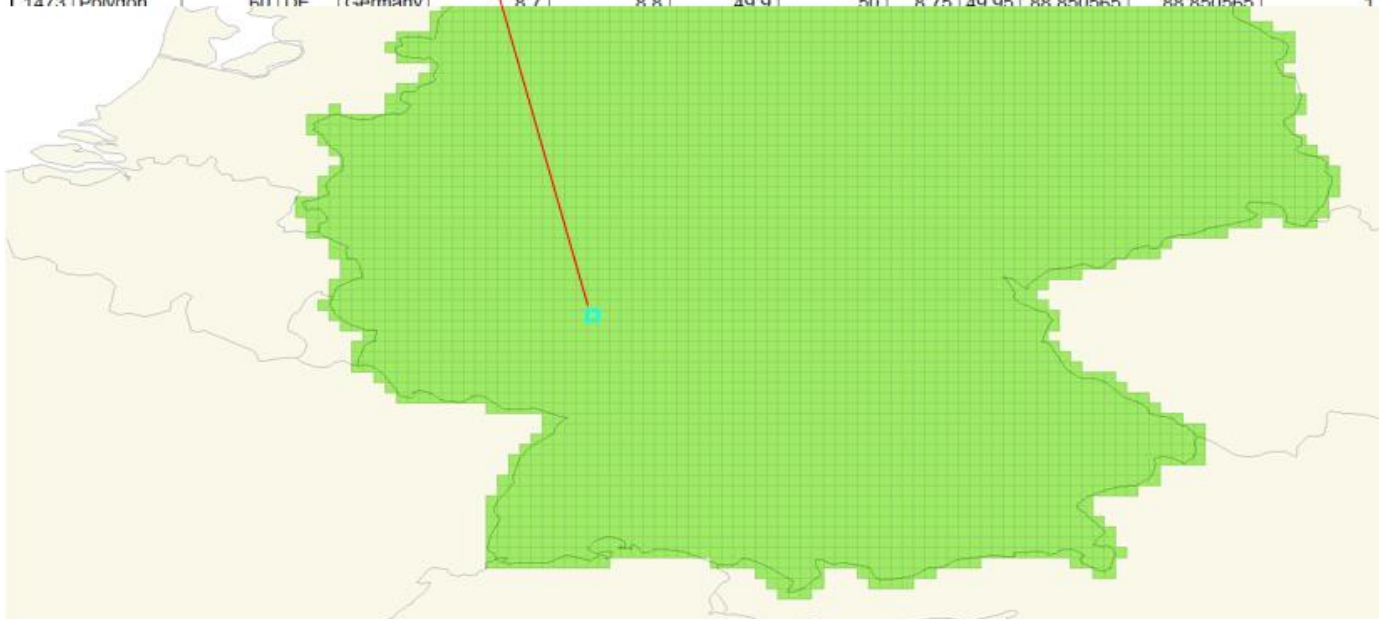|	CC	Country	Component	Gapfilling / Replacement required	Method	Start	End	Sectors	Extrapolation trend	Split	Ratio	Interpolation required	Interpolation years
2	AL	Albania	CO	Yes	Replacement	1990	2020	All				No	
3	AL	Albania	NH3	Yes	Replacement	1990	2020	All				No	
4	AL	Albania	NMVOC	Yes	Replacement	1990	2020	All				No	
5	AL	Albania	NOx	Yes	Replacement	1990	2020	All				No	
6	AL	Albania	SOx	Yes	Replacement	1990	2020	All				No	
7	AL	Albania	PM10	Yes	Replacement	1990	2020	All				No	
8	AL	Albania	PM2.5	Yes	Replacement	1990	2020	All				No	
9	AL	Albania	BC	Yes	Replacement	1990	2020	All				No	
10	AM	Armenia	CO	Yes	Replacement	1990	2020	All				No	
11	AM	Armenia	NH3	Yes	Replacement	1990	2020	All				No	
12	AM	Armenia	NMVOC	Yes	Replacement	1990	2020	All				No	
13	AM	Armenia	NOx	Yes	Replacement	1990	2020	All				No	
14	AM	Armenia	SOx	Yes	Replacement	1990	2020	All				No	

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GRID DEFINITION

- For all countries/areas within the new EMEP domain grid definitions can be downloaded in different formats from the CEIP website (https://www.ceip.at/the-emep-grid/grid-definition)

- Proxy grids as well as reported grids should be prepared using this grid definitions

- Available formats are:
  - Excel tables
  - CSV files
  - ESRI shape files

Party	Country Code	Grid definition tables for 0.1°x0.1° (long-lat) grid	ESRI shape files with 0.1°x0.1° (long-lat) grid definition	Number of grid cells
ALBANIA	AL	Excel / CSV	Shapefile	374
ARMENIA	AM	Excel / CSV	Shapefile	392
AUSTRIA	AT	Excel / CSV	Shapefile	1144
AZERBAIJAN	AZ	Excel / CSV	Shapefile	1094
BELARUS	BY	Excel / CSV	Shapefile	3004
BELGIUM	BE	Excel / CSV	Shapefile	465
BOSNIA & HERZEGOVINA	BA	Excel / CSV	Shapefile	661

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GRID DEFINITION

FID	Shape *	Number	ISO	Name	long_min	long_max	lat_min	lat_max	long	lat	area	frac_area	fraction
1467	Polygon	60	DE	Germany	8,1	8,2	49,9	50	8,15	49,95	88,850565	88,850566	1
1468	Polygon	60	DE	Germany	8,2	8,3	49,9	50	8,25	49,95	88,850565	88,850565	1
1469	Polygon	60	DE	Germany	8,3	8,4	49,9	50	8,35	49,95	88,850565	88,850565	1
1470	Polygon	60	DE	Germany	8,4	8,5	49,9	50	8,45	49,95	88,850565	88,850565	1
1471	Polygon	60	DE	Germany	8,5	8,6	49,9	50	8,55	49,95	88,850565	88,850565	1
1472	Polygon	60	DE	Germany	8,6	8,7	49,9	50	8,65	49,95	88,850565	88,850566	1
1473	Polygon	60	DE	Germany	8,7	8,8	49,9	50	8,75	49,95	88,850565	88,850565	1

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CEIP GRIDDING-SYSTEM

Grid Definition
(ISO2/area|x,y|fraction)

Proxy Grids
(ISO2/area|x,y|proxy-value)

Reported Grids
(ISO2|x,y|sector|emission)

Reported LPS
(ISO2|x,y|sector|emission)

Other LPS
(ISO2|x,y|sector|emission)

Gridding-Configuration
(ISO2/area|sector|
base-grid|LPS)

Gap-filled emissions
(ISO2/area|sector|emission)

SPATIAL

DISAGGREGATION

Spatial input data

Output data - grid datasets for 13 GNFR sectors and national total

Reported and gap-filled annual country/area emissions

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GAP-FILLING OF SPATIAL SECTOR EMISSION DISTRIBUTION ON GRID CELL LEVEL

In countries / areas where no reported gridded data is available, information on spatial distribution must be derived from other sources, like

- European anthropogenic emissions from the Copernicus Atmosphere Monitoring System (CAMS-REG-AP)
  - ➤ TNO Department of Climate, Air and Sustainability - Utrecht – Netherlands
  - ➤ https://eccad.aeris-data.fr/

- Global Air Pollutant Emissions from the Emissions Database for Global Atmospheric Research (EDGAR v6.1)
  - ➤ https://edgar.jrc.ec.europa.eu/dataset_ap61

- Large Point Sources from the European Pollutant Release and Transfer Register (E-PRTR)
  - ➤ https://prtr.eea.europa.eu/#/home

- Global shipping emissions from the Copernicus Atmosphere Monitoring System (CAMS-GLOB-SHIP)
  - ➤ Finnish Meteorological Institute - Helsinki – Finland
  - ➤ https://eccad.aeris-data.fr/

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GRIDDING-CONFIGURATION – BASE GRID ALLOCATION

For each country/GNFR sector combination the gridding system is searching for available reported grid- and LPS data and for other available proxy data (CAMS, EDGAR, E-PRTR) and is automatically setting the best proxy information for a certain country/sector combination based on a ruleset which is defined within the system.…

- Search for reported grid data within the configured timeframe and use it if available
    - For each country were reported grid data is available and it is configured that LPS information is not included in reported gridded emissions (e.g. GB), search for LPS data and use it in addition
    - If reported grid data is not available and the pollutant is a HM or POP, search for reported gridded PM10 data and use it if available
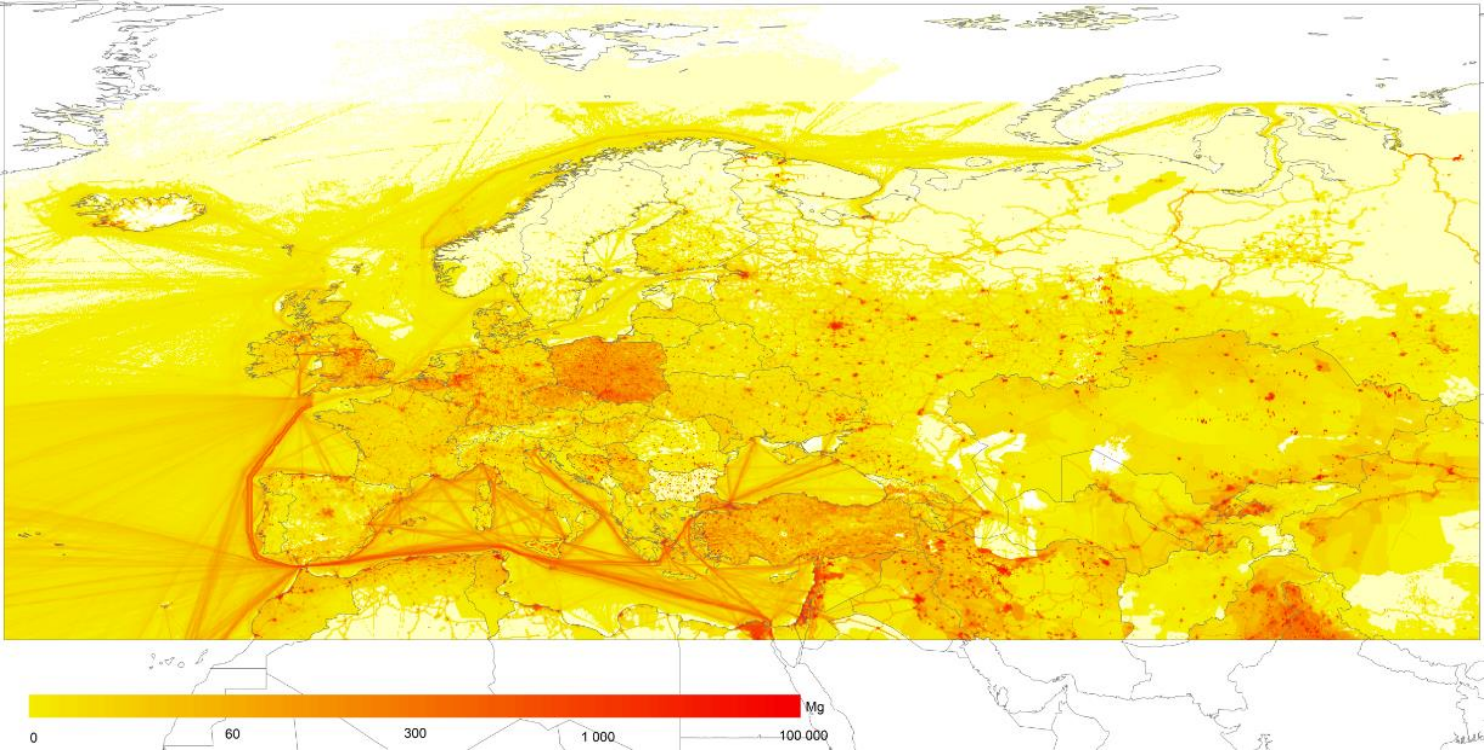
More details on the gridding can be found in this report:
DOCUMENTATION OF THE NEW EMEP GRIDDING SYSTEM
https://www.ceip.at/the-emep-grid/gridded-emissions

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WHAT IS DONE FOR YEARS WHERE NO GRIDDED DATA IS REPORTED?

- the latest inventory data reported in Annex I is aggregated to GNFR categories and spatially distributed following the spatial distribution reported in the latest submission of gridded data

- the years 2016, 2017, 2018 and 2019 were distributed regarding reported gridded data for 2015

- the years 2011, 2012, 2013 and 2014 were distributed regarding reported gridded data for 2010

- the years 2006, 2007, 2008 and 2009 were distributed regarding reported gridded data for 2005

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EXAMPLE RESULT – SO$_x$ NATIONAL TOTAL FOR 2018

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ADDITIONAL INFORMATION

- Download of gridded emissions on CEIP website
  - https://www.ceip.at/the-emep-grid/gridded-emissions

- Documentation of the CEIP gridding system
  - https://webdab01.umweltbundesamt.at/download/EMEP_gridding_system_documentation.pdf

- A summary about the main points of the 0.1x0.1 long/lat EMEP grid
  - http://www.unece.org/fileadmin/DAM/env/documents/2012/air/EMEP_36th/n_3_EMEP_note_on_grid_scale__projection_and_reporting.pdf

- Short presentation on the grid development over time
  - https://www.ceip.at/fileadmin/inhalte/ceip/6_grid_lps/ceip_new_emep_grid.pdf

- Methodologies applied to the CEIP GNFR gap-filling 2022
  - https://www.ceip.at/fileadmin/inhalte/ceip/00_pdf_other/2022/main_pm_bc_gap-filling_documentation_2022_final_logo.pdf

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AUTOMATED CHECKS

There are automated quality checks implemented to the gridding system – checks on the spatial input data as well as checks on the grid results

- Checks on spatial input data

  During the transformation of reported grid and LPS data, as well as proxy data from CAMS, EDGAR and E-PRTR, to the database files of the gridding system the following automated checks have been implemented so far:

  ➢ Sector name – only the exact GNFR sector names of the template are valid. Different names (e.g. „IndustrialComb" instead of „Industry") are not accepted.

  ➢ LPS coordinates outside country borders are not accepted

  ➢ Exception: in some cases LPS over sea areas are valid (e.g. drilling platforms from Nor-way in the North Sea)

  ➢ Grid cells outside country borders

  ➢ Exception: in some cases grid cells over sea areas are valid (e.g. national shipping emissions from Norway and the United Kingdom in the North Sea)

- Checks on grid results within the gridding system

  For each Country/Area/Pollutant combination is checked if the grid sum of the individual sectors and the national total matches exactly the gap-filled emission values
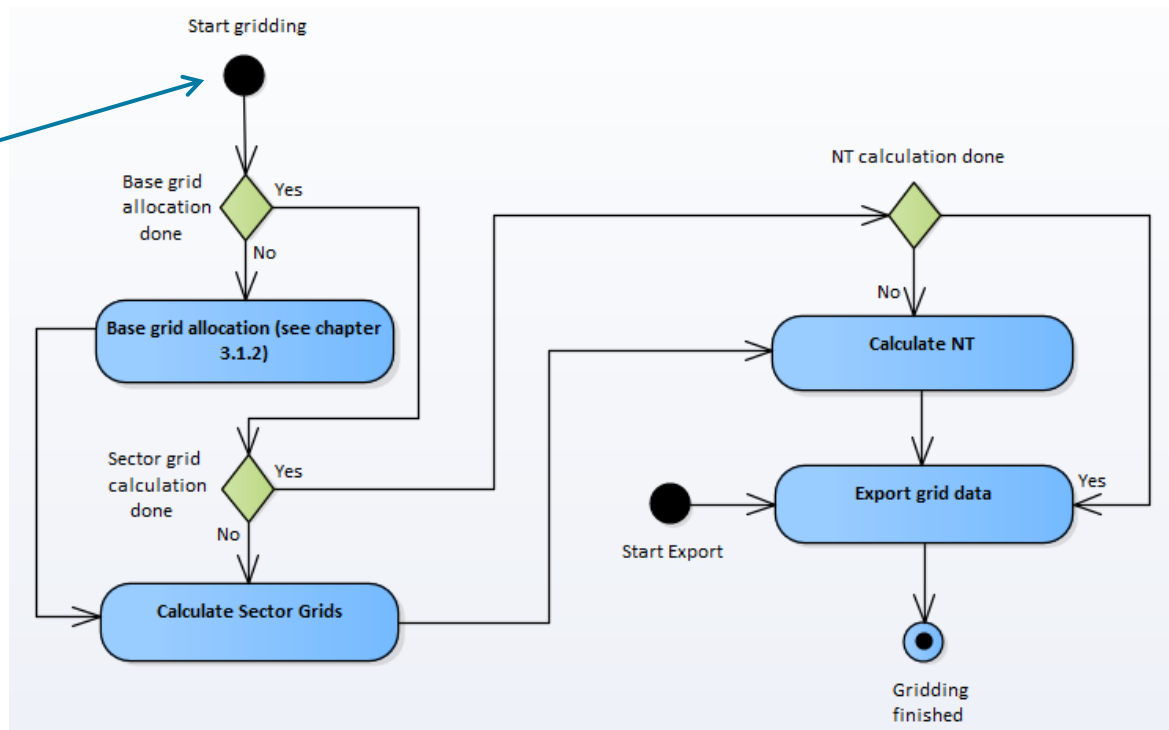
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GRID CALCULATION (SPATIAL DISAGGREGATION)

GRIDDING-CONFIGURATION – BASE GRID ALLOCATION

The table base grid allocation contains the gridding configuration for a specific pollutant and year.

ISO2	a	sector	pollutant	base_grid	lps
AT	2	A_PublicPower	NOx	Reported_Grids\Rep_GRID_NOx_2015	
AT	2	B_Industry	NOx	Reported_Grids\Rep_GRID_NOx_2015	
AT	2	C_OtherStationaryComb	NOx	Reported_Grids\Rep_GRID_NOx_2015	
AT	2	D_Fugitive	NOx	EDGAR_v4.2\v42_NOx_2008_D_Fugitive	
AT	2	E_Solvents	NOx	EDGAR_v4.2\v42_NMVOC_2008_E_Solvents	
AT	2	F_RoadTransport	NOx	Reported_Grids\Rep_GRID_NOx_2015	
AT	2	G_Shipping	NOx	Reported_Grids\Rep_GRID_NOx_2015	
AT	2	H_Aviation	NOx	Reported_Grids\Rep_GRID_NOx_2015	
AT	2	I_Offroad	NOx	Reported_Grids\Rep_GRID_NOx_2015	
AT	2	J_Waste	NOx	Reported_Grids\Rep_GRID_NOx_2015	
AT	2	K_AgriLivestock	NOx	Reported_Grids\Rep_GRID_NOx_2015	
AT	2	L_AgriOther	NOx	Reported_Grids\Rep_GRID_NOx_2015	
AT	2	M_Other	NOx	EDGAR_PROXY\edgar_proxy_population_2010	
AT	2	NATIONAL_TOTAL	NOx		
ATL	32	G_Shipping	NOx	EDGAR_PROXY\edgar_proxy_Ships_2007	
ATL	32	NATIONAL_TOTAL	NOx		
AZ	69	A_PublicPower	NOx	EDGAR_v4.2\v42_NOx_2008_A_PublicPower	
AZ	69	B_Industry	NOx		Reported_LPS\Rep_LPS_NOx_2013

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GRIDDING-CONFIGURATION – RULESET DEFINITION

For each country/sector combination the gridding system is searching for available reported grid- and LPS data and for other available proxy data (CAMS, EDGAR, E-PRTR) and is automatically setting the best proxy information for a certain country/sector combination based on a ruleset which is defined within the system.

- Between a configured timeframe (min and max year) the system is always searching for the most current reported grid and LPS data for each pollutant/area/sector combination
- For CAMS, EDGAR and E-PRTR proxy data a certain year must be defined
- For each pollutant/area/sector:
  - Search for reported grid data within the configured timeframe and use it if available
    - For each country were reported grid data is available and it is configured that LPS information is not included in reported gridded emissions (e.g. GB), search for LPS data and use it in addition
    - If reported grid data is not available and the pollutant is a HM or POP, search for reported gridded PM10 data and use it if available
    - If reported grid data is not available and the pollutant is BC, search for reported gridded PM2.5 data and use it if available
  - If reported grid data is not available
    - If the pollutant is a HM or POP, search for PM10 proxy data in the following steps
    - If the pollutant is BC, search for PM2.5 proxy data in the following steps
    - If sector is G_Shipping, search for proxy data derived from FMI shipping emissions and use it if available
    - Otherwise search for proxy data derived from CAMS and use it if available
      - If the pollutant is not NMVOC, the sector is E_Solvents and reported grid data as well as proxy data derived from CAMS is not available, search for NMVOC proxy data derived from CAMS for E_Solvents and use it if available
      - If the pollutant is not CO, the sector is D_Fugitive and reported grid data as well as proxy data derived from CAMS is not available, search for CO proxy data derived from CAMS for D_Fugitive and use it if available
      - If the sector is K_AgriLivestock and reported grid data as well as proxy data derived from CAMS is not available, search for proxy data derived from CAMS for L_AgriOther and use it if available
    - Otherwise search for proxy data derived from EDGAR and use it if available
      - If the pollutant is not NMVOC, the sector is E_Solvents and reported grid data as well as proxy data derived from EDGAR is not available, search for NMVOC proxy data derived from EDGAR for E_Solvents and use it if available
      - If the pollutant is not CO, the sector is D_Fugitive and reported grid data as well as proxy data derived from EDGAR is not available, search for CO proxy data derived from EDGAR for D_Fugitive and use it if available
      - If the sector is K_AgriLivestock and reported grid data as well as proxy data derived from EDGAR is not available, search for proxy data derived from EDGAR for L_AgriOther and use it if available
  - Search for reported LPS data
    - If reported LPS data is available and the sector is A_PublicPower or B_Industry and proxy data derived from EDGAR is used, replace it with reported LPS data
    - If reported LPS data is available and the sector is not A_PublicPower or B_Industry and proxy data derived from EDGAR is used, use reported LPS data in addition
  - If reported LPS data is not available search for LPS data from E-PRTR
    - If LPS data from E-PRTR is available and proxy data derived from EDGAR is used, use LPS data from E-PRTR in addition

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