Considerations of Changing the EMEP Grid

Document prepared by the EMEP Centres MSC-W, MSC-E, CEIP and CIAM
The chairperson of the TFEIP, Chris Dore and
The chairperson of EMEP SB, Sonja Vidič
Date: September 2012

Abstract

At the thirty-fifth session of the EMEP Steering Body the EMEP Centres were asked to prepare a document summarizing their viewpoints concerning modifications of the official EMEP grid (and in particular grid resolution,) grid projection and grid domain).

The EMEP Centres suggest a change of the official EMEP grid to a latitude-longitude projection, covering the geographic domain 30°N-82°N latitude and 30°W-90°E longitude.
The EMEP models will be run on different grid resolution scales (from country specific to global), depending on the needs and requirements.
A new emissions gridding system has to be developed with the TFEIP.

The gridding of emissions for models should be performed by CEIP, using the reported gridded emissions, proxy data and LPS data.

Introduction

The geographical scope of EMEP is defined as “the area within which, coordinated by the international centres of EMEP, monitoring is carried out." Since its adoption in 1984, this definition has been referred to in all protocols to the LRTAP Convention. As Parties have ratified or acceded to the EMEP Protocol, the geographical scope of EMEP has become larger and the EMEP grid has been modified twice so far, once in the late 1990s and then again in 2008.

From 1984 to 1998 a 150 × 150 km^2 polar-stereographic grid was used for EMEP reporting. From 1999, the grid resolution was changed to 50 × 50 km^2, but the area covered by the finer resolution EMEP grid remained unchanged.

In 2008, the domain covered by the EMEP grid was extended to its current domain to also include EECCA countries and a larger part of the Russian Federation, while keeping the resolution unchanged (Figure 1).

Developments in air pollution assessment imply new demands in regard to the geographical scope and model grid resolution:

- Atmospheric dispersion of some pollutants is global, which requires assessment on a global or hemispheric scale (HTAP 2010 Assessment Report).
- A number of tasks related to climate change and its effect on air pollution also require consideration on wider spatial scales.
- There is increasing interest among Parties to the Convention for more detailed information on pollution levels within their territories that require assessments with finer spatial resolution.

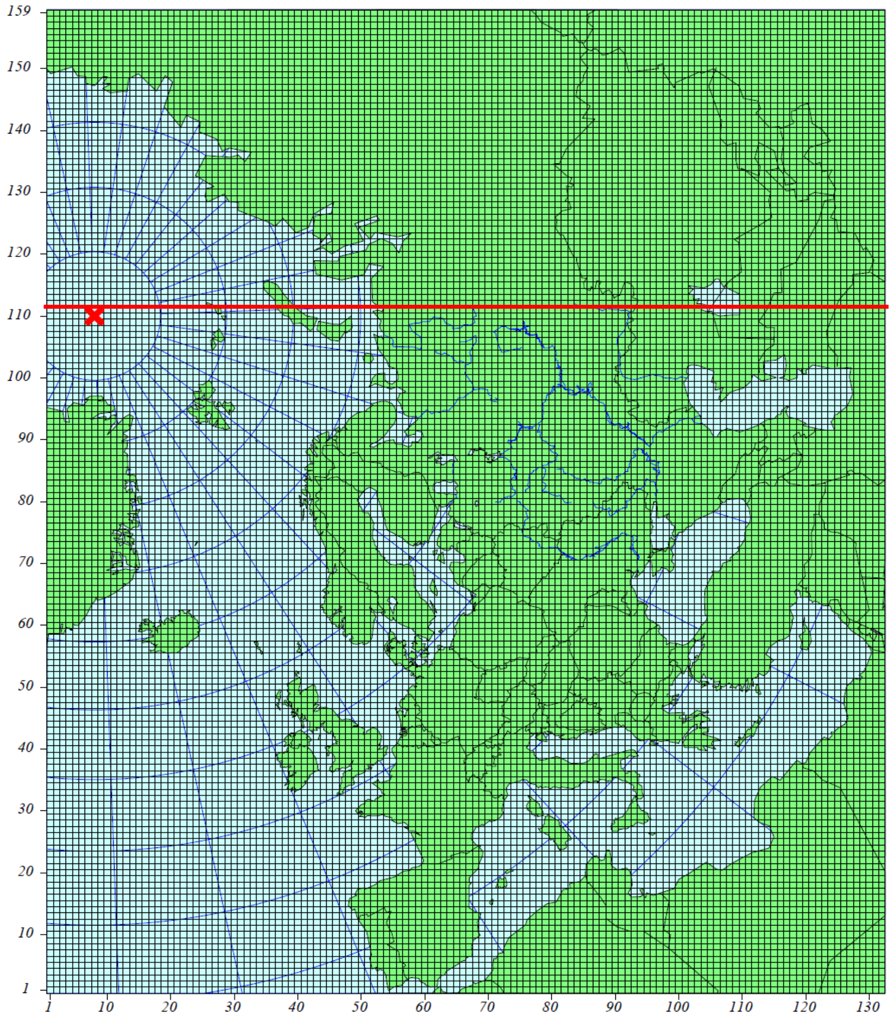

Figure 1: Map of the extended 50 × 50 km^2 grid, which has been in use since 2008.

Given the increasing resolution in state-of-the-art atmospheric models there has been on-going discussion about modifying the EMEP grid. The main issues related to the change of the EMEP grid can be divided into:

- **Change of the grid projection**: from the current polar-stereographic grid to a regular latitude-longitude grid

- **Increase of the grid resolution**: from the current 50 × 50 km^2 to finer resolutions

- **Change of the domain**

Grid projection

Table 1 below summarizes the pros and cons of using one of two different grid projections.

Table 1: Pros and cons of the two projections currently under consideration. Red font: specific to EMEP model runs; green font: specific to emission data/reporting; blue font: specific to provision of meteorological and other input data.

Grid projection	Favourable features	Challenges
Latitude-longitude grid	1. Enables consistent model studies from regional to global scales 2. Interpolation of meteorological fields is not required 3. Easily comparable to other emission data (EDGAR, TNO, APMoSPHERE) 4. Most commonly used grid throughout the scientific community (e.g. TF HTAP, the Climate community), i.e. easier exchange of data with other communities (increased usefulness of EMEP data to the scientific community, etc.)	1. Grid size varying from North to South 2. For geometric reasons, some countries that are outside EMEP and that do not provide emission data, will fall into the grid domain 3. Transition phase from one projection to another implies substantial changes of software, creating additional error sources. 4. There will be a detectable ‘cut’ in the trend series of modelled concentrations which happens when the model background data change.
Polar-stereographic grid	1. Grid size does not vary significantly over the model domain 2. Inclusion of countries outside EMEP within the model domain can be avoided by rotation and translation of the grid.	1. Interpolation of meteorological fields is required 2. Different from common projection (i.e. lat-lon) of other input data bases, such as meteorology, land use, population density, etc.; all easily accessible data produced in lat-lon projection have to be transformed.

Spatial resolution and geographical domain

The EMEP MSC-W model has for several years been run on a polar-stereographic grid with 50×50 km^2 resolution. Given increasing computational power, it has been considered for some years to increase the resolution of the EMEP model simulations to better account for chemical and physical processes that occur on spatial scales smaller than 50 km.

Technical feasibility and gain in accuracy

Given increasing computational power, it has been considered for some years to increase the resolution of the EMEP model simulations to better account for chemical and physical processes that occur on spatial scales smaller than 50 km, and in order to keep the EMEP modeling effort state-of-the-art. The underlying assumption is that higher resolution of the model will enhance the accuracy of its results, as emission sources can be placed more accurately, topography and land use can be accounted for on finer detail, sub-scale processes become grid-resolved rather than parameterized, and non-linear chemical and physical processes occurring on finer spatial scales can be captured better in the model. The rationale behind this is that nature, in the context of atmospheric chemistry, import and export fluxes, is a continuum, so the finer the discretization is the closer to reality one should get.

However, the additional accuracy to be gained from higher resolution depends on the quality of appropriate input data (meteorology, emissions data etc.), indicating therefore that refinement of the model grid should be accompanied by a corresponding increase in input data quality and resolution. Reporting of emissions from LPS by all Parties could significantly improve flexibility and accuracy of gridded emissions.

The additional accuracy will also depend on the formulation of the model and its assumptions (e.g. hydrostatic approximation, vertical resolution) that should still hold when the spatial scale of the model grid decreases. Simultaneously, better resolved input data will foster model developments hence, better and more reliable results.

Currently, the EMEP MSC-W model is capable, for example, of simulating air pollution and deposition on 10×10 km^2 resolution, as has been demonstrated in earlier EMEP status reports or even at 5×5 km^2 resolution as has been demonstrated in the EMEP4UK project (e.g. Vieno et al., 2009, 2010. The EMEP MSC-E model has been successfully applied for simulations of heavy metal pollution and source-receptor relationships at 5×5 km^2 resolution in the Czech Republic and some other countries. It was demonstrated that change from 50×50 km^2 grid to finer model resolution (5×5 km^2) leads to improvement of the model performance against observations (*Ilyin et al*., 2009; 2010, Jericevic, Ilyin, Vidic, 2011, Váňa, Machálek, MSC-E, 2012).

Model runs on fine resolution, especially those done for source-receptor relationships are computationally expensive. According to rough estimates made by MSC-W based on availability of CPU time, status runs with the EMEP MSC-W model can be performed on about 20 km resolution by 2012, while source-receptor calculations may be feasible in this resolution by 2014.

Computer resources will probably allow status runs on about 10 km resolution by 2014 and source-receptor calculations on the same resolution by 2019. Such estimates, going several years into the future, are obviously uncertain but it has to be noted that there are no conceptual obstacles. The limiting factor is rather the CPU time availability.

Interaction of scales

Bearing in mind the current uses and developments of EMEP models it proves reasonable to organize EMEP operational simulations at several levels with direct consistent links in between them and a spatial resolution that depends on the task of concern.

The first level simulations should cover the globe or the Northern Hemisphere to account for intercontinental transport and influence of external regions (e.g. Middle East and East Asia) on pollution levels in Europe. Results of the global/hemispheric simulations should be used for setting up initial and boundary condition data for the next level simulation on a regional scale. An example of a possible EMEP regional domain in lat-lon coordinates is given in Figure 2, along with the current EMEP domain. It covers Europe, Central Asia and the western part of the Russian Federation.

Grid resolutions for the standard EMEP regional simulations could be chosen within the range from 0.5° × 0.5° to 0.2° × 0.2° (some characteristics of possible grids are given in Table 2). The particular choice of the grid resolution requires additional research and more extensive discussion involving different assessment communities (emission experts, modelers, effects community etc.)

A more detailed assessment of pollution levels can be performed at national/local level on finer spatial resolution (0.1° × 0.1° or finer). Detailed input data available on a national scale (local-scale emissions, observations from national networks etc.) could significantly improve the quality of the assessment. The required initial and boundary condition data can be provided by the regional scale simulations.

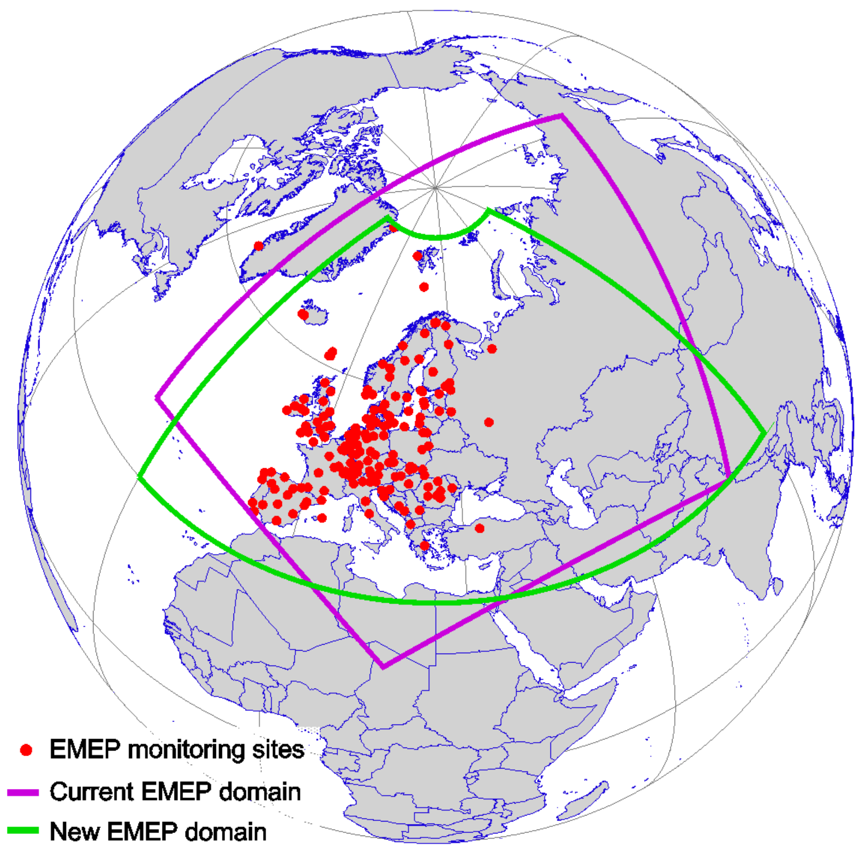

Figure 2: Current and suggested future EMEP domains. Magenta line: current EMEP domain in the polar-stereographic projection; green line: suggested EMEP domain in the latitude-longitude projection (30°N-82°N, 30°W-90°E); red circles: EMEP monitoring sites.

Comparison of some characteristics of different model grids (including the current EMEP grid), are shown in Table 2 below.

Table 2. Characteristics of the current EMEP grid and some lat-lon grids. Quantitative values of the lat-lon grids correspond to the domain 30°N-82°N, 30°W-90°E

Grid type	Projection	Grid size (I × J)	Number of grid cells	Size of grid cell at 40°N (Italy)	Size of grid cell at 60°N (Scandinavia)
Current EMEP	PS	159 × 135	~21,500	40 × 40 km^2	50 × 50 km^2
0.5° × 0.5°	lat-lon	240 × 104	~25,000	43 × 56 km^2	28 × 56 km^2
0.4° × 0.4°	**lat-lon**	**300 × 130**	**39,000**	**34 × 44 km^2**	**22 × 44 km^2**
0.2° × 0.2°	**lat-lon**	**600 × 260**	**156,000**	**17 × 22 km^2**	**11 × 22 km^2**
0.1° × 0.1°	lat-lon	1200 × 520	624,000	9 × 11 km^2	6 × 11 km^2

Several studies have shown that the EMEP modelling centres can provide more accurate results with increased resolution when more detailed input data are used. Significant improvements of modelling results can be achieved on a national/local scale with spatial resolution refined down to several kilometres. Therefore, fine grid resolution (0.1° × 0.1° or even finer) could be used for various research and policy relevant studies.

Gridding of emissions

Data from EMEP are intended to be useful for other users beyond the EMEP modelling centres, also in the years to come. Most national modellers and agencies require resolutions that are much finer than 50 × 50 km^2, in particular for population exposure to air pollution, health effect studies and ecosystem impact assessments.

If EMEP status calculations are to be done on resolutions down to 0.1°× 0.1°, emissions should be prepared on a resolution at least as fine as this. There are several possibilities that should be discussed within TFEIP, the Bureau and the Steering Body:

1) Countries report gridded emissions on 0.1°× 0.1° resolution following the same procedures as today,
2) The gridding is done completely by CEIP – a gridding system is based on proxy data and has to be developed,
3) Countries report gridded emissions on 0.1°× 0.1° resolution with LPS data following the same procedures as today. In parallel, a gridding system is developed by CEIP. The gridded emissions from the system are used to check the quality of reported emissions, and identify and discuss discrepancies with emission experts. In the end of the process the reported gridded emissions should substitute those gridded from the system. In case of missing data from some regions, gridded data from the system developed by CEIP should be used.

The three alternatives are presented in Table 3, together with pros and cons.

Table 3: Pros and Cons of Different Strategies for Gridding Emissions.

Alternatives	Pros	Cons
1. 0.1° × 0.1°, Parties report gridded data + LPS (same system as today)	Relatively easy to manage.	Limited flexibility.
2. Gridding done by CEIP	Flexible with respect to resolution/projection. Consistent data sets. Parties have to report LPS emissions.	High work load for CEIP. Need to develop procedures for QA/QC of gridded data.
3. Gridding done by CEIP and by countries	Flexible with respect to resolution/projection. Parties have to report LPS emissions.	High work load for CEIP. Need to develop procedures for QA/QC of gridded data.

Current status with respect to reporting of gridded emission data

Currently, approximately half of the countries report gridded data. However, many of the countries that report gridded emissions do already have them available on a very fine scale (1 km or similar), or they have the systems available to do so. Therefore, it might not be a much larger burden for countries to report emissions on a finer scale (e.g. 0.1°× 0.1°). On the other hand, it cannot be expected that countries that do not report gridded emissions today will start reporting emissions on finer scale straightaway.Moreover, specifying a specific grid might not be the best long-term solution (alternative 1 in Table 3.), as model runs will have different resolutions depending on their purpose. In any case, development of a centralised gridding system is necessary.

Development of a centralised gridding system at CEIP should ensure maximum flexibility and similar to the systems developed by TNO and VITO (REFS). In these emission gridding systems, proxy data (e.g. road traffic maps, position of power plants etc.) are used to grid the emissions. As such proxy data are available on a very fine resolution, a system that is flexible with respect to resolution could be set up (e.g. there could be a possibility to choose either 0.1 or 0.2 degree resolution). Another advantage is that emissions across Europe would be gridded in a consistent way, also for those countries that do not deliver gridded data. Often the best knowledge about the emissions is found in the countries themselves, and a centralized gridding system may not provide the best gridded emissions for all countries, unless close cooperation between the countries and the gridding centre is ensured, making best use of available knowledge within the countries. The setup of such a system would require a substantial amount of work. To ensure flexibility of the gridding system Parties have to report information on LPS.

The third alternative also requires the setup such as a gridding system. However, the reported fine scale emissions could replace the emissions from the centralized system if the quality is found acceptable (the emissions from the centralized system could be used to check the reported data). During the transition period to the new gridding system Parties have to report gridded data in agreed resolution plus information on LPS. Gridding of emissions by CEIP can be considered for countries which cannot produce gridded data.

Conclusions

As computational power increases, the development of atmospheric models throughout the scientific community is going towards finer resolutions. Keeping EMEP 'state-of-the-art' and useful for modelling for LRTAP and for national users of EMEP products (emissions, modelling tools, and model results) should be among EMEP's aims.

In modifying the EMEP grid, three issues can be distinguished:

- Changing the grid projection type (polar-stereographic vs latitude-longitude),
- Increasing the grid resolution (from 50 x 50 km^2 to a finer scale – 0.1° × 0.1°) andChanging the system for reporting of gridded emissions.

1. As far as projection is concerned, a strong argument in favour of a latitude-longitude projection is the possibility to perform consistent model simulations on different geographical scales (from global to national/local) without loss of accuracy connected to interpolation from one projection to another. The additional argument is that the Unified EMEP model of MSC-W can then be run on the native grid of the underlying NWP data (ECMWF-IFS), while using the EMEP emissions without interpolation. Also, the data (both reported emissions and EMEP model results) could be better compared to all other emission data bases known to us. While it is acknowledged that the lat-lon projection does have disadvantages, our view is that these are compensated by the benefits, which is why we recommend the transition to a latitude-longitude grid.

2. It has been shown with the MSC-E models that increase of the grid resolution does lead to improvement of the model results if sufficiently detailed input data are available. From a modelling point of view it seems reasonable to organize EMEP simulations on different scales with spatial resolution depending on the task of concern (e.g. 1° × 1° for global, 0.2° × 0.2° for regional, and 0.1° × 0.1° or even better for national/local scale) and with direct consistent links between the scales. We propose that reporting of the emission data is at 0.1° × 0.1° lat-lon scale.

3. Further, there is an increasing need to couple models and emission inventories of different scales.Finer-scale emissions greatly facilitates such tasks. We recommend that CEIP together with TFEIP and the other centres investigate and propose the best solution for gridding of emissions; either to keep the system we have at present (countries report gridded emissions every fifth year) but at finer scale (0.1 × 0.1°), develop a centralized gridding system based on proxy and LPS data or both, in order to minimise uncertainties in reported/assessed emissions.

The EMEP Centres suggest to the EMEP Steering Body at its thirty-sixth session to change the official EMEP grid to 0.2 × 0.2° latitude-longitude resolution, covering the geographic domain 30°N-82°N latitude and 30°W-90°E longitude, starting from 2013 or as soon as possible. This suggestion represents a balance between political needs, scientific needs and technical feasibility as of 2012 and for the next few years.

However, the particular choice of the grid resolution and technical aspects of reporting requires co-operation and additional work involving different assessment communities (emission experts, modellers, effects community etc.), but it also represents a significant step forward in a right direction.

The EMEP Centres also suggest the EMEP Steering Body to invite Parties to report gridded emissions and LPS data in the new scale/resolution from 2013 onwards or as soon as possible.

The changes in a gridding system will require revision of Reporting Guidelines (or EB decision) and relevant chapter in the EMEP/EEA Inventory Guidebook.

Gridding of emission data has always represented a challenging and demanding task for EMEP community and Parties. Reasons are manifold and country specific, but we hope that highly developed communication and exchange of knowledge and information supports our intention to achieve this ambitious goal. We believe that it is necessary to make the leap forward in this field, to combine efforts and knowledge that will all help improve the overall EMEP assessment system.

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