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# EMEP

## Products, Quality and Background Information


*Contributors :*

Álvaro M. Valdebenito B., Anna C. Benedictow (MET.NO, #20)

*Editors :*

Hendrik Elbern, R-EDA leader (FRIUUK, #21)
Vincent-Henri Peuch, R-ENS leader (METEO-FR, #15)
Laurence Rouïl, R-EVA leader (INERIS, #23)

*Contact :*
alvaro.valdebenito@met.no

# EMEP facts sheet

## 1. Products portfolio

| Name | Description | Freq. | Available | Species | Time span |
|---|---|---|---|---|---|
| FRC | Forecast at the surface, 500m, 1000m, 3000m, and 5000m above ground | Daily | 5 UTC | $O_3$, NO, $NO_2$, CO, $SO_2$, $PM_{10}$, $PM_{2.5}$ | 0-72h, hourly |

## 2. Performance statistics

Not available for the first reporting period (june/july/august 2009).

## 3. Availability statistics

Not available for the first reporting period (june/july/august 2009).

## 4. Assimilation and forecast system: synthesis of main characteristics

| Assimilation and Forecast System | |
|---|---|
| Horizontal resolution | 0.25° regular lat-lon grid |
| Vertical resolution | 20 layers (sigma) up to 100 hPa, with approximately 10 in the Planetary Boundary layer |
| Gas phase chemistry | Evolution of the "EMEP scheme", comprising 70 species and 140 reactions (Andersson-Sköld and Simpson, 1999) |
| Heterogeneous chemistry | AQSAM (Metzger et al., 2002a,b), oxidation of $NO_2$ by ozone on aerosols (night and winter) |
| Aerosol size distribution | 2 size fractions $PM_{2.5}$ and $PM_{10-2.5}$ |
| Inorganic aerosols | Thermodynamic equilibrium for the $H^+$-$NH_4^+$-$SO_4^{2-}$-$NO_3^-$-$H_2O$ system |
| Secondary organic aerosols | *Not implemented in current MACC version* |
| Aqueous phase chemistry | $SO_2$ oxidation by ozone and $N_2O_2$ (Jonson et al., 2000) |
| Dry deposition/sedimentation | Resistance approach for gases and for aerosol, including non-stomatal deposition of $NH_3$ |
| Mineral dust | *Not implemented in current MACC version* |
| Sea Salt | Included |
| Boundary values | Climatologies for $SO_2$, $SO_4$, NO, $NO_2$, $NO_3$, $NH_4$, PAN, $HNO_3$, CO and some VOCs. For |

| | |
|---|---|
| | ozone, the value is constant (40 ppb) |
| Initial values | 24h forecast from the day before |
| Anthropogenic emissions | EMEP 2003 emissions (Vestreng et al., 2005), projected onto the lat-lon grid 0.25°x0.25° |
| Biogenic emissions | Included |
| **Forecast System** | |
| Meteorological driver | 00:00 UTC operational IFS forecast |
| **Assimilation System *(not yet activated for daily operations)*** | |
| Assimilation method | Intermittent 3d-var |
| Observations | *Under development* |
| Frequency of assimilation | *Under development* |
| Meteorological driver | *Under development* |

# Evolutions in the EMEP suite

**2009/06/01:** start of MACC pre-operational forecasts

# EMEP background information

## 1. Forward model

The Unified EMEP model is the chemical transport model developed at the Norwegian Meteorological Institute under the EMEP programme. This Eulerian model is developed to be concerned with the regional atmospheric dispersion and deposition of acidifying and eutrophying compounds (S, N), ground level ozone ($O_3$) and particulate matter ($PM_{2.5}$, $PM_{10}$). The EMEP modelling system allows several options with regard to the chemical schemes used and the possibility of including aerosol dynamics. The Unified model is further described in EMEP Status Report 1/2003 (Simpson et al., 2003a). The forecast version of the EMEP Unified model (EMEP-CWF) is in operation since June of 2006. It is based on the version 2.4 of the Unified EMEP model from mid 2006. It is important to note that the EMEP-CWF results might differ from those presented in EMEP Status Reports for years 2006 (EMEP MSC-W 2008) and 2007 (EMEP MSC-W 2008), as those were obtained from a newer version of the Unified EMEP model source code (version 3.1). The Unified EMEP model source code is publicly available under the GNU General Public License version 3 since the beginning of 2008 (model version 3.0, http://www.emep.int/Opensource).

### 1.1 Model geometry

The EMEP-CWF covers the European domain [35°N-70°N]x[15°W-35°E] on lat-lon projection with a horizontal resolution of 0.25° x0.25°. Vertically the model uses 20 levels defined as sigma coordinates. The 10 lowest model levels are within the PBL and the top of the model domain is on 100 hPa.

### 1.2 Forcing and boundary conditions

Three-day meteorological forecasts from the IFS system of the ECMWF are retrieved daily around 06:40 UTC (00 UTC forecast). This meteorological files need to be pre-processed before EMEP-CWF can start to run. The ECMWF forecasts are interpolated to the desired projection at retrieval, but interpolation of the vertical levels performed by the pre-processing utilities. The ECMWF forecasts do not include 3D precipitation, which is needed by the model. Therefore, a 3D precipitation estimate is derived from large scale precipitation and convective precipitation (surface variables).

The EMEP emissions for 2003 (Vestreng et al., 2005) are used after interpolation from polar stereographic to lat-lon projection.

Lateral boundary concentrations are specified for $SO_2$, $SO_4$, NO, $NO_2$, $NO_3$, $NH_4$, PAN, $HNO_3$, CO and some VOCs. Concentrations are specified by annual mean concentrations and a set of parameters for each species describing seasonal, latitudinal and vertical distributions (Simpson et al., 2003b). Trends for $NO_x$ and $SO_2$ based on emissions from EPA are included to account for present and future scenarios. Boundary conditions for $O_3$ are prescribed to a constant level of 40 ppbv.

### 1.3 Dynamical core

The numerical solution of the advection terms of the continuity equation is based upon the scheme of (Bott, 1989). The fourth order scheme is utilised in the horizontal directions. In the vertical direction a second order version applicable to variable grid distances is employed.

For optimalization reasons an automatic time step control has been implemented in the model. The structure of the program is designed to allow for efficient parallelisation on a system with distributed memory. The most CPU demanding part of the program is the chemistry module, because of the large number of chemical components and reactions. But since the chemistry is local and the horizontal grid is subdivided into sub-domains assigned to a processor it suits well for parallelisation.

### 1.4 Physical and chemical parameterizations

#### 1.4.1 Deposition

Parameterisation of dry deposition is based on a resistance formulation, fully described in Status Report 1/2003 (Simpson et al., 2003a). The deposition module makes use of a stomatal conductance algorithm which was originally developed for ozone fluxes, but which is now applied to all gaseous pollutants when stomatal control is important (Emberson et al., 2000; Simpson et al., 2001, 2003c; Tuovinen et al., 2004). Non-stomatal deposition for $NH_3$ is parameterised as a function of temperature, humidity, and the molar ratio $SO_2/NH_3$, combining ideas from (Smith et al., 2000) and (Nemitz et al., 2001).

Parameterisation of the wet deposition processes includes both in-cloud and sub-cloud scavenging of gases and particles.

#### 1.4.2 Turbulence

The turbulent diffusion coefficients ($K_z$) are first calculated for the whole 3D mode domain on the basis of local Richardson numbers. The planetary boundary layer (PBL) height is then calculated using methods described in (Simpson et al., 2003a). For stable conditions, $K_z$ values are retained. For unstable situations, new $K_z$ values are calculated for layers below the mixing height using the O'Brien interpolation (Simpson et al., 2003a).

#### 1.4.3 Aerosol

The standard model version distinguishes two size fractions for aerosols, fine aerosol ($PM_{2.5}$) and coarse aerosol ($PM_{2.5-10}$). The aerosol components presently accounted for are $SO_4$, $NO_3$, $NH_4$, anthropogenic primary PM and sea salt. Also aerosol water is calculated. Dry deposition parameterisation for aerosols follows standard resistance-formulations, accounting for diffusion, impaction, interception, and sedimentation. Wet scavenging is treated with simple scavenging ratios, taking into account in-cloud and sub-cloud processes.

### 1.5 Chemistry

The chemical scheme couples the sulfur and nitrogen chemistry to the photochemistry using about 140 reactions between 70 species (Andersson-Sköld and Simpson, 1999).
The chemical mechanism is based on the "EMEP scheme" previously described in (Simpson et al., 1993; Simpson, 1995, Andersson-Sköld and Simpson, 1999) and EMEP Report 1/2003 Part II (Tarrasón, L., editor), while the reactions to cover acidification, eutrophication and ammonium chemistry are fully documented in EMEP Report 1/2003 and (Fagerli et al., 2004). The chemical equations are solved using the TWOSTEP algorithm tested by (Verwer and Simpson, 1995).

The photolysis reactions are taken from (Simpson, 1993) with a calculation of photo-dissociation rates (J-values) for clear sky conditions and for two predefined clouds using the "phodis" routine (Kylling et al., 1998).

In the model $SO_2$ is oxidised to sulphate both in the gas phase by OH and in the aqueous phase by $N_2O_2$ and $O_3$, as further described in (Jonson et al., 2000). Ammonium sulphate is formed instantaneously from $NH_3$ and $SO_4$. In the daytime and in summer, $NO_2$ oxidation occurs mainly through reaction with OH, while in the nighttime and in winter its oxidation is predominantly by ozone on deliquescent aerosols. Further, the EQSAM model by (Metzger et al., 2002a,b) is used to calculate the partitioning of inorganic species between the gas and aerosol phase. Coarse nitrate ($pNO_3$) formation from $HNO_3$ is presently assumed to take place at a rate which depends on Relative humidity (Eliassen at al., 1982).

## 2. Assimilation system

The EMEP data assimilation system (EMEP-DAS) is currently under development and it has not yet reached the pre-operational stage. It is based on the 3D-Var implementation for the MATCH model (Kahnert, 2008,2009}. The background error covariance matrix is estimated following the NMC method (Parrish and Derber, 1992). In its current stage, the EMEP-DAS is been developed around the Unified EMEP model version 3.1 (EMEP MSC-W, 2008, 2009). The model configuration for the EMEP-DAS follows the configuration of the forward model (EMEP-CWF) as described in the previous section.

## 3. Development plan

For the period between late 2009 and early 2010 three important developments are planned:

- In order to deliver the forecasts before 07 UTC, the driving meteorology will be changed from the 00 UTC IFS network of the current day to 12 UTC of the previous day. The possibility of two daily forecast deliveries (based on 00 as well as 12 UTC meteorology) will be considered.
- The forward model (EMEP-CWF) will be updated from version 2.4 to version 3.1. Additionally, the updated EMEP-CWF will include: the option for reading 3-hourly boundary conditions from MOZART-IFS forecast -as a fall-back option climatological boundary conditions for $O_3$ derived from the 3D ozone climatology of (Logan et al.,

1999) will be used ; the TNO-MACC-1 emission dataset (D-EMIS) will be used. In the case that TNO-MACC-1 dataset is not ready before the model update, the EMEP 2008 emission dataset (representative for 2006, Mareckova et al., 2008) will be considered.

- The development of the EMEP data assimilation system is planned to reach the testing stage before the end of 2009 and to enter the pre-operational phase on during 2010.

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# Verification report for quarter #1

This verification report covers the period june/july/august 2009. No report is expected (first months of MACC and set up of new configurations).

# Verification report for quarter #2

This verification report covers the period sept./oct./November 2009. It will be available in December 2009.