3. EMEP factsheet

3.1 Assimilation and forecast system: synthesis of the main characteristics

Assimilation and forecast system	
Horizontal resolution	0.1° x 0.1° (native model 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; Simpson et al. 2012)
Heterogeneous chemistry	Aerosol-uptake of HNO_3, HO_2 and O_3 (EMEP, 2015)
Aerosol size distribution	2 size fractions $PM_{2.5}$ and $PM_{10-2.5}$
Inorganic aerosols	MARS (Binkowski and Shankar, 1995), thermodynamic equilibrium for the $H^+-NH_4^+-SO_4^{2-}-NO_3^--H_2O$ system
Secondary organic aerosols	EmChem09soa (Simpson et al., 2012, Bergström et al, 2012), now with explicit toluene and benzene (instead of o-xylene surrogate used previously)
Aqueous phase chemistry	SO_2 oxidation by ozone and H_2O_2 and metal ion-catalyzed O_2
Dry deposition/sedimentation	Resistance approach for gases and for aerosol, including non-stomatal deposition of NH_3
Mineral dust	Boundary conditions from global C-IFS are used, EMEP dust source inside the model domain
Sea Salt	Boundary conditions from global C-IFS are used
Boundary values	Boundary conditions from global C-IFS are used
Initial values	From end file of D-2 analysis, i.e. valid at D-1, 00UTC
Anthropogenic emissions	CAMS-REG-AP_v4.2/2017
Biogenic emissions	Included
Forecast system	
Meteorological driver	12:00 UTC operational IFS forecast (yesterday's)
Assimilation system	
Assimilation method	Intermittent 3d-var
Observations	NO_2 columns from OMI. NO_2, O_3, SO_2, CO, $PM_{2.5}$ and PM_{10} surface concentrations, distributed by *Meteo-France and INERIS*
Frequency of assimilation	Hourly
Meteorological driver	00 UTC operational IFS forecast

3.2 Forward model

The EMEP MSC-W model is a chemical transport model developed at the Norwegian Meteorological Institute under the EMEP programme (UN Convention on Long-range Transboundary Air Pollution). 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 MSC-W model system allows several options with regard to the chemical schemes used and the possibility of including aerosol dynamics. Simpson et al. (2012) describes the EMEP MSC-W model in detail, as well as the main model updates since 2006. The forecast version of the EMEP MSC-W model (EMEP-CWF) is in operation since June 2006. The scheduled model updates in CAMS_50 ensure that the model version stays as close as possible to the official EMEP Open Source version. Nevertheless, the EMEP-CWF results and performances in CAMS_50 might differ from those presented in the annual EMEP Status Reports, because of different input data (emissions and meteorological driver) and model run modes (Forecast in EMEP-CWF versus Hindcast in EMEP Status Reports).

3.2.1 Model geometry

The EMEP-CWF covers the European domain [30°N-76°N] x [25°W-45°E] on a geographic projection with a horizontal resolution of 0.1° x 0.1° (longitude-latitude). 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 at 100 hPa.

The lowermost layer has a thickness of approximately 90 meters. Vertical downscaling is used to derive surface concentrations at 3 meters altitude, as described in Simpson et al. (2012). We make use of the assumptionthat the vertical deposition flux density remains approximately constant within the atmospheric surface layer. Referring to the model concentrations of species i (any species being delivered to CAMS50) at reference height 45m (half the thickness of the lowermost later) as $x^i(45m)$, we obtain the concentrations at any other height z within the surface layer from

$$x^i(z) = x^i(45m) * V_g^i(45m) / V_g^i(z)$$

where $V_g^i(z)$ is thedepositionvelocityat height z calculated using a resistance approach:

$$V_g^i(z) = 1 / (R_a(z) + R_b^i + R_c^i)$$

R_a is the height-dependent aerodynamic resistance between height z and the top of the vegetation canopy (formally, d+z0, where d is the displacement height and z0 the roughness length), R_b^i is the quasi-laminar layer resistance to species i, and R_c^i is the surface (canopy) resistance to species i.

3.2.2 Forcings and boundary conditions

3.2.2.1 Meteorology

4-day meteorological forecasts from the IFS system of the ECMWF are retrieved daily around 18:15 UTC (12 UTC forecast, used for the EMEP-CWF forecasts) and at 06:15 UTC (00 UTC forecast, used for the EMEP-CWF analyses). The ECMWF forecasts do not include 3D precipitation, which is needed by the EMEP-CWF model. Therefore, a 3D precipitation estimate is derived from large-scale precipitation and convective precipitation (surface variables). Currently the 12 UTC forecast from yesterday's forecast is used, so that there is sufficient time to run the EMEP-CWF well before the deadline for delivery.

3.2.2.2 Chemistry

If available at the start of the forecast run, boundary conditions are taken from the C-IFS. In cases where C-IFS boundary conditions are not available, default boundary conditions are specified for O_3, CO, NO, NO_2, CH_4, HNO_3, PAN, SO_2, isoprene, C_2H_6, some VOCs, Sea salt, Saharan dust and SO_4, as annual mean concentrations along with a set of parameters for each species describing seasonal, latitudinal and vertical distributions.

Table 3. The chemical and aerosol species taken from C-IFS and used in EMEP. In EMEP 'F' stands for the fine fraction (diameters smaller than 2.5 µm) and 'C' stands for the coarse fraction (diameters between 2.5 and 10 µm). The mapping of IFS size bins into EMEP size bins is based on consideration of typical size distributions. [a]For sea salt a correction factor of 1/4.3 is applied, since C-IFS Sea Salt is calculated for 80% relative humidity while the EMEP Sea Salt contains only the dry component.

C-IFS Species	Coupled to EMEP Species	Comments
GO_3	O_3	
CO	CO	
NO	NO	
NO_2	NO_2	
PAN	PAN	
HNO_3	HNO_3	
HCHO	HCHO	
SO_2	SO_2	
CH_4	CH_4	
C_5H_8	C_5H_8	
C_2H_6	C_2H_6	
aermr01 (sea salt 0.03-0.5 µm)	SEASALT_F (0-2.5 µm)	SEASALT_F=aermr01/4.3 [a]
aermr02 (sea salt 0.5-5 µm)	SEASALT_C (2.5-10 µm)	SEASALT_C=aermr02/4.3 [a]
aermr03 (sea salt 5-20 µm)		Not used
aermr04 (dust 0.03-0.55 µm)	DUST_SAH_F (0-2.5 µm)	
aermr05 (dust 0.55-0.9 µm)	DUST_SAH_F (0-2.5 µm)	
aermr06 * 0.15 (dust 0.9-20 µm)	DUST_SAH_F (0-2.5 µm)	15% of aermr06 used

C-IFS Species	Coupled to EMEP Species	Comments
aermr06 * 0.35 (dust 0.9-20 µm)	DUST_SAH_C (2.5-10 µm)	35% of aermr06 used
aermr11	SO$_4$	

3.2.2.3 Surface emissions

CAMS-REG-AP_v4.2/2017is used, interpolated on the model's native grid, i.e. 0.1° x 0.1° (lon-lat) resolution.

For fire emissions the GFAS product is used. The latest available 24-hour cycle of GFAS fire emissions is downloaded (pulled from pull fromftp://dissemination.ecmwf.int) before the EMEP forecast starts. That cycle is than repeated in the model simulation for 3 days. For example, if the latest available 24-hour cycle covers the period from D-2 16UTC to D-1 16UTC, then the model repeats it from D-1 16 UTC to D+2 (day after tomorrow) 16 UTC. After D+2, 16 UTC there are no fire emissions in the model.

3.2.3 Dynamical core

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

3.2.4 Physical parameterisations

3.2.4.1 Turbulence and convection

The turbulent diffusion coefficients (Kz) 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., 2012). For stable conditions, Kz values are retained. For unstable situations, new Kz values are calculated for layers below the mixing height using the O'Brien interpolation (Simpson et al., 2012).

3.2.4.2 Deposition

Parameterisation of dry deposition is based on a resistance formulation, fully described in Simpson et al. (2012). 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., 2003; 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$_3$.

3.2.5 Chemistry and aerosols

The chemical scheme couples the sulphur and nitrogen chemistry to the photochemistry using about 140 reactions between 70 species (Andersson-Sköld and Simpson, 1999; Simpson et al. 2012).

The chemical mechanism is based on the 'EMEP scheme' (EmChem), as well as reactions to cover acidification, eutrophication and ammonium chemistry, as described in Simpson et al., 2012 and references therein. Since June 2020 we are using version EmChem19a.

The standard model version distinguishes 2 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. For secondary organic aerosol (SOA) the so-called EmChem09soa scheme is used, which is a somewhat simplified version of the mechanisms discussed in detail by Bergström et al. (2012) but now also has explicit toluene and benzene with different SOA yields to the o-xylene surrogate that was used previously.

3.3 Assimilation system

The EMEP data assimilation system (EMEP-DAS) is based on the 3D-Var implementation for the MATCH model (Kahnert, 2009). The background error covariance matrix is estimated following the NMC method (Parrish and Derber, 1992). The EMEP-DAS is described in detail in Valdebenito B. and Heiberg (2009), Valdebenito B. et al. (2010) and Valdebenito B. and Tsyro (2012).

The EMEP-DAS delivers analyses of yesterday (driven by the operational IFS forecast of 00UTC of yesterday) for NO_2, using NO_2 columns of OMI and in-situ measurements of NO_2 surface concentrations. For ozone, SO_2, and PM_{10}, only surface measurements are assimilated. CO surface observations can be assimilated, but this feature is currently switched off in the operational chain as it does not lead to a significant improvement. EMEP-DAS has been in operation since November 2012, with the following major updates (see also 'Evolutions in the EMEP suite'):

- October 2012: version rv4.1, including DA of NO_2.
- June 2013: version rv4.4.
- May 2014: version rv4.5.
- January 2015: ozone DA included.
- December 2016: version rv4.10 (this corresponds to the EMEP Open Source version, with only some minor modifications in the pollen and DA modules).
- December 2016: SO_2 DA included.
- November 2017: update to version rv4.15. This version corresponds to the EMEP Open Source that was publicly available at the time, except for the chemistry module (EmChem09 is used in CAMS_50, while EmChem16 is used in the Open Source version) as well as some minor modifications in the pollen and DA modules.
- June 2018: Inclusion of CO assimilation (first used only in VRA runs)
- September 2018: update to version rv4.17a (but still with chemistry module EmChem09).
- September 2018: PM_{10} DA included.
- June 2019: EMEP model update to version rv4.33 (but still with chemistry module EmChem09).
- September 2019: PM_{10} DA switched off.
- February 2020: EMEP model update to version rv4.34 (now with chemistry module EmChem19a), $PM_{2.5}$ and CO DA included, PM_{10} DA switched on again, NO_2 column DA improved.
- November 2020: EMEP model update to version rv4.36