

EMEP Fact sheet

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1.1 Assimilation and forecast system: synthesis of the main characteristics

Discretisation	Horizontal resolution	0.1° x 0.1° regular lat-lon
	Number of vertical levels	20
	Top altitude	100hPa
	Depth of lower most layer	50m
	Number of lower layers	10 in PBL
Initial & boundary conditions & meteorology	Meteorological driver	D-1 12:00 UTC IFS, 3hrly
	Boundary values	CAMS-Global IFS
	Initial values	Previous analysis
Emissions: anthropogenic	Inventory	CAMS-REG v6.1 REF2 2022
	Temporal disaggregation	CAMS-REG-TEMPO_v4.1
Emissions: natural & biogenic	In-domain soil and road dust emissions	Marticorena and Bergametti (1995), Marticorena et al. (1997), Alfaro and Gomes (2001), Gomes et al. (2003), Fécan et al. 1999.
	In-domain sea-salt emissions	Mårtensson et al. (2003), Monahan et al. (1986), Tsyro et al. (2011)
	Birch, Grass, Olive, Ragweed, Alder, Mugwort Pollen provided by FMI	yes
	Biogenic emissions	Simpson et al. (2012)
	Soil NOx	CAMS-GLOB-SOIL
	Wildfires emissions	Hourly emissions from D-2 cycled for AN (D-1) and FC (D+0 and D+1, zero for the remaining days)
Chemistry/ Physics	Gas phase chemistry	EmChem19a, 127 species and 198 reactions (Simpson et al. 2020, Bergström et al., 2022)
	Heterogeneous chemistry	Aerosol-uptake of HNO ₃ , HO ₂ and O ₃ (EMEP, 2015, Stadtler et al., 2018)
	Aerosol size distribution	2 size fractions: PM _{2.5} and coarse fraction of PM ₁₀
	Inorganic aerosols	MARS (Binkowski and Shankar, 1995), thermodynamic equilibrium for the SO ₄ -HNO ₃ -NO ₃ -NH ₃ -NH ₄ -H ₂ O system
	Secondary organic aerosols	VBS approach (NPAS scheme, Simpson et al., 2012, Bergström et al, 2012)
	Aqueous phase chemistry	SO ₂ oxidation by ozone and H ₂ O ₂ and metal ion-catalyzed O ₂
	Dry deposition: gases	resistance approach, including non-stomatal deposition of NH ₃
	Dry deposition: aerosols	Simpson et al., (2012)
	Wet deposition	In-cloud and sub-cloud scavenging ratios for gases; in-cloud scavenging ratios and sub-cloud scavenging efficiencies for aerosols.
Assimilation	Assimilation method	Intermittent 3d-var
	Assimilated surface pollutants	NO ₂ , O ₃ , CO, SO ₂ , PM _{2.5} , PM ₁₀

assimilated satellite	NO2 (OMI) until 2021, none currently
Frequency of assimilation	Hourly

1.2 Model Overview

The EMEP MSC-W (European Monitoring and Evaluation Programme Meteorological Synthesizing Centre-West) model is a chemical transport model developed at the Norwegian Meteorological Institute under the EMEP programme of the United Nations Geneva Convention on Long-range Transboundary Air Pollution. 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. (2012a) described an early version of the EMEP MSC-W model in detail, while updates to the model since 2012 have been documented and evaluated in the annual status reports of EMEP (see (EMEP, 2023) and references therein). The forecast version of the EMEP MSC-W model (EMEP-CWF) has been in operation since June 2006. The scheduled model updates in CAMS ensure that the model version stays as close as possible to the official EMEP Open Source version (<https://github.com/metno/emep-ctm>). Nevertheless, the EMEP-CWF results and performances in CAMS might differ from those presented in the annual EMEP Status Reports, due to different input data (emissions and meteorological driver) and model configurations (Forecast in EMEP-CWF versus Hindcast in EMEP Status Reports).

1.3 Model geometry

The EMEP-CWF covers the European domain [30°N-76°N] x [30°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 50 meters. Vertical downscaling is used to derive surface concentrations at 3 meters altitude, as described in (Simpson et al., 2012).

1.4 Forcing Meteorology

The forcing meteorology is retrieved from the IFS model vertical layers covering the EMEP vertical extent on a 0.1°x0.1° horizontal grid resolution with a temporal resolution of 3 hours. The forecast released at 12:00UTC of the previous days is used. The meteorological parameters included to force the EMEP forecast are: 3D fields of the horizontal wind components (U,V), potential temperature, specific humidity, and cloud fraction. The 2D fields are land-sea mask, surface pressure, friction velocity (u^*), large scale and convective precipitation, soil water, snow depth, fraction of snow cover, fraction of ice cover, sensible heat flux, latent heat flux, sea surface temperature, 2m temperature and 2m relative humidity. The IFS 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). Also, it should be noted that the meteorological data received from ECMWF through a dissemination via the Norwegian Meteorological Institute is shifted by 0.05° in both the longitude and latitude directions so that regridding has to be done during preprocessing. This is going to be changed in future updates.

1.5 Chemical initial and boundary conditions

Boundary conditions are taken from chemical species available in the global IFS forecast model of the previous day at 3hr temporal resolution. In cases where IFS chemical boundary conditions are not available, default boundary conditions are specified for O₃, CO, NO, NO₂, CH₄, HNO₃, PAN, SO₂, isoprene, C₂H₆, some VOCs, Sea salt, Saharan dust and SO₄, as annual mean concentrations along with a set of parameters for each species describing seasonal, latitudinal and vertical distributions. The EMEP forecasts are initialised by the EMEP 3D VAR analysis of the previous day.

1.6 Emissions

The common annual anthropogenic emissions CAMS-REG v6.1 ry (recent year) REF2 for 2022 are used. The temporal disaggregation is based on CAMS-REG-TEMPO v4.1. Chemical disaggregation for PM species follows the tables that come with CAMS-REG while VOC emissions are speciated for each source-sector based on a lumped-species approach as described in (Simpson et al., 2012; Bergström et al., 2022).

The hourly GFAS wildfire emission for D-2 (i.e. the last full day available when launching the forecast system) are used for the analysis (D-1) and the first two days of the forecast (D+0 and D+1). Fire emissions are set to zero for the remainder of the forecast horizon.

The mineral dust source in the EMEP model is based on (Alfaro and Gomes, 2001; Fécan et al., 1998; Gomes et al., 2003; Marticorena and Bergametti, 1995; Marticorena et al., 1997).

Natural emissions of Biogenic Volatile Organic Compounds (BVOCs) are based on (Simpson et al., 2012a).

1.7 Solver, advection and mixing

The numerical solution of the advection terms of the continuity equation is based on 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.

The turbulent diffusion coefficients (K_z) are first calculated for the whole 3D model domain on the basis of local Richardson numbers. The planetary boundary layer (PBL) height is read in from the meteorological driver (IFS). 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.

1.8 Deposition

Parameterisation of dry deposition is based on a resistance formulation. 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., 2000b; Simpson et al., 2003; Tuovinen et al., 2004). Non-stomatal deposition for NH₃ is parameterised as a function of temperature, humidity, and the molar ratio SO₂/NH₃.

Both gaseous and particulate nitrogen species are scavenged in the EMEP model according to their wet scavenging ratios and collection efficiencies listed on (Simpson et al., 2012a). In-cloud and sub-cloud scavenging ratios are considered for gases and in-cloud scavenging ratios and sub-cloud scavenging efficiencies for particles.

1.9 Chemistry and aerosols

The EmChem19 chemical scheme couples the sulphur and nitrogen chemistry to the photochemistry and organic aerosol formation using about 200 reactions between ca. 1300 species (Simpson et al., 2020; Bergström et al., 2022; Andersson-Sköld and Simpson, 1999). 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 SO₄, NO₃, NH₄, anthropogenic primary PM, organic aerosols 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, considering in-cloud and sub-cloud processes. For secondary organic aerosol (SOA) a volatility-basis set approach (Simpson et al., 2012) is used, which is a somewhat simplified version of the mechanisms discussed in detail by (Bergström et al., 2012). The EmChem19a scheme also has explicit toluene and benzene with different SOA yields to the o-xylene surrogate that was used previously.

1.10 Assimilation system

The EMEP data assimilation system (EMEP-DAS) is based on the 3D-Var implementation for the MATCH model (Kahnert, 2008). The background error covariance matrix is estimated following the NMC method (Parrish and Derber, 1992). Recent changes resulted in increased computational efficiency, tuning of model and observation representation uncertainties, and improved impact of the assimilation in the vertical.

The EMEP-DAS delivers analyses of yesterday (driven by the operational IFS forecast of 00UTC of yesterday) assimilating O₃, NO₂, CO, PM_{2.5} and PM₁₀ surface observations. For NO₂, satellite observations from OMI used to be assimilated until 2021, but this feature was switched off because in the assimilation method used back then, the model performance did not improve.