EMEP Fact sheet

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: 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
	Wildfiles 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 HNO3, HO2 and O3 (EMEP, 2015, Stadtler et al., 2018)
	Aerosol size distribution	2 size fractions: PM2.5 and coarse fraction of PM10
	Inorganic aerosols	MARS (Binkowski and Shankar, 1995), thermodynamic equilibrium for the SO4-HNO3-NO3-NH3-NH4-H2O system
	Secondary organic aerosols	VBS approach (NPAS scheme, Simpson et al., 2012, Bergström et al, 2012)
	Aqueous phase chemistry	SO2 oxidation by ozone and H2O2 and metal ion-catalyzed O2
	Dry deposition: gases	resistance approach, including non-stomatal deposition of NH3
	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	NO2, O3, CO, SO2, PM2.5, PM10
	assimilated satellite	NO2 (OMI) until 2021, none currently
	Frequency of assimilation	Hourly

1.2 Model Overview

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). 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) described 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 Simpson et al., 2021 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 (EMEP, 2021), because of different input data (emissions and meteorological driver) and model run modes (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).

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 are implemented as explained in Section 3.2. Temporal disaggregation is based on the GENEMIS tables (Ebel et al., 1997). 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).
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.
As described in Simpson et al. (2012), the mineral dust source in the EMEP model is based on Marticorena and Bergametti (1995), Marticorena et al. (1997), Alfaro and Gomes (2001), Gomes et al. (2003), Fécan et al. 1999.
Natural emissions of Biogenic Volatile Organic Compounds (BVOCs) are based on Simpson et al. (2012, their Table 3).

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 utilized in the horizontal directions. In the vertical direction, a second order version applicable to variable grid distances is employed.
The turbulent diffusion coefficients (Kz) are first calculated for the whole 3D model 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.

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., 2000; 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 in Simpson et al. (2012, their Table S20). 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 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' (EmChem19a as of June 2020),

as well as reactions to cover acidification, eutrophication and ammonium chemistry. The standard model version distinguishes 2 size fractions for aerosols, fine aerosol (PM2.5) and coarse aerosol (PM2.5-10). The aerosol components presently accounted for are SO4, NO3, NH4, 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 EmChem09soa scheme is used, which is a somewhat simplified version of the mechanisms discussed in detail by Bergström et al. (2012) but 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, 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 NO2, using NO2 columns of OMI (until 2021) and in-situ measurements of NO2 surface concentrations. For ozone, SO2, CO, PM2.5 and PM10, only surface measurements are assimilated.