LOTOS-EUROS 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	12
	Top altitude	200hPa
	Depth of lower most layer	20m
	Number of lower layers	7 below 1km
Initial & boundary conditions & meteorology	Meteorological driver	D-1 00:00/12:00 UTC IFS, 3hrly
	Boundary values	CAMS-Global IFS
	Initial values	Previous forecast
Emissions: natural & biogenic	In-domain soil and road dust emissions	Marticorena and Bergametti (1995) and soil moisture inhibition as in Fécan et al. 1999
	In-domain sea-salt emissions	Mårtensson et al. (2003), Monahan et al. (1986)
	Birch, Grass, Olive, Ragweed, Alder, Mugwort Pollen provided by FMI	yes
	Biogenic emissions	(Guenther et al. 1993) with detailed tree types for Europe
	Soil NOx	Yienger and Levy (1995)
	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	Modified CBM-IV
	Heterogeneous chemistry	(Schaap et al., 2004)
	Aerosol size distribution	Hydrolysis of N2O5
	Inorganic aerosols	5 size bins for dust and sea-salt, 2 size bins for other aerosols
	Secondary organic aerosols	ISORROPIA-2
	Aqueous phase chemistry	(Fountoukis, 2007)
	Dry deposition: gases	not included
	Dry deposition: aerosols	SO2 oxidation
	Wet deposition	resistance approach (Erisman et al. 1994)
Assimilation	Assimilation method	Zhang (2001)
	Assimilated surface pollutants	Banzhaf et al. (2012)
	assimilated satellite	ENKF
	Frequency of assimilation	NO2, O3, PM2.5, PM10

1.2 Model Overview

The LOTOS-EUROS model is a 3D chemistry transport model aimed to simulate air pollution in the lower troposphere. The model has been used in a large number of studies for the assessment of particulate air pollution and trace gases (e.g. O3, NO2) (e.g. Timmermans 2022, Thürkow 2021, Hendriks 2016 , Schaap et al 2013). A detailed description of the model is given in Manders et al. (2017).

1.3 Model geometry

The domain of LOTOS-EUROS is the CAMS regional domain from 25°W to 45°E and 30°N to 72°N. The projection is regular longitude-latitude, at 0.1°x0.1° grid spacing. In the vertical and for the forecasts there are currently 12 model layers and 2 more reservoir layers at the top, defined by coarsening in a mass conservative way the first 77 model levels of the IFS. For the analyses there are 4 dynamic layers up to 5km agl and a surface layer with a fixed depth of 25 m. The lowest dynamic layer is the mixing layer, followed by 3 reservoir layers. The heights of the reservoir layers are determined by the difference between the mixing layer height and 5 km. For output purposes, the concentrations at measuring height (usually 2.5 m) are diagnosed by assuming that the flux is constant with height and equal to the deposition velocity times the concentration at height z. This applies for several of the gaseous species, namely O3, NO, NO2, HNO3, N2O5, H2O2, CO, SO2 and NH3. For aerosols, the same approach is utilized, only sedimentation velocity is used instead of deposition velocity.

1.4 Forcing Meteorology

The forcing meteorology is retrieved from the 00:00 and 12:00 UTC runs of the IFS model at hourly (surface fields) or 3-hourly temporal resolution (model layer fields). The meteorological data is retrieved on a regular horizontal resolution of about 15 km and for all layers covered by the model's vertical extent. The meteorological variables included are 3D fields for wind direction, wind speed, temperature, humidity and density, substantiated by 2D gridded fields of mixing layer height, precipitation rates, cloud cover and several boundary layer and surface variables.

1.5 Chemical initial and boundary conditions

The lateral and top boundary conditions for trace gases and aerosols are obtained from the CAMS-global daily forecasts (see Table 2). LOTOS-EUROS uses a bulk approach for the aerosol size distribution differentiating between a fine and a coarse fraction, but for dust and sea salt there are 5 distinct size classes: ff: 0.1-1 µm, f:1-2.5 µm, ccc: 2.5-4 µm, cc: 4-7 µm, c:7-10 µm. When the dynamic boundaries from C-IFS are missing, the model uses climatological boundary concentrations derived from C-IFS data. The forecasts are initialised with the LOTOS-EUROS forecast of the previous day.

1.6 Emissions

The common annual anthropogenic emissions CAMS-REG are implemented as explained in Section 3.2. Injection height distribution from the EuroDelta study is implemented, which is per SNAP (or more recently, GNFR) category. Time profiles used are defined per country and GNFR emission category type.
Biogenic isoprene emissions are calculated following the mathematical description of the temperature and light dependence of the isoprene emissions, proposed by (Guenther et al., 1993), using actual meteorological data. Sea salt emissions are parameterised following (Monahan et al., 1986) from the wind speed at 10-meter height.

The fire emissions are taken from the near real-time GFAS fire emissions database. For the forecast, we assume persistence, so that the latest downloaded emission for the specific hour is used. When the hourly emission is more than 3 days old, it is set to zero.
Mineral dust emissions within the modelling domain are calculated online based on the sand blasting approach by Marticorena & Bergametti (1995) with soil moisture inhibition as described by Fécan et al (1999). Finally, a parameterization using land cover and temperature is used for handling soil NOx emissions, based on Yiegner and Levy (1995).

1.7 Solver, advection and mixing

The transport consists of advection in 3 dimensions, horizontal and vertical diffusion, and entrainment/detrainment. The advection is driven by meteorological fields (u,v), which are input every 3 hours. The vertical wind speed w is calculated by the model as a result of the divergence of the horizontal wind fields. The improved and highly accurate, monotonic advection scheme developed by (Walcek, 2000) is used to solve the system. The number of steps within the advection scheme is chosen such that the Courant restriction is fulfilled.
Vertical diffusion is described using the standard Kz theory. Vertical exchange is calculated employing the new integral scheme by (Yamartino et al., 2004). Atmospheric stability values and functions, including Kz values, are derived using standard similarity theory profiles.

1.8 Deposition

The dry deposition in LOTOS-EUROS is parameterised following the resistance approach. The laminar layer resistance and the surface resistances for acidifying components and particles are described following the EDACS system (Erisman et al., 1994). Wet deposition is divided between in-cloud and below-cloud scavenging. The in-cloud scavenging module is based on the approach described in Seinfeld and Pandis (2006) and Banzhaf et al. (2012).

1.9 Chemistry and aerosols

LOTOS-EUROS uses the TNO CBM-IV scheme, which is a modified version of the original CBM-IV (Whitten et al., 1980). N2O5 hydrolysis is described explicitly based on the available (wet) aerosol surface area (using $\gamma = 0.05$) (Schaap et al., 2004). Aqueous phase and heterogeneous formation of sulphate is described by a simple first order reaction constant (Schaap et al., 2004; Barbu et al., 2009). Inorganic aerosol chemistry is represented using ISORROPIA II (Fountoukis, 2007) but organic aerosols are not included in this operational forecast version.

1.10 Assimilation system

The LOTOS-EUROS model is equipped with a data assimilation package with the ensemble Kalman filter technique (Curier et al., 2012). The ensemble is created by specification of uncertainties for emissions (NOx, VOC, NH3 and aerosol), ozone deposition velocity, and ozone top boundary conditions. Currently, data assimilation is performed for O3, NO2, PM10 and PM2.5 surface observations, OMI NO2 is also assimilated.