# MATCH Fact sheet

*updated JUNE 2024*

## 1.1 Assimilation and forecast system: synthesis of the main characteristics

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|---|---|---|
| **Discretisation** | Horizontal resolution | 0.1° x 0.1° regular lat-lon |
| | Number of vertical levels | 26 |
| | Top altitude | 8000m |
| | Depth of lower most layer | 45m |
| | Number of lower layers | 10 below 850hPa |
| **Initial & boundary conditions & meteorology** | Meteorological driver | D-1 12:00 UTC IFS, 3hrly |
| | Boundary values | CAMS-Global IFS |
| | Initial values | Previous forecast |
| **Emissions: anthropogenic** | Inventory | CAMS-REG v6.1 REF2 2021 |
| | Temporal disaggregation | GENEMIS |
| **Emissions: natural & biogenic** | In-domain soil and road dust emissions | Road dust from Schaap et al. (2009) and Omstedt et al. (2005) and mineral dust based on the DEAD model of Zender et al. (2003) (mainly attributed to the Mediterranean area). |
| | In-domain sea-salt emissions | Sofiev et al (2011) |
| | Birch, Grass, Olive, Ragweed, Alder, Mugwort Pollen provided by FMI | yes |
| | Biogenic emissions | Simpson et al., (1995, 2012) |
| | Soil NOx | none |
| | Wildfiles emissions | Hourly emissions from D-1 for AN (D-1) and last available 24h from D-2 and D-1 cycled for FC (D+0 to D+4) |
| **Chemistry/ Physics** | Gas phase chemistry | EmChem09 (Simpson et al., 2012) and Langner et al., 1998 |
| | Heterogeneous chemistry | Hydrolysis of N2O5, aerosol uptake of HNO3 and CH3O2H |
| | Aerosol size distribution | 2 size fractions: PM2.5 and coarse fraction of PM10 |
| | Inorganic aerosols | Mozurkewich, 1993 |
| | Secondary organic aerosols | VBS schemes for ASOA and BSOA (Bergström, 2015, Bergström et al., 2012, Hodzic et al., 2016) |
| | Aqueous phase chemistry | SO2 oxidation |
| | Dry deposition: gases | resistance approach (Simpson et al., 2012) |
| | Dry deposition: aerosols | resistance approach (Simpson et al., 2012) |
| | Wet deposition | gases: species dependent in-cloud and sub-cloud scavenging ratios; particles: in-cloud scavenging ratio, sub-cloud scavenging Berge (1993) and Simpson et al. (2012) |
| **Assimilation** | Assimilation method | Intermittent 3d-var |
| | Assimilated surface pollutants | NO2, O3, CO, SO2, PM2.5, PM10 |
| | assimilated satellite | |
| | Frequency of assimilation | Hourly |

## 1.2 Model Overview

The Multi-scale Atmospheric Transport and Chemistry model (MATCH) (Robertson et al., 1999) is an off-line chemical transport model (CTM) with a flexible design, accommodating different weather data forcing on different resolutions and projections, and a range of alternative schemes for deposition and chemistry.

## 1.3 Model geometry

The model geometry is taken from the input weather data. The vertical resolution is reduced with respect to the ECMWF operational model by combining pairs of IFS layers; hybrid vertical coordinates are used. The horizontal geometry of the MATCH simulation is the same as the meteorological forcing (currently a lat-lon grid with 0.1° resolution). The lowest 76 layers of the ECMWF model are lumped in 26 levels, which then are used for the air quality simulations. The model top is at about 8000 m height. The model domain covers the area between 28.8° W to 45.8° E and 29.2° N to 72.0° N. The grid is an Arakawa C-grid with staggered wind components. The current operational system uses various tiles of physiography derived from CLC/SEI inventory (Simpson et al., 2012).

## 1.4 Forcing Meteorology

The forcing meteorology is retrieved from the 12:00 UTC run of the IFS modelling system on a 0.1°×0.1° spatial grid and with a temporal resolution of one hour. For the analyses, the 00:00 UTC analysis of the IFS is used at 0.2°×0.2° resolution. The meteorological variables included are 3D fields of the horizontal wind components (U, V), temperature, specific humidity, cloud cover, cloud water content, cloud ice water content, and surface fields of surface pressure, logarithm of surface pressure, surface temperature, sea surface temperature, snow depth, albedo, roughness height, total cloud cover, precipitation and volumetric soil water at the surface.

## 1.5 Chemical initial and boundary conditions

The lateral boundary conditions for trace gases and aerosols are obtained from the IFS global forecasts at 3-hourly resolution for the following species: O3, CO, HCHO, NO, NO2, SO2, HNO3, PAN, CH4, C5H8, o-xylene, sulphate and C2H6. When the chemical boundary conditions from IFS are missing, the model uses seasonal climatological boundary concentrations instead.

## 1.6 Emissions

The common annual anthropogenic emissions CAMS-REG are implemented as explained in Section 2.6.1. Temporal disaggregation is based on the GENEMIS tables (Ebel et al., 1997), using a GNFR to SNAP matrix. The vertical distribution of the emissions depends on the sector. Near-surface emission sources (SNAP 2,6,7,8,10) are distributed in the lowest 90 m; for other sectors the emissions are allocated over varying model levels up to a maximum of about 1100 m height. According to the sector, the anthropogenic VOC emissions are split into the MATCH chemical mechanism surrogate species: C2H6, n-C4H10, C2H4, C3H6, o-

xylene, benzene, toluene, CH3OH, C2H5OH, HCHO, CH3CHO, CH3COC2H5; the particulate matter components elemental carbon, organic matter, anthropogenic dust (other than soil and road dust) are allocated to two bins (PM2.5 and PM-coarse), as well as the road dust estimated according to (Schaap et al., 2009; Omstedt et al., 2005) and the teluric dust calculated according to (Zender et al., 2003).

Biogenic emissions of isoprene, monoterpenes and sesquiterpenes are calculated following (Simpson, 1995; Simpson et al., 2012) and (Bergström et al., 2012a), considering temperature at 2 m, radiation fluxes and the vegetation cover.

The dimethyl sulphide - DMS – emissions from the Ocean and Baltic Sea are also considered; whereas the particulate matter from sea salt are calculated according to the parameterisation proposed by (Sofiev et al., 2011).

The GFAS biomass burning emissions are taken into the model mapping the following species into the MATCH chemical mechanism: NOx, SO2, CO, CH4, C2H4, C2H6, C3H6, C4H10, benzene, toluene, xylenes CH3OH, C2H5OH, formaldehyde, acetaldehyde, OC, BC, PM2.5 and PM10. Half of these grid emissions are vertically distributed between the surface and the top of the plume (GFAS parameter) according to a parabolic curve and the other half is uniformly distributed among the same levels.

## 1.7    Solver, advection and mixing

Mass conservative transport schemes are used for advection and turbulent transport. The advection is formulated as a Bott-like scheme (Robertson et al., 1999). A second order transport scheme is used in the horizontal as well as the vertical. The vertical diffusion is described by an implicit mass conservative first order scheme, where the exchange coefficients for neutral and stable conditions are parameterised following (Holtslag and Nieuwstadt, 1986). In the convective case, the turbulent Courant number is directly determined from the turnover time in the boundary layer.

Part of the dynamical core is the initialisation and adjustment of the horizontal wind components. This is a very important step to ensure mass conservative transport. The initialisation is based on a procedure proposed by (Heimann and Keeling, 1989), where the horizontal winds are adjusted by means of the difference between the input surface pressure tendency and the calculated pressure tendency assumed to be an error in the divergent part of the wind field.

Boundary layer parameterisation is based on surface heat and water vapour fluxes as described by (Van Ulden and Holtslag, 1985) for land surfaces and (Burridge, 1977) for sea surfaces. The boundary layer height is calculated from formulations proposed by (Zilitinkevich and Mironov, 1996) for the neutral and stable case, and from (Holtslag et al., 1995) for the convective case. These parameterisations drive the formulations for dry deposition and vertical diffusion.

## 1.8 Deposition

Dry deposition of gases and aerosols is modelled using a resistance approach (based on the scheme in (Simpson et al., 2012)), which includes stomatal and non-stomatal pathways for vegetated surfaces. MATCH uses 3D-precipitation (estimated in the model, based on the surface precipitation and 3D cloud water information from the IFS forecast) and separates wet scavenging into in-cloud and sub-cloud scavenging. For most gaseous components the scavenging is assumed to be proportional to the precipitation intensity (with higher scavenging ratios in-cloud than sub-cloud). For the particulate components in-cloud scavenging is also treated using simple scavenging ratios while the sub-cloud scavenging is treated using a scheme based on (Berge, 1993) with size dependent collection efficiencies (as in (Simpson et al., 2012)).

## 1.9 Chemistry and aerosols

The photochemistry scheme is based on the EMEP MSC-W chemistry scheme (Simpson et al., 2012), with a modified scheme for isoprene, based on the so-called Carter-1 mechanism (Carter, 1996; Langner et al., 1998). The MATCH gas phase mechanism has been revised to consider new recommendations for reaction rates from IUPAC and the EmChem19 mechanism (Bergström et al., 2022). The SOA description is based on (Hodzic et al., 2016).

## 1.10 Assimilation system

The model for data assimilation is an integrated part of the MATCH modelling system. The data assimilation scheme is a variational spectral scheme (Kahnert, 2008), implying that the background covariance matrices are modelled in spectral space. The limitation is that covariance structures are described as isotropic and homogeneous. The advantage is that the background error matrix becomes block diagonal, and there are no scale separations as the covariance between spectral components are explicitly handled. The block diagonal elements are the covariance between wave components at model layers and chemical compounds.

Modelling the background error covariance matrices is the central part in data assimilation. This is conducted by means of the so-called NMC approach (Parrish and Derber, 1992). The CTM (MATCH) is run for a 3-month period for photochemistry and aerosols with analysed and forecasted ECMWF weather data. The differences are assumed to mimic the background errors, and the statistics in spectral space are generated for different combinations of the model compounds: O3, NO2, NO, SO2, CO, PM2.5 and PM10.

The scheme is fully intermittent in hour-by-hour steps and the above-listed components are assimilated from in-situ measurements. The analysed components are propagated by chemistry and transport into unobserved components as NMVOCs, PAN and NH3.