6. MATCH factsheet

6.1 Assimilation and forecast system: synthesis of the main characteristics

Assimilation and forecast system	
Horizontal resolution	0.1° regular lat-lon grid
Vertical resolution	26 levels (using reduction of IFS levels), 10 layers in the boundary layer (below 850 hPa)
Gas phase chemistry	Based on EMEP (Simpson et al., 2012), with modified isoprene chemistry (Carter, 1996; Langner et al., 1998)
Heterogeneous chemistry	HNO_3-formation from N_2O_5; equilibrium reactions for NH_3-HNO_3
Aerosol size distribution	2bins: 0.01–2.5, 2.5–10 µm
Inorganic aerosols	Sulphate, Nitrate, Ammonium
Secondary organic aerosols	Based on Bergström, 2015, Bergström et al., 2018, Hodzic 2016, Lane et al., 2014, and Ots et al., 2016
Aqueous phase chemistry	SO_2 oxidation by H_2O_2 and O_3
Dry deposition/sedimentation	Deposition scheme from the EMEP MSC-W model, Simpson et al., Atmos Chem Phys 12, 7825-7865 (2012)
Mineral dust	Road dust emissions are based on the formulation by Schaap et al. (2009). A factor 2.5 higher emissions is assumed related to studded tyres in the period Feb-April based on Omstedt et al. (2005).
Sea Salt	Based on parameterisation by Sofiev et al. (2011)
Boundary values	C-IFS forecast for the day before (zero boundaries for sea-salt)
Initial values	MATCH 24h forecasts from the day before
Anthropogenic emissions	CAMS-REG-AP_v3.1/2016
Biogenic emissions	Isoprene (Simpson, 1995; updated biogenic emissions of isoprene and monoterpenes, based on Simpson et al., 2012, implemented but not yet in operational version)
Wild fire emissions	Wild fire emissions are used from hourly GFAS inventories. Injection height is taken from the MAMI parameter with a parabolic injection profile. In forecast mode the hourly fire emissions are taken from latest day and then rotated for each forecast day.
Forecast system	
Meteorological driver	12:00 UTC operational IFS forecast for the day

	before (0.1°, 78 levels)
Assimilation system	
Assimilation method	Intermittent 3Dvar data assimilation embedded in the MATCH model
Observations	NRT in-situ observations (O_3, NO_2, CO, SO_2, PM_{10}, $PM_{2.5}$) distributed by Meteo-France
Frequency of assimilation	Hourly, performed once a day for the previous day
Meteorological driver	IFS forecast and analyses 00Z for the same day (0.2°, 26 levels, reduction of IFS levels)

6.2 Forward model

The Multi-scale Atmospheric Transport and Chemistry model (MATCH) 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.

In CAMS, MATCH is forced by IFS weather data from ECMWF MARS archive.

6.2.1 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 is defined when retrieving the weather data from the MARS system (currently a lat-long grid with 0.2° resolution). The lowest 52 layers of the ECMWF model are used for the air quality simulations. The model top is at ca 8000 m height. The model domain covers the area between 28.8° W to 45.8° E and 29.2° N to 70.0° N. The grid is an Arakawa C-grid with staggered wind components.

The surface layer delivered is the very lowest model level of about 40m depth. No downscaling is made given by sub-grid profile accounting for deposition. If desired we may make a shift. Applying this sort of downscaling may hamper other downstream services where this core service is the boundary.

6.2.2 Forcings and boundary conditions

6.2.2.1 Meteorology

2 sets of IFS data are used during a diurnal cycle retrieved on 0.1° resolution for the forecast model and 0.2° resolution for the analyses. The model forecast using IFS starting at 12Z the day before the first forecast day, while the data assimilation is based on the 00Z analysis from the same day as valid for the MATCH analyses.

6.2.2.2 Chemistry

The operational MATCH CAMS version uses dynamical boundary concentrations from the global CAMS C-IFS model for the following species: O_3, CO, HCHO, NO, NO_2, SO_2, HNO_3, PAN, CH_4, C_5H_8, o-xylene, sulphate and C_2H_6 (see Table 6); these boundaries are updated every 3 hours. The model top boundary is defined as the mean of the horizontal boundaries at the model top (due to empty global boundaries in the internal of the domain). The dynamic boundary fields are re-distributed in the vertical in a mass-conservative way, to fit into the vertical hybrid coordinates used by ECMWF.

Table 6. The chemical and aerosol species taken from C-IFS and used in MATCH

C-IFS Species	Coupled to MATCH Species	Comments
HCHO	HCHO	
CO	CO	
C_2H_6	C_2H_6	
SULFATE	SULFATE	
NO_2	NO_2	
NO	NO	
HNO_3	HNO_3	
PAN	PAN	
SO_2	SO_2	
CH_4	CH_4	
GO_3	O_3	
aermr07	EC_2_5	IFS size bins merged a)
aermr07	EC_coarse	IFS size bins merged a)
aermr09	OC_2_5	IFS size bins merged a)
aermr09	OC_coarse	IFS size bins merged a)
aermr04, aermr05,aermr06	DUST_2_5	IFS size bins merged b)
aermr04, aermr05,aermr06	DUST_coarse	IFS size bins merged b)
aermr01, aermr02	NACL_2_5	IFS size bins merged c)
aermr01, aermr02	NACL_coarse	IFS size bins merged c)
aerm11	SULFATE	Upcoming in CIFS-137
Aerm16	NO_4NO_3	Upcoming in CIFS-137
Aerm17	NITRATE	Upcoming in CIFS-137
Aerm18	NH_42SO_4	Upcoming in CIFS-137

The conversion from C-IFS bins and fine and coarse mode follows advice from Miha Razinger (ECMWF).

a) Conversion between IFS EC/OC and MATCH two bins for EC/OC
EC_2_5   =0.7* aermr07
EC_coarse=0.15*aermr07

OC_2_5   =0.7* aermr09
OC_coarse=0.15*aermr09

b) Conversion between IFS DUST and MATCH two bins for DUST
DUST_2_5   =   1* aermr04 + 1* aermr05 + 0.11* aermr06
DUST_coarse=0.44*aermr06

c) Conversion between IFS NACL and MATCH two bins for NACL
NACL_2_5   =   1* aermr01/4.3 + 0.4* aermr02/4.3
NACL_coarse = 0.6*aermr02/4.3

For the other model species fixed boundary conditions are used, in most cases with seasonal variation.

When the dynamic boundaries from C-IFS are missing, the model uses climatological boundary concentrations instead – this means the model will run with reasonable boundaries even when the global data are missing.

6.2.2.3 Land use

The current operational system using various tiles of physiography derived from CCS/SEI inventory.

6.2.2.4 Anthropogenic emissions

The present CAMS version of MATCH uses CAMS-REG-AP_v3.1/2016 (split into 10 GNFR classes). Temporal variations is based on the Eurodelta GENEMIS temporal profiles for countries, compounds, and snap sectors. The GNRF classes in the emission data are mapped into the SNAP classes to benefit from the temporal profiles available. Biogen emissions are derived on-line for isoprene and monoterpenes, based on Simpson et al., 2012.

Wild fire emissions are based on GFAS operational inventories, where for the forecasts the latest GFAS emissions available are rotated for each forecast day. For analyses the GFAS inventory for the full day is available.

6.2.3 Dynamical core

Mass conservative transport schemes are used for advection and turbulent transport. The advection is formulated as a Bott-like scheme (see 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 parameterized following Holtslag et al. (1991). In the convective case the turbulent Courant number is directly determined from the turnover time in the ABL.

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.

6.2.4 Physical parameterisations

6.2.4.1 Turbulence and convection

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 and Gadd (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.

6.2.4.2 Deposition

Dry deposition of gases and aerosols is modelled using a simple resistance approach, which depends on surface type and season[3]; the deposition of gases to vegetated surfaces is coupled to soil moisture, temperature, vapour pressure deficit, and photo synthetically active radiation. The wet scavenging is assumed to be proportional to the precipitation intensity for most gaseous and aerosol components.

6.2.5 Chemistry and aerosols

---

3   For a few components, the deposition is also affected by snow cover: O_3, NO_2, SO_2, H_2O_2; or sub-zero temperatures: O_3.

The photochemistry scheme is based on the standard 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 SOA description is based on Hodzic et al., 2016 (Atmos. Chem. Phys. 2016, 16, 7917).

6.3 Assimilation system

The model for data assimilation is an integrated part of the MATCH modelling system. The data assimilation scheme as such 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 (Parish 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:

- O_3, NO_2, NO
- SO_2
- CO
- $PM_{2.5}$, PM_{10}

The scheme is fully intermittent in hour-by-hour steps and the above-listed components are assimilated from in-situ measurements. The following unobserved components are indirectly assimilated through the projection of the forecast model: NMVOCs, PAN and NH_3.