

# MINNI Fact sheet

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

<b>Discretisation</b>	Horizontal resolution	0.15° x 0.1° regular lat-lon
	Number of vertical levels	14
	Top altitude	7040m
	Depth of lower most layer	40m
	Number of lower layers	8 below 1km
<b>Initial &amp; boundary conditions &amp; meteorology</b>	Meteorological driver	D-1 12:00 UTC IFS, 1hrly
	Boundary values	CAMS-Global IFS
	Initial values	Previous forecast
<b>Emissions: anthropogenic</b>	Inventory	CAMS-REG v6.1 REF2 2022
	Temporal disaggregation	CAMS-REG-TEMPO_v3.2
<b>Emissions: natural &amp; biogenic</b>	In-domain soil and road dust emissions	Erosion and resuspension from Vautard et al. (2005), soil suitable for mobilization parameterized following Zender et al. (2003)
	In-domain sea-salt emissions	Zhang et al. (2005)
	Birch, Grass, Olive, Ragweed, Alder, Mugwort Pollen provided by FMI	yes
	Biogenic emissions	MEGAN v2.04 (Gunther et. al 2006)
	Soil NOx	Williams et al. (1992)
	Wildfires emissions	Hourly emissions from D-1 for AN (D-1) and FC (D+0 and D+1, zero for the remaining days)
<b>Chemistry/ Physics</b>	Gas phase chemistry	SAPRC99 (Carter, 2000)
	Heterogeneous chemistry	none
	Aerosol size distribution	3 log3 log-normal model: Aitken, accumulation and coarse
	Inorganic aerosols	ISORROPIA v1.7 (Nenes et al., 1998)
	Secondary organic aerosols	SORGAM (Schell et al., 2001)
	Aqueous phase chemistry	SO2 oxidation (Seinfeld and Pandis, 1998)
	Dry deposition: gases	resistance approach (Wesely, 1989)
	Dry deposition: aerosols	gravitational settling (Binkowski and Shankar, 1995)
	Wet deposition	Simpson et al. (2003)
<b>Assimilation</b>	Assimilation method	Optimal Interpolation
	Assimilated surface pollutants	NO2, O3, CO, SO2, PM2.5, PM10
	assimilated satellite	none
	Frequency of assimilation	Hourly

## 1.2 Model Overview

MINNI (Italian Integrated Assessment Modelling System for supporting the International Negotiation Process on Air Pollution and assessing Air Quality Policies at national/local level;

(D'Elia et al., 2021; Mircea et al., 2014) has been developed to support the Italian Ministry for Environment and Territory and Sea. The core of the modelling system is the 3-dimensional offline Eulerian CTM FARM (Flexible Air quality Regional Model, Silibello et al., 2008) that accounts for the transport, chemistry and removal of atmospheric pollutants.

### **1.3 Model geometry**

For the CAMS regional production, the model is configured with a regular latitude-longitude grid of  $0.15^\circ \times 0.10^\circ$  resolution. The domain spans from  $-25^\circ$  to  $45.05^\circ$  East and from  $30^\circ$  to  $72^\circ$  North. The model uses z-level terrain following mesh with the first central grid point at 20 m AGL (above ground level) and the last one at 6290m AGL. No vertical downscaling is applied to extrapolate concentrations from 20 meters above the ground to the surface..

### **1.4 Forcing Meteorology**

The forcing meteorology is retrieved from the D-1 12:00 UTC run of the IFS modelling system on a  $0.1^\circ \times 0.1^\circ$  spatial grid and with a temporal resolution of one hour. The meteorological variables included are 3D fields such as temperature, relative humidity, pressure, wind velocity and 2D fields such as boundary layer height, roughness length, albedo, sea surface temperature, total cloud cover and precipitation.

### **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 with a 3-hour temporal resolution. The initial condition is taken from the previous forecast of the MINNI model.

### **1.6 Emissions**

The common annual anthropogenic emissions CAMS-REG are implemented as explained in Section 2.6.1. Point emissions are summed up to diffuse emissions for each GNFR sector, since no information was available about the characterisation of the point sources in terms of injection height. Conservative mass horizontal interpolation has been applied to map the emissions on the actual model domain. Vertical splitting has been applied for each GNFR sector adapting the vertical injection profiles provided by TNO to the actual model levels. Temporal emission profiles for each GNFR sector, as they were provided by TNO, have been applied considering local hour (i.e. the time zones shift has been considered).

PM<sub>2.5</sub> has been speciated following the TNO table as a function of country and sector and AERO3 (Binkowski and Shankar, 1995; Binkowski, 1999) species size fractions below  $2.5\mu\text{m}$ . The coarse component (PM<sub>10</sub> - PM<sub>2.5</sub>) was associated to unspciated coarse mode since MINNI dispersion model considers all the secondary aerosol fraction as PM<sub>2.5</sub>. This method leaves the detailed chemical speciation out but ensures mass conservation.

The NMVOC speciation originated from the TNO table as a function of country and sector obtaining the v01-v25 species. The mapping among the v01-v25 species to SAPRC99 species has been done in agreement with the choices made and tested in the frame of EURODELTA III intercomparison exercise (Colette et al., 2017).

Biogenic emissions are computed with the MEGAN model v.2.04 (Guenther et al., 2006), and NO<sub>x</sub> emissions from soil following (Williams et al., 1992) approach.

Erosion and resuspension of the dust are calculated by means of method proposed by (Vautard et al., 2005). Road dust emissions are parameterised following (Zender et al., 2003).

Fire emissions are considered using hourly data from the GFAS database considering emissions from D-1 for AN (D-1) and FC (D+0 and D+1, zero for the remaining days).

### **1.7 Solver, advection and mixing**

FARM is a 3-dimensional Eulerian model with first order turbulence closure. Physical and chemical processes influencing the concentration fields within the modelling domain are described by a system of partial differential equations (PDE). The numerical integration of the above system of PDEs is performed by a method that splits the multi-dimensional problem into time dependent one-dimensional problems, which are then solved sequentially over the time step.

Partial differential equations involved in horizontal and vertical advection-diffusion operators are solved in FARM using the schemes employed in CALGRID model (Yamartino et al., 1992). In particular, horizontal advection-diffusion operators are solved using a finite elements method based on Blackman cubic polynomials. The coefficients of a cell-centered cubic polynomial are constrained to maintain high-accuracy and low-diffusion characteristics and to avoid undesirable negative concentrations. In addition, a filter is used for filling undesired short wavelength minima. The numerical integration of the vertical diffusion equation is performed in a hybrid way employing a hybrid semi-implicit Crank-Nicholson / fully implicit scheme (Yamartino et al., 1992).

The calculation of horizontal diffusion coefficients is based on Stress tensor formulation of (Smagorinsky, 1963) also including a dependence on the local stability class and wind speed. For the calculation of vertical diffusion coefficients, the (Lange, 1989) approach to boundary layer scaling regimes is used. Mixing due to deep convection is not explicitly considered.

Two different schemes to compute the PBL scaling parameters are used. In the daytime, the (Maul et al., 1980) version of (Carson, 1973) encroachment method is used. During nighttime, the minimum value between (Nieuwstadt, 1981) and (Venkatram, 1980) is used.

### **1.8 Deposition**

The dry deposition velocities are modelled following a resistance analogy approach, as an inverse sum of a series of 3 resistances: the aerodynamic resistance, the quasi-laminar layer resistance and the surface resistance. Aerodynamic resistance is dependent on surface characteristics and atmospheric stability conditions (described through friction velocity and Monin-Obukhov length). Quasi-laminar layer resistance is parameterised using (Hicks et al., 1987). Surface resistance is approximated as a set of parallel resistance associated with leaf stomata, leaf cuticles, lower canopy and surface soil, litter and water (Wesely, 1989). Deposition to water surfaces is based on (Slinn et al., 1978) work.

The deposition velocity of particulate species also depends on particle size distribution and density because of gravitational settling. Sedimentation velocity acts in parallel to the other resistances. Hygroscopic growth is considered over water for particles less than 2  $\mu\text{m}$ . For particles ranging from 0.1 to 1  $\mu\text{m}$  deposition velocity is computed as the inverse of the resistance computed from canopy height, friction velocity and Monin-Obukov length.

The parameterisation of wet deposition follows the (Simpson et al., 2012a) approach, including in-cloud and below-cloud scavenging of gas and particles.

### **1.9 Chemistry and aerosols**

The gas-phase chemical mechanism used for CAMS productions is SAPRC-99 (Carter, 2000) with the inclusion of Polycyclic aromatic hydrocarbons (PAHs) and Mercury chemistry; moreover, a simplified aqueous phase mechanism is included for SO<sub>2</sub> oxidation and chemical processes involving Mercury in both gas and aqueous phases.

A simple approach is used to estimate photolysis rates based on look-up tables to calculate the rate constants for photolysis reactions (Nenes et al., 1998b). Photolysis rates are computed and adjusted according to local solar zenith angle using an empirical formula based on (Peterson, 1976) data.

The aerosols module is AERO3 (Binkowski and Shankar, 1995; Binkowski, 1999). In AERO3 the representation of the particle size is three-modal (Aitken, accumulation and coarse), following lognormal distributions. The aerosol dynamics considers nucleation, condensation and coagulation processes. The gas/particle mass transfer is implemented by means of ISORROPIA v1.7 (Nenes et al., 1998a) and SORGAM (Schell et al., 2001) for secondary inorganic and organic aerosol, respectively.

### **1.10 Assimilation system**

The assimilation scheme used in CAMS is optimal interpolation: the correlation function is factorized in vertical and horizontal components. The horizontal component has pollutant dependent fixed correlation length with a terrain-following exponential decay. The vertical component is modelled with a Cressman function dependent on the boundary layer height. The system assimilates NO<sub>2</sub>, O<sub>3</sub>, SO<sub>2</sub>, CO, PM<sub>10</sub> and PM<sub>2.5</sub>. In case of aerosol components, the correction applied to each of them is proportional to their content in PM. At present, only data from surface stations are assimilated. More details are available in (Adani and Uboldi, 2023).