MINNI Fact sheet

1.1   Assimilation and forecast system: synthesis of the main characteristics

Discretisation	Horizontal resolution	0.15° x 0.1° regular lat-lon
	Number of vertical levels	14
	Top altitude	7500m
	Depth of lower most layer	40m
	Number of lower layers	8 below 1km
Initial & boundary conditions & meteorology	Meteorological driver	D-1 12:00 UTC IFS, 1hrly
	Boundary values	CAMS-Global IFS
	Initial values	Previous forecast
Emissions: natural & biogenic	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)
	Wildfiles emissions	Hourly emissions from D-1 for AN (D-1) and FC (D+0 and D+1, zero for the remaining days)
Chemistry/ Physics	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)
Assimilation	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; Mircea et al., 2014, D'Elia et al., 2021) 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 forecast, the model is configured with a regular latitude-longitude grid of 0.15° * 0.10° resolution. The domain spans from -25° to 45.05° degree East and from 30° to 72° degree 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 6290 m 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 00:00 UTC run of the IFS modelling system on a 0.1°x0.1° spatial grid and with a temporal resolution of one hour. The meteorological variables included are 3D fields such as temperature, relative humidity, pressure and 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-hr 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 3.2. Point emissions are summed up to diffuse emissions for each GNFR sector, since no information was available about the characterization 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 taken into account).

PM2.5 has been speciated following the TNO table as a function of country and sector and AERO3 species size fractions below 2.5µm. The coarse component (PM10-PM2.5) has not been speciated and it was associated to ACOARS variable (Binkowski and Shankar, 1995) (Binwkonski et al. 1999).
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 (Gunther et al., 2006), and NOx emissions from soil following Williams et al. (1992) approach.
Fire emissions are taken into account 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. 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 taken into account.

Two different schemes to compute the PBL scaling parameters are used. In the daytime, the Maul (1980) version of Carson (1973) encroachment method is used. During night-time, 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 μm. For particles ranging from 0.1 to 1 μm deposition velocity is computed as the inverse of the resistance computed from canopy height, friction velocity and Monin-Obukov length.

The parameterization of wet deposition follows the EMEP (2003) 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 forecast is SAPRC-99 with the inclusion of Polycyclic aromatic hydrocarbons (PAHs) and Mercury chemistry; moreover, a simplified

aqueous phase mechanism is included for SO2 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. (1998). 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 modal with 3 modes (Aitken, accumulation and coarse), following a lognormal distribution. The aerosol dynamics takes into account nucleation, condensation and coagulation processes. The gas/particle mass transfer is implemented by means of ISORROPIA v1.7 (Nenes et al, 1998) and SORGAM (Shell 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 NO2, O3, SO2, CO, PM10 and PM2.5. 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.