CMIP6 Model Documentation

Institute:	CNRM-CERFACS
Model:	CNRM-ESM2-1
Topic:	aerosol
Doc. Generated:	2020-04-08
Doc. Seeded From:	Spreadsheet
Specialization Version:	1.0.2
Further Info:	https://es-doc.org/cmip6
Note:	* indicates a required property

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1 Key Properties

Key properties of the aerosol model

1.1.1 Top level properties

Key properties of the aerosol model

1.1.1.1 Name *

Name of aerosol model code

TACTIC_v2

1.1.1.2 Keywords *

Keywords associated with aerosol model code

Aerosol, aerosol-radiation interactions, deposition, emission, transport, sedimentation

1.1.1.3 Overview *

Overview of aerosol model.

TACTIC (Tropospheric Aerosols for ClimaTe In CNRM) is an interactive tropospheric aerosol scheme, able to represent the main anthropogenic and natural aerosol types in the troposphere. Originally developed in the GEMS/MACC project (Morcrette et al., 2009), this scheme has been adapted to the ARPEGE/ALADIN-Climat models (Michou et al., 2015 and Nabat et al., 2015). Aerosols are included through sectional bins, separating desert dust (3 size bins), sea-salt (3 size bins), sulphate (1 bin, as well as 1 additional variable for sulfate precursors considered as SO2), organic matter (2 bins: hydrophobic and hydrophilic particles) and black carbon (2 bins: hydrophobic and hydrophilic particles) particles. All these 12 species are prognostic variables in the model, submitted to transport (semi-lagrangian advection, and convective transport), dry deposition, in-cloud and below-cloud scavenging. The interaction with shortwave and longwave radiation, is also taken into account through optical properties (extinction coefficient, single scattering albedo and asymmetry parameter) calculated using the Mie theory. Sulfate, organic matter and sea salt concentrations are used to determine the cloud droplet number concentration following Menon et al. (2002), thus representing the cloud-albedo effect (1st indirect aerosol effect).

1.1.1.4 Scheme Scope *

Atmospheric domains covered by the aerosol model

- ☒ Troposphere
- ☐ Stratosphere
- ☐ Mesosphere
- ☐ Whole atmosphere
- ☐ Other - please specify:

1.1.1.5 Basic Approximations *

Basic approximations made in the aerosol model

The conversion from sulphate precursors into sulphate aerosols is calculated from an exponential decay based on a time constant depending only on the latitude.

1.1.1.6 Prognostic Variables Form *

Prognostic variables in the aerosol model

- ☒ 3D mass/volume ratio for aerosols
- ☐ 3D number concentration for aerosols
- ☐ Other - please specify:

1.1.1.7 Number Of Tracers *

Number of tracers in the aerosol model

12

1.1.1.8 Family Approach *

Are aerosol calculations generalized into families of species?

☐ True ☐ False

1.2.1 Software Properties

Software properties of aerosol code

1.2.1.1 Repository

Location of code for this component.

Enter TEXT:

1.2.1.2 Code Version

Code version identifier.

Enter TEXT:

1.2.1.3 Code Languages

Code language(s).

Enter COMMA SEPARATED list:

1.3.1 Timestep Framework

Physical properties of seawater in ocean

1.3.1.1 Method *

Mathematical method deployed to solve the time evolution of the prognostic variables

- ☐ Uses atmospheric chemistry time stepping
- ☐ Specific timestepping (operator splitting)

- ☐ Specific timestepping (integrated)
- ☐ Other - please specify:

1.3.1.2 Split Operator Advection Timestep

Timestep for aerosol advection (in seconds)

900

1.3.1.3 Split Operator Physical Timestep

Timestep for aerosol physics (in seconds).

900

1.3.1.4 Integrated Timestep *

Timestep for the aerosol model (in seconds)

900

1.3.1.5 Integrated Scheme Type *

Specify the type of timestep scheme

- ☐ Explicit
- ☐ Implicit
- ☒ Semi-implicit
- ☐ Semi-analytic
- ☐ Impact solver
- ☐ Back Euler
- ☐ Newton Raphson
- ☐ Rosenbrock
- ☐ Other - please specify:

1.4.1 Meteorological Forcings

1.4.1.1 Variables 3D

Three dimensional forcing variables, e.g. U, V, W, T, Q, P, conventive mass flux

Enter COMMA SEPARATED list:

1.4.1.2 Variables 2D

Two dimensional forcing variables, e.g. land-sea mask definition

Enter COMMA SEPARATED list:

1.4.1.3 Frequency

Frequency with which meteorological forcings are applied (in seconds).

Enter INTEGER value:

1.5.1 Resolution

Resolution in the aerosol model grid

1.5.1.1 Name *

This is a string usually used by the modelling group to describe the resolution of this grid, e.g. ORCA025, N512L180, T512L70 etc.

TL127L91

1.5.1.2 Canonical Horizontal Resolution

Expression quoted for gross comparisons of resolution, eg. 50km or 0.1 degrees etc.

1.4 degrees

1.5.1.3 Number Of Horizontal Gridpoints

Total number of horizontal (XY) points (or degrees of freedom) on computational grid.

24572

1.5.1.4 Number Of Vertical Levels

Number of vertical levels resolved on computational grid.

91

1.5.1.5 Is Adaptive Grid *

Set to true if the grid resolution changes during execution.

☐ True ☐ False

1.6.1 Tuning Applied

Tuning methodology for aerosol model

1.6.1.1 Description *

General overview description of tuning: explain and motivate the main targets and metrics retained. Document the relative weight given to climate performance metrics versus process oriented metrics, and on the possible conflicts with parameterization level tuning. In particular describe any struggle with a parameter value that required pushing it to its limits to solve a particular model deficiency.

No tuning

1.6.1.2 Global Mean Metrics Used

List of metrics of the global mean state used in tuning model/component

Enter COMMA SEPARATED list:

1.6.1.3 Regional Metrics Used

List of metrics of regional mean state used in tuning model/component

Enter COMMA SEPARATED list:

1.6.1.4 Trend Metrics Used

List observed trend metrics used in tuning model/component

Enter COMMA SEPARATED list:

2 Grid

Aerosol grid

2.1.1 Top level properties

Aerosol grid

2.1.1.1 Name

Name of grid in aerosol model.

Enter TEXT:

2.1.1.2 Overview

Overview of grid in aerosol model.

Enter TEXT:

2.1.1.3 Matches Atmosphere Grid *

Does the atmospheric aerosol grid match the atmosphere grid?

☐ True ☐ False

2.2.1 Resolution

Resolution in the atmospheric aerosol grid

2.2.1.1 Name *

This is a string usually used by the modelling group to describe the resolution of this grid, e.g. ORCA025, N512L180, T512L70 etc.

TL127L91

2.2.1.2 Canonical Horizontal Resolution

Expression quoted for gross comparisons of resolution, e.g. 50km or 0.1 degrees etc.

Enter TEXT:

2.2.1.3 Number Of Horizontal Gridpoints

Total number of horizontal (XY) points (or degrees of freedom) on computational grid.

24572

2.2.1.4 Number Of Vertical Levels

Number of vertical levels resolved on computational grid.

91

2.2.1.5 Is Adaptive Grid *

Set to true if grid resolution changes during execution.

Select either TRUE or FALSE:

☐ True ☐ False

3 Transport

Aerosol transport

3.1.1 Top level properties

Aerosol transport

3.1.1.1 Name

Commonly used name for the transport in aerosol model.

Enter TEXT:

3.1.1.2 Overview

Overview of aerosol transport in aerosol model.

Enter TEXT:

3.1.1.3 Scheme *

Method for aerosol transport modelling

- ☐ Uses atmospheric chemistry transport scheme
- ☐ Specific transport scheme (eulerian)
- ☒ Specific transport scheme (semi-lagrangian)
- ☐ Specific transport scheme (eulerian and semi-lagrangian)
- ☐ Specific transport scheme (lagrangian)

3.1.1.4 Mass Conservation Scheme *

Methods used to ensure mass conservation.

- ☐ Uses atmospheric chemistry transport scheme
- ☐ Mass adjustment
- ☒ Concentrations positivity
- ☐ Gradients monotonicity
- ☐ Other - please specify:

3.1.1.5 Convention *

Transport by convention

Select MULTIPLE options:

- ☐ Uses atmospheric chemistry transport scheme

- ☐ Convective fluxes connected to tracers
- ☐ Vertical velocities connected to tracers
- ☐ Other - please specify:

4 Emissions

Atmospheric aerosol emissions

4.1.1 Top level properties

Atmospheric aerosol emissions

4.1.1.1 Name

Commonly used name for the emissions in aerosol model.

Enter TEXT:

4.1.1.2 Overview

Overview of atmospheric aerosol emissions in aerosol model.

Natural (sea-salt and dust) emissions are dynamic (fully interactive). Fossil-fuel and biomass burning CMIP6 inventories are used for sulphate precursors, black carbon and organic matter.

4.1.1.3 Method *

Method used to define aerosol species (several methods allowed because the different species may not use the same method).

- ☐ None
- ☐ Prescribed (climatology)
- ☐ Prescribed CMIP6
- ☐ Prescribed above surface
- ☐ Interactive
- ☐ Interactive above surface
- ☐ Other - please specify:

4.1.1.4 Sources

Sources of the aerosol species are taken into account in the emissions scheme

- ☐ Vegetation
- ☐ Volcanos
- ☐ Bare ground
- ☐ Sea surface
- ☐ Lightning
- ☐ Fires
- ☐ Aircraft

☐ Anthropogenic

☐ Other - please specify:

4.1.1.5 Prescribed Climatology

Specify the climatology type for aerosol emissions

☐ Constant

☒ Interannual

☐ Annual

☒ Monthly

☐ Daily

4.1.1.6 Prescribed Climatology Emitted Species

List of aerosol species emitted and prescribed via a climatology

Secondary organic aerosols (Dentener et al., 2006) DMS (Kettle et al., 1999)

4.1.1.7 Prescribed Spatially Uniform Emitted Species

List of aerosol species emitted and prescribed as spatially uniform

Enter COMMA SEPARATED list:

4.1.1.8 Interactive Emitted Species

List of aerosol species emitted and specified via an interactive method

Dust, sea-salt

4.1.1.9 Other Emitted Species

List of aerosol species emitted and specified via an "other method"

Enter COMMA SEPARATED list:

4.1.1.10 Other Method Characteristics

Characteristics of the "other method" used for aerosol emissions

Enter TEXT:

5 Concentrations

Atmospheric aerosol concentrations

5.1.1 Top level properties

Atmospheric aerosol concentrations

5.1.1.1 Name

Commonly used name for the concentrations in aerosol model.

Enter TEXT:

5.1.1.2 Overview

Overview of atmospheric aerosol concentrations in aerosol model.

Enter TEXT:

5.1.1.3 Prescribed Lower Boundary

List of species prescribed at the lower boundary.

Enter COMMA SEPARATED list:

5.1.1.4 Prescribed Upper Boundary

List of species prescribed at the upper boundary.

Enter COMMA SEPARATED list:

5.1.1.5 Prescribed Fields Mmr

List of species prescribed as mass mixing ratios.

Enter COMMA SEPARATED list:

5.1.1.6 Prescribed Fields Aod Plus Ccn

List of species prescribed as AOD plus CCNs.

Enter COMMA SEPARATED list:

6 Optical Radiative Properties

Aerosol optical and radiative properties

6.1.1 Top level properties

Aerosol optical and radiative properties

6.1.1.1 Name

Commonly used name for the optical radiative properties in aerosol model.

Enter TEXT:

6.1.1.2 Overview

Overview of aerosol optical and radiative properties in aerosol model.

Enter TEXT:

6.2.1 Absorption

Absortion properties in aerosol scheme

6.2.1.1 Black Carbon

Absorption mass coefficient of black carbon at 550nm (if non-absorbing enter 0)

Enter FLOAT value:

6.2.1.2 Dust

Absorption mass coefficient of dust at 550nm (if non-absorbing enter 0)

Enter FLOAT value:

6.2.1.3 Organics

Absorption mass coefficient of organics at 550nm (if non-absorbing enter 0)

Enter FLOAT value:

6.3.1 Mixtures

6.3.1.1 External *

Is there external mixing with respect to chemical composition?

☐ True ☐ False

6.3.1.2 Internal *

Is there internal mixing with respect to chemical composition?

☐ True ☐ False

6.3.1.3 Mixing Rule

If there is internal mixing with respect to chemical composition then indicate the mixing rule

Enter TEXT:

6.4.1 Impact Of H2o

The impact of H2O on aerosols

6.4.1.1 Size *

Does H2O impact size?

☐ True ☐ False

6.4.1.2 Internal Mixture *

Does H2O impact aerosol internal mixture?

☐ True ☐ False

6.4.1.3 External Mixture *

Does H2O impact aerosol external mixture?

☐ True ☐ False

6.5.1 Radiative Scheme

Radiative scheme for aerosol

6.5.1.1 Overview *

Overview of radiative scheme

The longwave radiation scheme is based on the Rapid Radiation Transfer Model (RRTM,Mlawer et al. 1997) included in the IFS ECMWF model. The radiative transfer equation is solved by a two-stream method. The RRTM scheme computes fluxes in the spectral range encompassing the 103,000 cm-1 band. The computation is organized in 16 spectral bands and includes line absorption by H2 O, CO2 , O3 , CH4 , N2 O, CFC-11, CFC-12, and aerosols. The shortwave part of the scheme, originally developed by Fouquart and Bonnel (1980), integrates the fluxes over the whole

shortwave spectrum between 0.2 and 4 mm, including three bands in the UVvisible spectral range (185250, 250440 and 440690 nm) and three bands for the near infrared (6901,190, 1,1902,380 and 2,3804,000 nm). The scheme includes Rayleigh scattering, absorption by water vapour and ozone, both varying in space and time, and by CO2 , N2 O, CO, CH4 , and O2 , which are treated as uniformly mixed gases.

6.5.1.2 Shortwave Bands *

Number of shortwave bands

6

6.5.1.3 Longwave Bands *

Number of longwave bands

16

6.6.1 Cloud Interactions

Aerosol-cloud interactions

6.6.1.1 Overview *

Overview of aerosol-cloud interactions

Sulfate, organic matter and sea salt concentrations are used to determine the cloud droplet number concentration following Menon et al. (2002), thus representing the cloud-albedo effect (1st indirect aerosol effect). No representation of the other effects of aerosols on cloud microphysics are included.

6.6.1.2 Twomey *

Is the Twomey effect included?

☐ True ☐ False

6.6.1.3 Twomey Minimum Ccn

If the Twomey effect is included, then what is the minimum CCN number?

Enter INTEGER value:

6.6.1.4 Drizzle *

Does the scheme affect drizzle?

☐ True ☐ False

6.6.1.5 Cloud Lifetime *

Does the scheme affect cloud lifetime?

☐ True ☐ False

6.6.1.6 Longwave Bands *

Number of longwave bands

Enter INTEGER value:

7 Model

Aerosol model

7.1.1 Top level properties

Aerosol model

7.1.1.1 Name

Commonly used name for the model in aerosol model.

Enter TEXT:

7.1.1.2 Overview *

Overview of atmospheric aerosol model

TACTIC (Tropospheric Aerosols for ClimaTe In CNRM) is an interactive tropospheric aerosol scheme, able to represent the main anthropogenic and natural aerosol types in the troposphere. Originally developed in the GEMS/MACC project (Morcrette et al., 2009), this scheme has been adapted to the ARPEGE/ALADIN-Climat models (Michou et al., 2015 and Nabat et al., 2015). Aerosols are included through sectional bins, separating desert dust (3 size bins), sea-salt (3 size bins), sulphate (1 bin, as well as 1 additional variable for sulfate precursors considered as SO2), organic matter (2 bins: hydrophobic and hydrophilic particles) and black carbon (2 bins: hydrophobic and hydrophilic particles) particles. All these 12 species are prognostic variables in the model, submitted to transport (semi-lagrangian advection, and convective transport), dry deposition, in-cloud and below-cloud scavenging. The interaction with shortwave and longwave radiation, is also taken into account through optical properties (extinction coefficient, single scattering albedo and asymmetry parameter) calculated using the Mie theory. Sulfate, organic matter and sea salt concentrations are used to determine the cloud droplet number concentration following Menon et al. (2002), thus representing the cloud-albedo effect (1st indirect aerosol effect).

7.1.1.3 Processes *

Processes included in the aerosol model.

- ☒ Dry deposition
- ☒ Sedimentation
- ☒ Wet deposition (impaction scavenging)
- ☒ Wet deposition (nucleation scavenging)
- ☐ Coagulation
- ☐ Oxidation (gas phase)
- ☐ Oxidation (in cloud)
- ☒ Condensation
- ☒ Ageing
- ☒ Advection (horizontal)
- ☒ Advection (vertical)

☐ Heterogeneous chemistry

☒ Nucleation

7.1.1.4 Coupling

Other model components coupled to the aerosol model

☒ Radiation

☒ Land surface

☐ Heterogeneous chemistry

☐ Clouds

☐ Ocean

☐ Cryosphere

☐ Gas phase chemistry

☐ Other - please specify:

7.1.1.5 Gas Phase Precursors *

Gas phase aerosol precursors.

☒ DMS

☒ SO2

☐ Ammonia

☐ Iodine

☐ Terpene

☐ Isoprene

☐ VOC

☐ NOx

☐ Other - please specify:

7.1.1.6 Scheme Type *

Type(s) of aerosol scheme used by the aerosol model (potentially multiple: some species may be covered by one type of aerosol scheme and other species covered by another type).

☐ Bulk

☐ Modal

☒ Bin

☐ Other - please specify:

7.1.1.7 Bulk Scheme Species *

Species covered by the bulk scheme.

Select MULTIPLE options:

- ☐ Sulphate
- ☐ Nitrate
- ☐ Sea salt
- ☐ Dust
- ☐ Ice
- ☐ Organic
- ☐ Black carbon / soot
- ☐ SOA (secondary organic aerosols)
- ☐ POM (particulate organic matter)
- ☐ Polar stratospheric ice
- ☐ NAT (Nitric acid trihydrate)
- ☐ NAD (Nitric acid dihydrate)
- ☐ STS (supercooled ternary solution aerosol particule)
- ☐ Other - please specify: