CMIP6 Model Documentation

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Documentation Contents

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

GFDL AM4 Predicted Aerosols

1.1.1.2 Keywords *

Keywords associated with aerosol model code

Sulfate, organics, black carbon, sea-salt, dust

1.1.1.3 Overview *

Overview of aerosol model.

The model prognose mass distribution of five aerosol types including sulfate, dust, black carbon, organic carbon, and sea salt based on their emissions (and precursor emissions), chemical production for sulfate and secondary organics, dry and wet (rainout and washout) deposition, transport by advection, and dry and wet convection.

1.1.1.4 Scheme Scope *

Atmospheric domains covered by the aerosol model

- [x] Troposphere
- [ ] Stratosphere
- [ ] Mesosphere
- [ ] Whole atmosphere
- [ ] Other - please specify:

1.1.1.5 Basic Approximations *

Basic approximations made in the aerosol model

Bulk aerosol model

1.1.1.6 Prognostic Variables Form *

Prognostic variables in the aerosol model

- [x] 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

16.0

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.

Https://github.com/NOAA-GFDL/AM4

1.2.1.2 Code Version

Code version identifier.

Warsaw

1.2.1.3 Code Languages

Code language(s).

Fortran

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)

1800.0

1.3.1.3 Split Operator Physical Timestep

Timestep for aerosol physics (in seconds).

1800.0

1.3.1.4 Integrated Timestep *

Timestep for the aerosol model (in seconds)

1800.0

1.3.1.5 Integrated Scheme Type *

Specify the type of timestep scheme

- [x] 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

U, V, T, Qv, Ql, Qi, P, convective mass flux, precipitation, boundary layer height

1.4.1.2 Variables 2D

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

Land-sea mask, dust source function, ocean productivity, leaf area index

1.4.1.3 Frequency

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

1800.0

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.

C96 (Cubed-sphere topology with 96x96 grid boxes per cube face)

1.5.1.2 Canonical Horizontal Resolution

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

100km

1.5.1.3 Number Of Horizontal Gridpoints

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

55296.0

1.5.1.4 Number Of Vertical Levels

Number of vertical levels resolved on computational grid.

33.0

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.

The model was tuned to improve simulations of present-day climatological distribution of aerosol properties (i.e. surface concentration, aerosol optical depth, vertical extinction coefficient)

1.6.1.2 Global Mean Metrics Used

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

Global dust emission coefficient

1.6.1.3 Regional Metrics Used

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

None

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.

C96

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.

C96

2.2.1.2 Canonical Horizontal Resolution

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

100km

2.2.1.3 Number Of Horizontal Gridpoints

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

55296.0

2.2.1.4 Number Of Vertical Levels

Number of vertical levels resolved on computational grid.

33.0

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.

Advection: finite volume with vertical lagrangian; Diffusion: implicit LU decomposition; Convection: explicit convective mass flux;

3.1.1.3 Scheme *

Method for aerosol transport modelling

- [ ] Uses atmospheric chemistry transport scheme
- [ ] Specific transport scheme (eulerian)
- [ ] Specific transport scheme (semi-lagrangian)
- [x] 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.

GFDL-AM4-aerosol-model

4.1.1.2 Overview

Overview of atmospheric aerosol emissions in aerosol model.

SO4 precursor, organics and black carbon aerosols emitted from CMIP-6 emission inventories; sea-salt and dust mechanically emitted from the surface as a function of surface winds.

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

SO2, SO4, Organics, black carbon

4.1.1.7 Prescribed Spatially Uniform Emitted Species

List of aerosol species emitted and prescribed as spatially uniform

None

4.1.1.8 Interactive Emitted Species

List of aerosol species emitted and specified via an interactive method

Dust, sea-salt, dimethyl-sulfide

4.1.1.9 Other Emitted Species

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

None

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.

GFDL-AM4-aerosol-model

5.1.1.2 Overview

Overview of atmospheric aerosol concentrations in aerosol model.

Sulfate production uses a simplified scheme with prescribed O3 and radicals varying monthly and interannually and are extracted from CMIP-5 historical simulation

5.1.1.3 Prescribed Lower Boundary

List of species prescribed at the lower boundary.

N/A

5.1.1.4 Prescribed Upper Boundary

List of species prescribed at the upper boundary.

N/A

5.1.1.5 Prescribed Fields Mmr

List of species prescribed as mass mixing ratios.

O3, radicals OH, HO2, NO3

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.

GFDL-AM4-aerosol-model

6.1.1.2 Overview

Overview of aerosol optical and radiative properties in aerosol model.

Absorption coefficients are given at 550 nm for dry aerosols in units of m2/kg. Dust is divided in 5 bins. The absorption coefficient for each 5 size bins defined by minimum and maximum radii in parenthesis: dust1 (0.1-1 um)=0.069; dust2 (1-2 um)=0.056; dust3 (2-3 um)=0.046; dust4 (3-6 um)=0.035; dust5 (6-10)=0.026. Black carbon is internally mixed with sulfate and the optical properties of their internal mixing depend on relative humidity, as for each 5 bins of sea-salt, and phyllic organic carbon.

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)

7.33

6.2.1.2 Dust

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

0.069

6.2.1.3 Organics

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

0.111

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

Volume weight average of optical properties (extinction coeff, single scattering albedo and asymmetry) of sulfate (assumed entirely ammonium sulfate) and black carbon

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

Enter TEXT:

6.5.1.2 Shortwave Bands *

Number of shortwave bands

18.0

6.5.1.3 Longwave Bands *

Number of longwave bands

7.0

6.6.1 Cloud Interactions

Aerosol-cloud interactions

6.6.1.1 Overview *

Overview of aerosol-cloud interactions

Enter TEXT:

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.

GFDL-AM4-aerosol-model

7.1.1.2 Overview *

Overview of atmospheric aerosol model

Enter TEXT:

7.1.1.3 Processes *

Processes included in the aerosol model.

- [x] Dry deposition
- [x] Sedimentation
- [x] Wet deposition (impaction scavenging)
- [x] Wet deposition (nucleation scavenging)
- [ ] Coagulation
- [x] Oxidation (gas phase)
- [x] Oxidation (in cloud)
- [ ] Condensation
- [x] Ageing
- [x] Advection (horizontal)
- [x] Advection (vertical)
- [x] Heterogeneous chemistry
- [ ] Nucleation

7.1.1.4 Coupling

Other model components coupled to the aerosol model

- [x] Radiation
- [ ] Land surface

- [ ] Heterogeneous chemistry
- [x] Clouds
- [ ] Ocean
- [ ] Cryosphere
- [ ] Gas phase chemistry
- [ ] Other - please specify:

7.1.1.5 Gas Phase Precursors *

Gas phase aerosol precursors.

- [x] DMS
- [x] SO2
- [ ] Ammonia
- [ ] Iodine
- [x] 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).

- [x] Bulk
- [ ] Modal
- [x] 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: