CMIP6 Model Documentation

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Documentation Contents

1 Key Properties

Atmosphere key properties

1.1.1 Top level properties

Atmosphere key properties

1.1.1.1 Name *

Name of atmos model code

GFDL AM4.0.1

1.1.1.2 Keywords *

Keywords associated with atmos model code

AMIP, prescribed SST and sea-ice concentration, atmosphere-land-vegetation coupled model

1.1.1.3 Overview *

Overview of atmos model.

GFDL Atmosphere Model (version 4.0.1) is the Atmosphere and Land component of GFDL coupled model CM4.0 for use in CMIP6. The Atmospheric compoent is identifical to the AM4.0 model documented in Zhao et. al (2018a, 2018b). The vegetation, land and glacier models differ from AM4.0 in the following aspects: 1) dynamical vegetation was used instead the static vegetation used in AM4.0. 2) glacier albedo is retuned. 3) other minor tuning in the land model.

1.1.1.4 Model Family *

Type of atmospheric model.

- [ ] AGCM - Atmospheric General Circulation Model
- [ ] ARCM - Atmospheric Regional Climate Model
- [ ] Other - please specify:

1.1.1.5 Basic Approximations *

Basic approximations made in the atmosphere.

- [x] Primitive equations
- [ ] Non-hydrostatic
- [ ] Anelastic
- [ ] Boussinesq
- [x] Hydrostatic
- [ ] Quasi-hydrostatic
- [ ] Other - please specify:

1.2.1 Resolution

Characteristics of the model resolution

1.2.1.1 Horizontal Resolution Name *

This is a string usually used by the modelling group to describe the resolution of the model grid, e.g. T42, N48.

C96

1.2.1.2 Canonical Horizontal Resolution *

Expression quoted for gross comparisons of resolution, e.g. 2.5 x 3.75 degrees lat-lon.

1 degree

1.2.1.3 Range Horizontal Resolution *

Range of horizontal resolution with spatial details, eg. 1 deg (Equator) - 0.5 deg

Quasi-uniform 1 degree

1.2.1.4 Number Of Vertical Levels *

Number of vertical levels resolved on the computational grid.

33.0

1.2.1.5 High Top *

Does the atmosphere have a high-top? High-Top atmospheres have a fully resolved stratosphere with a model top above the stratopause.

☐ True ☒ False

1.3.1 Timestepping

Characteristics of the atmosphere model time stepping

1.3.1.1 Timestep Dynamics *

Timestep for the dynamics in seconds

=30*60

1.3.1.2 Timestep Shortwave Radiative Transfer

Timestep for the shortwave radiative transfer in seconds.

3600.0

1.3.1.3 Timestep Longwave Radiative Transfer

Timestep for the longwave radiative transfer in seconds.

=60*60*3

1.4.1 Orography

Characteristics of the model orography

1.4.1.1 Type *

Type of orographic representation.

☒ Fixed: present day

☐ Fixed: modified - Provide details of modification below

☐ Other - please specify:

1.4.1.2 Modified

If the orography type is modified describe the adaptation.

Select MULTIPLE options:

☐ Related to ice sheets

☐ Related to tectonics

☐ Modified mean

☐ Modified variance if taken into account in model (cf gravity waves)

☐ Other - please specify:

1.4.1.3 Time-varying

Describe any time varying orographic change

No change with time

1.5.1 Tuning Applied

Tuning methodology for atmospheric component

1.5.1.1 Description *

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

Model simulated present-day global top-of-atmsphere radiative fluxes are tuned towards the observational estimates from CERES. Model development focus on model performance in simulating present-day climatolgy such as precipitation, winds, TOA radiative fluxes.

1.5.1.2 Global Mean Metrics Used

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

Global mean OLR and SW absorption at top-of-atmosphere

1.5.1.3 Regional Metrics Used

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

No specific regional metrics/diagnostic of mean state are used in tuning the model. However, model development has used global RMSE of precipitation, TOA radiative flux for model evaluation.

1.5.1.4 Trend Metrics Used

List observed trend metrics used in tuning model/component

Enter COMMA SEPARATED list:

2 Grid

Atmosphere grid

2.1.1 Top level properties

Atmosphere grid

2.1.1.1 Name

Name of grid in atmos model.

GFDL Finite-Volume Cubed-Sphere Grid

2.1.1.2 Overview

Overview of grid in atmos model.

GFDL Finite-Volume Cubed-Sphere Dynamical Core (FV3)

2.1.2 Horizontal

Atmosphere discretisation in the horizontal

2.1.2.1 Scheme Type *

Horizontal discretisation type

- [ ] Spectral
- [x] Fixed grid
- [ ] Other - please specify:

2.1.2.2 Scheme Method *

Horizontal discretisation method

- [ ] Finite elements
- [x] Finite volumes
- [ ] Finite difference
- [ ] Centered finite difference

2.1.2.3 Scheme Order *

Horizontal discretisation function order

- [ ] Second
- [ ] Third
- [x] Fourth

☐ Other - please specify:

2.1.2.4 Horizontal Pole

Horizontal discretisation pole singularity treatment

☐ Filter

☐ Pole rotation

☐ Artificial island

☐ Other - please specify:

2.1.2.5 Grid Type *

Horizontal grid type

☐ Gaussian

☐ Latitude-Longitude

☒ Cubed-Sphere

☐ Icosahedral

☐ Other - please specify:

2.1.3 Vertical

Atmosphere discretisation in the vertical

2.1.3.1 Coordinate Type *

Type of vertical coordinate system

Select MULTIPLE options:

☐ Isobaric - Vertical coordinate on pressure levels

☐ Sigma - Allows vertical coordinate to follow model terrain

☐ Hybrid sigma-pressure - Sigma system near terrain and isobaric above

☐ Hybrid pressure

☐ Vertically lagrangian

☐ Other - please specify:

3 Dynamical Core

Characteristics of the dynamical core

3.1.1 Top level properties

Characteristics of the dynamical core

3.1.1.1 Name

Commonly used name for the dynamical core in atmos model.

FV3

3.1.1.2 Overview

Overview of characteristics of the dynamical core in atmos model.

GFDL Finite-Volume Cubed-Sphere Dynamical Core

3.1.1.3 Timestepping Type *

Timestepping framework type

- ☐ Adams-Bashforth
- ☒ Explicit
- ☐ Implicit
- ☐ Semi-implicit
- ☐ Leap frog
- ☐ Multi-step
- ☐ Runge Kutta fifth order
- ☐ Runge Kutta second order
- ☐ Runge Kutta third order
- ☐ Other - please specify:

3.1.1.4 Prognostic Variables *

List of the model prognostic variables

- ☐ Surface pressure
- ☒ Wind components
- ☐ Divergence/curl
- ☐ Temperature
- ☒ Potential temperature

- [ ] Total water
- [x] Water vapour
- [x] Water liquid
- [x] Water ice
- [ ] Total water moments
- [ ] Clouds
- [ ] Radiation
- [ ] Other - please specify:

3.2.1 Top Boundary

Type of boundary layer at the top of the model

3.2.1.1 Top Boundary Condition *

Top boundary condition

- [ ] Sponge layer
- [ ] Radiation boundary condition
- [ ] Other - please specify:

3.2.1.2 Top Heat *

Top boundary heat treatment

Zero flux

3.2.1.3 Top Wind *

Top boundary wind treatment

Zero flux

3.3.1 Lateral Boundary

Type of lateral boundary condition (if the model is a regional model)

3.3.1.1 Condition

Type of lateral boundary condition

- [ ] Sponge layer
- [ ] Radiation boundary condition
- [ ] Other - please specify:

3.4.1 Diffusion Horizontal

Horizontal diffusion scheme

3.4.1.1 Scheme Name

Horizontal diffusion scheme name

Monotonic constraint and divergence damping

3.4.1.2 Scheme Method *

Horizontal diffusion scheme method

- [x] Iterated Laplacian
- [ ] Bi-harmonic
- [ ] Other - please specify:

3.4.2 Tracers

Tracer advection scheme

3.4.2.1 Scheme Name

Tracer advection scheme name

- [ ] Heun
- [ ] Roe and VanLeer
- [ ] Roe and Superbee
- [ ] Prather
- [ ] UTOPIA
- [ ] Other - please specify:

3.4.2.2 Scheme Characteristics *

Tracer advection scheme characteristics

- [ ] Eulerian
- [ ] Modified Euler
- [ ] Lagrangian
- [ ] Semi-Lagrangian
- [ ] Cubic semi-Lagrangian
- [ ] Quintic semi-Lagrangian
- [ ] Mass-conserving

☒ Finite volume

☐ Flux-corrected

☐ Linear

☐ Quadratic

☐ Quartic

☐ Other - please specify:

3.4.2.3 Conserved Quantities *

Tracer advection scheme conserved quantities

☒ Dry mass

☒ Tracer mass

☐ Other - please specify:

3.4.2.4 Conservation Method *

Tracer advection scheme conservation method

☐ Conservation fixer

☐ Priestley algorithm

☐ Other - please specify:

3.4.3 Momentum

Momentum advection scheme

3.4.3.1 Scheme Name

Momentum advection schemes name

☐ VanLeer

☐ Janjic

☐ SUPG (Streamline Upwind Petrov-Galerkin)

☐ Other - please specify:

3.4.3.2 Scheme Characteristics *

Momentum advection scheme characteristics

☐ 2nd order

☒ 4th order

- [ ] Cell-centred
- [ ] Staggered grid
- [ ] Semi-staggered grid
- [ ] Other - please specify:

3.4.3.3 Scheme Staggering Type *

Momentum advection scheme staggering type

- [ ] Arakawa B-grid
- [ ] Arakawa C-grid
- [ ] Arakawa D-grid
- [ ] Arakawa E-grid
- [ ] Other - please specify:

3.4.3.4 Conserved Quantities *

Momentum advection scheme conserved quantities

- [ ] Angular momentum
- [ ] Horizontal momentum
- [ ] Enstrophy
- [x] Mass
- [ ] Total energy
- [x] Vorticity
- [ ] Other - please specify:

3.4.3.5 Conservation Method *

Momentum advection scheme conservation method

Select SINGLE option:

- [ ] Conservation fixer
- [ ] Other - please specify:

4 Radiation

Characteristics of the atmosphere radiation process

4.1.1 Top level properties

Characteristics of the atmosphere radiation process

4.1.1.1 Name

Commonly used name for the radiation in atmos model.

GFDL-AM4-radiation-model

4.1.1.2 Overview

Overview of characteristics of the atmosphere radiation process in atmos model.

The basic shortwave and longwave radiation algorithms are described in Freidenreich and Ramaswamy (1999) and Schwarzkopf and Ramaswamy (1999), respectively, modified as in GFDL Global Atmospheric Model Development Team (2004). Modifications to both schemes are described in Zhao et al (2018b). The principal changes for longwave scheme are: 1) use of HITRAN 2012 line data 2) use of mt_ckd 2.5 formulation for the H2O continuum 3) inclusion of the CO2 10 um band 4) capability to compute longwave CO2 absorption with amounts up to 10000 ppmv; CH4 absorption up to 6000 ppbv; N2O absorption up to 800 ppbv. The principal changes for shortwave scheme are: 1) inclusion of shortwave water vapor continuum 2) inclusion of new o2 bands 3) updated ESF parameters for H2O, now has 66 integration points rather than 38. 4) CO2 now calculated with ESF

4.1.1.3 Aerosols *

Aerosols whose radiative effect is taken into account in the atmosphere model

- [x] Sulphate
- [ ] Nitrate
- [x] Sea salt
- [x] Dust
- [ ] Ice
- [x] Organic
- [ ] BC - 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 particle

☐ Other - please specify:

4.2.1 Shortwave Radiation

Properties of the shortwave radiation scheme

4.2.1.1 Name

Commonly used name for the shortwave radiation scheme

Enter TEXT:

4.2.1.2 Spectral Integration *

Shortwave radiation scheme spectral integration

☐ Wide-band model

☐ Correlated-k

☒ Exponential sum fitting

☐ Other - please specify:

4.2.1.3 Transport Calculation *

Shortwave radiation transport calculation methods

☒ Two-stream

☐ Layer interaction

☐ Bulk - Highly parameterised methods that use bulk expressions

☐ Adaptive - Exploits spatial and temporal correlations in optical characteristics

☐ Multi-stream

☐ Other - please specify:

4.2.1.4 Spectral Intervals *

Shortwave radiation scheme number of spectral intervals

18.0

4.2.1.5 General Interactions *

General radiative interactions e.g. with aerosols, cloud ice and cloud water

☐ Emission/absorption,

☒ Scattering

☐ Other - please specify:

4.3.1 Shortwave GHG

Representation of greenhouse gases in the shortwave radiation scheme

4.3.1.1 Greenhouse Gas Complexity *

Complexity of greenhouse gases whose shortwave radiative effects are taken into account in the atmosphere model

Select MULTIPLE options:

☐ CO2 - Carbon Dioxide

☐ CH4 - Methane

☐ N2O - Nitrous Oxide

☐ CFC-11 eq - Summarize the effect of non CO2, CH4, N2O and CFC-12 gases with an equivalence concentration of CFC-11

☐ CFC-12 eq - Summarize the radiative effect of the Ozone Depleating Substances, ODSs, with a CFC-12 equivalence concentration

☐ HFC-134a eq - Summarize the radiative effect of other fluorinated gases with a HFC-134a equivalence concentration

☐ Explicit ODSs - Explicit representation of Ozone Depleting Substances e.g. CFCs, HCFCs and Halons

☐ Explicit other fluorinated gases - Explicit representation of other fluorinated gases e.g. HFCs and PFCs

☐ O3

☐ H2O

☐ Other - please specify:

4.3.1.2 ODS

Ozone depleting substances whose shortwave radiative effects are explicitly taken into account in the atmosphere model

Select MULTIPLE options:

☐ CFC-12 - CFC

☐ CFC-11 - CFC

☐ CFC-113 - CFC

☐ CFC-114 - CFC

☐ CFC-115 - CFC

☐ HCFC-22 - HCFC

☐ HCFC-141b - HCFC

☐ HCFC-142b - HCFC

☐ Halon-1211 - Halon

- [ ] Halon-1301 - Halon
- [ ] Halon-2402 - Halon
- [ ] Methyl chloroform - CH3CCl3
- [ ] Carbon tetrachloride - CCl4
- [ ] Methyl chloride - CH3Cl
- [ ] Methylene chloride - CH2Cl2
- [ ] Chloroform - CHCl3
- [ ] Methyl bromide - Ch3Br
- [ ] Other - please specify:

4.3.1.3 Other Flourinated Gases

Other flourinated gases whose shortwave radiative effects are explicitly taken into account in the atmosphere model

Select MULTIPLE options:

- [ ] HFC-134a - HFC
- [ ] HFC-23 - HFC
- [ ] HFC-32 - HFC
- [ ] HFC-125 - HFC
- [ ] HFC-143a - HFC
- [ ] HFC-152a - HFC
- [ ] HFC-227ea - HFC
- [ ] HFC-236fa - HFC
- [ ] HFC-245fa - HFC
- [ ] HFC-365mfc - HFC
- [ ] HFC-43-10mee - HFC
- [ ] CF4 - PFC
- [ ] C2F6 - PFC
- [ ] C3F8 - PFC
- [ ] C4F10 - PFC
- [ ] C5F12 - PFC
- [ ] C6F14 - PFC
- [ ] C7F16 - PFC

- [ ] C8F18 - PFC
- [ ] C-C4F8 - PFC
- [ ] NF3
- [ ] SF6
- [ ] SO2F2
- [ ] Other - please specify:

4.4.1 Shortwave Cloud Ice

Shortwave radiative properties of ice crystals in clouds

4.4.1.1 Physical Representation *

Physical representation of cloud ice crystals in the shortwave radiation scheme

Select MULTIPLE options:

- [ ] Bi-modal size distribution - Small mode diameters: a few tens of microns, large mode diameters: typically hundreds of microns
- [ ] Ensemble of ice crystals - Complex shapes represented with an ensemble of symmetric shapes
- [ ] Mean projected area - Randomly oriented irregular ice crystals present a greater mean projected area than spheres
- [ ] Ice water path - Integrated ice water path through the cloud kg m-2
- [ ] Crystal asymmetry
- [ ] Crystal aspect ratio
- [ ] Effective crystal radius
- [ ] Other - please specify:

4.4.1.2 Optical Methods *

Optical methods applicable to cloud ice crystals in the shortwave radiation scheme

Select MULTIPLE options:

- [ ] T-matrix - For non-spherical particles
- [ ] Geometric optics - For non-spherical particles
- [ ] Finite difference time domain (FDTD) - For non-spherical particles
- [ ] Mie theory - For spherical particles
- [ ] Anomalous diffraction approximation
- [ ] Other - please specify:

4.5.1 Shortwave Cloud Liquid

Shortwave radiative properties of liquid droplets in clouds

4.5.1.1 Physical Representation *

Physical representation of cloud liquid droplets in the shortwave radiation scheme

Select MULTIPLE options:

- [ ] Cloud droplet number concentration - CDNC
- [ ] Effective cloud droplet radii
- [ ] Droplet size distribution
- [ ] Liquid water path - Integrated liquid water path through the cloud kg m-2
- [ ] Other - please specify:

4.5.1.2 Optical Methods *

Optical methods applicable to cloud liquid droplets in the shortwave radiation scheme

Select MULTIPLE options:

- [ ] Geometric optics - For non-spherical particles
- [ ] Mie theory - For spherical particles
- [ ] Other - please specify:

4.6.1 Shortwave Cloud Inhomogeneity

Cloud inhomogeneity in the shortwave radiation scheme

4.6.1.1 Cloud Inhomogeneity *

Method for taking into account horizontal cloud inhomogeneity

Select SINGLE option:

- [ ] Monte Carlo Independent Column Approximation - McICA
- [ ] Triplecloud - Regions of clear sky, optically thin cloud and optically thick cloud, Shonk et al 2010
- [ ] Analytic
- [ ] Other - please specify:

4.7.1 Shortwave Aerosols

Shortwave radiative properties of aerosols

4.7.1.1 Physical Representation *

Physical representation of aerosols in the shortwave radiation scheme

Select MULTIPLE options:

- ☐ Number concentration
- ☐ Effective radii
- ☐ Size distribution
- ☐ Asymmetry
- ☐ Aspect ratio
- ☐ Mixing state - For shortwave radiative interaction
- ☐ Other - please specify:

4.7.1.2 Optical Methods *

Optical methods applicable to aerosols in the shortwave radiation scheme

Select MULTIPLE options:

- ☐ T-matrix - For non-spherical particles
- ☐ Geometric optics - For non-spherical particles
- ☐ Finite difference time domain (FDTD) - For non-spherical particles
- ☐ Mie theory - For spherical particles
- ☐ Anomalous diffraction approximation
- ☐ Other - please specify:

4.8.1 Longwave Radiation

Properties of the longwave radiation scheme

4.8.1.1 Name

Commonly used name for the longwave radiation scheme.

Simplified Exchange Approximation (SEA)

4.8.1.2 Spectral Integration *

Longwave radiation scheme spectral integration

- ☒ Wide-band model
- ☐ Correlated-k
- ☐ Exponential sum fitting

☐ Other - please specify:

4.8.1.3 Transport Calculation *

Longwave radiation transport calculation methods

Select MULTIPLE options:

☐ Two-stream

☐ Layer interaction

☐ Bulk - Highly parameterised methods that use bulk expressions

☐ Adaptive - Exploits spatial and temporal correlations in optical characteristics

☐ Multi-stream

☐ Other - please specify:

4.8.1.4 Spectral Intervals *

Longwave radiation scheme number of spectral intervals

Enter INTEGER value:

4.8.1.5 General Interactions *

General radiative interactions e.g. with aerosols, cloud ice and cloud water

☒ Emission/absorption,

☐ Scattering

☐ Other - please specify:

4.9.1 Longwave GHG

Representation of greenhouse gases in the longwave radiation scheme

4.9.1.1 Greenhouse Gas Complexity *

Complexity of greenhouse gases whose longwave radiative effects are taken into account in the atmosphere model

Select MULTIPLE options:

☐ CO2 - Carbon Dioxide

☐ CH4 - Methane

☐ N2O - Nitrous Oxide

☐ CFC-11 eq - Summarize the effect of non CO2, CH4, N2O and CFC-12 gases with an equivalence concentration of CFC-11

- [ ] CFC-12 eq - Summarize the radiative effect of the Ozone Depleating Substances, ODSs, with a CFC-12 equivalence concentration
- [ ] HFC-134a eq - Summarize the radiative effect of other fluorinated gases with a HFC-134a equivalence concentration
- [ ] Explicit ODSs - Explicit representation of Ozone Depleting Substances e.g. CFCs, HCFCs and Halons
- [ ] Explicit other fluorinated gases - Explicit representation of other fluorinated gases e.g. HFCs and PFCs
- [ ] O3
- [ ] H2O
- [ ] Other - please specify:

4.9.1.2 ODS

Ozone depleting substances whose longwave radiative effects are explicitly taken into account in the atmosphere model

Select MULTIPLE options:

- [ ] CFC-12 - CFC
- [ ] CFC-11 - CFC
- [ ] CFC-113 - CFC
- [ ] CFC-114 - CFC
- [ ] CFC-115 - CFC
- [ ] HCFC-22 - HCFC
- [ ] HCFC-141b - HCFC
- [ ] HCFC-142b - HCFC
- [ ] Halon-1211 - Halon
- [ ] Halon-1301 - Halon
- [ ] Halon-2402 - Halon
- [ ] Methyl chloroform - CH3CCl3
- [ ] Carbon tetrachloride - CCl4
- [ ] Methyl chloride - CH3Cl
- [ ] Methylene chloride - CH2Cl2
- [ ] Chloroform - CHCl3
- [ ] Methyl bromide - Ch3Br
- [ ] Other - please specify:

4.9.1.3 Other Flourinated Gases

Other flourinated gases whose longwave radiative effects are explicitly taken into account in the atmosphere model

Select MULTIPLE options:

- [ ] HFC-134a - HFC
- [ ] HFC-23 - HFC
- [ ] HFC-32 - HFC
- [ ] HFC-125 - HFC
- [ ] HFC-143a - HFC
- [ ] HFC-152a - HFC
- [ ] HFC-227ea - HFC
- [ ] HFC-236fa - HFC
- [ ] HFC-245fa - HFC
- [ ] HFC-365mfc - HFC
- [ ] HFC-43-10mee - HFC
- [ ] CF4 - PFC
- [ ] C2F6 - PFC
- [ ] C3F8 - PFC
- [ ] C4F10 - PFC
- [ ] C5F12 - PFC
- [ ] C6F14 - PFC
- [ ] C7F16 - PFC
- [ ] C8F18 - PFC
- [ ] C-C4F8 - PFC
- [ ] NF3
- [ ] SF6
- [ ] SO2F2
- [ ] Other - please specify:

4.10.1 Longwave Cloud Ice

Longwave radiative properties of ice crystals in clouds

4.10.1.1 Physical Reprenstation *

Physical representation of cloud ice crystals in the longwave radiation scheme

☐ Bi-modal size distribution - Small mode diameters: a few tens of microns, large mode diameters: typically hundreds of microns

☐ Ensemble of ice crystals - Complex shapes represented with an ensemble of symmetric shapes

☐ Mean projected area - Randomly oriented irregular ice crystals present a greater mean projected area than spheres

☐ Ice water path - Integrated ice water path through the cloud kg m-2

☐ Crystal asymmetry

☐ Crystal aspect ratio

☒ Effective crystal radius

☐ Other - please specify:

4.10.1.2 Optical Methods *

Optical methods applicable to cloud ice crystals in the longwave radiation scheme

Select MULTIPLE options:

☐ T-matrix - For non-spherical particles

☐ Geometric optics - For non-spherical particles

☐ Finite difference time domain (FDTD) - For non-spherical particles

☐ Mie theory - For spherical particles

☐ Anomalous diffraction approximation

☐ Other - please specify:

4.11.1 Longwave Cloud Liquid

Longwave radiative properties of liquid droplets in clouds

4.11.1.1 Physical Representation *

Physical representation of cloud liquid droplets in the longwave radiation scheme

Select MULTIPLE options:

☐ Cloud droplet number concentration - CDNC

☐ Effective cloud droplet radii

☐ Droplet size distribution

☐ Liquid water path - Integrated liquid water path through the cloud kg m-2

- [ ] Other - please specify:

4.11.1.2 Optical Methods *

Optical methods applicable to cloud liquid droplets in the longwave radiation scheme

Select MULTIPLE options:

- [ ] Geometric optics - For non-spherical particles
- [ ] Mie theory - For spherical particles
- [ ] Other - please specify:

4.12.1 Longwave Cloud Inhomogeneity

Cloud inhomogeneity in the longwave radiation scheme

4.12.1.1 Cloud Inhomogeneity *

Method for taking into account horizontal cloud inhomogeneity

Select SINGLE option:

- [ ] Monte Carlo Independent Column Approximation - McICA
- [ ] Triplecloud - Regions of clear sky, optically thin cloud and optically thick cloud, Shonk et al 2010
- [ ] Analytic
- [ ] Other - please specify:

4.13.1 Longwave Aerosols

Longwave radiative properties of aerosols

4.13.1.1 Physical Representation *

Physical representation of aerosols in the longwave radiation scheme

Select MULTIPLE options:

- [ ] Number concentration
- [ ] Effective radii
- [ ] Size distribution
- [ ] Asymmetry
- [ ] Aspect ratio
- [ ] Mixing state - For shortwave radiative interaction
- [ ] Other - please specify:

4.13.1.2 Optical Methods *

Optical methods applicable to aerosols in the longwave radiation scheme

Select MULTIPLE options:

- [ ] T-matrix - For non-spherical particles
- [ ] Geometric optics - For non-spherical particles
- [ ] Finite difference time domain (FDTD) - For non-spherical particles
- [ ] Mie theory - For spherical particles
- [ ] Anomalous diffraction approximation
- [ ] Other - please specify:

5 Turbulence Convection

Atmosphere Convective Turbulence and Clouds

5.1.1 Top level properties

Atmosphere Convective Turbulence and Clouds

5.1.1.1 Name

Commonly used name for the turbulence convection in atmos model.

AM4-PBL-moist-convection-scheme

5.1.1.2 Overview

Overview of atmosphere convective turbulence and clouds in atmos model.

PBL convection described in Lock (2000) and GAMDT (2004). Double plume moist convection described in Zhao et al (2018b) and Bretherton et al (2004)

5.2.1 Boundary Layer Turbulence

Properties of the boundary layer turbulence scheme

5.2.1.1 Scheme Name

Boundary layer turbulence scheme name

- ☐ Mellor-Yamada
- ☐ Holtslag-Boville
- ☐ EDMF - Combined Eddy Diffusivity Mass-Flux
- ☐ Other - please specify:

5.2.1.2 Scheme Type *

Boundary layer turbulence scheme type

- ☐ TKE prognostic
- ☐ TKE diagnostic
- ☐ TKE coupled with water
- ☒ Vertical profile of Kz
- ☐ Non-local diffusion
- ☐ Monin-Obukhov similarity
- ☐ Coastal Buddy Scheme - Separate components for coastal near surface winds over ocean and land
- ☐ Coupled with convection

- [ ] Coupled with gravity waves
- [ ] Depth capped at cloud base - Boundary layer capped at cloud base when convection is diagnosed
- [ ] Other - please specify:

5.2.1.3 Closure Order *

Boundary layer turbulence scheme closure order

1.0

5.2.1.4 Counter Gradient *

Uses boundary layer turbulence scheme counter gradient

- [ ] True - [x] False

5.3.1 Deep Convection

Properties of the deep convection scheme

5.3.1.1 Scheme Name

Deep convection scheme name

Double Plume scheme with one bulk plume for deep and one for shallow convection (Zhao et al 2018)

5.3.1.2 Scheme Type *

Deep convection scheme type

- [x] Mass-flux
- [ ] Adjustment
- [ ] Plume ensemble - Zhang-McFarlane
- [ ] Other - please specify:

5.3.1.3 Scheme Method *

Deep convection scheme method

- [ ] CAPE - Mass flux determined by CAPE, convectively available potential energy.
- [ ] Bulk - A bulk mass flux scheme is used
- [ ] Ensemble - Summation over an ensemble of convective clouds with differing characteristics
- [ ] CAPE/WFN based - CAPE-Cloud Work Function: Based on the quasi-equilibrium of the free troposphere
- [ ] TKE/CIN based - TKE-Convective Inhibition: Based on the quasi-equilibrium of the boundary layer
- [ ] Other - please specify:

5.3.1.4 Processes *

Physical processes taken into account in the parameterisation of deep convection

- ☐ Vertical momentum transport
- ☒ Convective momentum transport
- ☒ Entrainment
- ☒ Detrainment
- ☒ Penetrative convection
- ☒ Updrafts
- ☐ Downdrafts
- ☐ Radiative effect of anvils
- ☒ Re-evaporation of convective precipitation
- ☐ Other - please specify:

5.3.1.5 Microphysics

Microphysics scheme for deep convection. Microphysical processes directly control the amount of detrainment of cloud hydrometeor and water vapor from updrafts

- ☒ Tuning parameter based
- ☐ Single moment
- ☐ Two moment
- ☐ Other - please specify:

5.4.1 Shallow Convection

Properties of the shallow convection scheme

5.4.1.1 Scheme Name

Shallow convection scheme name

Modified UW Shallow Cumulus Scheme (Bretherton et. al 2004, Zhao et. al 2008, Zhao et. al 2018)

5.4.1.2 Scheme Type *

Shallow convection scheme type

- ☒ Mass-flux
- ☐ Cumulus-capped boundary layer
- ☐ Other - please specify:

5.4.1.3 Scheme Method *

Shallow convection scheme method

- ☐ Same as deep (unified)
- ☒ Included in boundary layer turbulence
- ☒ Separate diagnosis - Deep and Shallow convection schemes use different thermodynamic closure criteria
- ☐ Other - please specify:

5.4.1.4 Processes *

Physical processes taken into account in the parameterisation of shallow convection

- ☒ Convective momentum transport
- ☒ Entrainment
- ☒ Detrainment
- ☒ Penetrative convection
- ☒ Re-evaporation of convective precipitation
- ☐ Other - please specify:

5.4.1.5 Microphysics

Microphysics scheme for shallow convection

Select MULTIPLE options:

- ☐ Tuning parameter based
- ☐ Single moment
- ☐ Two moment
- ☐ Other - please specify:

6 Microphysics Precipitation

Large Scale Cloud Microphysics and Precipitation

6.1.1 Top level properties

Large Scale Cloud Microphysics and Precipitation

6.1.1.1 Name

Commonly used name for the microphysics precipitation in atmos model.

Tietke large-scale cloud scheme, Rotstayn microphysics

6.1.1.2 Overview

Overview of large scale cloud microphysics and precipitation in atmos model.

Large-scale cloud scheme is described in Tiedtke (1993) with the cloud microphysics described in Rotstayn (1997) and Rotstayn et al. (2000). Fluxes of large-scale rain and snow are diagnosed and the amount of precipitation flux inside and outside of clouds is tracked separately following Jakob and Klein (2000).

6.2.1 Large Scale Precipitation

Properties of the large scale precipitation scheme

6.2.1.1 Scheme Name

Commonly used name of the large scale precipitation parameterisation scheme

Diagnostic scheme (Jakob and Klein 2000)

6.2.1.2 Hydrometeors *

Precipitating hydrometeors taken into account in the large scale precipitation scheme

- [x] Liquid rain
- [x] Snow
- [ ] Hail
- [ ] Graupel
- [ ] Other - please specify:

6.3.1 Large Scale Cloud Microphysics

Properties of the large scale cloud microphysics scheme

6.3.1.1 Scheme Name

Commonly used name of the microphysics parameterisation scheme used for large scale clouds.

Rotstayn (1997) and Ming et al. (2006)

6.3.1.2 Processes *

Large scale cloud microphysics processes

Select MULTIPLE options:

- ☐ Mixed phase
- ☐ Cloud droplets
- ☐ Cloud ice
- ☐ Ice nucleation
- ☐ Water vapour deposition
- ☐ Effect of raindrops
- ☐ Effect of snow
- ☐ Effect of graupel
- ☐ Other - please specify:

7 Cloud Scheme

Characteristics of the cloud scheme

7.1.1 Top level properties

Characteristics of the cloud scheme

7.1.1.1 Name

Commonly used name for the cloud scheme in atmos model.

Tiedtke prognostic cloud scheme (1993)

7.1.1.2 Overview

Overview of characteristics of the cloud scheme in atmos model.

Prognostic cloud liquid, ice, amount, and drop number with parameterized sources and sinks

7.1.1.3 Scheme Type *

Describes the type(s) of cloud scheme: prognostic, diagnostic, other.

- [x] Prognostic
- [ ] Diagnostic
- [ ] Other - please specify:

7.1.1.4 Uses Separate Treatment *

Description for when different cloud schemes are used for different types of clouds e.g. convective, stratiform and boundary layer)

Yes

7.1.1.5 Processes *

Processes included in the cloud scheme

- [ ] Entrainment
- [ ] Detrainment
- [ ] Bulk cloud
- [ ] Other - please specify:

7.1.1.6 Prognostic Variables

List the prognostic variables used by the cloud scheme, if applicable.

- [x] Cloud amount
- [x] Liquid

- [x] Ice
- [ ] Rain
- [ ] Snow
- [ ] Cloud droplet number concentration - To document the use of two-moment cloud microphysics schemes
- [ ] Ice crystal number concentration - To document the use of two-moment cloud microphysics schemes
- [ ] Other - please specify:

7.1.1.7 Atmos Coupling

Atmosphere components that are linked to the cloud scheme

- [x] Atmosphere_radiation
- [x] Atmosphere_microphysics_precipitation
- [x] Atmosphere_turbulence_convection
- [ ] Atmosphere_gravity_waves
- [ ] Atmosphere_natural_forcing
- [x] Atmosphere_observation_simulation

7.2.1 Optical Cloud Properties

Optical cloud properties

7.2.1.1 Cloud Overlap Method

Method for taking into account overlapping of cloud layers

- [ ] Random
- [ ] Maximum
- [ ] Maximum-random - Combination of maximum and random overlap between clouds
- [x] Exponential
- [ ] Other - please specify:

7.2.1.2 Cloud Inhomogeneity

Method for taking into account cloud inhomogeneity

Stochastic

7.3.1 Sub Grid Scale Water Distribution

Sub-grid scale water distribution

7.3.1.1 Type *

Sub-grid scale water distribution type

- ☒ Prognostic
- ☐ Diagnostic

7.3.1.2 Function Name *

Sub-grid scale water distribution function name

Tiedtke (1993) for stratiform clouds; Bretherton et al. (2004) for convective clouds

7.3.1.3 Function Order *

Sub-grid scale water distribution function type

Enter INTEGER value:

7.3.1.4 Convection Coupling *

Sub-grid scale water distribution coupling with convection

- ☒ Coupled with deep
- ☒ Coupled with shallow
- ☐ Not coupled with convection

7.4.1 Sub Grid Scale Ice Distribution

Sub-grid scale ice distribution

7.4.1.1 Type *

Sub-grid scale ice distribution type

- ☒ Prognostic
- ☐ Diagnostic

7.4.1.2 Function Name *

Sub-grid scale ice distribution function name

Tiedtke (1993) for stratiform clouds; Bretherton et al. (2004) for convective clouds

7.4.1.3 Function Order *

Sub-grid scale ice distribution function type

Enter INTEGER value:

7.4.1.4 Convection Coupling *

Sub-grid scale ice distribution coupling with convection

Select MULTIPLE options:

- [ ] Coupled with deep
- [ ] Coupled with shallow
- [ ] Not coupled with convection

8 Observation Simulation

Characteristics of observation simulation

8.1.1 Top level properties

Characteristics of observation simulation

8.1.1.1 Name

Commonly used name for the observation simulation in atmos model.

COSP: CFMIP Observation Simulator Package

8.1.1.2 Overview

Overview of characteristics of observation simulation in atmos model.

COSP version 1.4.1 was used for all CMIP6 experiments

8.2.1 Isscp Attributes

ISSCP Characteristics

8.2.1.1 Top Height Estimation Method

Cloud simulator ISSCP top height estimation methodUo

- ☐ No adjustment
- ☒ IR brightness
- ☒ Visible optical depth
- ☐ Other - please specify:

8.2.1.2 Top Height Direction

Cloud simulator ISSCP top height direction

- ☐ Lowest altitude level
- ☒ Highest altitude level
- ☐ Other - please specify:

8.3.1 Cosp Attributes

CFMIP Observational Simulator Package attributes

8.3.1.1 Run Configuration

Cloud simulator COSP run configuration

- [x] Inline
- [ ] Offline
- [ ] Other - please specify:

8.3.1.2 Number Of Grid Points

Cloud simulator COSP number of grid points

Enter INTEGER value:

8.3.1.3 Number Of Sub Columns

Cloud simulator COSP number of sub-cloumns used to simulate sub-grid variability

25.0

8.3.1.4 Number Of Levels

Cloud simulator COSP number of levels

40.0

8.4.1 Radar Inputs

Characteristics of the cloud radar simulator

8.4.1.1 Frequency

Cloud simulator radar frequency (Hz)

=94000000000

8.4.1.2 Type

Cloud simulator radar type

- [ ] Surface
- [x] Space borne
- [ ] Other - please specify:

8.4.1.3 Gas Absorption

Cloud simulator radar uses gas absorption

- [x] True
- [ ] False

8.4.1.4 Effective Radius

Cloud simulator radar uses effective radius

☒ True ☐ False

8.5.1 Lidar Inputs

Characteristics of the cloud lidar simulator

8.5.1.1 Ice Types

Cloud simulator lidar ice type

☒ Ice spheres

☐ Ice non-spherical

☐ Other - please specify:

8.5.1.2 Overlap

Cloud simulator lidar overlap

Select MULTIPLE options:

☐ Max

☐ Random

☐ Other - please specify:

9 Gravity Waves

Characteristics of the parameterised gravity waves in the atmosphere, whether from orography or other sources

9.1.1 Top level properties

Characteristics of the parameterised gravity waves in the atmosphere, whether from orography or other sources

9.1.1.1 Name

Commonly used name for the gravity waves in atmos model.

Garner 2005, Alexander and Dunkerton 1999

9.1.1.2 Overview

Overview of characteristics of the parameterised gravity waves in the atmosphere, whether from orography or other sources in atmos model.

Subgrid orographic drag parameterization is decribed in Garner (2005) and Zhao et. al (2018). Convective gravity wave parameterization is described in Alexander and Dunkerton (1999).

9.1.1.3 Sponge Layer *

Sponge layer in the upper levels in order to avoid gravity wave reflection at the top.

- ☐ Rayleigh friction
- ☒ Diffusive sponge layer
- ☐ Other - please specify:

9.1.1.4 Background *

Background wave distribution

- ☐ Continuous spectrum
- ☒ Discrete spectrum
- ☐ Other - please specify:

9.1.1.5 Subgrid Scale Orography *

Subgrid scale orography effects taken into account.

- ☒ Effect on drag
- ☐ Effect on lifting
- ☐ Enhanced topography - To enhance the generation of long waves in the atmosphere
- ☐ Other - please specify:

9.2.1 Orographic Gravity Waves

Gravity waves generated due to the presence of orography

9.2.1.1 Name

Commonly used name for the orographic gravity wave scheme

Garner 2005

9.2.1.2 Source Mechanisms *

Orographic gravity wave source mechanisms

- [x] Linear mountain waves
- [ ] Hydraulic jump
- [ ] Envelope orography
- [x] Low level flow blocking
- [ ] Statistical sub-grid scale variance
- [ ] Other - please specify:

9.2.1.3 Calculation Method *

Orographic gravity wave calculation method

- [ ] Non-linear calculation
- [ ] More than two cardinal directions
- [ ] Other - please specify:

9.2.1.4 Propagation Scheme *

Orographic gravity wave propogation scheme

- [x] Linear theory
- [ ] Non-linear theory
- [ ] Includes boundary layer ducting
- [ ] Other - please specify:

9.2.1.5 Dissipation Scheme *

Orographic gravity wave dissipation scheme

- [ ] Total wave
- [ ] Single wave
- [ ] Spectral

- [ ] Linear
- [ ] Wave saturation vs Richardson number
- [ ] Other - please specify:

9.3.1 Non Orographic Gravity Waves

Gravity waves generated by non-orographic processes.

9.3.1.1 Name

Commonly used name for the non-orographic gravity wave scheme

Alexander and Dunkerton (1999)

9.3.1.2 Source Mechanisms *

Non-orographic gravity wave source mechanisms

- [ ] Convection
- [ ] Precipitation
- [x] Background spectrum
- [ ] Other - please specify:

9.3.1.3 Calculation Method *

Non-orographic gravity wave calculation method

- [x] Spatially dependent
- [ ] Temporally dependent

9.3.1.4 Propagation Scheme *

Non-orographic gravity wave propogation scheme

- [x] Linear theory
- [ ] Non-linear theory
- [ ] Other - please specify:

9.3.1.5 Dissipation Scheme *

Non-orographic gravity wave dissipation scheme

Select SINGLE option:

- [ ] Total wave
- [ ] Single wave

- ☐ Spectral
- ☐ Linear
- ☐ Wave saturation vs Richardson number
- ☐ Other - please specify:

10 Natural Forcing

Natural forcing: solar and volcanic.

10.1.1 Top level properties

Natural forcing: solar and volcanic.

10.1.1.1 Name

Commonly used name for the natural forcing in atmos model.

Enter TEXT:

10.1.1.2 Overview

Overview of natural forcing: solar and volcanic. in atmos model.

Enter TEXT:

10.2.1 Solar Pathways

Pathways for solar forcing of the atmosphere

10.2.1.1 Pathways *

Pathways for the solar forcing of the atmosphere model domain

Select MULTIPLE options:

☐ SW radiation - Shortwave solar spectral irradiance.

☐ Precipitating energetic particles - Precipitating energetic particles from the sun (predominantly protons) and the magnetosphere (predominantly electrons) affect the ionization levels in the polar middle and upper atmosphere, leading to significant changes of the chemical composition

☐ Cosmic rays - Cosmic rays are the main source of ionization in the troposphere and lower stratosphere.

☐ Other - please specify:

10.3.1 Solar Constant

Solar constant and top of atmosphere insolation characteristics

10.3.1.1 Type *

Time adaptation of the solar constant.

☐ Fixed

☒ Transient

10.3.1.2 Fixed Value

If the solar constant is fixed, enter the value of the solar constant (W m-2).

Enter FLOAT value:

10.3.1.3 Transient Characteristics

Solar constant transient characteristics (W m-2)

From Kopp et al. (2005, Solar Physics)

10.4.1 Orbital Parameters

Orbital parameters and top of atmosphere insolation characteristics

10.4.1.1 Type *

Type of orbital parameter

- [x] Fixed
- [ ] Transient

10.4.1.2 Fixed Reference Date

Reference date for fixed orbital parameters (yyyy)

23.0

10.4.1.3 Transient Method

Description of transient orbital parameters

Enter TEXT:

10.4.1.4 Computation Method

Method used for computing orbital parameters.

Select SINGLE option:

- [ ] Berger 1978
- [ ] Laskar 2004
- [ ] Other - please specify:

10.5.1 Insolation Ozone

Impact of solar insolation on stratospheric ozone

10.5.1.1 Solar Ozone Impact *

Does top of atmosphere insolation impact on stratospheric ozone?

☒ True ☐ False

10.6.1 Volcanoes Treatment

Characteristics and treatment of volcanic forcing in the atmosphere

10.6.1.1 Volcanoes Characteristics *

Description of how the volcanic forcing is taken into account in the atmosphere.

Enter TEXT:

10.6.1.2 Volcanoes Implementation *

How volcanic effects are modeled in the atmosphere.

Select SINGLE option:

☐ High frequency solar constant anomaly

☐ Stratospheric aerosols optical thickness

☐ Other - please specify: