CMIP6 Model Documentation

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Documentation Contents

1 Key Properties

Key properties of the model

1.1.1 Top level properties

Key properties of the model

1.1.1.1 Name *

Name of coupled model

IPSL-CM6A-LR

1.1.1.2 Keywords *

Keywords associated with coupled model

IPSL, climate model, earth system model, LMDz atmospheric general circulation model, NEMO oceanic general circulation model, ORCHIDEE land surface model

1.1.1.3 Overview *

Top level overview of coupled model

Enter TEXT:

1.2.1 Flux Correction

Flux correction properties of the model

1.2.1.1 Details *

Describe if/how flux corrections are applied in the model

None.

1.3.1 Genealogy

Genealogy and history of the model

1.3.1.1 Year Released *

Year the model was released

2018

1.3.1.2 CMIP3 Parent

CMIP3 parent if any

IPSL-CM4

1.3.1.3 CMIP5 Parent

CMIP5 parent if any

IPSL-CM5B-LR

1.3.1.4 CMIP5 Differences

Briefly summarize the differences between this model and its CMIP5 parent, if applicable

IPSL-CM6A-LR includes new versions of LMDz, of NEMO and of ORCHIDEE. Improved conservation of energy and water. Resolutions were increased from 96x95x39 to 144x142x79 for atmosphere and land-surface, and from 2 to 1 for ocean. The tuning phase was longer and more thorough with IPSL-CM6A-LR than with IPSL-CM5B-LR.

1.3.1.5 Previous Name

Previously known as

Enter TEXT:

1.4.1 Software Properties

Software properties of model

1.4.1.1 Repository

Location of code for this component.

Http://forge.ipsl.jussieu.fr/igcmg/svn/modipsl/trunk

1.4.1.2 Code Version

Code version identifier.

6.1.1 to 6.1.9 with various changes in model output

1.4.1.3 Code Languages

Code language(s).

Shell (ksh), XML, C++ (in XIOS), Fortran90

1.4.1.4 Components Structure

Describe how model realms are structured into independent software components (coupled via a coupler) and internal software components.

LMDz atmospheric general circulation model and ORCHIDEE land surface model (incl. land surface carbon and a very simplified model of land ice) are grouped into a one executable (ORCHIDEE being embedded in LMDz). NEMO (ocean, sea ice, ocean biogeochemistry) is another executable. LMDz and NEMO are coupled through OASIS-MCT. XIOS (output) is a stand alone component in charge of managing all the output, driven by a set of XML files. Each of the components includes an XIOS client, that communicates to the XIOS server which flushes the output to disk.

1.4.1.5 Coupler

Overarching coupling framework for model.

- [ ] OASIS - The OASIS coupler - prior to OASIS-MCT
- [x] OASIS3-MCT - The MCT variant of the OASIS coupler
- [ ] ESMF - Vanilla Earth System Modelling Framework
- [ ] NUOPC - National Unified Operational Prediction Capability variant of ESMF
- [ ] Bespoke - Customised coupler developed for this model
- [ ] Unknown - It is not known what/if-a coupler is used
- [ ] None - No coupler is used
- [ ] Other - please specify:

1.5.1 Coupling

1.5.1.1 Atmosphere Double Flux *

Is the atmosphere passing a double flux to the ocean and sea ice (as opposed to a single one)?

- [ ] True
- [ ] False

1.5.1.2 Atmosphere Fluxes Calculation Grid

Where are the air-sea fluxes calculated

- [x] Atmosphere grid
- [ ] Ocean grid
- [ ] Specific coupler grid
- [ ] Other - please specify:

1.5.1.3 Atmosphere Relative Winds *

Are relative or absolute winds used to compute the flux? I.e. do ocean surface currents enter the wind stress calculation?

- [ ] True
- [ ] False

1.6.1 Tuning Applied

Tuning methodology for model

1.6.1.1 Description *

General overview description of tuning: explain and motivate the main targets and metrics/diagnostics retained. Document the relative weight given to climate performance metrics/diagnostics versus process oriented metrics/diagnostics, 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 tuning of IPSL-CM6A was targeting the representation of key processes involved in climate and climate sensitivity and the reduction of well known biases of the mean climatology rather than modes of variability or user oriented metrics. Also the tuning was done to the present-day climate and not to historical trends, except for some late tuning of the indirect aerosol effect. The surface temperature, both on continental surface and ocean were given a particular importance, with a specific work on continental mid-latitude, polar ice sheets, and semi arid tropical region (in particular Sahel). Over ocean tuning was targeting specifically the reduction of the well known SST warm biases over the eastern Side of Tropical Ocean and around the Antarctic. Eyes have also kept track of a possible warm bias in the austral ocean, which was prominent in previous versions of the model but happily didnt appear persistently in IPSL-CM6A-LR. Most of the sea ice tuning was done offline, through a long history of forced-atmosphere OMIP-type runs. Ice dynamics were adjusted during that procedure (in particular the ice strength parameter P*) and satisfactory results were easily obtained in such setups. The targets were: the observed seasonal cycle of Arctic and Antarctic sea ice extents, and an annual mean Arctic sea ice volume of 20,000 km3. We did not control the Southern Ocean ice volume. The tuning was approximate in that there was no strictly applied criterion, but only a visual verification. Once in coupled mode, it was a bit more complicated to achieve reasonable Arctic sea ice. The atmospheric tuning targeted the observed SST from 50S to 50N, which left positive winter air temperature biases in the Arctic. As a consequence, winter ice would insufficiently grow and summer ice would typically disappear. To compensate for these deficiencies, we increased the surface albedo for all surface types (to reduce melting), giving 0.58 for the diffuse broadband melting bare ice albedo and the thermal conductivity of snow to 0.5 W/m/K (to increase winter growth), up to what we considered their largest acceptable values. That we did not go beyond unphysical boundaries for these parameters left a low summer sea ice extent bias of about 1-2 million sq km2 (depending on ensemble members). Similarly, the North Atlantic Meridional Overtuning Circulation (AMOC) was too weak in the first versions of the model, and having a strong enough Atlantic overturning circulation was also considered as an important target. Unfortunately, summer Arctic sea ice extent and AMOC strength were very strongly tied in the model, with a strengthened AMOC yielding more poleward heat transport and less Arctic sea ice. While this chain of interactions may have physical basis (e.g. Zhang et al., 2017), we had to find ways around it so as to enable a tuning of both of the crucial elements of the climate system. The representation of clouds and of their radiative effect were a dominant target of the tuning as well as the representation of surface meteorology. This part benefited from significant improvements in the model content which helped make the tuning not extreme. The tuning was targeting the present-day climate and not the historical trend. In fact, during all the development phase and tuning of the model, it was suspected that the model ECS (Equilibrium Climate Sensitivity) was probably in the upper range, or even maybe outside the range of previously estimated values. However, this was never seen as a metrics for target, conserving thus the idea that ECS should be an emerging property of the model. The amplitude of the historical warming was only somewhat adjusted when it was discovered that the overestimation was probably due for a large part for the cancellation of the aerosol indirect radiative effect after changes in the cloud tuning. Only this amplitude of the aerosol radiative forcing (in terms of present-day/preindustrial contrast) was adjusted but not giving too much importance to the agreement between the simulated and observed XXth century. In order to make full use of observations of the last decade, the adjustment of the coupled model was done on present-day conditions first. For this, the missing oceanic heat uptake, which should normally prevent running equilibrium simulation in present-day conditions, was replaced by an artificial offset of the oceanic albedo by 0.007. The SST between 50N and 50S was favored as a target for this tuning because of the robustness of the observations. However, the compromise was made accepting an underestimation of this averaged SST to allow to a more realistic Arctic sea ice extent. This choice can also be related to the fact that the bias in SST is generally more positive in the 50N-50S band than on the full globe. Once this present-day tuning accomplished, the simulation is then continued with preindustrial conditions removing the surface albedo offset.

1.6.1.2 Global Mean Metrics Used

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

The main global target of the fully coupled model was the present-day global temperature. While both global near surface air temperature and SSTS were considered, it was finally chosen to use as a target the mean SST averaged between 50S and 50N which, because of the absence of sea ice all year long, is a much more robust metric than global 2m atmospheric temperature or global SST. As explained in the introduction, this target was used for present-day equilibrium simulations, done with the historical forcing of the decade 1990-2010, introducing an 0.007 offset of the oceanic albedo in order to compensate for the absence of oceanic heat uptake. At the end, the final tuning of the mean SST was adjusted about 0.4 K colder than observed, as a compromise, in order to keep enough sea ice over the Antarctic in summer, while all the sea ice parameters were already been pushed to their maximum tolerance (maximum value of albedo and thermal conductivity in particular). Whatever its tuning, the model reaches equilibrium for a slightly positive value (0.7 W/m2) of the global top-of-atmosphere radiative balance, due to non conservation problems in the model. In the limit of our possibilites, the target was a reasonable seasonal cycle of ice extent in both hemispheres and 20,000 km3 for the Arctic sea ice volume in winter. Not only the global radiative balance (or global temperature in the coupled model) was used as a target for tuning, but also the individual value of the global absorbed solar radiation and of the global outgoing longwave radiation. Also the decomposition of each of this fluxes in terms of clear sky and radiative effect of clouds were considered. The total rainfall was also looked at. As is often the case in climate models, it is larger than observations. Although it was not used really as a target (knowing the observation errors on this global metrics are not well known), it may have pushed some model choices toward a reduced global rainfall.

1.6.1.3 Regional Metrics Used

List of regional metrics/diagnostics of mean state (e.g THC, AABW, regional means etc) used in tuning model/component

Several regional regional metrics were directly used for tuning: 1/ The latitudinal distribution of radiation (and its decomposition between LW/SW and clear sky/clouds) in the sand alone atmospheric simulations (checking that it was not much affected by coupling with ocean). 2/ The surface temperature on continental surfaces in coupled continent-atmosphere simulations. Some regions were particularly looked at because the availability in the team of site observations and associated expertise: Sirta (Paris area, France), Dome C (Antarctica) and AMMA-Catch observatory (Sahel, Africa). The averaged continental surface temperature over Europe, Siberia and North America were considered as targets for tuning, through eyes control of maps of seasonal of near surface air temperature biases. 3/ Spatial contrasts in top-of-atmosphere radiative fluxes or surface fluxes (turbulence and radiation) in stand alone atmospheric simulations, targeting some classical SST warm biases over the East Tropical Oceans and around Antarctica. The metrics were computed as an index contrasting two parts of the ocean with masks. The effect of this tuning on SST was checked using root mean square errors of the SST mean seasonal cycle between 50S and 50N, removing or not the mean bias, as well as by checking seasonal climatological maps. 4/ The seasonal distribution of sea ice was monitored and looked at regularly, and the extension of the northern sea ice in autumn (as it minimum seasonal value) was used directly as a metric for tuning. 5/ The temperature profiles in the ocean 6/ The intensity of the Atlantic overturning circulation was a target of the tuning and the geographical distribution and intensity of deep water convection was looked at regularly for configuration selection. 7/ The stationary waves in the Northern Hemisphere were tuned by adjusting the values of the subgrid scale orographic scheme in LMDZ. 8/ Some choices of configuration were made based on ENSO behavior. Some constraints which were checked rather systematically and may have influenced some choices: 1/ Position of mid latitude atmospheric Jets 2/ Monsoon rainfall distribution 3/ Structure of the ITCZ 4/ The intensity of overturning cell associated with AABW.

1.6.1.4 Trend Metrics Used

List observed trend metrics/diagnostics used in tuning model/component (such as 20th century)

It was deliberately chosen not to use the XXth century as a tuning of the model ECS. No choice in the cloud or convective schemes were guided by a particular target on the ECS nor by a matching of the historical temperature trends. However, looking at simulations with an extreme

warming in the temperature evolution over the XXth century, it was realized that, because of changes in the tuning of the cloud model, the aerosol indirect effect (difference between present day and preindustrial period) was null. The relationship used to relate the aerosol climatology to the condensation nuclei concentration was thus readjusted which helped reduce the discrepancy with trend observations. However, the indirect effect of the final version is quite weak and this tuning has no effect on the ECS.

1.6.1.5 Energy Balance *

Describe how energy balance was obtained in the full system: in the various components independently or at the components coupling stage?

The energy balance of the full coupled system comes automatically from the model self consistency. At equilibrium, the unbalance comes in fact from model energy conservation problems. The energy balance of the atmosphere-continent surface forced by SST was tuned with an additional offset, in order to get the target SST in coupled model. Because of the model climate sensitivity, there is about a 1K to 1W/m2 relationship between a modification of the top-of-atmosphere global radiative budget in the forced by SST stand alone atmospheric model and a modification of the global mean temperature in coupled atmosphere-ocean simulations. Because probably of errors in the relationship between TOA and surface fluxes, or because of biases in coupled SSTs that can change the TOA unbalance, there is an offset between the radiative balance at present-day with forced SSTs (2.4 W/m2) and the top-of-atmosphere budget in the coupled model for present-day conditions (0.7 W/m2). Energy conservation is not fully conserved by the model. It is not properly conserved in particular for water phase changes in the atmospheric models. But the offset between the global balance in coupled and stand-alone atmospheric simulations makes it possible to target a change of SST in the coupled model by targeting a change in the global radiative balance in the stand alone atmospheric simulations, which can be obtained in very short simulations (of a few years).

1.6.1.6 Fresh Water Balance *

Describe how fresh_water balance was obtained in the full system: in the various components independently or at the components coupling stage?

Water conservation was checked carefully within the model components and in their couplings. Transfers between the various components were not tuned.

1.6.2 Heat

Global heat convervation properties of the model

1.6.2.1 Global *

Describe if/how heat is conserved globally

The coupled model does not completely conserve energy as a number of (very) small fluxes between the components are not fully represented in the coupled model (e.g. energy flux in run-off or precipitation). Therefore the energy balance is not quite achieved, and the model equilibrates with a net top-of-atmosphere radiative imbalance of 0.7 W.m-2.

1.6.2.2 Atmos Ocean Interface

Describe if/how heat is conserved at the atmosphere/ocean coupling interface

Fluxes of latent heat, sensible heat and radiation are conserved at the atmos-ocean interface. Nevertheless fluxes of energy associated with the temperature of hydrometeors are not conserved at the surface (hydrometeors are assumed to reach the ocean surface at the sea surface (or sea-ice) temperature).

1.6.2.3 Atmos Land Interface *

Describe if/how heat is conserved at the atmosphere/land coupling interface

Budget tests (bils + latent heat of melting and accumulating snow) showed an imbalance for continents of 0.7 W/m2. Favouring surface coupling rather than energy conservation induces an imbalance in the upwards LW radiation on surface of 0.2 W/m2 between ORCHIDEE and LMDz. Ice thermodynamics were activated in LMDz, and therefore snow is differentiated from rain (solid/liquid water). Taking into account the sensible heat flux due to the temperature difference between falling rain and surface was tested during the preparation of CMIP6 (Wang et al., 2016): on average, the impact on the energy balance on the surface and in the meteorological variables in the vicinity of the surface was feeble. The option was not retained for CMIP6. The order of magnitude on continents was -0.3 W/m2, yearly average (Wang et al., 2016). In those tests, the rain temperature was considered equal to that of the air in the first atmospheric layer.

1.6.2.4 Atmos Sea-ice Interface

Describe if/how heat is conserved at the atmosphere/sea-ice coupling interface

See 2.8.2.

1.6.2.5 Ocean Seaice Interface

Describe if/how heat is conserved at the ocean/sea-ice coupling interface

Perfectly conserved.

1.6.2.6 Land Ocean Interface

Describe if/how heat is conserved at the land/ocean coupling interface

Energy fluxes associated with lateral water fluxes at the land-ocean interface are not accounted for. Liquid water from river flow and coastal runoff are assumed to reach the ocean at the local SST. Iceberg (calving) are assumed to be at -4C, and their melting is assumed to be at 0C.

1.6.3 Fresh Water

Global fresh water convervation properties of the model

1.6.3.1 Global *

Describe if/how fresh_water is conserved globally

The fresh water balance was achieved to a very good precision (0.002 Sv) by ensuring quasi-conservation within each model component and across components (atmosphere-land, atmosphere-land ice, ocean-land, ocean-atmosphere).

1.6.3.2 Atmos Ocean Interface

Describe if/how fresh_water is conserved at the atmosphere/ocean coupling interface

Quasi-conserved.

1.6.3.3 Atmos Land Interface *

Describe if/how fresh water is conserved at the atmosphere/land coupling interface

Perfectly conserved.

1.6.3.4 Atmos Sea-ice Interface

Describe if/how fresh water is conserved at the atmosphere/sea-ice coupling interface

Quasi-conserved.

1.6.3.5 Ocean Seaice Interface

Describe if/how fresh water is conserved at the ocean/sea-ice coupling interface

Perfectly conserved.

1.6.3.6 Runoff

Describe how runoff is distributed and conserved

Runoff is transferred to river flow and coastal runoff and is quasi-conserved into the ocean.

1.6.3.7 Iceberg Calving

Describe if/how iceberg calving is modeled and conserved

Snow accumulates but also evaporates over land ice. It generates iceberg calving when snowdepth exceeds a threshold. Hence freshwater is conserved when the change in snowpack over land ice is accounted for.

1.6.3.8 Endoreic Basins

Describe if/how endoreic basins (no ocean access) are treated

Enter TEXT:

1.6.3.9 Snow Accumulation

Describe how snow accumulation over land and over sea-ice is treated

Enter TEXT:

1.6.4 Salt

Global salt convervation properties of the model

1.6.4.1 Ocean Seaice Interface

Describe if/how salt is conserved at the ocean/sea-ice coupling interface

Perfectly conserved.

1.6.5 Momentum

Global momentum convervation properties of the model

1.6.5.1 Details

Describe if/how momentum is conserved in the model

Enter TEXT:

2 Radiative Forcings

Radiative forcings of the model for historical and scenario (aka Table 12.1 IPCC AR5)

2.1.1 Top level properties

Radiative forcings of the model for historical and scenario (aka Table 12.1 IPCC AR5)

2.1.1.1 Name

Commonly used name for the radiative forcings in toplevel model.

Enter TEXT:

2.1.1.2 Overview

Overview of radiative forcings of the model for historical and scenario (aka table 12.1 ipcc ar5) in toplevel model.

GHG (CO2, CH4, N2O, CFC11, CFC12 including HCFC), aerosols (sulfate, OC, BC, nitrate), radiation and cloud interactions, landuse, Ndep, stratospheric aerosols, solar

2.1.2 CO2

Carbon dioxide forcing

2.1.2.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.2.2 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.3 CH4

Methane forcing

2.1.3.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.3.2 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.4 N2O

Nitrous oxide forcing

2.1.4.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.4.2 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.5 Tropospheric O3

Troposheric ozone forcing

2.1.5.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.5.2 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.6 Stratospheric O3

Stratospheric ozone forcing

2.1.6.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.6.2 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.7 CFC

Ozone-depleting and non-ozone-depleting fluorinated gases forcing

2.1.7.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.7.2 Equivalence Concentration *

Details of any equivalence concentrations used

☐ N/A - Not applicabale (CFCs not included or emissions and concentrations determined by the model state)

☐ Option 1 - CFCs, including CFC-12, are provided as actual concentrations

☐ Option 2 - CFC-12 is provided as actual concentrations and any other gases are provided as an equivalence concentration of CFC-11

☒ Option 3 - Ozone depleting gases, including CFC-12, are provided as an equivalence concentration of CFC-12 and all other fluorinated gases are provided as an equivalence concentration of HFC-134a

☐ Other - please specify:

2.1.7.3 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.8 SO4

SO4 aerosol forcing

2.1.8.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.8.2 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.9 Black Carbon

Black carbon aerosol forcing

2.1.9.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.9.2 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.10 Organic Carbon

Organic carbon aerosol forcing

2.1.10.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.10.2 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.11 Nitrate

Nitrate forcing

2.1.11.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.11.2 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.12 Cloud Albedo Effect

Cloud albedo effect forcing (RFaci)

2.1.12.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.12.2 Aerosol Effect On Ice Clouds *

Radiative effects of aerosols on ice clouds are represented?

☐ True ☐ False

2.1.12.3 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.13 Cloud Lifetime Effect

Cloud lifetime effect forcing (ERFaci)

2.1.13.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☒ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☐ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.13.2 Aerosol Effect On Ice Clouds *

Radiative effects of aerosols on ice clouds are represented?

☐ True ☐ False

2.1.13.3 RFaci From Sulfate Only *

Radiative forcing from aerosol cloud interactions from sulfate aerosol only?

☐ True ☐ False

2.1.13.4 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.14 Dust

Dust forcing

2.1.14.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.14.2 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Concentrations obtained from LMDzORINCA v6 runs with interactive dust emission parametrization. Depositions obtained from LMDzORINCA v6 runs (for biogeochemistry).

2.1.15 Tropospheric Volcanic

Tropospheric volcanic forcing

2.1.15.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☒ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☐ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.15.2 Historical Explosive Volcanic Aerosol Implementation *

How explosive volcanic aerosol is implemented in historical simulations

☐ Type A - Explosive volcanic aerosol returns rapidly to zero (or near-zero) background.

☐ Type B - Explosive volcanic aerosol returns rapidly to constant (average volcano)

☐ Type C - Explosive volcanic aerosol returns slowly (over several decades) to constant (average volcano) background.

☐ Type D - Explosive volcanic aerosol set to zero

☐ Type E - Explosive volcanic aerosol set to constant (average volcano) background

☐ Other - please specify:

2.1.15.3 Future Explosive Volcanic Aerosol Implementation *

How explosive volcanic aerosol is implemented in future simulations

☐ Type A - Explosive volcanic aerosol returns rapidly to zero (or near-zero) background.

☐ Type B - Explosive volcanic aerosol returns rapidly to constant (average volcano)

☐ Type C - Explosive volcanic aerosol returns slowly (over several decades) to constant (average volcano) background.

☐ Type D - Explosive volcanic aerosol set to zero

☐ Type E - Explosive volcanic aerosol set to constant (average volcano) background

☐ Other - please specify:

2.1.15.4 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.16 Stratospheric Volcanic

Stratospheric volcanic forcing

2.1.16.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.16.2 Historical Explosive Volcanic Aerosol Implementation *

How explosive volcanic aerosol is implemented in historical simulations

☐ Type A - Explosive volcanic aerosol returns rapidly to zero (or near-zero) background.

☐ Type B - Explosive volcanic aerosol returns rapidly to constant (average volcano)

☐ Type C - Explosive volcanic aerosol returns slowly (over several decades) to constant (average volcano) background.

☐ Type D - Explosive volcanic aerosol set to zero

☐ Type E - Explosive volcanic aerosol set to constant (average volcano) background

☐ Other - please specify:

2.1.16.3 Future Explosive Volcanic Aerosol Implementation *

How explosive volcanic aerosol is implemented in future simulations

☐ Type A - Explosive volcanic aerosol returns rapidly to zero (or near-zero) background.

☒ Type B - Explosive volcanic aerosol returns rapidly to constant (average volcano)

☐ Type C - Explosive volcanic aerosol returns slowly (over several decades) to constant (average volcano) background.

☐ Type D - Explosive volcanic aerosol set to zero

☐ Type E - Explosive volcanic aerosol set to constant (average volcano) background

☐ Other - please specify:

2.1.16.4 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Future: return in 10 years to average historical conditions.

2.1.17 Sea Salt

Sea salt forcing

2.1.17.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.17.2 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Obtained through LMDzORINCA v6 runs with interactive emission parametrization.

2.1.18 Land Use

Land use forcing

2.1.18.1 Provision *

How this forcing agent is provided (e.g. via concentrations, emission precursors, prognostically derived, etc.)

☐ N/A - Not applicable - forcing agent is not included

☐ M - Emissions and concentrations determined by the model state rather than externally prescribed

☒ Y - Prescribed concentrations, distributions or time series data

☐ E - Concentrations calculated interactively driven by prescribed emissions or precursor emissions

☐ ES - Surface emissions (and 3-D concentrations away from the surface) derived via the model from the prescribed surface concentration

☐ C - Fixed prescribed climatology of concentrations with no year-to-year variability

☐ Other - please specify:

2.1.18.2 Crop Change Only *

Land use change represented via crop change only?

☐ True ☐ False

2.1.18.3 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT:

2.1.19 Solar

Solar forcing

2.1.19.1 Provision *

How solar forcing is provided

☐ N/A - Not applicable - solar forcing is not included

☒ Irradiance - Solar irradiance forcing

☐ Proton - Proton pathway to solar forcing

☐ Electron - Electron pathway to solar forcing

☐ Cosmic ray - Cosmic ray pathway to solar forcing

☐ Other - please specify:

2.1.19.2 Additional Information

Additional information relating to the provision and implementation of this forcing agent (e.g. citations, use of non-standard datasets, explaining how multiple provisions are used, etc.).

Enter TEXT: