CMIP6 Model Documentation

Institute:	CSIRO
Model:	ACCESS-ESM1-5
Topic:	seaIce
Doc. Generated:	2020-04-08
Doc. Seeded From:	Spreadsheet
Specialization Version:	1.0.3
Further Info:	https://es-doc.org/cmip6
Note:	* indicates a required property

Documentation Contents

1 Key Properties

Sea Ice key properties

1.1.1 Top level properties

Sea Ice key properties

1.1.1.1 Name *

Name of seaice model code

CICE 4.1

1.1.1.2 Keywords *

Keywords associated with seaice model code

Sea ice, Los Alamos Sea Ice Model

1.1.1.3 Overview *

Overview of seaice model.

The Los Alamos sea ice model (CICE) (Hunke and Lipscomb 2010) has several interacting components: a thermodynamic model that computes local growth/melt rates of snow and ice due to vertical conductive, radiative and turbulent fluxes, along with snowfall; a model of ice dynamics, which predicts the velocity field of the ice pack based on a model of the material strength of the ice; a transport model that describes advection of the areal concentration, ice volumes and other state variables; and a ridging parameterization that transfers ice among thickness categories based on growth rates, energetic balances and rates of strain. External routinesprepare and execute data exchanges through a coupler (OASIS-MCT) with the atmospheric model (UM) and the ocean model (MOM). The CICE model acts as a coupling medium between the atmosphere and ocean models (Bi et al, 2013).

1.2.1 Variables

List of prognostic variable in the sea ice model.

1.2.1.1 Prognostic *

Select all prognostic variables in the sea ice component.

- [ ] Sea ice temperature
- [x] Sea ice concentration
- [ ] Sea ice thickness
- [x] Sea ice volume per grid cell area
- [x] Sea ice u-velocity
- [x] Sea ice v-velocity
- [x] Sea ice enthalpy
- [x] Internal ice stress

- [ ] Salinity
- [ ] Snow temperature - Snow on ice temperature
- [ ] Snow depth - Snow on ice thickness
- [ ] Other - please specify:

1.3.1 Seawater Properties

Properties of seawater relevant to sea ice

1.3.1.1 Ocean Freezing Point *

What is the equation used to compute the freezing point (in deg C) of seawater, as a function of salinity and pressure?

- [ ] TEOS-10 - Thermodynamic equation of seawater 2010.
- [ ] Constant - Constant value of seawater freezing point is used.
- [ ] Other - please specify:

1.3.1.2 Ocean Freezing Point Value

If using a constant seawater freezing point, specify this value.

Enter FLOAT value:

1.4.1 Resolution

Resolution of the sea ice grid

1.4.1.1 Name *

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

ACCESS grid

1.4.1.2 Canonical Horizontal Resolution *

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

One degree

1.4.1.3 Number Of Horizontal Gridpoints *

What are the total number of horizontal (XY) points (or degrees of freedom) on computational grid?

108000

1.5.1 Tuning Applied

Tuning applied to sea ice model component

1.5.1.1 Description *

Provide a 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 ice model set up used in the ACCESS ESM1.5 is identical to the parameter set up for the CMIP5 model ACCESS1-3. The only tunings to maintain the ice cover have been in the land surface scheme because the earlier ESM1.0 the ice was over sensitive to some of the choices that had been made and the ESM modellers had not recognised this had occured until too late. In ACCESS 1-3 we tuned the ice and snow albedos (Uotila et al, 2013) to give a realistic Arctic sea ice cover after the switch to the CABLE land surface scheme led to higher NH temperatures, this led too much ice being retained around Antarrctic coast in summer, this same excess ice in summer is present in the ACCESS ESM1.5.

1.5.1.2 Target *

What was the aim of tuning, e.g. correct sea ice minima, correct seasonal cycle?

Realistic ice cover, thickness, extent and seasonal cyclein the Arctic in pre-industialsimulations.

1.5.1.3 Simulations *

Which simulations had tuning applied, e.g. all, not historical, only pi-control?

The CMIP6 ice model in ACCESS ESM1.5 has not been tuned, the tunings from the pre-industrial CMIP5 ACCESS1-3 model have been applied.

1.5.1.4 Metrics Used *

List any observed metrics used in tuning model/parameters

We look at the IceSat sea ice thickness in the Arctic, PIOMAS thickness estimates, and the mean NSIDC ice extent from 1979 to the present day.

1.5.1.5 Variables

Which (if any) variables were changed during the tuning process?

Enter COMMA SEPARATED list:

1.6.1 Key Parameter Values

Values of key parameters

1.6.1.1 Ice Strength

Ice strength (P) in units of N m-2*

27500

1.6.1.2 Snow Conductivity

Snow conductivity (ks) in units of W m-1 K-1

0.3

1.6.1.3 Ice Thickness In Leads

Minimum thickness of ice created in leads (h0) in units of m

0.05

1.6.1.4 Additional Parameters

If you have any additional paramterised values that you have used (e.g. minimum open water fraction or bare ice albedo), please provide them here as a comma separated list in the form parameter1: value1, parameter2: value2, etc.

Emissivity = 0.95, dragio = 0.00536, iceruf = 0.0005 m, hs_min = 0.0001 m, rhos = 330 kg/m3, Cf = 17, rhoi = 917 kg/m3

1.7.1 Assumptions

Assumptions made in the sea ice model

1.7.1.1 Description *

*Provide a general overview description of any *key* assumptions made in this model.*

See Hunke and Lipscomb 2010

1.7.1.2 On Diagnostic Variables *

Note any assumptions that specifically affect the CMIP6 diagnostic sea ice variables.

The flux exchange of salt and water with the ocean component assumes a constant sea ice salinity of 5 psu and an ocean reference salinity of 34.7. The salinity in the thermodynamics is only used internally for the thermal properties of the ice. Snow fraction only impacts the albedo and shortwave calculation.

1.7.1.3 Missing Processes *

*List any *key* processes missing in this model configuration? Provide full details where this affects the CMIP6 diagnostic sea ice variables?*

See Hunke and Lipscomb 2010

1.8.1 Conservation

Conservation in the sea ice component

1.8.1.1 Description *

Provide a general description of conservation methodology.

We conserve fresh water, energy, and salt.

1.8.1.2 Properties *

Which properties conserved in sea ice by the numerical schemes?

- [x] Energy
- [ ] Mass
- [x] Salt

☐ Other - please specify:

1.8.1.3 Budget *

For each conserved property, specify the output variables which close the related budgets. as a comma separated list. For example: Conserved property, variable1, variable2, variable3

For each conserved property, specify the output variables which close the related budgets. as a comma separated list. For example: Conserved property, variable1, variable2, variable3 Energy, siflsenstop, siflswdtop, siflswutop, siflswdbot, sifllwdtop, sifllwutop, siflsensupbot, sisnhc, sihc : Fresh Water, sidmassevapsubl, sidmassgrowthbot, sidmassgrowthwat, sidmasslat, sidmassmeltbot, sidmassmelttop, sidmasssi, siflfwbot, sipr, : Salt, sidmassgrowthbot, sidmassgrowthwat, sidmasslat, sidmassmeltbot, sidmassmelttop, sidmasssi, siflsaltbot ... Note that to balance with changes in sea ice and snow thickness, these are monthly mean values and the changes must be estimated from these. Note the Heat flux terms (short wave, long wave, sensible and latent heat) are part of the thermodynamic calculation which is done in the atmospheric code, See section 4.

1.8.1.4 Was Flux Correction Used *

Does conservation involved flux correction?

☐ True ☐ False

1.8.1.5 Corrected Conserved Prognostic Variables

*List any variables which are conserved by *more* than the numerical scheme alone (e.g. has correction applied).*

Enter COMMA SEPARATED list:

2 Grid

Sea Ice grid

2.1.1 Top level properties

Sea Ice grid

2.1.1.1 Name

Name of grid in seaice model.

ACCESS grid

2.1.1.2 Overview

Overview of grid in seaice model.

Tripolar arctic grid, equatorial grid with exra refinement, Southern Ocean and Antarctic Mercator grid (Bi et al, 2013a).

2.1.2 Horizontal

Sea ice discretisation in the horizontal

2.1.2.1 Grid *

On which grid is the sea ice horizontal discretisation?

- ☐ Ocean grid - Sea ice is horizontally discretised on the ocean grid.
- ☐ Atmosphere Grid - Sea ice is horizontally discretised on the atmospheric grid.
- ☐ Own Grid - Sea ice is horizontally discretised on its own independent grid.
- ☐ Other - please specify:

2.1.2.2 Grid Type *

What is the structure type of the sea ice grid?

- ☒ Structured grid
- ☐ Unstructured grid
- ☐ Adaptive grid - Computational grid changes during the run
- ☐ Other - please specify:

2.1.2.3 Scheme *

What is the horizontal discretization (advection) scheme?

- ☒ Finite differences
- ☐ Finite elements

- [ ] Finite volumes
- [ ] Other - please specify:

2.1.2.4 Thermodynamics Time Step *

What is the time step in the sea ice model thermodynamic component in seconds.

3600

2.1.2.5 Dynamics Time Step *

What is the time step in the sea ice model dynamic component in seconds.

3600

2.1.2.6 Additional Details

Specify any additional horizontal discretisation details.

Enter TEXT:

2.1.3 Vertical

Sea ice vertical properties

2.1.3.1 Layering *

What type of sea ice vertical layers are implemented for purposes of thermodynamic calculations?

- [ ] Zero-layer - Simulation has no internal ice thermodynamics.
- [ ] Two-layers - Simulation uses two layers (i.e. one ice and one snow layer).
- [ ] Multi-layers - Simulation uses more than two layers.
- [ ] Other - please specify:

2.1.3.2 Number Of Layers *

If using multi-layers specify how many.

Enter INTEGER value:

2.1.3.3 Additional Details

Specify any additional vertical grid details.

Enter TEXT:

2.2.1 Seaice Categories

What method is used to represent sea ice categories?

2.2.1.1 Has Mulitple Categories *

Set to true if the sea ice model has multiple sea ice categories.

☒ True ☐ False

2.2.1.2 Number Of Categories *

If using sea ice categories specify how many.

5

2.2.1.3 Category Limits *

If using sea ice categories specify each of the category limits.

0, 0.645, 1.391, 2.470, 4.567, unlimited

2.2.1.4 Ice Thickness Distribution *

Describe the sea ice thickness distribution.

The sea ice thickness distribution is described in Bitz__2001 and Lipscomb__2007.

2.2.1.5 Other

If the sea ice model does not use sea ice categories specify any additional details. For example models that paramterise the ice thickness distribution ITD (i.e there is no explicit ITD) but there is assumed distribution and fluxes are computed accordingly.

Enter TEXT:

2.3.1 Snow On Seaice

Snow on sea ice details

2.3.1.1 Has Snow On Ice *

Is snow on ice represented in this model?

☒ True ☐ False

2.3.1.2 Number Of Snow Levels *

Number of vertical levels of snow on ice?

1

2.3.1.3 Snow Fraction *

Describe how the snow fraction on sea ice is determined.

The snow fraction is a function of the snow depth and the snow patchiness.

2.3.1.4 Additional Details

Specify any additional details related to snow on ice.

Enter TEXT:

3 Dynamics

Sea Ice Dynamics

3.1.1 Top level properties

Sea Ice Dynamics

3.1.1.1 Name

Commonly used name for the dynamics in seaice model.

EVP

3.1.1.2 Overview

Overview of sea ice dynamics in seaice model.

The elastic-viscous-plastic (EVP) model (Hunke_1997) represents a modification of the standard viscous-plastic (VP) model for sea ice dynamics. It reduces to the VP model at time scales associated with the wind forcing, while at shorter time scales the adjustment process takes place by a numerically more efficient elastic wave mechanism. While retaining the essential physics, this elastic wave modification leads to a fully explicit numerical scheme which greatly improves the models computational efficiency. We use the incremental remapping option for advection from Lipscomb_2004.

3.1.1.3 Horizontal Transport *

What is the method of horizontal advection of sea ice?

☐ Incremental Re-mapping - (including Semi-Lagrangian)

☐ Prather

☐ Eulerian

☐ Other - please specify:

3.1.1.4 Transport In Thickness Space *

What is the method of sea ice transport in thickness space (i.e. in thickness categories)?

☐ Incremental Re-mapping - (including Semi-Lagrangian)

☐ Prather

☐ Eulerian

☐ Other - please specify:

3.1.1.5 Ice Strength Formulation *

Which method of sea ice strength formulation is used?

☐ Hibler 1979

☒ Rothrock 1975

- [ ] Other - please specify:

3.1.1.6 Redistribution *

Which processes can redistribute sea ice (including thickness)?

- [x] Rafting
- [x] Ridging
- [ ] Other - please specify:

3.1.1.7 Rheology *

Rheology, what is the ice deformation formulation?

Select SINGLE option:

- [ ] Free-drift
- [ ] Mohr-Coloumb
- [ ] Visco-plastic - VP
- [ ] Elastic-visco-plastic - EVP
- [ ] Elastic-anisotropic-plastic
- [ ] Granular
- [ ] Other - please specify:

4 Thermodynamics

Sea Ice Thermodynamics

4.1.1 Top level properties

Sea Ice Thermodynamics

4.1.1.1 Name

Commonly used name for the thermodynamics in seaice model.

Bitz and Lipscomb, 1999

4.1.1.2 Overview

Overview of sea ice thermodynamics in seaice model.

The model uses zero layer themodynamics within the Bitz and Lipscomb 1999 schemewith the surfaceheat flux and the conductive heat flux passed into the calculation (Hewitt et al 2011). The surface snow/ice temperature is calculated in the atmospheric model (UM) surface scheme further details are provided in Hewitt et al 2011 paper.

4.2.1 Energy

Processes related to energy in sea ice thermodynamics.

4.2.1.1 Enthalpy Formulation *

What is the energy formulation?

- [x] Pure ice latent heat (Semtner 0-layer)
- [ ] Pure ice latent and sensible heat
- [ ] Pure ice latent and sensible heat + brine heat reservoir (Semtner 3-layer)
- [ ] Pure ice latent and sensible heat + explicit brine inclusions (Bitz and Lipscomb)
- [ ] Other - please specify:

4.2.1.2 Thermal Conductivity *

What type of thermal conductivity is used?

- [ ] Pure ice
- [x] Saline ice
- [ ] Other - please specify:

4.2.1.3 Heat Diffusion *

What is the method of heat diffusion?

- ☐ Conduction fluxes
- ☐ Conduction and radiation heat fluxes
- ☒ Conduction, radiation and latent heat transport
- ☐ Other - please specify:

4.2.1.4 Basal Heat Flux *

Method by which basal ocean heat flux is handled?

- ☐ Heat Reservoir - Brine inclusions treated as a heat reservoir.
- ☐ Thermal Fixed Salinity - Thermal properties depend on S-T (with fixed salinity).
- ☐ Thermal Varying Salinity - Thermal properties depend on S-T (with varying salinity.
- ☐ Other - please specify:

4.2.1.5 Fixed Salinity Value

If you have selected Thermal properties depend on S-T (with fixed salinity), supply fixed salinity value for each sea ice layer.

Enter FLOAT value:

4.2.1.6 Heat Content Of Precipitation *

Describe the method by which the heat content of precipitation is handled.

Heat content of precipitation is ignored.

4.2.1.7 Precipitation Effects On Salinity

If precipitation (freshwater) that falls on sea ice affects the ocean surface salinity please provide further details.

Snowfall on sea ice is accumulated and accounted for in the snow component of the model. Rainfall on the sea ice goes directly to the ocean via the fresh water flux.

4.3.1 Mass

Processes related to mass in sea ice thermodynamics.

4.3.1.1 New Ice Formation *

Describe the method by which new sea ice is formed in open water.

Frazil ice is formed in the ocean when the temperature drops below the salinity-dependent freezing point. This implied heat flux is given to the sea ice model and it must form this amount of ice. Salt water rejected by the sea ice is sent back to the ocean as a part of the salt fluxes.

4.3.1.2 Ice Vertical Growth And Melt *

Describe the method that governs the vertical growth and melt of sea ice.

Vertical melt and growth is computed based on the balance of fluxes at the base or surface of the sea ice.

4.3.1.3 Ice Lateral Melting *

What is the method of sea ice lateral melting?

☒ Floe-size dependent (Bitz et al 2001)

☐ Virtual thin ice melting (for single-category)

☐ Other - please specify:

4.3.1.4 Ice Surface Sublimation *

Describe the method that governs sea ice surface sublimation.

If latent heat is transferred from the ice to the atmosphere, snow or snow-free ice sublimates at the top surface. If the latent heat flux is positive (transferred from the atmosphere to the ice), vapor from the atmosphere is deposited at the surface as snow or ice.

4.3.1.5 Frazil Ice *

Describe the method of frazil ice formation.

Frazil ice is formed in the ocean when the temperature drops below the salinity-dependent freezing point. This implied heat flux is given to the sea ice model and it must form this amount of ice.

4.4.1 Salt

Processes related to salt in sea ice thermodynamics.

4.4.1.1 Has Multiple Sea Ice Salinities *

Does the sea ice model use two different salinities: one for thermodynamic calculations; and one for the salt budget?

☒ True ☐ False

4.4.1.2 Sea Ice Salinity Thermal Impacts *

Does sea ice salinity impact the thermal properties of sea ice?

☒ True ☐ False

4.4.2 Mass Transport

Mass transport of salt.

4.4.2.1 Salinity Type *

How is salinity determined in the mass transport of salt calculation?

- ☒ Constant
- ☐ Prescribed salinity profile
- ☐ Prognostic salinity profile
- ☐ Other - please specify:

4.4.2.2 Constant Salinity Value

If using a constant salinity value specify this value in PSU?

5

4.4.2.3 Additional Details

Describe the salinity profile used.

Enter TEXT:

4.4.3 Thermodynamics

Salt thermodynamics

4.4.3.1 Salinity Type *

How is salinity determined in the thermodynamic calculation?

- ☒ Constant
- ☐ Prescribed salinity profile
- ☐ Prognostic salinity profile
- ☐ Other - please specify:

4.4.3.2 Constant Salinity Value

If using a constant salinity value specify this value in PSU?

5

4.4.3.3 Additional Details

Describe the salinity profile used.

Enter TEXT:

4.5.1 Ice Thickness Distribution

Ice thickness distribution details.

4.5.1.1 Representation *

How is the sea ice thickness distribution represented?

- [x] Explicit
- [ ] Virtual (enhancement of thermal conductivity, thin ice melting)
- [ ] Other - please specify:

4.6.1 Ice Floe Size Distribution

Ice floe-size distribution details.

4.6.1.1 Representation *

How is the sea ice floe-size represented?

- [ ] Explicit
- [x] Parameterised
- [ ] Other - please specify:

4.6.1.2 Additional Details

Provide further details on any parameterisation of floe-size.

Constant value of 300m. This is based on Steele_1992.

4.7.1 Melt Ponds

Characteristics of melt ponds.

4.7.1.1 Are Included *

Are melt ponds included in the sea ice model?

- [ ] True
- [x] False

4.7.1.2 Formulation *

What method of melt pond formulation is used?

Select SINGLE option:

- [ ] Flocco and Feltham (2010)
- [ ] Level-ice melt ponds
- [ ] Other - please specify:

4.7.1.3 Impacts *

What do melt ponds have an impact on?

Select MULTIPLE options:

- [ ] Albedo
- [ ] Freshwater
- [ ] Heat
- [ ] Other - please specify:

4.8.1 Snow Processes

Thermodynamic processes in snow on sea ice

4.8.1.1 Has Snow Aging *

Set to True if the sea ice model has a snow aging scheme.

Select either TRUE or FALSE:

- [ ] True
- [ ] False

4.8.1.2 Snow Aging Scheme

Describe the snow aging scheme.

Enter TEXT:

4.8.1.3 Has Snow Ice Formation *

Set to True if the sea ice model has snow ice formation.

Select either TRUE or FALSE:

- [ ] True
- [ ] False

4.8.1.4 Snow Ice Formation Scheme

Describe the snow ice formation scheme.

Enter TEXT:

4.8.1.5 Redistribution *

What is the impact of ridging on snow cover?

Enter TEXT:

4.8.1.6 Heat Diffusion *

What is the heat diffusion through snow methodology in sea ice thermodynamics?

Select SINGLE option:

- [ ] Single-layered heat diffusion
- [ ] Multi-layered heat diffusion
- [ ] Other - please specify:

5 Radiative Processes

Sea Ice Radiative Processes

5.1.1 Top level properties

Sea Ice Radiative Processes

5.1.1.1 Name

Commonly used name for the radiative processes in seaice model.

CCSM3 for parts calculated within CICE.

5.1.1.2 Overview

Overview of sea ice radiative processes in seaice model.

All the albedos for the ice/snow cover are implemented in the UM radiation code the remaining radiation calculations are done within the CCSM3 option in the CICE shortwave code. The settings in ESM1.5 are the same as in ACCESS1.3 (Bi et al,2013b) and are at the high end due to tunings we applied at that time, they are: cold deep snow 0.84, melting deep snow 0.72, bare ice 0.68. The temperature range melting snow parmeterization is imlepented is 0.5 below zero, and at 0.25 below zero for melting bare ice.

5.1.1.3 Surface Albedo *

Method used to handle surface albedo?

☐ Delta-Eddington

☐ Parameterized - Sea ice albedo is parameterized.

☐ Multi-band albedo - Albedo value has a spectral dependence.

☐ Other - please specify:

5.1.1.4 Ice Radiation Transmission *

Method by which solar radiation through sea ice is handled?

Select MULTIPLE options:

☐ Delta-Eddington

☐ Exponential attenuation

☐ Ice radiation transmission per category - Radiation transmission through ice is different for each sea ice category.

☐ Other - please specify: