Name	Symbol	Units	Description
Total alkalinity	A_T	mol kg^{-1}	Concentration of ions that can be converted to uncharged species by a strong acid. The model assumes A_T =[HCO_3^-] + [CO_3^{2-}], often referred to as carbonate alkalinity. Alkalinity and DIC together quantify the equilibrium state of the seawater carbon chemistry.
Nitrate	[NO_3^-]	mg N m^{-3}	Concentration of nitrate. In the absence of nitrite [NO_2^-] in the model, nitrate represents [NO_3^-] + [NO_2^-].
Ammonia	[NH_4^-]	mg N m^{-3}	Concentration of ammonia.
Dissolved Inorganic Phosphorus	P	mg P m^{-3}	Concentration of dissolved inorganic phosphorus, also referred to as orthophosphate or soluble reactive phosphorus, SRP, composed chiefly of HPO_4^{2-} ions, with a small percentage present as PO_4^{3-}.
Dissolved inorganic carbon	DIC	mg C m^{-3}	Concentration of dissolved inorganic carbon, composed chiefly at seawater pH of HCO_3^-, with a small percentage present as CO_3^{2-}.
Dissolved oxygen	[O_2]	mg O m^{-3}	Concentration of oxygen.
Chemical Oxygen Demand	COD	mg O m^{-3}	Concentration of products of anoxic respiration in oxygen units. This represents products such as hydrogen sulfide, H_2S, that are produced during anoxic respiration and which, upon reoxidation of the water, will consume oxygen.
Dissolved Organic Carbon	O_C	mg C m^{-3}	The concentration of carbon in dissolved organic compounds.
Dissolved Organic Nitrogen	O_N	mg N m^{-3}	The concentration of nitrogen in dissolved organic compounds.
Dissolved Organic Phosphorus	O_P	mg P m^{-3}	The concentration of phosphorus in dissolved organic compounds.

Table 38: Name in model output files, symbol and units used in this document, and a description of all dissolved state variables. When the concentration of an ion is given, the chemical formulae appears in [] brackets.

Name	Symbol & Units	Description
Phytoplankton N	B [mg N m^{-3}]	Total structural biomass of nitrogen of the phytoplankton population. All microalgae have a C:N:P ratio of the structural material of 106:16:1. Thus the mass of phosphorus in the structural material of a population with a biomass B is given by: $\frac{1}{16}\frac{31}{14}B$ and the mass of carbon by: $\frac{106}{16}\frac{12}{14}$ B. The number of cells is given by B/m_N.
Phytoplankton N reserves	BR_N^* [mg N m^{-3}]	Total non-structural biomass of nitrogen of the phytoplankton population. Phytoplankton N reserves divided by Phytoplankton N is a number between 0 and 1 and represents the factor by which phytoplankton growth is inhibited due to the internal reserves of nitrogen.
Phytoplankton P reserves	$\frac{1}{16}\frac{31}{14}BR_P^*$ [mg P m^{-3}]	Total non-structural biomass of phosphorus of the phytoplankton population. Phytoplankton P reserves divided by (Phytoplankton N $\times\frac{1}{16}\frac{31}{14}$) is a number between 0 and 1 and represent the factor by which phytoplankton growth is inhibited due to the internal reserves of phosphorus.
Phytoplankton I reserves	$\frac{1060}{16}\frac{1}{14}BR_I^*$ [mmol photon m^{-3}]	Total non-structural biomass of fixed carbon of the phytoplankton population, quantified in photons. Phytoplankton I reserves divided by (Phytoplankton N $\times\frac{1060}{16}\frac{1}{14}$) is a number between 0 and 1 and represent the factor by which phytoplankton growth is inhibited due to the internal reserves of energy (or fixed carbon).
Phytoplankton chlorophyll	nc_iV [mg m^{-3}]	Concentration of the chlorophyll a pigment of the population. The four phytoplankton classes have two pigments, a chlorophyll a-based pigment and an accessory pigment. As the pigment concentration adjusts to optimise photosynthesis, including the presence of the accessory pigment, the intracellular content, c_iV, represents only the chlorophyll a-based pigment. As the model does not distinguish between mono-vinyl and di-vinyl forms of chlorophyll, this c_i represents either form, depending on the phytoplankton type.
Zooplankton N	Z [mg N m^{-3}]	Total biomass of nitrogen in animals. With only small and large zooplankton categories resolved, small zooplankton represents the biomass of unicellular fast growing animals (protozoans) and large zooplankton represents the biomass of all other animals (metazoans). All zooplankton have a C:N:P ratio of 106:16:1. Thus the mass of phosphorus of a population with a biomass Z is given by: $\frac{1}{16}\frac{31}{14}Z$ and the mass of carbon by: $\frac{106}{16}\frac{12}{14}$ Z.

Table 39: Name in model output files, symbol and units used in this document, and description of all biological particulate state variables in the model. The model contains four catagories of phytoplankton: small, $r < 2$ μm phytoplankton; large: $e > 2$ μm phytoplankton; trichodesmium: nitrogen fixing phytoplankton; and benthic microalgae: fast-sinking diatoms that are suspended primarily in the top layer of sediment porewaters. The elemental ratio of phytoplankton including both structural material and reserves is given by: C:N:P $= 106(1+R_I^*) : 16(1+R_N^*) : (1+R_P^*)$.

Name	Symbol	Units	Description
Mud	Mud	[kg m^{-3}]	Small sized, re-suspending particles with a sinking velocity of 17 m d^{-1}.
Fine Sediment	$FineSed$	[kg m^{-3}]	Identical to Mud, except that it is initialised to zero in the model domain, and enters only from the catchments.
Sand	$Sand$	[kg m^{-3}]	Medium sized, re-suspending particles with a sinking velocity of 173 m d^{-1}.
Gravel	$Gravel$	[kg m^{-3}]	Large, non-resuspending particles.
Particulate Inorganic Phosphorus	PIP	[mg P m^{-3}]	Phosphorus ions that are absorbed onto particles. It is considered a particulate with the same properties as Mud.
Immobilised Particulate Inorganic Phosphorus	$PIPI$	[mg P m^{-3}]	Phosphorus that is permanently removed from the system through burial of PIP.
Labile Detritus Nitrogen Plank	D_{Red}	[mg N m^{-3}]	Concentration of N in labile (quickly broken down) organic matter with a C:N:P ratio of 106:16:1 derived from living microalgae, zooplankton, coral host tissue and zooxanthellae with the same C:N:P ratio. Thus the mass of phosphorus in D_{Red} is given by: $\frac{1}{16}\frac{31}{14}D_{Red}$ and the mass of carbon by: $\frac{106}{16}\frac{12}{14}D_{Red}$.
Labile Detritus Nitrogen Benthic	D_{Atk}	[mg N m^{-3}]	Concentration of N in labile (quickly broken down) organic matter with a C:N:P ratio of 550:30:1 derived from living seagrass and macroalgae with the same C:N:P ratio. Thus the mass of phosphorus in D_{Atk} is given by: $\frac{1}{30}\frac{31}{14}D_{Atk}$ and the mass of carbon by: $\frac{550}{30}\frac{12}{14}D_{Atk}$.
Refractory Detritus Carbon	D_C	[mg C m^{-3}]	Concentration of carbon as particulate refractory (slowly breaking down) material. It is sourced only from the breakdown of labile detritus, and from rivers.
Refractory Detritus Nitrogen	D_N	[mg N m^{-3}]	Concentration of nitrogen as particulate refractory (slowly breaking down) material. It is sourced only from the breakdown of labile detritus, and from rivers.
Refractory Detritus Phosphorus	D_P	[mg P m^{-3}]	Concentration of phosphorus as particulate refractory (slowly breaking down) material. It is sourced only from the breakdown of labile detritus, and from rivers.

Table 40: Name in model output files, symbol, unit used in this document, and description of all non-biological particulate state variables in the model.

Name	Symbol	Description
Macroalgae	MA [g N m^{-2}]	Concentration of nitrogen biomass per m^2 of macrolagae. Macroalgae (or seaweed) grows above all other benthic plants (corals, seagrasses, benthic microalgae). It is parameterised as a non-calcifying leafy algae, with a C:N:P ratio of 550:30:1, and a formulation for calculating the percentage of the bottom covered as $1 - \exp(-\Omega_{MA}\ MA)$. In the model, in the absence of both calcifying macroalgae (particularly *Halimeda*) and unicellular epiphytes, macroalgae represents the biomass of all seaweeds and epiphytes.
Seagrass	SG [g N m^{-2}]	Concentration of nitrogen biomass per m^2 of a seagrass form parameterised to be similar to *Zostera*. This form captures light after it has passed through macroalgae and before it passes through *Halophila*. This form is better adapted to high light, low nutrient conditions than *Halophila* as a result of a deeper root structure and being able to shade it. See macroalgae for elemental ratio and bottom cover.
Halophila	SG [g N m^{-2}]	Concentration of nitrogen biomass per m^2 of a seagrass form parameterised to be similar to *Halophila*. This form captures light after it has passed through the *Zostera* seagrass form. The *Halophila* form is batter adapted to low light conditions than *Zostera*, having a faster growth rate and lower minimum light requirement. See macroalgae for elemental ratio and bottom cover.
Coral host N	CH [g N m^{-2}]	Concentration of nitrogen biomass per m^2 of coral host tissue in the entire grid cell. Unlike other epibenthic variables, corals area is assumed to exist in communities that are potentially smaller than the grid size. The fraction of the grid cell covered by corals is given by A_{CH}. Thus the biomass in the occupied region is given by CH/A_{CH}. The percent coverage of the coral of the bottom for the whole cell is given by $A_{CH}\,(1 - \exp(-\Omega_{CH}\ CH/A_{CH}))$. With only one type of coral resolved, CH represents the biomass of all symbiotic corals. Since the model contains no other benthic filter-feeders, CH best represent the sum of the biomass of all symbiotic filter-feeding organisms such as corals, sponges, clams etc. C:N:P is 106:16:1.
Coral symbiont N	CS [mg N m^{-2}]	Concentration of nitrogen biomass per m^2 of coral symbiont cells, or zooxanthellae. To determine the density of cells, use $n = CS/m_N$. The percentage of the bottom covered is given by $\frac{\pi}{2\sqrt{3}} n \pi r_{zoo}^2$ where πr^2 is the projected area of the cell, n is the number of cells, and $\pi/(2\sqrt{3}) \sim 0.9069$ accounts for the maximum packaging of spheres. C:N:P is 106:16:1.
Coral symbiont chl	nc_iV [mg chl m^{-2}]	Concentration of chlorophyll biomass per m^2 of coral symbiont cells. As chlorophyll is the only pigment resolved in the coral symbiont, c_i represents the sum of the concentration of all photosynthetic pigments within the cell and has an absorption spectrum of divinyl chlorophyll *a*.

Table 41: Name in model output files, units, symbol used in this document, and description of all epibenthic state variables in the model. The order in the above table corresponds to their vertical position, and therefore the order in which they access light. Benthic microalage, being suspended in porewaters, is consider as a particulate in Table 40.

Name	Units	Description
Absorption at 440 nm	m^{-1}	Total absorption due to clear water, CDOM, microalgae and suspended sediments at 440 nm.
Scattering at 550 nm	m^{-1}	Total scattering due to clear water, microalgae and suspended sediments at 550 nm.
Vertical attenuation at 490 nm	m^{-1}	Vertical attenuation (along z axis not along zenith angle) of light at 490 nm.
Average PAR in layer	mol photon m^{-2} d^{-1}	Mean downwelling photosynthetically available radiation (400 - 700 nm) within the layer.
Light intensity above seagrass	mol photon m^{-2} d^{-1}	Mean downwelling photosynthetically available radiation (400 - 700 nm) above seagrass canopy.
Light intensity above sediment layer	mol photon m^{-2} d^{-1}	Mean downwelling photosynthetically available radiation (400 - 700 nm) at the sediment-water interface.
Vertical attenuation of heat	m^{-1}	Vertical attenuation (along z axis not along zenith angle) of heat energy.
Bicarbonate [HCO_3^-]	mmol m^{-3}	Concentration of bicarbonate ions calculated from carbon chemistry equlibra at water column values of T, S, DIC and A_T.
Carbonate [CO_3^{2-}]	mmol m^{-3}	Concentration of carbonate ions calculated from carbon chemistry equlibra at water column values of T, S, DIC and A_T.
Oxygen % saturation	%	Dissolved oxygen concentration as a percentage of the saturation concentration at atmospheric pressure and local T and S.
pH	$\log_{10}$ mol m^{-3}	pH based on [H^+] calculated from carbon chemistry equlibra at water column values of T, S, DIC and A_T.
Sea-air CO_2 flux	mg C m^{-2} s^{-1}	Flux of carbon from sea to air (positive from sea to air). The value is given in the layer in which it was deposited (must be thicker than 20 cm), but still represents an areal flux.
Sea-air O_2 flux	mg O m^{-2} s^{-1}	Flux of oxygen from sea to air (positive from sea to air). The value is given in the layer in which it was deposited (must be thicker than 20 cm), but still represents an areal flux.
Delta pCO_2	ppmv	Partial pressure of CO_2 in the ocean minus that of the atmosphere (396 ppmv).
Oceanic pCO_2	ppmv	Partial pressure of CO_2 in the ocean.

Table 42: Name in model output files, units, and description of gas and optical diagnostic variables. Unless otherwise stated quantities are cell centred vertical averages.

Name	Units	Description
Total C, N, P	mg m^{-3}	Sum of dissolved and particulate C, N, and P.
Total chlorophyll a	mg m^{-3}	Sum of chlorophyll concentration of the four microalgae types ($\sum nc_i V_i$).
Ecology Fine Inorganics	kg m^{-3}	Sum of fine sediment and mud concentrations.
Ecology Particulate Organics	kg m^{-3}	Weight of carbon in microalgae, zooplankton, and particulate detritus.
Large phytoplankton net production	mg C m^{-3} d^{-1}	Rate of large phytoplankton organic matter synthesis from inorganic constituents.
Small phytoplankton net production	mg C m^{-3} d^{-1}	Rate of small phytoplankton organic matter synthesis from inorganic constituents.
Trichodesmium net production	mg C m^{-3} d^{-1}	Rate of *Trichodesmium* organic matter synthesis from inorganic constituents.
Microphytobenthos net production	mg C m^{-3} d^{-1}	Rate of microphytobenthos organic matter synthesis from inorganic constituents.
Total phytoplankton net production	mg C m^{-3} d^{-1}	Rate of total phytoplankton organic matter synthesis from inorganic constituents.
Large zooplankton removal rate from small zooplankton	mg C m^{-3} d^{-1}	Rate of carnivory of large zooplankton on small zooplankton.
Small zooplankton removal rate from small phytoplankton	mg C m^{-3} d^{-1}	Secondary production of small zooplankton.
Large zooplankton removal rate from large phytoplankton	mg C m^{-3} d^{-1}	Secondary production of large zooplankton.
Zooplankton total grazing	mg C m^{-3} d^{-1}	Total secondary pelagic production - feeding of both zooplankton classes on phytoplankton.
N_2 fixation	mg N m^{-3} s^{-1}	Nitrogen fixation by *Trichodesmium*.

Table 43: Name in model output files, units, and description of pelagic diagnostic variables.

Name	Units	Description
Total epibenthic C, N, P	mg m^{-2}	Sum of C, N, and P in epibenthic plants and corals.
Coral inorganic supply	mg N m^{-2} s^{-1}	Flux of dissolved inorganic nitrogen into coral polyps from the water column, absorbed by zooxanthellae.
Coral organic supply	mg N m^{-2} s^{-1}	Flux of particulate organic nitrogen into coral polyps from the water column, consumed by the coral host.
Net calcification	mg C m^{-2} s^{-1}	Net calcification (calcification minus dissolution) at the sediment-water column interface leading to a change in the water column properties.
Halophila production	g N m^{-2} d^{-1}	Gross production of nitrogen in *Halophila*, where N fluxes are not accounted for in respiration.
Halophila growth rate	s^{-1}	Turnover time of above-ground *Halophila* biomass.
Seagrass growth rate	s^{-1}	Turnover time of above-ground *Zostera* biomass.
Seagrass production	g N m^{-2} d^{-1}	Gross production of nitrogen in *Zostera*, where N fluxes are not accounted for in respiration.
Macroalgae growth rate	s^{-1}	Turnover time of macroalgae biomass.
Macroalgae production	g N m^{-2} d^{-1}	Gross production of nitrogen in macroalgae, where N fluxes are not accounted for in respiration.

Table 44: Name in model output files, units and description of benthic diagnostic variables.

Description	Calculation	Application
Monthly bottom light (eqival. to daily dose]	1 hourly running-mean $\frac{1}{\tau}\int_0^t E_{d,\lambda,t}\exp(-\tau t)dt$ [mol m^{-2} d^{-1}]	seagrass viability
Aragonite dissolution exposure	$\int_{t-t_{\Omega<3}}^{t}(3-\Omega)\,dt$ reset time 1 day, [unit days]	acidification stress
Monthly net calcification rate	1 hourly running-mean $\frac{1}{\tau}\int_0^t g_{net,t}\exp(-\tau t)dt$	calcification index coral accretion
Temperature exposure (degree heating weeks)	$\int_{t-t_{T>T_{clim}}}^{t}(T-T_{clim})\,dt$ rest time 7 day, [°C weeks]	thermal coral bleaching
Weekly inorganic N uptake by corals	1 hourly running-mean $\frac{1}{\tau}\int_0^t G_t\exp(-\tau t)dt$	oxidative stress
Salinity exposure	$\int_{t-t_{S<28}}^{t}(28-S)\,dt$ reset time 1 day, [PSU days]	freshwater coral bleaching
Weekly net deposition rate (sinking / resuspension / diffusion)	1 hourly running-mean $\frac{1}{\tau}\int_0^t D_t\exp(-\tau t)dt$ [cm d^{-1}]	coral smothering
Hypoxic exposure	$\int_{t-t_{[O_2]<2000}}^{t}(2000-[O_2])\,dt$ rest time 1 hour, [mg O m^{-3} d^{-1}]	low oxygen stress
Weekly bottom light attenuation (approx. from 490 nm)	1 hourly running-mean $\frac{1}{\tau}\int_0^t K_{d,490,t}\exp(-\tau t)dt$ [m^{-1}]	predator visibility prey behaviour
Remote-sensing reflectance R_{rs}	see Section 3.2.2 412, 443, 488, 531, 547, 648, 667, 748 nm	comparison with ocean colour products
MODIS algorithms - Kd, OC3, TSS, POC - Kd, OC3, TSS, POC	empirical algorithms using remote-sensing reflectance	comparison with ocean colour products
Simulated true colour	RGB additive colour model using remote-sensing reflectance	water quality non-expert communication
Plume classification (1-6) + clear water	categorical from spectra matching using RMS errors on OC bands 1-7	plume extent

Table 45: Diagnostic variables. In addition to 60+ state variables, derived diagnostic variables have been developed in consultation with researchers and managers that provide metrics for improve understanding and application. For those metrics with a time scale, τ, the coefficient represents an exponential decay time - thus for a weekly running average, the impact of the value 1 week earlier on the running average is $100 \times \exp(-1)$, or 37 % of the impact of the present value.