Metos3D

Biogeochemical Models

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1 Introdution

Metos3D can be coupled to every (biogeochemical) model that conforms to the following interface:

```
subroutine metos3dbgc(n, nz, m, nb, nd, dt, q, t, y, u, b, d)
    integer :: n           ! tracer count
    integer :: nz          ! layer count
    integer :: m           ! parameter count
    integer :: nb          ! boundary condition count
    integer :: nd          ! domain condition count
    real*8  :: dt          ! ocean time step
    real*8  :: q(nz, n)    ! bgc model output
    real*8  :: t           ! point in time
    real*8  :: y(nz, n)    ! bgc model input
    real*8  :: u(m)        ! parameters
    real*8  :: b(nb)       ! boundary conditions
    real*8  :: d(nz, nd)   ! domain conditions
end subroutine
```

The interface decouples biogeochemical models and driver routines (ocean circulation, forcing, geometry) programmatically. It gives you the possibility to provide a free number of tracers, parameters, boundary and domain conditions. It suits well an optimization as well as an Automatic Differentiation (AD) context.

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2 BGC Models

Every model archive contains an `option` and a `job` directory. You can find examples of option files in the former and job files for high performance clusters in the latter. Use them as a starting point for your own work.

2.1 I-Cs

The Iodine (I) and Caesium (Cs) model was actually implemented to show the flexibility of Metos3D. It was used to the predict the Caesium distribution after the Fukushima accident. See http://www.ozean-der-zukunft.de/fukushima/ for more (german only).

2.1.1 Equations

The model equations describe the radioactive decay of the I^{131} and Cs^{137} isotops named y_1 and y_2, respectively. The decay depends on the half-life. The tracers do not react with each other. The equations read:

$$q_1(y_1, y_2) = \log(0.5)\, 360.0/8.02070\, y_1$$
$$q_2(y_1, y_2) = \log(0.5)\, 1.0/30.17\, y_2$$

2.2 N-DOP

The nutrients (N) and dissolved organic phosphorous (DOP) model is a simple and well known one among biogeochemical modelers. It is based on the model presented in [4].

2.2.1 Equations

The tracers are denoted by $y = (y_1, y_2)^T = (y_{PO4}, y_{DOP})^T$. The biological production (the net community productivity) is calculated as a function f_1 of nutrients and light I. The production is limited using a half saturation function, also known as Michaelis-Menten kinetics, and a maximum production rate parameter α.

$$f_1(y_1, I) = \alpha \frac{y_1}{y_1 + K_1} \frac{I}{I + K_I}$$

Light, here, is a portion of short wave radiation I_{SWR}, which is computed as a function of latitude and season following the astronomical formula of Paltridge and Platt [3]. The portion depends on the photo-synthetically available radiation σ_{PAR}, the ice cover σ_{ice} and the exponential attenuation of water.

$$I = I_{SWR}\, \sigma_{PAR}\, (1 - \sigma_{ice})\, \exp(-z\, K_{H2O})$$

A fraction of the biological production σ_2 remains suspended in the water column as dissolved organic phosphorus, which remineralizes with a rate λ_2'. The

remainder of the production sinks as particulate to depth where it is remineralized according to the empirical power law relationship determined by Martin et al. [2]. Similar descriptions for biological production can be found in [4], [1] and [5].
Moreover the model formulation consists of a production (sun lit, euphotic) zone, with a depth of l', and a noneuphotic zone, Ω_1 and Ω_2 respectively. The equations read

$$\begin{aligned} q_1(y) &= -f_1(y_1, I) + \lambda_2' \, y_2 && \text{in } \Omega_1 \\ q_1(y) &= +\bar{\sigma}_2 \, \partial_z \, F_1(y_1, I) + \lambda_2' \, y_2 && \text{in } \Omega_2 \end{aligned}$$

$$\begin{aligned} q_2(y) &= +\sigma_2 \, f_1(y_1, I) - \lambda_2' \, y_2 && \text{in } \Omega_1 \\ q_2(y) &= -\lambda_2' \, y_2 && \text{in } \Omega_2, \end{aligned}$$

where

$$F_1(y_1, I) = (z/l')^{-b} \int_0^{l'} f_1(y_1, I) \, d\xi \, .$$

The following table summarizes the parameters within the N-DOP model:

Symbol	Description	Unit
α	maximum community production rate	$1/y$
K_{H2O}	attenuation of water	$1/m$
K_1	half saturation constant of PO4	$m\,molP/m^3$
K_I	half saturation constant of light	W/m^2
λ_2'	remineralization rate of DOP	$1/d$
σ_2	fraction of DOP, $\bar{\sigma}_2 = (1 - \sigma_2)$	$-$
b	sinking velocity exponent	$-$

References

[1] S. Dutkiewicz, M. Follows, and P. Parekh. Interactions of the iron and phosphorus cycles: A three-dimensional model study. *Global Biogeochemical Cycles*, 19:1–22, 2005.

[2] J. H. Martin, G. A. Knauer, D. M. Karl, and W. W. Broenkow. Vertex: carbon cycling in the northeast pacific. *Deep Sea Research Part A. Oceanographic Research Papers*, 34(2):267–285, 1987.

[3] G. W. Paltridge and C. M. R. Platt. Radiative processes in meteorology and climatology, 318 pp, 1976.

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