Coupled ocean-sediment model REcoM/MEDUSA

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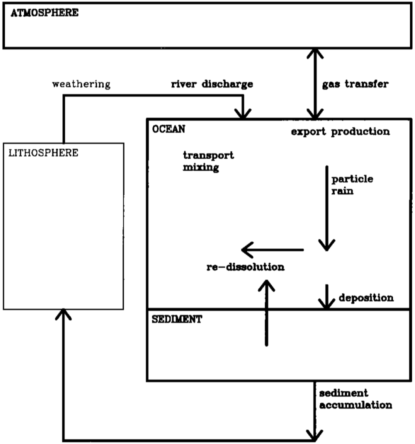
DLR Project Management Agency

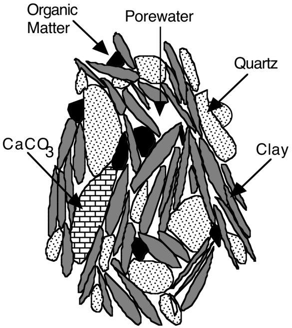
Why a sediment model?

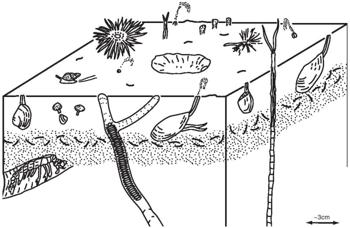
- fluxes between ocean and sediment particularly important for more realistic parameterisation of iron source
- sediment accumulation $\rightarrow$ lithosphere
- and long-term climate impact through weathering

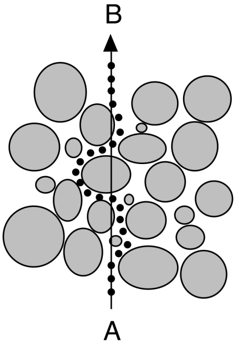


Heinze et al. 1999, Glob. Biogeochem. Cycles

Composition of sediment and processes regulating fluxes

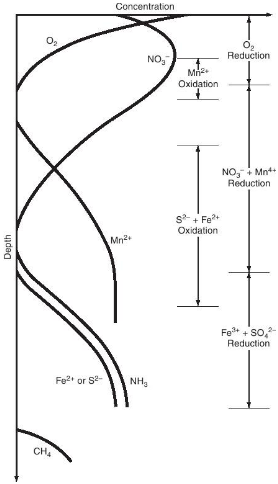






Boudreau, 1996, Diagenetic Models and their Implementation

Reactions in sediment



Sarmiento & Gruber 2006

Microbial remineralization of organic matter $\rightarrow$
typical sequence of redox zones (different electron acceptors):

- oxic remineralization
- denitrification
- Fe/Mn reduction
- Sulfur reduction ...

Dissolution of $CaCO_3$: depends on local pH, TAlk, DIC, pressure, dominant $CaCO_3$ form

Dissolution of biogenic opal depends on lokal $Si(OH)_4$

REcoM uncoupled with MEDUSA

- sinking flux of POC, PON, calcite, opal and lithogenic particles into benthic layer
- release of dissolved components: proportional to microbial degradation of POM in benthic layer and dissolution of calcite and opal

$$\kappa \frac{\partial A}{\partial z}\bigg|_{z=-H} = \begin{cases} d^{C} \cdot \mathrm{POC}_{sed} + d^{CaCO_3} \cdot \mathrm{CaCO_3}_{sed} & \text{for} \quad A = \mathrm{DIC} \\ d^{N} \cdot \mathrm{PON}_{sed} & \text{for} \quad A = \mathrm{DIN} \\ (1+1/16) \cdot d^{N} \cdot \mathrm{PON}_{sed} + 2d^{CaCO_3} \cdot \mathrm{CaCO_3}_{sed} & \text{for} \quad A = \mathrm{TA} \\ d^{Si} \cdot \mathrm{Si}_{sed} & \text{for} \quad A = \mathrm{DSi} \\ q^{Fe} \cdot d^{C} \cdot \mathrm{POC}_{sed} & \text{for} \quad A = \mathrm{DFe} \\ 0 & \text{for} \quad \text{all other tracers} \end{cases}$$

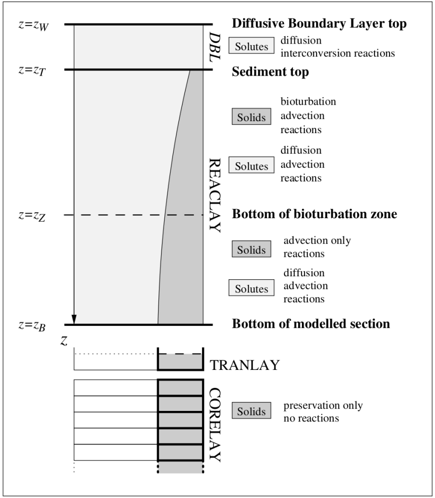
Hauck et al. 2014

- calcite dissolution independent of Ω
- bottom water O_2 and different redox processes not involved
- no permanent burial

MEDUSA = layered sediment model

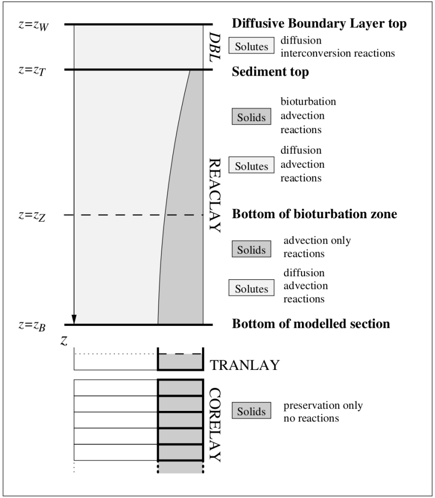
A 1-dimensional sediment column defined at each horizontal grid point

- diffusive boundary layer on top (optional)
- reactive layer, with prescribed porosity profile and bioturbation depth
- consolidated sediment for recording old states (optional)



Components and reactions considered

Solids	POM (particulate organic matter) $CaCO_3$ (calcite only, no aragonite) SiO_2 (diatom frustules) lithogenic particles
Solutes	carbonate system NO_3^-, $Si(OH)_4$, O_2
Reactions	oxic remineralization denitrification $CaCO_3$ and SiO_2 dissolution dissolved chemical equilibria



Interaction between sediment and water column

REcoM $\rightarrow$ Medusa

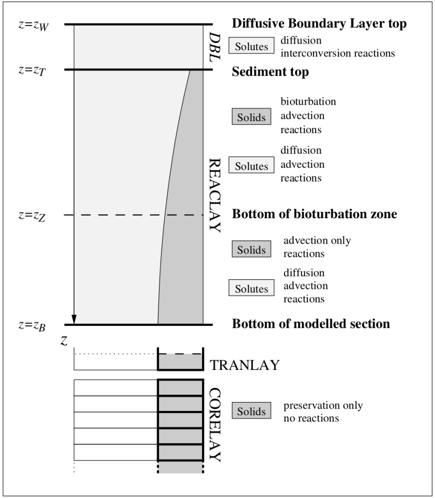
- bottom water T, S, p
- bottom DIC, TAlk, O_2, NO_3^-, $Si(OH)_4$
- sinking fluxes: $CaCO_3$, SiO_2, POC, PON, dust

Medusa $\rightarrow$ REcoM

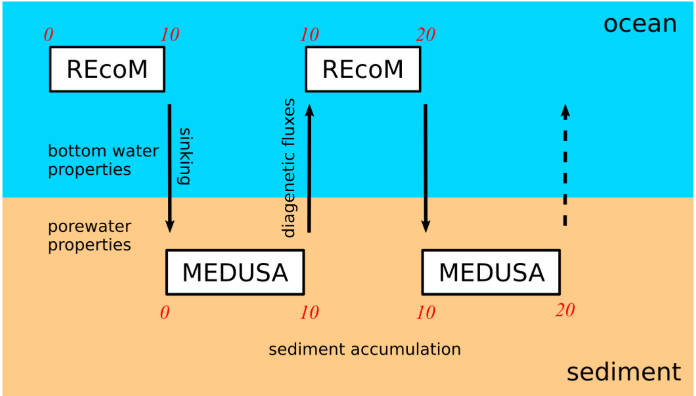
- diffusive fluxes: DIC, TAlk, O_2, NO_3^-, $Si(OH)_4$

To close the system

- permanent burial of $CaCO_3$ and SiO_2
  $\rightarrow$ terrestrial input (e.g. riverine)
- denitrification and PON burial
  $\rightarrow$ nitrogen fixation/atmospheric N input

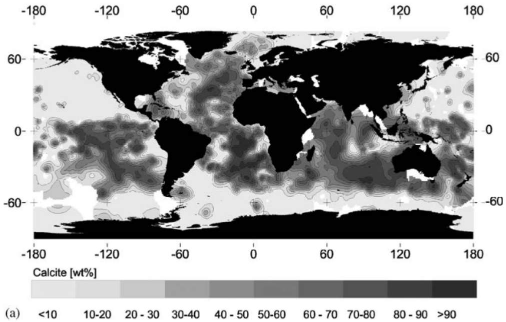


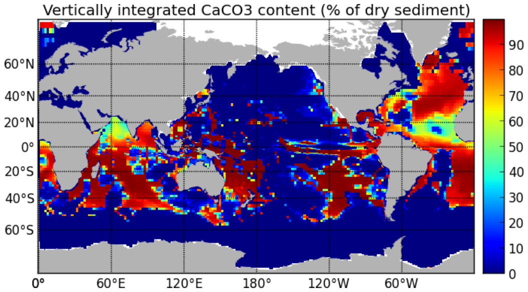
Coupled run



- at time step 0, MEDUSA first calculating until equilibrium

First results: $CaCO_3$

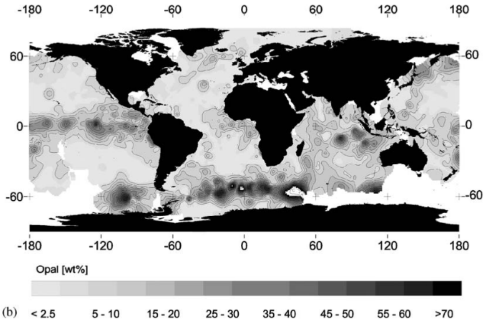


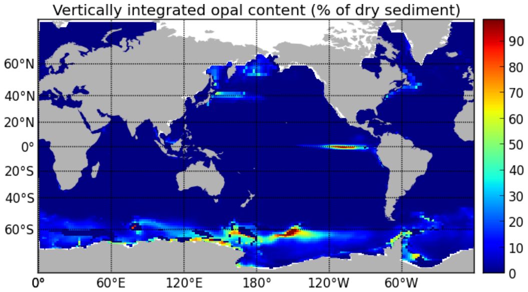


left: Seiter et al. 2004, right: REcoM/Medusa

- mainly distributed in Atlantic,Indian Ocean and part of South Pacific
- lower fraction in dust regions

First results: opal





left: Seiter et al 2004, right: REcoM/Medusa

- mainly in high latitudes and equatorial Pacific
- data: also elevated in Indian Ocean

First results: particulate organic matter

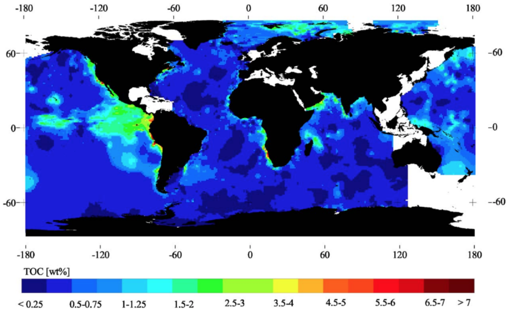
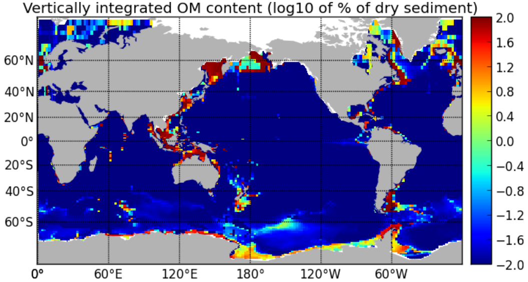


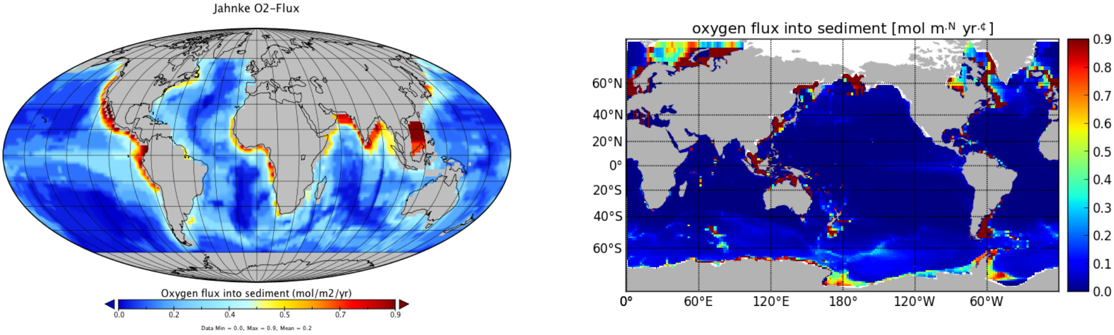
Fig. 11. Global distribution pattern of the TOC content in surface sediments (<5 cm sediment depth).



left: Seiter et al 2004, right: REcoM/Medusa

- model: too high in coastal regions and too low in open ocean
- sinking and remineralisation in water column? degradation in sediment?

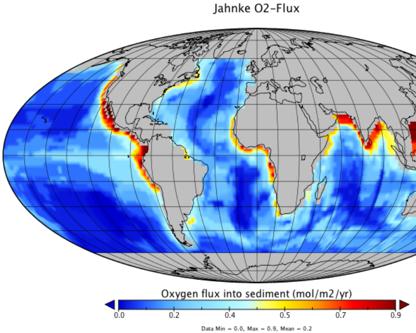
First results: oxygen utilization in sediment

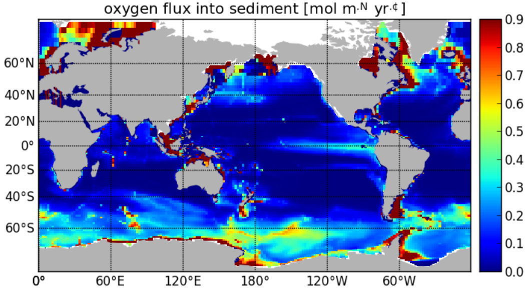


left: Jahnke 1996, right: REcoM/MEDUSA

- high in coastal regions
- data: higher in open ocean e.g. Atlantic and equatorial Pacific →sinking?

First results: oxygen utilization in sediment





left: Jahnke 1996, right: REcoM (increased sinking)

- clear change in high latitudes, EP and small change in northern IO
- nutrients and DIC in water column also affected → NPP
- sediment model provides additional constraints and requires more tests

Next steps

- Further analysis of the first simulation, e.g. comparing with uncoupled model run
- other components and processes, e.g. C isotopes and Fe, balancing denitrification and burial
- validation for present-day and then LGM and transition run
- coupling with FESOM

Thanks for your attention!

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Thanks for your attention!