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Norwegian institute for water research

Model based assessment of environmental impact of deployment of biomass (wood chips and calcium carbonate) on the bottom biogeochemistry in the Norwegian Sea

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Background

The ocean is the largest natural carbon sink on our planet, that provides a range of biological and chemical pathways by which this natural fast-to-slow carbon transfer occurs. This gives an opportunity for elaborating of carbon removal systems aiming to shift carbon between the fast carbon cycles (years to decades) and slow carbon cycles (100s millions of years). These carbon removal systems must be designed to have a measurable net positive environmental and ecological impact, meaning that the benefits of the intervention must outweigh any potential negative impacts. An idea behind this project is to produce the carbon containing "biomass" consisting of mixtures of sustainably sourced forestry residues (both hardwood and softwood), calcium carbonate, lime kiln dust, and water that is mixed and passively cured. This "biomass" should be deployed to the deep Ocean bottom (Norwegian Sea) and therefore the containing carbon should be excluded from the fast carbon cycle.

Modelling

To investigate the spatial and temporal scales of the "biomass" impacts on the water column and benthic biogeochemistry, we used a coupled model consisted from the FABM family C-N-P-Si-O-S-Mn-Fe biogeochemical model BROM and 2-dimensional benthic-pelagic transport model (2DBP), considering vertical and horizontal transport in the water and upper sediments along a transect centered on a impacted region.

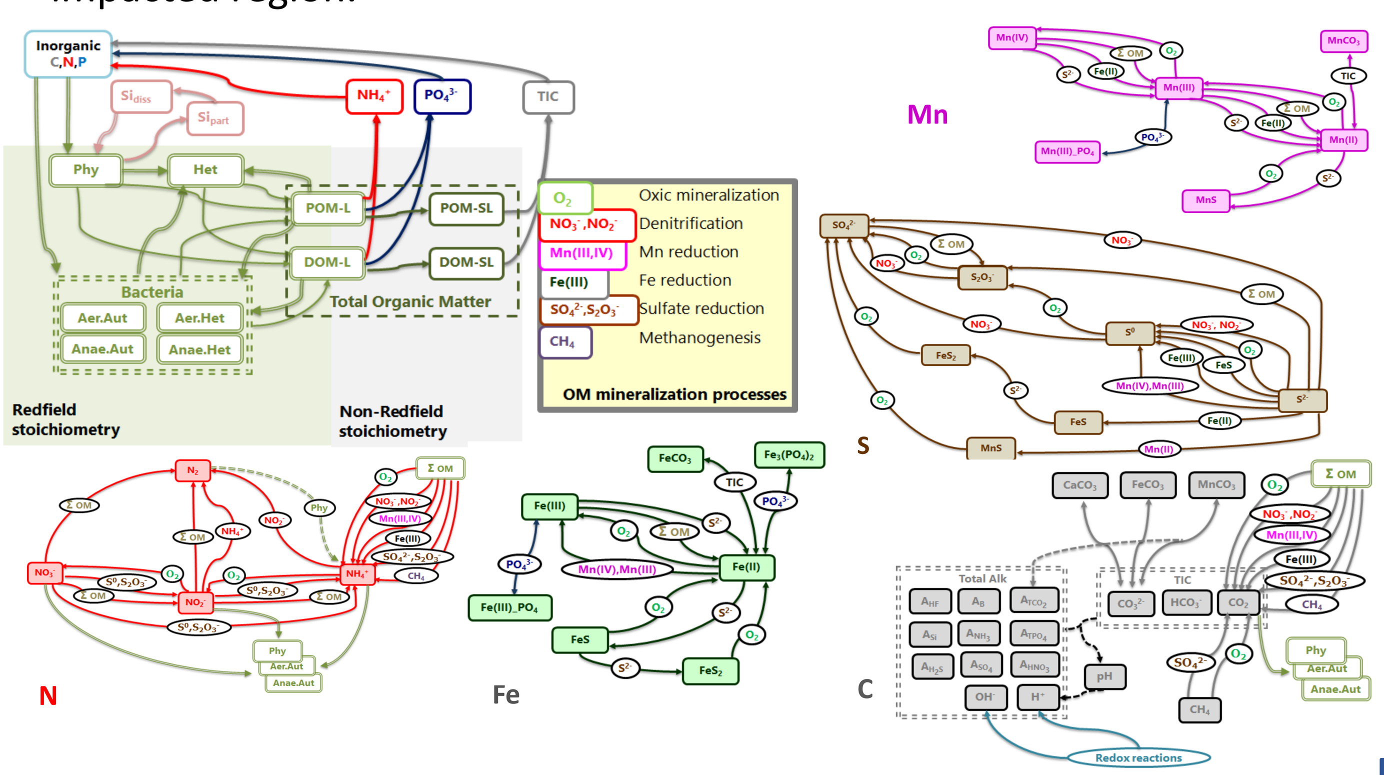

Fig. 2. Flow chat of biogeochemical transformations in the model BROM

The model describes in detail the processes of organic matter mineralization in oxygen-depleted conditions that are vitally important for assessing biogeochemical impacts (i.e., denitrification, metal reduction, sulfate reduction). This model was previously used for the investigation of the fish farming waste impact on the bottom biogeochemistry (Yakushev et al., 2020). In this study we evaluated the maximum amount of the "biomass" that can be accumulated on the bottom surface without dramatic changed in the oxygen regime, acidification and biogeochemistry that can negatively affect the ecosystem.

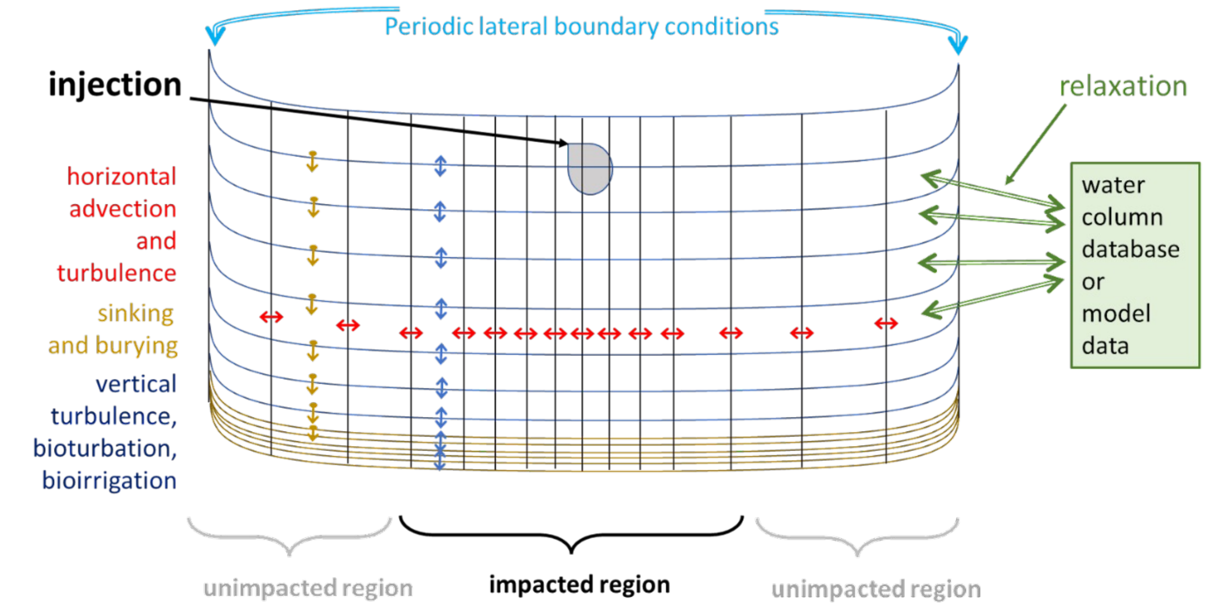

Fig. 1. Scheme of 2-Dimensional Benthic -Pelagic Model 2DBP with the injection point in the center of the transect.

Highlights

- There was simulated baseline biogeochemistry of the deep- sea bottom that was used for numerical experiments on influence of the woodchips deployment
- The model estimated that the maximum amount of woodchips that can be accumulated on the seafloor without dramatic changes in the oxygen regime, acidification and biogeochemistry was a deployment of 2000 metric tonnes of woodchips in 24 hours in 1 km^2 surface area.
- To avoid most of the potential risks, the deployment strategy should include the recommendation of constant ship movement during the deployment, that will increase the surface area over which woodchips will be deployed.
- An addition of $CaCO_3$ (as 5% of weight of the added woodchip mass) is necessary, because it buffers lowering of pH (acidification) that occurs during the decomposition of woodchips and organic matter on the seafloor. .

Results

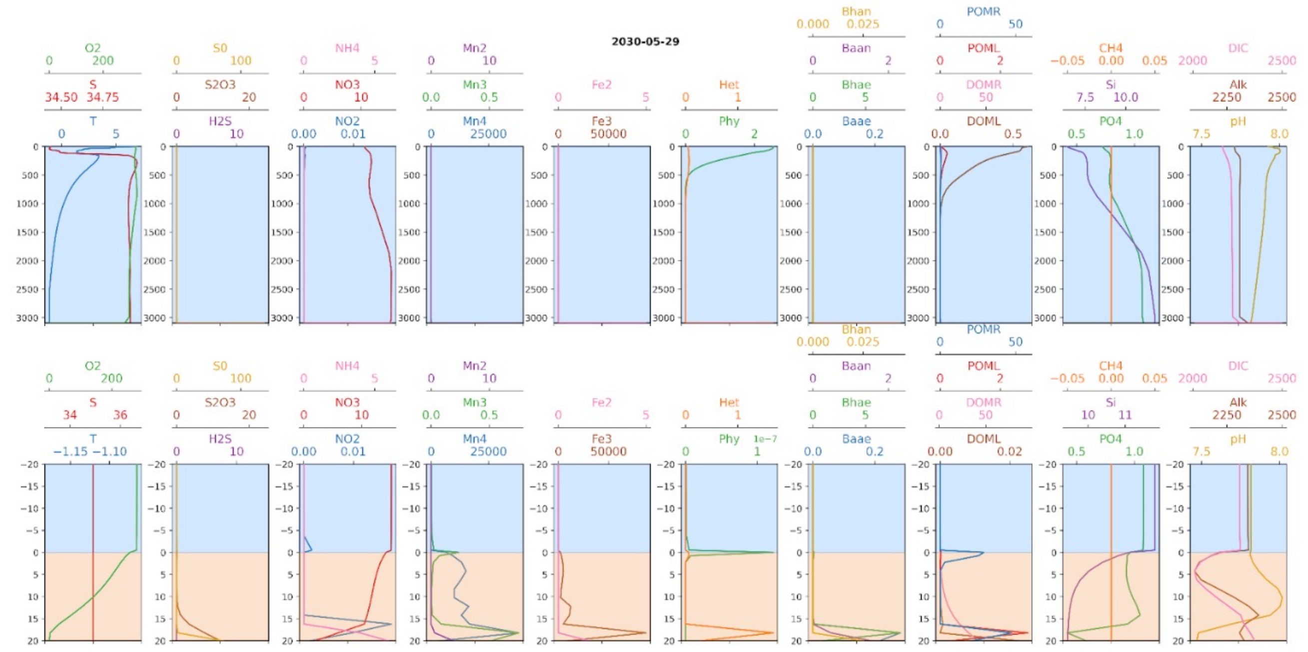

Fig. 3. Baseline vertical distributions of model variables in the water column (upper panels, vertical axis in m) and at the SWI (bottom panels, vertical axis in centimeters from the sediment surface).

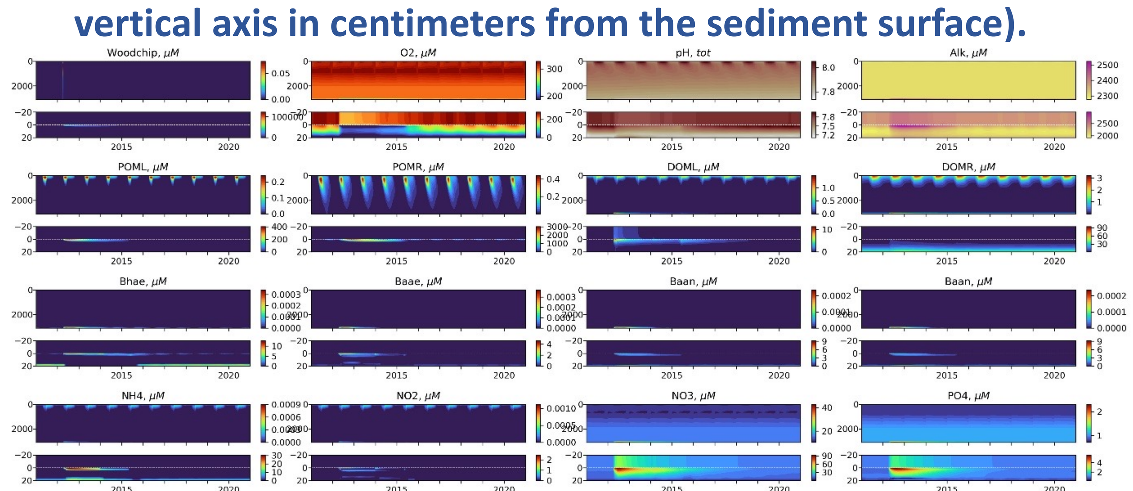

Fig. 4. Interannual changes in the water column and sediments over a 10-year period; 1 year before woodchip deployment and 9 years after

Modeled woodchips deployment characteristics:

- Injection rate: ~2000 t d^{-1} of woodchips for 1 deployment in April.
- Area of deployment: (1000 m X 1000 m)
- r_woodchip_decomp: 0.001 # Specific rate of decomposition into "natural" POM, (d^{-1})
- r_woodchip_diss: 0.0001 # Specific rate of leaching into DOM (d^{-1})
- r_woodchip_miner: 0.001 # Specific rate of waste oxic mineralization into inorganic nutrients (d^{-1})
- Sinking rate: 1.5 cm s^{-1}, 0.75 cm s^{-1}, 0.375 cm s^{-1}

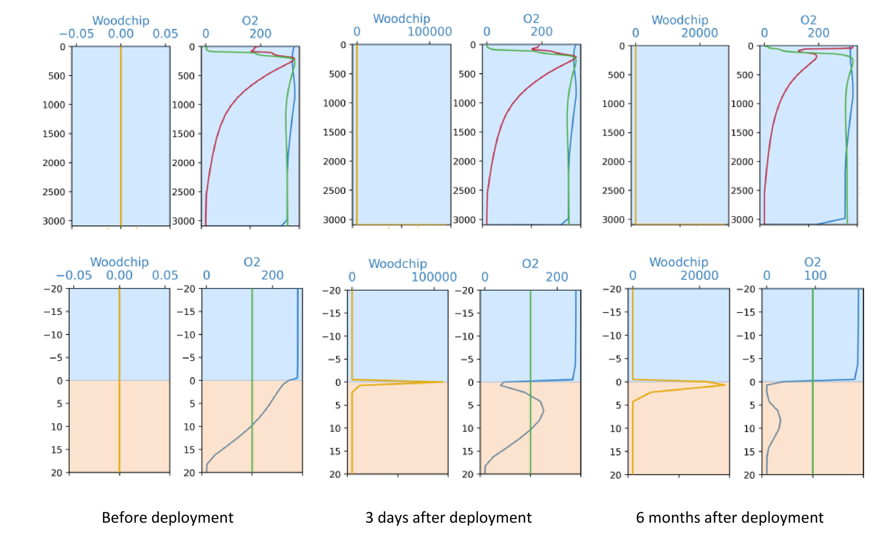

Fig. 5. Vertical distributions of woodchips (yellow; µM N), dissolved oxygen (blue; µM), temperature (red; °C) and salinity (green; psu) at the deployment position before deployment (left), 3 days after the deployment (middle) and 6 months after the deployment (right)

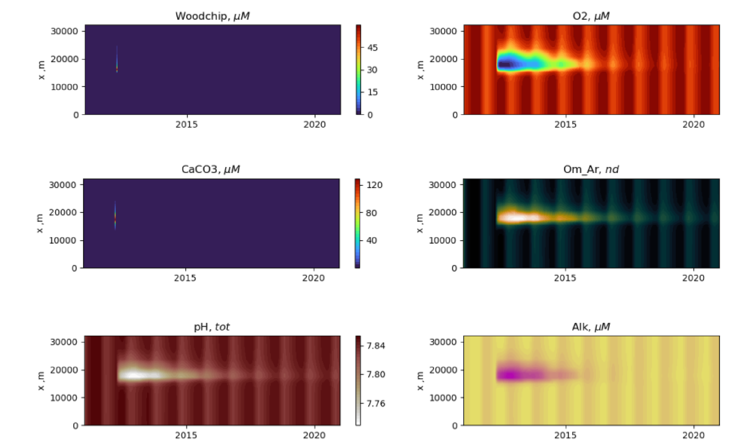

Fig. 6. Interannual changes on the seafloor surface over a 10-year period; 1 year before woodchip deployment and 9 years after

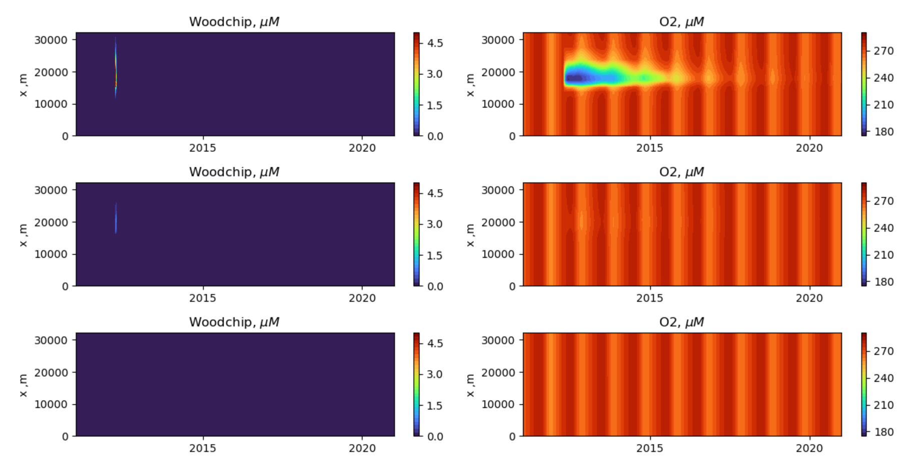

Fig. 7. Interannual variability of woodchips (µM N) and DO (µM) at the sediment surface with woodchip sinking rate 1.5 cm s^{-1} (top), 0.75 cm s^{-1} (middle), 0.375 cm s^{-1} (bottom).

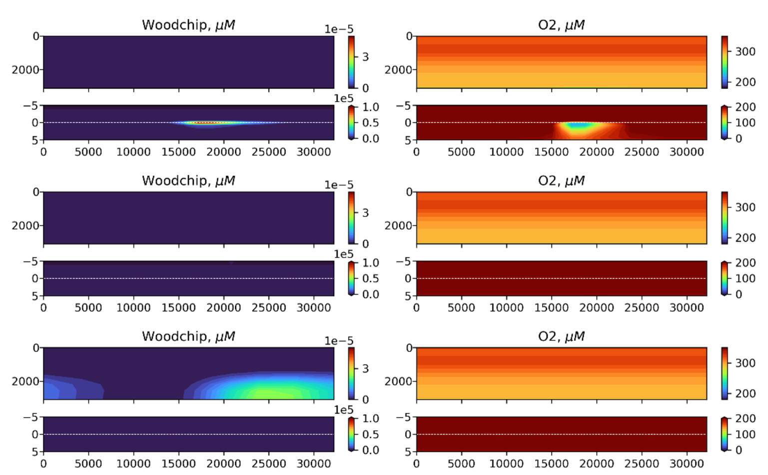

Fig. 8. Influence of the sinking rate on the woodchips (µM N) and oxygen (µM) distribution in a 30000m transect through the deployment point after 15 days of deployment with woodchip sinking rate 1.5 cm s^{-1} (top), 0.75 cm s^{-1} (middle), 0.375 cm s^{-1} (bottom).

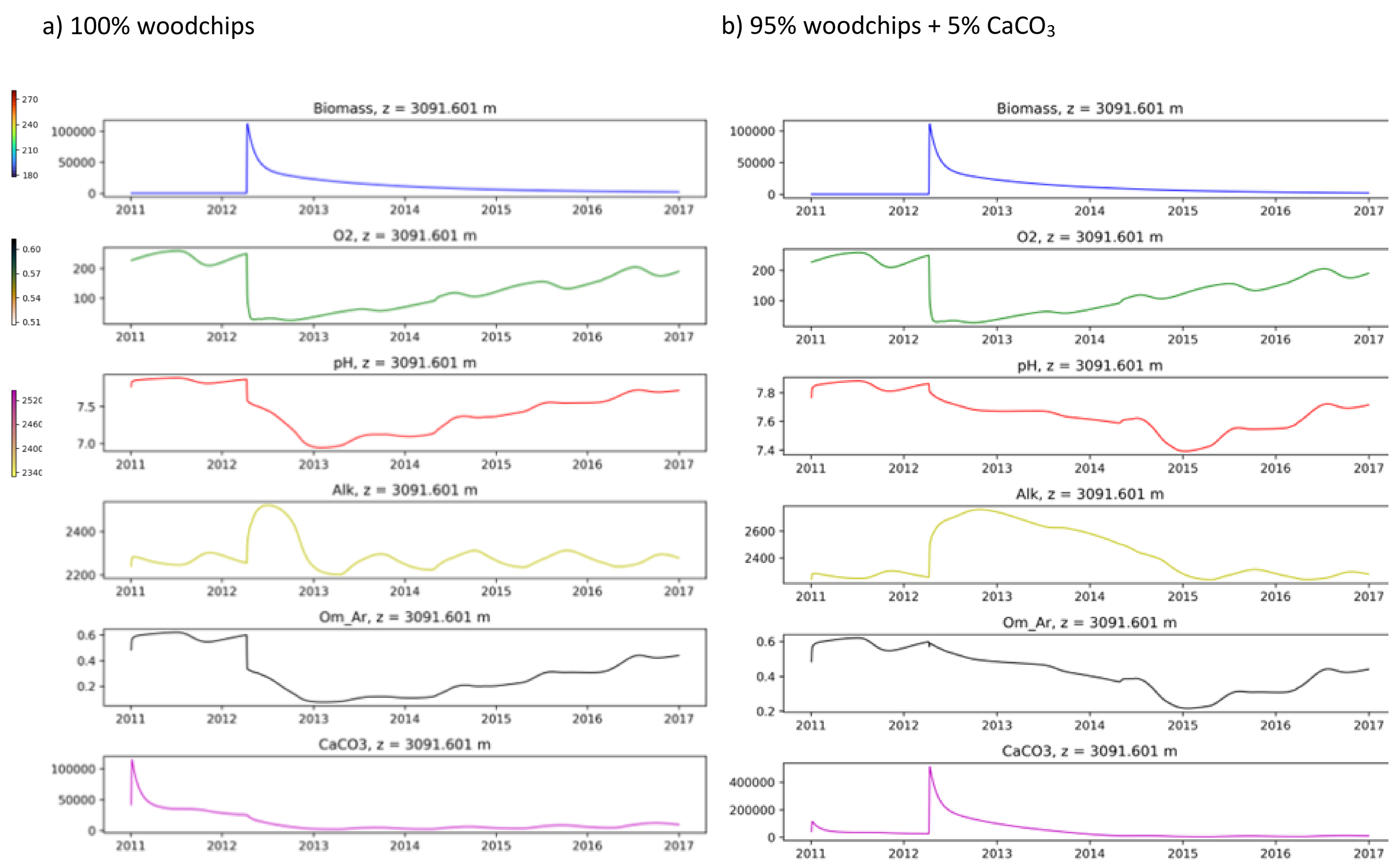

Fig. 9. Interannual variability at the sediment surface of woodchips (µM N), oxygen (µM), pH, TA (µM), Ωar, CaCO3 (µM), in case of deployment of 100% of woodchips (left) and 95% of woodchips and 5% of CaCO3.

References

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