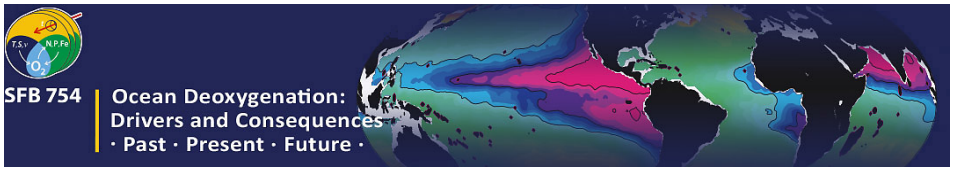

Contribution ID : **103** Type : **Oral**

Ocean Phosphorus Inventory and Oceanic Deoxygenation: Large Uncertainties in Future Projections on Millennial Timescales

Wednesday, 5 September 2018 15:15 (15)

Observations indicate an expansion of oxygen minimum zones over the past 50 years, likely related to ongoing global deoxygenation. Here we analyze the processes and feedbacks, which contribute to global deoxygenation on millennial timescales using an Earth system model of intermediate complexity for a business-as-usual CO2 emission scenario. Particularly, we discuss how terrestrial weathering and redox processes in marine sediments in conjunction with marine feedbacks modulate marine inventories of P and O2.
Higher availability of phosphorus, e.g. from intensified weathering, enhances biological production, remineralisation and oxygen consumption and promotes deoxygenation. Release of sedimentary phosphorus from anoxic sediments plays only a minor role in our simulations, indicating a weak oxygen-nutrient feedback. One reason for such a weak oxygen-nutrient feedback is the slow response of the nitrogen cycle to an increasing P inventory. Locally, nitrogen limitation in upwelling regions is intensified due to a strong oxygen-denitrification feedback. Globally, nitrogen fixation is not able to counteract the nitrogen loss due to denitrification in our model, which is in contrast to conclusions from palaeo-reconstructions of large-scale deoxygenation events. Considerably large amounts of the added P (up to 90%) leave the ocean surface unused, increasing preformed P.
Our model results further indicate a large spread in weathering and benthic fluxes of P, given a range of plausible parameterizations tested. In year 5000, phosphorus weathering anomalies range from 0.1 to 0.6 Tmol P/yr and benthic-release flux anomalies range from 0.0 to 0.2 Tmol P/yr. This results into a large range of possible future phosphorus inventories from 110 to 160% of the current value and suboxic volumes from 1 to 5% of the ocean volume. Uncertainties originate from differences in the parameterization of weathering and of benthic fluxes, in the representation of sediment P inventories, and in the representation of slope and shelfs in the coarse model bathymetry of UVic. Applying a detailed sub-grid bathymetry leads to 5 times higher organic matter fluxes on the shelfs than with a standard model bathymetry, which improves the fit to estimates based on observations.

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Session Classification : 10 Biogeochemical Cycles: Feedbacks and Interactions

Track Classification : 10 Biogeochemical Cycles: Feedbacks and Interactions