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Mutual dependency between benthic fauna and early diagenesis in a shelf sea

Wenyan Zhang (1), Alexa Wrede (2), Ute Daewel (1), Corinna Schrum (1), and Kai Wirtz ()

(1) Institute of Coastal Research, Helmholtz-Zentrum Geesthacht, Geesthacht, Germany (wenyan.zhang@hzg.de), (2) Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany

Field data collected for the North Sea indicate a prominent seasonal variation in the vertical distribution of total organic carbon (TOC) and macrobenthic biomass in sediments. The vertical TOC profiles classify into three modes, with maximum at surface, middle and deep part of sediments, respectively. We here present a mechanistic model to quantify, for the first time, the dynamic interaction between sedimentary TOC and benthic fauna. The major model principles include that (i) the vertical distribution of macrobenthic biomass is a trade-off between nutritional benefit (quantity and quality of TOC) and the costs of burial (respiration) and mortality, and (ii) the vertical transport of TOC is in turn modulated by macrobenthos through bioturbation. A novelty of our model is that bioturbation is resolved dynamically depending on variation of local food resources and macrobenthic biomass. This allows capturing of the benthic response to both depositional and erosional conditions and improving estimates of the material exchange flux at the sediment-water interface. The coupling of the TOC-benthos model with 3D hydrodynamic-ecological simulations reveals that the three profile modes of sedimentary TOC (in both quantify and quality) can be explained as a combined response to pelagic conditions (shear stress and primary production) and the synergy between bioturbation, vertical redistribution of higher quality TOC and vertical positioning of benthic organisms.
A model reconstruction of the benthic status in the North Sea from 1950s to 2010s indicates that despite a relatively stable pattern at decadal and regional scales, significant variations exist at smaller scales characterized by seasons and local areas. In addition, inter-annual and multi-year cycle-like variations are also prominent especially in coastal areas.