Ocean Biogeochemical Fingerprint of Fast-Sinking Tunicate and Fish Detritus

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Introduction

- Gelatinous zooplankton (GZ) and fishes have fast-sinking detritus (700-1500 m/d) which is ~10x faster than bulk oceanic detritus.
- Studies show that fast-sinking GZ detritus increases the transfer efficiency of the biological pump, but their broader impact on ocean biogeochemical cycles in the deep-sea is unknown.
- Especially unknown are the impacts of fast-sinking detritus on ocean oxygen, both in the oxygen minimum zones (OMZs) and at the seafloor.
- We use a coupled physical-biogeochemical model with explicit GZ (specifically, pelagic tunicates) and implicit fish to investigate the model sensitivity to fast-sinking detritus from GZ, fish, and both.

Methods

- We used a modified version of the GFDL-COBALT model with two explicit size classes of pelagic tunicates (GZ-COBALT; Luo et al. 2022) and implicit higher trophic level predators (fish) (Fig. 1).
- Fast-sinking detritus were separated from bulk detritus, and sank at 1000 m d⁻¹ compared to the bulk rate (100 m d⁻¹).
- Fast-sinking detritus included:
  - Fish: all detritus (represents fecal pellets only)
  - GZ: all detritus from jelly-falls, and 75% of the fecal pellets.
- 4 experiments were run with
  1) no fast-sinking detritus (Control)
  2) fast-sinking GZ detritus only
  3) fast-sinking fish detritus only
  4) fast-sinking fish and GZ detritus combined.
- Simulations were run with MOM6, SIS2, and GZ-COBALT at 0.5 degree horizontal resolution for 300 years with 56-year repeating COREII-AF cycles, representing 1948-2008. The last 20 years of the 5th cycle was averaged for analysis.

Results

- Incorporating fast-sinking detritus resulted in a global decrease in NPP and surface export flux. This effect was strongest in the subtropical gyres, where nutrients were already limiting (Fig. 2).
- POC flux at 1000 m and to the seafloor increased, particularly at upwelling zones and high latitudes. In the combined fish + GZ case, POC flux at 1000 m increased 37%, and to the seafloor increased 11%.
- Remineralization length scales increased globally, except near OMZs, where fast-sinking detritus reduced remineralization overall, leading to less oxygen loss and less anaerobic remineralization.
- This leads to smaller OMZs with fast-sinking detritus, and associated improvements in simulated nitrate and N* at the mid-depths (Fig 5).
- Comparisons between the Jørgensen et al. (2022) control and our fast-sinking GZ and fish data fits near the OMZs. The fit at other sites were degraded — but this is consistent with modifying a component of a tuned model (Laufkotter et al. 2017).
- Increased supply of POC to seafloor increased benthic oxygen utilization rates (OUR) (Fig. 4).
- But, compared to the Jørgensen et al. (2022) data product, simulated OUR even with fast-sinking detritus is significantly lower.

Discussion

- Fast-sinking detritus cases with fish- and GZ-only had similar global values. The fish-only case was higher at the coasts and in high-productivity areas, consistent with the broad contrast between fish and GZ.
- NPP and export flux decreased globally due to the stripping of nutrients from the surface oceans, and persisted for at least 300 years.
- Modeled OMZs expanded slower with fast-sinking detritus. OMZs did shift deeper, but the total hypoxic and suboxic volume were still lower than the Control. This is due to the interactive effect of fast-sinking detritus on oxygen and remineralization rates.
- This implies at a biological mechanism for improving models’ representation of OMZ size and change with climate change — a key model bias.
- Sedimentary oxygen utilization may be an independent constraint on fast POC fluxes. Recent seafloor OUR observations (Fig. 4) suggest at significantly more benthic oxygen consumption than our model suggests.
- This is a puzzling discrepancy—possibly due to biases in both observations and coastal productivity in models—but nonetheless suggests that the observations are able to accommodate increased bottom fluxes from fast-sinking detritus.

References